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Stacked Ring Coupled Rectangular Microstrip Antenna with Slots

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ABSTRACT: This paper discusses the effect of stacking on the performance of a ring coupled rectangular microstrip patch antenna. The antennas have been designed at a frequency of 2 GHz and they have been simulated using Mentor Graphics IE3D simulation software. The substrate used in the design is FR-4 glass epoxy which has a dielectric constant of 4.2. The operating frequency range is from 1-6 GHz. The antennas have been fabricated and the measured results are compared with the simulated results. The measured results are in agreement with their counterparts. The ring coupled rectangular microstrip antenna stacked on ring coupled rectangular microstrip antenna with U-slot on ring yields the widest bandwidth of 9.635%. The ring coupled rectangular microstrip antenna stacked on ring coupled rectangular microstrip antenna with U-slot on ring and patch yields the lowest resonant frequency of 1.27 GHz; thereby producing the best size reduction of 18.862%.

KEYWORDS: Center patch, Ring Coupled, Stacking, U-Slot.

I. INTRODUCTION

Microstrip patch antennas are prominent and popular because of their advantages - light weight, planar structure and ease of integration and compatibility with monolithic microwave integrated circuits (MMIC's). A serious limitation of these antennas is they posses narrow bandwidth. Many modern communication systems and emerging technologies require antennas with broad bandwidth compact size. New motivation to research is given to enhance the bandwidth and reduce the virtual size of the microstrip antennas [1-3].

A microstrip patch antenna basically consists of a radiating patch on one side of the dielectric substrate which has a ground plane on the other side. Conducting material such as copper or gold is used to make the radiating patch. Microstrip antennas radiate because of the fringing fields between the edges of the patch and the ground. The design of the following microstrip patch antennas have been dealt – Rectangular microstrip antenna (RMA), Ring coupled rectangular microstrip antenna (RCRMA), Ring coupled rectangular microstrip antenna stacked on Ring coupled rectangular microstrip antenna with U-slot on ring (Antenna - 1), Ring coupled rectangular microstrip antenna stacked on Ring coupled rectangular microstrip antenna with U-slot on centre patch(Antenna - 2), Ring coupled rectangular microstrip antenna stacked on Ring coupled rectangular microstrip antenna with U-slot on ring and patch(Antenna - 3).[4-9]

II. RELATED WORK

In [3] authors have presented the simulated and practical investigation on the effect of rectangular slot on resonance frequency, return loss and bandwidth of a novel , single layer, single probe – fed rectangular microstrip antenna. The design is achieved by cutting the rectangular slots at the one radiating edge of the patch antenna. In [6] authors have considered the design of compact single layer dual polarized and dual frequency rectangular patch antenna by placing the square slot at its centre. A good impedance matching of the two operating frequencies has been obtained by using a microstrip feed line. In [7] authors have considered the evaluation of frequency reconfigurable patch antenna for X-

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band using PIN diode as a switch. A PIN diode is incorporated in the slot etched on rectangular patch antenna. The frequency band selectivity is achieved by controlling the state of the switch inserted in the antenna. In [8] authors have designed a dual frequency dual polarized microstrip antenna fed along the diagonal, embedded with a square slot having three extended stubs for frequency tuning. Two additional stubs of the same dimensions are also incorporated at right angles to the base arm. By changing the dimensions of the base arm and stubs in a uniform manner the ratio of the operating frequencies can be lowered. In [9] a broadband high gain microstrip patch antenna using slot is proposed. The slot use on the patch's surface affects the radiation characteristics of the proposed antenna. By using slot on rectangular patch with coaxial probe feed a wide bandwidth is achieved.

III. DESIGN OF ANTENNAS

A. RECTANGULAR MICROSTRIP ANTENNA.

Fig. 1 depicts the schematic of rectangular microstrip antenna.

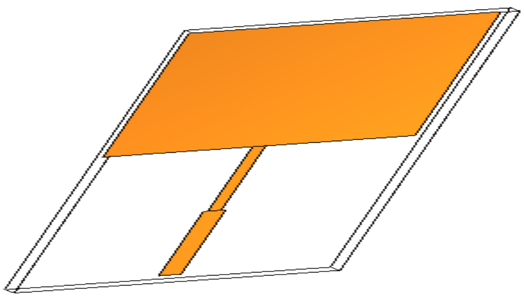

Fig. 1. Rectangular microstrip antenna.

