International Journal of Advanced Technology and Engineering Exploration, Vol 10(99)
ISSN (Print): 2394-5443 ISSN (Online): 2394-7454
http://dx.doi.org/10.19101/IJATEE.2021.875390

Research Article

A novel design of triangular-shaped hexagonal fractal antenna for satellite communication

Bhojraj Agrawal*, Ruchi Sharma and R. K. Khanna
Electronics and Communication Engineering, Vivekananda Global University, Jaipur, India

Received: 29-December-2021; Revised: 05-February-2023; Accepted: 06-February-2023

Abstract
The fractal antenna is a diverse kind of antenna that utilizes a fractal as well as a self-similar design to increase the effective length to enhance the material perimeter. This could obtain or transfer electromagnetic (EM) radiation in the specified full surface arena or the volume. In comparison to traditional possible antennas, modern satellite communication applications require antennas with wider bandwidths and smaller dimensions. It has sparked antenna research in a variety of directions. One of them is the use of the fractal form of the antennas in the satellite communication field due to various attractive features such as small size and wide bandwidth, etc. In this paper, a novel design of a triangular patch hexagonal multiband fractal antenna optimized for satellite communication applications has been proposed. This proposed fractal antenna was designed with flame retardant (FR4) substrates of a relative permittivity to 4.3 and comprises dimensions 28×28×1.6 mm3. The proposed antenna is fed with a coaxial probe feeding method having an outer dielectric radius (Ro) and inner conductor radius (Ri) is 0.56 mm and 0.1 mm, respectively. The designed antenna operates in the upper C band and X band (8 to 12 GHz). This design undergoes three iterations and in the third iteration, it radiates at multiple frequencies like 7.17 GHz, 8.37 GHz, 10.82 GHz, and 11.30 GHz, respectively. The proposed antenna design is simulated by utilizing the computer simulation technology (CST) Microwave Studio 2020. The results are analyzed and validated in terms of return losses, voltage standing wave ratio (VSWR), radiation patterns, gains, as well as directivity. The simulation outcome validates that the proposed triangular-shaped hexagonal fractal antenna could be effectively utilized for satellite communication applications. The measured return loss values on 7.17 GHz, 8.37 GHz, 10.82 GHz, and 11.30 GHz frequencies are -30dB, -22dB, -28dB, and -35dB, respectively. Thereby, this proposed fractal antenna is the most suitable option for satellite communication applications due to its compact size as well as its lightweight and optimal return loss values.

Keywords
Fractal antenna, Gain, Hexagonal, Iteration, Patch, Return losses.

1.Introduction
Modern telecommunications systems required antennae along with wider bandwidths including the smaller dimension as compared to conventional possibly antennas [1, 2]. It has initiated the antenna's research in various directions, one form which utilizes the fractal shape antenna's element [3, 4]. There exist important relations between antenna dimensions and wavelengths. The relation states that if an antenna's sizes are lesser than the λ/4 then the antenna isn't effective because of the radiation's resistances, and gains, as well as the bandwidth, gets reduced [5, 6]. Further, to overcome the limitation of the antenna's size got increased, which again problems with the handheld device.

Fractal geometry is considered a pragmatic solution for the existing aforementioned problem [7–9].

The term fractal means the irregular or broken fragment. This is defined from Benoit's Mandelbrot derived from the Latin word 'fractus' that means fracture or the broken [10–12]. The Fractal's antennas get inspired by the nature. A fractal antenna has two main properties that are space-filling as well as self-similarities [13–15]. The space-filling properties reduced the size of antennas and this makes antennas electronically larger in the smaller physical spaces [16–18]. Self-similarities property means that the patches of the antennas are sub-divided into small parts as well as every smaller part is the smallest portion of the reduced sizes of main geometries [19–22].

*Author for correspondence

In our work, a simple structure of multiple hexagonal rings fractal antenna has been investigated and demonstrated as well. The length and width of the substrate and patch are the same due to the use of the coaxial probe feeding method which results in reduced antenna size. The feeding point is located near the edge of the antenna to get better impedance matching [23, 24]. In comparison to traditional possibly antennas, modern telecommunications networks needed antennas with wider bandwidths and smaller dimensions. It has begun antenna research in a variety of directions. One of them is the utilization of the fractal form antenna's feature. The measurements of the antenna and the wavelengths had a strong relationship. According to the relationship, if an antenna size is smaller than λ/4, it is inefficient so radiation resistance, gain, and bandwidth are limited [25‒28]. To address these drawbacks, the antenna's sizes must be larger, that being a challenge to hand-held applications. For this problem, fractal geometry is an excellent approach. Fractal refers to fragmented or broken bits. Benoit Mandelbrot coined the term, which is derived from the Latin word called fractus, which means shattered or broken. Nature is the source of inspiration for fractal antennas. Space fillings, as well as self-similarity, are two major features of fractal antennas. In a small physical vacuum, the space-filled property decreases the antenna's size and makes it electrically longer.

The term "self-similarity" refers to the fact that an antenna patch is subdivided into small parts. Each part is smaller of the portions or gets reduced sizes of main geometries. A basic arrangement of multiple hexagonal rings fractal antenna has been investigated and demonstrated in the proposed work. Because of the use of the coaxial probe feeding system, the lengths including the widths of substrates and patch are the same, which form a smaller antenna. The aerospace and defense communication systems require a compacted wide-bandwidth antenna that could effectively operate through multi-frequency bands [29‒31]. The hexagonal ring iterates wherever the sides of the ring are bound to the triangular part in hexagonal metal patches. The propagation of line-feeding strategies is being used for signal feeding. The slot and perturbed patches are used by the grounded planes to achieve the broadband characteristic. The returned losses, radiation pattern, as well as gain of the proposed antenna, have been presented as well as compared with simulation outcomes. The gap-filled property reduces the antenna's size and makes it electrically longer in a tight spatial vacuum. The expression "self-similarity" describes the separation of an antenna patch into a small part. Each of these is smaller of the part or reduced sizes of main geometries [32, 33].

The computer simulation technology (CST) Microwaves studio 2020 simulation software has been utilized for the designing of the suggested antenna geometry for this fractal antenna as well as the triangular patch's base geometry. The patch is made of the same size as the substrate. A 28×28 sq. mm base form patch is mounted on a substrate of the same size. For this aerial, the authors selected the flame retardant (FR4) substrate due to many reasons. This substrate is the cheapest in comparison to the other substrate materials such as Roger 4350 and Duroid 6010. Furthermore, the FR4 substrate is more versatile due to the diverse physical properties such as rigidity, etc. the FR4 are high insulating materials types utilized in the field of diverse antenna designing. The ratio of intensity into specified directions for the intensity of radiation that would be received if power accepting antennas were radiating isotopically is known as antenna gain. The basic antenna parameters are directivity as well as polarization. These parameters can be determined by the antenna's orientation. An antenna that radiated uniformly in both directions would effectively have zero direction and the directive to the form of antenna would be 1.

