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Compact and Broadband Triangular Microstrip Patch Antenna Design Utilizing Shorting Pin

A. Roy[1*], S. Bhunia[2], D.C. Sarkar[3], P.P. Sarkar[4]

[1*]Dept. of Electronics & Communication Engineering, Haldia Institute of Technology, Haldia, East Medinipur, WB, India
[2] Dept. of Electronics & Communication Engineering, Central Institute of Technology, Kokrajhar, Assam, India
[3]Dept. of Engineering & Technological Studies, University of Kalyani, Kalyani, Nadia, WB, India
[4]Dept. of Engineering & Technological Studies, University of Kalyani, Kalyani, Nadia, WB, India

[*]Corresponding Author: avisankar.roy@gmail.com, Tel.: 8001630503

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Abstract— In this paper a design of single layered compact and broadband monopole triangular microstrip patch antenna utilizing shorting pin has been proposed. It has been theoretically and practically investigated that defecting ground plane leads to bandwidth enhancement and shorting pin lowers the resonant frequency which results size reduction. Using only defected ground plane the bandwidth has been achieved 47.6% and using shorting pin the size of the antenna is reduced by 89% compared to reference patch, with dual band and enhanced bandwidth of 46%.

Keywords*— Triangular Microstrip Patch Antenna, Defected ground, Shorting pin, Compact, Broadband*

I. INTRODUCTION

Broadband communication technology has a great attraction because of its advantages such as high data rate over short ranges. Thus bandwidth enhancement along with miniaturization of microstrip patch antenna is on demand to keep its importance in modern communication systems [1]. Microstrip patch antenna has several attractive features of small size, light weight, easy integration capability with circuits. Due to these advantages, microstrip patch antennas are used in portable devices such as mobile phones, laptops etc. [2].Various research articles have discussed different types of realization techniques of compact and broadband microstrip patch antenna.

The realization of compact multi frequency microstrip patch antenna has been reported by various authors in their articles using several techniques like cutting the slots on the patch, cutting slots on ground plane, monopole structure with defected ground plane, C shaped ring loading, using parasitic element etc. *S. Bhunia et al*. [3] has investigated over compactness of microstrip patch antenna with the variation of slot length on the patch and he has found 85% size reduction with respect to conventional patch. He has also found 67% size reduction using unequal finger like slots on the patch [4].Miniaturization of microstrip patch antenna by cutting the slots on the patch has been discussed in many more literatures [5-6]. Another technique of achieving multi frequency operation with monopole antenna structure and defected ground plane has been discussed in some articles [7-8]. *Richard H. Chen et al*. [9] has proposed a novel miniaturized design of a microstrip fed slot antenna loading with a pair of C shaped ring inside a half wavelength slot and he has achieved 50% size reduction in this design. *Debasis Mitra et al.* [10] has designed a compact microstrip patch antenna loading with a pair of split ring resonator and he has found 26% size reduction in comparison to slot antenna without split ring resonator. *Jun-Won Kim et al.* [11] has proposed another new design of a compact multiband microstrip patch antenna using inverted L and T shaped parasitic element. Along with the miniaturization of microstrip patch antenna various bandwidth enhancement techniques have been also discussed in some literature. *Yikai Chen et al.* [12] has proposed a simple bandwidth enhancement method by introducing a distributed LC circuit to the patch antenna. *Gaojian Kang et al.* [13] has investigated on inverted S monopole structure and he has achieved about 560MHz and 500MHz bandwidth at 2GHz and 3GHz resonant frequencies respectively. *Rajesh K Vishwakarma et al*. [14] has studied over dual band operation of equilateral triangular microstrip patch antenna. In this paper a design of a compact and broadband monopole triangular microstrip patch antenna has been presented with simulated and measured results. The bandwidth enhancement as well as size reduction has been achieved very successfully and the measured results have been found very close to the simulated one. By defecting the ground plane and introducing a shorting pin at optimum location, the 46% bandwidth and about 89% size reduction have been found.

