A Polygonal Shape Patch Antenna with Triangular Mini-Fractals for Wideband Wireless Local Area Network Applications

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Abstract— This paper presents a miniaturized hexagonal fractal antenna. The mini triangular fractals of self-duplicating structures are inserted for the bandwidth improvement. The antenna is designed for Wireless Local Area Network (WLAN) application at 2.4 GHz. The antenna middle dimensions are: length is 28 mm and the breadth is 40 mm. The substrate used is FR4 with the height of 1.56 mm. The design is simulated and optimized with a ZELAND IE3D package. There is bandwidth enhancement of 700 MHz at -16db return loss .We also obtained moderately high gain of 4.0 dB. Several iterations are carried out to achieve better performance.

Key words: Hexagonal Fractal; Bandwidth; ZEELANDIE3D; Directivity; Wireless Local Area Network (WLAN)

I. INTRODUCTION

The geometry generating method of a patch antenna begins with a basic calculation of dimensions of a patch antenna [1].Then inserting the self-similarfractal slots [6, 7]. Elementarybuildings blocks of a fractal cannot be differentiated as a result of theyare scaled versions of the leader [1, 2, 3]. The present vibrant area of research in the field of antenna is that the immoderate broadband response with miniaturized size that may be mounted on two-dimensional surfaces.Wireless LAN, Wi-Fi, satellite and alternative broadband applications are attracting the researchers.Shrinking the antenna size [2] while not adversely affecting the antenna performance is an art of the researchers, and a method to do this is to implement the fractal geometry. Fractal geometries structure the antenna with little space and geometry resistance within the structure. Fractals can be of any shape,like triangular[4], Star, hexagons etc. in this paper we have created a hexagonal shape patch antenna with the triangular fractals leading to augmented bandwidth, higher performance and ease of Use. The major factor to maximize the response of antenna is to match the line impedance to the antenna input impedance[3] for maximum power transfer. One way of doing this is to introduce a Quarerwave transformer [1].

The paper includes the following concepts:

- Mathematical steps for designing a simple patch antenna.
- Significance of fractal geometries.
- Quarter wavetransformer forimpedance matching.
- Implementation of proposed antenna in ZEELAND IE3D.
- Optimization and tuning of proposed antenna.
- Software Results and discussions.
- Hardware implementation and testing of antenna using antenna measurement system.
- Comparison between ZEELAND IE3D simulated results withresults obtained from testing of antenna.
- Conclusion and references.

II. DESIGN OF A SIMPLE PATCH ANTENNA

Before we proceed to construct any type of antenna, we must calculate the dimensions of simple patch antenna [1, 2, 3]. The design follows the following steps. Because of fringing field effect the length of ground plane is taken somewhat greater than the actual size of antenna.

1) Step 1:

The width of a patch is calculated using the formula,

$$w_p = \frac{c}{2f}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

Where $\varepsilon_r$the dielectric constant, c isis velocity of light and f is the resonant frequency of antenna.

2) Step 2:

The next step is to compute the effective dielectric constant by using equation below,

$$\varepsilon_{\text{reff}} = \frac{\varepsilon_r + 1}{\varepsilon_r} + \frac{\varepsilon_r - 1}{\varepsilon_r} * \left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}}$$

Where h is the height if substrate and w is width of the patch.

3) Step 3:

Calculation of effective length

$$L_{eff} = \frac{c}{2f\sqrt{\varepsilon_{reff}}}$$

4) Step 4:

Determining the length extensionΔL

$$\Delta L = h * 0.412\left[\frac{\varepsilon_{\text{reff}} + 0.300}{\varepsilon_{\text{reff}} - 0.258}\right] * \left[\frac{\frac{w}{h} + 0.262}{\frac{w}{h} + 0.813}\right]$$

5) Step 5:

Deciding actual length of a patch antenna.

$$L_p = L_{eff} - 2\Delta L$$

6) Step 6:

Calculating the ground plane dimensionsL_g and w_g.Length of ground plane is given as:

$$L_g = L + 6h$$

Width of ground plane isgiven as:

$$w_g = w + 6h$$

A picture of an ideal basic square patch antenna is shown below.

