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Triangular Fractal Patch Antenna with Triple Band for Wireless Applications

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Abstract— Recent technology demands multiple band antennas with miniaturized size. Application of Fractals or Fractional geometries to antenna design is a successful approach. The reason behind is capability of adjusting into compact areas. In this paper, Triangular Fractal (TF), operating between 2-11 GHz. The proposed antenna with rectangular ground plane, is modelled and simulated with Finite Element Method (FEM) based High Frequency Structure Simulator (HFSS) and an improvement in performance parameters (Return loss, Bandwidth (BW) and VSWR) is observed with change in design parameters. The proposed antenna is suitable for application in Wi-Fi, terrestrial data links and WLAN etc.

Index Terms— Fractal, Triangular Fractal, Patch Antenna, Bandwidth.

I. INTRODUCTION

There is a great demand for small sized multiband and wideband antennas with high directivity for handheld devices. The geometry of the fractal antenna encourages its study both as a multiband solution and also as a small (physical size) antenna. First, because one should expect a self similar antenna (which contains many copies of itself at several scales) to operate in a similar way at several wavelengths [1]. That is, the antenna should keep similar radiation parameters through several bands. Second, because the space-filling properties of some fractal shapes (the fractal dimension) might allow fractal shaped small antennas to better take advantage of the small surrounding space. The triangular shaped fractal, Sierpinski gasket, is named after the Polish mathematician who first described its properties [Puente, April 1998]. With few exceptions (most notably exception being the log-periodic), we typically use a single antenna (size) for each application [2]. In this work, Realization has been made with the help of fractal geometries. Fractal, one of the fundamental concepts in nature, means "fractured" or "broken", coined by Benoit B. Mandelbrot (French Mathematician) from a Latin word "fractus". The dimensions of these phenomena are fractional numbers and are self-similar at different scales. Application of fractals to antenna design has proved to be a boon to wireless communication system. Studies in this field proved that fractals result in high bandwidth, good gain and improved radiation pattern as compared to traditional antennas [3]. Many fractal antennas have been studied like Sierpinski gasket, Sierpinski Carpet, Koch loop, Cantor slot patch, Minkowski and fractal tree antennas etc. in past years [4]. If we conclude that certain electrical properties of an antenna are directly a function of certain physical properties of the antenna, then we must also conclude that significantly modifying these physical properties must significantly modify the antenna's electrical properties. Alternately, if we significantly modify an antenna's physical properties and its electrical properties do not significantly change, then we must conclude that these electrical properties are not primarily determined by these physical properties. In the same manner, if we conclude that the multiband behavior of the Sierpinski gasket is solely or uniquely a function of its total self-similar fractal gap structure, then we must also conclude that significantly modifying this self-similar gap structure must significantly modify the gasket's multiband behavior. Alternately, if we significantly modify the Sierpinski gasket's self-similar fractal gap structure and its multiband behavior does not significantly change, then we must conclude that the modified portions of the fractal gap structure do not significantly contribute to the gasket's multiband behavior.

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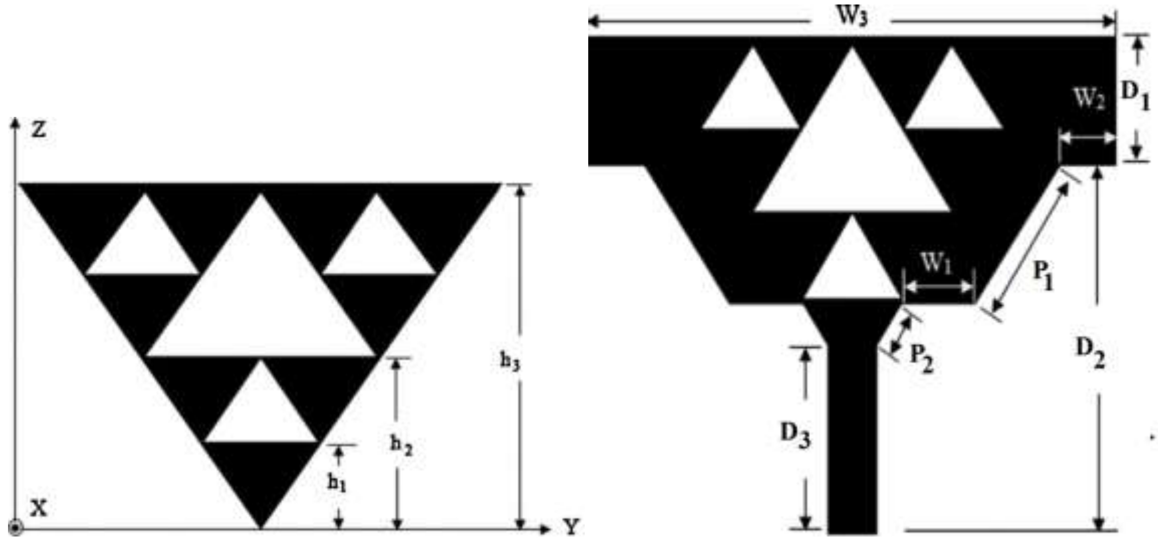
The first application of fractals to the antenna design, Thinned fractal linear and planar array, was studied by Kim in 1986. In 1996, Werner worked on the same concept [5-7].

