COMPARATIVE STUDY OF DIFFERENT SHAPES OF MICROSTRIP PATCH ANTENNA ARRAYS AT 2.5 GHZ

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Abstract

A microstrip patch antenna compromises a radiating patch on one side of a dielectric substrate and a ground plane created by a metal layer on the other. The patch can be formed in almost any shape and made up of conducting substance such as gold, or copper. A disadvantage of using single-element microstrip antennas is its low gain. On the other hand, microstrip patch antenna arrays present a higher gain than a single patch so they are frequently utilized in wireless applications nowadays.

This paper aimed to design and simulate three different antenna arrays, namely, rectangular, circular, and triangular at 2.5 GHz. The arrays were made of eight elements "2x4". The performance of the antenna array was evaluated using the Agilent Advanced Design System. The main findings of this study show that the proposed antenna arrays provide a gain of 12.5983, 12.6951, and 12.3117 dBi for the rectangular, circular and triangular, respectively. Moreover, the rectangular patch array got the best bandwidth performance, which was 42 MHz, while the circular had 28 MHz and the triangular got only has 24 MHz.

Keywords: Microstrip Patch Antenna; WiMAX; Antenna Array.

Introduction

The antenna is used to convert electrical signals into electromagnetic waves and vice versa. Antennas are frequency-dependent devices; each antenna is intended to capture a particular range of frequencies, and to eliminate the wireless signals outside this range (Sadiku, 2001). The advancement of telecommunications and mobile communication has significantly increased the need for smaller antennas, so major developments are carried out to design compact, minimal weight, low profile antennas for both academic and industrial telecommunication communities (Saunders & Zavala 2007).

The patch antenna can take almost any shape, and it is constructed of conductive materials such as gold or copper. However, the main drawback of single-element microstrip antennas is their low gain. On the other hand, microstrip patch antenna arrays have a greater gain than a single patch. Hence, patch arrays are commonly used in modern wireless applications (Sadiku, 2001).

The work presented in this paper is based on our past contribution on the same topic (Elkwash & Abdulrahman, 2021). While earlier work focused on designing and simulation of single element microstrip antenna, this paper focuses on the design and simulation of antenna array instead.

The antenna array has been commonly used in a wide variety of applications using the possibility of beam forming, conformation and nulling pattern. In addition, the behaviour of the array can be corrected in real time by adjusting the feed signal from different individual radiators separately, offering an adaptive solution. Because of its well-known obvious benefits, such as low profile, conformability, ease of fabrication, and cost effectiveness, microstrip technology has become a popular choice for the implementation of antenna arrays, especially after the development of various enhancement techniques aimed at overcoming the traditional technology drawbacks (limited bandwidth, spurious radiation of the feeding lines, etc.). In this paper, the design of the patch antenna has been extended to an array of eight elements to increase the main beam gain and reduce side lobe radiation. It also compares the performance of rectangular, circular, and triangular patch microstrip antennas arrays by using Agilent advanced design (ADS) software.

Libya Telecom and Technology (LTT) launched its WiMAX wireless network that works on 2.5 GHz band to provide internet access to users within 50km of one of its towers. WiMAX technology provides many benefits such as that no need for line of sight, little or no on- site installations, less setup time, and low service cost. Such advantages make it a viable alternative to the existing cable and other wired systems. One equipment that may distant users from accessing a reliable WiMAX service is its antenna. However, the antenna array, designed in this paper, can provide a good signal in bad coverage areas (Elkwash *et al*., 2013).

Single Element Microstrip Patch Antenna Design

The design of an array starts with designing a single element in each shape fora certain frequency. Single element antennas were previously designed at 2.5 GHz (Elkwash & Abdulrahman, 2021). FR4 is used as substrate of thickness 1.6mm, and relative permittivity 4.4.

The rectangular microstrip patch antenna is illustrated in Figure (1). The length of the patch is 8.22mm, the width is 37.6mm, the width of feed line is 3mm and length of the feed line is 10.4 mm.

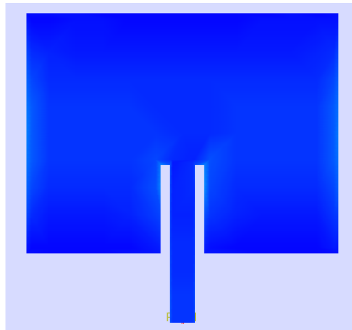


Figure (1):Geometry of the Rectangular Microstrip Patch Antenna.

