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INVESTIGATIONS ON THE RADIATION CHARACTERISTICS OF CANTOR FRACTAL ARRAY

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ABSTRACT: Fractal geometry proved to have wide applications in electromagnetics with their frequency independent and multiband characteristics. Of the several typical geometries Cantor set has close analogy with a simple linear array. Hence for this paper antenna array whose geometry obeys the Cantor fractal representation is considered. Investigation based on E field radiation patterns are performed and compared with that of conventional uniform linear array (ULA). A relation between the fractal size and its radiation characteristics like its maximum side lobe level, beam width are inferred from the radiation curves. The similarity between the conventional and the fractal arrays are discussed..

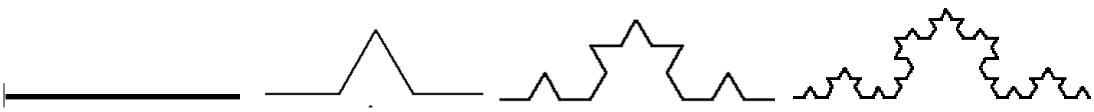
Keywords: Fractal Array, Cantor Set, Radiation Characteristics, Uniform Linear Array.

I.INTRODUCTION

A. Fractal Geometry

A man is confronted by many undescribed shapes in the universe [1]. The shapes of the sea coasts and leaves which are not circles, clouds which are not spherical, hills are not conical, and path of a lightening which is not straight line are some of them to name[2]. This is due to the constraint of the Euclidean geometry in representing the shapes in dimensions only in whole numbers. Fractal geometry is the solution for this. Since the fractal geometry took the role of explaining undescribed shapes, it captured the attention of many engineers from many disciplines. This is made possible with key feature of fractal geometry in describing the dimensions in fractals along with whole number like 1D,2D and 3D. Fractal can be defined as an irregular geometric representation with an infinite nesting of structure at different scales. This made it possible to describe any object in the universe with a unique dimension. The well known fractal geometries with extensive applications in antennas are Sierpinski, Koch, Contor, Hilbert Curves etc [3]. The Structure of various Koch, Sierpinski and Cantor are as shown in the fig. 1(a) through 1(c).

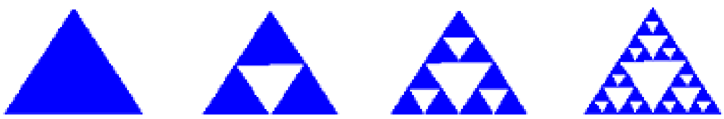
KOCH:



Initiator Length =1 | Generator Length = 4/9 | Iteration 2 Length = 16/27 | Iteration 3 Length = 64/27

Fig.1(a)

Sierpinski :



Initiator | Iteration 1 | Iteration 2 | Iteration 3

Fig.1(b)

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CONTOR DUST:

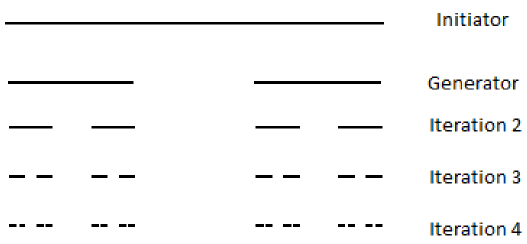

Fig.1(c)

Fig.1. Representation of the geometries of (a) Koch (b) Sierpinski (c) Cantor

B. *Fractal Array*

Improved Directivity, capability of Beam Steering, Beam Forming, Control over the Beam Width, Arrangement of Nulls in the desired direction are some characteristics that are possible with Arrays with which they have proved to be the ultimate choice over single element antennas. In the due course they occupied a paramount role in Electromagnetics, Wireless Communications etc. Since their first application it observed many variations, whether it may be the case with its geometry, type of excitation or choice of elements of the array. With the same trend when the galaxy of electromagnetic engineers are fascinated by the concept of applying fractals for their regular applications in communications, the arrays have also started adopting them for some specific reasons.

II. FORMULATION

The geometry of the array that is considered is as shown in the fig.2. The elements are arranged on a straight line to depict a linear array.

