Spectrum of Engineering Sciences
ISSN (e) 3007-3138 (p) 3007-312X Volume 3, Issue 8, 2025

ASYMMETRICAL FOUR U-SLOTS MICRO-STRIP CIRCULAR PATCH ANTENNA FOR WLAN AND WI-FI COMMUNICATION APPLICATIONS

Arshad Wahab*1, Waleed Ahmad[2], Muhammad Kashif Khattak[3], Bilal Ahmad[4], Aamir Hayyat[5], Anum Mushtaq[6]

*1,2,3,5,6 University of Poonch Rawalakot, AJK, Pakistan
[4]University of Kotli, AJK Pakistan.

*1arshadwahab90@gmail.com, [2]drwaleedahmad@upr.edu.pk, [3]mkashifkhattak@upr.edu.pk, [4]bilal_ahmad919@yahoo.com, [5]aamirhayyat@upr.edu.pk, [6]anummushtaq@upr.edu.pk,

DOI: https://doi.org/10.5281/zenodo.16784903

Keywords
Patch antenna, Microstrip, Asymmetrical U-slots, WLAN, Wi-Fi, Gain, Directivities, Bandwidth.

Article History
Received: 06 May, 2025
Accepted: 02 July, 2025
Published: 09 August, 2025

Copyright @Author
Corresponding Author: *
Arshad Wahab

Abstract
The modern communication systems require broad band, compact size and multipurpose antennas for the emerging technologies like 5G and satellite communication. The limitations of micro strip patch antennas include narrow bandwidths and low gains, which make it incompatible with the modern communication systems. The proposed antenna is composed of asymmetrical four U-slots in the patch. The slots are introduced to obtain the broadband characteristics of the antenna. The parameters such as changing the width and length of the U-slots, the radius of the patch and variation in feed point location can improve the efficiency and can remove the bottlenecks of the microstrip patch antennas. The proposed antenna is designed for WLAN and Wi-Fi applications. The aim is to analyze parametric studies and to discuss about how the variations in different parameters of antenna can enhance the gain and the narrow bandwidth. The size and weight of the antenna will be reduced by using an air substrate between the patch and ground.

1. INTRODUCTION

Modern wireless communication systems require communication devices that have low profile and low cost, high efficiency, and reliable. The microstrip patch antennas have the disadvantages of lower bandwidth and gain [1].IEEE 802.11b system is a commonly used WLAN system nowadays that has a maximum throughput of 11Mbps and uses a narrowband system. With the advancement of the broadband new WLAN system are designed to have a maximum data transfer rate of 54Mbps [2]. The broadband WLAN requires a versatile system that performs well. For this broadband, an 802.11a system is needed which has coverage and signal strength. The good coverage and strength of the signal depend on the performance of the antenna [3]. The antenna which is used for the WLAN system should be low profile and broadband. The microstrip patch antenna is a good choice for the broadband WLAN system. There are different types of broadband antenna available in the market [15-18]. For example, Omni directional discone antennas are capable of transmitting in all direction and have performed well [4]. But due to large size and less security it cannot be used for WLAN systems.

The security issues along with the interference from the nearby WLAN systems are needed. So the demand for the broadband WLAN antenna which has all the desired requirements is needed for modern communication systems. It makes the microstrip patch antenna very well suited for broadband wireless applications [5] and [6].

The size of patch antenna is almost one-half as compared with the transmission line wavelength [7-9]. The size of the microstrip patch antenna decreases by increasing the thickness of the substrate. The fringing effect increases the electrical length of the patch antenna [10-14].

The parameters which are required for designing of any microstrip patch antenna are the operating frequency For example, for the antenna designed for the mobile communication system the resonant frequency should be within the range of 2100-5600 MHz the antenna design here has a resonant frequency of 2.45 GHz. The materials of different dielectric constant use in substrate also inversely change the size of the antenna. The higher the dielectric constant the size of the antenna decrease. The weight of the antenna increases with the increasing the thickness of substrate. If the antenna is used in the wireless communication system the height should be less.

The rest of the paper is organized as follows: Dimensions and material of the antenna used are discussed in section 2. In Section 3 Simulation results are presented and discussed. The research article is concluded in section 4.

