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# Design and development of Modified Hybrid Fractal Antennas for wireless applications

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**Abstract**:
This paper presents the three modified designs of Hybrid Fractal Antenna (HFA) which are named as Ant-1, Ant-2 and Ant-3. Ant-1 is designed by integrating Minkowski and Sierpinski geometries, Ant-2 is designed by fusing Koch and Minkowski geometries over Microstrip Patch Antenna (MPA) Where as Ant-3 is the combination of Koch and Koch geometries over MPA. A U-shaped ground plane has been introduced in the geometry of Ant-1 to attain the desired results. Similarly, L-shaped ground plane has been introduced in the geometries of Ant-2 and Ant-3. The FR4 glass epoxy substrate has been used to design the proposed antennas with $\varepsilon_r = 4.4$ and h (thickness) = 1.6 mm. The proposed antennas have been designed and simulated by using software HFSS version 13.0.

Ant-1 operates at three distinguished frequency bands 3.21 GHz, 5.46 GHz and 7.64 GHz and exhibits reflection coefficients -13.44 dB, -17.06 dB and -10.5 dB with corresponding gain 1.25 dB, 1.25 dB and 4.47 dB. Ant-2 exhibits pentavalent bands with resonant frequencies 2.36 GHz, 3.49 GHz, 5.79 GHz, 8.21 GHz and 9.97 GHz and corresponding reflection coefficients -26.02 dB, - 18 dB, -14.07 dB, -12.06 dB and -15.79 dB and gain 2.03 dB, 3.44 dB, 5.39 dB, 5.39 dB and 6.49 dB. Ant-3 also reports pentavalent bands with resonant frequencies 1.67 GHz, 2.69 GHz, 3.46 GHz, 5.69 GHz and 8.51 GHz and corresponding reflection coefficients -18.98 dB, - 32.37 dB, -13.5 dB, -13.15 dB and -12.7 dB and respective gain 1.8 dB, 1.73 dB, 3.37 dB, 5.44 dB and 7.52 dB. Ant-2 and Ant-3 also reports the omnidireational gain at specified frequencies. The proposed antennas are useful in the wireless communication like Bluetooth, WiMax, WLAN, Point-to-Point high speed communication and Satellite applications

**Keywords**: Microstrip Patch Antenna (MPA), Hybrid Fractal Antenna (HFA), Koch, Sierpinski, Minkowski

## 1. Introduction:

We all are living in the technological era, an era where everything is based on technology. Technology is improving day-by-day, rather advancements in the technology is never ending process. Latest technology is used to communicate the messages either in a form of speech, text, images, audio or video. To accomplish this, an organized and advanced communication system is required, and the significant part of the communication system is **Antenna**. An Antenna may be a metallic device used to transfer the signals between one end to another [1]. So, a planned management is essential for transferring the signals between different ends, and which is incomplete without the proper antenna designing. This has attracted various researchers to carry out the research in this field. As per the need of the hour, distinguished researchers have focused to design high performance compact sized antennas [2]. Though antennas have covered the long journey from dipole to fractals but MPAs and Fractal antennas almost fulfill the aforementioned requirements [3]. In 1975, B. Mandelbort was the first to introduce the fractal geometry [4]. In this paper, we are focusing about fusion of fractal antennas. To know this, first of all, we must get familiar with fractals, a Latin word which means "Broken" [5]. Even fractals can be generated by using recursive complex procedures [6]. Fractal geometries have created the revolution in the field of antennas because of its self similarity and space filling properties. The self similarity of fractal shapes can be obtained by taking the infinite iterations with the use of Multiple Reduction Copy Machine algorithm [7]. The space filling property is useful in the reduction of antenna size [8]. Fractal geometries have been fused together to improve the performance of the designed antennas, and named as HFA [9]. These fractal geometries are helpful to attain the multiband characteristics [10-12]. In this paper, we have used the integration of various fractal geometries, explained in Section 2, to get the improved performance of proposed antennas.

**2. Antenna Design and Configuration:**

The proposed antennas have been designed by combining the Sierpinski, Minkowski and Koch fractal Geometries. The Sierpinski Carpet geometry is obtained from the rectangular patch. Further, 1/3$^{rd}$ sized rectangle is subtracted from the centre of the main rectangle, and this procedure is repeated various times to achieve the desired geometry [13]. The Koch curve is the simplest fractal. It can be formed by dividing the straight line into three equal parts. The middle part of the straight line is being bent into the triangular shape keeping flare angle $60^0$ [14]. This procedure is also repeated various times to attain the desired geometry. The Koch curve fractal dimension (D) and curve length (l) is given as [15-16]:

$$D = \frac{\log(N)}{\log(1/r)}, \quad r \rightarrow 0 \qquad \text{and} \qquad l = h\left(\frac{N}{r}\right)^n$$

Minkowski curve is generated by using Iterated Function System (IFS). The procedure is somehow similar to Koch geometry but only difference is that in Minkowski geometry the rectangles are used instead of triangles. The length of the rectangle is $L/3$ and height is $Lr/3$, where L denotes length of original antenna and r denotes ratio coefficient [17].

