Optimization of Silver Paste Printed passive UHF RFID Tags

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Abstract

Passive UHF (Ultra High Frequency) RFID (Radio Frequency Identification) is a promising technology for products tracking in logistics or routing packages in supply chain. Usually, the UHF RFID antenna is made by etched copper, or aluminum. These etching process introduce chemical wastes during the etching process. Recently, printing silver paste becomes popular due to its environmental friendly manufacturing process. However, there are two drawbacks on printed silver paste RFID antenna. One is low conductivity compared to metal and the other is the high material cost. In this paper, we exam the effects of printing thickness on the performance of UHF RFID tags and summarize the optimized thickness for different read range requirements. A commercial conductive silver paste is printed on PET film as RFID tag antennas. Both finite element simulations and experiments are conducted to evaluate the effects of printed thickness. The simulation results presents that the 10 μm thick RFID antenna exhibits relatively good radiation efficiency. The results indicate that 10 μm thick RFID tag antenna presents the minimum turn-on power of 18 dBm to 22 dBm which is enough for most applications. The simulation and measurement results present that thinner printed silver paste RFID tag antenna is a potential solution for low cost UHF RFID tags. The cost of these tags could be lower than current etched Al/Cu RFID tags because of material saving.

I. Introduction

The recent development of radio frequency identification (RFID) technology for item-level tracking has been accelerated due to pressing industry demand. RFID technology is an automatic identification method which can be used conveniently for product tracking. It has the advantage that the track process requires only minimal human input and thus further reduces the labor cost in logistics operation. RFID has many potential applications in different areas such as item identification and retail management. It makes it possible to locate the items at the right place. Passive UHF RFID tags are commercially used in cases such as pallet and container tracking because of its low cost.

A RFID system typically consists of transponders and transceivers such as tag and reader. The objectives of RFID system is enabling the tag be read by a RFID reader. Usually, there is no power source inside the passive RFID tag, so the voltage needed to power RFID COMS chip is obtained from reader via remote activation. The reader transmits a modulated signal to the tag and the tag backscatters a signal with identification data to reader at the same time. A passive UHF RFID tag usually includes an antenna and a RF chip which has a memory to store identification data.

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chemical wastes during the etching process. Recently, printing silver paste becomes popular due to its environmental friendly manufacturing process. However, there are two drawbacks on printed silver paste RFID antenna. One is low conductivity compared to metal and the other is the high material cost. In order to maximize the read range, the thickness of printed RFID tag antenna should be higher than skin depth. Since the cost of silver paste is high, the thick RFID antenna material costs more than traditional RFID tag antennas.

Previous research papers indicated that the silver paste printed RFID antenna exhibited good antenna efficiency [1] [2]. But these papers only focus on the benchmarking of different materials; there are stills lots of outstanding issues on printed RFID antenna. In this paper, we exam the effects of printing thickness on the performance of UHF RFID tags and summarize the optimized thickness for different read range requirements. A commercial conductive silver paste is printed on PET film as RFID tag antennas. Two types of tag antennas, dipole based directional and quasi-isotropic antennas, are chosen to evaluate the effects of skin depth on RFID tag performance [3]. We validate these designs by conducting finite element analysis and experiments.

II. Evaluation method design and simulation

To evaluate the effects of silver paste thickness on RFID tag performance, we applied finite element simulations to design RFID tags. The designs of two types of modified dipole are shown in figure 1. Figure 1 (a) is a directional RFID tag antenna and figure 1 (b) is an isotropic RFID tag antenna. As shown in figure 2, it is found that the radiated power of isotropic design at any direction is almost the same. To match with Alien's RFID straps, we fine tuned the impedance of RFID tag antennas.

Figure 1. Design layout of directional RFID tag antenna and isotropic RFID tag antenna

The radiation efficiency is selected as the factor to evaluate the thickness effects. The radiation efficiency is defined as the ratio of the power delivered to the radiation to the power received. The loss of antenna mainly due to ohmic loss, especially for dipole based antennas. In simulations, we defined different antenna layer thickness and simulated the radiation efficiency.