It spurred antenna research in several directions, including the use of the fractal type antenna's function. The specification of a triangular patch hexagonal multiband fractal antenna designed for satellite applications is presented in this article. It's made out of an FR4 substrate with a relative permittivity of 4.3 and dimensions of 28×28×1.6 mm3. The suggested antenna is fed using a coaxial probe feeding system with a 0.56 mm outer dielectric radius (Ro) and 0.1 mm inner conductor radius (Ri). The antenna is planned to operate in the upper C band as well as the X band (8 to 12 GHz). This configuration goes through three variations. In the third iteration, it is to be found that the proposed fractal antenna operates at different frequencies such as 7.17 GHz, 8.37 GHz, 10.82 GHz, and 11.30 GHz in a pragmatic manner.

In the modern era, satellite communication systems need such kinds of aerials that offer a wide bandwidth compared with the existing aerials utilized nowadays in satellite communication. Furthermore, the aerials must offer the accurate and required impedance-matching on the specified operating frequency bands. There have already been fabricated multifarious fractal aerials during the last era for satellite communication applications. But these existing aerials have multifarious limitations such as lower matching of the impedance, lower operating frequency, and many more due to the constant technological advancements, which require more attention for the novel design of the fractal aerials. To resolve this, in this work, the authors designed a novel rich-featured triangular-shaped hexagonal fractal antenna for satellite communication applications. The main contribution of our work is that our proposed aerial is capable to operate multi-band operating frequencies and offers the optimal values of the return-loss which are considered by the satellite communication applications. Moreover, because of its distinctive superiority namely the low volume, minimal price in fabrication as well as and easy installation within satellite communication applications, the novel design of the fractal aerial is to be one of the right candidates in the modern era.

In this work, a novel design of a triangular-shaped hexagonal fractal antenna has been presented for the satellite communication application. This research study is structured as follows. The introduction part has been introduced in section 1. The related studies about the fractal aerial have been explained in section 2. The suggested fractal aerial methodology is introduced and structured in section 3. The simulated results of the suggested triangular-shaped hexagonal fractal antenna for satellite communication applications have been presented in section 4. The last section 5 introduces the conclusion and future scope of the study.

2.Literature review

Darimireddy et al. [34], discussed the miniatures of the hexagonal triangular fractal's antenna to the wider band's application. The aerospace and defence communication system need a compacted widely banded antenna that is appropriate to the multiple frequency bands operations. The iteration is made by the hexagonal ring wherever the side of the ring is connected from the triangular element in the hexagonal metal's patches. The transmission of the line feeding techniques is utilized for feeding signals. The antenna performance is examined from the different parameters studies as well as the fields and current distribution analysis.

Hwang [35] studied the modified Sierpinski fractal antenna for multiple band applications. The broadband planers Sierpinski fractal's antenna to the multiple band applications is proposed. This antenna has been designed as well as tested with a high degree of precision for the validation purpose of measuring the antenna efficiency in real-time. The perturbed patches and the slot that the grounded planes are employing for achieving the broadband characteristic. The measuring returned losses, radiation pattern, as well as the gain of proposing antennas, are presented as well as get compared along with the simulated result.

Deepak et al. [36], studied the designing and the analysis of the hetero triangle that links to the hybrid of the web fractal antennas to the wider band's application. The designing and the analysis of the novel wider band's coverings and the hetero triangle that gets linked to the web fractal's antennas. These triangles get linked to the hybridized web structures designed by the multiple iterations into the CST microwave studio (MWS) 2020 electromagnetically simulations tools as well as fabricated with dielectric including the constants and the heights.

Kumar et al. [37], proposed a lightweight quadrilateral structure fractal slit planar aerial utilizing the improved fractal structure. In this work, the authors selected the circular as well as hexagonal along with the triangular themes for iteration purposes for making this aerial. However, this aerial has a few limitations nowadays such as low impedance matching as well as narrow bandwidth which require attention towards the fresh designs of the fractal aerial as per satellite communication applications.

Benkhadda et al. [38], investigated a tri-wideband Sierpinski hexagonal fractal antenna with a modified ground plane for wireless communication applications. The frequency ranges where the examined antenna worked were 2.19-4.43 GHz, 4.8-7.76 GHz, and 8.04-11.32 GHz. Additionally, at the resonant frequencies, the gains and radiation efficiencies were 1.074, 4.19, and 4.01 dBi and 68.35%, 64.15%, and 62.7%, respectively. In the E- and H-planes, the Sierpinski hexagonal fractal antenna also displayed virtually omnidirectional emission patterns. Due to its many benefits, including its compactness, simplicity, good resonance and radiation proprieties, and 5G spectrum band, C-band, and X-band applications, the designed Sierpinski hexagonal-shaped fractal antenna is the ideal choice.
Ezhumalai et al. [39], inspected fractal aerials utilizing the international operational system within

the patches aerials. The fractal aerial is one of the suitable choices in the modern era for numerous engineering sectors namely surface physics as well as communication and many more. Nowadays, in communication, the need for compact fractal aerials is increasing constantly because of many reasons such as higher bandwidth and many more.

Olatujoye and Saturday [40], has built and simulated a 4-element multiband circular microstrip antenna (CMSA) microstrip antenna array for several operating frequencies such as 2.4/5.2/6.5/7 GHz. Clarifications have been provided regarding a number of characteristics, including return loss, bandwidth, and directivity. The relative permittivity (Ɛr) of the dielectric material under the patch, the width (Wf) of the microstrip line, the location of the array elements making up the array patch, and the radius (a) of the patch were found to be the main parameters that determined the behavioural characteristics of the antenna. The suggested multiband array antenna has achieved the goals set forth for the study, having a total bandwidth of 710 MHz and antenna gains better than those of a standard single band microstrip antenna > 5 dB at design frequencies taken into account.

Vasujadevi et al. [41], presents another design of the fractal aerial for multiband applications. This aerial has been simulated over 2.4 GHZ and designed by using the FR4 epoxy substrate. This fractal aerial was evaluated for C band resonance frequency 6.20 GHz as well as Ku band resonance frequency 13.80 GHz. Further, this developed geometry of fractal aerial suffers from some restrictions such as design complexity and many more, which needs more attention to investigate new fractal aerial geometry.