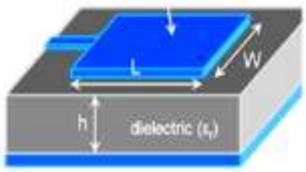


Fig. 1: Ideal square patch antenna.

Design Frequency	Substrate Height	Dielectric Constant	Length Of The Patch	Width Of The Patch	Length Of Ground Plane	Width Of The Ground Plane
2.4GHz	1.56mm	4.4	28mm	40mm	40mm	50mm

Table 1: Designed Parameters

III. GEOMETRY INITIALIZATION AND CUTTING

First a simple patch antenna is designed in mgrid and simulated in ZEELAND IE3D software. Again the simple patch is cut in a gradual manner to form a regular hexagon. And the simulated results are observed. The following geometries will clear the geometry formation.

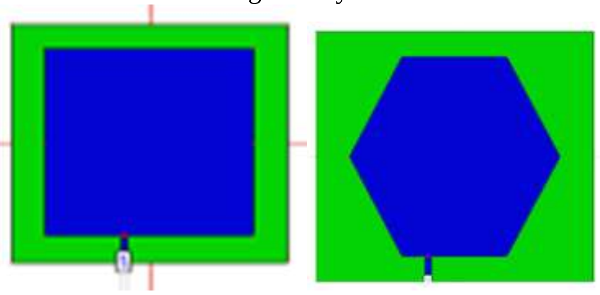


Fig. 2: Initialization of Geometry

IV. SIMULATION OF PROPOSED ANTENNA IN ZELAND IE3D

The designed patch antenna is constructed in ZEELAND IE3D software. The mid length of patch is 28mm and the midwidth of patch is 40mm. the peripheries of simple patch are cut to form a hexagonal structured patch antenna and different iterations [4] are done changing the feed locations. The inset feeding method is used here. A Quarter wave transformer [1] is utilised at the input to match the line impedanceof input feed with antenna input impedance.At last the geometry with the maximum output response is chosen.

V. OPTIMIZATION AND TUNING OF GEOMETRY FOR AUTOMATIC ADJUSTMENT

The proposed geometry is optimised in ZEELAND IE3D software taking a Powel optimiser and the geometry is tuned to arrive at the minimum return loss[16], resulting in the maximum power transfer to antenna thus minimising the reflected waves towards the antenna and hence maximum gain,directivity and bandwidth.Maximum problems of antenna are connected with termination of feed network. Impedance matching accuracy is generally tested in alaboratory room in an absorber box [3]. The tuned geometry issaved and simulated in the ZEELAND IE3D software.

VI. DIFFERENT ITERATIVE STAGES AND DISCUSSION

A novel way of constructing any type of patch antenna is to start constructing it with a simple patch of computed dimension then iteratively cutting the structure to arrive at the desired geometry and satisfactory results.

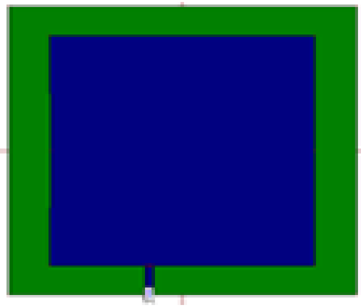


Fig. 3: Square Patch.

