Low-cost Flexible RFID Tag for On-metal Applications

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***Abstract*—This paper documents the design of a low-cost RFID tag that is operable among metallic surfaces. The tag uses a loop type antenna that is small, flexible, and vialess. In addition, the design only requires low-cost, easy-to-obtain materials. The tag has been successfully tested on metal at 915MHz. Thus, the tag can be used in non-ideal settings or as surface mounts on metallic objects. Simulation and experimental results are also discussed in the paper.**

I. Introduction

A typical Radio Frequency Identification (RFID) system has two main components: the reader and the tag. The reader transmits an interrogating signal and receives any responding signals. The tag comprises of an antenna component and the RFID chip, and it is placed on the articles that are being tracked by the system. Therefore, the tag is exposed to a harsh environment that can damage or affect the tag behavior. One critical problem is when the surroundings contain metal surfaces as they can cause disruptive reflections and render the tags useless. In addition, tags may be required to be mounted on to metallic objects which also necessitate a special tag design. The loop antenna design negates the destructive characteristics of a conductive environment [1].

There are some existing designs that also provide a solution. Some use brittle, hard material, which is undesirable in most RFID application settings [1]. Also, some require vias, making the fabrication process more difficult [2]. Some may avoid the aforementioned downfalls, but require hard-to-acquire materials such as a special ceramic polymer ($BaTiO_3$) [3]. The design outlined in this paper is both flexible and easy to fabricate. The tag can be made with readily available materials and with just simple cutting and taping.

II. RFID Tag Design

This particular tag is designed for a center frequency of 915MHz. The antenna impedance must also be made to match the conjugate impedance of the RFID chip (13.3–j122).

A. Simulation

The simulations have been run using ANSYS HFSS software. The simulated impedance of the tag is 8.7+j125 at 915MHz. The reflection coefficient (S_{11}) has been calculated and shown in Fig. 1. The tag is optimal for use at the design frequency of 915 MHz. Next, the radiation pattern is shown in Fig. 2. The simulated gain is -4.64 dBi.

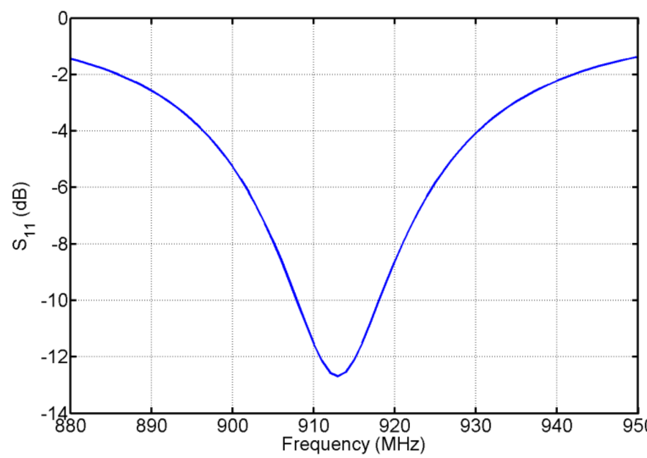
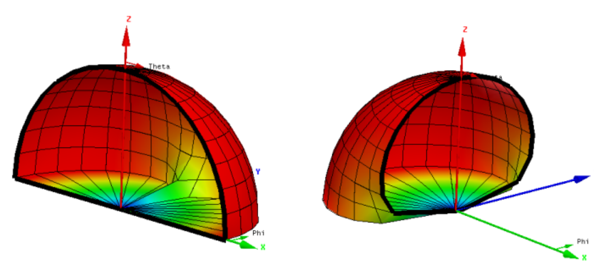


Fig. 1. Reflection coefficient (S_{11}).



(a) (b)

Fig. 2. Simulated radiation patterns: (a) E-plane and (b) H-plane

B. Design

The strength of this design is that it only contains a few necessary materials, Teflon (PTFE) sheets and copper tape along with a cutting and measuring tool. The dimensions of the tag antenna have been determined to be 40 mm x 28 mm x 3.0 mm.

The Teflon sheets can be either acquired at half the overall thickness, or thinner sheets can be stacked together to achieve a desired thickness. It is necessary to have at least two and an even number of Teflon sheets because a piece of metal sheet should be layered in the middle as floating ground. In this prototype, there are 6 sheets of 0.508 mm (.020 in.).

