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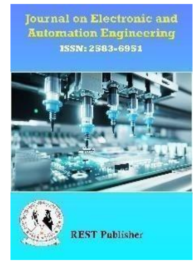


# Design of Circular Patch Array Antennas for WLAN, Wi-Fi & Bluetooth Applications

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***Abstract:*** *The study is a pioneering initiative in the field of antenna engineering, concentrating on the replacement of rectangular patch antennas with circular patch antennas in 2.4GHz applications. Through a detailed assessment of three various configurations—1x1, 2x1, and 4x1—the study used the HFSS tool to facilitate simulations, allowing a full evaluation of each antenna's performance parameters. These characteristics include critical metrics like gain, directivity, and radiation pattern, which are important in determining antenna efficacy in wireless communication systems. By rigorously comparing circular patch array antennas to their rectangular counterparts, the study hopes to offer insight on the subtle complexities and possible benefits of circular patch designs.The findings of this work have the potential to not only develop antenna design approaches, but also to significantly improve the efficacy and efficiency of present wireless communication technologies operating in the 2.4GHz frequency region. The transition from rectangular to circular patch antennas represents a paradigm shift in design considerations, potentially providing novel insights into antenna performance and paving the way for next-generation wireless communication systems with improved reliability and throughput.Furthermore, by elucidating the optimal design parameters for circular patch array antennas, this study lays the groundwork for future antenna engineering innovations, allowing wireless communication technologies to evolve and refine themselves in response to the ever- increasing demands of modern connectivity.*
***Keywords:*** *HFSS software, circular patch antenna, gain, directivity, radiation pattern.*

## 1. INTRODUCTION

These microstrip patch antennas are used in wireless communication systems due to their low profile, ease of production, and conformal characteristics. Circular patch designs have several advantages, including omnidirectional radiation patterns in the azimuth plane. However, achieving high gain and directivity remains challenging, particularly for single-element systems. This paper addresses this by investigating circular patch array topologies for improved performance in the commonly used 2.4 GHz frequency range. [1].Wi-Fi has been an incredibly successful technology during the last decade [2]. A basic patch antenna emits owing to the fringing field effect between the ground plane and the radiating patch [2, 3]. Thus, a basic patch has only one resonant frequency (fr) [3]. Deschamps et al. [4] created the first MPA in 1953. The suggested application of MPAs is to transmit RF signals. Today, MPAs are employed in a wide range of applications, including WLANs, mobile communications, WiMAX, LTE, military and satellite communications, and phase array antenna systems [3].

One of the primary reasons to use thecircular geometry is its prevailing benefits such as ease ofmodification to produce variety of impedance values, radiationpatterns and frequency of operation[4-5].The MPAs are low profile, compatible with theexisting integrated circuits and easy to design and fabricate[3]This research investigates three different configurations: a single element (1x1), a two-element linear array (2x1), and a four-element linear array

(4x1). The High-

Frequency Structure Simulator (HFSS) program is used to undertake thorough simulations of each antenna design's important performance characteristics [6]. The parameters are gain, directivity, and radiation patterns. A complete comparison of the collected data is provided, providing significant insights into how array arrangement affects the antenna's overall performance.

The results of this study present a substantial advancement in the optimization of circular patch array antennas tailored for 2.4 GHz applications. Through a comprehensive comparative analysis, this research offers valuable insights into enhancing the design parameters crucial for achieving high gain and improved directivity. Such findings hold significant promise for the development of high-performance antennas vital for various wireless communication systems operating within the 2.4 GHz frequency band.

