A Long Range Passive RFID Tag Antenna for Some Special Applications

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Abstract

We have proposed a new passive RFID tag antenna design methodology using field-coupling between the tag and a metallic cavity. Our tag antenna shows a reading distance longer than 20 m under a 36 dBm transmission power, which is obviously very long at a 900 MHz frequency band.

Keywords : RFID Tag antenna Coupling effect Metallic cavity

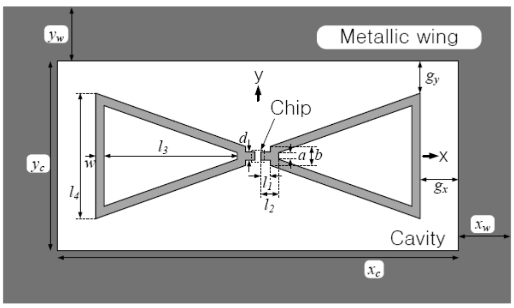
1. Introduction

An RFID industry has been continuously developing in terms of both quantity and quality including various applications areas such as stock control, tracking goods in the line of product or the supply chain, and security management, etc [1]. To show good performance in such various application areas, one of the important abilities needed for an RFID tag antenna is its tolerance and identification efficiency for a diversity of platform materials. In practice, a high-dielectric material or a metallic body are well-known as big challenges for exact identification at a practical distance [2, 3]. To solve that problem, we proposed a low-profile passive UHF tag with an artificial magnetic conductor (AMC) ground plane, which showed good and stable performance on both a plastic container filled with water and a large aluminium plate [3, 4].

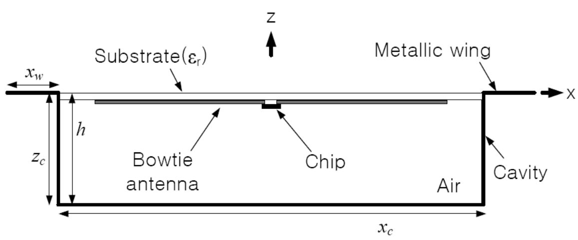
In this paper, we propose a new concept of an impedance matching method directly applicable to the design of RFID tag antennas. Main application targets are relatively big metallic objects such as metallic containers, vehicles, airplanes, etc.

2. Antenna design and performance evaluation

Figure 1 shows the geometry of a proposed tag antenna structure. A bowtie-shaped tag antenna is located on top of a recessed volume of a cavity filled with an air. A strap type Higgs-2 chip fabricated from Alien Technology co. is attached in-between the two bowtie arms. The chip impedance is about 11-j130Ω at 910MHz.



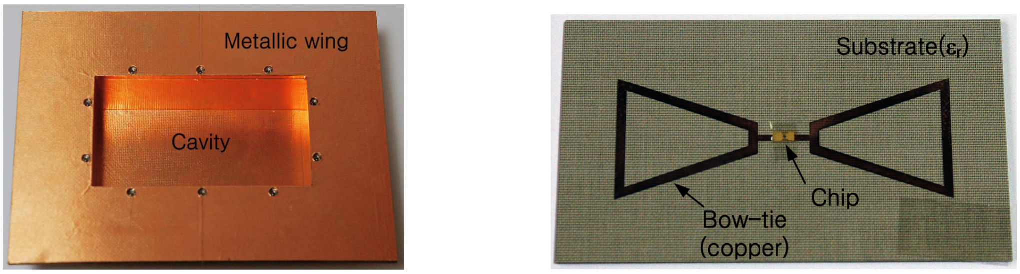
(a) Top view of the tag



(b) Cut view of the tag

Figure 1: Geometry of a proposed RFID tag antenna with a = 5 mm, b = 10 mm, d= 2mm, l_1 = 5 mm, l_2 = 8 mm, l_3 = 44.5 mm, l_4 = 38 mm, w = 3 mm, g_x = 13.5 mm, g_y = 21 mm, x_c = 140 mm, y_c = 80 mm, x_w=y_w=50 mm, and ε_r =4.5.

