Performance of Microstrip Patch Antennas for Wireless Applications

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***Abstract*— The spread of mobile communication devices has pushed scientists and researchers to invent small size antennas. The most appreciated among small antenna selections is the micro-strip patch antenna due the advantages it offers. This paper demonstrates the design and simulation of three different shapes of microstrip patch antennas, namely, rectangular, circular and triangular as a single elements at 2.5 GHz utilizing ADS software. Afterwards, a performance comparison in terms of Return Loss ,Bandwidth , Gain , and Directivity are presented. It is found that the rectangular patch antenna presented best performance in this comparison whereas triangular patch antenna has the worst performance.**

***Keywords*—Microstrip patch Antenna, Rectangular Antenna, Circular Antenna, Triangular Antenna.**

I. INTRODUCTION

The antenna is a piece of equipment that is developed to convert guided electromagnetic waves into electrical signals and vice versa (i.e. in both directions, transmitting and receiving mode). Antennas are designed for specific frequency range and inside this range, the antenna accepts the signal. With the progress in communication industry, particularly in mobile communication, the need for compact antenna has increased significantly. Accordingly, major developments are performed to create small weight, compact and low profile antennas. Microstrip antennas have become increasingly popular and are the most mainly utilized antenna, and that is because of its unique features [1][2]. Microstrip antennas are generally characterized by simplicity in design, inexpensive to fabricate, light weight and uncomplicated to integrate in small gadgets. Microstrip antenna basically is a metallic copper piece, patched on top of a dielectric substrate with a ground plane and can be designed in several shapes [3]. This paper presents a comparison among microstrip antennas with three different shapes, namely, rectangular, circular and triangular for WiMAX applications at 2.5GHz. [4] Moreover, the antennas are simulated using ADS Software. These all microstrip patch antennas are designed with FR4 substrate (εr=4.4) with 1.6mm thickness and the height of the copper is 0.035mm, which is very small and it can be neglected. The designed Microstrip patch antennas will be fed by inset feed with a gap (about 1mm) between the patch and the inset-fed. This paper is divided into three sections: the first section presents the proposed microstrip patch antennas design and gives an overview of the patch antennas[5]. The second section describes results and discusses the important parameters for proposed antennas. Finally, a comparison between the designed antennas and a brief conclusion is presented in the third section.

II. METHODOLOGY

A. *Rectaungular patch antenna*

The dimensions of a rectangular microstrip patch antenna are illustrated in Figure 1. the length and the width of the rectangular antenna can be calculated based on the formulas below[6]:

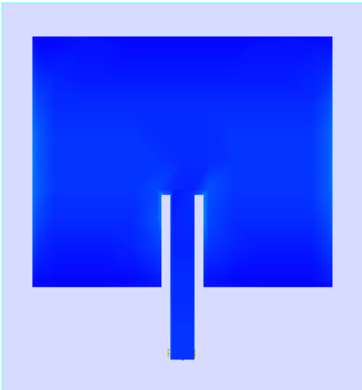

Fig. 1. Geometry of the rectangular microstrip patch antenna.

$$W = \frac{v_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (1)$$

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (2)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\frac{1}{\sqrt{1+12\,{}^{h}/_{W}}} \quad (3)$$

$$L_{reff} = \frac{v_o}{2f_r\sqrt{\varepsilon_{reff}}} \quad (4)$$

Where: (h) is height of substrate, (fr) operation frequency,(εr) dielectric constant, (vo) free-space velocity of light.

The actual length of the patch can now be computed using the following equation:

$$L = L_{reff} - 2\Delta L \quad (5)$$

The calculation of the length of inset (Fi) and the width (Wf) of the feed line is determined using equations (6) and (7) with a gap (about 1mm) between the patch and the inset-fed.

$$Z_0 = \frac{87}{\sqrt{\varepsilon_r+1.41}} ln\left(\frac{5.98h}{0.8wf+t}\right) \quad h < 0.8wf \tag{6}$$

$$Fi = 10^4(0.001699 \times \varepsilon_r^7 + 0.13761 \times \varepsilon_r^6 - 6.1783 \times \varepsilon_r^5 + 93.187 \times \varepsilon_r^4 - 682.69 \times \varepsilon_r^3 + 2561.9 \times \varepsilon_r^2 - 4043 \times \varepsilon_r + 6697) \times \frac{L}{2} \tag{7}$$

The simulation results were not satisfying satisfying using default parameters, therefore, the parameters were modified until results improved. Table I shows the final dimensions for the rectangular patch antenna.