The shape of the circular microstrip patch antenna is depicted in Figure (2). The radius of the patch is $R = 17.1$ mm, the width of feed line $W_f = 3$mm and length of the feed line $F_i = 14$ mm.

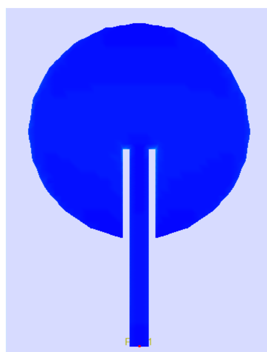


Figure (2): Geometry of the Circular Microstrip Patch Antenna.

The geometry of the equilateral triangular microstrip patch antenna is shown in Figure (3). The length of equilateral triangle a=37.6mm, the width of feed line $W_f =$ 3mm and length of the feed line $F_i = 8.5$ mm.

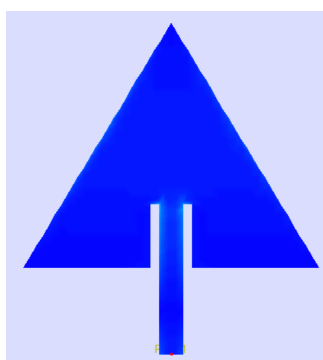


Figure (3): Geometry of the Triangular Microstrip Patch Antenna.

Microstrip Patch Arrays Design

Feed Network Design

The feed network of the quarter wavelength transformer technology is used to feed all antenna components. This method is easy to implement and may be done at the same time as the antenna fabrication. The quarter wavelength transformer technology is suitable for all the microstrip arrays due the fact that this technique works best when load impedance is real. The real and imaginary values of microstrip antenna input impedance are 50 ohms and 0 respectively at resonance (Elkwash & Abdulrahman, 2021).

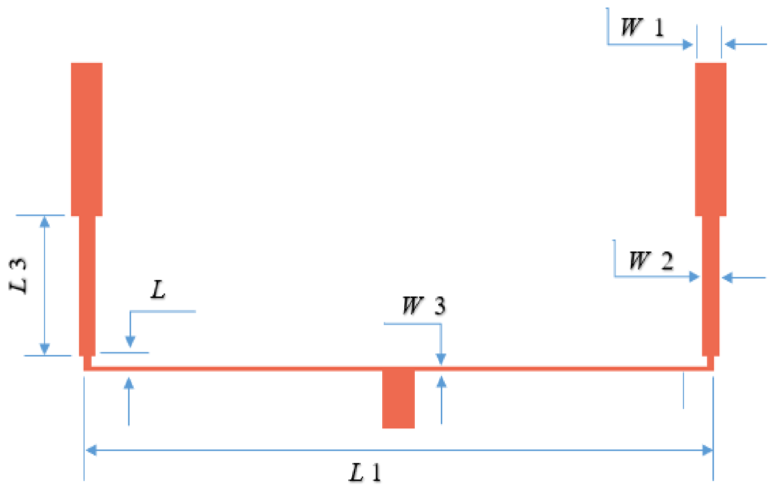


Figure (4): Feed Network Array 1×2.

The two array elements are kept at a distance of 90mm of each other, while the 1×2 array is kept at a distance of 60mm. This optimal distance was chosen to maximize the emitted power in free space while minimizing side lobes in the radiation pattern. Table (1) shows the final dimension of feeding networks that produced the greatest result. These optimized dimensions were obtained by using the trial-and-error approach (Ramachandran et al., 2007).

Table (1): Final Feeding Networks Dimension.