2. PROBLEM STATEMENT:

The proposed model has the bandwidths requirement for WLAN and Wi-Fi devices according to IEEE 802.11 standards. The simulations results are obtained by CST Microwave studio. The parametric study of the antenna is composed of varying the different parameters of the antenna such as by changing the length and widths of different sides of the asymmetrical U-slots or by changing the position of the feed. By doing this the performance of the antenna for the desired bandwidths is improved. The resultant antenna has sufficient bandwidth for the desired operation of WLAN and Wi-Fi applications

3. MATERIALS AND GEOMETRY

The single layer patch of thickness 0.5mm and the ground of dimension 50 x 50mm^2 and thickness of 2mm is used in the proposed antenna. Four asymmetrical U-slots are made in the patch. The lengths and widths of the slots are changing to different values to achieve a bitter performance of the antenna for the desired operations. The position of the feed is varied to different positions and the antenna performances are analyzed. The dimension of the ground and substrate are kept similar. The patch and ground are made electrically conducted by assigning the material copper. The electromagnetic waves are reflected back from fully ground plane.

The geometrical view of the antenna is given below in "Fig 1".

Fig.1. Geometrical representation of four U-slot micro strip patch antenna. (Dimensions are in mm).

3. SIMULATIONS & DISCUSSIONS:

In this section we can see that S11 can be changed by adjusting the different parameters. The first parameter that can change the characteristics of S11 is by adjusting the position of the feed point. The feed point is changed to five different positions; 5mm, 5.375mm, 5.75mm, 6.125mm, and 6.5mm and S11 is analyzed as shown in "Fig.2". The efficiency of the antenna can be analyzed from the ratio of its power radiation and the power supply. The matching impedance of the antenna can be adjusted by changing the feed point position. This technique is used to achieve higher matching and lowest input impedance. The correct feeding point position not only helps to decrease the input impedance but also improves the return loss, gain, efficiency, and directivity.

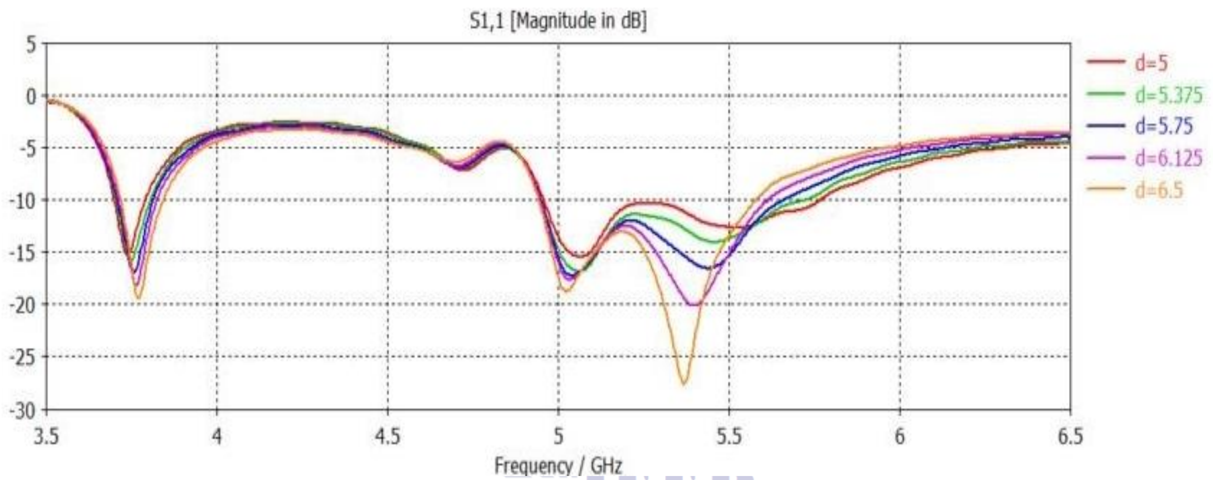

Fig.2. Effect on S11 by changing the feed point.

The second parameter of the proposed antenna that can affect the S11characteristics is by changing the radius of the patch. The curvature radius in mm depends on the different resonance frequencies of the proposed antenna. The changes in the curvature radius affect the fringing field and the fringing field effect the effective dielectric constant which change all other antenna parameters.

In Fig.3 the radius 'rp' of the proposed antenna is varied to three different values which affect the resonance frequencies, fringing field, effective dielectric constant, and all other parameters of the antenna such as the gain and bandwidths. The real and imaginary parts of the input impedance are also affected by different radii of curvatures.

