A Novel Design of Fractal Dipole Antenna for Enhanced Ultra Wide bandwidth Wireless Applications.

Sarang Patil
Department of RCVT
Technical University of Sofia
Sofia, Bulgaria
sarang.p86@gmail.com

Prof.Peter Zhelev Petkov
Department of RCVT
Technical University of Sofia
Sofia, Bulgaria
pjpetkov@tu-sofia.bg

Prof.Boncho Georgiev Bonev
Department of RCVT
Technical University of Sofia
Sofia, Bulgaria
bbonev@tu-sofia.bg

Hitesh Singh
Department of RCVT
Technical University of Sofia
Sofia, Bulgaria
hsingh@tu-sofia.bg

***Abstract*— Design of bandwidth-enhanced fractal dipole antenna is proposed in this article. Fractal geometry is implemented on FR-4 substrate along with substrate thickness t = 1.6 mm, Ɛr=4.4. Fractal geometry is preferred for multiband frequency requirement because of its self-similarity properties in its structures, and it exhibits multiband resonance. In this hexagonal shaped fractal dipole antenna design, noticed that no of frequency bands increased along with the betterment in VSWR when the number of iteration is increased. The simulation module provides better results in last iterations; the obtained frequency spectrum is 2.8 GHz to 12.0 GHz range along with characteristics impedance is 51.8 Ω. The antenna is designed and simulated using finite element simulation platform, i.e., HFSS 18.0.**

Keywords—Fractal geometry, Fractal dipole antenna, hexagonal dipole antenna, ultra wide band (UWB).

I. INTRODUCTION

In the digital era, the demand for compact and portable communication systems for the use of the military as well as a commercial application has increased. For the modernization in the field of wireless communication, need of a multiband, wideband and low profile has expected. The headway of wireless communication instruments is accelerating towards the accomplishment of the global society, placing more importance on the antenna technology day by day.

As wireless devices improve in compactness and functions in recent years, the antenna for this equipment has come under the spotlight. Recently impression of antenna transforming an accessory of wireless communication equipment into a key-device for wireless communication.

Mostly all antenna operates for one or two frequency bands, so for covering significant applications in a single device needs to use multiple antennas to cover the desired spectrum but which cause space limiting problem [1], to resolve this space limiting problem having unique solutions, i.e., a Fractal antenna. This single multiband antenna can operate in many frequency bands. The applications of fractal antenna found in various branches of science & engineering described in [2-7], one such area of the fractal are in antenna engineering described in [8-9]. Recently several fractal antennae based on self-similarity and space filling property has been designed [10-12] which leads to miniaturization of an antenna. The design characteristics of the Sierpinski gasket have described in [13].

The primary challenge for wideband operating range antenna design is miniaturization in antenna structure, and it is possible only due to the introducing fractal geometry in dipole antenna. The fractal geometry uses self-similar properties to maximizes the length as to increase the perimeter. As reported several fractal structures such as Koch fractal monopole, Sierpinski carpet fractal monopole and circular patch antenna with pentagonal cut and so many have been introduced [14-18]

The primary aim of this paper is to design a dipole antenna for ultra-broad bandwidth applications with a new set of fractal shapes. In this proposed hexagonal dipole antenna, area and volume of the active patch are miniaturized by the 3rd iterative process, the dimensions of the proposed antenna are 44*30*1.6 mm, The resonant occurs at a frequency band of 2-12GHz.The return loss (S11) is below -10db for desired frequency spectrum. The average radiation efficiency is observed during measurement. The proposed ultra wide bandwidth fractal dipole antenna is designed simulated on HFSS.

II. THEORETICAL BACKGROUND

Ritesh Kumar Saraswat et el [19], proposed a miniaturized UWB dipole antenna, antenna designed by fractal using hexagonal shaped double printed dipole antenna with size miniaturization. This antenna covers frequency spectrum from 2.99 to 10.45GHz for feeding linearly tapered Microstrip line is used instead of the stepped feed line. This antenna provides simulation gain is 3.31dBi and measured 2.06 dBi, so total bandwidth is 110% achieved.