For problem identification, we have studied numerous research articles from reputed journals, and conference proceedings including various magazines. In this literature, the authors discussed the latest research work done in the field of fractal antennas. These existing designed fractals' aerial geometry suffers from various limitations such as narrow bandwidth and low impedance matching. Moreover, the existing designed aerials are incapable to integrate into satellite communication applications where the antenna size matters most. For resolving the aforementioned drawbacks of the existing literature, the authors designed a novel design of triangular-shaped hexagonal fractal antenna for satellite communication.

3.Methodology

3.1Proposed fractal antenna

The proposed fractal antenna geometry has been designed utilizing the CST Microwaves Studio 2020 software along with the base geometry of the triangular patch. The dimensions of the patch, as well as the substrate, were considered similar for the testing and validation of the suggested antenna design. For base shape patch of size, 28×28 sq. mm is placed over the substrate of the same size. The block diagram of the complete working mechanism of the proposed triangular-shaped hexagonal fractal antenna is illustrated in *Figure 1*.

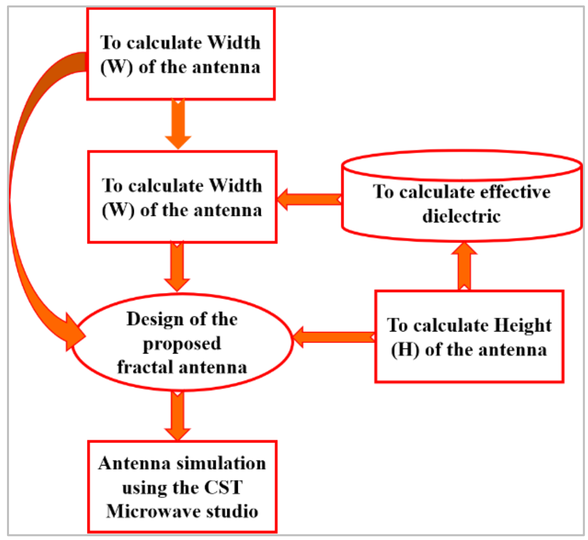

Figure 1 Illustrates the block diagram to show the complete working mechanism of the proposed triangular-shaped hexagonal fractal antenna

For the first iteration, a hexagon is cut from the center, which has a radius of 4.2 mm. For the second iteration, three hexagons of radius 2.1 mm which is exactly half the size of the hexagon removed in the first iteration are iterated from three corners of the triangle. In the third iteration, nine hexagons are iterated around the hexagons of the second iteration. The radius of a hexagon of the third iteration is 1.05 mm. The feed point location was considered for the testing (-2, -5.5) as depicted in *Table 1*.

3.2Parameters

Table 1 illustrates the overall parameter values along with the complete values of the hexagon. For the testing of our suggested triangular-shaped hexagonal fractal antenna for satellite communication, the patch length and width were selected at 28×28 mm. The height of the substrate was chosen as 1.6 mm and the thickness of the ground was 0.035 mm. The location of feed (-2,-5.5), dielectric constant selected FR4 Glass Epoxy, and the radius of Hexagonal first, second and third iterations are 4.2 mm, 2.1mm, and 1.05 mm, respectively.

Table 1 Illustrating the complete parameters along with the complete values of the hexagon

Parameter	Value
Patches length	28mm
Patches width	28mm
Substrates heights	1.6mm
Ground thickness	0.035mm
Feed location	(-2,-5.5)
Dielectric constant	FR4 Glass
The radius of hexagonal	Epoxy
First iteration	4.2mm
The radius of the hexagonal second iteration	2.1mm
The radius of hexagonal third iteration	1.05mm

3.3Designs of proposed antenna

The design of the proposed triangular-shaped hexagonal fractal antenna for satellite communication has been depicted in *Figure 2*. The base shape geometry of the proposed fractal aerial is depicted in *Figure 2 (a)*, the geometry of the proposed fractal antenna in 1st iteration is depicted in *Figure 2 (b)*, and the geometry of the proposed fractal antenna in 2nd iteration is depicted in *Figure 2 (c)*, as well as the geometry of the proposed fractal antenna on 3rd iteration for the satellite communication applications is shown in *Figure 2 (d)*.

This aerial radius dimension could be evaluated utilizing the following Equation 1. The value of the ε_e can be calculated by using Equation 2.

$$a = \frac{8.791}{f_0\sqrt{\varepsilon_0}} - \frac{h}{\varepsilon_r} \quad (1)$$

$$\varepsilon_e = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + \frac{12h}{w}\right]^{-\frac{1}{2}} \quad (2)$$

Where the substrate thickness is denoted by h, w denotes the overall width, and relative permittivity is described by ε_r, and a represents the radius.

3.4Coaxial feeding

The center's conductors of coaxial connectors are soldered to the patches. The major advantage of the coaxial feeding in the proposed fractal antenna can be placed over any of the required locations in the patches for matching within its input impedances [42, 43]. The major disadvantage is that holes are being drilled into substrates as well as connectors protruding outside the bottom grounded planes, such that it isn't completely planers. Furthermore, the feeding arrangements make up the configurations asymmetrical [44]. In this design coaxial feeding has been used which has a dimension as follows. The radius of the inner conductor measures 0.1 mm and the radius of the outer dielectric coating measures 0.56 mm as depicted in *Figure 3*.

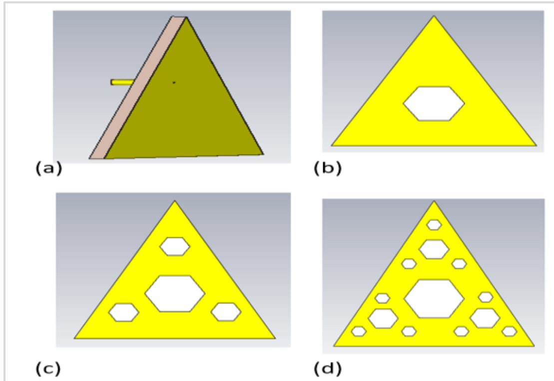

Figure 2 Illustrating the Geometries of the proposed antennas (a) Base Shapes (b) 1st iterations (c) 2nd iterations (d) 3rd iterations

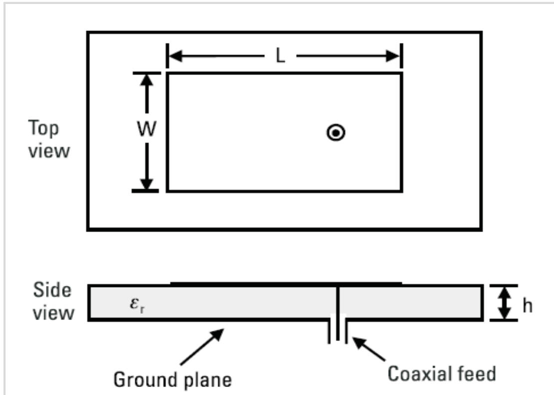

Figure 3 Illustrating the coaxial feed of the centre conductor of the coaxial conductor

4.Results

4.1Simulation results

The fractals antenna designs including their various iterations have been studied as well as simulated and validated by utilizing the CSTs microwaves studios 2020. CST MWS is the result of decades of work as well as an exploration into the more practical as well as precise computational methods for three-dimensional (3D) layouts. The CST MWS specializes in offering very high-frequencies electromagnetic simulations in 3D. Virtual prototype precedes actual trials, as well as optimization, replaces testing which results in quicker developmental processes for consumers. For the testing and validation of the suggested triangular-shaped hexagonal fractal antenna for satellite communication, several parameters such as return losses, voltage standing wave ratio (VSWR), radiations patterns as well as gains have been measured and compared with a high degree of precision for accurate testing of the proposed fractal antenna design.

