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DESIGN AND ANALYSIS OF FRACTAL MICROSTRIP PATCH ANTENNA USING DEFECTED GROUND STRUCTURE

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Abstract— Currently, wireless networks operate at a maximum of 4G, but an increase to 5G is in the works. Numerous programmes now operate on fourth-generation communication systems. The study of 5G communications is a relatively new field of study. Microstrip antenna study is important because of its potential use in cutting-edge 5G technologies. The high bandwidth provided by the microstrip fractal antenna is essential to satisfying the criteria for 5G. To address the issues of limited bandwidth, cross-polarization, and weak gain in microwave circuits, a novel approach called deflected ground structure (DGS) has been implemented. This study puts forward a microstrip fractal antenna with a flawed ground structure for use in 5G wireless communication systems. This antenna has a resonance frequency of 5.4GHz. The proposed antenna has a total bandwidth of 1064 MHz.
Keywords— Fractal, Microstrip, Differential Gain Structure, Antenna, Cross Sectional Area, Voltage Standing Wave Ratio, Return Loss. "

I. INTRODUCTION

Currently, wireless networks operate at a maximum of 4G, but an increase to 5G is in the works. Numerous programmes now operate on fourth-generation communication systems. The study of 5G communications is a relatively new field of study. Microstrip antenna study is important because of its potential use in
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5G improves the user experience and paves the way for unprecedented levels of connection among humans, machines, and even between the two. Since it allows for low-latency transmissions, it may be used to deploy cutting-edge applications like virtual reality and augmented reality in medicine, autonomous vehicles, and more. Wireless service providers face unprecedented problems in addressing a worldwide bandwidth constraint [1] due to the proliferation of mobile data and the usage of smart phones.

An antenna with a fractal, self-similar design maximises the effective length, or the perimeter (on internal sections or the exterior structure) of material capable of receiving or transmitting electromagnetic radiation within a given total surface area or volume.

The main feature of such fractal antennas is the recurrence of a theme over two or more scale sizes,[2] sometimes known as "iterations." Fractal antennas are multiband or wideband despite their small size, making them ideal for usage in wireless networks like cellular phones and microwave ovens. In contrast to conventional antennas, fractal antennas may provide good to exceptional performance over a wide range of frequencies all at once. Conventional antennas need to be "cut" to match the operating frequency, so they can only be used effectively on that particular frequency [3].

Cellular service providers today are constrained by a carrier frequency range from 700 MHz to 2.6 GHz as they work to provide you high-quality, low-latency video and multimedia services on your wireless devices. Each major wireless operator has access to around 200 MHz across all of the various cellular bands, and the total spectrum bandwidth allotment for all cellular technologies worldwide does not exceed 780 MHz [4]. Managing various technologies in the same band-limited spectrum at the same time is necessary to serve both legacy users with older, less-efficient mobile phones and consumers with newer, more-advanced smart phones. As it stands, operators' spectrum allocations are broken up into discrete frequency bands, each of which uses a unique set of radio networks with their own unique characteristics for propagation and building penetration losses. As a result, base station designs need to support a wide range of frequencies across a wide variety of cell sites, with numerous base stations deployed at each location (one for each frequency or technology use, such as 3G, 4G, and LTE-A) [5]. Managing the acquisition of additional spectrum via organisations like the International Telecommunications Union (ITU) and the Federal Communications Commission of the United States may take a decade or more (FCC). Incumbent users must be relocated off the spectrum after licencing is complete, adding even more time and money to the process [6].