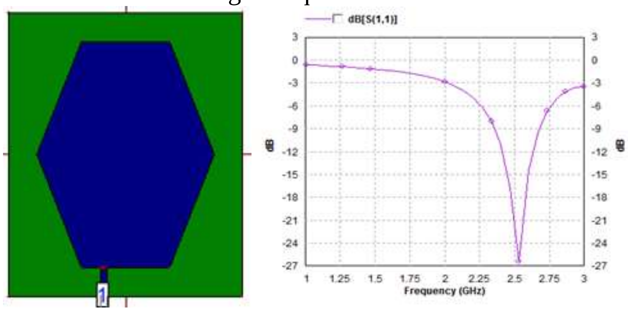


Fig. 3: A Hexagonal Patch and Return Loss

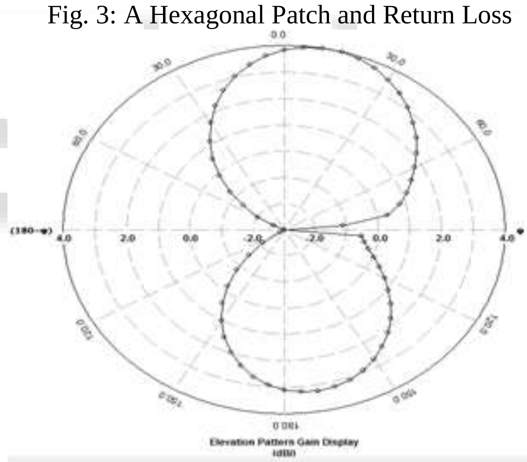


Fig. 4: Elevation Pattern Gain Display of Hexagonal Patch. AtE Theta, Phi=90 Degrees

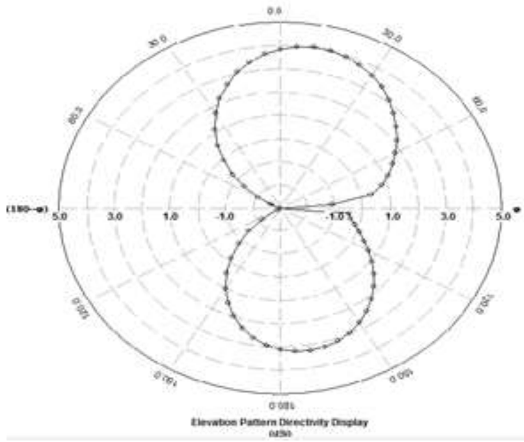


Fig. 5: Elevation Pattern Directivity Display at E Theta, Phi=90 Degrees.

The structure of a hexagonal geometry of patch is as shown in the fig.3. The fractals are introduced in the hexagonal patch [9] at each level and the output is checked. Finally we arrived at the geometry with maximum outputs.

The structure given in iteration 3 is again modified; a $\frac{\lambda}{4}$ transformer is inserted for impedance matching. The characteristic resistance of the transformer is just the geometric average between the original line impedance and also the load seen by the transformer. we remove the metal from antenna each time when we insert a level of fractals, because of this reason the Radiating metal area reduces and there will be relatively less gain for this type of antennas. But it increases the frequency range of the antenna, and also shows frequency results at multiple points. As a result of removal of metal there will be a large impedance mismatch in case of fractal antennae,

The simulation results of all the iteration is discussed below. At every stage a new ring of fractals is inserted [4], simulates and the geometry is optimised [18] for automatic adjustment of dimensions to arrive at best results.

The first iteration is done by itching the triangular self-similar fractals called a Sierpinskigasket fractal [1,15] the return loss plot showing the multi-frequency operation [14]with -27 db return loss at WLAN range.

