3A3-1

Design of a small wideband RFID tag antenna of metallic objects

#S.H. Lim, Y.C. Oh, H. Lim, K.U. Bae, and N.H. Myung

School of Electrical Engineering and Computer Science
Korea Advanced Institute of Science and Technology (KAIST)
373-1 Guseong-dong, Yuseong-gu, Daejeon 305-701, Korea, limsangho@kaist.ac.kr

1. Introduction

In recent years, the advancement of Radio Frequency Identification (RFID) systems has rapidly increased to realize ubiquitous communications environment. RFID systems can be used in automatically identifying objects such as animals, men, goods, and etc. Requirement for long-range identification has enlarged and it has raised the RFID frequency region into the microwave region. Due to the moved up RFID frequency, an adequate design of antennas becomes more important to maximize the performance of RFID systems. In lots of practical applications, RFID tag antennas need to be mounted on metallic objects. In such a case, antenna characteristics such as impedance, pattern, and radiation efficiency are remarkably affected by those which antenna is placed on. Especially typical dipole-like label-type tag antennas do not operate well on metallic objects. Hence, RFID tag antennas should be designed with considering the effects.

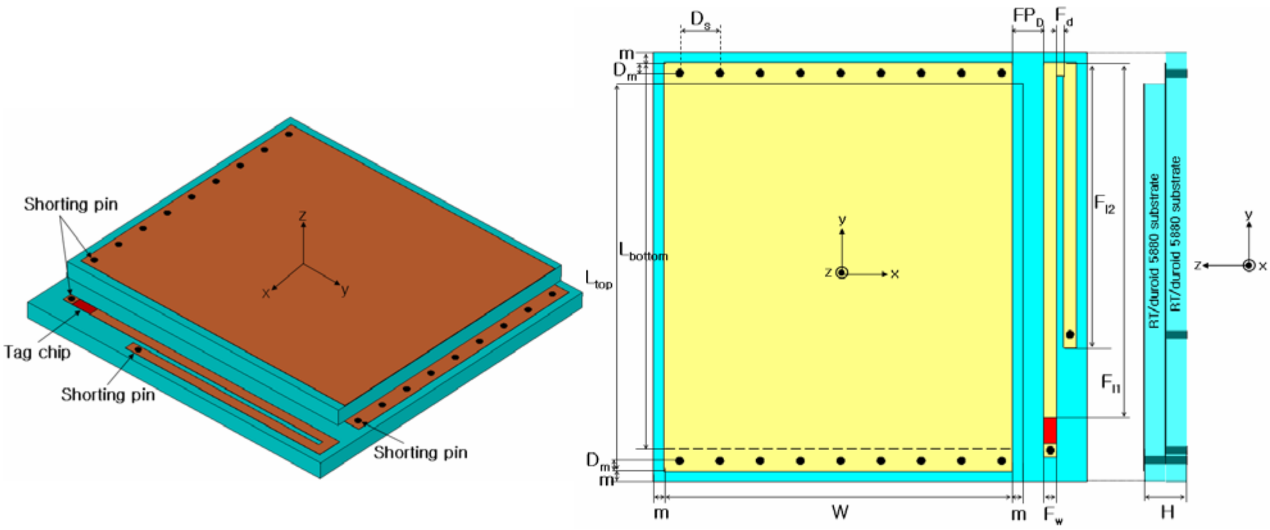
To solve this problem, several researches on tag antennas of metallic objects have been proposed and discussed. The tag antenna by using planar inverted-F antennas (PIFAs) or EBG ground plane is widely used but its half-power bandwidth is too narrow (15 ~ 21 MHz) at operating frequency [1,2]. Even through the PIFA antenna with L-shaped slit has wide bandwidth, its size is large (90 x 54 x 5 mm^3) [3]. So the small sized antenna which has bandwidth of at least 26 MHz (902 ~ 928 MHz) for continual use in North America is highly desirable. Due to the RFID tag chips which have big capacitance and small resistance, it is difficult to get wide bandwidth. A novel proximity-coupled feed structure has proposed to easily design RFID tag antenna with guaranteeing wide bandwidth (57 MHz). It provides convenient way to match between an antenna and a tag chip, but its size is relatively large (74.5 x 24.5 x 3 mm^3) [4]. In conventional micro strip patch antenna, the length of the patch is generally $\lambda_g/2$, but it can be reduced $\lambda_g/8$ by using the technique of folded shorted-patch antenna [5]. In this paper, we present a design of a small wideband RFID tag antenna of metallic objects by using the novel proximity-coupled feed structure and the technique of folded shorted-patch antenna.