In 1995, the first antenna element was designed by bending the wire in a systematic way, using the Koch fractal geometry, using the concept of fractals. In 1998, Puente designed the fractal shape Sierpinski gasket, named after polish mathematician Sierpinski, as antenna [8-10]. In the same year, Xu designed fractal based tree which could give better performance as compared to already designed Sierpinski gasket. Hohfeld proposed that the scaling factor effects the position of frequency bands in frequency spectrum [11, 12].

In the following work, antenna parameters are adjusted to analyze the effect on bandwidth coverage and bandwidth gain enhancement. The aim of present work is to design a TF patch antenna and examine resonant frequency. The outline of paper is as follows: Section II describes the proposed Triangular Fractal patch antenna model. Section III presents results and discussions. Section IV gives the conclusion of the paper.

II. TRIANGULAR FRACTAL

The TF antenna has been designed and simulated on Rogers RT/duriod 5880 substrate, with dimensions of 30 x 28 x 2.58 mm^3 , having relative permittivity 2.2 and tangent loss 0.0009. The ground taken is semi-elliptical, having length 11.1mm and width 30mm and used lumped port as feed to achieve 50Ω characteristic impedance. The TF antenna has been simulated using Finite Element Method based Ansoft HFSS version 13 w hich divides the problem domain into number of sub-domains and each sub-domain is represented by a set of element equations. For the final calculation, Systematic recombination of all sets of element equations is converted into a global system of equations. The model of TF antenna and the dimensions of layout of the model are shown in the fig.1 and table 1 respectively.



(a) (b)

Fig. 1 Layout of Triangular Fractal (a) with basic structure (b) with patch fractal antenna

TABLE 1
DIMENSIONS OF TRIANGULAR FRACTAL ANTENNA

Sr. no.	Name of the parameters	Dimensions(mm)
1	Height of 1st triangle (h_1)	4
2	Height of 1st triangle (h_2)	8.5
3	Height of 1st triangle (h_3)	18]
4	Length of patch (D_1)	7
5	Length of patch (D_2)	20
6	Length of patch (D_3)	10.24
7	Slope of patch (P_1)	8.74
8	Slope of patch (P_2)	2.6
9	Width of patch (W_1)	3.9
10	Width of patch (W_2)	3
11	Width of patch (W_3)	28

