Fractal Micro Strip Patch Antenna with Defected Ground Structure for 5G Wireless Communication Applications

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Abstract : Microstrip antenna design is promising structure for advance wireless communication applications or in 5G. Fractal pattern is also very trending research area among antenna researchers. Various combination of fractal antenna designs using in various electronics applications. The frequency range of C band is 4-8GHz. Most of the 5G wireless communication application will lie in this range. This paper proposed single band microstrip fractal antenna with defected ground structure. These types of antennas can be used in 5G mobile communication applications.CST microwave studio software is used for design and simulation. Structure of proposed antenna is simple and compact in size of approx 32 X 32 X 1.64 mm3. The simulated results show that the frequency bandwidth covers 4-8GHz, at centre frequencies 5.4GHz for VSWR less than 2. The return loss values are -24.36 dB for 5.4GHz resonant frequency. The achieved bandwidth is 1064 MHz.

***IndexTerms* – Fractal, Microstrip, Antenna, Bandwidth, Return loss, VSWR.**

I. INTRODUCTION

Antenna designers are always looking to come up with new ideas to push the envelope for antennas, using a smaller volume while striving for every higher bandwidth and antenna gain. One proposed method of increasing bandwidth (or shrinking antenna size) is via the use of fractal geometry, which gives rise to fractal antennas. Fractals are those fun shapes that if you zoom in or zoom out, the structure is always the same.

They have wild properties, like having a finite area but infinite perimeter. They are often constructed via some sort of iterative mathematical rule, that generates a fractal from a simple object step by step. In the last section of this page, we will do that in designing a fractal antenna. The different wireless applications require distinct antenna, whereas, a multipurpose antenna is always a prime requirement of the market. Due to less weight, small size, ease of fabrication, low profile, multiband/wideband characteristics, Microstrip Patch Antenna (MPA) and Fractal Antennas are gaining huge popularity.

Such fractal antennas are also referred to as multilevel and space filling curves, but the key aspect lies in their repetition of a motif over two or more scale sizes, or "iterations". For this reason, fractal antennas are very compact, multiband or wideband, and have useful applications in cellular telephone and microwave communications. A fractal antenna's response differs markedly from traditional antenna designs, in that it is capable of operating with good-to-excellent performance at many different frequencies simultaneously. Normally standard antennas have to be "cut" for the frequency for which they are to be used and thus the standard antennas only work well at that frequency.

This makes the fractal antenna an excellent choice for wideband and multiband applications. In addition the fractal nature of the antenna shrinks its size, without the use of any components, such as inductors or capacitors. A fractal antenna is an antenna that uses a fractal, self-similar design to maximize the effective length, or increase the perimeter (on inside sections or the outer structure), of material that can receive or transmit electromagnetic radiation within a given total surface area or volume.

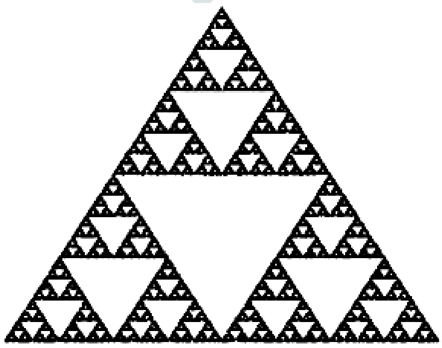

Figure 1: Fractal antenna

Such fractal antennas are also referred to as multilevel and space filling curves, but the key aspect lies in their repetition of a motif over two or more scale sizes,[1] or "iterations". For this reason, fractal antennas are very compact, multiband or wideband, and have useful applications in cellular telephone and microwave communications. A fractal antenna's response differs markedly from traditional antenna designs, in that it is capable of operating with good-to-excellent performance at many different frequencies simultaneously. Normally standard antennas have to be "cut" for the frequency for which they are to be used—and thus the standard antennas only work well at that frequency.

A fractal is a rough or fragmented geometric shape that can be subdivided in parts, each of which is (at least approximately) a reduced-size copy of the whole. Fractals are generally self-similar and independent of scale. There are many mathematical structures that are fractals; e.g. Sierpinski's gasket, Cantor's comb, von Koch's snowflake, the Mandelbrot set, the Lorenz attractor, et al. Fractals also describe many real-world objects, such as clouds, mountains, turbulence, and coastlines that do not correspond to simple geometric shapes.