4.2Return losses

Return losses are just a measurement of several signals which got reflected in the signals sources from devices because of an impedance mismatch. This measure the hole well of the diverse devices or the lines that are needed to be matched. The values of the return losses are measured in dB. When the value of the S11 parameters is 0 dB, this defines all of the power gets reflects by antennas as well as there is nothing gets radiating. Return losses for the various iteration executed in our experiment are shown in *Figure 4*. The third iteration values of the returned loss values are -30dB, -22dB, -28dB, and -35dB on 7.17 GHz, 8.37 GHz, 10.82 GHz, and 11.30 GHz, respectively. The return loss values are optimal and improved in comparison to the existing work done by Wang et al. in [45]. The values of the return loss may be evaluated as per the following Equation 3.

$$R = 10\log_{10}\left(\frac{P_i}{P_r}\right) \quad (3)$$

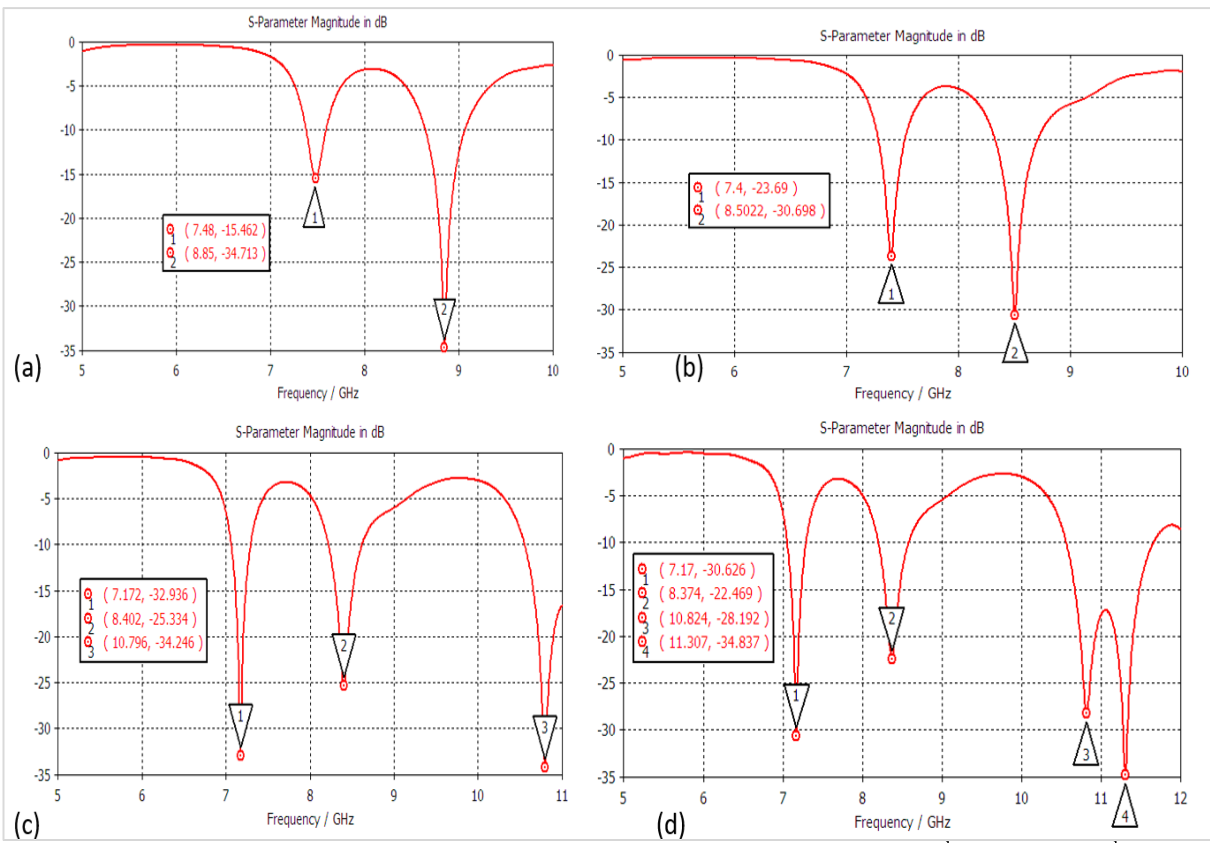

Figure 4 Illustrating the return losses plots of the (a) bases shapes, (b)1st iteration, (c) 2nd iteration (d) 3rd iterations

4.3Voltages standing wave's ratio (VSWR):

In the field of telecommunication as well as radio engineering, the standing wave ratio (SWR) is a measurement of the pragmatic impedance matching of the loads along with impedance characteristics of the line of transmission or the waveguide. SWR is generally thought concerning nominal as well as highest alternating current (AC) voltage with a transmission line, therefore named VSWR. This gets measured by impedances that match to load of characteristic impedance lines or the waveguides. Simplified this showed an amount of mismatch among the antenna as well as feed lines that connect for it. This ranges the value to the VSWR from 1 towards the ∞. A value that is under 2 is considered suitable for most antenna applications. *Figure 5* shows the VSWR plot for the proposed antenna to the numerous iterations. The VSWR is lesser as compared to the 2 to each of the iterations over radiating frequency. To the base shapes it: 1.03, 1.40 at 7.48 GHz, 8.85. For the first iteration, it is 1.13, 1.06 at 7.4GHz, and 8.5 GHz. For the second iteration, it is 1.05, 1.11, 1.04 at 7.17GHz, 8.4 GHz, and 10.79GHz. For the final iteration, it is 1.06, 1.16, 1.08, and 1.04 at 7.17GHz, 8.37GHz, 10.82GHz, and 11.3GHz, respectively. The value of VSWR may be calculated as per the following Equation 4.

