Design of Compact UHF-RFID Tag Antenna with Meander Line Technique

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Abstract. In this paper, a compact UHF RFID tag antenna that can operate at Malaysia UHF RFID frequency (860 MHz – 960MHz) is proposed. The antenna with a common geometry structure without any shorting pin consists of 90degree angled line (meander line) and double T-match structure. The proposed antenna has been designed and simulated using CST Simulation software. The proposed tag antenna design shows a good performance in terms of size, gain and impedance with a dimension of 36 mm x 25 mm x 1.6 mm. The simulated gain of antenna obtained is -0.135 dB at 910 MHz with 19 MHz bandwidth.

1. Introduction

RFID is a technology which is working on radio frequency or radio wave. This technology is used to automatically identifying or tracking the objects. The detectable object can be anything such as book in library, an item which is purchased from shopping mall or a car such as implemented with RFID in Malaysia which is known as MyRFID. In RFID technology, the RFID tag will be stickered on the object’s surface and tracked by the reader. Therefore, to detection and tracking, the RFID reader will continuously send the radio waves. When the object is in the range of the reader, RFID tag will send their feedback to the reader and the object can be tracked easily.

RFID tags have a potential to replace barcode due to its long reading range, non-line-of-sight reading and automated identification and tracking. However, due to its highly price compared to the barcodes technologies, the current RFID technology are still not fully accepted, especially in the field of item-level tagging of cheap item [1]. Thus, the reduces the cost, a modern RFID tag with a duo-triangle using paper as a substrate was developed [2]. To achieved a good impedance, the author in [2] had chosen the short dipole dimension, the length of duo-triangles and T-matching network for designing the tag.
T-matching has been a favourite method that used by the researcher while modelling the tag antenna. This is because to easily match the chip impedance could be easily matched with the impedance of the antenna without much affecting the whole dimension of the tag antenna [3]. T-matching structure have also enhanced the robustness of the tag detuning effects from material loading [4].

For the past two decades, increasing the substrate permittivity and meandering the radiation arms were among the popular techniques used to achieve miniaturization. Those techniques have been explored to achieved high compactness in designing tag antenna [5]. In that work, a small slot antenna with a single-layer structure for passive metal mountable was designed using high permittivity ceramic BaTiO$_3$ as a substrate. BaTiO$_3$ was used for size-reduction purpose. In another related work, it has shown that by increasing the electrical separation, lower antenna resonance frequency could be achieved [6]. Meandering line with arc structure also found to be useful for reducing the size of the tag antenna [7].

This paper presents the design of the passive RFID tag antenna using T-matching technique in order to achieve conjugate matching condition between the impedance of chip tag antenna. A simple meander line structure is also implemented when designing this tag antenna to ensure the compactness of the antenna structure. The antenna is designed to operate at 910MHz UHF band. Since this work considers low-cost antenna design, FR-4 is used as a substrate. The tag was designed and simulated using CST Simulation software.

2. Antenna Design

Figure 1 shows the 2D view structure of the proposed antenna. The dimension of this tag antenna is 36 x 25 x 1.6 mm. It consists of two layers which are copper trace and FR-4. The substrate used for this project is FR-4 with a relative permittivity 4.3, loss tangent of 0.03 and a thickness 1.6 mm. In the copper layer, several structures are formed, including double T-match (red) and meander line (blue) as shown in Figure 1. SOT1040-1 chip with impedance value of 14.8-j127.1Ω from NXP Semiconductor is deployed at the center of the tag antenna. In the CST Simulation software, the chip had been represented as discrete port.

Table 1 shows the parameters location with the dimension of tag antenna.

| Parameters | Dimensions (mm) |
|------------|----------------|
| a          | 25             |
| b          | 36             |
| c          | 1              |
| d          | 8              |

Figure 1. 2D view structure of antenna created.

Table 1. Parameters and dimensions value of tag antenna.
To scale down the tag antenna size, 90-degree angled line is embodied in the physical structure of the tag antenna. By folding the antenna in 90 degree angled line structure, the antenna will resonate at much lowest frequency than a single element antenna of equal size. This is due to disruption of the current flow that leads to the inductance and capacitance of antenna increase. Thus, this lead with an increasing additional charges at the corner of the 90 degree angled line [3]. Frequency shifting will be affected to the resonant frequency from the highest to the lowest frequency. Therefore, to optimize back the resonant frequency near to the desired frequency, scaling down the antenna size is a must. Hence, a compact RFID tag antenna can be attained.

