IJCDS 1570994292

International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. #, No.# (Mon-20..)

# Modeling of Inscribed Dual Band Circular Fractal Antenna for Wi-Fi Application Using Descartes Circle Theorem

**SatheeshKumar Palanisamy[1,*], Anitha R Vaddinuri[2], Khalaf Ibrahim Osamah[3], Sameer Algburi[4]**

*[1]Department of ECE, BMS Institute of Technology and Management, Bengaluru India-5600064, satheeshp@bmsit.in*
*[2]Department of ECE, BMS Institute of Technology and Management, Bengaluru India-5600064, anithavr@bmsit.in*
*[3]Department of Solar, Al-Nahrain Research Center for Renewable Energy, Al-Nahrain University, Jadriya, Baghdad, Iraq. usama81818@nahrainuniv.edu.iq*
*[4]Al-Kitab University, College of Engineering Techniques, sameer.algburi@uoalkitab.edu.iq*

*Received ## Mon. 20##, Revised ## Mon. 20##, Accepted ## Mon. 20##, Published ## Mon. 20##*
**Corresponding author*

**Abstract-**
This study focuses on the modeling of a dual-band circular fractal antenna designed for Wi-Fi applications, utilizing the Descartes Circle Theorem. The antenna's geometry is characterized by self-similar fractal patterns, enabling enhanced performance in dual frequency bands relevant to Wi-Fi communication. Multi-frequency and Broadband Configurations: Current research is trending towards the development of antennas capable of operating across various Wi-Fi bands, and the emerging 6 GHz band. There is also a focus on achieving ultra-wideband functionality to cater to the requirements of future wireless technologies. Incorporation with Circuits and Systems: Ongoing efforts are directed at seamlessly integrating these antennas with RF circuits and communication systems to enhance their practical utility and applicability. Innovative Fractal Geometries and Optimization Approaches: The exploration of unconventional fractal shapes and the utilization of advanced optimization algorithms present promising avenues for enhancing antenna performance and achieving miniaturization. This research contributes to the advancement of compact and efficient antenna designs for wireless communication systems. Detailed considerations are given to the 2.4 GHz and 5.2 GHz bands to ensure compatibility with standard Wi-Fi protocols. The designed circular fractal antenna is compared with the conventional circular patch antenna and the results were analysed. At the resonating frequency of 2.4GHz and 5.4GHz, circular patch antenna has a reflection Coeffecient(S11) of -7.2817dB and -10.5186dB respectively with the gain of 4.0465dB, whereas, the designed circular fractal antenna shows a improved reflection S11 of-21.1737dB and -15.1494dB at the same resonating frequency with a gain of 11.7920dB. The radiation pattern shows that the antenna radiated in unidirectional pattern with the Front-to-back ratio of 101.4 which is higher than circular patch antenna. The miniaturized antenna is fabricated through photo etching process, tested and validated.

**Keywords:** Descartes, Fractal, Circle (DC) Theorem,Front-to-back ratio,

## 1. Introduction

There have been lot of design changes of patch antenna with thousands of publications relating to its design, analysis and optimization. Over the period new design concepts have been introduced for miniaturized design with multi band behaviour. One the most utilized application of antenna is for Wi-Fi application.

A fractal antenna offers superior enhancements when compared to antenna arrays. Some of the advantages of using fractals include increased bandwidth, the ability to operate on multiple bands, reduced size load, and the facilitation of optimal smart antenna technology. The utilization of fractal components results in 'fractal loading,' making the antenna smaller for a given operating frequency. Achieving a practical size reduction of 2-4 times while maintaining performance is feasible. Multiband behavior is evident at non-harmonic frequencies, with certain bands experiencing broadening. At higher frequencies, the Fractal Element Antenna (FEA) is inherently and extremely broadband and can achieve frequency independence without adhering to a log periodic geometry. Consequently, compact yet highly wideband FEAs are attainable.
It is analysed that the problem faced by the Apollonian circle is overcome by using DC theorem.

Enhancing the antenna gain involves the creation of an L slot on the bottom ground plane [24]. The use of Coplanar Waveguide (CPW) enhances compatibility with compact wireless communication devices. A microstrip antenna array is designed with an Electromagnetic Band Gap (EBG) structure to improve reflection Coeffecient(S11), directivity, and gain at a frequency of 5.85 GHz [4].

The antenna design incorporates circular fractal patterns, utilizing self-similarity to enhance performance characteristics. The chosen geometry facilitates dual-band functionality.
Through a parametric analysis involving the manipulation of key parameters such as the number of iterations, scaling factor, and feed position, researchers fine-tune the antenna

design to achieve the desired resonant frequencies and bandwidths. After optimization in simulation, the antenna prototypes are created on appropriate substrates, and their real-world performance is assessed using network analyzers and antenna chambers to corroborate the simulation outcomes.

**Literature Works:**

A Fractal Ultra-Wideband (UWB) Antenna with Circular Geometry and Band Rejection Capability Utilizing the Descartes Circle Theorem[31]. This research introduces a Circular Fractal Ultra-Wideband (UWB) Antenna constructed through the application of the Descartes Circle Theorem. The antenna exhibits broad frequency coverage extending beyond the Wi-Fi spectrum, and it incorporates a mechanism for rejecting undesired frequency bands. This highlights the adaptability and versatility of the proposed approach.

Fractal Slot Antenna with Irregular Circular Geometry for Dual Wideband Applications. [30]. This study introduces a Fractal Monopole Antenna fed by Coplanar Waveguide (CPW), featuring irregular circular shapes derived from the Descartes Circle Theorem. The antenna demonstrates dual wideband properties, effectively covering the 2.4 GHz and 5.2 GHz Wi-Fi bands while maintaining stable radiation patterns.

Fractal Antenna with Altered Half-Circle Geometry Utilizing the Descartes Circle Theorem for WLAN Applications at 2.4/5.2 GHz[29]. This article introduces a circular fractal antenna created through the utilization of the modified half-circle shape derived from the Descartes Circle Theorem. The design accomplishes dual-band operation with commendable impedance matching and stable radiation patterns in both the 2.4 GHz and 5.2 GHz frequency bands.