II. BACKGROUND

M. Manohar et al., [1] The proposed antenna has a compact size of $17 \times 29 \times 0.787$ mm ^{3} and has a stable radiation pattern over the entire frequency spectrum. For pattern stability, an I-shaped parasitic element was utilised. Moreover, the typical antenna parameters such as return loss, gain, radiation pattern and group delay have been simulated and verified experimentally. Time-domain characteristics have also been studied.

P. R. Prajapati et al., [2] proposed for the first time in design of CP antennas. 44.74% size reduction in patch size, enhancements of 62.73% in AR bandwidth, 70.74% in return loss bandwidth and 4.03% in radiation efficiency is achieved as compared with conventional patch antenna, after incorporation of Koch curve fractal DGS in the ground plane.

S. Costanzo et al., [3] The achieved size reduction effect allows to choose array grids with smaller interelement spacing, thus offering the opportunity to have wide-angle scanning capabilities. As validation test, a fractal-shaped X-band reflectarray element, embedded into a $0.3\lambda \times 0.3\lambda$ cell, is designed to give a high phase agility range, greater than 300°.

V. V. Reddy et al., [4] show that 10-dB return loss and 3-dB axial-ratio bandwidths of the proposed fractal boundary Ant 2 are 162 and 50 MHz, respectively, at operating frequency of around 2540 MHz. Results show that an excellent CP is achieved with a single probe feed, besides reduction in the antenna size by applying fractal boundary concept.

M. R. da Silva et al., [5] This work presents a fractal design methodology for frequency selective surfaces (FSSs) with Peano pre-fractal patch elements. The proposed FSS structures are composed of periodic arrays of metallic patches printed on a single-layer fibreglass dielectric. The shapes presented by pre-fractal patches allow one to design compact FSSs that behave like dual-polarised band-stop spatial filters.

H. Oraizi et al., [6] it is investigate the possibilities and properties of the application of Giuseppe Peano fractal geometry for the miniaturization of microstrip patch antennas and compare its performance with those of the usual fractals, such as Koch, Tee-Type and Sierpinski. The length of the Giuseppe Peano fractal patch perimeter increases, while its surface area remains constant without any more space occupation.

D. Oloumi et al., [7] it has been proven for conventional phased array antennas, this size reduction can lead to a decrease in mutual coupling in reflectarray antennas. Alternatively, it allows for smaller distance between reflectarray antenna elements, which renders a wider beam-scanning range.

R. Tiwari et al., [8] presents we reviewed WBAN communication architecture, security and privacy requirements and security threats and the primary challenges in WBANs to these systems based on the latest standards and publications. This paper also covers the state-of-art security measures and research in WBAN.

V. Shrivastava et al., [9] focused on study based various types of microstrip antenna. Return loss, VSWR, bandwidth, resonant frequency and gain is key parameters to judge antenna performance. Good value of return loss is less than -10dB. Considerable range of VSWR is 1-2. CST microwave studio is a advance software to design and simulation of all types of antenna, filter etc.

R. Tiwari et al., [10] 5G antenna frequency range is divided in majorly two bands. First is 5G lower band, which cover 600MHz to aprox 10GHz. Second is 5G upper band, which cover 24GHz to 84GHz. The antenna C-band is lying under 5G lower band. Wi-Fi is most commonly used application in domestic and industrial under 3G/4G network. In 5G wi-fi communication required enhanced bandwidth and high speed performance.

III. PROPOSED DESIGN

The proposed research work is summarized is as follows-

- To design fractal micostrip patch antenna at C-band wireless frequency range.
- To enhance bandwidth and improve other performance parameters.
- To calculate parameters and compare with existing design results.

