Multiband Wireless Microstrip Antenna with Embedded Meta-materials for MIMO

Arun Balan[1], R.Ramesh[2], Usha Kiran K.[3]
School of Electronics Engineering, VIT University, Chennai, Tamil Nadu, India
[1]arun.balan2013@vit.ac.in
[3]usha.kiran@vit.ac.in
[2]ramesh.r@vit.ac.in

Abstract—In this paper, a novel meta-material embedded symmetric multi-slot antenna is presented. This paper investigates the profound variations of meta-material embedded microstrip antenna characteristics from the conventional microstrip antenna. Microstrip antennas used for MIMO application can be made up by embedding meta-material for good bandwidth requirements and good isolation characteristics. Slot loading method is used for getting multi band. Proposed antenna shows an electromagnetic resonant state at 7.7GHz, with a return loss of -39.99dB and good bandwidth.

Keywords-Channel Bandwidth, Isolation, Meta-Materials, Microstrip, MIMO, Slot Loading.

I. Introduction

Energy conservation in wireless communication is an important factor, which we want to take care in recent days of revolutionary usage of wireless devices. As per [4] One of the advanced physical layer technique MIMO have been proposed to address this issue, MIMO is an acronym that stands for Multiple Input Multiple Output, which employs multiple antennas at the transmitter and receiver side, it helps to create different channel to transmit and receive data. Along with energy conservation, demand for high data rate and channel bandwidth is always prominent area of concern, so this technology demands for antenna with wide bandwidth and good isolation characterisation. The main focus of this paper is on meta-material embedded symmetric multi-slot antenna, Meta-materials are artificially structured materials, whose electromagnetic properties can be tailored and tuned in ways not easily accomplished with conventional materials. Meta-materials are much smaller than the wavelength of the electromagnetic waves propagating through the material typically on the order of 1/10th the wavelength's size.

Embedding meta-materials in to microstrip antenna design gives a new dimension towards performance enhancement, versatile characteristics of meta-materials like negative permittivity and permeability rise up a lot of possibilities in microstrip antenna design. Specialty of Meta-materials is, they have a negative index of refraction, so it can bend RF wave's more than normal antennas, which result in much smaller antennas. Slot loading method is employed in the above mentioned microstrip antenna because It is easy to construct and by only adjusting length, width, and position of the slot we can optimize the output and obtain satisfactory performance. In [5] authors design and implement a symmetric multi-slot antenna which provides multi-band and good isolation characteristics, Idea of making different current paths In [5] are employed to improve the performance of antenna in the proposed paper, for modelling the design we make the use of the software HFSS (High Frequency Structural Simulator). The software gives a convenient environment to model and optimize the designed antenna.

II. Antenna Design

Before designing an antenna we need to fix three parameters, such as antenna height (h), permittivity of the substrate (Ɛr), and resonant frequency (fr). It is convenient to write a mat-lab program for rectangular patch to get various sensitive parameters. Antenna designed at [fr=3.4GHz, h=1.6mm, Ɛr=4.4] is given below.

- Width of the patch

$$W = \frac{C}{2 \cdot fr} \cdot \sqrt{\frac{2}{(\varepsilon r + 1)}} \tag{1}$$

- Effective dielectric constant

$$\varepsilon reff = \frac{\varepsilon r + 1}{2} + (\frac{\varepsilon r - 1}{2}) \cdot (1 + 12 \cdot \frac{h}{W})^{-\frac{1}{2}} \tag{2}$$

- Effective increment in length

$$\Delta L = \frac{h \cdot 0.412 \cdot (\varepsilon reff + 0.3) \cdot ((\frac{W}{h}) + 0.264)}{(\varepsilon reff - 0.258) \cdot ((\frac{W}{h}) + 0.8)} \tag{3}$$

