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Design and Analysis of Modified Sierpinski Gasket Fractal Antenna

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***Abstract*- A Modified Sierpinski Fractal patch antenna has been designed and analyzed in this paper. As research in the field of antenna design has already established, therefore it is exceptional that a novel approach is used over conventional antenna design methods to optimize the existing sierpinski fractal antenna. This fractal structure is implemented on square and several iterations are applied on initial shape. The space filling and self-similarity property are used to design above said antenna. The proposed fractal antenna is designed on RT-DUROID substrate of thickness 1.6mm and relative permittivity of 2.2 and mounted above the ground plane at a height of 6mm using IE3D simulation software. Here, microstrip line feed is used to excite the antenna. Performance has been analyzed in terms of return loss, VSWR, input impedance, gain, and bandwidth in the 1 GHz to 5 GHz frequency range. The proposed antenna provides an impedance bandwidth of 56 % and high gain around the resonant frequency of 0.55 GHz .This antenna design can be used in Ground Penetration Radar (GPR), which is found to be suitable for land mine detection.**

Keywords-Fractal Antenna, Return Loss, VSWR, IE3D, Sierpinski Gasket, Simulation.

I. INTRODUCTION

Antennas enable wireless communications between two or more stations by directing signals toward the stations. An antenna is defined by Webster's Dictionary as - "a usually metallic device (as a rod or wire) for radiating or receiving radio waves" [1]. The antenna types can be classified based on frequency band of operation, physical structure, and electrical/electromagnetic design. For wireless communication system, antenna is one of the most critical components. A good design of the antenna can thus improve overall system performance.

Microstrip patch antennas are widely implemented in many applications due to their attractive features such as low profile, lightweight, high efficiency, comfortable to planer & non-planer surfaces and easy integration to circuits [2]. A MSA in its simplest form consists of a radiating patch on one side of dielectric substrate and a ground plane on the other side. Often microstrip antennas are also referred to as patch antennas. There are various types of radiation patch shapes etched on substrate such as square, circular, rectangular, triangular, sectoral, circular ring, semicircular, octagon, dipole and elliptical. However, the major disadvantage of the micro-strip patch antenna is its inherently narrow impedance bandwidth. Further, the requirements of modern wireless communication system are small size, low profile multiband antenna, lesser cost, and wider bandwidth. Researchers have suggested the fractal shape used in microstrip patch antenna to meet above said requirements. Many approaches have evolved over the years, which can be used to achieve one or more of these design objectives. Fractal based antenna has gathered lot of attention recently.

The paper is arranged as follows. The Section 2 defines the fractal antenna, different geometries and advantages. Section 3 illustrates the feeding mechanism. The basic concept behind the design of proposed antenna is described in Section 4. Section 5 presents the discussion of simulated results of proposed fractal patch antenna. The conclusion of the paper is presented in Section 6.

II. FRACTAL ANTENNA

The term fractal, which means broken or irregular fragments, was originally coined by Mandelbrot to describe a family of complex shapes that possess an inherent self-similarity or self-affinity in their geometrical structure [3]. The word fractal is derived from the Latin word "fractus" meaning broken, uneven, any of various extremely irregular curves or shape that repeat themselves at any scale on which they are examined. A fractal antenna is an antenna that uses a fractal, self-similar design to maximize the length, or increase the perimeter of material that can receive or transmit electromagnetic radiation within a given total surface area or volume[4] .

Fractal characterized properties are space filling and self-similarity. Self similarity property denotes that the pattern develops into similar if the portion of the pattern is expanded by a long way. Space filling properties show the way to curves that are electrically very long but fit into compressed physical shape. This can lead to decrease of antenna size and more transformation of energy from transmission line to free space in less volume.

The original inspiration for the development of fractal geometry came largely from an in-depth study of the patterns of nature [5]. For example, fractals have been successfully used to model such complex natural objects as galaxies, cloud boundaries, mountain ranges, coastlines, snowflakes, trees, leaves, ferns, and much more as shown in figure 1.

