An Optimal Design of Fractal Antenna Using Modified Sierpinski Carpet Geometry for Wireless Applications

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Abstract. The paper explains an optimal design of fractal antenna using modified Sierpinski Carpet geometry for wireless applications. The proposed antenna is designed on substrate (FR4 glass epoxy) by considering the thickness of 1.6 mm and $\mathcal{E}_r = 4.4$. The resonant frequency taken for proposed antenna is 2 GHz. It is observed that on increasing the antenna iterations the gain also increases with it. The (HFSS V13) High Frequency Structure Simulator is used for designing and simulation of proposed antenna. The performance parameters of antenna like Voltage Standing Wave Ratio (VSWR), Return loss and gain for different iterations are also observed and explained in this paper.

Keywords: VSWR · HFSS · Return loss · Sierpinski carpet antenna

1 Introduction

The fractal geometries have been widely used in the wireless communication systems because of their wideband and multiband characteristics [1]. It was first developed by N. Cohen in 1995 [3]. Fractal geometries are designed by using two distinctive properties like space filling and self-similarity [2, 4]. Space filling is used to minimize the size of antenna and self-similarity describes the multiband and wideband nature of an antenna [6]. To overcome the drawbacks caused by printed and microstrip patch antenna like low bandwidth and low gain [5], the fractal antennas are used in the various wireless devices. Because they provide high gain, high bandwidth and also exhibits multiband and wideband characteristics [8, 9].

The fractal antenna is also capable to receive and transmit the signal over the wide range of frequencies [1]. A discontinuity in the geometry of fractal antenna increases the directivity and radiation properties of the antenna. Fractal geometries of antenna allow it to operate on different resonant frequencies [7]. The main advantages of fractal antennas are its less cost, compact size, easy to fabricate, portability because of light weight etc.

A. Unal et al. (Eds.): SmartCom 2016, CCIS 628, pp. 400–407, 2016.
DOI: 10.1007/978-981-10-3433-6_48

2 Antenna Design and Configuration

The antenna is designed on substrate (FR4 glass epoxy) by considering the thickness of 1.6 mm, $\varepsilon_r = 4.4$ with resonant frequency of 2 GHz. The dimensions of the substrate like length = 60 mm and width = 60 mm are taken for designing the antenna. The length and width of patch are computed by taking the Eqs. (1)–(4). The calculated dimensions of antenna are given in Table 1. The 0^{th} iteration, 1^{st} iteration and 2^{nd} iteration of designed antenna is depicted in Figs. 1, 2 and 3 respectively.

Table 1. Dimensions (Parametric values) of antenna

S. No.	Dimensions	Value (in mm)
1.	Substrate Length	60
2.	Substrate Width	60
3.	Ground Plane Length	60
4.	Ground Plane Width	60
5.	Patch Length	35
6.	Patch Width	45
7.	Length of Feed-line	19.78
8.	Width of Feed-line	2

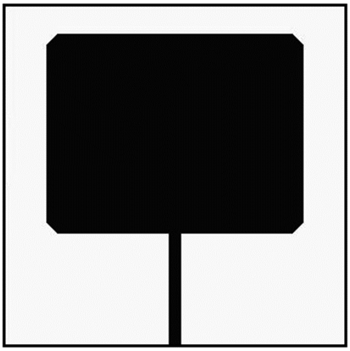

Fig. 1. 0^{th} iteration of antenna

Width of patch is found by considering equation as:

$$w = \frac{C}{2fo\sqrt{\frac{\in r + 1}{2}}} \tag{1}$$

Whereas, ε_{reff} is calculated by taking equation as:

$$\in reff = \frac{\in r + 1}{2} + \frac{\in r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{\frac{1}{2}} \tag{2}$$

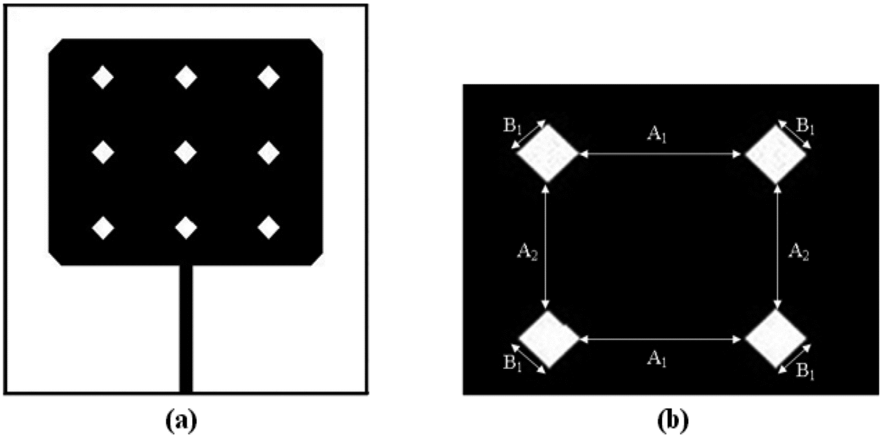

Fig. 2. (a) 1st iteration of antenna and (b) Slots dimensions for 1st iteration of antenna

