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Design Antenna Using Fractal Geometries & Conductive Thin Films

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Abstract- The use of fractal geometries has significantly impacted many areas of science and engineering; one of which is antenna. Designing antenna using fractal geometries has been shown to improve several antenna features. Moment method based simulation code was applied to perform a detailed parametric study for H-Shape model. The use of this model reduces the size of a resonant antenna compared with square antenna. This model is studied as single element and arrays which shows improvement in antenna gain.

Keywords- Fractal, H-Shaped, Conductive thin film, polyacetylene polypyrrole and poly p-phenylene – benzobis – thiazole

I. INTRODUCTION

Fractal is a term coined by Mandelbrot in 1975 while studying irregular shapes [1]. Fractal objects have two common properties: self-similarity that means the object has many copies of itself at several scales, and fractal dimension, which represents the space-filling properties of the object [2,3].

The most important fractal application is fractal antenna design. Fractal antennas are very useful tools to solve two of the limitations of classical antennas, the single band performance and the dependence of antenna's size on the operating frequency [4].

A fractal antenna is an antenna that uses a fractal, self-similar design to maximize the length, or increase the perimeter (on inside sections or the outer structure), of material that can receive or transmit electromagnetic radiation within a given total surface area or volume.

A fractal antenna's response differs markedly from traditional antenna designs, in that it is capable of operating with good-to-excellent performance at many different frequencies simultaneously. Normally standard antennas have to be "cut" for the frequency for which they are to be used—and thus the standard antennas only work well at that frequency. This makes the fractal antenna an excellent design for wideband and multiband applications.

The first scientist to work in this field was Dr.Nathan Cohen at Boston University. He published his first article "Fractal Antennas" on 15August 1995 [5]. Few months later, Dr.Carles Puente at University of Catalonia, Barcelona in Spain published papers about fractal antennas [6,7]. Fractal electrodynamics is a research area connecting the fractal geometry and electromagnetic theory, the term was coined by Dr. Dwight L. Jaggard [8].

In present work, H-Shape model is studied as a single element and as array using NEC4WIN code.

II. FRACTAL ELEMENT ANTENNAS & PERFORMANCE

Many fractal element antennas use the fractal structure as a virtual combination of capacitors and inductors. This makes the antenna so that it has many different resonances which can be chosen and adjusted by choosing the proper fractal design. Just like any other antenna, the physical size of the antenna is related to its potential bandwidth, and the resonant frequency changes depending on the amount of fractal reactive loading. In this manner, the fractal antenna, just like any other antenna with reactive loading (i.e. dielectric, ferrites, capacitors, inductors, etc.), can have its resonant frequency lower than that of the typical free-space half-wavelength fundamental resonant frequency predicted by setting the largest physical dimension of the antenna equal to half a wavelength. False claims that these antennas do not follow the basic laws of electromagnetic that govern antenna behavior abound.

This complexity arises because the current on the structure has a complex arrangement caused by the inductance and self capacitance. In general, although their effective electrical length is longer, the fractal element antennas are themselves physically smaller, again due to reactive loading.

Fractal element antennas are shrunken compared to conventional designs, and do not need additional components, assuming the structure happens to have the desired resonant input impedance. In general the fractal dimension of a fractal antenna is a poor predictor of its performance and application. Not all fractal antennas work well for a given application or set of applications. Computer search methods and antenna simulations are commonly used to identify which fractal antenna designs best meet the need of the application.

Although the fractal element technology in real-life applications, such as RFID and cell phones. After full review study we conclude that the geometry is a key aspect in uniquely determining the EM behavior of frequency independent antennas.

III. COMPUTER SIMULATION TECHNIQUE

Method of Moments is a numerical method for solving integral equations. The general form of this equation is [9]:

$$\int I(z')K(z,z')dz' = -E^i(z) \quad (1)$$

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The kernel K(z, ź) depends on the specific integral equation formula. The procedure of moments' method is, reducing this integral equation to a system of linear algebraic equations in terms of the unknown current I(ź). Most electromagnetic radiation problems are expressed as integral equations with a source term on the right hand side and the unknown within the integral.

