Comparison of The Radiation Pattern of The Fractal and Uniform Linear Array Antennas

Chiranjevulu Divvala[1], Simma Raju[2], Yerra Anuradha[3]

[1] *Project Guide,* [2]*Student,* [3]*Student*

Abstract - Basically an antenna is a metallic device for radiating or receiving radio waves. The antenna has the important characteristics like directive gain and beamwidth which are the properties required in modern wireless communication. There are so many techniques which improve gain and bandwidth of antenna .A fractal is recursively generated object having a fractal dimension .Fractal antenna have the important properties like develop rapid beam forming algorithms. There are many fractal applications worked by fractals methods :Cantor linear array, Sierpinski gaskets and Carpets Fractal trees, Hilbert ,Koch and Murkowski curves etc. These arrays have Fractal dimensions that are found from generating sub array used to recursively create fractal array. Fractal antenna theory uses a modern(fractal) geometric that is natural extension of Euclidian geometry .Here a comparison is made between fractal array and uniform linear array and it is proved that fractal arrays give better performance than uniform linear array.

Keywords - Fractal Antenna, Radiation Pattern, Sierpinski, beamwidth.

I. INTRODUCTION

In various applications it is necessary to be design antennas with very directive characteristics (very high gains) to meet the demands of long distance communication; this can be accomplished by antenna array [1]. The increasing range of wireless telecommunication services and related applications is driving the attention to the design of multifrequency (multiservice) and small antennas. The telecom operators and equipment manufacturers can produce variety of communication systems, like cellular communications, global positioning, satellite communications ,and others ,each one of this systems operates at several frequency bands. To give service to the users, each system needs to have an antenna that has to work in the frequency band employed for. the specific system. The tendency during last years had been to use one antenna for each system ,but this solution is inefficient in terms of space usage, and it is very expensive. The variety of communication system suggests that there is a need for multiband antennas the use of fractal geometry is a new solution to the design of multiband antennas and arrays . Fractal geometries have found an intricate place in science as a representation of some of the unique geometrical features occurring in nature. Fractal was first defined by Benoit Mandelbrot [2] in 1975 as a way of classifying structure whose dimensions were not whole numbers .These geometries have been used previously to characterized unique occurances in nature that were difficult to define with Euclidean geometries, including the length of coastlines ,the density of clouds ,and branching of trees[3]. fractals can be divided into many types, as shown in fig. 1.

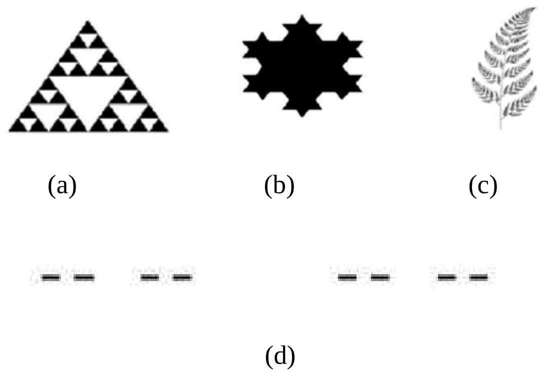


Figure 1: Three fractal examples. (a)sierpinski gasket . (b) Koch snow flake. (C) tree(d) cantor set

II. CONVENTIONAL LINEAR ARRAY ANTENNA

An array usually comprised of identical elements position in a regular geometrical arrangement. A linear array of isotropic elements N, uniformly spaced a distance d apart along the z-axis ,is shown in Fig. 2[4].the array factor corresponding to this linear array may be expressed in the form[1,5].

