

A Compact Square and Hexagonal Antennas with Fractal DGS for Mobile Satellite Applications

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Abstract

A miniaturized Circularly Polarized Microstrip Patch Antenna with fractal Defected Ground Structure (DGS) is proposed. For the purpose of realizing Circularly Polarized radiation, two square notches and an asymmetric length of two rectangular slots that are perpendicular to one another are printed on square and hexagonal shaped patches, respectively. The antenna size is decreased and circular polarization is achieved by employing koch snowflake-shaped Defected Ground Structure. The proposed antenna is appropriate for use in India with mobile satellite communications. The suggested antennas resonate at 1.5GHz. Axial Ratio, VSWR, Radiation Efficiency, FBR (Front to Back Ratio), and Area of Patch are the metrics used to evaluate the antenna performance to that of the existing antenna. It is observed that the proposed structures are better in many aspects mentioned above. The antennas are simulated using HFSS v.2017.2 software.

Keywords: Square Patch, Koch snowflake Fractal, Defected Ground Structure (DGS) and Slow Wave Effect.

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INTRODUCTION

Patch antennas are good choice especially for satellite applications because of their good traits like low profile, small size and ease of fabrication. Also for satellite applications circularly polarized antennas are preferred because of antenna placement constraints and to overcome multi path constraints. The design and simulation of square notch printed antenna with koch snowflake fractal defected ground structure is discussed in this paper. This antenna can be used for data acquisition, monitoring and control applications in L band. By using this antenna the cost to establish technology can be reduced to great extent [1].

By using DGS concept the size of the patch can be reduced and hence antenna miniaturization can be achieved [2]. Removing portion of the ground plane is called DGS, and different shapes can be used like dumbbell, annular ring, spiral or any other shape can be used for DGS. By introducing DGS phenomenon the electrical length can be increased so that the resonance frequency is decreased or in other terminology, for the given operating frequency, the size of the antenna is made smaller. In this paper fractal koch snowflake shape is used as DGS [3]. The term 'fractal' means having self-similarity property. Because of this self-similarity property electrically larger dimensions can be fit into smaller areas. If we use fractal shape as DGS maximum benefit of slow wave effect can be obtained.

RELATED WORKS

Nadir Hakem [4] designed a miniature stacked patch antenna with two frequencies for the IRNSS that works at 1.176GHz and 2.492GHz in the L and S bands. To obtain the required operating frequency, the patch has been chopped at its diagonal corners. To obtain dual frequency of operation, stacked patch technique has been employed. Proposed antenna includes two radiators, each of which controls a single operating frequency. The proposed antenna can work at two different frequencies: 1.176GHz and 2.492GHz, with a gain of 2.19dB and 5.26dB for each frequency. The proposed antenna was created with a commercial 3D simulator called Ansys HFSS.

Bhargav Pansuria [5] created a micro-strip patch antenna with a single band for the Indian Regional Navigational Satellite Systems (IRNSS) receiver. The IRNSS positioning and accuracy services send signals over the L5 (1.176GHz) and S (2.492GHz) bands. So, to meet the needs of IRNSS receiver modules, researchers present a single-band micro-strip patch antenna with a simpler design. The microstrip patch antenna is also fed by a coaxial feed mechanism, and many factors like return loss, VSWR, axial ratio, gain, and radiation pattern are explored.

In order to work with the GPS satellite system, Thanh Nghia Cao [6] created a fractal antenna with two frequencies of 0 GHz, 1.228 GHz, and 1.5745 GHz. Compact dimensions and dual frequency operation were made possible by using the Minkowski fractal island and the radiating element's

shorting pin. For the design and numerical simulations, HFSS software was employed. A microwave laminate made of FR4 was used to create the antenna.

Using the log periodic approach, Raja Narendra [7] developed a circular microstrip patch antenna with frequency adaptability. Using the inset feeding method and a single transmission line, three parts of a circular microstrip patch were fed. The Log periodic Circular Microstrip array can be used at frequencies between 2.90 GHz and 3.4 GHz. At the transmission line, there are three diodes. Depending on how they switch, they can be changed to make the specified antenna work over two sub-bands.

