World Academy of Science, Engineering and Technology
International Journal of Electronics and Communication Engineering
Vol:11, No:2, 2017

Comparison of CPW Fed Microstrip Patch Antennas with Varied Ground Structures for Fixed Satellite Applications

Deepanshu Kaushal, T. Shanmuganantham

***Abstract*—**This paper draws a comparison between two microstrip patch antennas having different ground structures. The designs utilize 45 mm x 40 mm x 1.6 mm FR4 epoxy substrate (relative permittivity of 4.4 and dielectric loss tangent of 0.02) and CPW feeding technique. The design 1 uses conducting partial ground plates along the two sides of the radiating X'mas tree shaped patch. The design 2 utilizes an X'mas tree shaped slotted ground structure that features a circular radiating patch. A comparative analysis of results of both designs has been carried. The two designs are intended to serve the fixed satellite applications in X and Ku band respectively.

***Keywords*—**CPW feed, partial ground structures, slotted ground structures, fixed satellite applications.

I. Introduction

OVER the recent years, a wide research interest has been witnessed in the field of satellite communication technology. Today, the entire world seems to be interconnected by the satellite communication networks. Based on the revised FCC regulations, the range of frequencies covering 11.28 GHz and those around 12.52 GHz may be utilized for fixed satellite ((space to earth) and (earth to space)) applications. The microstrip patch antennas have extremely thin profile, light weight and they occupy less volume of the satellites on which they get mounted. Their planar structure accounts for their conformability to the satellite structure. These antennas (single element/array) may be fabricated together with the feeding network using simple etching technique thus making the fabrication economical. Also, the microstrip patch antennas may be integrated with the active components and circuits into one module and it is easy to realize circular polarization, dual-frequency, and dual polarization operations for them.

Several existing literatures related to the works over the microstrip patch antennas have been referred. In [1], the swastik shaped patch antenna that was proposed by Shanmuganantham for fixed satellite applications achieved a reflection coefficient of -11.6 dB and a gain of 3.3 dBi. The microstrip danger shaped patch antenna proposed by Kaushal [2] offered a gain of 4.9 dBi with a bandwidth of 4.61 MHz. The wideband circularly polarized antenna proposed by Wu et al. [3] that used a metasurface superstrate for C- band satellite communication application achieved an average gain of 5.8 dBi. The compact antenna proposed by Islam [4] for small satellite applications achieved a gain of 7.2 dBi and a bandwidth of 13 MHz. The compact high gain antenna for small satellite applications proposed by Arnieri [5] achieved a bandwidth of 80 MHz. The design 1 proposed in this paper achieves a reflection coefficient of -19.1 dB at 12.52 GHz with a peak gain of 9.45 dBi and a bandwidth of 780 MHz while the design 2 attains a reflection coefficient of -15.8 dB at 11.28 GHz with a peak gain of 8.68 dBi and a bandwidth of 1.38 GHz. Both designs may be used for fixed satellite applications [6] in X and Ku bands respectively. Section I briefly describes the microstrip patch antennas and their suitability for satellite applications. The two proposed antenna designs are described in Section II. Section III gives the parametric study of the two designs. The results for the two designs have been given and compared in Section IV.

Deepanshu Kaushal is with Department of Electronics Engineering, Pondicherry University, Pondicherry (e-mail: deepanshu_kaushal@yahoo.com).
T. Shanmuganantham is with Department of Electronics Engineering, Pondicherry University, Pondicherry (phone: +919486640168, e-mail: shanmuga.dee@pondiuni.edu.in).

II. Antenna Designs

A. Design 1

The design 1 shown in Fig. 1 uses a X'mas tree shaped patch (green) over a 45 mm x 40 mm x 1.6 mm FR4 epoxy substrate [7] (blue). The CPW feeding technique [8] has been utilized. The conducting plates on either side of the patch constitute a partial ground (brown). The specifications of the antenna design 1 have been listed in Table I.