$$AF(\psi) = \begin{cases} a_0 + 2\sum_{n=1}^{N} a_n \cos(n\psi) & \text{for } (2N+1) \text{ elements} \\ 2\sum_{n=1}^{N} a_n \cos\left(\left(\frac{2n-1}{2}\right)\psi\right) & \text{for } (2N) \text{ elements} \end{cases} \quad (1)$$

$$\psi = kd\cos\theta + \alpha \quad (2)$$

$$k = \frac{2\pi}{\lambda} \quad (3)$$

Where,

AF(Ψ)=The array factor

D=spacing between adjacent elements in the array α= progressive phase shift between elements

k=2π/λ=The wave number

θ=elevation angle1

III. FRACTAL LINEAR ARRAYANTENNA

Fast recursive algorithms for calculating the radiation patterns of fractal arrays have been recently developed in[6-8]. These algorithms are based on the fact that fractal arrays can be formed recursively through the repetitive application of generating array .A generating array is a small array at level one(p=1) used to recursively construct larger arrays at higher levels (i.e., p >1). In various cases, the generating sub array has elements that are turned off in a certain pattern .a set formula for copying ,scaling, and translating of the generating array is then followed in order to produce a family of higher order arrays.

The array factor for a fractal antenna array may be expressed In the general form[6-8]

$$AF_P = \prod_{p=1}^{P} GA\left(\delta^{p-1}\psi\right) \quad (4)$$

Where GA (Ψ) represents the array factor associated with the generating array. The parameter δ is a scaling or expansion factor that governs how large the array grows with each successive application of the generating array and p is a level of iteration.

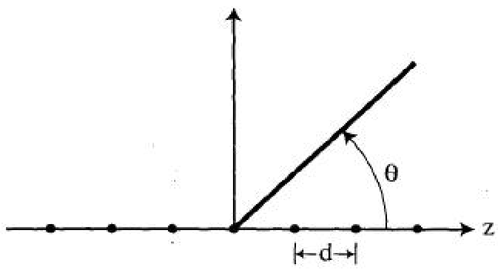


Figure 2. linear array geometry of uniformly spaced isotropic sources

One of the simplest scheme for constructing a fractal linear array follows the recipe for the cantorset[9].Cantor arrays own also multiband properties ,so it has multi frequencies(F_n):

$$F_n = \frac{F_0}{\delta^n} \quad n=0,1,2\ldots\ldots(p-1)(5) \quad (5)$$

where F_0 is the design frequency.

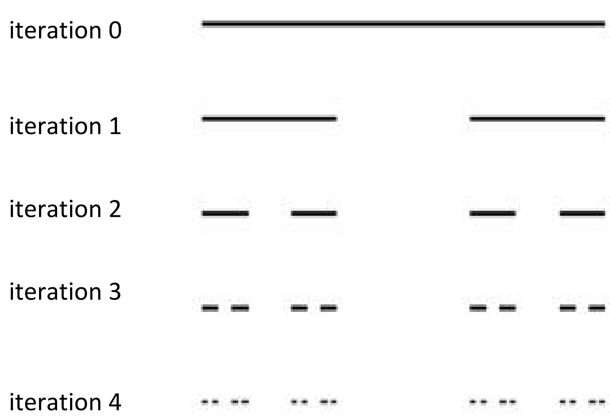


Figure 3. The first four iterations in the constructions in the cantor set array.

The basic cantor array , as shown in fig.3 may be created by starting with a three element generating sub array , and then applying it repeatedly over p scales of growth. The generating sub array in this case has three uniformly spaced elements, with the center element turned off or removed ,i.e., 101. The cantor array is generated recuSrsively by replacing 1 by 101 and 0 by 000at each level of the construction. Table 1 provides the array pattern for the first four levels of the cantor array.

The array factor of the three element generating sub array with the representation 101 is

$$GA(\Psi)=2\cos\Psi \quad (6)$$

Which may be derived from Eq.(1) by setting N=1,a_0=0.substtuning Eq.(6) into Eq.(4) and choosing an expansion factor of three (δ=3),the results in an expression for the cantor array factor given by

Table 1. First four levels of the fractal cantor linear array

P	Elements array pattern	Active elements	Total elements
1	101	2	3
2	101000101	4	9
3	1.01E+26	8	27
4	1.01E+26 1 1E+24	16	81

For each iteration n=0,1,2,3,………N-1.

