Sierpenski Gasket Monopole Antenna Design

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Abstract - The use of fractal geometry in designing antenna has been a recent topic of interest. It have already proved that fractal shaped have their own unique characteristics that improved antenna achievement. This paper presents about one of familiar geometry in fractal antenna, Sierpinski gasket monopole antenna is proposed for a multiband application. Two different dimension of the antenna has beeen designed and investigated. The design achieves a good multiband throughout the frequency range from 1 to 10 GHz for both designed

1. Introduction

The general concept of fractal can be applied to develop various antenna elements. Applying fractals to antenna elements allows for smaller, resonant antennas that are multiband frequency. The fact that most fractals have infinite complexity and detail can be used to reduce antenna size and develop low profile antennas. The concept of fractal can be seen occurring in nature. It is define as a set for which the Haussdorf Besicovich dimension strictly exceeds its topological dimension [1]. Furthermore the dimension of geometries can be defined through Euclideaan dimension, self-similarity dimension, and Haussdorf dimension. Through implementation of these natural phenomena in antenna design, a new class of antenna term as fractal antenna can be design to achieve smaller and multiple resonant frequencies.

The Sierpinski gasket is named after the Polish mathematician who described some of the properties of this fractal shape in 1915 and has been appearing in Italian art from the 13th century [2]. The Sierpenski gasket self similar structure is an ideal Sierpenski gasket, each one of its three main parts is exactly equal to the whole object but scaled by a factor of two and so each of three gaskets that compose any of those parts. The self similarity properties of the fractal shape are translated into its electromagnetic behavior and result in multiband antenna. The variation on the antenna flare angle shifts the operating bands, changes the impedance level and alters the radiation pattern [3]. Some of common fractal antenna geometries that have been found to be useful in developing new design of antenna are such as Sierpinski, Carpet, Koch island, Hilbert curve and Miskowsi loop.

2. Sierpenski Gasket Monopole Antenna

Sierpenksi gasket geometry is widely studied fractal geometry for antenna application. Sierpenski gaskets have been investigated extensively for monopole and dipole antenna configuration. The self similar current distribution on theses antenna is expected to cause multi band characteristic. It has been found that by perturbing the geometry the multi band nature of these antennas can be controlled. Variation of the flare angle of these geometries have also been explored to change the band characteristics of the antenna. Antennas using this geometry have their performance closely linked to conventional bow tie antennas. However some minor differences can be noticed in their performance characteristics.

Figure 1 shows the geometry of Sierpinski gasket monopole antenna.

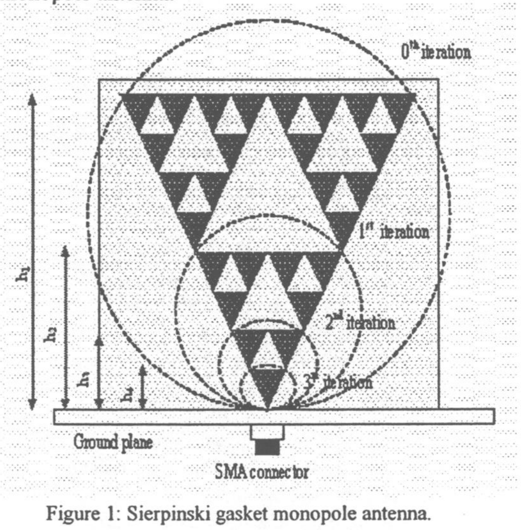


Figure 1: Sierpinski gasket monopole antenna.

The design of the antenna starts with an equilateral triangular antenna. An equilateral triangle patch antenna may be designed using equation [4]

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}}\sqrt{m^2 + mn + n^2} \qquad (1)$$

m,n = various mode
f_r = resonance frequency
a = side length
c = velocity of light

Then the central triangle is removed with vertices that are located at the midpoints of the sides of the original triangle. This process is repeated for the three remaining triangles until 3rd iteration. The scale factor will determined the high of each sub gasket and is given as

$$\delta = \frac{h_n}{h_{n+1}} \qquad (2)$$

h is the height of the antenna as shown in figure 1.

Figure 2 shows the Sierpinski gasket geometry with third iteration. The high of each subgasket will determined the resonance frequency of the antenna.