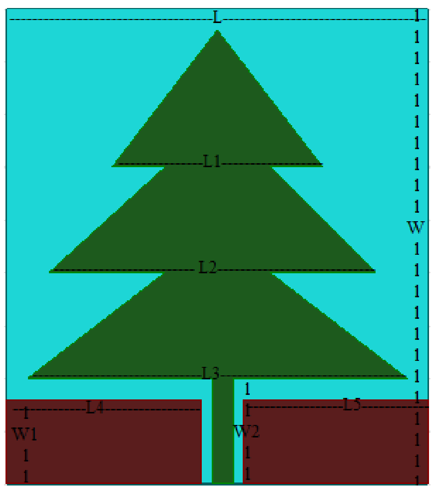

Fig. 1 Geometry of the Proposed Design 1

TABLE I
GEOMETRIC SPECIFICATIONS OF PROPOSED DESIGN 1

Parameter	Value (mm)
L	40
W	45
L1	20
L2	30
L3	35
L4	18.5
L5	17.5
W1	8
W2	10

B. Design 2

The design 2 uses a ground plane (brown) that has been slotted in the form of a X'mas tree. The slotted ground features a circular conducting patch (green). The feeding technique used is again CPW feed. The design is shown in Fig. 2 and the geometrical specifications are listed in Table II.

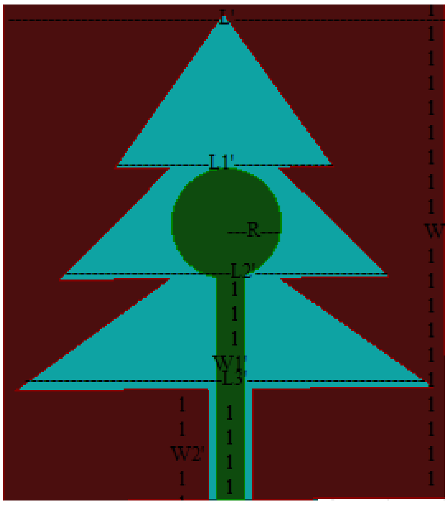

Fig. 2 Geometry of the Proposed Design 2

III. PARAMETRIC ANALYSIS

Both designs utilize FR4 epoxy substrate of relative permittivity [9] 4.4 and dielectric loss tangent of 0.02 [10]. The feeding technique used is CPW feed. The design 1 uses conducting partial ground plates on the either sides of a centrally placed X'mas tree shaped patch. The design 2 uses a ground plane that has X'mas tree shaped slot. The slotted ground plane features a circular conducting patch. The designs have been simulated over HFSS v-15 [11]. The two designs have been analyzed for various plots including the reflection coefficient, bandwidth, radiation pattern, gain, directivity, VSWR and field patterns (E-field, H-field and surface current). Finally, the results are compared.

TABLE II
GEOMETRIC SPECIFICATIONS OF PROPOSED DESIGN 2

Parameter	Value (mm)
L'	40
W	45
L1'	20
L2'	30
L3'	35
L4	18.5
W1'	20.1
W2'	10
R	5

IV. RESULTS

A. Design 1

1. Reflection Coefficient and Bandwidth

Fig. 3 shows that the proposed design 1 achieves a reflection coefficient [12] of -19.1 dB at 12.52 GHz with a bandwidth [13] of 780 MHz around it.

2. Radiation Pattern and Gain

Fig. 4 shows the radiation pattern [14] plot for the proposed design 1. A maximum gain [15] of 9.2 dBi achieved at 12.52 GHz was discussed.

3. Directivity

Fig. 5 shows that a peak directivity [16] of 5.7 dB is achieved at 12.52 GHz.

4. VSWR

Fig. 6 indicates that a VSWR [17] value of 1.25 is achieved at 12.52 GHz.

5. Distribution of Fields

Figs. 7-9 indicate the E-field [18], H-field [19] and the surface current distributions [20] for the proposed design 1 at 12.52 GHz.