In 2003, Wang et al. [26] unveiled a UWB monopole antenna featuring a coaxial probe feed that integrated a shorted square patch with a monopole and rectangular ground plane. Concurrently, Daviu et al. [27] proposed a planar monopole antenna with a double feed, employing a modified feeding structure in the same year. Nevertheless, the double feed had adverse effects on polarization properties and impedance bandwidth performance. To remedy this, the bandwidth was enhanced by introducing bevels to the lower corners of the radiating patch.

In 2004, Su et al. [28] broadened the bandwidth of a square monopole antenna fed by a coaxial probe by introducing rectangular notches at the lower two corners of the patch. Ammann and Chen [29] suggested a method for augmenting the bandwidth of a square monopole antenna by shifting the feeding position away from the center of the patch. This asymmetrical feeding not only reduced the E-plane null but also resulted in slight offsets in the H-plane patterns.

On a different front, Rikuta and Kohno [30] presented four configurations of UWB planar monopole antennas utilizing a dual-frequency square monopole patch. In the initial configuration, two rectangular patches were connected by a shorting pin, while in the second configuration, the upper patch was replaced by a wire monopole. The remaining two configurations involved connecting the first antenna configurations orthogonally, leading to a lower resonance shift towards lower frequency as the antenna size increased.

## 2. FRACTAL ANTENNA DESIGN

### *A. DESIGN EQUATION OF FRACTAL PATCH, SUBSTRATE AND GROUND*

The thickness of the substrate depends on the resonant frequency of an antenna that determines the gain of an antenna. The thickness of the substrate is chosen within the range of $0.003\lambda_0 < h < 0.05\,\lambda_0$ [19].

$$\lambda_0 = C/f_r,$$

Where C is velocity of light = $3 \times 10^8$

$f_r$ is resonant frequency.

For the frequency of 2.4GHz, the thickness of substrate be 1.6mm. The relative permittivity is a parameter which varies depends on the substrate material used. The material used is depends on application of antenna. The dielectric constant $\epsilon_r = 4.4$ for FR4 material has been chosen. Length ($L_{sub}$) and Width ($W_{sub}$) of the substrate should be [19]

$$L_{sub} = 6h + L,$$
$$W_{sub} = 6h + W$$
$$L_{eff} = L + 2\Delta L \qquad (1)$$

$L_{eff}$ is effective length.

$$W = \frac{c}{2 f_r \sqrt{\frac{\epsilon_r + 1}{2}}} \qquad L = \frac{c}{2 f_r \sqrt{\epsilon_{eff}}}$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\left(\frac{1}{2}\right)} \qquad (2)$$

Fig.1 shows the flowchart of designing and analysing the circular fractal antenna

**Design:**

**Specify Requirements:** Clearly outline the desired operating frequencies, bandwidth, gain, radiation pattern, and size limitations.

**Choose Fractal Geometry:** Opt for a circular fractal shape based on methods such as the Descartes Circle Theorem. Examples include circular Sierpinski carpets, spirals, or Koch snowflakes.

**Parameterize the Design**: Define crucial parameters like the number of iterations, scaling factor, and feed position. Utilize these parameters to control the antenna's size and resonant frequencies.

International Journal of Computing and Digital Systems
ISSN (2210-142X)
Int. J. Com. Dig. Sys. #, No.# (Mon-20..)

**Modeling and Simulation:** Utilize HFSS, to construct an antenna model and assess its performance through parameters like S-parameters, radiation patterns, and gain.

**Parametric Optimization:** Iterate on the design parameters guided by simulation results, striving to attain the intended performance characteristics. This might involve employing optimization algorithms.

**Analysis:**

**Examine Simulation Results:** Scrutinize S-parameters (reflection coefficient, return loss) to ensure appropriate impedance matching at the target frequencies. Evaluate radiation patterns for directivity and gain across the desired bands.

**Validate with Measurements**: Construct a prototype of the optimized antenna on a suitable substrate (e.g., FR4, Rogers Duroid). Measure its S-parameters and radiation patterns using network analyzers and antenna chambers to compare with simulation results.

**Performance Verification:** Confirm if the measured performance aligns with the design objectives. If not, refine the design and repeat the analysis process.

The theoretical formula for calculating radius of the circular patch antenna is given by

$$a = \frac{F}{\left\{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \qquad (3)$$

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

Where F is fractal constant [1].

The Descartes circle theorem asserts that when four circles are tangent to each other in the plane, with non-overlapping interiors, their curvatures follow a specific relationship, $b_j = 1/a_j$ satisfy the relation

$$(b_j + b_{j+1} + b_{j+2} + b_{j+3})^2 = 2(b_j^2 + b_{j+1}^2 + b_{j+2}^2 + bj+3^2).$$

Where $a_j$is a radius and j is Number of iterations.

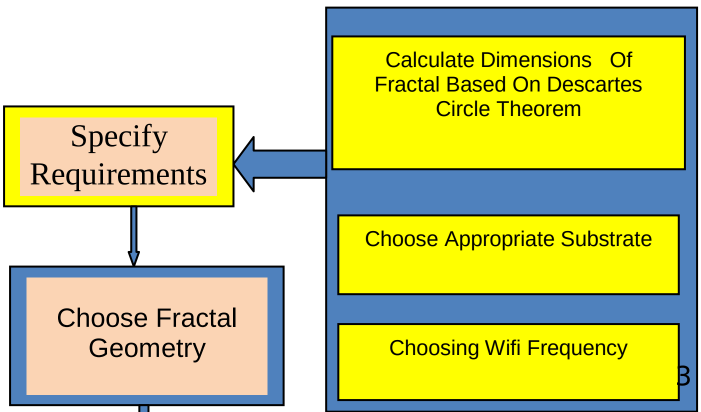


Figure 1: Flowchart for antenna design.

A. *Complex Descartes Circle Theorem*

In a Descartes configuration involving four circles mutually tangent to each other, their curvatures adhere to the relationship specified in [11].

$$\left(\sum_{i=1}^{4} b_i\right)^2 = 2\left(\sum_{i=1}^{4} b_i^2\right)$$

$$\therefore\ b_i = \frac{1}{r_i} \qquad (4)$$

Any arrangement of four circles that are mutually tangent, following Descartes' configuration, with curvatures represented by aj and centers denoted as $z_j = x_j + i*yj$, meets the specified conditions[11].

$$\left(\sum_{i=1}^{4} b_i z_j\right)^2 = 2\left(\sum_{i=1}^{4} (b_i z_j)^2\right) \qquad (5)$$

$$\therefore\ Z_j = X_j + Y_j$$

Where $Z_j$ is circle centre position represented in complex form.