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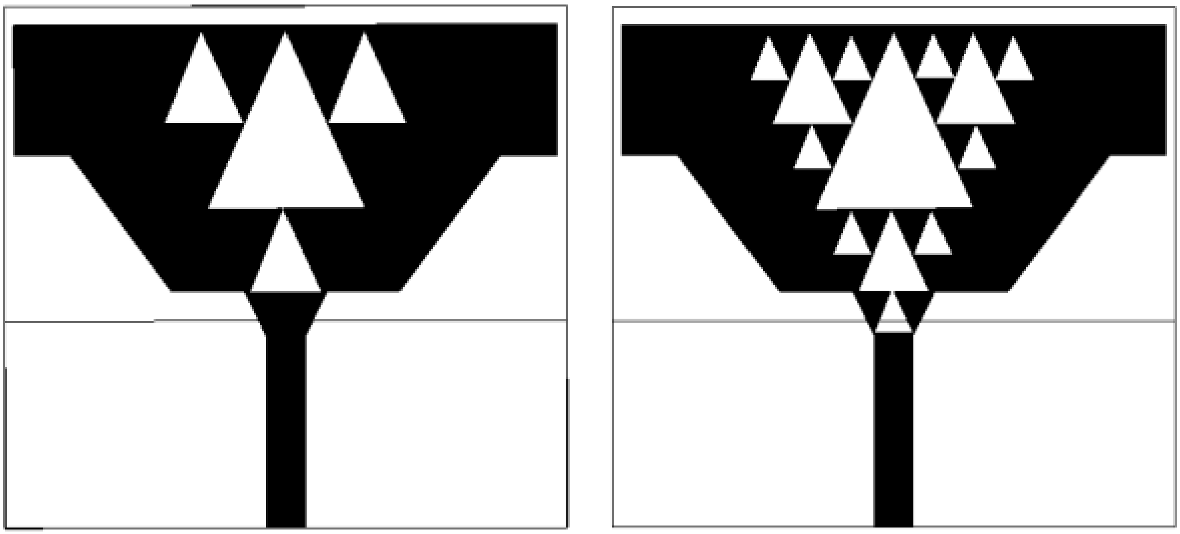
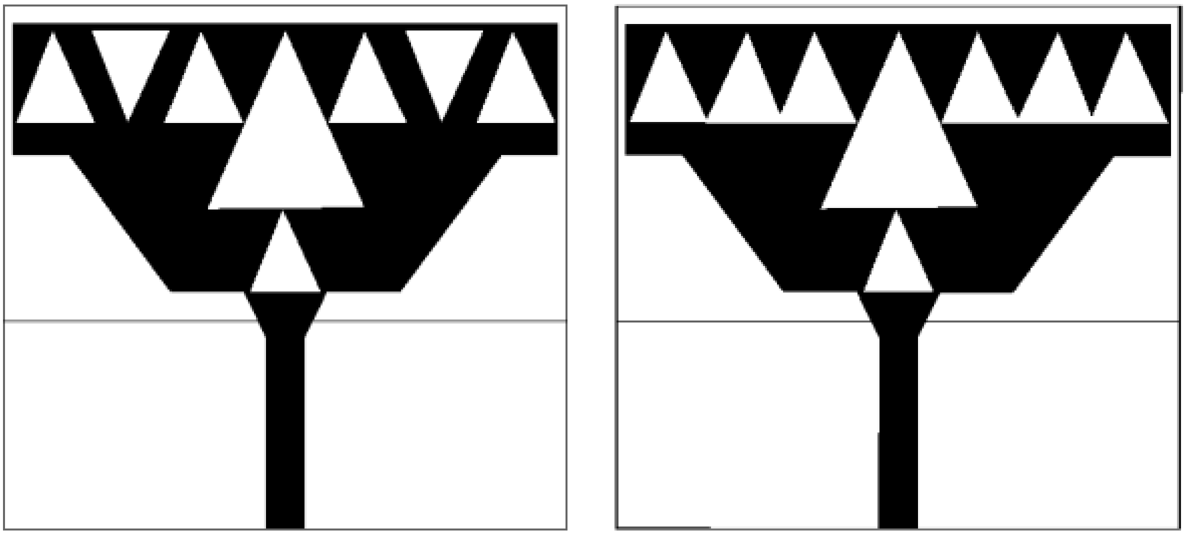
The triangular fractal with two different iterations is shown in fig. 2. By adding the one more iteration in the triangular fractal patch antenna have decrease the base material, which directly reduces the cost of the antenna and improve the performance of antenna also.



(a) (b)

Fig.2 Triangular fractal antenna (a) with 1st iteration (b) with 2nd iteration.

The triangular fractal with two different configurations is shown in the fig. 3. The TF patch antenna with symmetrical triangle have same symmetry and have good performance but unsymmetrical triangles have poor response because doesn't follow the property of fractal antenna.



(a) (b)

Fig.3 Triangular fractal antenna (a) with symmetrical side triangles (b) with unsymmetrical side triangles.

