A Miniatured UHF RFID Tag Antenna with Double Loop Structure

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1. Introduction

Radio frequency identification (RFID) is a technology used ever more widely for identification in many applications such as in warehousing, retail, transportation, manufacturing especially supply chain systems[1]. RFID technology is used for supply chain for the purpose of tracking products and checking samples, such as labeling RFID at the cans and each can has the code. The code in RFID labeling indicates the product description. Therefore, the count and verification of the product can be sent to various locations that can quickly and easily operate, RFID system can be used in the different frequency bands. One frequency band becoming a standard for supply chain management is the ultra-high-frequency (UHF) band. The operating range of UHF band is further than the LF- and HF-RFID systems. The LF- and HF-RFID systems use the near-field coupling techniques whereas the UHF-RFID utilizes the far-field radiation technique. The UHF frequency band in different countries have different frequency ranges allocated for RFID application such as 865-868 MHz in Europe, 902-928 MHz in North and South Americas, 950-956 MHz in Japan and some Asian countries whereas Thailand used 920-925 MHz[2]. The typical system operation consists of tag, reader and information management system. The reader uses an antenna to transmit radio energy to interrogate a transponder or tag that is attached to the item to be identified. RFID tags are directly attached to objects. In supply chain system, objects can be made of different materials such as cardboard, glass, plastic, wood and others. The antenna parameters such as input impedance and radiation pattern will be changed that is affected from material. Especially, when the RFID tags are placed near objects with high conductivity, the performance of RFID tag is dramatically degraded[3]-[4]. The different approaches have been presented in the literature to overcome this problem. The inverted-F antenna (IFA)[5], planar inverted-F antenna (PIFA)[6], and patch-type antenna structures[7] are specifically antennas for identification of metallic objects. Their performances still considerably depend on the condition of the supporting metallic objects such as conductivity, size and shape[8]. Mainly, the sizes of these antennas are very large and very thick. The large size and thickness of tag antenna may restrain the use of RFID from certain practical application as the bar code with this structure to accompany the products that is the metallic material. In this case, the thickness of the packaged RFID metal tag needs to be less than 1.5 mm, where this size is similar to the barcode. This paper presents a miniatured RFID tag antenna design for metallic material. The allocated UHF band in Thailand is 920–925 MHz. The simulation and experimental results of the antenna characteristics is presented.

2. Antenna Configuration

Figure 1 illustrates the antenna configuration. The proposed antenna consists of two layer of printed circuit board with radiating element in one side and ground plane in the opposite side. The radiating structure consists of outside slit loop and inside feeding small loop. The width and length of the small loop is w and l, respectively. The line width of both loops is b. The spacing between inside small loop and outside slit loop is denoted by s. p_1 and p_2 is the gap of inside small loop and outside slit loop, respectively. The antenna is designed on substrate of the thickness h (0.8 mm) with the dielectric constant of 4.3. The simple design and easy fabrication is the objective of this antennas design.

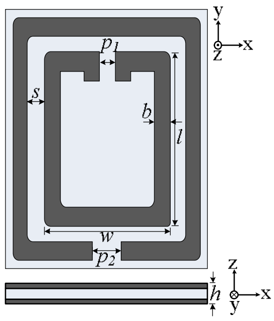


Fig. 1 The proposed antenna configuration

3. Results

In this section, the antenna design and the simulation results will be addressed. The antenna is simulated using the CST Microwave Studio[9]. The antenna evolution is initialized with a small loop antenna to study the impedance characteristic variations. Next, the second step will add the slit loop to surround the small loop antenna. This can be used to reduce the size of the antenna to meet the required specifications.

In this paper, the small loop antenna is designed to use with UCODE G2XL chip[10] whose input impedance is about 10.65-j191.70 Ω at 922.5 MHz. Figure 2 shows the configuration of the initial structure. It consists of the small loop with the length *l* and the width *w*. This structure is placed on the substrate with the thickness ***h*** of 0.8 mm. The small loop has the gap width p_1 (the gap to attach IC chip). ***b*** is the line width of the loop. The gap and line widths of the antenna are 2.5 mm and 2 mm, respectively. From the simulation, the optimum parameters are that *l* equal to 66 mm and *w* equal to 60 mm to achieve impedance of the 29.56+j186.47 Ω at the operating frequency of 922.5 MHz. Therefore, the structure of this antenna is larger than bar code to use with product of metallic box. Typically, the size of barcode is 3.2×2.5 mm^2 to use with the box of the size 260×60 mm^2. In the next step, the slit loop will be added to surround the small loop antenna.

