ISSN (e): 2250 – 3005 || Volume, 06 || Issue, 09|| September – 2016 ||
International Journal of Computational Engineering Research (IJCER)

Comparison between Rectangular and Circular Patch Antennas Array

Melad M. Olaimat
Department of Power Engineering, Faculty of Engineering Technology, Al-Balqa Applied University

ABSTRACT

In this paper, several designs of micorstip arrays antennas, suitable for wireless communication applications, are presented. This paper demonstratesseveral shapesof microstrip array antennas, such as rectangular and circular patch antennas array. Specifically, 4x1, 2x1, and single element of both shapes are designed and simulated bya full wave simulator(IE3d). Moreover, this paper presents acomparison between both rectangular and circular antenna arrays.Since, the resonance frequency of these antennas is 2.4 GHz, these antennas are suitable for ISM band and WLAN.

Keywords:*microstrip antennas array, rectangular microstrip antennas, circularmicrostrip antennas, resonant frequency of patch antennas.*

I. INTRODUCTION

Modern wireless communication systems require low profile, lightweight, high gain and simple structure antennas to assure reliability, mobility, and high efficiency [1]. A microstrip patch antenna is very simple in construction using a conventional microstrip fabrication technique. Microstrip antennas consist of a patch of metallization on a grounded dielectric substrate. They are low profile, lightweight antennas, most suitable for aerospace and mobile applications. Microstripantennas have matured considerably during the past 40 years, and many of their limitations have been overcome [2]-[6].

The conducting patch can take any shape, but rectangular and circular configurations are the most commonly used configurations. In this paper, several designs of rectangular patchantennas arrays and circular patch antennas arrays are presented. Specifically, 4 by 1, 2 by 1, and single element of both shapes are designed. Moreover, these designs are simulated using IE3d (full wave simulator). Based on the simulation results, comparison between both rectangular and circular patch antennas array is achieved.This paper is divided into fivesections:thefirst section is devoted to give an overview of the microstrip antennas.Second section gives a preface of the important parameters in single element designs, for both rectangular and circular. Third section discusses the patch antenna design and the necessity of the antenna array. Forth section demonstrates the results of the paper as a whole and a comparison between both shapes (rectangular and circular) is presented. Finally, a brief conclusion is presented in the fifth section.

II. SINGLE ELEMENT DESIGN ISSUES

2.1 Introduction

A microstrip antenna element can be used alone or in combination with other like elements as part of an array. In either case, the designer should have a step-by-step element design procedure [2]. Usually, the overall goal of a design is to achieve specific performance at a stipulated operating frequency. If a microstrip antenna configuration can achieve these overall goals, then the first decision is to select a suitable antenna geometry. In this paper, both rectangular and circular patch antenna arrays are designed and compared, as it will be shown in the subsequent sections.

2.2 Side Length and Resonant Frequency

Figure 1 shows the geometry of single element of both rectangular and triangular patch antennas.Based on the cavity model, the resonant frequency of the rectangular patch antenna, of length L, can be calculated using the following formula [2]:

$$f_{1,0} = \frac{c}{2L\sqrt{\epsilon_r}} \qquad (1)$$

Where*c* is the speed of light in free space, andϵ_r is the dielectric constant of the substrate.

It is worth to mention that, the rectangular patch width W has a minor effect on the resonant frequency and radiation pattern of the rectangular patch antenna [2].
Regarding the circular patch antenna, of radius *a*, the resonant frequency can be calculated using the following formula [7]:

$$f_{1,1} = \frac{Knm * c}{2\pi a\sqrt{\epsilon_r}} \qquad (2)$$

K_{nm} is m^{th}zero of the derivative of the Bessel function of order n. In our application we have considered the fundamental mode TM11, for which k value is 1.84118.

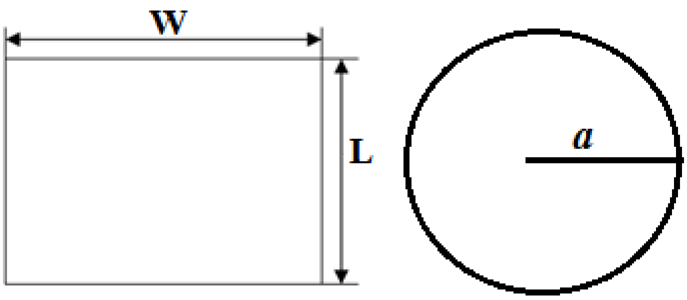


Figure 1: Geometry of both rectangular andcircular patch antennas.