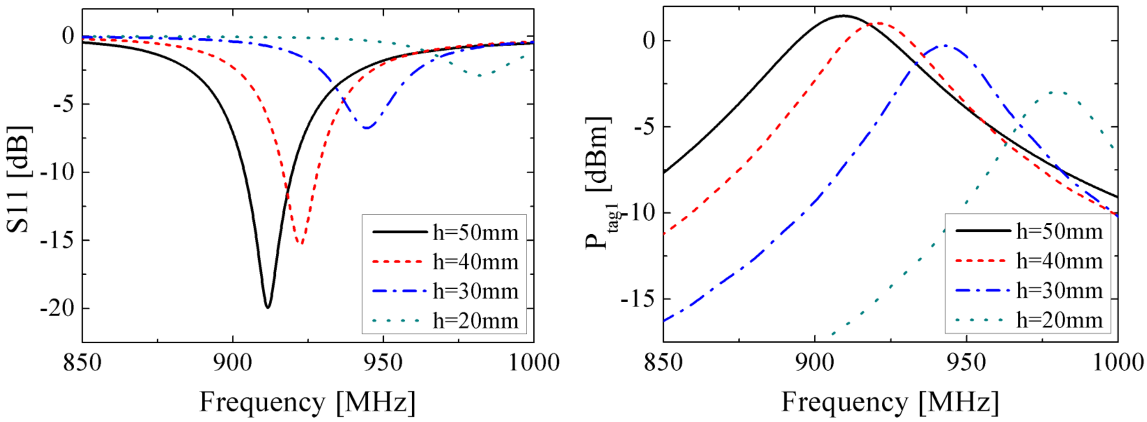
To alleviate possible impedance changes that might be caused by attaching the tag on various platform materials, and to make it easier to install our tag on large metallic bodies, we intentionally included the four metallic wings in our tag design. The fabricated cavity and the bowtie tag are shown in Fig. 2.



(a) Metallic cavity (b) Bow tie tag

Figure 2: Fabricated tag antenna structure.

As was shown in Fig. 2, the geometry of our tag is very simple and there are not many design parameters that raises the successful impedance matching possibility much higher. Instead of following a conventional way, we suggest a new impedance tuning process using a coupling effect between the bowtie tag and the cavity. To do that, we have analyzed the effect of antenna height (h) on antenna performance, which is shown in Fig. 3.



(a) S_{11} (b) Induced power on the chip

Figure 3: Effect of antenna height (h) on the antenna performance.

Figure 3 tells us that the higher antenna height (h) gives the better antenna performance especially in the sense of a reading distance. At h = 50mm, the input impedance of the tag is 13.8+j131Ω, which yields S_{11} = -20 dB and realized gain of about 7.1 dB. In Fig. 3, to calculate the induced power on the chip, we assumed an x-polarized plane wave with electric field strength of 1V/m, which emulates a reader antenna signal. The maximum received power is 1.44 dBm.

To see the effect of a cavity size on the tag performance, we have changed x_c and y_c, and analyzed an S_{11} parameter. The result is given in Fig. 4. From Fig. 4, we have found that changing each cavity length of x_c and y_c yields opposite result in the variation of a resonant frequency. In other words, while the longer y_c lowers the resonant frequency, the longer x_c raises it. It is obvious that the effect of the cavity size together with the cavity height can be of great importance in impedance matching procedure.

To compare the reading distance of our tag with that of a reference commercial ALN-9540 tag from Alien Technology Co., we derived a simple but very useful formula describing the difference in reading distances like the following [5]:

$$\Delta_d = 10^{\left[\left(P_{ref}+G_{ref}-P_{tag1}-G_{tag1}\right)/20\right]}. \quad (1)$$

In (1), P_{ref} and P_{tag1} are powers at the reference and the proposed RFID tag antenna terminals, and G_{ref} and G_{tag1} are gain of the two antennas. Based on the values of P_{ref} and G_{ref} of the reference ALN-9540 tag, which are computed from a 3D simulation, we observe that our tag shows about a three times longer reading distance. See table 1 for detailed results.

