Comparison of the Behavior of the Sierpinski Multiband Fractal Antenna in Vertical and Horizontal Orientation

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Abstract

The behavior of the fractal Sierpinski antenna in vertical and horizontal orientations is compared in this paper. Due to its mainly triangular shape, the antenna is compared to the well-known single-band bow-tie antenna. Both horizontal and vertical antenna has different characteristics which are compared in this paper using simulation in hfss. A deeper physical insight on such a behavior is achieved by means of the computed radiation patterns, S11 over different frequencies.

Keywords- Antennas, fractals, multi-frequency antennas.

1.INTRODUCTION

The interaction of electromagnetic waves with fractal bodies has been recently studied. Fractal is a new branch of mathematics, which studies objects and phenomena with characteristics of instability, irregularity, a lack of characteristically length, and self-similarity. Most fractal objects have self-similar shapes, which means that some of their parts have the same shape as the whole object but at a different scale. The construction of many ideal fractal shapes is usually carried out by applying an infinite number of times an iterative algorithm such as the multiple reduction copy machine (MRCM) algorithm . In such iterative procedure, an initial structure called generator is replicated many times at different scales, positions and directions, to grow the final fractal structure. D. L. Jaggard [3] showed that the same kind of geometrical similarity relations at several growth stages were found in the electromagnetic behavior of the fractal body. A first attempt to explore the multi-frequency properties of fractals as radiating structures was done in [1]. The aim in that paper was to essay a new set of shapes for the design of multi-frequency antenna arrays. Wide-band and frequency-independent antennas were developed and thoroughly analyzed in the early sixties [2] and some convoluted shapes were investigated to try to elude the principle of the antenna radiation parameters dependence on its physical size relative to wavelength.

In this paper, the behavior of both the Sierpinski multiband fractal antenna in vertical and horizontal orientation is described by means of experimental and computational results and the comparison with the triangular (bow- tie) antenna is done. Sierpinski gasket, which was formed by systematically removing smaller and smaller triangles from the original structure. Both horizontal and vertical antenna has different characteristics which are compared. The radiation pattern of the measured fractal antanna clearly shows a better resemblance at different frequencies. Also, the electric current density distribution over the fractal structure has been computed, giving some insight on the multi-frequency behavior of the antenna.

2. LITERATURE SURVEY

- Puente.C [4]et al. Proposed Fractal multiband antenna based on the Sierpinski gaske. The experimental and computed results show a multiband behaviour over five bands for the new fractal Sierpinski antenna. Such a behaviour is based on the self-similarity properties of fractral antenna.
- Puente-Baliarda.Carles [5]et al. Proposed On the Behavior of the Sierpinski Multiband Fractal Antenna. Due to its mainly triangular shape, the antenna is compared to the well-known single-band bow-tie antenna. Both experimental and numerical results show that the self-similarity properties of the fractal shape are translated into its electromagnetic behavior. A deeper physical insight on such a behavior is achieved by means of the

computed current densities over the antenna surface , which also display some similarity properties through the bands.

- H. Werner. Douglas [6] et al. proposed a Fractal Antenna Engineering: The Theory and Design of Fractal Antenna Arrays. This paper gives an overview of recent developments in the field of fractal antenna engineering, with particular emphasis placed on the theory and design of fractal arrays with some important properties of fractal arrays, including the frequency-independent multi-band characteristics, schemes for realizing low-side lobe designs, systematic approaches to thinning, and the ability to develop rapid beam-forming algorithms by exploiting the recursive nature of fractals.
- Werner.D [7] et.al proposed a An Overview' of Fractal Antenna Engineering Research. In this paper the Fractal antenna engineering research has been primarily focused in two areas: the first deals with the analysis and design of fractal antenna elements and the second concerns the application of fractal concepts to the design of antenna arrays. Fractals have no characteristic size, and are generally composed of many copies of themselves at different scales. These unique properties of fractals have been exploited in order to develop a new class of antenna-element designs that are multi-band and/or compact in size. On the other hand, fractal arrays are a subset of thinned arrays, and have been shown to possess several highly desirable properties, including multi-band performance.

