Long Range UHF RFID Tag with a Rectangular Metallic Cavity Structure

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Abstract

A long range UHF RFID tag with a rectangular metallic cavity structure is proposed for various applications with metallic objects. The proposed tag consists of a rectangular metallic cavity structure and a folded dipole antenna which is located on top of the cavity. The tag is designed for Korean UHF RFID band(910～914 MHz) and the bandwidth, which satisfies the －10 dB input reflection coefficient requirement, is approximately 1.3 %(904～916 MHz). Measurement demonstrates that the proposed tag shows long reading range up to 15 m when it is placed on a metallic plate.

Key words: RFID, UHF, Tag, Long Range, Metallic Cavity.

Ⅰ. Introduction

As a rapidly developing technology in automatic identification and data capture(AIDC) industries, radio frequency identification(RFID) has been increasingly used in many applications such as supply chain management, inventory control, security management, and logistics[1]. To meet the requirements for these applications, RFID tags need to be attached on various objects with different shapes and material properties. Therefore, an RFID tag antenna that is attached to a target object plays a crucial role in determining the overall performance of an RFID system. A big challenge in designing a tag antenna is to alleviate the influence of material properties of objects and the presence of other object near the tag[2],[3]. This effect is most severe in UHF band for metallic objects.

Planar inverted-F type antennas have been most widely used for applications with metallic objects because they have their own ground planes with which a variation of input impedance can be minimized[4]. In some applications with large metallic objects such as containers, airplanes, ammunitions, and heavy equipment, the reading range should be appropriately extended because the reader and the tag attached on the objects would be remotely located. Therefore, to extend the reading range, an antenna structure providing higher gain should be applied as the tag. Arrays, EBG substrates, and superstrates have been used widely in various applications to increase the gain of antennas[5].

In this paper, we propose a long range UHF RFID tag with a rectangular metallic cavity structure, which is applicable to metallic objects. It is comprised of a folded dipole antenna placed on top of a rectangular metallic cavity structure. The input reflection coefficient, the input impedance, the realized gain, and the radiation pattern of the proposed tag are compared with those of the free standing folded dipole tag and the proposed tag with a metal plate. All simulation data are obtained using CST Microwave Studio[7].

Ⅱ. Design of a Long Range RFID Tag with a Rectangular Metallic Cavity

The geometry of a proposed tag antenna with a rectangular metallic cavity structure is shown in Fig. 1. A folded dipole type antenna printed on FR4($\varepsilon \fallingdotseq 4.5$) substrate is placed on top of the cavity structure with air spacing between the dipole antenna and the bottom of the cavity. The thickness of the FR4 substrate(=h_{sub}) is 2 mm and the air spacing is 29 mm. The reference chip impedance of the tag antenna is $13-j133\,\Omega$ of Alien Higgs strap. The designed values of the geometrical parameters of the proposed tag shown in Fig. 1 are as follows: cavity length l_c=176 mm, cavity width w_c=61 mm, cavity height h_c=31 mm, tag length l_t=136.4 mm, tag width w_t=12 mm, slot length l_s=66.4 mm, and slot width w_s=4 mm.

Fig. 2 shows the input reflection coefficient characteristics of the folded dipole tag without a cavity, the proposed tag antenna, and its placement on a metallic plate, respectively. The input reflection coefficient is computed

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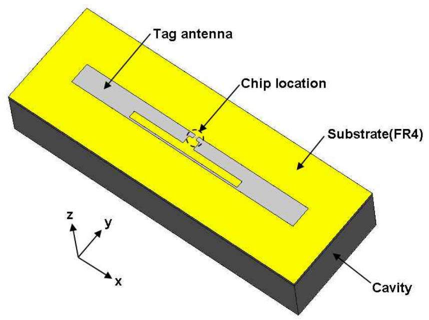
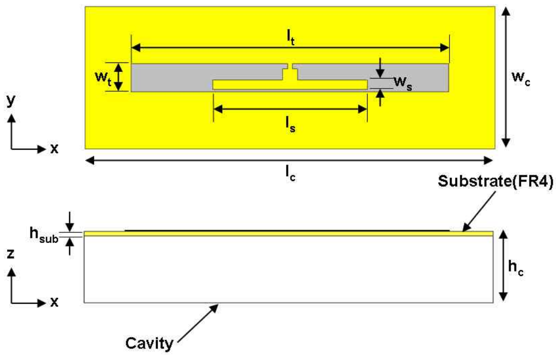


(a) 3D view



(b) Top and side views

Fig. 1. Geometry of a proposed tag.

