Design and Development of UHF RFID Reader Antenna for Livestock Monitoring

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***Abstract*—This paper presents a circularly polarized E shaped microstrip single layer patch antenna with parasitic element for the reader of the UHF RFID livestock monitoring system. The antenna is designed to operate at a frequency of 919 MHz to 923 MHz allocated for UHF RFID systems in Malaysia. The antenna simulation is analyzed using CST Studio Suite 2013 based on Finite Integral Techniques (FIT). In order to ensure the design is in good performance, all of the antenna parameters are optimized using Quasi Newton Method. The result show that this antenna is able to operate from 919 MHz to 923 MHz frequency bandwidth with optimum frequency at 918 MHz. Furthermore the result of antenna parameter such as radiation pattern, bandwidth, gain, return loss and voltage standing wave ratio are also discussed. The proposed antenna is lightweight, low profile, simple structure and easy fabrication.**

***Keywords*—Microstrip Antenna, Frequency, Return Loss (S_{11}), Livestock, Computer Simulation Technology.**

I. Introduction

Radio Frequency Identification (RFID) is a modern term used to label a system that wirelessly transmits the identity of an object, using radio waves. These transmissions are of unique serial numbers, or codes. This is known as a contact-less technology, whereby the tag or item does not to be manually touched or wired.

A reader (also called an RFID interrogator) is basically a transceiver that reads the content of RFID tags in the vicinity. The maximum distance between the reader's antenna and the tag vary, depending on application. In addition the role of antenna for reader and tag is very important. The antenna allows the chip to transmit the information that is used for identification. The RFID reader with circular polarized antennas radiate in a 90 degree pattern and are less sensitive to the tag's orientation on the package [1].

The first applications used in RFID system in livestock monitoring initially started only for identification purposes [2-3]. However, it has gained a growth potential exploration on RFID systems combined with sensors to create other advanced applications in animal rearing sections such as for monitoring the health status of a livestock, breeding climate changes and real-time monitoring on livestock location using GPS [4-6]. In addition, several important general health parameters that can be measured for quick scan of livestock health using sensors are like heart rate, body core temperature, feed intake, head motion and body weight [7-9].

There are three common primary RFID frequency bands; Low Frequency, LF (30-300 kHz) is used for implant in trees and animal tracking according to ISO 11784 and ISO 11785 standards. The High Frequency, HF (3 MHz-300 MHz) used for up short ranges, up to about 1.5 meter reads, with metal and water not affecting signals. For Ultra High-Frequency, UHF (300 MHz- 3 GHz), this one offers the better read ranges with faster reading speeds when compares with LF and HF. But they use more power and are less likely pass through material. The use Super High frequency, SHF (2.4-2.48 GHz) is to avoid interference from metal and water, and thus is practically use for climate monitoring and pallet.

In recent years, there are many types of designed antenna produced for handheld RFID reader such as helical antenna [10], loop antenna [11], PIFA antenna [12], monopole antenna [13] and three element printed Yagi antenna [14]. By adopting the same printed antenna methods as mention above, this proposed antenna design take advantages on FR-4 substrate material.

Microstrip antenna configuration consists of a dielectric substrate having patch geometry on one side and ground plane on the other side [15]. It has several advantages such as low weight, low profile, planer configuration, low fabrication costs and capability to integrate monolithic microwave integrated circuit (MMIC). Even the microstrip antenna comes with these advantages, in contrast, it also has a certain limitations as well, such as lesser gain, low bandwidth and low efficiency which affect the performance of this antenna [16]. Many researches are being done by the researchers to reduce these disadvantages by using different approach of patch geometry such as using E shaped patch [17], U shaped patch [18], L shaped patch [19] etc. Other methods to reduce these disadvantages includes the use of different thickness [20], use of substrate of dielectric materials, cutting various slots and notches in the patch geometry, antenna array [21] etc. for improving the performance which make this antennas have been widely seen in wireless applications such as military purpose, GPS, satellite communication and RFID system. In this paper, a single band E shape microstrip patch antenna is designed on FR4 substrate for the reader of RFID livestock monitoring.

This paper organized as follows: Section II describes the antenna design procedures outlines which guides to practical design of E shape rectangular microstrip antennas. Section III describes result and discussion and followed by conclusion in Section IV.

