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Modified Sierpinski Carpet Fractal Antenna for 4G Handheld Set

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Abstract

This paper describes the design and fabrication of Modified Sierpinski carpet fractal antenna. The investigation took place between ranges of 1 GHz to 10 GHz. This modified Sierpinski carpet fractal antenna is capable to resonate at multiband frequencies. The proposed antenna resonates at frequencies 2.13 GHz, 4.81 GHz, 6.82 GHz and 7.45 GHz with overall bandwidth of 378.8 MHz at second iteration and with size reduction of 15.92%.The stimulation process is done on HFSS.

Keywords: 4G Handheld, Sierpinski Carpet Fractal Antenna.

Introduction

Fractal was first defined by Benoit Mandelbrot [1] in 1975 as a way of classifying structures whose dimensions were not whole numbers. These geometries have been used previously to characterize unique occurrences in nature that were difficult to define with Euclidean geometries, including the length of coastlines, the density of clouds, and branching of trees [1].

A self-similar [2] set is one that consists of scaled down copies of itself, i.e., a contraction which reduces an image by same factors horizontally and vertically. Self-affine [2] set is a contraction which reduces an image by different factors, horizontally and vertically.

If there are n such copies of the original geometry scaled down by a fraction f, the similarity dimension, D defined as [3]

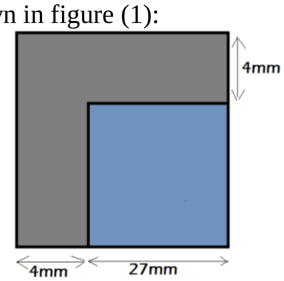
$$D = (\log (n))/\log (1/f) \quad \ldots\ldots (1)$$

The Sierpenski carpet antenna [6] is designed from an initial square patch. The first iteration is constructed by devised the square into nine small square and removed the center one. The same procedure is repeated from iteration to other.

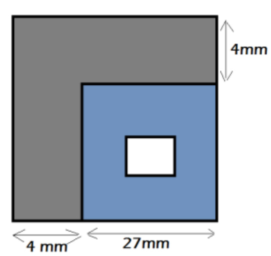
Antenna Configuration

The antenna was feed with transmission line feeding technique. The iteration process is done till second iteration. The design is fabricated using FR-4 board with relative permittivity,

$\varepsilon r = 4.4$, substrate thickness, d = 1.6mm.The iteration of the antenna from zero stage until second stage is shown in figure (1):



(a).Zero iteration



(b) Second iteration

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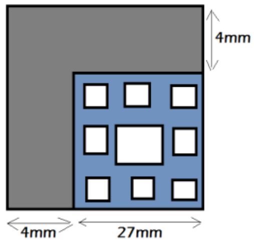

(c) Third iteration

Fig.1: The stages iteration of proposed Sierpinski Carpet Fractal antenna

The design of the antenna was start with single element using basic square patch micro strip antenna. The operating frequency is at 2.3 GHz. The dimension 'a' of the square edge is calculated using equation [4] (2):

$$a = c/(2f\sqrt{\varepsilon_r}) \;\ldots.\; (2)$$

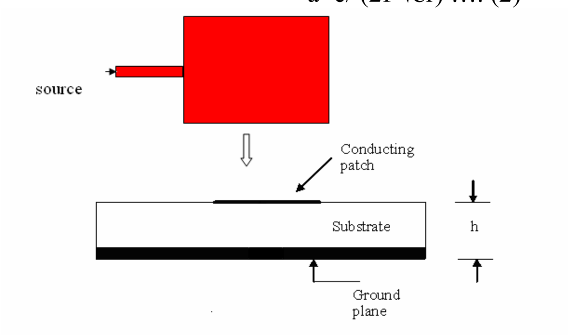

Fig 2: Square Patch

Proposed Antenna Design using IFS KIT

The self-affine fractal geometry considered in this paper is constructed by scaling a square by a factor of 3 in the horizontal direction and by a factor of 3 in the vertical direction, giving nine squares, out of which the 1 central square is removed as shown in figure.1 (a). This is the first iteration. The process is now repeated on the remaining squares in the second iteration. This procedure is known as the iterated function system (IFS) and is described by the matrix equation (3) [5]

$$W(x,y) = \begin{bmatrix} a & b \\ c & d \end{bmatrix}\begin{bmatrix} x \\ y \end{bmatrix} + \begin{bmatrix} e \\ f \end{bmatrix} \;\ldots\ldots..\; (3)$$

Table -1: IFS Transformation coefficients for the proposed fractal

W	a	b	c	d	e	f
1.	0.333	0.00	0.00	0.333	0.00	0.00
2.	0.333	0.00	0.00	0.333	0.333	0.00
3.	0.333	0.00	0.00	0.333	0.666	0.00
4.	0.333	0.00	0.00	0.333	0.00	0.333
5.	0.333	0.00	0.00	0.333	0.00	0.666
6.	0.333	0.00	0.00	0.333	0.666	0.333
7.	0.333	0.00	0.00	0.333	0.333	0.666
8.	0.333	0.00	0.00	0.333	0.666	0.666

Results and Discussions

In this paper, the results were analyzed using HFSS. The simulation result of input return loss at zero iteration is shown in figure (3):

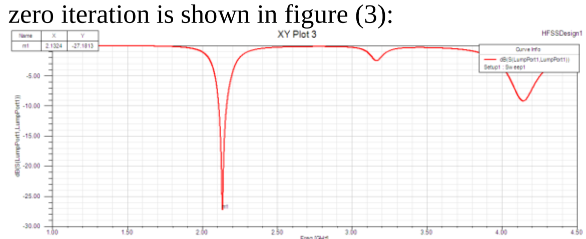

Fig 3: Showing return loss at zero iteration

Table2: Showing return loss and bandwidth at zero

Frequency(GHz)	Return-Loss (dB)	Band- Width (MHz)
2.13	-27.18	52.9

In figure 3, the return loss -27.18dB with bandwidth 52.9 was obtained from simulation. The stimulation result of the input return loss at first iteration is shown in figure (4).