2. Antenna structure and design

Fig. 1 is the proposed antenna structure which has proximity-coupled feeding part and radiating part with double folded shorted-patch antenna. Both parts are fabricated on RT/duroid 5880 substrate (ε_r =2.2, $\tan\delta$ = 0.0009, h=1.6 mm). Fig. 1(a) shows 3-dimensional geometry of the antenna and Fig. 1(b) shows x-y plane view and y-z plane view. The radiating part consists of the bottom patch with length L_{bottom}, width W, and top patch with length L_{top}, width W. The patches are connected to the ground by using shorting pins with a distance D_s between pins. The resonance frequency of the radiating structure can be easily adjusted by varying the length of bottom or top patch and the difference D_m between the edge of a patch and the centre of a shorting pin. The feeding part (width F_w, length F_{l1}, F_{l2} and a space F_d between main-feed line and sub-feed line) is a banded transmission line. The edge of the sub-feed line is shorted to the ground via a shorting pin and the tag chip is placed between the edge of the main feed line and the pad shorted to the ground via a shorting pin. To deliver maximum power to the tag chip, the antenna is conjugated matched to the tag chip. Thus feeding part can be used to cancel the high capacitance of the tag chip by changing the length F_{l1}, F_{l2}. The inductance of the feeding part is approximately estimated using

ISBN: 978-4-88552-223-9 C3055©IEICE

the shorted-ended transmission line theory and can be readily obtained with the change of the length F_{l1}, F_{l2}. The radiating part is separated from the feeding part by the FP_D, and its location is parallel to the feeding part. The real part of the antenna impedance is easily adjusted by varying the distance FP_D. The margin m is used to reduce practical fabrication errors. This small antenna structure has successfully the impedance capable of transferring maximum power delivery to the tag chip with changing the length of the feeding part and distance FP_D.



(a) 3-dimensional geometry of the antenna (b) x-y plane view and y-z plane view

Figure 1: Antenna Structure

3. Simulation and measurement results

The tag antenna is designed to be matched to the tag chip which has impedance, 6.2-j127Ω [4]. To obtain the resonance frequency at 915 MHz as the centre frequency between 902 MHz and 928 MHz for use in North America, the top and bottom length of the patch are 29.5 mm (approximately $\lambda_g/8$), and the difference D_m between the edge of a patch and the centre of a shorting pin is 0.8mm. Although the width W does not nearly affect the resonance frequency, it is set 26.5 mm to gain the appropriate radiation efficiency. The feeding part length F_{l1} and F_{l2} are 27 mm, 21.7 mm respectively, the feeding part width F_w is 1 mm and the space F_d between main-feed line and sub-feed line is 0.5 mm to get an inductance, j127Ω at 915 MHz for cancelling the tag chip's capacitance. The distance FP_D between the radiating part and the feeding part is 2.4 mm to get a resistance, 6.2Ω at 915MHz and the margin m is 0.8mm. The simulation results (impedance, return loss, and radiation efficiency) of the tag antenna were obtained by using HFSS under the assumption that the tag antenna is placed on infinite ground. However the measurement was performed by using 400 x 400 mm^2 copper plate due to impossible realization of an infinite ground.

3.1 Return loss and radiation efficiency

Fig. 2 shows the wideband characteristic of the tag antenna and radiation efficiency. The simulated result of 3-dB bandwidth is 40 MHz (898 ~ 938 MHz) and the measured result is 46 MHz (896 ~ 942 MHz). Both results are satisfied with the assigned frequency bandwidth (902 ~ 928 MHz) for use in North America. The simulated radiation efficiency is 25~58 % within the frequency bandwidth (902 ~ 928 MHz). Hence the prototype tag antenna can be used constantly.

3.2 Radiation patterns

To maximize a read range, the tag antenna needs to be directly faced with a reader. In many cases, because it is impossible to always satisfy this condition, the tag antenna should have an omni-directional characteristic. Fig. 3(a) shows the radiation pattern of x-y plane (θ=90°, 0°≤φ≤360°) and fig. 3(b) shows the radiation pattern of z-x plane (θ=0°, -180°≤ θ ≤180°). The characteristics show the omni-directional pattern.