### 2.1 Design of 1X1 circular patch antenna

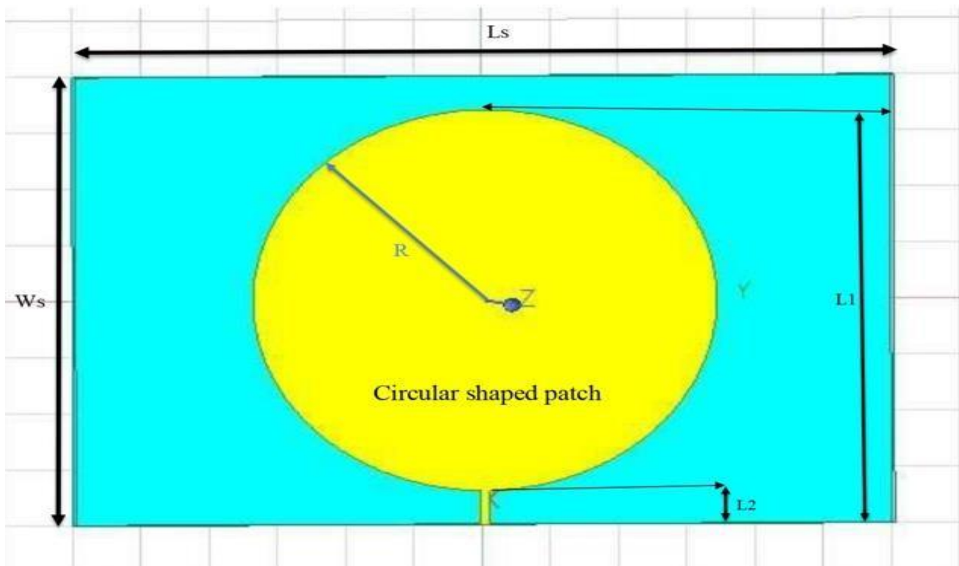



Fig 1 Top View

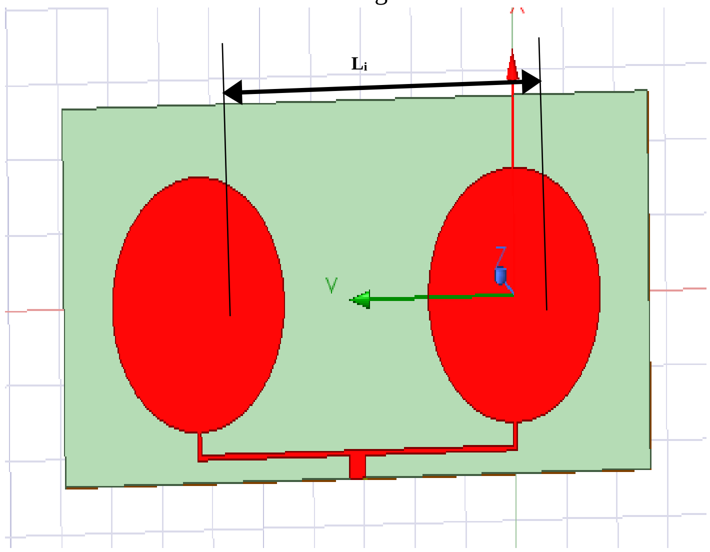
| Dimensions | |
|---|---|
| Patch Radius (R) | 17mm |
| Feed Length (L2) | 3mm |
| Width of Feed(Wf) | 0.7mm |
| Length of Substrate(Ls) | 60mm |

### 2.2 Design of 2X1 circular patch array antenna

The first stage in developing the 2x1 circular patch antenna is to determine critical characteristics that are appropriate for the specified needs. Because of its superior dielectric qualities and widespread availability, FR4 epoxy is chosen as the substrate material for this antenna arrangement. The antenna's form is then designed using simulation software such as HFSS, with substrate dimensions of 50x115 mm serving as a suitable base. To maximize performance parameters like as directivity and gain, the dimensions of the circular patch array are carefully considered, including each patch's radius and the spacing between individual components. Engineers may precisely and efficiently design the 2x1 circular patch antenna by following to these essential principles and utilizing simulation tools.

Fig 2




$L_i$ = inter element spacing

The inter element spacing should be lambda/2 to lambda.

Lambda=c/f

f= Centrefreq for which antenna is designed c=3x10$^8$ m/s

f=2.4GHz

The dimensions of the 2X1 circular patch antenna are the same asthe 1X1 circular patch antenna.

$$Z_c = \begin{cases} \dfrac{60}{\sqrt{\epsilon_{\text{reff}}}} \ln\left[\dfrac{8h}{W_0} + \dfrac{W_0}{4h}\right], & \dfrac{W_0}{h} \le 1 \\ \dfrac{120\pi}{\sqrt{\epsilon_{\text{reff}}}\left[\frac{W_0}{h} + 1.393 + 0.667\ln\left(\frac{W_0}{h} + 1.444\right)\right]}, & \dfrac{W_0}{h} > 1 \end{cases}$$

By using the above formula, we can find the widths of 100Ω feedline as 0.7mm and width of 50Ω feedline as 3mm.