Rajni Bala et el [20], has designed square-shaped fractal dipole antenna for a multiband application. The antenna is designed on FR-4 substrate with thickness h-1.4mm, Ɛr=4.4, using HFSS 13.0.This antenna provides resonance for 2.75GHz, 3.75GHz,4.75GHz, 5.15GHz and 6.15GHz with 4th iterations. Fractal geometry is implemented with square-shaped dipole

XXX-X-XXXX-XXXX-X/XX/$XX.00 ©20XX IEEE

structure. In these design number iterations provide more bandwidth is proved with simulation results.

Y.S.Hu et el [21], proposed novel double-printed trapezoidal pattern dipole for ultra-wideband applications. In this design T-shaped slot is inserted to achieve the band-notched characteristics. This antenna design covers 3.1-10.6GHz band with total dimensions is 48*46*0.8mm and relative permittivity of 2.78.

A.Hirata [22] developed double-sided printed bow-tie antenna for UWB applications, the dimensions of the substrate is 36*36*1.27mm, and relative permittivity of the substrates is 6.15.

Abdelnasser A. Eldek et el [23], proposed wide-band modified printed bow-tie antenna with single and double polarization for C and X band applications, This covers band from 5.5 to 12.5GHz. Overall active antenna area is minimal, and full bandwidth is 91%. The two element array is formed with distance between both is 14mm. This geometry is support for dual polarization with beam width 95^0.

Sarawuth chaimool et el [24] has presented the design of dual-band printed dipole antenna based on fractal geometry. This antenna is fabricated on FR-4 substrate with 4.4 dielectric constant and 1.6 mm of thickness. The length of the dipole is 280mm and width is 5mm. This design reduces size around 42% as compared to a conventional dipole.

H.Kimouche et el [25], reported compact printed dipole antenna for radio frequency identification using fractal geometry. This antenna is proposed with three iterations for small size, these occupy $78*30*1.58mm^3$ of volume and antenna covers the two bands with the frequency of 915MHz and 2.4GHz with overall size is 78mm*30mm*1mm. The obtained simulation peak gain is about 1.11dBi, 1.15dBi for 915MHz and 2.4GHz respectively.

Fei Gao et el [26], has invented short dipole type antenna with enhanced gain. This proposed design provides ultra-wide bandwidth frequency spectrum from 2.12-6GHz. These antennae had two arms on one side of a substrate and two wings on another side.As per the measured results, achieved the gain of 2.2-3.8 dBi across a VSWR =2. The antenna is fabricated on TalconicTLT substrate, dielectric constant er=2.55; measured results show that it can provide 2:8:1 bandwidth and useful level of gain.

III. Fractal Dipole antenna structure

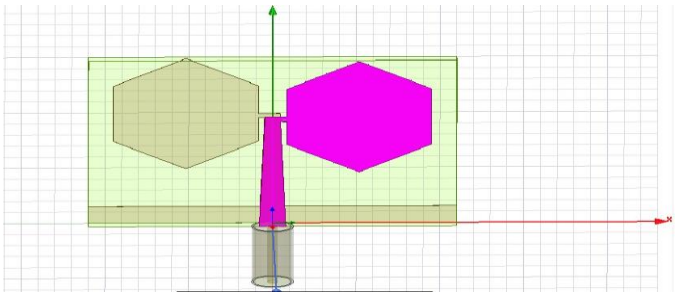


Fig. 1. Proposed wide band hexagonal fractal dipole.

"This material is based upon work supported by the Bulgarian Science Fund under Grant No DN07/19/15.12.2016".

The geometry of fractal-based antenna structure with different iterations is shown in figure 1, 4, 6 and 7. The antenna has been designed using the FR-4 substrate with thickness t =1.6mm and relative permittivity ε_r = 4.4with loss tangent of 0.02.

The hexagonal shape with 3rd iterative fractal geometry is working as the radiator of an antenna structure. The hexagonal fractal geometry is placed on two sides of the FR-4 substrate because of its ultra-wide bandwidth with good radiation characteristics. This improves overall radiation performance of the antenna. To miniaturize active patch area fractalization approach is introduced, it's the success of reducing the overall dimensions and also reduces the active patch are by inserting the 3rd iterated fractal geometry as shown in fig. 6

At the lower side of the antenna, a rectangular shape strip is used as a ground, to feed the antenna, so many ways are present but for a smooth transition between feed line and dipole linearly tapered Microstrip is used.