The curvature, assuming a normal pointing outward (r = -1), is determined on the premise that the original circular aperture represents a unit circle.

During the self-similar design iteration with i = 1, the radii of the three identical inner circles [18], portrayed in Figure 2, are determined through the application of equation 6 and showcased as.

$$r_{d1} = r_{c1} = r_{b1} = 6/\,(6+4\sqrt{3}) \qquad (6)$$

Utilizing the Descartes Circle Theorem, curvatures for the initial four circles are calculated, and Table 1 is generated to encompass approximately five iterations.

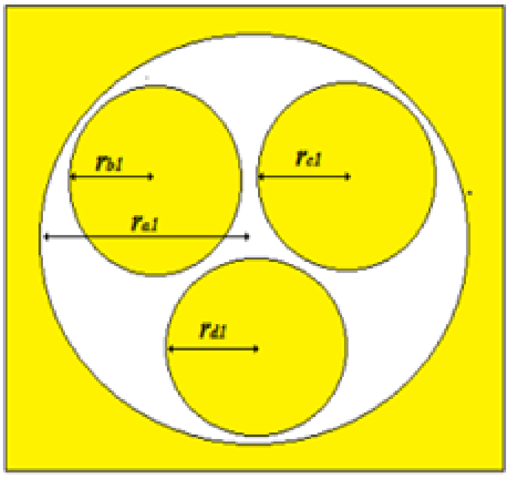


Fig. 2 Initial Iteration of the proposed fractal antenna

During the second phase, the radii of five circles are determined based on the initial four circles established in the first stage.

$$f_j^i = a_j + b_j + c_j + 2\sqrt{a_j b_j + b_j c_j + a_j c_j} \qquad (7)$$

Where, $f_j^i$ is the radius of second iterative circles,

Table 1: Radius and Position of fractal by DC theorem

| Circle | Radius | Curvature | Position |
|---|---|---|---|
| 1 | 4.32 | 231.48 | (15,20,1.6) |
| 2 | 5.236 | 190.98 | (25,25,1.6) |
| 3 | 5 | 200 | (15,30,1.6) |
| 4 | 0.7335 | 1339.32 | (10,15,1.6) |
| 5 | 1.3 | 769.2 | (5,25,1.6) |
| 6 | 2.82 | 231.17 | (22,14,1.6) |
| 7 | 2 | 496 | (24,36,1.6) |
| 8 | 2.8 | 500.46 | (24,16,1.6) |

Where circle 1, 2 and 3 were parent circles. Using the parent circles as base, the 4th circle's radius and position were computed using Descartes Equation. For 2nd iteration, 5th circle's radius and position were computed using the base circles 2, 3 and 4. These steps were repeated by changing the base circle. The iteration process has been repeated till obtaining the desired results.

## B. RESULTS AND DISCUSSION

The paper discusses various performance metrics, including but not limited to bandwidth, reflection Coeffecient(S11), and directivity. These metrics are crucial for evaluating the efficiency of the proposed antenna design in practical Wi-Fi scenarios. Rigorous simulations and modeling are conducted to validate the proposed design. Advanced tools and techniques are employed to analyze the antenna's behavior and performance under different conditions. Figure 3 shows the top view of simple circular patch antenna which was designed in HFSS 13.0 software for the frequency of 2.4GHz and 5.4GHz. The feeding techniques used in the antenna is line feed and the excitation used is wave port excitation. The circular patch and the line fed were united. The ground plane and the patch were made of copper material. The boundary is considered to be an air medium.

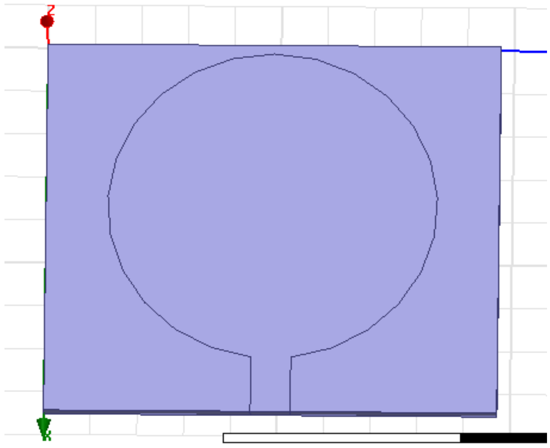

Fig.3 : Circular patch antenna design gemotery

### *A. Circular Fractal design:*

The top view of the proposed circular fractal antenna is shown in the Figure 4. The antenna was designed for the frequencies of 2.4GHz and 5.4GHz using the Descartes circle theorem. The excitation used is wave port excitation and the feeding techniques used in the antenna is line feeding. The substrate material used is FR4 which has the dielectric constant of 4.4. The ground plane and the patch were made of copper material. The boundary is consider to be an air medium.

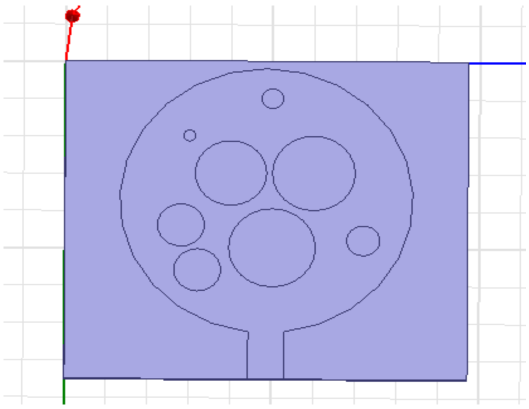

Figure 4: Circular fractal antenna design gemotery

### *B. Circular patch-Reflection Coeffecient($S_{11}$) Analysis*

The paper presents comprehensive results obtained from simulations, comparing them against desired specifications. The discussion interprets the findings, highlighting the effectiveness of the dual-band circular fractal antenna in Wi-Fi applications. The Figure 5 shows the reflection Coeffecient(S11) of the circular patch antenna. At 2.4GHz and 5.4GHz, the reflection Coeffecient(S11) is -7.28dB and -10.51dB respectively. Practically the reflection Coeffecient(S11) should be lesser than -10dB. Hence circular patch has less gain.