- Effective length of the patch

$$Leff = \frac{c}{2 \cdot fr \cdot \sqrt{\varepsilon reff}} \tag{4}$$

- Length of the patch

$$L = Leff - 2 \cdot \Delta L \tag{5}$$

- Dimension of ground and substrate

$$Wg = (6 \cdot h) + W \tag{6}$$

$$Lg = (6 \cdot h) + L \tag{7}$$

III. rectangular patch antenna design and simulation results

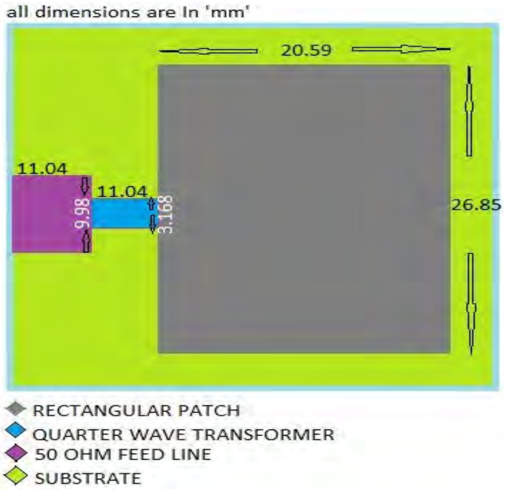
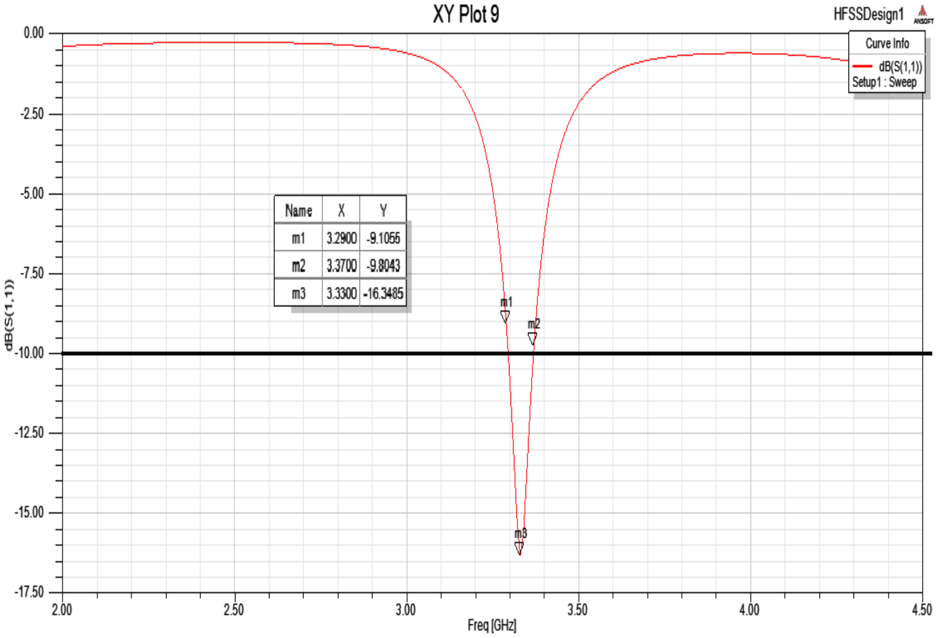


Fig. 1. Rectangular patch antenna

Rectangular patch antenna is a common micro-strip antenna. Here we use micro-strip line feed with quarter wave transformer to feed the micro-strip antenna. Return-loss plot of Fig. 1 antenna provides the extend of matching with transmission line and patch, from Fig. 2 we got -16.34dB return-loss at 3.4GHz with a bandwidth of 80MHz.



Name	X	Y
m1	3.2900	-9.1056
m2	3.3700	-9.8043
m3	3.3300	-16.3485

Fig. 2. S_{11} parameter of rectangular patch antenna

Radiation pattern of an antenna gives the overall idea about the performance of an antenna, far field zone radiation pattern is the crucial parameter for an antenna, directive gain and efficiency of antenna is calculated from far field zone radiation pattern. Radiation pattern of rectangular patch antenna is given in Fig. 3, shows a gain total of 1.84dB.