II. ANTENNA GEOMETRY AND DESIGN

In the field of RFID antenna design, Circularly Polarized (CP) E shape microstrip patch antenna has become preferred choices among the antenna designers due to effective combination of circular polarization characteristics and microstrip. For circular polarization, it can reduce the transmission loss affected by a misalignment between the two connected antennas. On the other hands, because livestock barn environment is dusty and dirty as well also with animal acts are unpredictable, circular polarized antennas is a wise selection for livestock data collection since it radiate in a 90 degree pattern and are less sensitive to the tag's orientation on the package. In addition, the circular polarization offers better system performance, weather problems and better mobility compared to linear polarization. The Fig. 1 shows a basic rectangular microstrip antenna while Fig. 2 shows the side view of the proposed of E shaped microstrip antenna;

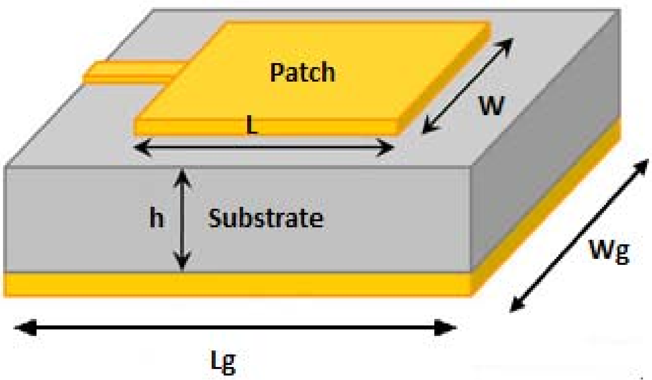

Fig. 1 Basic Rectangular Microstrip Antena

where

W_g = substrate ground plane width
L_g = antenna ground plane length
L = antenna length
W = antenna length
L_f = antenna feed length
W_f = feed width
t = truncated segment

The proposed antenna component as seen in Fig. 2 consists of antenna E patch which are placed on a FR4 (loss-free) substrate with dielectric constant (ε_r) of 4.7, thickness of 1.6 mm and loss tangent of 0.019. PEC material was used for ground and patch with the standard thickness of 0.035 mm. The following antenna dimension of the proposed patch antenna with circular polarization are listed in Table 1.

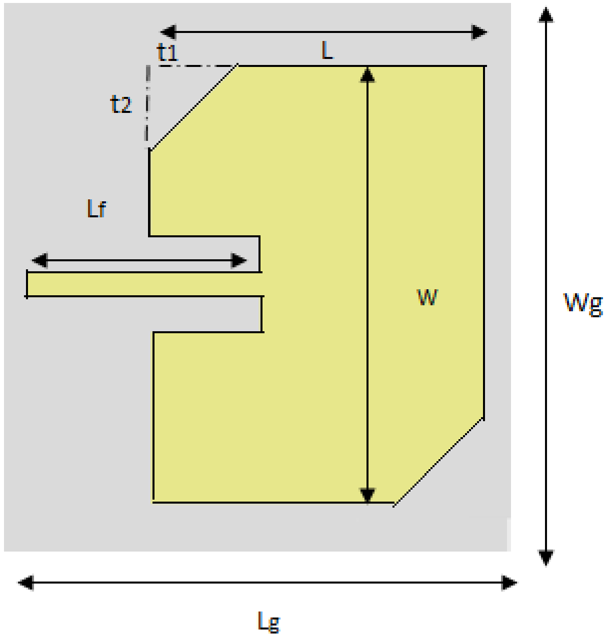

Fig. 2 Proposed of E shaped CP Microstrip Antenna

The following mathematical model has been considered in designing the E-shaped microstrip patch antenna [22-23]:

The relationship between patch width (W), operating frequency (f_o), dielectric constant (ε_r) and speed of light (c) given as;

$$W = \frac{c}{2fo}\left[\frac{\varepsilon r + 1}{2}\right]^{-1/2} \tag{1}$$

The relationship between effective dielectric constant (ε_{reff}), dielectric constant (ε_r), substrate thickness (h) given as;

$$\varepsilon_{reff} = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \tag{2}$$

