UHF RFID tag antenna for both dielectric and metallic objects

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Abstract

This paper presents a label tag and a radiator for both dielectric and metallic target objects of radio frequency identification (RFID). Good impedance matching is achieved by a cross-shaped loop when it places on dielectric objects and radiating patches, printed on a plastic substrate and a finite ground plane. After optimization and fabrication based on geometrical study, the manufactured tag shows half power bandwidth of 65 MHz (7.1%) and 17 MHz (1.9%), in free space and on the underlying radiator, respectively. Moreover we confirmed reading range of about 8 m in condition of 36 dBm EIRP in UHF RFID frequency band.

Keywords : Cross-shaped Feeding Loop, Impedance Matching

1. Introduction

Recently, passive radio frequency identification (RFID) in the ultra-high frequency (UHF) band has gained popularity as state of art technology due to its superior capability to detect object automatically. Especially the tag antenna in passive RFID systems is one of the most important components in practical applications and should overcome performance degradation from nearby dielectric and metallic materials. To remedy this problem, some research has derived useful T-matching network for various dielectrics [1], where the proposed tag is characterized by almost constant readability on many kinds of dielectric objects. However the suggested label tag has certain limitation in that it cannot works well on metallic objects due to drastically changed antenna characteristics such as operation frequency, radiation efficiency, radiation pattern and input impedance. As another approach, metal-friendly tags including an inserted ground plane have been proposed [2-4]. These antennas consistently operate on diverse dielectric as well as metallic objects because the inserted ground plane can properly get rid of influence from underlying objects. However in terms of configuration, its rigid, bulky and complicated geometry with ground plane not only limits their applicability in soft objects like water and clothes but increases production cost and difficulty of fabrication in the view of the mass production. Therefore the required is a general label tag that is able to operate well on both dielectric and metallic objects.

In this paper, we firstly suggest the novel label-type tag combined with a simple and low cost radiator to overcome afore-mentioned limitation. The proposed tag works not only as a label tag for dielectric objects but also as feeder to activate an underlying radiator using proximity coupling. In design process, we have attained excellent impedance matching both on dielectric and metallic objects by employing the cross-shaped feeding loop of the tag. And we confirmed that vertical and horizontal dimension of the cross-shaped loop are important design factor to adjust antenna impedance by geometrical study

2. Antenna Design

Fig. 1 illustrates overall configuration of the proposed underlying radiator and the tag antenna. Particularly, the suggested underlying radiator for metallic objects consists of both radiating patches and a bottom conductive layer as ground plane in Fig. 1(a). And the proposed tag antenna for a flexible label is basically divided by dipole arms and a cross-shaped feeding loop for

T-matching network in display of Fig. 1(b). Also the antenna, attached to underlying radiator as shown in Fig. 1(b), acts as a feeder of proximity coupling to generate induced current on patches. And thus corresponding surface current causes excitation of electromagnetic wave between patches as like dipole. The proposed antenna is etched on the inexpensive polyethylene (PET, $\varepsilon_r = 3.9$, tanδ = 0.003, thickness = 30 μm) as a flexible substrate and underlying radiating patches are also printed on a plastic substrate ($\varepsilon_r = 2.1$, tanδ = 0.002, thickness = 3 mm). For our research, we employ a commercial microchip (Alien Corporation's Higgs 3) whose measured input impedance (Z_{chip}) and the minimum operating power are 10–j168 Ω and -18 dBm at 912 MHz, respectively.

The proper size and position of the cross-shaped loop geometrically allow the proposed antenna to match with a microchip well since its input impedance is mainly determined by perimeter, namely inductance, of the loop. For case that the antenna is mounted on underlying radiator, the gap (*G*) between radiating patches makes surface current on the feeding loop shortly flow by twice of H_3. And thus the shortened current path consequently results in decrease in series inductance of the loop which efficiently compensates the additional parallel capacitance between radiating patches and bottom conductive layer.