2.3 Substrate Selection

One of major steps in designing a patch antenna is to choose a suitable dielectric substrate of appropriate thickness h and loss tangent. A thicker substrate, besides being mechanically strong, will increase the radiation power, reduce conductor loss, and improve impedance bandwidth. However, it will also increase the weight, dielectric loss, surface wave loss, and extraneous radiations from the feeder. The substrate dielectric constantϵ_r plays a role similar to that of substrate thickness. A low value of ϵ_r, for the substrate, will increase the fringing field at the patch periphery, and thus, radiated power. Therefore, substrate with ϵ_r< 2.5 are preferred unless a smaller patch size is desired, and thus we used substrate with ϵ_r=2.2 is used in our designs. An increase in the substrate thickness has similar effect on antenna characteristics as the decrease in the value of ϵ_r. A high loss tangent increases dielectric loss and therefore reduces antenna efficiency [2].

2.4 Design of Single Element

Figure 2 shows the design of both rectangular and circular patch antennas and its dimension. As shown in the Figure, both patches are fed by microstrip line inset feed. A Substrate with ϵ_r=2.2 and thickness h=1.6 mm is used in both designs, as well. Figure 3 shows the radiation pattern for both designs in Figure 2. It can be seen that the radiation pattern in both designs is in broadside direction. Both designs are resonating at 2.4 GHz as shown in Figure 4. The reflection coefficient in both designs is falling below -10 dB. Actually, the reflection coefficient in rectangular is approximately -40 dB, whereas it is -20 dB in circular.

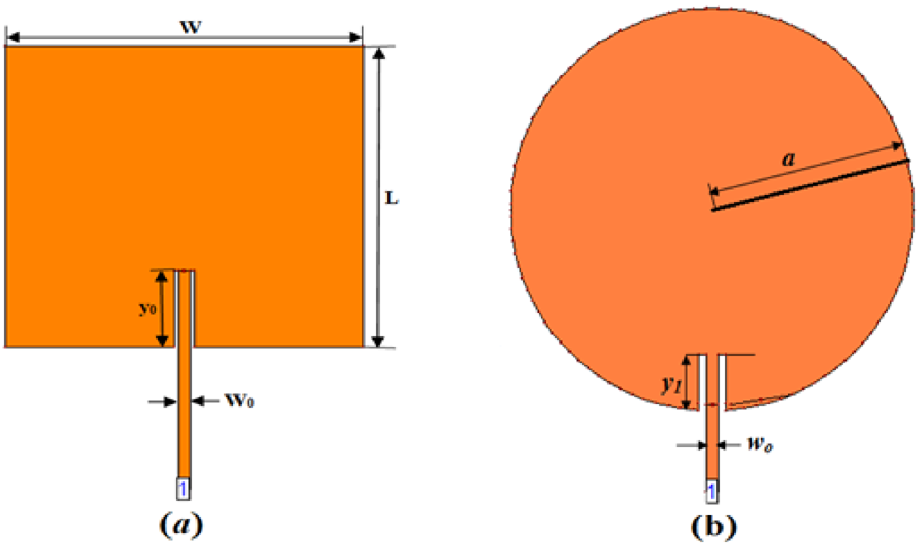
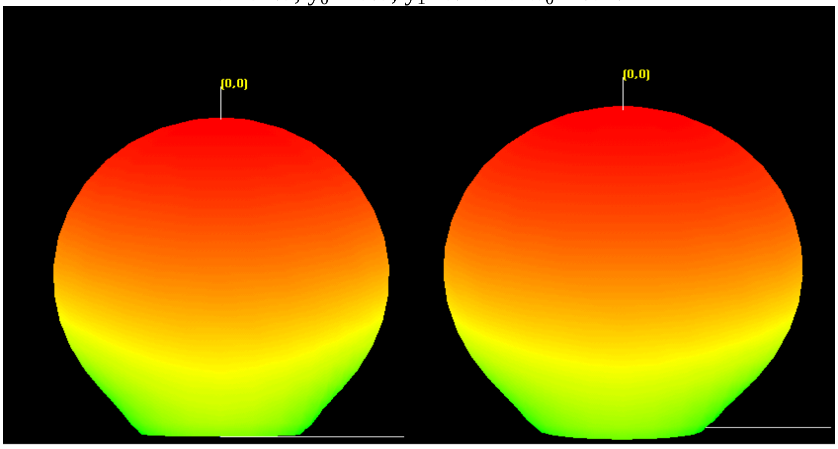