Another parameter of interest for comparing the fractal and conventional linear array is the directivity D(Θ) that is obtained .

$$D(\theta) = 2\frac{f^2(\pi/2u)}{\int_{-1}^{1} f^2(\pi/2u)du} \tag{7}$$

Where we defined Ψ=π/2u and u=cos(θ) and where,

$$f^2(\pi/2u) = \prod_{n=1}^{N} \cos\left(\frac{3^{n-1}}{2}\pi u\right) \tag{8}$$

Substituting (9) into(8) we finally obtain the directivity for a linear cantor array fractal array as afunction of the angle Θ

$$D(\theta) = 2^N \prod_{n=1}^{N} \cos^2\left(\frac{3^{n-1}}{2}\pi u\right) \tag{9}$$

Evidently the maximum directivity D_{max} occurs when u = cos(π/2)=0 hence we have D_{max}=D(0)

$$D(0) = 2^N$$

Or $D_{Db}(0)$ = 3.01N Db where N=1,2,3,…….. Finally it is worth nothing that the nulls of the fractal array can easily be calculated from the fact that or D_{dB} (0) = 3.01N in dB where N = 1, 2, 3, ….

$$\cos\left(\frac{3^{n-1}}{2}\pi u\right) = 0$$

With solution given by

$$u_j^{(N)} = \pm(2j-1)(1/3)^{N-1}$$

Thus the angles at which the nulls appear are now determined from

$$\theta_j^{(N)} = \cos^{-1}\left(\pm(2j-1)(1/3)^{N-1}\right)$$

Where the dimension j=1,2,3,….1/2($1+3^{N-1}$) since there are 1+3N-1 nulls for the array. It is also important to check that such an array is indeed a fractal array. This can be determined by considering.

$$d = \frac{\log(\frac{\delta+1}{2})}{\log(\delta)} = \frac{\log(2)}{\log(3)} \tag{10}$$

Hence the dimension is indeed that of a fractal since d=0.6309. Suppose that we consider a linear array design such that the operating frequency is f0=8.1 GHz. Then for this frequency the corresponding wavelength is λ=0.037m.Furthermore let the inter –element spacing be d=λ0/4 and the phase shift between the elements be set to zero (α=0) for simplicity. We will compare a 16 – element conventional array with its corresponding fractal version. For the later this means performing N=4 iterations of the fundamental . D which for the array considered here must lie in the interval 0≤d≤1.

IV. COMPUTR SIMULATION RESULTS

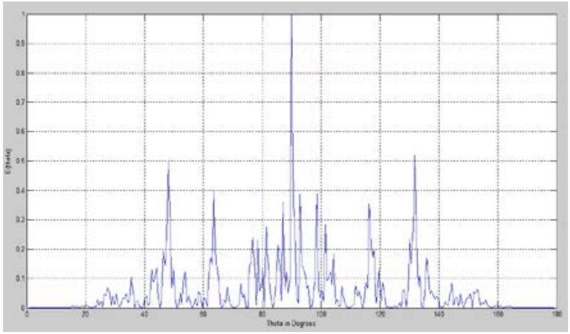
In this work, Matlab programming language version 7.6(R2008a) used to simulate and design the conventional and fractal linear array antenna and their radiation pattern. Let , a linear array will be design and simulate at a frequency F0 equal to 8100MHz,(then the wavelength λ0=0.037m), with quarter-wavelength(d=λ0/4)spacing between array elements and 16 active elements in the array and progressive phase shift between elements (α) equal to zero. The level four of cantor linear array (101) have the number of active elements of 16 and the total elements number of 81.this array will operate at four frequencies depending on the Eq.(5). These frequencies are 72900MHz, 24300MHz, 8100MHz, 2700MHz, 900MHz, and 300MHz. depending on the frequencies of the fractal cantor linear array will be design and simulate of conventional linear array antenna then compare the radiation field pattern properties for them. The array factor for fractal and linear array antenna is plotted with uniformly amplitude distribution which they are feeding to active elements. The field patterns are illustrating shown in Fig.4 and Fig.5. While , the values of the side lobe level half power beamwidth, and directivity are illustrating in Table 2 and Table 3.

