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A Miniature L-slot Microstrip Printed Antenna for RFID

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Abstract

This work presents a miniature microstrip antenna at 2.45 GHz by using the slots technique. This microstrip antenna is fed by a CPW technique and designed for RFID reader system on FR4 substrate. A size reduction equal to 66.6% has been obtained compared to the conventional rectangular microstrip antenna. The total area of the final circuit is 19x31 mm^2. The validated antenna has good matching input impedance with a stable radiation pattern, a loss return of -40 dB, and a gain of 1.78 dBi, a prototype of the proposed antenna has been fabricated and measured.

***Keywords**: miniature antenna, microstrip antenna, RFID, L slot, CPW fed.*

1. Introduction

This paper presents the slot technique to miniaturize the microstrip antenna for RFID application. The abbreviation RFID stands for radio frequency identification, i.e. information carried by electromagnetic waves. An RFID system is generally composed from a reader, and one or more tags. The communication between the reader and the tag is achieved by modulated backscattering of the reader's carrier wave signal. The RFID system is used in many applications as transport, payment systems, access control, and logistic. Most RFID systems operate in either the low frequency region (30-300 kHz), the high frequency band (3-30 MHz), the ultra-high-frequency band (300 MHz-3 GHz), or in the microwave band (3GHz-40 GHz) [1-6].

The microstrip antennas are widely used because of their good characteristics; they are low-profile, low weight, ease of fabrication, and mechanically robust. They are composed of three parts which are radiating element, substrate and ground, and can be designed on many structure shapes such as rectangular, elliptic, circular and triangular, etc. Rectangular patch is the basic and the most used microstrip antenna in wireless communication [7,8].

The RFID antennas must be designed on small size and light weight structures. One of the techniques used to design a miniature antenna is the use of the slots technique; this technique is based in the use of certain approaches to manipulate the current distribution of the structure to change its resonant frequency [9-26].

In this paper, a novel design of a miniature low cost microstrip antenna is proposed at frequency of 2.45 GHz, this antenna is designed by using the symmetric L-slots inside the patch with the CPW (Coplanar Wave Guide) fed. The final circuit is validated by optimization methods integrated in CST-MW Studio; and realized with conventional Printed Circuit Board (PCB) techniques.

2. Research Method

The structure of the proposed antenna is a rectangular radiating patch as shown in Figure 1, and fed by a 50 ohms Coplanar Wave Guide line. This antenna uses an FR4 substrate with dielectric constant εr=4.4, loss tangent tanδ=0.025, thickness h=1.58 mm, and metal thickness t=0.035 mm.

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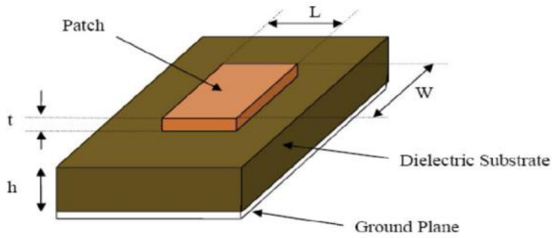

Figure 1. Patch antenna configuration

2.1. Conventional microstrip antenna

Conventional microstrip antenna has the length L and the width W, which are related to the resonant frequency, to the permittivity and to the thickness of substrate; this length and width can be calculated, theoretically by the following conventional equations discussed in [27]:

$$W = \frac{c}{2f\sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{1}$$

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

where c is the speed of light, f is the resonant frequency and ε_r is the substrate's dielectric constant. L_{eff} is the effective length given by:

$$L_{eff} = \frac{c}{2f\sqrt{e_{eff}}} \tag{3}$$

and ΔL is the length extension, given by:

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

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

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

In this case, the dimensions of the conventional patch antenna at frequency 2.45 GHz are: L=26.86 mm, W=37 mm.

