© NOV 2023 | IRE Journals | Volume 7 Issue 5 | ISSN: 2456-8880

Design and Improvement of Microstrip Patch Antenna Parameters Using Deflected Ground Structure

SUNUSI SULAIMAN DAUDA[1], MUSEFIU ADERINOLA[2], ISIAKA SHUAIBU[3]
[1, 2, 3] *Department of Electrical and Electronic Engineering, Hussaini Adamu Federal Polytechnic, Kazaure, Jigawa State.*

Abstract- A microstrip patch antenna is a type of antenna that operates at microwave frequencies and commonly used in wireless communication system. Despite the widespread utilization of microstrip patch antenna in diverse wireless communication systems, the demand for an efficient antenna that can transmit signals with minimal return loss, high data rate and broad bandwidth remain a critical requirement. In this study 2.4GHz Microstrip patch antenna with length of 59mm, width of 93mm and height of 1.2mm. the simulation result obtained were compared to default microstrip patch antenna using impedance, return loss, voltage standing wave ratio(VSWR), azimuth and elevation peak dataset. The Proposed microstrip patch antenna (PMPA) shows better performance with impedance resistance and reactance of 43Ω and 50Ω, return loss of 3.1dB, VSWR of 3.1dB, peak dataset of azimuth of 1.9793dB and peak dataset elevation of -7.706dB compared to default microstrip patch antenna (DMPA) with 42Ω and 72Ω for impedance resistance and reactance, return loss 3.2 x 10^6 dB, VSWR of 0dB, peak dataset of azimuth 1.9736dB and peak dataset of -7.108dB.

I. INTRODUCTION

A microstrip patch antenna is a type of antenna that operates at microwave frequencies and commonly used in wireless communication system. Microstrip patch antenna has gained significant popularity in the field of wireless communication due to their compact size, ease of fabrication and compatibility with integrated circuit technologies. These antennas offer practical and efficient solution for various applications, ranging from satellite communication and wireless network to mobile devices and radar system.

Micro strip antennas are designed to operate in circular, rectangular, Square and triangular on several communication devices [1]. Micro strip antenna is made up of three components; radiating patch found at the top surface, dielectric substrate found at the right side and ground plane at the middle side [2]. The shape of the patch can be rectangular, square, circular, helican, triangular, ring etc. Band width increment is required for practical usage since by default micro strip antenna narrow bandwidth.

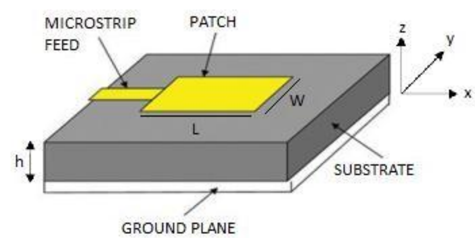

Fig 1.1: Diagram of Microstrip patch antenna

Despite the widespread utilization of microstrip patch antenna in diverse wireless communication systems, the demand for an efficient antenna that can transmit signals with minimal return loss, high data rate and broad bandwidth remain a critical requirement. On the other hand, patch antenna encounter challenges such as low gain, limited bandwidth and relatively larger size, particularly at lower frequencies.

The objective of this study is to enhance and optimize the parameters of the microstrip patch antenna. The proposed antenna utilizes a method that involves adjusting the length, width and height of the antenna to achieve the optimal output performance.

II. LITERATURE REVIEW

According to [3], microstrip antenna was constructed using a 1.4 mm thick FR4 substrate with a relative permittivity of 4.4. A microstrip line feed was

utilized in the design. The circular patch of the antenna has a chosen radius of 7.62mm. In order to improve the performance and reduce the size of the antenna, a circular slot was added to the circular patch and a square slot with dimensions of 30mm x 30mm was etched on the ground plane. The antenna resonates at 5.5GHz with wider bandwidth of 702MHz. it exhibits a low return loss of -31.58dB, a good gain of 3.23dB, and a directivity of 4.28dBi. Additionally, the antenna achieves high efficiency of approximately 79% around the resonance frequency.
In a study conducted by [4], a hexagonal-shaped slotted antenna was designed to meet the specification of 5G technology. The antenna configuration included front lengths of 1 x2, 1x4, and 1x 8arrays, with an overall dimension of 200 x160 x6mm. Computer simulation software was utilized to simulate the wireless communication performance of the antenna at frequency of 3.5GHz. The study focused on the development of single antenna elements up to the 1x 8 array configuration demonstrated excellent quality and capacity, providing network connectivity with a gain of 6.93dB at 3.5GHz and a return loss of -10dB. These results indicate that the antenna is well suited for use in 5G communication systems.

