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Fractal Antenna Design for UWB Applications

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Abstract— Development and advancement in the field of wireless communication has led to the demand of high data rate and compact antenna design with broadband characteristics. Frequency from 3.1 GHz to 10 GHz has been allowed by FCC for commercial use from 2002. This frequency range is usually used for short range communication. This calls upon the problem of interference with other system working on same frequency band. Fractals means discontinuous or irregular in shape, its geometry cannot be described by normal geometry. The term was coined by Manderbolt. It contains multiple copies of it in different dimensions. Fractals have been used here to design an antenna for the same. The reason for fractals is smaller size, it produces discontinuity i.e. corners and bends which in turn produces higher efficiency and provide multiband characteristics as well.

Index Terms— Fractal, Iteration, multiband and Ultra Wide Band.

I. Introduction

The development of communication system has led to the demand of high functioning antennas for short range communication.FCC commercialized the frequency band from 3.1 to 10.6 GHz (UWB) in 2002, the demand further increased for high data rate, smaller size and having multiband or broadband characteristics. As a result of such demand led to a lot of research in the field of antennas as well as UWB. This band is generally used for very short distance communication.

Many antennas for UWB band were developed in the past decade due to their simplicity in fabrication and lower complicity and larger bandwidth in the order of GHz. The antenna for UWB is made with the help of a rectangular patch, on which the ground plane and the design is made i.e. the fractal design. There are several methods by which the efficiency and the performance can be improved; some of them are partial ground plane, slits introduced in ground plane, feed gap optimization. Feeding techniques used here is wave port.

In this paper a fractal antenna is made by using circular shape and hexagonal shape. The iteration is the process of repeating a particular pattern again and again with change in dimension. Here in this design a hexagon is removed from a circular patch and again a circle is inscribed in the resultant patch and again a hexagon is removed from the patch, this gives the unique shape.

II. Fractal Concept

The idea or the concept of fractal was introduced by B.B. Mandelbrot, a French mathematician in the year 1970. The term fractal was also coined by him. As per his findings, fractals can be defined as the set F such that, F has such fine structure with details on small scales where F cannot be defined by the normal or traditional geometry. 'F' has the self similarity properties, which can be statistical or geometrical. The fractal dimension of F is always greater than the topological or actual dimension.

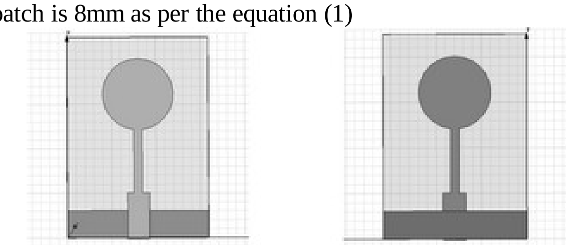
III. Design and Implementation

Circular monopole antenna is initially considered as conventional design which operates in UWB range. The UWB range which is from 3.1 to 10.6GHz has a band range of 7.5GHz. The antenna is designed for 5.24GHz. The antenna design is realized on FR4 Substrate which has a relative permittivity of 4.4 and a tangent loss of 0.019. Radius of the circular patch is calculated using the equation as follows

(1)

Where f_r is the frequency in GHz, $_r$ is the relative permittivity and the tangent loss of the material FR4 is 0.019.

The dimension of the substrate is (W_{sub} x L_{sub}) 31.7mmx50.96mm and the radius of the outer circular patch is 8mm as per the equation (1)



(a) (b)

Figure 1 Conventional Antenna (a) front view, (b) Rear view

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A. Iterations

In this design up to four iterations are made to study how the antenna behaves as the pattern differs in the patch, when all the other parameters are kept alike or same.

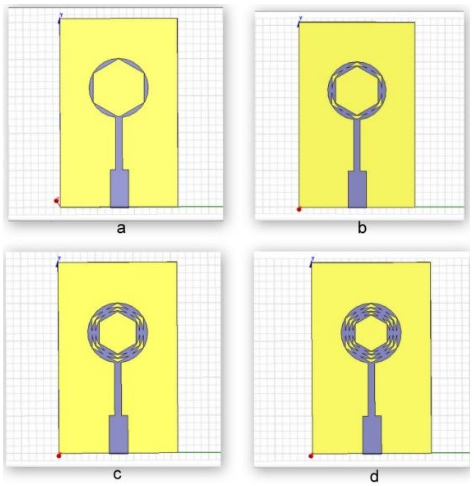

Figure 2 Four iterations of the fractal design (a) the first iteration (b) the second iteration (c) the third iteration and (d) the fourth iteration.