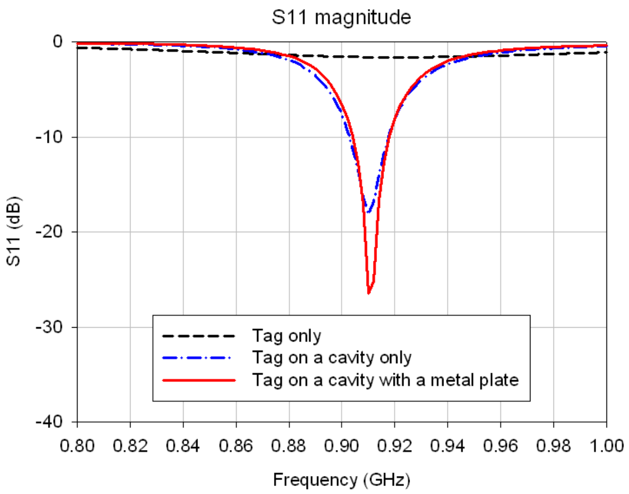
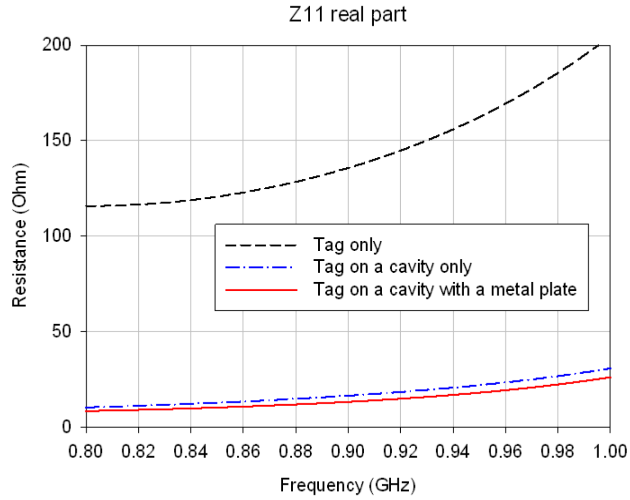
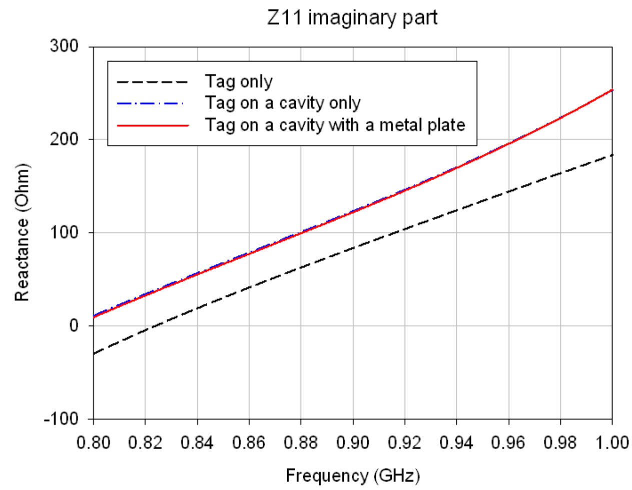


Fig. 2. Simulated input reflection coefficients of the folded dipole tag without a cavity, the proposed tag antenna, and the proposed tag antenna with a metal plate.

with the assumption that the chip is substituted with a feeding discrete port with a reference resistance of 13 Ω and serially connected to a capacitor of 1.315 pF, which gives reactance of about $-j133\Omega$ at 910 MHz. The length and the width of the metallic plate are 400 mm and 200 mm, respectively. The input reflection coefficient of the folded dipole tag without the cavity is not matched to the input impedance of the tag, but it be-



(a) Real part



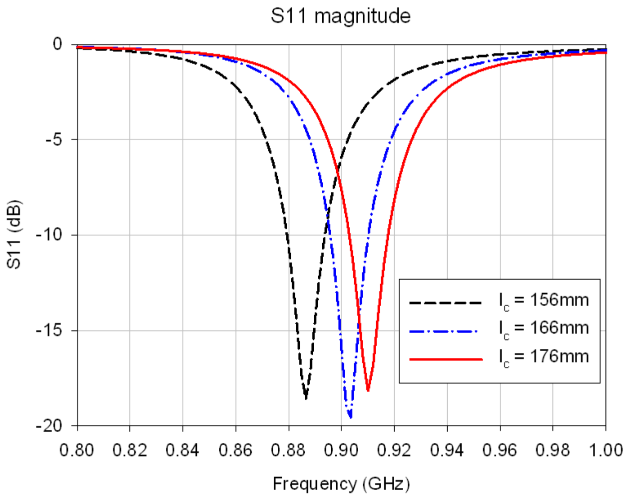
(b) Imaginary part

Fig. 3. Input impedance comparison of the folded dipole tag without a cavity, the proposed tag antenna, and the proposed tag antenna with a metal plate.