ΔL (Increase in length) is occurred because of fringing effect and calculated as:

$$\Delta L = 0.412h \frac{(\in reff + 0.3)}{(\in reff - 0.258)} \frac{\left(\frac{w}{h} + 0.264\right)}{\left(\frac{w}{h} + 0.8\right)} \tag{3}$$

L(Actual length of patch) is calculated by the following equation:

$$L = \frac{c}{2fo\sqrt{\in reff}} - 2\Delta L \tag{4}$$

The above stated dimensions in the Table 1 are considered for designing the rectangular patch. In the 0th iteration, all the four corners of rectangular patch are being cut in equal size of 2.82 mm, as shown in Fig. 1.

The 1st iteration is being derived by considering the dimensions of 0th iteration, and also assumed as base geometry. The design of 1st iteration is depicted in Fig. 2(a). The dimensions of slots and distance among the various slots are indicated in Table 2 and Fig. 2(b) respectively.

Table 2. Dimensions of slots for 1st iteration of antenna

S. No.	Dimensions	Value (in mm)
1.	A_1	9.76
2.	A_2	7.76
3.	B_1	2.75

The 2nd iteration of antenna is designed by taking the dimensions of 1st iteration as a base geometry. The design of 2nd iteration (Final geometry of proposed design) of antenna is depicted in Fig. 3(a). The dimensions of the slots used to design the 2nd iteration of proposed antenna to make it a sierpinski carpet fractal antenna as shown in Fig. 3(b) and its dimensions are given in Table 3.

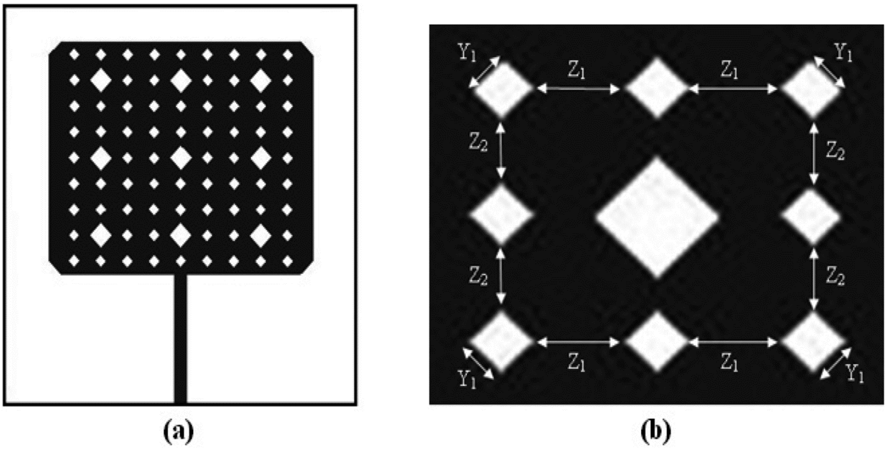

Fig. 3. (a) 2nd iteration of antenna (Final geometry of proposed design) and (b) Slots dimensions for 2nd iteration of antenna

Table 3. Dimensions of slots for 2nd iteration of antenna

S. No.	Dimensions	Value (in mm)
1.	Z_1	2.55
2.	Z_2	1.89
3.	Y_1	1.41

3 Results and Discussions

Simulated return loss versus frequency curves of 0th, 1st, and 2nd iteration of proposed antenna are discussed in Figs. 4, 5 and 6 respectively. The proposed antenna resonates on five distinct frequencies for all the three iterations. The value of the return losses for all the iterations at different frequencies is less than −10 dB which is the acceptable range for the practical use of antenna. The values of return loss for all the iterations with respect to frequency are given in Table 4.