TABLE 2:SLL, D AND HPBW FOR FRACTAL LINEAR ARRAY ANTENNA

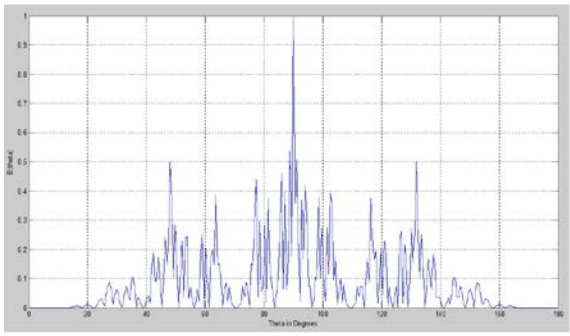
F(MHz)	D(dB)	HPBW(Degree)	SLLmax(DB)
8100	12.0436	2.0233	-5.451
2700	9.1969	6.0721	-5.446
900	6.204	18.2852	-5.446
300	3.1848	56.9372	-∞

TABLE 3: SLL, D AND HPBW FOR CONVENTIONAL LINEAR ARRAY ANTENNA

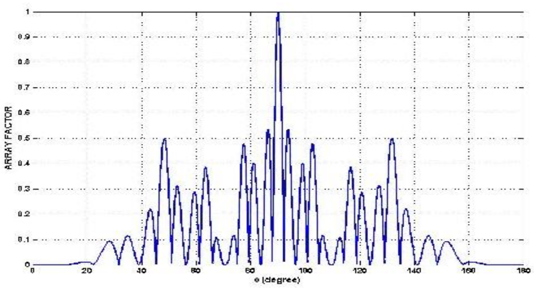
F(MHz)	D(dB)	HPBW(Degree)	SLL max (dB)
8100	9.1202	12.7372	-13.148
2700	4.6369	38.8742	-13.593
900	0.893	----	-∞
300	0.106	----	-∞