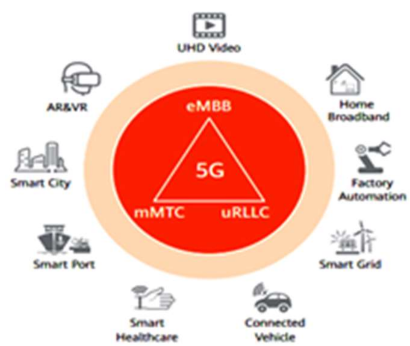


Figure 1: 5G service models

Figure 1 shows 5G services need 5G networks with 1000 times higher capacity and 10 to 100 times better data rates. An antenna with a fractal, self-similar design maximises the effective length, or the perimeter (on internal sections or the exterior structure) of material capable of receiving or transmitting electromagnetic radiation within a given total surface area or volume. The main feature of such fractal antennas is the recurrence of a theme over two or more scale sizes [7] sometimes known as "iterations." Fractal antennas are multiband or wideband despite their small size, making them ideal for usage in wireless networks like cellular phones and microwave ovens. In contrast to conventional antennas, fractal antennas may provide good to exceptional performance over a wide range of frequencies all at once. Conventional antennas need to be "cut" to match the operating frequency, so they can only be used effectively on that particular frequency. Because of this, the fractal antenna is fantastic for using in wideband and multiband settings [8].

There are five main parts to this study. Section I presents the background, rationale, and goals of the study, Section II provides a survey of relevant prior literature, Section III details the research's methodology and mathematical studies, Section IV discusses the study's simulation results, and Section V provides a summary and suggestions for further study.

II. LITERATURE SURVEY

S. Akkole proposes a Defected Ground Structure (DGS)-based multi-band microstrip fractal antenna. Because of its self-affine quality, it finds use in fractal geometry. The microstrip antenna's ground plane has undergone at most two rounds of the geometry's application. The antenna has a resonant frequency in the 2-8 GHz range, making it suitable for use in the military, in telecommunications, and even in the C-band. Wi-Fi, RDR, and satcom are only a few of the many uses for this technology [1].

Antenna designs based on a Y structure are presented and simulated by F. Lihua et al. at frequencies between 0.8 GHz and 5 GHz. The authors suggest and investigate relationships among antenna parameters including the angle, length, ordering, and sum of the structure's branches. The parameters and design iteratively until the optimum solution is found [2]. An innovative Circular Microstrip Patch Antenna (CMPA) with great efficiency and a circular defective ground plane is presented by I. Masroor et al. The suggested antenna operates between 5.1725 to 5.3254 GHz and resonates at 5.248 GHz; it was developed at 5.12 GHz using the HFSS (High Frequency Structure Simulator) 13.0 programme. To pinpoint the precise geographic location of the geometrical epicentre of the patch's circular fractal slots, [3] MATLAB R2015a was utilised.

By applying this new method to the ground plane of a patch antenna, R. V. H. Prasad et al. are able to simultaneously decrease the size of the radiating patch and boost the antenna's gain. For use with Wi-Fi networks, engineers have developed a rectangular microstrip antenna operating at 2.45 GHz. Fractals are self-symmetric structures that may be scaled down to minuscule proportions. The ground plane of the 2.4 GHz-frequency rectangular patch antenna is modified with Sierpinski carpet fractal slots [4]. For various wireless/multiband applications, M. Manohar et al. provide a communication that investigates the Koch snowflake fractal monopole slot antenna. An altered star-shaped patch serves as the antenna's radiating element, while a triangularly tapered feedline, a partially slot-loaded ground plane, and an I-shaped parasitic element complete its construction. Koch iteration technique's self-similarity and space-filling properties were used to the triangular patch to achieve the antenna's small size and wideband performance [5].

A new kind of miniaturised microstrip patch design for 10 GHz wireless communications is proposed by G. P. Mishra et al. Here, a highly capacitive modified Minkowski fractal (type-2) defective ground structure (MFDGS-II) is loaded underneath the radiating patch's precise centre, allowing for the antenna's miniaturisation. In order to determine the optimal DGS setup, we use a sensitivity analysis in the current approach. Without altering the antenna's footprint, integrating MFDGS-II reduces the patch's resonance frequency from 16.832 GHz to 10 GHz. By doing so, the antenna's bandwidth and efficiency may be increased while its volume is decreased by as much as 84%. We build an antenna prototype and characterise its operational characteristics [6]. Based on the Koch fractal geometry, meandering slits, and defected ground structure, the present antenna topology developed by A. Arif et al. has a small physical footprint, high structural conformability, and wide impedance bandwidth (BW) for use in the

2.45 GHz ISM (Industrial, Scientific, and Medical) band. The prototype antenna that was built has proven that numerical and experimental findings correlate well [7].