The design value of dipole with balun is specified in table 1.

TABLE I. Calculable reference dipole antenna design specifications

Sr. No	Antenna design parameters		
	Parameter Symbols	***Description***	***Value***
1	L	Total length of Substrate	44mm
2	W	Total width of Substrate	30mm
3	t	Thickness of Substrate	1.6mm
4	GL	Gap between two symmetrical Patch	7mm
5	Ch	Height of dipole from coaxial top end outer	19.8mm
6	Cr_o	Inner radius of connector	0.68mm
7	Cr_i	Outer radius of connector	2.5mm

IV. Experiment Results and Discussion

A. *Result for Iteration 1*

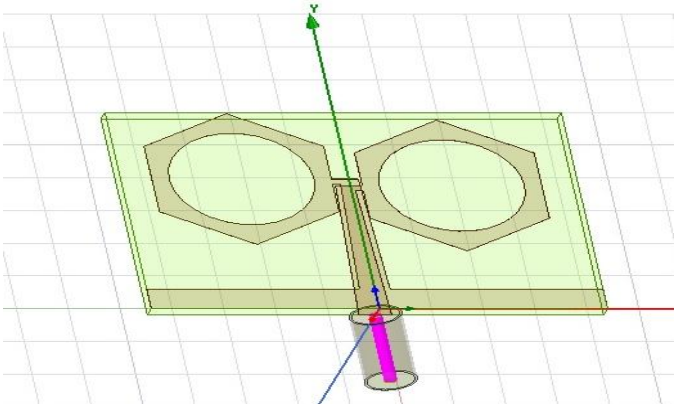


Fig. 2. Hexagonal Fractal Dipole Antenna for Iteration 1

The structure of square fractal dipole antenna with the first iteration has been shown in Figure 2. For the first iteration, only single resonant frequencies were obtained shown in Figure 3

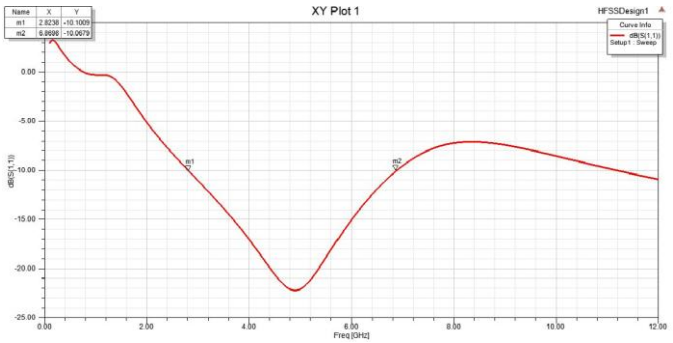


Fig. 3. Return Loss Response of Antenna at Iteration 1

The Table 2 shows that during iteration 1, for obtained resonant frequencies with return loss and VSWR. The antenna starts to resonant from 2.82GHz to 6.86 GHz frequencies.

TABLE 2: SIMULATION RESULT FOR ITERATION 1

Iteration 1		
Resonant Freq (GHz)	Return Loss dB (S11)	VSWR
4.88	-22.20	1.16

B. Result for Iteration 2

The structure of hexagonal fractal dipole antenna with the second iteration is shown in fig. 4.For second iteration the antenna resonates at frequencies 2.2 GHz, 3.14GHz, 5.88GHz, 8.0 GHz and 11.07 GHz as shown in Figure 5. The first frequency does not give good VSWR, but at other frequencies, the value of VSWR is approximately equal to 1 as shown in Table 3.