Parameters	Dimension(mm)
W_1	3
W_2	0.775
W_3	1.686
L_1	91.498

L_2	1.05
L_3	14.86
L_4	135.7
L_5	135.7

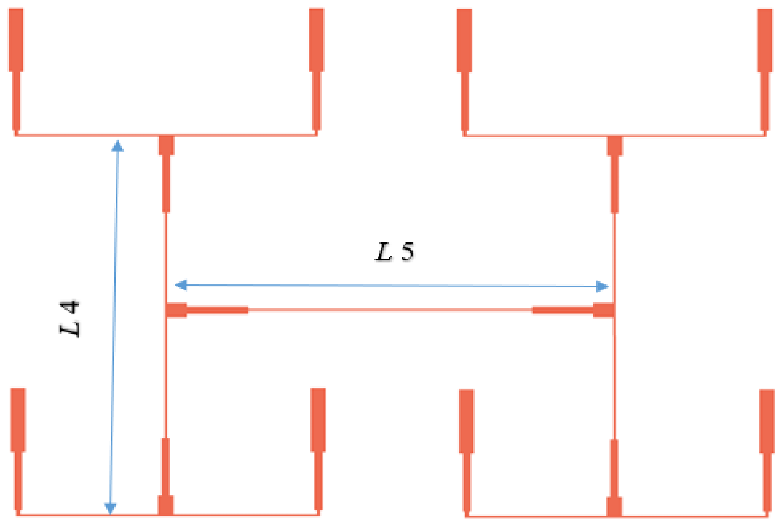


Figure (5): Feed Network Array 2×4.

Because the feed network shown in Figure (5) was designed for microstrip rectangular patch arrays, circular and triangular patch array feed networks were very similar, assuming that the feed network shown in Figure (5) is suitable for all microstrip rectangular, circular, and triangular patch arrays in this paper.

Rectangular Patch Array

The patch arrays for rectangular, circular and triangular with feeding networks are illustrated in Figures (6),(7) and (8).

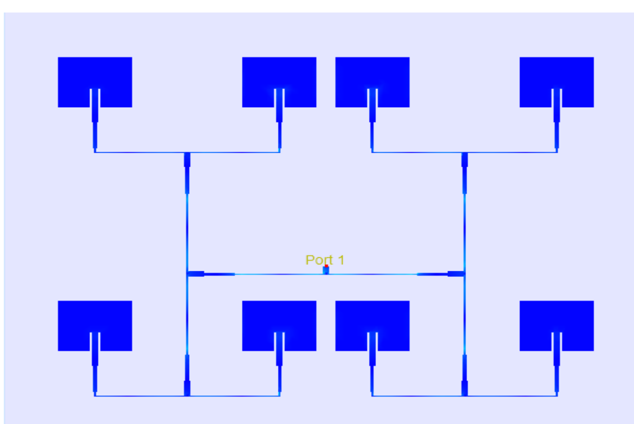


Figure (6):The Rectangular Patch Array as Seen from the Top.

Circular Patch Arrays

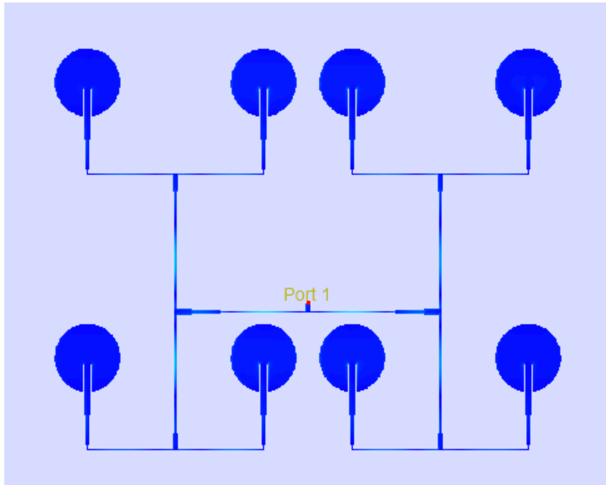


Figure (7): The Top View of the Circular Patch Array.

Equilateral Triangular Patch Arrays

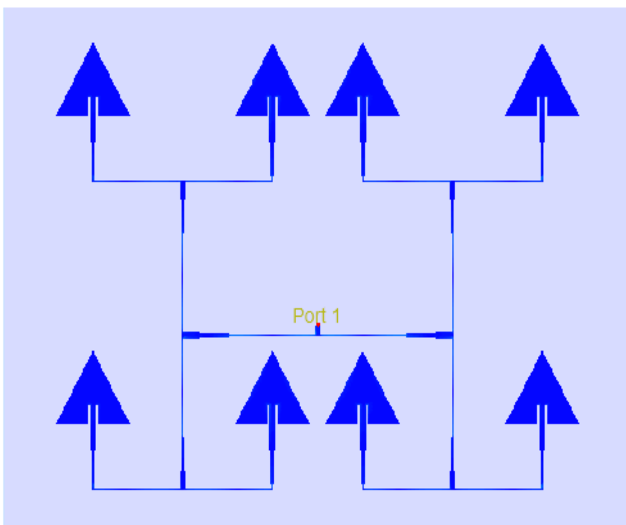


Figure (8): The Top View of the Triangular Patch Array.