2.2. Microstrip antenna with slots technique

The L slots are inserted into the microstrip antenna in order to modify the resonance frequency, by forcing the current to flow through a long path around the slots. Four symmetric L-slots are inserted inside the patch with the length Ls1 and Ls2, and the width Ws, as shown in Figure 2. The microstrip antenna with the L-slots has the length L and the width W which are dependent on the resonant frequency as shown in equation (1). It is connected to a Coplanar Wave Guide line with the width Wf and the length Lf. The length substrate Lsub is defined by the patch length L and fed length Lf. The width subtrate Wsub is determinated by the coplanar wave guide width Wcpw and adjusted to meet the good impedance matching and correct gain. The distance from the patch to the substrate edge is slightly larger, at least 3* substrate thickness, to reduce fringe effects. Figure 2 illustrates the face of the antenna. The following table indicates the dimensions of the proposed antenna as shown in Table 1.

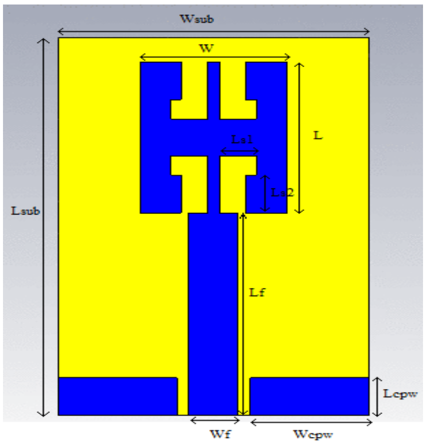

Figure 2. Geometry of the proposed antenna: Top Face

Table 1. Antenna Dimensions

Antenna Dimensions	Optimized Value (mm)
L	12.4
W	9
Lsub	31
Wsub	19
Lf	16.6
Wf	3
Ls1	3.1
Ls2	2.25

3. Results and Analysis

A new antenna structure with four symmetric L-slots and Coplanar Wave Guide fed is proposed. The width and length value of patch antenna are optimized on CST EM solver. As shown in Figure 3, the size characteristics of the proposed antenna structure, WsubxLsub=19x31 mm^2, is very small compared to the conventional rectangular microstrip antenna at the operating frequency, WsubxLsub=39x45.21 mm^2.

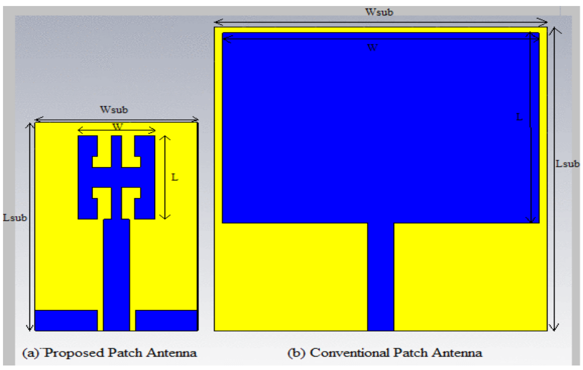

Figure 3. (a) Proposed Patch Antenna, (b) Conventional Patch Antenna

3.1. Simulation results

Figure 4 shows the return loss S11 result for the antenna, it has good matching input impedance at frequency 2.45 GHz. A return loss (S11) equal to -40 dB is obtained with this antenna. The bandwidth value is approximately 235 MHz. The gain and directivity are respectively 1.78 dBi and 1.87 dB. Figure 5 illustrates the 2D radiation patterns at E-plane and H-plane respectively. The proposed antenna has an omni-directional radiation pattern for E-plane. The angular width is 86.2 degree at 2.45GHz. Figure 6 illustrates the surface current distribution of the proposed antenna at 2.45 GHz. A maximum current is observed around the L slots placed at low side, and around the feed line.