The initial design of proposed antennas is being initiated with rectangular microstrip patch as shown in Figure 1 but Minkowski and Sierpinski geometries is used for Ant-1, Koch – Minkowski geometries used for Ant-2, whereas Koch geometry is used for Ant-3.

The Low cost FR4 Epoxy is used as a Substrate material with design specifications as: 3.2 GHz resonant frequency, 4.4 relative permittivity and 1.6 mm thickness. The dimensions of the patch are computed as [18-19]:

$$W_p = \frac{c}{2f_r\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

The Effective Dielectric Constant, Extended incremental length and Effective Length are calculated from the equations (2), (3) and (4), given below:

$$\varepsilon_{reff} = \left[\frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\right]\frac{1}{\sqrt{1+12h/W_p}},\ 1 < \varepsilon_{reff} < \varepsilon_r \tag{2}$$

$$\Delta L = h * 0.412\left[\frac{(\varepsilon_{reff}+0.3)\left(\frac{W_p}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W_p}{h}+0.8\right)}\right] \tag{3}$$

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \tag{4}$$

The Actual Length of patch is as: $$L_P = L_{eff} + \Delta L \tag{5}$$

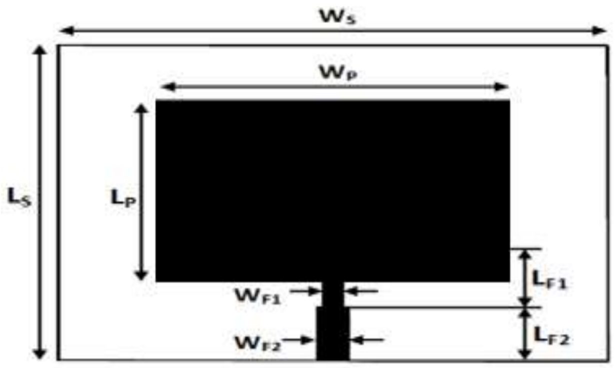


**Figure 1: Basic Geometry of proposed Antennas**

The parametric values used in the patch are $L_S$ = 38.92 mm, $W_S$ = 45 mm, $L_{F1}$= 7.54 mm, $W_{F1}$ = 2 mm, $L_{F2}$ = 6mm and $W_{F2}$ = 3mm.

### 2.1 Ant-1 (Modified HFA using Minkowski and Sierpinski geometries)

In this design, Minkowski and Sierpinski geometries are combined together in rectangular MPA and named as Ant-1, shown in Figure 2. U-Shaped ground plane has been introduced to improve the performance of the antenna and to achieve the desired frequency band at 3.2 GHz. The parametric values of the dimensions of Ant-1 are: $Z_X$ = 8 mm, $Z_Y$ = 25 mm, $P_X$ = 45 mm and $P_Y$ = 10 mm.

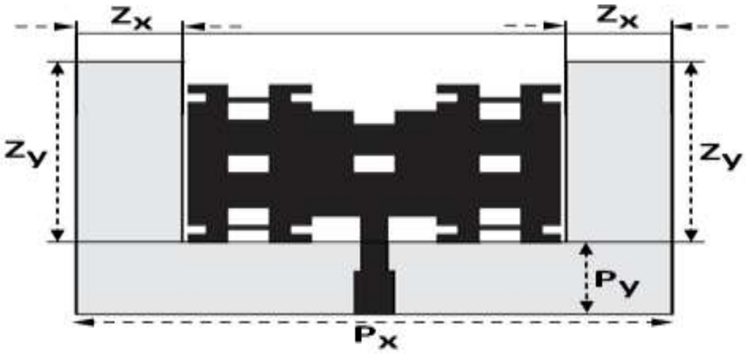


**Figure 2: Geometry of Ant1 with U-shaped ground plane**

### 2.2 Ant-2 (Modified MPA with Koch-Minkowski Hybrid Slot)

In this proposed design, Koch and Minkowski geometries are fused together, and hybrid fractal slot is evolved. This hybrid fractal slot is applied in rectangular MPA and demonstrated as Ant-2, shown in Figure 3. L-Shaped ground plane has also been introduced to improve the performance of the antenna as well as to attain the desired frequency band at 3.2 GHz. The parametric values used to the vertical side of L-Shaped ground plane are $V_X$ = 6 mm and $V_Y$ = 30.92 mm.

