Z-SHAPED DIPOLE ANTENNA AND ITS FRACTAL ITERATIONS

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ABSTRACT

Z-shaped dipole and fractal Z-shaped dipole antennas made of wires are introduced. Theses antennas exhibit lower resonant frequencies and small space occupations. The performance characteristics of the proposed antennas are examined and compared with successive iterations for the same wire length. The radiation properties are considered including input impedance and VSWR as functions of frequency. Also the comparison between the third iteration of fractal Z-shaped dipole antenna and linear dipole antenna with the same wire length are presented.

KEYWORDS

Wire antennas, fractal, MoM, input impedance, resonant, gain, VSWR, current distribution, polarization

1. INTRODUCTION

Wire-type antennas are made of conducting wires and are generally easy to construct, thus the cost is normally low. Examples include dipoles, monopoles, loops, helices, Yagi–Uda and log-periodic antennas. Arrays of dipoles-the famous form of the wire antennas- are commonly used as base-station antennas in mobile systems [1, 2].

Fractal is a word that describes the complex geometries that are created through successive iterations when applying a geometric generator to a simple Euclidean basis or iteration geometry. In general, there are no strict guidelines as to what geometric shapes constitute fractal geometry. However, there are geometric properties used to describe fractals such as self-similarity, in which a small region of the geometry repeats the whole geometry and space-filling [3]. Mathematically, the fractal geometry is principally defined by the characteristic of fractal-dimensions. The fractal-dimension can be interpreted as measure of the space-filling properties and complexity of the fractal shape [4]. Fractals provide a new approach to antenna design. The geometrical properties of fractals challenge the traditional constraints of classical antennas. Fractals can be used in two ways to enhance antenna designs. The first method is in the design of miniaturized antenna elements. This can lead to antenna elements which are more discrete for the end user. The second method is to use the self-similarity in the geometry to design antennas which are multiband. This would allow the operator to incorporate several aspects of their system into one antenna. Antenna elements utilizing both these tactics can be incorporated into highly advanced array and smart antenna designs [4-9].

To obtain completely accurate solutions for wire antennas, the current on the wire must be solved for, subject to the boundary condition that the tangential electric field is zero along the wire. This approach gives rise to an integral equation which can be solved by numerical methods [1].

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The method of moments (MoM) solution is a numerical procedure for solving the electric field integral equation. Basis functions are chosen to represent the unknown currents (i.e., triangular basis functions). Testing functions are chosen to enforce the integral equation on the surface of the wires. With the choice of basis and testing functions, a matrix approximating the integral equation is derived. If this matrix is inverted and multiplied by the local sources of electric field, the complex magnitudes of the current basis functions are derived. All antenna performance parameters can be determined from the derived current distribution. In this paper commercial software (NEC-win professional) is used to obtain all the radiation characteristics of the proposed S-shaped antennas. [1,10]

2. Z-Shaped Dipole Antenna (ZDA) And Fractal Z-Shaped Dipole Antenna

2.1 Antenna Structure

This antenna is made of a Z-shaped thin wire and is fed symmetrically as shown in Figure 1. The antenna is located in the *xz*–plane. The fractal first, second and third iterations of Z-shaped dipole antenna are depicted in figures 2, 3 and 4. Each iteration is formed by replacing the half of the free arm of Z-shape by another Z-shape. All of these antennas have the same wire length (202 cm) and a radius of 0.1 cm. The MoM with one-volt delta gap source is applied to theses antennas. The previous antennas occupy different spaces as shown in the figures and table 1. The antenna performance properties are obtained using commercial software (NEC-WIN Pro V.1.6) [11].