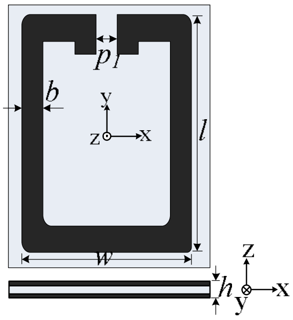
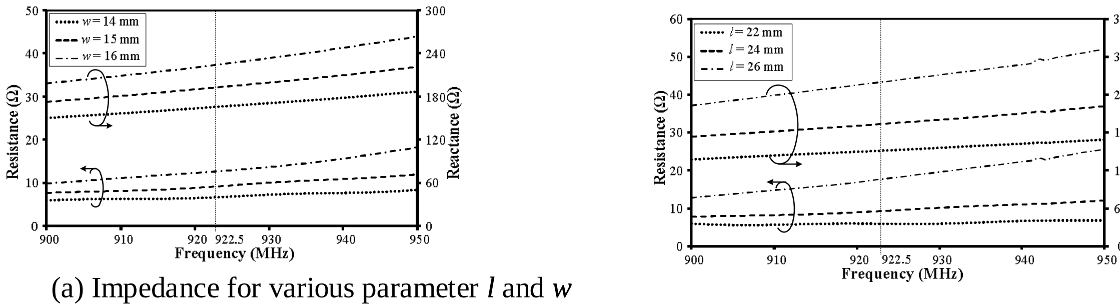
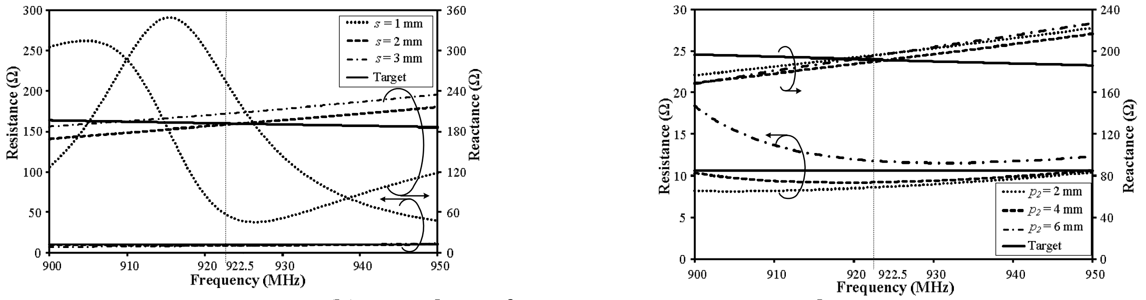


Fig. 2 Small loop antenna configuration

Figure 1 shows the configuration of the proposed antenna that the slit loop is added to surround the small loop antenna. Subsequently, the parametric study of the proposed antenna such as *l, w, s* and p_2 will be presented to observe the influence of impedance in free space. The impedance for various parameters to be determined are shown in figure 3. By using optimum *l, w, b,* p_1 parameters, the remaining parameters are *s* and p_2 that is 2 mm (spacing between small loop and slit loop) and 4 mm, respectively. In figure 3 (a), it can be seen that the increase of *l* and *w* that enlarge the size of slit loop result in increasing reactance and resistance at the operating frequency. Therefore, *l* and *w* can be used to adjust the impedance of the tag antenna. Next, other antenna parameters that affect the impedance will be studied. The larger *s* and p_2 will result in increasing the impedance as can be found from figure 3 (b). Finally, the optimum parameters of *l, w,* p_1, p_2, *b,* and *s* are 24, 15, 2.5, 4 and 2 mm, respectively. These parameters can achieve the impedance of 9.21+j189.73 Ω at the operating frequency of 922.5 MHz. After determining the appropriate antenna parameters as shown in figure 3, the next step is to simulate the tag antenna on metallic object. The size of metallic object is 200×200×7 mm^3. The impedance of tag in free space and on metallic box at the operating frequency (922.5 MHz) are 9.21+j189.73 Ω and 9.47+j195.03 Ω respectively. It is apparent that the impedance of both cases has slightly difference. Therefore, this antenna can be used to reduce the influence of metallic material.



(a) Impedance for various parameter *l* and *w*



(b) Impedance for various parameter *s* and p_2

Fig. 3 Impedance for different antenna parameters

The radiation patterns in XZ-plane and YZ-plane in free space and on metallic object are shown in figure 4. The proposed antenna radiates the unidirectional pattern. The half-power beamwidth in XZ-plane and YZ-plane on metallic material is 94.8 degrees and 83.11 degrees, respectively. The directivity is 6.57 dBi at 922.5 MHz.