$$VSWR = \frac{1+\Gamma}{1-\Gamma} \quad (4)$$

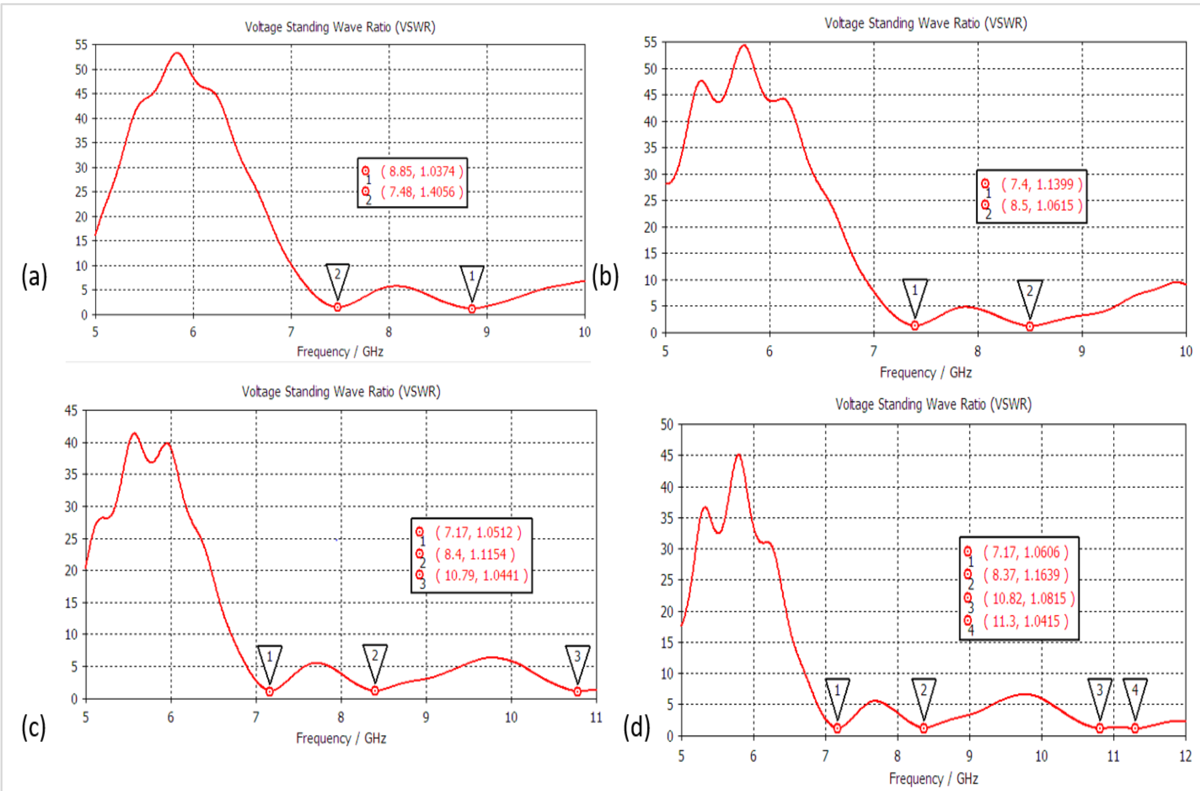

Figure 5 Illustrating the VSWR Plot of (a) Base shapes (b) 1st Iterations (c) 2nd Iterations (d) 3rd iterations

4.4Radiation pattern

Radiation patterns are the graphic representation of the radiation's property of antennas as a function of the space coordinates. These electronic-field patterns to all of the iterations over the numerous frequencies are described in *Figure 6.* This shows that the proposed antenna radiates into the +Z directions as well as numerous patterns of the back radiations. The radiation pattern is also recognized by the aerial pattern many times which is referred to as the far-field pattern. This mentions the angular dependency of overall radio signal strength from an aerial or additional source.

4.5Gain

Antenna's gain is defined as the ratio of intensity in given directions. For radiation, the intensity would be obtained as if power accepted from the antenna were radiating isotropically. *Figure 7* depicts gains vs. the frequency plots of the third iteration. This value of gain is 1.7dBi, 3.61dBi, 4.01dBi, 3.81dBi at 7.17GHz, 8.37GHz, 10.82GHz, 11.30 GHz respectively. These maximum gains occurred over 10.82GHz to regarding 4.01dBi as shown in *Figure 7.* The aerial gain has been considered one of the main performance constraints that combine aerial directivity as well as radiation efficacy in electromagnetics. While considering transmittal aerial, gain labels how fine the aerial changes the input signal power in radio waves controlled within any specific path. While considering the scenario of a receiving aerial, gain labels on how fine aerial changes the radio waves coming via a specific pathway in the electrical signal. The antenna gain may be calculated as per the following Equation 5.