An innovative antenna layout was created using a five-step procedure, as shown by the work of A. T. Abed et al. Each iteration of the dual fractal-structure antenna was formed by adding a new modified square patch that was half the size of the one used in the preceding iteration. The antenna's dual operating bands (2.4-2.65 and 4.8-6.4 GHz) were measured, and they conform to the requirements of both Wi-Fi and WiMAX networks [8]. The authors (X. Yang et al.) show a fractal UC-EBG structure between the two bright spots. In addition, three ground-plane cross-slots are inserted to dampen the mutual coupling even more. The design is simple to fabricate without the need for metal vias, and a row of fractal UC-EBG may help provide a more compact array with an edge-to-edge distance of 0.22 0 that works well in a patch antenna array [9].

Two spiral slots are carved into the patch, as shown by H. Oraizi et al., to lessen interference with commercial bands at 5.8 and 8.3 GHz. There is a comparison made between their frequency and time-domain activities, as well as their miniaturisation, and what is found in the existing literature. We assess and demonstrate the claimed features and specifications [10] by fabricating and measuring a prototype model of an end-fire log-periodic microstrip antenna with the Giuseppe Peano fractal applied to the edges of truncated rhombic branches. It is the first time that P. R. Prajapati, et al., use an approach combining fractal theory and defective ground structure (DGS) to construct CP antennas, which improves performance metrics like axial ratio (AR) bandwidth, return loss bandwidth, radiation efficiency, and so on. Through the use of Koch curve fractal DGS in the ground plane, we are able to reduce the size of the patch by 44.74 percent, increase the bandwidth by 62.73 percent, decrease the bandwidth by 70.74 percent, and increase the radiation efficiency by 4.03 percent, compared to a conventional patch antenna [11].

By keeping the patch length constant while adjusting the fractal scaling factor, S. Costanzo et al. achieve excellent reflectarray phase agility. As a result of the size reduction effect, array grids with reduced interelement spacing may be used, opening up the possibility of wide-angle scanning. An X-band reflectarray element with a fractal form, housed in a 0.30.3 cell, is intended to provide a phase agility range of more than 300° as a proof-of-concept exercise. In order to demonstrate the fixed-beam large-angle pointing capability, [12] also presents the design and experimental validation of a 15 x 15 reflectarray prototype.

Asymmetry along the main axis of the structure has been shown by V. V. Reddy et al (x, y). Small CP antennas may be created by adjusting the indentation parameter of the fractal boundary curve. It has been determined experimentally that at a frequency of around 2540 MHz, the bandwidths of the current fractal boundary Ant 2 are 162 MHz for a return loss of 10 dB and 50 MHz for an axial ratio of 3 dB. With the use of the fractal boundary idea, we were able to reduce the size of the antenna by half, and the results demonstrate that we can obtain outstanding CP with a single probe feed.

In order to create frequency selective surfaces (FSSs), M. R. da Silva et al. describe a fractal design process based on Peano pre-fractal patch components. The current FSS architectures are made from printed metallic patches arranged in periodic arrays atop a fibreglass dielectric. Miniature FSSs with the characteristics of dual-polarized band-stop spatial filters may be

created from the forms offered by pre-fractal patches. Patch components might be arranged in a wide variety of ways due to Peano fractals' space-filling and self-similarity features [14].
These issues with preexisting antennas have been identified after reviewing the literature:

- Inadequate bandwidth.
- Low productivity.
- Reduced gain.
- The feeds and connectors emit additional radiation.

Antenna length and width.
The following is a objective of the planned study:

- As part of the development of 5G wireless networking, it is necessary to create ultra-wideband (UWB) fractal defective ground structures operating in the C-band.
- To expand data transfer rates and minimise reflected interference.
- To derive new parameters and evaluate them against preexisting design outcomes.

