Wideband Sierpinski Carpet Monopole Antenna

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Abstract -- This paper described the design and fabrication of the fractal Sierpenksi Carpet monopole antenna. The properties of antennas such as bandwidth and radiation pattern have been investigated. Wide bandwidth with input return loss of -10 dB has been achieved from 1 GHz to 10 GHz using this fractal antenna. The radiation patterns have been investigated at 2.73 GHz and 4.29 GHz. The cross polar isolation is in the range of -20 dB for both frequencies. The radiation pattern is in the direction of the main lobe.

1. Introduction

Modern telecommunications system require antennas with wider bandwidths and smaller dimension than conventional. .In recent years several fractal geometries have been introduced for antenna application with varying degrees of success in improving antenna characteristics. Some of these geometries have been particularly useful in reducing the size of the antenna. Several antenna configurations based on fractal geometries have been reported in recent years [1,2]. These are low profile antennas with moderate gain and can be operative at multiple frequency bands.

Fractal geometry allows designing miniature antenna and integrating multiple telecommunications services into single devices. One of the most relevant trends for wireless devices in miniaturization. Miniaturization become important for next generation of antennas for wireless application which have to integrate several services in one system. In this situation the need of smaller antenna to be used at different frequency band is possible with multiple band antenna design.

The term fractal means broken or fragmented. Benoit Mandelbrot [1,2] showed that many fractals existed in nature and those fractals could accurately model certain irregular shaped objects or spatially non uniform phenomena in nature that can not be accommodated by Euclidean geometry, such as trees or mountains, this mean that fractals operating in non integer dimension.

The estimated length, L, of an object equals the length of the ruler, r, multiplied by a number, N; of such rules needed to cover the measured object. If we reduce an object in Euclidian dimension D and reduce its linear size $\frac{1}{r}$ in each spatial direction its measure would increase to $N = r^D$.

Solving for D,

$$D = \frac{\log N}{\log r}.$$

This is known as the Hausdorff dimension

Fractals can be either random or deterministic. Most fractal objects found in nature are random, that have been produced randomly from asset of non determined steps. Fractals that has been produced as a result of an iterative algorithm, generated by successive dilations and translations of an initial set are deterministic

Several fractals shapes has been introduced in many recent works. Certain fractal designs have been shown to be self-similar, small, space filling and have log periodic performances when used as antennas [4]. In this paper, sierpinski carpet monopole has been designed. This kind of antenna has been shown to be capable of multiband and also wideband operation. Figure 1 shows the sierpinski carpet square with second iteration.

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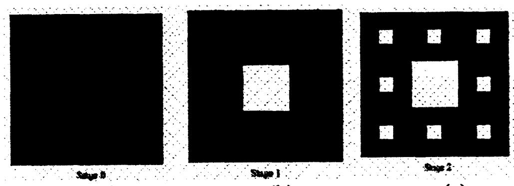


(a) (b) (c)

Figure 1 Sierpinski carpet antenna with
(a) Zero iteration
(b) First iteration
(c) Second iteration

2. Sierpenksi Carpet Antenna Design

Sierpenksi carpet is a deterministic fractal which is generalize of the Cantor set into two dimensions. In order to construct this fractal, a square in plane will be divided into nine smaller congruent squares of which one of the squares in the middle will be drop. The process continue with subdivided the eight remaining squares in nine small congruent squares in each of which one in the middle will be drop. The process continue as long as the limitation of the subdivided is not too small.

Let N_n be the number of black boxes,

L_n The ratio for the length,

A_n The ratio for the fractional area after the n[th] iteration and

d_n is the capacity dimension. Then

$$N_n = 8^n \tag{1}$$

$$L_n = \left(\frac{1}{3}\right)^n \tag{2}$$

$$A_n = \left(\frac{8}{9}\right)^n \tag{3}$$

$$d_n = -\lim_{n \to \infty}\left(\frac{\ln N_n}{\ln L_n}\right) = 1.89 \tag{4}$$

Figure 2 shows the sierpinski carpet monopole antenna that has been constructed. The radiating elements were printed on a copper clad material FR-4 with $\varepsilon_r = 4.6$, thickness of 1.6 mm and $\tan\delta = 0.019$. The design of the antenna starts with a design of a single element using a basic square microstrip antenna resonance frequency at 1.8 GHz. The element size of L and W were obtained using equation [5,6]

$$L = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 2\Delta l \tag{4}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + \frac{12h}{w}\right)^{-1/2} \tag{5}$$

$$\Delta l = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{w}{h} + 0.262\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{w}{h} + 0.813\right)} \tag{6}$$

Δl = fringing field

The antenna size for operating frequency of 1.8 GHz is 38 mm x 38 mm.