The mathematical model has been analyzed while designing a slotted circular patch antenna. [15-17]. The mathematical relationship of the radius of a circular patch (a), resonance frequencies (f_r), dielectric constant (ε_r), and thickness of the substrate (h).

$$a = \frac{F}{\{ 1 + \frac{2h}{\pi \varepsilon_{rF}}[\left(\frac{\pi F}{2h}\right) + 1.7726]\}^{1/2}}$$

$$F = \frac{8.791X10^9}{f_r\sqrt{\varepsilon_r}}$$

The above situation is not applicable due to the fringing effect which increases the electrical size of the antenna. So the effective radius a_e of the patch should be considered..

$$a_e = a\left[\{ 1 + \frac{2h}{\pi \varepsilon_{rF}}[\left(\frac{\pi F}{2h}\right) + 1.7726]\}^{1/2}\right]$$

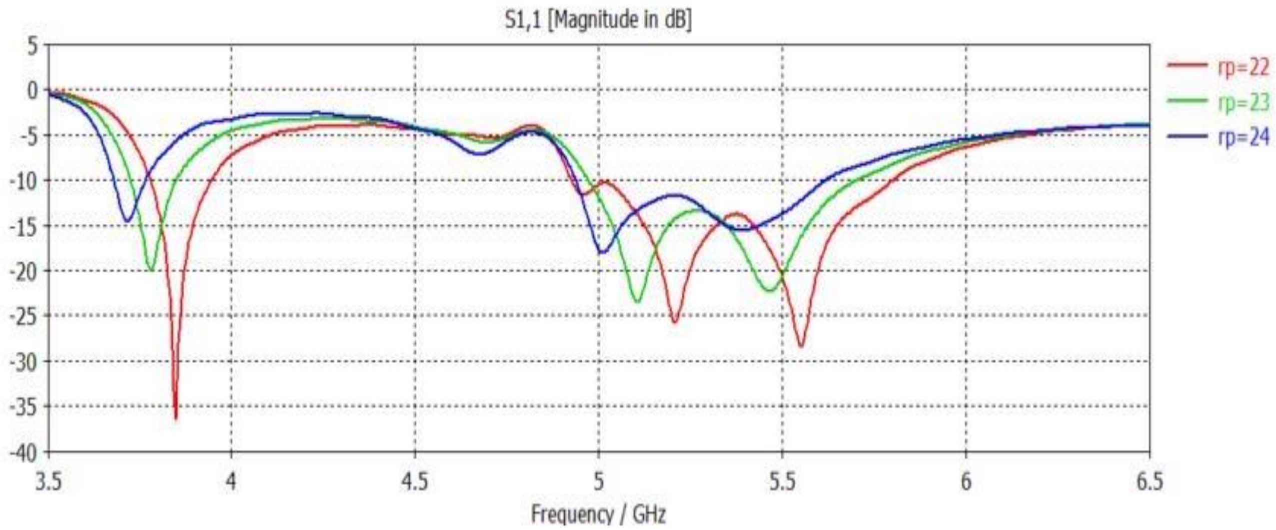

Fig.3. Effect on S11 by changing the radius

The variations in return loss with different patch radii that as 22mm, 23mm, and 24mm. The resonance frequencies are shifting towards the left by increasing the radius of the patch.

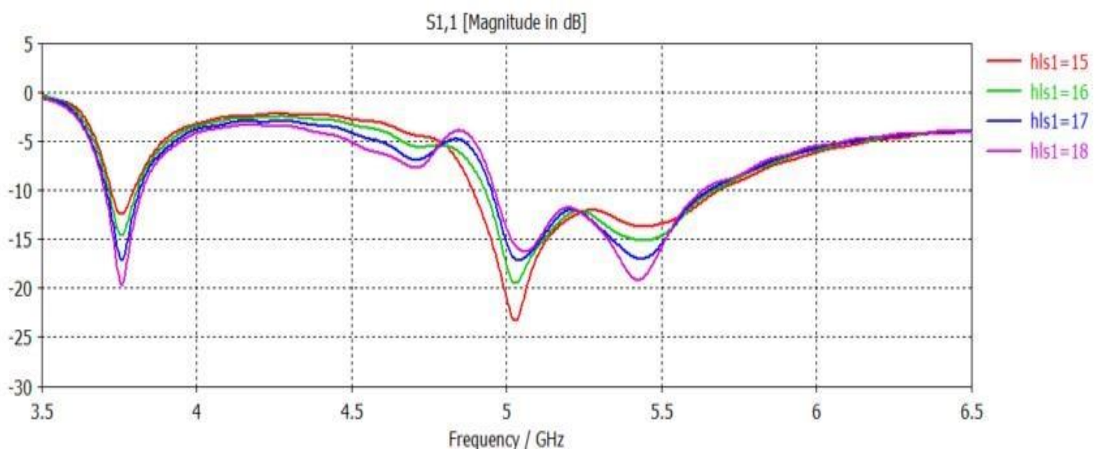

Fig.4.Effect on S11 by changing the length and width of the first slot.