[5] Used micro strip antenna for wireless gigabit alliance (WiGig). The WiGig operates at two different frequencies; at 60GHz for short distances multimeter wave band application and at 95GHz using electromagnetic radiation for military weapons. The WiGig make microstrip antenna suitable for wireless personal area network (WPA), Wireless local area Network and 5G application.

Work on frequency turnability was conducted by [6]. A fabricated microstrip antenna with low profile material FR4 was compared with simulated microstrip antenna based on four modes, namely: resonating frequency, reflective response, gain bandwidth and electric field through the use of pin diodes. The band frequency turnability are S, C, X and Ku. The result shows that a maximum frequency 700MHz and a reflective response of -28.22dB were obtained.

Comparison of four different models was conducted by [7]. Using Roger RT5880 as substrate, model 1, a square shape element with antenna dimension of 5.5 x5 x0.56mm^3, relative permittivity of 2.2 with reconfigure frequency of 4 resistor. Model 2 was fed same way with reconfigure frequency of 2 resistor, model 3 with 5 x 5 x 1.571 mm^3 with thickness of 0.9mm and model 4 with dimension of antenna of 5 x5 x 1.3mm^3. The result show that at 60GHz, Model 1 has return loss of -34.2dB, model 2has -33.6dB, model 3 has 27.3dB and model 4 has 26.5dB. Only model 1 has diverse frequency reconfigurable value. The model has same voltage standing wave ratio of 1.017

[8] Carried out studies on 28GHz microstrip patch antenna for 5G communication technology. The simulated result via CST software show the return loss of -38.35dB, gain of 8.20dB, radiation efficiency of 77% and side lobe of -18.3dB. this show that it will meet the needs of 5G communications.

A 4x 4 filtering microstrip patch antenna array Dolph-Chebyshev distribution were investigated by [8]. The antenna array composed of 1 x4 subarrrays with sub array of four patch antenna coupled-fed by single microstrip line with phase current induction. A sidelobe level (SLL), four subarrays were implemented for 4x 4 filtering microstrip antenna and fed by Dolphy-chebyshev excitation method. The result presents 14.7dB as passband gain while suppressed in pass band above 25dB.

III. METHODOLOGY

The methodology employed in this work are grouped into three stages namely; Design, Simulation and Result

3.1 Antenna Design

The design of microstrip patch antenna using deflected ground structure involves careful consideration of various parameters, including the patch shape, dimension substrate properties and feed mechanism. These parameters directly influence the antenna's radiation pattern, bandwidth, and gain.

One of the key advantages of microstrip patch antenna is their low profile, making them suitable for application where space is limited. Their ease of fabrication using standard printed circuit board

(PCB) manufacturing technique further contributes to their popularity.

According to [10], the width of micro strip patch antenna is expressed as

$$W = \frac{C}{2fr\sqrt{(er+1)/2}} \qquad (1)$$

Where c = free space velocity of light. Substituting c = 3.0e8 m/s, ε_r = 4.4 and f_o = 2.4 GHz

Effective dielectric constant calculation **(** ε_{reff}**)**: The effective dielectric constant is:

$$ereff \overset{=}{} \frac{er+1}{2} - \frac{er-2}{2}\left[1 + 12\frac{h}{W}\right]^{--}\left(\frac{1}{2}\right) \qquad (2)$$

Effective length calculation **(** L_{eff}**)**: The effective length is:

$$Leff = \frac{C}{2fr\sqrt{ereff}} \qquad (3)$$

Length extension calculation **(ΔL)**: The length extension is given by:

$$\Delta L = 0.412h\frac{(ereff+0.3)(\frac{W}{h}+0.264)}{(ereff-0.258)(\frac{W}{h}+0.8)} \qquad (4)$$

Actual length of patch calculation **(L)**:
The actual length is obtained by:

$$L = Leff - 2\Delta L \qquad (5)$$

Ground plane dimensions' calculation ($L_g$and W_g)**:**

$$Lg = 6h + L \qquad (6)$$

$$Wg = 6h + W \qquad (7)$$

Return loss is given as

$$Rin|_{(y\ =\ y\ 0)} = Rin|_{(y\ =\ 0)} \cos^2(\pi * y_0/L) \qquad (8)$$

Voltage standing wave ratio is given by $VSwr = \frac{1+RC}{1-Rc}$ (9)

Two microstrip patch antenna are considered in this work. The default and proposed Microstrip patch antenna. The detail of their design features is given below.