Results

The Return loss

Figures (9),(10), and (11) illustrate the change in return loss with frequency for rectangular, circular, and triangular patch arrays, respectively. The rectangular, circular, and triangular patch arrays have return loss values of –20.725 dB, –16.337

dB, and –18 dB respectively. Based on a − 10 dB return loss, the bandwidth for rectangular, circular, and triangular patch arrays are 42 MHz (1.68% fractional bandwidth), 28 MHz (1.12% fractional bandwidth), and 24 MHz (0.96% fractional bandwidth) respectively. Fractional bandwidth is defined as the absolute bandwidth divided by the centre frequency.

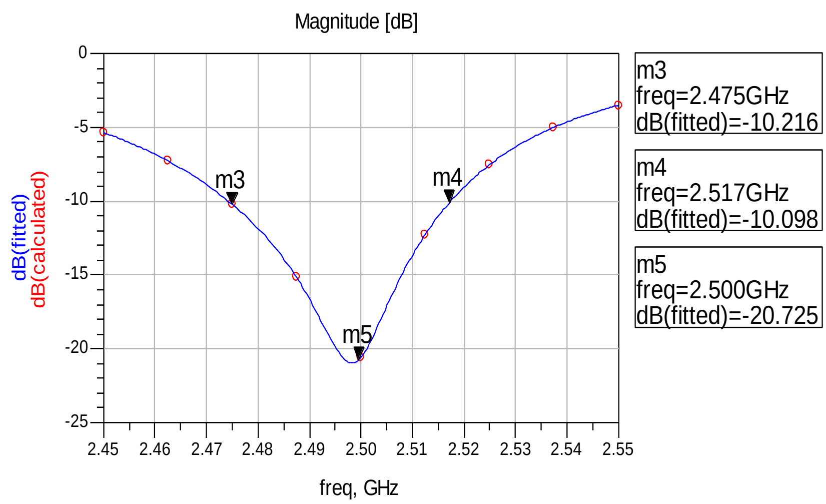


Figure (9): The Return Loss of Rectangular Patch Array.

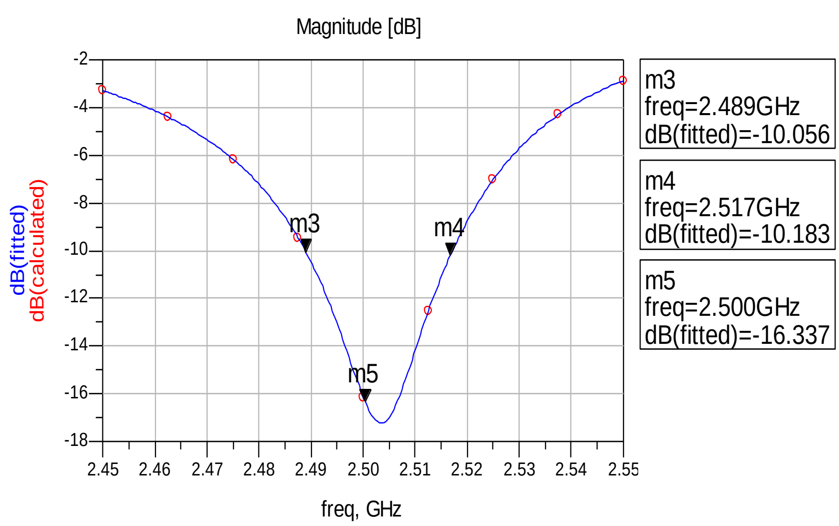


Figure (10): The Return Loss of Circular Patch Array.