The length, width, and position of the first slot are changed to four different values that; 15mm, 16mm, 17mm, and 18mm, and the characteristics of the S11 parameters are analyzed as shown in "Fig.4".The antenna resonates at the resonance frequency of 3.76GHZ and the S11 is -15.95dB. In the second band, the antenna resonates in the range from (4.95GHz to 5.68GHz) and the bandwidth is 0.73GHz.

At 3.76GHz the bandwidth is (3.65-3.70) GHz which is suitable for WLAN applications according to IEEE 802.1y standard for WLAN. The second resonance frequency on which the antenna resonate has a wide bandwidth from (5.15-5.82) GHz.

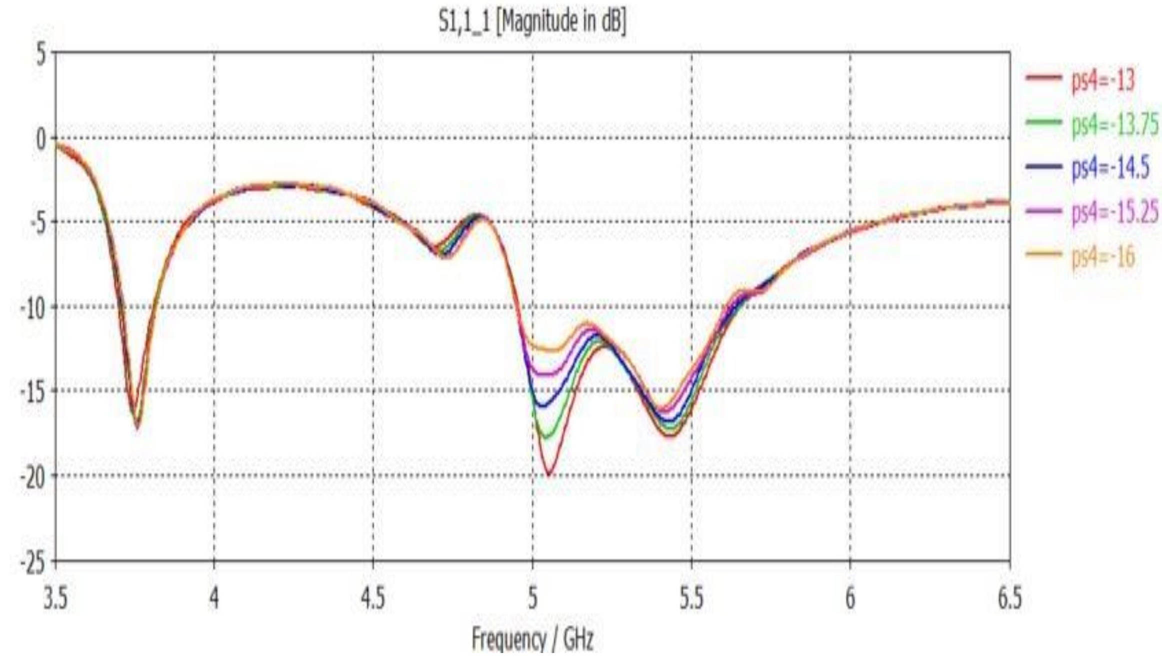

Fig.5. Effect on S11 by changing the position of the fourth slot.

The S11 is -14.40dB at the resonance frequency of 5.54GHz and -15.75dB at the resonance frequency of 5GHz.