II. ANTENNA CONFIGURATION AND DESIGN CONCEPT

The resonance frequency of a triangular microstrip patch antenna corresponding to a various mode is given by the equation [15],

$$f_r = \frac{ck_{mn}}{2\pi\sqrt{\varepsilon_r}} = \frac{2c}{3a\sqrt{\varepsilon_r}}\sqrt{m^2 + nm + n^2} \quad (1)$$

Where *c* is the velocity of light in free space, *a* is the length of side of triangular patch and k_{mn}= wave number, given by,

$$k_{mn} = \frac{4\pi}{3a}\sqrt{m^2 + mn + n^2} \quad (2)$$

So the equation of resonant frequency in lowest order is,

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}} \quad (3)$$

More accurate value of resonant frequency may be determined by considering fringing field effect and replacing ε_r and *a* with ε_{reff} and a_{eff}. Where,

$$\varepsilon_{reff} = \frac{1}{2}(\varepsilon_r + 1) + \frac{1}{4}\frac{(\varepsilon_r - 1)}{\sqrt{1 + \frac{12h}{a}}} \quad (4)$$

and, $$a_{eff} = a + \frac{h}{\sqrt{\varepsilon_r}} \quad (5)$$

Hence, $$f_r = \frac{2c}{3a_{eff}\sqrt{\varepsilon_{reff}}} \quad (6)$$

Thus according to equation no (3), for 5.8GHz resonant frequency the length of the side of the triangular patch is $a = 16mm$. The antenna with mentioned dimension has been constructed using FR4 substrate ($\varepsilon_r = 4.4$) with the thickness of $h = 1.6mm$.

Figure 1 shows the geometry of the reference antenna. The radiating patch is coaxially probe fed at the position mentioned in the figure to obtain optimum impedance matching.

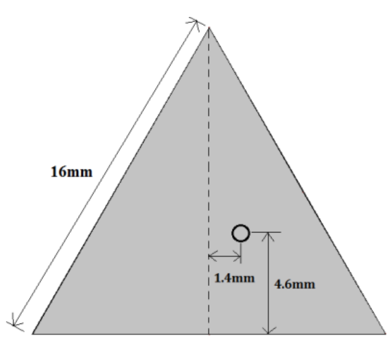

Fig.1- Antenna 1 geometry with infinite ground plane

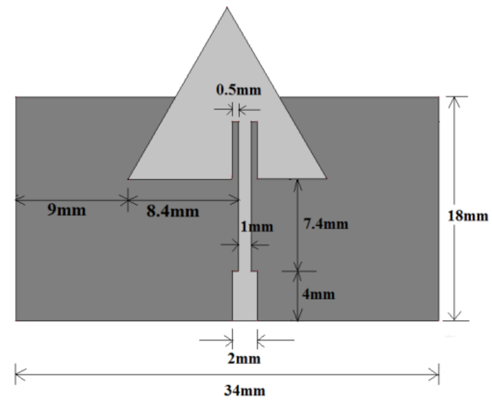

Fig.2- Antenna 2 geometry with finite ground plane.

Figure 2 shows the Antenna 2 geometry with finite ground plane. The optimum result has been found for ground plane with dimensions of width $W_g = 34mm$ and length $L_g = 18mm$ and Antenna 2 is fed by inset microstrip line for proper impedance matching and to avoid the generation of higher order modes which produce cross polarization radiation. The proposed Antenna 3 structure with shorting pin at optimum location is shown in figure 3. The shorting pin with radius 0.2mm is placed through a via hole at a distance 2mm from width side of the ground plane and 14.8mm from length side of the ground plane as shown in the figure 3.