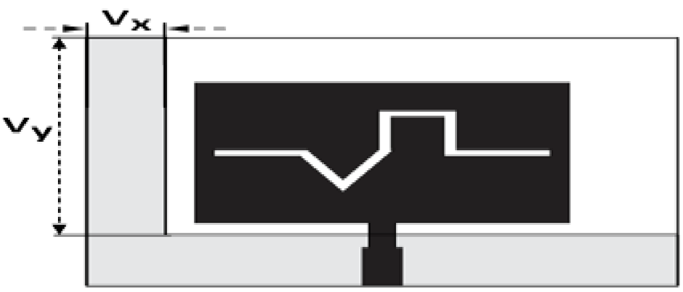


**Figure 3: Geometry of Ant-2 with L-shaped ground plane**

### 2.3 Ant-3 (Modified MPA with Koch-Koch Hybrid Slot)

In this proposed design, Koch and Minkowski geometries are fused together, and hybrid fractal slot is formed. This hybrid fractal slot is removed from rectangular MPA and termed as Ant-3, shown in Figure 4. L-Shaped ground plane is also being introduced to enhance the performance of the antenna as well as to achieve the desired frequency band at 3.2 GHz. The parametric values used to the vertical side of L-Shaped ground plane are $W_X$ = 5 mm and $W_Y$ = 30.92 mm.

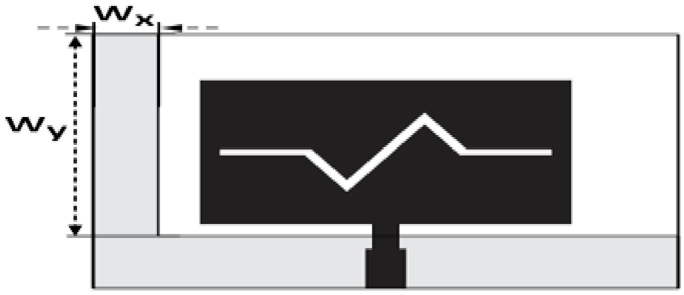


**Figure 4: Geometry of Ant-3 with L-shaped ground plane**

## 2. Results and Discussions

In this section, the simulated proposed antennas are analyzed to achieve the desired simulated results. The performance parameters which are depicted in this section are Reflection Coefficient, frequency range and gain. In order to obtain the desired results, the ground plane has been introduced in the geometries of antennas. The simulated results of Ant1, Ant-2 and Ant-3 have been explained in the sub-sections 3.1, 3.2 and 3.3.

### 3.1 Results and Discussions of Ant-1

U-shaped ground plane is introduced in the geometry of Ant-1, and graph of Reflection Coefficient verses frequency is shown in Figure 5.

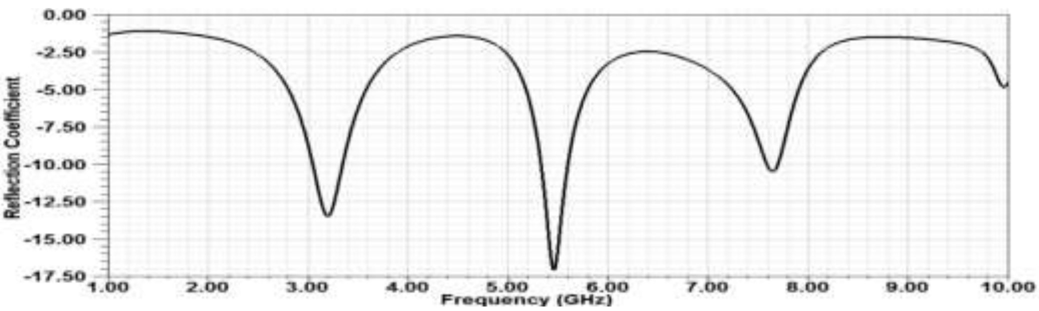


**Figure 5: Reflection coefficient v/s frequency curve of proposed Ant-1**

It can be premeditated from the Figure 5 that Ant-1 covers the designed frequency 3.2 GHz and resonates at three unique frequencies 3.21 GHz, 5.46 GHz and 7.64 GHz with reflection coefficient -13.44 dB, -17.06 dB and -10.5 dB respectively. The resonant frequencies, reflection coefficient and frequency range have been delineated in Table 1.

