Characterization of Shape Curving Effects on Multi-Band Fractal Antenna Design

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Abstract

The modern telecommunication systems require antennas with the wider bandwidths, the smaller dimensions, and the ability to resonate on several frequencies of interest. The fractal antennas have the capability to cater to all of the aforementioned requirements. Moreover, the fractal geometries tend to have improved level of the impedance and the standing wave ratio on the reduced physical area, in comparison with the non-fractal Euclidean geometries. This paper focuses on the design of multi-band fractal patch antennas, which can resonate at different frequencies at the same time. It is demonstrated by computer simulation results that the significant number of resonant frequencies increases with the increase in number of iterations in the fractal geometry. Besides, some simulation results are presented using the fractal geometries to give an insight into the frequency response variations with respect to the change in the curved shape of the patch of the fractal antenna.

Keywords: *Fractal antenna, multiband antenna, microstrip antenna, and iterative fractal geometry.*

1. Introduction

The term fractal was originally coined by Benoit Mandelbrot in the year 1975, to describe a family of complex shapes that possess an inherent self-similarity or self-affinity in their geometrical structures. The field is quite extensive with many applications from statistical analysis, natural modelling, compression, and computer graphics. The major area of concentration lies in the understanding of the physical processes and mathematical background of the interaction between electromagnetic waves and fractal structures [1]. The key aspect lies in their repetition of a design over two or more scale sizes or "iterations". The properties of self-similarity and space-filling, which are inherently possessed by the fractal geometries, are used to design an optimum antenna, which has smaller dimensions and can resonate on various frequencies of interest [2],[3]. Such antennas are used to improve the functionality of the modern communication systems, particularly mobile communication systems, in respect to size, portability, and the ability to work on different technologies over a single unit. The realization of fractal geometries in the design of antenna is based on microstrip antennas. The ease of fabrication, analysis and compatibility of the microstrip antennas with the printed-circuit technology make them useful for implementing the fractal geometries in an optimum manner [4]. In a nutshell, the fractal antennas provide an optimum way in implementing the antennas for modern day requirements, which is effective in many ways rather than Euclidean geometries used for designing the antennas.

In this paper, we present a design of a multiband antenna which consists of a circular patch with four / five triangles on its circumference, as shown in Fig. 1. The simulation results are provided, for studying the effects of iterations and shape curving of the triangles on the number and range of the resonant frequencies, using CST Microwave Studio 2010.

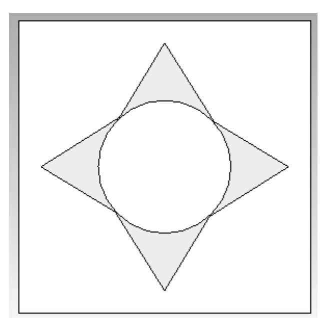

Fig.1. Proposed multiband antenna design (Antenna-1).

2. Geometric Aspects of Proposed Antenna and Simulation Results

The presented multiband fractal microstrip antenna is constructed using a substrate of thickness as 1.4 mm. The dimensions of the substrate used are 140 x 140 mm, with FR-4 (Fire Retardant - 4) as the substrate element, having the relative dielectric constant of 4.3. The patch of the antenna is made of Copper having the thickness of 0.02 mm. The ground plane is also required, which is having the same element as patch but having the thickness, three times the thickness of the substrate, of 4.2 mm. The antenna is excited with the help of coaxial feeding in the frequency range within 10 GHz.

The first antenna designed, named as Antenna-1 shown in Fig.1, is excited though coaxial feeding in the frequency range of 0-10 GHz. The simulation result, regarding return loss, of the antenna is presented in Fig.2.

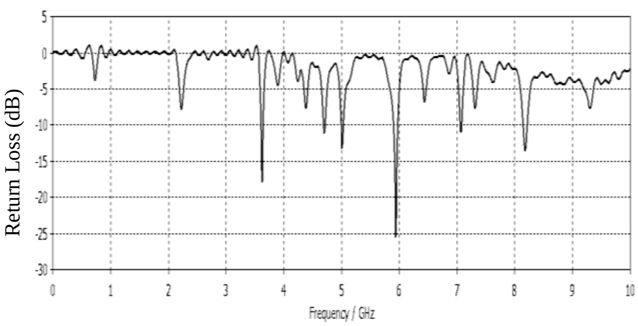

Fig. 2. Return loss vs frequency graph for Antenna-1.

