A Novel Design of Compact 2.5GHz Fractal Antennas

Nehya Chaudhary[1], Sonika Sindhiya[2] and **Dr. K.K. Tripathi[3]**
Department of Electronics and Communication Engineering, Ajay Kumar Garg Engineering College,
27 Km Stone, NH-24, Ghaziabad 201009 UP India
n.choudhary.ec@gmail.com[1], sonikasindhiya@gmail.com[2], kamlakanttripathi@gmail.com[3]

Abstract -- **Small physical size and multi-band capability are important features in the design of multiband antennas. Fractals have unique properties such as self-similarity and space-filling. The use of fractal geometry in antenna design provides a good method for achieving the desired miniaturization and multi-band properties. In this communication, a multi-band antenna based on a new fractal geometry is presented, where the radiating patch is designed in fractal configuration, namely , crown and slotted octagonal shape respectively. The design is simulated through IE3D software. Proposed shapes are suitable for 2.5 GHz WLAN and Bluetooth (IEEE-802.11b/g standard), 3.5 GHz WIMAX (IEEE-802.11y standard). The results show that the proposed slotted orthogonal Fractal Antenna can be used for 0.1GHz – 5 GHz frequency range more effectively.**

Keywords: Fractal antenna, Multiband antenna, Micro-strip antenna.

I. INTRODUCTION

WIRELESS communication plays a major role in our daily existence, with antennas being of continuously increasing significance. Microstrip antennas are a type of antennas that is popular with wireless communication equipment because of its outstanding physical properties, such as light weight, low profile, low production cost, conformability, reproducibility, reliability, and ease in fabrication and integration with solid state devices and wireless technology equipments [1]. However, the size of a conventional microstrip antenna is typically large when designed in microwave frequency regime causing problems for mounting on transmitter/receiver and repeater systems. These antenna types also have limitations in terms of their narrow bandwidth, low gain, and weak radiating patterns. The gain reduction is caused by the overall reduction in the antenna size. It can also be attributed to the substrate characteristics which may lead to surface wave excitation and hence a reduction in gain. Therefore, it is challenging to design microstrip antennas to have better radiating properties and in the same time have a smaller size. There are several techniques used to decrease the size of the radiating patch which leads to a smaller antenna size, such as: using super-substrates to generate high dielectric constant [2], incorporating a shorting pin in a microstrip patch [3], using short circuit [4], cutting slots in radiating patch [5-7], by partially filled high permittivity substrate [8], or by fractal microstrip patch configuration [1,9-10]. Still, it remains quite difficult to miniaturize microstrip antennas since these efforts generally conflict with electrical limitations or cost considerations [1]. This paper proposes a size reduction technique for microstrip antennas by using a novel fractal radiating patch, yet improving the radiating properties, including returning loss, VSWR. The fractal patches are designed in crown and octagonal shape in order to improve the spreading fields.

II. ANTENNA DESIGN

For microstrip antennas, the width (w) and length (L) of the radiating patch and the effective permittivity of the microstrip structure (ε_e) which support the operation at the required resonant frequency (or the free-space wavelength (λ_0) can be designed as follows, using the formulas given in [12].

