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A Compact Fractal Antennabased on Sierpinski Geomentry for "S" Band Applications

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Abstract:
In this paper, we have achieved a compact fractal antenna based on Sierpinski gasket geometry. Operators are looking for systems that can perform over a broadband width. To satisfy the requirements, a novel Low Profile, Fractal Antenna (LPFA) which is a new paradigm in communication is proposed. Miniaturization of fractal antenna is achieved through fractal geometry. Fractal geometry on microstrip platform is a methodology through which the miniaturization is achieved. The proposed antenna exhibit broadband characteristics with a small return loss and high efficiency at design frequency of 2.45GHz. The ultimate aim of implementing self-similar fractal concept in antenna design makes it flexible in controlling the resonance and bandwidth. This project is aimed at examining novel self-similar fractal geometry to reduce the size and to resonate for 2.45 GHz frequencies. It covers ISM (Industrial Scientific Medica) l band, microwave oven, cardless phones, Bluetooth devices and wireless applications.

Keywords: *Fractal antenna, microstrip, antenna, size reduction, Sierpinski gasket, return loss*

1. Introduction

According to Webster's Dictionary a fractal is defined as being "derived from the Latin 'Fractus' meaning broken, uneven: any of various extremely irregular curves or shape that repeat themselves at any scale on which they are examined." Mandelbrot offered the following definition: "A fractal is a shape made of parts similar to the whole in some way".

Antennas are regarded as the largest components of integrated, conformal & low-profile wireless communication systems. Therefore, it is desired for the antenna miniaturization in achieving an optimal design for wireless communications. It is well known that the dimension of the antenna is i.e., if the antenna's λ function of its operating wavelength (size is less, it becomes inefficient because its radiation resistance, gain, directivity and bandwidth are insolvent. Fractal geometry provides a pleasant solution for this problem on account of its two major characteristics: self-similarity and space filling. So, fractal theories have become a pioneering approach for designing & characterizing wideband and multiband antennas.

A 'Fractal' is a repeated generated structure having a fractional dimension which provides wide flexibility in antenna design & analysis. Fractal antenna engineering is the field, which utilizes fractal geometries with IFS for antenna design. Presently, it has become one of the budding fields of antenna engineering due to its advantages over conventional antenna design. Most of the fractal geometries have the following characteristic features: infinite complexity and detail, fractional dimension self-similarity, space filling & frequency independent.