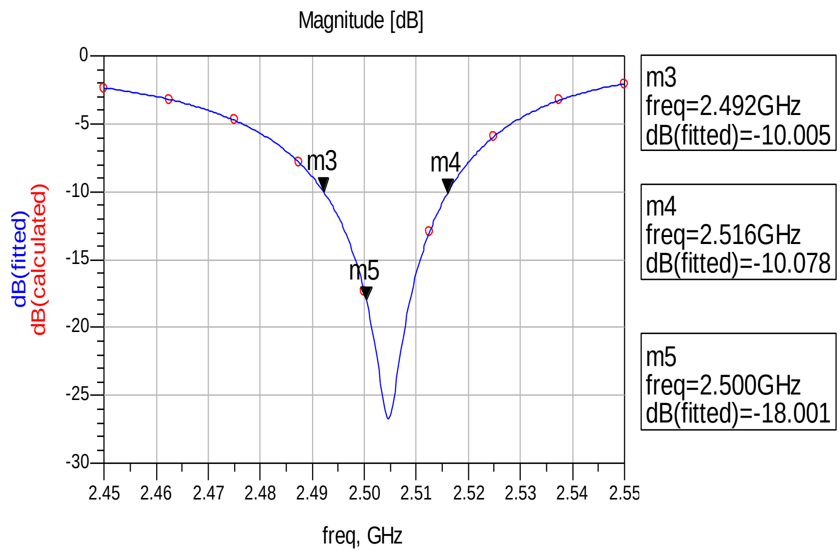


Figure (11): The Return Loss of Triangular Patch Array.

VSWR Versus the Frequency

The VSWR at the resonant frequency for each of the developed patch arrays is 1.203, 1.360, and 1.314 respectively, as shown in Figures (12),(13), and (14).

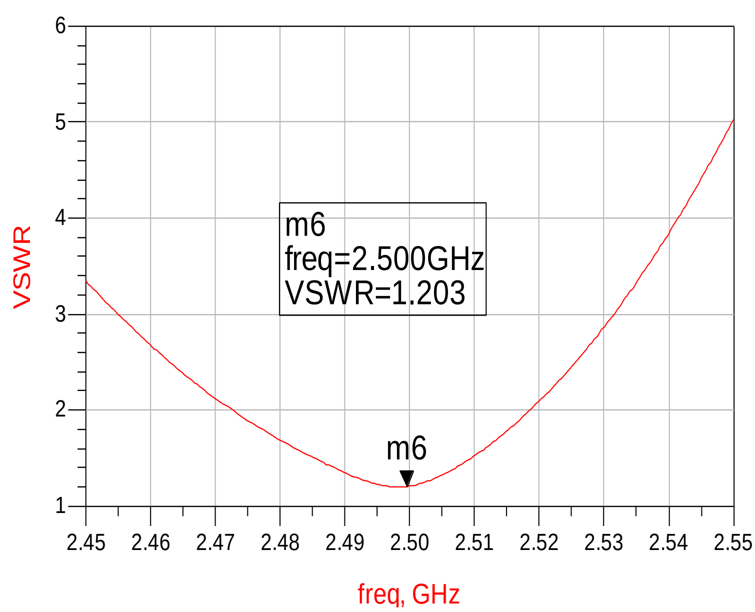


Figure (12): The VSWR of Rectangular Patch Array.

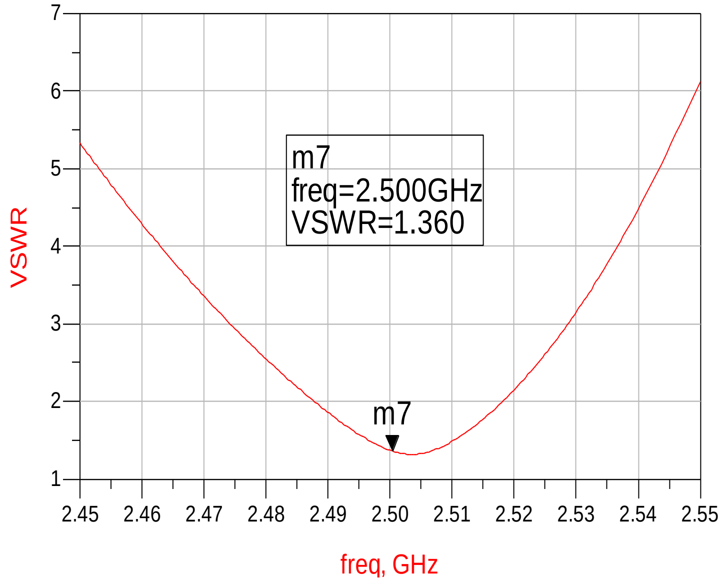


Figure (13): The VSWR of Circular Patch Array.

