Tag Antennas for Attaching to Various Surface Materials

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1. INTRODUCTION

In RFID, the reading performances of tags, such as the readable range and the reading stability, change depending on the characteristics of the surface materials that the tags are attached to. For example, if the surfaces are made of dielectric materials, the readable range is decreased due to the resonant frequency shifting. The efficiency of tag antenna also decreases based on the electrical property of the surface materials. Moreover, if the objects have metallic surface with high conductivity, this degradation of the reading performance becomes significant since the tangential electrical currents on the antenna is almost cancel out due to the image current on the metal surface. To overcome these problems, some researchers have proposed a tag antenna using a planar inverted-F or microstrip structure [1]-[3]. These antennas can operate well on high conductivity materials, since they already have large ground planes as their antenna bodies. Nevertheless, these structures have some shortcomings, such as high cost and difficulty in fabrication because they require multiple shorting pins and a large ground plane, as well as thick dielectric substrates.

In this paper, we propose a novel tag antenna; it has a very simple structure that does not require a ground plane or shorting pins. The proposed tag antenna has significant advantages over other types of tag antennas [1]-[3], such as low cost, light weight, and ease of fabrication. The antenna is printed as a single planar strip line on a thin PET substrate (polyethylene, ε_r=3.9, $\tan\delta$=0.003) and it is mounted on foam substrate (ε_r=1.0). The detail design parameters of the proposed antenna were optimized using the Pareto genetic algorithm (GA) [4] in conjunction with the IE3D EM simulator. We built a sample antenna to verify optimized result and it showed broad bandwidth with 2.8 m readable range in free-space. The sample antenna also showed 1.8 m and 2.6 m readable range on the metal surface and low dielectric materials respectively.

2. DESIGN METHODOLOGY AND RESULTS

Fig. 1 shows the geometry of proposed tag antenna which is printed on a 50-μm-thick PET substrate. The foam is attached on the back of a PET and it is used to maintain the efficiency of the antenna when the tag is placed on materials with dielectric or high conductivity. The tag antenna consists of the outer bent dipole (with *L1* and *L2*), inner spiral dipole (with *L3*, *L4* and *L5*), and matching network (with *D1*, *D2* and *D3*). In free-space, both the dipoles make the broadband operation near the operating frequency. When the tag is attached to the high conductivity or low dielectric materials, each dipole with the matching network minimize the variation of the input reactance of the antenna and achieve the improved reading stability.

To determine the detail design parameters of the proposed antenna, we used the Pareto GA conjunction with the commercial EM software. Fig. 2 shows the optimized readable ranges when the tag is in air as well as on metallic object. The results are classified based on the various foam thicknesses of 3 mm, 7 mm and 10 mm. As the foam thickness is increased, the readable ranges both in air as well as on metal are increased since the foam between the antenna and the metallic surface prohibits drastic drops in antenna efficiency. But for the given foam thickness, the readable ranges are in the trade-off between in free-space and on metal. To verity the optimized result, we built a sample antenna which has the size of about 30 mm x 90 mm with 3 mm foam thickness.

Fig. 3 shows the VSWR and efficiency of the sample antenna when it is placed on free-space. The VSWR is computed using the conjugate impedance of the commercial tag chip (All-9238, 9250 [5]). The measured and simulated results are plotted as solid and dashed lines, respectively, and they show fairly good agreement. The measured half power bandwidth (HPBW: VSWR < -5.8) is from 904.5 to 974 MHz, which includes the required bandwidths in Korea and Japan, and from 856.5 to 872 MHz, which includes the required bandwidth in Europe. The efficiency is measured using Wheeler cap method [6], [7] and it shows over 75% in the operating frequency. The measured readable range of the tag antenna using with a commercial tag chip and a reader system [5] is about 2.8 m. Next we examine the VSWR and efficiency of the tag antenna when the tag antenna is placed on metallic surface and the results are shown in Fig. 4. The measured HPBW is 7.5 MHz, from 909 to 916.5 MHz, and the sample antenna shows about 19% of efficiency and 1.8 m of readable range. We also measure the readable range of the tag antenna when the antenna is attached on low dielectric materials such as FR-4 or wood. The resulting readable range in this condition is about 2.6 m and this verifies that the proposed antenna operates well on various surface materials.

Fig. 5(a) and (b) show the high order circuit model of the antenna in free-space and on metallic surface, respectively. Both the outer and inner dipoles are represented as series RLC circuit and the double T-matching network is modeled as four inductors. From Fig. 5(b), it can be seen that the inductance of the inner dipole is decreased while its outer dipole is increased. So the input impedance of the antenna can maintain the reactance value similar as in free-space. This can achieve the stable readability on various surface materials.

