Advanced Design of RFID Tag Antennas using Artificial Magnetic Conductors

Dongho Kim
Department of Electronic Engineering, Sejong University, 209, Neungdong-ro, Gwangjin-gu, Seoul, Korea
dongkim@sejong.ac.kr

***Abstract* – We summarize a successful method to increase reading distances of passive radio frequency identification (RFID) tag antennas, which is integrated with an artificial magnetic conductor (AMC) ground plane. By introducing the AMC ground plane, our tags become insensitive to target platform materials. In other words, our tags can be directly attached onto metal or dielectric materials with high permittivity with almost no degradation in their performance. In addition, using the reflection phase variation property of the AMC, we can increase a recognition distance and reduce overall height of the tag antenna, remarkably.**

***Index Terms* — RFID, Tag antenna, AMC, Reading distance, Low-profile.**

I. Introduction

We can find a variety of RFID applications in our daily lives such as transportation payment, asset management, product tracking, etc.

One of the major drawbacks of conventional RFID tag antennas is limitation on target tagging materials or platforms. Dielectrics with high permittivity and metallic objects are typical materials on which the RFID tag is hardly recognizable by readers [1].

To solve the problem, many approaches have been attempted using a planar inverted F antenna or an AMC ground plane [2] - [6]. Among those approaches, we focus on the AMC technique and summarize design steps of tag antennas.

II. Design of a Tag Antenna using AMCs

Figure 1 shows general operation environment of RFID tag antennas. In the figure, the metallic or the AMC ground planes can be interpreted as target platform materials (or products) that should be recognized by reader systems. When the tag is brought to near the metallic surface, the reflected wave from the surface interferes with the direct wave radiated from the tag, which causes strong destructive interference between them because of the reversed phase response of the metallic object. Therefore, if the distance (h) far much reduced, then the current flowing on the tag would be shorted out. Consequently, the tag cannot be identified by a reader system any more.

Now, let us consider Fig. 1(b) in which the metallic ground is replaced with the AMC ground plane. In this case,

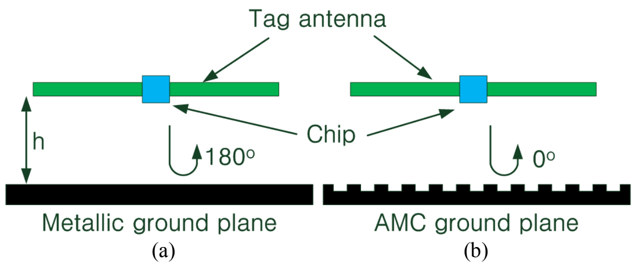


Fig. 1. Scenarios of a RFID tag identification.

reflection phase of the ground becomes 0 at the frequency of interest, which means that even if the tag is located very close to the ground, the current on the tag is not disturbed by the reflected wave. One important merit of this configuration is in the increase of a recognition distance owing to in-phase reflection phase from the AMC ground. Hence, the tag operates very well at a desired target frequency band even with the extended reading distance, which is obviously fairly attractive at some special applications of identifying metallic or high dielectric materials [3].

Another important property of the AMC is in its reflection phase variation behavior, which is shown in Fig. 2. In the

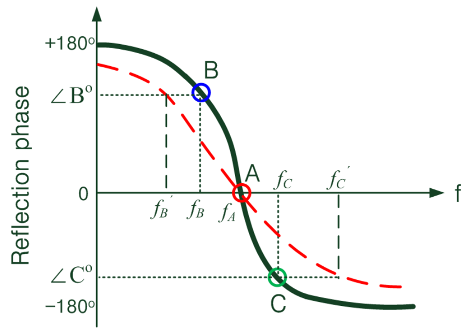


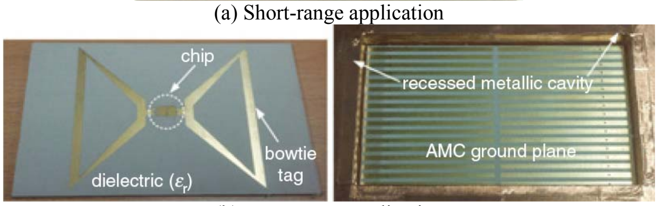
Fig. 2. Typical behavior of reflection phase response of AMCs.

figure, f_A indicates a frequency of zero reflection phase. Similarly, f_B or f_C are frequencies of required phase values of $\angle B^o$ and $\angle C^o$, respectively. Not only f_A, but also f_B or f_C can be used to increase the reading distance of a tag antenna [5, 7]. In this case, phase delay caused by the distance between the tag and the AMC should be carefully treated to maximize constructive interference occurred by cooperative phase state of the reflected wave from the AMC.

