Design of an UHF RFID tag antenna utilizing a size-reduction technique in roll to roll (R2R) process

*Youngbaek Choi, Uisheon Kim, Gyubong Jung, #Jaehoon Choi
Department of Electrical and Computer Engineering, Hanyang University 17 Haengdang-Dong, Seongdong-Gu, Seoul, 133-791, Korea
Tel: +82-2-2220-0376, Fax: +82-2-2293-0377
Email: *choi0100@hanyang.ac.kr, #choijh@hanyang.ac.kr (corresponding author)

1. Introduction

With the recent growth of radio frequency identification (RFID) systems, the research on the design of tag antennas has mainly focused on how to achieve ultra-low-cost mass production as well as size-reduction with high efficiency [1]. Since hybrid solutions with silicon identity generating chips and printed antennas are commercially available, the roll to roll (R2R) process has become one of the great interesting solutions for fast-fabrication and low-cost mass manufacturing [2]. However, tag antennas designed with silver ink as conductor in R2R process yield reduced reading range compared to that made of copper since the conductivity of silver ink is lower than the conductivity of copper. Thus, it is great concern in R2R production to achieve high efficiency enough for practical applications.

In this paper, an UHF band RFID tag antenna utilizing a size-reduction technique is proposed. The efficiency of the proposed tag antennas printed by silver ink on polyester substrate in R2R process is compared to that of the same designed tag antenna made of copper on FR-4 substrate.

2. Antenna Configuration

The configuration of the proposed antenna which consists of element 1 and element 2 is shown in Fig.1. Element 1 has a loop-like structure and the input terminals are directly connected to the chip. The loop having Π-shape makes it possible to have long current path so that the high reactance in small area is obtained. When the parameters of element 1 have the values of L1=14 mm, H2=0.5 mm, W1=0.7 mm, and W2=1.5 mm, the impedance characteristic of element 1 for variation in H1 is shown in Fig.2 and Fig.3. In contrast with that the resistance of element 1 is nearly zero, the reactance is increased proportionally to the length of H1. Element 2 having a circle-load is symmetrically connected with element 2 to have the required resistance for conjugate matching with the impedance of chip. L2 is a meander-line having opposite phases to increase mainly the resistance of antenna and to miniaturize the size of antenna. The resistance and reactance of antenna for variation in R1+R2 is shown in Fig.4 and Fig.5, respectively. Both resistance and reactance of antenna are increased proportionally to the value of radius R1+R2. Fig.6 shows the resistance of antenna for variation in the number of slits having the width of D and the length of R2. The first slit is placed at the circle-load and is connected with the trace L2. The remaining slits are located along the circumference 90 degrees apart from the adjacent slit. From Fig.6, we see that the resistance of antenna with slits is much higher than that of antenna without a slit. This technique provides the size-reduction of antenna because the smaller radius of a circle-load with slits can generate the same resistance as that of a circle-load having larger radius without a slit. Fig.7 shows the reactance variation of antenna for changing the number of slits. Unlike the antenna without a slit, the reactance of antenna with reaches at the peak value at near 910 MHz, and then starts decreasing. Thus choosing the peak reactance value as the conjugate-reactance of a chip is beneficial to obtain wide impedance bandwidth. The width S of slot is used to control the reactance of antenna in detail and W3 is fixed as 1 mm. The proposed antenna of A-type is printed by silver-ink (ε_r=1, μ_r=0.99998, bulk conductivity=9.346 e+6 S/m) with thickness of 2 μm on a thin polyester substrate (ε_r=3.2, tanδ=0.03) with thickness of 75 μm.(=0.075 mm). The proposed antenna of B-type is made of copper (ε_r=1, μ_r=0.999991, bulk conductivity=5.8 e+7 S/m) with thickness of 0.47 mil.(=0.012 mm) on FR-4 substrate (ε_r=4.7, tanδ=0.02) with thickness of 0.4 mm. Impinj class 1 Gen 2_Monza 1 RFID chip with impedance of 33-j112 ohms at 911 MHz is mounted on the proposed antenna terminals of A-type and B-type [3]. The overall dimension of the proposed tag antenna is 84.8 mm × 30.2 mm for A-type and 84mm × 29.4 mm for B-type. The design parameters are optimized at 910 MHz and listed in Table 1.