Figure 2: Geometry of patch antenna *a*) Rectangular; b) Circular; with dimensions (in mm): L=42, w=42.4, *a*=54.9, y_0=13.5, y_1=6.7 and w_0=4.82.



(*a*) **(b)**

Figure 3: The radiation pattern at 2.4GHz for: *a*) Design in figure 2.*a*; b) Design in figure 2.b.

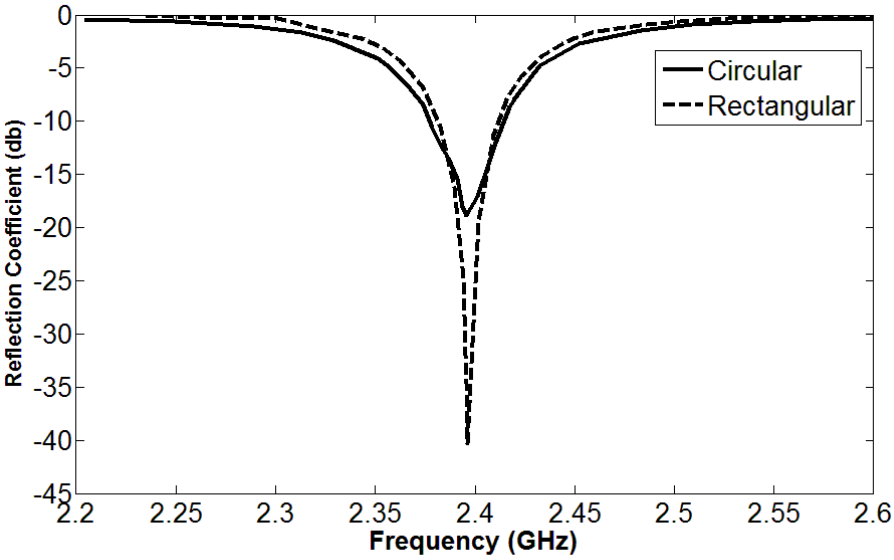


Figure 4: Simulated reflection coefficient (in dB) of the designs shown in Figure 2.

III. ARRAY DESIGN

3.1 Introduction

In certain applications, desired antenna characteristics may be achieved with a single microstrip element. However, as in the case of conventional microwave antenna, characteristics such as high gain, beam scanning, or steering capability are possible only when discrete radiators are combined to form arrays. The elements of an array may be spatially distributed to form a linear, planar, or volume array. A linear array consists of elements located finite distances apart along a straight line. In practice, the array type is usually chosen depending on the intended application [2].Feeding methods, that are employed to feed microstrip array in this paper, are parallel and quarter-wave-transformer methods.

3.2 Design of Linear 2x1 Array

Actually, in order to make fair comparison, the same substrate used in single element (ϵ_r= 2.2 and thickness h=1.6 mm), is used in the 2x1 array. Figure 5 shows the configuration of 2x1 linear rectangular patch antenna array. To obtain 50 Ohms input impedance, feeding line with width W_1=4.85 mm is used. This line is split into two 100 Ohmslines, with width W_o=1.41 mm for each as shown in Figure 5. Figure 6 shows the configuration of 2x1 linear circular patch antenna array. The same design procedure, that was used for rectangular, is used in circula array. It is worth to mention that, the patches (rectangular and circular) dimensions used in the arrays have same dimensions used in single patches design that are shown in Figure 2. Figure 7 shows the reflection coefficient for both designs shown in Figures 5 and 6. Obviously, both designs resonate at approximately 2.4 GHz with different levels of reflection coefficient.

