3A3-2

Small Wideband RFID Tag Antenna Mountable on Metallic Surfaces

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1. Introduction

The RFID (Radio Frequency Identification) system has recently become very popular in many industries. Inductively-coupled short-range RFIDs have already been used, but the demand for long-range identification has increased. Consequently, the RFID frequency has gone into the microwave region, which means that the tag antenna design has become an important factor in maximizing the read range of the RFID system. Since the tag antenna is attached to objects, it must be designed in consideration of the material of objects. RFID tags for metallic objects are required in many applications, however, the label-style tags generally do not work well on metallic surfaces. Therefore, a novel tag antenna design for mount on metallic surfaces is needed.

RFID tag antennas mountable on metallic surfaces have been proposed in several papers, but there are problems with the bandwidth being too narrow (approximately 15-20 MHz for the 3dB bandwidth) [1]. Although the antenna in [2] has wide bandwidth, its size is large (90 mm × 54 mm × 3 mm) because the radiating section is a microstrip patch. In the RFID system, the frequency bandwidth for data transfer per channel is less than 1 MHz, however, for continual identification, the tag antennas must operate within a designated frequency bandwidth in the RFID system. In North America, the designated frequency bandwidth for the RFID system is 902~928 MHz. Therefore, tag antennas must have a minimum bandwidth of 26 MHz. However, it is difficult to obtain wideband characteristics because tag chips generally have large capacitances and small resistances. Such chip impedances with high Q increase the difficulty of designing a matched antenna and narrow the impedance bandwidth of the antenna. To reduce both the cost and the size, tag antennas must be directly matched to tag chips and have a simple structure. In this letter, we propose a novel small wideband tag antenna that is directly matched to the tag chip and mountable on metallic surfaces.

2. Antenna Structure

Figure 1 shows the geometry of the proposed antenna. The antenna consists of two sections; proximity-coupled radiating and feeding sections. Both sections are fabricated on RF-35 substrate (ε_r=3.5, tanδ=0.002, and h=1.52 mm). The radiating section has PIFA (Planar Inverted-F Antenna) shape, and it consists of a radiating patch with length L, width W, and shorting pins with a distance D_p between two adjacent pins. The resonance frequency is easily controlled by varying L and displacement D_m between the radiating patch edge and pin core. The feeding section is a short-ended transmission line with width W_f and length L_f. One edge is shorted to the ground plane through a pin. The tag chip is located between the opposite edge and the pad connected to the ground plane. To maximize the power delivery, the impedance of the tag antenna needs to be a complex conjugate value of the tag chip impedance. Therefore, at the resonance frequency, the feeding section is adjusted to include the inductance, which compensates the capacitance of the tag chip. The feeding section is a short-ended transmission line, so the inductance can be calculated using the transmission line expression;

$$Z_{in} = jZ_0 \tan \beta l \qquad (1)$$

where Z_o is the characteristic impedance, β is the phase constant, and l is the length of the short-ended transmission line. However, this is not an ideal microstrip transmission line, so the equation (1) is not an exact calculation. By varying L_f, the inductance is controlled easily. The feeding section is separated from the radiating section by D and its direction is parallel to the radiating section.

The ground plane of the tag antenna is the same size as that of the substrate, but when the tag antenna is mounted on metallic surfaces, the metallic surface is used as the ground plane. The margin M is set for reducing the fabrication error. This structure with the separated radiating and feeding sections ensures easy control of the input impedance and operating frequency of the antenna. Thus, a wideband tag antenna can be designed, easily by varying some parameters.