### 2.3 Design of 4X1 circular patch array antenna

The first stage in constructing the 4x1 circular patch antenna is a comprehensive evaluation of important attributes customized to the required needs. FR4 epoxy is used as the substrate material owing to its extensively understood dielectric characteristics and accessibility. The antenna's shape is methodically constructed using advanced modeling tools such as HFSS, with the 51x237 mm substrate dimensions serving as the basic framework. The circular patch array's dimensions, including individual patch radii and inter- patch spacing, are carefully optimized to enhance performance metrics like as directivity and gain. Through methodical iteration and analysis, engineers painstakingly develop the antenna design to achieve or surpass the required goals.Following the design process, simulation runs are performed to assess the antenna's performance characteristics, such as directivity and gain. To verify that the simulation results are in accordance with the design specifications, rigorous post-processing and analysis are carried out. Validation against experimental data or industry standards ensures that the antenna functions properly and meets severe operating criteria. This complete technique allows the accurate creation of a 4x1 circular patch antenna, resulting in remarkable performance and dependability that meets professional requirements.

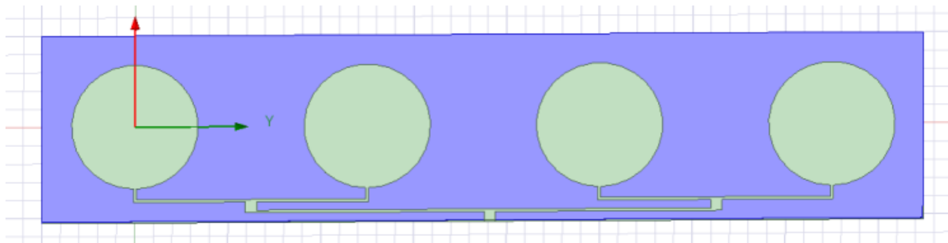


Fig 3

Circular patch antennas operating at 2.4 GHz are widely used in many wireless communication systems, including WLAN (Wireless Local Area Network), Wi-Fi, Bluetooth, and RFID (Radio Frequency Identification) applications. Their small size, simplicity of manufacture, and omnidirectional emission pattern make them ideal for various uses. In WLAN and Wi-Fi networks, these antennas are extensively employed in access points, routers, and client devices to offer dependable wireless communication in homes, workplaces, and public places.

## 2. SIMULATION AND RESULTS

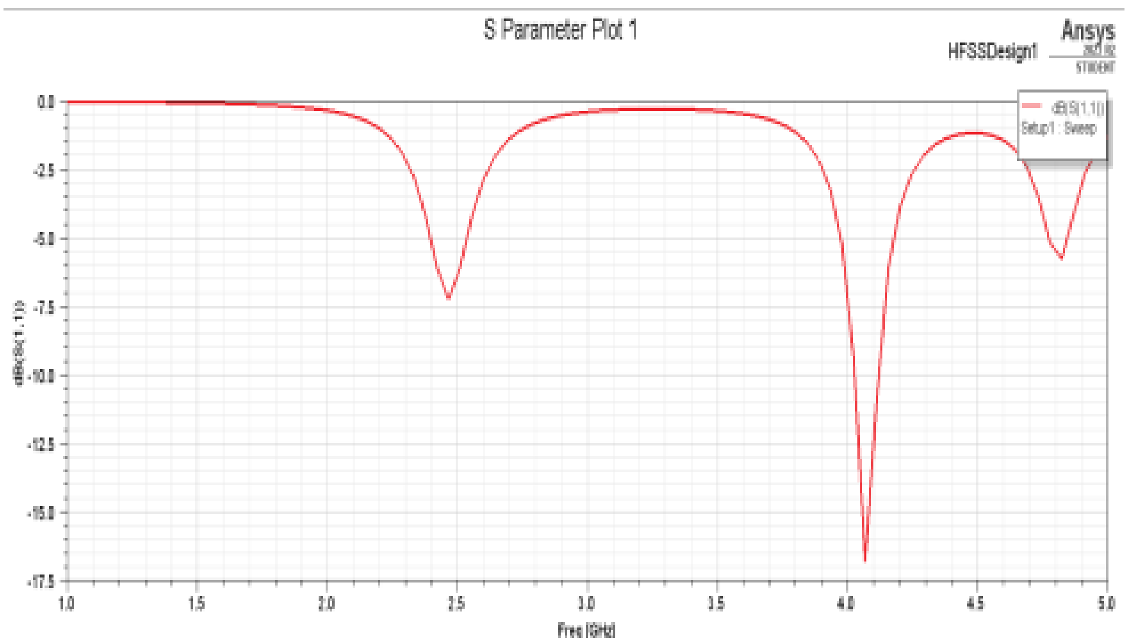



Fig 4 S11 Parameter of 1X1 Circular Patch

The S11 parameters varies with respective frequency from the range of 1GHz to 5GHz. The M1=2.4GHz, M2=4.1GHz and M3=4.8GHz