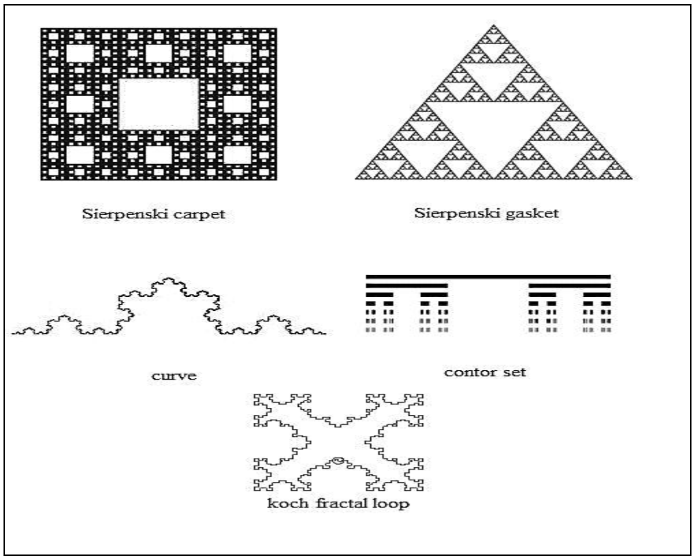

Figure 1: Types of fractal antenna patterns

These important characteristic features of fractals can be utilized in antenna design to achieve the following advantages:
Miniaturization: We know that an antenna radiates efficiently only when its size is a corresponding fraction of the wavelength of operation. Therefore, size of the antennas will be very large that operate at very low frequencies. The benefit of fractal antenna is that using fractional dimension of the fractals provides antennas that are electrically very long but physically small. Multiband/wideband antennas: We know that an antenna must have no characteristic size or it must have many characteristic sizes to operate over multiple frequencies simultaneously to be frequency independent. Due to the self-similarity & space filling property of fractals there are multiple copies of the geometry in a fractal object and hence they can be utilized for multiband/wideband antennas.
Efficiency: Fractal geometry have sharp corners and edges that cause rapid changes in the direction of current and can be used to increase the radiation parameters. So fractals are efficient radiators of electromagnetic energy that can be used designing antennas with better efficiency. Now-a-days, the advancement of wireless communication systems led to the development of several wireless communication applications including compact antenna design. To incorporate more than one communication service in a wireless system device, multiband antennas should be used. Multiband antenna provides solution to the space problem comparative to the traditional way of using different antennas for different frequency bands.
The self-affine fractal structure in this project is constructed by scaling a rectangle as shown in Figure1a. The initiator S0 by a factor of two along its width and two along its length, which leads to four rectangles of equal dimension, is presented. The upper topmost corner region is eliminated, thereby their retaining the remaining regions, i.e., 75% of the total area is retained and 25% are eliminated. First, the initiator S_0 is made to resonate at design frequency 2.4GHz by adopting the coaxial feed technique. This process is a repetitive procedure and is continued upto nth iteration.
The main goals of this project are to overcome these disadvantages and to develop an antenna with the following characteristics such as operates in 2.45GHz frequency range, has a bandwidth of 20 to 30%, Light weight, Dual-Linear polarization and good polarization orthogonally at scan corners, Low loss of input signal, Compact size, High Efficiency.

2. Antenna Design

Figure 2 shows the geometric structure and parameters of the proposed fractal antenna. This antenna is printed on a FR-4Substrate with a dielectric constant of 4.4 and a thickness of 1.6 mm. The antenna is placed at xy-plane. The xy-plane is used as E-plane and the yz-plane is set as H-plane.

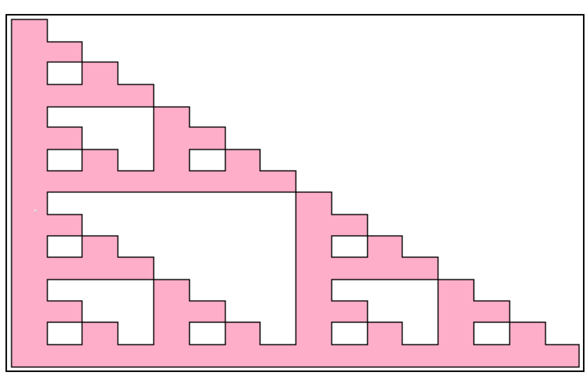

Figure 2: Geometric structure of the proposed antenna

The novel self–similar antenna structure is developed on a FR4 substrate (thickness 1.6 mm, $\varepsilon_r = 4.4$, tan $\delta = 0.01$) with ground plane at the bottom of the substrate. The patch antenna is initiated with (S1) of dimension 38 mm X 25.81 mm X 1.6 mm which resonates near 2.45GHz. Then, the initiator is iterated into segments, to resonate the antenna in all the iteration and to exhibit characteristics and the size is optimized as shown in Figs.1. The performance of the antenna at different iteration has been investigated using ADS momentum. The resonant behavior of novel self-similar fractal antenna is plotted against different feed positions, comparisons between S1, S2 and S3.

The antenna tends to exhibit broadband characteristics. The antenna covers the neighboring frequency bands thereby providing a return loss of nearly -20dB for a feed position and broadband characteristics for all the other positions. As iteration (n) increases, the slots expand at the centre and the staircase projections increase diagonally from left to right projecting the self similar concept and finally, the volume reduces compared to the original size. The slots and the stair case projections generate the other resonant modes and the resonating bands in turn depend on the ground plane. Simulated return loss covers and fulfills ISM band, microwave oven, cardless phones, Bluetooth devices and wireless applications.

Mathematical calculations were carried out for the dimensions of our fractal Antenna, at frequency of 2.45GHz.Calculations, carried out for the fractal are as under.

2.1. Calculation of the Width

The width of the Microstrip patch antenna is given by

$W = c/(2f_o\sqrt{(\in r+1)/2})$

Substituting $c = 3\text{x}10^8$ m/s

$\varepsilon_r = 4.4$

$f_o = 2.45$ GHz

We calculated the width and it came out to be

W=38mm

2.2. Calculation of the Length

The formula for the Effective length is given as

$L_{eff} = c/(2f_o\sqrt{\in reff})$

Substituting the mentioned values as

$\varepsilon_{reff} = 4.4$

c = 3e8 m/s

$f_o = 2.45$ GHz

We get

L=25.81 mm

Height	25.81mm
Width	38 mm
Return loss	-20dB
Gain	6.003 dB
Band width	200 MHz
Directivity	6.35 dB