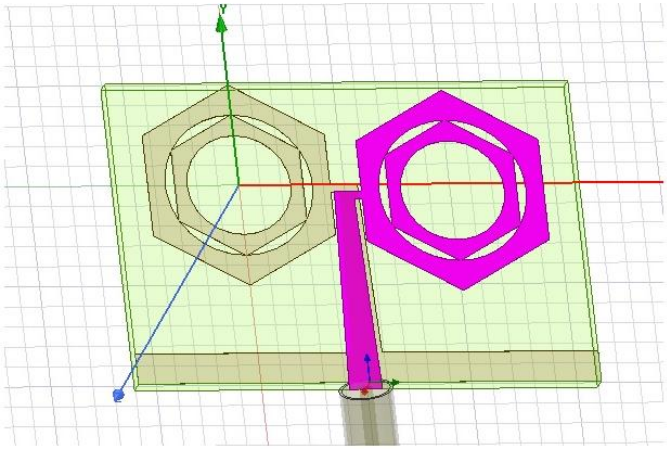


Fig. 4. Hexagonal Fractal Dipole Antenna for Iteration 2

The improvement in bandwidth at second iteration is comparatively lesser than that obtained in the first iteration.The resonating frequencies are increased in the second iteration but getting less bandwidth. The return loss S11 fir second iteration is displayed in fig.5

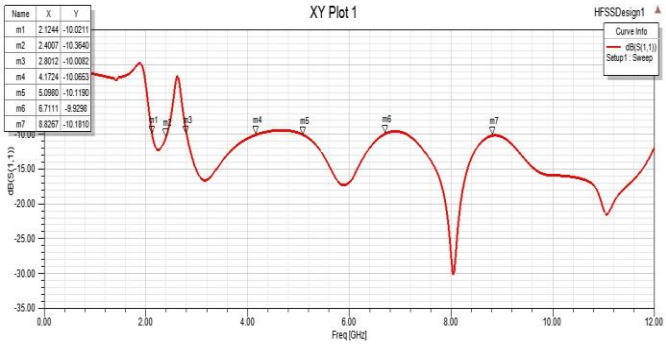


Fig. 5. Return Loss Response of Antenna at Iteration 2

TABLE 3: SIMULATION RESULT FOR ITERATION 2

Iteration 2		
Resonant Freq (GHz)	Return Loss dB (S11)	VSWR
2.2	-12.26	1.6
3.14	-26.59	1.34
5.88	-17.29	1.31
8.0	-30.15	1.06
11.07	-21.44	1.18

C. Result for Iteration 3

The structure of hexagonal fractal dipole antenna with the third iteration is shown in fig. 6 and 7.For the third iteration, the antenna resonates at start frequencies from 2.2 GHz to 12.0 GHz as shown in Figure 9. The first and second iteration does not give good bandwidth but at third iteration frequencies of resonating along its value of VSWR is improved. Resonating frequency band and its VSWR and S11is displayed in table no.4

