A Cost-Effective Antenna Design for Printed UHF RFID

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Abstract

In this paper, the printed UHF RFID tag dipole antenna design is optimized to reduce the consumption of conductive material. The optimized design is achieved by narrowing the width of the low current density areas. The proposed optimized dipole antenna design requires less amount of conductive ink to achieve the equivalent radiation efficiency level as the ideal copper-trace dipole antenna. The simulation results indicate the saving amount of approximately 43% when comparing with the silver ink printed flat dipole antenna design.

Keywords : Antenna, Printed RFID, Cost effective

1. Introduction

The Radio Frequency Identification (RFID) has emerged as the technology-of-choice for a vast variety of applications including logistics, supply chain, traceability, access control, and security management applications [1]. The RFID technology has various desirable advantages. Unlike the legacy bar code technology, for example, the modern RFID systems allow the more applicable non-line-of-sight wireless data transfer between a RFID reader and a RFID tag, and also offer sizable data storage and real-time data rewritability. Currently, there are 3 widely-used operating frequency bands for the current RFID technology: low frequency (LF), high frequency (HF), and ultra-high frequency (UHF). This work focuses on the more modern UHF RFID system that allows the longer operating distance for wireless data transfers between the RFID reader and the RFID tag [2]. Since a massive number of RFID tags are usually required in typical RFID applications, it is generally desirable to lower the cost of RFID tag fabrication as much as possible in order to reduce the overall expense of the system.

The printing technique, e.g., screen printing, gravure printing, flexography, and ink-jet printing [3], is a promising solution for lowering the cost of RFID tag fabrication since the designated amount of conductor or conductive ink is directly printed on the tag substrate to form the designed shape. Hence, no conductor is unnecessarily wasted and the cost of fabrication is considerably reduced. Various aspects of printed RFID have been studied in the past several years [4]-[8]. However, the conductivity of the conductive ink is rather poor comparing with pure copper or silver, which has a strong effect on the antenna efficiency and the wireless data transfer performance. The research works for improving the efficiency of printed RFID antenna have been conducted [9], [10]. It was suggested in [9] that by thickening the conductive ink layer to least one skin depth, the antenna efficiency can be improved. The thickened conductive ink layer can be obtained by reprinting the antenna several times until the desired thickness is achieved. Hence, the cost of the RFID tag depends on the amount of the conductive ink printed on the antenna. In order to reduce the conductive ink consumption, [10] demonstrated that the antenna efficiency is still maintained by thickening the conductive ink layer only in the high current density areas. However, the size of thickened areas in [10], which is set to one-third of the antenna length, is not an optimal one. The authors have conducted the study on the optimization of the thickened conductive layer size for the conventional dipole antenna design.

In this paper, we further optimize the size of the printed dipole antenna design in order to produce the high-performance RFID tag that requires the lowest amount of conductive ink. In the proposed designs, the width of both the high current density and low current density areas are varied

to obtain the best cost-effective design for dipole antenna configurations. The simulation results show that the width of the thickened feed areas should be about 2 mm and the width of thinned areas should be set narrower to about 0.5 of the thickened feed areas in order to achieve the optimal enhanced performance. In addition, the optimized dipole antenna can save 43% of the conductive ink comparing with the conventional flat dipole antenna.

