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A Miniature UHF Rectangular Microstrip RFID Tag Antenna for Aluminium Can Application

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Abstract: This paper presents a design of single element rectangular microstrip antenna, where it can be embedded on an aluminium tin can for radio frequency (RF) application. The microstrip antenna was designed using a Liquid Crystalline Polymer (LCP) substrate with dielectric constant, $\varepsilon_r = 2.9$ and aluminium patch with electrical conductivity, $\gamma = 3.72 \times 10^7$ S/m. The microstrip antenna was originally designed using Computer Simulation Technology (CST) Microwave Studio software for operation at 2.45 GHz frequency band application. Furthermore, the return loss, S_{11} parameter of microstrip antenna is investigated. Some optimizations and analyses are performed such as varying the patch length and width with fixed dielectric constant. In addition, the related simulated value of impedance and return loss are examined and compared.

Key words: Rectangular Microstrip Antenna · Aluminium Patch · LCP · CST and RFID

INTRODUCTION

Microstrip antenna is the one of the existing technology in wireless industry. It is widely used because of its advantages such as small size, low profile, light weight and low fabrication cost. It consists of three parts which are radiating element, substrate and ground [1]. Furthermore, the antenna can be designed in many structures such as rectangular, eclipse, circular and triangular. Rectangular patch is the basic and most commonly used microstrip antenna in wireless communication. This patch can be used for the simplest and the most demanding applications due to its omnidirectional radiation pattern and circular polarization features [2]. This simplicity has lead to the large number of researches that has been made.

Radio Frequency Identification (RFID) is an automatic identification method on storing and remotely retrieving data using devices called RFID tags or transponders. It is widely used in current wireless communication systems. RFID uses radio frequency wave to identify and obtain the data from a developed tag [3-4]. It consists of transponder, reader and data collection application. Communication between the reader and tag is achieved by modulated backscattering of the reader's carrier wave signal [5-6]. It can undertake the near and far distance of item identification without needs of human supervision. By having this knowledge, a lot of developments have been made in order to exploit the available technology. For example clothing tag [7], food production control and vehicle identification [8-9]. In addition, a RFID system utilizes the available frequency ranges which have been specifically allocated for industrial, scientific or medical applications [10-12]. It is known as Industrial Scientific and Medical (ISM) frequency bands.

Today's RFID technologies are highly demanding for identification process [13-14]. In business application, RFID technology becomes popular for goods identification using tagging antenna, instead of bar code system. This refers to the advantages of RFID technology, which can be read when soiled or dirty, can be read through any obstacle and can carry much information than a bar code system [15-17]. The fast growth of this technology applied in identification of products shows that almost 1.7 billion dollars have been invested in developing the system [18-20].

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There are many examples of papers which focus on design of RFID antenna recently [21]. Example, in [22], a novel of folded microstrip patch antenna was implemented on a cigarette carton. It acts as a passive RFID antenna to provide some related information. An antenna's reader is required to extract the information from cigarette carton. Furthermore, a conveyor belt is used to ensure the cigarette carton can travel from one position to another position and will pass through the antenna's reader with constant speed.

For [23], it proposed a microstrip antenna with single patch and feeding line. It can remove the complexity of an extra matching network and excitation of two different radiating patches. The antenna can be placed along any of the vertical edges of a pallet or box where there is no radiation back into the pallet or box on which it is fixed. Thus, the antenna is ideal for warehouse uses, where pallets or boxes are stored one over the other [24-26].

In this paper, a novel of microstrip antenna is presented, where it can be attached on the aluminium can. The antenna designed is small and solid. It is particularly planned for the aluminium can to replace the barcode system. By having this antenna, the information of the aluminium can or tin such as price, weight and expired date are easily determined. The manufacturer needs to develop an unique identification for the antenna. Thus, the proposed antenna could potentially improve the functionality and reliability of wireless communication system.

Microstrip Antenna Design: A design of rectangular microstrip antenna was developed by using a low dielectric constant substrate of Liquid Crystal Polymer (LCP) and aluminium material to construct its patch and ground. LCP is a thermoplastic polymer made of aligned molecule chains with crystal-like spatial regularity. LCP substrate was chosen because of its advantages such as easy to fabricate, wide frequency range, offers low loss tangent, light weight, thickness variety, low cost and others [27]. Besides that, it also has a low permittivity characteristic. LCP substrate has permittivity approximately 3 which is valuable for packaging. Meanwhile, aluminium patch was selected to implement it on the aluminium can. Thus, the aluminium at the can will acts as its ground.

