Meander-Line UHF RFID Tag Antenna with Semi-Circular Structure

#P. Wongsiritorn[1], C. Phongcharoenpanich[1], D. Torrungrueng[2] and M. Krairiksh[1]
[1]Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand. E-mail: kpchuwon@kmitl.ac.th
[2]Faculty of Engineering and Technology, Asian University, Chon Buri 20150, Thailand.
E-mail: dtg@asianust.ac.th

1. Introduction

Recently, the demand of the Radio Frequency Identification (RFID) system is increased for using in many applications such as personal access control, logistics, industrial process, product management, including identifying people, animals and products. The frequency band of the RFID system can be divided into four bands such as low frequency (125-134.2 kHz), high frequency (13.56 MHz), ultra high frequency (433, 860-960 MHz) and microwave frequency (2.45, 5 GHz). Each frequency band is used in different applications [1]. The main application of ultra-high frequency (UHF) RFID is used in the process of logistics, product and commercial managements. However, the standard of the UHF RFID in each country is different. In Thailand, the allocated frequency of the UHF RFID is 920-925 MHz [2].

This paper presents the RFID tag antenna design for the standard of UHF RFID in Thailand. An important requirement for the tag antenna design is that the impedance of the tag antenna must be conjugately matched with the impedance of the IC chip for the maximum power transfer from the tag antenna to the IC chip [3]. The proposed size of the antenna is relatively small ($0.10\lambda_0 \times 0.25\lambda_0$), where λ_0 is wavelength in free-space of 922.5 MHz. It is found that the tag antenna possesses good performance for using in UHF RFID systems.

2. Antenna Design

The tag antenna design starts with the printed strip dipole antenna of size $0.10\lambda_0 \times 0.25\lambda_0$ as shown in Fig. 1, where λ_0 is wavelength in free-space of 922.5 MHz. It is designed on an FR-4 substrate (ε_r = 4.3, tanδ = 0.025, thickness = 0.15 mm). The gap (s) between the radiating patch is fixed at 2 mm, where the length (l_s) is 3 mm, and the width (w_s) is fixed at 4 mm to match with the chip configuration. The input impedance of the NXP G2XL IC chip [4] at 922.5 MHz is about 21.3-j191.7 Ω. Thus, the tag antenna should have the input impedance of 21.3+j191.7 Ω for the maximum power transfer from the tag antenna to the IC chip. Fig 2 shows the simulation results when the length (l_d) of the strip dipole antenna is varied. Note that the input resistance of the printed strip dipole antenna tends to increase along its length. From Fig. 2, the input resistance of the tag antenna is relatively low and needed to be increased for conjugate matching. Therefore, the antenna structure must be improved.

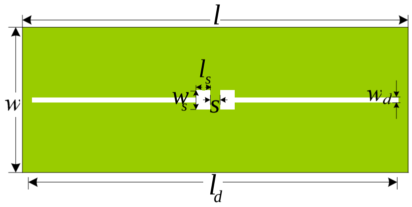


Figure 1: Printed strip dipole tag antenna of size $0.10\lambda_0 \times 0.25\lambda_0$.