We can also transform a single-band tag antenna into a dual-band one just by adjusting the slope of the reflection

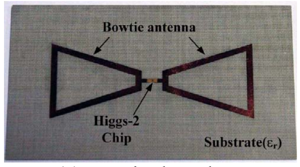
Proceedings of ISAP 2014, Kaohsiung, Taiwan, Dec. 2-5, 2014

(a) Short-range application

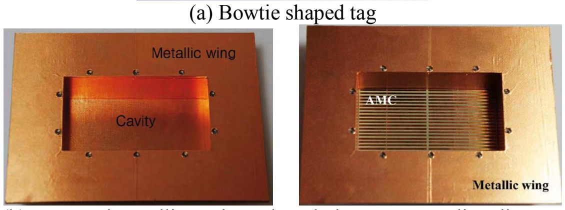


(b) Long-range application

Fig. 3. Low-profile tag antennas installed on AMC ground planes [3, 7].



(a) Bowtie shaped tag



(b) Recessed metallic cavity to largely increase a reading distance

Fig. 4. Long-range single- or dual-band tag antennas installed in metallic cavities with or without an AMC ground plane [5, 6].

phase response and the distance between the tag and the AMC [6].

III. Experimental Verification

Fabricated low-profile tags operating in a 900MHz frequency band are given in Fig. 3. In Fig. 3(a), the meandered dipole tag is installed right on the AMC, but in Fig. 3(b), there is a small gap between the tag and the AMC ground plane. In other words, the tag is located 6.6 mm above the AMC. In Fig. 3(b), both the tag and the AMC are placed in a recessed metallic cavity to increase a reading distance.

At this point, we have to focus on geometrical differences between the two antennas; first, the shape of the tags, second, existence of the cavity, which enables us to design the tag far much simpler than conventional approaches. As a matter of fact, in Fig. 3(b), the tag is a simple bowtie dipole antenna, which is nearly impossible to obtain good impedance matching with the attached Higgs-2 chip whose impedance is 11-j130Ω. However, we can adjust the input impedance of the tag very easily by using coupling effect between the tag and the cavity walls, which is a strong point of our design method.

The measured reading distances of the tag in Fig. 3(a) and (b) are 4.8 m and 12.2 m under the transmission power of 30 dBm through a 6 dBi direction antenna, respectively.

In order to obtain a longer recognition distance, we have enlarged the overall dimension of a metallic cavity, which are shown in Fig. 4. As is in Fig. 3, the bowtie tag is located above the ground plane. Namely, the tag blocks up the top opening of the cavity keeping the required air spacing between the tag and the AMC with thin four acrylic posts.

There are two types of cavities with or without an AMC ground plane. Without the AMC, our tag operates in a single frequency band. But, when we install the AMC, our tag operates in dual bands of European (869 MHz) and Korean (910 MHz) frequency regions. We can make the tag resonate at dual frequency bands by designing the AMC to provide required reflection phase values at two target frequencies. For instance, f_B (or f_B') and f_C (or f_C') in Fig. 3, can be European and Korean frequency bands, respectively. In case that we need more (or less) frequency separation between the target applications, all we should do is just changing the reflection property of the AMC, which can be done by simply tailoring its shape, dimension, etc. The two tags provide more than a 20 m reading distance at the same experimental environment used in Fig. 3.

IV. Conclusion

We summarize a new design method of RFID tag antennas using an AMC, which has been proposed by our research group. The main operational principle of the AMC is that it operates as a reflection phase modulator to maximize constructive interference that enables remarkable improvement in a reading distance. In addition, by setting the AMC to provide appropriate reflection phase values at more than two target frequency bands, we can easily design a dual-band tag. Last but not least improvement in design procedure is simplicity of our approach, which can be achieved by optimizing coupling effect between the tag and the cavity.

Acknowledgment

This work (2014R1A2A2A01007708) was supported by Mid-career Researcher Program through NRF grant funded by the Ministry of Science, ICT and Future Planning (MISP) of Korea.

References

[1] D. K. Cheng, *Fundamentals of Engineering Electromagnetics,* Englewood Cliffs, NJ: Prentice-Hall, 1993, pp. 304-330.

[2] M. Hirvonen, K. Jaakkola, P. Pursula, and J. Saily, "Dual-band platform tolerant antennas for radio-frequency identification," *IEEE Trans. Antennas Propagat.*, vol. 54, no. 9, pp. 2632–2637, Sep. 2006.

[3] D. Kim and J. Yeo, "Low-profile RFID tag antenna using compact AMC substrate for metallic objects," *IEEE Antennas Wireless Propagat. Lett.*, vol. 7, pp. 718–720, 2008.

[4] D. Kim, J. Yeo, and J. I. Choi, "Low-profile platform- tolerant RFID tag with artificial magnetic conductor (AMC)," *Microw. Opt. Tech. Lett.*, vol. 50, no. 9, pp. 2292–2294, 2008.

[5] D. Kim and J. Yeo, "A passive RFID tag antenna installed in a recessed cavity in a metallic platform," *IEEE Trans. Antennas Propagat.*, vol. 58, no. 12, pp. 3814–3820, 2010.

[6] D. Kim and J. Yeo, "Dual-band long range passive RFID tag antenna using an AMC ground plane," *IEEE Trans. Antennas Propagat.*, vol. 60, no. 6, pp. 2620–2626, 2012.

[7] I. Y. Park and D. Kim, "Artificial magnetic conductor loaded long-range passive RFID tag antenna mountable on metallic objects," *Electronics Lett.*, vol. 50, no. 5, pp. 335-335, 2014.