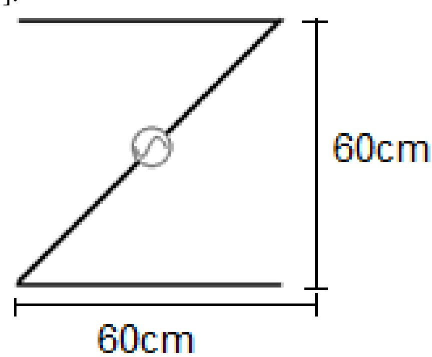

Figure1.a .Z-shaped dipole antenna

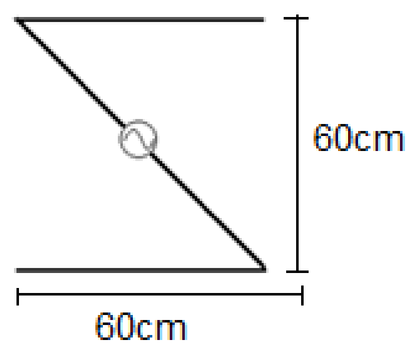

Figure 1.b. Inverted Z-shaped antenna

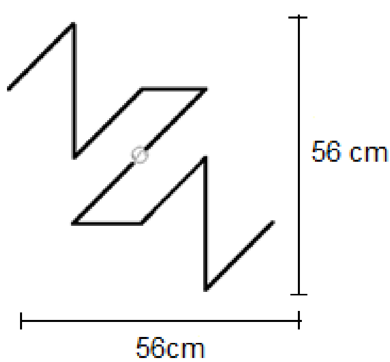

Figure 2a. 1st iteration of fractal ZDA

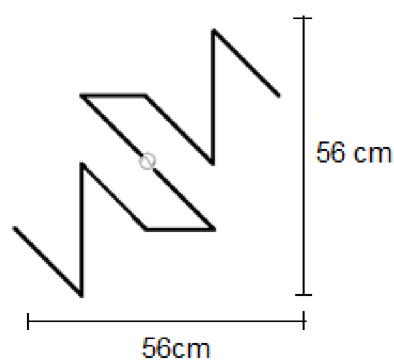

Figure2b.1st iteration of fractal inverted ZDA

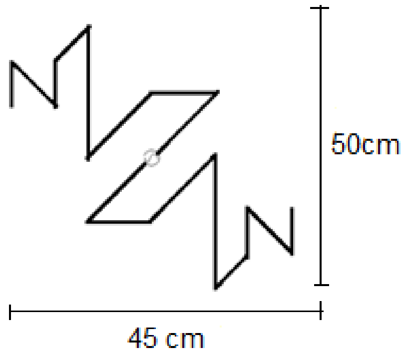

Figure 3a. 2nd iteration of fractal ZDA

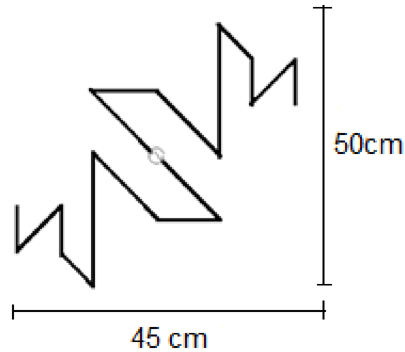

Figure 3b: 2nd iteration of fractal inverted ZDA

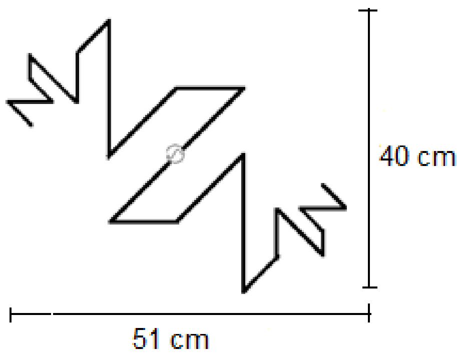

Figure 4a. 3rd iteration of fractal ZDA

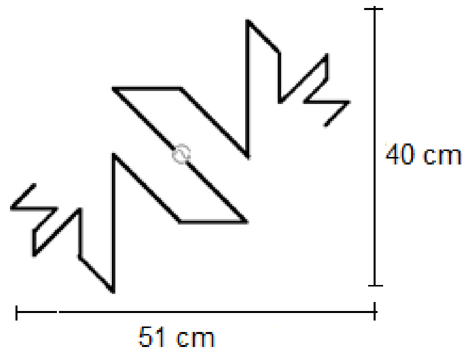

Figure 4b. 3rd iteration of fractal ZDA

Table 1. Space dimensions for ZDA and fractal ZDA

Antenna type	Space dimension
Z-shaped dipole antenna	60 cm x60cm
1st iteration fractal Z-shaped dipole antenna	56 cm x56cm
2nd iteration fractal Z-shaped dipole antenna	50 cm x43cm
3rd iteration fractal Z-shaped dipole antenna	51 cm x40cm

2.2 Results and Discussions

2.2.1 The Input Impedance and The Resonant Performance

The input impedance as a function of frequency for ZDA and the successive fractal iterations of ZDA are presented in figures 5 and 6.

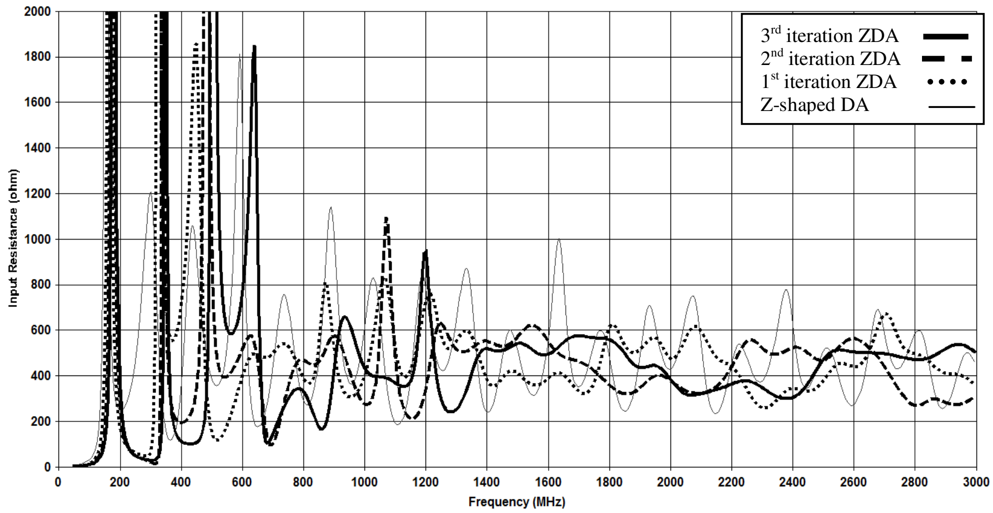

Figure 5. The input resistances of ZDA and the successive fractal iterations of ZDA

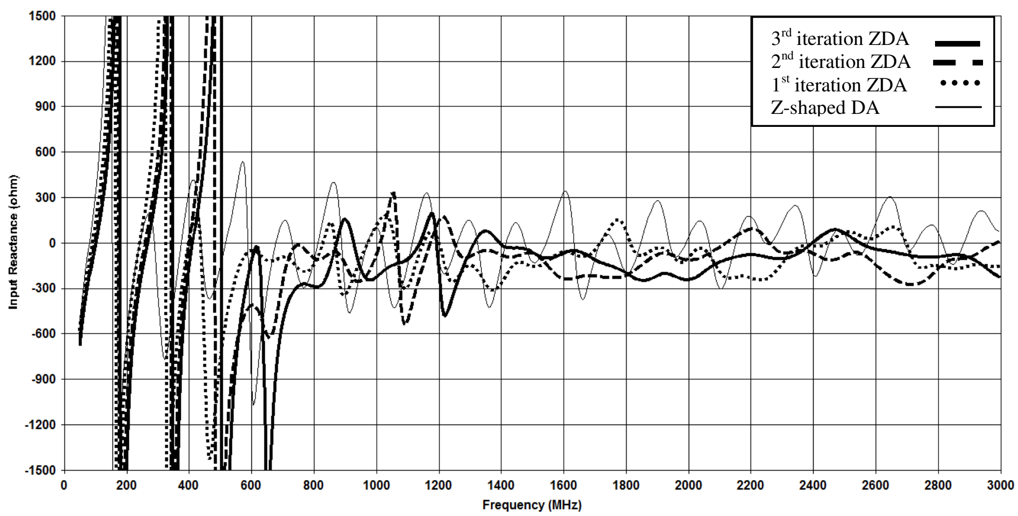

Figure 6. The input reactance of ZDA and the successive fractal iterations of ZDA