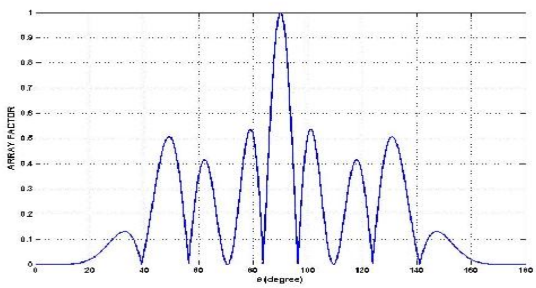
F5= 72.9GHz



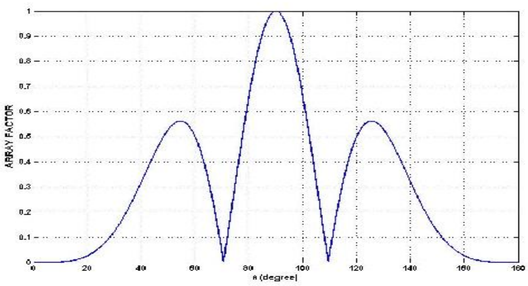
F4= 24.3GHz



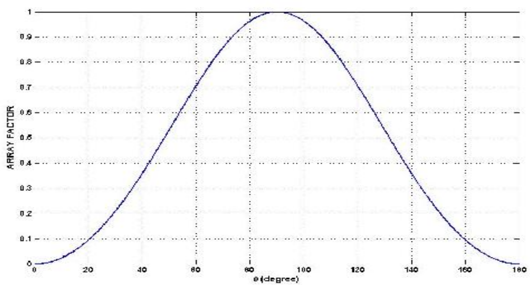
F0=8100MHZ



F1= 2700MHZ

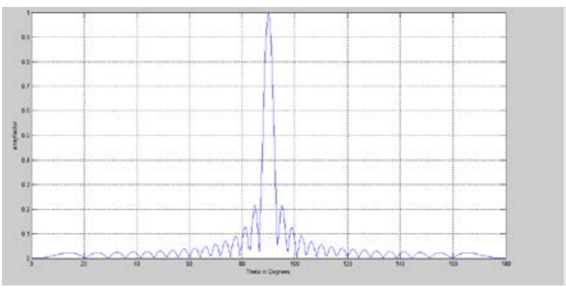


F2=900MHZ

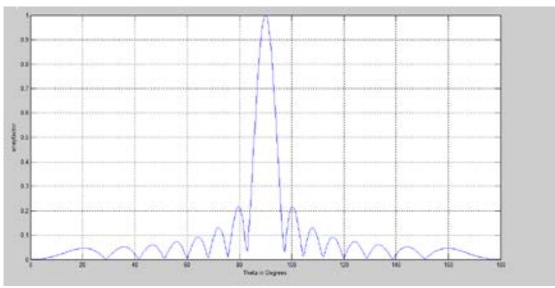


F3=300MHZ

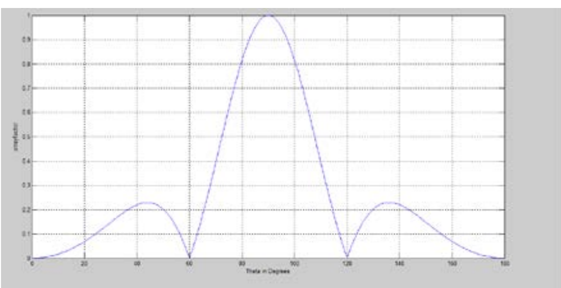
Figure 4. Array factor of a fractal cantor linear array antenna.