A. Default Microstrip patch Antenna (DMPA)

The default Microstrip patch antenna is shown in fig 3.1 while the pattern can be seen in fig 3.2.

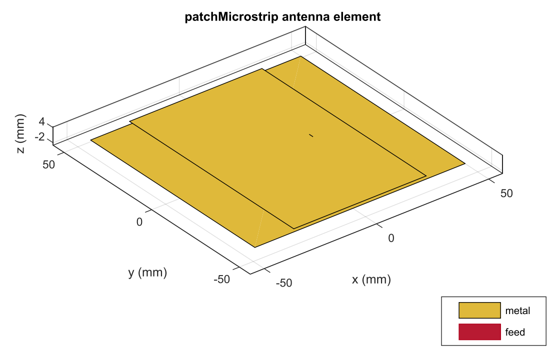

Fig 3.1: Microstrip patch antenna element

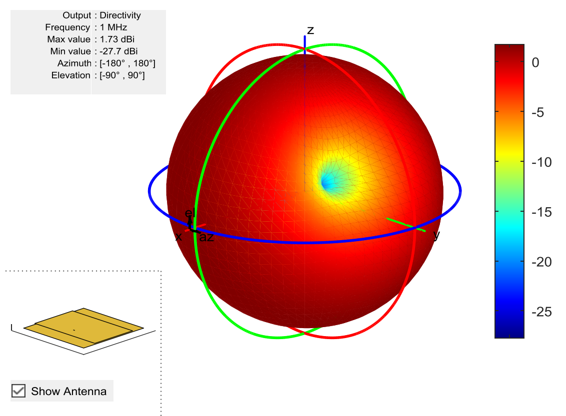

Fig 3.2: Pattern for Microstrip patch antenna.

B. Proposed Microstrip patch Antenna (PMPA)

The design Microstrip patch antenna is shown in fig 3.3 with frequency of 2.4GHz, length of 59mm, width of 93mm and height of 1.2mm. The size of the along y-axis range from 40mm to -40mm while x-axis range from -80mm to 80mm. the detail of other parameters can be found in table 3.1.

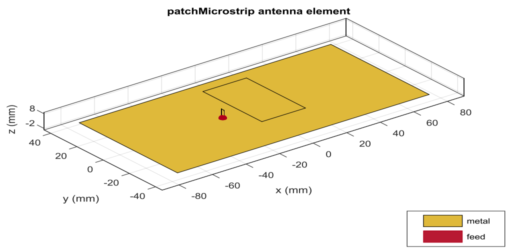

Fig 3.3: Proposed Microstrip patch element

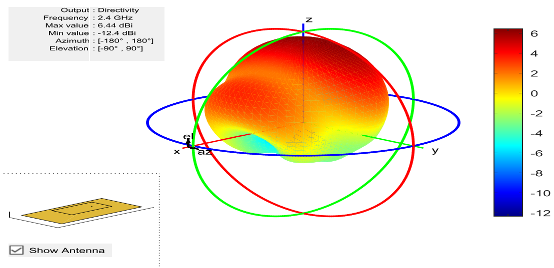

Fig 3.4: Pattern for Proposed Microstrip patch antenna

Table3.1: Parameters for Microstrip patch antenna

Parameters	Default	improved
Length	75mm	59mm
Width	37.5mm	93mm
Height	6mm	1.2mm
Ground Plane Length	150mm	93mm
Ground Plane Width	75mm	93mm
Substrate Material	Air	FR4
Dielectric	1	1
Major axis	6.4 dB	8.11dB
Minor Axis	-12.4dB	-24.9dB
Frequency	2.4GHz	2.4GHz
Azimuth	-180^0 to 180^0	-180^0 t0 180^0
Elevation	-90^0 to 90^0	-90^0 to 90^0

