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Comparison of Radiation Characteristics of Fractal Arrays with Random and Periodic Arrays

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Abstract: ***In recent years, Antenna design has become one of the important consideration in communication technology. Different antenna designs serve different purposes basing on their performance characteristics, physical design constraints and radiation characteristics. This paper discusses the concept of fractal geometry and correlates to antenna theory. This paper aims to investigate how a random array antenna radiation characteristics can be improved by the choice of fractal geometry of Sierpinski gasket over random and periodic array antenna. Matlab code is used to generate antenna geometry and also its radiation pattern along with its array factor curves.***

Keywords: Fractal geometries, Antenna arrays, Radiation pattern, Sierpinski gasket, Side lobe ratio

1. Introduction

Wireless communication has been advancing day by day with ever increasing demand for wireless devices, but works have been still going on to achieve desired radiation characteristics for specific applications. Designing a low profile antenna i.e small in size with wide band or multi-band application and less complexity in design is one of the most important concern. Many attempts have been made to achieve multi-band operation but in most of the cases size reduction may not be possible. This size reduction along with multi-band operation can be achieved using fractal geometries as antenna designs. Antenna arrays provide high gain, diversity, beam steering and also maximize SNR and cancel interference patterns when compared with single antennas. An array of antennas can be of antenna elements placed on a plane in either a periodic or random fashion. These two patterns of arrangement show different radiation properties. Side lobe reduction can be achieved by periodic arrangement of array elements but require more number of array elements. On the other hand, random arrays have higher side lobes, but require less number of array elements and are likely to work in case if one or two elements in array may fail hence they are more reliable. This concept of antenna arrays can be extended to Fractal geometry to fill the gap between random and periodic configurations in antenna arrays. This paper is organized as follows. Basics of fractal Geometry in section II, Linear arrays in section III, periodic arrays in section IV, random arrays in section V, Sierpinski Fractal in section VI, radiation pattern comparisons are shown in section VII, advantages and future scope in section VIII and conclusions section XI followed by references

2. Fractal Basics

Fractal geometries can be defined as geometries, a part of which exhibits same characteristics as that of whole structure. Fractal geometries are subset of Euclidean Geometry. Self-Similarity is a properties exhibited fractal geometries that play a crucial role in fractal based antenna designs. Self-similarity can be defined as at any magnification a part of structure always looks exactly similar to that of original structure. For example consider figure1 which is called Sierpinski carpet

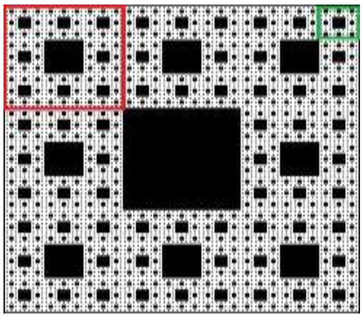


Figure 1: Sierpinski carpet

In above figure both large and small square boxes are exactly similar to that of whole structure even though they are at different magnification hence it is a self-similar structure. We can obtain a relation for fractal dimension if we know the scaling factor. Suppose if there are “N” such copies of original geometry scaled down by a fraction “F”, then the dimension of the fractal is given by D , where

$$D = \frac{\log(N)}{\log(1/F)}$$

Examples of some fractals are Sierpinski gasket, von koch snowflake, Malinowski curve etc which are classified as deterministic. On the other hand there are another classification of fractals which represent naturally occurring objects like tress, mountains etc these fractals called as random fractals

Deterministic Fractals

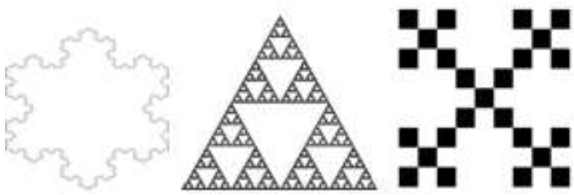


Figure 2A: Deterministic fractals

Random Fractals

Figure 2B: Random fractals

There may be many more fractal geometries in both deterministic and random fractals but this paper limits the discussion to Sierpinski fractal only. Fractal geometries can be generated using computer graphics with recursive algorithm. There are different procedure for both deterministic and random fractals. However this paper mainly focuses on Sierpinski triangle