In [8], fractal geometry was used to make a new structure that lets the antenna work in the X (8–12 GHz), Ku (12–18 GHz), and Ka (26.5–40 GHz) bands. The proposed antenna can work in the X, Ku, or Ka band by changing how the switch is set (ON or OFF). Frequency-configurable antennas usually have PIN diodes, MEMS switches, and other parts. Several antenna parameters were also figured out, such as the reflection coefficient, gain, VSWR, radiation pattern, and bandwidth.

ANTENNA GEOMETRY

The geometrical structure of the proposed square patch of side 40.67mm with notches along diagonal is shown in the Figure 1 [9-10]. The slots along diagonal generate two orthogonal modes, which is an essential requirement of circular polarized radiation [11-14]. The antenna is fed by a method called "proximity coupled feeding." The microstrip line sandwiched between two layers of the substrate offers 50 Ω impedance. The feed line is 45mm long and 4.5mm wide, and the ground plane is 90mm wide and 90mm long. The upper and lower substrate thickness is 1.5748 mm each and the relative dielectric constant is $\epsilon_r = 2.5$ with loss tangent $\tan \delta = 0.0024$. The Koch snowflake shaped fractal DGS of iteration 2 is impressed in the middle of ground plane.

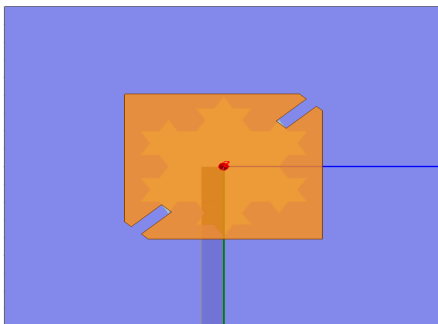


Figure 1. Top view of square patch antenna with notches

On varying the length of notches, the performance of the antenna varies. On increasing the notch length, return loss and VSWR performance improves but axial ratio performance mitigates [15]. Thus, at particular length of notches all parameters are improved. The feed line and the

rear view of the proposed antenna is shown in figure 2 and figure 3 respectively [16-17]. HFSS is used for optimizing antenna parameters.

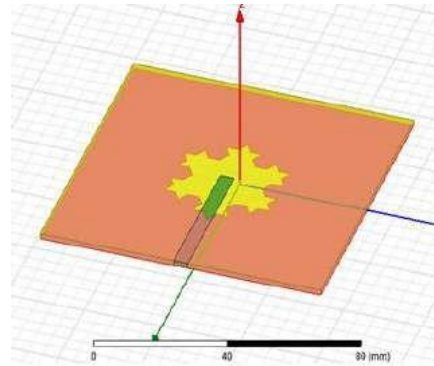


Figure 2. Antenna with DGS, lower Substrate and feed line

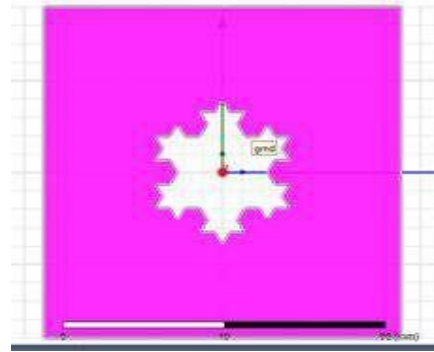


Figure 3. Bottom view of defected ground structure with Koch snowflake fractal shape

The circular patch in the existing antenna design is replaced with regular hexagonal patch [18] of side 25mm with same orthogonal slots at the center as shown in the figure 4. The orthogonal slots at the center is responsible for circular polarization and based on its tilting angle, performance of the antenna improves. The slots in the middle make a 60-degree angle with the Y-axis. The area of the hexagonal patch is 1531.81mm² which is reduced compared to circular patch. Hexagonal patch antenna performs better compared to circular patch antenna.