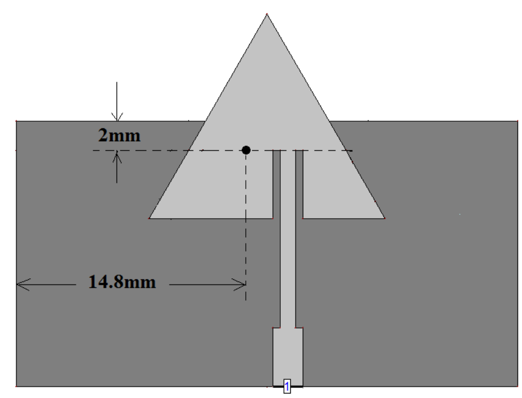

Fig.3- Antenna 3 geometry with shorting pin

III. EQUIVALENT CIRCUIT

The conventional microstrip patch antenna can be modelled as simple RLC circuit shown in figure 4. For the Antenna 2 the partial ground plane introduces a parallel capacitive reactance [16] in the conventional microstrip patch antenna which forced the antenna to resonate at lower frequency in addition to the main resonant frequency. These two frequencies are close to each other and as a result a wide bandwidth has been achieved like the staggering effect. The equivalent circuit is shown in figure 5. When shorting pin is loaded in the patch a series LC circuit is loaded with the input impedance of the antenna [17]. Since the shorting pin is located close to the feed point, a strong capacitive coupling between the feed and short takes place. This capacitive effect counters the usual inductive nature of the patch antenna which introduced another distinct resonant frequency much lower than the earlier. Thus shorting pin loading in the microstrip patch antenna can produce dual band operation. The equivalent circuit for microstrip patch antenna with shorting pin is shown in figure 6.

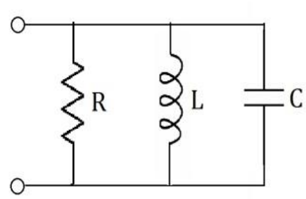

Fig.4- Equivalent circuit for reference Antenna 1

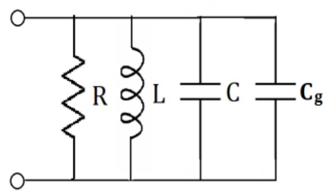

Fig.5- Equivalent circuit for proposed Antenna 2

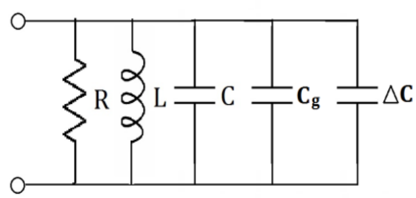

Fig.6- Equivalent circuit for proposed Antenna 3 with shorting pin.

IV. RESULTS AND DISCUSSION

The simulated return losses of the reference and proposed antenna have been studied using method of moment based IE3D software and shown in Table-1. The measured results of fabricated antennas have been studied in vector network analyser and the results are shown in Table-2. It has been observed from simulated and measured results that bandwidth has been increased about 47.6% with respect to the bandwidth of reference patch for defecting the ground plane. With the utilization of the shorting pin dual band operation has been found and resonant frequency has been lowered to 2GHz that causes about 89% of size reduction with respect to reference patch. With dual band operation bandwidth has been also found about 46%.

Table-1 Simulated results

Antenna	Resonant Frequency (GHz)	Return Loss (dB)	Bandwidth (MHz), %
Antenna 1	5.58	35	114, 2.04%
Antenna-2	5.26	17	1782, 33.9%
Antenna-3	2.5	13	138, 5.42%
	5.17	17	2000, 38.67%

Table-2 Measured results

Antenna	Resonant Frequency (GHz)	Return Loss (dB)	Bandwidth (MHz), %
Antenna 1	5.3	32	200, 3.77%
Antenna 2	5.25	18	2500, 47.6%
Antenna 3	2	17	210, 10.5%
	5.45	16	2500, 46%

Thus utilizing shorting pin and defected ground plane the triangular microstrip patch antenna shows dual band (S and C band) and broadband operation. Figure 7 shows the simulated and measured frequency vs return loss graphs for reference Antenna 1. The simulated and measured frequency vs return loss graphs for Antenna 2 and proposed Antenna 3 are shown in figure 8 and figure 9 respectively.

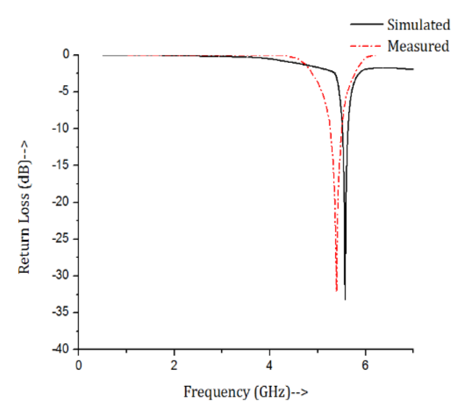

Fig.7- Frequency vs return loss graph for Antenna 1

The radiation pattern for reference Antenna 1, Antenna 2 and proposed Antenna 3 are shown in figure 10-13. The 3dB beam width for proposed Antenna 3 at 2GHz and 5.45GHz are 150^0 and 110^0 respectively.