3. SIMULATION

HFSS (High Frequency Structure Simulation) There exists many software such as, CST, IE3D, Feko, EMPro, SIMetric, SuperNEC etc. for the simulation of fractal antenna designs. In this paper, the structure has been designed and simulated using HFSS electromagnetic simulation software. HFSS is the electromagnetic simulation of high- Frequency and high –speed components. HFSS is one of the commercial tool used for antenna design, design of complex RF electronic circuits, PCB interconnects and high-frequency IC package.

4. RESULTS AND DISCUSSION

THE SIERPINSKI VERTICAL

A. Antenna Description

The Sierpinski gasket is named after the Polish mathematician Sierpinski who described some of the main properties of this fractal shape in 1916 [8], [26]. The original gasket is constructed by subtracting a central inverted triangle from a main triangle shape (Fig.1). After the subtraction, three equal triangles remain on the structure, each one being half of the size of the original one. One can iterate the same Subtraction procedure on the remaining triangles and if the iteration is carried out an infinite number of times, the ideal fractal Sierpinski gasket is obtained. In such an ideal structure, each one of its three main parts is exactly equal to the whole object, but scaled by a factor of two and so is each of the three gaskets that compose any of those parts. Due to these particular similarities properties, shared with many other fractal shapes, it is said that the Sierpinski gasket is a self-similar structure [23]. The Sierpinski gasket (also Sierpinski triangle) was chosen as the first candidate for a fractal antenna due to its resemblance to the triangular or bow-tie antenna. As shown in Fig.1, the gasket was printed on a 1.588mm thick Cuclad 250 substrate (ε=2.5) and mounted over 80x80 mm ground plane. The structure was fed through a 1.5mm diameter, 50Ω coaxial probe with an SMA connector on the bottom side of the plane.

The antenna is a scaled version of the antenna described in [20] with a thicker substrate to provide the printed fractal a stiffer support. The gasket has been constructed through four iterations in this particular case, so four-scaled versions of the Sierpinski Gasket are found on the antenna (circled regions in Fig.1), the smallest one being feeder should concentrate over a region that is comparable in size to the wavelength, a behavior operating at its resonant frequency) could be expected. The scale factor among the four gaskets is, therefore, one should look for a single triangle. similar to four scaled bow-tie antennas (each one If one neglects the contribution of the similarities at frequencies also spaced by a factor of two center holes to the antenna performance and admits that the current flowing from the feeder should concentrate concentrate over a region that is comparable in size to the wavelength, a behavior similar to four scaled bow-tie antennas (each one operating at its resonant frequency) could be expected. The scale factor among the four gaskets is therefore, one should look for similarities at frequencies also spaced by a factor of two.

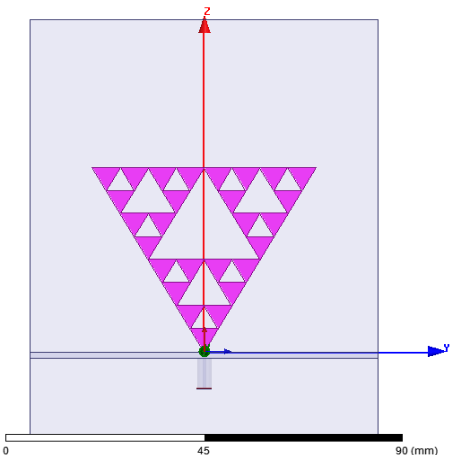


Fig1. Vertical four iteration antenna

B. Input return loss and radiation patterns

Return loss of antenna for frequencies ranging 1 – 18 Ghz has been plotted in figure 2 and it can be clearly seen that it resonates at four different frequencies corresponding to four iterations of the model. It can be seen that antenna matched frequencies approximately at

$$f_n \approx 0.26\ c/h\ \delta^n$$

where c is velocity of light in vaccum, h is the height of the the largest gasket, δ is the log period, and *n* a natural number.

