

Design, Realization and Measurements of Compact Dual-band CPW-fed Patch Antenna for 2.45/5.80 GHz RFID Applications

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ABSTRACT

In this paper, a Coplanar Wave Guide (CPW)-Fed microstrip octagonal patch antenna for RFID Applications is proposed. The studied structure is suitable for 2.45/5.80 GHz applications. The octagonal shape is obtained by making triangular cuts in the four angles of the rectangular microstrip patch antenna; in addition the using of CPW-Fed allows obtaining UWB characteristics in the higher band. The miniaturization in the antenna size for lower band is achieved by introducing an inverted E slot in the radiating element. The proposed antenna is designed on a single and a small substrate board of dimensions 29.5×29.5×1.6 mm³. Moreover the miniaturized antenna has a good impedance matching and an enhanced gain. The simulation analysis was performed using the CADFEKO software, a Method of Moment (MoM) based solver, and a prototype of this antenna was fabricated, good agreement with the simulation providing validation of the design procedure. The measurements are done with ANRITSU MS2026C Vectorial Network Analyzer.

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1. INTRODUCTION

“RFID stands for Radio Frequency Identification, a term that describes any system of identification wherein an electronic device that uses radio frequency or magnetic field variations to communicate is attached to an item” [1]. The two most talked-about components of an RFID system are the tag, which is the identification device attached to the item we want to track, and the reader, which is a device that can recognize the presence of RFID tags and read the information stored on them. The reader can then inform another system about the presence of the tagged items. The system with which the reader communicates usually runs software that stands between readers and applications. This software is called RFID middleware [1].

In a typical RFID system [2], passive tags are attached to an object such as goods, vehicles, humans, animals, and shipments, while a vertical/circular polarization antenna is connected to the RFID reader. The RFID reader and tag can radio-communicate with each other using a number of different frequencies, and currently most RFID systems use unlicensed spectrum. The common frequencies used are low frequency (125 KHz), high frequency (13.56 MHz), ultra high frequency (860–960MHz/2.45GHz), and microwave frequency (3.6/3.9/5.8/5.9/8.2GHZ [3]). The typical RFID readers are able to read (or detect) the tags of only

a single frequency but multimode readers are becoming cheaper and popular which are capable of reading the tags of different frequencies [4].

The miniaturization can affect radiation characteristics, bandwidth, gain, radiation efficiency and polarization purity. The miniaturization approaches are based on either geometric manipulation (the use of bend forms, meandered lines, PIFA shape, varying distance between feeder and short plate, using fractal geometries[5-8]) or material manipulation (Loading with a high-dielectric material, lumped elements, conductors, capacitors, short plate [9]), or the combination of two or more techniques [10]. Also several works [11-15] have appeared in the literature in which the size of the microstrip patch antenna has been reduced by introducing various types of slots in the microstrip patch antenna. Antenna miniaturization can be also achieved using metamaterials [16-18].

In this paper, the authors propose a compact CPW-Fed microstrip octagonal patch antenna with an inverted E slot loading in the radiating element. The studied antenna is suitable for 2.45/5.80 GHz RFID applications. The design methodology of the antenna is included in section 2, in this section the proposed antenna is designed in two steps. In the first step, we describe the design procedure of a simple CPW-Fed octagonal patch antenna at 5.80 GHz. In the second step an inverted E slot is introduced in the radiating element which leads to generate a new resonant frequency and therefore allow covering the lower bandwidth. In the section 3 the designed antennas are manufactured and measured and results are discussed.

2. DESIGN METHODOLOGY

2.1. Step 1: Design of CPW-feed octagonal patch Antenna at 5.80 GHz

As demonstrated in several studies, the CPW-Feeding allows having a wide bandwidth comparing with the probe feeding [19-21]. In this step we make a cut of a small triangular shape in the four angles of the microstrip patch antenna as shown in Figure 1. With this manner we obtain an octagonal patch antenna. To study the behavior of the obtained antenna regarding the dimension (L_{cut} and W_{cut}) of the triangular cut, a new parameter D is defined: $L_{cut}=L/D$ and $W_{cut}=W/D$. we set $W_s=29.5$ mm, $L_s=29.5$ mm, $W=28$ mm, $L=20.5$ mm, $S=0.3$ mm, $G=0.2$ mm, $W_f=3.06$ mm and $Y_g=7.8$ mm.