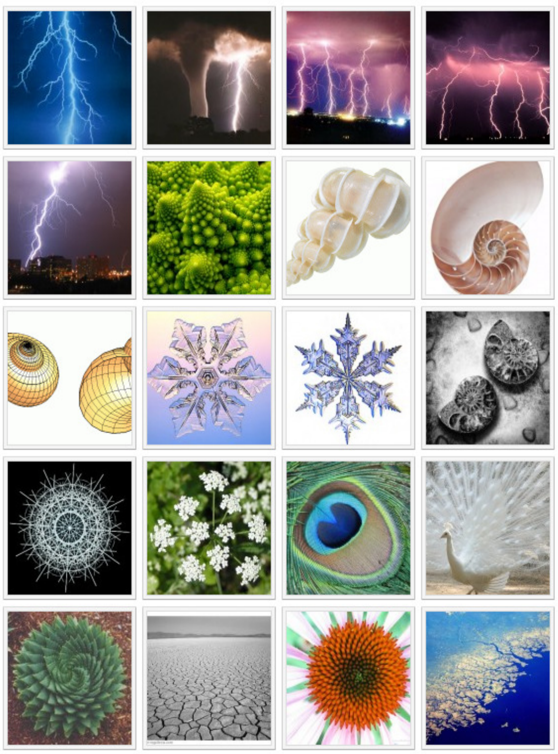


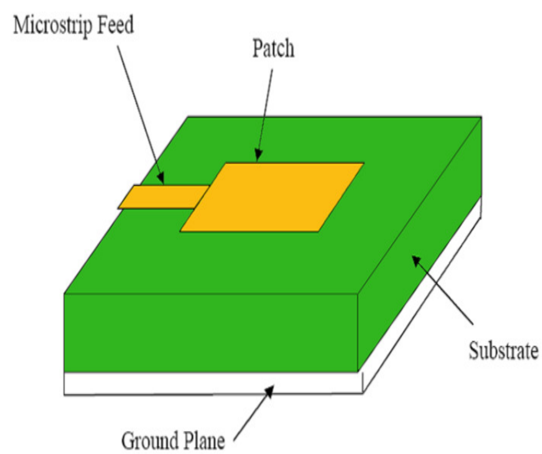
Figure 1. Fractals in nature

After the initial work of Mandelbrot and others wide range of applications for fractals developed in many branches of science and engineering. Fractal geometry is mixed with electromagnetic theory for the purpose of discovering new class of radiation, propagation and scattering problems [6]. One of the recent areas of fractal electrodynamics research is in its application to antenna theory and design of antenna [7].

There are many fractal geometries that have been found to be useful in developing new and innovative designs for antennas [8]. These geometries have been used to characterize structure in nature that were difficult to define with Euclidean Geometries. These fractal geometries are Minkowski, Sierpinski Carpet, Crown Square, Sierpinski Gasket, Hilbert Curve, Koch curve and so on. In this work modified sierpinski fractal antenna has been designed using Sierpinski gasket class of fractal antenna as discussed below.

III. FEEDING TECHNIQUE

Antenna performance depends upon the feeding technique and its suitable position. A feeding technique can be chosen based on factor power transformation between patch and feed point for proper impedance matching [9]. In this work microstrip line feed has been used because it is an easy feeding scheme, since it provides ease of fabrication and simplicity in modeling as well as impedance matching. In microstrip line feed [10], a conducting strip is connected directly to the edge of the micro strip patch as shown in Figure 2. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure.



Figu re 2. Microstrip Line Feed

The purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without the need for any additional matching element. This is achieved by properly controlling the inset position. However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna.

IV. ANTENNA DESIGN

The Sierpinski gasket is a well-known fractal and developed by Waclaw Sierpinski in 1916 [11]. Four important factors decide the shape of the Sierpinski gasket triangle, which are the height 'h' of the triangle, the flare angle 'α', the scaling factor ' S_f' and the number of iterations 'n' [12]. The proposed antenna has been designed using a RT- DUROID substrate with a dielectric constant of 2.2 and with a substrate thickness of 1.6mm.The, microstrip line feed is used to excite the antenna. The feed point must be located at that point where in put impedance is of 50 ohm for resonant frequency. IE3D simulation software has been used to simulate the proposed antenna design [13].