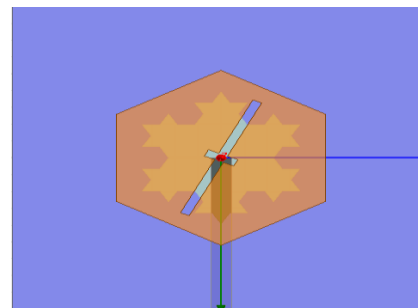


Figure 4. Top view of Hexagonal patch antenna

RESULTS & DISCUSSION

Utilizing the High Frequency Structure Simulator software, the proposed antenna is optimized. Various parameters of the antenna are analyzed as follows.

a) Return Loss

Return loss is a parameter that describes the impedance matching between radiating element and the transmission line. The proposed square patch antenna has return loss of -11.1875dB and return loss bandwidth 7.81% with center frequency 1.5GHz is obtained as shown in figure 5. The return loss is within an acceptable range.

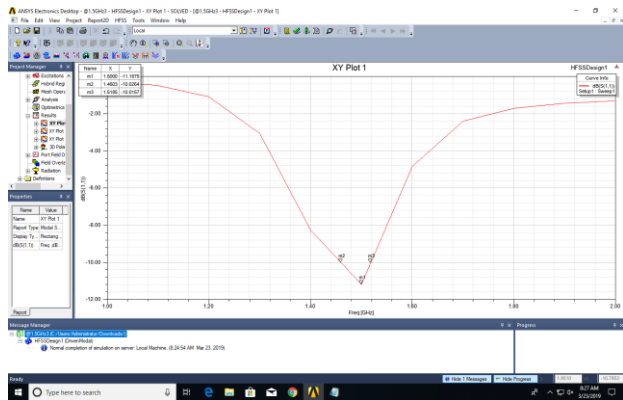


Figure 5. Return Loss (S11) of the square patch antenna

Thus, the hexagonal patch microstrip patch antenna has return loss of -10.9222dB and return loss bandwidth 7.5% with center frequency 1.5GHz as shown in figure 6.

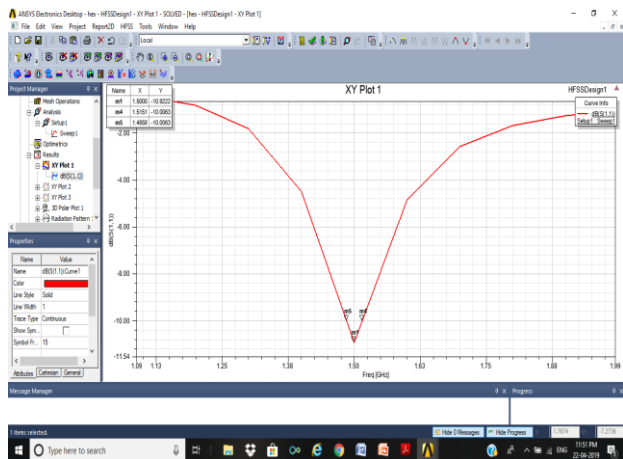


Figure 6. Return Loss (S11) of the square patch antenna

b) VSWR

Voltage Standing Wave Ratio is another parameter related with antenna which should be less than 2, and from the graph in figure 7, it is observed that the value is 1.7617.

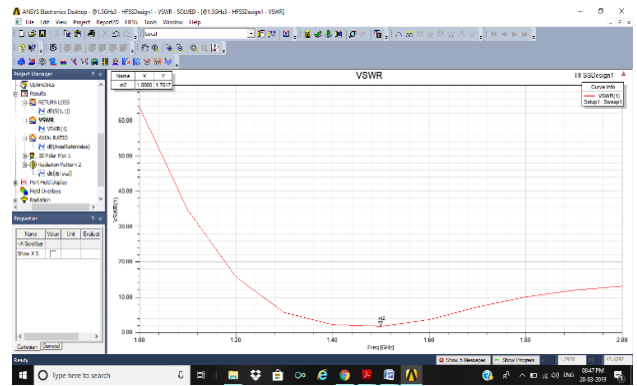


Figure 7. VSWR of the square patch antenna

Figure 8 shows that the VSWR for a hexagonal patch antenna is 1.7948. A hexagonal patch antenna has a better VSWR than a circle patch antenna.

