DESIGN AND ANALYSIS OF A DUAL BANDD KOCH CURVE DIPOLE FRACTAL ANTENNA

تصميم وتحليل هوائي كسوري ثنائي قطب لمنحني كوخ ثنائي الحزمة

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Abstract :
In this study ,the analysis and design of small size dual band Koch curve dipole antenna is presented .The proposed antenna design ,analysis and characterization were done using NEC4 which is moment –method (MoM) based software. The radiation characteristics ,voltage standing wave ratio(VSWR)and input impedance are also calculated. The new design antenna has operating frequencies 470,940 and 2670 MHz and so it can be used in communication system.

الخلاصة:
تعرض هذه الدراسة تحليل وتصميم هوائي منحني كوخ ثنائي قطب صغير الحجم ثنائي الحزمة.
تصميم ،تحليل ،وتوصيف الهوائي المقترح انجز بأستخدام برنامج NEC4 والذي يعتمد طريقة العزوم **(MoM)** كأساس.
أيضا تم حساب الخواص الاشعاعية ،نسبة الموجة الواقفة **(VSWR)** وممانعة الدخل.التصميم الجديد للهوائي له ترددات عمل 470 ،940 ، 2670 **MHz** لذا يمكن استخدامه في انظمة الاتصالات.

1.INTRODUCTION

In the last few years, the dramatic development of telecommunication technology brought the need for devices that entail their parts to be ever smaller and lighter and also capable of operating optimally at many different frequencies simultaneously. Fractal antenna is the power tool to meet the telecommunication operator requirements [1] . In many cases the use of fractal antennas can simplify circuit design ,reduce construction costs and improve reliability, furthermore they are self loading ,so no antenna parts such as coils and capacitors are needed to make them resonant. The first application of fractals to antenna design was thinned fractal linear and planner array [2-6] , i.e. arranging the elements in a fractal pattern to reduce the number of elements in the array and obtain wideband array for multiband performance, consequently fractal shape antenna are becoming a useful way to design advanced antennas such as multiband antennas with approximately the same input characteristics for different frequency bands [7-8] ,and also as small size antennas [9-12] . Other fractals have also been explored to obtain small size and multiband antennas such as Hilbert curve fractal [13] ,the minkowski island fractal [8] ,and the Koch fractal [14] .
This study presents the design and simulation of wire dipole antenna based on Koch curve geometry by using a numerical simulation.

2. FRACTAL ANTENNA DESIGN AND SIMULATION

Antenna design and simulation are performed using (NEC4) software application .This program is based upon the method of moments (MoM) in which the electromagnetic interaction between wire segments can be analyzed and this simulation technique incorporates periodic boundary conditions. This allows for only one element of the periodic array to be simulated. For fractal shapes ,this method saves time and allows wide frequency sweeps. To build most fractal structures ,an iterated function system concept is used , it provide a unified approach to the theory of fractal geometry and represents an extremely versatile tool for conveniently generating a wide variety of useful fractal structures[16-17] .iterated function system algorithm is based upon a series of affine transformations (w) defined as [18]

$$w\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} a & b \\ c & d \end{pmatrix}\begin{pmatrix} x \\ y \end{pmatrix} + \begin{pmatrix} e \\ f \end{pmatrix} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

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

An affine transformation in the plane can be written as[19]

$$w_q(x) = A_q x + t_q = \begin{bmatrix} r_{q1}\cos\theta_{q1} & -r_{q2}\sin\theta_{q2} \\ r_{q1}\sin\theta_{q1} & r_{q2}\cos\theta_{q2} \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} t_{q1} \\ t_{q2} \end{bmatrix} \quad \ldots\ldots.(2)$$

Where r_q is the scale factor , θ_q is the rotation angle, x_1 and x_2 are the coordinates of point x , if r_{q1}, r_{q2}, r_q with $0< r_q <1$ and $\theta_{q1}, \theta_{q2}, \theta_q$ the iterated function system (IFS) transformation which is a contractive similarity (angles are preserved), t_q (the column matrix) is just a translation on the plane.

A fractal geometry can be obtained by repeatedly applying (w) to the previous geometry in an iterative fashion.