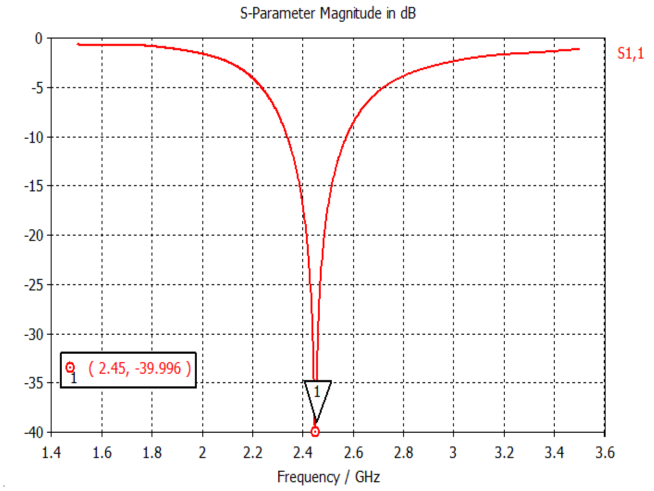

Figure 4. Return loss (S11) value of the proposed antenna

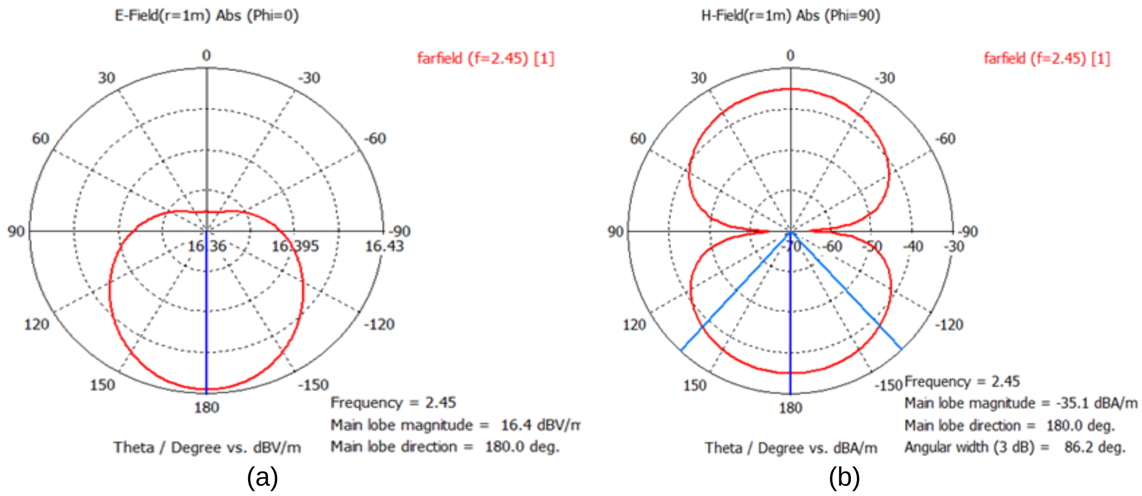

Figure 5. 2D radiation patterns of the proposed antenna in E-plane (a) and H-plane (b)

The simulated gain versus frequency is illustrated in Figure 7, the peak gain is 1.78 dBi at 2.45 GHz.The results obtained by CST_MW are compared to ADS, a 3D electromagnetic solver. Figure 8 illustrates the return losses obtained by simulation. These results present an acceptance agreement between CST-MW and ADS, results obtained by CST are more pessimist than ADS results.