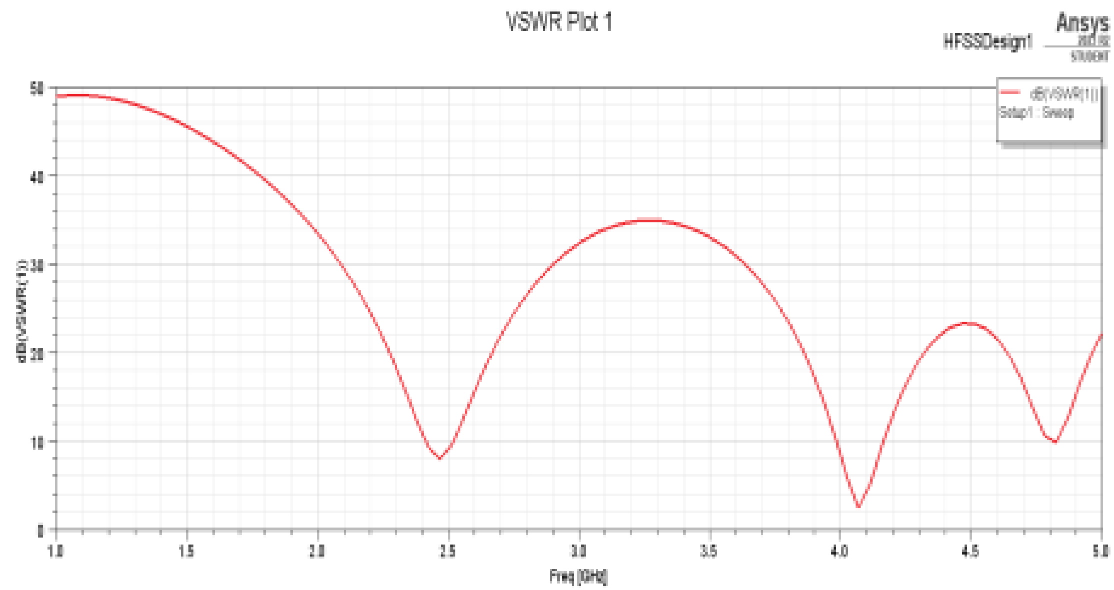



Fig 5 VSWR Plot of 1X1 Circular Patch

The VSWR varies with respective frequency from the range of 1GHz to 5GHz. The M1=2.4GHz, M2=4.1GHz and M3=4.8GHz

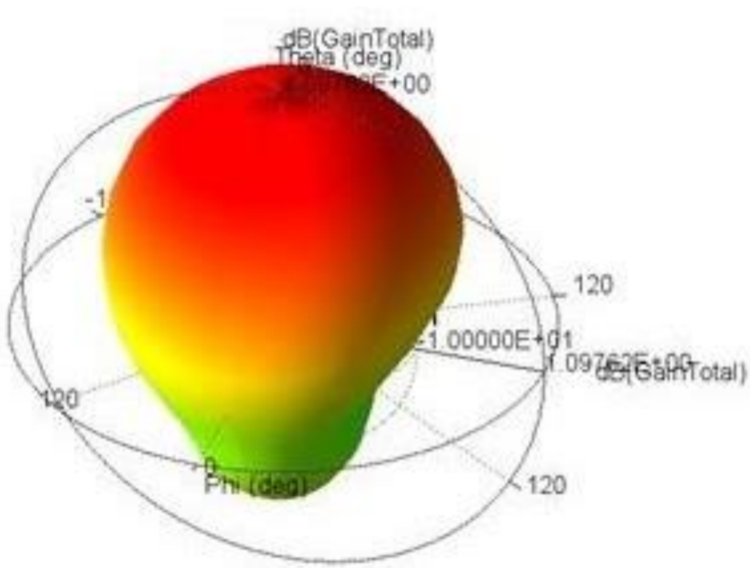



Fig 6

Gain plot of 1X1 circular patch antenna with has the Max gain of 1.10dB and Min gain of -21.63dB