**Table 1: Results of proposed Ant-1**

| Resonant Frequency (GHz) | Reflection Coefficient (dB) | Frequency Range (GHz) |
|---|---|---|

| | | |
|---|---|---|
| 3.21 | -13.44 | 3.05 – 3.35 |
| 5.46 | -17.06 | 5.33 – 5.60 |
| 7.64 | -10.50 | 7.59 – 7.69 |

The gain plot of Ant-1 is depicted in figure 6, and it can be illustrated from the plot that gain is 1.25 dB at 3.21 GHz, 1.25 dB at 5.46 GHz and 4.47 dB at 7.64 GHz.

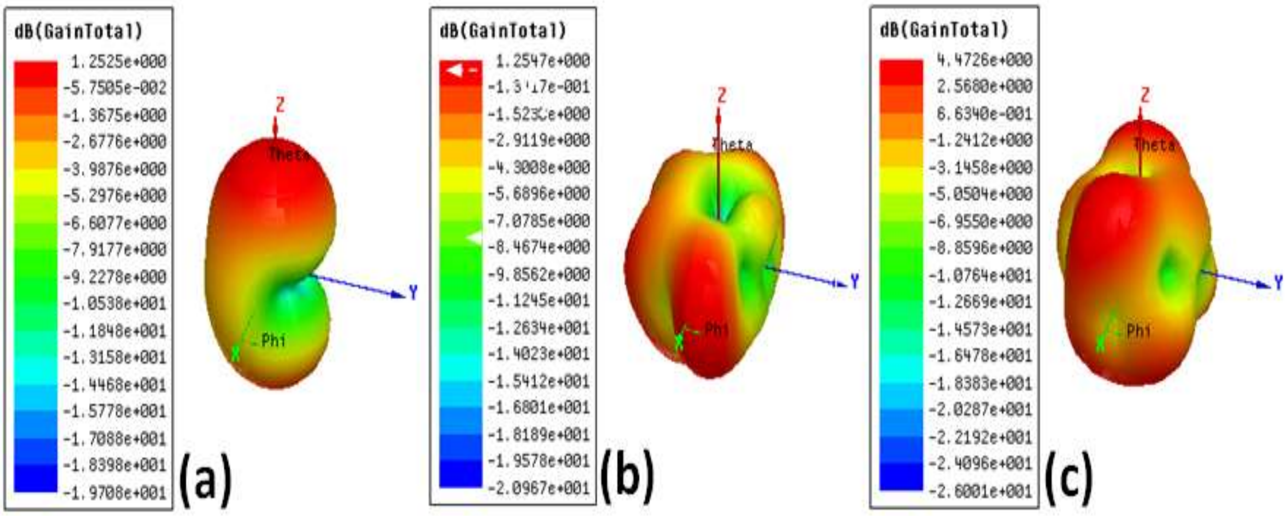


**Figure 6: Gain plot of Ant-1**

### 3.2 Results and Discussions of Ant-2

L-shaped ground plane is introduced in the geometry of Ant-2, and graph of Reflection Coefficient verses frequency is shown in Figure 7.

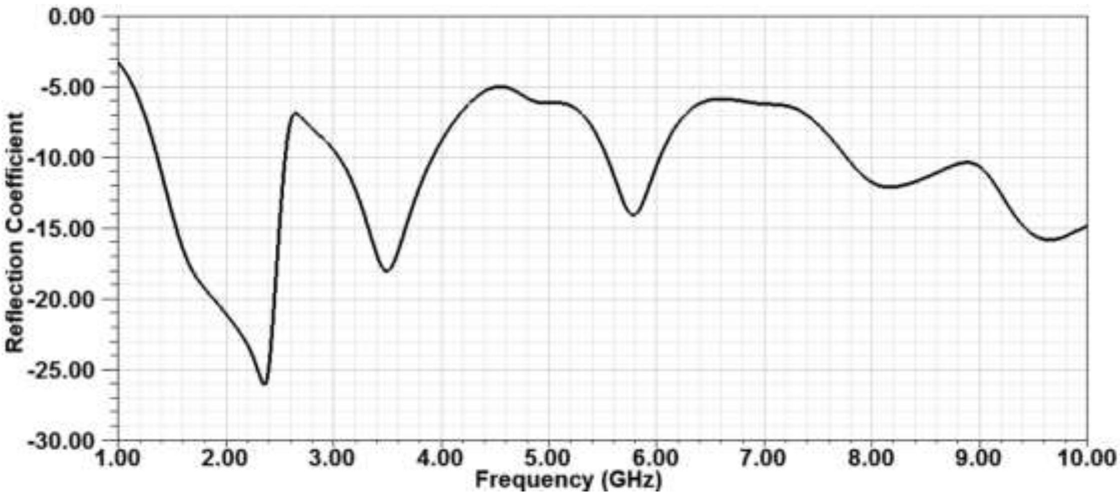


**Figure 7: Reflection coefficient v/s frequency curve of proposed Ant-2**

It can be contemplated from the Figure 7 that Ant-2 works at five different operating frequencies 2.36 GHz, 3.49 GHz, 5.79 GHz, 8.21 GHz and 9.97 GHz and exhibits reflection coefficients -26.02 dB, - 18 dB, -14.07