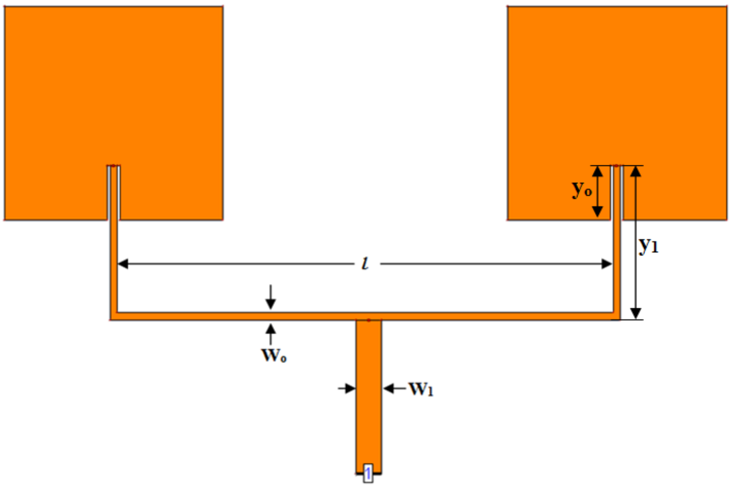


Figure 5: Configuration of 2x1 linear rectangular patch antenna array; with W_o=1.41 mm, W_1=4.89 mm, y_o=10.5 mm, y_1=30 mm, and l=96 mm.

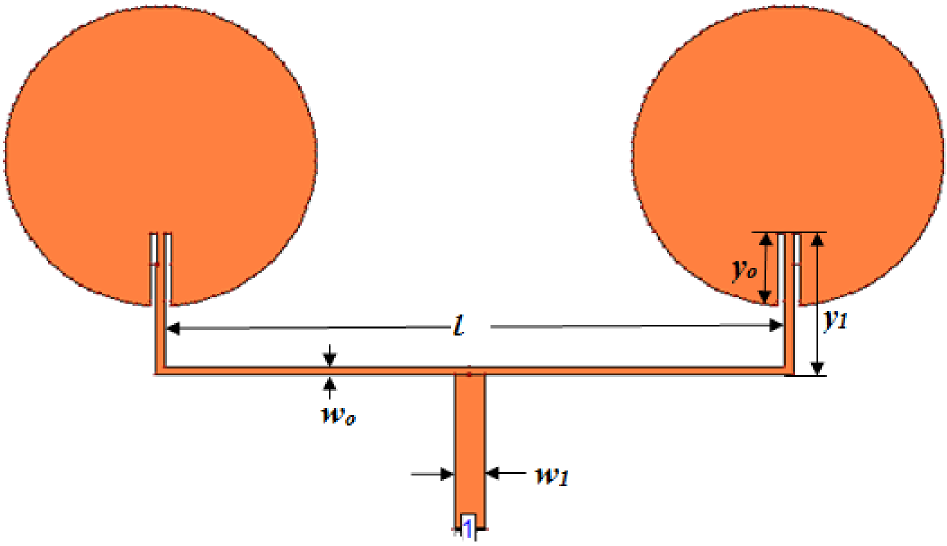


Figure 6: Configuration of 2x1 linear circular patch antenna array; with W_o=1.41 mm, W_1=4.89 mm,y_o=11.7 mm, y_1=23 mm, and l=96 mm.

Figure 8 shows the radiation pattern for both designs in Figures 5 and 6. It can be seen that the radiation patterns in both designs are in broadside direction. Small side lobes appear in rectangular. Side lobes approximately disappear in circular design.

