RFID Tag Antenna Coupled by Shorted Microstrip Line for Metallic Surfaces

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ABSTRACT—*This letter presents the design of a small and low-profile RFID tag antenna in the UHF band that can be mounted on metallic objects. The designed tag antenna, which uses a ceramic material as a substrate, consists of a radiating patch and a microstrip line with two shorting pins for a proximity-coupled feeding structure. Using this structure, impedance matching can be simply obtained between the antenna and tag chip without a matching network. The fractional impedance bandwidth for S_{11}<3 dB and radiation efficiency are about 1.4% and 56% at 911 MHz, respectively. The read range is approximately from 5 m to 6 m when the tag antenna is mounted on a metallic surface.*

Keywords—*RFID, tag antenna, small antenna, impedance matching.*

I. Introduction

Radio frequency identification (RFID) has been widely used in supply chain and logistics applications in identifying and tracking goods. In RFID systems, tags are attached to objects having various shapes and materials. Data is transferred between a tag and reader by backscattering of an electromagnetic wave. That is, a tag partially rectifies the electromagnetic wave from a reader and uses it as a power source, while the tag sends a coded signal back to the reader, backscattering a portion of the electromagnetic wave by means of load modulation. The performance of a tag mounted on a specific object is mainly determined by the antenna. Many tag antennas have been developed for placement on various objects made with different materials. One of the biggest challenges is to design a tag antenna mountable on metallic objects because metallic surfaces can negatively affect the performance of an antenna in terms of resonant frequency and radiation efficiency [1], [2]. The resonant frequency of a typical dipole-like antenna changes, and its radiation efficiency decreases when it is located on or near metallic surfaces [3]. Therefore, tag antennas for metallic objects must be designed to enable RFID tags to be used on conductive surfaces without performance degradation. Planar inverted-F antennas and microstrip patch antennas are attractive choices for tagging metallic objects. Several papers have been published on RFID tag antennas mountable on metallic surfaces [4]-[6]. This letter presents a small antenna with a novel feeding structure suitable for an RFID tag to identify metallic objects. The proposed antenna is composed of a radiating patch and a microstrip line with two shorting pins for a proximity-coupled feeding structure.

II. Tag Antenna Design

The structure of the designed antenna is shown in Fig. 1. The antenna comprises a proximity-coupled radiating patch, a microstrip line for feeding, and the ground plane. The radiating patch, which is 25 mm × 25 mm in size, and the microstrip line are implemented by printing silver paste on a ceramic slab (ε_r=37) 3 mm thick. The microstrip line is located in the slot formed in the radiating patch, and both ends are shorted to the ground plane by pins that are 0.8 mm in diameter. The terminal on which the tag chip is mounted is placed close to shorting pin 1

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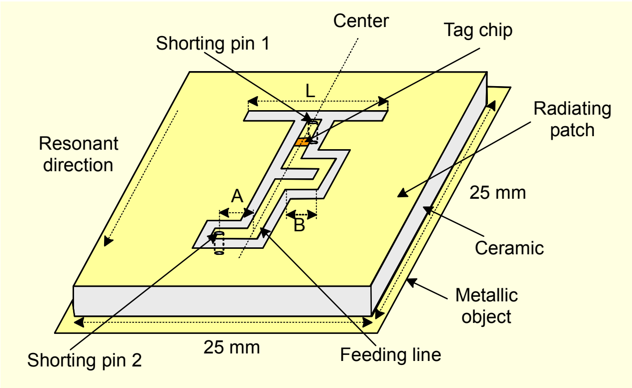

Fig. 1. Designed antenna structure.

on the microstrip line.

Generally, an RFID tag chip may have a complex impedance different from 50 Ω. That is, the chip impedance is a complex combination of low resistance and high capacitive reactance. Therefore, it is important that the tag antenna is designed to realize the conjugate-match between the antenna and chip. The proposed antenna has a proximity-coupled feeding structure composed of a microstrip line shorted to the ground plane. Using this feeding structure, we can almost independently control the real and imaginary parts of the antenna impedance. As shown in Fig. 1, the real part of the antenna impedance depends on distance A. As distance A increases, the resistance (real part) of the antenna impedance increases. The imaginary part is adjusted by altering distance B. When distance B increases, the reactance (imaginary part) of the impedance also increases. The tag chip employed in our study is a commercial product of Alien Technologies, USA, and its input impedance is about 12-j145 Ω at 911 MHz.

III. Simulation and Measurement

The proposed antenna is designed for an RFID tag chip with an input impedance of about 12-j145 Ω at 911 MHz. Based on the structure shown in Fig. 1, we obtained the simulation results presented in Figs. 2 and 3 using the Microwave Studio. The figures show impedance characteristics with various A and B values, which control the input impedance. The figures show the conjugate impedance as well. As shown in Figs. 2 and 3, the resistance part of the antenna impedance changes most at the resonant frequency of 911 MHz when A is varied from 0.5 mm to 0.7 mm and B is fixed at 1 mm. The reactance part changes most at 911 MHz when B is varied from 0.8 mm to 1.2 mm and A is fixed at 0.5 mm.

