Wideband UHF RFID Tag

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1. Introduction

The Radio Frequency Identification (RFID) technology, especially in ultra-high frequency (UHF) band, is widely used in many applications such as supply chain, logistics, and healthcare [1]. In the UHF RFID system, the information in the transponder (tag) is transferred to the interrogator (reader) using radiative coupling mechanism [2]. This mechanism provides longer communication distance between tag and reader comparing to the inductive coupling mechanism used in low frequency (LF) or high frequency (HF) RFID system. The communication distance of the UHF RFID system strongly depends on the frequency of use. However, the UHF RFID band allocation is different worldwide. For example, the UHF RFID band of USA is 902-928 MHz, that of European countries is 865-868 MHz, that of Japan is 952-954 MHz, and that of Thailand is 920-925 MHz. The UHF RFID band of all countries ranges within 860-960 MHz. In the applications such as supply chain, the RFID tag is attached to the products that are transferred worldwide. In such a case, the RFID tag should have high communication distance in the UHF RFID bands of all countries worldwide. Various antenna designs have been proposed for improving the communication distance or read range [3], [4] but the bandwidth cannot cover the worldwide UHF RFID band. In order to increase the bandwidth, wideband UHF RFID tags for metal mount have been proposed [5]-[7].

In this paper, we proposed the wideband UHF RFID tag antenna for using worldwide. The bandwidth of this tag antenna can cover UHF RFID band with high read range within the band. The antenna parameters are varied to determine how we can adjust the antenna in case the different IC chip is used or different frequency of the highest read range is needed. Finally, we optimize the proposed tag antenna to achieve the high read range within the UHF RFID band of Thailand, together with the band of European countries and USA.

2. Antenna Configuration

Figure 1 shows the configuration of the proposed wideband UHF RFID tag antenna. The antenna consists of meander line for size reduction and shorting stub for IC chip conjugate impedance matching. The antenna is designed for NXP UCODE G2XL chip with the input chip capacitance of 0.9 pF, quality factor of 9, and minimum operating power of -15 dBm [8]. The antenna substrate is 0.2-mm FR4 (ε_r = 4.3, tanδ = 0.02) with 1-oz. copper (σ = 5.8 x 10^7). The dimensions of this antenna are: h_1 = 10.25 mm, h_2 = 3.5 mm, h_3 = 4.0 mm, l_1 = 32.0 mm, l_2 = 28.0 mm, l_3 = 6.0 mm, l_4 = 2.0 mm, s = 2.0 mm, and w = 1.0 mm. The overall size of this antenna is 88 mm x 11.5 mm.
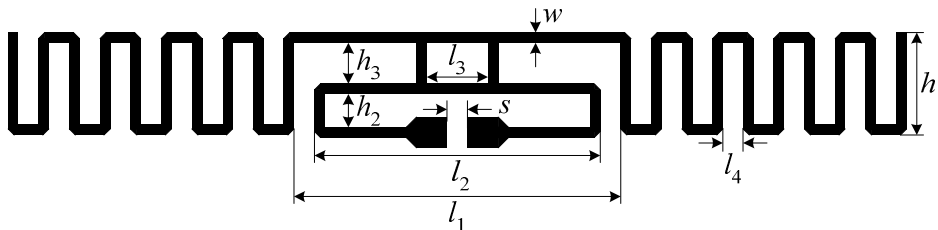

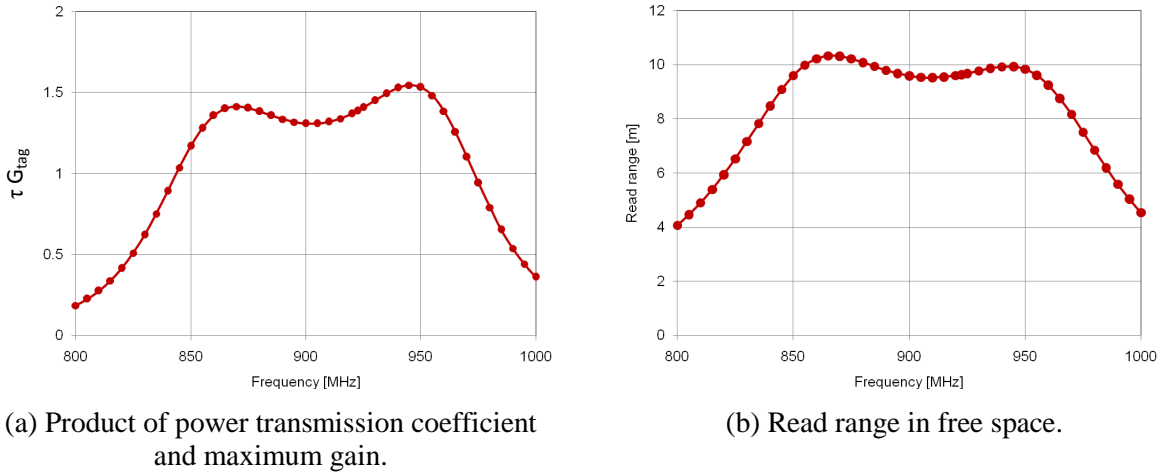Figure 1: Configuration of the wideband UHF RFID tag antenna.