3. Experimental results

The simulated impedance of the proposed antenna for both types are nearly 33 + j112 ohms, respectively as shown in Figs. 8. The -10 dB impedance bandwidth for both types, as shown in Fig.9, is 60 MHz (888 MHz ~ 948 MHz) which covers the whole Korean UHF RFID band (908 MHz ~ 914 MHz). Fig.10 shows the measured radiation patterns in anechoic chamber. Fig.11 shows the wakeup sensitivity for both A and B type antennas. The wakeup is the minimum required power for operating tag antenna and the gain of tag antenna can be obtained by substituting the chip sensitivity for the wakeup sensitivity. Since the chip sensitivity is -9dB at 910 MHz [3], the gain of A-type antenna is 1.5 dBi and the gain of B-type antenna is 3.5 dBi. The reading distances are 4.05 m for A-type antenna and 5.05 m for B-type antenna, respectively. Then the efficiency of A-type antenna is 63.1% of that of B-type antenna.

4. Conclusion

The proposed antenna is designed by utilizing a size reduction technique having slits on circle-loads to increase the resistance of antenna. The proposed antenna printed by silver-ink in R2R process has the impedance bandwidth of 60 MHz (888 MHz ~ 948 MHz) for S_{11} less than -10 dB and the reading distance is 4.05 m with the efficiency of 63.1% of that of an antenna made of copper.

5. Acknowledgement

This work was supported by Seoul R&D program, Korea.

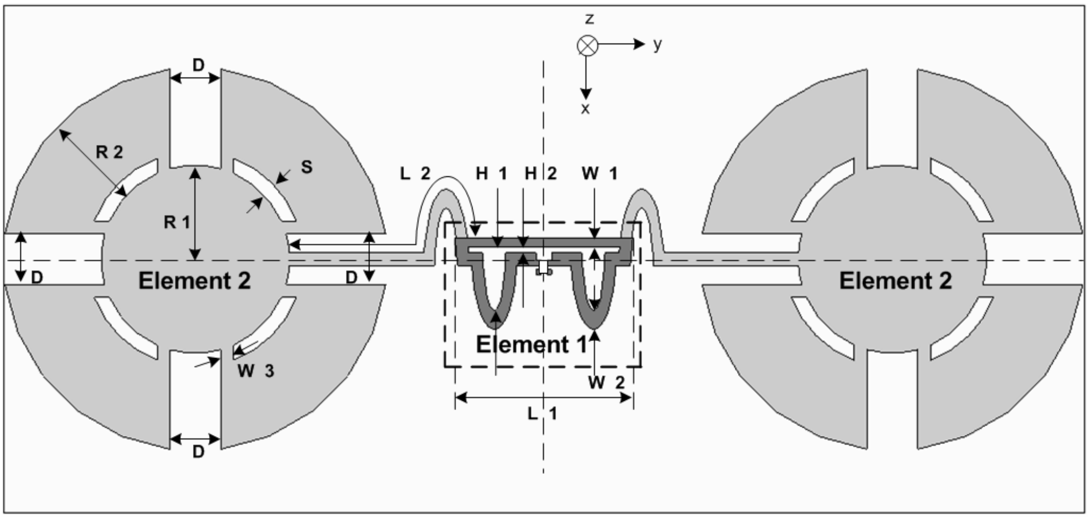

Fig.1 Configuration of the proposed antenna.

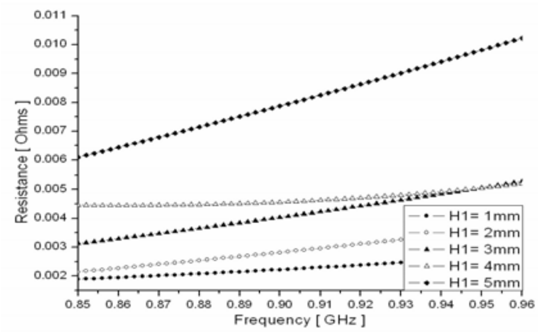

Fig.2 Resistance of the proposed antenna for variation in H1.