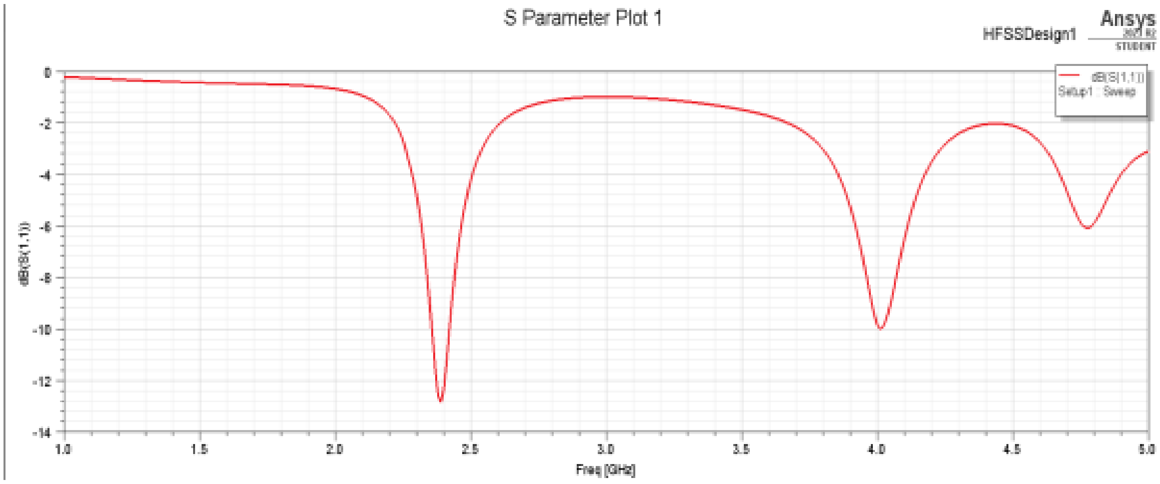



Fig 7 S11 Parameter of 2X1 Circular Patch

The S11 parameters varies with respective frequency from the range of 1GHz to 5GHz. The M1=2.4GHz, M2 =4.02GHz and M3=4.7GHz

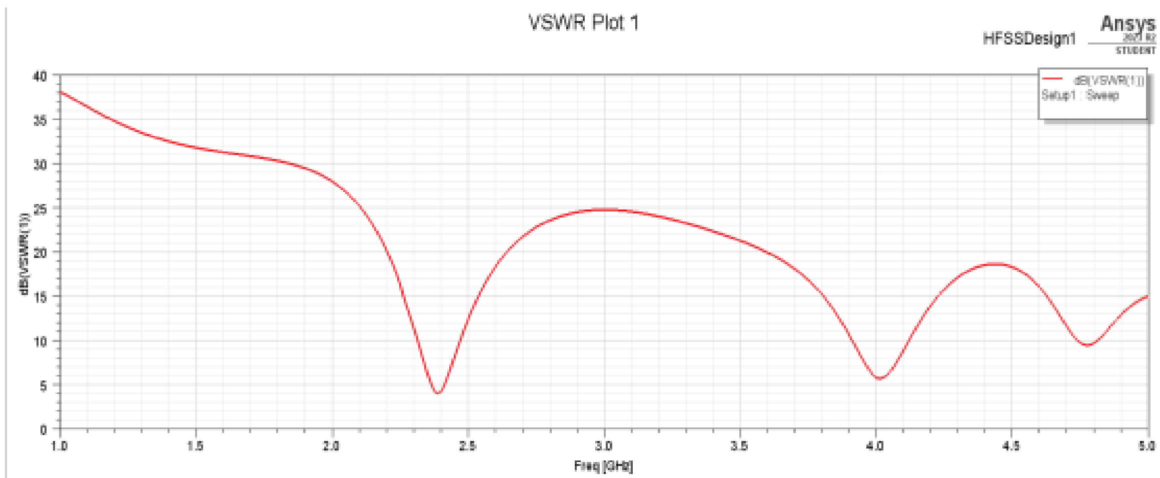



Fig 8 VSWR Plot of 2X1 Circular Patch

The VSWR varies with respective frequency from the range of 1GHz to 5GHz. The M1=2.4GHz, M2 =4.02GHz and M3=4.77GHz

