A Novel Broadband Compact Microstrip Patch Antenna for C band Applications

[1]Smarajit Maity, [2]Tapas Tewary, [3]Sunandan Bhunia
[1] Dept. of AEIE, Academy of Technology, India
[2]Dept. of ECE, Academy of Technology, India
[3]Dept. of ECE, Central Institute of Technology, India

Abstract
This paper proposes very thin broadband microstrip patch antenna for dual frequency operation. The designed antenna is highly compact with overall dimension of only 40×24×1.6 mm3. Inexpensive and well characterized FR4 substrate with 1.6 mm thickness, dielectric constant of 4.4 is used for the antenna design. Two resonance frequencies at 2.8 GHz and 5.2 GHz respectively with a -10 dB impedance bandwidth of 3.5 GHz, ranging from 2.6 GHz to 6.1 GHz is observed in the designed antenna. The VSWR of the proposed antenna is less than 2 throughout the bandwidth which exhibits good matching characteristics. Above 75% radiation efficiency with very low cross polarization is found at all resonance frequencies. Also 88% bandwidth is obtained in the proposed antenna.

Keywords
Microstrip Patch Antenna, Wideband, Wireless Communication, Compact

I. Introduction

Planar Microstrip patch antenna is very popular in many wireless application due to its various advantages like affordable cost, reduced size, and easy compatibility with other components [1]. But modern wireless communication needs antenna which are both compact and broadband to meet the needs of various application at the same time. Narrow bandwidth is one of the major disadvantage which limited its application in many areas earlier. But now researchers have identified various methods to increase bandwidth of microstrip patch antenna. Gain, radiation pattern, co-polarization, cross polarization are often compromised in the process of increasing bandwidth of patch antenna. Keeping the proper balance of the properties of the antenna has been one of the many challenges for the researchers. Staggering effect, slots loading in radiating patch and in ground plane, change of ground dimension, introducing defects in the ground plane have been the major activity to increase the bandwidth [2-10]. Along with broadband compactness is also a requirement in modern days. Pin loading, slot loading, defective ground structure are the major thrust areas to achieve compactness [11].

This proposed work utilizes the defected ground structure in combination with the radiating plane made of two elliptical structure and one rectangular structure to achieve wideband characteristics. A large -10 dB impedance bandwidth of 3.5 GHz with a percentage bandwidth of 88% along with simulated peak gain of 4.2 dBi are obtained for the proposed antenna. The CST Microwave studio is used to design, simulate and analyse the proposed antenna.

II. Antenna Design

The traditional equations [12] have been utilized to determine the proposed antenna initial Length and Width. The proposed antenna radiating patch consists of two ellipses and a small rectangle connecting them. These two ellipses are different in dimensions. The size of the upper ellipse is greater than the size of the lower ellipse. The major axis of the lower ellipse 14 mm long and length of minor axis is 12.4 mm. The length of major axis of upper ellipse has a dimension of 24 mm and the length of minor axis 20 mm. The rectangle connecting these two ellipses has a length of 6 mm and width of 5 mm. The radiating plane of the proposed antenna is printed on the one side of FR4 substrate having 1.6 mm thickness. The dimension of the substrate is $L_s \times W_s$. The patch of the proposed antenna is fed through a micro-strip line of length L_f mm and width W_f mm. The width Wf and the length Lf of micro-strip feed line is varied until a 50Ω characteristics impedance is obtained. The final length and width of the feed line are 5 mm and 2.92 mm respectively. One side of the substrate we have the radiating plane and on the other side of the substrate, a rectangular conducting ground plane having a dimension of $L_G \times W_G$ is printed. From the rectangular ground plane four small rectangular slots are cut and they are having different dimensions. Two of them have a area of 11×2 mm² and other two have the area of 12×1 mm². The area and location of the slots have been modified and they are optimized to achieve the broadband nature of the proposed antenna. The geometrical structure of the radiating plane and ground plane of the proposed antenna are given in Fig. 1 and Fig. 2. The detail of antenna design parameters and characteristics parameters of the proposed antenna are illustrated in Table no. 1.

