Indian Journal of Science and Technology, *Vol 10(5), DOI: 10.17485/ijst/2017/v10i5/111270, February 2017*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Radio Frequency Identification (RFID) Tag Antenna Design at Ultra High Frequency (UHF) Band

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Abstract

This project is to design a Radio Frequency Identification (RFID) high sensitivity tag antenna which operates at UHF frequency band in Malaysia between 919 MHz to 923 MHz. RFID is a type of wireless and radio wave technology that allows for a small RFID chip to be embedded in certain physical object and uniquely identified by an RFID reader. The major contemplation is that the tag antennas will have longer read ranges but in small sizes. While reducing the size of these antennas cause gain decrease will cause reduction in the read range. Another challenge in designing passive RFID tags antennas is to have the highest impedance matching to achieve high efficiency and low effects of the electromagnetic environment. This project was providing two methods to overcome those problems. Firstly, construct meander line structure to reduce the antenna size and design proposed tag antenna with T-match circuit to achieve conjugate matching with the application-specific integrated circuit so that the reading range of the RFID tag is greatly enhanced. On the other hand, the result show the tag directivity and gain was meets the RFID tag design requirements. This project is useful to be implemented in the RFID industry based on today's technology.

Keywords: Radio Frequency Identification (RFID), Tag Antenna, Ultra High Frequency (UHF)

1. Introduction

Radio-Frequency Identification (RFID) is an automatic identification technology used to detect, track and control items carrying tags by using radio-frequency electromagnetic fields. This wireless system is a contactless and non-line-of-sight data transmission and reception technique which was developed to eventually replace barcodes that require a line-of-sight. The RFID is an example of Automatic Identification (Auto-ID). There is an electronic chip that contains data build inside the tag. The data can be collected by the reader. There are two main communication techniques, coupling and backscattering.

A typical RFID system is making up of three main parts: Tag, Reader and Data. RFID tags generally present a transponder (also known as tag or label) which contains electronic chip and an antenna to flow data or information into the interrogator system (RFID reader system). When the tag detected the RF wave signal from the reader, the tag will be activated, and complete the corresponding signal receives process according to the order from the reader. The information from the RFID tag which was written in an electronic chip is based on its application. Each tag carries a unique identification code to be recognized as particular items. The capacity unit of the tag chip can be repeatedly interrogate more than

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10,000 times[1]. Some electronic chips of the RFID tag have few other memories in which users can write, modify and wipe off their own data. These memories are varying in size which is from a few bits to hundred thousand bits[2-5]. RFID usage is steadily mushrooming across many industries and applications. There are some companies are now looking forward at RFID system which able to operate efficient and meet regulatory requirements.

RFID tag antennas are consisting of transceiver antenna, an Integrated Circuit (IC) and substrate as show in Figure 1. Tags are available in various sizes, designs, and form of factors. Amicrochip or chip is also called as Integrated Circuit (IC) where it is used to store data. The antenna is the largest part in a tag where there are many turns of conductor wire to form coil antenna. The antenna receives the signals from the interrogator, and then it either transmits or reflects the received signal back depends on the tag type[6-8].

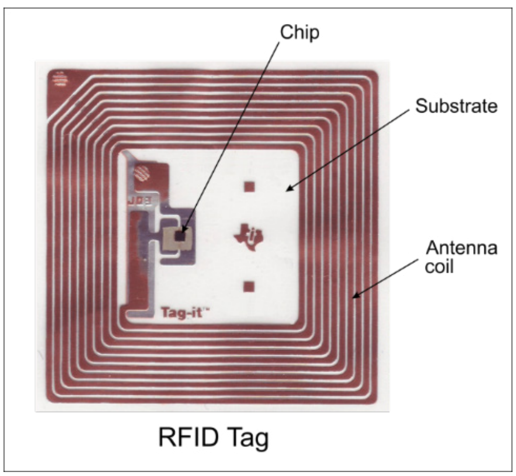


Figure 1. RFID tag components[8]

This project is mainly focusing on the RFID antenna design that applicable at Ultra High Frequency range. The antenna will be applied into passive RFID tag for item-level tracing systems. This project will illustrates on a proper calculation of the tag power reflection coefficient for maximum power transfer by taking into account of the changing chip impedance versus frequency. The RFID antenna performance will be analyzed to ensure the robust design with far field radiation and high sensitivity characteristic are achieved. Integration of the optimized sensor into the RFID system will be tested in future for the real condition by following the guideline, tested, and finally results will be discussed.