A. Iteration I

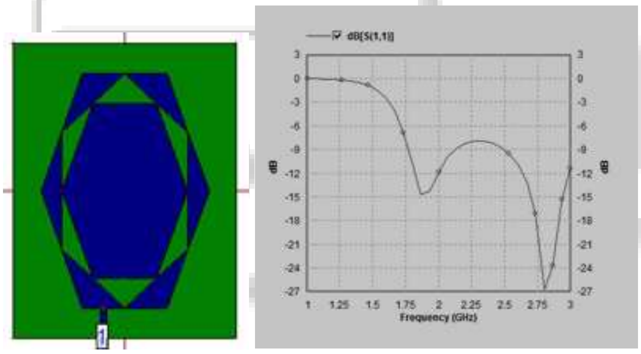


Fig. 6: (a) Geometry and (b) Return Loss of Iteration

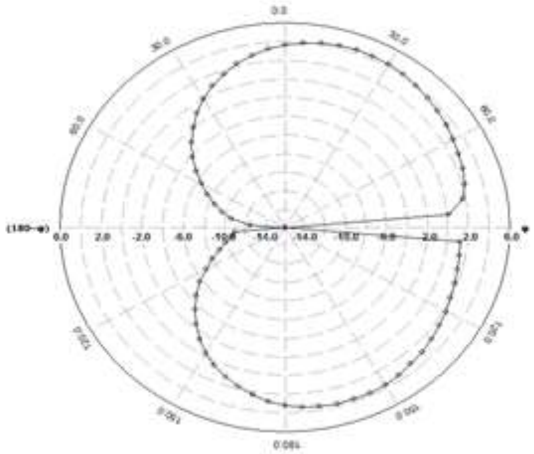


Fig. 6: (c): Elevation Pattern Gain Display E Theta E phi=90

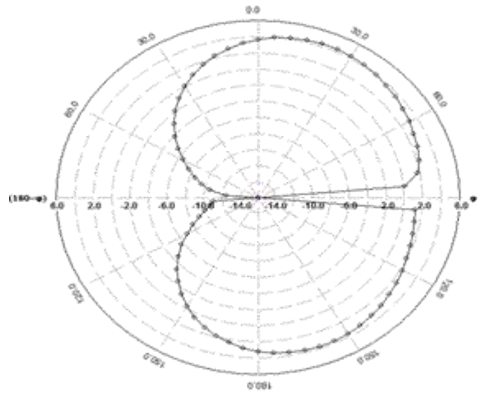


Fig. 6: (d): Elevation Pattern Gain Display E Theta E Phi=90

B. Iteration II

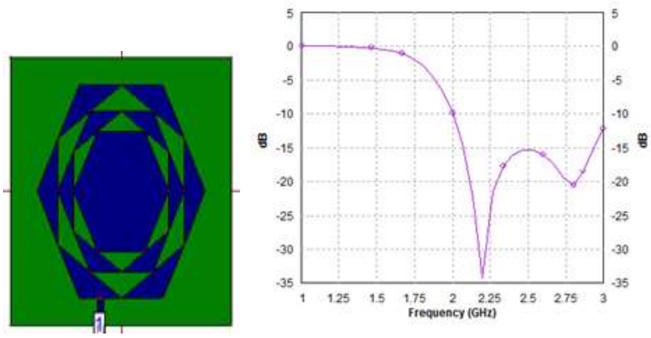


Fig. 7: (a) Geometry and (b) Return Loss of Iteration II

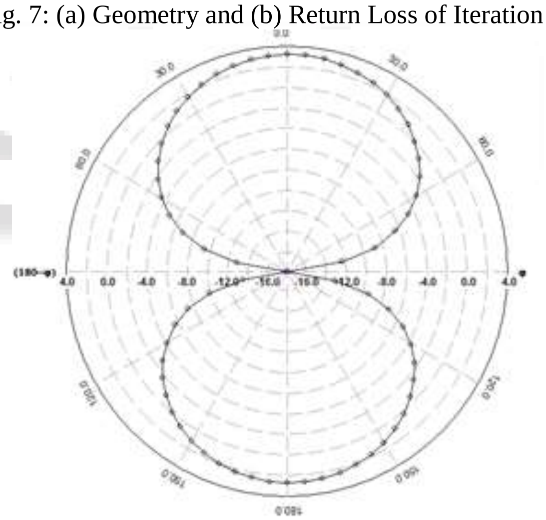


Fig. 7: (c):Elevation Pattern Gain Display E Theta, Phi=0

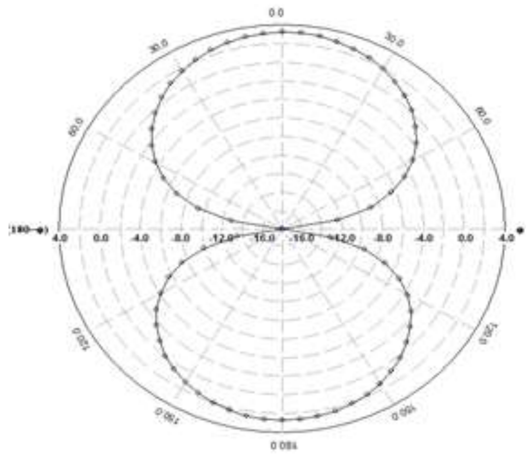


Fig. 8: (d): Elevation Pattern Gain Display E Phi, Phi=0

C. Iteration III

fractal antennae exhibits frequency response at different multiple places , as frequency of operation will vary the length of a quarter wave transformer will no more remains as 1/4 the of wavelength and so it is necessary to overcome for this large mismatch we can use a quarter wave transformers. But asadjust the length of a quarter wave transformer to the actual operating frequency of