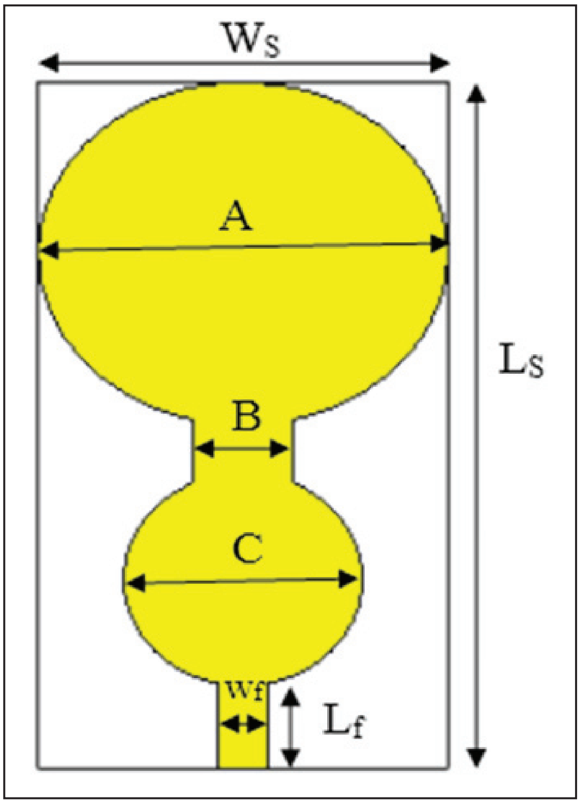


Fig. 1: Radiating Plane Structure

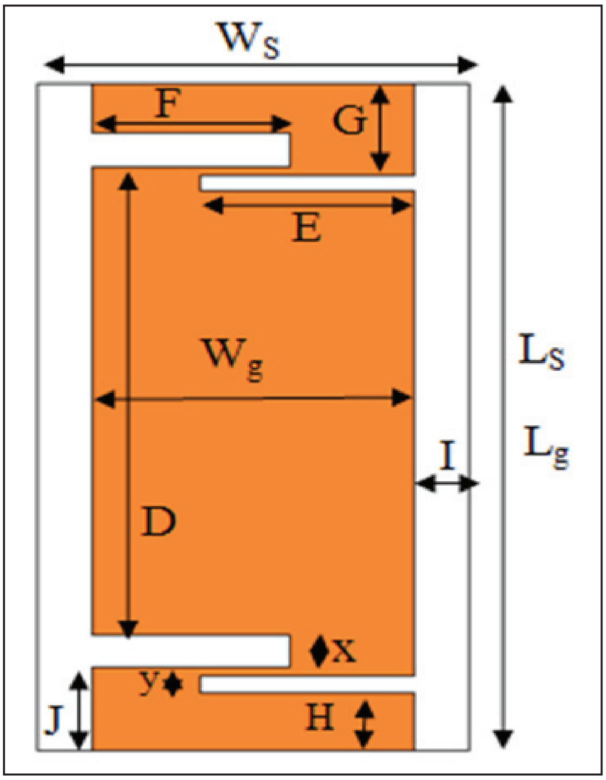


Fig. 2: Ground Plane Structure

Table 1: Antenna Parameter With Dimension

Antenna Parameters	Values
Operating bandwidth	2.6 GHz-6.1 GHz
Substrate	FR4 epoxy
Substrate Thickness (h)	1.6 mm
Relative permittivity	4.3
Loss Tangent	0.02
Characteristic Imp.	50Ω
W_S	24 mm
L_S, L_g	40 mm
W_f	2.92 mm
L_f	5 mm
W_g	18 mm
A	24 mm
B	6 mm
C	14 mm
D	28 mm
E	12 mm
F	11 mm
G	5.5 mm
H	3.5 mm
I	3 mm
J	5 mm
x	2 mm
y	1 mm

III. Antenna Simulation Results and Discussions

CST Microwave Studio is utilized to simulate the proposed antenna and also to obtain the simulation results. To achieve the final bandwidth of the proposed antenna the width of the ground plane is varied and these are named as design 1, design 2 and design 3. The reflection coefficients of design 1, design 2 and design 3 are shown in Fig. 3. This figure giving us the variation in the reflection coefficient of the proposed antenna w.r.t. the width of the ground plane. When the ground plane width is 24 mm which is equal to the substrate width, the design 1 shows dual band characteristics. The design 1 has first frequency band of (2.60 GHz -4.20 GHz) and second frequency band of (5.10 GHz – 5.36 GHz).When the ground plane width is shifted to 20 mm then the reflection co-efficient of design 2 shows slightly modified dual band nature. The Design 2 has first frequency band of (2.60 GHz-4.50 GHz) and second frequency band of (5.08 GHz-5.43 GHz). Finally the width of the ground plane is optimized to 18 mm (design 3, proposed) to achieve broadband characteristics. The CST simulation result of design 3 shows the wideband (2.60 GHz – 6.10 GHz) impedance characteristics of the proposed antenna. From the Fig. 3 it is obvious that the proposed antenna (design 3) resonates at two frequencies which are at 2.80 GHz and 5.20 GHz having reflection coefficients of -20.00 dB and -23.00 dB respectively.