In Figure 1, it illustrates the side view of the microstrip antenna, while Figure 2 shows its total configurations.

The antenna can be divided into three parts. The first part is the top side of the substrate, consists of a rectangular patch which acts as a radiating element and a feeding line. Second part is a middle layer which known as a dielectric substrate. And the last part is at the bottom side, known as a microstrip ground. Regularly, for a directional microstrip antenna, the size of ground is equal to the size of the dielectric's substrate.

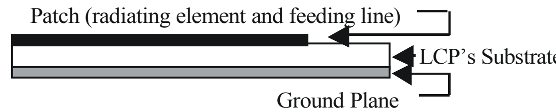

Fig. 1: Side view of can microstrip antenna

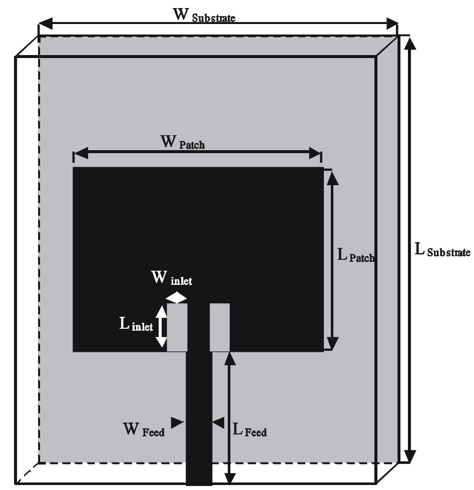

Fig. 2: Configuration of rectangular microstrip antenna

Table 1: LCP substrate properties

Parameter	Value
Height, *h*	0.508 mm
Dielectric constant, ε_r	2.9
Tangent loss, δ	1.19 F/m

Table 2: Aluminium patch properties

Parameter	Value
Height, *h*	0.035 mm
Electric conductivity, γ	3.72×10^7 S/m

Since the microstrip antenna is divided into three layers, so every layer has its material. Throughout the simulation, the aluminium element with electrical conductivity, $\gamma = 3.72 \times 10^7$ S/m was selected to apply at the patch, feeding line and ground. LCP material was selected as a dielectric substrate at the middle layer with dielectric constant, $\varepsilon_r = 2.9$ and loss tangent, $\delta = 0.019$.

In Table 1, it shows the summarization of LCP substrate specifications. Meanwhile, Table 2 indicates the specifications of aluminium in microstrip antenna.

The transmission line model is used, which is ideal for rectangular microstrip patch antenna design. It is easy to implement and provide a good output performance such as efficiency and return loss [28]. By selecting a suitable targeted frequency, a substrate with appropriate permittivity and thickness, the length and width of the patch are calculated as:

$$W_{Patch} = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

where c is the speed of light with 3×10^8 m/s value, f_o is the resonance frequency and ε_r is the substrate's dielectric constant. Moreover, consequent equation was used to calculate the length of patch, L_{Patch}:

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

where L_{eff} is the effective length and ΔL is the length extension. L_{eff} and ΔL were determined by using:

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \tag{3}$$

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

where, h is the height of substrate and ε_{reff} is the effective dielectric constant which can be determined by using:

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\left(\frac{h}{W}\right)\right]^{-\frac{1}{2}} \tag{5}$$

Besides that, the antenna was fed by 50 ohms feeding line characteristic impedance. Thus, the width of feeding line, W_{Feed} can be figured out by using:

$$W_{Feed} = \frac{5.98h}{0.8} \div e\left[\frac{Z_o}{87} \times \sqrt{\varepsilon_r + 1.41}\right] \tag{6}$$

Based on the microstrip antenna theory, the feeding line and patch should be connected to each other in order to allow signal pass through from port to the patch. Since this typical rectangular patch microstrip antenna produce approximately 250 ohms patch impedance which is high input impedance, while the feeding line impedance is 50 ohms. So, the feeding line and radiating patch cannot be simply connected. Thus, there are several techniques can be used to match these two elements such as inlet feed and quarter wavelength transmission line techniques. However, inlet feed technique has been chosen and used.