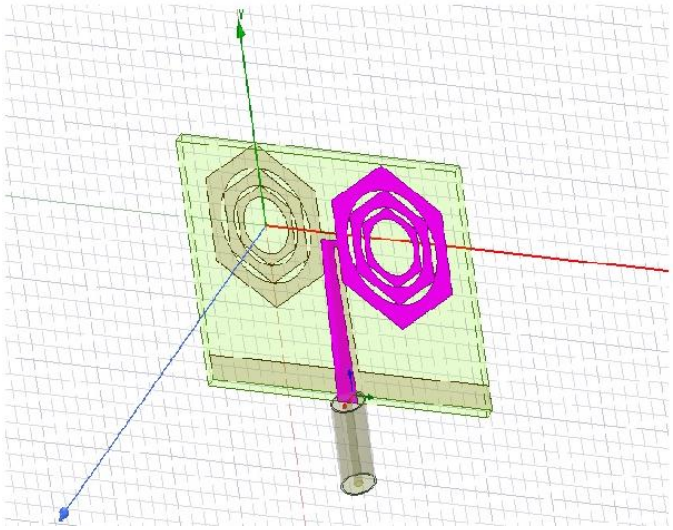


Fig. 6. Hexagonal Fractal Dipole Antenna for Iteration 3

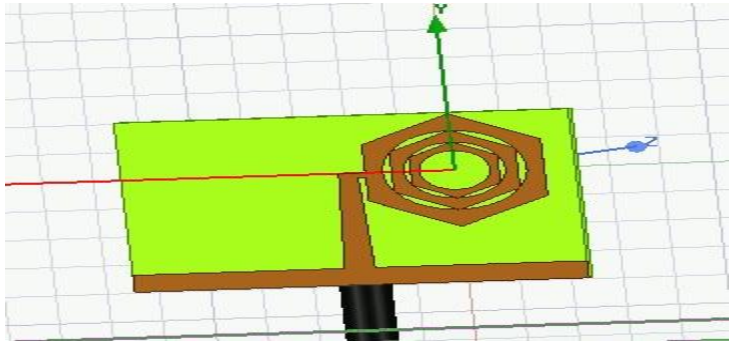


Fig. 7. Ground side of Hexagonal Fractal Dipole Antenna for Iteration 3

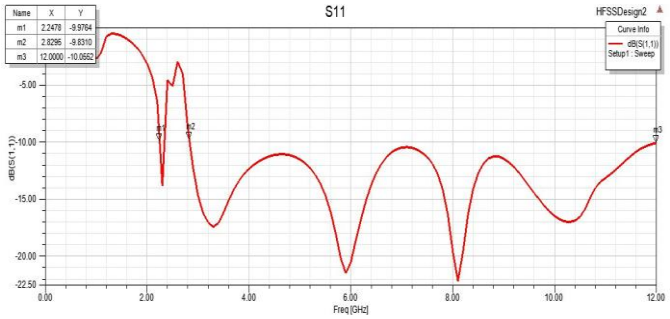


Fig. 8. Return Loss Response of Antenna at Iteration 3

Polar radiation pattern at frequency 3 GHz is shown in figure 9(a), 9(b) and 9(c) respectively, antenna provides very good pattern with maximum gain is 3.58 dB for phi = 310 degree, 15.80 dB for Phi= 0 and 24.8 dB at 90^{o}.3D radiation pattern is shown in figure 10.

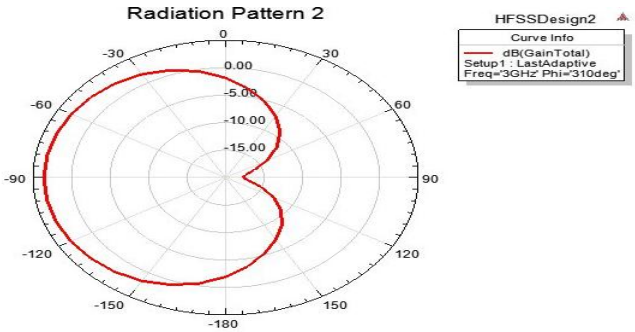


Fig. 9. (a)

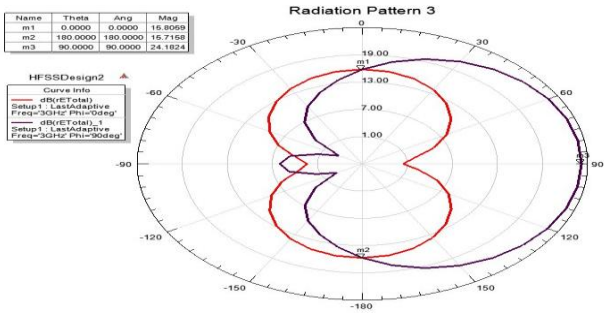


Fig.9 (b)

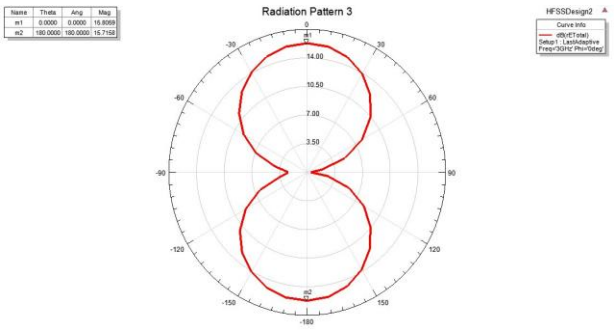


Fig. 9 (c)

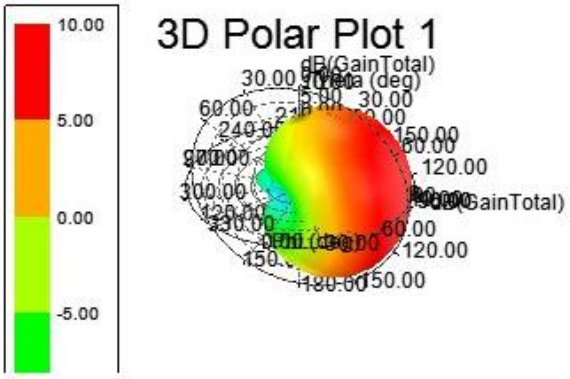


Fig. 10. 3D Polar plot.