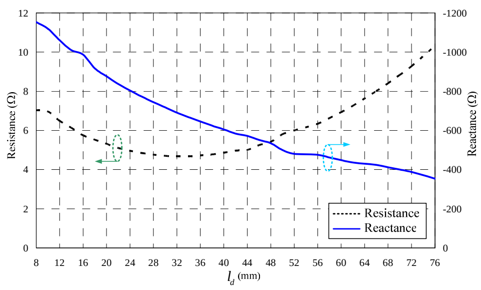
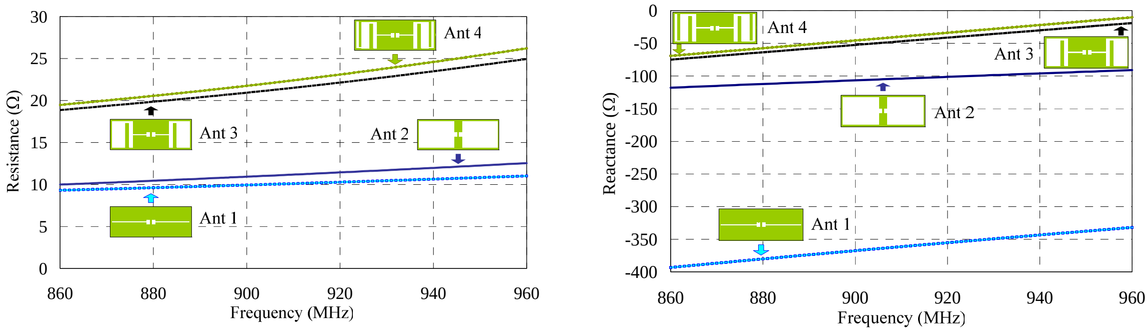


Figure 2: Input impedance of the printed strip dipole antenna for various lengths at 922.5 MHz

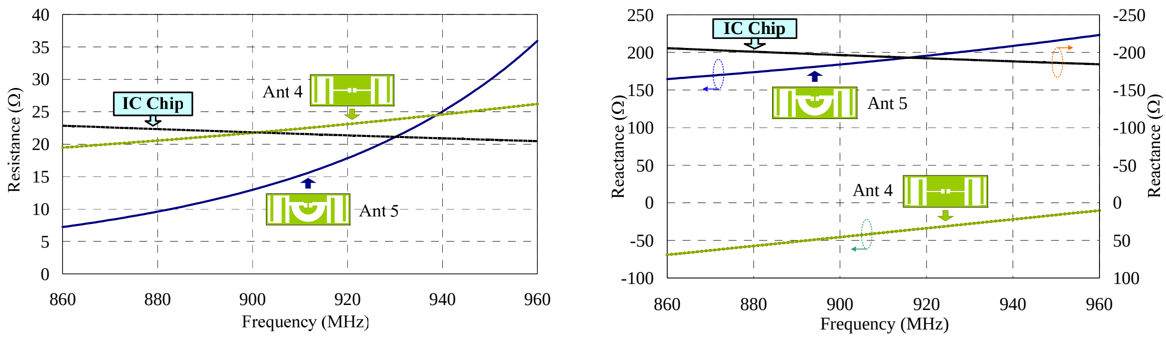
Fig. 3 shows the simulation results of the input impedance of different improved structures. The first structure (Ant 1) is the basic printed strip dipole antenna. The second one (Ant 2) is a wide dipole antenna. The third structure (Ant 3) is a simple meander line antenna. The final one (Ant 4) is the improved meander line antenna. Note that the input impedance of the tag antenna is increased for both resistance and reactance along the development of the structures. For the improved meander line structure, the input impedance of the tag antenna is 23.3-j32.12 Ω at 922.5 MHz.



(a) Input resistance. (b) Input reactance.

Figure 3: Input impedance of different antenna structures of size $0.10\,\lambda_0 \times 0.25\,\lambda_0$.

To further improve the impedance matching, the semi-circular loop is added to the improved meander line structure as shown in Fig. 4, called Ant 5. After adjusting the input impedance of the proposed tag antenna by adding semi-circular loop, the reactance of the tag antenna is increased significantly. At 922.5 MHz, the input impedance of the proposed tag antenna is equal to 18.59+j197.1 Ω that is nearly conjugate match with the IC chip.



(a) Input resistance. (b) Input reactance.

Figure 4: Input impedance of tag antennas when adding the semi-circular loop.