$$w = \frac{c}{2 f_0 \sqrt{\frac{(\varepsilon_r + 1)}{2}}} \tag{1}$$

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

$$L_{eff} = \frac{c}{2 f_0 \sqrt{\xi_{eff}}} \tag{3}$$

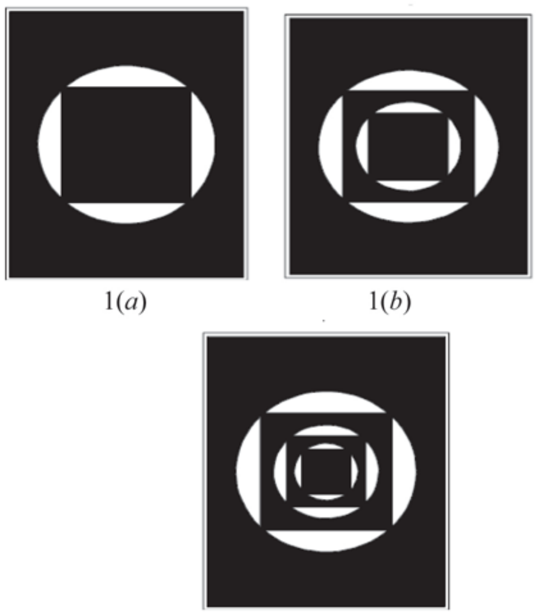
$$\Delta L = 0.412h \frac{(\varepsilon_{eff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{w}{h} + 0.8\right)} \tag{4}$$

$$L = L_{eff} - 2\Delta L \tag{5}$$

A conventional microstrip antenna, having square radiating patch, with patch dimensions L = 32mm w = 32 mm, designed to operate at 2.5 GHz, the standard frequency for wireless LAN. A printed circuit board (PCB) with the permittivity å$_r$ = 4.4 (compared to the commercial PCB, FR-4) is used as the dielectric substrate placed on top of the group plane to form the microstrip antenna. The thickness of the substrate is 1.6 mm.

III. FRACTAL ANTENNA

Crown shape fractal antenna: Figure 1(*a*) shows the starting shape of the fractal antenna, and the modified crown square fractal antenna is represented in figure 1 *(a)* 1 *(b)* and 1 (*c*) respectively.

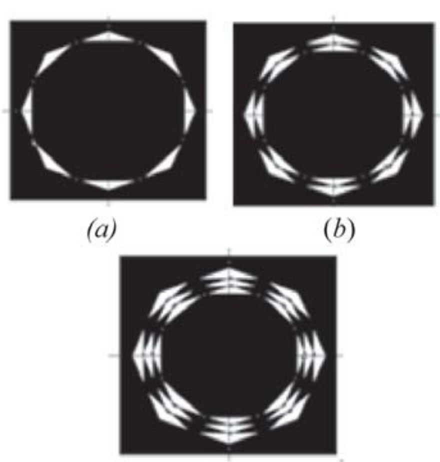


1(*a*) 1(*b*)

1(*c*)

Figure 1. Iterations of the proposed fractal geometry (crown shape).

In the geometric construction (Fig. 1), there are three shapes: first fractal shape starts with a crown, called the base shape, which is shown in Fig. 1*a* (first iteration). By adding another crown inside the base shape, the first version of the new fractal geometry, shown in Fig. 1*b* (second iteration) is created. The process is repeated in the generation of the second iteration which is also shown in Fig. 1*c* (third iteration).



(a) *(b)*

(c)

Figure 2. Iterations of the proposed fractal geometry.

Slotted Octagonal fractal antenna: In the geometric construction of Fig 2, there are three shapes. The first fractal shape starts with an octagonal, called the base shape, which is shown in Fig. 2*a* (first iteration). By adding another octagon inside the base shape, the first version of the new fractal geometry, shown in Fig. 2*b* (second Iteration) is created. The process is repeated in the generation of the second iteration which is also shown in Fig. 2*c* (third iteration).

In this communication, the third iteration of Fig. 2*c* of the octagonal fractal geometry is considered since higher order iterations do not make significant effect on antenna properties.

IV. SIMULATION RESULTS

For this antenna, with patch dimensions $L = 32$mm $w = 32$ mm, designed to operate at 2.5 GHz, the standard frequency for wireless LAN. A printed circuit board (PCB) with the relative permittivity $\varepsilon_r = 4.4$ (compared to the commercial PCB, FR-4) is used as the dielectric substrate placed on top of the group plane form the microstrip antenna. The thickness of the substrate is 1.6 mm.