The first iteration of sierpenski carpet structured designed is by dividing the square into 9 smaller squares and removed the square at the center so that the remaining square is 8. If the scale factor is L_1 and L_1 = 0.33. Then multiply L_1 with 38 mm the length of the small square is equal to 12.7 mm.

From equation (1) to (3)

$N_1 = 8^1 = 8$
$L_1 = 0.33$
$A_1 = 0.889$

The second iteration of sierpenski carpet structured was designed by dividing each remaining eight into nine smaller squares. Then drop the entire center square for each remaining square. The remaining smaller square for this stage is 64 L_2 is the scale factor for second iteration. When L_2 is multiplied by 38 mm the length for the smaller squares is 4.2 mm. using equation (1) to (3)

$N_2 = 8^2 = 64$
$L_2 = 0.111$
$A_2 = 0.791$

In this design the iteration is only up to 2[nd] iteration. This process has been stop due to a very small area. If the area is too small the fabrication will be difficult to be done.

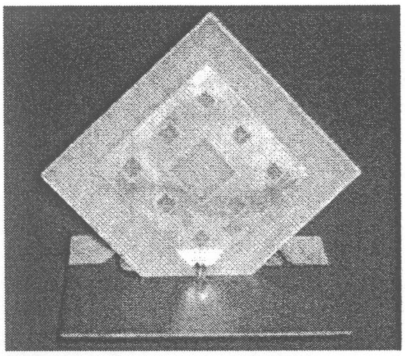


Figure 2: Sierpenksi Carpet monopole antennas.

3. Measurement Results

3.1 Input return loss

Figure 3 shows the input return loss of the sierpinski carpet monopole antenna. Good performance is achieved throughout the pass band from 2-10 GHz. The best return loss is -39.74dB at 4.3GHz. The other return loss that achieved more than 15 dB are at frequency 2.4 GHz, 7.1 GHz and 9.5 GHz.

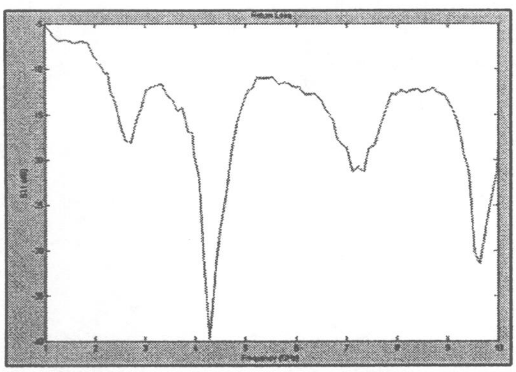
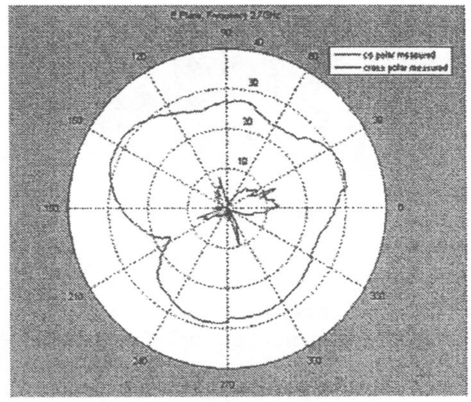


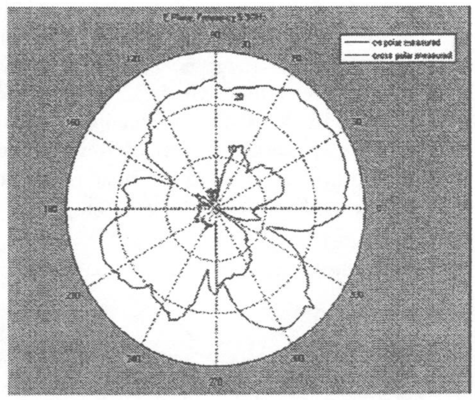
Figure 3: Input return loss.

3.2 Radiation pattern

Radiation pattern measurements were carried out in an anechoic chamber. The typical measured co-polar and cross-polar radiation patterns at 2.7GHz and 5.3GHz are illustrated in Figure 4. Half power beamwidth for 2.7GHz is 46 degree and 70 degree for 5.3GHz. The cross-polar for both frequencies is much smaller compared to the co-polar.



(a) 2.7 GHz



(b) 5.3 GHz

Figure 4: Co and cross polar radiation pattern for sierpinski carpet monopole antenna.

4. Conclusion

A sierpinski carpet monopole antenna was constructed using fractal geometry for wideband operation. The design has been started using a single element equation from patch antenna. When the number of iteration increased the number of resonant frequency will increase. In this design the iteration is at 2^{nd} iteration with a wide bandwidth of antenna had been obtained. The return loss at – 10 dB will cover a frequency range from 2 – 10 GHz.

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