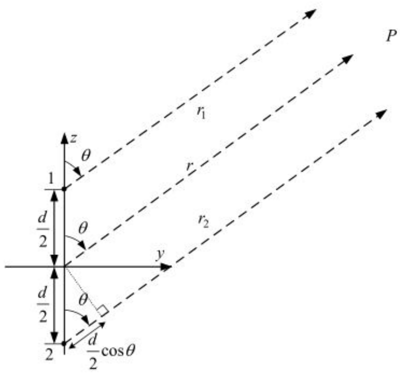

fig.2. Geometry of linear Array

The corresponding array factor for the above mentioned array in which uniform spacing and non uniform amplitude distribution is considered is given as [4]

for array of even number of elements

$$(\mathrm{AF})_{2N} = \sum_{n=1}^{N} a_n \cos[\frac{(2\mathrm{n}-1)}{2}\mathrm{kd}\cos\theta] \qquad -(1)$$

for array of odd number of elements

$$(\mathrm{AF})_{2N+1} = \sum_{n=1}^{N+1} a_n \cos[(\mathrm{n}-1)\mathrm{kd}\cos\theta] \qquad -(2)$$

or

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$$a_0 + \sum_{n=1}^{N} a_n \cos[(n-1)\,kd\cos\theta] \quad -(3)$$

where N= Number of elements

$$k = \frac{2\pi}{\lambda},$$

θ = Scan angle,

d= Spacing between the elements

For simplicity we consider the amplitude distribution to be uniform and unity to conveniently transform to cantor array. Now we can compare the generator form of the cantor as shown in the fig. 1(c) with a linear array of 3 elements with the excitation to the extreme end elements as 1's and centre element as 0. Now this is considered as generator element array. The next generation cantor is obtained by replacing 1's in the previous array with '101' and 0's with '000'. The same is repeated over generations. This is tabulated in the table(1).

TABLE I : Excitation Coefficients for various Iterations for a scalling factor of 3

Iteration	**Excitation Coefficients**	**Number of Elements**
Generator	101	3
2	101 000 101	9
3	101 000 101 000 000 000 101 000 101	27

The distribution can be formulated as [5,6,8]

c(z) = f(z) * f(3*z) * f(3^2 *z)......f(3^(n-2)*z). -(4)

where c(z) is cantor set and the f(z) is function generator analogous to equation (3). With the aid of the above discussion we can arrive at the following equations

for generator set the array factor can be represented as $c(1,\theta) = 2\cos(kd\cos\theta)$ -(5)

whereas for iteration 2 it is given as $c(2,\theta) = 2\cos(9 * kd\cos\theta)$ -(6)

likewise after n-iterations $c(n,\theta) = 2\cos(3^{(n-1)} * kd\cos\theta)$ -(7)

Similarly the multiband characteristics for frequencies other than the fundamental resonating frequency [5,7] is given after n iterations as

$$f_n = 3^{-n} f_0 \quad -(8)$$

III.SIMULATION RESULTS

The radiation characteristics with u= cosθ domain are simulated in MATLAB environment on i3 processor. The radiation characteristics of conventional array for number of elements n=3, n=9, n=27 and n=81 for a spacing d of λ/4 for an operating frequency of 8.1 GHz are as shown in the Fig.3(a) through 3(d). Scan angles theta in degrees is plotted on x axis and the corresponding normalised E field values based on the array factor are plotted on the y-axis.

For the same spacing and operating frequency a cantor array weights are generated over iterations of i=1, i=2, i=3 and i=4. The corresponding radiation pattern is plotted as shown in the Fig.4(a) through 4(b).

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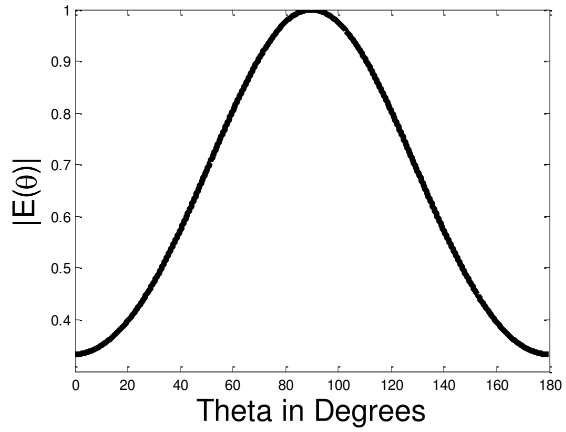