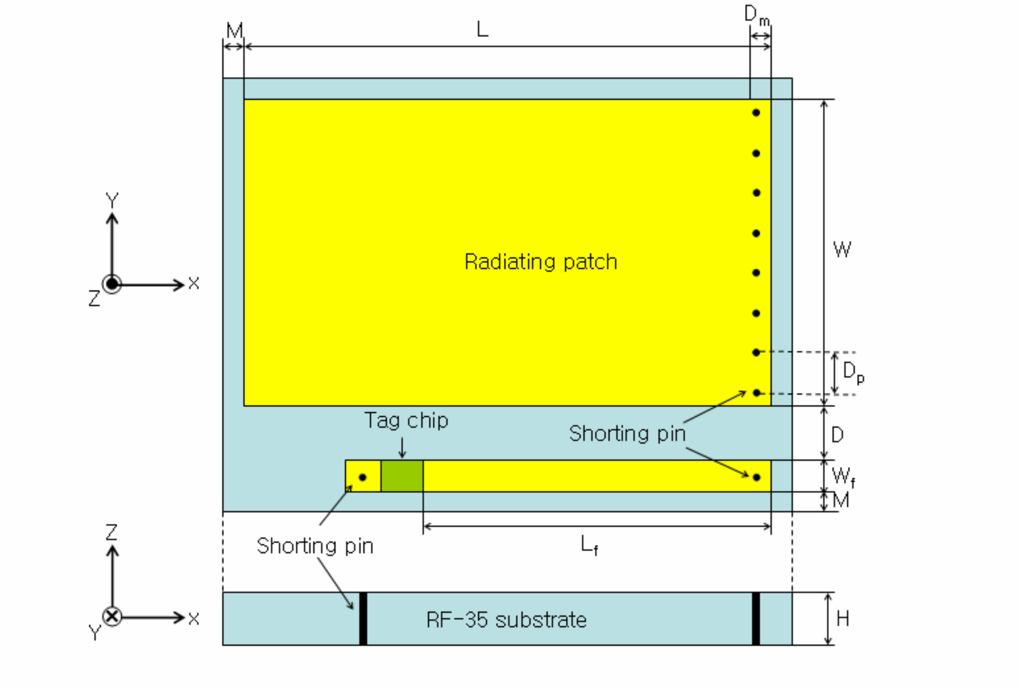


Figure 1: Antenna geometry

3. Antenna simulation and measurement

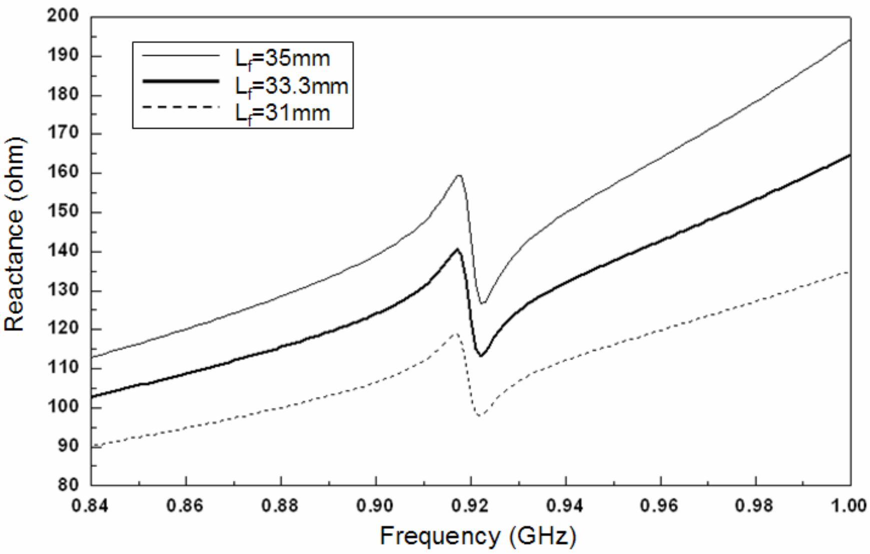
The prototype tag antenna is designed to match the tag chip impedance of $Z_c = (6.2 – j127)$ Ω at the 919 MHz operation frequency [3]. The length L of the radiating section is 43 mm (approximately a quarter of a guided wavelength) and the displacement D_m is 0.7 mm. The resonance frequency is not affected by W which is set to 38.5 mm to ensure radiation efficiency. The antenna height is 1.52 mm and the dimension of the feeding section is $W_f \times L_f = 2$ mm × 33.3 mm. The distance D between the radiating and feeding sections is 4.5 mm. The margin M is set to 1 mm.

Figure 2 shows the simulation results for the input impedance characteristic of the tag antenna when it is attached to an infinite ground plane with the varying feeding section length L_f and the varying distance D between the radiating and feeding sections.

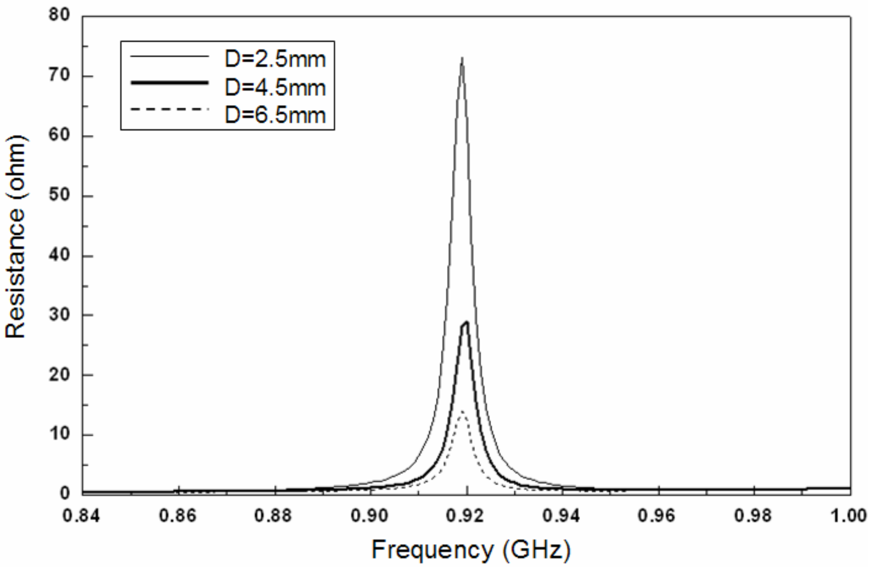
Figure 2(a) shows reactance for the different feeding section length L_f without changing other parameters. The value of L_f controls the input reactance of the tag antenna. It is dependent on the tag chip due to the maximization of the power delivery to the tag antenna. The length L_f of 33.3 mm gives a complex conjugate value for the chip impedance. As the length L_f increases, the reactance of the antenna increases. Therefore, it is easy to control the reactance of the tag antenna. A number of tag chips were fabricated with various impedances according to the chip provider. Therefore, this method using a short-ended transmission line is convenient for the design of tag antennas.