Impedance matching technique become compulsory while modelling the tag antenna to ensure that the waves are radiated in the most efficient. In this regard, the antenna can be matched and highly inductive with the chip impedance. In this work, a double T-match structure is implemented when designing the antenna structure. The double T-match structure easily match the impedance of the antenna without affecting the whole dimension properties of the tag antenna. The double T-match structure can be modelled by joining a slotted rectangular shape to the meandered feed line which is indicated with parameter $e$ and $d$ as shown in Figure 1. T-matching method technique with the proposed antenna circuit arrangement is illustrated as in Figure 2.

$$Z_{in} = \frac{2j Z_0 tan \frac{k a}{2}(1 + a)^2 Z_a}{2j Z_0 tan \frac{k a}{2} + (1 + a)^2 Z_a}$$  \hspace{1cm} (1)$$

The power reflection coefficient is adapted to deal with the complex impedance of the chip and proposed antenna. The power reflection coefficient formula is given as follows [10]:

$$\Gamma^* = \frac{Z_a - Z_{chip}^*}{Z_a + Z_{chip}}$$  \hspace{1cm} (2)$$
3. Results and Discussion

For RFID systems, the performance of tag antenna directly affects the range and the quality of use of these systems. Based on the results of these characteristics such as reflection coefficient ($S_{11}$), gain, directivity and radiation pattern of the tag antenna, the quality of adaptation between antenna and the chip and the read range can be estimated.

To make sure the tag antenna has a better performance, the reflection coefficient must be less than -10 dB. The resonant frequency can be controlled by the width of the meander line. In the simulation, a parameter sweep is carried out for the value of $c$ need to optimise the $S_{11}$ until the desired frequency range is obtained. The parameter sweep result for the meander line width, $c$ is shown in Figure 3. Figure 4 shows the final optimized $S_{11}$ result of the RFID tag antenna.

**Figure 3.** Simulation results of the parameter sweep for the width of the meander line.

**Figure 4.** Simulated reflection coefficient, $S_{11}$ in CST.
The simulated bandwidth obtained by CST microwave software is 19 MHz (901 MHz to 920 MHz) which covers the operating frequency of UHF RFID in Malaysia with $S_{11}=-17.80$ dB at 910MHz.

![Figure 5. 3D radiation pattern for tag antenna at 910 MHz.](image)

Figure 5 shows the 3D radiation pattern of the RFID tag antenna with almost omni-directional radiation pattern. The negative gain is obtained due to the small size of the tag antenna, which is definitely smaller than a wavelength at the operating frequency 910 MHz. The realized gain for tag antenna at 910 MHz is -0.135 dB as shown in Figure 5. The simulation read range can be calculated theoretically using Friss free space equation as listed in (3) and (4) [11]:

$$r = \frac{\lambda}{4\pi} \sqrt{\frac{P_t G_r G_t \tau}{P_{th}}}$$  \hspace{1cm} (3)

$$\tau = \frac{4R_c R_a}{|Z_c + Z_a|^2}$$  \hspace{1cm} (4)

where $P_t$ is the power transmitted from RFID reader. While for $G_r$ and $G_t$ is the gain obtained from the RFID reader and tag. $P_{th}$ is the threshold power and $\tau$ is the power transfer coefficient. The power transfer coefficient measures how much the antenna impedance is matched to the chip impedance. The calculated simulated read range obtained is estimated at 3m using equation in (3).
4. Conclusion
A compact UHF RFID tag antenna has been successfully designed and optimized using CST Microwave Studio software. The simulated result obtained shows that the proposed antenna operates in the frequency band (860 MHz to 960 MHz), which covers the UHF RFID operating frequency in Malaysia. The proposed antenna is very compact, easy to fabricate and low-cost. In future work, the tag antenna with flexible substrate will be proposed for bending purposes and the for the use on non-planar objects.

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