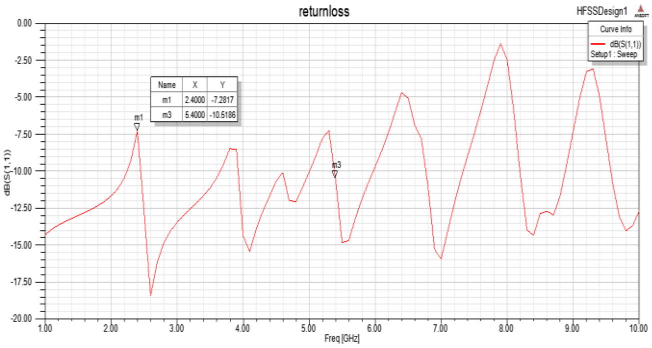


Fig. 5 Reflection Coeffecient($S_{11}$) for circular patch antenna.

*C. Circular Fractal patch-Reflection Coeffecient($S_{11}$) Analysis*

The Figure 6 shows the reflection Coeffecient($S_{11}$) for circular fractal antenna. The antenna has maximum reflection Coeffecient(S11) of -20.5549dB and -15.1494dB at frequencies 2.4GHz and 5.4GHz respectively. It depicts that the antenna operates at multiple frequencies and can be used for the Wi-Fi application. The reflection Coeffecient(S11) is also maximum at some other frequencies also and these are consider as harmonic frequency.

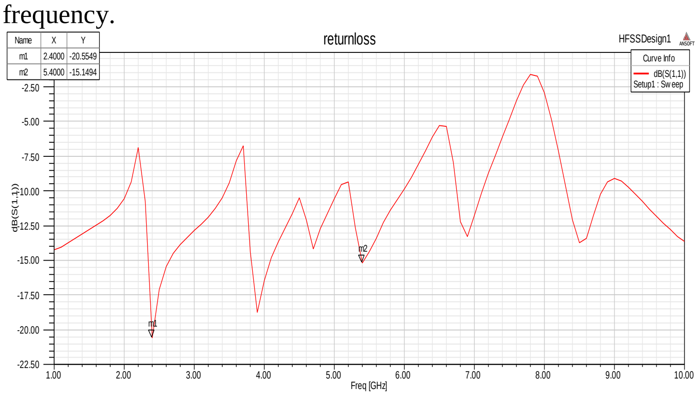


Figure 6 Reflection Coeffecient(S11) for circular fractal antenna.

*D. Circular patch-VSWR Analysis*

The Figure 7 shows the VSWR (Voltage Standing Wave Ratio) for circular patch antenna. The VSWR should be minimum of 1 for the best case and for worst case it should be ∞. Practically the VSWR should be maximum of 2. At 2.4GHz and 5.4GHz, the VSWR is 6.36 and 3.417 respectively. It seems that the antenna can't be operated effictively at 2.4GHz and 5.4GHz. Hence, the antenna couldnot be used for Wi-Fi application.

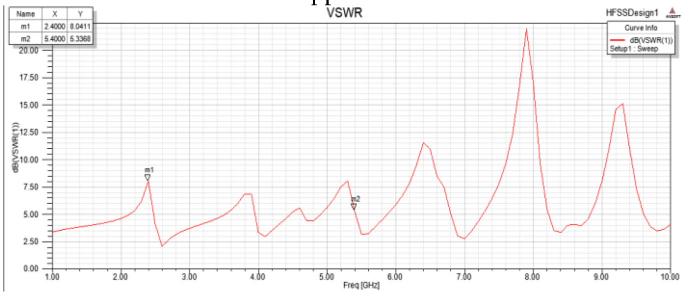


Figure7: VSWR of circular patch antenna.

*E. Circular Fractal patch- VSWR Analysis*

The Figure 8 shows the VSWR of circular fractal antenna. At 2.4GHz and 5.4GHz, the VSWR is 1.45 and 1.791. On compared to circular patch, circular fractal antenna has minimum VSWR. Hence, the reflected signal in the input port is minimum and hence the gain is maximum.

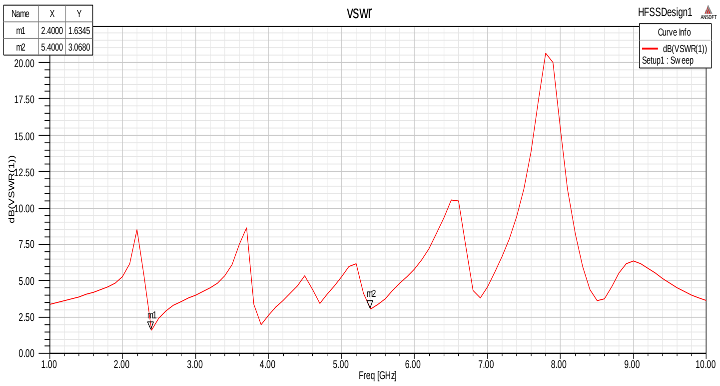


Figure 8 VSWR of circular fractal antenna.

*F. Circular patch -Output Impedance Analysis*

The Figure 9 shows the output impedance of the circular patch antenna. Basically, the antenna output impedance should be 1+1j or 50Ω. At 2.4GHz and 5.4GHz the antenna impedance is 1.8932-0.9716j and 1.0842-0.6644j respectively. It seems that the reactance part of the impedance is capacitive.

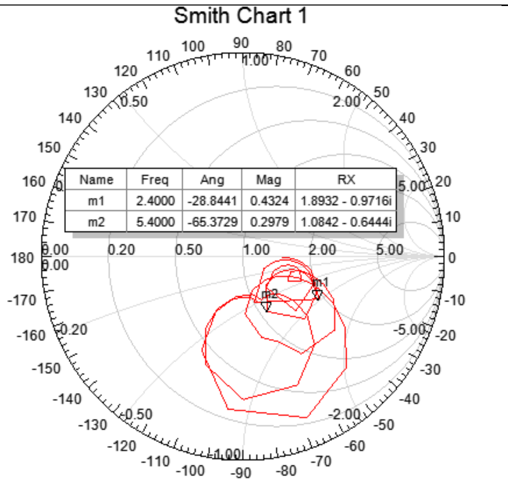


Figure 9 Output impedance of circular patch antenna.

