Broadband Fractal Antennas

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1. Introduction

Design of fractal antennas is currently targeted for highly desirable characteristics such as compact size, low profile, conformal, multi-band and broadband, as described in [1], [2], and [3]. Most of the designers adopt operations such as translation, rotation, iterations, etc. on the fractal generator motifs, such as Koch, Minkoski, Cantor, Torn Square, Mandelbrot, Caley Tree, Monkey's Swing, Sierpinski Gasket, Julia etc. for the creation of the self-similar shapes. To further improve the frequency responses, they applied modifications on the created shapes, such as in [4]. Recently, new approaches, such as Generic Algorithm, are studied for handling antenna optimization on multi-dimensional parameters [5].

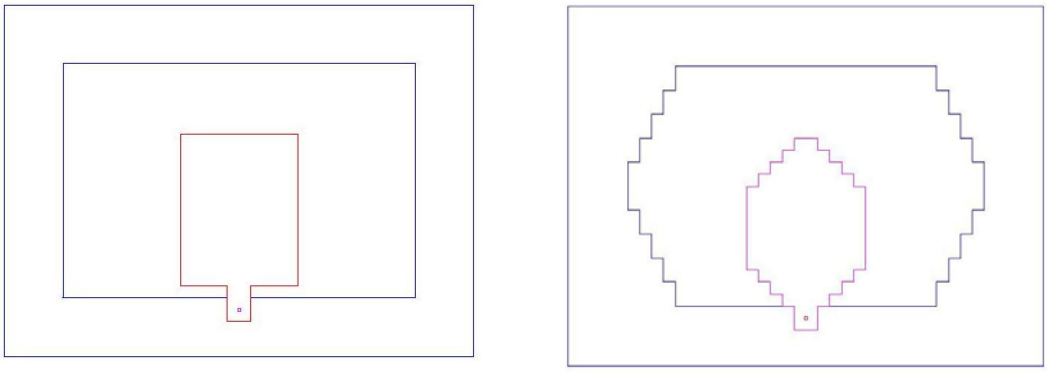
For commercial use, the fractal antennas need to comply with engineering requirements, such as antenna efficiency, directivity, gain, radiation pattern etc. in addition to the aforementioned desirable characteristics. These requirements are critical to the signal integrity, such as specified in UWB standard. However, most of broadband antennas are not capable of maintaining conformal characteristics due to different radiating areas, generation of harmonics etc. which alter antenna characteristics, such as radiation pattern, drastically and subsequently limit the bandwidth that the antennas can perform.

Recently, we have developed a new approach to design fractal antennas based on Herman Rings [6,7 and 8]. Herman Rings are characterized by fractal internal and external contours. This approach is based on the methodologies used in the area of dynamic systems in conjunction with fractal geometry as described in [9], [10], and [11]. In this paper, we further explore this new approach and examine antenna efficiency, directivity, gain, radiation pattern of such antennas. We study the features based on the comparison of antennas at different order of iterations.

2. Herman Ring Fractal Antennas

As previous works adopting square shapes for fractal antennas, we adopt rectangular ground shape and complementary antenna to increase the number of the excited modes and to balance the impedance shift. Fig. 1a shows a rectangular ring serves as ground plane with size of 4 cm by 3 cm externally and 3 cm by 2 cm internally. The antenna body maintains the 3:2 ratios with size of 2 cm by 1.5 cm, but it rotates 90 degrees in direction and shifts toward one side in order to connect to the signal feed-in area (shown as a point in Fig. 1). Since we elongate the square shape to the rectangular shape, this rotation serves for balancing the inductive and capacitive values caused by the shape modification.

Fig. 1b shows a similar antenna with higher order of fractal iteration. The internal contour of the ground plane and the external contour of the antenna body constitute a Herman Ring fractal. Similar to the shape of the antenna shown in Fig. 1a, the antenna body in Fig. 1b also rotates 90 degrees against the internal fractal boundary of the ground plane. Additional rectangular steps in fractal form are the areas, where the broader EM modes can be excited. In the following, we present a set of antenna characterizations based on FR4 PCB materials with thickness at 1.6 mm.