Figure (1) shows the first two iterations in the construction of Koch curve.

Construction of Koch curve is started from a straight line as the 0^{th} iteration.

The unit line is divided into three equal segments and replacing the middle segment by two sides of an equilateral triangle of the same length as the segment being removed (iteration 1).This step is the generator of the curve ,and by repeatedly replacing each of the segment by two sides of an equilateral triangle ,Koch curve has been formed. Fig.2 shows the second iteration of Koch curve dipole antenna using (NEC4) software.

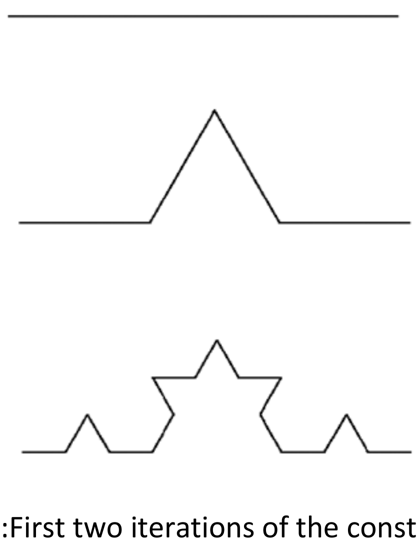


Fig.1 :First two iterations of the construction of the Koch curve

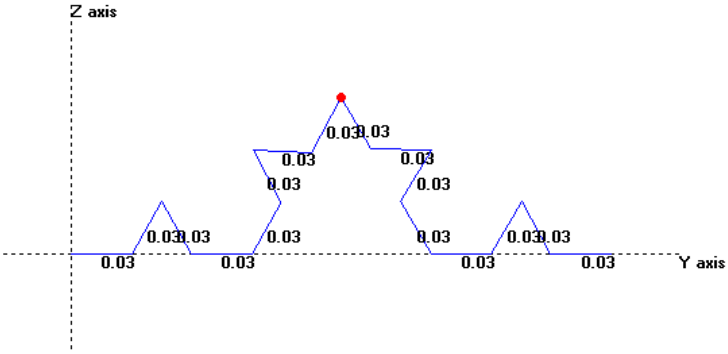


Fig.2: Koch curve dipole antenna second iteration

3.Results and Discussion

For y-directed line source, the vector potential is given by[20]

$$A = \hat{y}\ \mu \frac{e^{-jkr}}{4\pi r} \int I(y) e^{jk\cos\theta} dy \qquad \text{.................(3)}$$

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

The current distribution of any dipole with length L=2h
((where h is the length arm of the dipole))
placed on y-axis is given by

$$I(y) = I_m \sin(kh - ky) \qquad \text{for } y \geq 0 \quad \text{...................(4)}$$

$$I(y) = I_m \sin(kh + ky) \qquad \text{for } y<0 \quad \text{...................(5)}$$

Where I_m is the maximum value of the current ,which occur at the center of the dipole where y=0 , and since the electric field vector of y-directed source is given by

$$E_\theta = j\ w \sin\theta A \hat{\theta} \qquad \text{...(6)}$$

Then for half-wave dipole (HWD)
where ($h = \frac{\lambda}{2}$) , one can obtain

$$E_\theta = j\ w\mu \frac{2I_M}{K} \frac{e^{jkr\cos\frac{\pi}{2}\cos\theta}}{4\pi r \sin\theta} \qquad \text{..........(7)}$$

So

$$E_\theta = E_{\max} \frac{\cos(\frac{\pi}{2}\cos\theta)}{\sin\theta} \qquad \text{..............(8)}$$

Equation (8) gives the electric far field vector of the HWD .The radiation pattern was generated at the resonant frequency of the antenna.

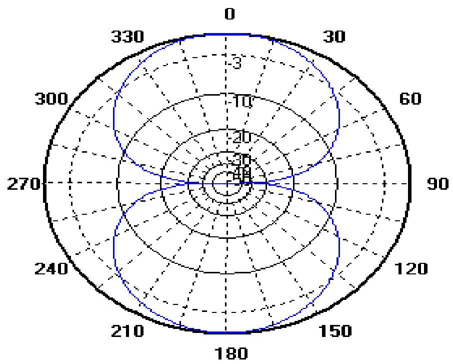
The computed pattern of Koch curve antenna first and second iterations at the resonant frequency of (470 MHz) are depicted in Fig. 3, and the

corresponding three dimensional plots are given in Fig.4.