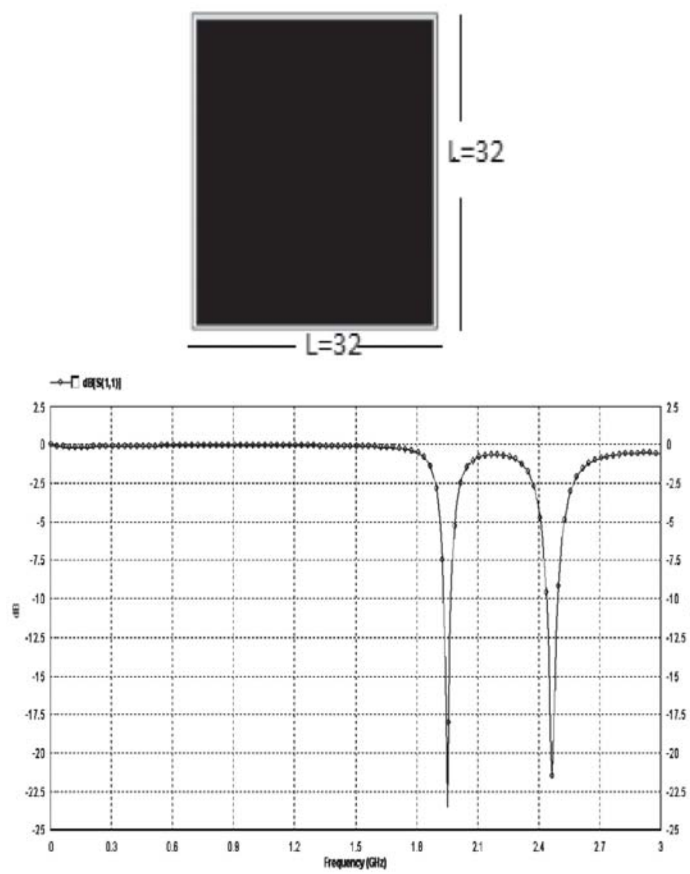


Figure 3. Geometry of a conventional square microstrip patch (Basic shape) L = W = 32 mm and it return loss.

Return loss for third iteration

After completion of simulation setup IE3D provides various antenna parameters through its easily accessible in user graphics format for analysis point of view. Figure 2 represents the simulated curve of Return Loss parameter (in dB). As far a freq. to be resonant freq. it must follow the rule of $S_{11} < -10$ dB. On this rule our proposed Crown geometry antenna provides multiple frequency sample point where $S_{11} < -10$ .The same is also verified by VSWR curve as in figure 3 (VSWR < 2).

Figure 4. Crown antenna structure after third iteration.

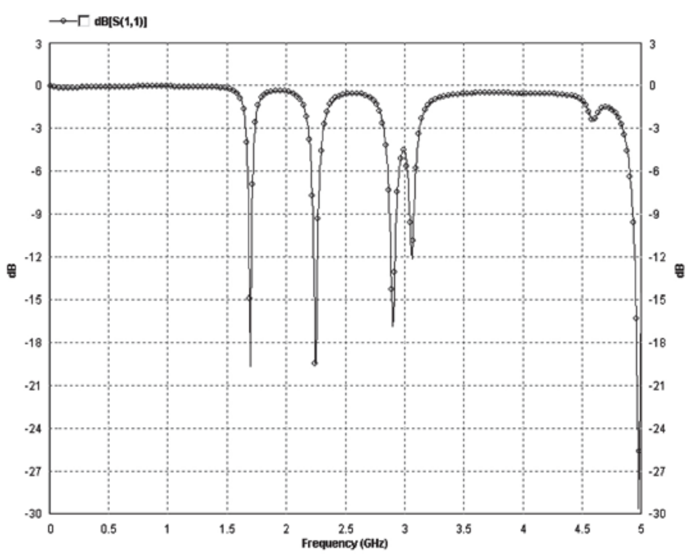


Figure 5. Return Loss curve: for crown shaped fractal antenna geometry for 3rd iteration.