The relationship between the effective length (L_{eff}), operating frequency (f_o), effective dielectric constant (ε_{reff}) and speed of light (c) given as;

$$L_{eff} = \frac{c}{2fo\left[\varepsilon_{reff}\right]^{1/2}} \tag{3}$$

The relationship between the length extension (*ΔL*), substrate thickness (*h*), patch width (*W*) and effective dielectric constant (ε_{reff}) given as;

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(W/h+0.264)}{(\varepsilon_{reff}+0.258)(W/h+0.8)} \tag{4}$$

The relationship between actual patch length *L*, effective length (L_{eff}) and length extension (*ΔL*) given as;

$$L = L_{eff} - 2\Delta L \tag{5}$$

For the ground plane extension;

$$Lg = 6h + L \tag{6}$$

$$Wg = 6h + W \tag{7}$$

The relationship between feed length (L_f) and effective dielectric constant (ε_{reff}) given as;

$$Lf = \frac{L}{2[\varepsilon_{reff}]^{1/2}} \tag{8}$$

The relationship between line impedance (Zo), feed width (W_f), effective dielectric constant (ε_{reff}) and substrate thickness (*h*) given as;

$$Zo = \frac{60}{[\varepsilon_{reff}]^{1/2}}\ln\left[\frac{8h}{W_f}+\frac{W_f}{4h}\right] \tag{9}$$

To obtain the value of feed width (W_f), equation (9) can be manipulated with inserting 50 ohm for line impedance (Z_o). Table 1 shows the calculation result for the antenna designed that operating at optimum frequency of 918 MHz.

Table 1 The optimum design antenna dimension

Parameters	Size in mm
W	98
L	76
Wg	107
Lg	87
Wf	2
Lf	35
t_1	10
t_2	10

III. Results and Discussions

In order to analyze the performance of an antenna, the important aspects that always be considered in the design antenna such as VSWR, S_{11}, Gain and directivity of the antenna. Thus, all the desired simulation result parameter of the patch antenna as mention above can be implemented by adjusting the substrate ground plane width (W_g), antenna ground plane length (Lg), antenna length (W), antenna feed length (Lg), feed width (L_f), substrate material, thickness and size of the truncated segment (t_1 and t_2).

Antenna return loss is the difference between forwarded and reflected power, where antenna efficiency is the measure of electrical losses occurs. In order to design a better performance of an antenna, the value of return loss should be less than -10 dB. Furthermore, the simulated S_{11} return loss shows in Fig.4. It is clear that the value of S_{11} is about – 12.14 dB.

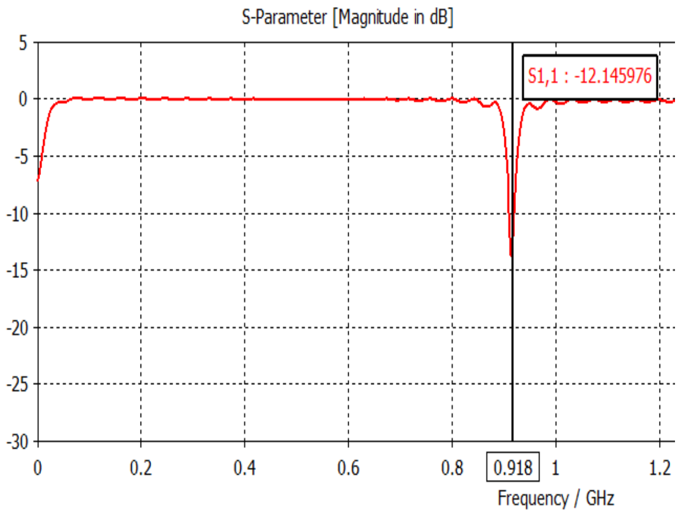

Fig. 4 Simulated |S11| versus frequency

Fig. 5 shows the simulated VSWR of the antenna. The VSWR value is less than 2 over the frequency range of 919–923 MHz (0.43%), which can easily cover the entire Malaysia assigned frequency band.