$$G_{dB} = 10\log_{10}(4\pi\eta\, A/\lambda^2) \quad (5)$$

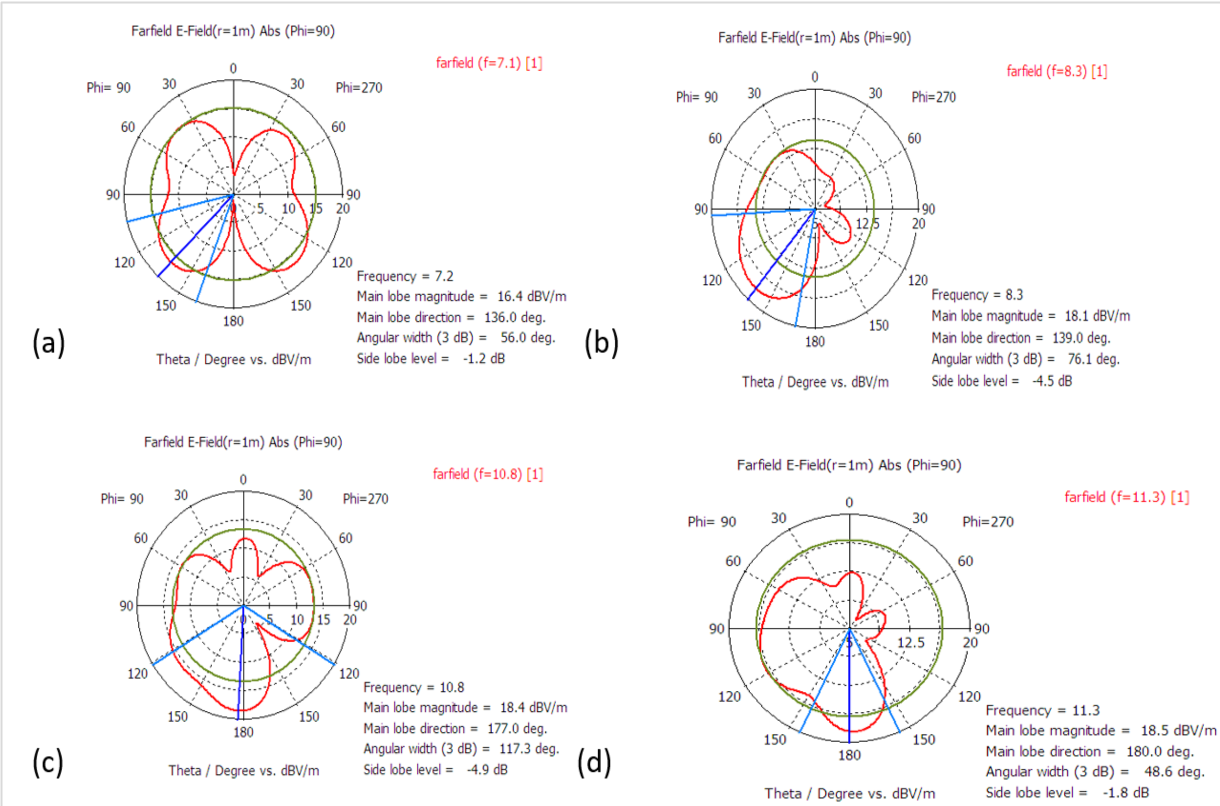

Figure 6 Illustrating the E-Field's pattern of third iteration (a) 7.1GHz (b) 8.3GHz (c) 10.8GHz (d) 11.3GHz iterations

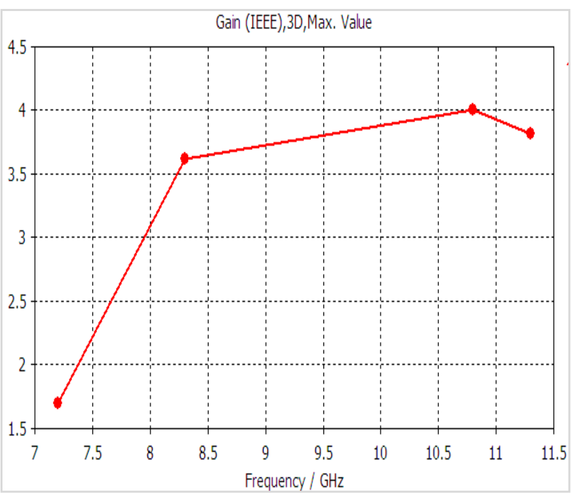

Figure 7 Illustrating the gains plots over the different frequencies for the 3 iterations

4.6Directivity

Directivity is one of the fundamental antenna parameters. This gets measured that how the direction of the antenna for accurate signal transmission as well as the reception in real-time communication or data translation. An antenna that radiated equally into all directions would effectively have the zero direction, as well as a directive to the type of the antenna would be 1 (or 0dB). *Figure 8* shows the directivity plot for the proposed fractal antenna after the simulation in the third iteration.

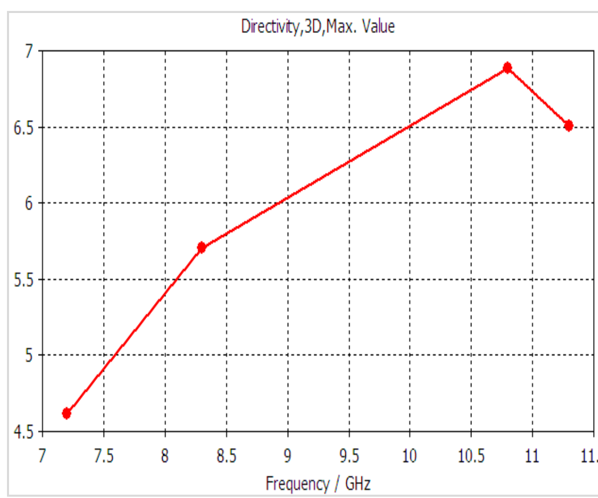

Figure 8 Illustrating the directivity at different frequencies of third iterations

5.Discussion

In this article, the authors proposed a novel design of a triangular-shaped hexagonal fractal antenna for satellite communication applications by utilizing the CST MWS 2020 for the testing and validation of the suggested antenna. The measurements of this designed antenna are 20×20×1.6mm^3. We used coaxial feeding to achieve efficient impedance matching. The experiment has been performed with a high degree of precision to eliminate the chances of errors. There have been measured and compared various parameters for diverse iterations such as return losses, directivity, VSWR, and many more similar parameters for the comparative analysis purpose. The measured return loss values on 7.17 GHz, 8.37 GHz, 10.82 GHz, and 11.30 GHz frequencies are -30dB, -22dB, -28dB and -35dB, respectively. The values of VSWR for the first iteration are 1.13, 1.06 at 7.4GHz, and 8.5 GHz. For the second iteration is 1.05, 1.11, 1.04 at 7.17GHz, 8.4 GHz, 10.79GHz and for the final iteration is 1.06, 1.16, 1.08, 1.04 at 7.17GHz, 8.37GHz, 10.82GHz, 11.3GHz, measured gain were 1.7dBi, 3.61dBi, 4.01dBi, 3.81dBi at 7.17GHz, 8.37GHz, 10.82GHz, 11.30GHz respectively. All the parameters are compared with the existing work done on the fractal antenna design in the earlier paper, Wang et al. [45]. This proposed novel design of a triangular-shaped hexagonal fractal antenna for satellite communication is improved in terms of various parameters such as return losses, gain, as well as VSWR in comparison to the existing work.

The surface current distribution of the proposed fractal aerial is to be found considerable and optimal in comparison to the existing work done by the research in recent years. The radiation through the fractal aerial may be evaluated through the field distribution among the aerial's patches as well as the ground plane. The aforementioned radiation pattern may be defined as a surface current distribution over aerial patch metals. Group delay values of the suggested aerial are pragmatic and considerable in comparison to the existing aerials. Aerial group delay may be evaluated nearly by considering input impedance stages of frequencies derivative. Group delay values of aerial normally composed through two diverse parameters namely input impedance as well as a far-field stage. A complete list of abbreviations is shown in *Appendix I.*

6.Conclusion and future work

New telecommunications networks needed antennas with larger bandwidths and smaller dimensions than conventional likely antennas. It spurred antenna research in many directions, including the use of the fractal-type antenna's function. The measurements of the antenna and the wavelengths had a strong relationship. According to the relationship, if an antenna size is smaller than λ/4, it is inefficient since radiation resistances, gains, as well as bandwidth is limited. To address these drawbacks, the antenna's size must be raised, which is becoming a challenge to the hand-held device yet again. To resolve the aforementioned problem, the fractal geometry of the antenna is an excellent approach and is easy to integrate into numerous satellite communication applications in real-time with minimal effort. Fractal refers to fragmented or broken bits. Benoit Mandelbrot coined the term, which is derived from the Latin word called fractus, which means shattered or broken. Nature is the source of inspiration for fractal antennas. Space fillings, as well as self-similarity, are two major features of fractal antennas.
In a small physical vacuum, the space-filled property decreases the antenna's size and makes it electrically longer. The term "self-similarity" refers to the fact that an antenna patch is separated into smaller bits, each of which is the smaller component or the reducing size of main geometries. The antenna geometry for this fractal was created using CST Microwaves Studio 2020. The patch and substrate dimensions were chosen similarly for the design. A 28×28sq.mm base form patch is mounted on a substrate of the same size. Three hexagons of radius 2.1mm, which is precisely half the size of the hexagon omitted in the first iteration, are iterated from the triangle's three corners in the second iteration. Nine hexagons are iterated around the hexagons in the second iteration. The third iteration's hexagon has a circumference of 1.05mm. The location of the feed point was selected (-2, -5.5).