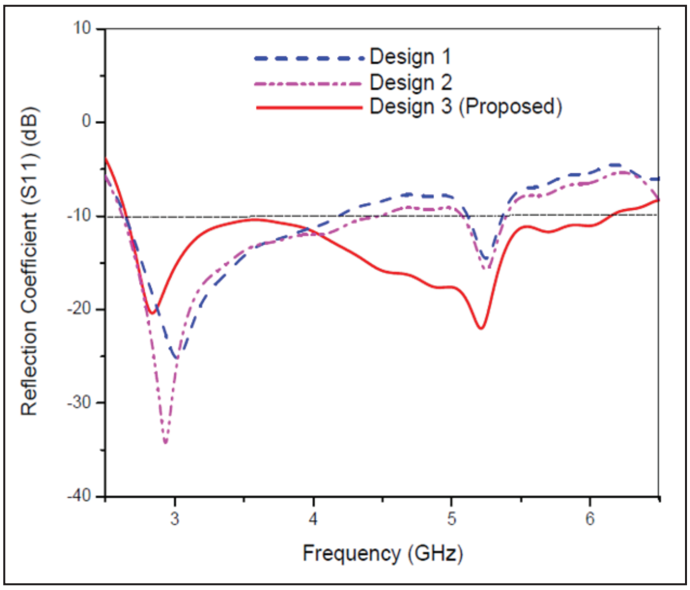


Fig. 3: Reflection coefficient vs. Frequency

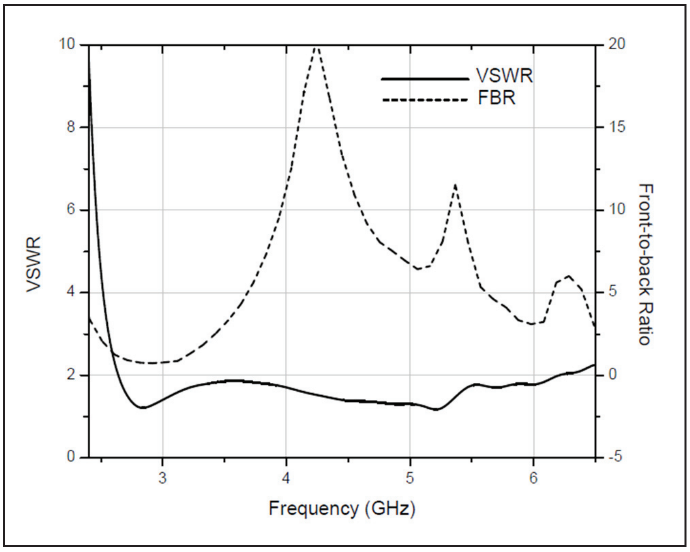
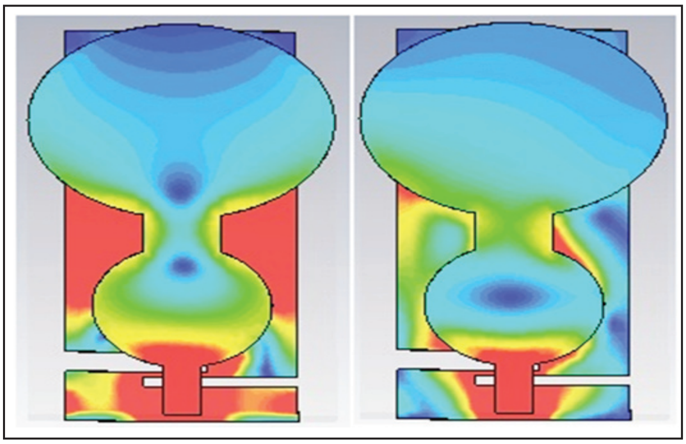
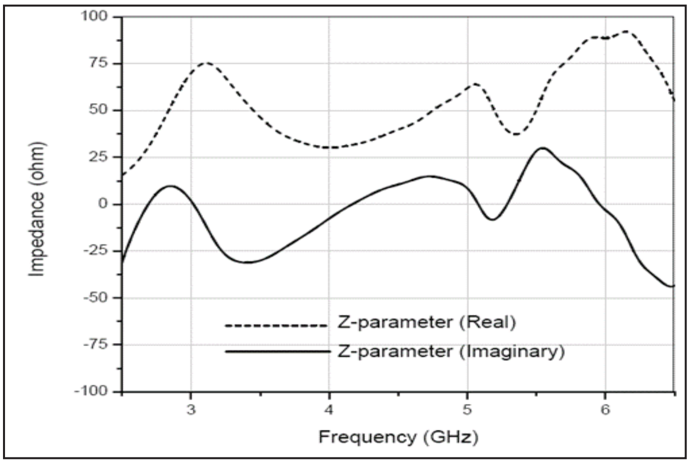


