Design and Analysis of a Multiband Fractal Microstrip Antenna

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Abstract— **The commercial and military telecommunication systems require multiband antennas. The small physical size and multi-band capability are very important in the design of multiband antennas. Fractals have unique properties such as self-similarity and space filling. The use of fractal geometry in antenna design provides a good method for achieving the desired miniaturization and multi-band properties. In this communication, a multi-band and broad-band Microstrip antenna based on a new fractal geometry is presented. The proposed design is an octagonal fractal Microstrip patch antenna. The simulation and optimization are performed using HFSS simulator. The results show that the proposed Microstrip antenna can be used for 3.44-4.09 GHz and second band is 7.04-7.59 GHz and third band is 9.40-9.8 GHz frequency ranges at the return loss of -17dB, - 21dB and -22 dB.**

Index Terms— **Bandwidth, fractal Microstrip antenna, fractals, ultra wideband.**

I. INTRODUCTION

Modern communication systems require antennas with more bandwidth and smaller dimension. One of the main components of multiband communication systems is an multiband antenna. Customarily, multiband antennas need different antenna elements for different frequency bands. If antenna size is less than a quarter of wavelength, antenna will not be efficient. Fractal geometry is a very good solution to fabricate multi-band and low profile antennas. Applying fractals to antenna elements allows for smaller size, multi-band and broad-band properties. Thus, this is the cause of spread research on fractal antennas in recent years [1]–[4].

Fractals have self-similar shapes and can be subdivided in parts such that each part is a reduced size copy of the whole. The self-similarity of fractals is the cause of multi-band and broad-band properties and their complicated shapes provides design of antennas with smaller size. Fractals have convoluted and jagged shapes such that these discontinuities increase bandwidth and the effective radiation of antennas. The space-filling property of fractals leads to curves which have long electrical length but fit into a compact physical volume. [5]-[9]. Several UWB antenna configurations based on fractal geometries have been investigated including Koch, Sierpinski, Minkowski, Hilbert, Cantor, and fractal tree antennas in recent years. The numerical simulation and experimental results of these antennas are available in literature to date. In this communication, a fractal Microstrip antenna is presented. This new fractal geometry is based on an iterative octagon. The huge bandwidth is the main advantage of this fractal antenna over conventional fractal antennas. The commercially available simulation software HFSS has been used for the design and simulation of the proposed Microstrip antenna. According to the results, this new fractal antenna is applicable **for 3.44-4.09 GHz and second band is 7.04-7.59 GHz**
And third band is 9.40-9.8 GHz frequency range and the gain of this fractal Microstrip antenna is reasonable in entire bandwidth.

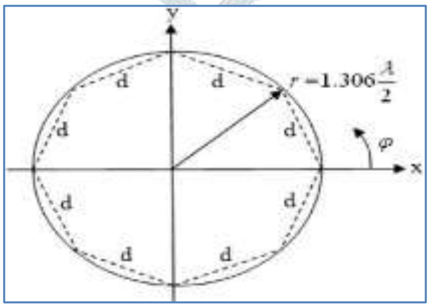

Figure 1: The geometry of octagonal circular sub array generator.

This communication is arranged in four sections. Design of proposed antenna is discussed in Section II. Simulated and measured results are presented in Section III and the conclusions are summarized in Section IV.

II. ANTENNA DESIGN

There are several types of fractal Microstrip patch antennas. The most well-known fractal patch antenna is Sierpinski patch antenna such that the various types of it are used greatly in telecommunication systems. The quadrilateral and hexagonal fractal

Microstrip antennas were discussed in some papers. In initial process of this project, many designs and simulations are performed over fractal patch antennas. The various types of quadrilateral, pentagonal and hexagonal fractal patch antennas are considered and finally the octagonal fractal shape is selected because of its good performances in bandwidth and gain.