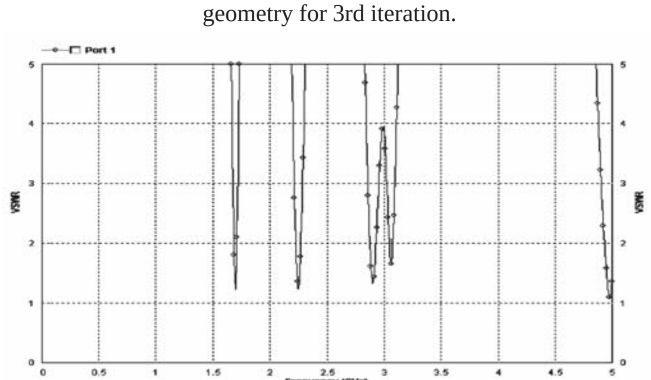


Figure 6. VSWR curve: for Crown shaped fractal antenna geometry for 3rd iteration.

TABLE 1- COMPARATIVE ANALYSIS OF RETURN LOSS FOR ALL ITERATION OF CROWN SHAPED ANTENNA

Freq.	S_{11}-3rd-Iter.	Freq.	S_{11}-2nd-Iter.	Freq.	S_{11}-1st-Iter.	Freq.	Basic shape
1.7	-20	1.7	-19	1.7	-14	1.9	-26
2.3	-20	2.3	-18	2.3	-15	2.4	-22
2.9	-17	2.9	-15	2.9	-13		
3.1	-12	3.1	-10				
5	-30	5	-27				

A Crown Shaped fractal antenna for wireless application has been proposed, constructed, and tested. The proposed antenna has simple iterative geometry. As the proposed antenna design provides adoptability of various frequencies ranging from 0.006 GHz up to 5 GHz.

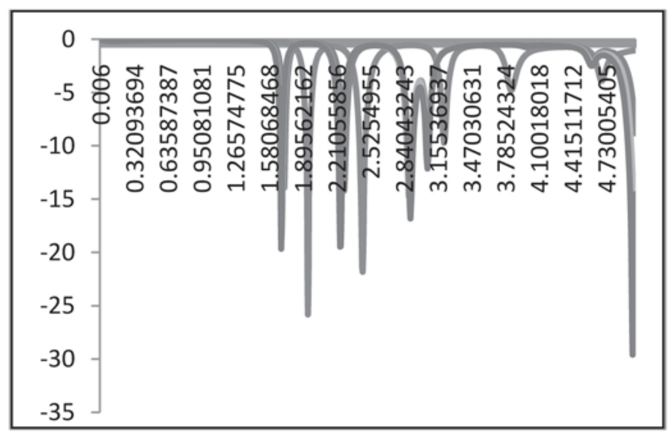


Figure 7. Comparison of Return Loss curve for all iterations.

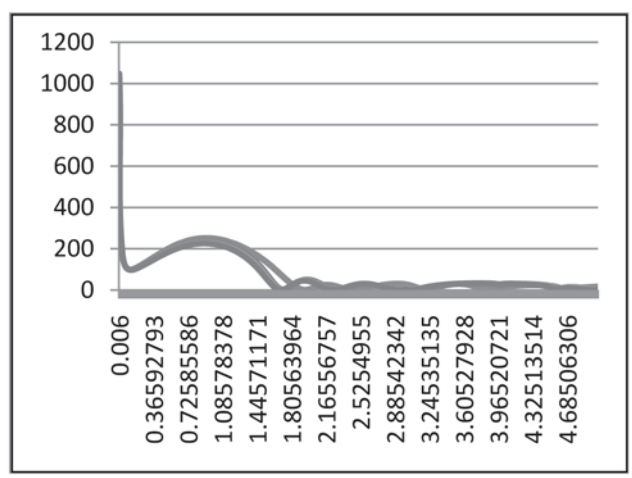


Figure 8. Comparison of VSWR curve for all iterations.

For this antenna, the length of each side of octagon is 2 cm. with patch dimensions L = 32mm W = 32 mm, designed to operate at 2.5 GHz, the standard frequency for wireless LAN. A printed circuit board (PCB) with the relative permittivity $å_r = 4.4$ (compared to the commercial PCB, FR-4) is used as the dielectric substrate placed on top of the group plane form the microstrip antenna. The thickness of the substrate is 1.6 mm.