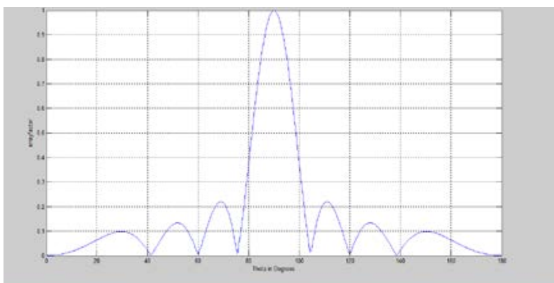


F5=72.9GHz

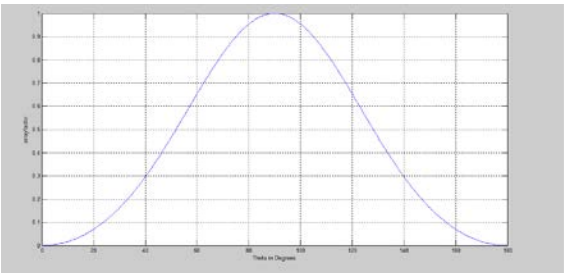


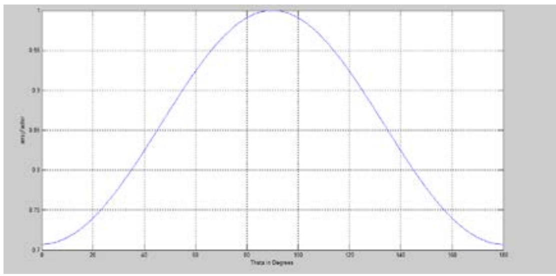
F4=4.3GHz





F0=8100MHz F1=2700MHz





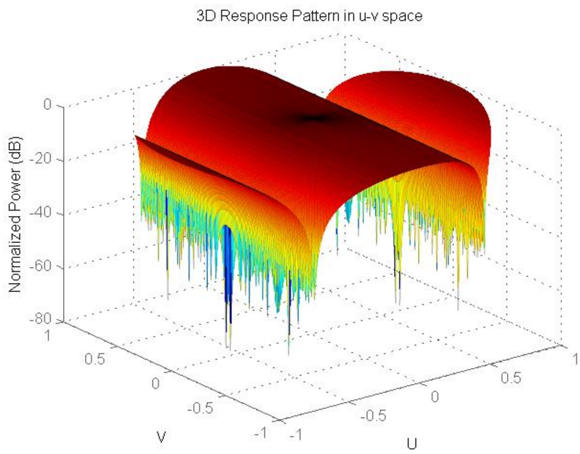
F2=900MHz F3=300MHz

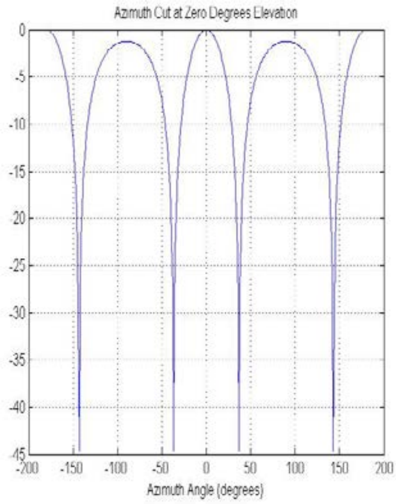
Figure 5. Array factor of a conventional non-fractal linear array antenna

5.UNIFORM LINEAR ARRAY :

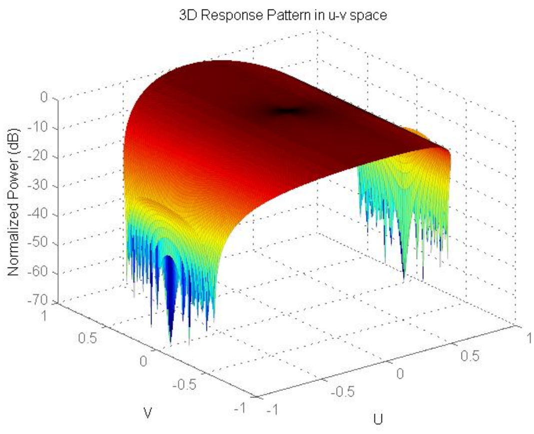
The uniform linear array (ULA) arranges identical sensor elements along a line in space with uniform spacing. You can design a ULA with phased.ULA. when you use the object. You must specify these aspects of the array

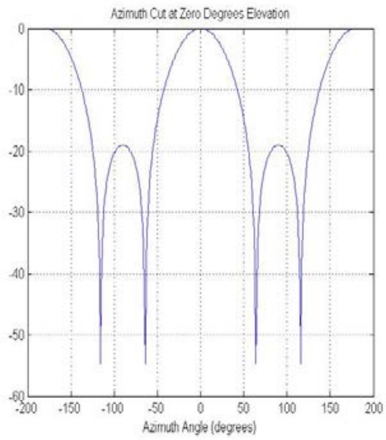
- Sensor elements of the array
- Spacing between array elements
- Number of elements on the array