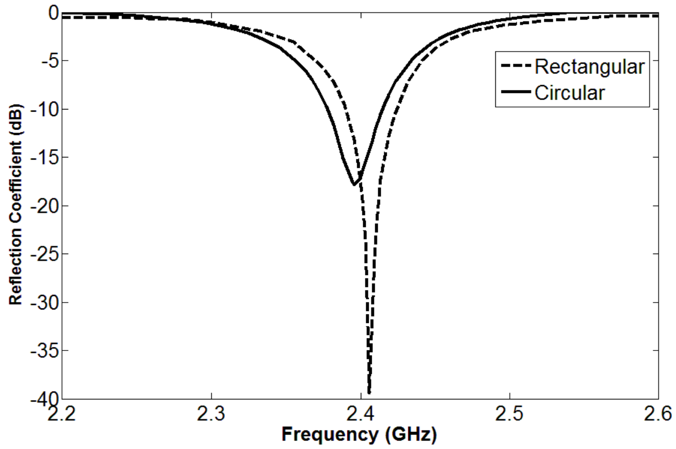


Figure 7: Simulated reflection coefficient (in dB) of the designs shown in Figures 5 and 6.

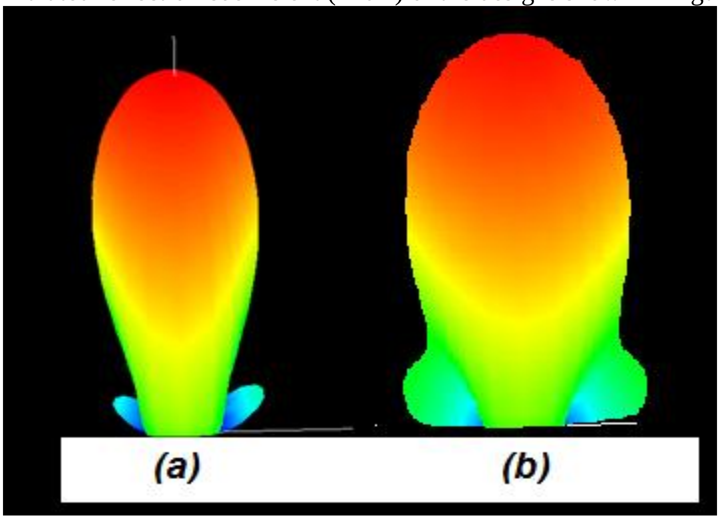


Figure 8: The radiation pattern at 2.4 GHz for: *a*) Design in Figure 5; b) Design in Figure 6.

3.3 Design of 4x1 Array

In an attempt to design 4x1 array, for both rectangular and circular, quarter wave transformer is used to feed the elements. Figure 9 shows the configuration of 4x1 rectangular patch antenna array. All dimensions are shown in the figure. The dimensions of quarter wave transformer are based on calculations. Figure 10 shows the configuration of 4x1 circular patch antenna array, as well. In order to compare between both rectangular and circular 4x1 array,the reflection coefficient of both designs (shown in Figures 9 and 10) are shown in Figure 11. It can be seen both designs resonate approximately at 2.4 GHz.

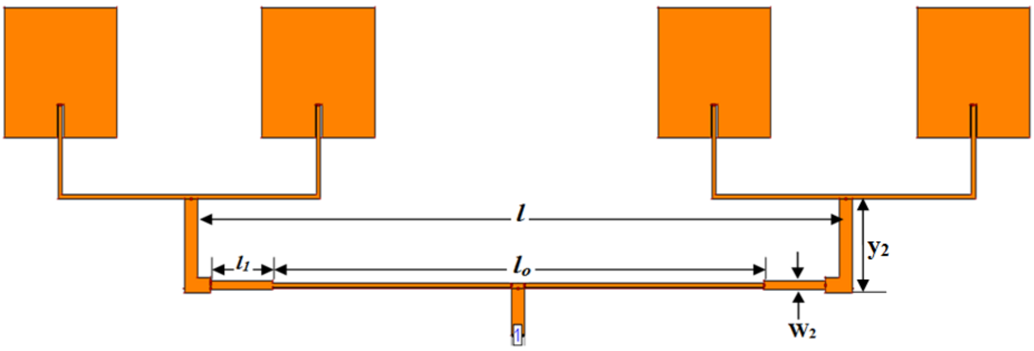


Figure 9: Configuration of 4x1 rectangular patch antenna array; with W_2=2.85 mm, y_2=30 mm, *l*= 201.2 mm,l_o=185 mm and l_1= 23.1 mm.