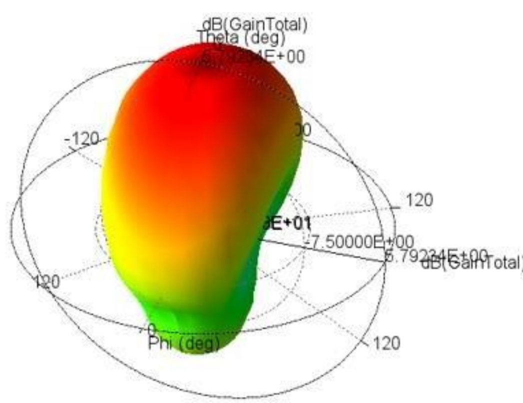



Fig 9 Gain plot of 2X1Circular Patch antenna Max gain of 5.79dB and Min gain of -24.26dB

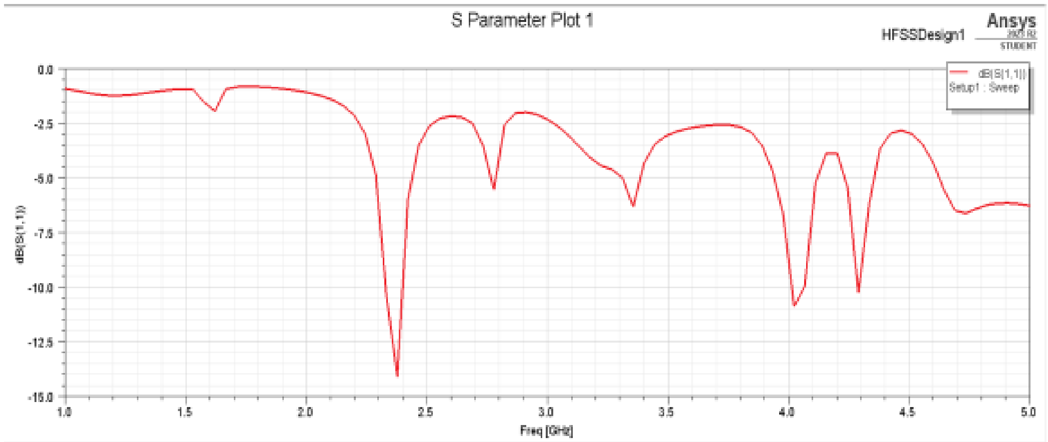



Fig 10 S11 Parameter of 4X1 Circular Patch Antenna

The S11 parameters varies with respective frequency from the range of 1GHz to 5GHz. The M1=2.4GHz, M2 =4.2GHz

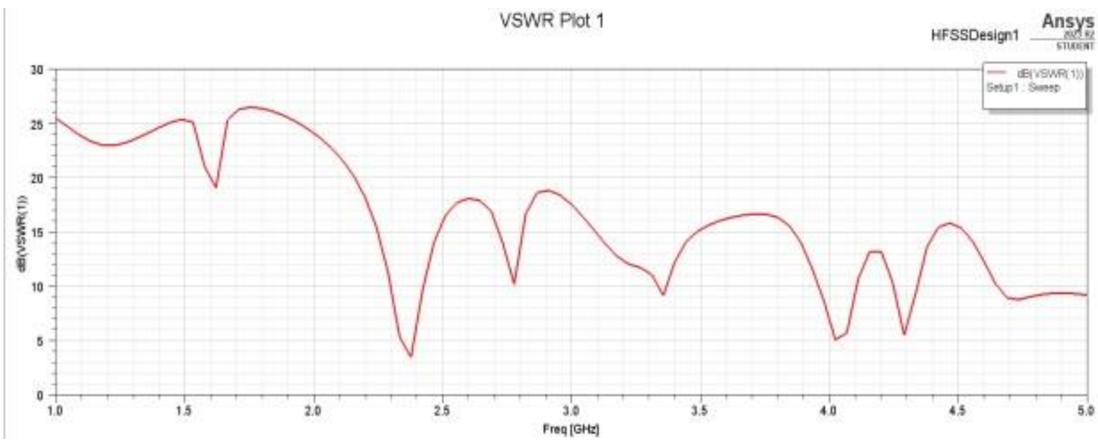



Fig 11 VSWR Plot of 4X1 Circular Patch Antenna

The VSWR varies with respective frequency from the range of 1GHz to 5GHz. The M1=2.4GHz, M2 =4.2GHz