From these figures (5 and 6) it is clear that the input resistance for the higher fractal iteration of ZDA more stable than ZDA especially for high frequencies. The fractal ZDA loses its resonant properties when the successive iteration increased and the antenna becomes a wideband antenna. For this property, these types of antennas can be used in many applications such as GSM bands, Bluetooth, Wi-Fi and other RF applications. Also the increased of successive iteration values forced the antenna reactance to become capacitive.

The resonance performance characteristics of the first, second and third iterations of fractal ZDA are presented in tables 2, 3 and 4. The second and third iterations, both have 7 resonant frequencies in the band f < 3000 MHz and the first iteration has 8 resonant frequencies at the same band.

Table 2. The resonance performance characteristics of the third iteration of fractal ZDA

Third iteration		
Resonant Frequency (MHz)	Resonant Resistances(Ω)	VSWR at Z_o = 300 Ω
100	9	30
267	400	7.5
411	105	2.8
872	182	1.6
1138	355	1.2
1313	280	1.1
2397	300	1

Table 3. The resonance performance characteristics of the second iteration of fractal ZDA

Second iteration		
Resonant Frequency (MHz)	Resonant Resistances(Ω)	VSWR at Z_o = 300 Ω
97	18	32
258	60	6.4
400	195	1.5
1011	274	1.1
1172	235	1.3
2120	330	1.1

Table 4. The resonance performance characteristics of the first iteration of fractal ZDA

First iteration		
Resonant Frequency (MHz)	Resonant Resistances(Ω)	VSWR at Z_o = 300 Ω
88	13	30
241	73	4.3
398	650	2.2
828	380	1.3
971	320	1.1
1150	427	1.4
1717	323	1.1
2444	330	1.1

2.2.2 The Voltage Standing Wave Ratio VSWR

The VSWR at Z_o =300 for the ZDA and fractal ZDA is shown in Figure 7.

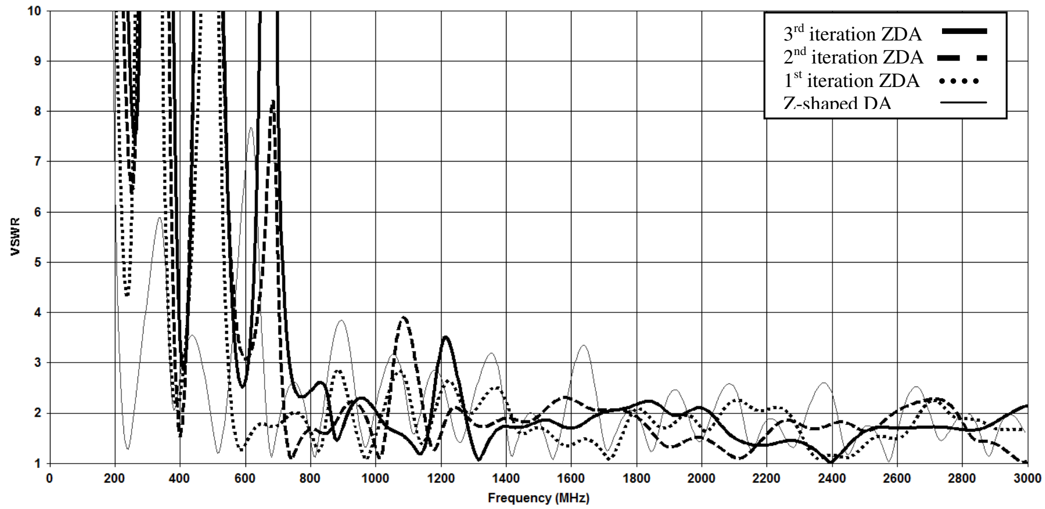

Figure 7. The VSWR of ZDA and the successive fractal iterations of ZDA at Z_{o} =300

2.2.3 The Radiation Pattern and the Gain

Typical power radiation patterns at 400 MHz , 900MGHz and 1900MHz for ZDA and the successive fractal iterations of ZDA in the free space are given in Figures 8to 13.

