Chapter 3
Design of Circular Patch Microstrip Antenna for 2.4 GHz RFID Applications

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Abstract This paper discusses about the design of circular patch microstrip antenna for Radio Frequency Identification (RFID) tags application in the microwave band. Circular microstrip patch antenna is designed with a rectangular slot with the addition of 45° rotation in antenna patch and feed line to use for electric current feed. The dimensions of microstrip antenna obtained through computation, and then performed simulations. The design of microstrip antenna using fiberglass epoxy material -FR-4 with dielectric constant (εr) = 4,5. Based on simulation results, the antenna shows the maximum performance at 2400 MHz with return loss < −10 dB and VSWR < 2. Return loss and VSWR consecutive minimum of −31.37 dB and 1.056; the gain value is 1.399 dBi with 83.4 MHz of bandwidth and the shape of the radiation pattern of the antenna is directional.

Keywords RFID · Antenna · Microstrip · Circular patch · Slot · Microwave band · Bandwith

3.1 Introduction

For decades, the wireless telecommunications technology have a major growing. The example of wireless telecommunications technology application is Radio Frequency Identification (RFID). RFID is the successor of the barcode that can perform automatic control for a lot of things. RFID systems offer increased efficiencies in inventory control, logistics and supply chain management.

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RFID technology can not be separated from the antenna as an important element of the radio frequency (RF) application. The antenna serves as a means to transmit or receive the information signals carried on radio waves. In other words, the antenna is as a medium of transition between the free space transmission line that serves to change the electromagnetic wave energy to electrical energy or vice versa (transducer).

The antenna performance will affects the quality of the received signal. The antenna should be designed as small as possible, flexible, practical and with a good quality. Microstrip antenna is the right choice to meet the needs of RFID systems. Microstrip antennas designed in this paper is a single microstrip patch antenna with a circular shaped as radiating element with the addition of a rectangular slot which is rotated by 45°. The addition of slots at radiating element is intended to improve the performance of the antenna. The design and manufacture of circular microstrip patch antenna using the FR4 substrate with 2.4 GHz as operating frequency.

3.2 Literature Review

3.2.1 Microstrip Antenna

Microstrip antenna is an antenna consisting of radiating elements (conductors) which is very thin and the conductor is placed in the ground plane [1], in which between the radiation field and the elements (conductors) separated by a dielectric substrate. Microstrip antenna works on several frequency allocation which is Ultra High Frequency (UHF) (300 MHz–3 GHz) to X band (5.2–10.9 GHz) [2].

3.2.2 Antenna Dimension

In this research the patch form is a circle, where the radius of the radiating elements can be obtained through the equation [3]:

$$a = \frac{F}{\left\{1 + \frac{2h}{\pi \varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{1/2}} \tag{3.1}$$

with:

a = circular radius dimension (cm)
h = Thick of substrate (m)
ε_r = Relative dielectric permittivity of substrate (F/m)
F = logaritmik function (F) of radiating element

While the logarithmic function (F) of the radiating element is determined by the equation [3]:

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\varepsilon_r}} \tag{3.2}$$

with:
f_r = Resonating Frequency (MHz)
ε_r = Relative dielectric permittivity of substrate (F/m)

As for the length and width of the slot is obtained by using the equation [4]:

$$L_s = \frac{\lambda_0}{5} \tag{3.3}$$

$$W_s = \frac{\lambda_0}{32} \tag{3.4}$$

with:
L_s = Length of slot (m)
W_s = Width of slot (m)
λ_0 = Wavelength in free space (m)

The design that complements microstrip antenna structure are in the form of the transmission line, impedance adjustment channels, the distance between radiating elements, wavelength in the microstrip transmission line refers to [3, 5].

3.3 Design of Microstrip Antenna

Specifications of Substrate and Conductor Materials used in the design of microstrip antennas are as follows:

Dielectric material : Epoxy fiberglass—FR 4

- dielectric Constant (ε_r) = 4.5
- dielectric Thick (h) = 1.6 mm
- Loss tangent (tan δ) = 0.018

Substrate coating material (conductor) copper:

- The thickness of the conductor material (t) = 0.0001 m
- Copper conductivity (σ) = 5.80 x 10^7 mho m^{-1}
- The characteristic impedance of line = 50 Ω

3.3.1 Design of Radiating Element

To determine the dimensions of the elements, the operating frequency of the antenna must be chosen first. The operating frequency of the antenna (f_r) is 2400 MHz, and then we calculated the amount of radius (a) of the radiating elements of microstrip antenna with Eqs. (3.1) and (3.2) with the specification microstrip of the material was obtained; for $f_r = 2400$ MHz; logarithmic function value $F = 1.7267$ and patch radius = 17.25 mm. The width of the microstrip transmission line with 50 Ω impedance is 3.217 mm, length (L_t) of the transformers channel is 0.25 λ_d, where λ_d values for 2400 MHz is 0.0589 mm with $L_t = 0.25\ \lambda_d = 3.906$ mm. To improve the performance of the antennas, a slot was added to this design. Slot size on the radiating element is obtained by using Eqs. (3.3) and (3.4), $L_s = 25$ mm and $W_s = 3.906$ mm. Then, perform the simulation so the value of S_{11} at 2400 MHz can be obtained, which is −0. 3539 dB.