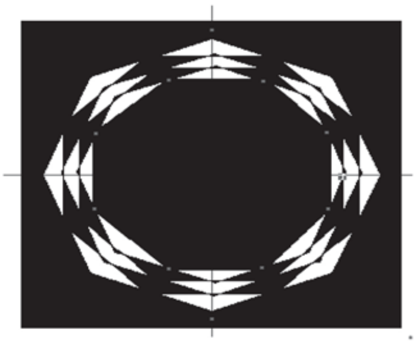


Figure 9. Octagonal antenna structure after third iteration.

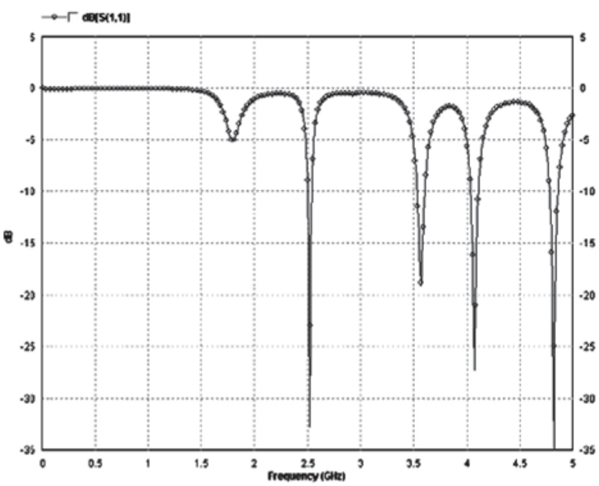


Figure 10. The simulated S_{11} for the third iteration.

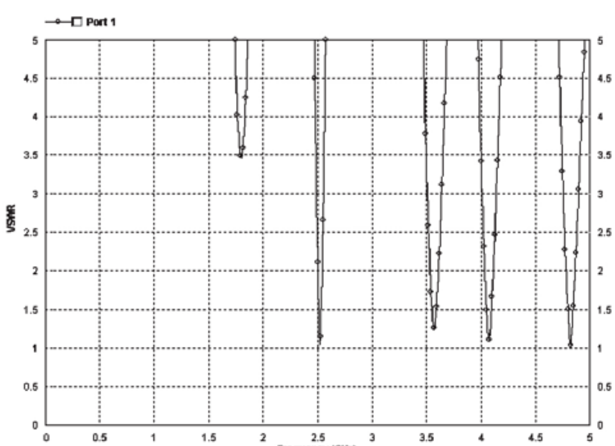


Figure 11. VSWR curve: for Slotted octagonal fractal antenna geometry for 3rd iteration.

After completion of simulation setup IE3D provides various antenna parameters through its easily accessible in user graphics format for analysis point of view. Figure 5 represents the simulated curve of Return Loss parameter (in dB). As far a freq. to be resonant freq, it must follow the rule of $S_{11} < -10$ dB. On this rule our proposed Slotted Octagonal geometry antenna provides multiple frequency sample point where $S_{11} < -10$ .The same is also verified by VSWR curve in VSWR < 2).

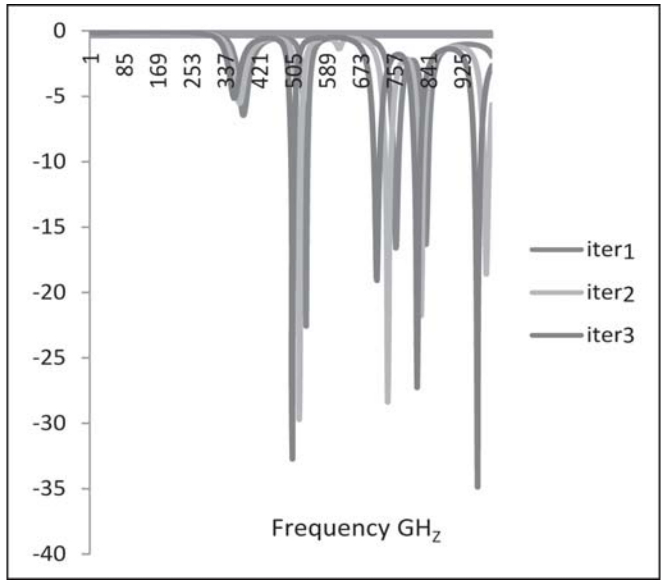


Figure 12. The Return loss curve for all iterations.