Table 1: Antenna Dimensions

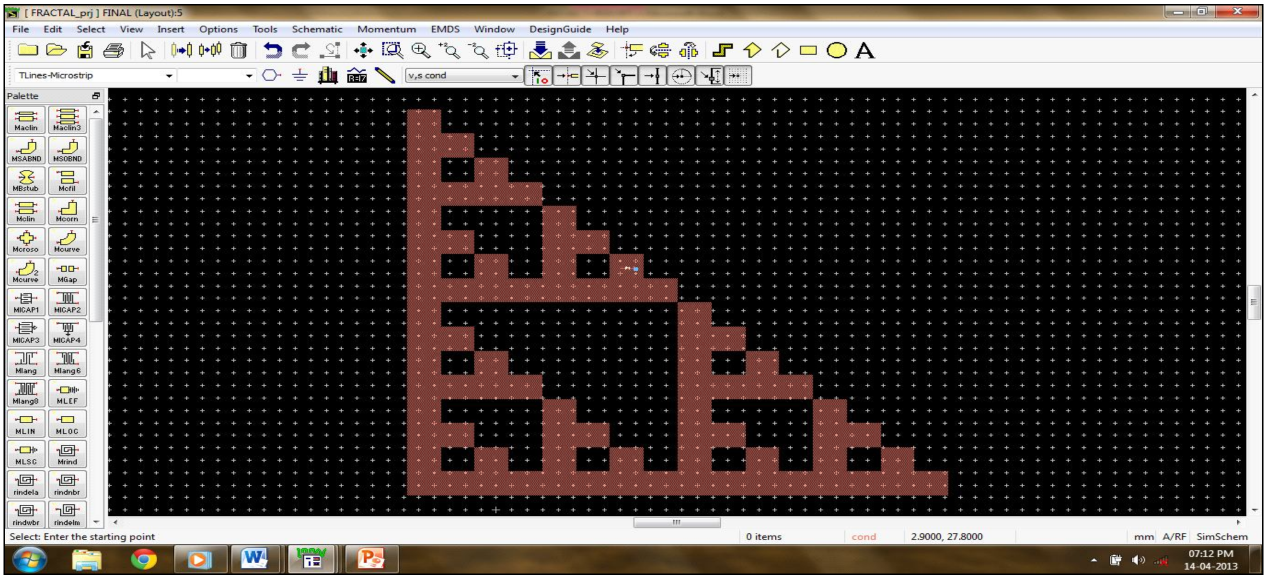

Figure 3: Layout design

3. Feeding Techniques

Feeding techniques are important in designing the antenna to make antenna structure so that it can operate at full power of transmission. Designing the feeding techniques for high frequency, need more difficult process. This is because the input loss of feeding increases depending on frequency and finally give huge effect on overall design.

There are a few techniques that can be used.

1. Microstrip Line feeding
2. Coaxial Probe feeding
3. Aperture Coupled feeding
4. Proximate Coupled feeding
5. CPW feeding

In this paper micro-strip line feeding has been used. In this type of feed technique, a conducting strip is connected directly to the edge of the micro-strip patch as shown in Figure 3. 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. The location of microstrip feed to the patch is adjusted to match with its input impedance (usually 50 ohm).

4. Experimental Result

Various iterations and optimization using ADS is performed and the patterns, results are performed.

