UHF-RFID Tag Antenna with Rectangular Loops

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Abstract

The feeding loop and the parasitic-line with rectangular loop technique is presented to minimize a size of a UHF passive tag antenna at the operating frequency of 920-925 MHz, corresponding to the standard of UHF RFID in Thailand. The electrical size of the proposed tag antenna is approximately $0.03\lambda_0 \times 0.24\lambda_0$. It is designed for NXP G2XL IC chip with the impedance of 21.29-j191.7 Ω at the frequency of 922.5 MHz. For the simulation results, the proposed tag antenna has omnidirectional pattern, the power transmission is around 98.75 % at the center frequency, and the gain is 1.19 dBi. The prototype antenna is fabricated on the FR4 substrate $(\varepsilon_r = 4.3)$ with thickness of 0.25 mm. The maximum read range was measured by 4 W EIRP reader which obtains 7 m.

Keywords: Rectangular Loops, Minimizing Tag Antenna, Loop Feed

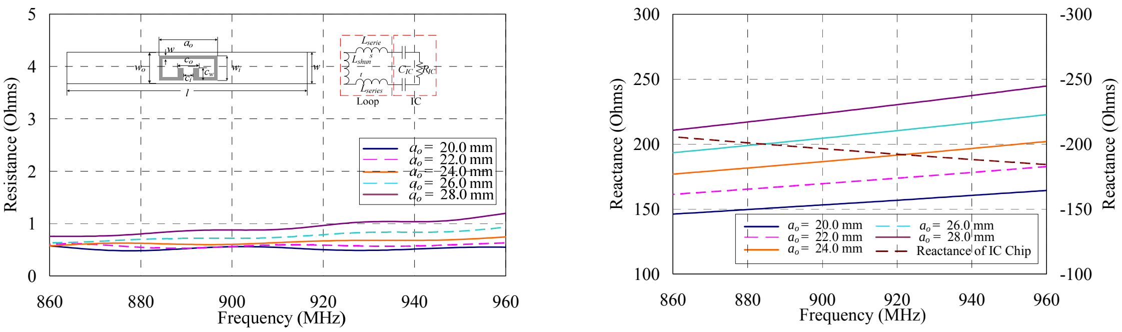
1. Introduction

The RFID system has been widely used in many applications such as supply chain, manufacture in industry and many others [1]. RFID system uses wireless radio communication technology to uniquely identify tagged objects. There are three basic parts, namely controller, reader and tag. The RFID tag is a small device, used for attaching the product. The UHF RFID in Thailand employs the frequency range between 920 and 925 MHz [2]-[3].

The design of tag antennas for UHF-RFID systems are very active research topic. Generally, the tag antenna design for RFID system uses some specific antenna types, such as dipole antennas, patch antennas and many others [2]-[5]. In addition, there are many novel techniques to improve the characteristics or use in many specific applications of RFID tag antenna [5]. Nevertheless, the compact and small size tag antenna is required for many RFID applications such as in logistics and supply chain. Moreover, its demand increases all the times. Therefore, this paper presents the design technique to achieve the small-scale tag antenna by using feeding loop and parasitic-line with rectangular loops.

