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Design of Fractal Defected Ground Structure for L-Band Wireless Communications Application

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ABSTRACT: The antenna designing and improvement is continues growing in the field of radio engineering and communication. A Low cost, high performance, compact size, wideband, and low profile antennas often meet the stringent requirements of modern wireless communication systems. This paper presents the fractal defected ground structure for L band wireless communication applications. The proposed antenna optimized the 201MHz bandwidth while previous it is 45MHz. The resonant frequency is 1.987GHz while previous it is 1.575 GHz. The size of fractal antenna is 32 X 32 X 1.64 mm³, while previously it is 83 X 45 X 1.6 mm³.

KEYWORDS: Fractal, Defected Ground Structure, L-band, Antenna, Frequency, Return Loss, Gain, Directivity.

I. INTRODUCTION

In radio engineering, an antenna or aerial is the interface between radio waves propagating through space and electric currents moving in metal conductors, used with a transmitter or receiver.[1] In transmission, a radio transmitter supplies an electric current to the antenna's terminals, and the antenna radiates the energy from the current as electromagnetic waves (radio waves). In reception, an antenna intercepts some of the power of a radio wave in order to produce an electric current at its terminals that is applied to a receiver to be amplified. Antennas are essential components of all radio equipment. L band refers to the operating frequency range of 1–2 GHz in the radio spectrum. The L band is one of the chief operating ranges used by various applications such as radars, global positioning systems (GPS), radio, and telecommunications and aircraft surveillance.

To round off the faculties that adorn the L Band satellite frequency, we must say that the L band operates in a range of frequencies ranging from 1,530 to 2.7 Ghz, being the one with the lowest frequency amongst satellite bands used in the market.

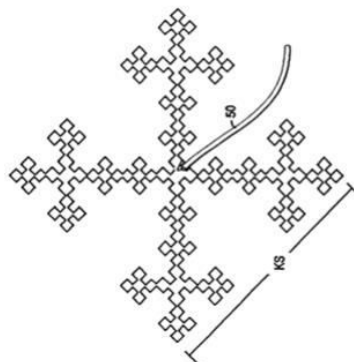


Figure 1: Fractal Antenna

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

K. Wei et al.,[1] proposes the circularly polarized (CP) antennas with a restored radiation pattern for the polarization diversity applications. The proposed CP antennas have dual polarizations, the left-handed circularly polarized (LHCP) antenna is designed for transmitting and the right-handed circularly polarized (RHCP) antenna is designed for receiving. The CP antenna operation and the radiation pattern restoration are realized by a fractal defected ground structure (FDGS). When achieving the radiation pattern restoration, the proposed CP antennas forward efficiencies are improved from 66.8% to 81% and the forward realized gains are improved from 2.56 dBi to 5.38 dBic, respectively.

W. Balani et al.,[2] With the recent advancement and phenomenal progress in the field of wireless communication technology, there is an ever increasing demand for high data rates and improved quality of service for the end users. In recent times various designs of super wideband antennas (SWB) fulfilling diverse objectives have been proposed for modern wireless networks..

A. T. Abed et al.,[3] In this study, an Amer fractal slot antenna is proposed as a multiple input, multiple output (MIMO) antenna with four ports. The antenna is excited by CPW (coplanar waveguide) to control the leakage of electromagnetic energy, which leads to a high match between the antenna and input impedance, thus achieving dual operating bands of 1.5-19.2 GHz and 25-37.2 GHz for port 1, dual operating bands of 1.4-19 GHz and 20-35.5 GHz for port 2, a wide operating band of 1.4-29 GHz for port 3, and dual operating bands of 1.6-21 GHz and 22-37 GHz for port 4.

X. Li, G et al.,[4] Wideband vehicular planar inverted-F antenna (PIFA) array with high isolation by using a fractal structure is presented in this letter. The PIFA antenna elements are placed face to face, and the decoupling structure (DS) consisting of four fractal unit slots and a narrow line slot is inserted between elements to reduce the mutual coupling. The proposed structure is fabricated, and the suppression effect of mutual coupling is verified by both the simulation and measurement. Measured results show that the impedance bandwidth is from 3.02 to 3.96 GHz, which covers the 5G working frequency.

X. Lin et al.,[5] This letter presents a novel design of a uniplanar compact electromagnetic bandgap (EBG) for millimeter-wave wearable antennas. The unit cell of the EBG has a flexible fractal design with self-similar window-like structure, which can be easily fabricated at millimeter scale. The fabricated EBG is a 3×3 cell array laser-cut from adhesive copper foil on polyester fabric substrate. Results show that the gain and -10 dB bandwidth of a wearable coplanar waveguide (CPW) antenna backed by the proposed EBG are improved by 3 dB and 40%, respectively, across the frequency range from 20 to 40 GHz.