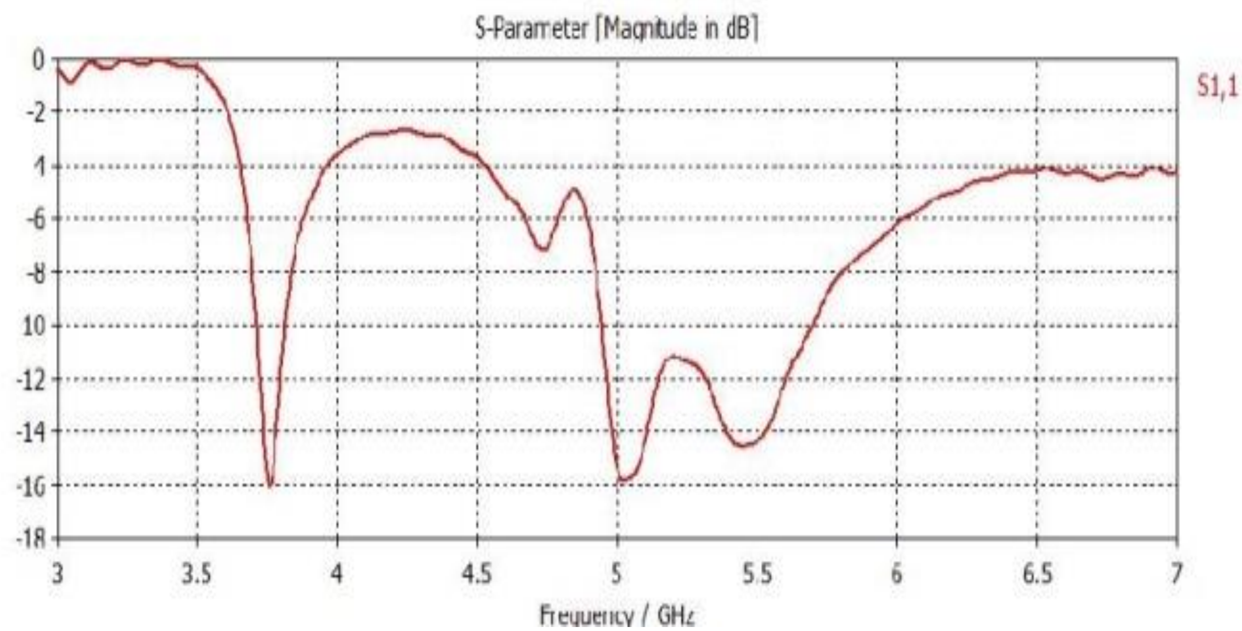

Fig.6. Reflection coefficient of proposed antenna.

The electromagnetic behavior of the proposed antenna can be studied from the current distribution in patch surface in "Fig.7".