The standard octagonal arrays are formed by placing elements in an equilateral triangular grid. These arrays can also be viewed as consisting of a single element at the centre, surrounded by several concentric eight element circular arrays. To investigate the designs for octagonal arrays via a recursive application, we consider the eight-element circular generating sub array of d= lambda/2 shown in Figure 1. According to the octagonal properties, the interior angle is 135 and the exterior angle is 45.

$$\mathrm{COS}\left(\frac{135^0}{2}\right) = \frac{\frac{D}{2}}{R} \rightarrow R = 1.306\left(D\ or\ \frac{\lambda}{2}\right)\text{------------}(1)$$

The array factor may expressed in the form of

$$\breve{A}F_p(\Theta,\Psi) = \frac{1}{8P}\prod_{P=1}^{p}\sum_{n=1}^{8} e^{-j\delta P-1[1.306\pi\sin\Theta\cos(\Psi-\Psi_n)+\alpha_n]}\text{--------}(2)$$

Where

$$\Psi_n = (n-1)\frac{\pi}{4}\text{-------------------------}(3)$$

$$\alpha_n = 1.306\pi\ \ sin\Theta\ cos(\Psi-\Psi n)\text{--------------------------}(4)$$

The parameter δ is a scale factor that controls the largeness of the array with each recursive generation application and P is the number of concentric octagons in the array. Therefore, the
Total number of elements with P octagons is
N_P= 4P (P+1) +1

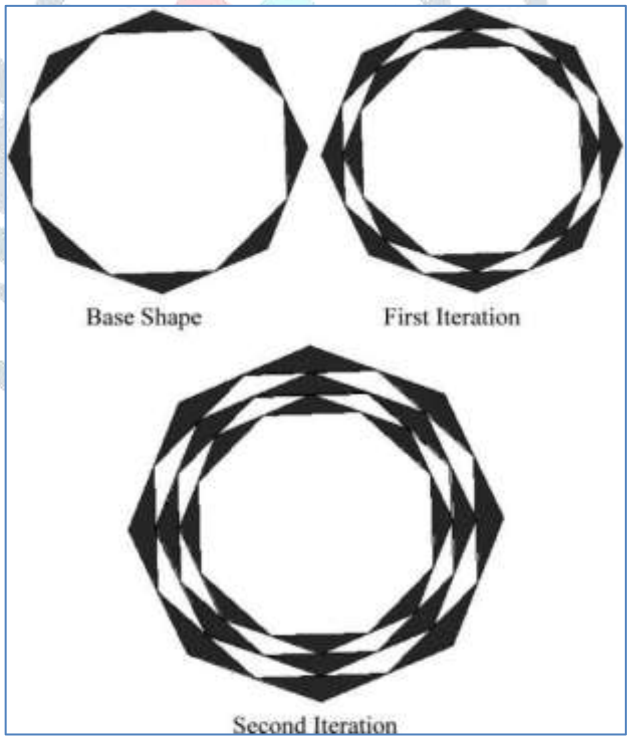

Figure 2: Iterations of the proposed fractal geometry.

The array factor may also written in the form of

$$\breve{A}F_p(\Theta,\Psi) = \frac{1}{8P}\prod_{P=1}^{p}\sum_{n=1}^{8} e^{-j\delta P-1[\Psi_n(\Theta,\Psi]}$$

The geometric construction of this fractal shape starts with an octagon, called the base shape, which is shown in Fig. 2 (Base Shape). By adding another octagon inside the base shape, the first iterated version of the new fractal geometry, shown in Fig. 2 (First Iteration) is created. The process is repeated in the generation of the second iteration which is also shown in Fig. 2 (Second

Iteration). In this communication, the second iteration of the octagonal fractal geometry is considered since higher order iterations do not make significant affect on antenna properties.

For this antenna, the length of each side of octagon is 2 cm. The proposed fractal geometry is placed on the Rogers TMM substrate with relative permittivity 4.4 and thickness 1.54 mm. The dimension of the ground plane is chosen to be 40 X 40 mm. The appropriate feeding location is in the maximum of electric filed. The position of strip line to match the input impedance Z=50Ω is founded exactly using simulation by this fact that the E-field must be maximum. Thus the location of the coaxial feed is placed on the patches which are 26.5 mm from the centre at the corner. Figure 3 shows the structure of antenna on the substrate