(a) Product of power transmission coefficient and maximum gain.

(b) Read range in free space.

Figure 2: Simulation results of the proposed wideband UHF RFID tag antenna.

3. Performance Evaluation Method

We simulate the antenna using the Advanced Design system (ADS) momentum analysis software. The performance of this tag antenna is evaluated using the read range, which is obtained from the Frii's transmission equation [3] as follows.

$$r = \frac{\lambda}{4\pi} \sqrt{\frac{P_t G_t G_{tag} \tau}{P_{th}}}$$ (1)

λ is the wavelength, P_t is the power delivered to the transmitting reader antenna, G_t is the gain of the transmitting reader antenna, G_{tag} is the gain of the receiving tag antenna, P_{th} is the minimum threshold power required to power up the IC chip, and τ is the power transmission coefficient given by $\tau = 4R_c R_a/|Z_c+Z_a|^2$, where $Z_c = R_c + jX_c$ is the impedance of the IC chip and $Z_a = R_a + jX_a$ is the impedance of the antenna. The read range is calculated for the transmitted power ($P_t G_t$) of 4 W EIRP. Furthermore, the bandwidth of tag antenna is defined as the frequency range that the product of power transmission coefficient and gain of tag antenna (τG_{tag}) is higher than $(1/2)[\tau G_{tag}]_0$, where $[\tau G_{tag}]_0 = 1$ is referenced from a perfectly matched isotropic antenna [4].

4. Simulation Results

The product of power transmission coefficient and gain of the wideband tag antenna is shown in Fig. 2 (a). We can see that the frequency range of this antenna can cover the worldwide UHF RFID band with the bandwidth of 18.4%, which is comparatively larger than that of the meander line antenna (3.3%) and the inverted-F antenna (4.0%) as indicated in [4]. However, the read range within the UHF RFID band of Thailand (920-925 MHz) as shown in Fig. 2 (b) is not a peak one. In order to optimize the antenna to increase the read range in the Thailand's UHF RFID band, the antenna parameters h_1 - h_3 and l_1 - l_3 are examined. The reactance of these parameter variations are shown in Fig. 3. We can see that the increase of parameter h_1 and l_1, which increase the length of the meander line, results in the shift of impedance to the higher frequency with lower inductive reactance values. For the increase of parameter h_2 and l_2 of the feed part, the inductive reactance increases, while the increase of parameter h_3 and the decrease of parameter l_3 can reduce the bandwidth of tag antenna. This means that we should vary the parameter h_1 and l_1 in case we want to shift the frequency band or the frequency of the highest read range. Moreover, the parameter h_2 and l_2 should be varied in case we want to adjust the level of the antenna reactance to be used with different IC chip with different chip impedance, while the parameter h_3 and l_3 should be varied in case we want to adjust the bandwidth of the tag antenna.
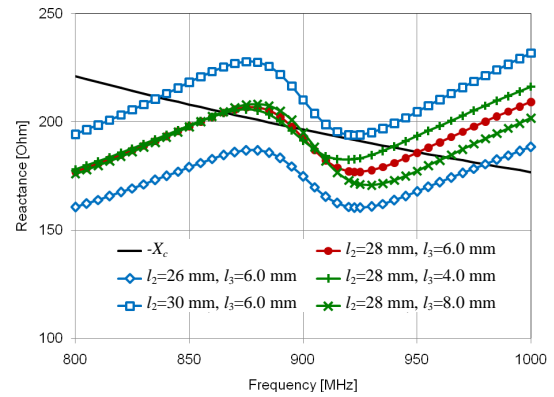
According to these results, we optimize the wideband UHF RFID tag antenna to increase the read range within 920-925 MHz. The new dimensions of this optimized wideband tag antenna are: $h_2 = 3.7$ mm, $h_3 = 4.2$ mm, and $l_3 = 4.0$ mm. The product of power transmission coefficient and
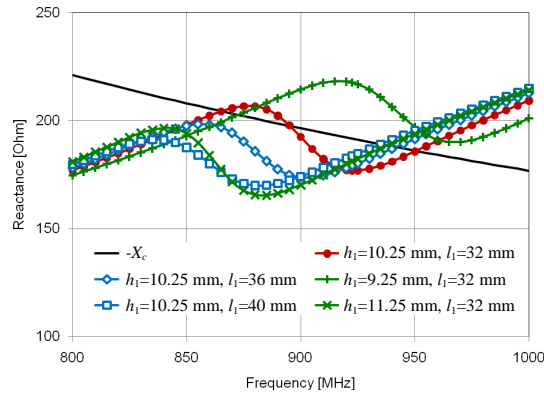
(a) Variation of h_1, l_1
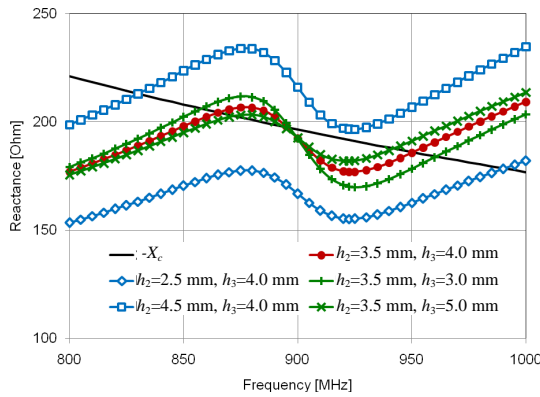
(b) Variation of h_2, h_3