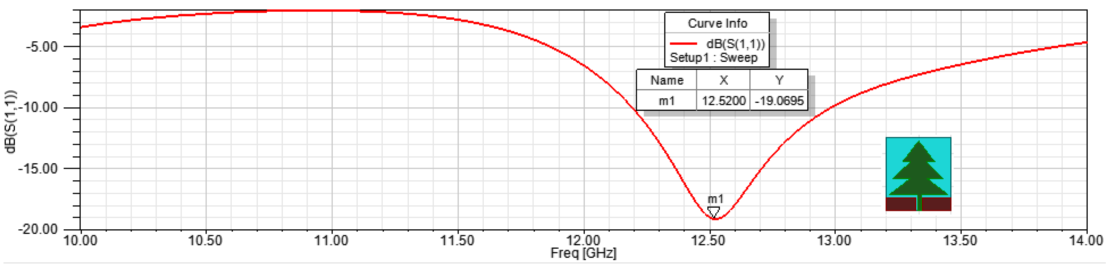

Fig. 3 Reflection Coefficient curve of the Proposed Design 1

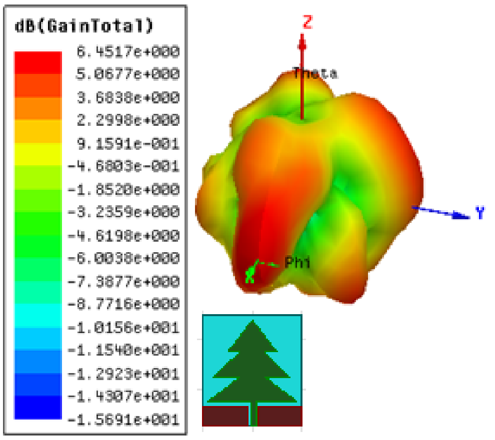

Fig. 4 Radiation Pattern Plot of the Proposed Design 1

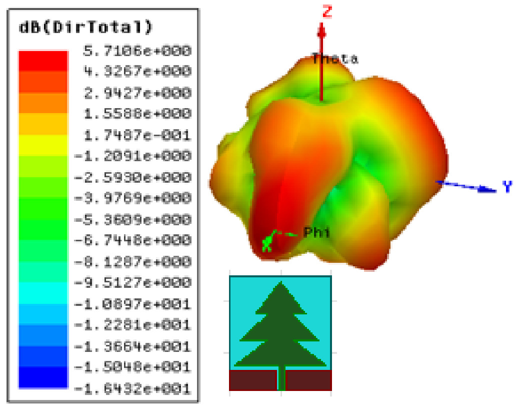

Fig. 5 Directivity Plot of the Proposed Design 1

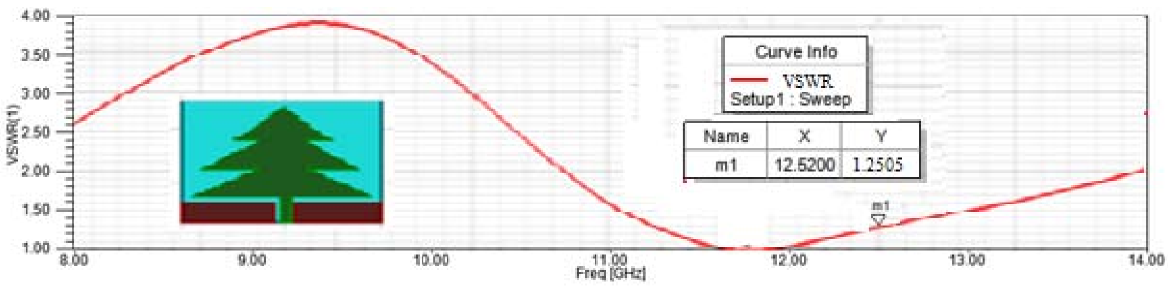

Fig. 6 VSWR Plot of the Proposed Design 1

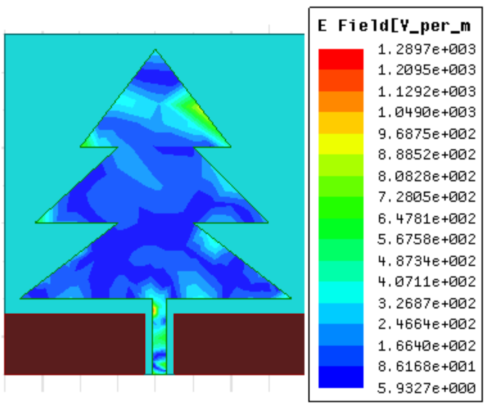

Fig. 7 E- field Distribution of the Proposed Design 1

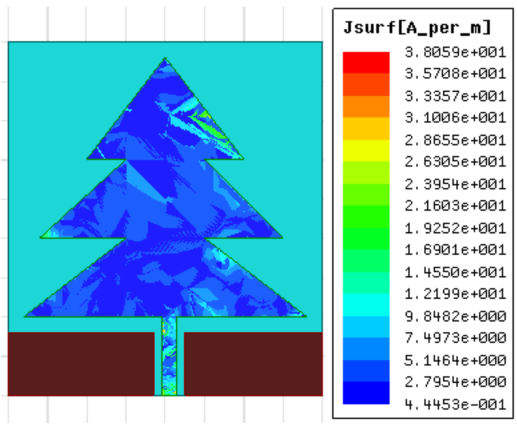

Fig. 9 Surface Current Distribution of the Proposed Design 1

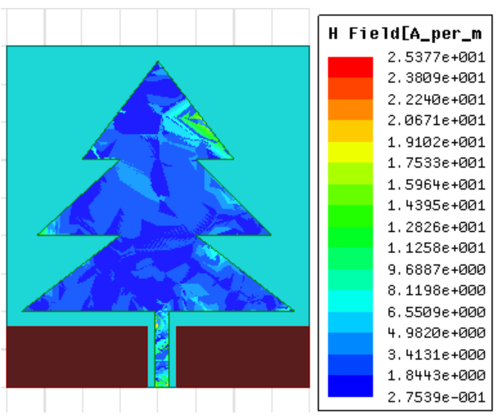

Fig. 8 H- field Distribution of the Proposed Design 1

B. Design 2

1. Reflection Coefficient and Bandwidth

Fig. 10 indicates that the proposed design [21] 2 achieves a reflection coefficient of -15.8 dB at 11.28 GHz.

2. Radiation Pattern and Gain

Fig. 11 shows the radiation pattern of the proposed design 2 and indicates a maximum gain of 9.9 dBi achieved at 11.28 GHz.

3. Directivity

As shown in Fig. 12, the maximum directivity achieved in case of the proposed design 2 at 11.28 GHz is 6.7 dB.