3. Results

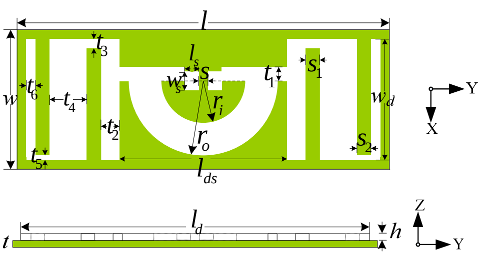


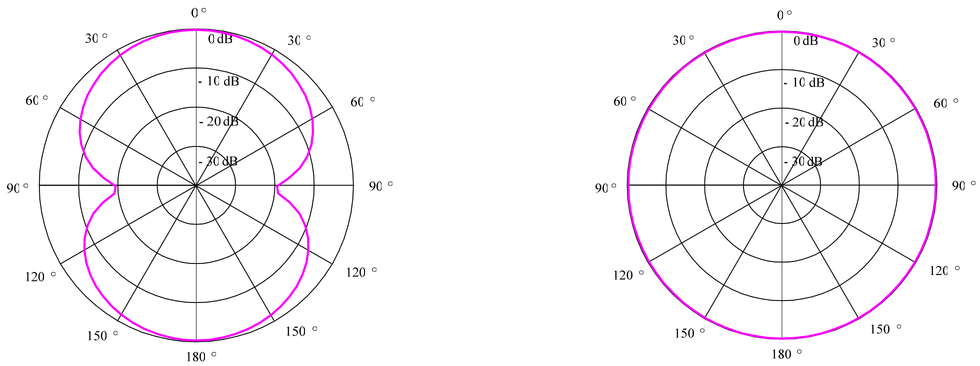
Figure 5: Antenna structure.

Table I: Parameters of the proposed tag antenna

Parameters	Physical Size (mm)	Parameters	Physical Size (mm)
w	30	t_2	4
w_s	4	t_3	2
w_d	26	t_4	8
l	80	t_5	1
l_s	3	t_6	2
l_d	76	s	2
l_{ds}	36	s_1	3
h	0.017	s_2	3
t	0.15	r_i	9
t_1	3	r_o	16

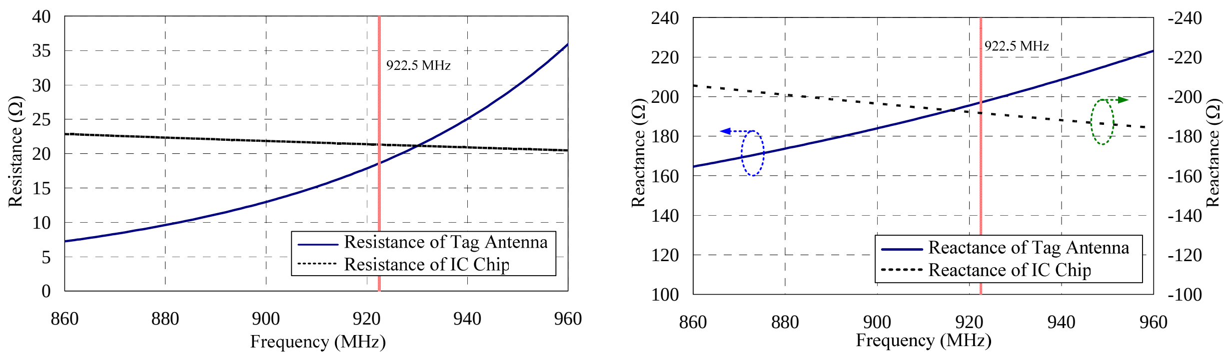
The structure of the proposed antenna is shown in Fig.5. The antenna consists of two symmetrical radiating patches (copper) that are the meander line structures with added semi-circular structure for adjusting the input impedance for conjugate matching. Table I illustrates the antenna parameters. The antenna length (*l*) is 80 mm and the antenna width (*w*) is 30 mm. The tag antenna is fabricated on an FR-4 substrate with 0.015 mm thickness.