ISSN (e) 3007-3138 (p) 3007-312X Volume 3, Issue 8, 2025

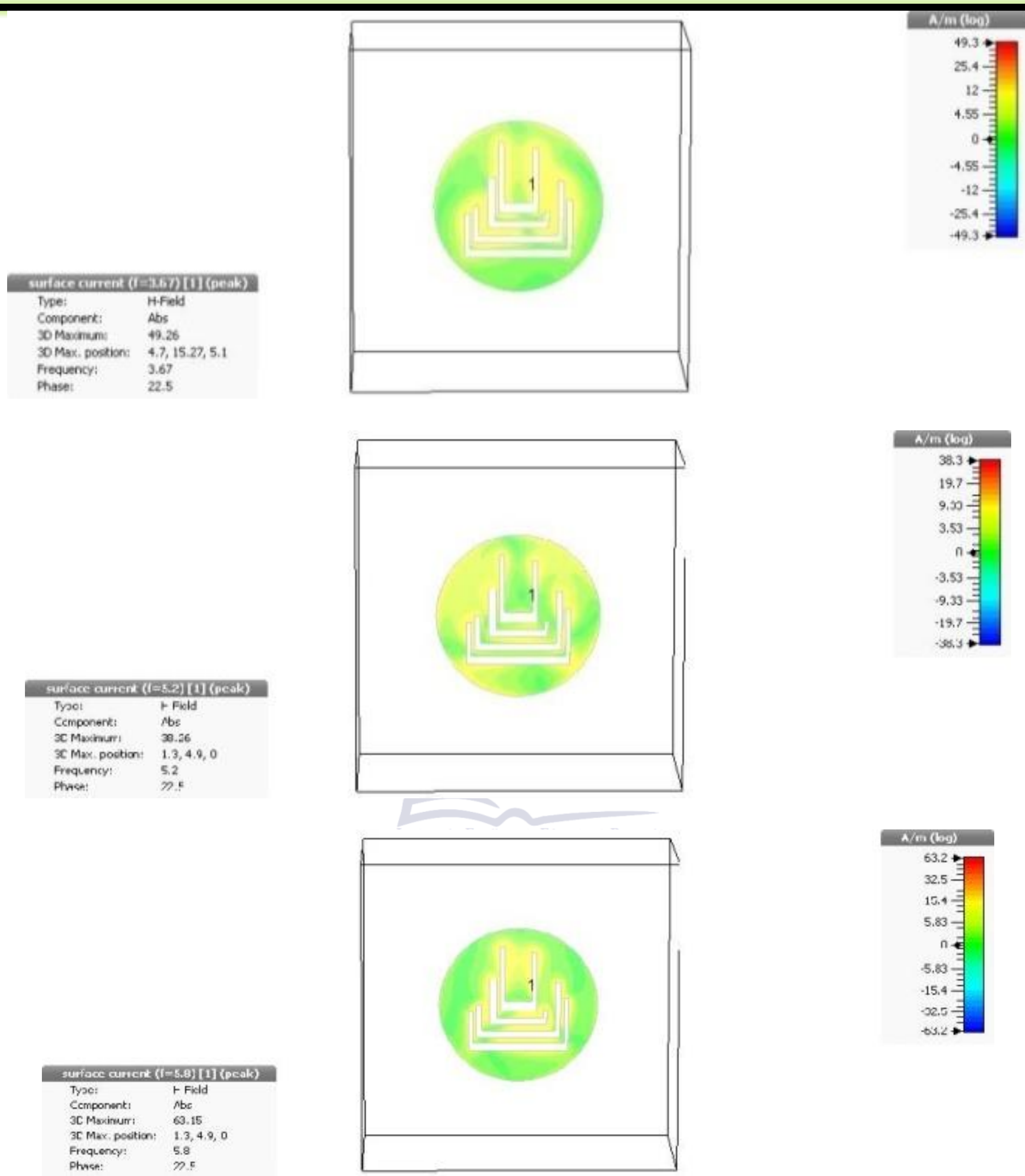

Fig.7.Simulated Current distribution of proposed antenna.

The surface current distribution is high at low operating frequency and a longer path is available to the flow of the current. On the other hand at highest operating frequency, the distribution of current is minimum and a short path is available to the flow of the current. As a future work direction