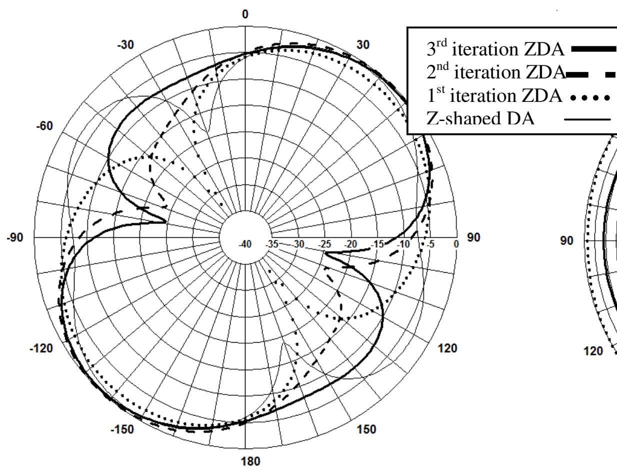

Figure 8. Power radiation pattern in *xz*-plane at 400 MHz

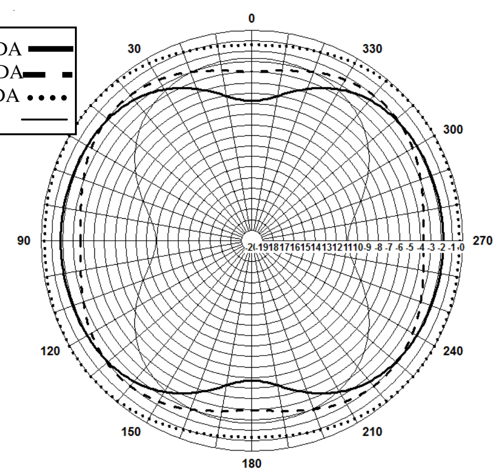

Figure 9. Power radiation pattern in *xy*-plane at 400 MHz

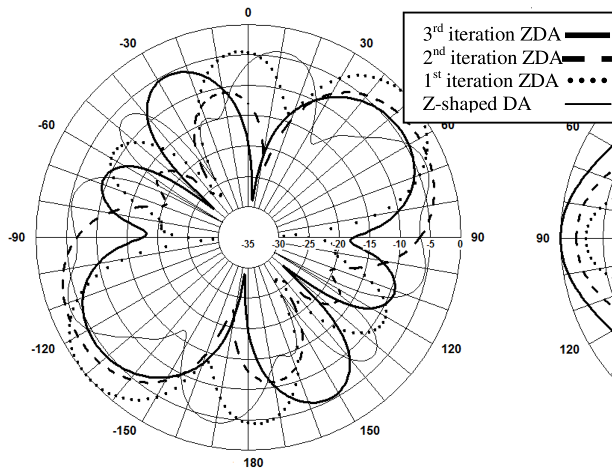

Figure10. Power radiation pattern in *xz*-plane at 900 MHz

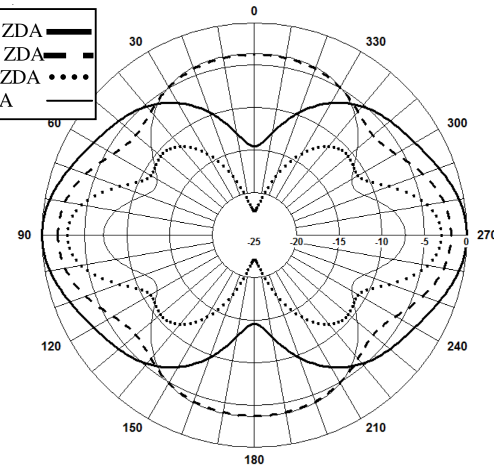

Figure11. Power radiation pattern in *xy*- plane at 900 MHz

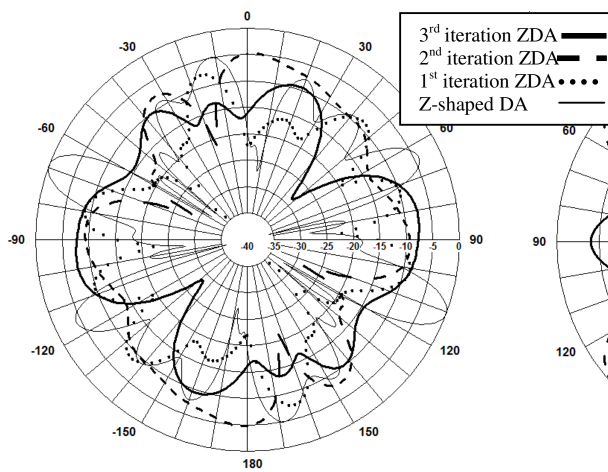

Figure 12. Power radiation pattern in *xz*-plane at 1900 MHz

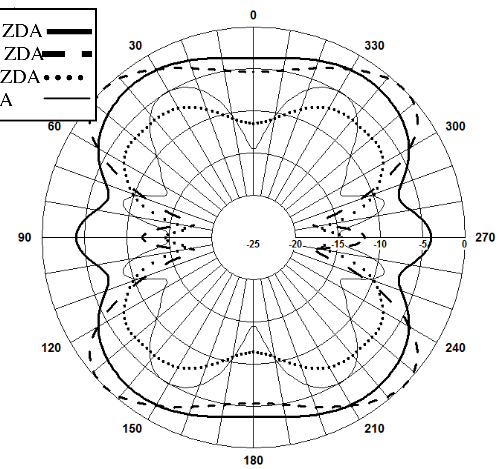

Figure 13. Power radiation pattern in *xy*-plane at 1900 MHz

The gain of theses antennas at the previous frequencies are presented in table 4

Table 4. The total gain in dB for ZDA and the successive fractal iterations of ZDA at different Frequencies

Antenna type	400MHz	900 MHz	1900 MHz
Z-shaped dipole antenna	4.4	4.1	10
1st iteration fractal Z-shaped dipole antenna	3	7.5	2.2
2nd iteration fractal Z-shaped dipole antenna	5.1	4.9	5.5
3rd iteration fractal Z-shaped dipole antenna	4.8	4.53	3.9

2.2.4 The Current Distribution

The current distribution at 400 MHz , 900MHz and 1900MHz for ZDA and the successive fractal iterations of ZDA are given in Figures 14 to 16. It is clear that the current distribution on the second iteration more efficient than the others at 400MHz and 1900MHz where the third iteration is the best at 900 MHz.