Fig. 4: VSWR and FBR

IV. Author na



(a) (b)



(c)

Fig. 5: Surface Current at (a) 2.8 GHz (b) 5.2 GHz and (c) Corresponding Z Parameter

The VSWR and front-to-back ratio (FBR) of the proposed antenna are illustrated in Fig. 4. It shows that the VSWR is less than 2 for the entire operating frequency band of the proposed antenna. Fig. 5(a) and Fig. 5(b) explain the surface current distributions of the proposed antenna for at the resonance frequencies of 2.8 GHz and 5.2 GHz respectively and Fig. 5(c) shows the corresponding Z parameter. It shows that the current is non zero all through the microstrip feed line of the proposed antenna. It is also observed that at both the resonance frequencies the current intensity is sufficiently large.

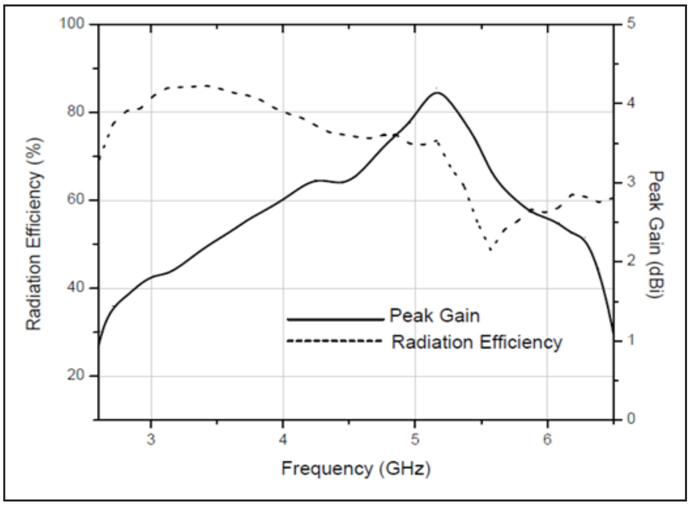
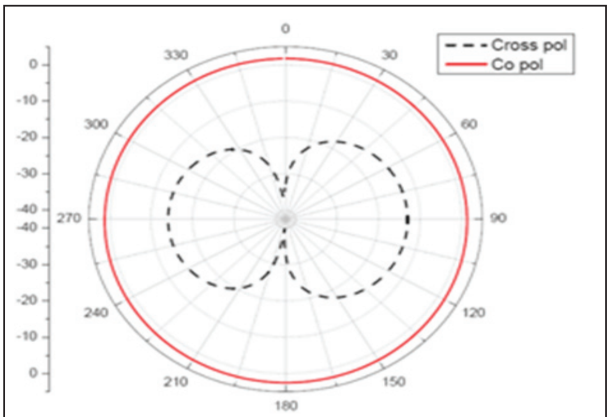
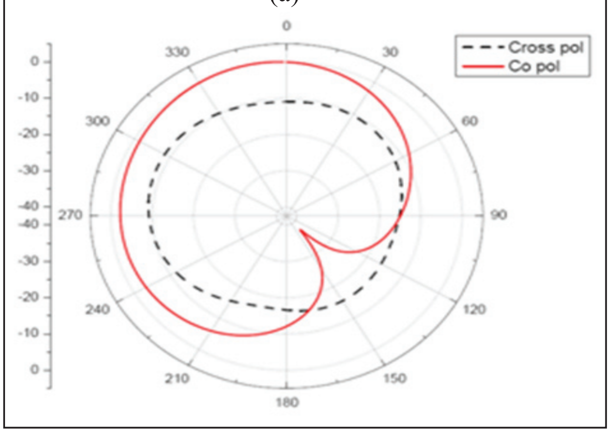


Fig. 6: Peak Gain and Radiation Efficiency

In Fig. 6 the simulated peak gain and radiation efficiency of the proposed antenna is represented against the frequency. It is noticed that a peak gain of 4.1 dBi is achieved at 5.20 GHz frequency. This figure also shows that the radiation efficiency is above 80% at 2.8 GHz and it is more than 70% at 5.2 GHz. The E plane co polarization and cross polarization radiation patterns are shown in Fig. 7(a) and Fig. 7(b). The H plane co polarization and cross polarization radiation patterns are shown in Fig. 8(a) and Fig. 8(b). From the radiation patterns it is observed that there is a good separation between co polarization and cross polarization in both the E plane and H plane.