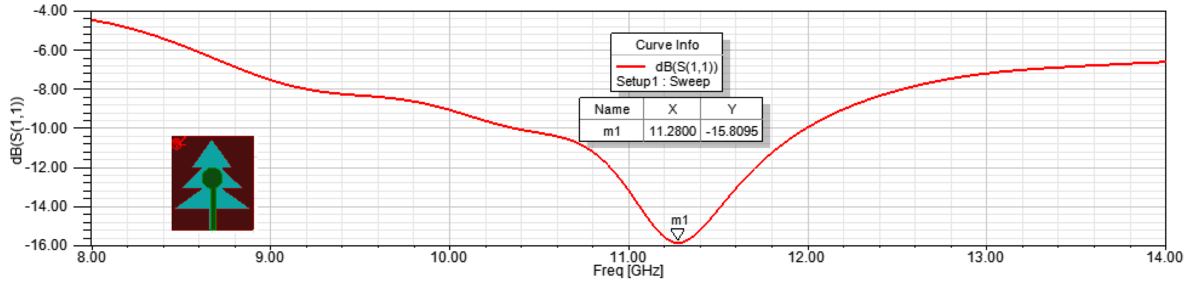

Fig. 10 Reflection Coefficient curve of the Proposed Design 2

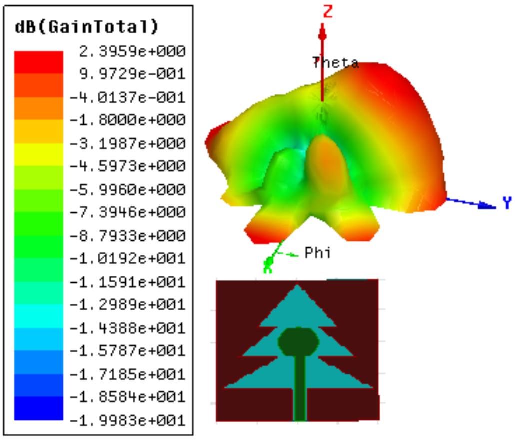

Fig. 11 Radiation Pattern Plot of the Proposed Design 2

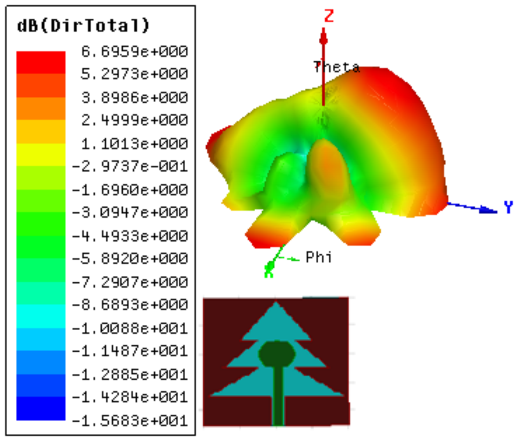

Fig. 12 Directivity Plot of the Proposed Design 2

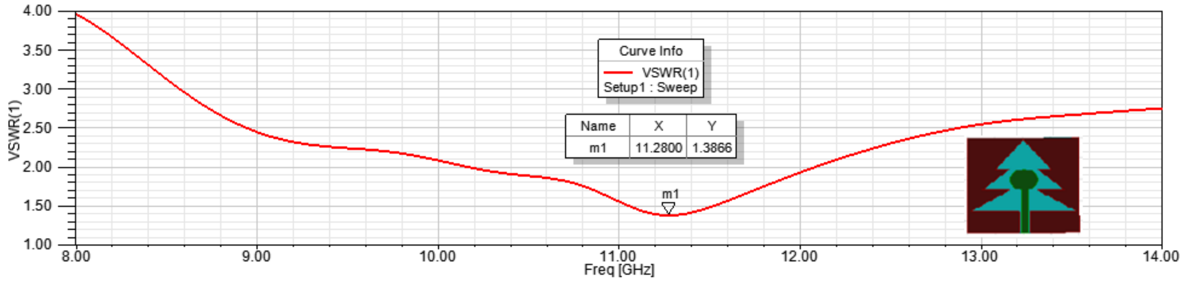

Fig. 13 VSWR Plot of the Proposed Design 2

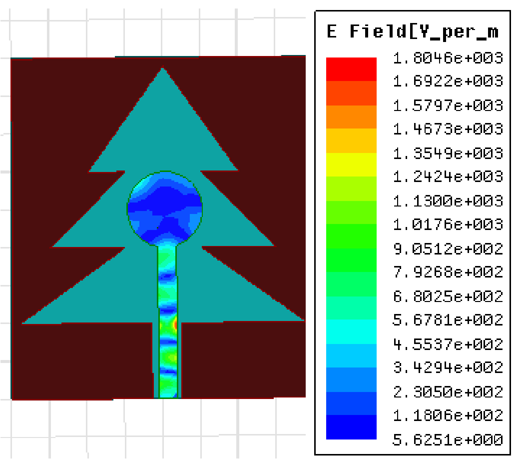

Fig. 14 E- field Distribution of the Proposed Design 2

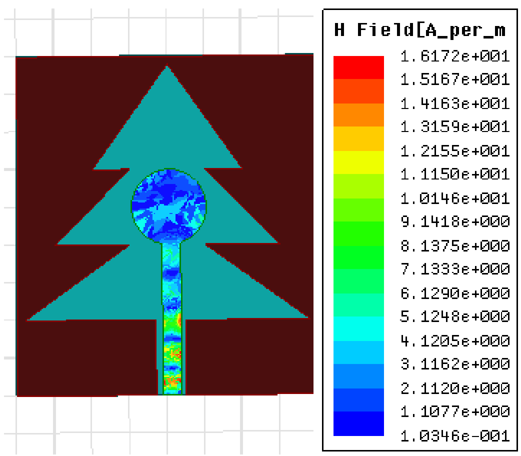