Total sharing of the electric field over the wire volume is :-

$$\vec{E}_z = \frac{1}{j\omega\varepsilon_0}\iiint\left[\frac{\partial^2\psi(z,z')}{\partial z^2}+\beta^2\psi(z,z')\right]Jdv' \quad (2)$$

$$\beta^2 = \omega^2\mu_0\varepsilon_0$$

$\psi(z, z')$ is the free space green function [10]

If we assume the conductivity is infinity, then the current is confined to the surface of the wire and by considering the distribution of the current as uniform with respect to (φ), then equation (2) is reduced to a line integral of current [11].

$$\vec{E}_z = \frac{1}{j\omega\varepsilon_0}\int_{-L/2}^{L/2}\left[\frac{\partial^2\psi(z,z')}{\partial z^2}+\beta^2\psi(z,z')\right] I(z')dz' \quad \ldots (3)$$

where: L is the wire length.

We can set the quantity ($\vec{E}_z$) in equation (2) as the scattered field ($\vec{E}_z^s$) that is radiated by the equivalent current I(z'). There is also the incident field ($\vec{E}_z^i$) at the surface of a perfectly conducting wire, and the sum of the scattered and incident fields must be zero, i.e., $\vec{E}_z^s = -\vec{E}_z^i$

Thus, equation (2) becomes:

$$\frac{1}{j\omega\varepsilon_0}\int_{-L/2}^{L/2} I(z')\left[\frac{\partial^2\psi(z,z')}{\partial z^2}+\beta^2\psi(z,z')\right]dz' = -\vec{E}_z^i(z) .. \quad (4)$$

This equation was derived by Pocklington [9] and it is equivalent to equation (1). The expansion functions are a stair step approximation to the current distribution on the wire.

$$\int_{-L/2}^{L/2} I(z')K(z_m,z')dz' \approx I_1 f(z_m,z_1') + I_2 f(z_m,z_2') + .. . + I_n f(z_m,z_n') + \ldots + I_N f(z_m,z_N') \approx -E_z^i(z_m) \quad \ldots. (5)$$

From the computed currents we can calculate the radiation pattern of the simulated antenna by using the standard far field approximations [11,12]:

$$\vec{E} = -j\omega\vec{A} \quad \ldots\ldots\ldots..(6)$$

$$\vec{H} = \frac{j\omega}{\eta}\times\vec{A} \quad \ldots\ldots\ldots(7)$$

where $\eta = \sqrt{\frac{\mu}{\varepsilon}}$ …… (8)

$$A(r) = \frac{\mu}{4\pi}\frac{e^{-j\beta r}}{r}\int_s J(r)e^{-j\beta r}ds \quad \ldots (9)$$

IV. CONDUCTIVE THIN FILM PROPERTY

Conductive polymers were first developed in the late 1970, these new materials combined the desirable electrical properties of semiconductor and metals with the attractive mechanical properties of polymers, all conductive polymers could be divided into the following: two broad branches, intrinsically conductive polymers which have backbones or pendant groups that are responsible for the generation and propagation of charge carriers. Variable Conductive is achieved by controlling the extent of oxidation or reduction of polymer chain. The other class of conductive polymer is extrinsically conductive polymer. These are made by adding conductive particles like silver or carbon black to a non – Conducting polymer matrix to produce a Conductive composite [13]

Conductive polymers in their pristine form are typically lightweight (much lighter than metals) low loss dielectrics with some characterized by high ductility and mechanical strength which make them useful to many applications such as ,field effect transistor, molecular devices electrolyte gated transistor [14-16] The micro wave Conductivity of some polymers synthesized by doping with p–type or n-type impurities such as (the polymers) polyacetylene polypyrrole and poly p-phenylene – benzobis – thiazole [17,18], is much higher than that of carbon impregnated nonmetallic composites and may even approach that of copper.

Conductive polymer products with embedded and improved electromagnetic interference (EMI) and electrostatic discharge (ESD) protection have led to both prototypes and products. Another use is for microwave-absorbent coatings, particularly radar absorptive coatings on stealth aircraft.

In this combination of low weight, high mechanical strength and high conductivity of conductive polymer which makes then ideal as a radar absorber for covering of metallic skin on airframes and for electromagnetic interference shielding [19].