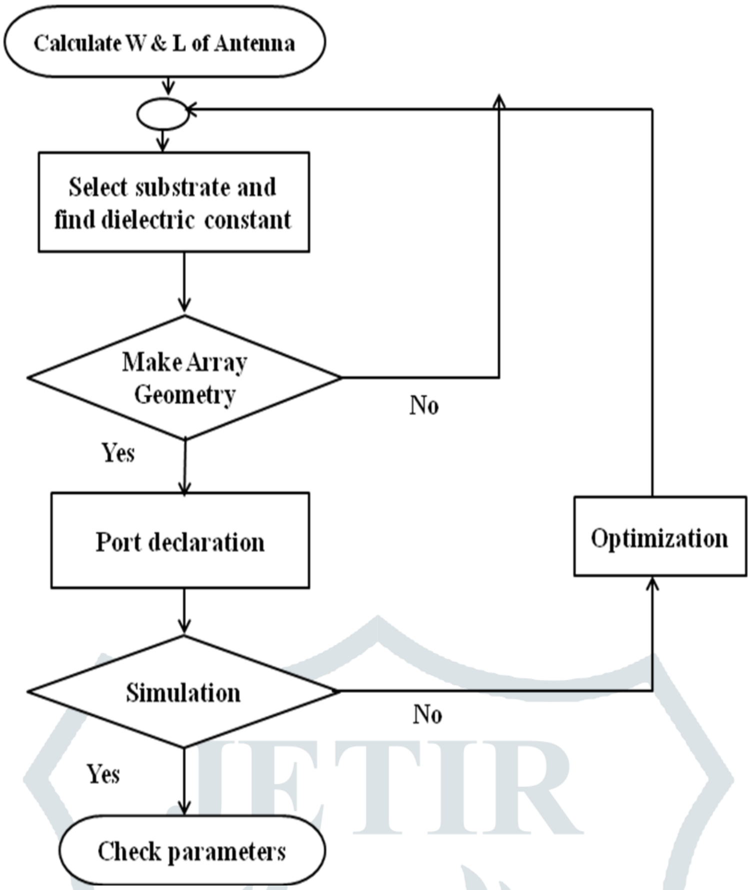

Figure 2: Flow Chart

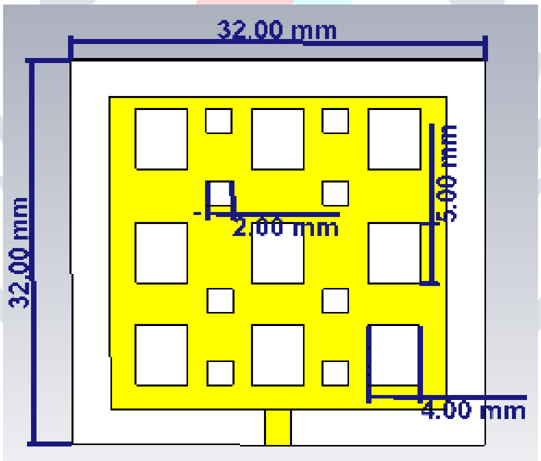

Figure 3: Dimension of proposed antenna

Figure 3 is showing dimension of different component of proposed antenna. This dimension is calculated based on standard formulas and optimization. Therefore the dimension of antenna is (LxWxH) 32 X 32 X 1.64 mm^3. The proposed antenna is based on fractal pattern so the dimension of first block is 4 X 5mm second block is 2 X 2 mm. The feed patch dimension is 4 X 3 mm. The substrate material which is using in proposed antenna is FR4 material.

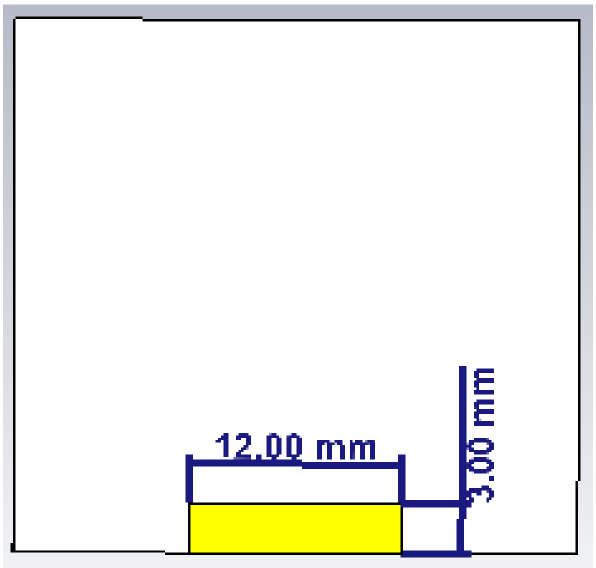

Figure 4: Bottom view of proposed antenna

Figure 4 is showing bottom view of antenna, this is also known as ground structure. Proposed antenna is using defected ground structure

IV. SIMULATION RESULT

Scattering parameters describe the electrical behavior of linear electrical networks when undergoing various steady state stimuli by electrical signals.S11 represents how much power is reflected from the antenna, and hence is known as the reflection coefficient or return loss. If S11=0 dB, then all the power is reflected from the antenna and nothing is radiated. Return loss is the difference, in dB, between forward and reflected power measured at any given point in an RF system and, like SWR, does not vary with the power level at which it is measured. Figure 5 shows the Return Loss (S_{11}) parameters for the proposed antenna.