TABLE 2- COMPARATIVE ANALYSIS OF RETURN LOSS FOR ALL ITERATION OF OCTAGONAL SHAPED ANTENNA

Freq.	S_{11}-3rd-Iter.	Freq.	S_{11}-2nd-Iter.	Freq.	S_{11}-1st-Iter.
2.5	-33	2.6	-30	2.7	-22.5
3.6	-19	3.7	-28.5	3.7	-17
4.1	-27	4.1	-22	4.2	-17
4.8	-35	4.9	-12		

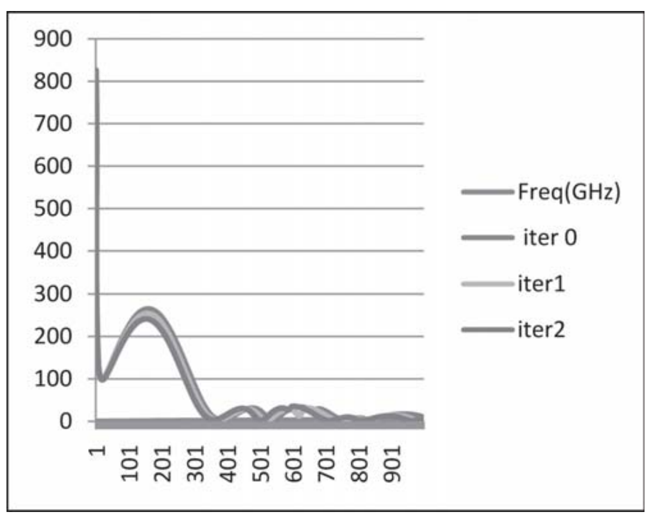


Figure 13. The VSWR curve for all iterations.

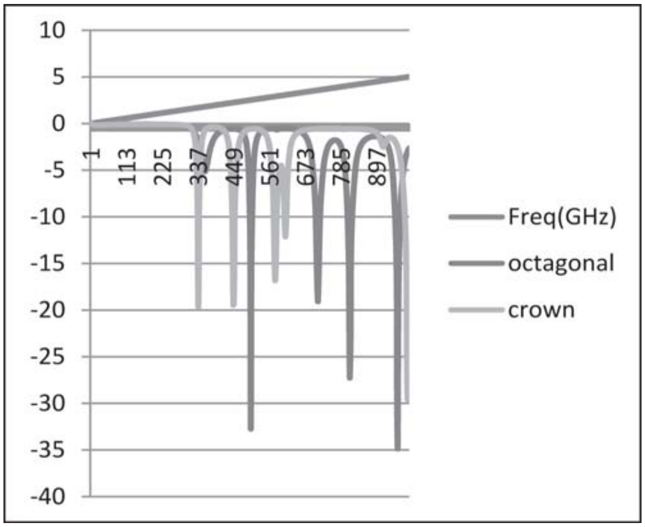


Figure 14. Comparison of Return loss for last iteration.

V. CONCLUSION

The crown and octagonal Fractal Antennas are observed to possess mulitiband behavior [1, 2,11], and it is possible to change the frequency separation as we want. It is easy to forecast the antenna's frequency; therefore, the Octagonal Fractal Antenna seems to be an interesting configuration for use in applications where multiband operation with a small and changed frequency separation is required. Same frequency slotted octagonal fractal antenna offers better result than crown shape fractal antenna.

When we need more than two resonant frequencies, we can use more iterations and use the same way to coordinate every square's circumcircle (R) to get the wanted frequencies.

VI. ACKNOWLEDGEMENT

Authors are grateful to Ajay Kumar Garg Engineering College for providing facilities.