3. 2. Simulation

The simulation for default Microstrip patch antenna (DMPA) along side with Proposed microstrip patch antenna (PMPA) for impedance, return loss and voltage standing wave ratio are shown in fig 3.5 to 3.8

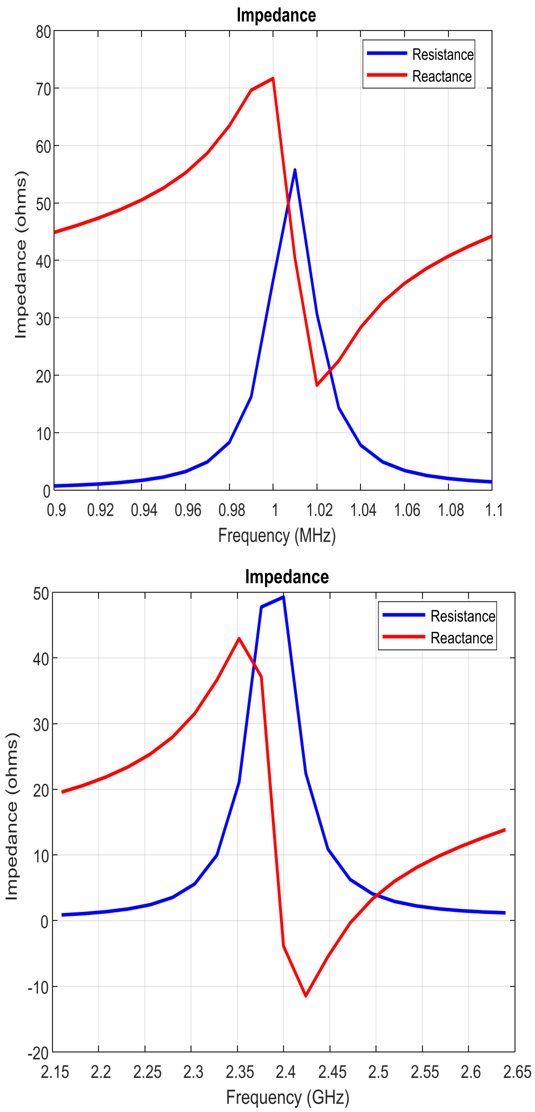

Fig 3.5 (a) Impedance for DMPA (b) Impedance for PMPA

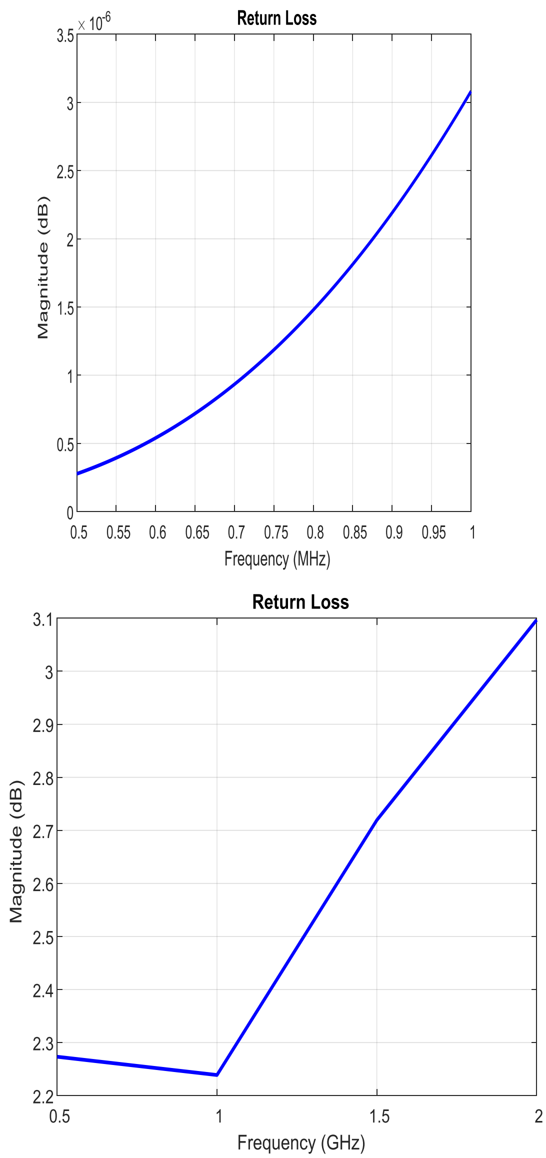