This proposed antenna has the dimensions 20×20×1.6mm^3. For the effective impedance matching purpose, we have utilized coaxial feeding. This proposed antenna is intended for having good gain over all the selected frequencies. This antenna executes X, as well as C band, ranges application along with the minimum antenna sizes as well as better impedance matching. This multiple banding capacity for proposed antennas is accomplished from the fractal's ideas. The simulation outcomes demonstrated the proposed antennas worked onto the resonance frequencies for the 10.4GHz. It is multiple bands antennas. The antennas get utilized for satellites, radars, space, and terrestrial communications applications such as telecom satellites, administration to the sea, aeronautics, or land applications. This distinctive parameter for proposed antenna such as return's losses, VSWRs, gains, radiation's patterns has the adequate esteems. There has already been developed various dimensions fractal antennas earlier according to various applications. However, there is indeed a huge demand of more compact and lightweight fractal antenna due to constant compact device development and technological advancements, thereby more investigation is required in the future.

Acknowledgment
None.

Conflicts of interest
The authors have no conflicts of interest to declare.

Author's contribution statement
Bhojraj Agrawal: Conceptualization, investigation, writing – original draft, writing – review and editing. **Ruchi Sharma:** Conceptualization, analysis and interpretation of results, supervision. **Ramesh Sharma:** Study conception, supervision, investigation on challenges and draft manuscript preparation.

References
[1] Annou A, Berhab S, Chebbara F. Metamaterial-fractal-defected ground structure concepts combining for highly miniaturized triple-band antenna design. Journal of Microwaves, Optoelectronics and Electromagnetic Applications. 2020; 19:522-41.
[2] Kamel AS, Jalal AS. Reconfigurable monopole antenna design based on fractal structure for 5G applications. Iraqi Journal of Information and Communication Technology. 2021; 1(1):177-86.
[3] Sharma V, Lakwar N, Kumar N, Garg T. Multiband low-cost fractal antenna based on parasitic split ring resonators. IET Microwaves, Antennas & Propagation. 2018; 12(6):913-9.
[4] Kumar S, Gupta A, Arya AK. Triple frequency S-shaped circularly polarized microstrip antenna with small frequency-ratio. International Journal of Innovative Research in Computer and Communication Engineering. 2016; 4(8):14740-7.
[5] Wang Y, Wang Z, Li J. UHF moore fractal antennas for online GIS PD detection. IEEE Antennas and Wireless Propagation Letters. 2016; 16:852-5.
[6] Keshwala U, Rawat S, Ray K. Design and analysis of eight petal flower shaped fractal antenna for THz applications. Optik. 2021; 241(2021):1-9.
[7] Dwivedi SK, Kumar M, Tharani L. A metamaterial loaded hybrid fractal hepta-band antenna for wireless applications with reconfigurability characteristics. Progress in Electromagnetics Research C. 2020; 100:187-203.
[8] Nhlengethwa NL, Kumar P. Fractal microstrip patch antennas for dual-band and triple-band wireless applications. International Journal on Smart Sensing and Intelligent Systems. 2021; 14(1):1-9.
[9] Ameen M, Chaudhary RK. Electrically small circularly polarized antenna using vialess CRLH-TL and fractals for L-band mobile satellite applications. Microwave and Optical Technology Letters. 2020; 62(4):1686-96.
[10] Anguera J, Andújar A, Jayasinghe J, Chakravarthy VS, Chowdary PS, Pijoan JL, et al. Fractal antennas: an historical perspective. Fractal and Fractional. 2020; 4(1):1-26.
[11] Gupta N, Saxena J, Bhatia KS. Optimized metamaterial-loaded fractal antenna using modified hybrid BF-PSO algorithm. Neural Computing and Applications. 2020; 32(11):7153-69.
[12] Ali T, Subhash BK, Biradar RC. A miniaturized decagonal sierpinski UWB fractal antenna. Progress in Electromagnetics Research C. 2018; 84:161-74.
[13] Awan WA, Hussain N, Le TT. Ultra-thin flexible fractal antenna for 2.45 GHz application with wideband harmonic rejection. AEU-International Journal of Electronics and Communications. 2019; 110:1-19.
[14] Singhal PK, Mathur S, Baral RN. Ultra-wide microstrip band pass filter using short circuited stubs. Journal of Electrical and Electronics Engineering Research. 2011; 3(6):101-7.
[15] El ND, Tajmouati A, Zbitou J, Errkik A, Elabdellaoui L, Latrach M. A novel low cost fractal antenna structure for ISM and WiMAX applications. TELKOMNIKA (Telecommunication Computing Electronics and Control). 2018; 16(5):1901-6.
[16] Jamil A, Rauf M, Sami A, Ansari A, Dawood IM. A wideband hybrid fractal ring antenna for WLAN applications. International Journal of Antennas and Propagation. 2022; 2022:1-8.
[17] Ogundiran YL, Griffo A, Sundeep S, Gonzalez FA, Wang J. A novel ring-shaped fractal antenna for partial discharge detection. In energy conversion congress and exposition 2021 (pp. 5111-7). IEEE.
[18] Prabhakar D, Babu CR, Adinarayana V, Prasad VV. A hybrid approach on metamaterial-loaded fractal antenna design. The Applied Computational Electromagnetics Society Journal. 2020:1022-9.
[19] Reha A, El AA, Benhmammouch O, Said AO. Fractal antennas: a novel miniaturization technique for wireless networks. Transactions Network Management. 2014; 2(5):165-93.
[20] Varadhan C, Arulselvi S, Ashine CF. Effects of the FR 4 substrate realized in a circularly polarized UHF-RFID reader antenna with fractal geometry for enhancing parameters. Advances in Materials Science and Engineering. 2021; 2021:1-7.
[21] Nichita MV, Paun MA, Paun VA, Paun VP. On the 5G communications: fractal-shaped antennas for PPDR applications. Complexity. 2021; 2021:1-12.
[22] Varadhan C, Ashine CF, Arulselvi S. Characterization of composite RFID antennas based on thermal properties: a survey. Advances in Materials Science and Engineering. 2021; 2021:1-9.