### G. *Circular Fractal patch -Output Impedance Analysis*

The Figure 10 shows the output impedance of the circular fractal antenna. At 2.4GHz and 5.4GHz the impedance of the antenna is 1.1481-0.1022j and 1.2913-0.1959j respectively. By comparing cirular patch and circular fractal antenna, fractal antenna has impedance nearer to unity. Hence, the fractal antenna has self impedance matching property.

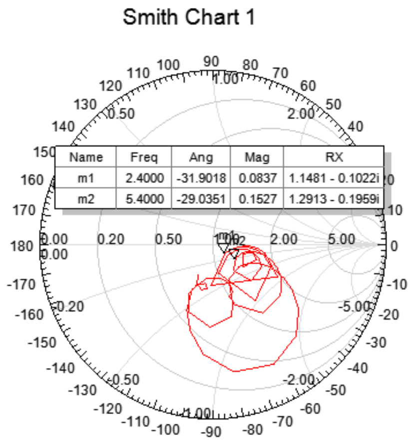


Figure 10: Output impedance of circular fractal antenna.

### H. *Circular Fractal patch - Radiation Pattern Analysis*

The Figure 11 shows the radiation pattern of circular fractal antenna. It depicts that the antenna radiate in unidirectional pattern and some of them radiated at back which is called side lobes. The front to back ratio for circular patch antenna is 101.2. the centre axis in radiation pattern is known as beam axis. At 0˚ of the beam axis, the gain is 11.7920. By compared to circular patch antenna, circular fractal antenna has high gain and front to back ratio. The HPBW (Half Power Band Width) of the antenna is 100˚ and the directivity of the antenna is also higher than circular patch.

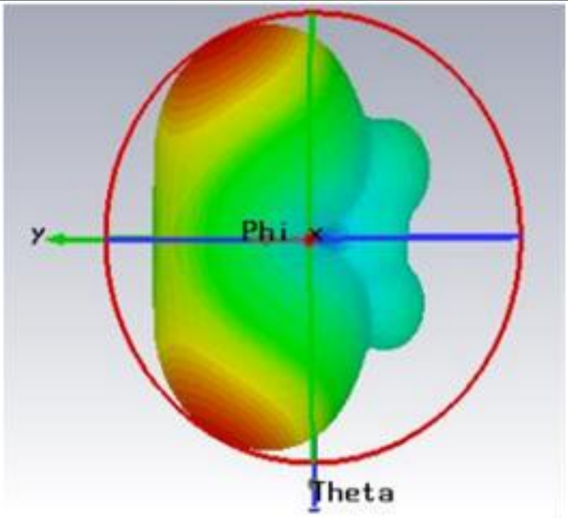


Figure 11: Radiation pattern for circular Fractal patch antenna.

## I. *RESULTS AFTER FABRICATION*

The fabricated antenna was tested using Vector Network Analyzer and analyzed reflection Coeffecient(S11), VSWR and output Impedance for both the circular patch and circular fractal antenna. The Figure 12 and Figure 13 shows the fabricated circular patch and fractal antenna.

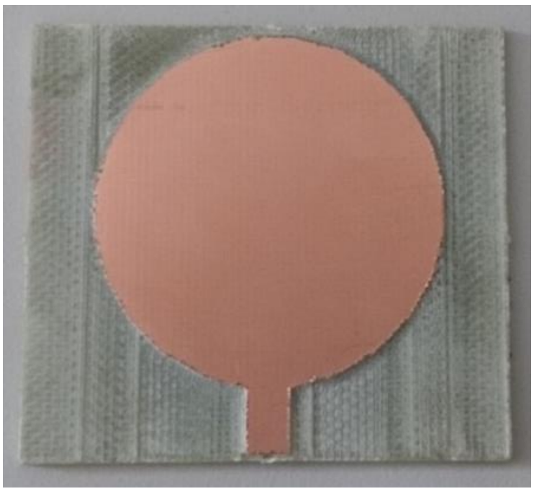

Figure 12: Fabricated circular patch antenna(Top View)

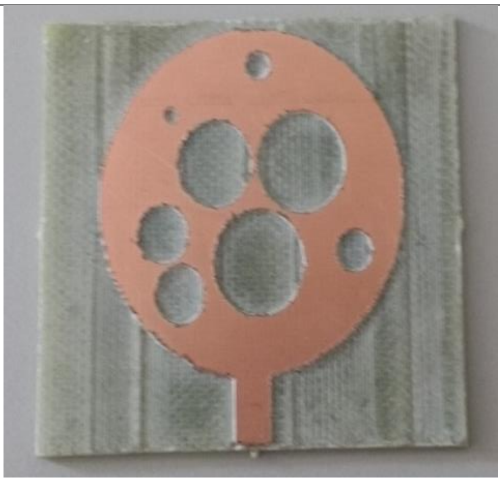

Figure 13: Fabricated circular fractal antenna(Top View)

From the Figure 14, it is analyzed that at 2.6GHz the antenna has a reflection Coeffecient(S11) of -30.004dB. The results obtained is greater than the simulation results, but the ripples in the stop band or other frequencies are greater. It means that the antenna can't operate only at 2.4GHz but also operate at someother frequencies also. Hence, practically this antenna can't be used for Wi-Fi application.

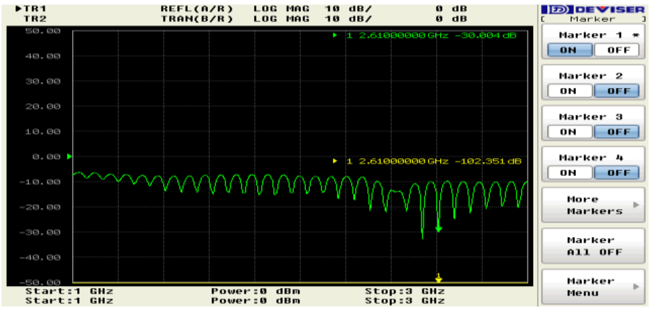

Figure 14: Reflection Coeffecient(S11) for circular patch antenna.

*Fabricated Circular Fractal patch -Reflection Coeffecient(S11) Analysis*

From the Figure 15, the reflection Coeffecient(S11) for fractal antenna is -12.2637dB and -28.7346dB at 2.44GHz and 5.3GHz respectively. It's reflection Coeffecient(S11) is greater than simple circular patch antenna. Also, the ripples at other frequencies are toosmall than simple patch antenna. Hence, the fractal antenna has high gain then circular patch and can be used for Wi-Fi application.