By varying the parameter D from 2.5 to 4, the S_{11} parameter of the octagonal patch antenna versus frequency is shown in Figure 2. Table 1 summarizes the resonant frequency and the bandwidth obtained by varying the D parameter. Note that there is a close relation between the parameter D and the final size of the radiating element, as D decreases the total size of the octagonal patch decreases also.

From Table 1 we note that making a triangular cut in the four angles of the microstrip patch antenna we obtain easily an UWB antenna. Also we can consider that $D=3$ is the most adapted value in term of bandwidth, compactness and also adaptation in the whole operating frequency band. This value allows the antenna covering the -10 dB operating bandwidth of 2.71 GHz (3.81 to 6.52 GHz).

The analysis of the S_{11} parameter (Figure 2) for the $D=3$ shows that, for the band of 2-7GHz, the antenna have one resonant frequency $f_r=5.80$ GHz. Figure 3 shows the 3D Total gain for the resonant frequency 5.80 GHz. We observe that the 3D-Total gain is almost Omnidirectional for the frequencies around 5.80GHz. Moreover the total gain of this antenna is about 3.7dB in the resonant frequency 5.80 GHz.

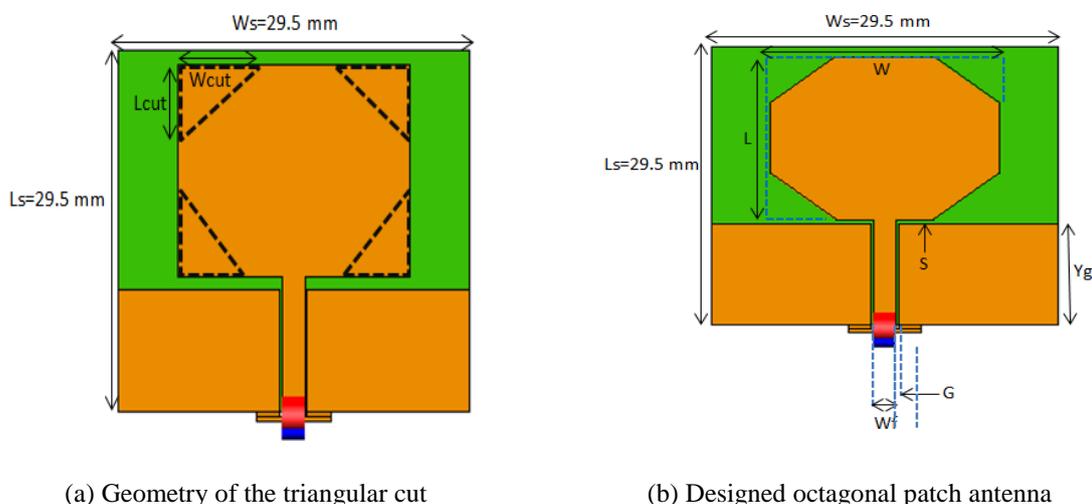


Figure 1. The design of the octagonal patch antenna

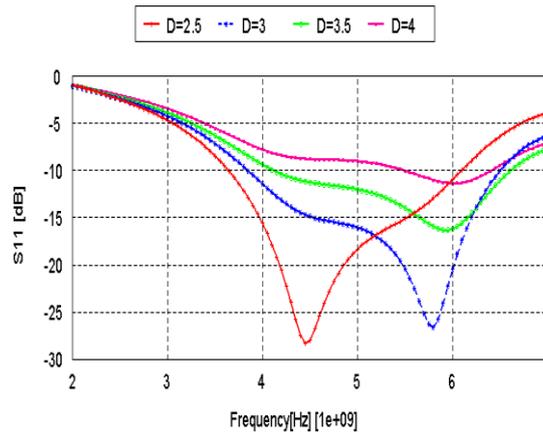


Figure 2. Simulated S11 versus frequency by varying D

Table 1. Resonant frequency and bandwidth versus the parameter D

D	Resonant frequency(GHz)/S11(dB)	Bandwidth (GHz)
2.5	4.45/-28.56	2.51 :3.61 to 6.12
3	5.80/-26.89	2.71 :3.81 to 6.52
3.5	5.94/-16.47	2.57 :4.07 to 6.64
4	6.01/-11.45	0.99:5.44 to 6.43