2. RFID Tag Antenna Design Specification

The development of a dipole antenna equivalent circuit model shown in Figure 2. Z_a is the microstrip feed line's characteristic impedance, Z_b is short-circuit's characteristic impedance of, Z_{ab} is characteristics impedance of the slotted between the dipole antenna arms, Z_L is radiation impedance, and Z_c is equivalent input impedance in the dotted line. According to antenna transmission line theory, input impedance, Z_{in} can be expressed as[3-5]:

$$Z_{in} = Z_a \frac{Z_c + jZ_a tan\theta_a}{Z_a + jZ_c tan\theta_a} \quad (1)$$

In the formula,

$$Z_c = jZ_b tan\,\theta_b + \frac{jZ_L Z_{ab} tan\theta_{ab}}{Z_L + jZ_{ab} tan\theta_{ab}} \quad (2)$$

θ_a, θ_b and θ_{ab} are represent to electrical length of corresponding part. The ratio of microstrip width, W_f and dielectric thickness, h, can be express as:

$$\frac{W_f}{h} = \frac{8e^A}{e^{2A} - 2}, W_f/h < 2 \quad (3)$$

$$\frac{W_f}{h} = \left[\frac{2}{\pi}\left(B - 1 - ln(2B - 1)\right) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left\{ln(B - 1) + 0.39 - \frac{0.61}{\varepsilon_r}\right\}\right], W_f/h > 2 \quad (4)$$

In the formula,

$$A = \frac{Z_a}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left[0.23 + \frac{0.11}{\varepsilon_r}\right] \quad (5)$$

$$B = \frac{377\pi}{2Z_a\sqrt{\varepsilon_r}} \quad (6)$$

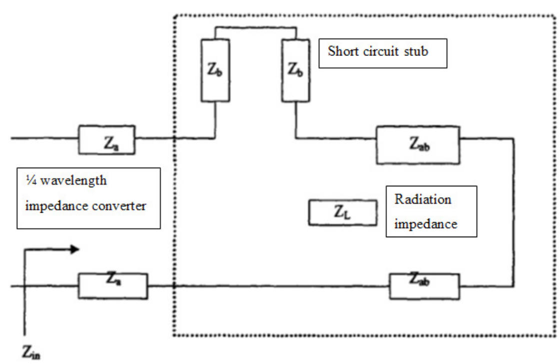


Figure 2. Equivalent circuit model of Balun fed dipole antenna.

Specifications of tag antenna design are shown in Table 1. Antenna type for this proposed project is dipole antenna with the frequency working at band 919-923 MHz (corresponding to Malaysia), antenna gain > 2 dBi, VSWR of feed input port < 2.5 (corresponding to 919-923 MHz), miniaturization antenna is required, the optimized size to achieve is smaller than 8 cm * 6 cm. RFID antennas need to match ideally with the chip that is get from the market.

Table 1. Tag antenna specifications

Working frequency	**919-923 MHz**
Gain of antenna	> 2 dBi
Feed input port VSWR	< 2.5
Size	<8 cm x 6 cm

Before the design of tag antenna, the impact of dielectric substrate on the performance of antenna has to be considered. For the selection of the dielectric substrate, consideration of the dielectric constant, ε_r, loss tangent, tan δ and the thickness of the dielectric substrate are needed. Microstrip antennas are generally use low dielectric constant materials in order to achieve better radiation efficiency.Some of the antenna designs is needed to reduce the antenna size which is adding an extra ceramic high dielectric constant material. Loss tangent, tan δ, is a parameter which showing dielectric loss size.

Taconic TLY-5 material was selected as a microwave substrate because of its low dielectric loss which will not affect the antenna gain. Next, the substrate thickness is considered with the micro-strip patch antenna microwave substrate thickness require h <0. 01λ. Common market micro-strip patch antenna substrate thickness is about 1 mm, appropriate increase the thickness can be improved the gain and bandwidth, but if the thickness is too large may encourage larger surface wave. Presence of surface wave will affect the antenna radiation that needs to be suppressed. Surface wave cut-off frequency of the TE mode is:

$$f_c = \frac{nc}{4h\sqrt{\varepsilon_r - 1}} \quad (7)$$

Wherein n represents mode, c is the speed of light in vacuum, ε_r is the relative dielectric constant of the medium, h is the thickness of the substrate. For the lowest TE l mode, n = l substituting ε_r=2.2 and h=0.13 mm, obtain cut-off frequency of approximately 526.7 GHz, much larger than the operating frequency of 915 MHz, it does not produce TE mode surface wave. While the surface wave cut-off frequency of TM0 mode is 0, it can be activated the surface wave. When selecting the substrate thickness h = 0.13 mm, h/ λ0 ≈ 0.0004, wave impact may not necessarily be considered based on experience. Therefore, based on the above analysis, selected substrate material is Taconic TLY-5, dielectric constant is 2.2, dielectric thickness, h = 0.13 mm, loss tangent, tan δ= 0.0009.

