Passive UHF RFID Tag Antenna Mountable on Both Metallic and Non-Metallic Surfaces

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1. Introduction

Several researches have been done on investigating the effects of the environment on the performance of UHF RFID tags [1]–[4]. Most of commercially available UHF RFID tags are designed for non-metallic environments. Mounting the tags on a metallic surface degrades its performance significantly. Many works have been published on tags for metallic surface [5]–[7].

This paper presents a passive UHF RFID tag antenna mountable on both metallic and non-metallic surfaces. The antenna is either a dipole-like antenna or a short circuit microstrip antenna when mounted on either a non-metallic surface or a metallic surface, respectively. The proposed structure gives a flexibility to tune the antenna impedance for each operation separately. The proposed antenna gives a good reading distance on a non-metallic surface and an acceptable reading distance on a metallic surface. The method to improve its performance is discussed.

2. Proposed Antenna

![Proposed Antenna Structure](image)

Fig. 1 shows the structure of the proposed antenna. The antenna is designed on a FR4 substrate with the thickness of 1.6mm. Fig. 1(a) shows the top layer of the antenna and Fig. 1(b) shows the bottom layer of the antenna. The antenna is designed with assumptions that the top layer of the antenna is attached to freespace and the bottom layer is attached to either freespace or infinite ground when the antenna is mounted on either a non-metallic surface or a metallic surface, respectively. The antenna is either a dipole-like antenna or a short circuit microstrip antenna when mounted on either a non-metallic surface or a metallic surface, respectively. The distance \(d+i+k+0.5j\) is used to adjust the antenna impedance like a stub tuning and \(g+l\) is used to adjust the antenna resonance when mounted on a non-metallic surface. When the antenna is mounted on a metallic surface, the bottom layer is attached to the surface. The part of the antenna on the bottom layer and the surface act as a large ground plane for the top layer patches. Only the distances \(d\) and \(g\) have effects to the antenna impedance. This gives a flexibility to adjust the impedance of the antenna mounted on different materials separately. In this work, NXP UCODE G2XM RFID chip is used. The chip impedance is given by NXP Semiconductors [8] as an 11-ohm resistor in series with a
0.9pF capacitor and the minimum operating power or the minimum threshold power required to power up to the RFID chip is –15dBm. The dimensions of the antenna given in Table 1 are designed to match the antenna at 945MHz. The size of the antenna is 93.2mm by 69.4mm. Frequency of 945MHz is used as a dummy to prove the idea. Depending on the regulations of each country, the allowed frequency bands are different. A simple scaling procedure can be applied to modify the antenna to operate at the specific frequency for specific country.

Table 1: Dimensions of Antenna on 60-mil-FR4

<table>
<thead>
<tr>
<th>Dimensions (mm)</th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
<th>i</th>
<th>j</th>
<th>k</th>
<th>l</th>
<th>m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td>21.1</td>
<td>2.4</td>
<td>31.9</td>
<td>1</td>
<td>7.8</td>
<td>33.3</td>
<td>58.8</td>
<td>15.7</td>
<td>35.4</td>
<td>6.9</td>
<td>2.9</td>
<td>20.6</td>
</tr>
</tbody>
</table>

Table 2: Reading Distance

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Reading Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-metallic</td>
<td>Metalic</td>
</tr>
<tr>
<td>850</td>
<td>860</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Fig. 2 shows the simulated reading distances of the proposed antenna. The expression for the reading distances are given as

\[ r = \frac{\lambda}{4\pi} \sqrt{\frac{EIRP G_r \tau}{P_{th}}} \]  

where \( \lambda \) is the wavelength, \( EIRP \) is the maximum allowed effective isotropic radiated power which is 4 watt, \( G_r \) is the gain of the tag antenna which obtained from the simulations. \( P_{th} \) is the minimum threshold power required to power up to the RFID chip which is –15dBm given by [8], and \( \tau \) is the power transmission coefficient given by

\[ \tau = \frac{4R_c R_a}{|Z_c + Z_a|^2} \]  

where \( Z_c = R_c + jX_c \) is the chip impedance which is about 11–j190 at 945MHz given by [8], and \( Z_a = R_a + jX_a \) is the antenna impedance which is obtained from the simulations. The simulated results show an excellent reading distance in both types of operations. The maximum reading distances at 945MHz are 9m and 16m for non-metallic and metallic surfaces, respectively.
3. Measurement Results

Fig. 3 shows the measured reading distances of the fabricated antenna shown in Fig. 4 for both types of operations. A 30cm by 30cm copper sheet is used as a metallic surface. The reading distances are measured using the fixed distance method [9] which is given by

\[ r = d \frac{EIRP}{P_{min} G_t} \]

where \( P_{min} \) is the minimum transmitted power required to communicate with tag, \( G_t \) is the gain of the transmitting antenna and \( d \) is a fixed distance between the transmitting antenna and the tag. In this experiment, the transmitted power is varied in 1dB step. The distance ‘d’ is 20cm when the expected ‘r’ is small and 90cm when the expected ‘r’ is large.

Figs. 2 and 3 show that the measured results do not agree with the simulated ones. The measured results for a non-metallic surface give a large distance but the peak distance is shifted from the simulated one. The measured results for a metallic surface give a very small distance. This measured results are discussed in the next section.

4. Discussions

There are two reasons to explain the discrepancy between two results. One is the method of mounting the tag on the metallic surface. The results show in Fig. 3 is the best performance from many different ways of mounting. Connecting some of the part of the antenna on the bottom layer to the surface does not mean that the whole part of the antenna on the bottom layer electrically connects to the surface at UHF band. At some locations, a gap between the bottom layer and the surface exist. This makes the antenna impedance change from the expected one.

To prove this explanation, the antenna is modified by attaching a copper sheet to the bottom layer and using pins to solder the top layer to the copper sheet at the via-holes as shown in Fig. 5. Soldering ensures that the top layer is electrically connected to the copper sheet at all important locations. Fig. 6 shows that the reading distance of this modified antenna mounted to a metallic surface improves significantly.

The second reason is that the chip impedance provided by [8] is possibly the on-wafer impedance measurements. The effect of the package is not included. The impedance of the chip in TSSOP8 package soldering to the antenna is provided by the recent work [10] published in May 2009. The measured chip impedance is given by [10] as a 25-ohm resistor in series with a 1.15pF capacitor (–150 ohms at 920MHz) and the minimum operating power is –13dBm. The simulated reading distances are recalculated with this new information and show in Fig. 6. Fig. 6 shows that the measured and simulated results are acceptably agreed.

5. Conclusions

This paper proposes a structure for a passive UHF RFID tag antenna mountable on both metallic and non-metallic surfaces. This structure gives a flexibility to tune the antenna impedance of each operation separately. The measured results show that the mounting methods are highly affects the performance of the tag mounted on a metallic surface. Soldering the proposed antenna to a copper sheet before mounting to a metallic surface improves the tag performance significantly. The research on minimizing the effect of the mounting methods is investigating.

Acknowledgments

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References