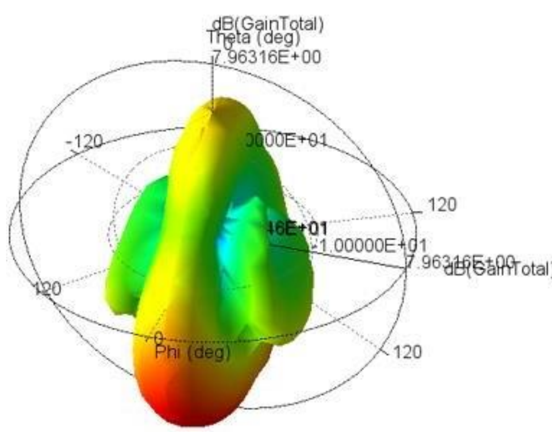



Fig 12 Gain plot of 4X1 circular patch array antennaMax gain of 7.96 dB and Min gain of -2

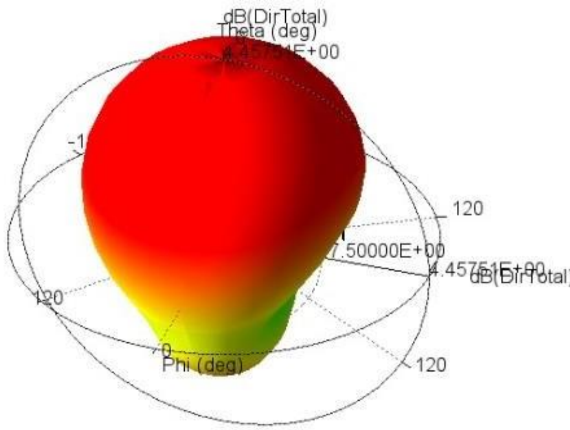



Fig 13 Directivity of 1X1 circular patch antenna of Max of 4.46dB and Min of -18.27dB8.88 dB

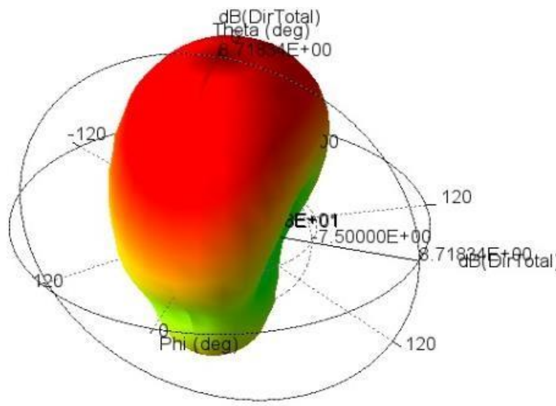



Fig 14 Directivity of 2X1 circular patch array antenna of Max of 8.72dB and Min of -21.33dB

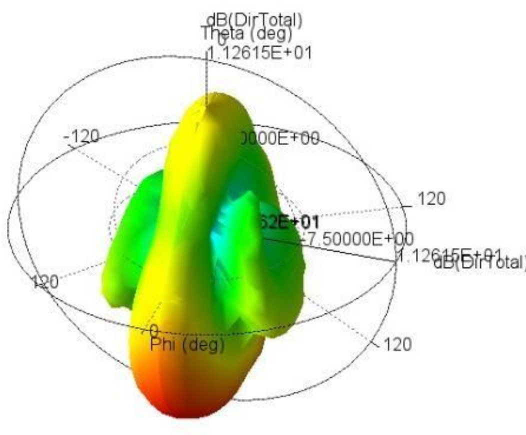



Fig 15 Directivity of 4X1 circular patch array antenna Max of 11.26 dB and Min of -25.59 dB

**TABLE 1.** Comparision Of 1x1, 2x1 And 4x1 Circular Patch Array Antennas Parameters

| Parameters | 1X1 | 2X1 | 4X1 |
|---|---|---|---|
| Min Gain | -21.63 | -24.26 | -28.88 |
| Max Gain | 1.10 | 5.79 | 7.96 |
| Peak System Gain | 0.89289 | 3.5696 | 5.415 |
| Max Directivity | 4.46 | 8.72 | 11.26 |
| Min Directivity | -18.27 | -21.33 | -25.59 |
| Peak Directivity | 2.7909 | 7.4445 | 13.371 |