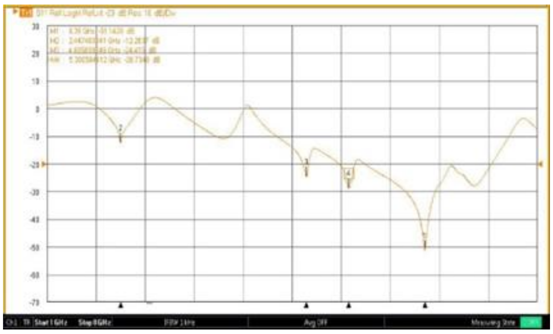

Figure 15: Practical Reflection Coeffecient(S11) for circular fractal antenna.

From the Figure 16, the VSWR at 2.4GHz is 1.53theoretical value of VSWR at 2.6GHz is 1.2387. Practically the value of VSWR should vary from 1 to 2. Hence this antenna can be used for the frequency 2.6GHz but not for Wi-Fi application.

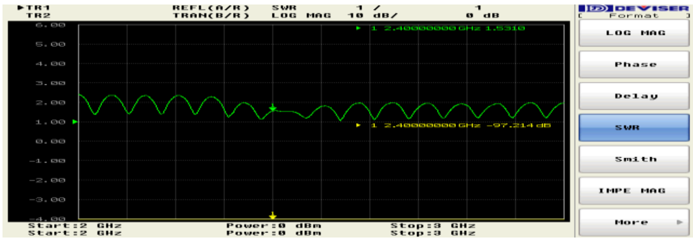

Figure 16: VSWR for circular patch antenna.

*Fabricated Circular Fractal patch- VSWR Analysis*

From the Figure 17, the VSWR for fractal antenna is 1.016. the ideal value of VSWR should be 1. The fractal antenna has VSWR nearly equal to 1. Hence fractal has high efficiency then simple patch antenna.

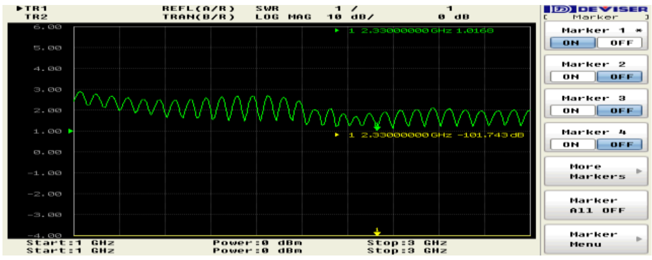

Figure 17: VSWR for circular fractal antenna.

*Circular patch-Output Impedance Analysis*

From the Figure 18, the antenna output impedance is 44.3Ω and 3pF capacitor at 2.4GHz. For ideal antenna, the characteristics impedance should be 50Ω.

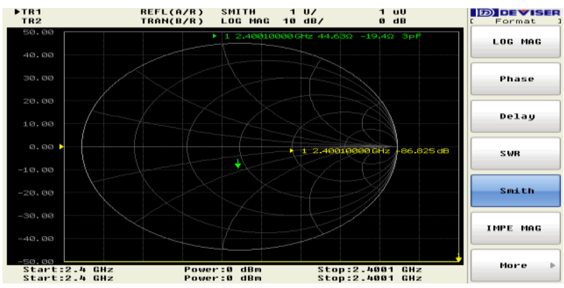

Fig. 18 Practical output impedance of circular patch antenna.

*Circular Fractal patch- Output Impedance Analysis*

The output impedance of fractal antenna is 56Ω and 129pH inductor at 2.4GHz. By comparing fractal and simple patch, fractal has good impedance matching, less VSWR and high reflection Coeffecient(S11). From the fabricated results, fractal antennas are good and enough for practical application.

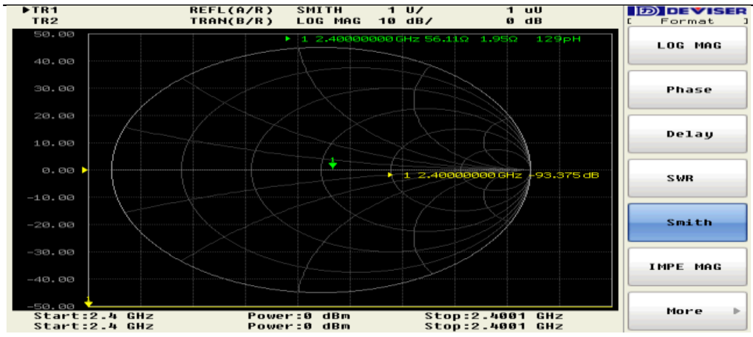


Figure 19: Practical output impedance of fractal antenna.

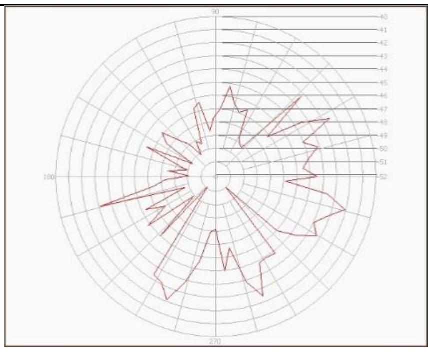

Figure 20 Radiation pattern of fabricated fractal antenna.

The Figure 20 shows the radiation pattern of fabricated circular fractal antenna. It is measured with respect to isotropic antenna. The pattern is more similar to the simulated antenna results. The front to back ratio of the antenna is 119.04. The antenna measured the pattern for every 0.5˚ angle with respect to isotropic antenna. The isotropic antenna used for the gain measurement have gain of 60dBi and the gain of AUT obtained is -42dB. The gain of the antenna is measured by using below formula,

Gain (dBi) = Gain of isotropic antenna + Gain of AUT.
= 60dBi + (-42dB) = 18dB.