TABLE I. FINAL DIMENSIONS OF RECTANGULAR PATCH ANTENNA

parameters	Dimensions (*mm*)
L	28.22
W	37.6
Wf	3
Fi	10.4

B. *Circular Patch Antenna*

The dimension of the circular microstrip patch antenna is shown in figure 2. The design of such configuration of microstrip patch antenna is much easier than other shapes, because only one parameter is needed i.e. radius. The radius of circular patch antenna is calculated by the equation below [7]:

$$r = \frac{F}{\sqrt{\left\{1+\left(\frac{2h}{\pi F \varepsilon_r}\right)\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}}} \tag{8}$$

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \tag{9}$$

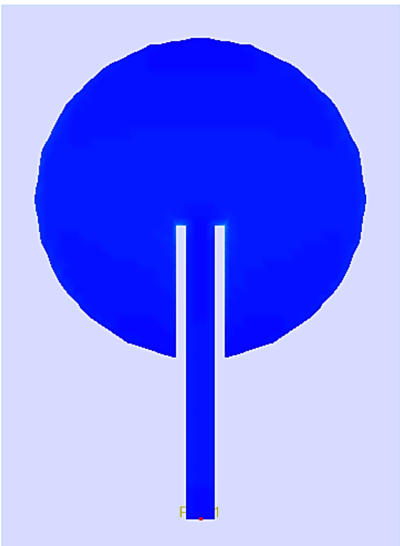

Fig. 2. Geometry of the circular microstrip patch antenna.

The length of inset (*Fi*) can be calculated using the same equation in rectangular patch antenna. Table II shows the final dimensions of the circular patch antenna after modification.

TABLE II. FINAL DIMENSIONS OF CIRCULAR PATCH ANTENNA

parameters	Dimensions (mm)
r	17.1
Wf	3
Fi	14

C. *Equilateral Triangular patch antenna*

The geometry of the equilateral triangular microstrip patch antenna is shown in Figure 3. The calculation of side length (a) of equilateral triangle is obtained by formula (10) [7]:

$$a = \frac{2v_o}{3f_{r_{10}}\sqrt{\varepsilon_r}} \tag{10}$$

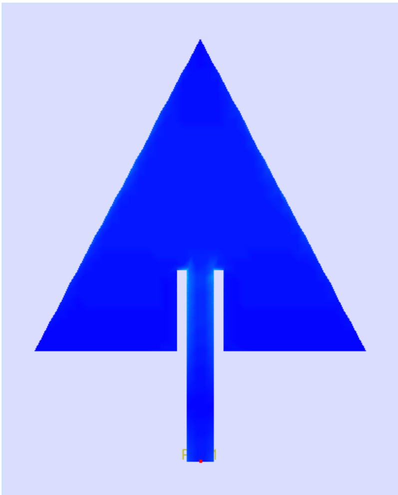

Fig. 3. Geometry of the triangular microstrip patch antenna.

The length of inset of the patch for microstrip line (*Fi*) can be obtained by the same equation in the rectangular patch by assuming L is equal to the side length of the triangle. As in the previous designed antennas, the parameters were modified to obtain better results. Table III shows the final dimensions for equilateral triangular patch antenna.

TABLE III. FINAL DIMENSIONS OF TRIANGULAR PATCH ANTENNA

parameters	Dimensions (*mm*)
a	37.6
Wf	3
Fi	8.5

III. RESULTS

- *The Return loss*

The variation of the return loss versus frequency for each rectangular, circular and triangular patch antennas are shown in figures (4) (5) and (6) respectively. The return loss of rectangular, circular and triangular patch antenna were– 31.531 dB, –34.515 dB and –23.46 dB respectively. The bandwidth for each rectangular, circular and triangular patch antenna is 28 MHz (1.12%), 26 MHz (1.04%) and 18 MHz (0.72%) respectively calculated at – 10 dB return loss.