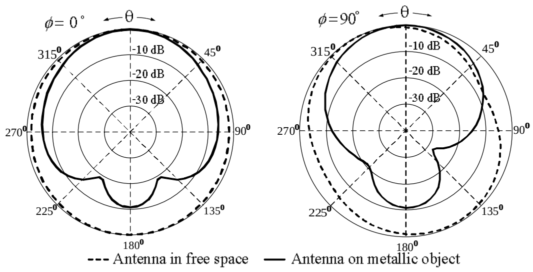


Fig. 4 Simulated radiation pattern of tag in free space and on metallic object

The important tag performance is the communication distance. Therefore, the maximum of energy transfer is significant. To demonstrate the maximum transfer energy between chip and the proposed antenna, the transmission coefficient is calculated from the antenna and chip impedances. Subsequently, the reflection efficiency and the $|S_{11}|$ are obtained. The $|S_{11}|$ of the proposed antenna in free space and on metallic object are less than -10 dB that cover the operating frequency of 913-925.5 MHz and 917-928.5 MHz, respectively. It is noted that this frequency range can cover the operating frequency of UHF RFID in Thailand (920-925MHz). In the experiment, the reader model is ALR-9900-WR1 whereas the antenna of reader is ALR-9610-AL. The linearly polarized reader antenna with the gain of 5.9 dBi[11] were used in the measurements. The photograph of the proposed tag antenna is depicted in figure 5. The maximum read range of tag antenna when placing in free space and mounting on metallic object with the size of 200×200 mm^2 are 0.42 m and 0.11 m, respectively.

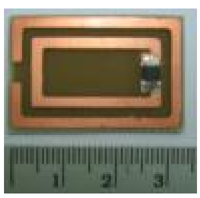


Fig. 5 Photograph of the prototype antenna

4. Conclusion

This paper presents the UHF RFID tag antenna design to use with metallic material for the application of supply chains such metallic box products. The structure of designed antenna utilizes two layers of printed circuit board with radiation element in one side and ground plane in the other side. The radiating structure consists of outside slit loop and inside feeding small loop. The ground plane of tag antenna is use to reduce the effect of the metallic material. The resistance and the reactance of the proposed antenna can be adjusted by changing the size of the inside small loop. The simulation results illustrate the performance of proposed antenna in terms of the $|S_{11}|$. The advantage of proposed antenna is the easy fabrication. This proposed RFID tag antenna design is useful for practical supply chain system where the product is the metallic material. Generally, the metallic product used bar code for identification because bar code is very thin. The overall size of the proposed antenna is $22\times33\times0.8$ mm^3 that is approximated to the size of bar code. The experimental result shows that the maximum read range of tag antenna in free space and on metallic object with size of 200×200 mm^2 are 0.42 m and 0.11 m, respectively. Therefore, this size of tag antenna is small and very thin similar to the bar code. However, the maximum read range of the antenna is relatively short, the improvement of antenna to obtain further distance is underway.

Acknowledgments

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References

[1] T. Koskien, and Y. Rahmat-Samii, "Metal-mountable microstrip RFID tag antenna for high impedance microchip," European Conference on Antennas and Propagation (EuCAP 2009), pp. 2791-2795, March 2009.
[2] D. Javier and P. Rafael, "Low-profile patch antenna for RF Identification Applications," IEEE Transactions on Microwave Theory and Techniques, vol. 57, No. 5, pp. 1406-1410, October 2009.
[3] D. M. Dobkin and S.M. Weigand, "Environmental effects on RFID tag antennas," IEEE MTT-S Int. Microw .Symp. Dig., pp. 135-138, 2005.
[4] C. S-Lin and L. K-Huang, "A slim RFID tag antenna design for metallic object applications," IEEE Antennas and Wireless Propagation Letters, vol. 7, pp. 729-732, 2008.
[5] L. Ukkonen, D. Engels, L. Sydanheimo and M. Kivikoski, "Planar wire-type inverted-F RFID tag antenna mountable on metallic objects," IEEE Antennas and Propagation Society International Symposium 2004, vol 1, pp. 101-104, 2004.
[6] W. Choi; N.-S. Seong; J. M. Kim; C. Pyo and J. Chae, "A planar inverted-F antenna (PIFA) to be attached to metal containers for an active RFID tag," IEEE Antennas and Propagation Society International Symposium 2005, vol 1B, pp. 508-511, 2005.
[7] Y. Um, U. Kim, W. Seong, and J. Choi, "A novel antenna design for UHF RFID tag on metallic objects," Proceeding Progress In Electromagnetics Research Symposium PIERS, pp. 158-161, 2007.
[8] B. Yu, S-J. Kim, B. Jung, F. J. Harackiewicz and B. Lee, "RFID tag antenna using two-shorted microstrip patches mountable on metallic objects," Microwave and Optical Technology Letters, vol. 49, No. 2, pp. 414-416, 2006.
[9] CST-Microwave Studio, User's Manual, 2006.
[10] NXP, Ultrahigh frequency smart label ICs [online] Available URL:http://www.nxp.com/acrobat_download/literature/9397/75016225.pdf.
[11] Alien technology, Model ALR-9900-WR1 [online] Available URL:http://www.alientechnology.com/readers/alr9900.php