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Fractal Sierpinski Square Patch Antenna for GPS Applications

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Abstract. The high demand of a miniature antenna for wireless applications, motivates the researchers to design special types of microstrip antenna such as fractal Sierpinski. Fractal Sierpinski antenna based on square patch structure is proposed, designed and simulated to operate at resonance frequency at 1.575 GHz for GPS applications. Antenna Simulation is done using CST Studio suite version-2014. The proposed antenna is simulated on Sierpinski carpet shaped substrate Arlon 250 AD lossy of dielectric constant equals to 2.5 and thickness of 1.6 mm. The thickness of patch is 0.6 mm. The results are reported in terms of reflection coefficient, VSWR, directivity and gain. According to the results, the fractal of 3rditeration exhibits good properties that it possesses gain of 7.79 dB and VSWR is 1.6. Significant reduction of antenna area can be realized when fractal Sierpinski carpet patch antenna is used instead of conventional antenna. Reduction area of 3rd iteration is about 36% less than 0th iteration. The results highlight that antenna becomes more efficient by applying fractal geometry.

1. Introduction

Square patch antenna consists of three layers radiated patch component, dielectric substrate, and ground plane. The first and the third layer are a thin good conductor such as gold or copper. The second layer is dielectric material which limits the size of the antenna. Conductor covers the bottom layer of the dielectric to construct the ground plane. In addition, the thickness of the dielectric will act as surface wave to attenuate the power but on other hand bandwidth and efficiency will be increased. Square patch antennas provide some superior qualities making them very suited to special applications such as low profile, light weight, low cost, small size and simple to installation.

Fractal antennas can be introduced as antennas that have the shaped of fractal structures. Fractal antennas consist of repeated geometrical shapes [1]. However, fractal geometry attracted the antenna researchers and designers to manufacture new types of fractal Sierpinski antenna. Fractal Sierpinski antennas have small size, multiband resonance frequencies operation, wideband and the gain will be optimized. Attributes is unity of each one of the figures. Fractal geometries have classified into Sierpinski (gasket& carpet), Koch, Hilbert curve and sausage Minskowsi [2], [3].

Recently, Sierpinski antennas have emerged as powerful solution for the integration of all applications for cellular (GSM 900 and GSM 1800), wireless LAN, GPS and Hiper LAN. Basically, the design of fractal must satisfy two criteria, firstly, objects display self-similarity on all scales and secondly, is fractal dimensions. Most researches were attracted to overcome the limitations of the antenna characteristics such as profile and cost using fractal technology.

A design up to second iteration of microstrip sierpinski carpet antenna using the feeding as transmission line was presented. The design used the material of copper clad FR-4 for printing the radiator elements [4]. Efficient design of sierprinski fractal antenna has the capability of working at

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various frequencies was reported [5]. A novel planar monopole antenna was designed and manufactured for IMT and WiMAX applications [6]. Study effects evaluation of sausage minkowski antenna using different dielectric materials on SAR level for head tissue [7].

Significant reduction of radiating element volume was realized when the Koch fractal method was applied instead of conventional methods [8]. Suitable designs for wireless applications such as Wi-Fi, Wi-MAX, WLAN, Bluetooth and WCDMA were simulated [9]. Presentation of the design of Sierpinski Carpet Fractal Antenna for 3rd iteration using HFSS software on FR4 substrate material was analyzed [10].

A novel design of a dual band microstrip fractal antenna was presented which based on the use of Sierpinski triangle shape and FR4 as substrate material operating in the frequency bands (GPS, WiMAX) [11]. A compact dual-band radiating element for applications of WLAN and Long Term Evolution (LTE) services in the 800 MHz band was designed [12], [13].

In this research article, the concept of a fractal is applied to the geometry of a square patch microstrip antenna to reduce the volume of the object and obtain acceptable antenna properties for GPS applications.

2. Antenna Design Specification

In 1916, Wacław Sierpinski was the first researcher who explain the sierpnski carpet. Walko puts the construction for this type as follow.