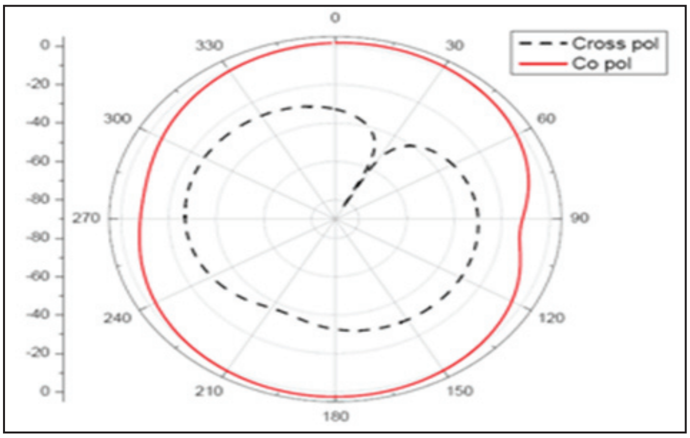


(a)

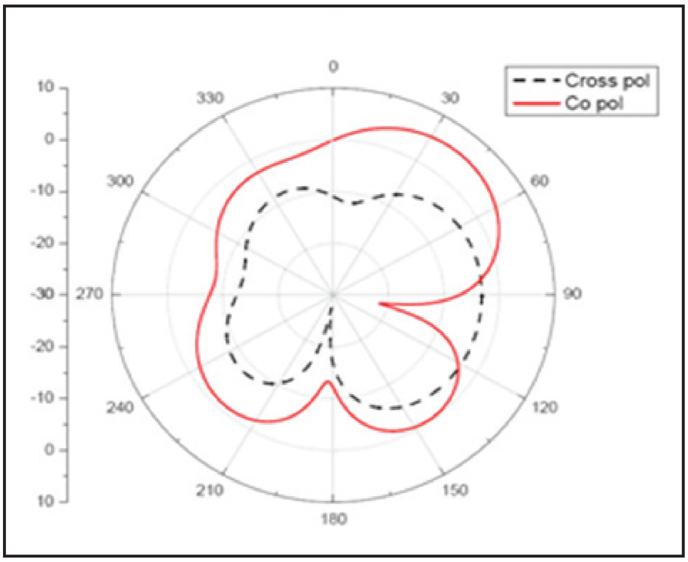


(b)

Fig. 7: Normalized E plane radiation pattern (a) 2.8 GHz and (b) 5.2 GHz



(a)



(b)

Fig. 8: Normalized H Plane Radiation Pattern (a) 2.8 GHz and (b) 5.2 GHz

Table 2: Comparison of Proposed and Reference Antenna

Ref. No.	Max B.W.	% of B.W.	Dimensions (mm²)
[2]	(1.01-2.01)GHz	66.2	120 x 120
[3]	(2.23-5.35) GHz	80	37 x 37
[4]	(1.38-3.5) GHz	86.9	65 x 30
[7]	(1.61-3.45) GHz	72.7	150 x 150
[8]	(1.46-1.68) GHz	25.31	120 × 120
[9]	(0.7-1.15) GHz	49	120 x115.2
[10]	(2.99-5.16) GHz	54.79	30 x 20
proposed	(2.6-6.1) GHz	88	40 × 24

V. Conclusion

The Table no 2 illustrates that the proposed antenna is a wideband and compact in dimension. The proposed antenna is designed, simulated and analyzed by using CST Microwave studio. From the CST simulation result of proposed antenna it is found that the antenna bandwidth has been increased to 88% which is comparatively high when it is compared with the previously designed antennas which are illustrated in Table no 2. From this table it is also observed that the physical dimension of the proposed antenna for the operating frequency range is comparatively compact than the previously given antennas. A low cost and reliable FR4 substrate has been used to model the proposed antenna. So the proposed model can easily be manufactured in large quantities with low cost. This antenna model may be very useful for any C band applications.