III. PROPOSED ANTENNA DESIGN

"The CST programme was used to create the proposed antenna's layout. Figure 2 shows a top view of the proposed microstrip fractal DGS antenna, where one side of a dielectric substrate acts as an emitting fractal and the other acts as a ground plane. Top views on a rectangular fractal radio wire with coaxial feed show that the fractal and ground plane together produce surrounding fields, and it is this field that is responsible for creating the radiation from the antenna, as seen in Figure 2. Due to its compact size and improved reference, the microstip fractal receiving equipment is presented. The suggested receiving equipment has a resonant frequency of 5.4 GHz, which places it squarely inside the realm of C-band frequencies.
After these three factors have been optimised, the size of the radiating patch may be determined.
Step 1: Estimate of dimension in term of width (W)

For an efficient radiator, practical width that leads to good radiation efficiencies is:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}}$$

Where, μ_0 is the free permeability, ε_0 is the free space permittivity and ε_r is relative permittivity.

Step 2: Assuming a dielectric constant of, the second step is to calculate the effective dielectric coefficient.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}[1 + 12\frac{h}{W}]^{1/2}$$

Step 3: Calculation of Effective Length (L_{eff})

The effective length is $L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}}$

Step 4: Calculation of Length Extension (ΔL)

$$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon_{reff}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{rff}-0.258)(\frac{W}{h}+0.8)}$$

Step 5: Calculation of actual Length of Patch (L)

The actual length of radiating patch is obtained by

$$L=L_{eff}-2\Delta L$$

Step 6: Calculation of Ground Dimensions (Lg, Wg)

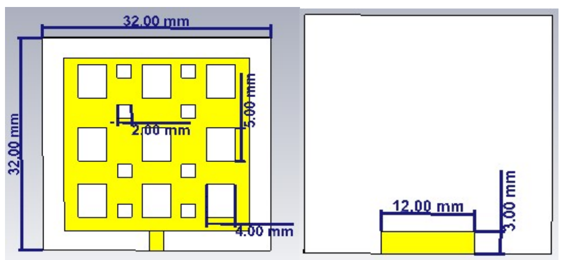
Only infinite ground planes are suitable for the transmission line model. However, a small footprint on the ground is essential for practical reasons. If the ground plane is larger than the patch dimensions by a factor of about a few times the substrate thickness all around the perimeter, then one may get results that are comparable to those for a finite ground plane, as provided by:

$$L_g = 6h + L \ , \ W_g = 6h + W$$

The simulation results are obtained by treating the ground plane as infinite.

$$\boldsymbol{Z_{in}} = j\omega L_p + \frac{R}{1+jQ(f_R - \frac{1}{f_R})}$$

The patch's input impedance may be calculated with a little bit of knowledge about circuit theory, as follows: j Where, the frequency ratio is defined as fR= f/f0, where f0 is the resonance frequency of the patch hole (the resonance frequency of the RLC circuit).



(a) (b)

Figure 2: Antenna Design (a) Top view (b) Bottom View

The design for the suggested microstip fractal antenna is shown in Figure 2. The top and ground layers are crafted from the lossy copper substance, while the substrate is crafted from the FR4 material, which has a dielectric steady worth of 4.4.

IV. SIMULATION AND RESULTS

Figure 2 depicts the suggested microstrip fractal geometry for C-band applications. The construction is engraved on fire resistant 4 (FR4) and measures 32mm by 32mm by 1.64mm overall, with an overall permittivity of 4.4 and a loss digression of 0.024. This proposal's antenna components are listed in Table 1. A 50- and 0.5W coaxial link or a simple connection take care of the antenna.