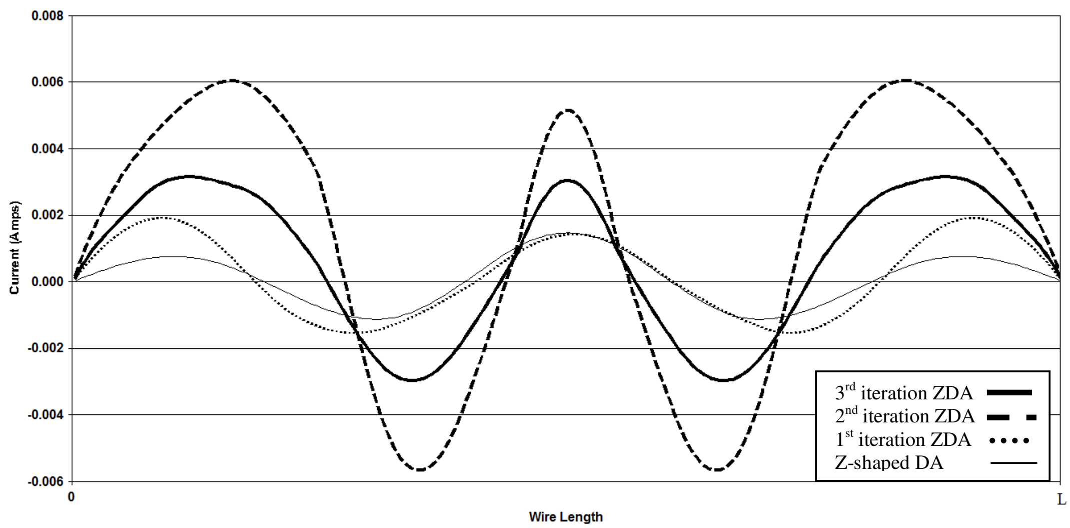

Figure 14. The current distribution for the ZDA and the successive fractal iterations of ZDA at the 400 MHz

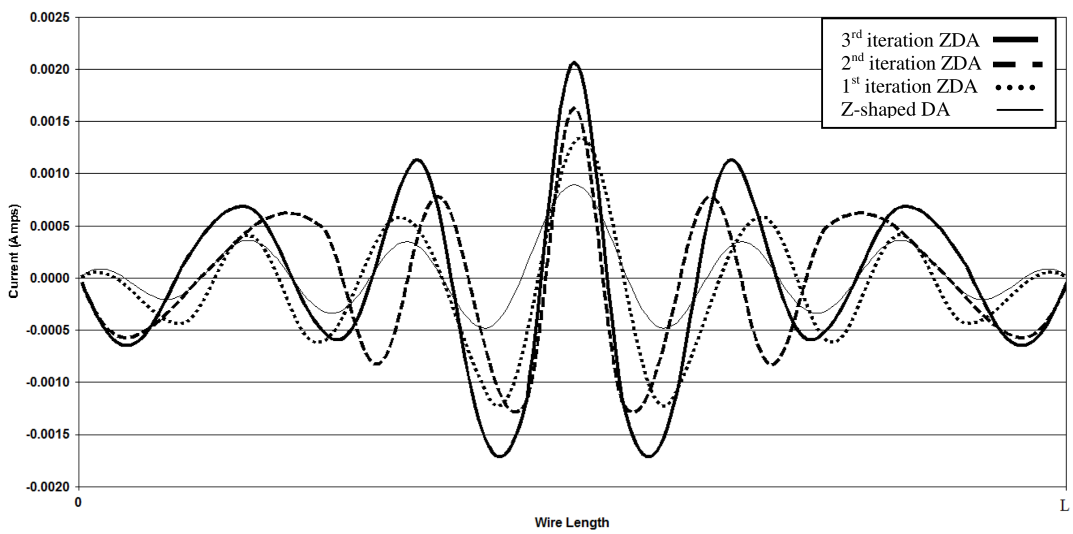

Figure 15. The current distribution for the ZDA and the successive fractal iterations of ZDA at the 900 MHz

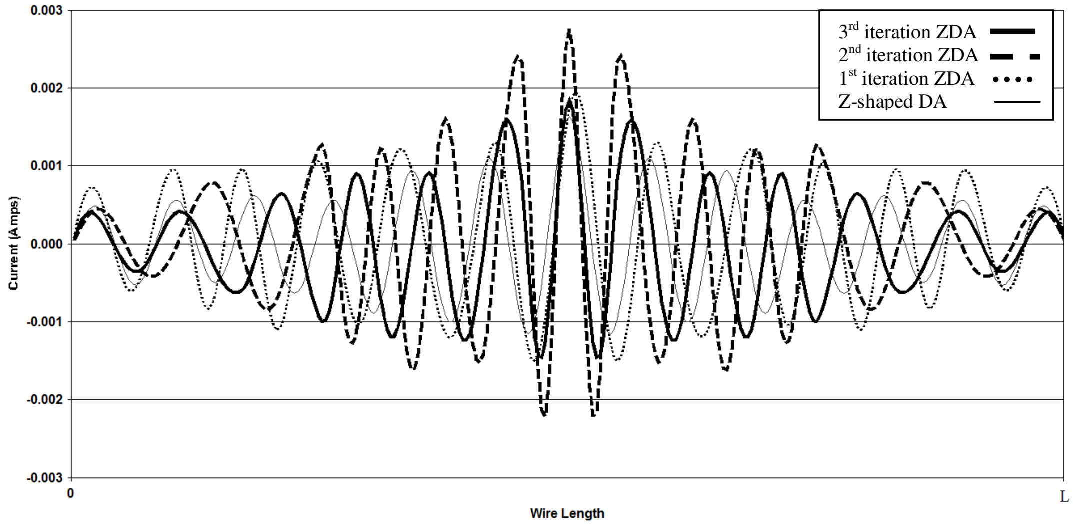

Figure 16. The current distribution for the ZDA and the successive fractal iterations of ZDA at the 1900 MHz

2.2.5 Polarization and Axial Ratio

The axial ratio (AR) of the ZDA and successive fractal iterations of ZDA is depicted in figure 17. from this figure and the simulation results, it is clear that the ZDA and fractal ZDA radiate left elliptically polarized (LEP) waves where the inverted ZDA and fractal inverted ZDA radiate right elliptically polarized (REP) waves.