From the three parameters analyzsed in VNA for circular patch, it is understand that the antenna can be used for the frequency range 2.5- 2.6GHz with VSWR 1.53. To improve gain of an antenna, self impedance matching and to get frequency at 2.4GHz and low profile of an antenna, circular fractal antenna were designed using DC theorem. The designed DC therem based Circular Patch Fractal Antenna earned better results, as shown the comparison table.2

**COMPARITIVE ANALYSIS OF CIRCULAR PATCH AND CIRCULAR FRACTAL ANTENNA**

Table 2: Comparison of simple patch and fractal antenna.

| **PARAMETER** | **CIRCULAR PATCH ANTENNA (in simulation)** | **CIRCULAR FRACTAL ANTENNA (in simulation)** | **CIRCULAR PATCH ANTENNA (in hardware)** | **CIRCULAR FRACTAL ANTENNA (in hardware)** |
|---|---|---|---|---|
| Reflection Coeffecient(S11) | -7.28dB at 2.4GHz<br>-10.51dB at 5.4GHz | -20.55dB at 2.4GHz<br>-15.14dB at 5.4GHz | -30dB at 2.33GHz | -12.26dB at 2.4GHz<br>-28.73dB at 5.3GHz |
| VSWR | 6.36 at 2.4GHz<br>3.417 at 5.4GHz | 1.45 at 2.4GHz<br>1.791 at 5.4GHz | 1.53 at 2.33GHz | 1.29 at 2.4GHz<br>1.08 at 5.3GHz |
| Impedance | 1.8-0.97j at 2.4GHz<br>1.08-0.6j at 5.4GHz | 1.1-0.1j at 2.4GHz<br>1.2-0.19j at 5.4GHz | 44.63+120j | -18.9+49.9j at 2.4GHz<br>50.9+36.4j at 5.3GHz |
| Gain | 4.04dB | 11.792dB | - | - |
| Front to back ratio | 94.75 | 101.4 | - | - |
| Bandwidth % | 21 | 36 | 19.8 | 35 |

Based on the observations, it is evident that all designs resulted in dual-band and wideband characteristics. Notably, employing a cut as an additional measure to achieve wideband functionality proved to be an effective solution. This improvement is reflected in the bandwidth efficiency, which increased from 21% at the third stage to 35% for the circular patch design and further to 55.9% for the circular fractal at the first frequency. However, it is worth noting that in both cases, the disparities between gain and directivity were not substantial.

## C. CONCLUSION

The paper discusses the significance of the proposed design in the context of Wi-Fi applications and potential applications in wireless communication systems. The application of the Descartes Circle Theorem proves to be a valuable resource in the creation of dual-band circular fractal antennas tailored for Wi-Fi applications. The examined studies underscore the efficacy of this method in attaining target operating frequencies, bandwidths, and radiation characteristics. Future avenues of research are geared towards broadening the capabilities of these antennas to encompass wider bandwidths, multi-band operation, and seamless integration with real-world systems. A circular patch antenna was simulated for the frequency of 2.4GHz and 5.4GHz using HFSS 13.0. It has a reflection Coeffecient(S11) ($s_{11}$) of -7.2817dB and -10.5186dB at the frequency 2.4GHz and 5.4GHz respectively with the gain of 4.0465dB. In order to improve the gain and reflection Coeffecient(S11) of an antenna, to achieve low profile and for self-impedance matching, a circular fractal antenna using Descartes Circle theorem were designed. The simulated results has a reflection Coeffecient(S11) of -21.1737dB and -15.1494dB at the frequency of 2.4GHz and 5.4GHz respectively with a gain of 11.7920dB. The antennas were fabricated using PCB prototype machine and tested using VNA. The fabricated antenna has the reflection Coeffecient(S11) of -12.2637dB and -28.7346dB at 2.44GHz and 5.3GHz respectively for circular fractal antenna. It is analyzed that the obtained results for circular fractal antenna has high gain and reflection Coeffecient(S11) than the circular patch antenna. The future scope of the project is to remove the harmonic frequencies using band stop filter.

The report introduces compact, multi-band circular fractal designs as a noteworthy alternative to conventional antenna systems in mobile wireless receivers. Despite the various research efforts by scholars in the field of electrical engineering, fractional antenna technology remains at an early stage, with limited existing literature. The study's findings indicate promising research opportunities in the realm of antenna configuration. Consequently, the researcher proposes that future investigations should explore integrating reusable technology to enhance the adaptability of antennas, allowing seamless switching to the desired operating range.