Fig. 15 H- field Distribution of the Proposed Design 2

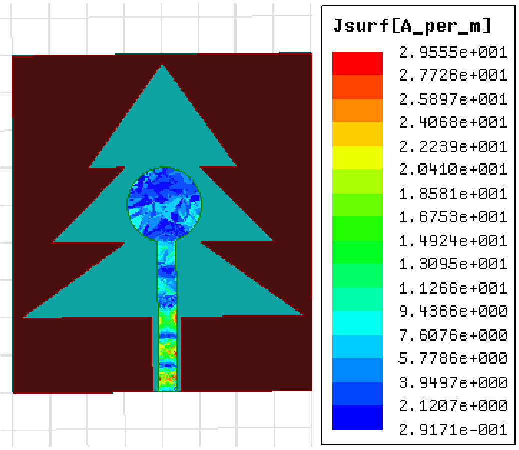

Fig. 16 Surface Current Distribution of the Proposed Design 2

TABLE III
COMPARATIVE ANALYSIS OF THE RESULTS

Parameter	Proposed Design 1	Proposed Design 2
Number of Bands	Single (1)	Single (1)
Operating Frequency (GHz)	12.52	11.28
Reflection Coefficient (dB)	-19.1	-15.8
Gain (dBi)	9.15	9.972
Directivity (dB)	5.7	6.7
VSWR	1.25	1.38
Applications	Fixed Satellite	Fixed Satellite

3. VSWR

Fig. 13 indicates that the proposed design 2 achieves a VSWR value of 1.38 at 11.28 GHz.