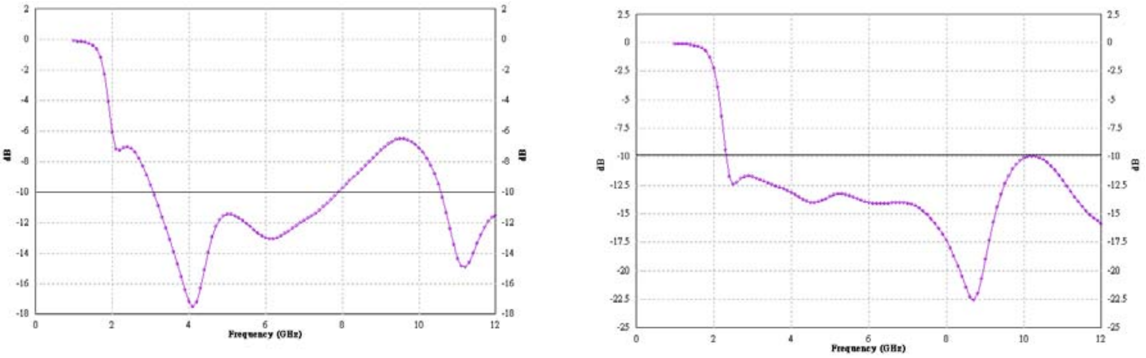


a **b**

Figure 1 Fractal Antennas

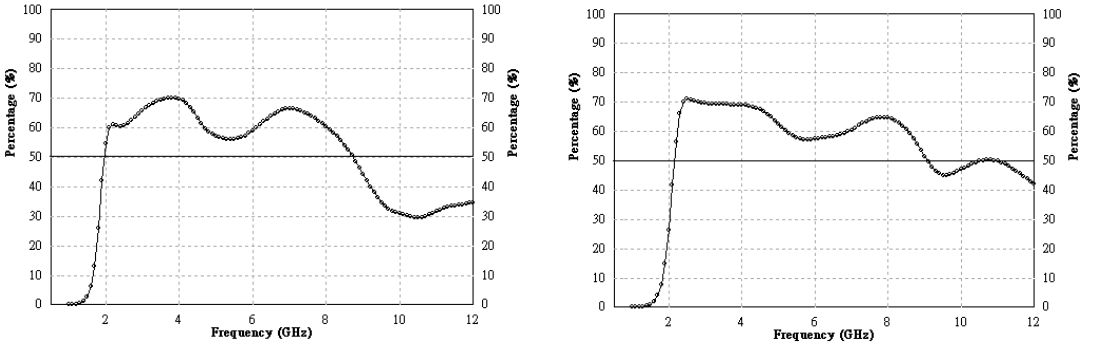
3. Characterization

We adopted commercially available tools and platforms, such as Matlab and Zeland (IE3D), for antenna performance analysis. Fig. 2a and 2b show the return loss (S_{11}) of the antennas in Figure 1 individually. The reference lines as indicated in the Figure are at -10dB level. We observe that the antenna with higher order iteration (Fig. 1b) demonstrates better impedance matching.



a **b**

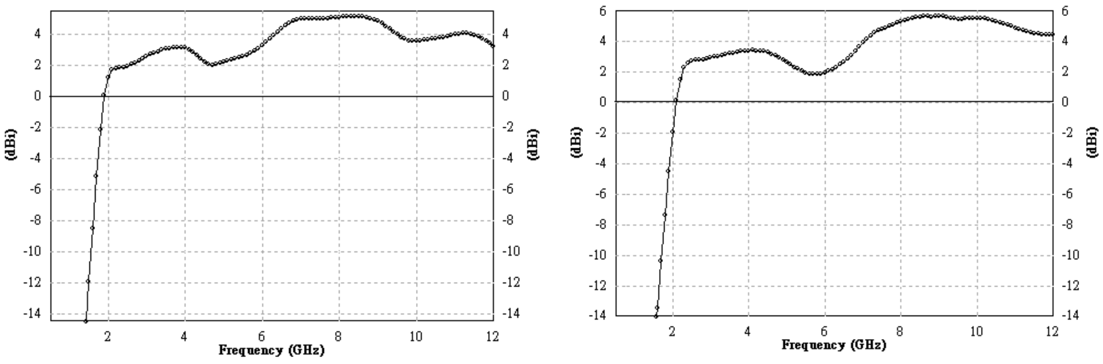
Figure 2 Return Loss S_{11} of Antennas in Fig. 1