## IV. REFERENCES

[1]. Anil Kumar Gupta, Shardanand Prabhakar, Priyanka Usha (2015), "A Multiband Modified Circle Fractal Antenna for wireless Applications", International Journal of Engineering Research and General Science vol.3, Issue 3, pp. 22-26.
[2]. Balanis. C.A, John Wiley and Sons Inc, Hoboken (2005), "Antenna Theory Analysis and Design", IEEE Microwave and Wireless Components Letters, vol. 16, No. 4, pp. 224-226.
[3]. Baliarda. C, Romeu. J, Pous. R, and Cardama. A (1998), "On the behaviour of the Sierpinski multiband fractal antenna," IEEE Trans. Antennas and Propagation, vol. 46, pp. 517–524.
[4]. Behera. S. K, Sujeet Rai, Yogesh Kumar (1996), "Modified Half-Circle Fractal Antenna Using DC Theorem for 2.4/5.2 GHz WLAN Application", IEEE Trans. Antennas and Propagation, vol.32, pp. 213-259.
[5]. Borau, C. B, Rodero. M. N, and Robert. J. R (2000), "An iterative model for fractal antennas: Application to the Sierpinski gasket antenna," IEEE Trans. Antennas and Propagation, vol. 48, pp. 713–719.
[6]. Gursimranjit Singh and Amanpreet Kaur (2014), "A Review Paper on Fractal Antenna Engineering", IJAREEIE, vol. 3, Issue 6, pp. 318-323.
[7]. Heinz-Otto Peitgen, Hartmut Jürgens, Dietmar Saupe (2004), "Chaos and Fractals", New York, 2nd edition.
[8]. Jeffrey C. Lagarias, Colin L. Mallows, Allan R. Wilks (2002), "Beyond the Descartes Circle Theorem", IEEE antenna and Propagation, vol. 109, pp. 102- 107.
[9]. Iqbal Jebril & P. Dhanaraj & Ghaida Muttashar Abdulsahib & SatheeshKumar Palanisamy & T.Prabhu & Osamah Ibrahim Khalaf, 2022. "Analysis of Electrically Couple SRR EBG Structure for Sub 6 GHz Wireless Applications," Advances in Decision Sciences, Asia University, Taiwan, vol. 26(Special), pages 102-123, December.
[10]. E. Suganya, T. Prabhu, Satheeshkumar Palanisamy, Praveen Kumar Malik, Naveen Bilandi, Anita Gehlot, "An Isolation Improvement for Closely Spaced MIMO Antenna Using λ/4 Distance for WLAN Applications", International Journal of Antennas and Propagation, vol. 2023, Article ID 4839134, 13 pages, 2023. https://doi.org/10.1155/2023/4839134.
[11]. Xue, X.; Shanmugam, R.; Palanisamy, S.; Khalaf, O.I.; Selvaraj, D.; Abdulsahib, G.M.A Hybrid Cross Layer with Harris-Hawk-Optimization-Based Efficient Routing for Wireless Sensor Networks. Symmetry 2023, 15, 438.https://doi.org/10.3390/sym15020438.
[12]. Jiang W. and W. Che (2012), "A novel UWB antenna with dual notched bands for WiMAX and WLAN applications", IEEE antenna and Wireless Propagation Letters, vol. 11, pp. 621- 628.
[13]. Kwaha. B. J, Inyang. O. N, Amalu. P (2011), "The Circular Microstrip Patch Antenna – Design and Implementation", IJRRAS, vol.8, Issue 1, pp. 270- 276.
[14]. Liang P. Li, J, and X. Chen (2006), "Study of printed elliptical/circular slot antennas for ultra wide-band applications," IEEE Trans. Antennas Propag., vol. 54, no. 6, pp. 670-675.
[15]. AngurajKandasamy, SaravanakumarRengarasu, Praveen KittiBurri, SatheeshkumarPalanisamy, K. Kavin Kumar, Aruna Devi Baladhandapani, Samson AlemayehuMamo, "Defected Circular-Cross Stub Copper Metal Printed Pentaband Antenna", Advances in Materials Science and Engineering, vol. 2022, Article ID 6009092, 10 pages, 2022. https://doi.org/10.1155/2022/6009092.
[16]. Sam P.J.C., Surendar U., Ekpe U.M., Saravanan M., Satheesh Kumar P. (2022) A Low-Profile Compact EBG Integrated Circular Monopole Antenna for Wearable Medical Application. In: Malik P.K., Lu J., Madhav B.T.P., Kalkhambkar G., Amit S. (eds) Smart Antennas. EAI/Springer Innovations in Communication and Computing.Springer, Cham.https://doi.org/10.1007/978-3-030-76636-8_23 Lui. W.J, Cheng. C. H and Zhu. H. B (2006), "Compact Frequency Notched Ultra-Wideband Fractal Printed Slot Antenna", IEEE Microwave and Wireless Components Letters, Vol. 16, No. 4, pp. 224-226.
[17]. Mandelbrot. B. B (1983), "The Fractal Geometry of Nature", Rev ed. 2.
[18]. Palanisamy, S, Thangaraju, B. Design and analysis of clover leaf-shaped fractal antenna integrated with stepped impedance resonator for wireless applications. Int J Commun Syst. 2022; 35( 11):e5184. doi:10.1002/dac.5184.
[19]. Manish Sharma, Prateek Jindal, SushilaChahar (2014), "Design of Fractal Antenna for Multiband Application", International Journal of Advanced Research in Computer Science and Software Engineering, vol.4, Issue 6.
[20]. Pozar and Schaubert (1992), "Microstrip Antennas", Proceedings of the IEEE, vol. 80, pp. 361- 367.
[21]. Pradeep Kumar, Neha Thakur, Aman Sanghi (2013), "Micro strip Patch Antenna for 2.4 GHZ Wireless Applications", International Journal of Engineering Trends and Technology (IJETT) – vol. 4, Issue 8, pp. 527- 531.
[22]. Puente. C and Soler. J (2001), "Analysis of Fractal-Shaped Antennas Using the Multi-periodic travelling Wave Vee Model", Proceeding of IEEE Antennas and Propagator Society International Symposium, Boston, Massachusetts, pp. 158-161.
[23]. Puente-Baliarda. C, Romeu. J, Pous. R, and Cardama. A (1998), "On the behaviour of the Sierpinski multiband fractal antenna," IEEE Trans. Antennas and Propagation, vol. 46, pp. 517–524.
[24]. Randy Bancroft (2006), "Microstrip and Printed Antenna Design", Hall of India Private limited, 2nd edition.
[25]. Romeu.J and Soler.J (2001), "Generalized Sierpinski fractal multiband antenna," IEEE Trans. Antennas and Propagation, vol. 49, pp. 1237–1239.

[26]. Werner. D. H and Ganguly.S (2003), “An overview of fractal antenna engineering research,” IEEE Antennas and Propagation Magazine, vol. 45, pp. 38–57.

[27]. Werner. D. H, Haupt. R. L, and Werner. P. L (1999), “Fractal antenna engineering: The theory and design of fractal antenna arrays,” IEEE Antennas and Propagation Magazine, vol. 41, pp. 37–59.

[28]. Palanisamy, Satheeshkumar, BalakumaranThangaraju, Osamah Ibrahim Khalaf, YouseefAlotaibi, SalehAlghamdi, and FawazAlassery. 2021. "A Novel Approach of Design and Analysis of a Hexagonal Fractal Antenna Array (HFAA) for Next-Generation Wireless Communication" Energies 14, no. 19: 6204. https://doi.org/10.3390/en14196204.

[29]. Palanisamy S, Thangaraju B, Khalaf OI, Alotaibi Y, Alghamdi S. Design and Synthesis of Multi-Mode Bandpass Filter for Wireless Applications. Electronics. 2021; 10(22):2853. https://doi.org/10.3390/electronics10222853.

[30]. SatheeshKumar & Balakumaran T. (2021). Modeling and simulation of dual layered U-slot multiband microstrip patch antenna for wireless applications. Nanoscale Reports, 4(1), 15 – 18. https://doi.org/10.26524/nr.4.3.

[31]. S. Namagiri, P. Pokkunuri, B. T. P. Madhav, K. Udaykiran and S. Gandu, "Design and Analysis of a UWB patch antenna for Wireless Implantable Body Area Network (Wi BAN) Applications," 2021 International Conference on Innovative Computing, Intelligent Communication and Smart Electrical Systems (ICSES), Chennai, India, 2021, pp. 1-4, doi: 10.1109/ICSES52305.2021.9633863.