dB, -12.06 dB and -15.79 dB respectively. The resonant frequencies, reflection coefficient and frequency range have been delineated in Table 2.

**Table 2: Results of proposed Ant-2**

| Resonant Frequency (GHz) | Return Loss (dB) | Frequency Range (GHz) |
|---|---|---|
| 2.36 | -26.02 | 1.374 – 2.555 |
| 3.49 | -18.00 | 3.060 – 3.920 |
| 5.79 | -14.07 | 5.545 – 6.030 |
| 8.21 | -12.06 | 7.770 – 10.000 |
| 9.97 | -15.79 | |

The gain plot of Ant-2 is reported in figure 8, and can be observed that Ant-2 exhibits the gain 2.03 dB at 2.36 GHz, 3.44 dB at 3.49 GHz, 5.39 dB at 5.79 GHz, 5.39 dB at 8.21 GHz and 6.49 dB at 9.97 dB. It also has been observed from the figure 8(a) that proposed Ant-1 exhibits almost omnidirectional gain at 2.36 GHz.

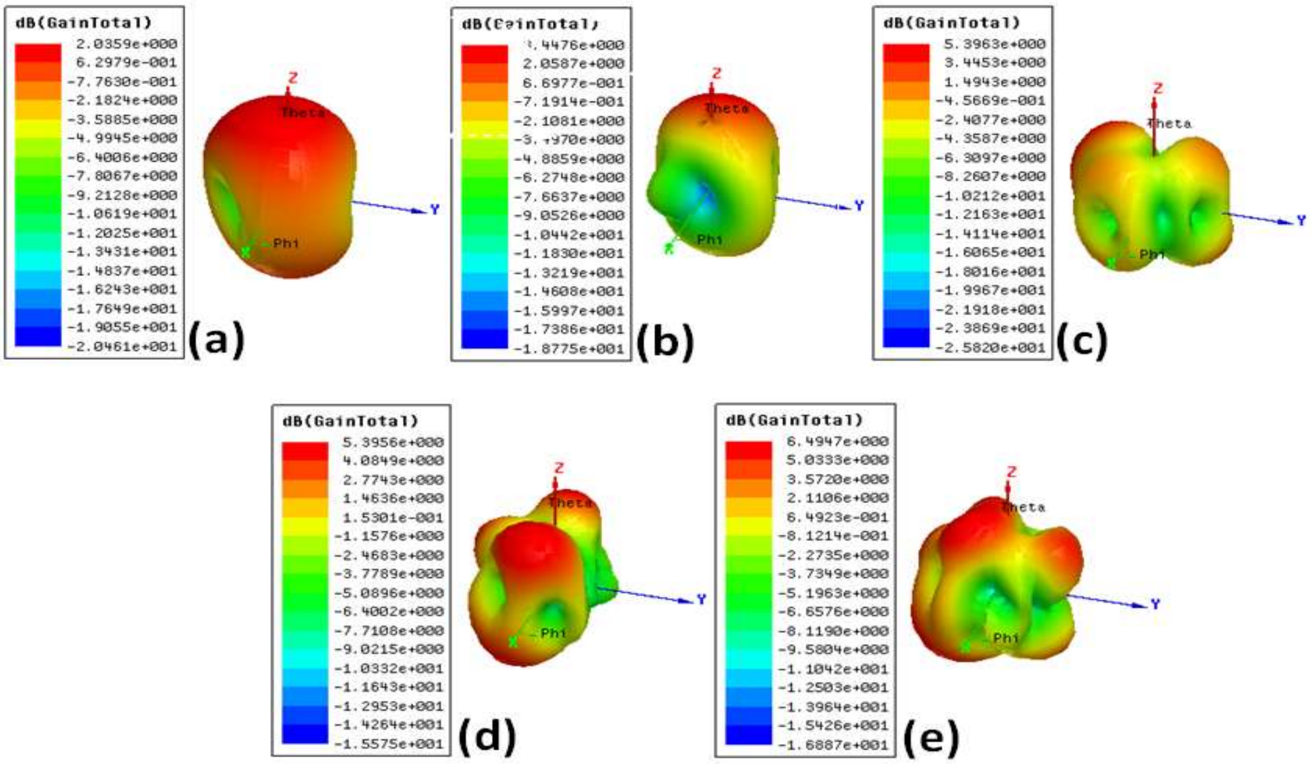


**Figure 8: Gain plot of Ant-2**

### 3.3 Results and Discussions of Ant-3

L-shaped ground plane is introduced in the geometry of Ant-3, and graph of Reflection Coefficient verses frequency is shown in Figure 9.

