Performance Assessment of Printed RFID Reader Antenna

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Introduction

Recently, RFID smart shelf system has received much attention because of increasing demand of large-scale item-level management for grocery products in the retail supply chain, large volumes of books in libraries and other media, tagged bottles in pharmaceutical industry, and important documentation in offices [1, 2]. Generally large number of reader antennas is required in a RFID smart shelf system to track and monitor the tagged items in real time. Low-cost reader antenna will benefit the large-scale system deployment because of the significant reduction of system implementation cost.

Compared to conventional antennas made by copper / aluminum wires and plate or etched metal traces onto dielectric substrate, the printed antennas are created by printing the low-cost conductive material such as silver ink on a cheap substrate such as PCB, paper, plastic film, and cloth. The significant cost reduction in material and fabrication of a printed antenna offers great advantage and more freedom for cost effective antenna design. Printing technology has been proposed for RFID electronics and antennas since 2002 [3, 4]. Printed antennas have been used in industry to configure ultra-low-cost RFID tags; however, the application of printing technology for RFID reader antennas has not been reported yet.

In this paper, we characterize a printed loop antenna at high frequency (HF). The low-cost printed antenna will be used in a HF RFID smart shelf system for a low cost solution. The performance of the printed antenna is compared with an antenna made of PCB (copper) at 13.56 MHz in terms of impedance matching, field response, Q-factor, and detection range. The investigation is carried out by experiments.

Antenna Configuration

Fig. 1 shows the loop antenna configuration used for this assessment. The antenna prototypes are made on a 20mils FR4 substrate. A few resistors and capacitors are used to tune the antenna to the required resonant frequency and Q factor [5]. “T” matching method is used to match the antenna to 50 ohm. The antenna is fed by

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using a coaxial cable which is split into two wires (screen & core); these wires are soldered to two matching stubs, respectively. Required impedance matching can be achieved by adjusting the length and width of the stubs. Fig. 2 illustrates the printed antenna prototype. It was fabricated by printing the conductive silver ink on a 20-mils FR4 substrate by Micro-tec Screen Printer. Some portions of the loop are specially processed to withstand heat due to the soldering of the coaxial line and lumped components. A copper made loop antenna prototype of identical geometry and feeding line configuration was fabricated as well for comparison testing purposes.

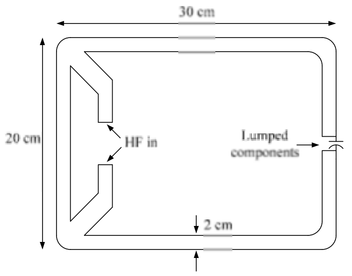

Fig. 1 HF loop antenna geometry

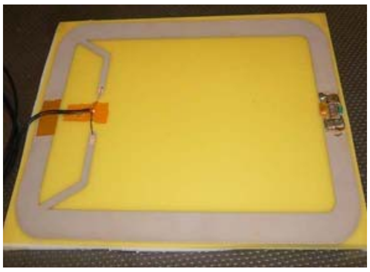
Fig. 2 Printed antenna prototype

Measurement Results and Discussion

- Impedance matching

The impedance matching of the printed antenna and copper made antenna is evaluated in terms of return loss which was measured by Agilent 8753E network analyzer (VNA). The antennas are tuned to 13.56 MHz with resistors and capacitors in free space. As shown in Fig. 3, both copper and printed antennas show good matching to the 50-Ω feed line. The $|S_{11}|$ graphs of the antennas are similar in position and bandwidth except for the larger dip at 13.56 MHz for the copper antenna. Although both antennas are identical in geometry, the copper antenna requires a larger value resistor to achieve good impedance matching. There is no resistor added to the printed antenna because the conductive silver ink offers extra ohmic loss because of its lower conductivity.

- Magnetic field response

The magnetic field strength of the loop antenna at a specified distance determines the reading range of a RFID system. The stronger the magnetic field, the larger the reading range. The magnetic fields of the printed antenna and copper antenna were measured at varying testing points. Measurement is conducted by using an Agilent 8753E VNA and Langer EMV-Technik near field probe, LF1. The antenna and the near field probe are connected to port 1 and port 2 of 8753E VNA, respectively. The strength of the measured field is indicated by $|S_{21}|$. Fig. 4 shows the field response against frequency with probe at 10cm away; similar responses are observed except that the copper antenna offers a larger peak value. The field strength of printed antenna is 2 dB lower than that of the copper antenna. A possible reason for lower near field response is the lower conductivity of conductive silver ink material causes more ohmic losses and results in lower antenna efficiency [6].