3. Methods of generating Sierpinski gasket

A. Removing central part

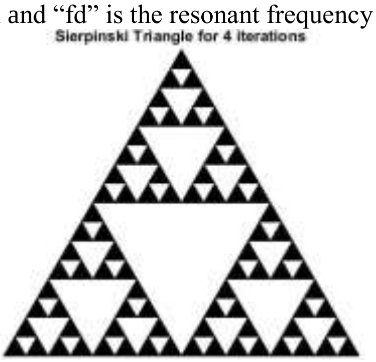
Sierpinski triangle can be formed by removing the central part of base triangle. Initially we take a base triangle and join the mid points. Now the mid points are joined and 4 scaled versions of actual triangle are formed from which central triangle is removed. This completes one iteration and remaining 3 triangles resembles the scaled version of actual triangle. Same procedure is applied to those scaled triangle to as many required number of iterations. Usually equilateral triangle is taken but it is not mandatory. This method is difficult to implement using matlab. This is pictorially shown in figure 2

Figure 2C: Sierpinski gasket

More are the number of iterations lesser are the resonant frequencies but it is significant over first few iterations only later it diminishes after few iterations. Also the amount of scale that is required for each iteration diminishes as no of iterations increase. This equation gives the relation between resonant frequency of linear dipole versus normalized frequency of fractal antenna

$$f = fd\left[1-\exp\left(\frac{n-1}{n}\right)\frac{\ln D}{D}\right]$$

Where "f" is normalized resonant frequency of fractal antenna and "fd" is the resonant frequency of linear dipole



B. Using Iterated function system (IFS)

Fractal geometries can be generated using Iterated function system (IFS). Again Iterated function system is a composite of affine transformations and random point generation. Affine transformations for Sierpinski triangle are simpler and are generally expressed as matrices namely transitional and transformational matrix

Affine transformation:

$$W\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix}\begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} e \\ f \end{pmatrix}$$

Or

W(x,y) = (ax+by+e, cx+dy+f)

where a,b,c,d,e,f are real

Rotation and scaling are controlled by parameters "a,b,c,d" while "e,f" control linear translation.

Now consider "A" be the original geometry and W1,W2,W3,....Wn be a set of linear transformations, then applying these set of transformations to original geometry A results in generation of new geometry by collecting results from $W(A) = \bigcup_{n=1}^{N} Wn(A)$

By repeatedly applying "W" to previous geometries new fractal geometry will be obtained

A1= W(A) , A2 =W(A1) .. Etc

while on the other hand random point generation algorithm generates Sierpinski triangle by specifying the number of points with which the fractal should be generated. This method makes use of matlab script that uses probability to randomly place points within a boundary which are specific to Sierpinski fractal. Matlab random number generator is used to create fractal aids in filling the ordered vs disordered gaps. This paper uses random point generation method to generate Sierpinski gasket

4. Antenna Arrays

Individual antenna elements when arranged in an array shows higher gain than any of the individual array elements. This happens because gain of individual elements add up resulting in higher gain than any of its elements in an array. There are two different ways of arrangement in array, namely linear fashion and planar fashion. In constructing linear and planar arrays the radiation properties of distinct patterns must be

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analyzed in order to optimize the array for certain uses. The linear arrays are considered upon which "N" number of elements are placed in linear fashion along a particular axis while in planar array, all the array elements are arranged in a plane. Theoretically radiation pattern for an array antenna can be found from pattern multiplication theorem which states

Array pattern = (array element pattern) X (Array factor)
Normalized value of array factor is obtained as follows

$$(AF)n = \frac{1}{N}\frac{\sin(N\Psi/2)}{\sin(\Psi/2)}$$

Here, N is the number of elements and Ψ is defined as the array phase function and is a function of the element spacing, phase shift, frequency and elevation angle.