antenna.one way to-do this is electromagnetic tuning of antenna for automatic adjustment of dimensions. With quarter wave transformer there will be impedance match up to some extent but not perfectly. Because with quarter wave transformer the Real resistive impedance will be matched but not conjugate impedances. In this paper we have tried to match the antenna impedance with line impedance for maximum power transfer by using 1/4 quarter wave transformer and electromagnetic tuning. And we arrived at the final geometry with optimised bandwidth [5, 10].

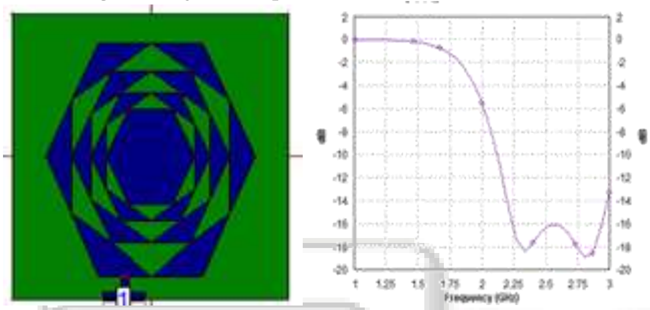


Fig. 9: (a) Geometry and (b) Return Loss of Iteration III

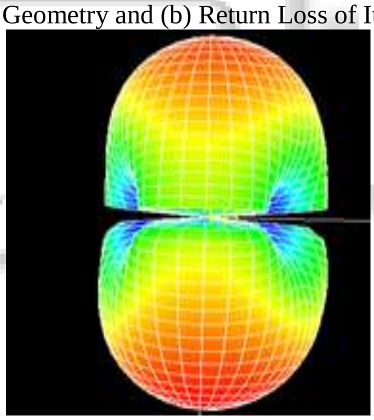


Fig. 5: 3D Pattern of Proposed Antenna

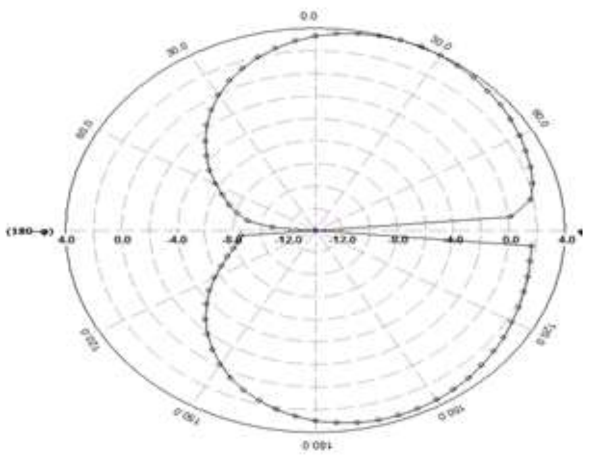


Fig. 7: (c):Elevation Pattern Gain Display E Theta, Phi=90

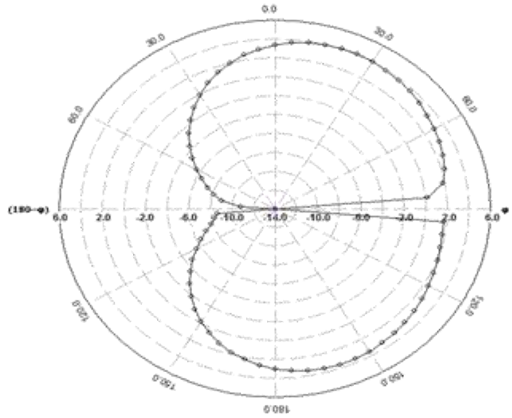


Fig. 7: (c):Elevation pattern directivity display Theta phi=90

Several iterative stages in the construction of the hexagonal fractal antenna are shown in the table below.