Figure 2. Radiation pattern of directional RFID tag antenna and isotropic RFID tag antenna

The thickness of 1 μm , 3 μm , 5 μm , 10 μm , and 20 μm were constructed for each designs. These simulated radiation efficiency were shown in figure 3. It is found that the radiation efficiency increases with the thickness. However, the radiation efficiency does not change too much when it is thicker than 10 μm . Since the silver paste's resistivity is $3.4 \times 10^{-7} \text{ ohm} \cdot \text{m}$, the calculated skin depth from equation (1) at 1 GHz is around 10 μm . When the silver paste thickness is much thicker than two skin depth, the current flow is only in the skin of material. From our results, we can find that 20 μm samples show best performance, which is consistent with skin depth theory.

$$\delta = \frac{1}{\sqrt{\pi \mu_o}} \sqrt{\frac{\rho}{\mu_r f}} \approx 503 \sqrt{\frac{\rho}{\mu_r f}} \quad (1)$$

Figure 3. Radiation efficiency at different thickness (a) meander line designs (b) modified dipole designs

III. Experiment results

To validate the simulation results, we used screen printing technology to pattern RFID tag antennas on 50 μm thick PET films. The silver paste with resistance of 15mΩ/25μm was printed by screen printers. Then the printed silver paste is cured at 110°C for 10 minutes. To evaluate the effects of thickness, we print the RFID tag for different times to form different layer thickness. In this paper, we prepared three different thickness, 3 μm, 8 μm, and 10 μm as shown in figure 4.

Figure 4 Screen printed RFID tag with different thickness

Then, we placed the RFID tag with bonded RFID straps at a fixed distance of 1 meter in anechoic chamber. The output power of RFID testing system was tuned to be minimal to

read RFID tags. The turn-on power is recorded to indicate the performance of RFID tags.

It can be observed from figure 5 that the turn on power of 8 μm thick RFID tags are the same with 10 μm thick ones. This is likely due to the small differences in the radiation efficiency.

Thicker layer RFID tags are found to be more efficient than thinner one due to the low ohmic losses. It is also found that the effects of layer thickness are validated for both directional RFID tag antenna designs and isotropic RFID tag antenna designs.

Figure 5 Measured turn-on power of (a) meander line design and (b) modified dipole.

Conclusions

In this paper, two types of tag antennas, dipole based directional and quasi-isotropic antennas, are chosen to evaluate the effects of skin depth on RFID tag performance. Both finite element simulations and experiments are conducted to evaluate the effects of printed thickness. The simulation results presents that the 10 μm thick RFID antenna exhibits better radiation efficiency, compared to thinner designs. These dipole-based antennas are designed to match with Alien's UHF RFID strap. Prototypes are prepared by screen printing technology. The measurements are conduct in an anechoic chamber by RFID tester. The results indicate that 10 μm thick RFID tag antenna presents the minmual turn-on power of 22 dBm and 18 dBm which is enough for most applications. The simulation and measurement results present that thinner printed silver paste RFID tag antenna is a potential solution for low cost UHF RFID tags. The cost of

these tags could be lower than current etched Al/Cu RFID tags because of material saving.

References

- 1 Afzal Syed, Kenneth Demarest, Daniel D. Deavours, "Effects of Antenna Material on the Performance of UHF RFID Tags." *IEEE RFID 2007*. March 26--28, 2007, Grapevine, TX, pp. 57-62.
- 2 Nikitin, P. V; Lam, S; Rao, K.V.S; "Low Cost Silver Ink RFID Tag Antennas." *Transactions on Antennas and Propagation Society International Symposium*, July 2005, pp. 353--356.
- 3 Rao, K.V.S. Nikitin, P.V. Lam, S.F., "Antenna design for UHF RFID tags: a review and a practical application", *IEEE Transactions on Antennas and Propagation*, Dec. 2005, Volume: 53, Issue: 12 pp. 3870- 3876