3.3.2 Microstrip Antenna Optimization

Based on simulation results, S_{11} value at 2400 MHz is greater than −10 dB, it indicates the antenna is not reach matching condition. Therefore, it needs to be optimized so that the antenna can be work as expected. Optimization is done by changing the dimensions of the patch, the slot and rotate the slot. Based on the rotation slot simulation result, S_{11} best value is obtained in 45° as shown in Table 3.1.

The dimensional result of the after microstrip antenna optimization is shown in Fig. 3.1.

Figure 3.2 shows the performance of the antenna with optimized S_{11}, the maximum frequency where antenna works is on 2400 MHz.

Table 3.1 The slot rotation simulation results versus return loss at 2.4 GHz

Degree (°)	S_{11} (dB)
0	−3.757
15	−4.39
30	−7.662
45	−31.37
60	−7.038
75	−3.18
90	−2.408
105	−3.156
120	−7.718
135	−27.57
150	−7.55
165	−4.384

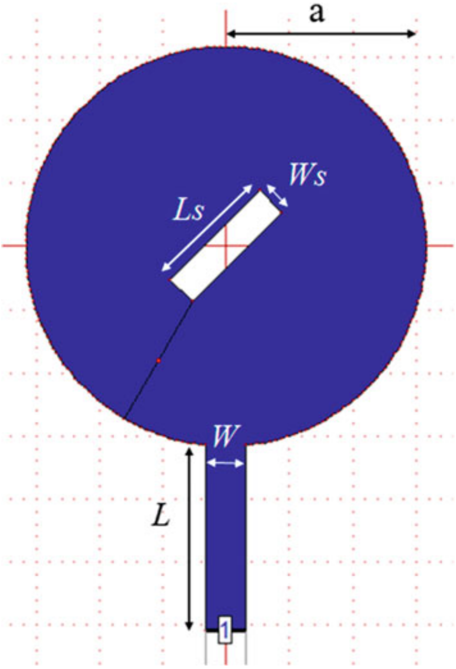

Fig. 3.1 Circular patch microstrip antenna after optimization, Caption: h = 1.6 mm; a = 15.825 mm; L = 14.7 mm; W = 3.217 mm; W_s = 2.5 mm; L_s = 10 mm

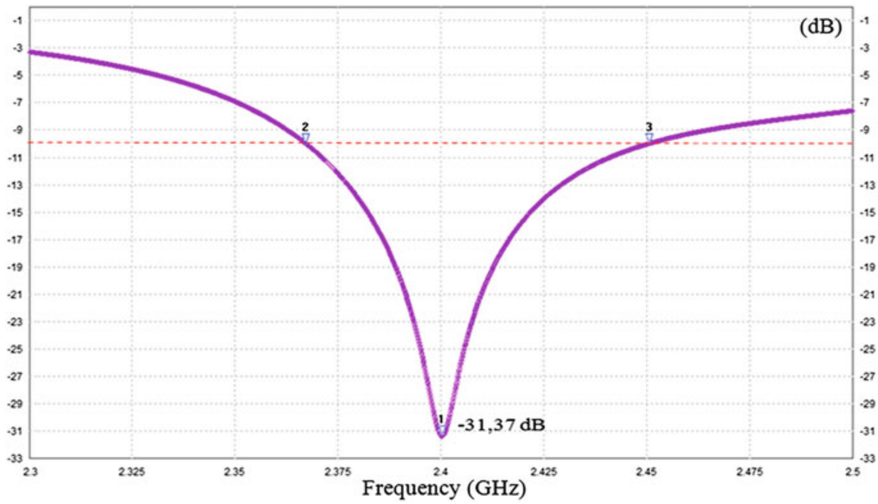

Fig. 3.2 S_{11} versus frequency chart of the optimized antenna

3.4 Simulation Result and Analysis

Based on Fig. 3.3, the antenna after optimized is able to work on the desired frequency 2400 MHz with a value of S11 of −31.37 dB and VSWR values of 1.056 and has qualified the extent permitted VSWR < 2 [6] and RL < −10 dB [7]. This antenna has 83.4 MHz bandwidth.

While the results of the gain simulation of circular patch microstrip antenna at 2400 MHz is 1.399 dBi. Figure 3.4 shows the radiation pattern of the antenna at 2400 MHz in 3D images. Based on the images obtained antenna has a directional radiation pattern with red to blue as the indicator.