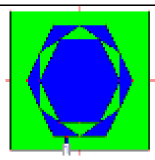
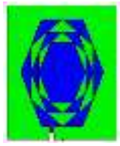
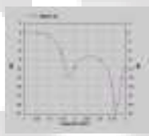
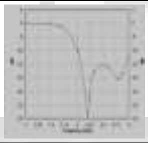
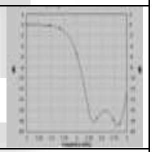
Paramete ↓	Iterations		
	Iteration 1	Iteration 2	Iteration 3
Geometry			
2D Gain Pattern	4.30699	3.1942	4.0035
2D Directiviy Pattern	4.31821	3.19606	4.0603
Return Loss			
Half Power Bandwidth	3.21	5.52	37.5

Table 2: Iterative Structures and Their Results

VII. FABRICATION OF PROPOSED STRUCTURE AND TESTING

The fabrication of proposed structure is done on a substrate of dielectric constant 4.4. A substrate height is chosen according to the design that is 1.56mm. The fabricated structure looks like as shown below.

Fig. 6: Photo of a Proposed Fractal Antenna

50Ω SMA connector is chosen to input as an inset feed [13]. And the structure is tested using an antenna measurement system. The transmitter and receiver are kept at 1meter distance apart. And the far field radiation pattern is as shown below.

There are many environmental factors that will affect the antenna performance like interferences occurring due to cellular phone signals, reflected waves, refracted waves, diffracted waves, and other radiating materials causes the antenna to behave slightly different compare to the simulated results. For this purpose the testing should be carried out in an anechoic chamber but if the antenna is to be operated in real time environment slight interferences from surrounding atmosphere is unavoidable so we tested the antenna using an antenna measurement system which works with existing interferences to give the resulting radiation pattern the results are shown in the following diagram.

VIII. TEST RESULTS

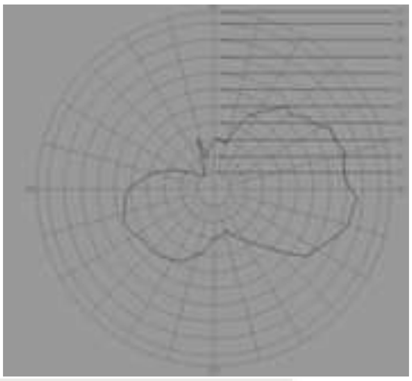


Fig. 7: radiation pattern of proposed antenna

The output values obtained after testing the antenna are listed in the following table

Serial Number	Parameters	Testing Results
1	Gain	3.03446
2	Directivity	3.90313
3	HPBW	97.2

Table 4: Test Results

A. *Comparison between Hardware and Software Results*

Parameters	Simulation Results	Tested Results
Gain	4.0035	3.03446
Directivity	4.0603	3.90313
Bandwidth	37.5	97.2

Table 3: comparison of simulated and test results

IX. CONCLUSIONS

The drawback of low band width of patch antennas is eliminated in this paper by inserting the triangular fractals. Such any types of fractals can be used. If we compare the bandwidth of a simple hexagonal patch and a hexagonal patch with fractals we can observe remarkable increase in the bandwidth. Thus giving wideband response.

In the first iteration we have introduced fractals we found a little bit increase in bandwidth in the second and third iterations we found the remarkable improvement in the bandwidth. But there is slight decrease in the gain because of the removal of metal areasof iterations.

Further improvement can be done by extending the iterations of inserting the fractals; we can also achieve the multi-frequency operation [11-12] with improved bandwidth [8].The same antenna can be designed in mobile frequency range (1.88 GHz) and increased bandwidth can be utilised for mobile harvesting applications.