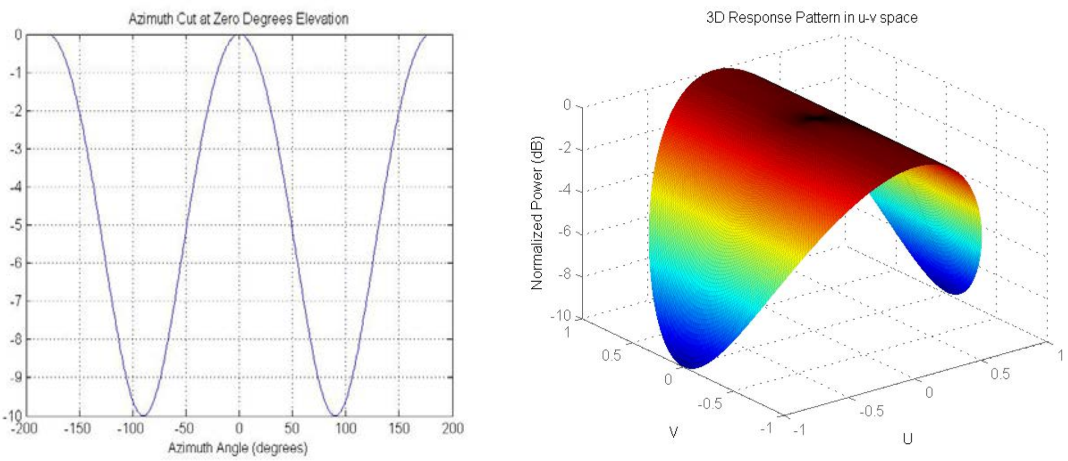


At frequency 300 MHZ

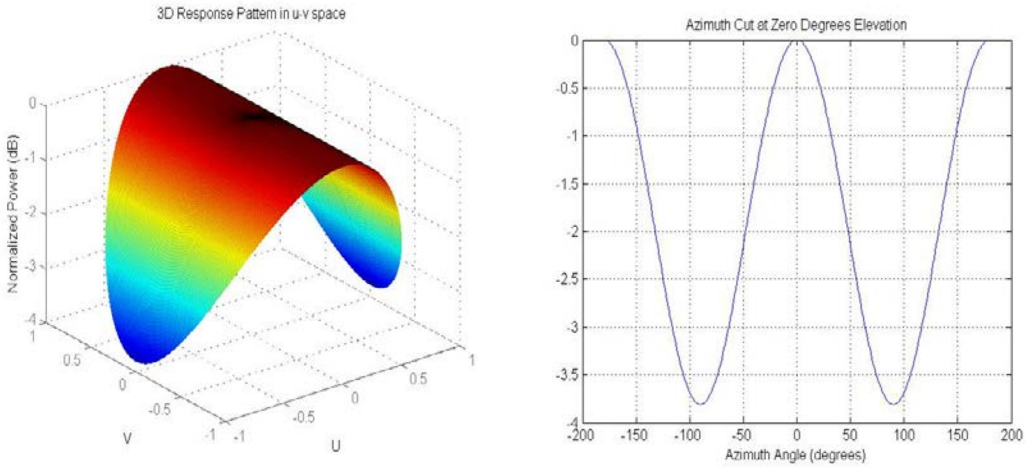




At frequency 900 MHZ



At frequency 2700 MHZ



At frequency 8100 MHZ

Figure 6.A uniform linear array with elements space λ/4. Obtain the arrays magnitude response for azimuth angles -180:180 and plot the normalized magnitude response in DB's and also visualize the array response using 3D-plot.

6 CONCLUSIONS

at design frequency F0=8100MHz,the field pattern for conventional linear array antenna has the side lobes and narrow beamwidth ,in other word ,the system work as a normal array antenna .But a frequencies very low from the design frequency such as 300 MHz, the array antenna operates as a point source. While fractal linear array antenna at all frequencies not operates as a point source so we conclude that the fractal cantor linear array have capable to operating in multiband while, the conventional linear array have not capable to operate in multiband. Also the field pattern of the fractal linear array antenna have high side lobe level, lower half power beam width and directivity ,while, the conventional linear array antenna have lower side lobe level ,high half power beam width and lower directivity.

7. FUTURE SCOPE

Since the area of fractal antenna engineering research is still in its infancy, there are many possibilities for future work on this topic. However, many possible fractal structures exist which may undoubtedly have desirable radiation properties .Thus, a possible approach for future work is to investigate other types of fractals for antenna applications. A novel development is the use of fractal patterns for antenna arrays. Fractal antennas At frequency 8100 MHZ can be studied in several areas. One area of development is to implement fractal antennas into current technologies in practical situations such as expanding wireless market. For this application an analysis of the polarization of these antennas will need to be looked. Another benefit that can be explored is lower covered area of resonant loop antennas. This may lead to antenna with lower cross sections. Also, fractals can be used into micro strip antennas.

REFERENCES

[1] Balanis ,c.a.," antenna Theory: Analysis and Design", 2 nd . edition , wiley,1997

[2] Mandelbrot, B. B., " The fractal geometry of nature", W. H. Freeman amd company, newyork,1983

[3] Gianvittorio, J.," Fractal antennas: design, characterization and application," Master's thesis, university of California , los

[4] Werner D. H., R. L. Haupt, and P. L. Werner," Fractal antenna engineering:" the theory and design of fractal Antenna arrays". IEEE antennas and propagation magazine, vol. 41,no.5,37-59,october1999.

[5] Stutzman, W. L. and G. A H. Thiele," Antenna theory and design", 2nd edition ,john wiley & sons, newyork,1998.