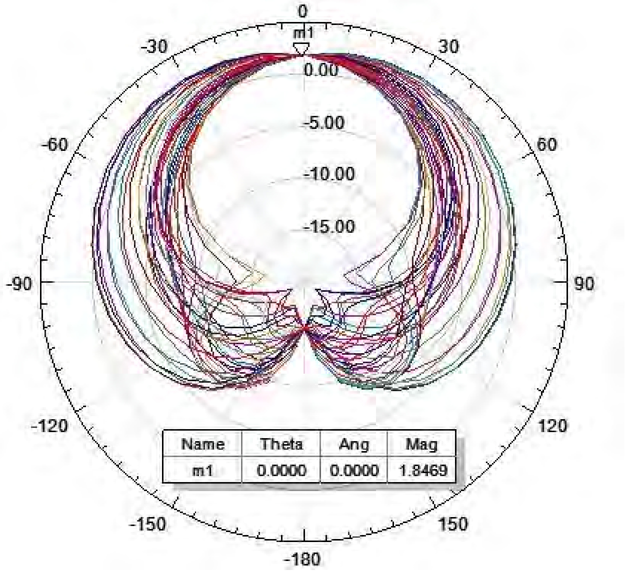


Fig. 3. Radiation pattern of rectangular patch antenna

IV. meta-material embedded rectangular patch antenna design and simulation results

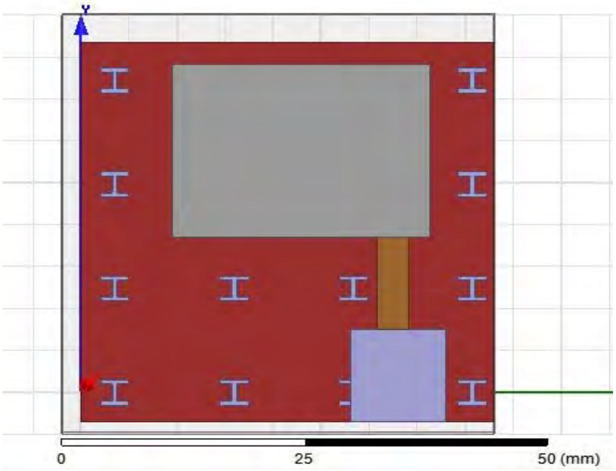


Fig 4. Meta-material embedded rectangular patch antenna

The Fig. 4, shows the meta-material embedded rectangular patch antenna, apart from conventional patch antenna in Fig. 1, I-shaped left-handed material is of size less than the wavelength of 1/10th wavelength of the antenna. I-shaped unit cell is periodically arranged in the substrate 1mm below from the patch just like as in [8]. Meta-material unit cell is given in Fig. 5.

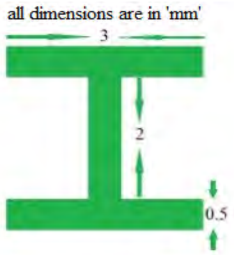


Fig. 5. Unit cell of meta-material used in patch antenna design

It resonates at three different frequencies 3.5, 7.3, 8.5GHz Return loss of corresponding frequencies are -24.2, -34.5, -24.6dB. It provide a good bandwidth at 7.3 and 8.5GHz, at 7.3 Bandwidth 3GHz= 39.7%, at 8.5 bandwidth 3GHz=34.1%. The bandwidth is improved up to 37% compared with rectangular patch antenna. Fig. 6 shows the S_{11} parameter.

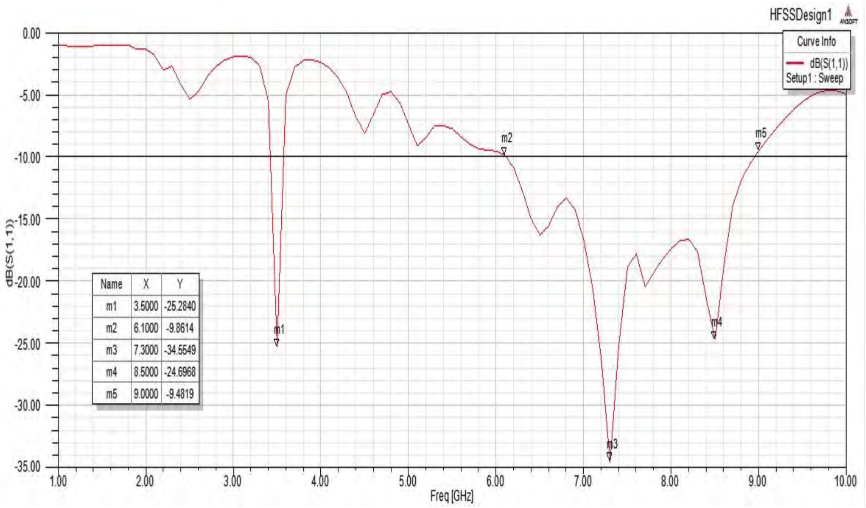


Fig. 6. S_{11} parameter of Meta-material embedded rectangular patch antenna

From the radiation pattern given in Fig. 7, meta-material embedded rectangular patch antenna gives an improved gain of 2.53dB.