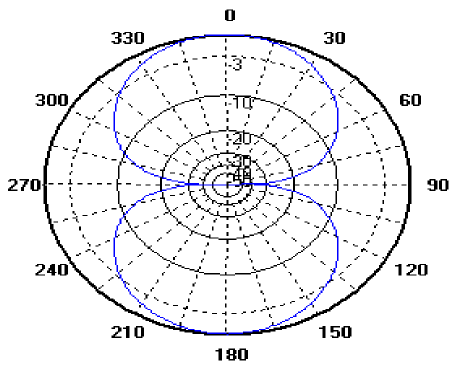
What is worth mentioning is the similarity between the band's patterns of the two iterations which is a verification of a multiband performance of the antenna. The comparison of voltage standing wave ratio (VSWR) versus frequency of the first and second iteration in Fig.5 shows that Koch curve antenna second iteration has less voltage standing wave ratio and the second minima of VSWR has shifted to about 940 MHz .

Figure (6) shows the smith chart of the investigated antennas centered at resonant frequency of (470MHz) which can be utilized to represent impedance of the antennas by a rotation on it to adjust the model of antenna to an RLC circuit.

It is clear from Fig.6 that the matching of Koch curve fractals impedances are similar at the two iterations .

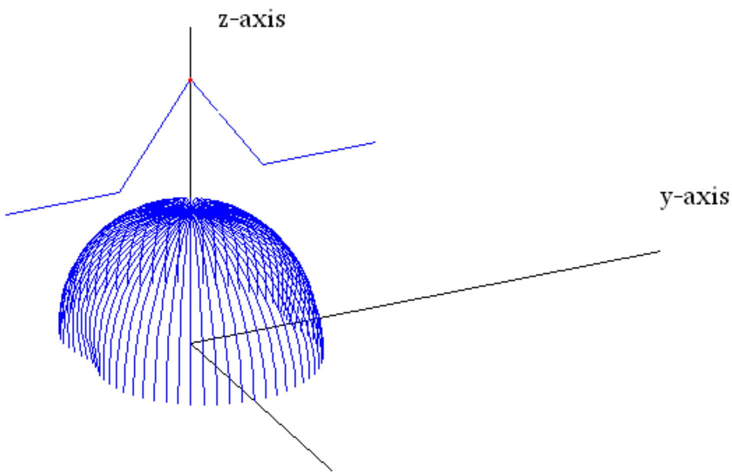


(a)

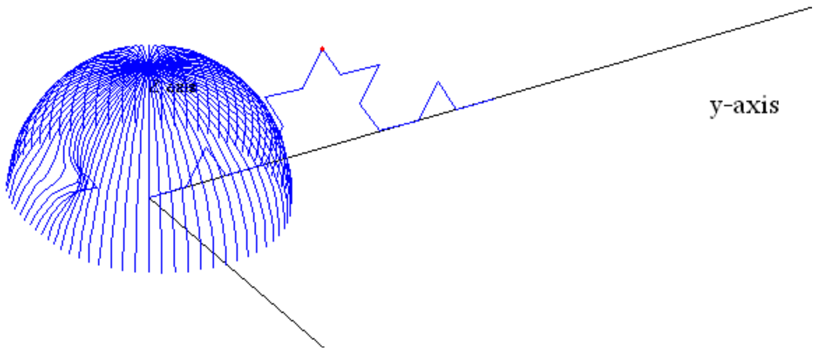


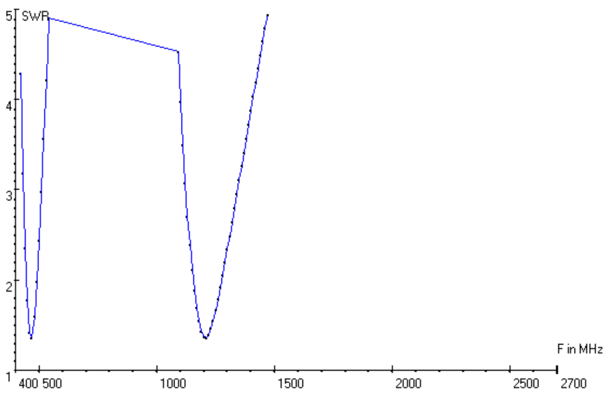
(b)