Shown in figure 11, the Smith chart of the antenna, characteristics impedance is most crucial aspect of antenna designing, theoretically port and cable impedance was considered as 50Ω, as per the simulation results with Smith chart characteristics impedance is calculate, impedance value is approximately equal to theorothecial consideration, as per the result characteristics impedance is 51.9 at 3.1 GHz frequency.

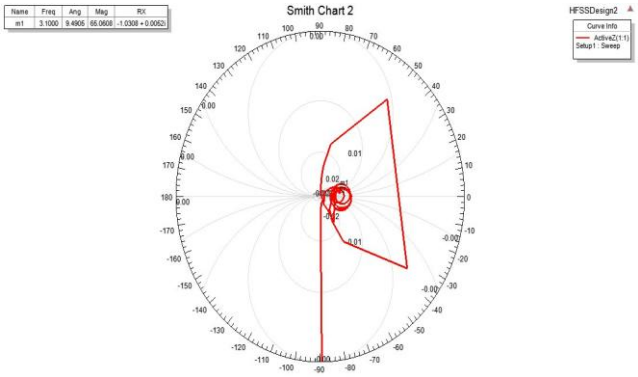


Fig. 11. 3D Smith chart

TABLE 4: SIMULATION RESULT FOR ITERATION 3

Iteration 3		
Resonant Freq (GHz)	Return Loss dB (S11)	VSWR
2.3	-13.82	1.51
3.3	-17.39	1.31
5.9	-21.43	1.18
8.1	-22.11	1.17
10.3	-16.95	1.33

V. CONCLUSION

A compact hexagonal fractal shaped dipole antenna has been designed for ultra bandwidth applications; it covers the frequencies from 2.8GHz to 12.0 GHz, In this design Microstrip feed line is used along with linear tapered, because of that good impedance matching is done and achieved characteristics impedance is 51.8. This design also provides good maximum gain and Omni-directional recitation pattern. The important noticeable point regarding this design is that, with increasing the number of iterations, the bandwidth of the antenna is increased along with improvement in VSWR and return loss S11.

Fractal dipole prototype antenna is designed and simulated using HFSS 18.0

REFERENCES

[1] Mr.sarang m. Patil, prof.Peter z. Petkov, and prof.boncho g. Bonev, "A review on recent antenna designing techniques For electromagnetic compatibility(EMC) test, "International Scientific Conference on Engineering, Technologies and Systems TECHSYS 2017, Technical University – Sofia, Plovdiv branch, May 2017

[2] Brendt Wohlberg, Gerhard de Jager,"A Review of the Fractal Image Coding Literature," IEEE Transactions on Image Processing, Vol. 8, No. 12, December 1999.

[3] Alexandru Bogdan,"The Fractal Pyramid with application to Image coding," IEEE Conf. ICASSP-95.May 1995.

[4] Akhlesh Lakhtaiua, Neal S. Holter, Vuay K.Varadan, "Self-Similarity in Diffraction by A Self-Similar Fractal Screen,"IEEE Transactions on Antennas Propagation, Vol. Ap-35,No. 2, February 1987.

[5] Aleksandr Nikolaevich Bogolyubov, Artem Aleksandrovich Koblikov, Natalia Evgenievna Shapkina,"Fractal Electrodynamics: Analysis and Synthesis of Fractal Antenna Radiation Pattern," Progress in Electromagnetics Research Symposium Proceedings, Moscow, Russia, August 2009.

[6] George Palasantzas,"Roughness spectrum and surface width of self-affine fractal surfaces via the K correlation model,"Physical review, Vol. 48, No. 19, November 1993.

[7] Yongping Chen, Chengbin Zhang, Mingsheng Shi, G. P.Peterson,"Role of surface roughness characterized by fractal geometry on laminar flow in microchannels," Physical Review E 80, 026301 _2009.