The measured gain of Antenna 3 for 2GHz and 5.45GHz are 2dBi and 1.5dBi respectively. Directivity and radiation efficiency (Simulated) of Antenna 3 for 2.5GHz and 5.17GHz are 3dBi, 4.5dBi and 80%, 50% respectively.

The graphs for gain, directivity and radiation efficiency of Antenna 3 are shown in figure 14-16.

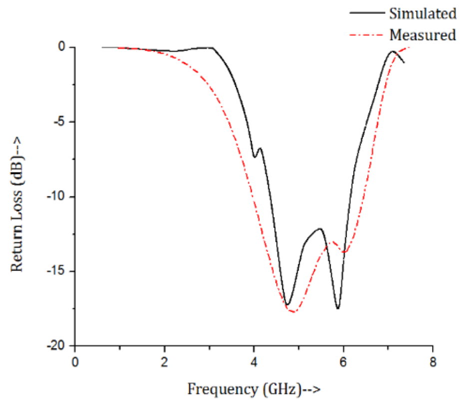

Fig.8- Frequency vs return loss graph for Antenna 2

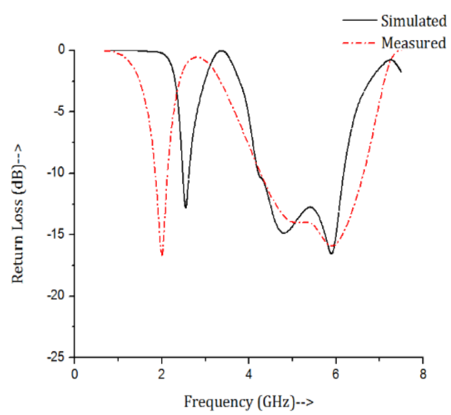

Fig.9- Frequency vs return loss graph for Antenna 3

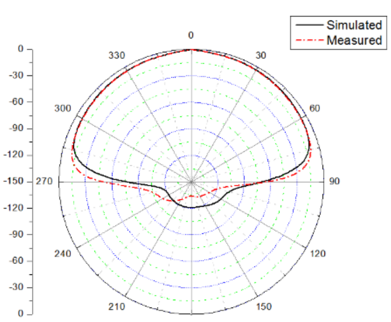

Fig.10- Radiation pattern of Antenna 1 at 5.3GHz

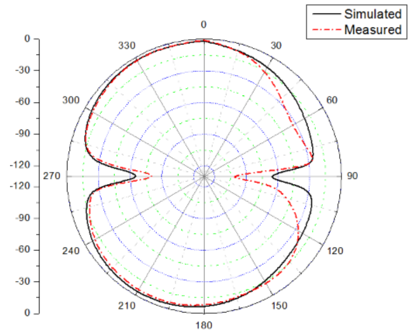

Fig.11- Radiation pattern for Antenna 2 at 5.25GHz

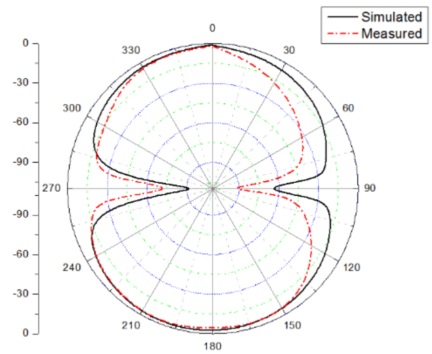

Fig.12- Radiation pattern for Antenna 3 at 2GHz

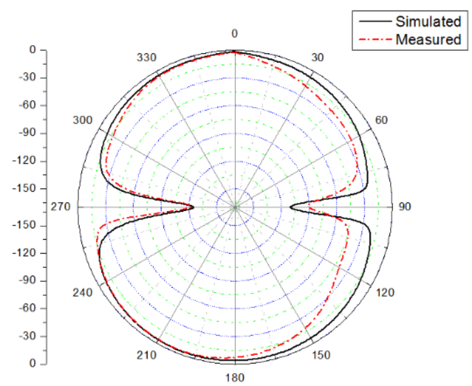

Fig.13- Radiation pattern for Antenna 3 at 5.45GHz

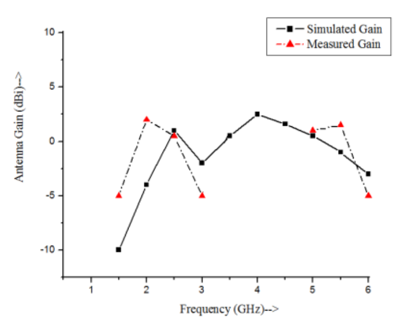

Fig.14- Frequency vs Gain for Antenna 3

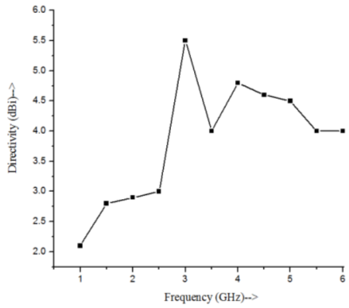

Fig.15- Frequency vs Directivity for Antenna 3

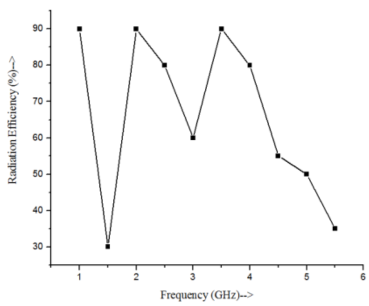

Fig.16- Frequency vs Radiation Efficiency for Antenna 3

V. CONCLUSION

A novel design for compact dual band and broadband triangular microstrip patch antenna utilizing shorting pin has been proposed, fabricated and experimentally studied. The measured results are well matched with the simulated results. With the defecting ground plane about 47.6% bandwidth has been achieved. It has also been discussed with equivalent circuit that shorting pin has an important role for the dual frequency operation as well as miniaturization of antenna. With shorting pin about 46% bandwidth has been found associating dual band operation with about 89% of size reduction. The proposed antenna radiates dual frequencies in S and C band that are very useful in wireless communication systems. This antenna is suitable for UMTS and WLAN applications.