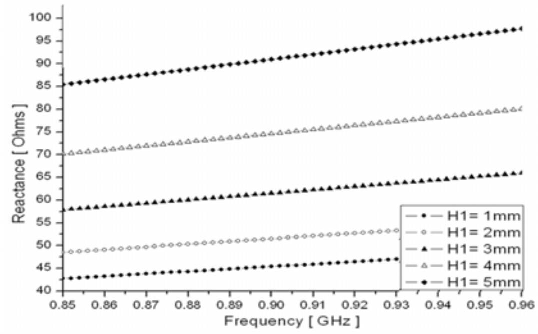

Fig.3 Reactance of the proposed antenna for variation in H1.

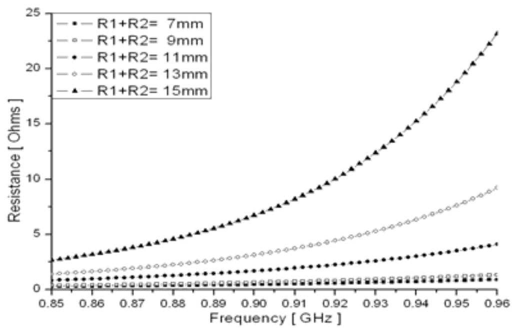

Fig.4 Resistance of the proposed antenna for variation in R1+R2.

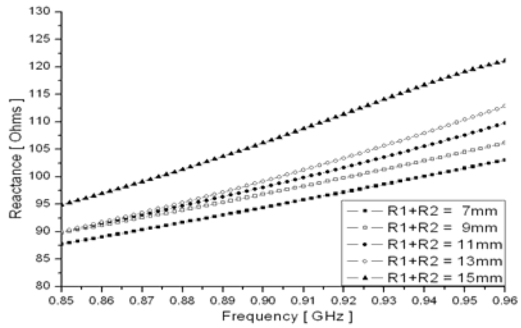

Fig.5 Reactance of the proposed antenna for variation in R1+R2.

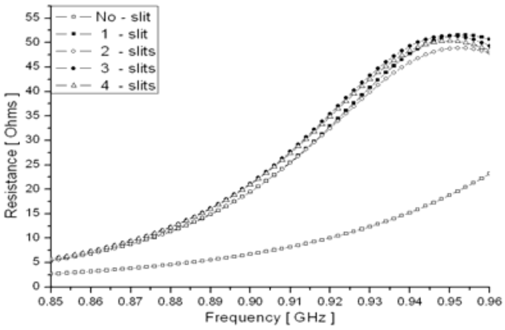

Fig. 6 Resistance of the proposed antenna for variation in the number of slits.

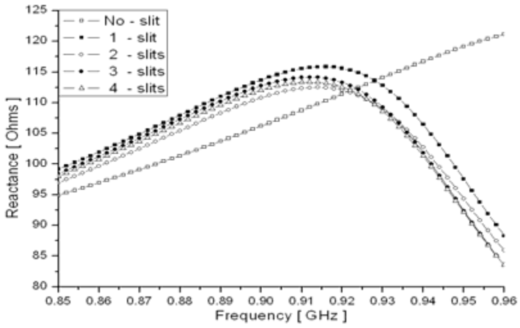

Fig.7 Reactance of the proposed antenna for variation in the number of slits.

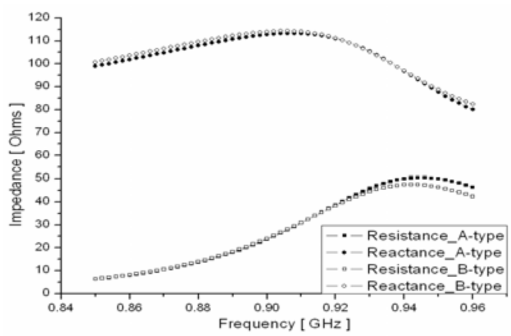

Fig.8 Impedance of the proposed antenna for A and B type.