To demonstrate the matching mechanism, Fig. 2 correspondingly exhibits computed input impedance using a commercial electromagnetic field simulator of HFSS (Ansoft) for two cases that both V_1 and V_2 vary and the *G* is only changed in combination with the underlying radiator as shown Fig. 2(b). As size of the cross-shaped loop horizontally increase, namely V_2 reduced and V_1 increase simultaneously, the reactance of the antenna enlarges as shown in Fig. 2(a) while the resistance nearly sustains the same value. Additionally the coupled radiator under the label tag antenna is featured by that the larger gap (*G*) is, hence reduced H_3, the lower self-resonating frequency is by change of both resistance and reactance. This geometrical approach explains that adjustment of only the cross-shaped loop achieves impedance matching easily without major modification of the antenna pattern. As a result, we optimized design parameters as V_1 = 7.5 mm, V_2 = 10.4 mm, *G* = 5 mm and H_3 = 11 mm.

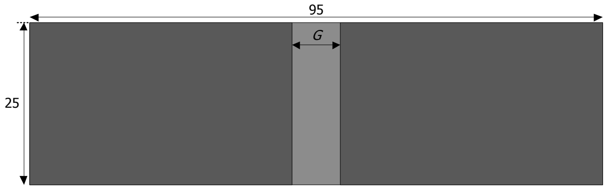
3. Result

To experimentally verify the performance of the proposed tag, the input impedance of the fabricated antenna is measured by using a coaxial balun probe and Agilent vector network analyzer E5071C. Curves on Smith Chart in Fig. 3 represent the measured and simulated impedance of the implemented antenna and the chip impedance, ranging from 612 MHz to 1212 MHz, for the conditions in free space, and combined with the underlying radiator. Even though the simulation and the measurement show a slight deviation for both cases, the overall results clearly exhibit similar fashion to each other. To confirm matching characteristics of the proposed tag, we illustrate power reflection coefficient in Fig. 4 when the tag is in free space and on underlying radiator. The half-power bandwidth (power reflection coefficient < -3 dB) of the proposed tag in measurement are 65 MHz (7.1%), from 848 MHz to 913 MHz, in free space condition, at the same time, 17 MHz (1.9%), from 896 MHz to 913 MHz, on the underlying radiator. Also we consider that the deviation between simulation and measurement comes from parasitic reactive component between a coaxial balun and the antenna. In addition, the fabricated tag has reading distance of about 8 m regarding to two case in free space and on the underlying radiator when reader emits power of 36 dBm EIRP. Accomplished results ensure that the suggested tag can apply to not only dielectric materials itself but also metallic objects possibly by just adding the simple underlying radiator without any geometric modification of the label tag.

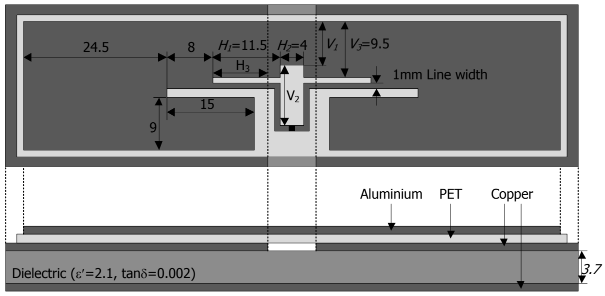
4. Conclusion

In this letter, we proposed a novel RFID tag antenna and an underlying radiator in the UHF band work on dielectric as well as metallic objects respectively. Also good impedance matching is achieved by adjusting cross-shaped feeding loop geometrically since horizontally overlapped square with patches of the underlying radiator reduces inductance of the loop to cancel out parasitic capacitance from bottom metal. After a study of the design parameters, the optimized antenna was manufactured and measured. As a result, the fabricated tag has half power bandwidth of 65 MHz (7.1%) and 17 MHz (1.9%), respectively in free space and on the underlying radiator. Finally, we confirmed reading distance of about 8 m in condition of 36 dBm EIRP in UHF RFID frequency band. These results demonstrate the suggested antenna is surely suitable to real and practical RFID applications including dielectric and metallic materials.

