Investigations of Miniaturized Meander Line Tag Antenna for UHF RFID System

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1. Introduction

Nowadays, the RFID systems have been used in many applications such as logistics, supply chain, access control, product management in warehouse and many others [1]. It can use for identification with the human, animal, product and others. Moreover, it can further use with the sensor applications to detect material or other system depending on the object of applications.

This paper presents the investigation of the passive tag meander-line antenna by T-matching technique for conjugate matching with the impedance of the NXP G2XL IC chip [2] of 21.29-j191.7 Ω at the frequency of 922.5 MHz. This impedance is determined at the center frequency [3]. The size of antenna is miniaturized by using the meander line structure for the maximum power transfer from the tag antenna to the IC chip. This antenna is used at the UHF frequency corresponding to the standard of UHF RFID in Thailand along the frequency of 920-925 MHz. The tag antenna design and analysis is included. The T-matching technique is used to improve the characteristic impedance of the antenna for matching with signal source (feed point). It has been extensively used in literature [4-5].

2. Antenna Design

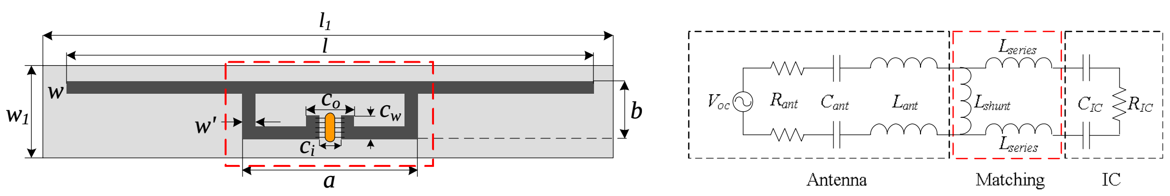
The standard frequency band of the UHF RFID used the frequency of 433/ 860/ 960 MHz [2]. The general matching technique from the recent literature is the nested slot that is useful for tag fabrication with large planar dipoles or suspended patches. The inductively coupled loop and the T-matching are also used [6]. The relation between the effective isotropic radiated power ($EIRP_R$) transmitted by the reader and the sensitivity (P_{chip}) of the tag transponder, the distance of the tag along the direction under the hypothesis of polarization matching between reader and tag antennas is given by [6]

$$d_{\max}(q,f) = \frac{c}{4pf}\sqrt{\frac{EIRP_R}{P_{IC}}\, t\, G_{tag}(q,f)}\,, \tag{1}$$

where $G_{tag}(q,f)$ is the tag gain and the factor

$$t = \frac{4R_{IC}R_A}{\left|Z_{IC}+Z_A\right|^2} \le 1 \tag{2}$$

is the power transmission coefficient which accounts for the impedance mismatch between antenna (Z_A=R_A+jZ_A) and microchip (Z_{chip}=R_{chip}+jZ_{chip}) [8].

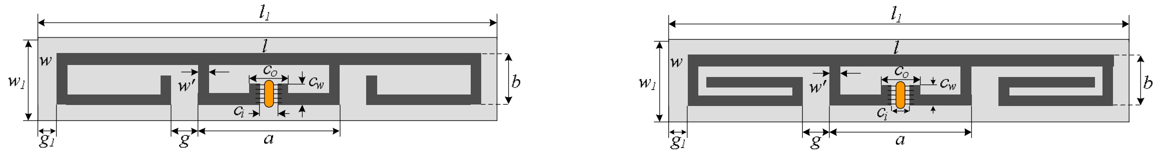


(a) (b)

Figure 1: The antenna structure and equivalent circuit with T-matching [7].

The tag antenna designed with this technique will use the IC chip of the impedance 21.29-j191.7 Ω at the frequency 922.5 MHz. Then, the impedance of the tag antenna should be 21.29+j191.7 Ω or nearly for conjugate matching with the IC chip to obtain acceptable efficiency.

To analyze the characteristics of the antenna from the equivalent circuit in the figure 1 (b), the part of T-matching will be related with the capacitance and inductance of the antenna. The bent dipole is related with the capacitance, inductance and resistance of the antenna. The small size of the antenna is first considered for convenient applications. The initial design of the antenna parameters is to fix w_1 = 10 mm which is the width of the antenna. Then, $l_1 \approx 0.5\lambda + 2g_1$ or 89 mm which is the total height of the antenna. g_1 = 1 mm is the distance from outside edge of substrate to inside edge (copper edge of the outermost) for all sides. w and w' will be fixed equal to 1 mm which is the width of the bent dipole and the T-matching line in both cases. C_i, C_o and C_w are the supporter to connect between the tag antennas with IC chip with the size of 3, 7 and 4 mm, respectively. Finally, a of 20 mm is fixed for the width of T-matching and $l \approx 1\lambda$ or 174 mm which is the extent of the bent dipole. b of 8 mm is the width of the bent dipole of meander line on substrate. g of 1 mm is the gap between T matching and the edge of the bent dipole. This is the initial structure of antenna design with T-matching technique as shown in the figure 2 (a).



(a) (b)

Figure 2: The initial and the meander line antenna structure designed by T-matching technique.