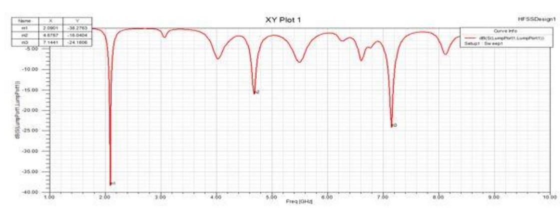

Fig4: Showing return loss at first iteration

Table 3: Showing resonant frequency, return loss and bandwidth at first iteration

Frequency(GHz)	Return Loss (dB)	Band-Width (MHz
2.09	-38.27	52.6
4.67	-16.04	82.4
7.14	-24.18	124.4

From figure (4), we obtain three resonant frequencies after first iteration at 2.09 GHz, 4.67 GHz and 7.14 GHz. From table 2, the return losses obtained are -38.27db at 2.09 GHz, -16.04db at 4.67 GHz and -

24.18db at 7.14 GHz. The bandwidths obtained are 52.6 MHz, 82.4MHz and 124.4MHz at frequency 2.09 GHz, 4.67 GHz and 7.14 GHz respectively.

The stimulation result of the input return loss and radiation pattern after second iteration is shown in figure (5) & (6).

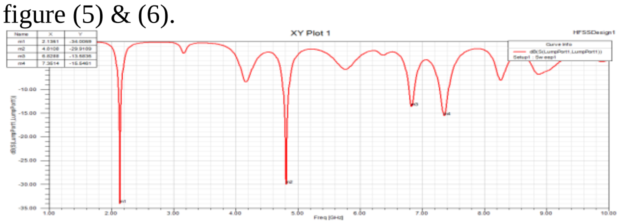

Fig5: Showing return loss at second iteration

Table 4: Showing resonant frequency, return loss and bandwidth

Frequency (GHz)	Return loss (dB)	Bandwidth (MHz)
2.13	-34.00	53.2
4.81	-29.91	94.5
6.82	-13.58	86
7.35	-15.54	145.1

From figure (5), we obtain four resonant frequencies after first iteration at 2.13 GHz, 4.81 GHz, 6.82 GHz and 7.35 GHz. From table 3, the return loss obtained are -34.00db at 2.13 GHz, -29.91db at 4.81 GHz, -13.58db at 6.82 GHz and -15.54db at 7.35 GHz.The bandwidth obtained are 53.2 MHz, 94.5MHz, 86MHz and 145.1MHz at frequency 2.13 GHz, 4.81 GHz, 6.82 GHz and 7.35 GHz respectively.

Table 5: Comparing the results at various iterations

Iteration	Frequency (GHz)	Return loss (dB)	Bandwidth (MHz)
Zero Iteration	2.3	-27.18	52.9
First Iteration	2.09	-38.27	52.6
	4.67	-16.04	82.4
	7.14	-24.18	124.4
Second Iteration	2.13	-34.00	53.2
	4.81	-29.91	94.5
	6.82	-13.58	86
	7.35	-15.54	145.1

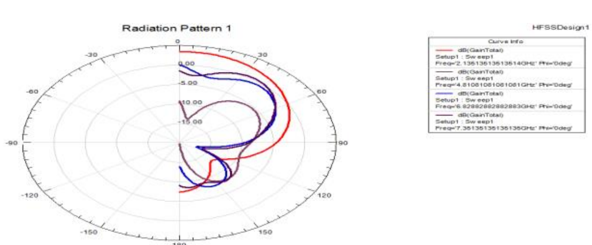

Fig 6: Showing radiation pattern at second iteration

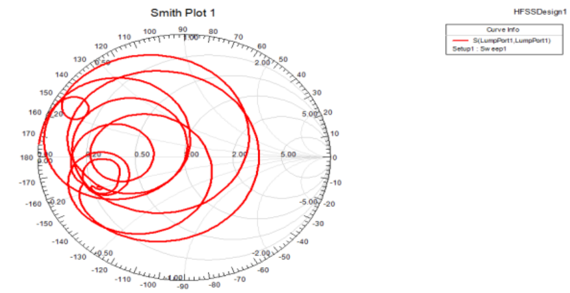

Fig 7: Showing smith chart at second iteration

Conclusion

The fractal antenna is observed to possess multiband behavior similar to the Sierpinski gasket antenna [6].This paper has presented a new patch design to implement multiband fractal antenna using Sierpinski gasket fractal pattern. The antenna is designed for four frequencies which are 2.13 GHz, 4.81 GHz, 6.82 GHz and 7.35 GHz. The proposed antenna show a significant size reduction compared to conventional rectangular micro strip patch antenna. The size of antenna is reduced to 15.92% at second iteration from conventional micro strip patch antenna. The total bandwidth occupied by the proposed antenna is 378.8 MHz after second iteration.

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