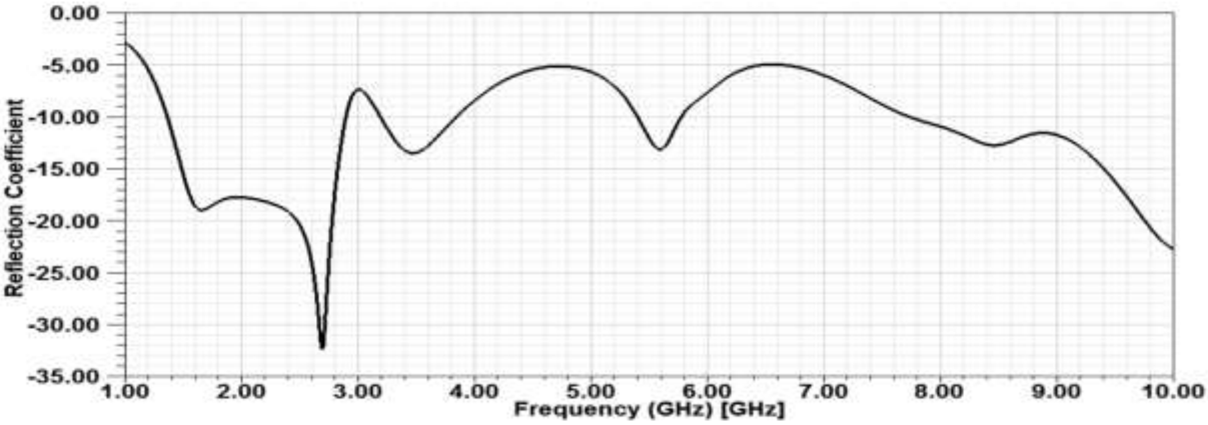


**Figure 9: Reflection coefficient v/s frequency curve of proposed Ant-3**

It can be noticed from the Figure 9 that Ant-3 also exhibits five different operating frequencies 2.36 GHz, 3.49 GHz, 5.79 GHz, 8.21 GHz and 9.97 GHz and corresponding reflection coefficients -26.02 dB, - 18 dB, -14.07 dB, -12.06 dB and -15.79 dB . The resonant frequencies, reflection coefficient and frequency range have been delineated in Table 3.

**Table 3: Results of proposed Ant-3**

| Resonant Frequency (GHz) | Return Loss (dB) | Frequency Range (GHz) |
|---|---|---|
| 1.67 | -18.98 | 1.365 – 2.895 |
| 2.69 | -32.37 | |
| 3.46 | -13.50 | 3.192 – 3.840 |
| 5.69 | -13.15 | 5.40 – 5.77 |
| 8.51 | -12.70 | 7.75 – 10.00 |

It can be explained from the Figure 9 that Ant-3 exhibits five different operating frequencies 2.36 GHz, 3.49 GHz, 5.79 GHz, 8.21 GHz and 9.97 GHz and corresponding reflection coefficients -26.02 dB, -18 dB, -14.07 dB, -12.06 dB and -15.79 dB . The resonant frequencies, reflection coefficient and frequency range have been delineated in Table 4. The gain plot of Ant-3 is shown in Figure 10, and gain can be depicted as 1.8 dB at 1.67 GHz, 1.73 dB at 2.69 GHz, 3.37 dB at 3.46 GHz, 5.44 dB at 5.69 GHz and 7.32 dB at 8.51 GHz.