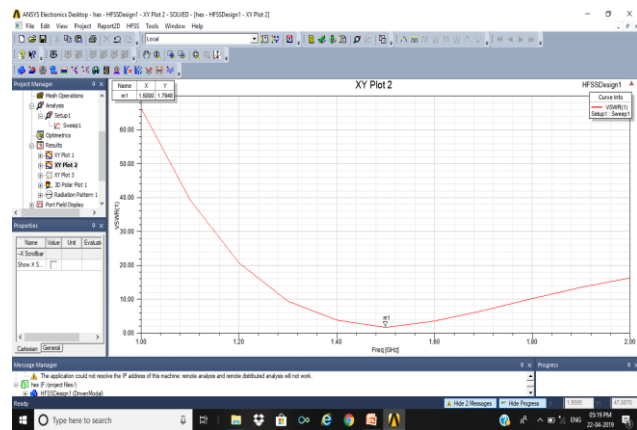


Figure 8. VSWR of the Hexagonal patch antenna

c) 3 dB-Axial Ratio

The ratio of the major axis to the minor axis is known as the axial ratio, and with respect to antennas it is the ratio of E_{θ} and E_{ϕ} . This is another important parameter of antenna that represents polarization of the antenna which should be less than 3dB for circular polarization. From the graph shown in figure 6, it is observed that the axial ratio at the desired resonance frequency is 2.1527dB.

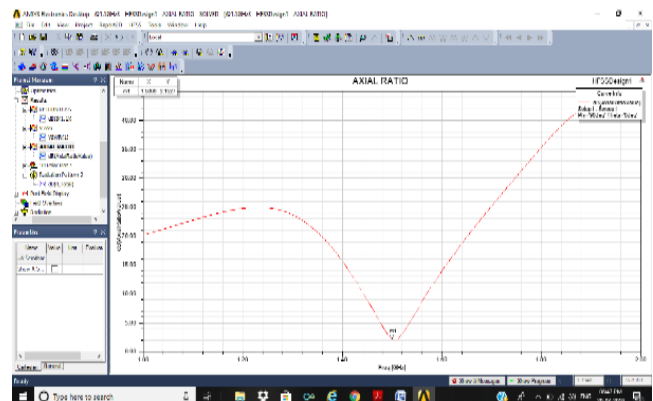


Figure 9. Axial ratio of the Square patch antenna

For hexagonal patch antenna the axial ratio is 0.9395 dB as shown in the figure 10. As compared to circular patch antenna it has better performance.

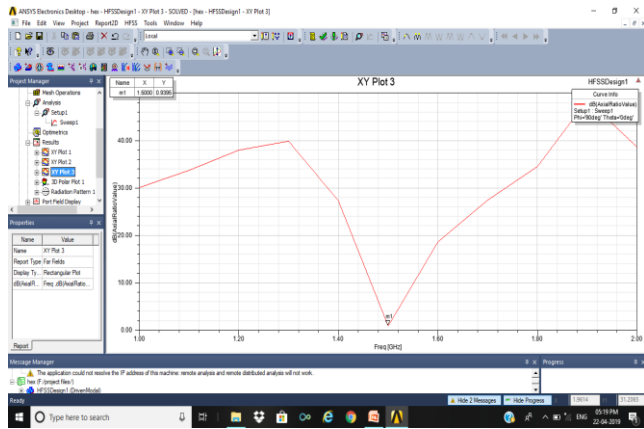


Figure 10. Axial ratio of the Hexagonal patch antenna

d) 3D Radiation Pattern

The polar plot of 3D radiation pattern for square patch and hexagonal is shown in the figure 11 and figure 12 respectively. The radiation is broadside and directional. The elevation Plane ($\phi=0^\circ$) radiation pattern and azimuthal plane ($\Theta=90^\circ$) radiation pattern also shown in the figures 13 and 14.