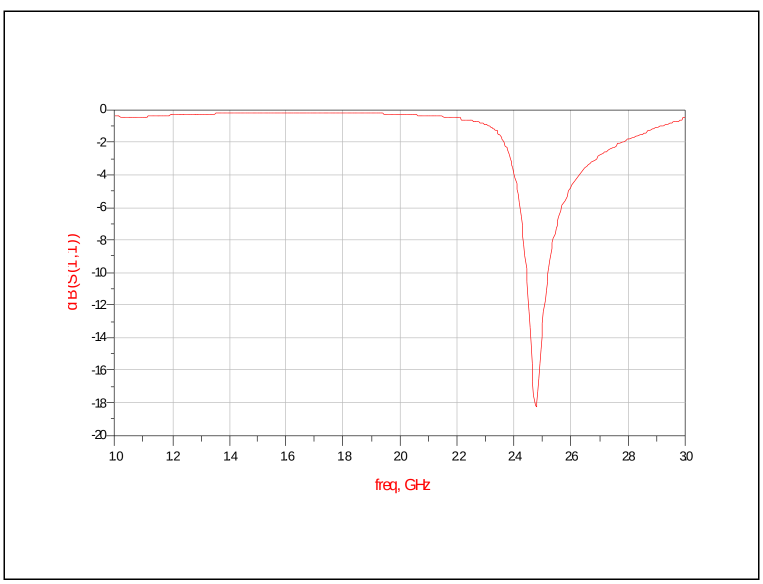

Figure 4: Return loss performance of the antenna

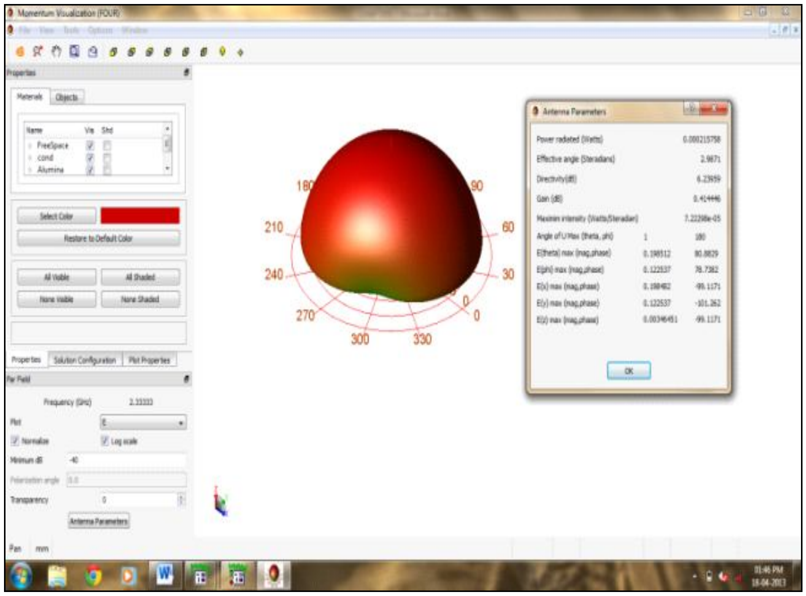

Figure 5: Gain and radiation pattern

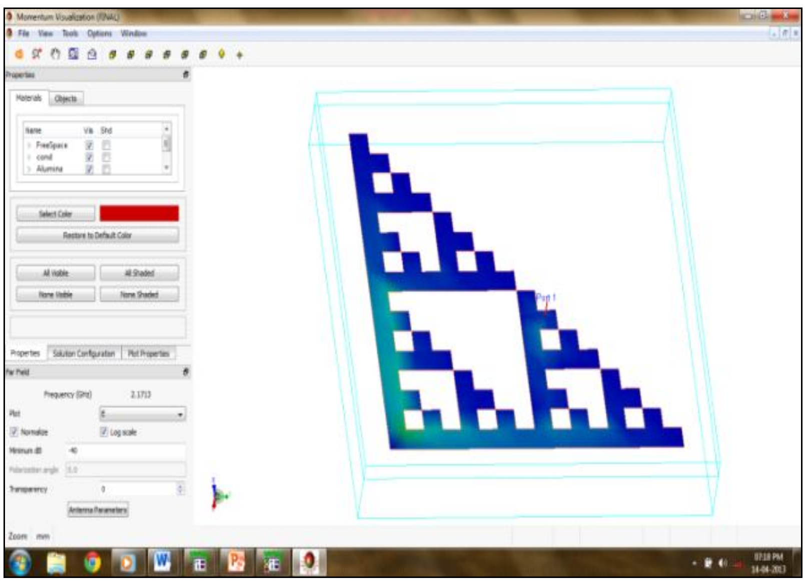

Figure 6: 3D visualization

Hence, validating the design of the antenna. The gain of the antenna is simulated at 2.45 GHz with a gain of 6.003 dB. From this table the frequency to be chosen is 2.45 GHz, which is having high gain and directivity.

The designed antenna was fabricated with the optimized parameters. The difference between the simulated and the measured results is due to the effect of the SMA connector and fabrication imperfections. In order to demonstrate the radiation characteristics of the fractal antenna, its radiation patterns are measured.

In order to further illustrate the effect of the directors, their effects on the reflection coefficient and F/B ratio are plotted in Fig. 4. It is observed that the directors have great effects on impedance matching and directivity in the higher operating frequency band.

4. Conclusion

Thus, the Microstrip fractal patch antenna for supporting ISM band, microwave oven, cardless phones, Bluetooth devices and wireless applications ***is*** designed. Frequency range from 2.45 GHz to 2.6 GHz below S_{11}= -20 dB and VSWR = 2. The return loss and VSWR plot show the step by step improvements and fifth iteration of the fractal structure proves the high bandwidth impedances. Finally, this proposed antenna is finely tuned for the ISM band, microwave oven, cardless phones, Bluetooth devices and wireless applications with the size of 25.81 * 38 mm^2.

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