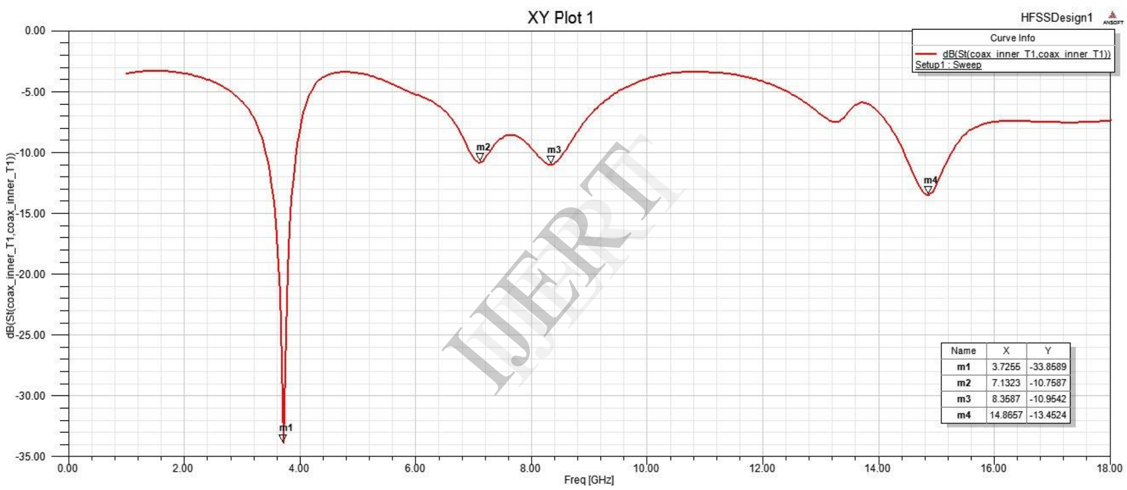
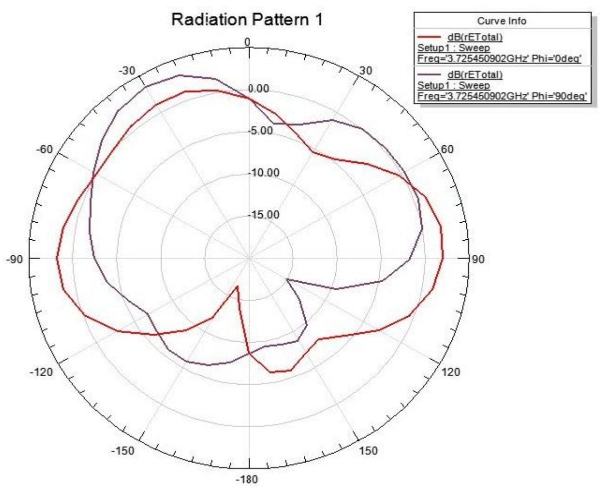
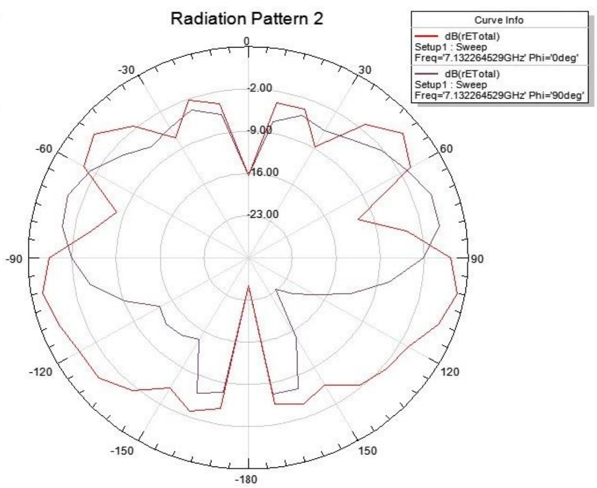


Fig.2 show S11 parameter of vertically mounted antenna has four solution frequencies (3.7, 7.1, 8.3 and 14.8 GHz)





