Modeling, Design and Experimentation of a UHF RFID Tag Antenna Embedded in Railway Tickets

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***Abstract*—RFID (radio frequency identification) tag antennas usually operate at UHF frequency band. One qualified tag antenna is designed and embedded in railway ticket with international standard ISO/IEC 18000-6C chip. Test results show that the maximum reading distance of the proposed tag antenna can reach 10 cm when the reader's RF transmit power is less than or equal to effective isotropic radiated power 18 dBm at 920 MHz.**

Keywords—UHF RFID; railway ticket; tag antenna; IC chip impedance; HFSS.

I. Introduction

RFID is a contactless automatic identification technology, which uses radio frequency signals to identify specific objects [1]. Some railway operating companies have adopted tickets which are based on RFID technology [2]. Passengers can deposit not only cash but also all kinds of traffic tickets including travel cards, bus passes and so on. In 1998, Japanese railway introduced the AFC (automatic fare collection) system based on RFID technology and issued the Suica (Super urban intelligent card) card. In 2007, the Moscow Metro started to use RFID technology with inexpensive paper RFID tickets. These tickets with built-in 13.56 MHz RFID tags used air interface standard of ISO 14443A. Oyster transportation card, issued by London in 2010, can be used as an electronic wallet. The OV-chipkaart transportation card issued by Rotterdan Netherlands in 2011 can also bind with bank cards in addition to storing many kinds of tickets. Travelers can use credit cards to pay travel expenses or recharge ticket directly. The Guangzhou-Shenzhen Railway Department in China uses one-way RFID paper tickets as ticket vouchers to realize express operating. Currently, the one-way tickets based on RFID technology have been widely adopted in both domestic and international cities railway transport system.

In this paper we propose a new passive UHF RFID tag antenna where the small size of 28 mm×23 mm for the tag antenna is easily embedded in railway tickets whose size is 90 mm×61 mm. In China, the industrial band is also from 902 MHz to 928 MHz. A Higgs-3 IC chip made by Alien Technology Corporation is chosen to perform impedance matching.

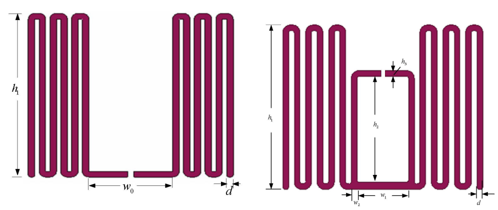

Fig. 1. Antenna model: the left is simple tag antenna model, the right is proposed tag antenna model

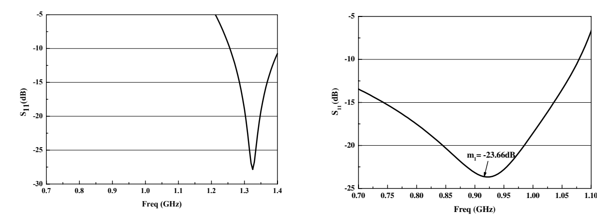

Fig. 2. Reflection coefficient diagram: the left is simple tag antenna model, the right is proposed tag antenna.

II. Tag antenna Layout and Design Procedures

A. Comparision of two tag antenna models

Fig. 1 is a meandered dipole antenna model. The gap in the middle is a feed port or a slot weld where the IC chip is placed. The following parameters are used in Fig. 1: w_0=10.4 mm, d=0.8 mm, h_1=23 mm. The substrate of this simple meandered dipole tag antenna is Polytetrafluoroethene(PTFE) with a relative dielectric constant of 2.5. The reflection coefficient S_{11} of this simple meandered dipole tag antenna is shown in Fig. 2, where the resonant frequency is high (1.325 GHz). The following methods can be used to reduce antenna's resonant frequency: increasing the number of meander or enlarging the middle length. An additional resonant branch is added in in proposed antenna. The following parameters are used in proposed antenna: w_1=7.2 mm, w_2=0.8 mm, d=0.8 mm, h_1=23 mm, h_2=15 mm, h_3=0.8 mm. The substrate of this proposed tag antenna also consists of PTFE with a relative dielectric constant of 2.5. This model realized the antenna's miniaturization by meandering the dipole antenna.