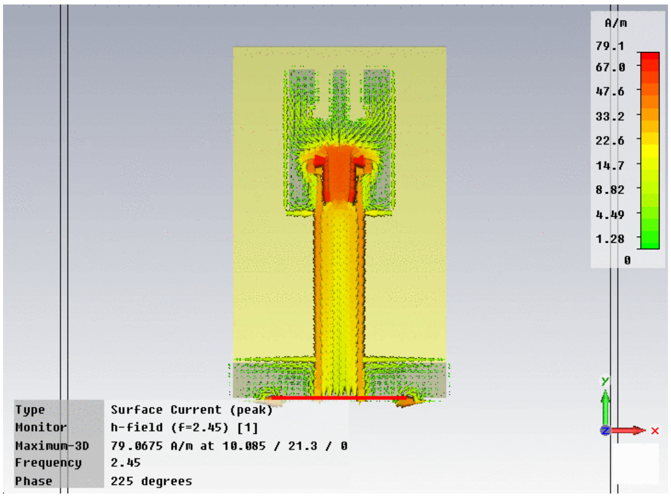

Figure 6. Surface current distributions of the proposed antenna

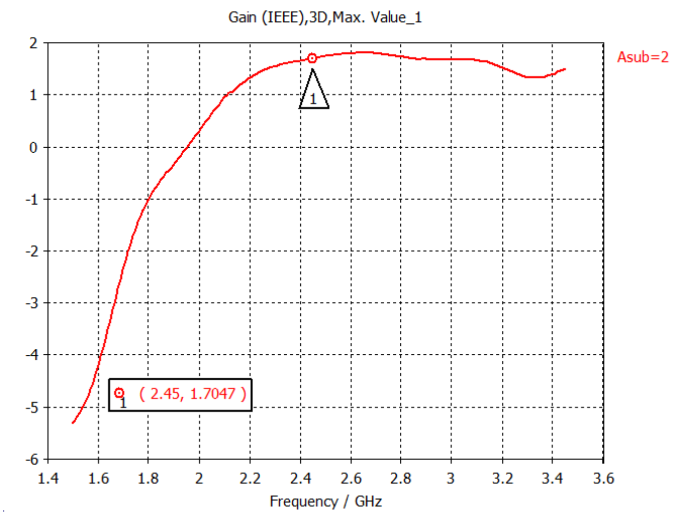

Figure 7. Gain versus frequency of the proposed antenna

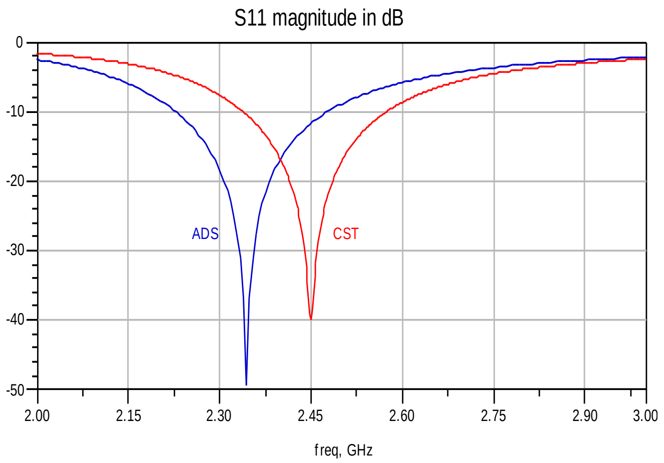

Figure 8. Comparison between return losses obtained by CST-MW and ADS

The results obtained of the proposed antenna, summarized in Table 2, show a good return loss S11, and a good bandwidth. The gain and directivity value are acceptable for RFID applications. A CPW-feed has a high bandwidth, compared to the microstrip line feed with a conventional microstrip antenna, as shown in Table 2.

Table 2. Result Comparison between Proposed Antenna and Conventional Patch with Microstrip Fed

Patch Antenna 2.45 GHz	S11 (dB)	Bandwidth (MHz)	Gain (dB)
Conventional antenna	- 43.5	60	1.76
Proposed Ante nna	- 40	235	1.78

3.2. Experimental results

A prototype of the proposed antenna has been realized to check the performance of the simulation results obtained by CST-MW and ADS, as shown in Figure 9. Figure 10 shows the simulated and measured return loss of the antenna. The results summarized in Table 3, show good agreement with a return loss of approximately -10 dB at frequency 2.45 GHz.