[8] Douglas H. Werner, Suman Gangul,"An Overview of Fractal Antenna Engineering Research," IEEE Antennas and Propagation Magazine, Vol. 45, No. 1, 2003.

[9] N. Cohen,"Fractal antenna applications in wireless telecommunications" , in Professional Program Proc. Of Electronics Industries Forum of New England, 1997, IEEE, pp. 43-49, 1997

[10] C. Puente, J. Romeu, R. Pous, Ramis, A. Hijazo,"Small but long Koch fractal monopole," Electronics Letters 8th January 1998 Vol. 34, No. 7

[11] A. Aggarwal, M. V. Kartikeyan,"Pythagoras Tree: A Fractal Patch Antenna for Multi-Frequency and Ultra-Wide Bandwidth operations," Progress in Electromagnetics Research C, Vol. 16, 25-35, 2010.

[12] Raj Kumar, P. Malathi,"On the Design of Wheel Shape Fractal Antenna," International Journal of Recent Trends in Engineering, Vol 2, No. 6, November 2009.

[13] Kuem C. Hwang,"A Modified Sierpinski Fractal Antenna for Multiband Application," IEEE Antennas and Wireless Propagation Letters, Vol. 6, 2007.

[14] D. Li, F.S. Zhang, and Z.-N. Zhao, "UWB antenna design using patch antenna with Koch fractal boundary," *In: International* Conference on Microwave and Millimetre Wave Technology *(ICMIMT)*, Shenzhen, China, 2012, pp. 1–3.

[15] R. Kumar and P.N. Chaubey, "On the design of inscribed pentagonal cut fractal antenna for ultra wide band applications," *Microwave Opt Technol Lett* 53 (2011), 2828–2830.

[16] S. Singhal, T. Goel, and A.K. Singh, "Inner tapered tree shaped fractal antenna for UWB applications," *Microwave Opt Technol Lett* 57 (2015), 559–567.

[17] Ritesh K. Saraswat, and Mithilesh Kumar, "Miniaturized Slotted Ground UWB Antenna Loaded with Metamaterial for WLAN and WiMAX Applications," Progress In Electromagnetics Research B, Vol. 65, 65–80, 2016.

[18] Ritesh K. Saraswat, and Mithilesh Kumar, "A Frequency Band Reconfigurable UWB Antenna for High Gain Applications," Progress In Electromagnetics Research B, Vol. 64, 29–45, 2015.

[19] Ritesh Kumar Saraswat and Chaitanya Shakdwipeeya, "A Miniaturized UWB Dipole Antenna Design by using Fractal Geometry," International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 6 Issue 02, February-2017.

[20] Rajni Bala and Dr. Jaswinder Singh, " A New Square Shaped Fractal Dipole Antenna for Multiband Application," International Journal of Computer Science And Technology, Vol. 3, Iss ue 4, Oct-Dec 2012.

[21] Y.-S. Hu, M. Li, G.-P. Gao, J.-S. Zhang, and M.-K. Yang, "A double-printed trapezoidal patch dipole antenna for uwb applications with the band-notched characteristic," Progress In Electromagnetics Research, PIER 103, 259{269, 2010.

[22] A. Hirata, " Double-sided printed bow-tie antenna with notch filter for UWB applications," J. of Electromagn. Waves and Appl., Vol. 23, 247–253, 2009.

[23] Abdelnasser a. Eldek, atef z. Elsherbeni and charles e. Smith, " wide-band modified printed bow-tie antenna with single and dual polarization for *c*– and *x*-band applications," IEEE transactions on antennas and propagation, vol. 53, no. 9, September 2005

[24] Sarawuth Chaimool and Prayoot Akkaraekthalin, "A Compact Dual-band Printed Dipole Antenna Based on Fractal Feature in ISM Band"

[25] H. Kimouche and h. Zemmour, "A compact fractal dipole antenna for 915mhz and 2.4ghz RFID tag applications", Progress In Electromagnetics Research Letters, Vol. 26, 105{114, 2011.

[26] Fei Gao, Fushun Zhang, Lu Lu, Tao Ni, and Yongchang Jiao, "Low-Profile Dipole Antenna With Enhanced Impedance and Gain Performance for Wideband Wireless Applications," IEEE antennas and wireless propagation letters, vol. 12, 2013.