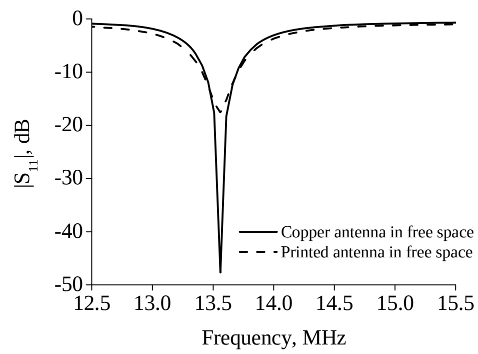

Fig. 3 Return loss of the printed antenna and copper antenna

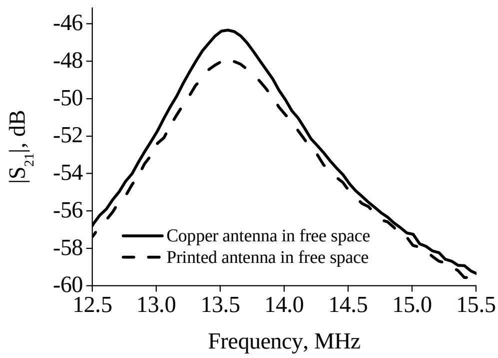

Fig.4 Field response of the printed antenna and copper antenna (10 cm away)

- Quality factor (Q)

The performance of the HF loop antenna can also be evaluated by using quality factor (Q factor). Q factor represents the amount of AC resistance of a system at resonance. In general, higher Q gives higher power output for a particular sized antenna is. However, a very high Q value may conflict with the band-pass characteristics of the reader and the increased ringing could create problems in the protocol bit timing. For these reasons, the Q of the single-loop antenna connected to a 50-Ω load (i.e. the reader) should be about 20 or less [5]. The Q factor can be determined by measuring the 3-dB bandwidth of the antennas' near field response. The measured Q factors for both antennas are as follows:

$$Q = \frac{F_0}{F_2 - F_1} = \frac{13.56}{3\text{ dB bandwidth}} \tag{1}$$

$$Q_{\text{copper antenna}} = 18.8 \text{ and } Q_{\text{printed antenna}} = 14.7$$

- Detection range

Fig. 5 shows the set-up of using the printed prototype in a HF RFID smart shelf system prototype which is configured to track and monitor the books in a library. The antenna connected to a reader is mounted in the shelf full of books in certain ways. The detection range of the antennas can be assessed by the detected maximum number of books. In this test, the copper antenna can detect 24 books while the printed antenna can detect 22 books. Therefore, the performance of the printed antenna and the copper antenna are comparable.

- Problems of printed antenna

Further improvement to the reliability of the printed antenna prototype is needed before using it for practical RFID applications. There are some problems to be solved for existing printed antenna. First, it is very difficult to solder the cable and lumped components to the printed strips. Despite using the minimum temperature of 290°C for soldering, the solderable portion and the conductive ink of the antenna still melted; disconnection might occur if precaution was not taken. Second, after soldering the cable and lumped components to the printed antenna, bending the antenna is absolutely not allowed. This is because the lumped components and the cable might become loose from the antenna due to the detachment of the solderable portion from the antenna. Cracks also formed on the silver conductive ink near the lumped components which could create an open circuit.

Fig. 5 Implementation of HF Antenna in RFID Smart Shelf

Conclusion

This paper has assessed the performance of a printed loop antenna at 13.56 MHz for RFID reader applications. The study has shown that the printed antenna has the performance in terms of reading capability comparable to the conventional copper made antenna. Therefore, the low cost printed antenna has potential for low cost RFID solutions in future. However, some vital improvements must be made to improve the fragility of the conductive ink material as well as its ability to withstand temperatures above 290°C for practical and massive production.

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