Figure 2(b) shows the results when the distance D between the radiating and feeding sections is varied. The input resistance of the tag antenna is dependant on the distance D. The proximity-coupled feeding method can control the input resistance of the antenna by varying the mutual coupling between the radiating and feeding sections. The input resistance of the tag antenna is in inverse proportion to the mutual coupling [4]. As the distance D increases, the mutual coupling decreases. It results in that the resistance of the antenna decreases. Therefore, the input resistance of tag antenna let easily adjustable.

In a proximity-coupled feeding antenna, the reactance of the radiating and feeding sections cancel each other out near the resonance frequency; thus, the impedance characteristics of tag antenna can be obtained, and as shown in Figure 2, it creates wideband characteristics [3, 4]. As also shown in Figure 2, the resonant frequency is independent of the feeding section length L_f and the distance D. On the contrary, the reactance of the tag antenna is dependant on the feeding section length L_f, and the resistance is dependant on the distance D. Moreover, the resonance frequency of the tag antenna is dependant on the radiating section length L. The input impedance of the antenna can be changed easily. Although the impedance of a chip varies, wideband characteristics can be obtained easily by varying the distance D and length L_f.



(a) Reactance with variation of the length L_f



(b) Resistance with variation of the distance D

Figure 2: Input impedance characteristics

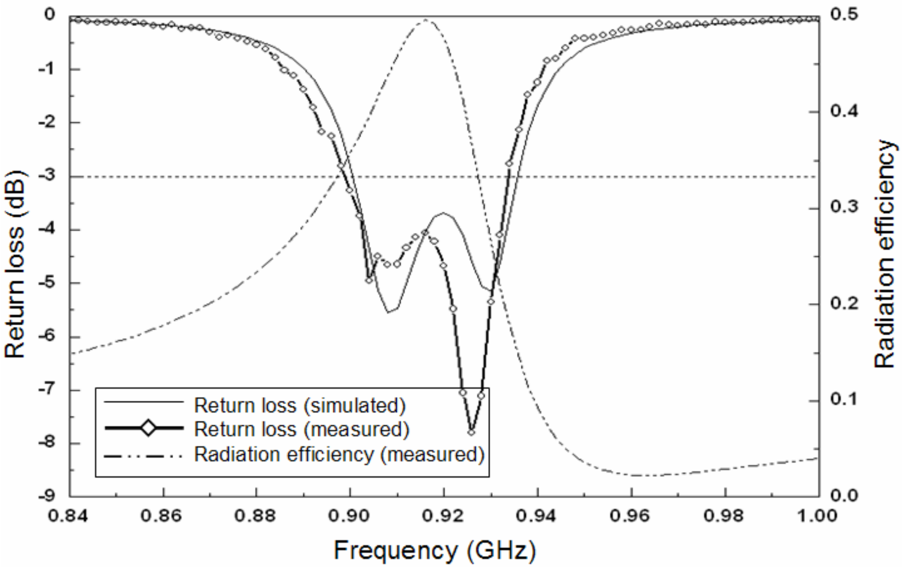


Figure 3: Return loss and radiation efficiency

The return loss and efficiency of the prototype antenna are shown in Figure 3. The simulation was performed with an infinite ground. However, the measurement was completed by using a 400 mm × 400 mm copper plate, whose length is large enough to function as an infinite ground plane. The simulation result at the reference level of 3 dB return loss was 34 MHz (901~935 MHz) and the measured result at the same reference level was 35 MHz (898~933 MHz). Both results cover the designated frequency bandwidth (902~928 MHz) in North America. The radiation efficiency is 30~50 % within the 902~928 MHz and 20~50 % within the simulated 3 dB return loss. Therefore, the prototype antenna can be operated continually in the 902~928 MHz range.

4. Conclusion

A novel small wideband antenna mountable on metallic surfaces which is using a modified proximity-coupled feeding structure has been proposed and measured for RFID tags mounted on metallic surfaces. Using the proposed feeding method, the tag antenna was fabricated easily for various chip impedances. The prototype antenna is small (47 mm × 45 mm × 1.52 mm) and has wide bandwidth (35 MHz), which covers the bandwidth for RFIDs in North America.

References

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