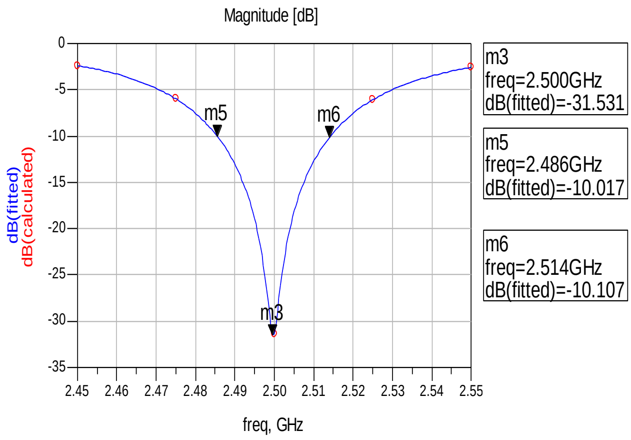

Fig. 4. The return loss of rectangular patch antenna.

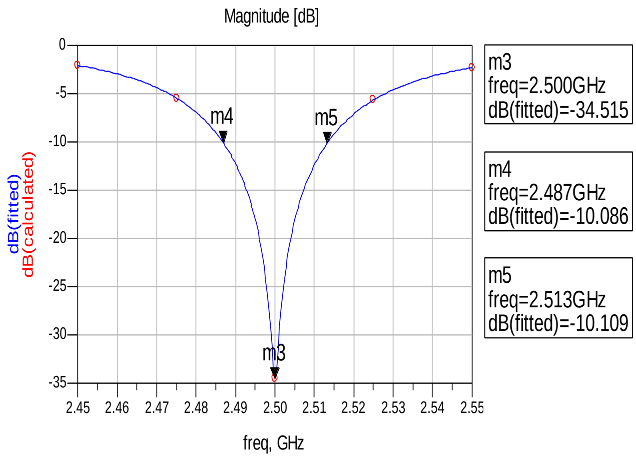

Fig. 5. The return loss of circular patch antenna.

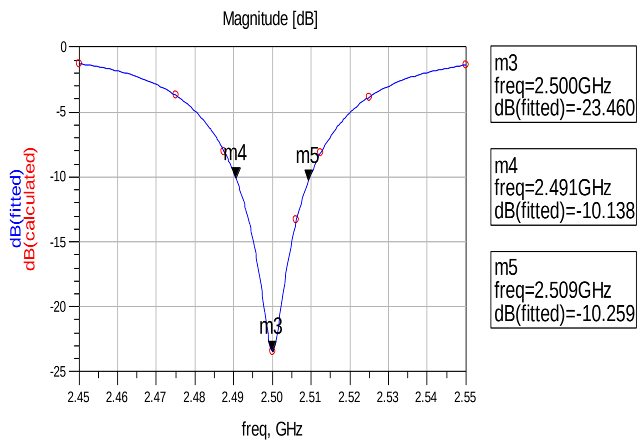

Fig. 6. The return loss of triangular patch antenna.

- *VSWR versus the frequency*

Figures(7) (8) and (9) illustrate the value of voltage standing wave ratio versus frequency for each antenna. The VSWR for rectangular patch antenna is 1.054, for circular patch antenna is 1.038 and for triangular patch antenna is 1.144 at resonant frequency.

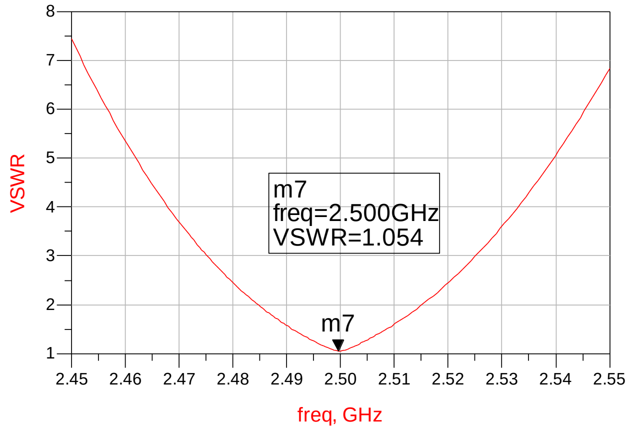

Fig. 7. The VSWR for rectangular patch antenna.