2. Antenna Design and Parametric Study

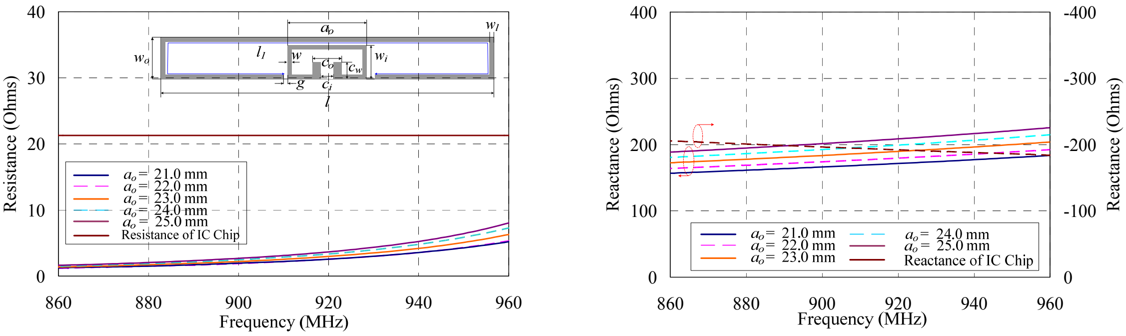
To achieve the maximum power transfer, the impedance of tag antenna should be conjugated match with the impedance of IC Chip (21.29-j191.7 Ω at the frequency of 922.5 MHz) [6]. Therefore, the best impedance of designed tag antenna considered at 922.25 should be 21.29+j191.7 Ω . At the beginning of tag antenna design, a loop structure is considered. It is located on FR4 as shown in figure 1. An initial size of substrate was fixed by the length of $0.5\lambda_d$ or 78 mm and the width of $0.064\lambda_d$ or 10 mm. Note that λ_d is the wavelength in material and λ_0 is the wavelength in free space. The C_i, C_o, C_w parameters are the supporters which are used as platform of the IC chip with the sizes of 3, 7 and 4 mm, respectively. Then, parameter a_0 , which is the width of loop structure, was varied to achieve the appropriate impedance. In figure 1, it is found that when parameter a_0 is increased, the resistances of the tag antenna slightly increase but it is relatively low and less than the suitable resistance. On the other hand, the reactance of the tag antenna is close to the conjugated impedance at $a_0 = 24$ mm.



(a) (b)

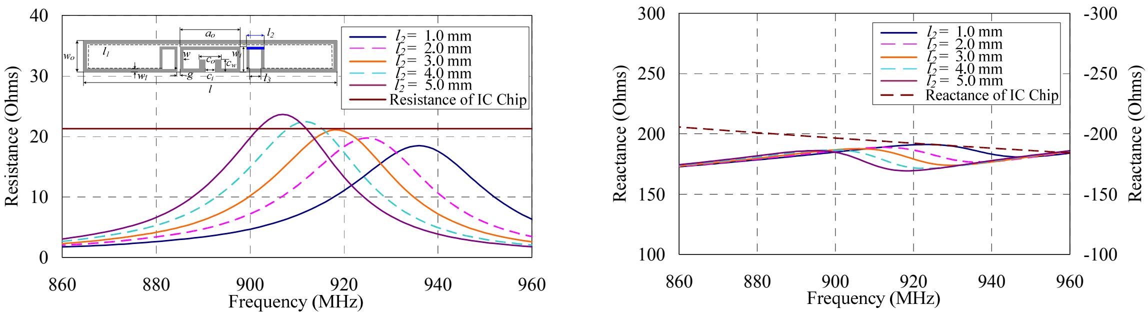
Figure 1: Input impedance of the tag antenna for various lengths a_0

Next, the parasitic line was added in order to adjust the impedance of tag antenna and its length is equal to λ_d (= 156 mm). From the simulation, it is obvious that the resistance is increased. Nevertheless, it is still less than the desired target. Thus, the loop length of a_0 is adjusted as illustrated in Fig 2. It can be seen that the good impedance can be achieved (3.13+j190.5 Ω at 922.5 MHz) with $a_0 = 23$ mm.



(a) (b)

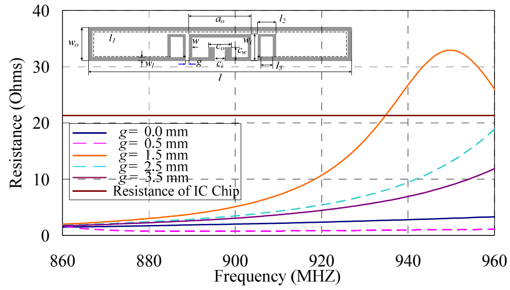
Figure 2: Input impedance of the tag antenna for various lengths a_0