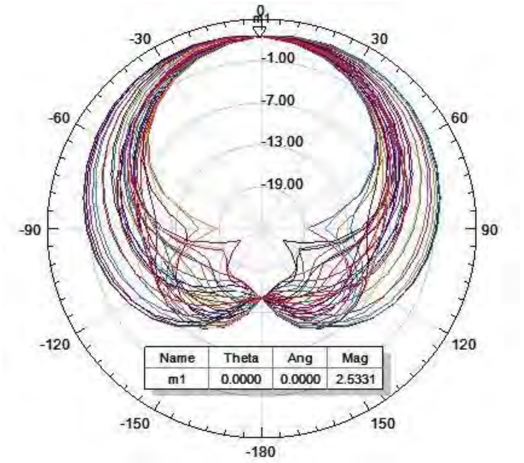


Fig. 7. Radiation pattern of meta-material embedded rectangular patch antenna

V. proposed microstrip antenna design and simulation results

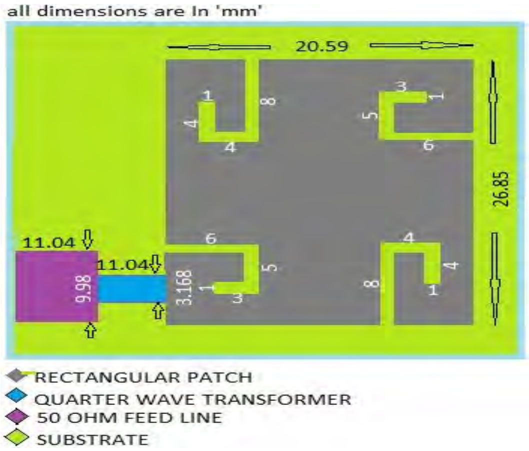


Fig. 8. Optimized patch dimensions for proposed antenna

Fig. 8. shows the diagrammatic representation of meta-material embedded rectangular patch antenna. Modelled antenna is shown in Fig. 9; it is optimized by varying the slots size and position. Here feed is given in such a way that to provide maximum isolation when this antenna is used in MIMO array. It gives a good return-loss plot compared with Fig. 6.

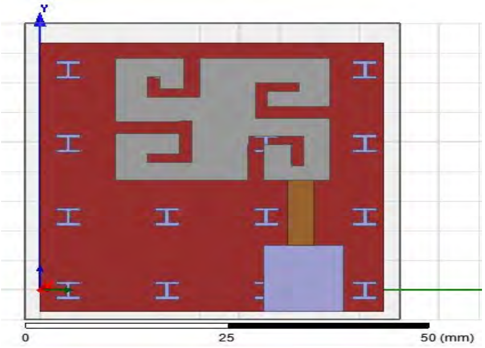
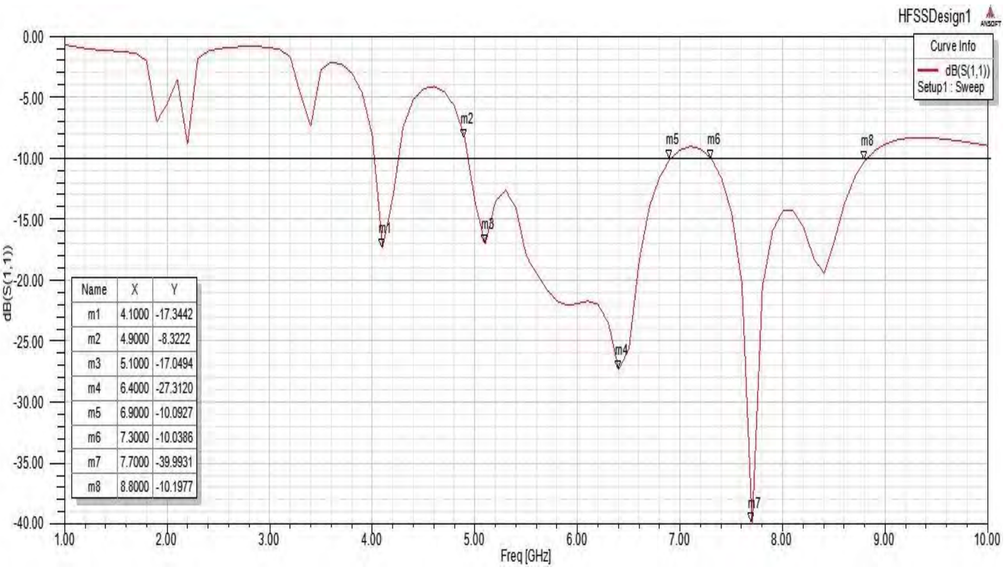