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REFERENCES

[1] K. L. Wong, "*Planer Antennas for Wireless Communications*", John Wiley & Sons Ltd, US, pp.1-440, 2003.

[2] Z. N. Chen, "*Antennas for Portable Devices*", John Wiley & Sons Ltd, US, 1-607, 2007.

[3] S. Bhunia, D. Sarkar, S, Biswas, P. P. Sarkar, B. Gupta, K. Yasumoto, "*Reduced Size Small Dual and Multi-Frequency Microstrip Antenna*" , Microwave and Optical Technology Letters, Vol. 50, No.4, pp.961-965, 2008.

[4] S. Bhunia, P. P. Sarkar, "*Reduced sized dual frequency microstrip antenna*", Indian Journal of Physics, Vol. 83, No. 10, pp. 1457-1461, 2009.

[5] M. N. Mahmoud R. Baktur, "*A Dual Band Microstrip-Fed Slot Antenna*", IEEE Transactions on Antennas and Propagation, Vol. 59, No. 5, pp. 1720-1724, 2011.

[6] U. Chakraborty, A. Kundu, S. K. Chowdhury, A. K. Bhattacharjee, "*Compact Dual-Band Microstrip Antenna for IEEE 802.11a WLAN Application*", IEEE Antennas and Wireless Propagation Letters, Vol. 13, pp.407-410, 2014.

[7] W. C. Liu, C. M. Wu, Y. Dai, "*Design of Triple-Frequency Microstrip-Fed Monopole Antenna Using Defected Ground Structure*", IEEE Transactions on Antennas and Propagation, Vol. 59, No. 7, pp.2457-2463, 2011.

[8] M. S. Ellis, Z. Q. Zhao, J. N. Wu, Z. P. Nie and Q. H. Liu, "*A New Compact Microstrip-Fed Monopole Antenna for Triple Band WLAN/WiMAX Applications*", Progress In Electromagnetics Research Letters, Vol. 48, pp.129-135, 2014.

