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Efficient Design of Sierpinski Fractal Antenna for High Frequency Applications

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Abstract
A wideband published slot antenna appropriate for wireless code division multiple access (WCDMA) and sustaining the international interoperability for microwave access (WiMAX) applications is planned here. The antenna is fractal line fed and its construction is based on fractal geometry where the resonance frequency of antenna is dropped by applying iteration methods. Fractal antennas are the most suited for aerospace and UWB applications because of their low profile, light weight and low power handling capacity. They can be designed in a variety of shapes in order to obtain enhanced gain and bandwidth, dual band and circular polarization to even ultra-wideband operation. For the simulation process ANSOFT HFSS (high frequency structure simulator) has been used. The effect of antenna dimensions and substrate parameters on the performance of antenna have been discussed. The antenna has been designed using the Arlon substrate with relative permittivity of 1.3 and a substrate of Sierpinski Carpet shaped placed on it. Feed used is the fractal line feed. The designed antenna is a low profile, small size and multiband antenna since it can be operated at different frequencies within the frequency range of 4.3GHz to 11GHz. It includes the frequencies used for wireless WCDMA application and used to receive and transmit a high-frequency signal.
Keywords— Fractal Antenna, WCDMA, WIMAX, Sierpinski Carpet, HFSS.

I. INTRODUCTION

In modern wireless communication systems wider bandwidth, multiband and low profile antennas are in great demand for both commercial and military applications. This has initiated antenna research in various directions; one of them is using fractal shaped antenna elements. Traditionally, each antenna operates at a single or dual frequency bands, where different antennas are needed for different applications.

Fractal shaped antennas have already [1] been proved to have some unique characteristics that are linked to the various geometry and properties of fractals. Fractals were first defined by Benoit Mandelbrot in 1975 as a way of classifying structures whose dimensions were not whole numbers. Fractal geometry has unique geometrical features occurring in nature. It can be used to describe the branching of tree leaves and plants, rough terrain, jaggedness of coastline, and many more examples in nature. Fractals have been applied in various field like image compression, analysis of high altitude lightning phenomena, and rapid studies are apply to creating new type of antennas.. Fractals are geometric forms that can be found in nature, being obtained after millions of years of evolution, selection and optimization.

We need fractal antennas due to the subsequent facts:

- Very broadband and multiband frequency response that originates from the inherent properties of the fractal geometry of the antenna.
- Compact size compared to antennas of conventional schemes, while maintaining good to excellent efficiencies and gains.
- Mechanical simplicity and robustness; the features of the fractal antenna are attained due to its geometry and not by the addition of discrete components.
- Enterprise to particular multi frequency characteristics containing specified stop bands as well as explicit multiple pass bands.

II. FRACTAL GEOMETRY

There are many fractal geometries [9] that have been found to be useful in developing new and innovative design for antennas.

A. Koch Curve

The von Koch curve was initially presented by the Swedish mathematician Helge von Koch. The Koch curve was created to demonstration how to construct a continuous curve that did not have some tangent line.

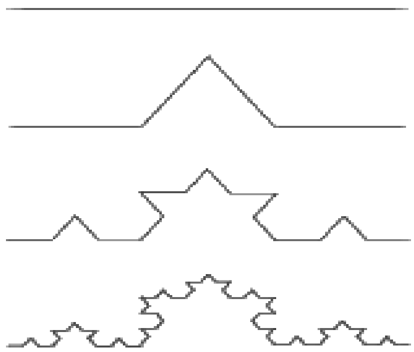

Figure 1: Three iterations of Koch fractal

It is built by starting with a straight line. Divide the line in three parts. Substitute the center part by a regular triangle with the base detached. This process is repeated on every straight line ongoing in an infinite procedure resulting in a curve with no smooth sections.

B. Sierpinski gasket

Sierpinski gasket geometry is the most widely studied fractal geometry for antenna applications. The steps for constructing this fractal are described.1st a triangle is taken in a plane. Then in next step a central triangle is removed with vertices that are located at the midpoint of the sides of the triangle as shown in the figure [10], the process is then repeated for remaining triangles as shown in figure. The Sierpinski gasket fractal is formed by doing this iterative process infinite number of times.

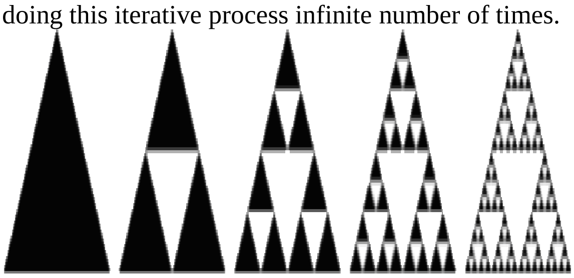

Figure 2: Four iterations of the Sierpinski fractal

C. Sierpinski Carpet

The Sierpinski carpet is constructed similar to the Sierpinski gasket, but it use squares instead of triangles. In order to start this type of fractal antenna, [10] it begins with a square in the plane, and then divides it into nine smaller congruent squares where the open central square is dropped.