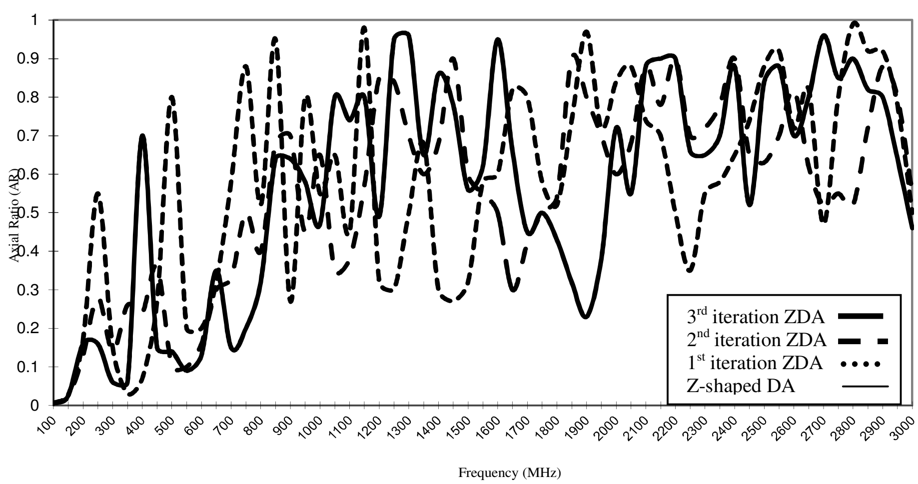

Figure 17. The axial ratio for the ZDA and the successive fractal iterations of ZDA

3. Comparison Between The Third Iteration Of Z-Shaped Dipole Antenna And Linear Dipole

Figures 18, 19 and 20 present the input resistance, input reactance and VSWR for the third iteration of fractal ZDA and linear dipole with the same wire length. Also the radiation patterns and current distribution are represented in figures 21 to 26.

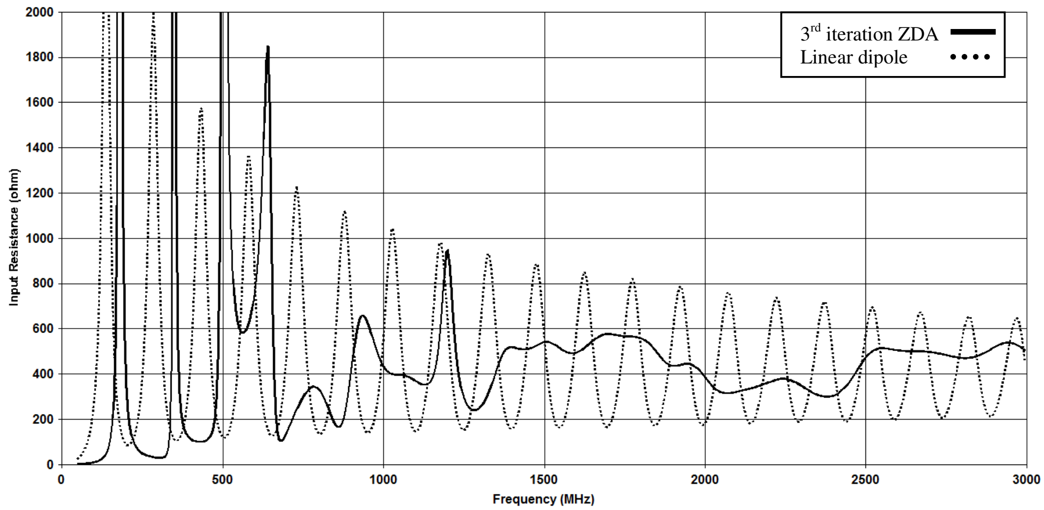

Figure 18. The input resistances of the third iteration of fractal ZDA and linear dipole with the same wire length

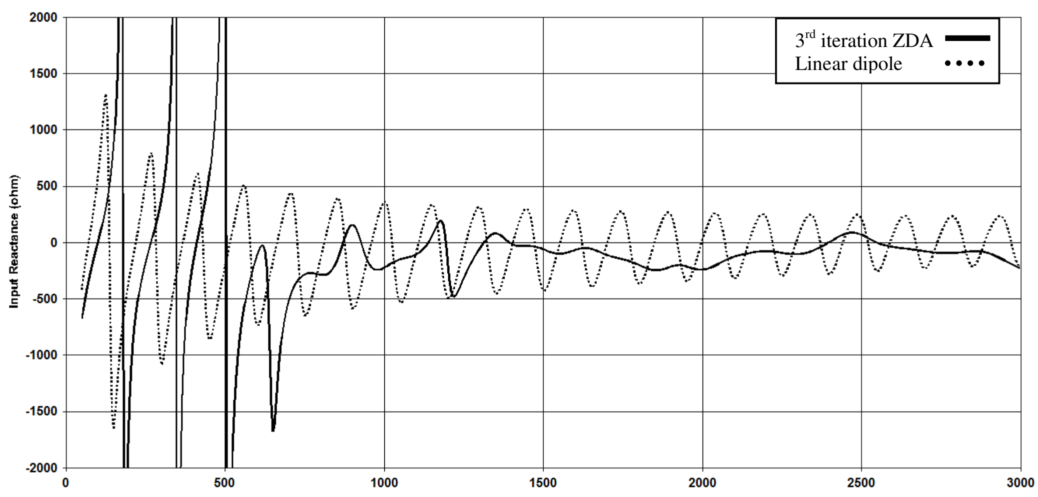

Figure 19. The input reactance of the third iteration of fractal ZDA and linear dipole with the same wire length