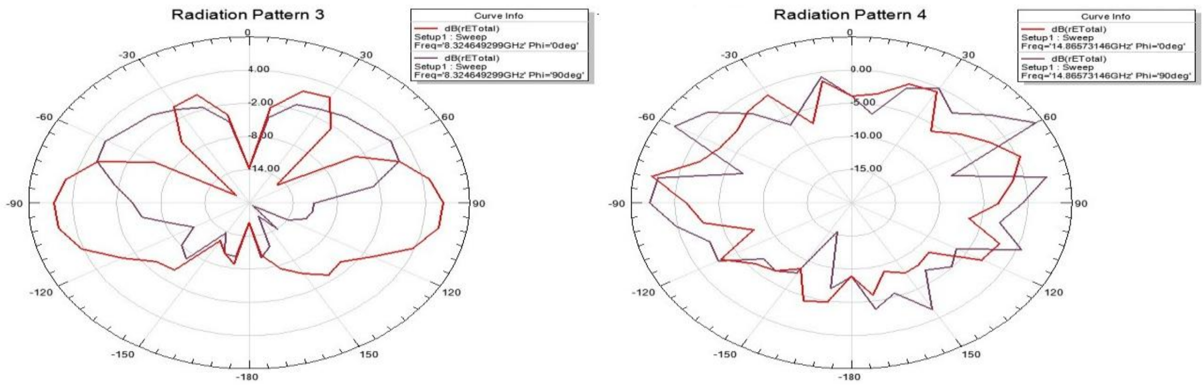


Fig.3 Radiation patterns of vertically mounted antenna at four resonant frequencies

THE SIERPINSKI HORIZONTAL

A. Antenna description

Antenna has same dimensions which a vertical antenna has but it is mounted in horizontal plane to that of substrate. A 50Ω coax probe is fed at bottom edge of antenna at an displacement of 1.9mm from the edge. Rest dimensions and properties remain the same.

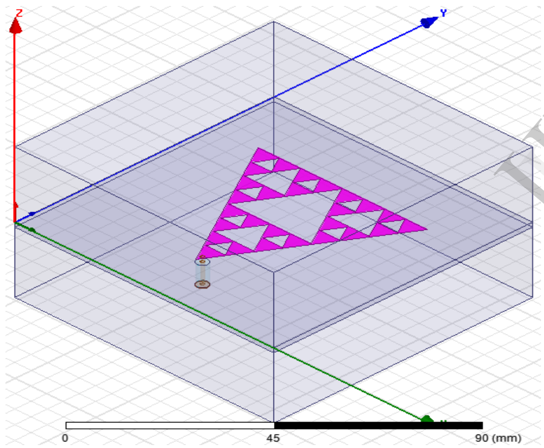


Fig. 4 horizontal antenna four iterations

Both antennas were solved for 1 to 18 GHz in high frequency structure simulator (HFSS) software and results are compared.

B. Input return loss and radiation patterns

Return loss of antenna for frequencies ranging 1 to18 Ghz has been plotted in figure 5 and it can be clearly seen that it resonates at four different frequencies corresponding to four iterations of the model. It can be seen that antenna matched frequencies approximately at

$$f_n \approx 0.26\ c/h\ \delta^n$$

where c is velocity of light in vacuum, h is the height of the largest gasket, δ is the log period, and *n* a natural number. Radiation in horizontal is far better than as compared to that in vertically mounted antenna. Radiation in case of horizontal antenna at all frequencies is approximately 8dB. Which is far better as compared to vertical antenna

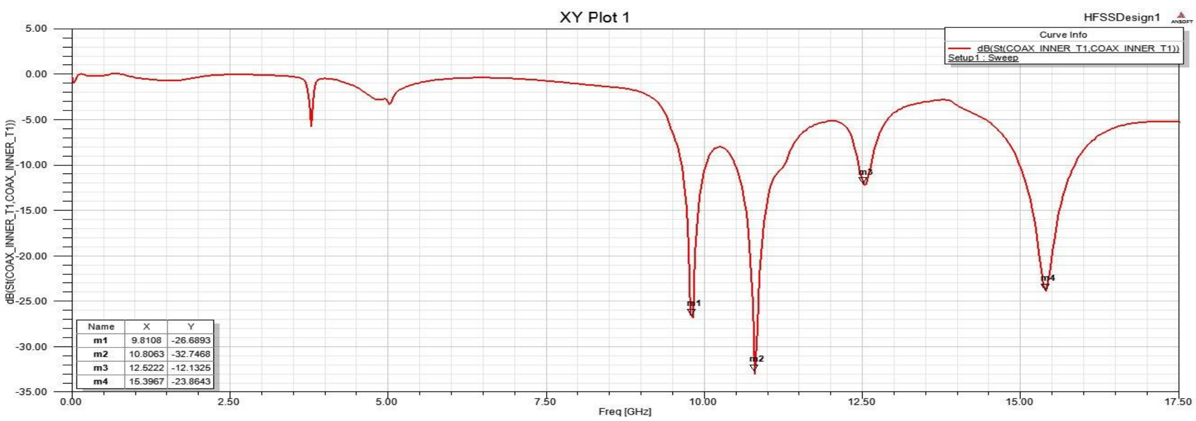


Fig.5 Shows S11 parameters of horizontal antenna has four solution frequencies (9.8,10.8,12.5 and15.3 GHz)