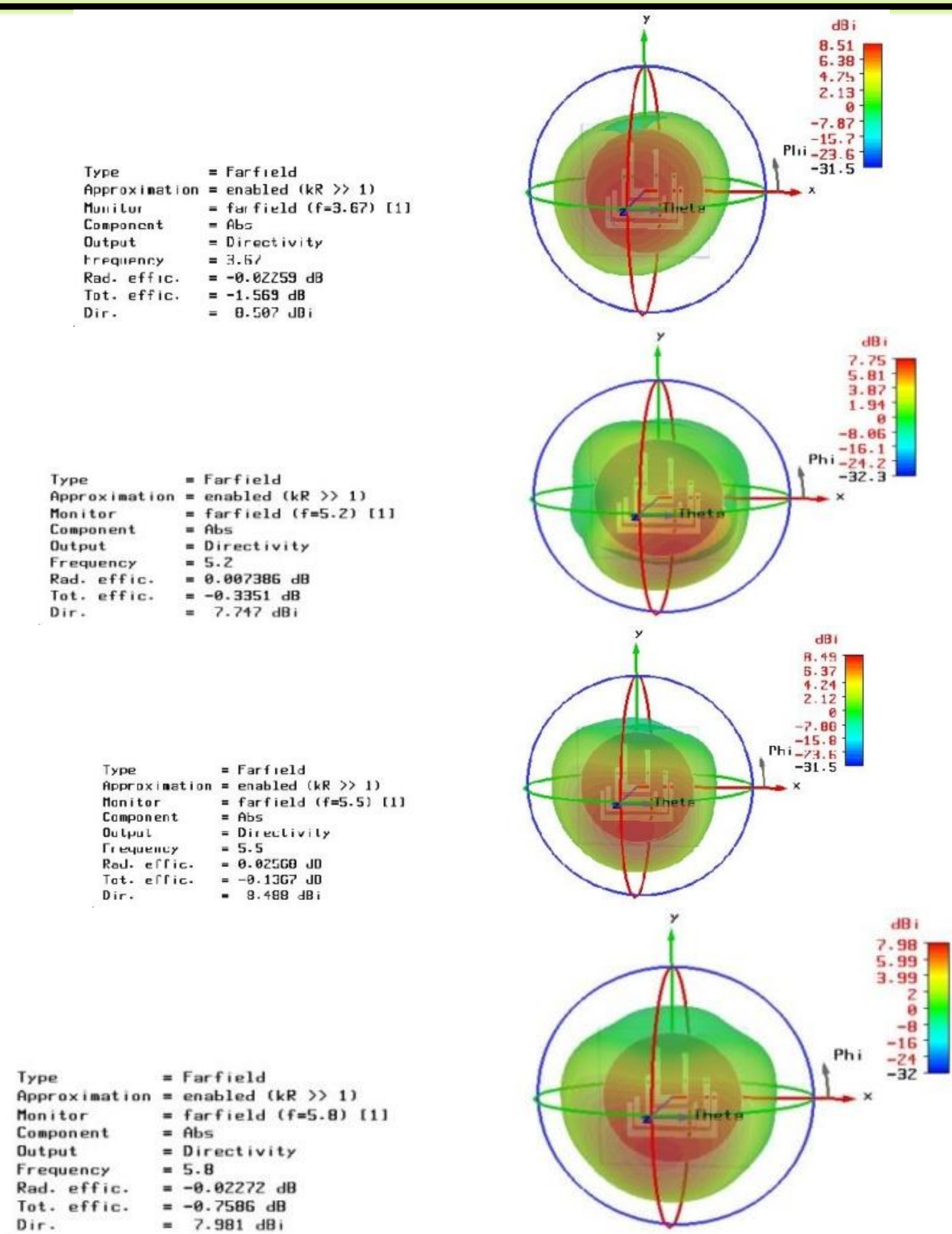

Fig.8. 3D Radiation pattern of proposed antenna.

In"Fig.8" The directivities of the antenna are 8.507dBi, 7.74dBi, 8.488dBi, and 7.981dBi. And the gains are 8.51dBi, 7.75dBi, 8.49dBi, and 7.98dBi at the operating frequencies in "Fig.8".

At the operating frequency of 3.67GHz the main lobe magnitude and direction are 8.5dBi and 3°. The angular width is 64.2°. At the resonance frequency 5.2GHz the main lobe magnitude and direction are 8.3dBi and 15°. The angular width is 55.6°. At the resonance frequency 5.8GHz the main lobe magnitude and direction are 8dBi and 17°. The angular width is 56.1°.

4. CONCLUSION:

The main objective is to design an antenna for WLAN and Wi-Fi applications which have high bandwidth and gain, compact size and less bulky and ease of fabrication. The parametric studies of the proposed antenna are observed using the CST simulation tools. The parameters such as changing the width, length of the U-slots, the radius of the patch and variation in feed point location have been analytically studied and simulation results have been shown for each and every change in parameters. By observing and analyzing the simulations it is clearly observed that the gain and the narrow bandwidth are improved significantly. The size and weight of the antenna are much reduced by using an air substrate between the patch and ground that made it light in weight and the proposed design is inexpensive. The matching impedance of the antenna is adjusted by setting the feed point position. The adjustment makes the design appropriate for higher matching and lower impedance. The adjustment technique improved the gain, efficiency and directivity. This technique is used to achieve higher matching and lowest input impedance. As a future research work the authors intend to fabricate the proposed antenna and compare the results in terms of their gain, return loss, directivities and bandwidths with the simulation analysis.

REFERENCES:

Alokkumar, Nancy Gupta, Gain and Bandwidth Enhancement Techniques in Microstrip Patch Antennas - A Review, International Journal of Computer Applications; August 2016. 148(7):9-14; DOI:10.5120/ijca2016911207.

Muhammad SaqibRabbani, HooshangGhafouri-Shiraz, IET the institute of Engineering and Technology, Improvement of microstrip patch antenna gain and bandwidth at 60 GHz and X bands for wireless applications,01 August 2016 https://doi.org/10.1049/iet-map.2015.067

Ayane L. Goshu, Mulugeta T. Gemeda, Kinde A. Fante, Qingsong Ai, Taylor and Francis's online, Cogent Engineering; Planar Microstrip Patch Antenna Arrays with Semi-elliptical Slotted Patch and ground Structure for 5G Broadband Communication Systems, 2069069 | Received 08 Dec 2021, Accepted 13 Apr 2022, Published online: 10 May 2022

S. Mohammad HassanJavadzadeh, HalehKarkhaneh&TaherehSadeghpour, Broadband Omnidirectional and Miniature Fold-up Discone Antenna in VHF/UHF Band, Electromagnetics, July 201232(5):266-273.