The edges of triangular patches of the antenna are now curved, as shown in Fig.3. The corresponding return loss graph is shown in Fig.4.

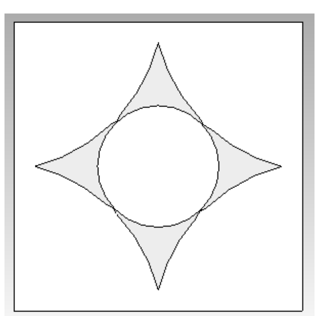

Fig. 3. Antenna-2 design with curved edges of the triangular patches.

It can be inferred from the Fig. 4 that by curving the edges of the antenna patch, the effective resonant frequencies (with return loss of -10dB and smaller) increases. The detailed comparison is presented in Table-1.

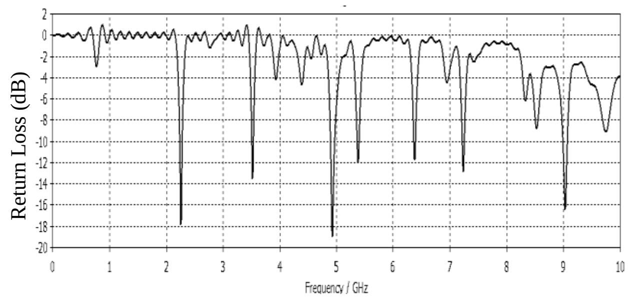

Fig. 4. Return loss vs frequency graph for Antenna-2.

The iterations of fractal geometry are applied to both, Antenna-1 and Antenna-2, to form fractal antennas of multiband operation, which are shown in Fig.5(a) and Fig.6(a), respectively. The corresponding Return Loss graphs of the antennas are shown in Fig.5(b) and Fig.6(b), respectively.

The similar process is done on a different design with five triangular patches in the circumference of the circular patch. Considering the same materials and dimensions, as of Antenna-1, the simulation of the antenna with five triangular patches is performed. The results and graphs of which are shown in the Fig. 7 – Fig. 10. The detailed comparison of the resonant frequencies and the return loss is presented in Table 2.

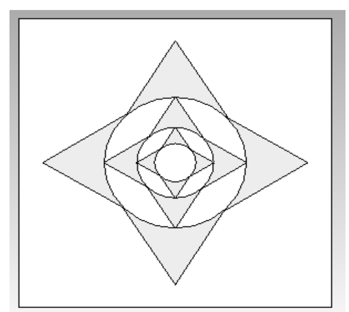

Fig. 5(a) Antenna-3 with straight edges and 3 fractal iterations

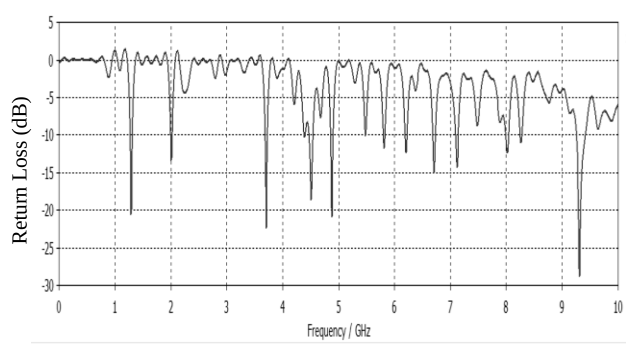

Fig. 5(b) Corresponding return loss vs frequency graph of Antenna-3.