Figure3 and figure4 gives the radiation pattern for linear array antenna with 25 elements and 50 elements respectively

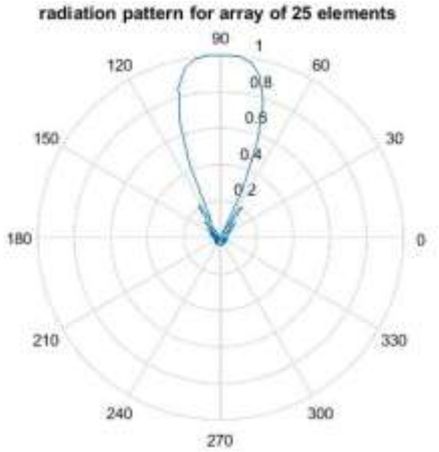

Figure 3: Radiation pattern of linear array with 25 elements

$\frac{d}{\lambda} = 0.33$, for both arrangements

d/λ is the ratio of the distance between each element in wavelengths. The charge is kept equal for all elements to make the calculations simpler. As the elements are placed within 1 wavelength, there is constructive interference such that there is one main lobe and side lobe ratio decreases as more and more elements are placed in an array. But here the width of main lobe is observed to become narrower with increase in number of elements.

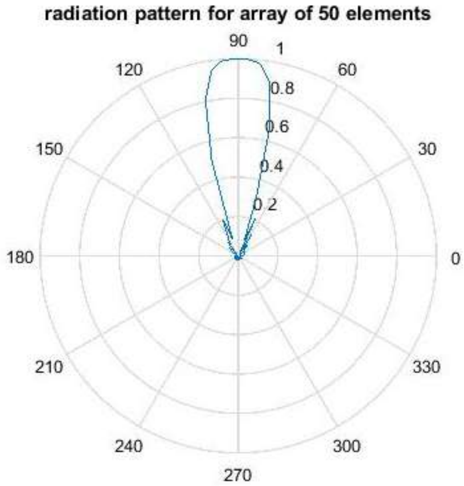

Figure 4: Radiation pattern of linear array with 50 elements

From the figures 3 and 4 we can say that side lobe are comparatively lower and main lobe is narrower in 50 element array compared to that of 25 element array. There is a trade of between gain and beam width in linear array arrangement. An optimized antenna will have no side lobes. The side lobes would easily cause air traffic control to confuse a large airplane at the height of the side lobes with a small plane at the peak of the main beam. Another characteristic of an optimized beam involves a thin single main beam.

5. Periodic Arrays

Planar arrays have all the antenna elements arranged on a plane in a grid. Side lobes are comparatively lesser in ratio to that of main lobe.This paper make use of matlab to generate periodic array consisting of 412 elements represented with "*" symbol in corresponding graphs. We have chosen the limits of axis as -0.5 to 1.0 since we have used matlab random point generator to generate random arrays and fractal arrays which by default takes axis from -0.5 to 1.0. These dimensions are chosen for scaling purposes, as our fractal array uses this size window. Matlab generated planar array of antenna is shown in figure 4A.The radiated field is shown in figure 4B in a gray-scaled color map where blue is the lowest point and Red is the highest point in radiation pattern.

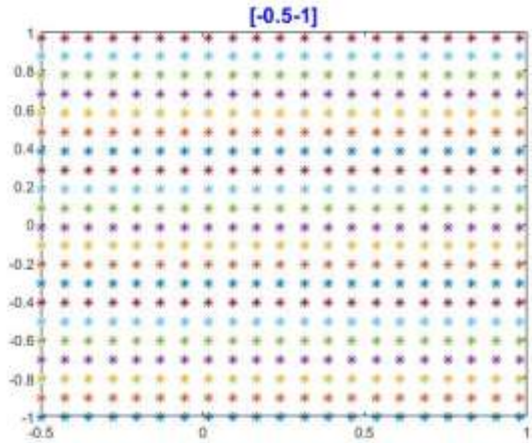

Figure 4A: Planar array with 412 elements having equal distances

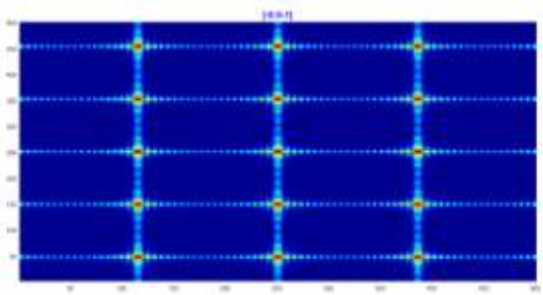

Figure 4B: Top view of radiation pattern for periodic array

6. Random Arrays

The radiation characteristics of random arrays are more desirable. The random arrays have an advantage of exhibiting favorable radiation characteristics with less number of elements. In this type of array even if some

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elements fail the radiation characteristics are least affected. Using matlab random point generator, we plotted 412 random array elements. Figure 5A represents the random array of 412 elements. The radiation pattern of random array with 412 antenna elements is represented in figure 5B. One point to note in radiation pattern of random array is there is a 180-degree symmetry, which is more apparent about the main beam.