4. Distribution of Fields

The distribution of different fields including the E- field, H-field and the surface current for the proposed design 2 are indicated in Figs. 14-16.

Table III draws a comparison of the significant characteristics of the two proposed designs.

V. CONCLUSION

The design of two CPW fed microstrip patch antennas with varied ground structures is proposed. Both designs utilize FR4 epoxy substrate of relative permittivity 4.4 and dielectric loss tangent 0.02. Design 1 utilizes partially conducting ground plates along the two sides of a radiating X'mas tree shaped patch and achieves a reflection coefficient of -19.1 dB, peak gain of 9.15 dBi, peak directivity of 5.7 dB and VSWR of 1.25. Design 2, on the other hand, uses an X'mas tree shape slotted ground plane featuring a conducting circular patch. Design 2 achieves a reflection coefficient of -15.8 dB, peak gain of 9.97 dBi, peak directivity of 6.7 dB and a VSWR of 1.38. The two designs may be used for fixed satellite ((earth-space) and (space-earth)) applications.

REFERENCES

[1] Deepanshu Kaushal, T. Shanmuganantham, "Design and Optimization of Microstrip Swastik Patch Antenna for space applications", *IEEE International Conference on Emerging Trends in Technology (ICETT)*, Kollam, India, 2016.

[2] Deepanshu Kaushal, T. Shanmuganantham, "Danger Shaped Microstrip Patch Antenna for Fixed Satellite Applications", *IEEE International Conference on Emerging Trends in Technology (ICETT),* Kollam, India, 2016.

[3] Zhao Wu, Long Li, Yongjiu Li and Xi Chen, "Metasurface Superstrate Antenna with Wideband Circular Polarization for Satellite Communication Application" ,*IEEE Antennas and Wireless Propagation Letters*, Vol. 15, pp. 374-377, February, 2016.

[4] M. T. Islam, Mengu Cho, M. Samsuzzaman and S. Kibria, "Compact Antenna for Small Satellite Applications", *IEEE Antennas and Propagation Magazine*, Vol. 57, No. 2, pp-30-36, April 2015.

[5] Emilio Arnieri, Luigi Boccia, Giandomenico Amendola and Giuseppe DiMassa, "A Compact High Gain Antenna for Small Satellite Applications", *IEEE Transactions on Antennas and Propagation*, Vol. 55, NO. 2, pp-277-282, February2007.

[6] Jaget Singh, Tejinderjit Singh and B. S. Sohi, "Design of Slit Loaded Rectangular Microstrip Patch Antenna", *RAECS UIET Panjab University Chandigarh 21-22nd December 2015.*

[7] Abha R. Karade and P.L. Zade, "A Miniaturized Rectangular Microstrip Patch Antenna using SSRR for WLAN Applications", *IEEE ICCSP 2015.*

[8] Angana Sarma, Kumaresh Sarmah and Kandarpa Kumar Sarma, "Low Return Loss Slotted Rectangular Microstrip Patch Antenna at 2.4 GHz", *2nd International Conference on Signal Processing and Integrated Networks (SPIN), 2015.*

[9] Tahsin Ferdous Ara Nayna, A. K. M. Baki and Feroz Ahmed, "Comparative Study of Rectangular and Circular Microstrip Patch Antennas in X Band", *International Conference on Electrical Engineering and Information & Communication Technology (ICEEICT) 2014.*

[10] Ujjal Chakraborty, Samiran Chatterjee, S.K. Chowdhury, P.P. Sarkar, "Triangular Slot Microstrip Patch Antenna for Wireless Communication", *Annual IEEE India Conference (INDICON), 2010.*