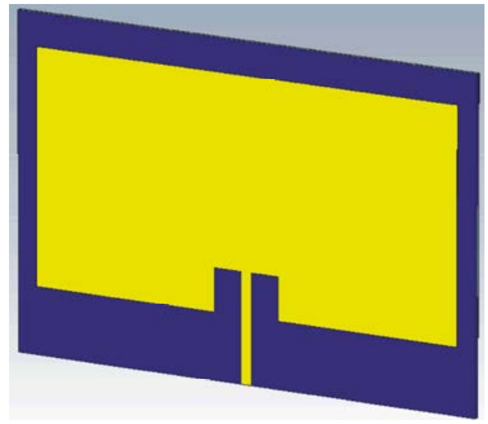

Fig. 3: Simulated rectangular microstrip antenna

Table 3: Dimensions of microstrip antenna

Parameter	Calculated (mm)	Optimized (mm)
Wfeed	1.15	1.22
WPatch	43.84	48.00
LPatch	35.82	35.10
WSubstrate	46.89	52.20
LSubstrate	38.87	50.00

Figure 3 shows the rectangular microstrip antenna designed by using CST software. In addition, from the simulation work the microstrip antenna has 249.3 ohms patch impedance and 49.9646 ohms line impedance which are approximately same with its original value.

Table 3 indicates two types of antenna's dimensions. Calculated value base on the available microstrip antenna theory and the other one are the adjusted value in order to get the targeted parameters for this microstrip antenna such as resonance frequency.

Based on Table 3, the calculated and optimized (simulation) values are not too much different between each other. However, each value has an interest of its own. The calculated values are used as reference values in starting the design process in simulation. While, optimized value is the ideal value to get the other targeted parameters or performances in microstrip antenna.

RESULTS AND DISCUSSION

The simulation results are obtained using CST Microwave Studio software. Figure 4 and Figure 5 show