T. Mondal et al.,[6] A compact circularly polarized wide-beamwidth patch antenna is presented here. The proposed antenna can be used for blind spot detection in the smart vehicle. Miniaturization and beamwidth enhancement of the antenna are the main areas of discussion. The size of the patch becomes 44% smaller than the conventional patch by folding the edge of the radiating patch with loading slots. Due to the small size, it can be placed in the compact aerodynamic wireless devices.

F. Wang et al.,[7] A compact and wideband ultra-high-frequency antenna is developed in this work. By applying the Minkowski fractal geometry into both the lateral boundaries of monopole and the upper boundary of ground plane and loading the asymmetric strips at the top of monopole simultaneously, the miniaturization is realized; by means of adjusting the fractal direction to produce a complementary structure and cutting the triangular notch on the ground plane, the impedance bandwidth is enhanced. The influences of critical parameters on the impedance bandwidth are determined through the sensitivity analysis.

B. Biswas et al.,[8] This communication presents a new approach to implement planar antipodal Vivaldi antenna design. A nature fern inspired fractal leaf structure is implemented here. Impedance bandwidth (-10 dB) of the proposed antenna is around 19.7 GHz starting from 1.3 to 20 GHz. The lower operating frequency of this antenna is reduced by 19% with the second iteration as compared to the first iteration of fractal leaf structure. The prototype antenna is fabricated and tested in frequency as well as in time domains to obtain various transfer characteristics along with common antenna parameters.

III. PROPOSED METHODOLOGY

The proposed research work is summarized is as follows -

- To design of fractal defected ground structure antenna at L-band for wireless communication applications.
- To improve the bandwidth and minimize the return loss and size of antenna.
- To calculate performance parameters and compare with existing design results.

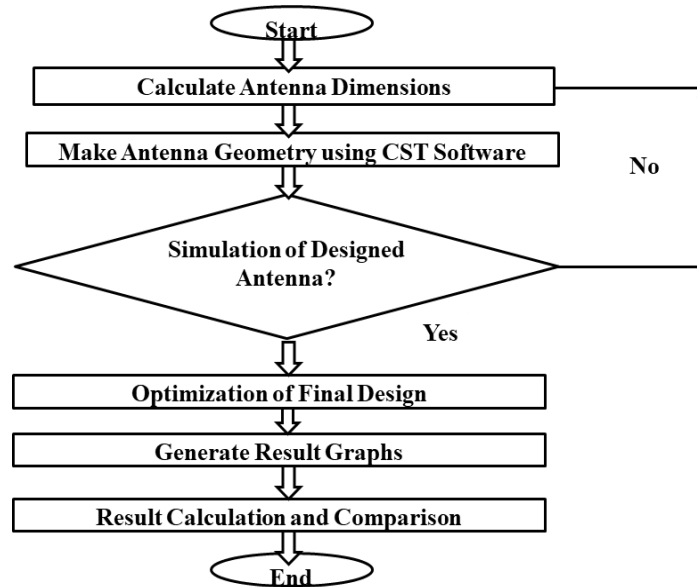


Figure 2: Flow Chart

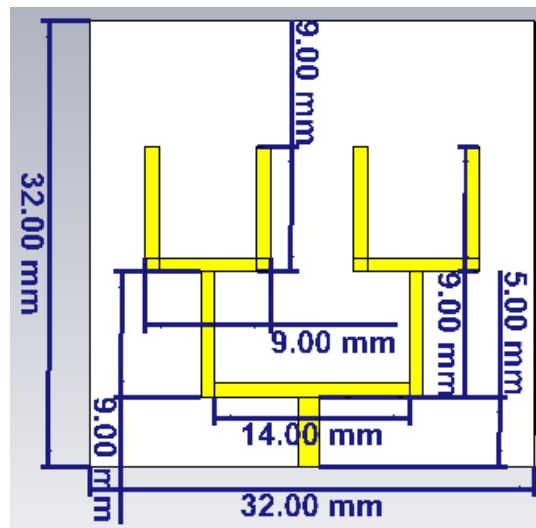


Figure 3: Dimension of proposed antenna

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 mm³. The proposed antenna is based on fractal pattern. The length of feed patch is 5mm and width is 2mm. The substrate material which is using in proposed antenna is FR4 material.