III. RESULTS & DISCUSSIONS

Triangular Fractal antenna is simulated inside a waveguide to attain the resonating frequency region. The Perfect Electric Conductor (PEC) boundary conditions are used on the z-faces of the unit cell. The Perfect Magnetic Conductor (PMC) boundary conditions are used on y-faces of the unit cell to exit the negative permeability behavior of antenna. The proposed structure is simulated with Ansoft software 'High Frequency Structure Simulator (HFSS)'. The reflection coefficient and VSWR of TF with single iteration is shown in fig. 5 and fig 6.

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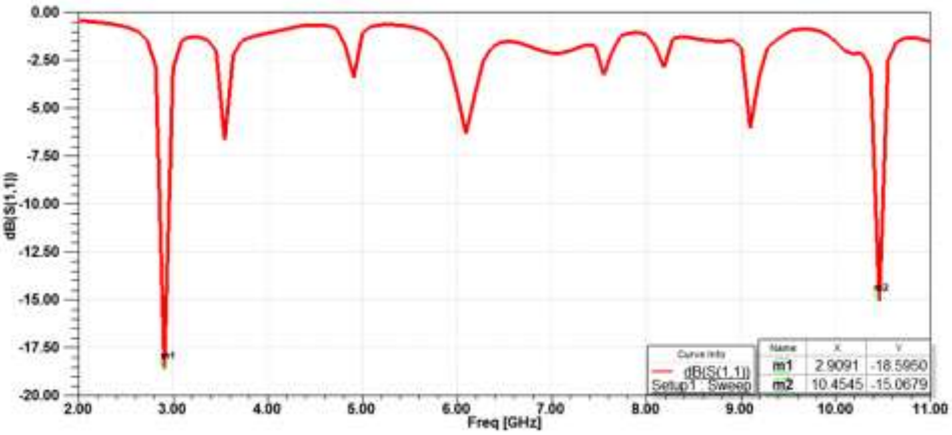

Fig.5 Reflection coefficient S_{11} of proposed TF antenna with 1st iteration.

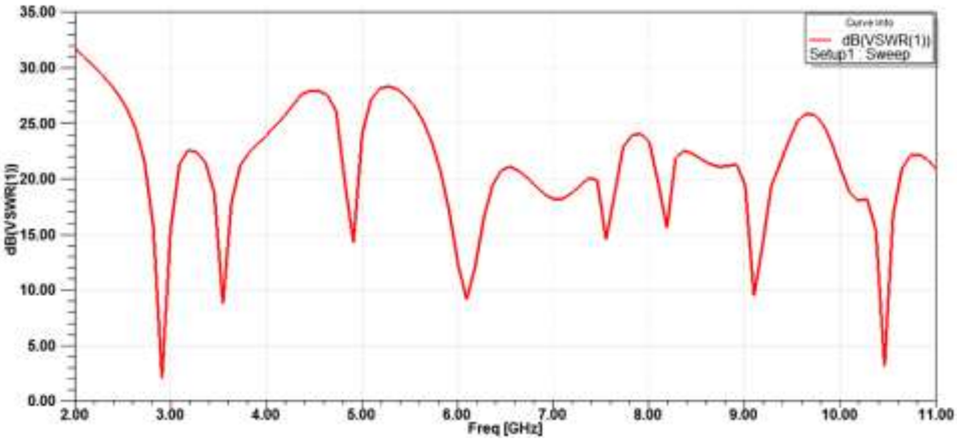

Fig.6 VSWR of proposed TF antenna with 1st iteration.