3. RFID Tag Antenna Design Simulation

The antenna has been simulated in CST Studio Suite. It is a specialist tool for the 3D structure electromagnetic simulation, which is a kind of numerical calculation software based on Finite Integration Time Domain method. It provides a powerful solid modeling and adaptive mesh generation function. After completing the design, the software will automatically applied the meshing procedure before the simulation solver is started. Besides that, the CST provided a built-in parametric optimizer that can help to appropriate dimensions in the design, this is the most efficient way to design and can help save a lot of time.

The antenna is simulated using CST microwave studio and various parameters (Return Loss, Gain, VSWR, Radiation pattern and Directivity) are measured. Figure 3 shows the preliminary design of meander line shape antenna.

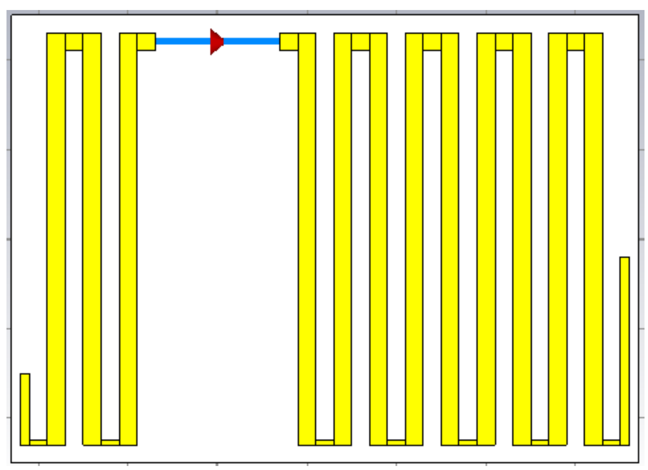


Figure 3. Meander line shape design.

Taking into account the need to match the input impedance of the chip and antenna miniaturization requirements, adopt meander dipole antenna structure that design as Figure 3. The resonant frequency can be controlled by adjusting the number and the length of leg of meander line antenna. Thus, the parameter sweep was done in order to obtain an optimized design of Figure 4. The darker part in the Figure 4 is a copper patch, the cuboids shape is Taconic TLY-5 dielectric plate, no metal base plate. The units of the dimension measurement are in mm.

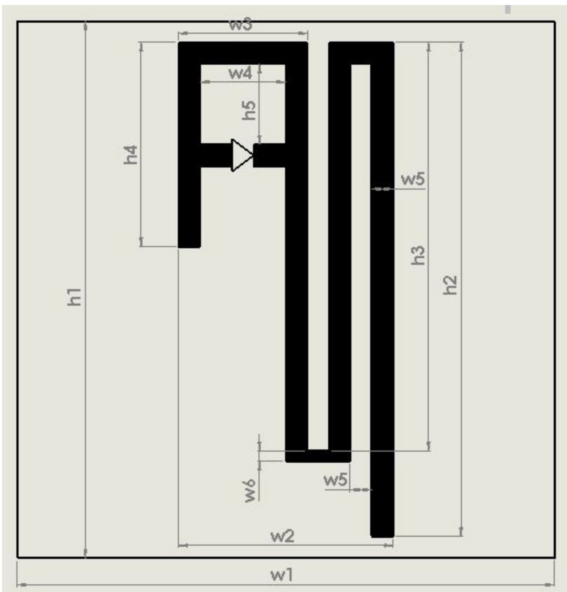


Figure 4. Design of meander line tag antenna.

Table 2. Dimension of designed meander line tag antenna

	Length (mm)
w1	77
w2	20
w3	12
w4	8
w5	2
w6	1
h1	60
h2	54.5
h3	45.5
h4	24.5
h5	8

4. Results and Discussion

The electromagnetic characteristic of the optimized antennas are simulated using CST Studio Suite. Results of both simulated and fabricated antennas are presented. The antenna was designed under an ideal condition by using CST software and verified by the simulation tool offered in CST.