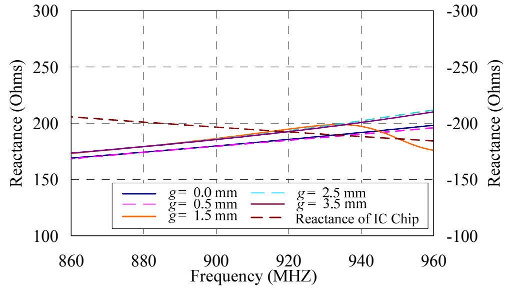
(a) (b)

Figure 3: Input impedance of the tag antenna for various l_2

From Figure 3, parameter l_2 is improved in order to increase the electrical length and vary to conjugate matching. It is obvious that resistance of the tag antenna is strongly affected by l_2. At this step, l_2 of 3 mm is chosen as the suitable parameter (22.1+j176 Ω at 922.5 MHz). However, the reactance of the tag antenna still needs to increase. Hence, in Figure 4, parameter g is varied and the suitable conjugate matching is obtained at g = 1.5 mm with 11.9+j195.3 Ω at 922.5 MHz. Although different g can improve the reactance of the tag antenna, the resistance is decreased. In figure 5, to increase the resistance of the tag antenna, l_2 is further varied and at l_2 = 5 mm. It is illustrated that resistance of the tag antenna is close to the resistance of IC Chip. At the last step, parameter l_3 is adjusted in order to increase the power transmission. From Figure 6, it is clear that when l_3 is equal to 1.5, the optimum matching, considering at 922.5 MHz is achieved which $|S_{11}|$ is equal to -18.97 dB and the power transmission is around 98.75 %. The final design of the tag antenna is shown in Fig 7.

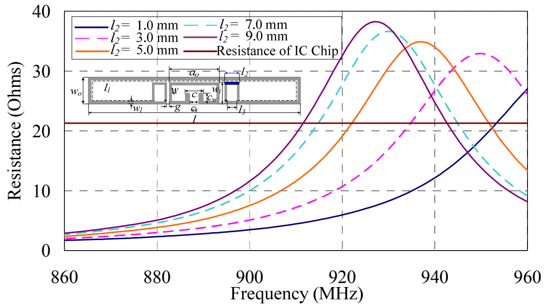


(a)

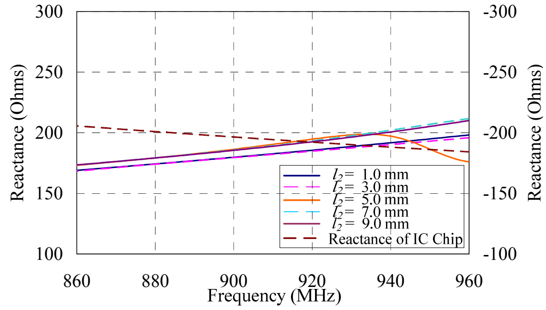


(b)

Figure 4: Input impedance of the tag antenna for various g



(a)



(b)

Figure 5: Input impedance of the tag antenna for various l_2

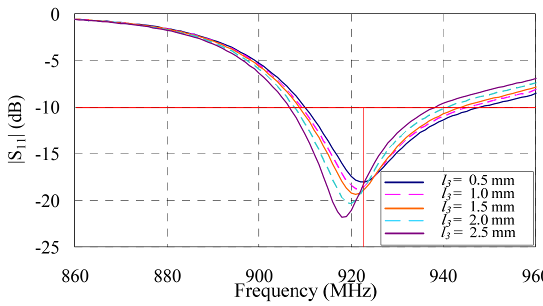


Figure 6: $|S_{11}|$ (dB) of the tag antenna for various l_3

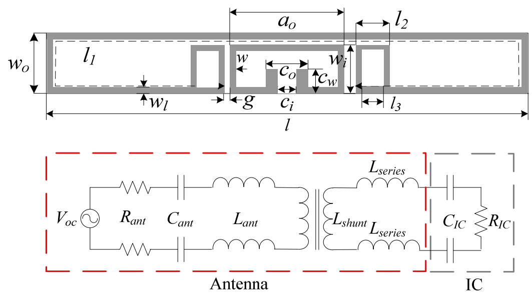


Figure 7: The proposed tag antenna and its equivalent circuit

3. Result

The simulated impedance of tag is illustrated in the Fig. 8. The impedance at 922.5 MHz of the tag is 22.39+j196.49 Ω. Figure. 9 shows the simulated $|S_{11}|$ of the proposed tag. It is seen that the $|S_{11}|$ of the tag antenna is -18.97 dB at the center frequency. Figure 10 shows the gain at the desired direction of the tag, which is equal to 1.19 dBi. The radiation pattern is omnidirectional beam as can be seen in Fig 11.