To see this operation principle more closely, we also examine the near magnetic field of the antenna with and without the high conductivity material. Fig. 6(a) separately plots the near magnetic fields of inner and outer dipole when the tag antenna is placed in free-space. Fig. 6(b) again shows the near fields when the tag antenna is placed on the high conductivity material. As we expected, the near magnetic field of the inner dipole is decreased, but its outer dipole is increased. So the impedance of each dipole changes in opposite and it makes the minimum changes on input reactance even with the surface material of high conductivities.

3. CONCLUSION

In this paper, we proposed a novel RFID tag antenna for attaching to various surface materials. The proposed tag antenna has a simple-structure, light-weight, and low-cost, since it does not require a ground plate or shorting pins and is printed on a cheap substrate. For detail design parameters, we used the Pareto GA with a full-wave EM simulator to obtain a tag antenna that can work in the air as well as on a high conductivity or low dielectric materials. The built sample antenna has measured HPBW of 15.5 MHz, from 856.5 to 872 MHz, and 69.5 MHz, from 904.5 to 974 MHz, when it is placed in free-space. In addition, it has a 7.5 MHz bandwidth from 909 to 916.5 MHz when it is placed on a metal surface. The maximum readable range in air is about 2.8 m and it is over 2.6 m on a low dielectric material. When the tag is placed on a metal surface, it has a readable range of about 1.8 m. To explain the operating principle of the proposed tag antenna, we constructed the high order circuit model and examined the near magnetic fields of tag antenna.

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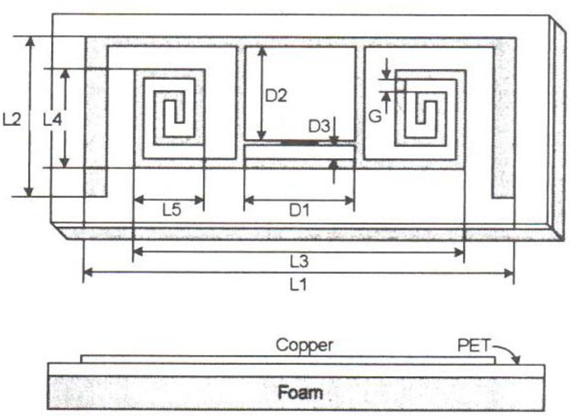