## 3. CONCLUSION

This comprehensive research delves into the intricacies of circular patch array antennas customized specifically for 2.4GHz applications, investigating configurations spanning 1x1, 2x1, and 4x1. Leveraging advanced simulation techniques powered by the HFSS program, the study meticulously assesses critical performance metrics such as gain, directivity, and radiation pattern. By meticulously scrutinizing these parameters, the research provides indispensable insights aimed at optimizing design parameters to achieve heightened gain and enhanced directivity, thus marking significant advancements in the optimization of circular patch array antennas tailored for 2.4 GHz applications.The findings of this study hold immense importance for the field of antenna engineering, offering novel strategies and techniques to enhance the performance of circular patch array antennas. These antennas, characterized by their compact form factor, ease of fabrication, and omnidirectional radiation patterns, are indispensable components in various wireless communication systems. From Wireless Local Area Networks (WLAN) to Wi-Fi, Bluetooth, and Radio Frequency Identification (RFID) applications, circular patch array antennas play a pivotal role in ensuring dependable wireless communication across diverse environments and scenarios.Furthermore, this research contributes significantly to the ongoing evolution of high-performance antennas that are crucial for the seamless operation of modern wireless communication systems operating within the 2.4 GHz frequency band. By shedding light on the intricacies of circular patch array antenna design and optimization, this study paves the way for improved connectivity, efficiency, and reliability in wireless networks, thereby addressing the burgeoning demands of contemporary communication infrastructures.In conclusion, this research marks a noteworthy milestone in antenna engineering, underscoring the transition from rectangular to circular patch antennas in the realm of 2.4GHz applications. Through rigorous simulations and meticulous analysis, the study offers invaluable insights into the performance characteristics of circular patch array antennas, propelling the field forward and opening up new avenues for innovation and advancement.

## REFERENCES

[1]. Huang, J. H., W. J. Chang, and C. F. Jou, “Dual-band MIMO antenna with high isolation application by using neutralizingline,” Progress In Electromagnetics Research Letters, Vol. 48,15–19, 2014.

[2]. L. Verma, M. Fakharzadeh, Choi Sunghyun, "WifiOn Steroids: 802.11ac And 802.11ad", IEEE Wireless Communications, Vol. 20, No. 6, pp. 30-31, Dec 2013

[3]. R. Garg, P. Bhartia, I. Bahl, "Microstrip Antenna Design Handbook",Artech House, USA, 2001

[4]. G. A. Deschamps, "Microstrip microwave antennas", 3rd USAF Symposiumon Antennas, Oct 1953

[5]. C. A. Balanis, "Modern Antenna Handbook", 2nd Ed. Wiley, New York,2008

[6]. Muhsin Ali, Bilal A. Khawaja, Munir A. Tarar and Muhammad Mustaqim,“A Dual Band U-Slot Printed Antenna Array for LTE and WiMAXApplications”, Wiley Microwave and Optical Technology Letters, Vol. 55,No. 12, Dec 2013, pp. 2879- 2883

[7]. A. A. Razzaqi, M. Mustaqim, B. A. Khawaja, "Wideband E- shaped antennadesign for WLAN applications," 2013 IEEE 9th Int.Conf. on EmergingTechnologies (ICET), pp.1-6, Dec. 2013

[8]. J. H. Lu and B. J. Huang, “Planar compact slot antenna with multibandoperation for IEEE 802.16m application,” IEEE Trans. Antennas Propag.,vol. 61, no. 3, pp. 1411–1414, Mar 2013

[9]. L. Dang, Z. Y. Lei, Y. J. Xie, G. L. Ning, and J. Fan, “A compact microstripslot triple-band antenna for

WLAN/WiMAX applications," IEEE AntennasWireless Propag. Lett., vol. 9, pp. 1178–1181, Dec. 2010

[10]. W. Hu, Y. Z. Yin, P. Fei, and X. Yang, "Compact triband square-slotantenna with symmetrical L-Strips for WLAN/WiMAX applications," IEEEAntennas Wireless Propag. Lett., vol. 10, pp. 462–465, May 2011