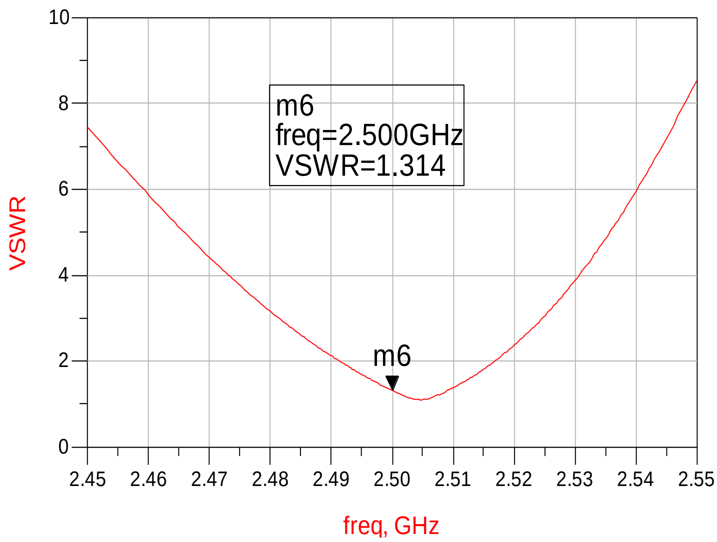


Figure (14): The VSWR of Triangular Versus the Array.

The Input Impedance

Here is the frequency variation of input impedances for each rectangular, circular, and triangular patch. Each design's input impedance is close to matching with a transmission line at 50 ohms.

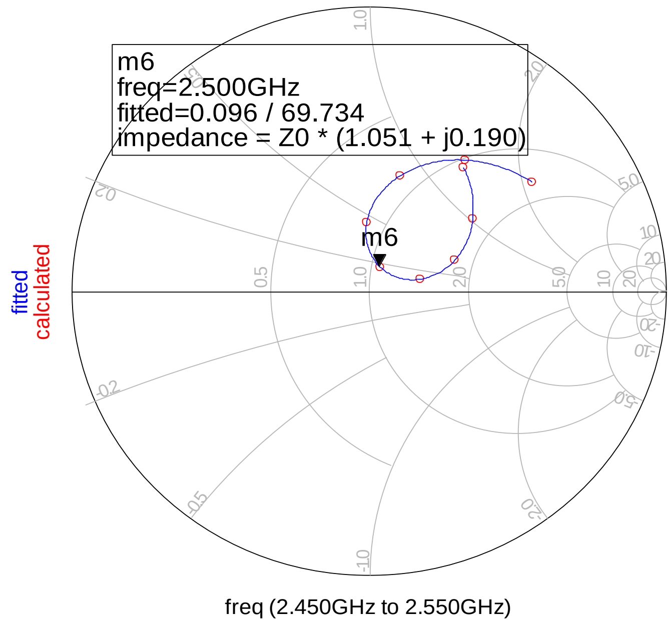


Figure (15): The Input Impedance of the Rectangular Patch Array.

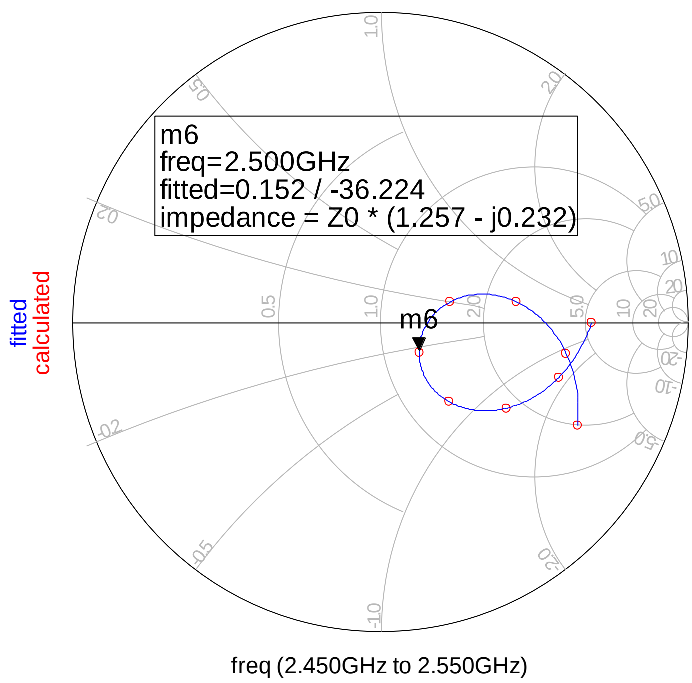


Figure (16): The Input Impedance of the Circular Patch Array.