Fig. 1. Proposed tag antenna structure

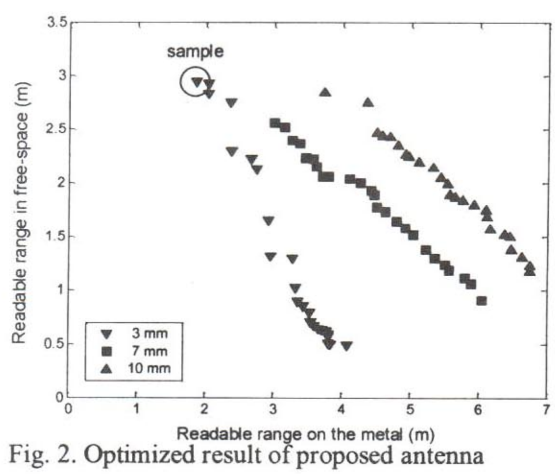


Fig. 2. Optimized result of proposed antenna

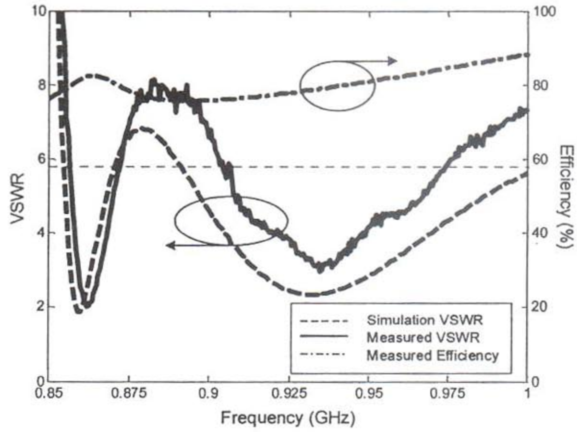


Fig. 3. VSWR and Efficiency in free-space

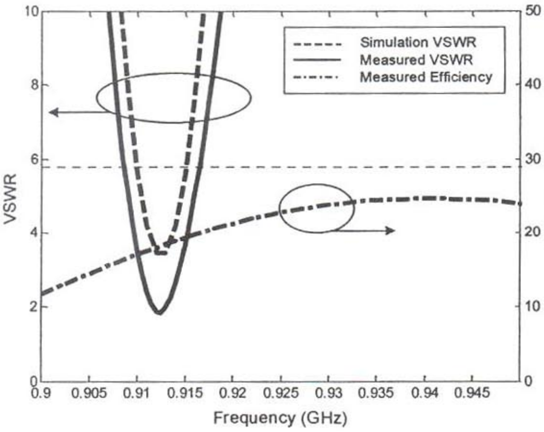
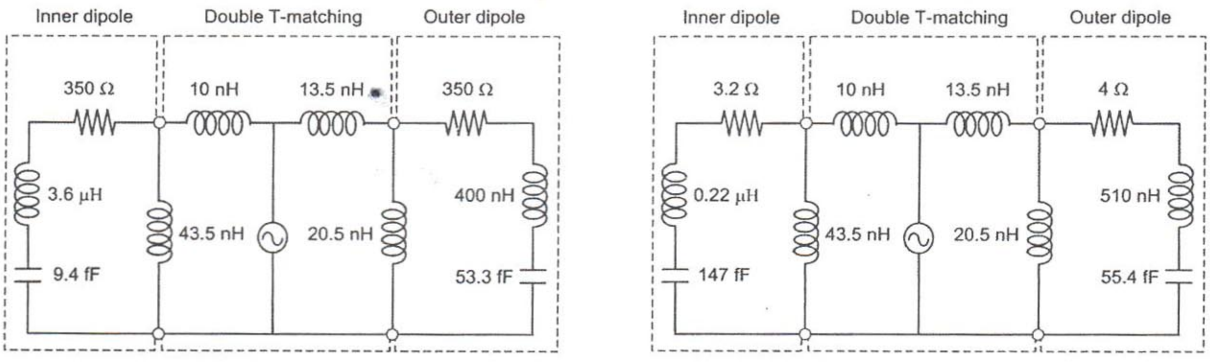
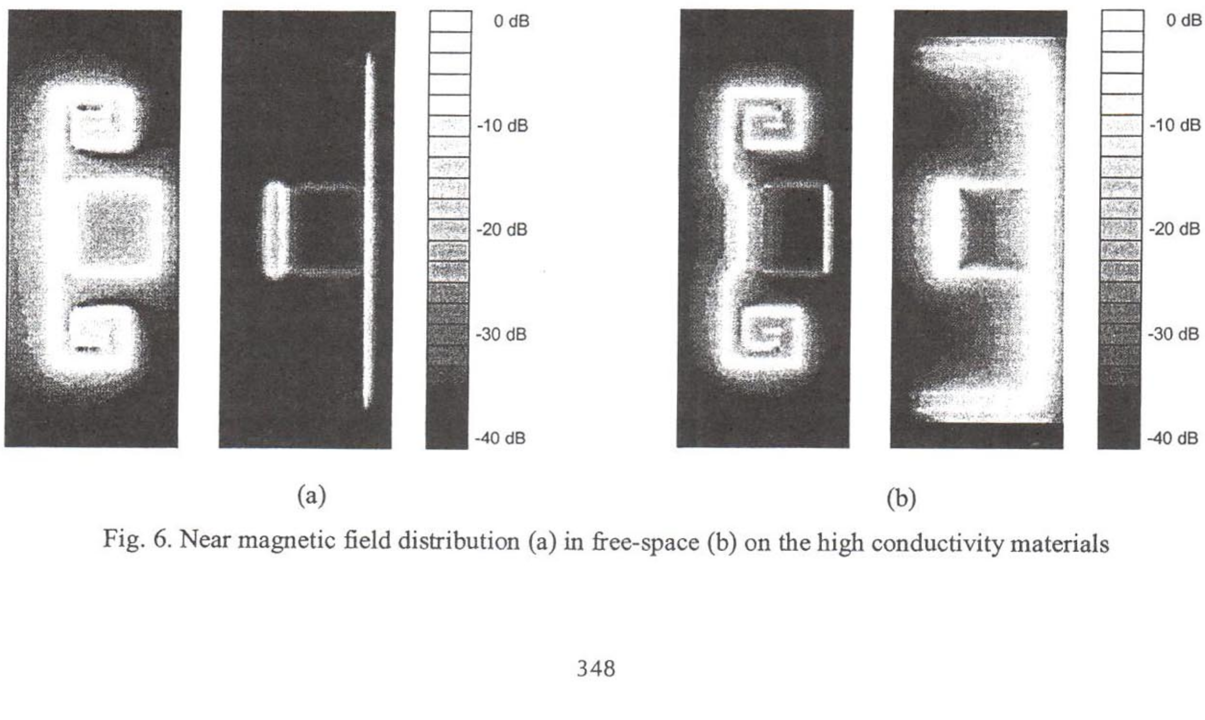


Fig. 4. VSWR and Efficiency on the metallic surface



(a) (b)

Fig. 5. High order circuit model and impedance of sample antenna



(a) (b)

Fig. 6. Near magnetic field distribution (a) in free-space (b) on the high conductivity materials