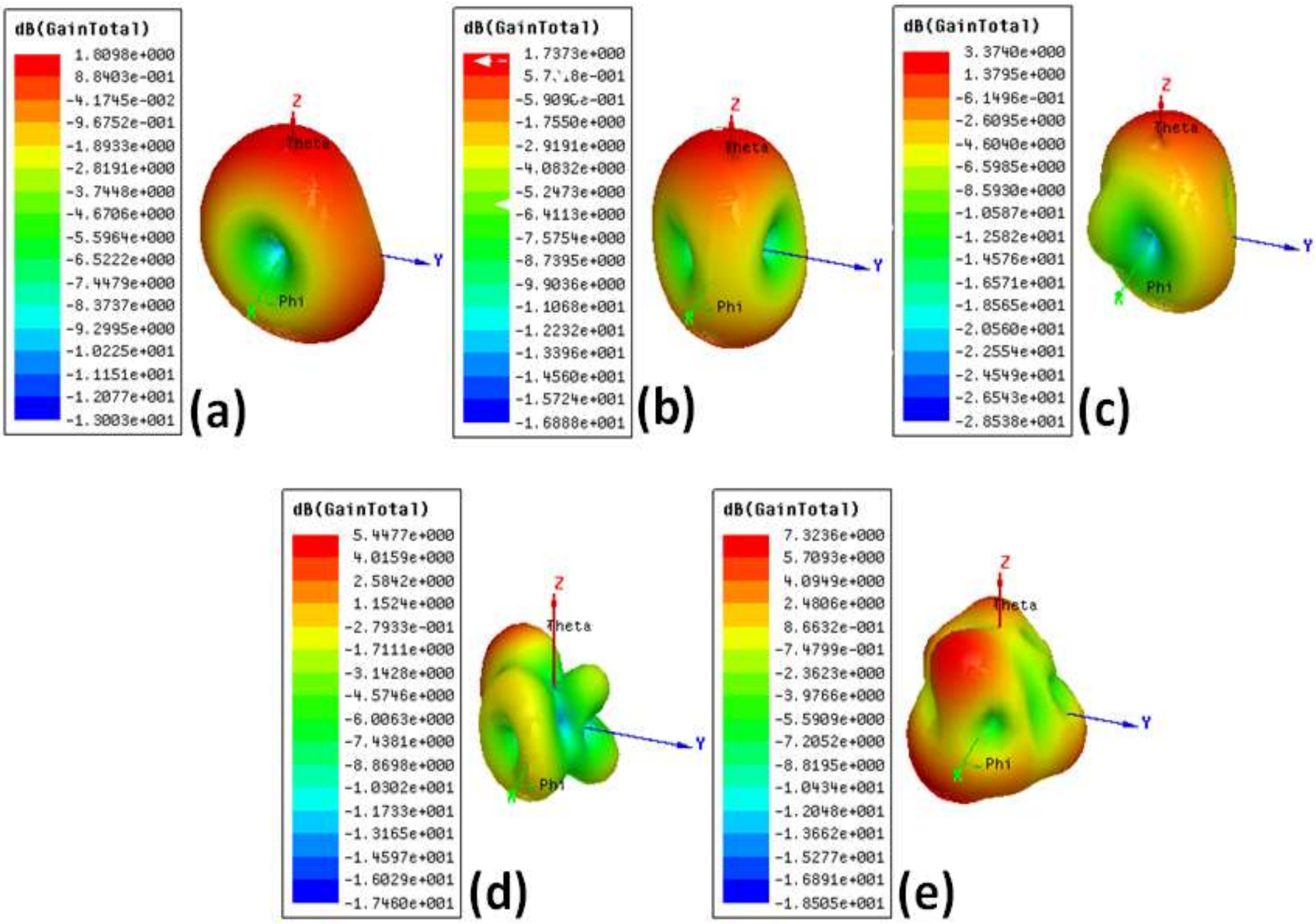


**Figure 10: Gain plot of Ant-3**

It can also be premeditated from Figure 10(a) and 10(b) that Ant-3 reports omnidirectional gain pattern at frequency 1.67 GHz and 2.69 GHz.

**Conclusion:**

Proposed Antennas have been simulated which exhibit multiband characteristics. To attain the, desired frequency band of 3.2 GHz the U-shaped ground plane has been introduced in the geometries of Ant-1 whereas and L-shaped ground plane has been applied in the geometries of Ant-2 and Ant-3. The reflection coefficient and bandwidth of proposed antennas are in the acceptable range i.e; $S_{11} \leq -10\ dB$. The gain of the proposed antennas is also positive, and omnidirectional for Ant-2 (at frequency 2.36 GHz) and Ant-3 (at frequencies 1.67 GHz and 2.69 GHz) at . Ant-1 exhibits tribands whereas Ant-2 and Ant-3 reports pentavalent band. Proposed antennas can be used for the Bluetooth, WiMax, WLAN, Point-to-Point high speed communication and Satellite applications.