Fig. 9. HFSS model of proposed antenna

In case of proposed antenna, it can observe that the simulation result shows a multi-band, low return loss, and considerably good band width with a fair gain. Optimized patch dimensions are shown in Fig. 8. Modeled antenna is shown in Fig. 9; the S_{11} parameter plot of Fig. 9 antenna gives the clear idea about the improved parameters, it shows 4-resonant frequencies 4.1, 5.1, 6.4 and 7.7GHz Return- loss of corresponding frequencies are -17.34, -17.04, -27.03, -39.99dB.



Name	X	Y
m1	4.1000	-17.3442
m2	4.9000	-8.3222
m3	5.1000	-17.0494
m4	6.4000	-27.3120
m5	6.9000	-10.0927
m6	7.3000	-10.0386
m7	7.7000	-39.9931
m8	8.8000	-10.1977

Fig. 10. S_{11} parameter plot of proposed antenna

Out of four, three resonant frequencies gives better bandwidth also, Bandwidth at 5.1GHz=39.2%, at 6.4GHz=31.2% and at 7.7GHz=19.4%. Reasons for improved bandwidth are presence of quarter wave transformer and multiple current paths. Use of this antenna in MIMO array will improve the MIMO characteristics such as bandwidth and isolation.

Embedding of meta-material would give an electromagnetic resonance state at 7.7GHz. And it gives a gain of 4.35dB, radiation pattern of above mentioned antenna is given below in Fig. 11.

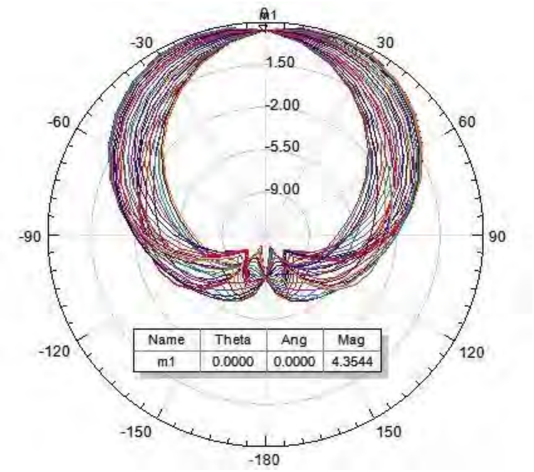


Fig. 11. Radiation pattern of proposed antenna

Result

Proposed antenna is designed using HFSS. Optimization is done by varying length, width and position of the slots. Embedding of Meta material gives a lower return loss in resonating frequencies with good gain of 4.35dB and considerably improved bandwidth of above 35%. It helps to enhance the performance when it used for MIMO applications.

Conclusion

From the Table.1 given below, we can easily analyze the enhancement of return loss characteristics, bandwidth and directivity gain. Proposed design gives an improved return loss of -39.99 dB at 7.7 GHz, that is embedding of meta-material give an electromagnetic resonance state at 7.7GHz, proposed antenna shows an improved directive gain of 4.35dB, since the antenna shows a lower return loss with good gain, radiation energy coupling into free space is improved and it enhances the radiation energy emitted into free space. Their by enhance the efficiency of the antenna.

TABLE.1
Performance Comparison Among The Three Designed Antennas.

Parameters of the Antenna	**Rectangular patch antenna**	**Meta-material embedded Rectangular patch antenna**	**Meta-material embedded slot loaded patch antenna (Proposed)**
Resonating frequencies	3.4 GHz	3.5 GHz 7.3 GHz 8.5 GHz	4.1 GHz 5.1 GHz 6.4 GHz 7.7 GHz
Corresponding bandwidth	80 MHz = 2%	100MHz=05.7% 3GHz=39.7% 3GHz=34.1%	200MHz=04.8% 2GHz=39.2% 2GHz=31.2% 1.5GHz=19.4%
Corresponding Return-loss	-16.34 dB	-25.2 dB -34.5 dB -24.6 dB	-17.34 dB -17.04 dB -27.03 dB -39.99 dB
Gain Of The Antenna	1.84 dB	2.53 dB	4.35 dB

Acknowledgment

I thank VIT for giving me such a great opportunity to do research on this topic also for providing all the necessary facilities.