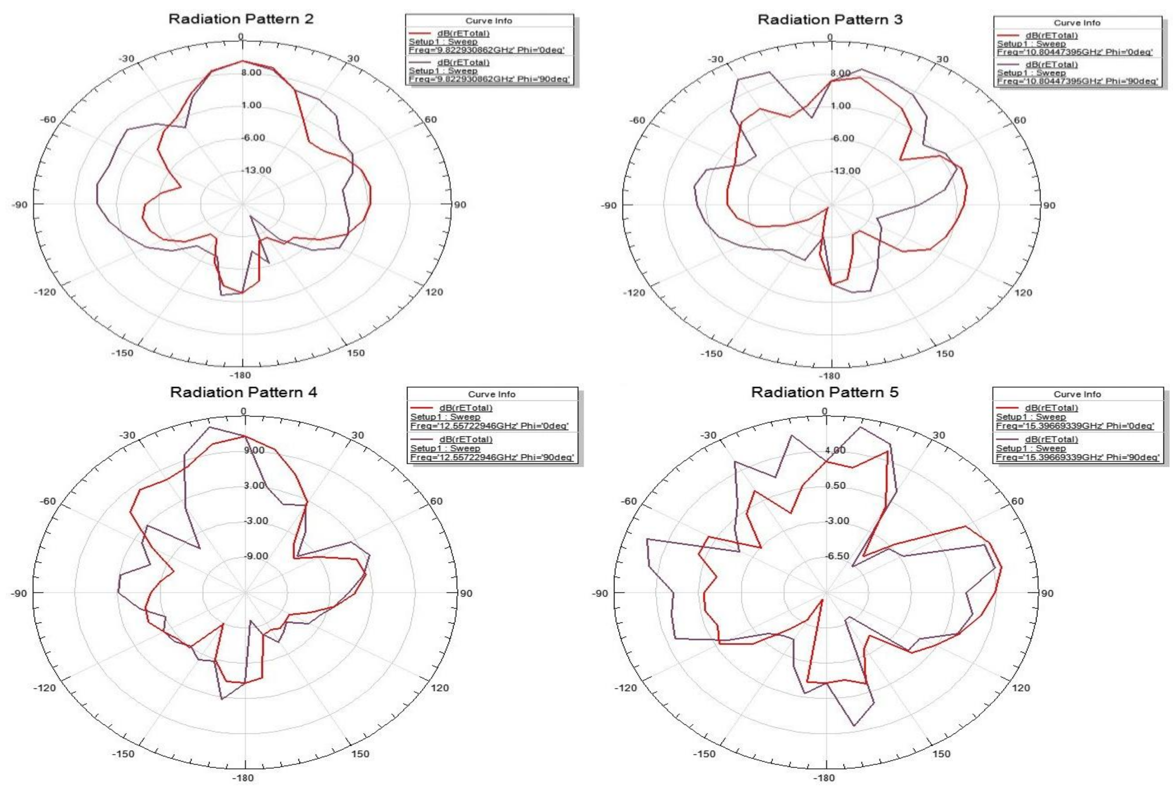


Fig.6 show radiation pattern of antenna at four solution frequencies

V. CONCLUSION AND FUTURE SCOPE

In both the antennas we have four resonant frequencies. In horizontally mounted antenna resonant frequencies are shifted to higher frequency range. Return losses are better in case of horizontally mounted antenna as compared to vertical Sierpinski antenna. Radiation patterns are far better in case of horizontal antenna so we can conclude that by mounting horizontally antenna return losses and radiation capabilities are improved. But we would need to make a larger antenna for transmitting lower frequencies. Seripinski is multiband antenna so it can be used where frequency hopping is a need of communication at different frequency and do not have space to mount different antenna for different frequencies. In the future, Seripinski multiband antenna can be designed to further improve performance by changing the iteration and size of triangle for batter results.

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