Shorted Microstrip Patch Antenna Using Inductively Coupled Feed for UHF RFID Tag

Jeong-Seok Kim, Wonkyu Choi, Gil-Young Choi, Cheol-Sig Pyo, and Jong-Suk Chae

ABSTRACT—A very small patch-type RFID tag antenna (UHF band) using ceramic material mountable on metallic surfaces is presented. The size of the proposed tag is 25 mm×25 mm×3 mm. The impedance of the antenna can be easily matched to the tag chip impedance by adjusting the size of the shorting plate of the patch and the size of the feeding loop. The measured maximum reading distance of the tag at 910 MHz was 5 m when it was mounted on a 400 mm× 400 mm metallic surface. The proposed design is verified by simulation and measurements which show good agreement.

Keywords—RFID, microstrip patch antenna, metal tag, ceramic, shorting plate, inductively coupled feed.

I. Introduction

Radio frequency identification (RFID) has been widely used in supply chain, service industries, distribution logistics, and manufacturing companies to identify goods. In some RFID applications such as metallic components, label tags generally cannot operate on the surface of conducting materials because of the degradation of tag antennas. Proper antenna design for RFID tag applications is becoming essential for the maximization of RFID system performance. Recently, there have been many studies on RFID tag antennas in the UHF band, especially at 900 MHz. In many applications, RFID tags need to be very small and mountable on metallic surfaces. To meet this application requirement, the planar inverted-F antenna which can be used on metallic surface has been proposed as a tag antenna [1], [2]. To reduce the size of the patch antenna, a microstrip antenna with two-shorted-patches and a feed loop has been proposed [3]. To expand the bandwidth of metal tag antennas, the use of orthogonal proximity-coupled patch antennas in RFID tags has been studied [4]. Also, a tag antenna must be directly matched to the tag chip, which in most cases has a complex impedance rather than 50 Ω. A impedance matching technique using inductive coupling has been studied in relation to RFID tag antennas [5].

In this paper, we present a very small tag antenna which is mountable on metallic surfaces and suitable for a UHF-band RFID tag. It is a patch antenna with a shorting plate and uses a ceramic material and an inductively coupled feed. It can be placed on conducting materials and measures 25 mm×25 mm× 3 mm. It can be used in applications which require small size.

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Jeong-Seok Kim (phone: + 82 42 860 1365, email: jskim0113@etri.re.kr), Wonkyu Choi (email: wkchoi@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 the IT Convergence Technology Research Laboratory, ETRI, Daejeon, Rep. of Korea.

II. Tag Antenna Design

The structure of the proposed antenna is presented in Fig. 1. The proposed tag consists of a tag chip, an inductively-coupled feed line, a radiating patch with shorting plates, the substrate filled with ceramic material ($\varepsilon_r = 48$), and the ground plate. The radiating patch is a metal plate with horizontal and vertical slits to adjust the radiation frequency. The vertical slit has a length of L_f. The tag chip is electrically connected to the feed line, which is located in the same plane as the radiating patch. The horizontal length of the feed line is L_i, and the width of the shorting plate is L_r. The proposed antenna is designed for a tag chip (commercial RFID tag chip: Alien Higgs) with an impedance of Z_c=(12-j140) Ω at a resonant frequency of 910 MHz. The conjugate match between the impedance of the proposed antenna and that of the tag chip is achieved by adjusting the width of the shorting plate and the feed line length.