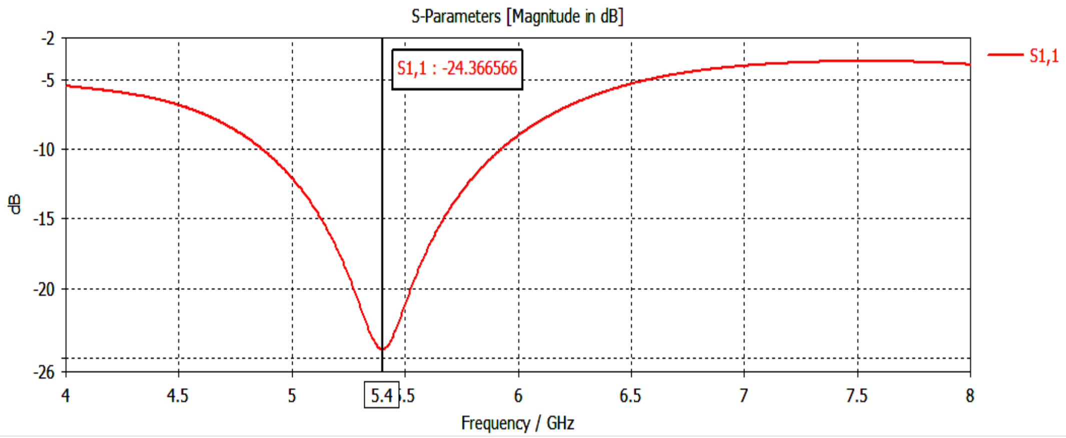

Figure 5: Return loss of band

The obtained value of S_{11} or return loss is -24.36 dB for 5.4 GHz resonant frequency, where antenna gives better performance.

The bandwidth of an antenna is defined as "the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard." For broadband antennas, the bandwidth is usually expressed as the ratio of the upper-to-lower frequencies of acceptable operation.

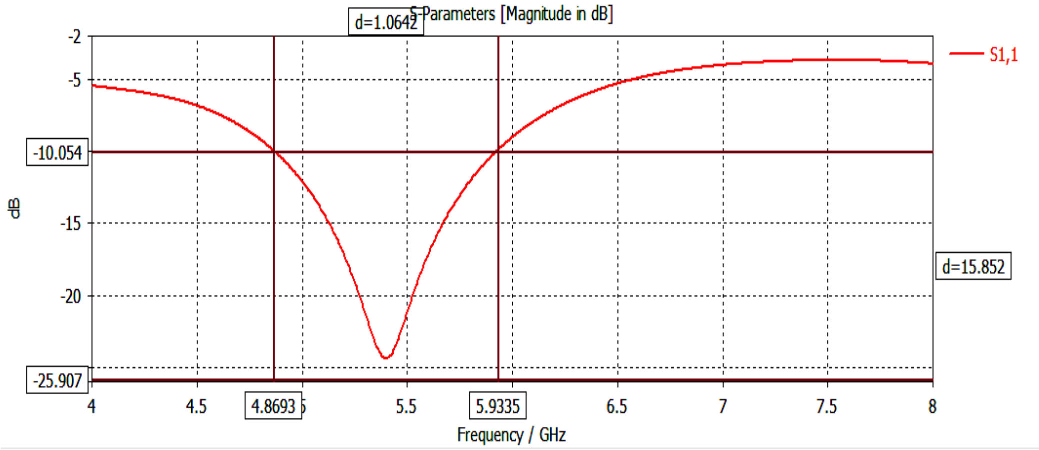

Figure 6: Bandwidth calculation of band

For broadband antennas, the bandwidth is expressed as a percentage of the frequency difference (upper minus lower) over the center frequency of the bandwidth. The bandwidth of proposed antenna is 1064 MHz (5.9335 GHz – 4.8639GHz) for optimize band.