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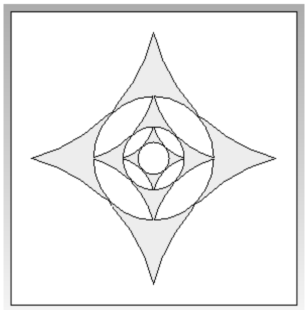
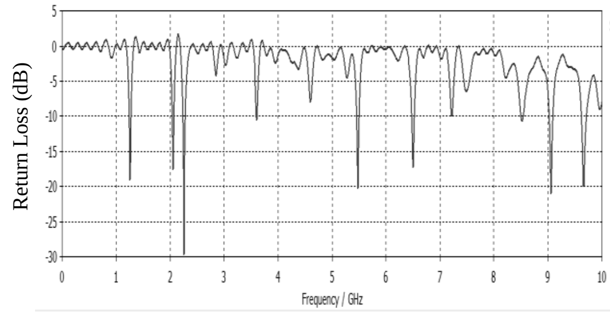


(a)



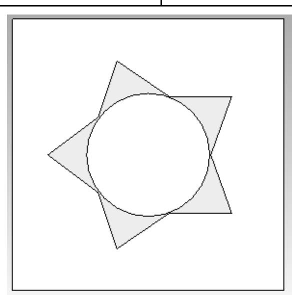
(b)

Fig. 6. (a) Antenna-4 with curved edges and 3 fractal iterations.
(b) Corresponding return loss vs frequency graph of Antenna-4.

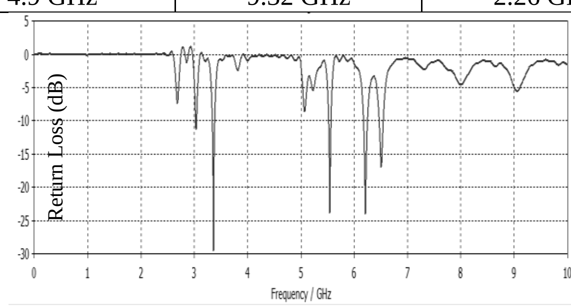
Table 1

Comparison of resonant frequencies and return losses for different antennas

Parameter	Antenna-1	Antenna-2	Antenna-3	Antenna-4
Resonant Frequencies (GHz)	3.63 4.7 5.0 5.95 8.2	2.25 3.52 4.9 5.38 6.38 7.24 9.03	1.28 2.0 3.71 4.51 4.88 6.21 6.71 7.12 9.32	1.25 2.05 2.26 5.48 6.5 9.06 9.66
Minimum Return Loss (dB)	-22.8 at 5.95 GHz	-18.9 at 4.9 GHz	-28.7 at 9.32 GHz	-29.6 at 2.26 GHz

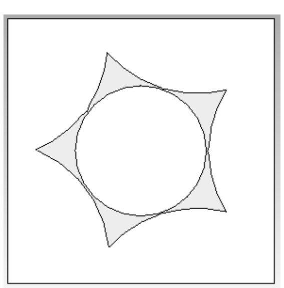


(a)

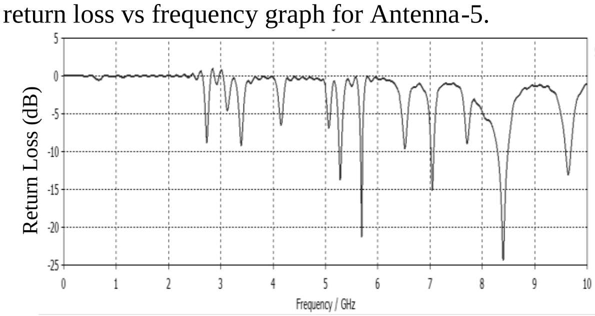


(b)

Fig. 7. (a) Antenna-5 with five triangular patches and straight edges.
(b) Corresponding return loss vs frequency graph for Antenna-5.