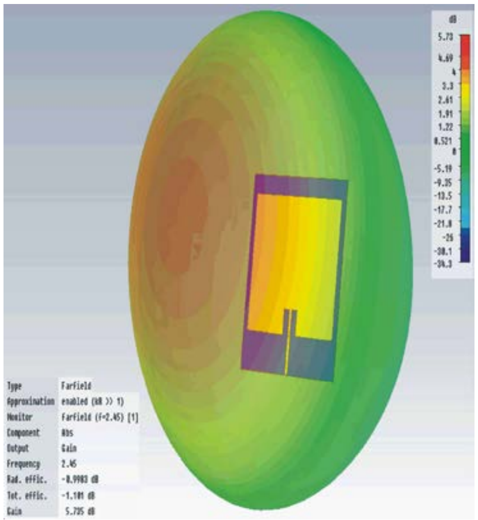

Fig. 4: Simulated 3D radiation pattern

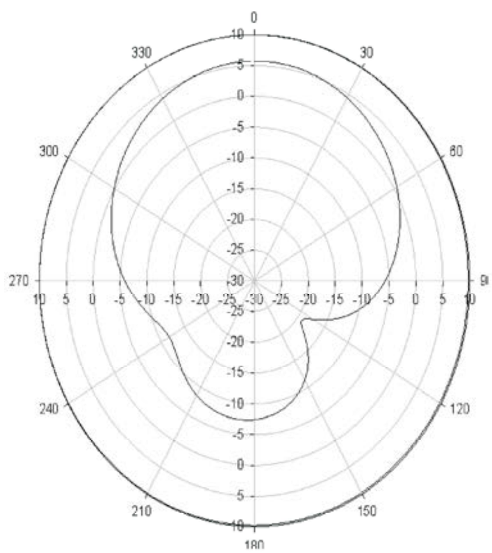

Fig. 5: Simulated 2D radiation pattern at E-plane

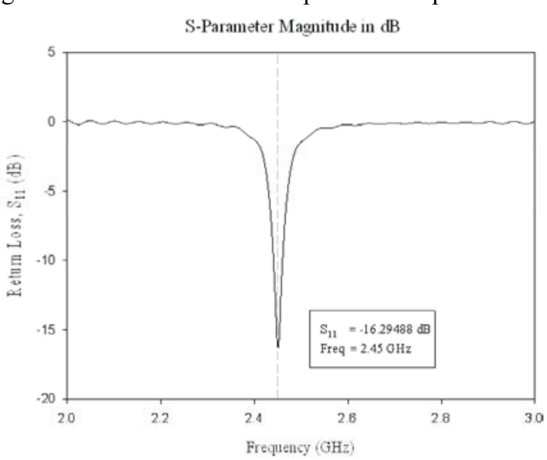

Fig. 6: Return loss (S_{11}) value of the antenna

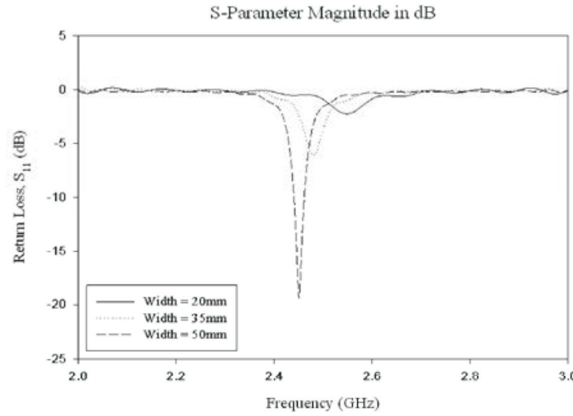

Fig. 7: S_{11} graph obtained after varying width of patch

Table 4: Frequency bands of microstrip antenna

Type of Frequency	Value (GHz)	VSWR
Resonance	2.45	1.36
Lower Band	2.44	2.01
Upper Band	2.46	1.92

the radiation pattern of the aluminium patch microstrip antenna, while Figure 6 shows the return loss, S_{11} value in decibels (dB).

In order to determine the resonance frequency of an antenna, the value of S_{11} should be considered. The good value of resonance frequency is when its S_{11} value is less than -10 dB. Hence, according to the result as shown in Figure 8, this rectangular microstrip antenna can operate properly at 2.45 GHz frequency band with S_{11} value is -16.29488 dB. In addition, the voltage standing wave ratio (VSWR) value for this microstrip antenna at 2.45 GHz is 1.36, as shown in Table 4. It shows that the maximum standing wave value is 1.36 greater than minimum standing wave. VSWR is used to measure the efficiency of the transmission lines.

Furthermore, the values of lower and upper band frequencies at -10 dB for this microstrip antenna are 2.44 GHz and 2.46 GHz respectively. Therefore, the available bandwidth for this microstrip antenna is 0.02 GHz. The bandwidth obtained is too small, but it is good for RFID technology to own it in terms of its protection. This is because by having a small bandwidth, the data that is carried by the antenna is more secured. Hence, it is hard for other signals to interfere with this rectangular microstrip antenna.

Furthermore, in Figure 6 and Figure 7, it shows that the antenna will radiate in forward direction with gain value is equal to 5.735 dB on major lobe. Meanwhile, the directivity value of the microstrip antenna is 6.733 dBi.

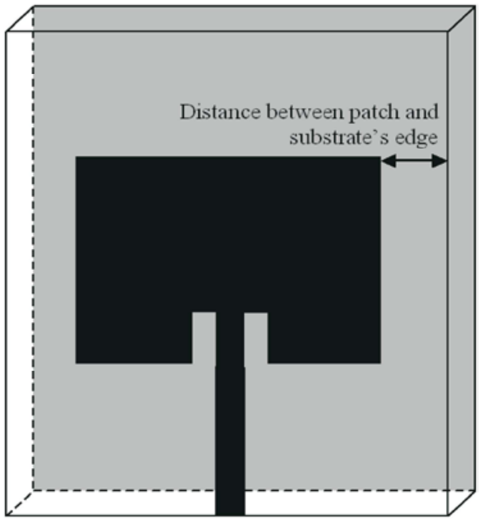

Fig. 8: Location of space to be examined

From the Figure 7, it also shows that the 3dB angular width or beamwidth value is 87.2 degrees. Angular width or beamwidth is the angular separation in which the magnitude of the radiation pattern decreases by 50% or -3 dB from the peak of the main beam. At this point, the gain is one half the maximum values. It is compulsory for each antenna to transmit or receive signal at least one half of it maximum values. It illustrates that the rectangular microstrip antenna is possible to transmit and receive signal properly in that specified direction. Therefore, this microstrip antenna can be categorized as a directional antenna.