TABLE 1. PARAMETERS AND DIMENSIONS OF PROPOSED FRACTAL ANTENNA

Antenna Parameters	**Design Value**
Dielectric Constant	2.2
Substrate Height(mm)	1.6
Loss Tangent	0.01
Length of Patch(mm)	30
Width of Patch(mm)	30
Length of Substrate(mm)	30
Width of Substrate(mm)	45
Feed Line Length(mm)	2
Feed Line Width(mm)	15

A. First Iteration of Proposed Antenna Design

The basic shape of the proposed antenna consist of square patch of each side length 30mm has been taken on the ground plane of length =30mm and width = 45mm.

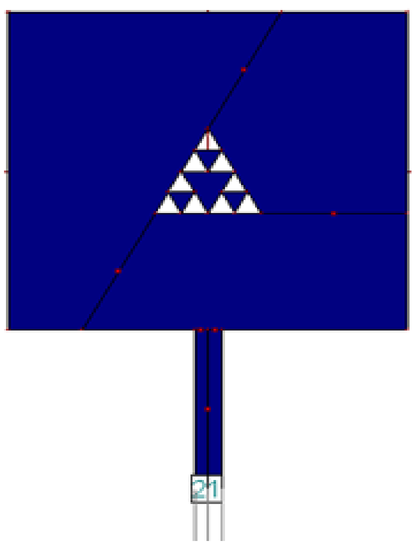


Figure 3. Geometry of first iteration of proposed fractal antenna

Figure 3. shows the first iteration of the proposed fractal antenna. It is achieved by cutting triangular fractal slot deploying sierpinski gasket geometry of each side length 8mm in the centre of the square patch. The Fig.4 represents the return loss versus frequency plot for the first iteration where a bandwidth of 54.18 % is seen at resonant frequency 0.55GHz with a return loss of -24.16 dB. A VSWR of 1.12 is noted at 0.55 GHz as shown in Fig.5.

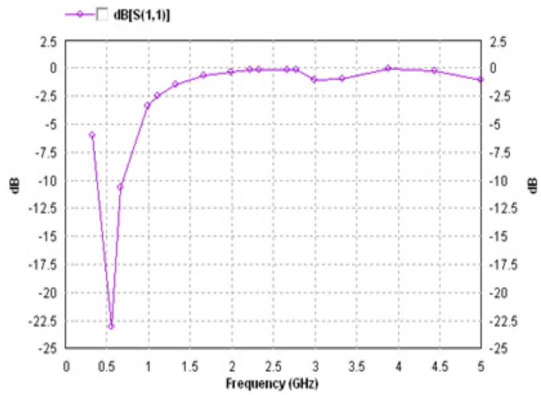


Figure 4. Return loss versus frequency plot of I[st] iteration of proposed fractal antenna

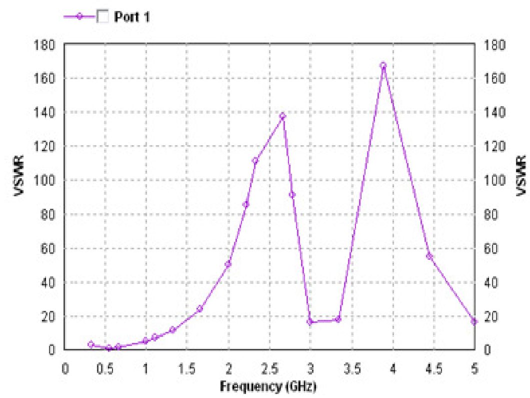


Figure 5. VSWR versus frequency plot of I[st] iteration of proposed fractal antenna