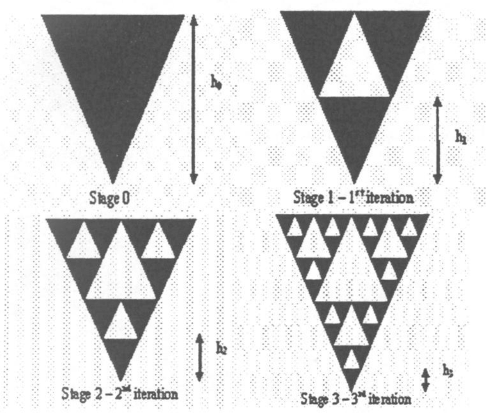


Figure 2: Sierpinski gasket antenna with 3rd iteration.

When higher iteration is done to Sierpinski gasket patch antenna, the structure doesn't radiate effectively. To overcome this problem as suggest by [6], coupling patches are introduced between two isolated triangles to provide low resistance conducting path to the current that attempts to penetrate into upper potion of the structure. The size of coupling patch depends upon triangles that are connected.
From [6], to determine the monopole Sierpinski gasket antenna, the simplified equation is given by:

$$fr = k\frac{c}{h}\cos(\alpha/2)(\delta)^n \qquad (3)$$

where
c = speed of light
h = height of monopole
α = flare angle
δ = scale factor
n = band number
k = 0.152

Flare angle is the angle of the inside of the triangle. In this project the flare angle was chosen to be 60° as a starting point. The constant k = 0.15 as given in [7], is depend on the dielectric substrate type and thickness used.

3. Antenna Design Consideration

The design of the antenna starts with a single element with basic triangle patch operating at the first resonance frequency [4]. Two antennas has been design. The first antenna Sierpenski Gasket Fractal Monopole 1 (SGFm1) is design with starting frequency of 1.8GHz. The scaling factor among the gasket geometry is δ = 2. The Sierpinski gasket geometry is mounted over a ground plane and the structure was fed through a 1 mm diameter 50 Ω coaxial probe with a SMA connector on the bottom side of the plane.

The second antenna Sierpenski Gasket Fractal Monopole 2 (SGFm2) was design at operating frequency of 2.4 GHz and 5.0 GHz. This frequency that has been chosen is for WLAN application for both bands. The scaling factor is the ratio of the resonant frequencies desired: f_2 = 2.4 GHz (second band that required) and f_3 = 5.0 GHz (third band that required). Here, the scaling factor = 2.08 ≈2 (5.0 GHz/2.4 GHz =2.08). So each triangle structure of the gasket is twice as large as its sub-structure.

The height of the triangular structure resonating at f_2 is h_2 = 3.1cm, the height of the monopole is calculated to be $h = 2*h_2$ = 6.2 cm. The number of iterations needed to generate is n_{max} = 4. This means the iteration that will be done until 3rd iteration. So there are four bands of frequencies, where f_1 and f_4 are included to provide continuity so that truncation effects do not affect the resonant bands of interest (f_2 and f_3). As mentioned in [1] the first resonant bands f_1, is not in scale of two.

4. Experimental Results

Figure 3 shows the input return loss of the Sierpinski gasket monopole antenna in the frequency range of 1 - 10 GHz. The antenna is well matched at three resonance frequency as shown in table 1. The resonance frequency has a scaling factor of 2.

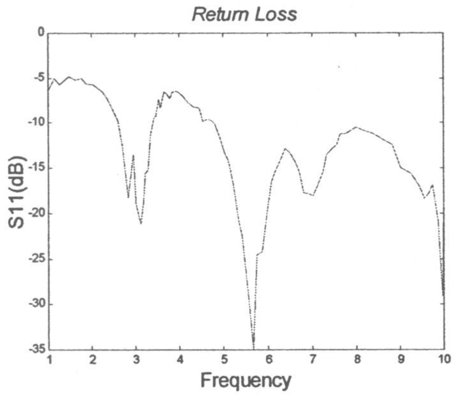


Figure 3: The input return loss for SGFm1.

The three bands given on table 1 correspond to the three minimum Return Loss of the antenna.

Table 1: Main parameter of the SGFm1.

Band	f (GHz)	S_{11}(dB)	BW	f_n/f_{n+1}
m1	3.115	-21.14	26.74	-
m2	5.68	-34.88	57.45	1.82
m3	9.977	-29.04	16.75	1.76

Figure 4 shows the input return loss of the Sierpinski gasket monopole antenna for SGFm2. The antenna is well matched at three different frequencies. The scaling factor of this antenna is 2.08.