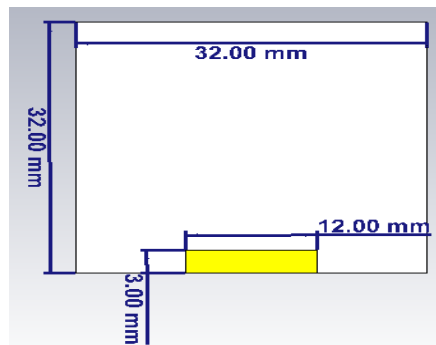


Figure 4: Bottom view of proposed antenna

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

IV. SIMULATION RESULTS

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 5.3 is showing the results in CST software window. Figure 5.4 shows the Return Loss (S11) parameters for the proposed antenna, which represents antenna band of frequency for which the antenna designed is optimized i.e. frequencies ranging from 1 GHz to 4 GHz with S11 value beyond -10 dB and the range of frequencies as per the results shows that it has a good bandwidth as compared to other fractal antenna.

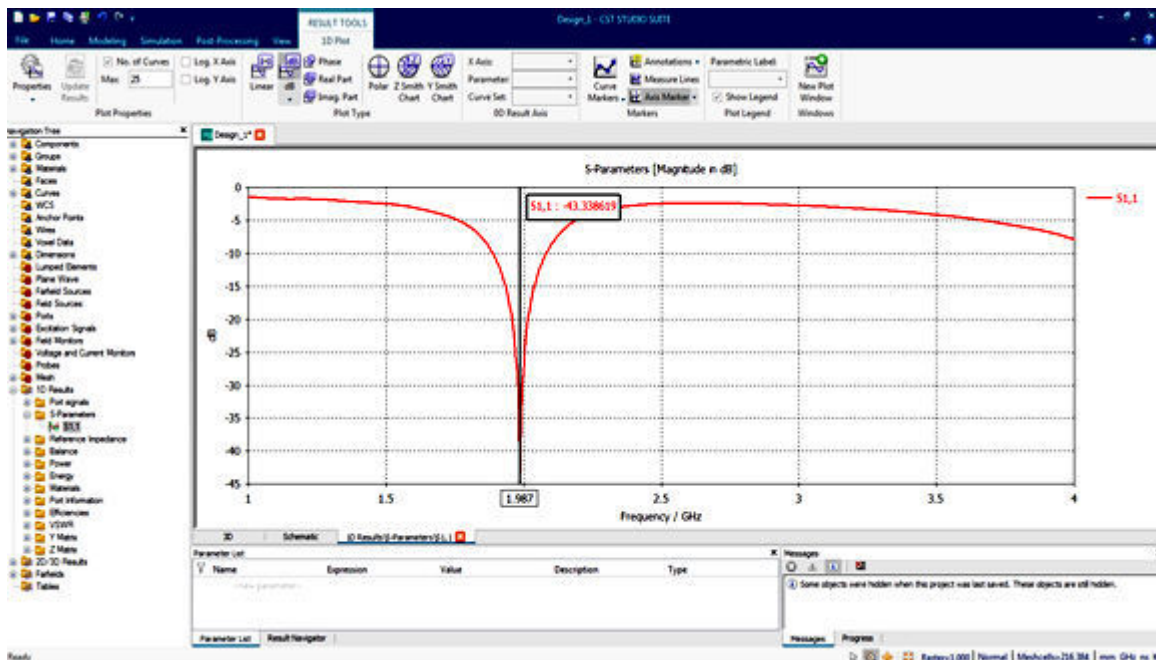


Figure 5: Return loss

The obtained value of S11 or return loss is -43.33 dB for 1.987 GHz resonant frequency, where antenna gives better performance.

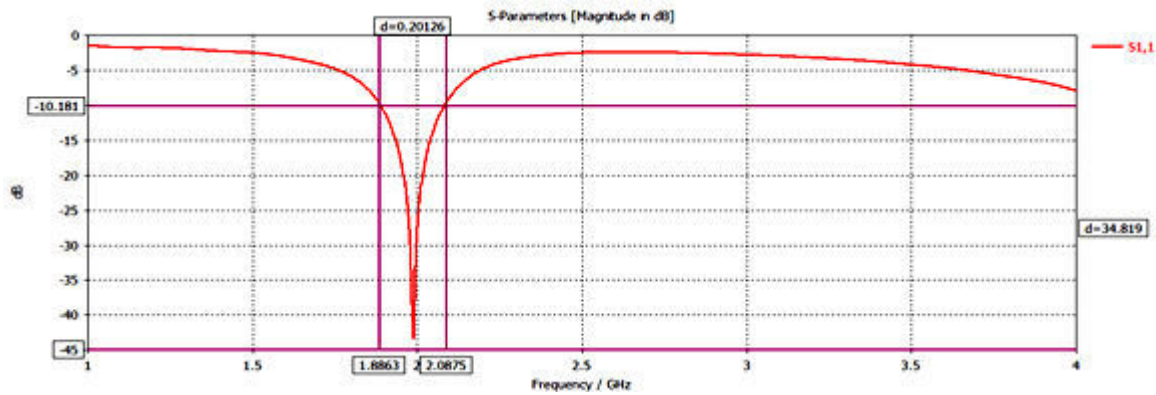


Figure 6: Bandwidth calculation of band

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 201 MHz, (2.0875GHz – 1.8863GHz).