1- The shape of sierpinski carpet are square or rectangle.
2- Dividing the shape into 9 copies itself, 3x3 grid.
3- Removing the central of sub square or sub rectangle.
4- Repeated these procedures to have 8 copies of sub square or sub rectangle for 2nd iteration [12].

Here the proposed Sierpinski Carpet antenna is designed from a simple square patch dimensions of Length (L) x Width (W) x Thickness (h) equal to 115 mm x 115 mm x1.6 mm for substrate and ground layers [2,6]. The substrate has relative permittivity (ε_r) of 2.5. The lengths of patch layer are changed according to number of iterations. Triple iterations are designed by using CST software. The starting for design the proposed fractal antenna begins with a square patch then divides it into nine smaller congruent squares where the open central square is dropped. The remaining eight squares are divided into nine smaller congruent square. The construction of the proposed fractal shape is carried out by applying a finite number of times an iterative process performed on a simple starting topology [14], [15].

The number of sub square is determined as shown in equation (1)

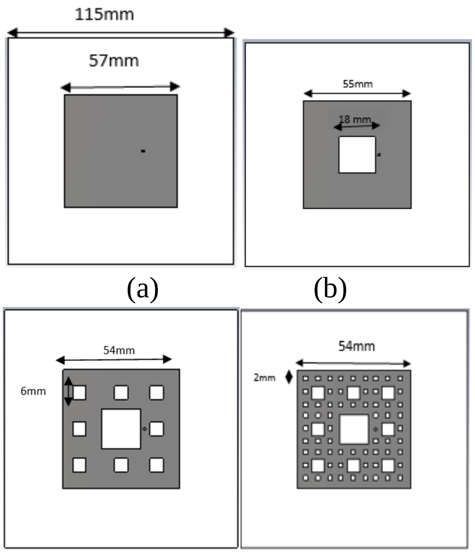
$$N_n = 8^n \qquad (1)$$

The equation (2) explains the calculation of sub square dimensions.

$$L_n = (1/3)^n \qquad (2)$$

Where, L_n is the length of sub square, n is the number of iterations

Figure 1 shows Sierpinski carpet fractal Square patch antenna for 0^{th} iteration, 1^{st} iteration, 2^{nd} iteration and 3^{rd} iteration respectively.



(a) (b) (c) (d)

Figure1. Sierpinski carpet fractal Square patch antenna (a) 0^{th} iteration, (b) 1^{st} iteration, (c) 2^{nd} iteration, (d) 3^{rd} iteration

3. Simulation Results & Analysis

This section depicts the results of the four iterations for Carpet sierpinski geometry applied on square patch antenna. The antenna performance for four iterations using fractal geometry is simulated using CST software 2014 at a frequency 1.575 GHz for GPS applications. Reflection coefficient for all the mode of iterations is plotted as function of frequency.

It has been observed in Figures (2, 4, 6 and 8) that the values of reflection coefficient will be decreased from (- 17 to - 25) dB with respect to the increasing of the number of iterations. other parameters which are gain, directivity and voltage standing wave ratio are simulated. Maximum directivity values were recorded 7.52, 7.51, 7.50, 7.48 for 0th iteration, 1st iteration, 2nd iteration and 3rd iteration respectively. Also, the gain of all modes of iteration has good agreement which was 5.48 dB, 5.74 dB, 6.15dB and 7.79 dB for the 0th iteration, 1st iteration, 2nd iteration and 3rd iteration respectively as shown in Figures (3, 5, 7 and 9).