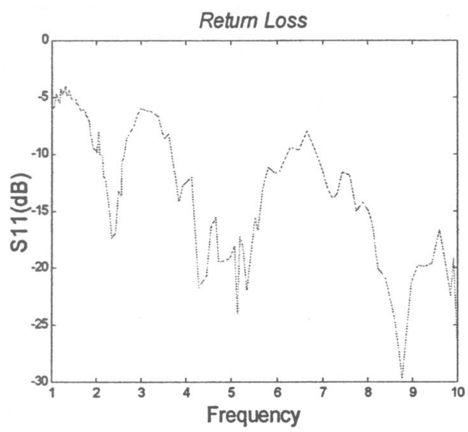


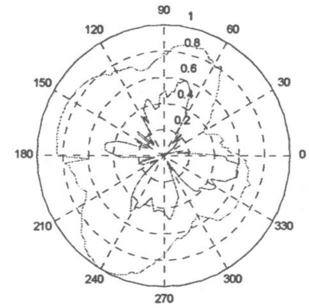
Figure 4: The input return loss for SGFm2.

Table 2 shows the measurement result of the second antenna (SGFm2). It shows good return loss on 2.4 GHz and 5 GHz frequency bands.

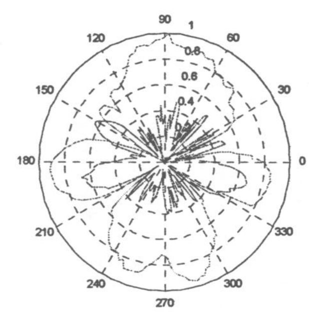
Table 2: Parameters for SGFm2

Band	f(GHz)	S_{11}(dB)	BW	f_n/f_{n+1}
M1	2.44	-16.88	19.67	-
M2	5.1	-23.91	49.42	2.09
M3	8.8	-29.66	34.09	1.73

Figure 5 shows the radiation pattern for SGFm1. The antenna was measured in far-field plot in anechoic chamber. The cross-polar reading is small compare to co-polar. When moving to second frequency band, two small side lobe can be seen on the right and left side of the antenna while two major lobe radiate in front and at the back of the antenna. At 3.15 GHz the radiation cross-polar isolation is in the range of 10-30 dB while at 5.68 GHz the cross-polar isolation is also in the range of 15 to 30 dB



(a) 3.15 GHz



(b) 5.68 GHz

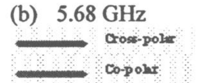
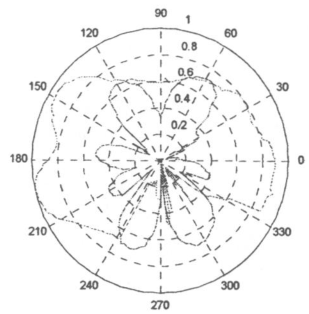
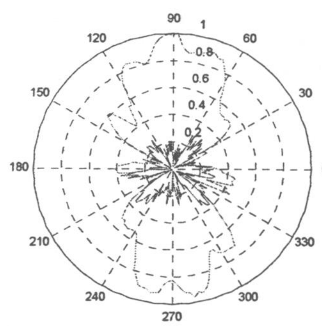


Figure 5: Co and cross polar radiation pattern for Sierpinski gasket monopole antenna (SGFm1).

The co-polar and cross-polar for SGFm2 at 2.44 GHz and 5.1 GHz are shown in figure 6. At 2.44 GHz band the radiation pattern of the antenna for co polar and cross polar is almost the same at 90°. The co polar radiation start increasing for 0° and 180° and the cross polar isolation is almost 25 dB. At frequency 5.1 GHz the radiation pattern is more directional. The cross-polar isolation at 5.1 GHz is more than 40 dB.



(a) 2.44 GHz



(b) 5.1 GHz

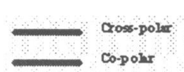


Figure 6: Co-polar and cross-polar for SGFm2.

5. Conclusion

The Sierpinski gasket monopole has a multiple band of resonant frequency (multiband). The frequencies band is highly influenced by the geometry of Sierpinski gasket itself especially the high of each subgasket. The high of each subgasket depend on scale factor and resonant frequency. The characteristic of radiation pattern have also been study in this chapter. For monopole it can be seen that the co-polar and cross-polar introduced more side lobe at the upper band. The upper band also show characteristic ripple. This is probably the high of the resonance triangle is too close to the ground plane. As mentioned before, the Sierpinski gasket monopole presents a log-periodic behavior with three bands with a scaling factor of 2

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