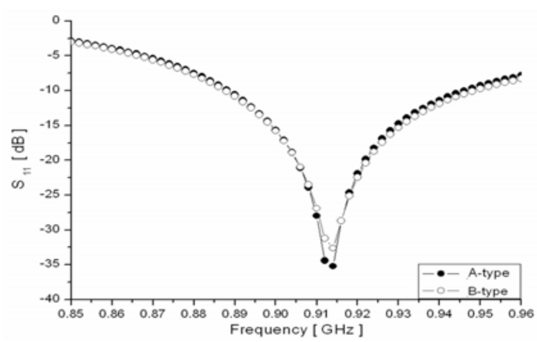

Fig.9 Calculated S_{11} characteristics of the proposed antenna for A and B type.

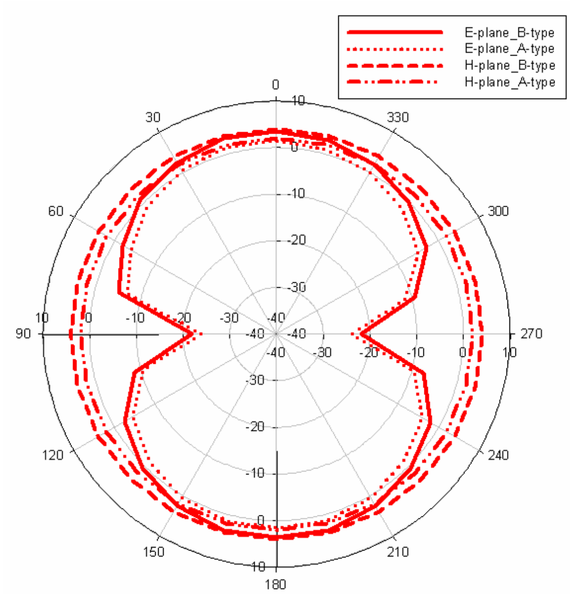

Fig.10 Measured radiation patterns for both A-type and B-type antennas at 910 MHZ

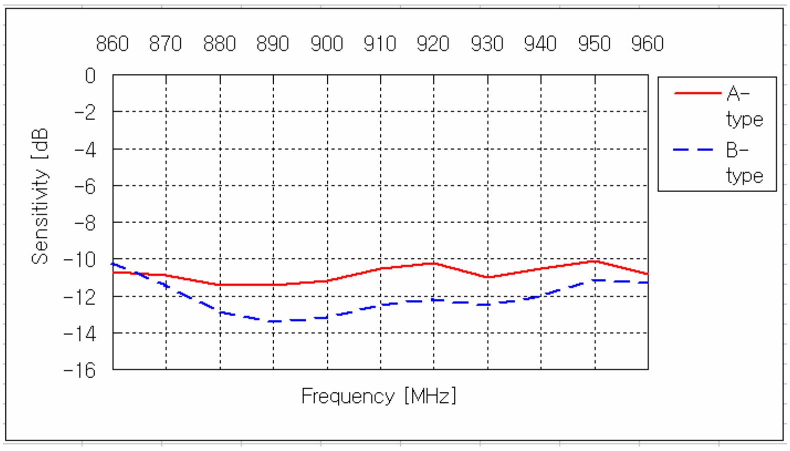

Fig. 11 Measured wakeup sensitivity for A-type and B-type antennas at 910 MHZ

Table 1. Design parameters of the proposed antenna for A-type and B-type [unit : mm].

	L1	L2	R1	R2	H1	H2	W1	W2	W3	D	S
A-type antenna	14	20	7.4	7.7	7	0.5	0.7	1.5	1	4	1.1
B-type antenna	14	20	7.3	7.4	7.2	0.7	1	1.5	1	4	1

References:

[1] Gaetano Marrocco, ”The Art of UHF RFID Antenna Design: Impedance-Matching and Size-Reduction Techniques”, IEEE Antennas and Propagation Magazine, Vol.50, N0.1, pp.66-79, February 2008
[2] H-E. Nilsson, J. Siden, T. Olsssson, P. Jonsson , A. Koptioug, “Evaluation of a printed patch antenna for robust microwave RFID tags”, IET Microw. Antennas Propag., Vol.1, No.3, pp.776-781, June 2007
[3] www.impinj.com