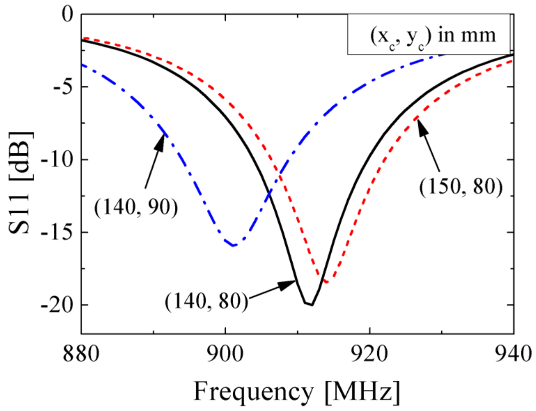
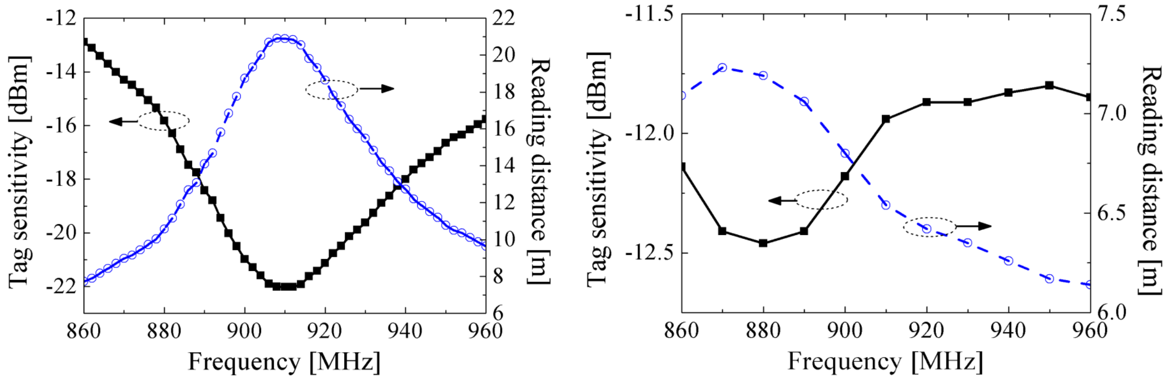


Figure 4: Effect of a cavity size on the antenna performance

Figure 5 shows the experimental results of tag sensitivity and a reading distance. We used a commercial TESCOM TC-2600A RFID tester with ALR-9800 reader with 36 dBm transmission power. As was previously expected using (1), we can confirm that the reading distance of our tag is about three times longer than that of the reference tag.



(a) Proposed tag (b) Commercial ALN-9540 tag

Figure 5: Experimental results for the sensitivity and reading distance

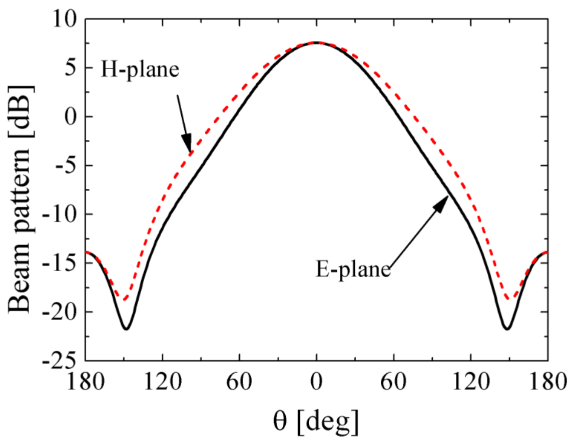


Figure 6: Radiation pattern of the proposed tag

Radiation pattern of the proposed antenna is computed in Fig. 6. The 3 dB beam width in E- and H-plane is 76° and 93°, respectively.

3. Conclusions

We have proposed a long-range passive UHF RFID tag antenna and a new impedance matching idea using a coupling effect. By installing the simple bowtie-shaped tag inside the metallic cavity, we have shown that the impedance matching process can be much simplified by using the coupling effect between the tag and the cavity, which is totally different from the conventional approaches. Our tag shows very long reading distance in 910 MHz frequency band, which is about 3.1 times longer than the identification distance of the reference commercial tag.

Table 1: Experimental result

	Experiment		Simulation			
	Min. Sensitivity	Max. reading distance	Max. realized gain	Best matching (Min. VSWR)	Max. induced power	Distance increase (relative range)
Proposed tag	-22.02 dBm	20.9 m	7.1 dB	1.22 At 912 MHz	1.44 dBm	3.1
Alien ALN-9540	-11.94 dBm	6.5 m	2.1 dB	1.1 at 915 MHz	-3.67 dBm	1.0 (reference)

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