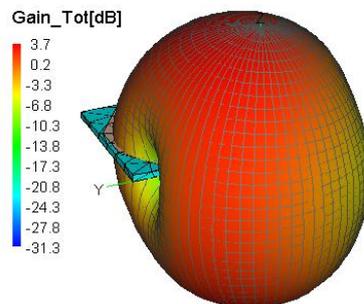


Figure 3. Simulated 3D-Total gain for the resonant frequency 5.80GHz

2.2. Step 2: The Setup of an Inverted E Slot Structure on the CPW-Fed Octagonal Patch Antenna

In this section we present the second step of Antenna design which consists of introducing an inverted E slot structure on the CPW-Fed octagonal patch antenna designed in section 2.1. The final designed Antenna is shown in Figure 4.

We set $W_s=29.5$ mm, $L_s=29.5$ mm, $W=28$ mm, $L=20.5$ mm, $Y_g=7.8$ mm, $W_f=3.06$ mm, $G=0.2$ mm, $S=1.1$ mm, $S_1=0.3$ mm, $E_h=19$ mm and $E_v=11.3$ mm, $e=2.1$ mm, $D=3.55$. Figure 5 shows the S11 parameter of the octagonal patch antenna with inverted E slot versus frequency. It's clear from Figure 5 that the setup of the inverted E slot allows generating new resonant frequency: $f_r=2.45$ GHz, we note that this resonant frequency is lower than the first resonant frequency obtained with the simple octagonal patch antenna and it does not belong to the higher bandwidth. Also two -10dB bandwidths are obtained, 140MHz (2.37 – 2.51 GHz) and 1.95 GHz (4.70- 6.65GHz) with the resonant frequencies/S11 are 2.45GHz/-16.34 dB and 5.80 GHz/-38.32 dB respectively. Therefore the proposed antenna is suitable for 2.45/5.80 GHz RFID applications.

Figure 6 shows the 3D Total gain for the two resonant frequencies 2.45/5.80 GHz of the octagonal patch antenna with inverted E slot loading, the total gain of this antenna is about 2.1dB and 3.5dB for the two

resonant frequencies 2.45 GHz and 5.80 GHz, respectively. We note that the 3D-Total gain is almost Omnidirectional for the two resonant frequencies 2.45 GHz and 5.80GHz.

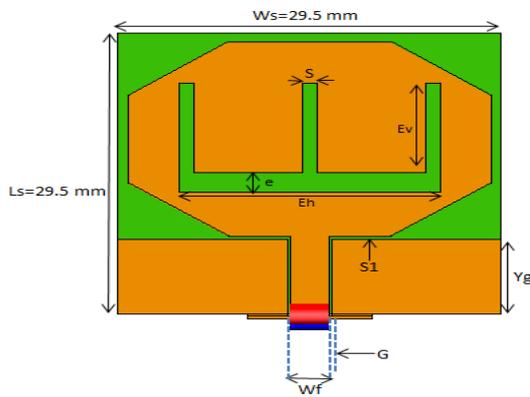


Figure 4. The CPW-Fed Octagonal patch antenna with inverted E slot loading

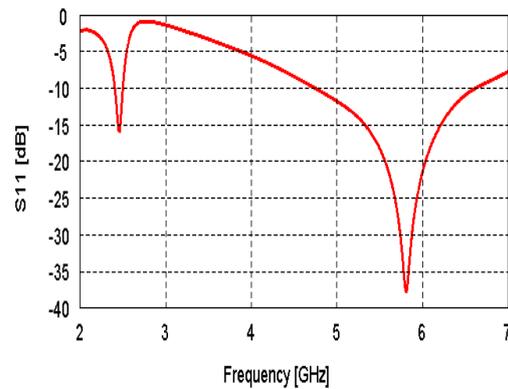
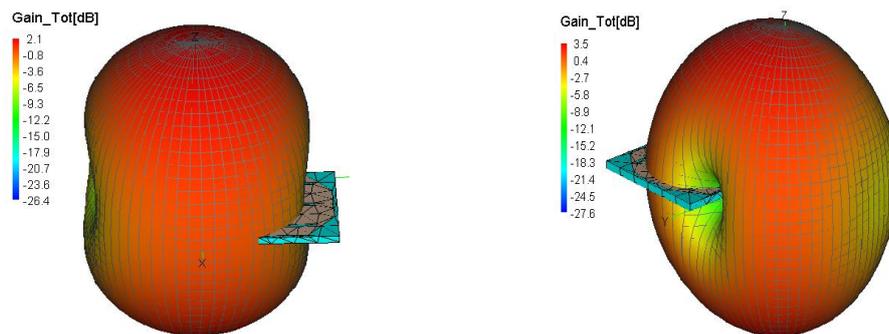