This paper bring the comparison between periodic arrays, Random arrays and attempt to show how the fractal arrays attempt to fill the void between the radiation characteristics of random array and periodic array. Fractal show that how the radiation characteristics of Random arrays can be achieved by using fractal geometries. In top view of radiation pattern Red indicate the highest point and blue indicate lowest point.

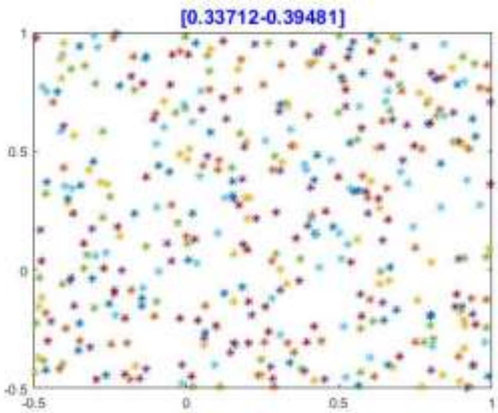

Figure 5A: Random array of 412 elements

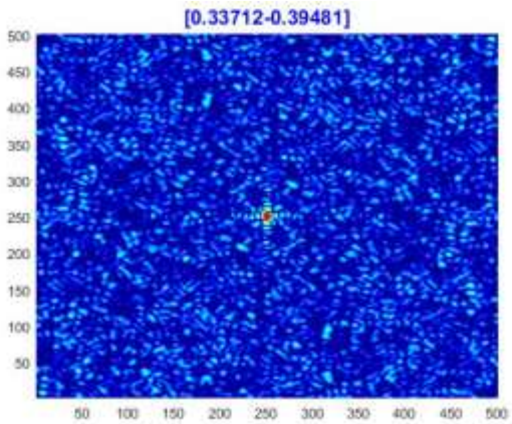

Figure 5B: Radiation pattern of Random array.

7. Sierpinski Frcatal

This paper makes use of Matlab code to generate Sierpinski triangle which essentially consists of 412 elements. The axis is by default taken between -0.5 and 1.0 by random point generator in matlab. Figure 6A shows the fractal geometry of fractal array and figure 6B shows the radiation pattern. The radiation pattern indicate that side lobes are lesser than that of in periodic array but larger than in random array. It can also be observed that if more number of elements are used in a fractal array, the side lobes are further reduced

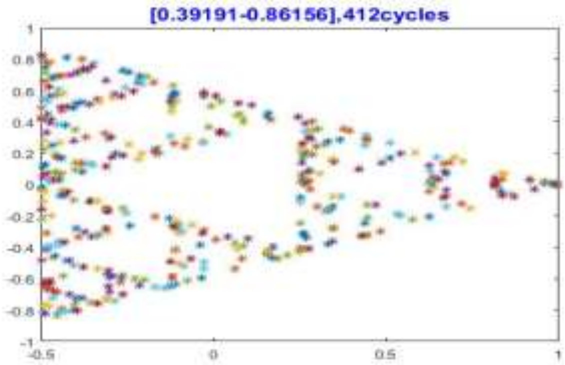

Figure 6A: Random-point-generated Sierpinski gasket.

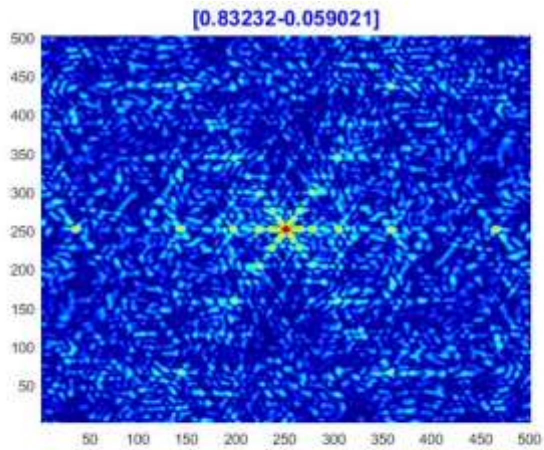

Figure 6B: Radiation from random-point-generated Sierpinski gasket.