The simulation of the tag antenna characteristics (radiation pattern, impedance, directivity, radiation efficiency and return loss) is carried out at 922.5 MHz by CST@ Microwave studio [5]. The measurement result of the maximum read range will be reported in this section as well. Fig. 6 shows the simulated result of the radiation patterns in the E-plane (YZ-plane) and H-plane (XZ-plane). In Fig. 6, it is obvious that the proposed tag antenna has omni-directional pattern. In Fig 7, the input resistance and reactance of the proposed tag antenna are increased with the frequency, and the impedance at 922.5 MHz is equal to 18.59+j197.1 Ω.



(a) E-plane (YZ-plane). (b) H-plane (XZ-plane).

Figure 6: Simulated radiation patterns.



(a) Input resistance. (b) Input reactance.

Figure 7: Input impedance of the proposed tag antenna.

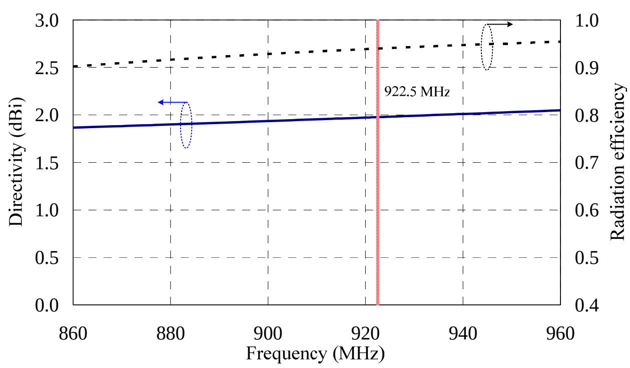


Figure 8: Directivity and radiation efficiency of the proposed tag antenna.

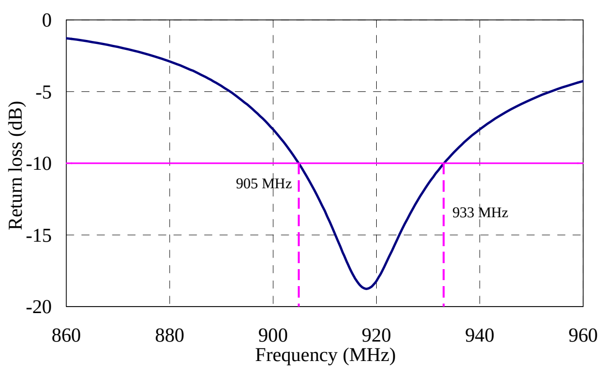


Figure 9: Return loss of the proposed tag antenna.

The directivity and radiation efficiency of the antenna are shown in Fig 8. The directivity is equal to 1.98 dBi at 922.5 MHz, and the radiation efficiency is equal to 0.94. Figure 9 shows the return loss of the proposed tag antenna. Note that the return loss is less than -10 dB for the frequency range of 905-933 MHz, which covers the operating frequency of the UHF RFID system in Thailand (920-925 MHz).

The prototype antenna was fabricated by using parameters in Table I. The photograph of the proposed antenna is depicted in Fig. 10. The maximum read range was measured by using the IE Technology Reader (RU-110U) [6], which radiates circular polarization. The obtained maximum read range is equal to 2.3 m.

Figure 10: Photograph of the prototype antenna.

4. Conclusions

The tag antenna for the UHF-RFID system in Thailand is presented in this paper. The small size antenna with the dimension of $0.10\lambda_0 \times 0.25\lambda_0$ can be achieved by using the meander-line structure to increase electrical length. The semi-circular structure is also added for the impedance matching of the tag antenna. The appropriate input impedance of the tag antenna for conjugate matching with the IC chip impedance is found to be 21.3+j191.7 Ω. The input impedance of the proposed tag antenna is equal to 18.59+j197.1 Ω at the centre frequency of 922.5 MHz resulting in the power transmission of about 97.7 %. The radiation pattern is omni-directional beam. From the measurement, the maximum read range of the proposed antenna is equal to 2.3 m. This tag antenna can be effectively employed in the national standard of the UHF RFID system in Thailand.

Acknowledgments

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