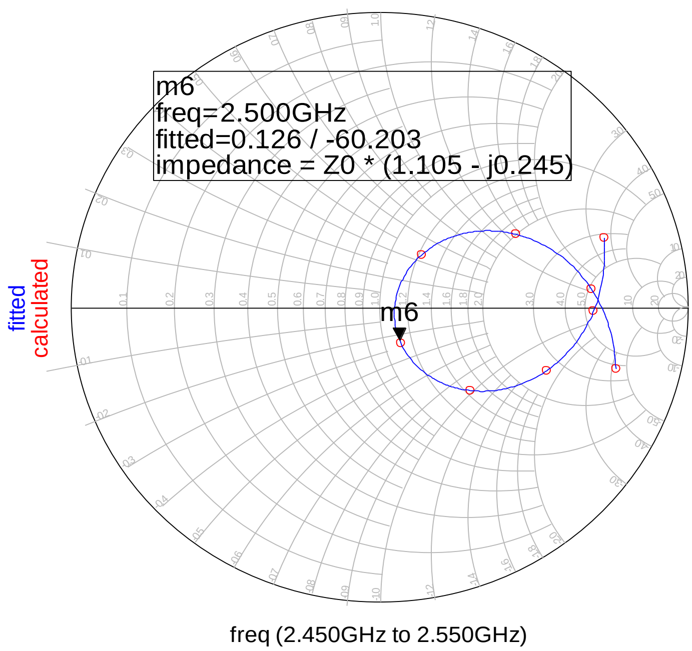
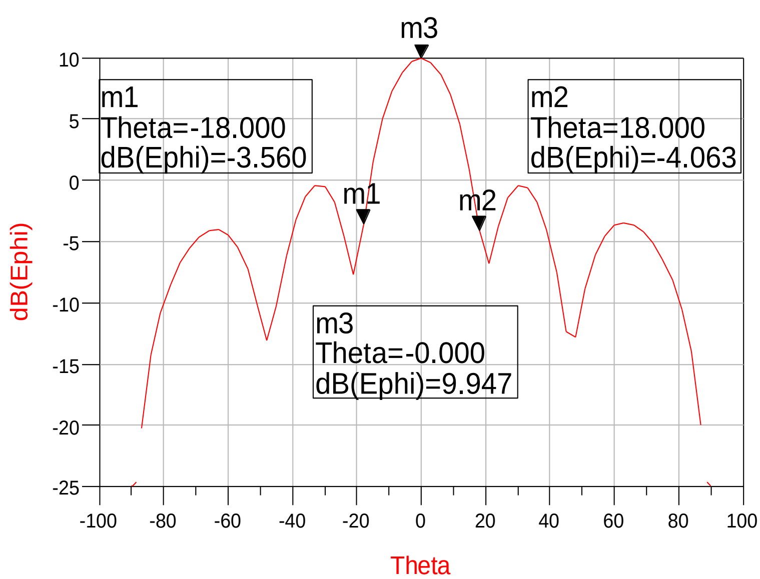


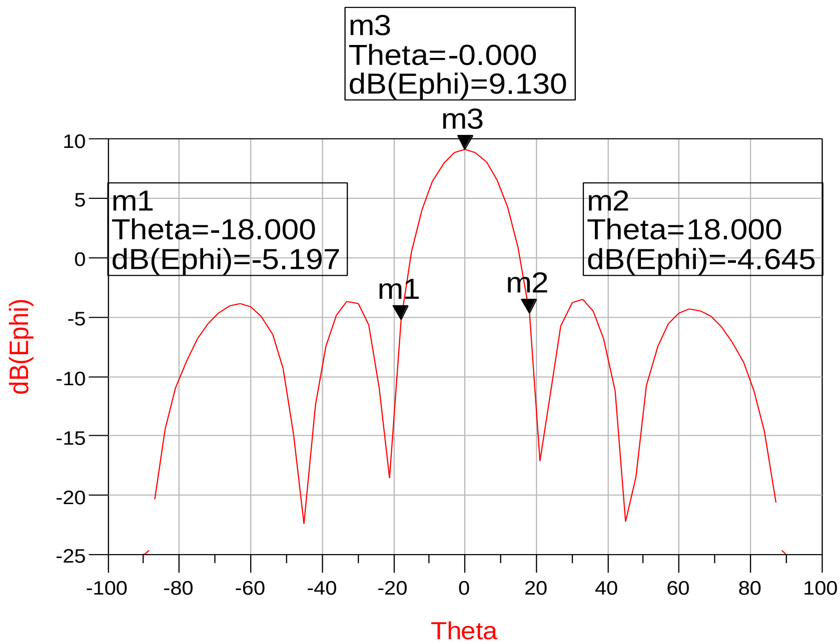
Figure (17): The Input Impedance of the Triangular Patch Array.