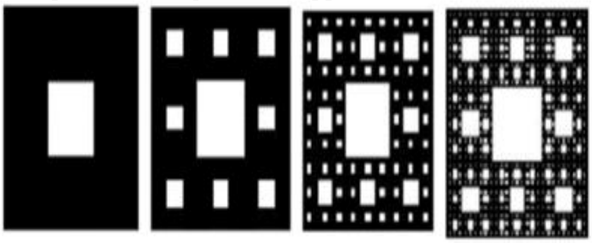

Figure 3: Steps of Iteration to get Carpet geometry

III. Literature Survey

Puente-Baliarda et al (1998), [11] defined that multiband behavior of the fractal Sierpinski antenna. Due to its mainly triangular shape, the antenna was 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. R. Steven et al (2002), [14] described the Koch fractal monopole antenna that had been shown the lower resonant frequency than a simple Euclidean monopole having the same overall height. It was demonstrated that the electromagnetic behavior of the Koch fractal monopole was not uniquely defined by its geometry alone. K. D. Deepti et al. (2008), [16] presented a dual wide-band CPW-fed modified Koch fractal printed slot antenna, suitable for WLAN and WiMAX operations. Studies on the impedance and radiation characteristics of the proposed antenna indicate that a modified Koch fractal slot antenna has an impedance bandwidth from 2.38 to 3.95 GHz and 4.95–6.05 GHz covering 2.4/5.2/5.8 GHz WLAN bands and the 2.5/3.5/5.5 GHz WiMAX bands. The antenna exhibits omnidirectional radiation coverage with a gain better than 2.0 dBi in the entire operating band. R. Mohanamurali et al (2012), [17] presented planar antenna with Microstrip feed Sierpinski carpet fractal geometry for multiband applications. The multiband behavior is analyzed through two fractal iterations. The Substrate chosen for implementing that antenna is FR4 of thickness 1.59 mm and $tan\delta = 0.012$. The simulated result showed that the antenna was suitable for 1.8/5.59/5.78/6.4/ 6.63/7.84 GHz wideband applications. L. Rui et al (2013), [18] proposed a dual-band PCB fractal monopole antenna using modified Sierpinski triangle for wireless applications. This antenna was fabricated on a 0.8mm thick FR4-epoxy substrate with dimensions 44mm×30.2mm, and has a partial ground plan. The proposed antenna was designed to effectively support WLAN applications, at frequencies of 2.4GHz and 5GHz, respectively. Also, good Omni-directional radiation patterns over the operating bands had been obtained.

IV. Proposed Work

A. Antenna configuration

A schematic diagram of fractal carpet antenna in a Sierpinski gasket is shown in figure 4.1 below:

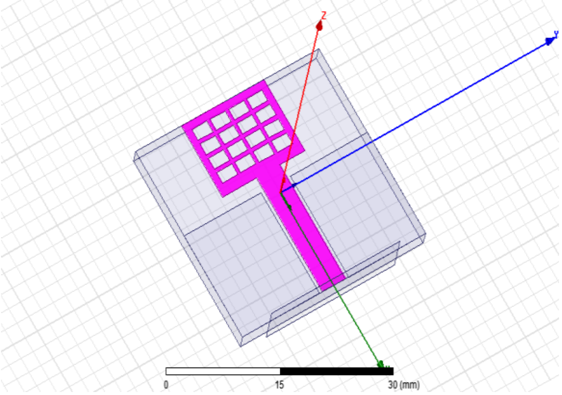

Figure 4: Geometry of the patch antenna

A scaling factor of 1/3 was chosen so as to maintain the perfect geometry symmetry of fractal structure.

B. Design parameters:

Substrate Dimension		
Width of the dielectric substrate	W	30
Thickness of the dielectric substrate	T	1.6 mm
Length of the dielectric substrate	L	26 mm
Patch Dimension		
W_s	W_s	13 mm
Port Dimension		
Width	W_p	21 mm
Height	W_h	4 mm
Other	W_f	12.6 mm
Feed Dimension		
Edge Feed	$L_g + d$	16 mm, s 3.8 mm

Table 1: Design parameters value

C. SIMULATION RESULTS

a. Scattering Parameters

Scattering Parameters graph also known as S-Parameters graph or return loss graph, are used to measure the reflection and transmission losses between the incident and reflection waves.