(c) Variation of l_2, l_3

Figure 3: Reactance of wideband tag antenna for parameter variations.

gain of the optimized wideband tag antenna is shown in Fig. 4 (a) comparing with the primary one. The values in Thailand's UHF RFID band increase, while those in the European countries' UHF RFID band are in the same level as the primary one. The frequency range of this optimized tag antenna can also cover the worldwide UHF RFID band. The bandwidth of this tag antenna reduced to 16.8% but the read range as shown in Fig. 4 (b) within the UHF RFID band of European countries, USA, and Thailand are approximately 10 m.

5. Conclusions

In this paper, we proposed the wideband UHF RFID tag antenna for using worldwide. The tag antenna is a simple meander line with a shorting stub for IC chip conjugate impedance matching. The bandwidth of this antenna can cover the entire UHF RFID band with high read range. The parameters of this tag antenna are examined to verify the effect of each parameter. We also optimize the tag antenna to obtain the maximum read range at the UHF RFID band of Thailand. The frequency range of the optimized tag antenna can still cover the entire UHF RFID band with the bandwidth of 16.8%. The read range of the optimized tag antenna is approximately 10 m all over the UHF RFID band of European countries, USA, and Thailand.

References

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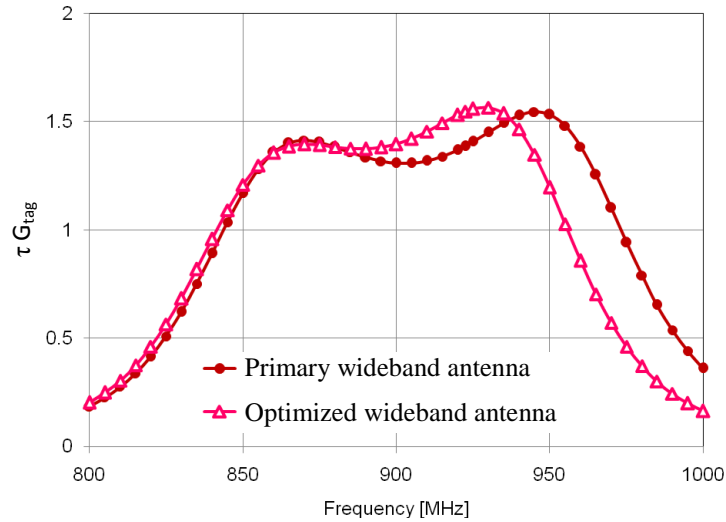
(a) Product of power transmission coefficient and maximum gain.
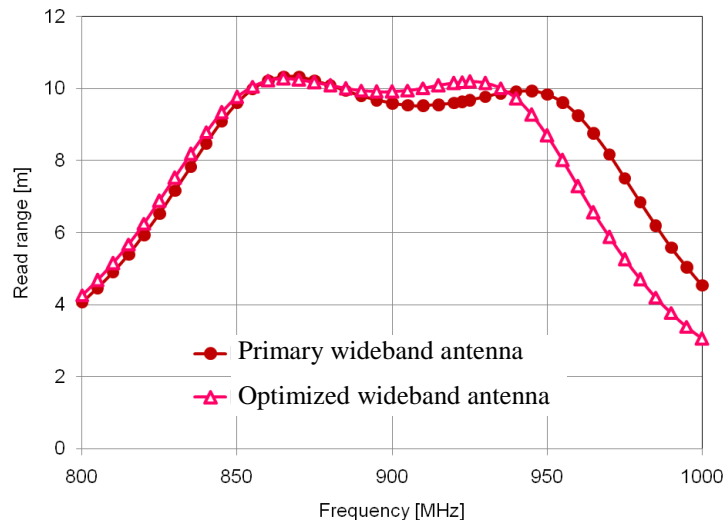
(b) Read range in free space.

Figure 4: Simulation results of the optimized wideband UHF RFID tag antenna.

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