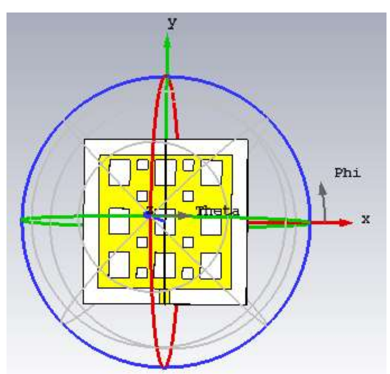


Figure 3: Simulation and fields of proposed antenna

CST microwave studio simulation and suggested antenna fields utilised to reproduce the design. Figure 3 depicts a circularly organised electric and attractive field simulation. ”

"Table 1: Design parameters for proposed Antenna

Sr No.	Parameter	Value
1	Frequency(f_r)	4-8 GHz
2	Dielectric constant(ε_r)	4.4 / FR4
3	Metal Height	0.035mm
4	Substrate Height(h)	1.57 mm
5	Line Impedance	50 Ω-70Ω
6	Antenna Length	32mm
7	Antenna Width	32mm
8	Tangent Loss	0.06
9	Feed patch length	4mm
10	Feed patch width	3mm
11	Feed patch height	0.035mm

Optimized Band: "

Return loss

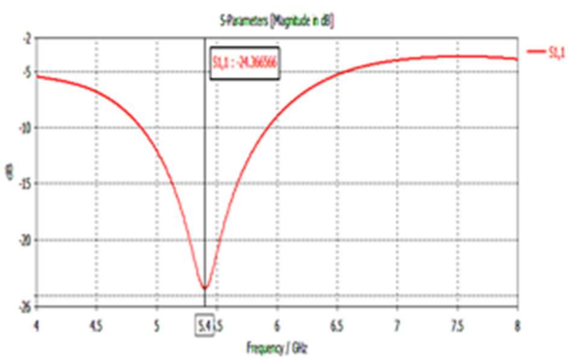


Figure 4: Return loss

The suggested structure's return loss is shown in Figure 4. By looking at this graph, we can easily deduce that the suggested antenna's return loss estimate is -24.36 dB at a resonant frequency of 5.4 GHz.

Bandwidth

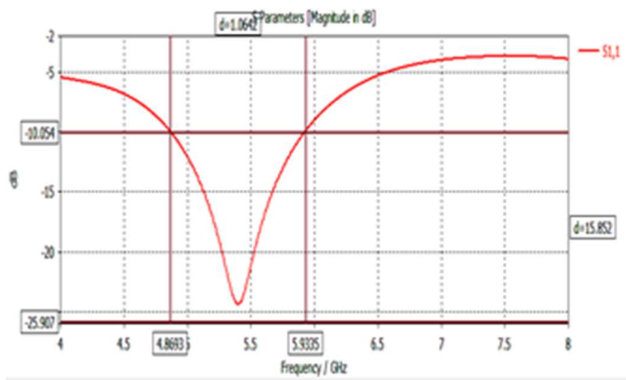


Figure 5: Bandwidth

The bandwidth of a broadband antenna is often represented as a fraction of the difference between the highest and lowest frequencies relative to the bandwidth's fundamental frequency. In this case, 1064 MHz is the bandwidth of the proposed antenna (5.93GHz – 4.86GHz)..

Voltage Standing Wave Ratio (VSWR)

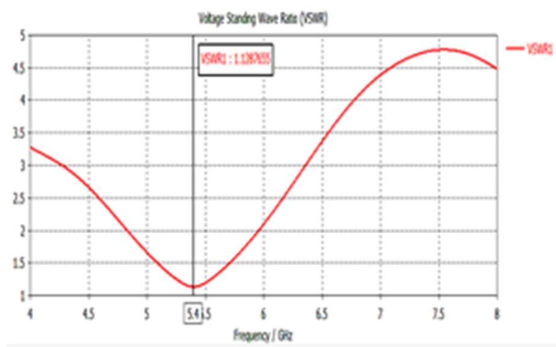


Figure 6: VSWR

The VSWR respect shown in Figure 6 has been attained at 5.4 GHz, where the required VSWR values are between 1.2 and 1.4. The VSWR value is 1.128.