VIII. References

[1] P. Paga, H. C. Nagaraj and T.S. Rukmini, "Design of a tri band frequency reconfigurable monopole antenna for GSM UMTS and Wi-Fi applications", IJECT, vol. 8, Issue 2, pp. 45-49, April-June 2017.

[2] R. Xu, J-Y Li and W. Kun, "A broadband circularly polarized crossed-dipole antenna", IEEE transactions on antennas and propagation, VOL. 64,No. 10,October 2016

[3] Y. Sung ,"Bandwidth enhancement of a microstrip line fed printed wide slot antenna with a parasitic center patch ",IEEE Transaction on Antennas and Propagation ,60(2012), 1712-1716.

[4] J. Zeng and K-M Luk, "A simple wideband magnetoelectric dipole antenna with a defected ground structure", IEEE antennas and wireless propagation letters, VOL. 17,No. 8, August 2018, pp 1497-1500

[5] P. Kalra, Roopan and E. Sidhu, "Novel Terahertz Microstrip patch Antenna Design Employing FR4 as substrate for detection of Riboflavin", IJECT, vol. 8, Issue 2, pp. 102-105, April-June 2017.

[6] G. Kaur, P. S. Saini and A. Singh, "design of triangular monopole Microstrip Patch Antenna for UWB wireless Application", IJECT, vol. 8, Issue 2, pp. 54-56, April-June 2017.

[7] L. Chang, L.L. Chen, J.Q. Jhang and D. Li, "A Broadband Dipole Antenna with Parasitic Patch Loading" ieee antennas and wireless propagation letters, VOL 17, NO 9, SEPTEMBER 2018,pp 1717-1721

[8] K. E. Kedze and I. Park, " Low-profile dipole Antenna With corner cut Parasitic Patches for Bandwidth enhancement", APCAP 2018, pp 294-295

[9] S. A. Rezaeieh and A. M. Abbosh, "Compact planar loop-dipole composite antenna with director for bandwidth enhancement and back radiation suppression," IEEE Trans. Antennas Propag., vol. 64, no. 8, pp. 3723–3728, Aug. 2016.

[10] S. Maity, T.Tewary and S. Bhunia, " Wideband dipole microstrip patch antenna for C-band application" SARC International Conference ,Kolkata,31st August 2020,pp-44-48

[11] L. K. Singh, B. Gupta and P.P. Sarkar "A wideband dual polarized dipole antenna with folded metallic plates", IJECT, vol. 2, Issue 4, pp. 71-76, Oct-Dec 2011.

[12] Antenna Theory, Analysis and Design, Constantine A.Balanis, Wiley

Mr. Smarajit Maity has obtained his B.E. in Electronics and Instrumentation Engineering from Vidyasagar University in 2002. He earned his M.E. degree in Electronics and Telecommunication Engineering from Bengal Engineering College (Presently known as Bengal Engineering and Science University/Indian Institute of Engineering Science and Technology, Shibpur) in the year 2005. He is currently working as Assistant Professor in the department of Electronics and Instrumentation Engineering, Academy of Technology, Adisaptagram, West Bengal. He has published 02 research articles in reputed conferences. His area of research interest includes Microstrip Antenna, Frequency Selective Surface, Optoelectronics devices, Photovoltaic system etc.

Mr. Tapas Tewary has obtained his B. Tech. in Electronics and Communication Engineering from Kalyani Govt. engineering College, Kalyani University, India in 2004. He earned his M. Tech. degree in VLSI Design from Institute of Radiophysics and Electronics, Calcutta University in the year 2008. He is currently working as Assistant Professor in the department of Electronics and Communication Engineering, Academy of Technology, Adisaptagram, West Bengal. He has published 05 research articles in reputed conferences. His area of research interest includes Microstrip Antenna, Frequency Selective Surface, VLSI Design, Optoelectronics devices etc.

Dr. Sunandan Bhunia has obtained his B. Tech and M. Tech from Institute of Radiophysics and Electronics, Calcutta University in 2002 and 2004 respectively. He has obtained PhD degree in engineering from Jadavpur University in 2009. He was awarded gold medal from Vidyasagar University for 1st class 1st in Physics (H) in 1999. He is currently working as Associate professor in the department of Electronics and Communication Engineering, Central Institute of Technology, BTAD, Assam. He has published about 50 research articles in reputed international & national journal and conferences. His area of research interest includes, Microstrip Antenna, Microstrip Filter, and Frequency Selective Surfaces, VLSI etc.