**References:**


1. C. A. Balanis, "Antenna Theory, Analysis and Design", John Wiley & Sons, New York, 1997.
2. S. S. Bhatia and J. S. Sivia, "A novel design of circular monopole antenna for wireless applications", Wireless personal Communication, Vol. 91, No. 3, pp. 1153-1161, 2016, DOI: 10.1007/s11277-016-3518-z.
3. N. Sharma and V. Sharma, "A journey of Antenna from Dipole to Fractal: A Review", Journal of Engineering Technology (AEEE– American Society for Engineering Education), pp. 317-351, Vol. 6, Issue 2, July 2016, ISSN: 0747-9964.
4. R. P. Dwivedi and D. Upadhyay, "High gain dual band antenna using fractal geometry for mobile communication," IEEE, 2nd International Conference on Signal Processing and Integrated Networks (SPIN), pp. 50-55, 2015.
5. J. S. Sivia and A. P. S. Pharwaha, and T. S. Kamal, "Analysis and design of Circular Fractal Antenna using Artificial Neural Networks", Progress In Electromagnetics Research B, Vol. 56, pp. 251-267, 2013.
6. C. Vardadhan, J. K. Pakkathillam, M. Kanagasabai, R. Sivasamy, R. Natarajan and S. K. Palaniswamy, "Triband antenna structures for RFID systems deploying fractal geometry," IEEE Antenna and Wireless Propagation Letter, Vol. 12, pp. 437-440, 2013, DOI: 10.1109/LAWP.2013.2254458.
7. M. Susila, T. R. Rao and A. Gupta, "A novel fractal antenna design for UWB wireless communications," IEEE, International Microwave and RF Conference (IMaRC), pp. 118-120, 2014.
8. K. Gangwar, R.P.S. Gangwar and Paras, "Enhancement of the gain and bandwidth of MPA using Metamaterial Structure", International journal of Engineering research & Management technology, Vol.2, No.2, pp. 295-300, March 2015.
9. Y. Kumar and S. Singh, "A Quad band hybrid fractal antenna for wireless applications," IEEE, International Advance Computing Conference (IACC), pp. 730-733, 2015.
10. S. Kundalia, V. Unadkat and S. Dwivedi, "Comparative Analysis of Fractal Based Nested Triangular Microstrip Antenna," 2nd International Conference on Emerging Technology Trends in Electronics, Communication and Networking (ET2ECN), pp. 1-7, 2014.
11. S. Singh and A. Singh, "Design and optimization of a modified Sierpinski fractal antenna for broadband applications", Applied Soft Computing, 2014, DOI: 10.1016/j.aeue.2014.09.016.
12. S. Tripathi, A. Mohan and S. Yadav, "Hexagonal fractal ultra-wideband antenna using Koch geometry with bandwidth enhancement," IET Microwaves, Antennas and Propagation, Vol.8, No.18, pp. 1445-1450, 2014.
13. B. L. Sahu, , N. Chattoraj and S. Pal,"A novel CPW fed sierpinski carpet fractal UWB slot antenna", International Confernce on Microwave and Photonics (ICMAP), pp. 1 - 4, 2013.
14. A.K. Singh, R. A. Kabeer, Z. Ali and D. Gurjar, "Performance Analysis of Compact Koch Fractal Antennas at Varying Iterations," Students conference on Engineering and Systems (SCES), pp. 1- 5, April 2013, DOI: 10.1109/SCES.2013.6547565.
15. S. Singh and Y. Kumar ,"A Compact Multiband Hybrid Fractal Antenna for Multistandard Mobile Wireless Applications" Wireless personal Communication, Vol. 84, No. 1, pp 57-67, April 2015, DOI: 10.1007/s11277 -015-2593-x.
16. "Fractal Antenna Applications" by Mircea V. Rusu and Roman Baican, University of Bucharest, Romania
17. N. Abdullah, M.A. Arshad, E. Mohd and S.A. Hamzah, "Design of Minkowsi Fractal Antenna for Dual Band Applications", Proc. IEEE- Conference on Computer and Communication Engineering, pp. 352-355, May 2015, Kuala Lumper,Malaysia.
18. N. Sharma and V. Sharma, "A Novel design of Circular Fractal Antenna using Inset line feed for Multiband Applications", First IEEE international Conference on Power Electronics, Intelligent

Control and Energy Systems (ICPEICES 2016), pp. 3087-3090, DTU, Delhi, during 4th – 6th July, 2016, DOI: 10.1109/ICPEICES.2016.7853608.

19. C. Singh and R. P. S. Gangwar, "Design and Simulation of Circularly Polarized Compact Microstrip Patch Antenna for C-Band Applications", International Journal on Computer Science and Engineering, Vol.3, No.3, pp. 1175-1182, March 2011.