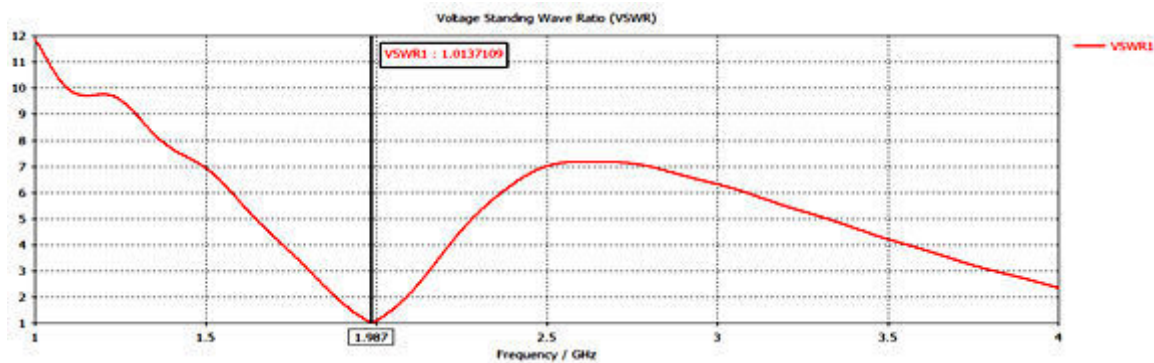


Figure 7: VSWR

VSWR must lie in the range of 1-2, which has been achieved for the frequencies 1.9 GHz. The value for VSWR is 1.0137.

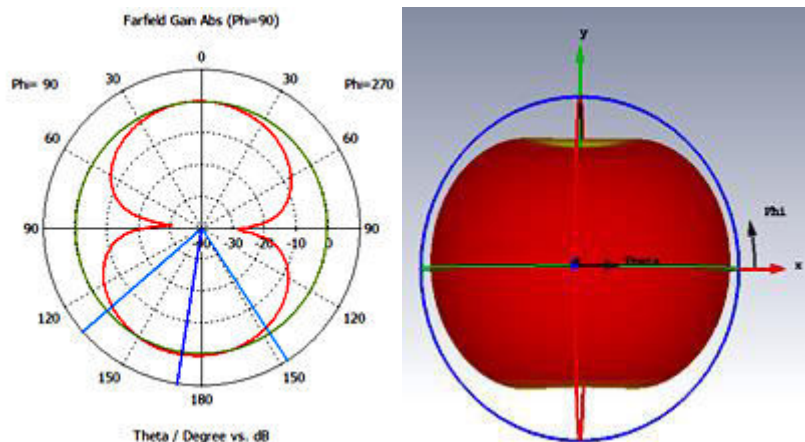


Figure 8: 3D Radiation pattern of proposed antenna

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	-43.33 dB
2	Band Width	201 MHz
3	VSWR	1.013
4	Resonant Frequency	1.987 GHz
5	Directivity	2.94 dBi
6	S11 or Return Loss	-43.33 dB

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

Sr No.	Parameter	Previous work[1]	Proposed work
1	S11 or Return loss	-40 dB	-43.33 dB
2	Band Width	45 MHz	201 MHz
3	VSWR	1.12	1.013
4	Resonant Frequency	1.575 GHz	1.987 GHz
5	Design type	Fractal DGS	Fractal DGS
6	Dimension	83 X 45 X 1.6 mm ³	32 X 32 X 1.64 mm ³

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

The antenna design for high-speed multimedia connectivity represents a challenging activity for designers of fixed and wireless communication systems. Therefore a single band, fractal defected ground structure antenna is designed and simulated using CST simulation software. The value of return loss is -40 dB in case of existing results while its -43.33 dB in proposed design results. The proposed antenna optimized the 201MHz bandwidth while previous it is 45MHz. The resonant frequency is 1.987GHz while previous it is 1.575 GHz. The size of fractal antenna is 32 X 32 X 1.64 mm³, while previously it is 83 X 45 X 1.6 mm³. Therefore proposed antenna reduces the overall size and achieves improved value of bandwidth and return loss.

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