a **b**

Figure 3 Antenna Efficiency of Antennas in Fig. 1

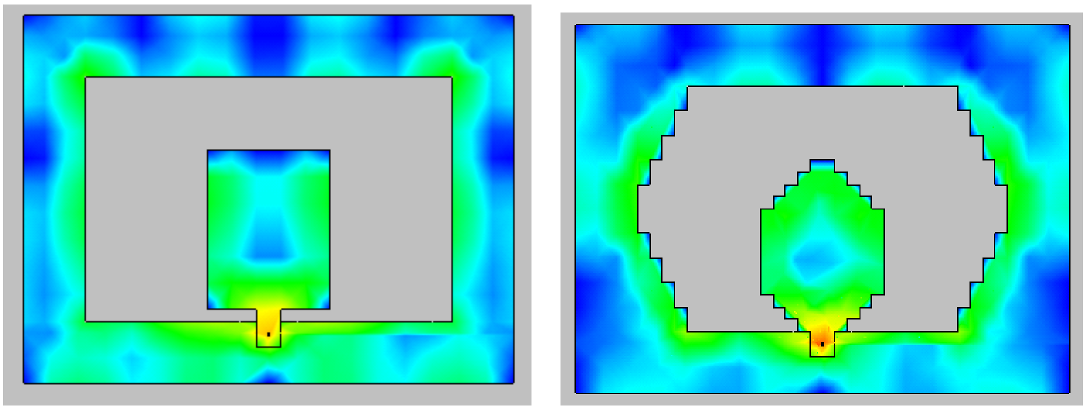
Fig. 3 shows the antenna efficiencies individually. The reference lines as indicated in the Fig. 3 are at 50% efficiency. We observe that the antenna with higher order fractal iteration has better performance at both low frequencies and high frequencies. Fig. 4 shows the antenna gains individually. The reference lines as indicated in Fig. 4 are at 0 dB. We observe that the antenna with higher order fractal iteration has more uniform gain profile and higher gains particularly around 10 GHz region.



a **b**

Figure 4 Antenna Gain of Antennas in Fig. 1

Fig. 5 shows the vector and scalar current distributions of the antennas radiating at 10 GHz individually. We observe that the current distribution of the antenna with higher order fractal iteration has more concentrated and uniform current distribution.



a **b**

Figure 5 Antenna Vector and Scalar current distribution at 10 GHz of Antennas in Fig. 1

Fig. 6 shows the radiation patterns (E-Total for Φ= 0 and 90 degrees) of the antennas at four frequencies: 3, 5, 8, and 10 GHz. We observe that the antenna with low order fractal iteration showing the generation of high order harmonics and subsequently introducing pattern tilting and distortion, while the antenna with high order fractal iteration showing more desirable radiation patterns through the UWB spectrum.

4. Conclusion

In this paper we investigate the impact of iteration order on the performance of Herman Ring fractal antennas. We adopted a complementary 90 degree rotations the next iteration for optimizing impedance of these antennas. We observe that the antennas with higher order fractal iteration have better performance in terms of return loss, antenna efficiency, antenna gain, and radiation patterns.

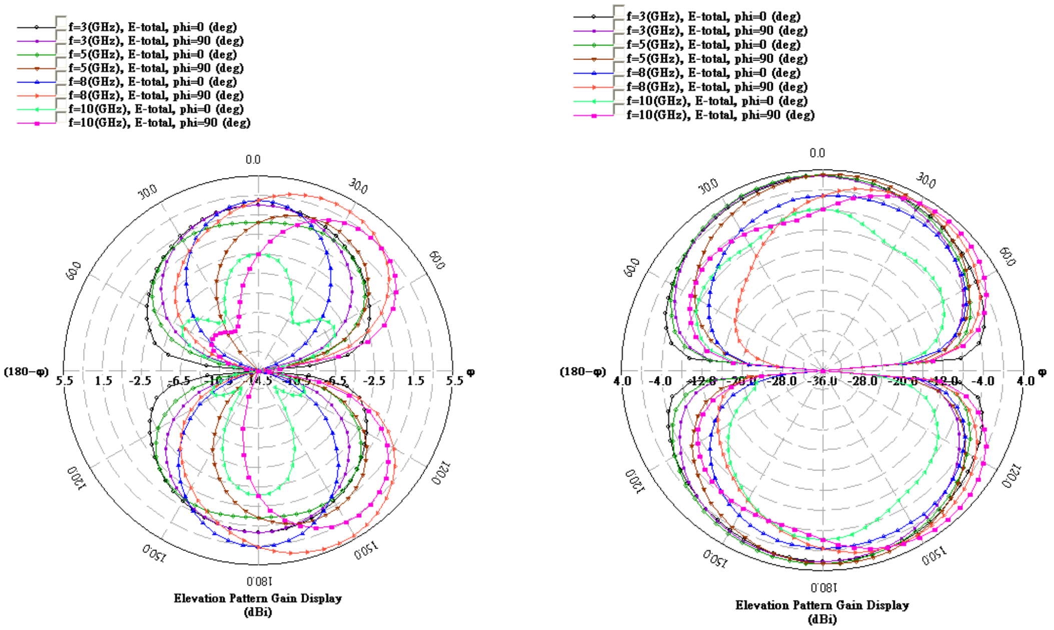


Figure 6 Antenna Radiation Patterns at frequencies of 3, 5, 8, and 10 GHz of Antennas in Fig. 1

Acknowledgments

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