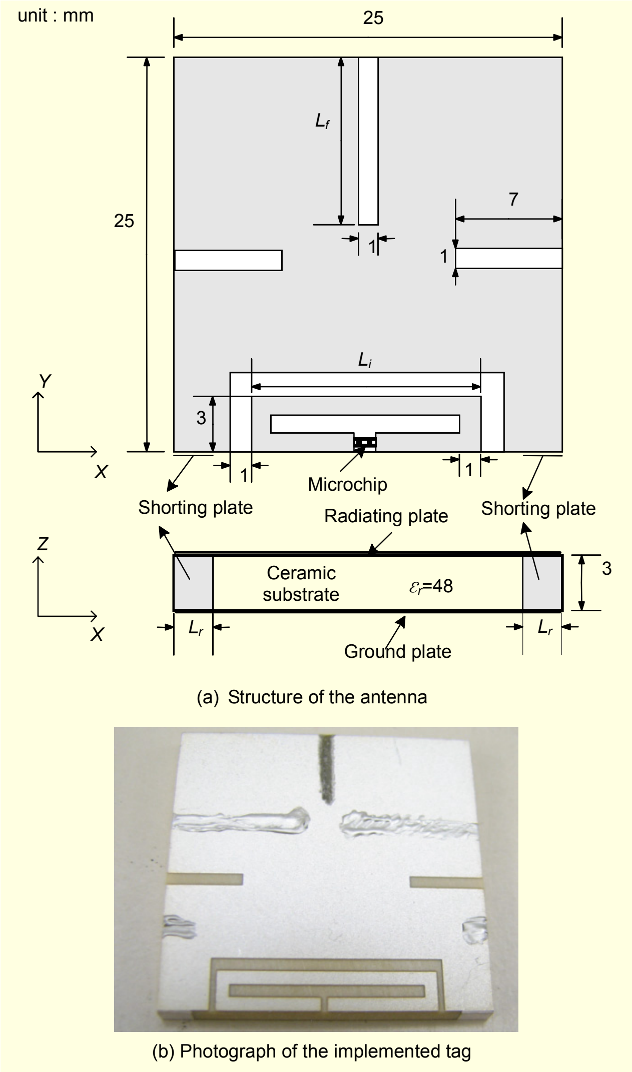

Fig. 1. Structure of the proposed antenna.

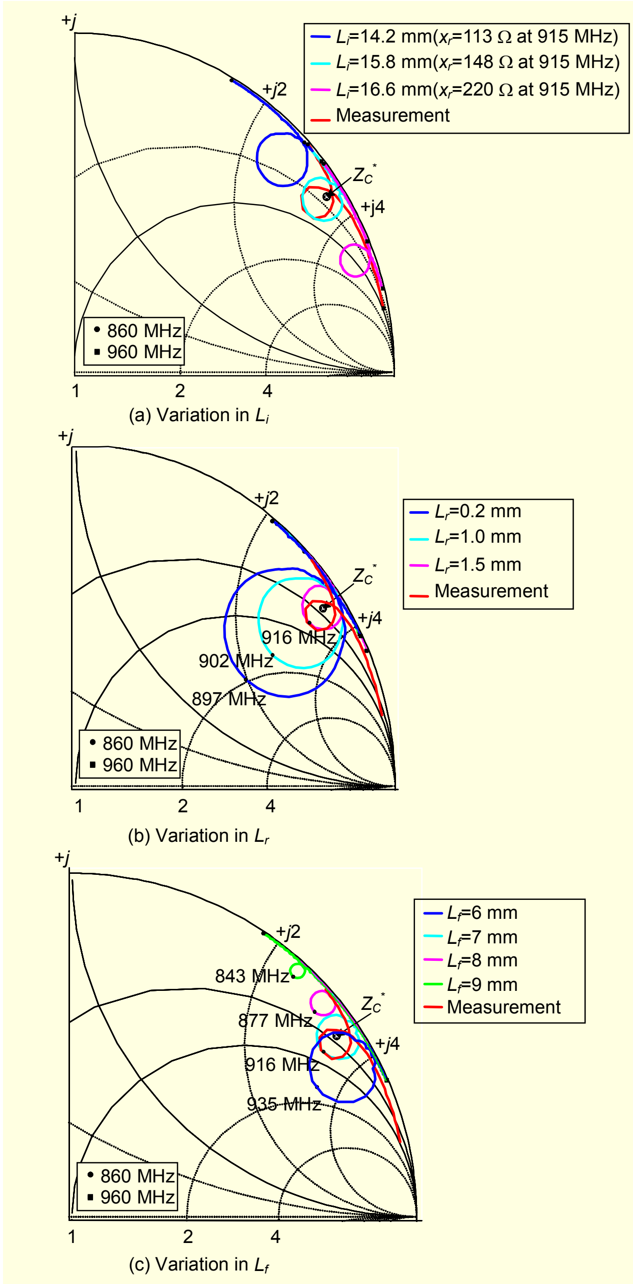

Fig. 2. Input impedance characteristics.

The operating frequency is adjusted by varying the slit length of the radiating patch, while the impedance of the antenna is almost unaffected.

III. Simulation and Measurement

A prototype antenna was designed and implemented for a tag chip with a complex conjugate impedance of Z_c^*=(12+j140) Ω. The operating frequency is 910 MHz.