8. Comparison of Radiation Pattern

In any antenna array it is always desired to have a low side lobe ratio. In figure 7c which represents the radiation pattern of periodic array the main lobe is in such a way that there is no chance of interference. Where as in figure 7A which represents the radiation pattern of random array has low side lobes unlike as in case of periodic array. Fractal array assumes the main lobe characteristics of periodic array and lower side lobe ratio like random array

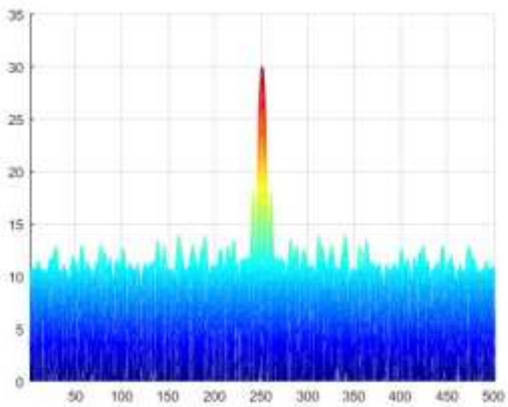

Figure 7A: Side view of radiation pattern of random array.

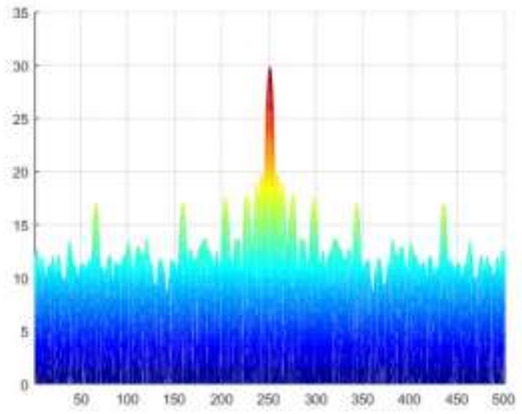

Figure 7B: Side view of radiation pattern of fractal array

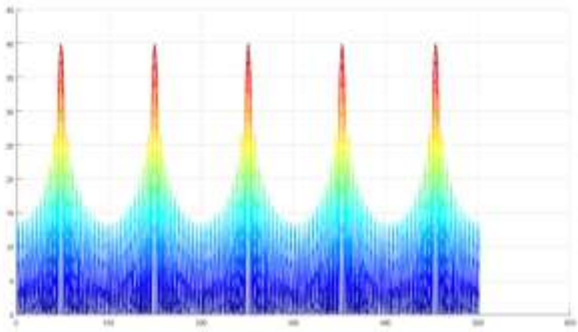

Figure 7C: Side view of radiation pattern of periodic array

As the number of elements elements in an fractal array increases the side lobes are much reduced. Figure 7D represents the radiation pattern of fractal array with 800 array elements. But one point to be noted here is the main lobe degradation which is undesirable occurs with increase in number of elements. Hence we can say that side lobes in radiation pattern of fractal antenna can be decreased at the cost of increase in main lobe degradation