Beam-width of the Antenna

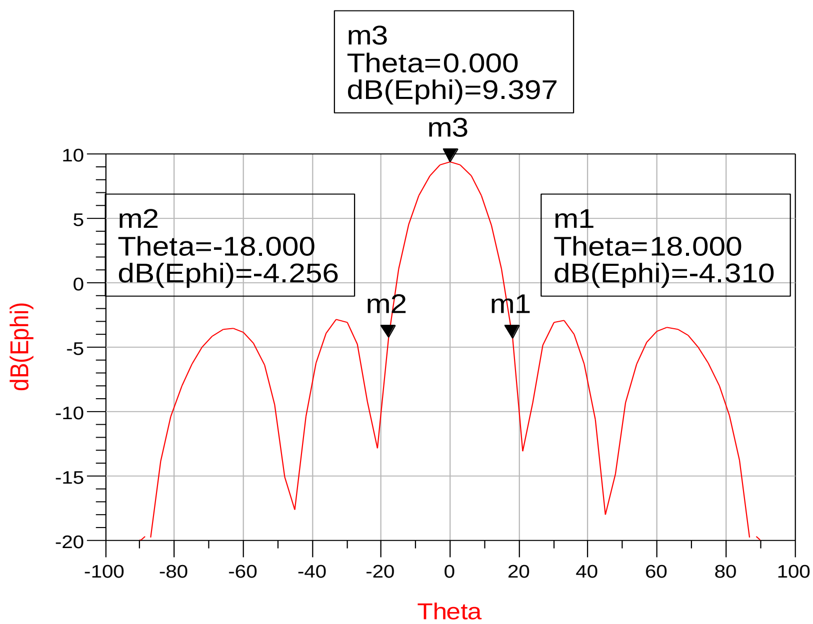
The beam-width of rectangular, circular, and triangular patch arrays is shown in Figure (18). It can be seen that the half-power beam-width (HPBW) for each design was around 18 degrees.



(a) Rectangular Patch Array.



(b) Circular Patch Array.



(c) Triangular Patch Array.

Figure (18): The Half Power Beam-Width.

The essential antenna parameters derived by modelling rectangular, circular, and triangular patch arrays are shown in Table (2).

Table (2): Comparison of Antenna Arrays Parameters.

Parameter	Rectangular	Circular	Triangle
Return Loss (dB)	−20.725	−16.33	−18
Bandwidth (MHz)	42	28	24
Gain(dBi)	12.5983	12.6951	12.3117
Directivity(dBi)	13.8996	14.0103	13.8489

Conclusion

In this paper, microstrip patch antennas array with three different shapes i.e. rectangular, circular, and triangular were implemented using the Agilent Advanced Design System (Khraisat & Olaimat, 2012). The work presented in this paper is based on our past design of a single element of each shape. The arrays were made of eight elements "2x4".

Rectangular patch arrays have the best return loss and bandwidth, whereas circular patch arrays have a larger bandwidth than triangular patch arrays. However, triangular patch arrays have a superior return loss than circular patch arrays.

The return loss and VSWR achieved from microstrip patch arrays were the best in rectangular patch arrays, with values of 20.725 dB and 1.203, respectively, a top rating frequency. Furthermore, the rectangular patch array outperformed the circular and triangular patch arrays in terms of b and width, with a value of 42 or 1.68%.

According to the simulation outcomes, the gain of rectangular, circular, and triangular antenna arrays is 12.5983 dBi, 12.6951 dBi, and 12.3117 dBi respectively, while the directivity is 13.8996 dBi, 14.0103 dBi, and 13.8489 dBi.

In conclusion, the rectangular patch antenna outperformed the triangular patch antenna, with the triangular patch antenna having the worst bandwidth values. Future work includes fabrication of designed antenna and increasing the bandwidth of microstrip patch antenna array by for example increasing the thickness of substrate with low dielectric constant.

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