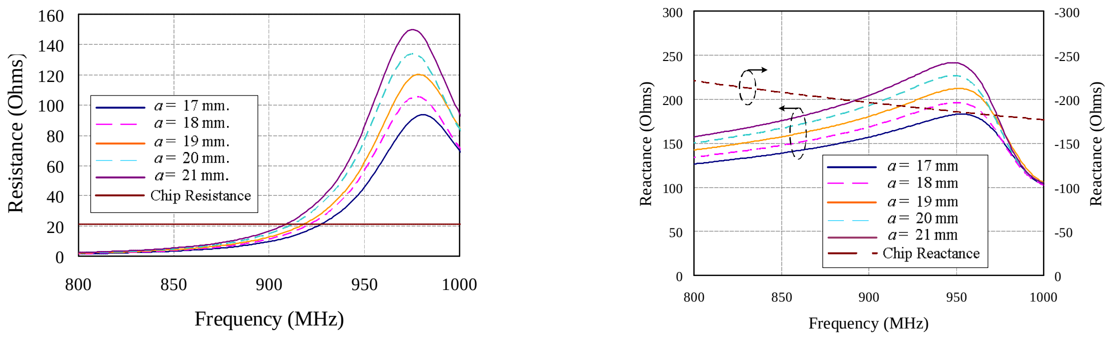


Figure 3: Impedance for various parameters a.

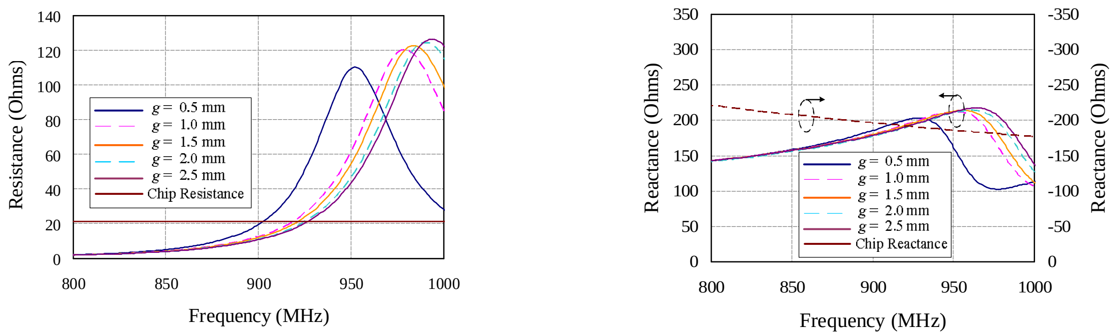


Figure 4: Impedance for various parameters g.

Figure 3 shows the impedance for various parameters a. It can be seen that when a is longer, the resistance and reactance will be increased. This also decreases the resistance and reactance at the frequency of 922.5 MHz. The impedance of the initial antenna structure at the center frequency yields the impedance closed to the conjugate match with the IC chip at a = 19 mm of 24.25+j195.88 Ω. By varying parameter g as shown in the figure 4, it is found that when g is increased the resistance and reactance will be reduced. When g is 1.5 mm, the impedance at the center frequency is 22.29+j194.67 Ω.

The compact size of the antenna is considered in this paper. The meander line technique is used to reduce the size of the antenna. First, l_1 of 0.4λ or 72 mm is selected. Then, a of 19 mm, g of 1 mm and l of 1λ or 174 mm (same as the initial antenna case) are fixed.

The next step is to vary the l parameter. The simulation result of meander line antenna structure with T-matching technique is shown in the figure 2 (b). From figure 5, it can be seen that when l is longer than 174 mm, the resistance and reactance will be increased. When l = 183 mm the resistance and reactance will be reduced. It is obvious that l of 180 mm is the optimum length to obtain the impedance of 25.56+j192.09Ω at the center frequency.

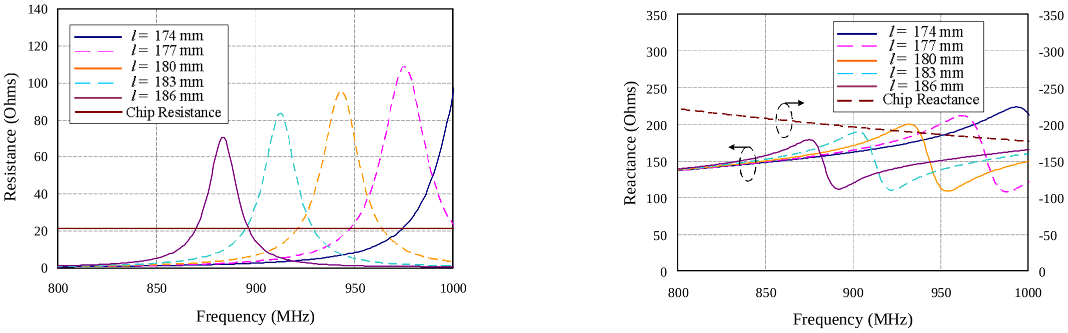
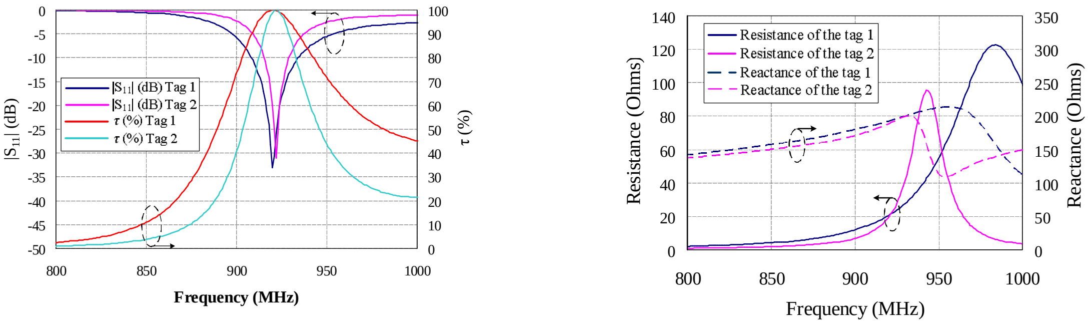