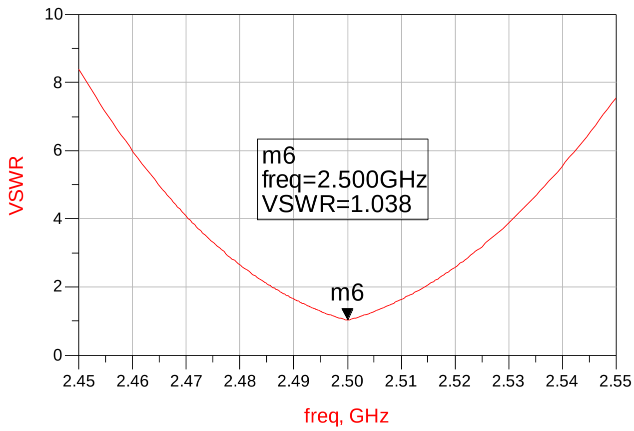

Fig. 8. The VSWR for circular patch antenna.

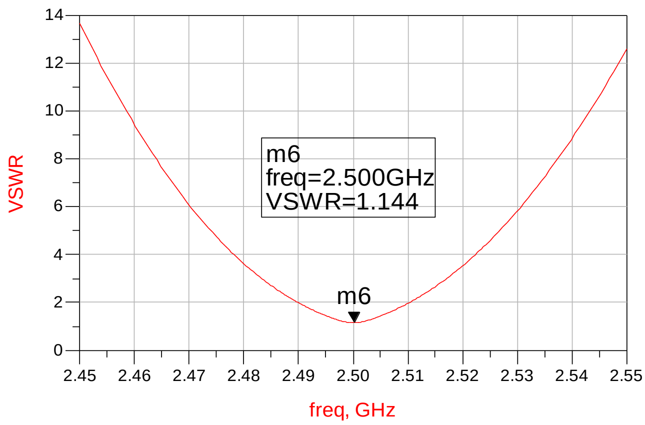

Fig. 9. The VSWR for the triangular patch antenna.

- *The Input Impedance*

Figures (10) (11) and (12) show the variation of input impedance with frequency for each rectangular, circular and triangular patch antennas. The input impedances are 53.05−j0.45, 51.75+j0.7 and 46.1+j5.3 respectively. It also can be observed that the input impedances for each design are matching with transmission line at 50Ω.

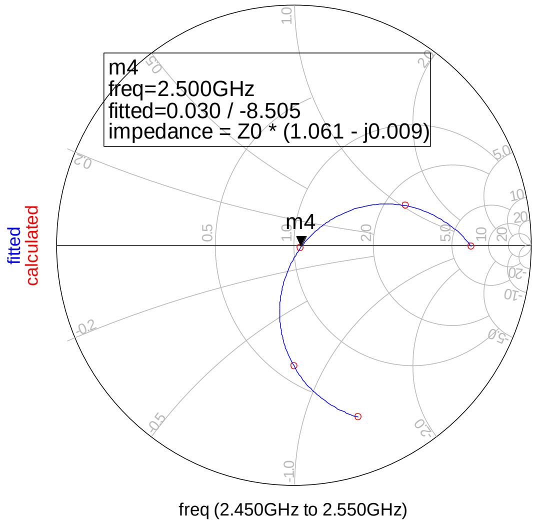

Fig. 10. The input impedance of the rectangular parch antenna.

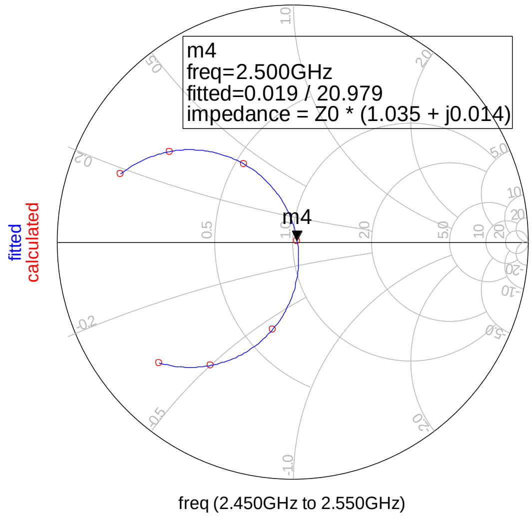

Fig. 11. The input impedance of the circular parch antenna.