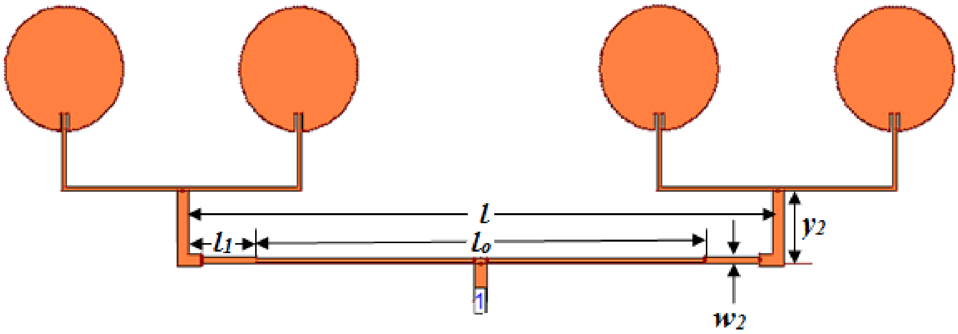


Figure 10: Configuration of 4x1 circular patch antenna array; with W_2=2.85 mm, y_2= 25 mm*l*= 201.2 mm,l_o=185 mm and l_1= 23.1 mm.

Figure 12 shows the radiation pattern for both designs in Figures 9 and 10. It can be seen that the radiation patterns in both designs are in broadside direction. The side lobes appear clearer in those designs. It is worth to mention that, the side lobe in rectangular patch (Figure 12.*a*) is better than that in circular patch antenna (Figure 12.b) for this array design.

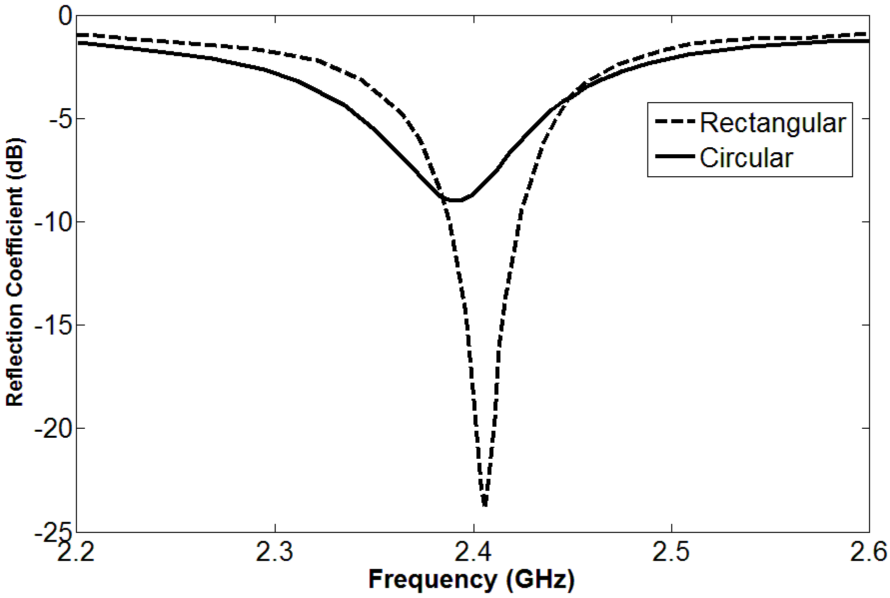


Figure 11: Simulated reflection coefficient (in dB) of the designs shown in Figures 7and 8.