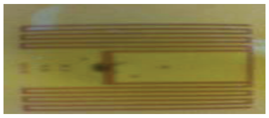

Fig. 3. Practical tag antenna.

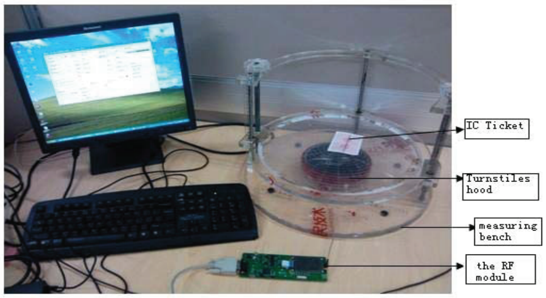

Fig. 4. Experimental platform.

The reflection coefficient S_{11} of the proposed tag antenna is shown in Fig. 2(right).

III. Reading distance experiment in Laboratory Configurations

A. Experimental environment and platform

The proposed RFID tag antenna as shown in Fig. 3 has been measured in laboratory in order to verify the effective reading distance. The experimental environment is as follows: a 900 MHz absorbing material and metal reflection board are added to the bottom of the antenna and a turnstile bonnet is mounted on the surface as shown in Fig. 4. The experimental platform mainly includes five parts: the RF module, measuring bench, turnstiles hood, IC ticket and computer testing interface. For convenience in tests, the selected reader's transmit power is 18 dBm.

Test specification: we tested the tag antenna at 8 positions as shown in Fig. 5. These 8 positions are located at 1 cm, 2 cm, 3 cm, 4 cm, 5 cm, 6 cm, 7 cm, 8 cm away the central axis, respectively. Each position is tested according to two cases: the tag antenna is perpendicular to the central axis of the turnstile and parallel to the central axis of the turnstile. All of the following distances are relative to the turnstile hood, not relative to the surface of the antenna. The distance between the antenna surface and turnstile hood is 6 mm.

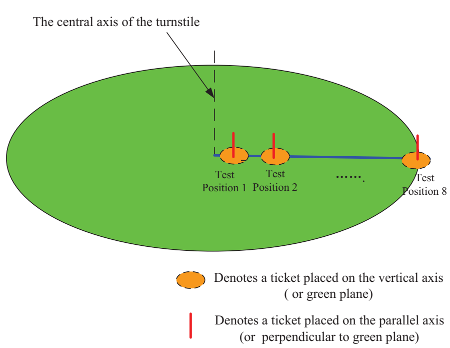

Fig. 5. The scenario in 8 test positions.

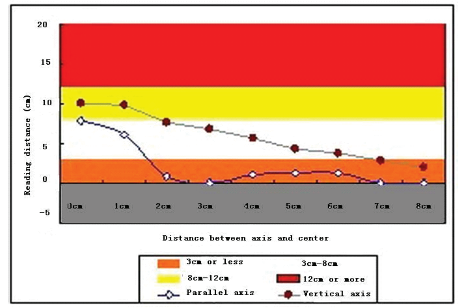

Fig. 6. Reading distances of the tag antenna in 8 positions: perpendicular to the central axis of the turnstile and parallel to the central axis of the turnstile.

B. Experimental results

We obtained the maximum reading distances of the tag antenna perpendicular to the central axis of the turnstile and parallel to the central axis of the turnstile through the test, as shown in Fig. 6. From Fig. 6, we can see i) when the railway ticket with tag antenna is located at "Parallel axis" (i.e. the ticket is parallel to the central axis), the tag reading distance meets the experimental requirement. However the tag reading distance declines sharply while the railway ticket is away from the central axis. ii) when the railway ticket with tag antenna is located at "Vertical axis" (i.e. the ticket is perpendicular to the central axis), the tag reading distance meets the requirements at the whole plane. iii) when the distance between the railway ticket and the central axis is 0 cm, the maximum reading distance at "Parallel axis" and "Vertical axis" positions is 7.8 cm and 10 cm, respectively.

IV. Conclusion

An RFID tag antenna in railway tickets was designed in this paper by HFSS and a practical system test was completed. When the frequency is 920 MHZ, the reader's RF transmission power is equal to or less than 18 dBm and the read distance of the proposed tag antenna can reach 10 cm.

Acknowledgement

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References

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