2D antenna radiation pattern from the point of view of 0° (E-Plane) and 90° (H-Plane) in the polar diagram shown in Fig. 3.5.

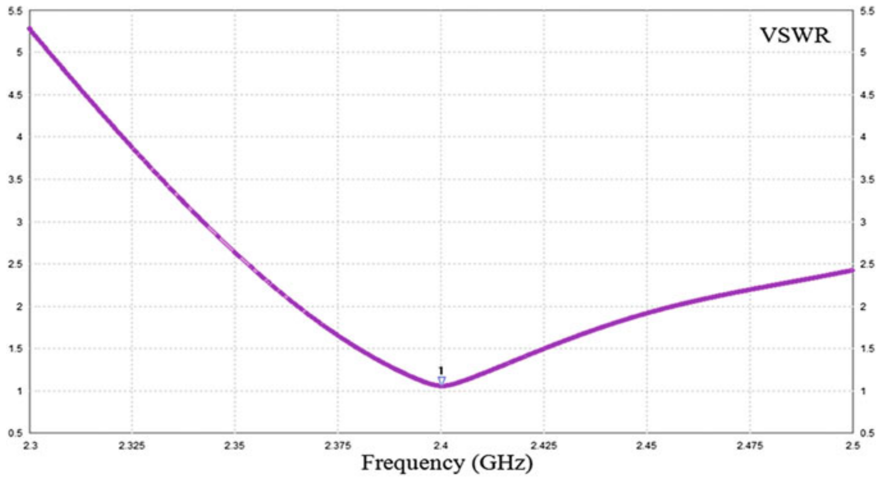

Fig. 3.3 VSWR against frequency chart at which the antenna has been optimized

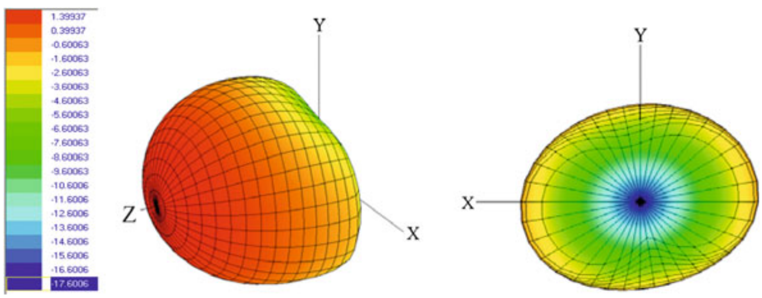

Fig. 3.4 3D radiation pattern

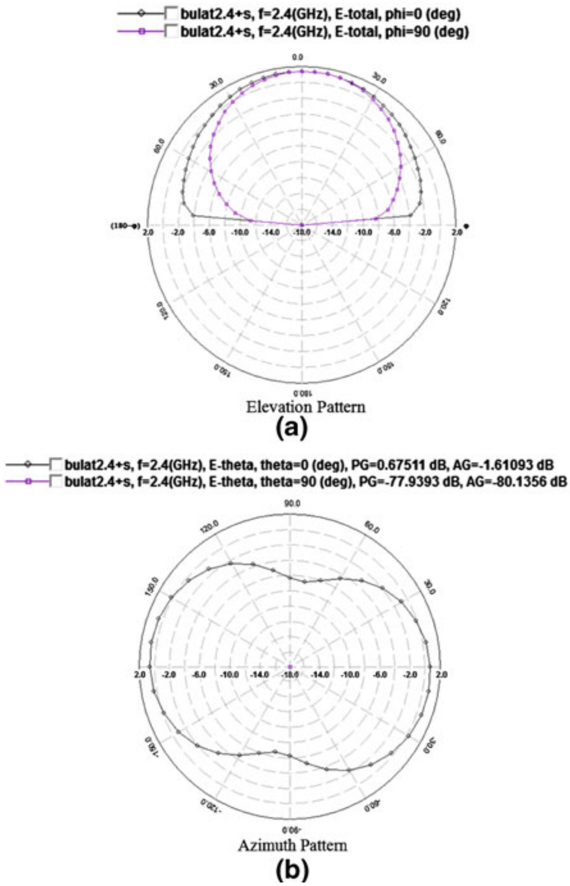

Fig. 3.5 2D radiation pattern: **a** vertical, **b** horizontal

3.5 Conclusion

Circular patch microstrip antenna designed indicate the desired performance. The addition of a slot on the patch can improve the performance of the antenna. Circular patch microstrip antenna designed is able to work a maximum at 2400 MHz with the value of S_{11} obtained is −31.37 dB, VSWR is 1.056, 83.4 MHz of bandwidth and antenna gain of 1.399 dBi. This antenna has a Directional radiation pattern shape.

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