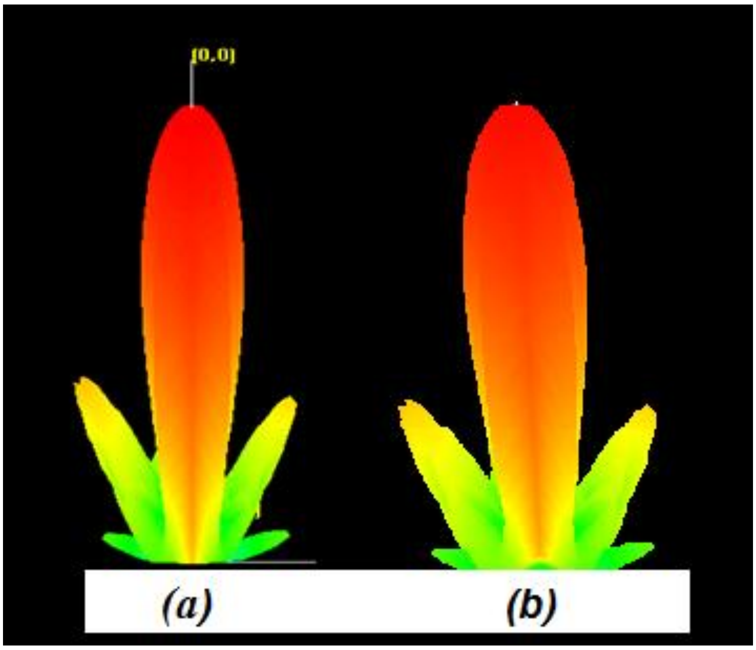


Figure 12: Radiation pattern at 2.4 GHz for: *a*) Design in Figure 9; b) Design in Figure 10.

IV. COMPARISON

Table 1 shows the obtained simulated results. As shown in the table, the results obtained from rectangular patch are very close to those obtained from circular patch. The reflection coefficient is best in single and 2x1 array for both shapes (Rectangular and circular). It could be because good matching is obtained in those cases. Both gain and directivity, for both shapes (Rectangular and circular), are increasing as the number of elements is increased, which is expected. Finally, the side lobe level is increasing as the number of elements is increased as shown in radiation pattern Figures (Figures 3, 8 and 12) with the advantage for rectangular patch antenna over circular patch antenna.

Table1: Comparison between rectangular (Rect) and circular (Circ) patch antenna arrays.

Number of Elements	S11 (dB)		Gain (dB)		Directivity (dB)	
	Rect	Circ	Rect	Circ	Rect	Circ
Single	-40	-20	6.7	6.7	7.4	7.4
2x1	-39	-18	9.6	9.2	10.5	10.8
4x1	-23.6	-10	12.5	11.4	13.6	13.4

V. CONCLUSION

In this paper,a comparison between both rectangular and circular patch array is achieved, for first time up to our knowledge. Several shapes of both rectangular patch antennas and circular patch antennas arrayswere designed, specifically, 4x1, 2x1 and single element. All designs are compatible for WLAN and ISM application. Good enhancement, on both gain and directivity, is obtained by employing the array techniques. In this paper, we proved the ability of using circular patch antenna array with same performance of rectangular approximately. Moreover, using rectangular patch antenna array, we could obtain better suppression for side lobe level than that obtained using circular patch antenna array, especially in 4x1 array.

REFERENCES

[1]. T. I. Huque, K. Hossain, S. Islam, and A. Chowdhury, " Design and Performance Analysis of Microstrip Array Antennas With Optimum Parameters For X-band Applications," *International Journal of Advanced Computer Science and Applications,* Vol. 2, No. 4, pp. 81-87, 2011.

[2]. R. Garg, P. Bhartia, I. J. Bahl, and P.Ittipiboon, *Microstrip Antenna Design Handbook,* Artech House, Boston. London, 2001.

[3]. S. Sudharani, P. Rakesh Kumar,"Microstrip Circular Patch Array Antenna for Electronic Toll Collection,"*International Journal of Research in Engineering and Technology (IJRET)*, Vol 2,Jan 2013.

[4]. M. M. Olaimat and N. I. Dib, " A Study of 15-75^o-90^o Angles Triangular Patch Antenna," *Progress In Electromagnetics Research (PIER)*, Vol. 21, pp. 1-9, 2011.

[5]. M. M. Olaimat and N. I. Dib, "Improved Formulae for the Resonant Frequencies of Triangular Microstrip Patch Antennas," *International Journal of Electronics,* Vol. 98, No. 3, pp. 407–424, March 2011.

[6]. Olaimat, M., "Design and analysis of triangular microstrip patch antennas for wireless communication systems," Master Thesis, Jordan University of Science and Technology, 2010.

[7]. FalguniRaval, JagutiMakwana,"Optimization of Resonance Frequency of Circular Patch Antenna at 5 GHz Using Particle Swarm Optimization,"*International Journal of Advances in Engineering & Technology (IJAET),* Vol. 1, pp.99-106, May 2011.