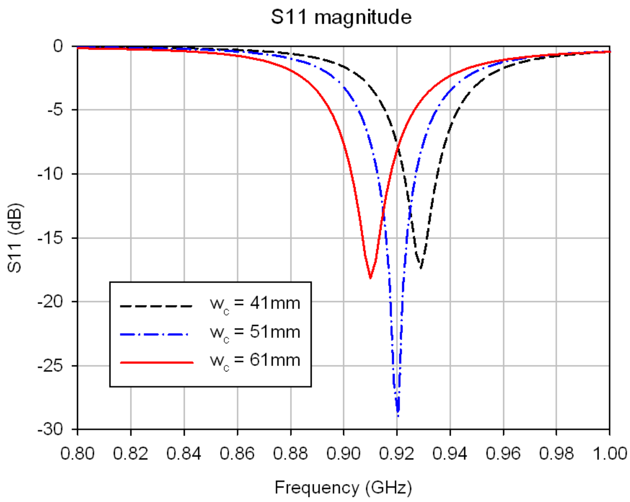
comes well matched when it is placed on the cavity. Note that the input reflection coefficient at around 910 MHz is further improved when the cavity is placed on the metallic plate.

The real and imaginary parts of the input impedance for the folded dipole tag without a cavity, the proposed tag antenna, and its placement on a metallic plate, respectively, are compared in Fig. 3. The simulated values of the input impedance at 910 MHz for the three cases are $140+j94$ Ω, $17.4+j134.8$ Ω, $14+j133.8$ Ω, respectively. We see that the real part of the input impedance becomes closer to that of the tag chip when the proposed tag is placed on the metallic plate.

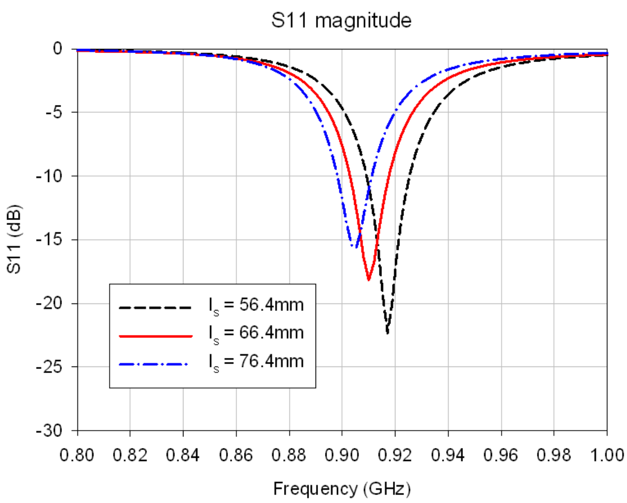
Next, Figs. 4(a), (b), and (c) show the variation of the S_{11} characteristic of the proposed tag when the cavity length(l_c), the cavity width(w_c), and the slot length(l_s) of



(a) Cavity length



(b) Cavity width



(c) Slot length

Fig. 4. Variation of the S_{11} characteristic of the proposed tag when the cavity length(l_c), the cavity width(w_c), and the slot length(l_s) of the folded dipole antenna are changed.

the folded dipole antenna are changed, respectively. It is observed that the resonant frequency of the tag moves toward low frequency as the cavity length decreases, while it shifts toward high frequency when the cavity width decreases. This phenomenon can be explained by the coupling between the folded antenna and the side walls of the cavity. The coupling between the folded antenna and the cavity's side walls becomes weaker as the cavity length increases, and, therefore, the resonant frequency of the tag with the cavity shifts toward high frequency because the coupling capacitance decreases. In addition, the resonant frequency moves toward high frequency as the slot length decreases. From this investigation, we see that the resonant frequency of the tag can be adjusted by varying the cavity length, the cavity width or the slot length.

To further investigate the reason for the behaviors shown in Fig. 4, the surface current distribution of the tag at 910 MHz is plotted in Fig. 5. We observe that the surface current is concentrated on the folded dipole antenna and the four side walls of the cavity. The coupling between the folded dipole antenna and the cavity side walls are very important for the impedance matching of the tag.