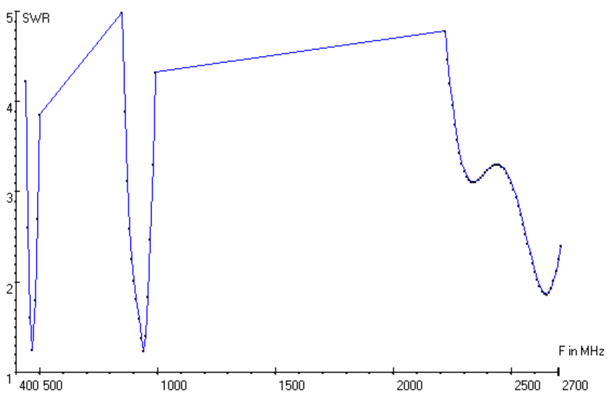
Fig.3:Two dimensional plots of the radiation pattern of Koch curve (a)first iteration and (b)second iteration



(a)

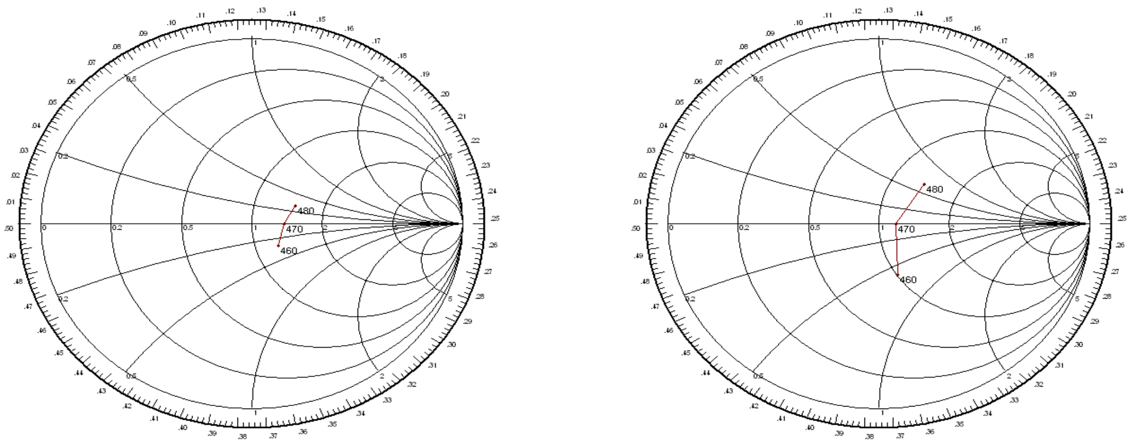






(a) (b)

Fig.5:VSWR versus frequency from 400 to 1500MHz of (a)first iteration and (b)second iteration



(a) (b)

Fig.6:Smith chart centered at resonant frequency of 470MHz of Koch curve (a)first iteration and (b) second iteration

The input impedance at (470MHz) of Koch curve first iteration is 67.98 + j 0.13,whereas for second iteration at (470 MHz) is 62.70 + j 0.46

4.CONCLUSION

In this study ,Koch curve dipole antenna based on 2^{nd} iteration has been investigated ,and its performance has been evaluated.

Since the radiation pattern of Koch curve fractal antenna is uniform and identical to that of traditional HWD antenna, it can be used in most types of wireless communications receiver ,furthermore the self - similarity properties of Koch curve fractal antenna are translated into its multiband behavior. Koch curve fractal antenna exhibits excellent performance at the resonant frequencies and has radiation properties nearly identical to that of the traditional straight wire dipole at that frequencies.

The resonant frequency bands of the proposed Koch curve are 470,940 and 2670 **MHz** which make it has many applications in UHF and S-band communication systems.

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