Figures 2 and 3 demonstrate that the simple structure of the proposed antenna matches the antenna impedance to the chip impedance by appropriately tuning distances A and B. The

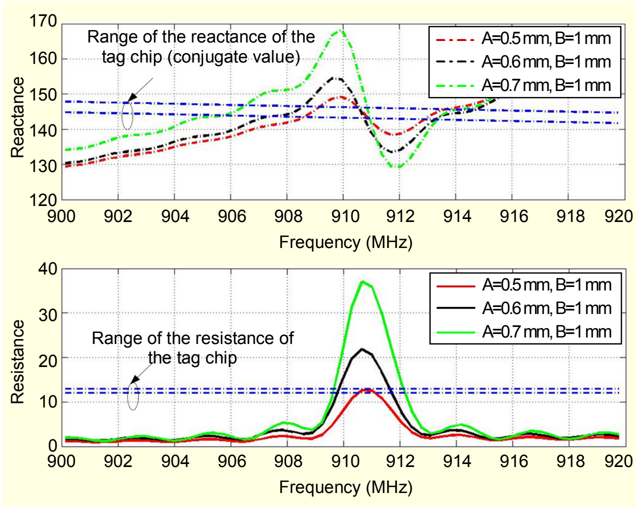

Fig. 2. Impedance characteristics with varying A values.

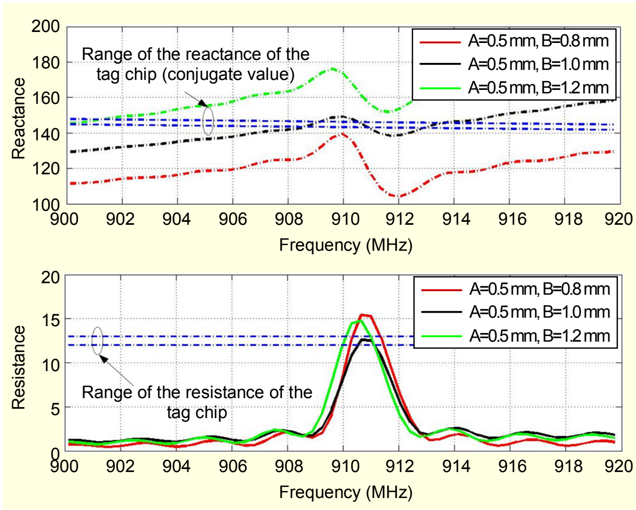

Fig. 3. Impedance characteristics with varying B values.

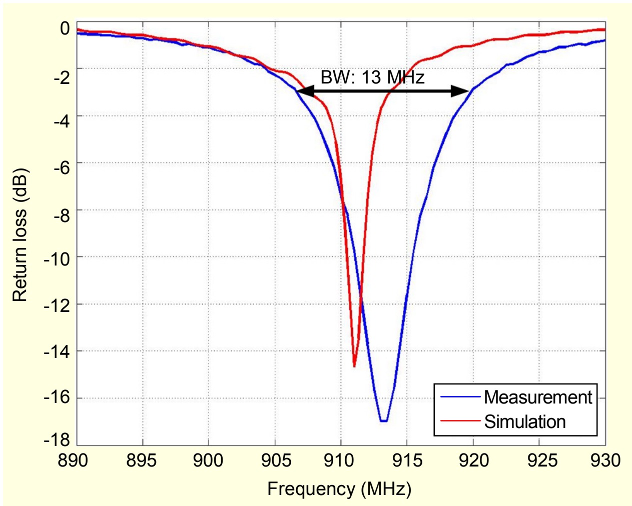

Fig. 4. Return loss of the tag antenna.

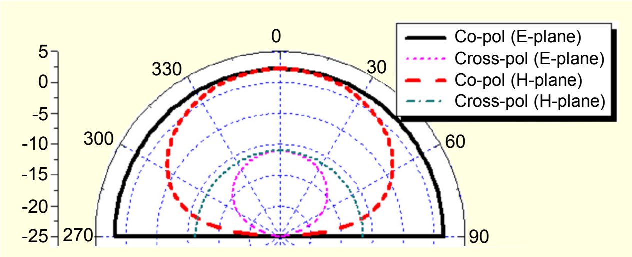

Fig. 5. Radiation pattern of the tag antenna.

Fig. 6. Photograph of the fabricated tag antenna.

resonant frequency of the antenna can easily be controlled by also adjusting length L. Figure 4 presents the simulated and measured return loss of the antenna. The measured half-power bandwidth (return loss less than 3 dB) is 13 MHz from 907 MHz to 920 MHz (fractional bandwidth 1.4%), which covers the 5.5 MHz bandwidth requirement of Korea for UHF RFID. The measured bandwidth is about 7 MHz wider than that simulated for S_{11} less than 3 dB. This difference results from the assumption that the ceramic slab (ε_r=37) is loss-free in the simulation.

The radiation pattern at 911 MHz is shown in Fig. 5, which illustrates the co-polarization and cross-polarization in the E- and H-planes. The radiation efficiency and gain are about 56% and 2 dBi, respectively, at 911 MHz. These results were obtained by simulation using Microwave Studio (CST). Figure 6 shows a photograph of the fabricated tag antenna, which is 25 mm × 25 mm in area and 3 mm thick. We measured the read range of the designed tag antenna in an anechoic chamber. The RFID reader fabricated by our ETRI team was used to measure the read range. It has a frequency hopping function in the range of 908.5 MHz to 914 MHz and radiates up to 4 W EIRP through a linearly polarized antenna. The read range is approximately between 5 m and 6 m for the boresight direction when the tag antenna is mounted on a metallic surface of 400 mm × 400 mm while the operating frequency of the reader hops to the frequency band in the range of 908.5 MHz to 914 MHz.

IV. Conclusion

This letter presented an RFID tag antenna which can be mounted on metallic surfaces in the UHF band. The proposed antenna has a proximity-coupled feeding structure composed of a microstrip line shorted to the ground plane. We can almost independently control the real and imaginary part of the antenna impedance using the proposed feeding structure. Therefore, we can directly match the impedance of the antenna to that of the tag chip. Moreover, the antenna has an impedance bandwidth of 13 MHz for S_{11} less than 3 dB, radiation efficiency of 56% at the center frequency of 911 MHz, and a read range from 5 m to 6 m on a metallic surface.

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