Fig. 6 shows the simulated realized gain of the folded dipole tag without a cavity, the proposed tag antenna, and its placement on a metallic plate, respectively. The realized gain values for these three cases at 910 MHz are −2.71 dBi, 6.25 dBi, and 7.3 dBi, respectively.

The radiation patterns(realized gain) of the proposed antenna for E- and H-planes are plotted in Fig. 7, and are compared with those of the folded dipole tag without the cavity and when it is placed on a metallic plate. It is observed that the front-to-back ratio of the proposed tag is increased when it is located on the metallic plate.

Ⅲ. Fabrication and Measurement

The proposed tag is fabricated as shown in Fig. 8. It consists of a folded dipole type antenna printed on the FR4 substrate and a cavity structure. The modified di-

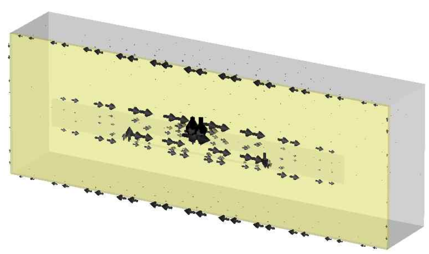


Fig. 5. Surface current distribution of the tag at 910 MHz.

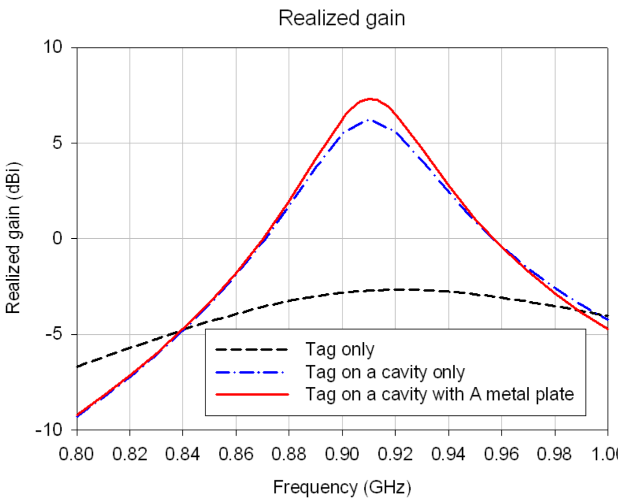


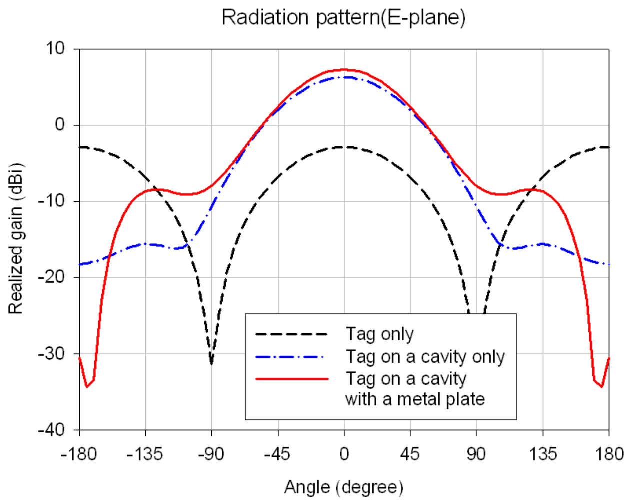
Fig. 6. Comparison of the realized gain of the foled dipole tag without a cavity, the proposed tag antenna, and the proposed tag antenna with a metal plate.

pole antenna is placed on top of the cavity with air spacing inside.

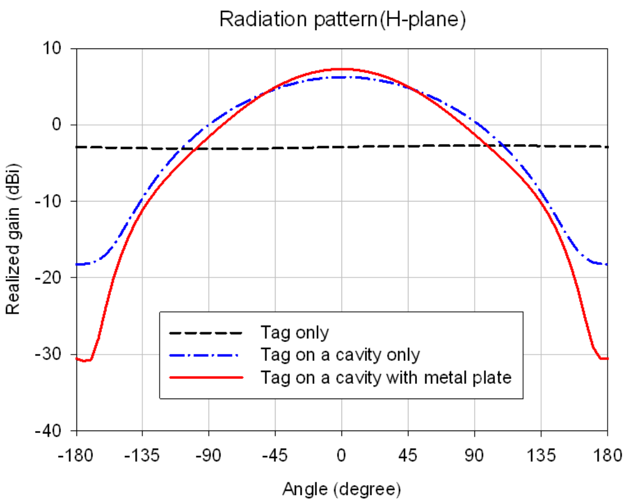
The reading range of the tag is measured at the UHF RFID anechoic chamber in RFID/USN Center, Incheon, Korea. At the reading range measurement of the tag, a reader of ALR-9800(Kor) from Alien Co. with 1 W power is used; the reader antenna used is ALR-9600 with 6 dBi gain. The EIRP of the reader system is 4 W. The maximum reading range of the proposed tag is measured to as 11 m in free space and 15 m when attached to a metal plate(400×200 mm^2), respectively. The measured reading range of the proposed tag in free space and when it is placed on the metal plate are compared with that of a commercial metal tag in free space and on the metal plate in Fig. 9. The commercial metal tag used as a reference is Albatross II Tag(P09717-37NMC) from Sontec Ltd., Korea, and the dimension of it is 97×17 ×3.7mm^3 [8]. The vertical axis in the plot is the reading number per 2 seconds, which means that 19 to 20 reader-to-tag communications have successfully been performed and this guarantees a continuous reading in the reader. We see that the reading range of the proposed tag is increased about 2.75 times in the free standing case and about 3 times when the tag is placed on a metal plate, respectively, compared to that of the commercial metal tag.