First, cut the Teflon sheets to the specified dimensions. Before stacking the Teflon sheets, a 36 mm x 24 mm copper tape rectangle is placed centered on the third sheet (at 1.5mm height) as floating ground. Next, the copper tape is cut at 82 mm x 20 mm to circumvent along the long side of the tag but leaving a 4 mm gap for the RFID chip. Then copper tape is used to cover the short sides and the bottom side fully. Finally a RFID chip is soldered, bridging the gap on the top side. NXP SL3ICS1002/1202 has been used as the chip. Fig. 3 shows the dimensions of the tag and Fig. 4 shows the fabricated tag.

C. *Test Setup*

Voyantic Tagformance combined with a circular polarized transceiver antenna has been utilized to measure the minimum transmitted power required to turn on the tag. It has been set up with 1 MHz step and 0.1 dB resolution of the transmitted power. The interrogation distance was 50 cm. A reference tag has been tested to calibrate the measurement setup. The proposed tag has been tested with the same setup except a metal plate has been placed directly behind the tag to confirm that the tag works on metal surfaces.

D. *Results*

The minimum transmitted power to turn on the tag has been collected for frequencies around the design frequency of 915 MHz. The reference tag is a dipole type antenna and does not operate on metal surfaces. In free space, its turn on power is observed to be -8 dBm. Fig. 5 shows that the designed tag does indeed work within the specified range and on a metal surface.

To predict the maximum read range for this tag, the Friis formula has been used in (1) [4]

$$D_p = \frac{\lambda}{4\pi}\sqrt{\frac{P_r G_r G_t \tau_t}{P_t}} \qquad (1)$$

where D_p is the predicted maximum read range, λ is the wave length, G_r is the gain of the reader antenna (8 dBi), G_t is the gain of the tag (-4.64 dBi), P_r is the radio power of the reader (30 dBm), P_t is the sensitivity of the RFID chip (-15 dBm), and τ_t is the power transmission coefficient. τ_t is calculated by (2) [5]

$$\tau_t = 1 - \left|\frac{Z_a - Z_c^*}{Z_a + Z_c}\right|^2 \qquad (2)$$

where Z_a and Z_c are the impedances of the tag antenna and RFID chip respectively. Through the calculations, the predicted maximum read range is 6.7 m on a metallic object.

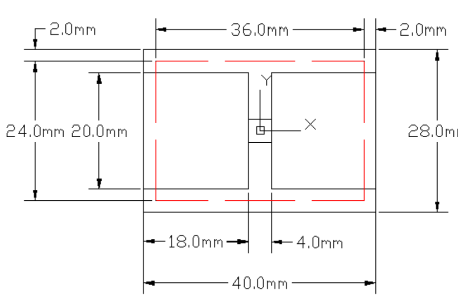


Fig. 3. Dimensions of the RFID tag where the red dashed lines show the location of the floating ground.

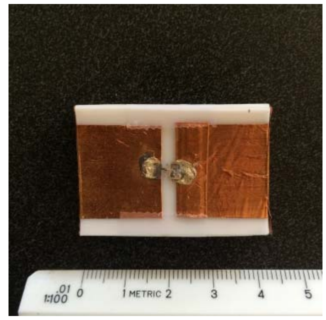


Fig. 4. The fabricated RFID tag.

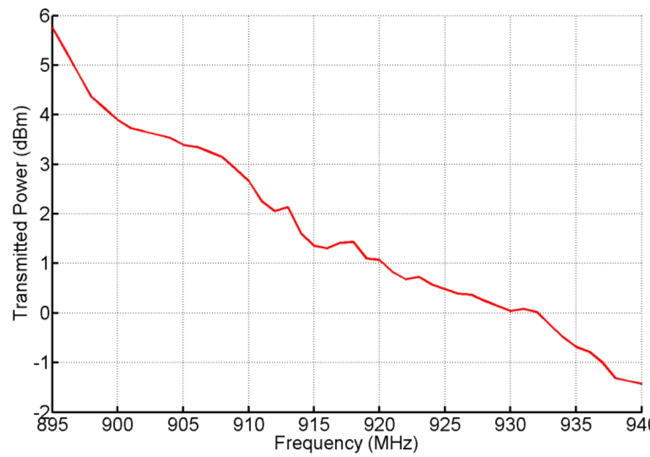


Fig. 5. Transmitted power required to turn on the designed tag on a metal surface.

III. CONCLUSION

Given the limited amount of supplies and materials necessary for the design, this tag is effective in handling the issues that RFID tags often face. First, it is made of a flexible Teflon sheet to protect the tag from a rough handling environment. Next, the tag operates on metals. And finally, the tag is easy to make and extremely low-cost. Therefore, this design is optimal for tracking metal objects in a harsh setting.

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