[11] Shalini Porwal, Ajay Dadhich, H S Mewara, M M Shanna and Sanjeev Yadav, "A novel E-shaped microstrip patch tri-band antenna for wireless applications", *International Conference on Soft Computing Techniques and Implementations- (lCSCTI), Faridabad, India, Oct 8-10, 2015.*

[12] Souryendu Das and SunandanGokhroo," Novel Hexagonal Pizza Shaped CPW Microstrip Patch Antenna for Applications in X band", *IEEE International Conference on Communication, Control and Intelligent Systems (ICCCIS), 2015.*

[13] A. Ghaznavi Jahromi, F. Mohajeri, "Design and Fabrication of a Miniaturized Microstrip Antenna Loaded by DNG Metamaterial", *WASET International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering*, Vol. 8, No.5, 2014.

[14] Deepanshu Kaushal, T. Shanmuganantham, "A Vinayak Slotted Rectangular Microstrip Patch Antenna Design for C-Band Applications", *John Wiley-Microwave and Optical Technology Letters*, Vol.59, No.8, pp. 1833-1837, August, 2017.

[15] Deepanshu Kaushal, T. Shanmuganantham, "Triple Band Microstrip Delete Patch Antenna for Satellite Related Applications", *Indian Journal of Innovations and Development*, Vol. 5, No. 12, pp.1-5, 2016.

[16] Deepanshu Kaushal, T. Shanmuganantham, "Comparative Analysis of Microstrip Moody Patch Antenna for Space Applications", *IEEE International Conference on Electromagnetic Interference and Compatibility (INCEMIC),* Bangalore, India, 2016.

[17] Sudhina H.K, Ravi M. Yadahalli, N. M. Shetti, "Bandwidth Control Using Reconfigurable Antenna Elements", *International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering*, Vol. 7, No. 12, 2013.

[18] Riki H. Patel, Arpan Desai, Trushit Upadhyaya, Shobhit K. Patel, "Design of S-Shape GPS Application Electrically Small Antenna", *WASET International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering*, Vol.9, No.4, 2015.

[19] Ankit Jain, Archana Agrawal, "Design and Optimization of a Microstrip Patch Antenna for Increased Bandwidth", *WASET International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering*, Vol. 7, No. 2, 2013.

[20] T. F. lai, Wan Nor, Liza Mahadi, Norhayati Soin, "Circular Patch Microstrip Array Antenna for Ku- band", *WASET International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering, Vol 2 No.12, 2008.*

[21] C. Elavarasi, T. Shanmuganantham, "Parametric Analysis of Water Lily Shaped Split Ring Resonator Loaded Fractal Monopole Antenna for Multiband Applications", *WASET International Journal of Electrical,*

Computer, Energetic, Electronic and Communication Engineering, vol.10, No.9, pp-1242-1245, 2016.

Deepanshu Kaushal completed B. Tech. in Electronics & Communication from Punjab Technical Universityin2014. He is currently a 2nd year M. Tech (E.C.E.) student of Pondicherry University and is doing his project on Microstrip Slotted Patch Antennas for Multiband Operation' under the guidance of Dr. T. Shanmuganantham (Assistant Professor, Department of Electronics Engineering, Pondicherry University, Pondicherry). His areas of interests include Antennas, Fractals and Metamaterials. He has presented 25 conference papers and written 12 journals till date.

T. Shanmuganantham received B.E. degree in Electronics and Communication Engineering from University of Madras, M.E. degree in Communication Systems from Madurai Kamaraj University and Ph.D. (Gold Medal) in the area of Antennas from National Institute of Technology, Tiruchirappalli, India under the guidance of Dr. S. Raghavan, Professor/ECE, NITT. He has 20 years of teaching experience in various reputed Engineering colleges such as PKIET, SSN College of Engineering, National Institute of Technology and Science. He is currently working as Assistant Professor in the Department of Electronics Engineering, School of Engineering & Technology, Pondicherry Central University, Pondicherry. His research interest includes Antennas, Microwave/Millimeter-Wave Circuits and Devices, MEMS/NEMS. He has published 350 research papers in various National and International Journals and Conferences. His biography was included in Marquis who is who in the world, USA in the year 2010. He received Fellow in ATMS and a member in IEEE, Life Member in ISSS, IETE, IE (India), CSI (India), Society of EMC, OSI, ILA, ISI and ISTE.