Figure 2 shows the simulated and measured data for the input impedance of the antenna when it is attached to an infinite metallic surface. The simulation was performed using CST Microwave Studio. The locus of the input impedance of the antenna has an α–shaped feature in the Smith chart. This is because the reactance component of the coupled impedance of the radiating patch and the self-reactance of the feed line cancel each other around the resonance frequency of the radiating patch in a manner similar to that of the inductively coupled feed [5]. The reactive component of the input impedance depends on the self-reactance of the feed line X_f, and we can easily match it to the conjugate impedance of the tag chip by varying the length of the feed line L_i. The resistive component of the input impedance has simple dependence on the width of the shorting plate L_r. The reactive and resistive components of the input impedance characteristics of the antenna for various values of L_i and L_r are shown in Figs. 2(a) and (b). As the value of L_i increases, the reactance of the input impedance increases.

As the value of L_r increases, the resistance of the input

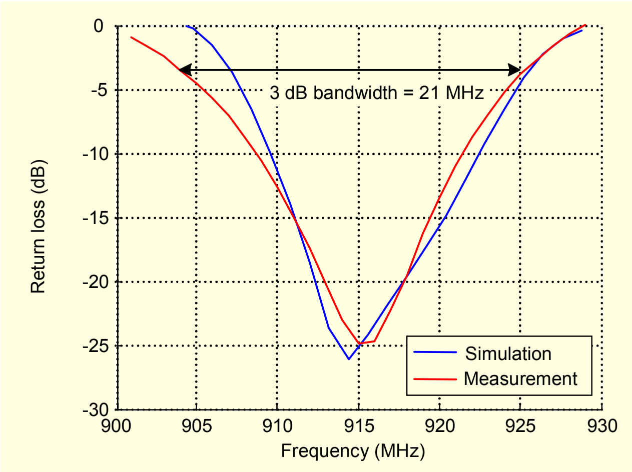

Fig. 3. Calculated and measured return loss of the antenna.

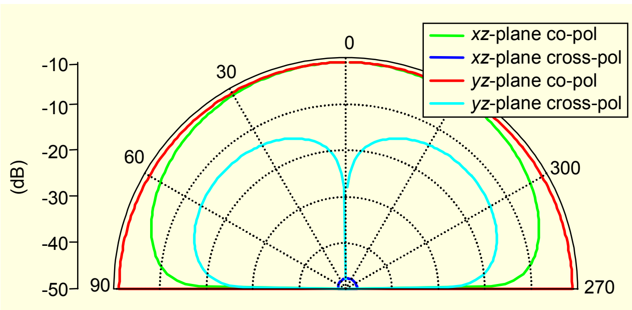

Fig. 4. Simulated radiation pattern.

impedance decreases, and the resonant frequency does not change. Figure 2(c) shows that the vertical length of the slit L_f in the radiating patch has the effect of moving the α-shaped locus with variation of the resonant frequency. Figure 2 shows that the measured impedance locus agrees well with the simulated result. The measurement was carried out with the tag placed at the center of a 400 mm×400 mm metallic surface. Figure 3 shows the return loss of the proposed antenna with the simulation and measurement results with respect to Z_c^*. The bandwidth at 3 dB return loss is 21 MHz, which covers the bandwidth of the Korean RFID frequency band (908.5 MHz to 914 MHz).

Figure 4 shows the simulated radiation pattern of the proposed antenna mounted on a metal surface at 910 MHz. The radiation pattern in the *yz* plane and *xz* plane has fairly good omni-directional performance. The simulated directivity of the proposed antenna with an infinite metallic surface is about 5.21 dBi, and the radiation efficiency is about 35%. These characteristics can be verified by measuring the reading distance of the proposed tag.

We measured the maximum reading distances of the tag on a metallic surface using the commercial RFID reader made by Alien Technologies (ALR-9800) in an anechoic chamber. The maximum reading distance was 5 m when a 400 mm×400 mm metallic surface was used, while the operating frequency of the reader hopped to the frequency band in the range from 908.5 MHz to 914 MHz. The simulated results were in good agreement with the measured results. The maximum reading distance rapidly decreased as the size of metallic surface was reduced to smaller than 200 mm×200 mm.

IV. Conclusion

A design for very small ceramic tag antenna (25 mm×25 mm×3 mm) for the UHF band mountable on metallic surfaces was implemented. The antenna can be directly matched to the arbitrary complex impedance of a tag chip. We verified that the proposed tag achieves good performance by measuring the bandwidth of 21 MHz at 3 dB return loss and a maximum reading distance of 5 m on metallic surfaces. The proposed tag may be used with conducting plates such as automobile components if necessary.

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