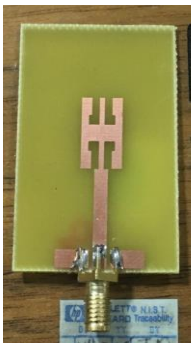

Figure 9. The antenna prototype achieved

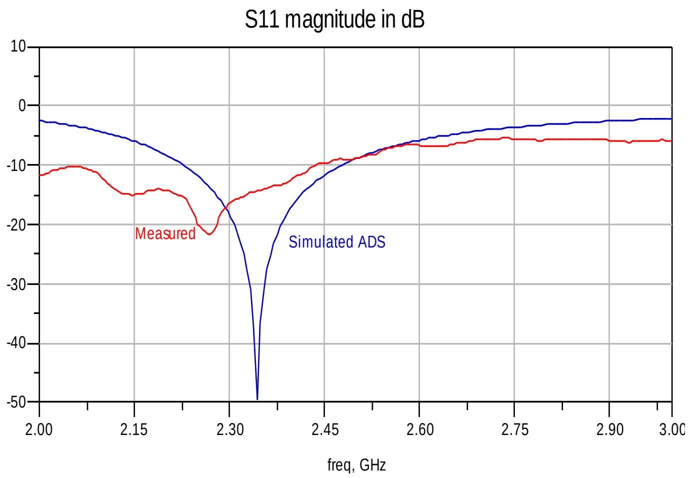

Figure 10. Measured and simulated return loss of the proposed antenna

Table 3. Resume of Simulated and Measured Results

Frequency	S11 (dB) Simulated	S11 (dB) Measured	Bandwidth (MHz) Simulated	Bandwidth (MHz) Measured
2.45 GHz	- 40	- 10.0	235	400

The results obtained of the proposed antenna, summarized in Table 4 and Table 5, present a good miniaturization of the antenna dimensions. As shown in Table 5, The total size reduction obtained, compared to some antennas that operate at the same frequency of 2.45GHz, is for example equal to 66.6% for the conventional rectangular microstrip antenna, 56.3% for the compact cpw-fed dual-band uniplanar antenna, realized by Ahmed and al [28], 54.5% for the dual band metamaterial printed antenna based on CSRR, obtained by Abdelhadi and al [29], 49.0% for the miniature planar microstrip antenna using DGS, realized by Er-rebyiy and al [30], and 49.0% for the compact low cost dual-band slot antenna, realized in a previous work [31].

Table 4. Patch Size Result Comparison Between Proposed Antenna And Others Antennas

Patch Antenna 2.45 GHz	W (mm)	L (mm)	Patch size reduction (WxL)
Conventional antenna	37	28.3	
Proposed Antenna	9	12.4	89.3 %

Table 5. Total Size Comparison Between Proposed Antenna And Others Antennas

Patch Antenna 2.45 GHz	Wsub (mm)	Lsub (mm)	Total size reduction (Wsub xLsub)
Proposed Antenna	19	31	
Conventional antenna	39	45.2	66.6 %
Compact CPW-Fed Dual Band Uniplanar antenna [28]	30	45	56.3 %
Dual Band Metamaterial Printed Antenna [29]	36	36	54.5 %
Miniature Planar Microstrip Antenna Using DGS [30]	34	34	49.0 %
Compact Low Cost Dual-Band Slot Antenna [31]	35	33	49.0 %

4. Conclusion

This paper presents a new rectangular microstrip antenna with symmetric L-slots and CPW fed. A size reduction of antenna dimension equal to 66.6% has been obtained compared to conventional microstrip antenna. It provides appropriate characteristics, with a return loss equal to -10 dB, a bandwidth of 400 MHz, the value of theoretical directivity is 1.87 dB, and that of theoretical gain is 1.78 dBi. The antenna has been designed on a standard FR4 substrate and realized with conventional Printed Circuit Board (PCB) techniques.

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