[9] R. H. Chen and Y. C. Lin, "*Miniaturized Design of Microstrip-Fed Slot Antennas Loaded With C-Shaped Rings*", IEEE Antennas and Wireless Propagation Letters, Vol. 10, pp.203-206, 2011.

[10] D. Mitra, S. R. B. Chaudhuri, "*CPW-Fed Miniaturized Split Ring-Loaded Slot Antenna*", Microwave and Optical Technology Letters. Vol. 54, No. 8, pp.1907-1911, August 2012.

[11] J. W. Kim, T. H. Jung, H. K. Ryu, J. M. Woo, C. S. Eun, D. K. Lee, "*Compact Multiband Microstrip Antenna Using Inverted-L and T-Shaped Parasitic Elements*", IEEE Antennas and Wireless Propagation Letters, Vol. 12, pp.1299-1302, 2013.

[12] Y. Chen, S. Yang, and Z. Nie, "*Bandwidth Enhancement Method for Low Profile E-Shaped Microstrip Patch Antennas*", IEEE Transactions on Antennas and Propagation, Vol. 58, No. 7, pp 2442-2447, 2010.

[13] G. Kang, Z. Du, "*A Novel Compact Broadband Printed Monopole Antenna for Mobile Handsets*", Microwave and Optical Technology Letters, Vol. 53, No. 1, Pp. 118-121, 2011.

[14] R. K Vishwakarma, J A Ansari and M K Meshram, "*Equilateral Triangular Microstrip Antenna for Circular Polarization Dual-Band Operation*", Indian Journal of Radio & Space Physics, Vol. 35, pp. 293-296, 2006.

[15] R. Garg & S. A. Long, "*An improved formula for the resonant frequencies of the triangular microstrip antenna*", IEEE Transaction on Antennas & Propagation (USA), Vol. 36, Issue 4, pp. 570, 1988.

[16] A. Nagar, AS. Mandloi , KS. Solanki, "*Microstrip Antenna Using Dummy EBG*", International Journal of Scientific Research in Network Security and Communication, Vol.1, Issue.2, pp.24-28, 2013.

[17] R. B. Waterhouse, "*Microstrip Patch Antennas: A Designer's Guide*", Kluwer Academic Publishers, USA, pp.1-421, 2003.

AUTHORS PROFILE

Mr. Avisankar Roy received his B.Tech and M.Tech degree in Electronics & Communication Engineering from Maulana Abul Kalam Azad University of Technology (formerly known as West Bengal University of Technology), WB, India, in the year of 2006 and 2009 respectively. His area of research interest includes Microstrip Antenna design and Frequency Selective Surfaces. He has contributed to numerous research articles in various journals and conferences of repute. He is working towards his Ph.D. degree.

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 40 research article in reputed international & national journal and conferences. His area of research interest includes, Microstrip Antenna, Microstrip Filter, and Frequency Selective Surfaces, VLSI etc.

Dr. Debasree Chanda Sarkar was felicitated with a Ph.D in engineering from Jadavpur University in the year 2005. She has obtained her M.E from Bengal Engineering and Science University, Shibpur in the year 1994. She earned her B.E degree in Electronics and Telecommunication Engineering from Bengal Engineering College (Presently known as IIEST, Shibpur) in the year 1991. She is presently working as Scientific Officer (Associate Professor Rank) at the Dept. of Engineering & Technological Studies, University of Kalyani. Her area of research includes, Microstrip Antenna, Microstrip Filter, Frequency Selective Surfaces, and Artificial Neural Network. She has contributed to numerous research articles in various journals and conferences of repute.

Dr. Partha Pratim Sarkar was felicitated with a Ph.D in engineering from Jadavpur University in the year 2002. He has obtained his M.E from Jadavpur University in the year 1994. He earned his B.E degree in Electronics and Telecommunication Engineering from Bengal Engineering College (Presently known as IIEST, Shibpur) in the year 1991. He is presently working in the rank of Professor at the Dept. of Engineering & Technological Studies, University of Kalyani. His area of research includes, Microstrip Antenna, Microstrip Filter, Frequency Selective Surfaces, and Artificial Neural Network. He has contributed to numerous research articles in various journals and conferences of repute. He is also a life Fellow of IETE and IE(India).