Fig. 10 shows the reading range patterns of the proposed tag in free space and when it is placed on the metal plate for E-plane, which looks very similar to the cases of the radiation patterns. In Figs. 9 and 10, 'UUMT 002' is the model name of the proposed antenna used for the data recording purpose of the measurement.

Table 1 shows the comparison of the predicted and



(a) E-plane



(b) H-plane

Fig. 7. Radiation patterns of the foled dipole tag without the cavity, the proposed tag antenna, and the proposed tag antenna on a metal plate.

Fig. 8. Photograph of the fabricated tag antenna.

the measured reading ranges of the proposed antenna with and without the metal plate. For the calculation of

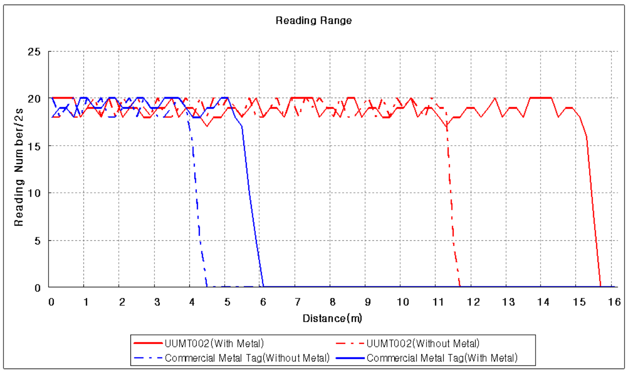


Fig. 9. Measured reading range of the proposed tag in free space and when it is placed on the metal plate.

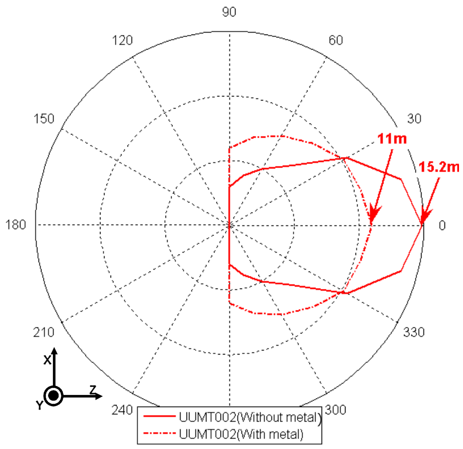


Fig. 10. Reading range patterns of the proposed tag in free space and when it is placed on the metal plate.

the predicted read range, a formula shown in [6] is used and −14 dBm(sensitivity of Alien Higgs strap) is used for the minimum threshold power necessary to provide enough power to the RFID tag chip. The predicted reading ranges of the proposed antenna with and without the metal plate are 19.2 m and 16.8 m, respectively, while the measured reading ranges are 15.2 m and 11 m, respectively. The discrepancy between the predicted and the measured reading ranges might result from a difference in input reflection coefficients and realized gain between the simulated and the fabricated antennas.

Ⅳ. Conclusion

In this paper, we have presented a long range UHF RFID tag with a rectangular metallic cavity structure for Korean UHF RFID band. The proposed tag consists of a folded dipole antenna placed on top of the cavity structure. The proposed tag shows a long reading range up to 15 m when it is placed on a metallic plate, so it will be useful for various applications requiring a long reading range.

Table 1. Comparison of the predicted and the measured read range of the proposed antenna with and without the metal plate

	Read range (m)	
	Predicted	Measured
Without the metal plate	16.8	11
With the metal plate	19.2	15.2

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