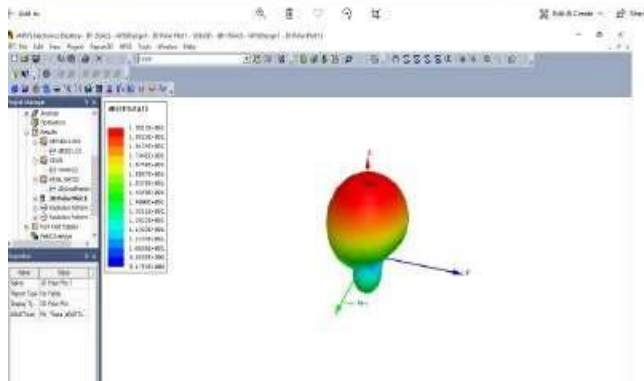


Figure 11. Square patch antenna's 3-D radiation pattern

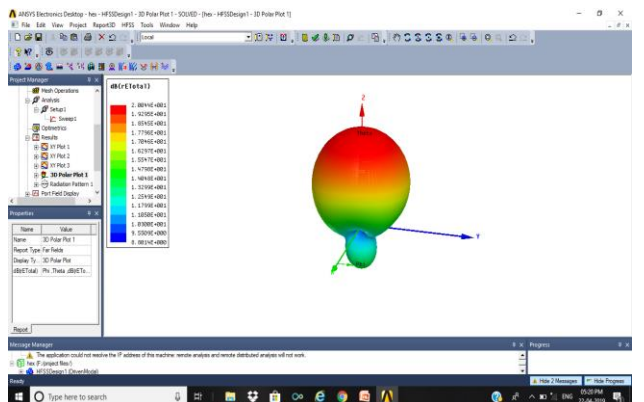


Figure 12. Hexagonal patch antenna's 3D radiation pattern

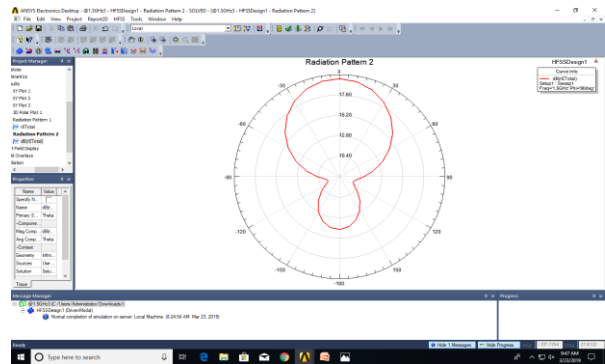


Figure 13. E-Plane radiation pattern of the square patch antenna

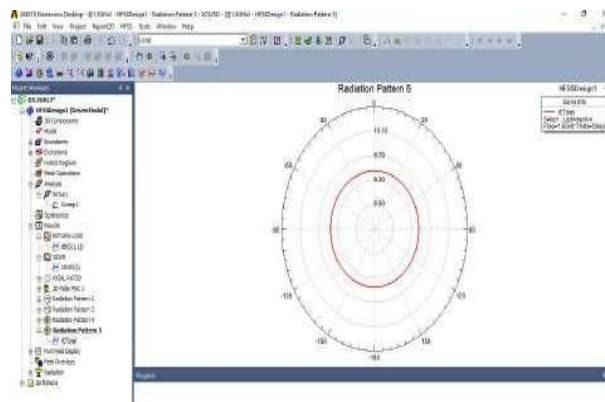


Figure 14. H-Plane radiation pattern of the square patch antenna

Figure 15 and Figure 16 show the 2-D radiation patterns of a hexagonal patch antenna in E-Plane ($=0^\circ$) and H-Plane ($=90^\circ$).

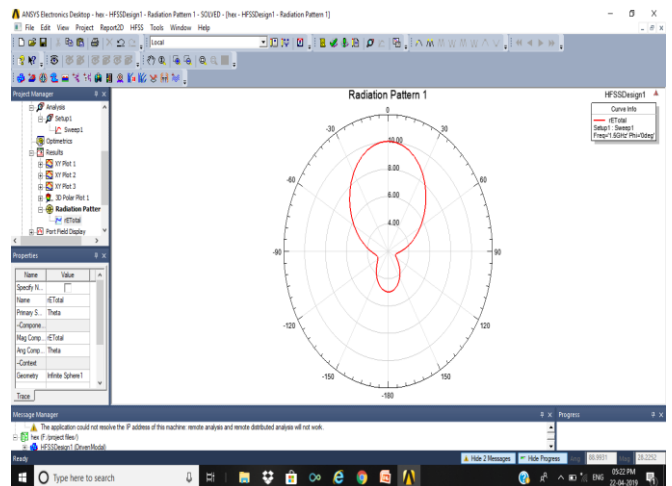


Figure 15. 2-D Radiation pattern in E-Plane of Hexagonal patch microstrip antenna