REFERENCES

[1] C. A. Ballanis, “Antenna Theory and Design”, Jhon Willy and Sons , Inc.,2nd Edition, 1996.
[2] Stutzman warren L &TuicleGray A. “Antenna Theory and Design”, Jhon Willy and Sons Inc., Ny, 1988.
[3] John d. Kraus, Ronald j. marhefka, Ahmad s khan “antennas and wave propagation” tatamcgraw hill education pvt ltd 4th edition
[4] Daotie Li, and Jun-fa Mao, “A Koch-Like Sided Fractal Bow-Tie Dipole Antenna.” IEEE transactions on antennas and propagation, vol. 60, no. 5, may 2012.
[5] Tuhinaoli, Raj Kumar and NagendraKushwaha “On the Design of Elliptical Shape Fractal Antenna for UWB Applications“ 978-1-4799-3267-2/13/$31.00 © 2013 IEEE.
[6] Shrivishal Tripathi, SandeepYadav, VivekVij,Ambesh Dixit, Akhilesh Mohan “a novel multi band notched octagonal shaped fractal uwb antenna” 978-1 -4799-1 607-8/1 3/$31 .00©201 3 I E EE.
[7] M. Naser-Moghadasi, R. A. Sadeghzadeh, T. Sedghi, T. Aribi, and B. S. Virdee, “UWB CPW-Fed Fractal Patch Antenna With Band-Notched Function Employing Folded T-Shaped Element” IEEE antennas and wireless propagation letters, vol. 12, 2013.
[8] Yongjiu Li, Long Li, , IEEE, Yongliang Zhang, and Chunsheng Zhao “Design and Synthesis of Multilayer Frequency Selective Surface Based on Antenna-Filter-Antenna Using Minkowski Fractal Structures” IEEE transactions on antennas and propagation, vol. 63, no. 1, january 2015 133.
[9] Carles Puente Baliarda, ,JordiRomeu, , and Angel Cardama, “The Koch Monopole: A Small Fractal Antenna The Koch Monopole: A Small Fractal Antenna” IEEE transactions on antennas and propagation, vol. 48, no. 11, november 2000.
[10] Satish K. Sharma, ,and LotfollahShafai “Investigations On Miniaturized Endfire VerticallyPolarized Quasi-Fractal Log-PeriodicZigzag Antenna”IEEE transactions on antennas and propagation, vol. 52, no. 8, august 2004 1957.
[11] Carles Puente-Baliarda, ,and Rafael Pous, “Fractal Design Of Multiband And Low Side-Lobe Arrays” IEEE transactions on antennas and propagation, vol. 44, no. 5, may1996.
[12] K. J. Vinoy, Jose K. Abraham, , and Vijay K. Varadan,” On The Relationship Between Fractal Dimension And The Performance Of Multi-Resonant Dipole Antennas Using Koch Curves” IEEE transactions on antennas and propagation, vol. 51, no. 9, september 2003.
[13] C. T. P. Song, Peter S. Hall, , And H. Ghafouri-Shiraz,” Perturbed Sierpinski Multiband Fractal Antenna With Improved Feeding Technique” IEEE transactions on antennas and propagation, vol. 51, no. 5, may 2003-1011.
[14] Sayantan Dhar, Kaushik Patra, RowdraGhatak, , Bhaskar Gupta, , And DipakRanjanPoddar “A Dielectric Resonator-Loaded Minkowski Fractal-Shaped Slot Loop Heptaband Antenna” IEEE

Transactions On Antennas And Propagation, Vol. 63, no. 4, april 2015 1521.
[15] C. T. P. Song, Peter S. Hall, , And H. Ghafouri-Shiraz, "Shorted Fractal Sierpinski Monopole Antenna"IEEE Transactions On Antennas And Propagation, Vol. 52, No. 10, October 2004.
[16] K.H. Sayidmarie1 M.E. Bialkowski "Fractal Unit Cells Of Increased Phasing Range And Low Slopes For Single-Layer Microstrip Reflectarrays"IET Microw. Antennas Propag., 2011, vol. 5, iss. 11, pp. 1371–1379 1371 doi: 10.1049/iet-map.2010.0581.
[17] AbolfazlAzari, Alyani Ismail, AduwatiSali, and FazirulhisyamHashim"A New Super Wideband Fractal Monopole-Dielectric Resonator Antenna" IEEE Antennas and Wireless Propagation Letters, Vol. 12, 2013.
[18] A.S. ABD El-Hameed, D. A. Salem, and E. A. Abdallah E. A. Hashish Crossbar "Fractal Quasi Self-Complementary UWB Antenna"978-1-4799-3540-6/14/$31.00 ©2014 IEEE.