3.3 Peak gain and read range

$$read\ range(m) = \frac{\lambda}{4\pi}\sqrt{\frac{P_r G_r G_{tag}}{P_{th,tag}}(1-|\Gamma_{tag}|^2)|\rho_r \rho_{tag}|} \quad (1)$$

The read range (1) can be calculated by using the Friis transmission equation. The λ is the wave length of the centre frequency (915 MHz) and the P_r and G_r are power and gain of a reader. The $P_{th,tag}$ and G_r are threshold voltage of the tag chip and gain of the tag antenna. The Γ_{tag} is the reflection coefficient between the tag chip and the tag antenna and the $|\rho_r \rho_{tag}|$ is polarization loss. The polarization loss of a reader antenna which has circular polarization is 0.5 and the reflection coefficient is 0.707 aimed at half-power bandwidth. Usually the threshold voltage of the tag chip is -10 dBm. The wave length can be calculated and the gain of the tag antenna can be obtained through a simulation. If assuming power and gain of a reader are 1 W (30 dBm) and 5.9 dBi, the read range can be calculated. The peak gain is -3 ~ 0.94 dB and the read range is 1.8 ~ 2.7 m within the bandwidth (902 ~ 928 MHz) in simulation.

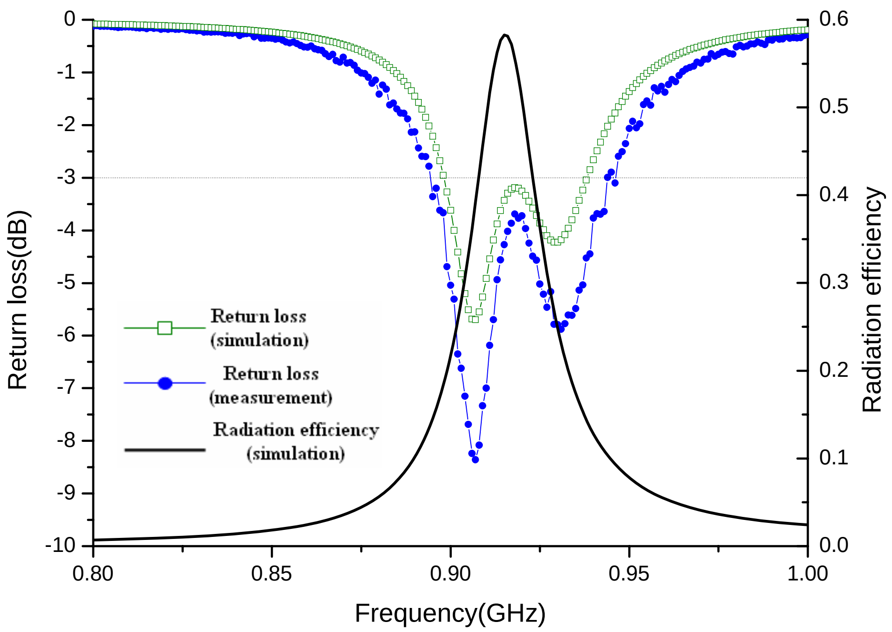
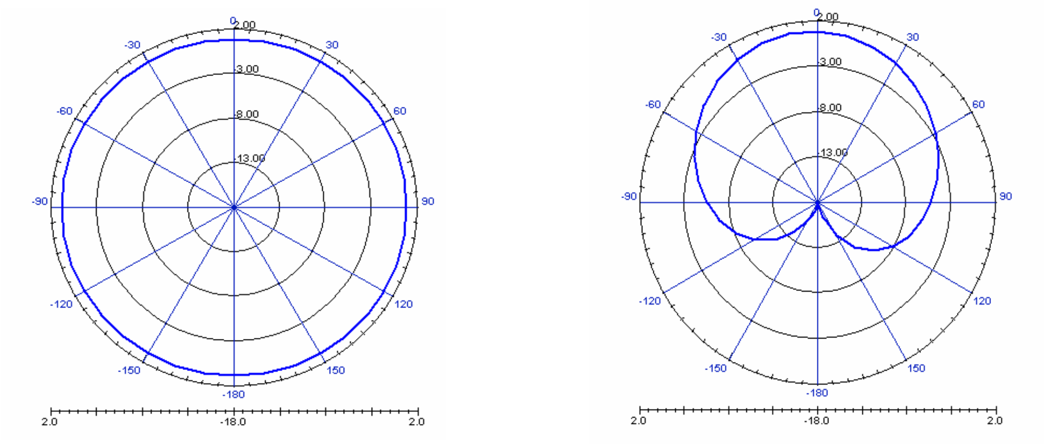