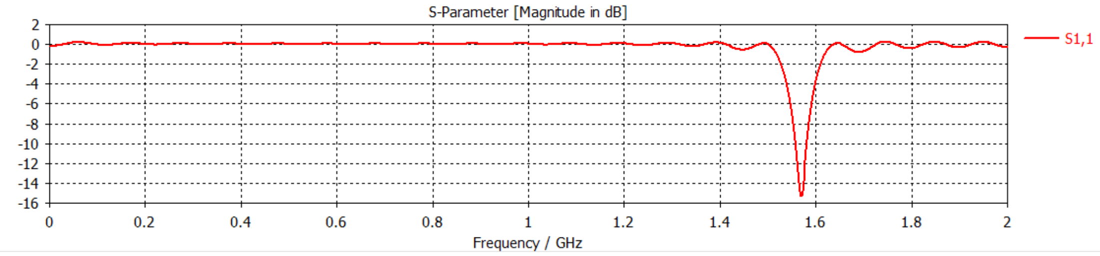


Figure 2. 0^{th} iteration Reflection coefficient at 1.575 GHz

Figure 3. 0^{th} iteration Radiation pattern (gain) in 3D

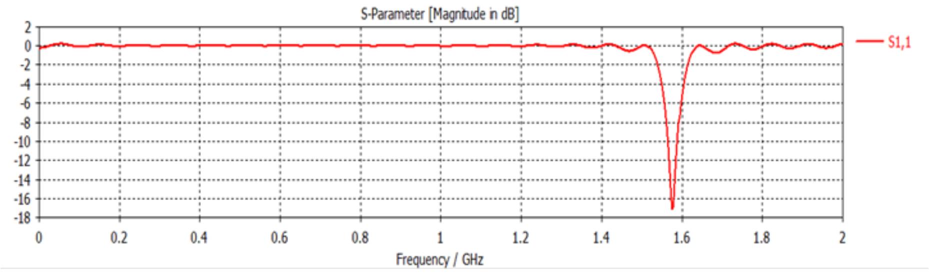


Figure 4. 1[st]iteration Reflection coefficient at 1.575 GHz

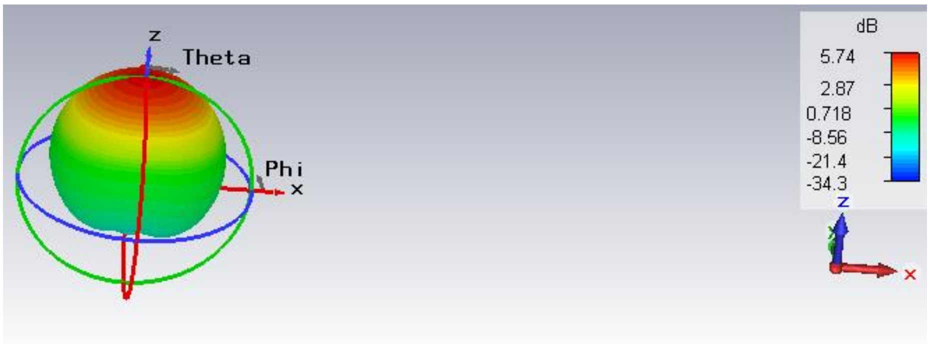


Figure 5. 1[st] iteration Radiation pattern (gain) in 3D

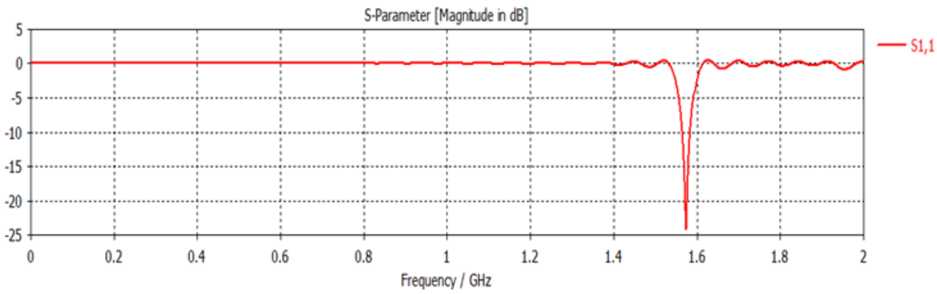


Figure 6. 2[nd] iteration Reflection coefficient at 1.575 GHz

Figure 7. 2[nd] iteration Radiation pattern (gain) in 3D

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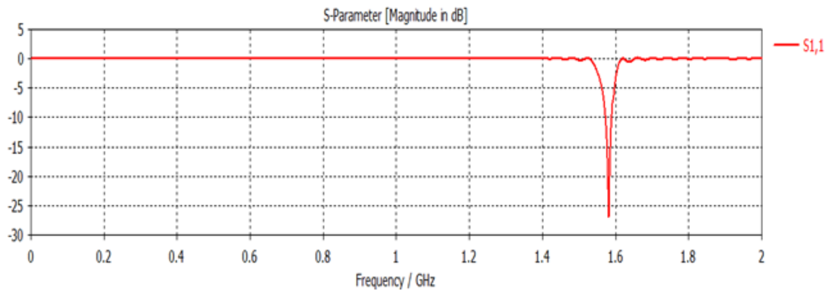

Figure 8. 3rd iteration Reflection coefficient at 1.575 GHz

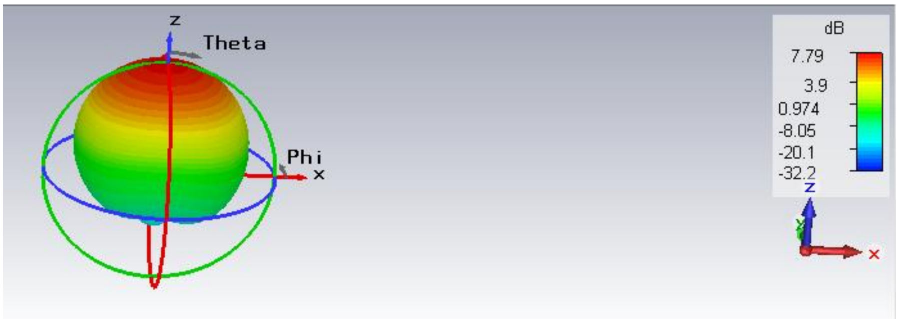

Figure 9. 3rd iteration Radiation pattern (gain) in 3D

Moreover, the Table (1) includes full details about the main parameters for the four modes of fractal geometry iteration such as reflection coefficient, gain, VSWR and the area of square patch. The value of VSWR will decreased with respect to the increasing of the number of iteration. These VSWR values were recorded 1.65, 1.65, 1.7 and 1.6 for the 0th iteration, 1st iteration, 2nd iteration, 3rd iteration respectively. The bandwidth is decreased with respect to increasing number of iteration where the values are 44MHz, 31.4 MHz, 29 MHz and 28 MHz for 0th, 1st, 2nd and 3rd iteration respectively. The reducible area from 3249 mm2 to 2701 