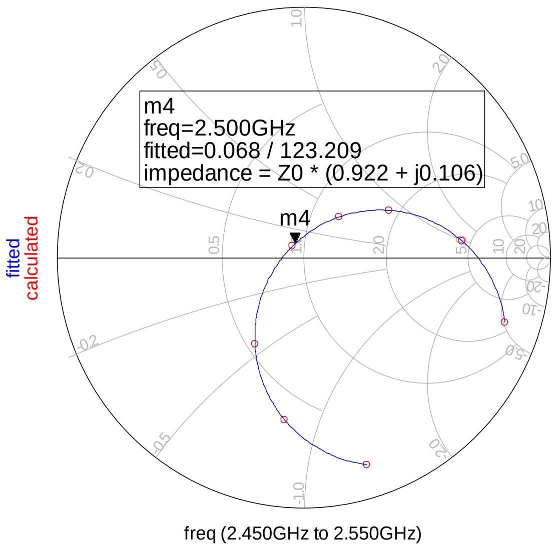

Fig. 12. The input impedance of the triangular parch antenna.

- *Radiation Pattern*

The 2D field pattern of the ($E\theta$) and ($E\emptyset$) with $\emptyset$=0° in elevation cut (x-z plane) for each rectangular, circular and triangular patch antennas are shown in category (a) of figures 13, 14 and 15 respectively; and in elevation cut (y-z plane) with $\emptyset$=90° are shown in category (b) of figures 13, 14 and 15 respectively. The Directivity for each rectangular, circular and triangle patch equals 6.477, 6.3036, 6.272 respectively and the equals 5.568, 5.1725 and 5.0102.

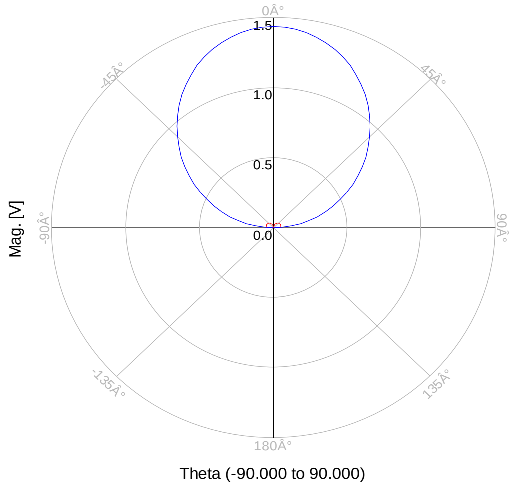

Fig. 13. The 2D field pattern of rectangular patch antenna $\emptyset$=0°.

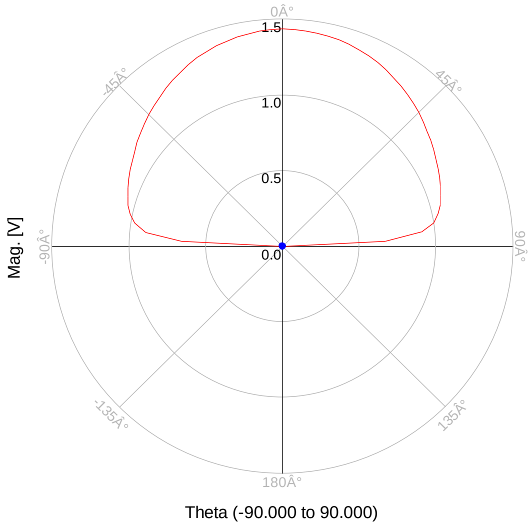

Fig. 14. The 2D field pattern of rectangular patch antenna $\emptyset$=90.

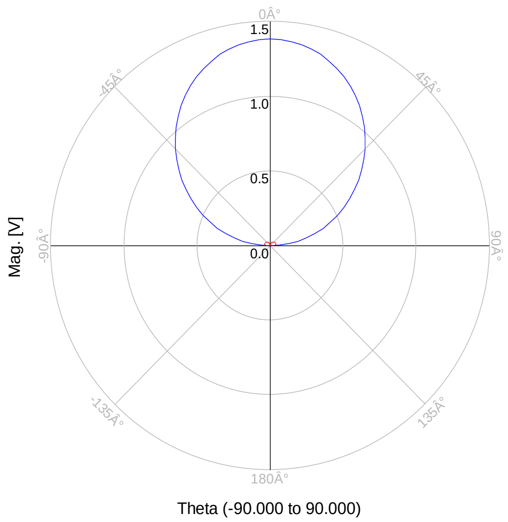

Fig. 15. The 2D field pattern of circular patch antenna Ø=0°.