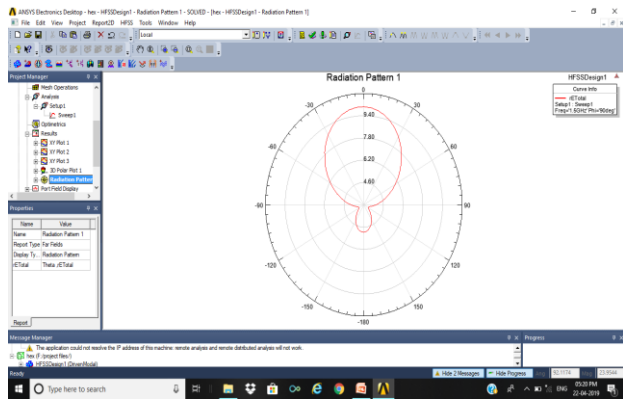


Figure 16. 2-D Radiation pattern in H-Plane of hexagonal patch microstrip antenna

Thus, at particular length of slots and notches all parameters are improved compared to circular patch. Table 1 shows the simulation results for the small circularly polarized microstrip patch antenna with the following parameters such as return loss, Axial ratio, VSWR, Impedance bandwidth, etc., for circular patch, square patch and hexagonal patch.

The above-mentioned parameters of different antennas are compared at the same resonating frequency i.e. 1.5GHz. When compared to circular and hexagonal patches, the square patch design has produced better outcomes in a variety of criteria like return loss (-11.1875db), Impedance bandwidth (7.81 %), VSWR (1.7617) and Radiation efficiency (95.51 %). In contrast, Area of the patch (1535.81 mm²), Axial Ratio (0.9395), Front to Back Ratio (4.0926) are achieved better in hexagonal patch design.

It is evident that every characteristic listed in Table 1 has been improved in the proposed designs (Square and Hexagonal) when compared with the existing circular patch antenna.

Table 1. Comparison of various parameters of antennas

Parameter	Circular Patch (Existing antenna)	Square Patch (Proposed antenna 1)	Hexagonal Patch (Proposed antenna 2)
Resonance Frequency (GHz)	1.5	1.5	1.5
Return Loss (dB)	-10.3	-11.1	-10.9
Impedance Bandwidth (%)	6.8	7.8	7.5
VSWR	1.8	1.76	1.79
Axial Ratio (dB)	2.8	2.1	0.9
Area of the patch (mm ²)	1975.5	1616.7	1535.8
Radiation Efficiency (%)	95.1	95.5	94.6
Front to Back Ratio	4.0	3.4	4.0

CONCLUSION

A square and hexagonal shaped fractal defected ground antennas are designed and simulated using HFSS software. Both the antennas offer circular polarization and they are suitable for the Indian mobile satellite communication band (1.492-1.518 GHz). The proposed antenna is smaller than the standard circular micro strip patch antennas and has good impedance matching, VSWR, Impedance bandwidth, a stable radiation pattern, and low return loss.

The simulation shows that the antenna radiates at a frequency of 1.5 GHz in the L-Band. All the parameters are in required satisfactory range. Hence the designed antenna is effective and efficient to work for mobile satellite applications.

REFERENCES

Pravin Ratilal Prajapati, Gannavarapu Gopala Krishna Murthy, Amalendu Patnaik, Machavaram, Venkata Kartikeyan, "Design and testing of a compact circularly polarised microstrip antenna with fractal defected ground structure for L-band applications", IET Microwave Antennas Propagation., vol. 9, Issue. 11, pp. 1179–1185, 2015.

Biswas, S., Guha, D., Kumar, C., "Control of higher harmonics and their radiation in microstrip antennas using compact defected ground structures", IEEE Trans. Antennas Propag., vol.61, pp. 3349–3354, 2013.