Fig 3.6 (a) Return loss for DMPA (b) Return loss for PMPA

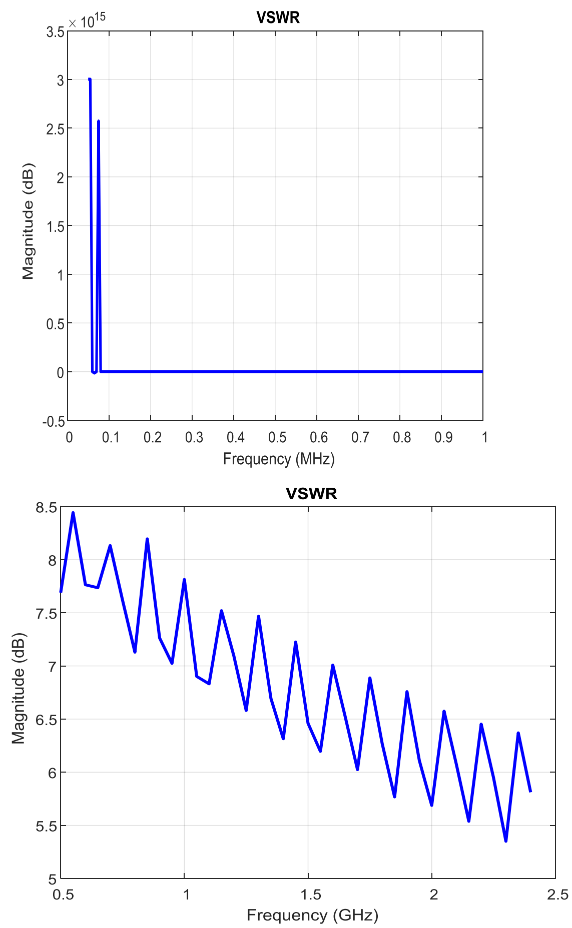

Fig 3.7 (a) VSWR for DMPA
(b) VSWR for PMPA

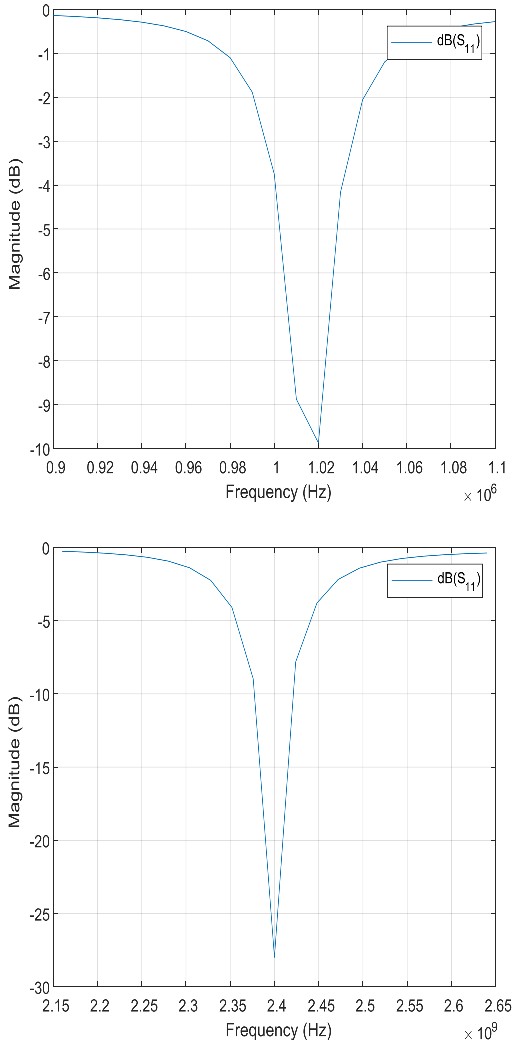

Fig 3.8 (a) dBS11 for DMPA
(b) dBS11 for PMPA

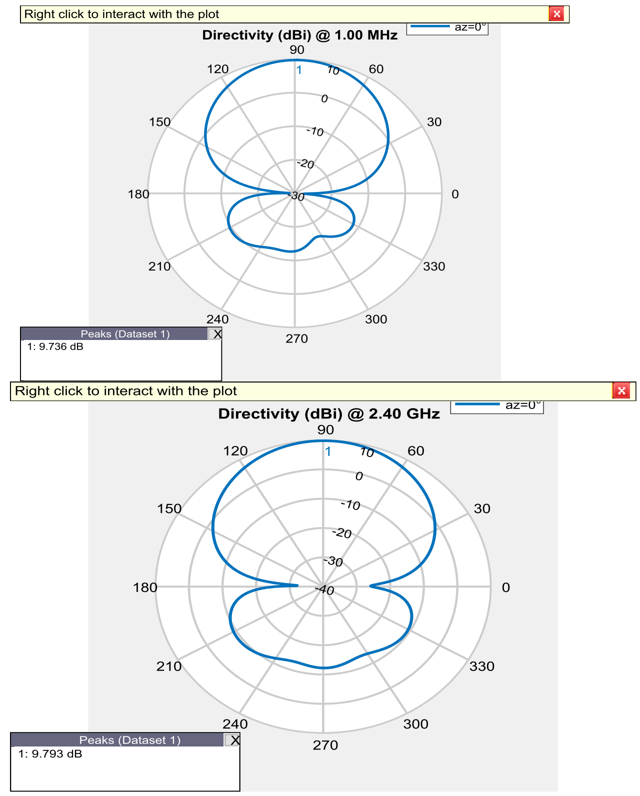

Fig 3.9 (a) Azimuth for DMPA (b) Azimuth for PMPA

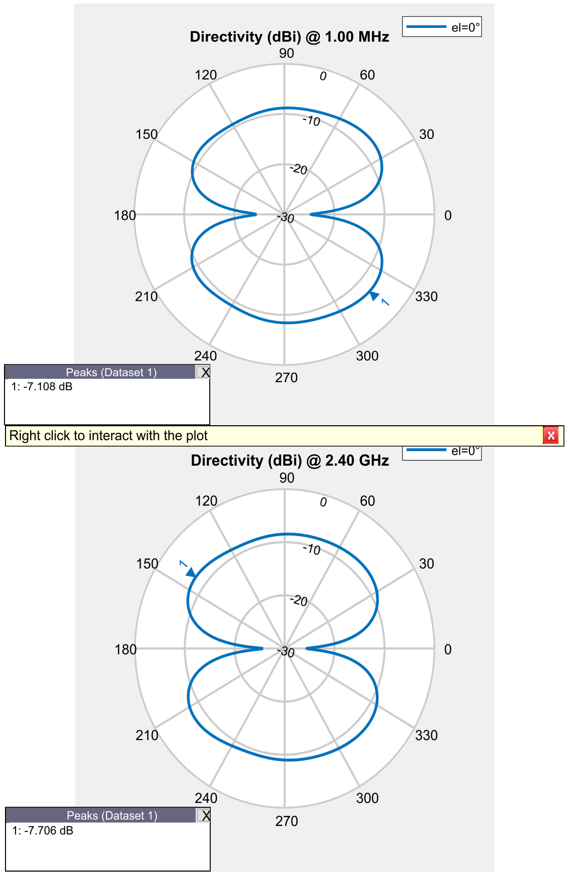

Fig 3.10 (a) Elevation for DMPA (b) Elevation for PMPA

3.3 Discussion of Result

From fig 3.5 (a) the impedance resistance and reactance are 42Ω to 72Ω at frequency of 1MHz for default microstrip patch while the impedance resistance and reactance are 50Ω and 43Ω at frequency of 2.4GHz as seen in fig 3.5 (b)

The return loss is 3.2 x 10^6 dB at frequency of 1MHz for DMPA while 3.1dB at frequency of 2GHz as seen in fig 3.6 (a) and (b).