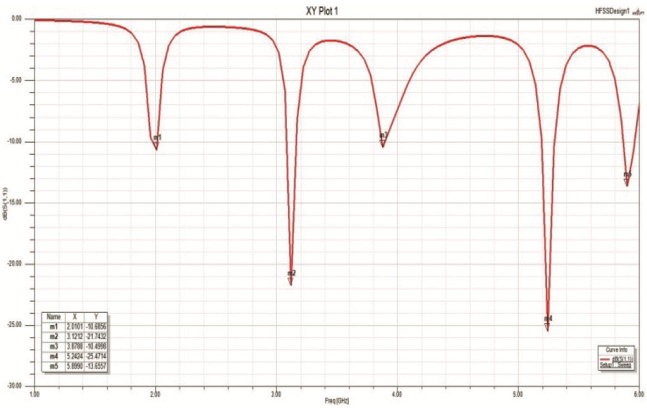

Fig. 4. 0th iteration - Return loss of proposed antenna

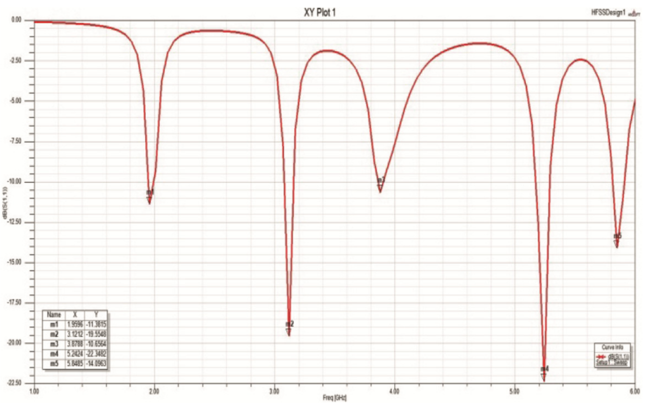

Fig. 5. 1st iteration - Return loss of proposed antenna

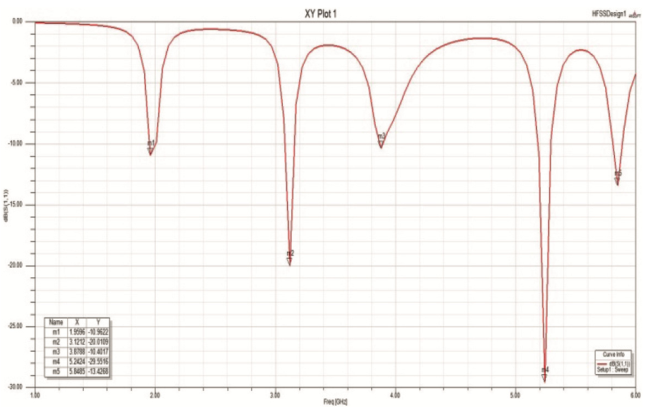

Fig. 6. 2nd iteration - Return loss of proposed antenna

Table 4. Values of return loss and VSWR for 0^{th} iteration, 1^{st} iteration and 2^{nd} iteration of antenna

Iteration	Frequency (in GHz)	Return loss (in dB)	VSWR
0^{th} iteration	2.01	−10.68	1.82
	3.12	−21.74	1.17
	3.87	−10.49	1.85
	5.24	−25.47	1.11
	5.89	−13.65	1.52
1^{st} iteration	1.95	−11.38	1.80
	3.12	−19.55	1.24
	3.87	−10.65	1.80
	5.24	−22.34	1.14
	5.84	−14.09	1.82
2^{nd} iteration	1.95	−10.96	1.78
	3.12	−20.01	1.22
	3.87	−10.40	1.86
	5.24	−29.55	1.06
	5.84	−13.42	1.54

Voltage Standing Wave Ratio (VSWR) describes the impedance matching of the antenna. It is the measure of impedance (Z) mismatch between the antenna and feed line. For practical use of antenna, it is necessary that value of VSWR should always be less than or equal to 2. The VSWR V/s frequency curves for 0^{th} iteration, 1^{st} iteration and 2^{nd} iteration are shown in Figs. 7, 8 and 9 respectively, and the values of VSWR for all the iterations are shown in Table 4.