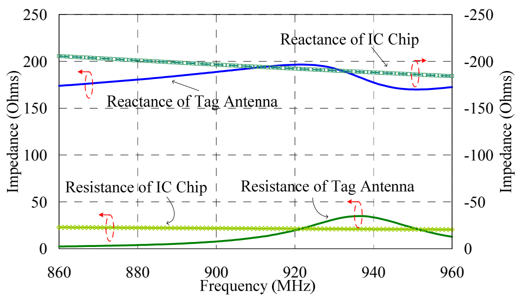


Figure 7: The input impedance of the proposed antenna.

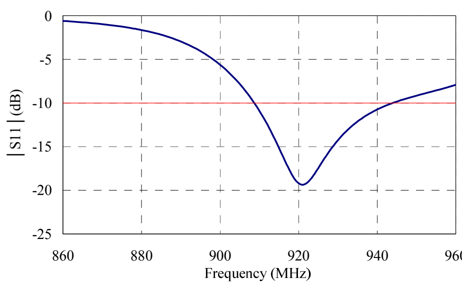


Figure 8: $|S_{11}|$ (dB) of the proposed antenna

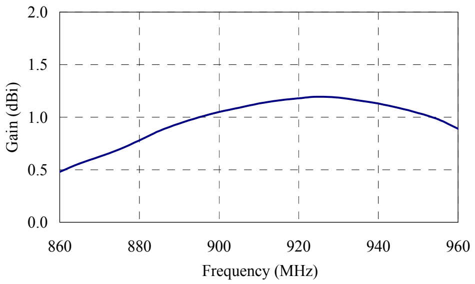


Figure 10: Gain of the proposed antenna

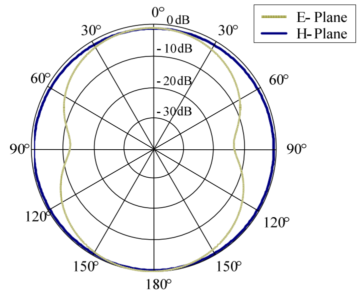


Figure 11: Radiation patterns of the proposed antenna

4. Fabrication and Measurement

The prototype antenna was fabricated by using the designed parameters. The tag has size of 78×10 mm^2. The photograph of the proposed antenna is depicted in Fig. 9. The maximum read range was measured by using Alien Technology Reader (ALR 9780). The reader antenna radiates linear polarization with the gain of 5.9 dBi. The obtained maximum read ranges of tag is 7 m.

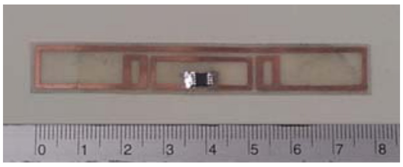


Figure 9: Photograph of the proposed tag antenna

5. Conclusion

The feeding loop and the parasitic-line with rectangular loop technique for decreasing the tag antenna size is presented in this paper. The tag antenna was designed for the UHF-RFID system in Thailand. The small size antenna with the dimension of $0.03\lambda_0 \times 0.24\lambda_0$ or $0.064\lambda_d \times 0.5\lambda_d$ can be achieved by using the parasitic-line with rectangular loops structure to increase electrical length, and the loop feed structure is also added for adjusting the impedance matching of the tag antenna. The input impedance of the proposed tag antenna is equal to 22.39+j196.49 Ω at the center frequency of 922.5 MHz, resulting in the power transmission of about 98.75 %. The radiation pattern is omnidirectional beam. From the measurement, the maximum read range of the proposed antenna is equal to 7 m. This tag antenna can be effectively employed in the national standard of the UHF RFID system in Thailand.

References

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Acknowledgments

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