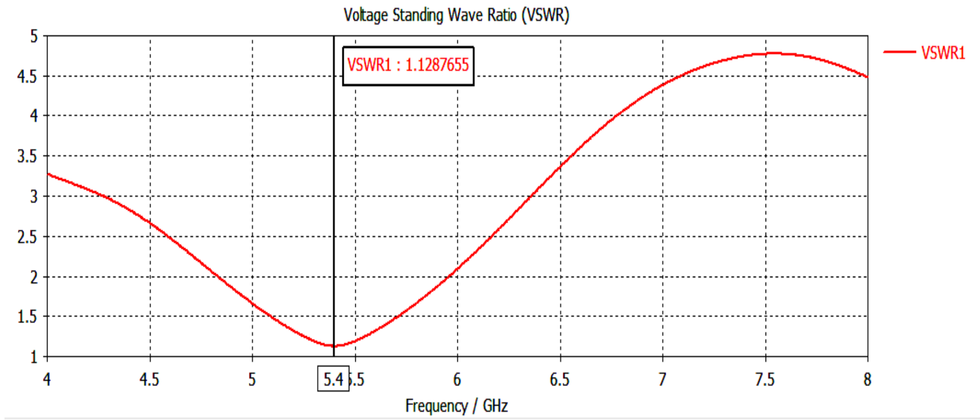

Figure 7: VSWR

VSWR must lie in the range of 1-2, which has been achieved for the frequencies 5.4 GHz.

The value for VSWR is 1.128

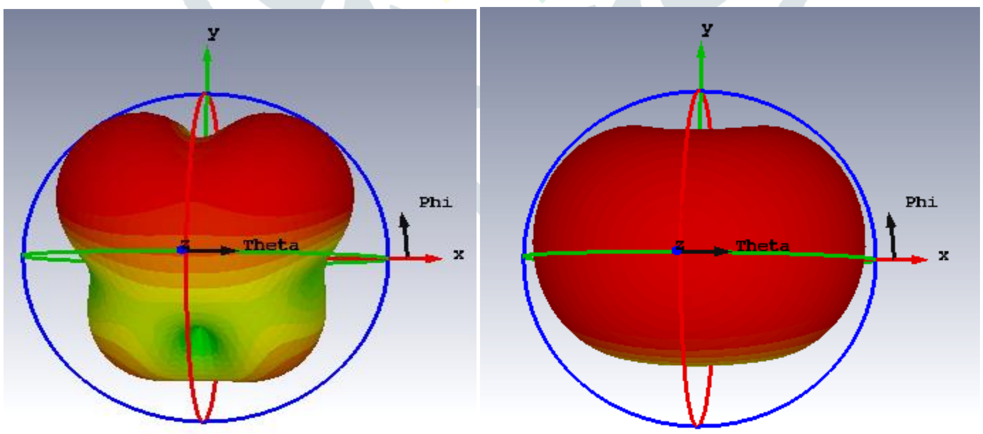

Figure 8: 3D Radiation pattern of proposed antenna

The radiation pattern of microstrip or patch antenna is broad. It has low radiation power and narrow frequency bandwidth. To have a greater directivity, an array is formed by using these patch antennas. In the field of antenna design the term radiation pattern (or antenna pattern or far-field pattern) refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source. Minor lobes usually represent radiation in undesired directions, so in directional antennas a design goal is usually to reduce the minor lobes. Side lobes are normally the largest of the minor lobes. The level of minor lobes is usually expressed as a ratio of the power density in the lobe in question to that of the major lobe.

Table 1: Result summary of proposed antenna

Sr. No.	Parameter	Band
1	S11 or Return Loss	-24.36 dB
2	Band Width	1064 MHz
3	VSWR	1.128
4	Resonant Frequency	5.4 GHz
5	Efficiency	65%
6	Directivity	3.08 dBi
7	Gain	2.08 dBi
8	Y- Parameter (Admittance)	0.012
9	Z-Parameter (Impedance)	76.96

Table 2: Comparison of proposed design results with previous design results

Sr No.	Parameter	Previous work	Proposed work
1	S11 or Return loss	-18.42 dB	-24.36 dB
2	Band Width	Approx 100 MHz	1064 MHz
3	VSWR	1.31	1.128
4	Resonant Frequency	2.4 GHz	5.4 GHz
5	Design type	Fractal	Fractal
6	Dimension	92 X 84 X 1.6 mm^3	32 X 32 X 1.64 mm^3
7	Design	Fractal	Fractal

Table 2 showing comparison of proposed antenna results with previous design result in terms of bandwidth, return loss, resonant frequency and VSWR etc

V. CONCLUSION

Therefore a single band, fractal microstrip patch antenna is designed and simulated using CST simulation software. The simulation results are presented and discussed. Structure of proposed antenna is simple and compact in size of approx 32 X 32 X 1.64 mm3 the compact size of designed antenna makes it easy to be incorporated in small devices. Results show that the frequency bandwidth covers 4-8 GHz, at resonant frequencies 5.4 GHz, VSWR less than 2, and S11 -24.36dB. The final results satisfy all the parameters of proposed antenna. The designed antenna works efficiently under all conditions with low return loss and proper impedance matching.

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