Fig.3(a)

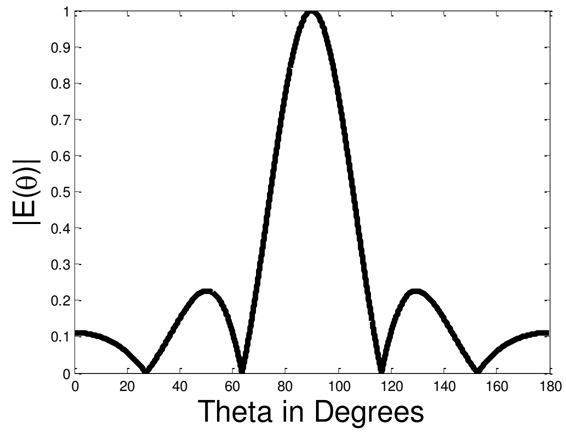

Fig.3(b)

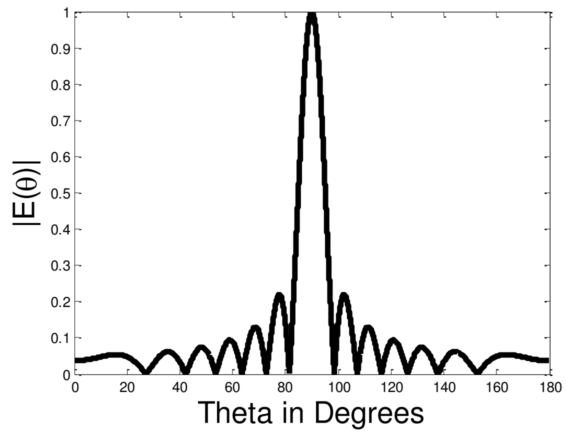

fig.3(c)

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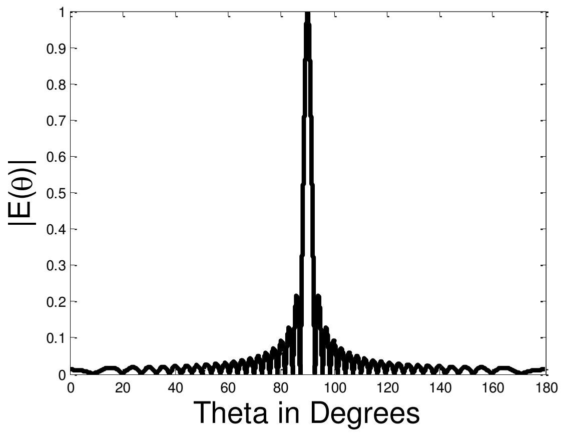

fig.3(d)

Fig.3. Radiation Pattern of Conventional linear array of number of elements (a) n=3 (b) n=9 (c) n=27 (d) n=81

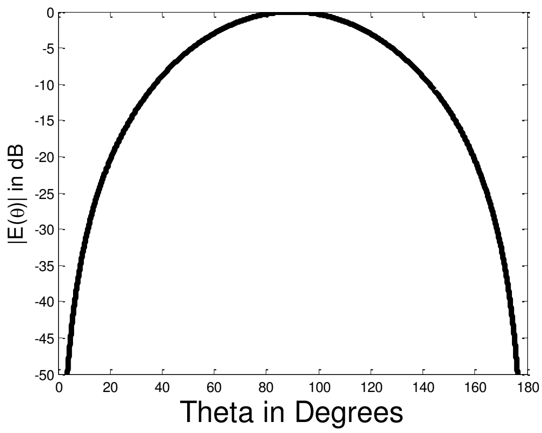

Fig.4(a)