Figure 5. The simulated S11 of the Octagonal patch antenna with inverted E slot



(a) the 3D-Gain of the antenna for $f_1 = 2.45\text{GHz}$ (b) the 3D-Gain of the antenna for $f_2 = 5.80\text{GHz}$

Figure 6. The 3D-Gain of the CPW-Fed Octagonal patch antenna with inverted E slot loading

3. ANTENNA REALIZATION : RESULTS AND DISCUSSION

From the previous study of the proposed antennas, we obtained optimized structures which have a compact size and an interesting reflection coefficient in the operating studied bands. After good results obtained by simulations, we manufactured the two obtained antennas in step 1 and step 2 on a PCB (Printed Circuit Board) and we measured the S11 of the antennas, Figure 7 shows a photograph of the realized antennas with the dimensions as found in section 2. ($W_s=29.5\text{ mm}$, $L_s=29.5\text{ mm}$, $W=28\text{ mm}$, $L=20.5\text{ mm}$, $Y_g=7.8\text{ mm}$, $W_f=3.06\text{ mm}$, $G=0.2\text{ mm}$, $S=1.1\text{ mm}$, $S_1=0.3\text{ mm}$, $E_h=19\text{ mm}$ and $E_v=11.3\text{ mm}$, $e=2.1\text{ mm}$).

Due to manufacturing imperfections, the measurement results are not exactly similar to the simulated results. The measured bandwidths of the fabricated antennas still have the UWB characteristics but the lower and the higher frequencies of the measured S11 parameter are shifted back to lower frequencies compared to the simulated results, also measured resonant frequencies are shifted from those simulated. For example, as shown in Figure 8(a), the measured resonant frequency is 5.49GHz while the simulated one is 5.80GHz. Moreover the measured bandwidth of the simple octagonal patch antenna [3.44-6. GHz] is shifted back compared to the simulated one [3.81-6.52 GHz]. Note that due to limitation in the measurement equipment we can only make measurement till 6 GHz.

The same for the new resonant frequency of the inverted E slot octagonal patch antenna (Figure 8(b)), the measured resonant frequency is 2.26MHz while the simulated one is 2.45GHz. In addition measurements show that the total obtained bandwidth of the octagonal patch antenna with inverted E slot is [2.10-2.36 GHz] & [5.11-6. GHz]

Also, small differences between measured and simulated S11 values are observed. For example, as shown in Figure 8(b), the measured S11 value corresponding to the second resonant frequency is higher (-25.58dB) compared to the simulated one (-38.32dB). Table 2 summarizes the comparison between simulated and measured S11 parameter and (-10dB) bandwidths.

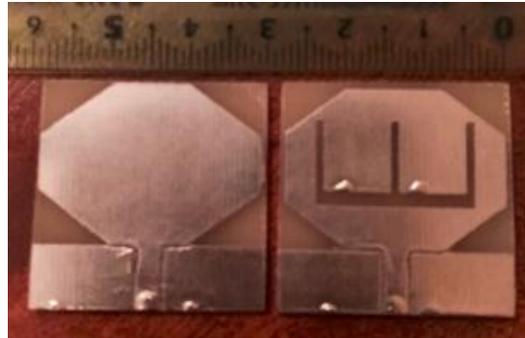
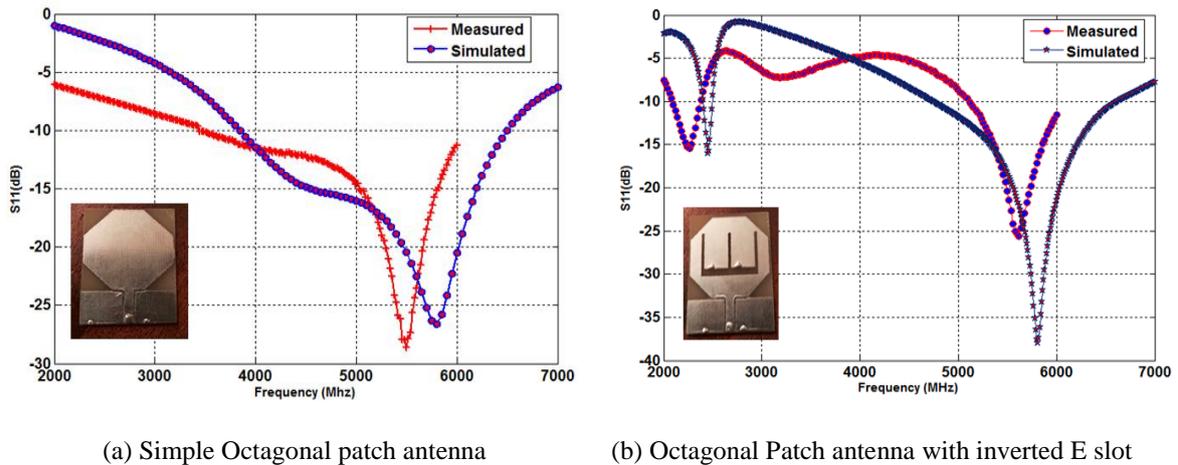