V. RESULTS

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In this work a Moment method based simulation code was applied to perform a detailed parametric study for H-Shape model antenna. The single element and array model were designed at 2.45 GHz for the wireless LAN application. The shape of the model is shown in figure(1). The substrate is chose to be 50 mm X 50 mm and thickness of 1mm.the antenna is fed by line of 50 Ω resistance. The size of the antenna is reduced compared with square antenna. The matching properties represented by return loss (s11) is very good as in figures (2,3). The shape of the radiation pattern (figure (4)) shows a good directivity for the single element and higher for arrays. The calculated gain for the single element is 5.6 dBi and 12.2 dBi for the array model.

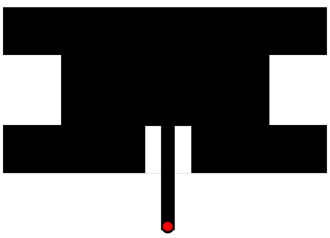
One advantage of fractal antennae is their larger bandwidth, which is good because it allows the same antenna to access more frequency bands, and the use of larger bandwidth for frequency modulated signals allows for also larger data throughput.

An imprecise and not-entirely-correct-in-the-details-of-electrical-engineering explanation for this increased bandwidth is that the presence of scaling symmetry means that the impedance of the antenna can be made roughly the same across a large range of frequencies, since the impedance depends on the difference between the resonant frequency and the signal frequency, and the resonant frequency depends on the size of characteristic features in the antenna.

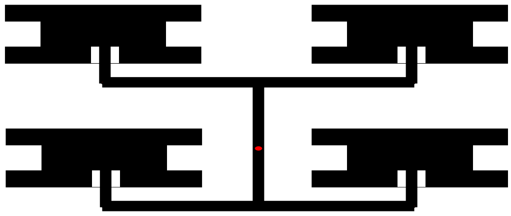
VI. CONCLUSIONS

The result of the present work presented in section (4) lead to the following conclusions:

1. The size of H-Shape model is smaller than that of square antenna.
2. The matching properties for this model are very good and make it applicable for wireless communications.
3. The directivity of the single element is high and for array is higher by more than 6 dB.
4. The active media of the antenna is thin film which make it easy to construct and low cost.



Single Element H-shaped Model Antenna



Array H-Shape model antenna

Fig. 1: H-Shape model antenna

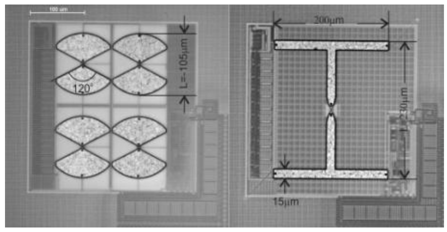
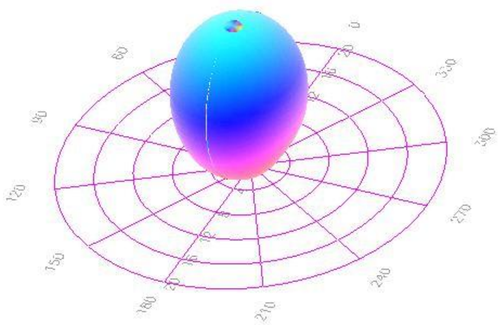
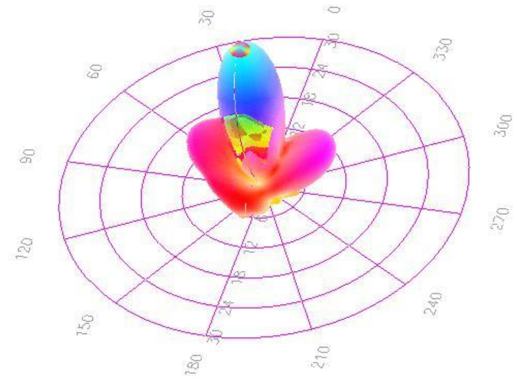


Fig. 2: Compact H-Shape model antenna



Radiation pattern for single element model



Radiation pattern for array model

Fig. 3: Radiation pattern for H-Shape

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