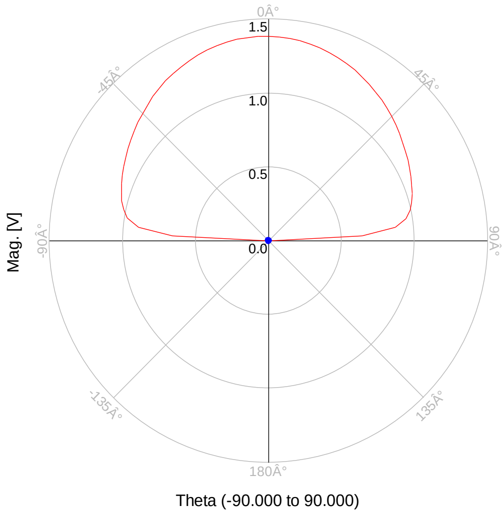

Fig. 16. The 2D field pattern of circular patch antenna Ø=90°.

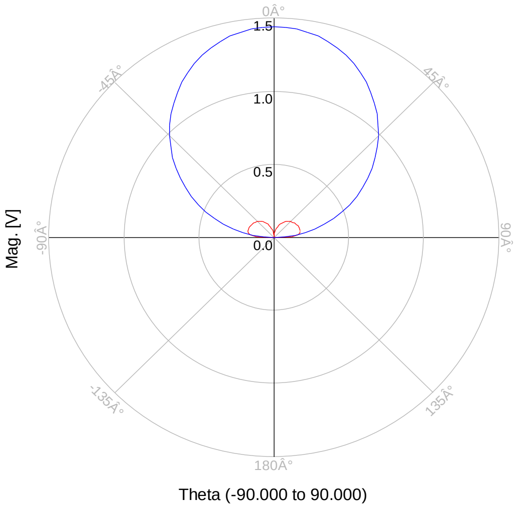

Fig. 17. The 2D field pattern of triangular patch antenna Ø=0°.

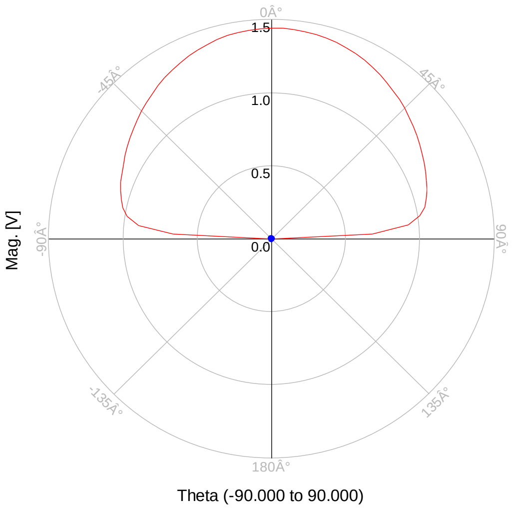

Fig. 18. The 2D field pattern of triangular patch antenna Ø=90°.

IV. Comparison and Conclusion

The main antenna parameters that obtained from simulation are return loss, bandwidth, gain and directivity. The return loss for the rectangular patch antenna is −31.531 dB, for the circular patch antenna equals to −34.515 dB and for the triangular patch antenna is −23.46 dB. However, the bandwidth of rectangular, circular and triangular patch antennas are 28MHZ, 26MHZ and 18MHZ receptively. The gain of the rectangular patch antenna is 5.568 dBi, for the circular patch antenna is 5.175 dBi and for triangular patch antenna equal to 5.0102 dBi. Finally, the directivity for rectangular, circular and triangular patch antennas are 6.477 dBi, 6.3036 dBi, and 6.272 dBi, respectively. The results proved that rectangular, circular and triangular patch antennas have similar performance approximately in terms of gain and directivity. The gain of rectangular, circular and triangular antennas are 5.568 dBi, 5.1725 dBi and 5.0102 dBi respectively and directivities are 6.477, 6.3036, 6.272 respectively. The best performance regarding return loss and VSWR was obtained from circular patch antenna, both values at operation frequency were −34.515 dB and 1.038 respectively. On the other hand, the rectangular patch antenna offered the best results in terms of bandwidth performance, that is 28MHz or 1.12%. In conclusion, the rectangular patch antenna presented best performance in this comparison whereas triangular patch antenna has the worst performance.

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