Prajapati, P.R., Murthy, G.G.K., Patnaik, A., Kartikeyan, M.V., 'Design of compact circular disc circularly polarized antenna with koch curve fractal defected ground structure'. Proc. of 31st Int. Union of Radio Science General Assembly and Scientific Symp., (URSI GASS 2014), Beijing, China, August 2014.

Nadir Hakem, "A Compact Dual Frequency Stacked Patch Antenna for IRNSS Applications," National Journal of Antennas and Propagation, vol.1, Issue 1, pp. 5-8, 2019.

B. Pansuria, S. Sharma and A. Rawat, "Design of 1.176GHz Micro-Strip Patch Antenna for IRNSS Applications," 9th International Conference on Computing, Communication and Networking Technologies (ICCCNT), pp. 1-4, July 2018.

T.N. Cao and W.J. Krzysztofik, "Hybrid Minkowski fractal island antenna operating in two bands of GPS satellite system," IEEE Antennas Propag. Soc. Int. Symp. APSURSI 2016 - Proc., no. 1, pp. 211–212, 2016.

Rajanarendra Sai, K. Sudha, H.D Praveena, "Design And Simulation of Circular Patch Log Periodic Microstrip Antenna Array With Frequency Reconfigurability Using IE3D Software," International Journal of Pure and Applied Mathematics, vol. 114, No. 10, pp. 301-308, 2017.

K. Sudha, H.D. Praveena, Sai Raja Narendra and R. Anjaneya Srujit, "Design and Simulation of Bow-Tie Shaped Hexagonal Rings Quasi Fractal Antenna for Satellite Applications" Indian Journal of Science and Technology, vol. 12, No. 6, pp. 1-5, February 2019.

R. Garg, P. Bhartia, I. Bahl, A. Ittipiboon, "Microstrip Antenna Design Handbook" Artech House, 2001.

Constantine A. Balanis "Antenna theory analysis and design" Third Edition 2005.

Karmakar, N.C., Bialkowski, M.E., "Circularly polarized aperture - coupled circular microstrip patch antennas for L-band applications," IEEE Trans. Antennas Propag., vol.47, pp. 933–940. 1999.

Gao, Steven, Luo, Q., Zhu, F.: "Circular polarized antenna" (Wiley Publication, U.K., 2014, 1st edn).

Sunkaraboina Sreenu, P. Gnanasivam, M. Sekhar, "Circular polarised Antenna Array for C Band Applications," Journal of Advanced Research in Dynamical & Control Systems, vol. 10, 14-Special Issue, 2018.

- T. Sreedhar, A.D. Sharma, P. Naveen Kumar, "Performance valuation of Onboard Wi-Fi Module Antennas in Terms of Orientation and Position for IoT Applications," *International Journal of Engineering, Transactions A: Basics*, vol. 35, Issue 10, pp. 1918-1928, doi: 10.5829/IJE.2022.35.10A.11.
- Adebayo, S., Aweda, F., Ojedokun, I. and Olapade, O., "Refractive index perception and prediction of radio wave through recursive neural networks using meteorological data parameters", *International Journal of Engineering, Transactions A: Basics*, Vol. 35, No. 4, pp. 810-818, 2022. doi: 10.5829/ije.2022.35.04A.21.
- P.C. Sharma, K.C. Gupta, "Analysis and optimized design of single feed circularly polarized microstrip antennas", *IEEE Trans. Antennas Propag.*, Vol. 29, pp 949-955, 1983.
- Sunkaraboina Sreenu, P. Gnanasivam, M. Sekhar, "Circular polarised Antenna Array for C Band Applications," *Journal of Advanced Research in Dynamical & Control Systems*, Vol. 10, 14-Special Issue, 2018.
- Chandni Bajaj, Dharmendra Kumar Upadhyay, Sachin Kumar, Binod Kumar Kanaujia, "Compact Dual-Compact Dual- Band Hexagonal Ring Antenna with Shorting Pins for RFID Reader Applications," 7th International Conference on Signal Processing and Integrated Networks (SPIN), 27th -28th Feb 2020.