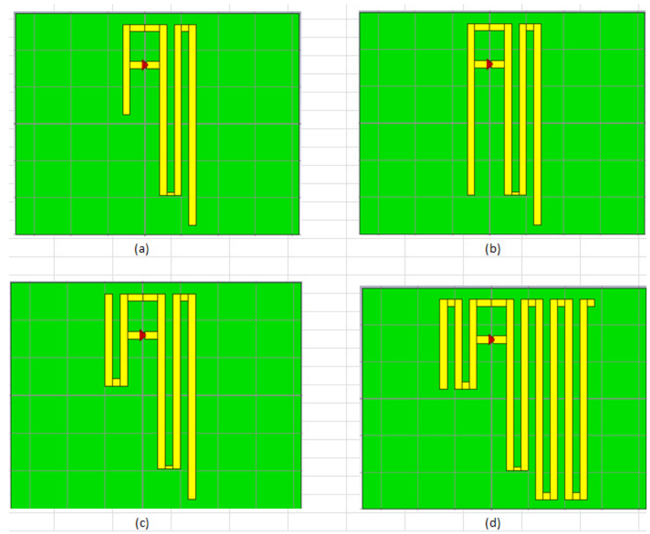


Figure 5. Antenna design with different number and length of legs: (a) S1,1 (b) S1,1_1 (c) S1,1_2 (d) S1,1_3.

Figure 6 shows the return loss characteristic of the simulated antenna. The resonant frequency can be controlled by adjusting the number and the length of leg of meander line antenna as can be seen in Figure 5. There is effect of the different numbers and length of the legs to the resonant frequency. The return loss (S11) for designed antenna S1,1 at 921 MHz is about -20.18 dB, -0.117 dB for antenna S1,1_1, -0.36 dB for antenna S1,1_2 and -0.374 dB for antenna S1,1_3.

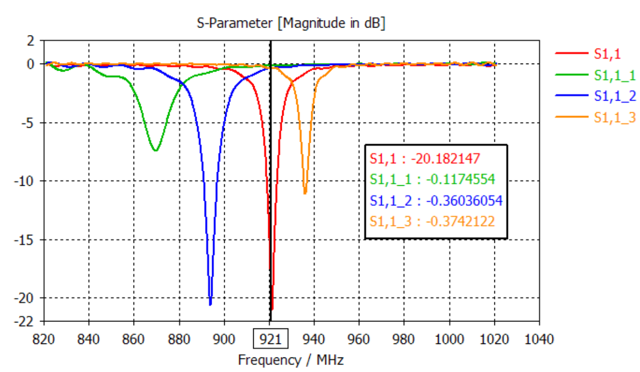


Figure 6. Simulated antenna |S11| vs. frequency of different design.

Figure 7 shows the bandwidth at -10 dB is measured to be about 4.6 MHz (919.06–923.69 MHz), which includes the UHF band (919–923 MHz) used in Malaysia for the RFID system.

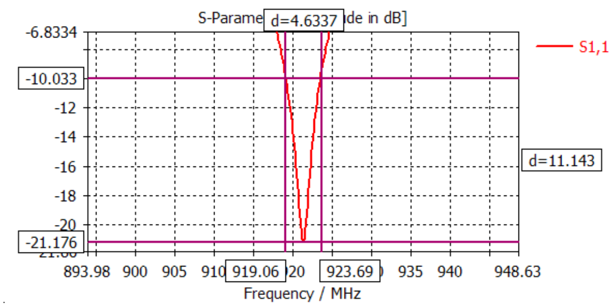
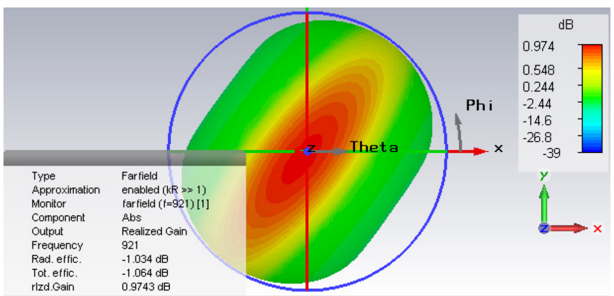
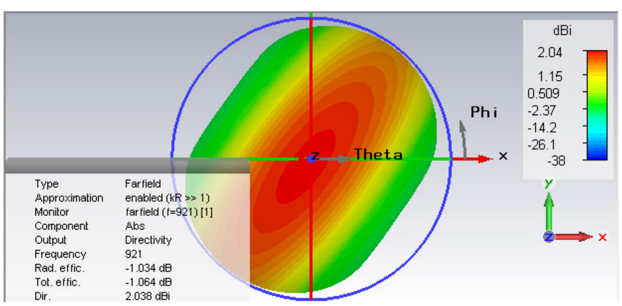


Figure 7. Simulated antenna with 4.6 MHz bandwidth.