Figure 2: Return loss and radiation efficiency



(a) x-y plane (b) z-x plane

Figure 3: Radiation patterns

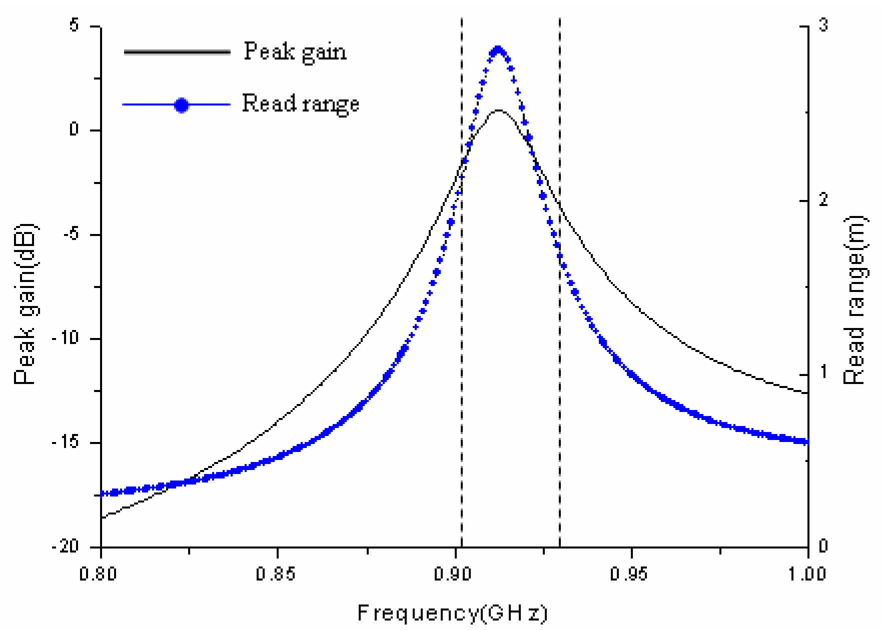


Figure 4: Peak gain and read range

4. Conclusion

A small wideband RFID tag antenna of metallic objects by using the novel proximity-coupled feed structure and the technique of folded shorted-patch antenna has been proposed. For use of the feed structure, it is easy to match to the complex impedance of a tag chip and for use of the double folded-shorted patch antenna structure, the small size antenna (approximately $\lambda_g/8$) could be obtained (33 x 32.7 x 3.2 mm^3). The prototype antenna has wide 3dB bandwidth of 46 MHz, omni-directional characteristic, and 1.8 m read range at least within the designated bandwidth (902 ~ 928 MHz).

Acknowledgments

This research was supported by KAIST BK 21(Brain Korea 21), and ADD (Agency for Defence Development) through the RDRC (Radiowave Detection Research Center) at KAIST.

References

[1] M.Hirvonen, P. Pursula, K. Jaakkola and K. Laukkanen, "Planar inverted-F antenna for radio frequency identification", *Electron. Lett.*, vol. 40, No. 14, pp. 848-850, 2004.
[2] L. Ukkonen, L. Syda¨nheimo and M. Kivikoski, "Patch antenna with EBG ground plane and two-layer substrate for passive RFID of metallic objects", *IEEE Antennas and Propagation Society Int. Sym.*, Vol. 1, Monterey, CA, USA, pp. 93-96, 2004.
[3] S.-J. Kim, B.-K Yu, H.-J Lee, M.-J. Park, F.J. Harackiewicz and B.-J. Lee, "RFID tag antenna mountable on metallic plates", *APMC 2005*, Dec. 4-7, 2005.
[4] H.-W. Son, G.-Y. Choi and C-S. Pyo, "Design of wideband RFID tag antenna for metallic surfaces', *Electron. Lett.*, vol. 42, No. 5, pp. 263-265, 2006.
[5] Li RongLin, Dejean Gerald, M.Tentzeris Manos and Laskar. Joy "Development and analysis of a Folded Shorted-Patch Antenna With Reduced Size", *IEEE Transactions on Antennas and Propagation,* Vol. 52, No.2, pp. 555 – 652, February 2004.