VII. REFERENCES

[1]. K. J. Falconer, *Fractal Geometry: Mathematical Foundations and Applications*. 1990 John Wiley & Sons, Inc. New York.

[2]. J. P. Gianvittorio, , Fractals, MEMS, and FSS electromagnetic devices miniaturization and multiple resonances," *Dissertation*, 2003, University of California, Los Angeles.

[3]. J. P. Gianvittorio, Y. Rahmat-Sammi, Fractal Antenna: A novel miniaturization Technique and Application, *IEEE Transactions on Antenna & Propagation*, Vol.44, No. 1, 2002, pp20-36.

[4]. B.J. Baron Rager, Fractal Landscape 280294 available at http://perso.club-internet.fu/regor/F- render/ index.html.

[5]. P.T. Selvan and S. Raghavan, A Novel Compact CPW-Fed Octagon Shaped Slot Antenna for WLAN Application, *WirelessCommunication, Vehicular Technology, Information Theory and Aerospace & Electronic System Technology*, 2011, pp.1-4.

[6]. Wojciech J. Krzysztofik, , "Modified Sierpinski Fractal Monopole for ISM-Bands Handset Applications", *IEEE Transactions on Antenna and Propagation*, Vol. 57, No. 3, March 2009.

[7]. Aidin Mehdipour, Iosif D. Rosca and Abdel-Razik Sebak, Full-Composite Fractal Antenna Using Carbon Nanotubes for Multiband Wireless Applications, *IEEE Antennas and Wireless Propagation,* Vol.9, 2010.

[8]. Mahdi Naghshvarian Jahromi and Abolfazl Falahati, Bandwidth and Impedance-Matching Enhancement of Fractal Monopole Antennas Using Compact Grounded Coplanar *Waveguide, IEEE Transactions on Antennas and Propagation*, Vol. 59, No.7, 2011.

[9]. Amanpreet Kaur, Nitin Saluja and J S Ubhi, "Design Of Sierpinski Gasket Multiband Fractal Antenna For Wireless Applications", *IOSR Journal of Electronics and Communication Engineering (IOSRJECE)* ISSN : 2278-2834 Volume 2, Issue 3 , July 2012 pp 05-06 www.iosrjournals.org.

[10]. Abolfazl Azari, , Slotted Octagonal Fractal Antenna, *IEEE Transactions on Antennas and Propagation,* Vol. 59, No. 5, May 2011.

[11]. Sachin Chauhan, A Design Of Crown-Shape Fractal Patch Antenna", *International Journal of Engineering and Innovative Technology (IJEIT)* Volume 2, No. 3, 2012.

[12]. A. Balanis Constantine *Antenna Theory, Analysis and Design* (Second Edition), 1938 John Wiley & Sons, Inc.

Nehya Choudhary (b. December 1986) obtained B. Tech in Electronics and communication engineering from S.D. College of Engineering & Technology, Muzaffarnagar in 2008. Her areas of interest are Mobile communication engineering. Currently, pursuing M. Tech at A. K. Garg Engineering College, Ghaziabad.

Sonika Sindhiya (b. November 1987) obtained B. Tech in Electronics and communication engineering from Sunderdeep Engineering College, Ghaziabad in 2010. Did B. Tech project on Laser based communication system. Her areas of interest are Switching theory, and communication engineering. Currently, pursuing M. Tech at A. K. Garg Engineering College, Ghaziabad.

Dr. K.K. Tripathi has vast experience of 48 years in field of technical education, in teaching, guiding research and administration. He was founder Professor and HOD of Electronics Engineering Deptt. of H.B.T.I. Kanpur. After completing 36 years of distinguished service at H.B.T.I. Kanpur, he joined premier technical institutions A.K.G.E.C., R.K.G.I.T., I.M.S. and H.R.I.T. Ghaziabad. His area of research interest includes Embedded Systems, Wireless Optical Communication. His current area of interest is I.C.T. specially Adhoc and Sensor networks. Presently he is Professor Emeritus in ECE Deptt. of A.K.G.E.C. Ghaziabad.