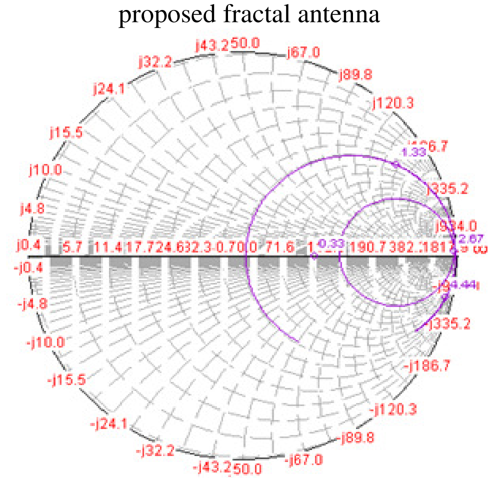


Figure 6. Input impedance loci using smith chart of I[st] iteration of proposed fractal antenna

B. Second Iteration of Proposed Antenna Design

Fig.7 shows the second iteration of the proposed fractal antenna. In the centre one triangular fractal slot deploying sierpinski gasket geometry each of side length 8mm is taken and similar four slots each of side length 4mm are taken on each corner of the central slot .

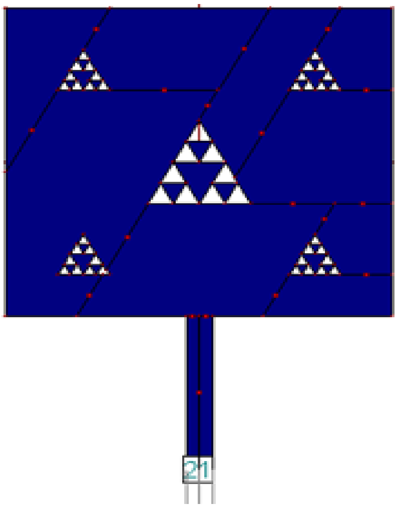


Figure 7. Geometry of second iteration of proposed fractal antenna

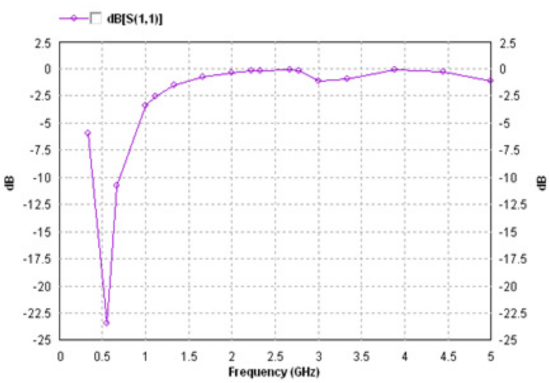
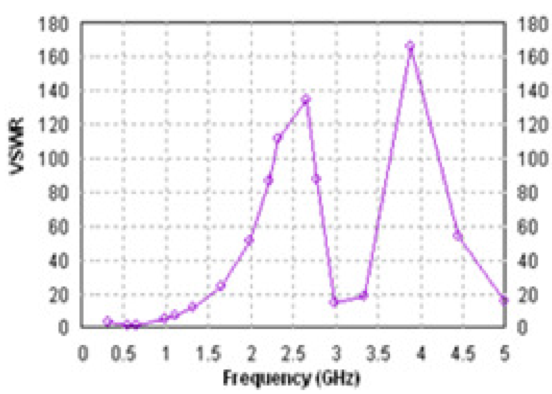


Figure 8. Return loss versus frequency plot of 2^{nd} iteration of proposed fractal antenna



Figur e 9. VSWR versus frequency plot of 2^{nd} iteration of proposed fractal antenna