III. SIMULATION AND MEASUREMENT RESULTS

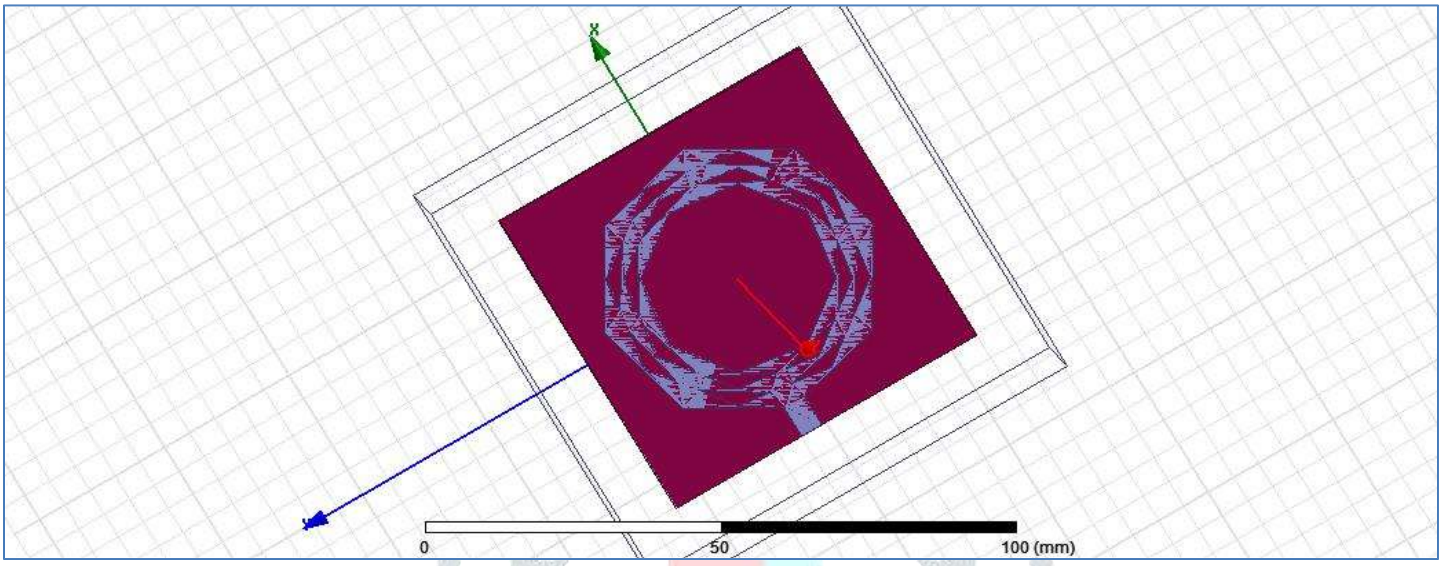

Figure 3: Antenna Structure

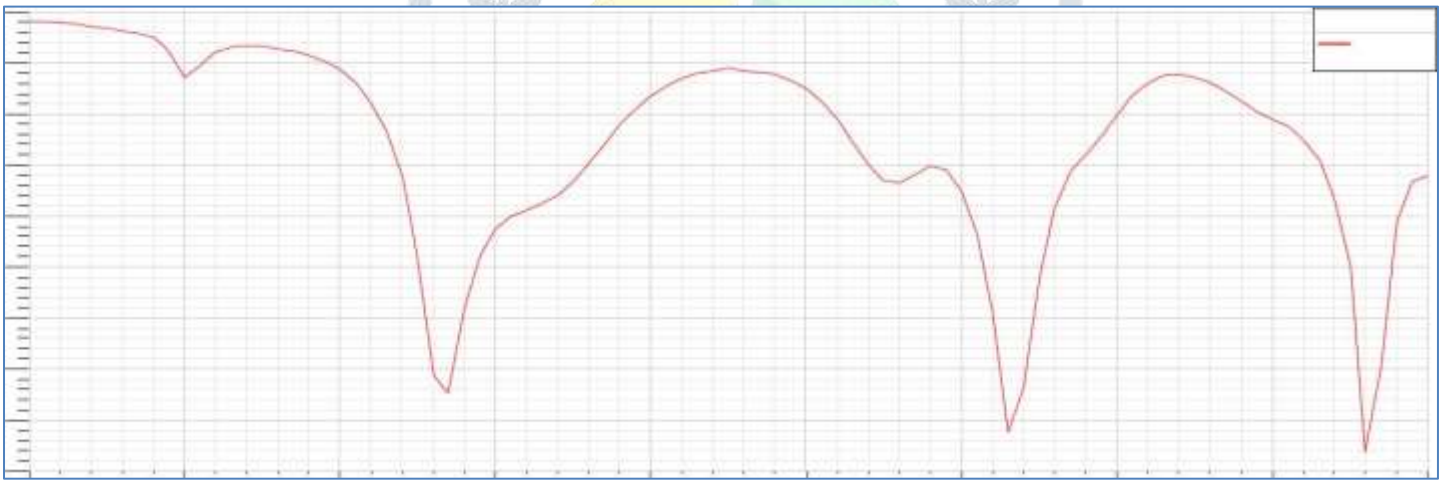

Figure 4: Return Loss

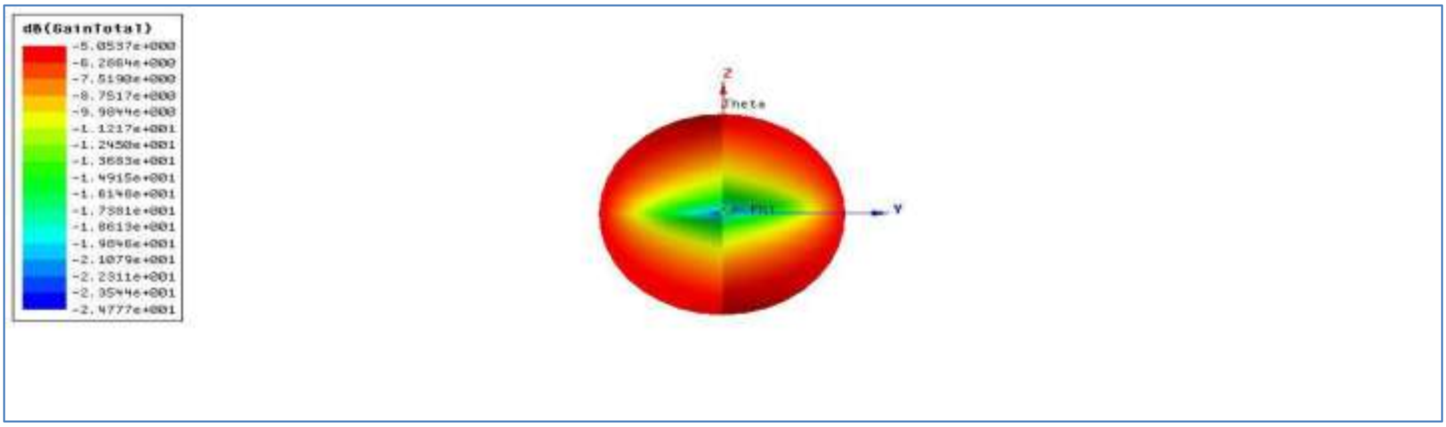

Figure 7: 3D Polar Plot

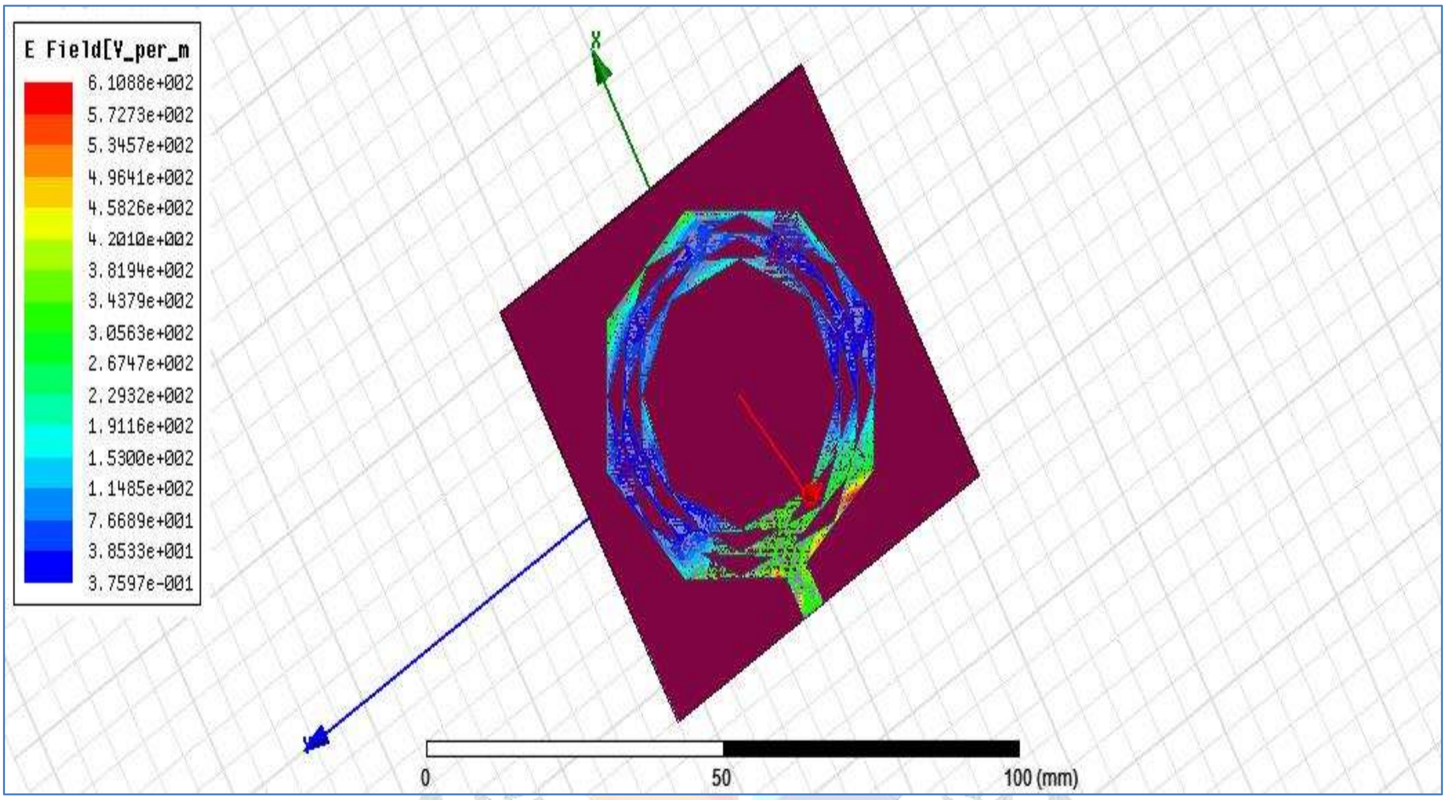

Figure 8: Current Distribution

This antenna is simulated using HFSS. The results show that the proposed Microstrip antenna can be used for 3.44-4.09 GHz and second band is 7.04-7.59 GHz and third band is 9.40-9.8 GHz frequency ranges at the return loss of -17dB, -21dB and -22 dB. VSWR is in the range of 1-2 that is suitable to operate. Fig. 8 shows the current distribution in some selected frequencies.

According to the figure, the multiband behaviour is due to the fact that the currents along the edges introduce additional resonances, which produce an overall broadband frequency response characteristic.

IV. CONCLUSION

The concepts of fractals can be applied to the design of multiband antennas. Applying fractals to antennas allows for miniaturization of antennas with multi-band and broad-band properties. Based on fractal geometry, a super wideband fractal Microstrip antenna is implemented. The proposed design is a second iteration of octagonal fractal geometry. The proposed structure has a dimension of 40 X 40 mm. The simulated results are obtained using simulator. The results show that it is a super multiband antenna which is applicable for frequencies between 3.44-4.09 GHz and second band is 7.04-7.59 GHz and third band is 9.40-9.8 GHz frequency ranges at the return loss of -17dB, -21dB and -22 dB. This Microstrip antenna is simple to design and easy to fabricate.

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