The reflection coefficient and VSWR of TF with second iteration is shown in fig. 7 and fig 8. It is observe from the reflection coefficient that with two iteration three resonant frequencies are Occur and the return loss of three are acceptable with one frequency has excellent return loss and good performance.Fig.7 Reflection coefficient s11 of proposed TF antenna with 2nd iteration

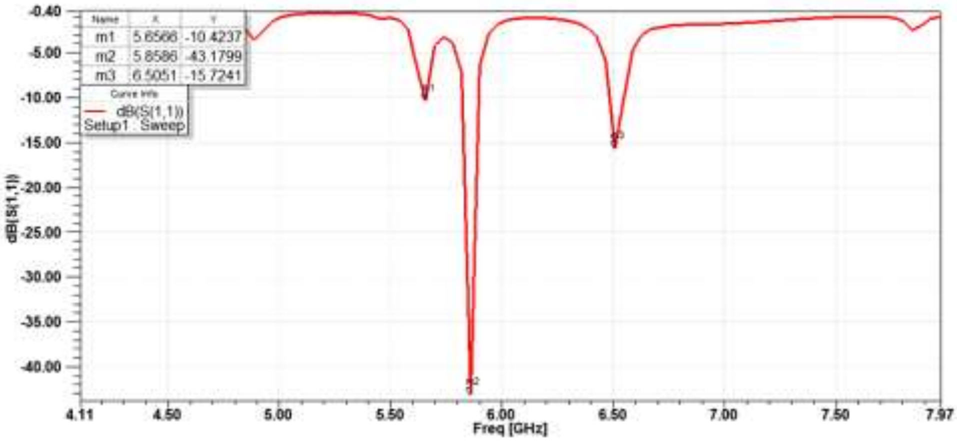

Fig.7 Reflection coefficient S_{11} of proposed TF antenna with 2nd iteration.

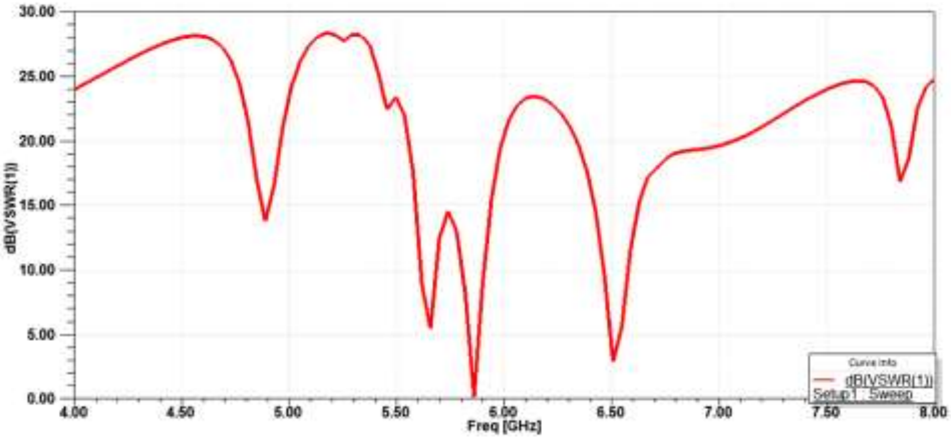

Fig.8 VSWR of proposed TF antenna with 2nd iteration.

The return loss (s_{11}) and VSWR of the triangular fractal with symmetrical triangles is shown in the fig. 9 and 10. It shows that, by loading the symmetrical triangles with the base fractal gives the triple band in antenna with better return loss and large bandwidth.

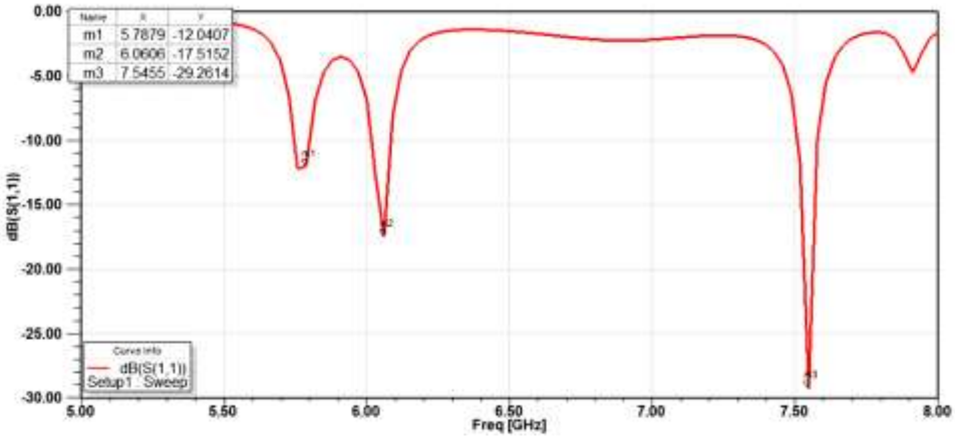

Fig. 9 Reflection coefficient S_{11} of proposed TF antenna with symmetrical triangles.