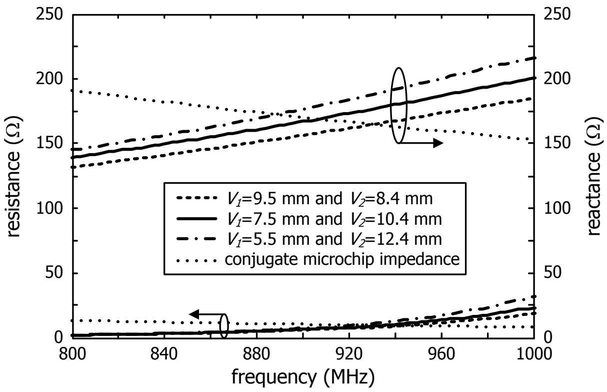
5. Figures and Tables



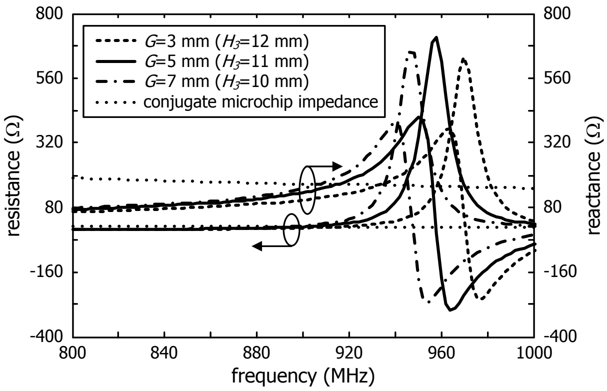
(a) Configuration of the underlying radiator.



(b) Configuration of the proposed antenna combined with the underlying radiator.
Figure 1: Proposed RFID tag antenna structure.



(a) Impedance with varying V_1 and V_2.



(b) Impedance on underlying radiator varying *G*.
Figure 2: Computed impedance characteristic.

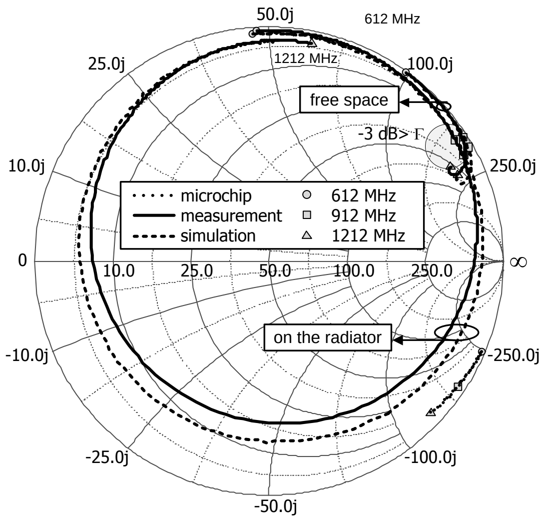


Figure 3: Impedance of proposed antenna.

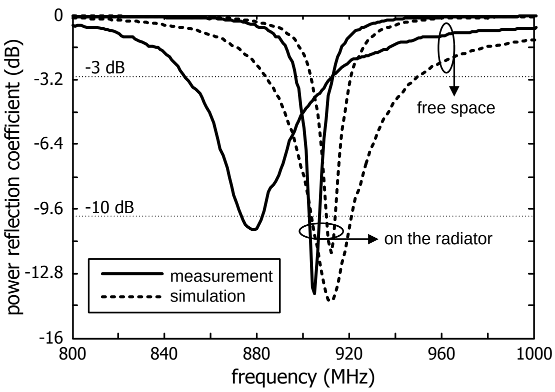


Figure 4: Power reflection coefficient of proposed tag.

References

[1] J. Choo, J. Ryoo, J. Hong, C. Choi, M. Tentzeris, "T-matching networks for the efficient matching of practical RFID tags," 39th European Microwave Conf, Italy, pp. 5-8, 2009.
[2] K. Kim, J. Song, D. Kim, H. Hu, J. Park, "Fork-shaped RFID tag antenna mountable on metallic surfaces," Electron. Lett., vol. 43, no. 23, pp. 1400-1402, 2007.
[3] L. Mo, H. Zhang, H. Zhou, "Broadband UHF RFID tag antenna with a pair of U slots mountable on metallic objects," Electron. Lett., vol. 44, no. 20, pp. 1173-1774, 2008.
[4] C. Cho, H. Choo, I. Park, "Design of planar RFID tag antenna for metallic objects," Electron. Lett., vol. 44, no. 3, pp. 175-177, 2008.

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