In the above designs the iterations are made as a result of removing or eliminating a hexagon from the circle; for every iteration the process is repeated.

IV. Results and Discussions

The Circular patch is made with the calculated dimensions. The simulation tool used for the performance evaluation is 'HFSS 12'. The dependency of return loss on ground plane was first studied. The Length of the patch is 50.96mm, and it was gradually decreased to find the optimal height 'h' (height of the ground plane) at which antenna performed better.

After several simulations it was observed that the antenna performed better when the ground plane had a height of 10mm, as a result this height of the ground plane is taken as the optimized value for the ground plane. Now all the iterations were done on the basis of this ground plane optimization.

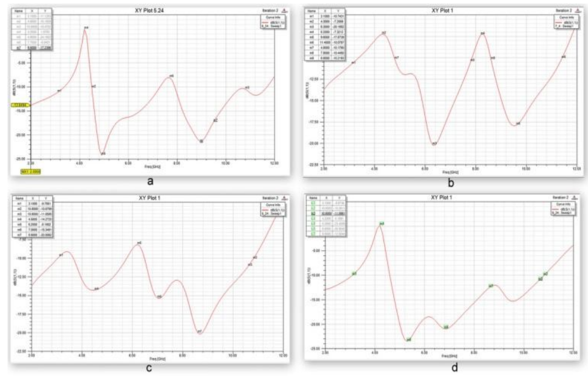

Figure 3: the effect of return loss on ground plane.

The above figure (fig:3) shows the effect on ground plane on return loss for various values of 'h' starting from (a) 30mm (b) 25mm (c) 20mm (d) 10mm; better results were observed at the point where the value of 'h' was 10mm.

The gain observed from all the four iterations are shown along with the radiation patterns.

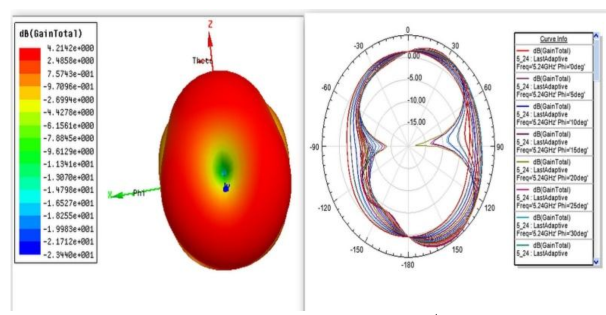

Figure 4: Gain and radiation pattern of 1st iteration.

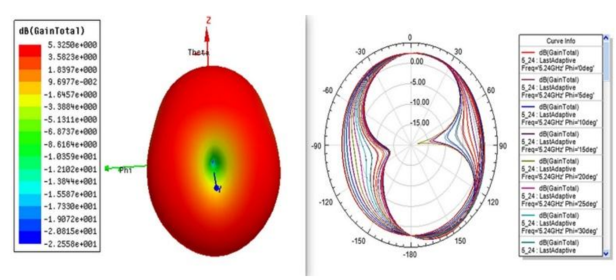

Figure 5: Gain and radiation pattern of 2nd iteration.

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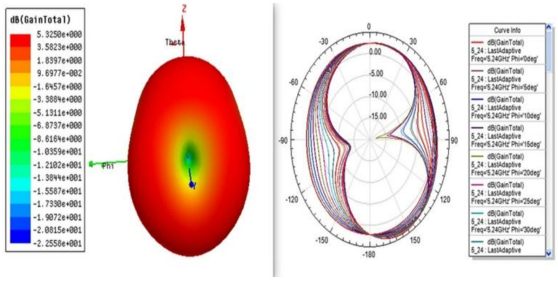

Figure 6: Gain and radiation pattern of 3rd iteration.

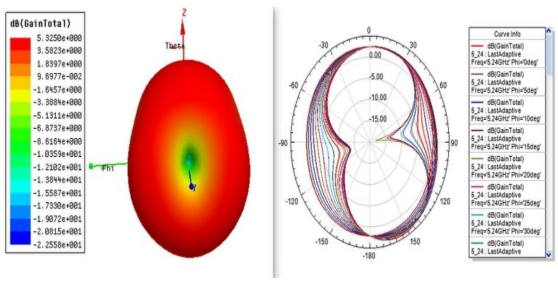

Figure 7: Gain and radiation pattern of 4th iteration.