2. Antenna Configuration

In this paper, the standard planar dipole antenna configuration is slightly modified such that the conductive layers near the feed point of the dipole antenna that have high current density are thickened while the conductive layers in the areas located further away from the feed point that have lower current density are thinned in order to achieve improved performance for a constrained amount of conductive ink requirement. As displayed in Fig. 1, the length, the width, and the thickness of the conductive layer in the feed area (Area a) of the proposed design are given as L_a, W_a, and T_a, while those of the conductive layer in the other area (Area b) located further away from the feed point are given as L_b, W_b, and T_b, respectively. The length of the dipole antenna arm L is equal to $L_a + L_b$, and s is the space to place the RFID chip. The optimal dipole antenna length (L) is chosen as the length of a standard dipole antenna that gives the best intrinsic impedance matching to the employed RFID chip, NXP UCODE G2XL that has C=0.9 pF and Q=9, at the given operating frequency via simulations [11]. The simulation results obtained using the Advanced Design System (ADS) momentum analysis software based on the method of moments (MoM) suggest that the dipole antenna design with the length $L = 92$ mm achieve the best intrinsic impedance matching at the operating UHF RFID frequency band of Thailand, 922 MHz. The optimum length and thickness of the thickened feed areas, L_a and T_a, that yield the best antenna radiation efficiency as determined in previous study are 2 mm and 40 μm, respectively, for the dipole antenna with the equal width along the entire antenna length ($W_a = W_b = 2$ mm).
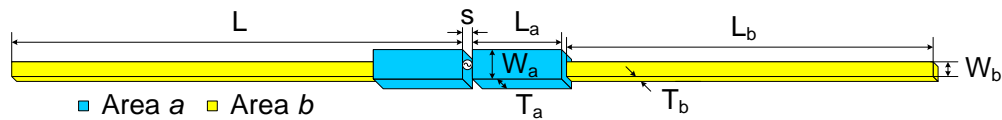

Figure 1: Proposed cost-effective dipole antenna structure.

3. Simulation Results

The results of antenna efficiency are obtained via the ADS analysis software are demonstrated in this section. In the simulations, we employ the antenna substrate as Polyester (PET) with the thickness of 51 μm. The dielectric constant and the loss tangent of the antenna substrate, PET, are given as 3.5 and 0.002, respectively. The silver ink with the electrical conductivity of 1.6×10^6 S/m [8] is employed as the antenna conductor. The operating frequency of 922 MHz is mainly considered.

Fig. 2 displays the radiation efficiency of the thickened feed dipole antenna as a function of the ratio of the width of the thinned areas W_b to the width of the thickened feed areas W_a for several width W_a with the conductor volume $V = 4$ mm^3 in order to demonstrate the influence of the width of both the thickened feed and thinned areas. The dipole antenna with $W_a = 2$ mm is the optimal design when the width of the thickened feed areas is equal to that of the thinned areas, $W_a = W_b$. It can be observed that the maximum radiation efficiency is achieved when the width of the thickened areas W_a is 2 mm and the width of the thinned areas W_b is decreased to approximately half of W_a, where the thickness of the thinned areas T_b is also approximately half of the thickness of the thickened areas T_a. The wider width of the thickened areas $W_a = 3$ mm results in the lower radiation efficiency where the maximum value is achieved when the width of the thinned areas $W_b = 0.4W_a$. The radiation efficiency of the dipole antenna with the width of the thickened areas $W_a = 1$ mm is comparatively low and decreases for the narrow W_b as the width of the thinned areas W_b is too small.
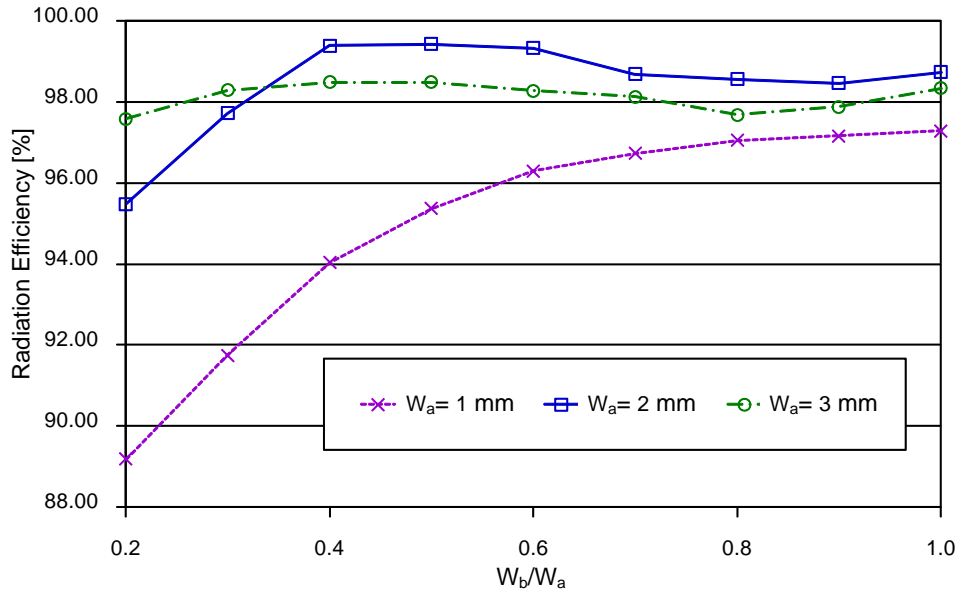
Figure 2: Radiation efficiency of dipole antenna for various widths.