The VSWR is 0dB at 1MHz for DMPA while PMPA has 3.1dB at 2.GHz as seen from fig 3.7 (a) and (b).
The dS(S11) for DMPA is -4.5dB at 1MHz and -27dB at 2.4GHz for PMPA as seen in fig 3.8 (a) and (b)
The peak data set for azimuth for DMPA is 1.9736dB at 1MHz, while PMPA has 1.9793dB at 2.4GHz as seen fig 3.9

The peak data set for elevation for DMPA is -7.108dB at 1MHz, while -7.706dB at 2.4GHz for PMPA as seen in fig 3.10 (a) and (b).

CONCLUSION

The design of 2.4GHz microstrip patch antenna has been designed with length of 59mm, width of 93mm and height of 1.2mm. The simulation result obtained shows better improvement over the default microstrip patch antenna with reduced impedance, minimal return loss, better VSWR, and higher peak dataset for azimuth and elevation as compared to DMPA.

ACKNOWLEDGEMENT

Our profound gratitude to the management of Hussaini Adamu Federal Polytechnic, Kazaure for giving us the opportunity for carrying out this research work. We specially thank the TETFUND Nigeria for sponsoring this research work as part of our own contribution to the field of learning. We also thank the Director College of Engineering, Engr. Dr. Hamza Muhammad and HOD Electrical/Electronic Engineering Technology forgiving us support during this work.

REFERENCES

[1] Rajaneesa Ganegar, Nanda Hunaguda, Shurti SHurangi, SUman Pantil Sachin patil, Design of Microstrip Patch Antenna Using ADS tools, International Journal of Recent and Innovation Trends in Computing and Communication, Vol. 5, Issue 5, 2017

[2] Alok Tiwari, Brijesah pandey, Abita V.K., Raghvendra Mishra, Amit Vasudeo Rane, and Jaya Suryawanshi. Simulation of Ultra-Wideband Co-planar Boat Microstrip Patch antenna With IE3D software for wireless Communication, International Scientific Organization, 2015

[3] Chantali Mukta, Mahfujur Rahman, Abu Zafor md. Touhidul Islam. Design of Compact Circular Microstrip Patch Antenna for WLAN Applications. International Journal on Adhoc Networking System, Vol. 11, No3. 2021

[4] Ahmed Jamal Abdullah Al-Gburi1, Imran Mohd Ibrahim1, Zahriladha Zakaria1, Elzameera Bt Abdul Halim. Microstrip Patch Antenna Arrays Design For 5G Wireless Backhaul Application At 3.5 GHz. 2022.

[5] Soumen Barua1, Abu Zafar Md. Imran1, Md. Emdadul Hoque Bhuiyan1, Subrata Barua, Syed Zahidur Rashid, Abdul Gafur1, Md. Razu Ahmed. Highly efficient microstrip patch antenna for wireless gigabit alliance applications (2022). Indonesian Journal of Electrical Engineering and Computer Science. Vol. 26, No. 3, June 2022, pp. 1451~1459.

[6] Sunil P. Lavadiya, Vishal Sorathiya, Sunny Kanzariya, Bhavik Chavda, Ahmad Naweed, Osama S. Faragallah, Mahmoud M. A. Eid, Ahmed Nabih Zaki Rashed. Low profile multiband microstrip patch antenna with frequency reconfigurable feature using PIN diode for S, C, X, and Ku band applications. Wiley 2022.

[7] M. Kamran Shereen, M.I. Khattak, Jamel Nebhen A review of achieving frequency reconfiguration through switching in microstrip patch antennas for future 5G applications Alexandria Engineering Journal, 2021

[8] Md. Sohel Rana, Md. Mostafizur Rahman Smieee. Design and analysis of microstrip patch antenna for 5G wireless communication systems. Bulletin of Electrical Engineering and Informatics Vol. 11, No. 6, pp. 3329~3337. December 2022

[9] WEI NIE HUAI-ZHI WEN1, KAI-DA XU (Senior Member, IEEE), YU-QUAN LUO6, XIAO-LONG YANG (Member, IEEE), AND MU ZHOU 1 (Senior Member, IEEE). A Compact 4×4 Filtering Microstrip Patch Antenna Array With Dolph-Chebyshev Power Distribution. Antenna and propagation, Open access Journal 2022

[10] Alaa M. Abdulhussein, Ali H. Khidhi and Ahmed A. Naser. 2.4 GHz Microstrip Patch Antenna for S-Band Wireless Communications. Journal of Physics. 2021