In order to operate in omnidirectional, it requires at least four units of this antenna to be combined and arranged properly, so that the total beamwidth is approximate 360 degrees.

In addition, some investigations had been made in order to determine the relationship of some parameters to the rectangular microstrip antenna characteristic. All the analyses were done by varying just one parameter (examined parameter) while the other parameters are maintained with the actual values. First analysis that has been made is to identify the relationship between width of the patch and the resonance frequency.

Table 5 and Figure 9 show the effects of varying patch's width to the antenna performance. Parameters involved are frequency and S_{11} values. From the results obtained, it indicates that when the width of patch is increased, the resonance frequency will decrease. So, it can be concluded that the resonance frequency of the antenna is inversely proportional to the width of the patch.

Table 5: Effect of varying patch's width

Width(mm)	Frequency(GHz)	Return Loss, S11(dB)
20	2.548	-2.240883
35	2.480	-6.147025
50	2.451	-19.41237

Table 6: Effect of varying substrate's width

Width (mm)	Frequency (GHz)	Return Loss, S11(dB)	Gain (dB)
50	2.454	-17.37535	5.679
55	2.453	-13.78955	5.771
60	2.456	-11.84776	5.841
65	2.455	-11.15978	5.878
70	2.456	-10.48937	5.937

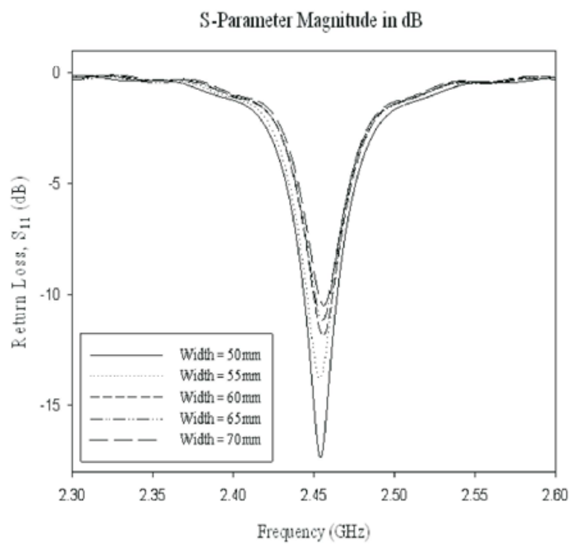

Fig. 9: Simulated 2D radiation pattern at E-plane

The next analysis is focus on the effect of varying substrate width. It is to observe the correlation of the distance between patch and substrate's edge to the antenna performance. Figure 8 illustrates where the distance is located and the affected parameters were recorded.

Figure 9 and Table 6 indicate the effect of varying width of substrate to the antenna performance such as resonance frequency, return loss and gain.

From the result obtained, it can be stated that the width of substrate not affect too much on resonance frequency. This is because the value of resonance frequency just gives a little change even there are much changes had applied on the width of substrate. However, there are many changes had occurred on the return loss, S_{11} and gain values. The S_{11} and gain values are increased when the width of substrate is increased. Thus, it can be stated that the S_{11} and gain values are proportional to the substrate's width.

CONCLUSION

This paper has presented a design of single element aluminium patch rectangular microstrip patch antenna. Throughout the CST Microwave Studio software, simulation results were obtained. Nevertheless, some adjustments to the antenna dimensions were necessary in order to achieve the 2.45 Ghz as a reference frequency.

In addition, the designed antenna has shown good performance in terms of return loss, VSWR and radiation pattern using simulation result. The variation in width of patch and substrate produced change in resonance frequency, gain and return loss, S_{11} values. All the results obtained were analyzed and studied. Minimum return loss occurs when the feeding line impedance, Zo approximately equals to 50 ohms, since impedance of patch and impedance of feeding line are matched.

Finally, the microstrip antenna design approach of rectangular patch can be used on aluminium container to obtain operation in wireless communication.

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