SezerKucukcan, Adnan Kaya, Dual-Band Microstrip Patch Antenna Design for Wi-Fi Applications, 2nd International Conference on Applied Engineering and Natural Sciences ICAENS 2022, March 10-13, 2022).

Dr. Yessar E. Mohammed Ali, Khalid A. Sultan Jasim, Design of Broadband Microstrip Patch Antenna for WLAN/WiMAX Applications, *Al-Rafidain Engineering Journal (AREJ), 2015,* Volume 23, Issue 1, Pages 154-163

Institute for Excellence in Educ

MounirBoudjerda, AbdelmalekReddaf, AbdellahKacha, , Khaled Hamdi-Cherif, Turki E. A. Alharbi, Mohammed S. Alzaidi, Mohammad Alsharef, and Sherif S. M. Ghoneim; Electronics 2022"Design and Optimization of Miniaturized Microstrip Patch Antennas Using a Genetic Algorithm" 6 July 2022;, 11, 2123. https://doi.org/10.3390/.

GokcenDemirbas, EkremAkar, Design, and Interpretation of Microstrip Patch Antenna Operating at 2.4GHz for Wireless WI-FI Application; European Journal of Science and Technology Special Issue 34, pp. 672-675, March 2022.

P. Rajalakshmi, and N. Gunavathi; Gain Enhancement of Cross-Shaped Patch Antenna for IEEE 802.11ax Wi-Fi Applications; Progress In Electromagnetics Research Letters, Vol. 80, 91–99, 2018.

RevanasiddappaKinagi, Ravi M. Yadahalli &SiddaramaPatil ,Compact and Hexaband Rectangular Microstrip Patch Antenna for Wireless Applications;*Wireless Personal Communications* (2022);

Sharma, M. (2020). Design and analysis of multiband antenna for wireless communication. *Wireless Personal Communications, 114*, 1389–1402. https://doi.org/10.1007/s11277-020-07425-9

Yang, G., Li, J., Yang, J., & Xing, Z. (2020). Dual-band slot microstrip patch antennas with dual-radiation modes for wireless communication. *International Journal of Microwave and Wireless Technologies, 12*(2), 155–162.

Hsu, C.-K., & Chung, S.-J. (2015). Compact multiband antenna for handsets with a conducting edge. *IEEE Transactions on Antennas and Propagation*. https://doi.org/10.1109/TAP.2015.2473657

Khan, Z., Iqbal, A. R. J., Qamar, A., &Zubair, M. (2018). Double circular ring compact antenna for ultra-wideband applications. *IET Microwaves, Antennas & Propagation, 12*(13), 2094–2097.

Ko, C.H., "Accessibility of Radio Frequency Identification Technology in Facilities Maintenance", Journal of Engineering, Project, and Production Management, 7(1): 45, 2017.

M. H. Ariff, I. Ismarani and N. Shamsuddin, "Microstrip antenna based on rectangular patch with arms and partial ground plane for UHF RFID readers". IEEE 6th Control and System Graduate Research Colloquium (ICSGRC), Shah Alam. pp. 61-65, 2015.

Kolhe, P.R., Dharaskar, R.M., Tharkar, M.H., Joshi, S., Desai, S. and Dapoli, B.S.K.K.V, "Information technology tool in library barcode & Radio Frequency Identification RFID", Int. J. Innov. Sci. Eng. Technol, 3, pp.81-6, 2016.

Sun, C., Zhao, W., & Bai, B. (2017). A novel compact wideband patch antenna for GNSS application. *IEEE Transactions on Antennas and Propagation, 65*(12), 7334–7339.

Nasimuddin, N., Chen, Z. N., &Xianming, Q. (2010). Dual-band circularly polarized S-shaped slotted patch antenna with a small frequency ratio. *IEEE Transactions on Antennas and Propagation, 58*, 2112–2115. https://doi.org/10.1109/tap.2010.2046851.

Shirazi, M., Li, T., Gong, X. (2015). Effects of PIN diode switches on the performance of a reconfigurable slot-ring antenna. In: IEEE wireless and microwave technology conference (WAMICON), Florida, USA.

Paul, P. M., Kandasamy, K., &Sharawi, M. S. (2018). A tri-band circularly polarized strip and SRR-loaded slot antenna. IEEE Transactions on Antennas and Propagation. https://idr.nitk.ac.in/jspui/handle/123456789/9760