References

[1] Yang,F.,zehong,X.,Ye,X.,and Rahmat-Samii,Y,"wide-band E-shaped patch antennas for wireless communications",IEEE Trans.Antennas Propag.,2001,49, p. 1094-1100.

[2] Varada Rajan Komanduri,David R.Jakson,Fellow,IEEE,Jeffery T.Williams,Senior Member,IEEE,and Amit R.Mehotra,"A General Method for Designing Reduced Surface Wave Microstrip Antennas",IEEE Trans.Antennas Propag.,VOL.61,NO.6,JUNE

[3] Atif Jamil1,Mohd Zuki Yusoff 1,Noorhana Yahya 2, 1.Electrical & Electronic Engg: Dpmt,2.Fundamental and Applied Science Dpmt,"Current Issues and Challenges of MIMO Antenna Designs", University Technology PETRONAS, Bandar Seri Islander

[4] Daquan Feng,Chenzi jiang, Gubong Lim, Leonard J Cimini Jr., Fellow IEEE gang Feng, senior member, IEEE, and GeOffray Ye Li, Fellow IEEE, "A Survey of Energy-Efficient Wireless Communications" IEEE Communication Surveys and Tutorials, Vol.15,No.1, First Quarter 2013.

[5] K.Jagadeesh Babu, K Seeramakrishna, L.Prathap Reddy, "A Symmetric Multi-Slot Patch Antenna with Improved Bandwidth and Isolation for Wireless MIMO Systems" International Conference on Communication Technology and System Design-2011.

[6] Constantine A. Balanis, "Antenna Theory Analysis and Design", Wiley Third Edition

[7] David M. Pozar, University of Massachusetts at Amherst "Microwave Engineering", Wiley Fourth Edition

[8] Xue-Hua Songa, Wen-Yun Wua,*, Ting-Gen Shena,b, Yue-Qun Zhoua, " Investigation of a patch antenna based on I-shaped left-handed material", Optik 122 (2011) 1426– 1429,ELSEVIER, Received 7 April 2010,Accepted 12 September 2010.

[9] Ji-jun Wanga, Zhi-pan Zhua,*, Yu-xin Sunb, Ting-gen Shena, Lei-lei Gonga, "Study on left-handed effect of composite helices and its application in square frame patch antennas", Optik 124 (2013) 5189– 5192,ELSEVIER, Received 12 October 2012,Accepted 14 March 2013.

[10] Yahong Liu & Xiaopeng Zhao, "High Gain Patch Antenna with Composite Right-Left Handed Structure and Dendritic Cell Metamaterials", Received: 24 May 2009 / Accepted: 19 November 2009 /Published online: 1 December 2009# Springer Science Business Media, LLC 2009.

[11] Prathaban Mookiah, Student Member, IEEE, and Kapil R. Dandekar, Senior Member, IEEE, "Metamaterial-Substrate Antenna Array forMIMO Communication System", IEEE Transactions On Antennas And Propagation, Vol. 57, No. 10, October 2009.

AUTHOR PROFILE

Arun Balan was born in Idukki district, Kerala, in 1989. He completed his B. Tech. in Electronics and Communication Engineering at Government Engineering College Idukki, Kerala, India, in the year 2012. At present he is pursuing his Master's degree in Communication Engineering at VIT University, Chennai, Tamil Nadu, India. He is doing his research in the field of Microstrip antennas and effective use of metamaterial in antenna field.

R. Ramesh got his B.E Electronics Engineering degree from Bangalore University and his M. Tech degree from Manipal Institute of Technology in 2002.He is working as an Assistant professor in VIT University Chennai since 2013.He is currently working in design of MIMO antennas for wireless communication. Also his areas of interest are in Image and signal processing.

Usha Kiran K Completed her Ph.D on Microwave Antennas from Gulbarga University, Karnataka in 2007. Then she joined as Project Associate to Microwave Lab, ECE, Indian Institute of Science (IISc), Bangalore. Also developed several RF MEMS SPDT & SPST switches from 2007-2009.She also worked at Indian Institute of Technology (I.I.T), Delhi as Project Scientist worked on RF MEMS from 2010-2012. At present working in Vellore Institute of Technology (VIT), Chennai form 2012 till date. She published above 50 papers in Journals and international Conferences on Microwave Antennas and RF MEMS.