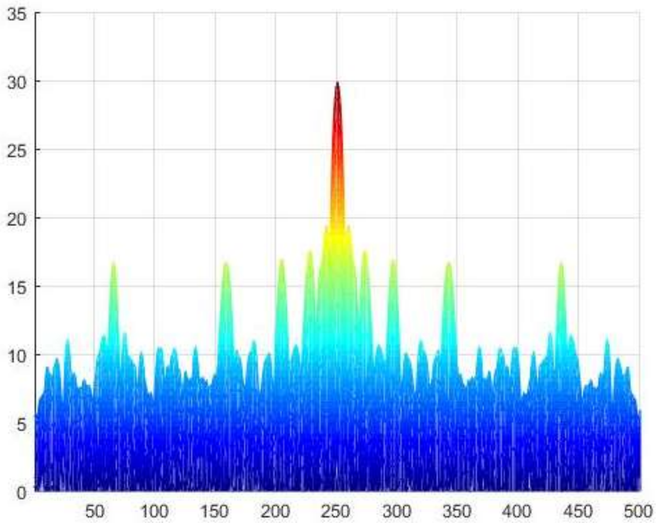

Figure 7D: Radiation pattern of fractal array with 800 elements

9. Future Scope & Advantages

1) Miniaturization of antenna size can be achieved while keeping high radiation efficiency using fractal antenna
2) Better impedance matching is possible using fractal antennas
3) Metamaterial applications like cloaks can be effectively done using fractal geometry
4) Shows consistency in performance over huge frequency range i.e (frequency independent)
5) Reduced mutual coupling in fractal array
6) Sierpinski gasket can be used as monopole and dipole elements whose peripherals are similar to cross section of monopole and dipole antenna

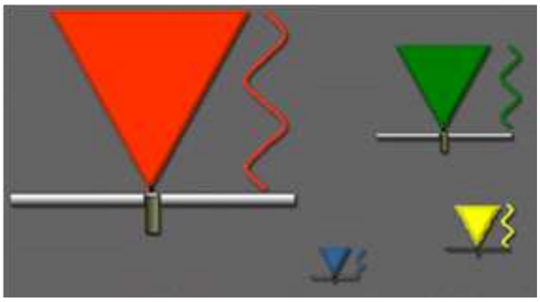

Figure 8A: Monopole antenna with 4 different bands

1. Multi-band operation can be achieved using fractal antennas. Figure 8A represents four Monopole antennas operating at 4 different frequencies but fractal antenna in figure 8B has multi-band operation covering those four frequency bands.

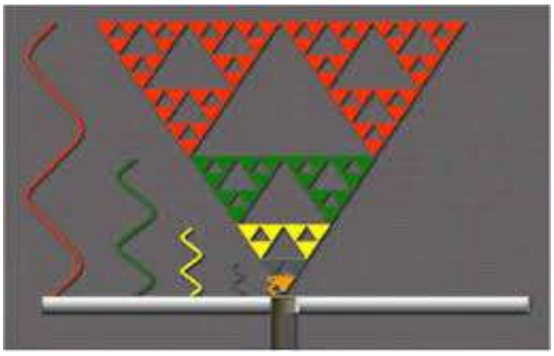

Figure 8B: Fractal monopole antenna

For linear dipole, the first resonance occur at λ/2 which may be higher for certain frequencies. For such frequencies height of antenna required will be higher which can obviously reduced by using Sierpinski triangle

10. Conclusions

This paper observes that random array performed better than the fractal array. There exists somewhere the number of elements in a fractal array and random array cause for the one to be more effective as the other.The more are the number of elements the better is the performance of fractal array. A draw back for random arrays with many elements at that, as the number of elements increases, main beam degradation is quite significant.

References

[1] Mandelbrot, B.B .*The Fractal Geometry of Nature*. W. H. Freeman and Company, New York. 1983.
[2] Weeks. W. L. *Antenna Engineering*. McGraw Hill.

London. 1968.
[3] Jaggard, D.L. *Fractals in Engineering. From Theory to Industrial Applications*. Springer.
[4] Jaggard, D.L., Jaggard A.D., *Cantor Ring Arrays. In Microwave and Optical Technology Letters.* Vol. 19 No. 2 October 5 1998.
[5] Jaggard, D.L., Jaggard A.D., Frangos V. P., *Fractal Electrodynamics Surfaces and Super lattices*. Jan. 1999.
[6] Jaggard, D.L., Jaggard A.D., *Cantor Ring Diffractals. In Optics Communications*. Elsevier. October 1998.
[7] Ulaby, Fawwaz. *Fundamentals of Applied Electromagnetics*. Prentice Hall, New Jersey.1999.
[8] Lee, S.W. Antenna Handbook, Theory, Applications, & Design. Reinhold Company. New York. 1998.
[9] Stutzman, W.L. Antenna Theory & Design. Wert company. Pennsylvania. 1995.
[10] Fractal antennas : design , characteristics and applications by Nemanja Poprsen, Mico Gacanovic
[11] Fractal concepts for antenna design and analysis by K.J Vinoy

Author Profile

R.Vikas, is a graduate (B.Tech) in Electroncs and Communication Engineering(ECE) from Gitam University. The motivation behind writing this paper is my immense interest in field of antennas and their applications in world of telecommunication.