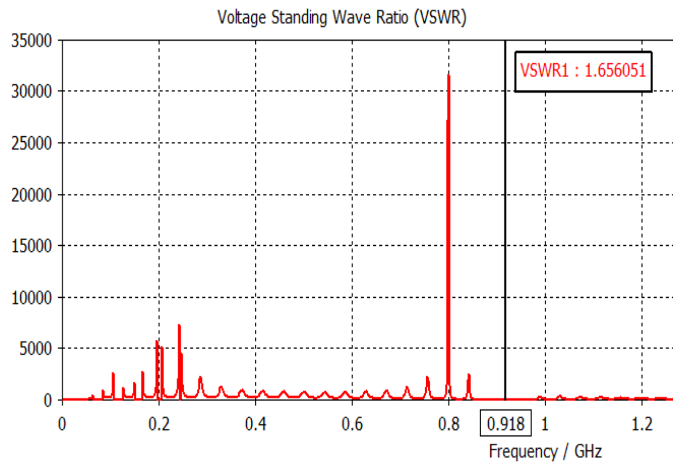

Fig. 5 Simulated Voltage Standing Wave Ratio

An antenna radiation pattern is defined as a mathematical function or graphical representation of the radiation properties of the antenna as a function of space coordinates. The radiation property of most concern is the two or three dimension spatial distribution of radiated energy as a function of the observer's position along a path or surface of constant radius. In fig. 6 shows the 3D radiation pattern for the designed antenna with 7.098 dB gain at 918 MHz.

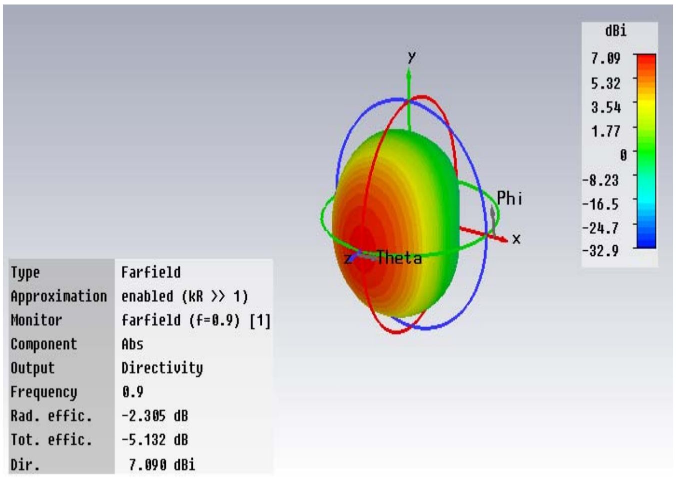

Fig. 6 Simulated Far-Field view 3D radiation pattern

Another useful measures describing the performance of antenna is the gain. Even, the gain of the antenna is closely related to the directivity, it is measures that into account efficiency of the antenna as well as its directional capabilities. The average simulated gain of an antenna in Fig. 7 shows the gain is 4.784 dB with main lobe 4.78 dB for polar plot of the designed antenna.

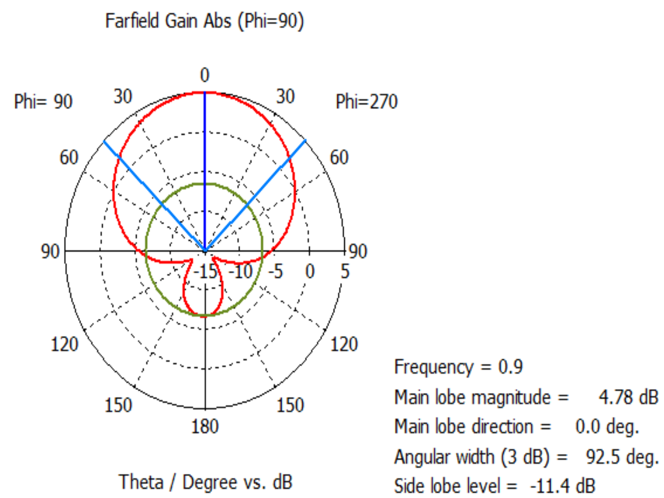

Fig. 7 Simulated Polar plot for Gain

IV. CONCLUSION

An E shaped rectangular microstrip patch antenna is designed and simulated over CST Studio Suite 2013 based on Finite Integral Techniques. The substrate used for the UHF RFID Reader purpose has a dielectric constant 4.7, loss tangent 0.019 and the substrate thickness of 1.6 mm. Thus, after reviewing all the simulation results, we can conclude that the designed antenna structure can work in UHF RFID system in Malaysia for a livestock monitoring with the frequency bands from 919 MHz to 923 MHz with return loss was below than 10 dB.

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