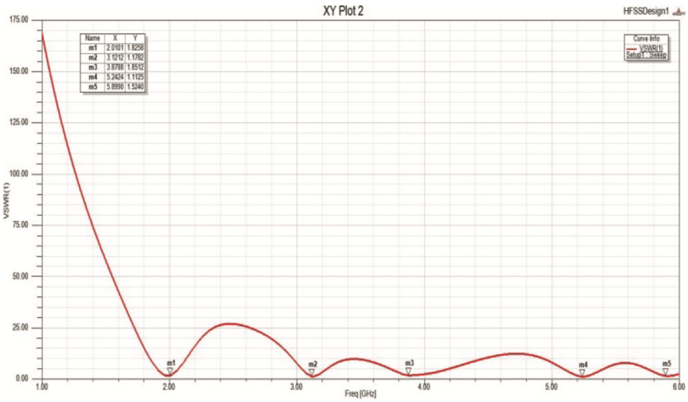

Fig. 7. 0^{th} iteration –VSWR of proposed antenna

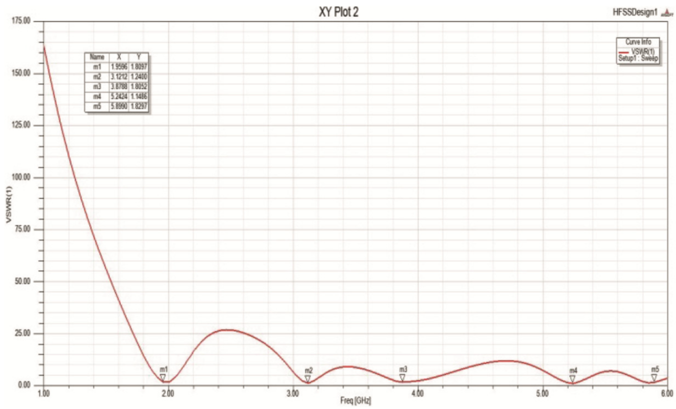

Fig. 8. 1st iteration -VSWR of proposed antenna

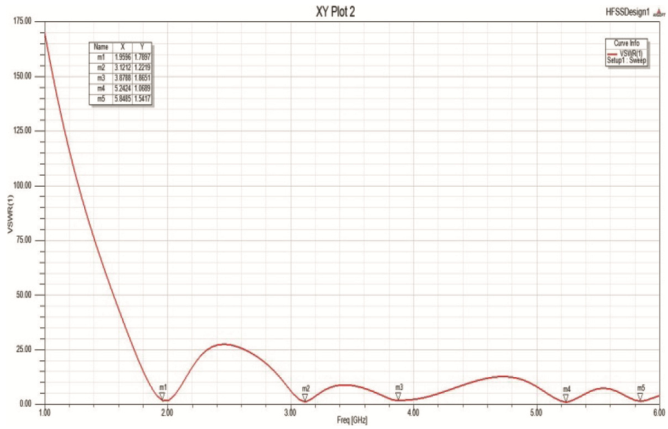

Fig. 9. 2nd iteration - VSWR of proposed antenna

Gain is the most important parameter of antenna it shows the efficiency and the directional capabilities of antenna. Basically the gain above 3 dB is required for the antenna to work efficiently. The 3-D gain plot at resonant frequency of 2 GHz for

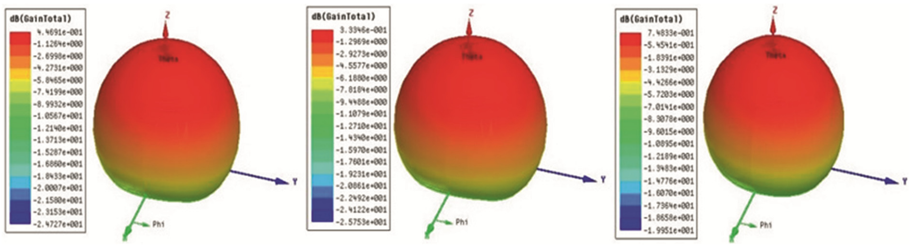

Fig. 10. 3D gain plots for 0th, 1st and 2nd iteration of antenna

0^{th} iteration, 1^{st} iteration and 2^{nd} iteration of antenna is depicted in Fig. 10. The value of gain for 0^{th} iteration, 1^{st} iteration and 2^{nd} iteration is 4.46 dB, 3.33 dB and 7.48 dB respectively.

4 Conclusion

An optimal design of fractal antenna using modified Sierpinski carpet geometry for wireless application has been presented in this paper. The designed antenna resonates at five different frequencies and the return loss is less than −10 dB for all the frequencies. The gain of antenna at resonant frequency is increases on increasing the iteration number and shows the gain above 3 dB which is the acceptable value of the antenna gain. The advantage of the designed antenna is to enhance the gain up to 7.48 dB.

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