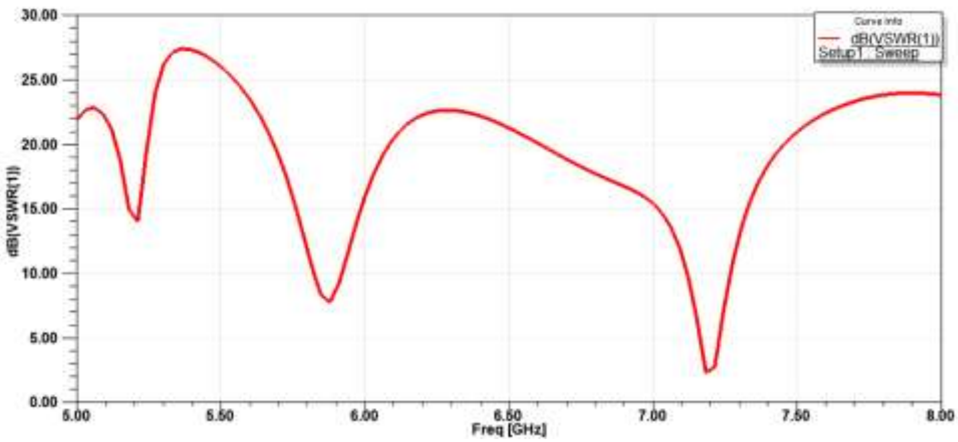

Fig. 10 VSWR of proposed TF antenna with symmetrical triangles.

The return loss (s_{11}) of the triangular fractal with unsymmetrical triangles is shown in the fig. 11. It shows that, by loading the symmetrical triangles with the base fractal which gives poor return loss and antenna cannot radiate with this structure.

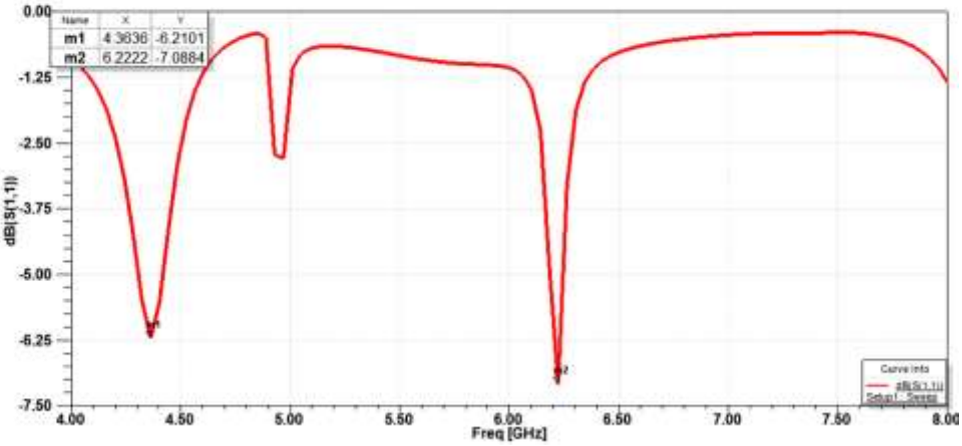

Fig. 11 Reflection coefficient S_{11} of proposed TF antenna with unsymmetrical triangles.

CONCLUSION

This paper presented a comparison of the multiband behavior of the fractal antenna with several modified shapes where major portions of the Sierpinski gasket's self-similar fractal gap structure were altered or eliminated completely. It was demonstrated that significant portions of the self-similar gap structure could be removed from the Sierpinski gasket without adversely affecting its multiband behavior. The TF antenna is presented and simulated better return loss, large bandwidth (2-11) GHz and good impedance matching. It has been shown in the work that by optimizing design parameters of antenna, improvement in the performance parameters, like return loss, VSWR, bandwidth and impedance matching, can be attained. The proposed TF antenna suitable for use in Wi-Fi, terrestrial data links and WLAN etc.

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