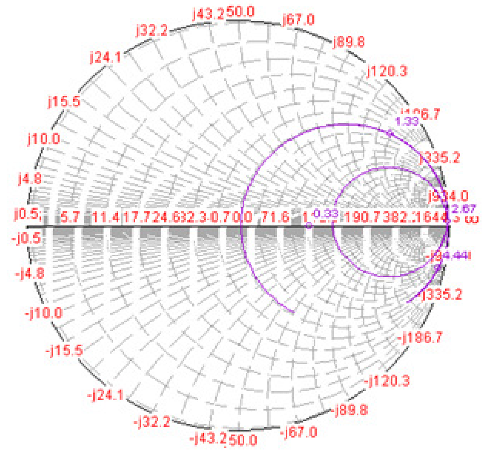


Figure 10. Input impedance loci using smith chart of 2^{nd} iteration of proposed fractal antenna

C. Third Iteration of Proposed Antenna Design

Fig.11 shows the third iteration of the proposed fractal antenna. In this one central triangular fractal slot, deploying sierpinski gasket geometry is cut and twenty similar structured fractal slots are taken on each corner of the central slot with reduction in their sizes. These fractal slots have dimension of each side equals $L_{1=}$8mm, L2=4mm,L3=2mm.

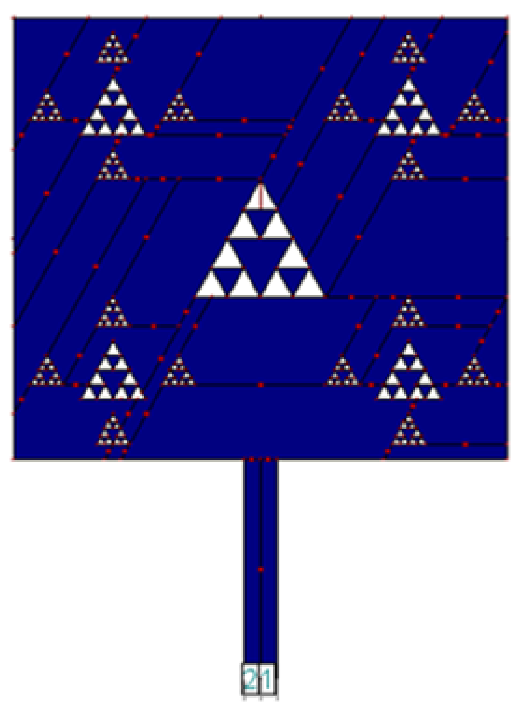


Figure 11. Geometry of third iteration of proposed fractal antenna

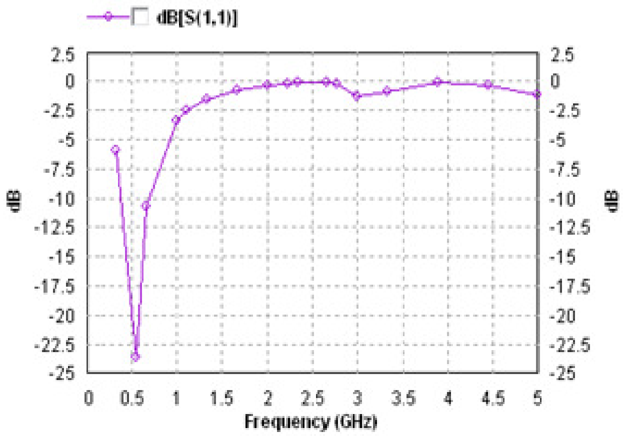


Figure 12. Return loss vs. frequency plot of 3rd iteration of proposed fractal antenna

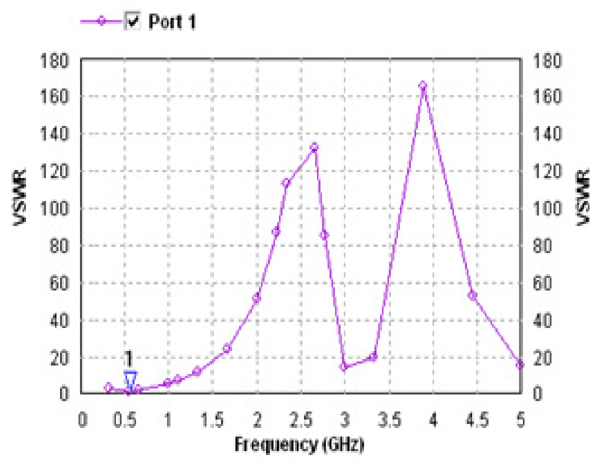


Figure 13. VSWR versus frequency plot of 3rd iteration of proposed fractal antenna