Figure 7. Fabricated prototypes of the proposed antennas

The measured and simulated results for the reflection coefficient of the proposed antennas are shown in Figure 8. The reflection coefficient magnitude was measured using ANRITSU MS2026C Vectorial Network Analyzer.



(a) Simple Octagonal patch antenna

(b) Octagonal Patch antenna with inverted E slot

Figure 8. Simulated and measured S11 versus frequency of the realized antennas

Table 2: Comparison between simulated and measured results

Antenna Number (Fig.7)	Simulated Results		Measured Results	
	Resonant frequencies (GHz)/S11(dB)	(-10dB) bandwidths (GHz)	Resonant frequencies (GHz)/S11(dB)	(-10dB) bandwidths (GHz)
1	5.80/-26.89	2.71:3.81 to 6.52	5.49/-28.60	2.56:3.44 to 6.X
2	2.45/-16.34 5.80/-38.32	0.14:2.37 to 2.51 1.95:4.70 to 6.65	2.26/-15.41 5.61/-25.58	0.26:2.10-2.36 0.89:5.11-6.X

Also, comparison between several different antennas for 2.45/5.80 GHz applications is illustrated in Table 3. From this table it's clear that our structure has a miniaturized design with very important gain compared to most other antennas. Moreover the proposed antenna has a reasonable bandwidth.

Table 3. Comparison of the proposed antenna to other antennas for 2.45/5.80 GHz applications

Ref	Size (mm ³)	Bandwidth	Gain (dB)
22	40*30*1.5	640M :(2.25-2.89 GHz) 920M : (5.30-6.22 GHz)	2.5 4
23	36*39*0.175	1.35GHz:(1.6-2.95) 1GHz:(5.4GHz-6.4GHz)	-3.25 -4.53
24	50*50*1.6	1.4GHz:(1.83–3.23 GHz) 1.17GHz:(4.99–6.16 GHz)	6.6 7.4
25	65×56×1.6	100 MHz (2.4 – 2.5 GHz) 200 MHz (5.6 - 5.8 GHz)	- -
25	44×41×1.6	100MHz : (2.4 - 2.5 GHz) 200MHz: (5.8 - 6.0 GHz)	- -
Our Work	29.5×29.5×1.6	260MHz:(2.10-2.36 GHz) 890MHz:(5.11-6.X GHz)	2.1 3.5

4. CONCLUSION

In this paper, a CPW-Fed microstrip octagonal patch antenna for 2.45/5.80 GHz applications was proposed. The antenna has a small size of 8.7 cm², which makes it suitable for use as an internal antenna for embedded systems. By making a triangular shape cut on the four angles of the rectangular patch antenna it was possible to implement UWB characteristics in the higher band. The setup of an inverted E slot on the octagonal patch antenna allows generating a new lower resonant frequency.

The proposed antennas are manufactured on a (29.5×29.5mm²) FR-4 substrate and their S₁₁ are measured and shows a good agreement with the simulated one. The obtained results show that the studied antennas have an important gain and a good impedance matching. Thereby, this result makes the CPW-Fed microstrip octagonal patch antenna with inverted E slot an adequate candidate for 2.45/5.80 GHz RFID applications.

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