Fig. 3 illustrates the comparisons of the radiation efficiency among the proposed optimized printed dipole antenna, the ideal copper-trace dipole antenna, silver ink printed flat dipole antenna, and the printed thickened feed dipole antenna suggested in [10]. It can be seen that superior antenna efficiency can be obtained from our proposed optimized dipole antenna design that has the width of the thickened areas $W_a = 2$ mm and the width of the thinned areas $W_b = 1$ mm comparing with the existing designs. In order to achieve the same level of efficiency, the proposed optimized design consumes significantly less amount of conductive ink. The proposed design employs only about 4 mm^3 of conductive ink to achieve the same radiation efficiency level of the ideal copper-trace dipole antenna, while the silver ink printed flat dipole antenna design and the existing thickened feed design in [10] employ around 7 mm^3 and 6 mm^3, respectively. Hence, the amount of conductive ink consumption of the proposed optimized dipole antenna design can be reduced by 43% when comparing with the silver ink printed flat dipole antenna design, and 33% when comparing with the existing thickened feed design in [10].
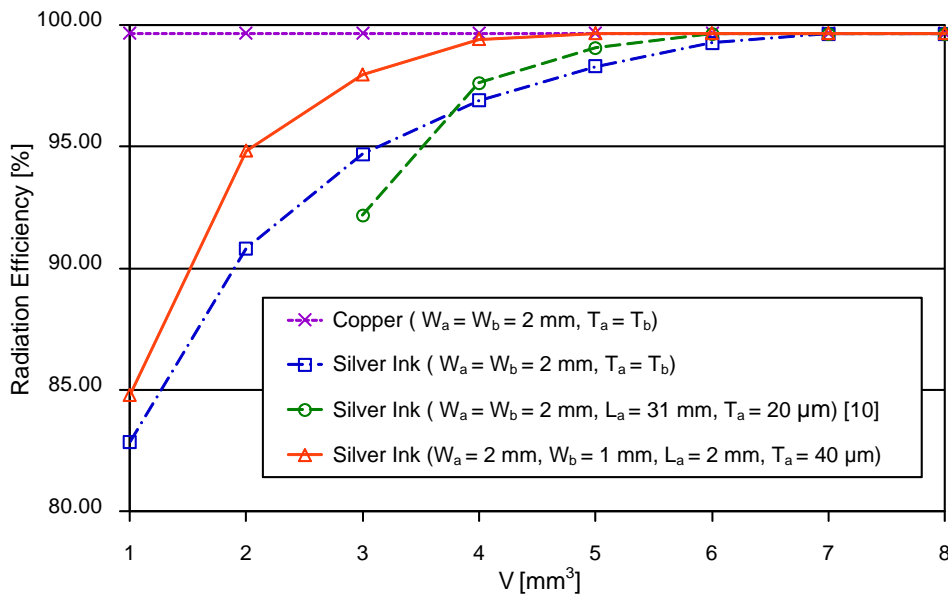

Figure 3: Radiation efficiency of dipole antenna for various conductor volumes.

4. Conclusion

In this paper, we proposed the optimized dipole antenna design for the cost-effective printed RFID tag. The optimized design of the dipole antenna with the thickened conductive layer in high current density areas and thinned conductive layer in low current density areas that yield the optimal radiation efficiency is achieved by narrowing the width of the thinned areas. The simulation results suggest that the width of the thickened areas should be 2 mm and the width of the thinned areas should be about half or 1 mm in order to achieve the optimal cost-effective design. The amount of conductive ink requires in our proposed optimized dipole antenna design to obtain the same radiation efficiency level as the ideal copper-trace design is significantly low. The proposed optimized dipole antenna design can save the amount of conductive ink around 43% when comparing with the silver ink printed flat dipole antenna design, and 33% when comparing with the existing thickened feed design in [10].

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