mm2 in first step of fractal iteration and then to the 2304 mm2 in the second step of fractal iteration and finally to the 2052 mm2 in the third iteration is good indicator to reduce the physical size in fractal iteration technique for GPS application. The reduction area of Sierpinski Carpet patch antenna in parallel form with the enhancement the antenna parameters.

Table 1. The Characteristics of Fractal Sierpinski Carpet Square Patch Antenna

Characteristics	Types of Fractal			
	0th iteration	1st iteration	2nd iteration	3rd iteration
Reflection coefficient (dB)	-16	-18	-25	-27
Band width (MHz)	44	31.4	29	28
Gain (dB)	5.48	5.74	6.15	7.79
Directivity (dBi)	7.52	7.51	7.50	7.48
VSWR	1.65	1.65	1.7	1.6
Area of patch (mm^2)	3249	2701	2304	2052

4. Conclusion

The proposed Sierpinski Carpet fractal antenna up to3rd iteration is built & simulated for Gps applications. It is observed that the increasing the number of iterations, the bandwidth of the antenna will be increased. On other side, increasing the number of iteration also led to improvement in various performance parameters like VSWR, directivity, gain & return losses.

Finally, we can conclude that the generated area of Carpet Sierpinski square patch antenna for all modes of fractal geometry can be reduced by factor of $(5.125/6)^{n}$ from the 0^{th} iteration area where n is the number of iterations.

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