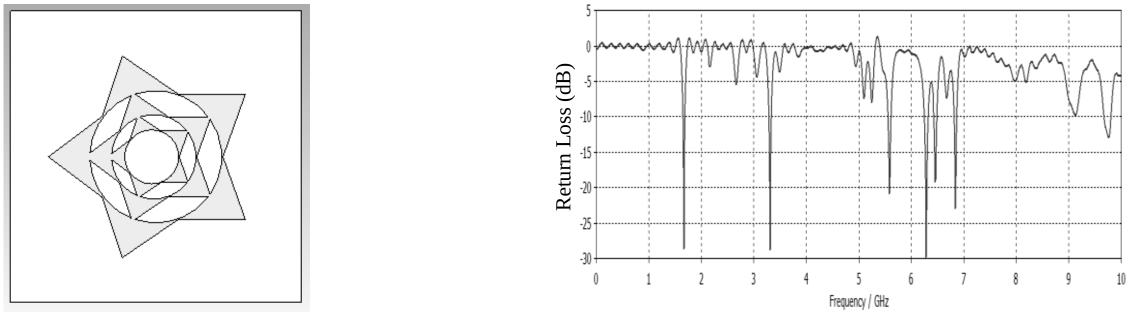


(a)



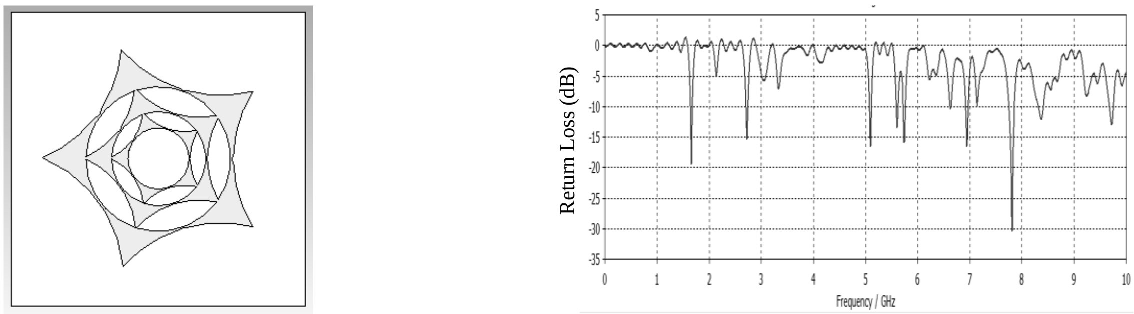
(b)

Fig. 8. (a) Antenna-6 with five triangular patches and curved edges.
(b) Corresponding return loss vs frequency graph for Antenna-6.



(a) (b)

Fig. 9. (a) Antenna-7 with five triangular patches, straight edges, and 3 iterations.
(b) Corresponding return loss vs frequency graph for Antenna-7.



(a) (b)

Fig. 10. (a) Antenna-8 with five triangular patches, curved edges, and 3 iterations.
(b) Corresponding return loss vs frequency graph for Antenna-8.

Table 2
Comparison of resonant frequencies and return losses for different antennas

Parameter	Antenna-5	Antenna-6	Antenna-7	Antenna-8
Resonant Frequencies (GHz)	3.04 5.5 6.21 6.38 6.59	5.28 5.69 7.0 8.4 9.6	1.67 3.31 5.58 6.28 6.46 6.84	1.66 2.72 5.1 5.6 5.75 6.9 7.81 8.4 9.73
Minimum Return Loss (dB)	-23.9 at 6.21 GHz	-24.3 at 8.4 GHz	-29.8 at 6.28 GHz	-30.3 at 7.81 GHz

4. Concluding Remarks

It can be demonstrated from the design and results, shown in Fig.1 - Fig.10 and Table 1-Table 2, that a simple antenna resonates at the frequencies less than the iterative fractal antenna. The iterations in the fractal geometry are not only helpful in the space-filling and the miniaturization of the antenna, but also they are helpful in making the antenna resonate at the different frequencies for multiband operation. The curving of the edges of the triangular patches makes the patch resonate effectively at distinct frequencies, resulting in better return losses and fewer effective resonating frequencies. As the curved edge geometry has lesser discontinuities, the spacing between the resonating frequencies is wider than the straight edge geometry of the patch antennas. The antennas, so designed, possess the multiband operation capability with smaller dimensions, which are ideal for modern wireless communication systems. The feeding method, i.e., coaxial feeding, used in the proposed designs and the feeding point in the geometry, may also be changed to get better results, which includes the future scope.

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