It is observed that even the second iteration has a better gain than the others; so the second iteration is preferred as it has better operation band. The third iteration design performs from 4.6GHz to 10.8GHz, a total of 6.2GHz of band and 6GHz out of the 7.5GHz band of the UWB range.

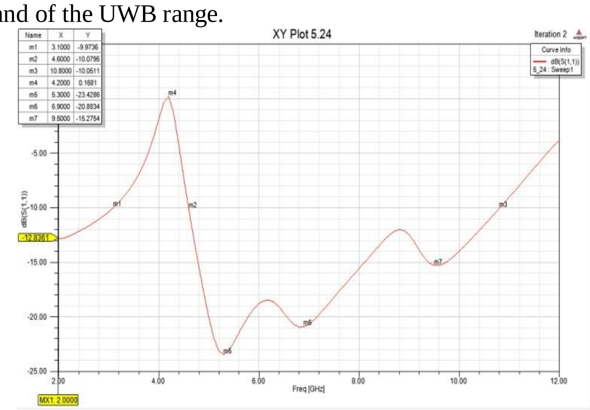

Figure 8: Return loss of 2nd Iteration.

DIMENSIONS OF CIRCLE USED AS SLOTS IN FRACTAL

Iterations	Dimensions of Circle(mm)
1st	8
2nd	6.87
3rd	5.88
4th	4.95

The dimensions for all four iterations are as above and the return loss for the same is shown in figure3. When all the parameters are kept constant like the materials, substrate ground plane etc, and then the change which occurs in the results is the effect of the designs or the iterations which we have executed. In short any modification or change in gain, return loss and efficiency is the result of the fractal.

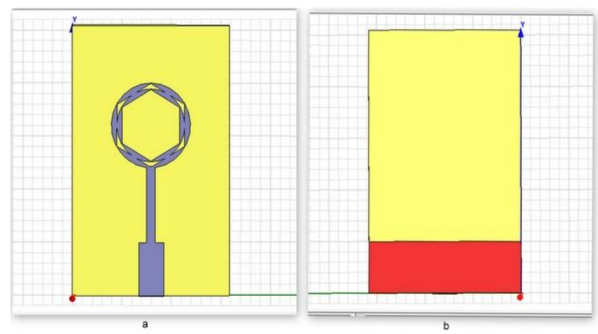

Figure 9: Proposed design (a) Front View (b) Back view

The radiation pattern of the proposed antenna can be observed from figure 5. The above figure (fig 9) shows the design geometry for the fractal antenna which is optimized. The impendence bandwidth of the antenna ranges from 4.6GHz to 10.8GHz; this provides the antenna a bandwidth of 6GHz.

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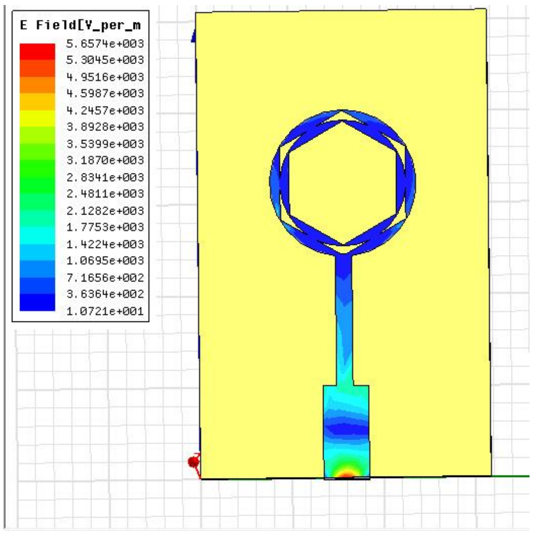

Figure 10 electric field density of the fractal.

V. CONCLUSION

The proposed design is better than the conventional antenna and has a good bandwidth as well. The introduction of fractal has reduced the volume of metallic part when compared to the conventional rectangular or circular slots, thus making the antenna lighter in weight and compact in size. Hence fractal can be used for designing compact antenna with higher efficiency.

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