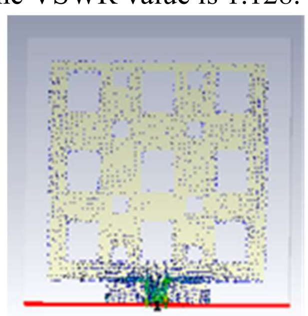


Figure 7: Surface current of proposed antenna

Surface current of the proposed antenna is shown in Figure 7. The proposed antenna's electric and magnetic fields are also shown, with electric field shown by blue dots and magnetic field shown by green dots.

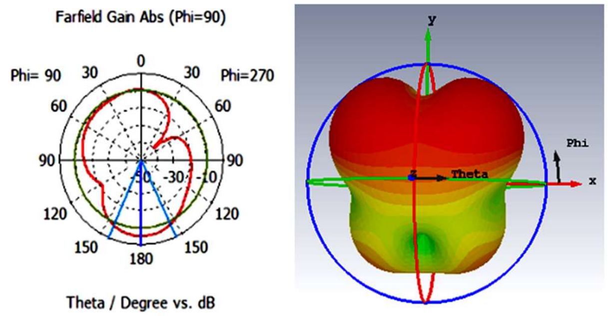


Figure 8: Radiation pattern

As can be seen in Figure 8, the suggested antenna bands have a certain radiation pattern. It's a twist on the force an antenna always sends out as part of the direction of the signal it receives.

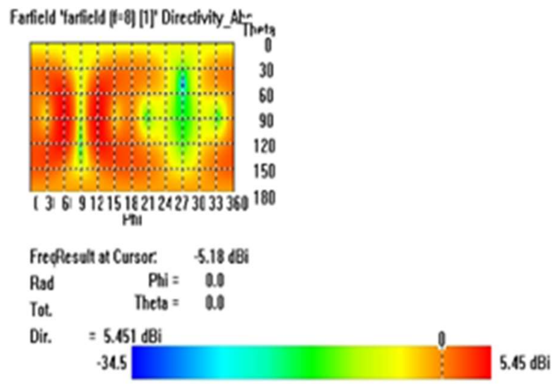


Figure 9: Directivity Analysis

An illustration of the proposed antenna's directional characteristics is shown in Figure 9. Value of directivity is 5.45dBi. "

Table 2: Simulated Results of Proposed Antenna

Sr No.	Parameter	Value
1	S11 or Return loss	-24.33 dB
2	Band Width	1064 MHz
3	VSWR	1.12
4	Resonant Frequency	5.4 GHz
5	Design type	Rectangular
6	Dimension	32 X 32 X 1.6 mm3

7	No of band	1
8	Directivity	5.45 dBi
9	Gain	3 dBi
10	Y- Parameter (Admittance)	0.012
11	Z-Parameter (Impedance)	76.96

Parameters such as return loss, bandwidth, VSWR, and resounding recurrence are summarised in Table 2. Table 2's recalculated data show that the proposed antenna produces a significant improvement over the status quo.

Table 3: Result Comparison

Parameter	Existing Design Results [1]	Proposed Design Results
S11 or Return loss	-17.85 dB	-24.36 dB
Band Width	162.735 MHz	1064 MHz
VSWR	1.31	1.128
Resonant Frequency	2.8 GHz	5.4 GHz
Gain	1.92 dBi	3.025 dBi
Dimension	39.7 X 47 X 1.6 mm^3	32 X 32 X 1.64 mm^3

V. CONCLUSION

We use CST simulation software to construct and test a single-band, fractal microstrip patch antenna. We show and debate the simulation findings. The existing antenna has a small and straightforward design, measuring just around 32 by 32 by 1.64 mm3. The developed antenna's modest size makes it suitable for use in portable gadgets. The results reveal that the frequency range is between 4 and 8 GHz, with resonance frequencies of 5.4 GHz, VSWRs less than 2, and S11s of -24.36dB. The achieved results match all the requirements of the current antenna. The developed antenna has a low return loss and good impedance matching, therefore it performs well in any environment. Proposed antenna is acceptable and satisfies to 5G wireless communication criteria and appropriate for C band applications. ”

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