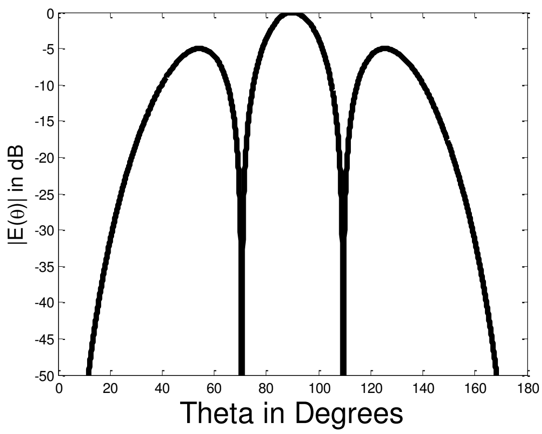

Fig.4(b)

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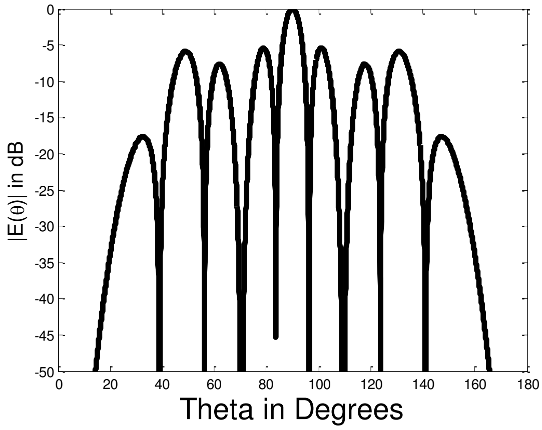

Fig.4(c)

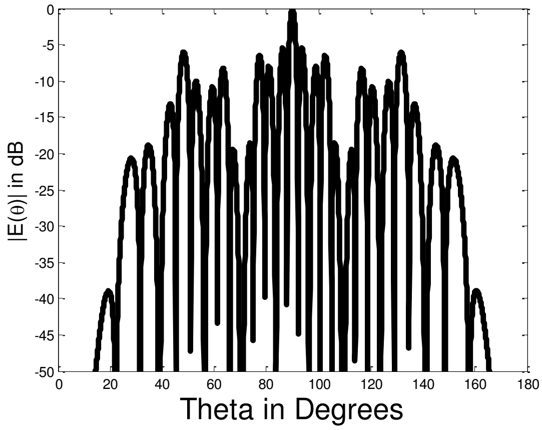

Fig.4(d)

Fig. 4. Radiation Pattern of Cantor linear array with scaling factor of 3 and generator set of '101' with iterations,i as (a) i=1 (b)i=2 (c) i=3 (d) i=4

IV.CONCLUSION

The radiation characteristics of the Cantor Fractal Array are plotted. They can be compared with conventional linear array to observe that there is considerable decrease in the side lobe level as well as thinning of the beam. It is observed that over iterations, two consecutive bands have common nulls. This is clear from the equation (4) through (8). The directivity characteristics over various resonating frequencies is disappointing. The directivity of the generating sub-array and that of the second iteration are same.

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REFERENCES

[1] Jampala, S., "Fractals: classification, generation and applications," Circuits and Systems, 1992., Proceedings of the 35th Midwest Symposium on , vol., no., pp.1024,1027 vol.2, 9-12 Aug 1992. doi: 10.1109/MWSCAS.1992.271120
[2] B. B. Mandelbrot, The Fractal Geometry of Nature, 1983 :W. H. Freeman
[3] Anguera, J., Puente, C., Borja, C. and Soler, J. 2005. Fractal Shaped Antennas: A Review. Encyclopedia of RF and Microwave Engineering.
[4] Constantine A. Balanis, Antenna Theory, 2ed, Wiley.

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[5] Carles Puente-Baliarda, Rafael Pous., "Fractal Design of Multiband and Low Side-Lobe Arrays,"IEEE Transactions on Antennas and Propagation, Vol.44, No.5, May 1996.

[6] A.Alexopoulos., "comparison of conventional and fractal shaped phased array," DSTO-TN-0913, Oct' 2009.

[7] Mushiake, Y.; "Self-complementary antennas," *Antennas and Propagation Magazine, IEEE* , vol.34, no.6, pp.23-29, Dec. 1992 doi: 10.1109/74.180638.

[8] R.T.Hussain, and F.J.Jibrael, "Comparison of the radiation pattern of fractal and conventional Linear Array", PIERS, Vol 4, 183-190, 2008.