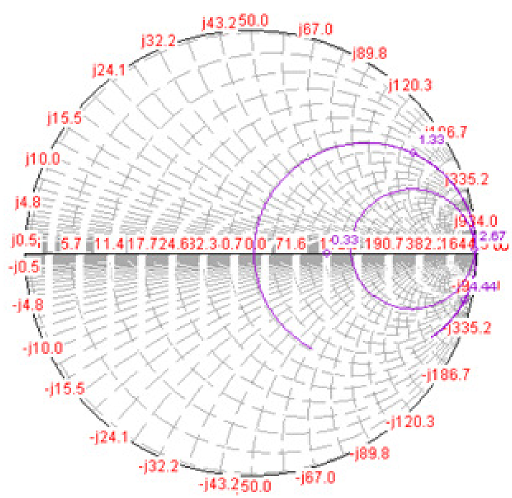


Figure 14. Input impedance loci using smith chart of 3rd iteration of proposed fractal antenna

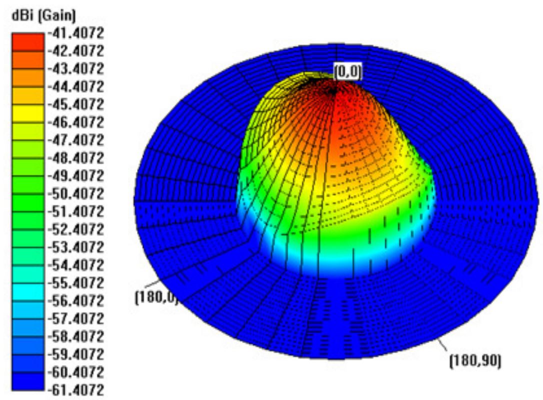


Figure 15. Gain of 3rd iteration of proposed fractal antenna

V. RESULT AND DISCUSSION

In order to assess the effectiveness and reliability of the design, analysis is carried out and some representative results are reported in the following to give an overview of the performance. Simulations of modified sierpinski fractal antenna up to 3rd iteration has been carried out in terms of return loss, VSWR, gain, and bandwidth at 0.55 GHz using IE3D software in this work.. IE3D, from Zeland software Inc. is an electromagnetic simulation and optimization software useful for circuit and antenna design. It has a menu driven graphic interface for model generation with automatic meshing, and uses a field solver based on full wave, method-of-moments to solve current distribution on 3D and multilayer structures of general shape. The simulated return loss characteristic of the proposed design is presented in Fig. 12.

TABLE 2. COMPARISON BETWEEN VARIOUS PARAMETERS OF THE THREE PROPOSED GEOMETRIES

Iteration	**1**	**2**	**3**
Resonant Frequency(GHz)	0.55	0.55	0.55
Return Loss(dB)	-22.57	-23.17	-23.63
VSWR	1.17	1.16	1.15
Impedance Matching	51.17	51.14	51.13
Bandwidth (%)	53.27	54.54	55.63

VI. CONCLUSION

In this work, Modified Sierpinski Fractal antenna has been designed up to 3rd iteration using IE3D software. The bandwidth and return loss comparison for the three geometries are described in table2. The proposed antenna has an impedance bandwidth of 55.63 % around the resonant frequency of 0.55 GHz. This antenna has VSWR of 1.15 and a return loss of -23.65, which are significant results. This iteration method results in achieving higher bandwidth [14,15,16]. This antenna is proposed for GPR, which is found to be suitable for land mine detection with 1 meter of Penetration depth. The given antenna is designed to operate at center frequency of approximate 0.55GHz with 50Ω microstrip line feed. This antenna is suitable for both kinds Anti tank and Anti personnel land mine detection.

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