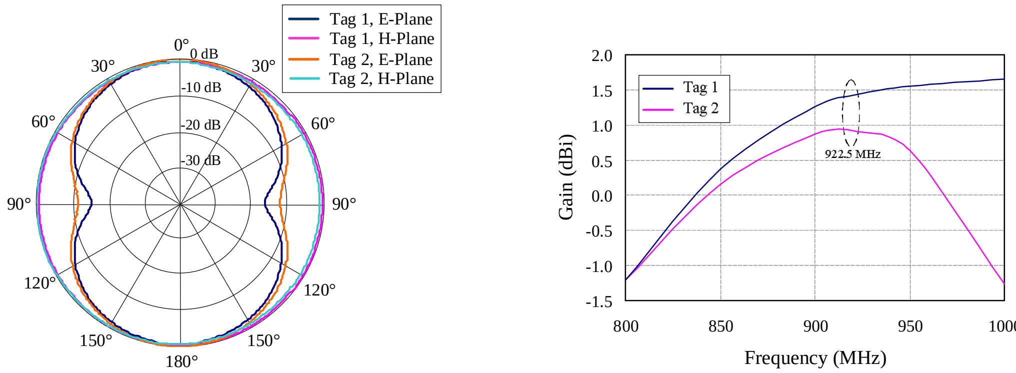
Figure 5: Impedance for various parameters l.

3. Antenna Characteristics



(a) (b)

Figure 6: $|S_{11}|$ (dB), power transmission coefficient and the impedance of the initial and meander line antennas with T-matching technique.



(a) (b)

Figure 7: Radiation patterns and gain of the initial and meander line antennas with T-matching technique.

Figure 6 (a) shows the simulated $|S_{11}|$ of tag 1 and tag 2. It is seen that $|S_{11}|$ of tag 1 and tag 2 are -22.60 dB and -25.07 dB at the center frequency. In the Figure 6 (b), the simulated impedance of both tags are illustrated. The impedance at 922.5 MHz of tag 1 and tag 2 are 22.29+j194.67Ω and 25.56+j192.09Ω, respectively. The radiation pattern of both tags are omnidirectional beam as can be seen in figure 7 (a). Figure 7 (b) shows the gain of tag 1 and tag 2 which are 1.43 dBi and 0.91 dBi, respectively.

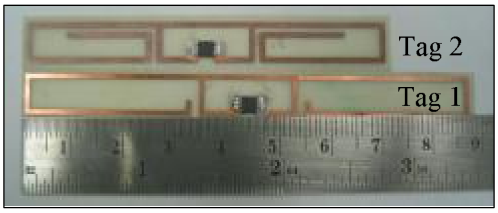


Figure 8: The photograph of the prototype tag

The prototype antenna was fabricated by using the designed parameters. Tag 1 has size of 89×10 mm^2 and tag 2 has size of 72×10 mm^2. The photograph of the proposed antenna is depicted in figure 9. The maximum read range was measured by using Alient Technology Reader (ALR 9900). The reader antenna radiates linear polarization with the gain of 5.9 dBi. The obtained maximum read ranges of tag 1 and tag 2 are 6.25 m and 6.02 mm, respectively.

4. Conclusion

The tag antenna for the UHF-RFID system in Thailand is presented in this paper. It has small size with the dimension of 89×10 mm^2 and 72×10 mm^2. The antenna is designed by using the meander-line structure to increase electrical length. The T–matching is added for the impedance matching of the tag antenna. The input impedance of the tag antenna for conjugate matching with the IC chip impedance is found to be 21.29+j191.7Ω. The input impedance of the proposed tag antenna is equal to 22.29+j194.67Ω and 25.56+j192.09Ω at the centre frequency of 922.5 MHz resulting in the power transmission of about 99.45% and 99.68%. The radiation pattern is omnidirectional beam. From the measurement, the maximum read range of the proposed antenna approximately 6 m. This tag antenna can be effectively employed in the national standard of the UHF RFID system in Thailand.

Acknowledgments

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