[23] Kumar A, Pharwaha AP. On the design of novel half T-square strip fractal antenna. International Journal of Electronics. 2021; 108(10):1774-89.
[24] Manikandan P, Sivakumar P. A novel pinwheel fractal multiband antenna design using particle swarm optimization for wireless applications. International Journal of Communication Systems. 2021; 34(15):1-14.
[25] Mohanty A, Sahu S. Compact wideband hybrid fractal antenna loaded on AMC reflector with enhanced gain for hybrid wireless cellular networks. AEU-International Journal of Electronics and Communications. 2021; 138(2021):1-12.
[26] Kaur M, Sivia JS. Giuseppe peano and cantor set fractals based miniaturized hybrid fractal antenna for biomedical applications using artificial neural network and firefly algorithm. International Journal of RF and Microwave Computer-Aided Engineering. 2020; 30(1):1-11.
[27] Sran SS, Sivia JS. PSO and IFS techniques for the design of wearable hybrid fractal antenna. International Journal of Electronics. 2021; 108(12):2039-57.
[28] Sharma N, Bhatia SS. Comparative analysis of hybrid fractal antennas: a review. International Journal of RF and Microwave Computer-Aided Engineering. 2021; 31(9):1-46.
[29] Barreto EL, Mendonça LM. A new triple band microstrip fractal antenna for C-band and S-band applications. Journal of Microwaves, Optoelectronics and Electromagnetic Applications. 2016; 15:210-24.
[30] Singhal S, Goel T, Singh AK. Hexagonal tree shaped ultra–wideband fractal antenna. International Journal of Electronics Letters. 2017; 5(3):335-48.
[31] Karimbu VA, A RMK, A. KB, Iqbal MN, Murad NA, Gajibo MM, et al. Complementary split-ring resonator and strip-gap based metamaterial fractal antenna with miniature size and enhanced bandwidth for 5G applications. Journal of Electromagnetic Waves and Applications. 2022; 36(6):787-803.
[32] Kakkar S, Kamal TS, Singh AP. On the design and analysis of I-shaped fractal antenna for emergency management. IETE Journal of Research. 2019; 65(1):104-13.
[33] Sawant KK, Kumar CS. CPW fed hexagonal micro strip fractal antenna for UWB wireless communications. AEU-International Journal of Electronics and Communications. 2015; 69(1):31-8.
[34] Darimireddy NK, Reddy RR, Prasad AM. A miniaturized hexagonal-triangular fractal antenna for wide-band applications [antenna applications corner]. IEEE Antennas and Propagation Magazine. 2018; 60(2):104-10.
[35] Hwang KC. A modified sierpinski fractal antenna for multiband application. IEEE Antennas and Wireless Propagation Letters. 2007; 6:357-60.
[36] Deepak BS, Madhav BT, Prabhakar VS, Lakshman P, Anilkumar T, Rao MV. Design and analysis of hetero triangle linked hybrid web fractal antenna for wide band applications. Progress in Electromagnetics Research C. 2018; 83:147-59.
[37] Kumar R, Sinha R, Choubey A, Mahto SK. A quadrilateral shaped fractal slot planar antenna for ultra-wide band applications. Australian Journal of Electrical and Electronics Engineering. 2022; 19(3):270-82.
[38] Benkhadda O, Saih M, Ahmad S, Al-gburi AJ, Zakaria Z, Chaji K, et al. A miniaturized tri-wideband sierpinski hexagonal-shaped fractal antenna for wireless communication applications. Fractal and Fractional. 2023; 7(2):1-18.
[39] Ezhumalai A, Ganesan N, Balasubramaniyan S. An extensive survey on fractal structures using iterated function system in patch antennas. International Journal of Communication Systems. 2021; 34(15):1-38.
[40] Olatujoye B, Saturday JC. Design and performance analysis of 4-element multiband circular microstrip antenna array for wireless communications. IOSR Journal of Electronics and Communication Engineering. 2023; 18(1):1-7.
[41] Vasujadevi M, Teja KA, Divya G. Fractal antenna design for multiple applications. International Journal of Engineering & Technology. 2018; 7(2.7):602-5.
[42] Ameen M, Chaudhary RK. ENG-TL inspired dual-polarized antenna using curved meander, two-arm Archimedean spirals and CSRR mushroom. Microwave and Optical Technology Letters. 2023.
[43] Pishkoo A, Darus M, Pashei R, Asgari MS. From calculating fractal dimension to fabrication of fractal antennas. Journal of Computational and Theoretical Nanoscience. 2016; 13(7):4323-30.
[44] Singhal S. Hexagonal fractal antenna for super wideband terahertz applications. Optik. 2020; 206:1-6.
[45] Wang L, Yu J, Xie T, Bi K. A novel multiband fractal antenna for wireless application. International Journal of Antennas and Propagation. 2021; 2021:1-9.

Bhojraj Agrawal received his B.E. degree from Rajasthan University in 2005 in Electronics and Communication engineering. M.Tech from MANIT, Bhopal in 2009 in Information Security. Areas of interest are Wireless Communication, Antenna Design, Cryptography, and Sensor Network Design.
Email: bhojrajagarwal003@gmail.com

Ruchi Sharma, working as a Professor in Electronics & Communication Engineering, Vivekananda Global University, Jaipur having 15+ years of experience in Corporate and Academics to display exceptional communication, teaching, interpersonal, and leadership abilities. She is B.E., M.Tech., Ph.D. in Electronics & Communication Engineering, and MBA in HR. Her interest area is Power systems, VLSI & Embedded

Systems. She has 20+publication in various national & International journals which makes her more confident to enhance her outreach in Industry for student teaching with hands-on practice.

Dr. R K Khanna is M.Sc., Ph.D. (IIT Madras) and PDF from U.K. He has about 40 years of experience and currently working in the field of Microwave Electronics, Antenna design, Electro-Optics, & Molecular Dynamic. Ha has 70+ publications in National and International Journals.
Email: rkkhanna.iitm@gmail.com

Appendix I

S. No.	Abbreviation	Description
1	3D	Three-Dimensional
2	AC	Alternating Current
3	CMSA	Circular Microstrip Antenna
4	CST	Computer Simulation Technology
5	EM	Electromagnetic
6	FR	Flame Retardant
7	MWS	Microwave Studio
8	Ri	Conductor Radius
9	RO	Radius
10	SWR	Standing Wave Ratio
11	VSWR	Voltage Standing Wave Ratio