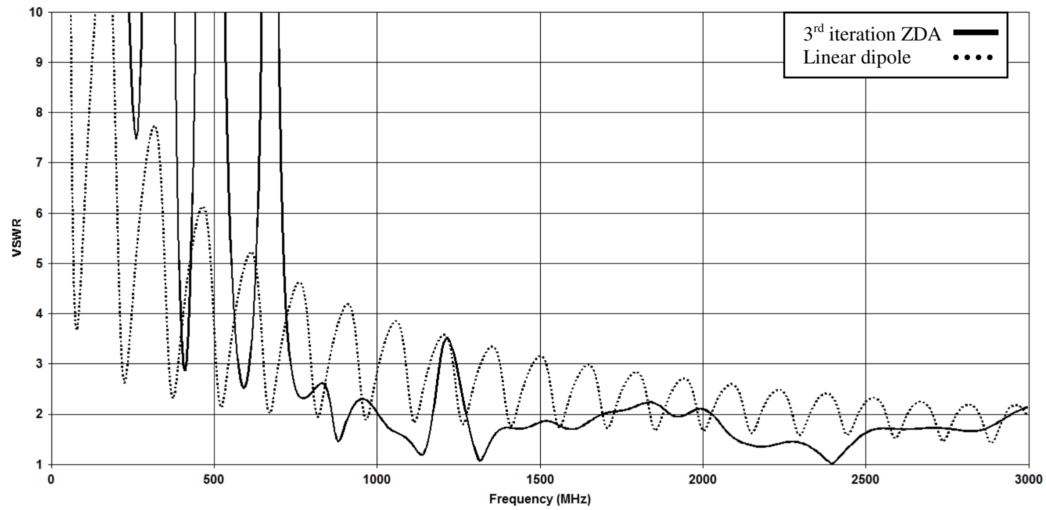

Figure 20. The VSWR of the third iteration of fractal ZDA and linear dipole with the same wire length at $Z_o = 300$