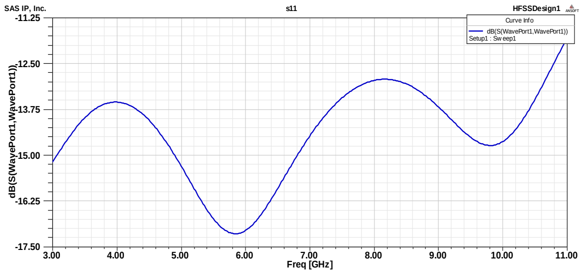

Figure 5: Return Loss parameter graph

b. VSWR

Voltage Standing Wave Ratio is the ratio of maximum radio-frequency voltage to minimum radio-frequency voltage on a transmission line. The best performance of an antenna is achieved when the VSWR under 2:1 or the return loss is -1.3dB or lower.

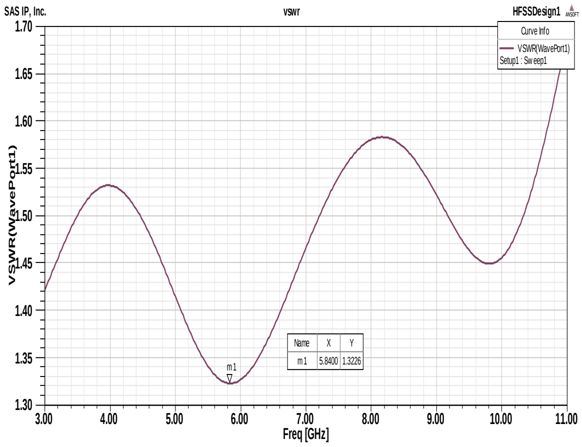

Figure 6: VSWR graph

c. Radiation Pattern

The Radiation pattern of an antenna can be defined as the variation in field intensity as a function of position or angle. Let us consider an anisotropic radiator, which has stronger radiation in one direction than in another. The radiation pattern of an anisotropic radiator is shown in figure 7.

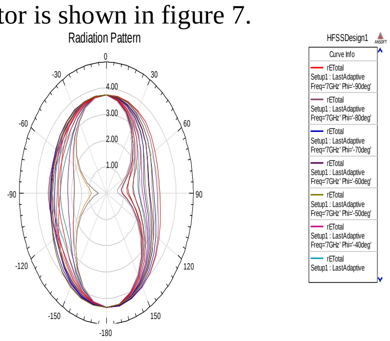

Figure 7: Radiation pattern

d. Total Gain

The efficiency of an antenna relates the power delivered to the antenna and the power radiated or dissipated within the antenna. A high efficiency antenna has most of the power present at the antenna's input radiated away.

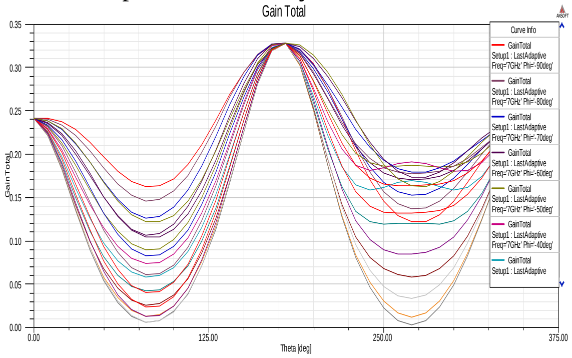

Figure 8: Total gain

e. Input Impedance

Generally, input impedance is important to determine maximum power transfer between transmission line and the antenna.

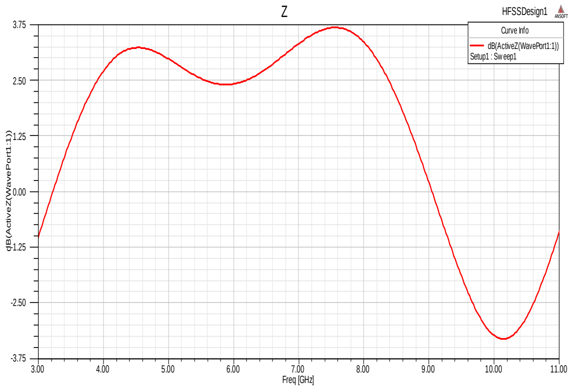

Figure 9: Input Impedance

D. CONCLUSION

The main goal behind this thesis work was to design an antenna capable of working at different frequencies which categorized it under Ultra Wideband antennas. The range of the operating frequencies is between 4.3GHz to 11GHz range, therefore it can be used for wireless WLAN application and used to receive and transmit a high-frequency signal. Return loss is bellow -10dB which is our margin, consequently the VSWR is always under 1.3, the radiation patterns show that these antennas have good gain. From the results we can conclude that there is an increase in bandwidth and decrease in the return loss. In order to improve the performance of the optimization process, some recommendations and further improvements of the particular antenna model are provided for further study.

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