Radiation patterns of the proposed tag antenna were also investigated. The 3D radiation patterns of the meander line antenna at 921 MHz is shown in the Figure 8. The directivity value for the antenna at 921 MHz is 2.038 dBi. While the realized gain of the antenna is 0.97 dB.



(a)



(b)

Figure 8. Simulated 3D radiation pattern of the proposed antenna at 921 MHz. (a) Directivity (b) Realized Gain.

Voltage Standing Wave Ratio (VSWR) is an indication of the quality of the impedance match. The simulated VSWR result is given in Figure 9. It is noted that, the value of VSWR is almost 1.18 at frequency 921 MHz which is very efficient in manufacturing process. It met the requirement which is between 1 and 2. The minimum VSWR can get the better performance as shown clearly from the definition of VSWR.

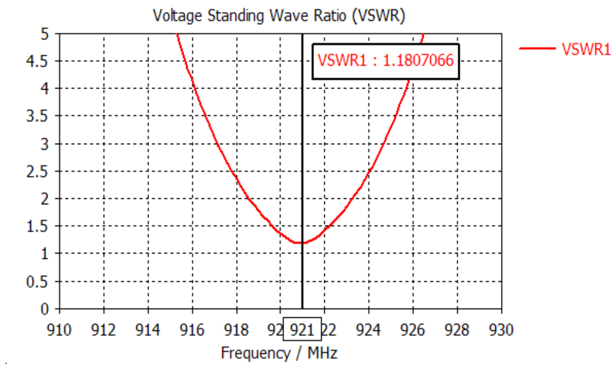


Figure 9. voltage standing wave ratio (VSWR).

5. Conclusions

Research and theory discovered in this project is very helpful to ensure the project is completed successful, especially in meander line and matching circuit design using CST. For the design, meander line antenna and matching circuit are created and placed on the microwave substrate board, Tarconic TLY- 5 with 1.575 mm thick. For the ideal condition, when using the CST to design, there is a problem that occurred was the antenna size was large to get a high frequency and gain. To troubleshoot the problem using the CST, the current flow distribution on the design is observed to detect which part of the antenna is low in the current intensity and getting useless. Operational UHF passive RFID tags were successfully designed and overall this design having the result as the expected result wanted in simulation with UHF band operational, 921 MHz and higher gain value with 1 dBi.

6. References

1. Xunxun W. Design of Passive UHF RFID Tag Antennas and Industry Application [Master thesis]. 2010.
2. Lahiri S. RFID Sourcebook. IBM Press; 2011. p. 304.
3. Karmakar NC. Handbook of smart antennas for RFID systems. In: Karmakar NC, editor. Hoboken, New Jersey: Wiley; 2010. https://doi.org/10.1002/9780470872178
4. Tuan S, Chou H, Liang S. Research for RFID tag implementation in vehicle environments. Progress in Electromagnetic Research Symposium (PIERS) Proceedings; 2012. p. 1261–5.
5. Cho J, Cobbs S, Curtiss E, Overton K, Redner M. Use of RFID in healthcare industry. Acad Bus Res Inst. 2013.
6. Jian-bin X, Fengjie H, Dong W. Analysis and design of tag antenna based UHF RFID for libraries. TELKOMNIKA

Indones J Electr Eng. 2015; 13(3):521–8. https://doi.org/10.11591/telkomnika.v13i3.7135

7. Lin X, Lu R, Kwan D, Shen X. REACT: An RFID-based privacy-preserving children tracking scheme for large amusement parks. Comput Networks. 2010. 54(15):2744–55. https://doi.org/10.1016/j.comnet.2010.05.005
8. Samadi S. Applications and opportunities for Radio Frequency Identification (RFID) technology in intelligent transportation systems: A case study. Int J Inf Electron Eng. 2013; 3(3):341–5. https://doi.org/10.7763/ijiee.2013.v3.330
9. Rajabi A, Tavassoli M, Mohammadi S, Javadi M. RFID for Cargo and Passenger Automation and Control in Airline Industry. 2012; 5:5–8.