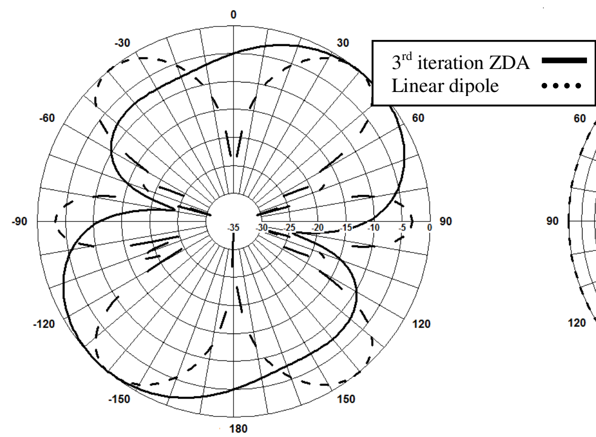

Figure 21. Power radiation pattern in *xz*-plane at 400 MHz

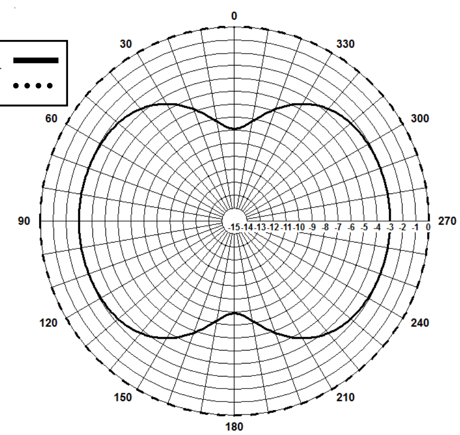

Figure 22. Power radiation pattern in *xy*- plane at 400 MHz

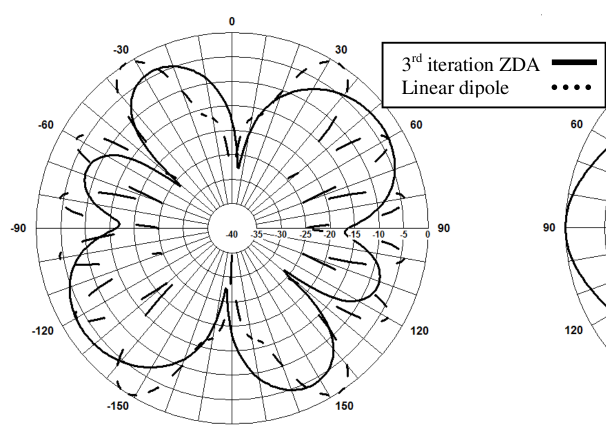

Figure 23. Power radiation pattern in *xz*-plane at 900 MHz

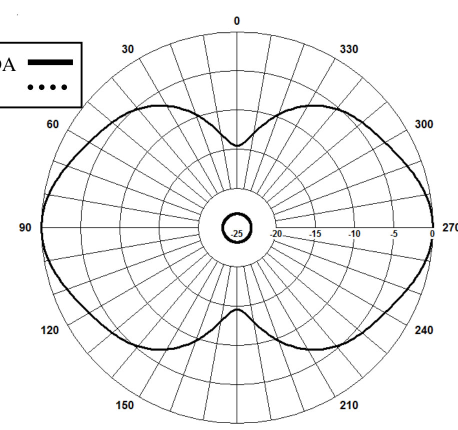

Figure 24. Power radiation pattern in *xy*- plane at 900 MHz

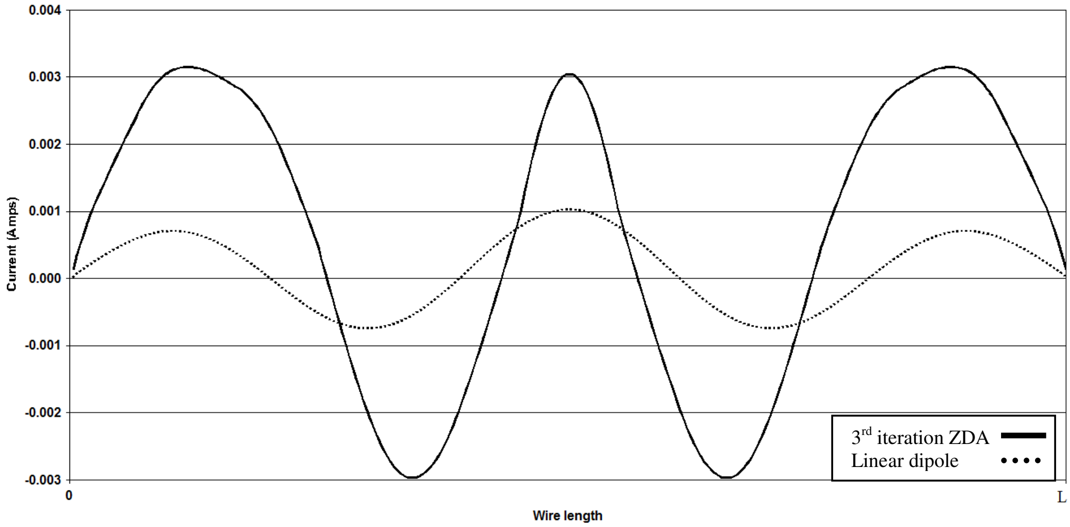

Figure 25. The current distribution of the third iteration of fractal ZDA and linear dipole with the same wire length at the 400 MHz

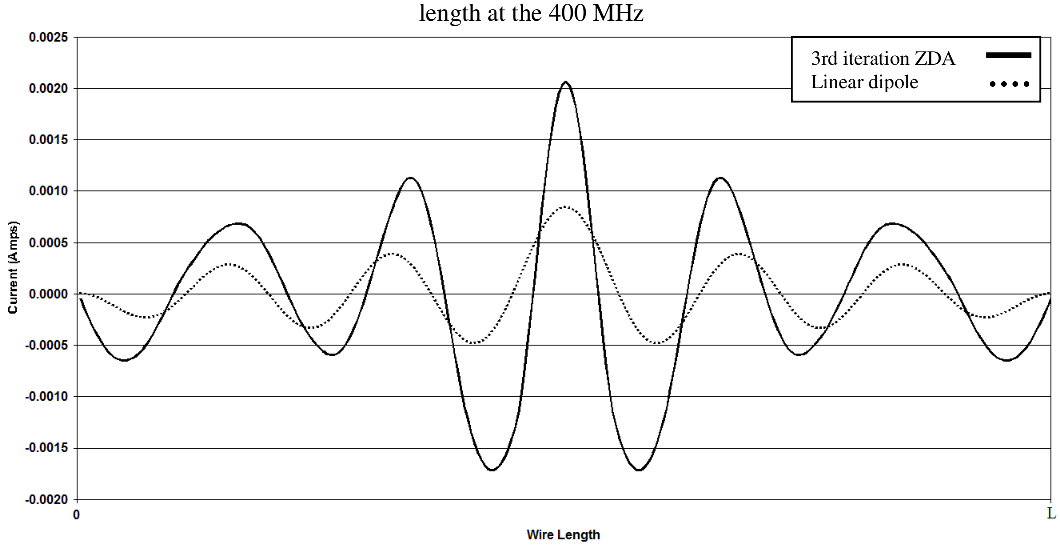

Figure 26. The current distribution of the third iteration of fractal ZDA and linear dipole with the same wire length at the 900 MHz

From the previous figures we notice that the fractal ZDA has superior performance over the linear dipole. The linear dipole is resonant antenna but fractal ZDAs show broad characteristics. The fractal ZDA has superior current distribution at the linear dipole. The main difference between these two antennas is the polarization where the linear dipole is linearly polarized antenna [1,2] but fractal Z-shaped dipole antenna is elliptically polarized antenna.

4. CONCLUSIONS

A new simple wire antenna is proposed and analyzed, namely the Z-shaped dipole antenna and fractal Z-shaped dipole which radiates left elliptically polarized (LEP) waves. Also the comparison between the third iteration Z-shaped dipole antennas and the linear dipole is presented. The analysis of the antenna is performed using the MoM. The field patterns and gains in the principal planes are obtained. Also the other radiation characteristics such as input resistance, reactance and the VSWR as functions of frequency are reported. The results show that the proposed antennas are very promising to be used in the VHF and UHF frequency ranges.

REFERENCES

[1] C.A. Balanis, (2005)“Antenna Theory Analysis and Design” third edition (John Wiley & Sons).

[2] Yi Huang and Kevin Boyle, (2008) "Antennas from Theory to Practice" first edition (John Wiley & Sons).

[3] Benoit B. Mandelbrot, (1977) "The Fractals Nature of Geometry", New York, W. H. Freeman and Company.

[4] Douglas H. Werner and Raj Mittr, (2000) "Fontiers in Electromagnetis" New York, IEEE Press.

[5] Rajeev Mathur, Sunil Joshiand Krishna C Roy, (2010) “A Novel Multiband Koch Loop Antenna Using Fractal Geometry For Wireless Communication System” International Journal of Wireless & Mobile Networks (IJWMN) Vol. 3, No. 5.

[6] Li, D. and J.-F. Mao, (2012)"Koch-like sided Sierpinski gasket multifractal dipole antenna," Progress In Electromagnetics Research , Vol. 126, 399-427.

[7] LIi Daotie and Mao Junfa , (2013)“ Multiband Multimode Arched Bow-Shaped Fractal Helix Antenna” Progress In Electromagnetics Research, Vol. 141.

[8] John P. Gianvittorio and Yahya Rabmat-Samii, (2002)“Fractal Antennas: A novel Antenna Miniaturization Technique, and Applications,” IEEE Antennas and Propagation Magazine, pp. 20-36.

[9] John Gianvittorio, (2003)“Fractals, MEMS, and FSS Electromagnetic Device: Miniaturization and Multiple Resonances,” PhD dissertation, University of California, Los Angeles.

[10] The NEC-2 Manual from (http://www.traveller.com/~richesop/nec/).