Table 1 depicts the design parameters of rectangular microstrip antenna.

Table 1: Design parameters of Rectangular microstrip antenna.

Parameter name	Value
Substrate thickness	1.6mm
Dielectric constant	4.2
Design frequency	2 GHz
Loss tangent	0.0245
Length of the patch	46.5mm
Width of the patch	36.2mm
Length of the feed	18.8mm
Width of the feed	3.324m
Length of the quarter wave transformer	18.8mm
Width of the quarter wave transformer	1.278mm

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B. RING COUPLED RECTANGULAR MICROSTRIP ANTENNA.

Fig. 2 depicts the schematic of ring coupled rectangular microstrip antenna.

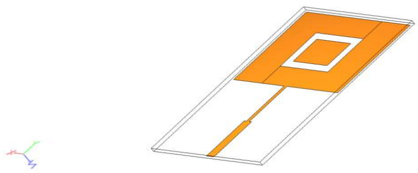

Fig. 2. Ring coupled rectangular microstrip antenna.

The length and width of the outer ring are equal to 21.11mm and 17.41mm.The length and width of the inner ring are equal to 15.21mm and 11.41mm.The other dimensions of the antenna are same as that of the conventional antenna.

C. RING COUPLED RECTANGULAR MICROSTRIP ANTENNA STACKED ON RING COUPLED RECTANGULAR MICROSTRIP ANTENNA WITH U-SLOT ON RING (ANTENNA -1).

Fig.3 depicts the schematic of ring coupled rectangular microstrip antenna stacked on ring coupled rectangular microstrip antenna with U-slot on ring.

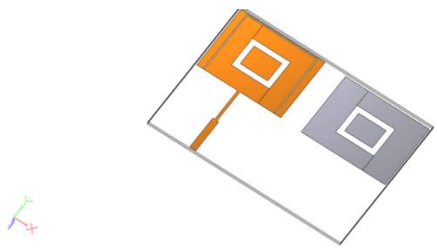

Fig. 3. Ring coupled rectangular microstrip antenna stacked on Ring coupled rectangular microstrip antenna with U-slot on ring (RCRMAUR-RCRMA).

In this configuration, ring coupled rectangular microstrip antenna with U-slot on ring is the bottom antenna and ring coupled rectangular microstrip antenna is the parasitic element placed on top of the bottom antenna. The length and width of the left and right parts of the U-slot on ring are equal to 35.2mm and 0.5mm.The dimensions of the centre part of the U-slot are 45.2mm×0.5mm.The left and right parts of the U-slot are at a distance of 3.5mm from the sides of the rectangular patch.

D. RING COUPLED RECTANGULAR MICROSTRIP ANTENNA STACKED ON RING COUPLED RECTANGULAR MICROSTRIP ANTENNA WITH U-SLOT ON PATCH (ANTENNA -2).

Fig. 4 depicts the schematic of ring coupled rectangular microstrip antenna stacked on ring coupled rectangular microstrip antenna with U-slot on patch.

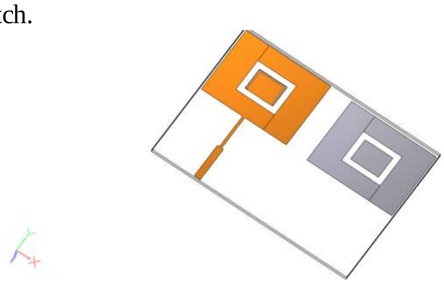

Fig. 4. Ring coupled rectangular microstrip antenna stacked on Ring coupled rectangular microstrip antenna with U-slot on patch (RCRMAUP-RCRMA).

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In this configuration, ring coupled rectangular microstrip antenna with U-slot on centre patch is the bottom antenna and ring coupled rectangular microstrip antenna is the parasitic element placed on top of the bottom antenna. The length and width of the left part and right part of the U-slot on patch are 10.41mm and 0.5mm.The dimensions of the centre part of the U-slot are 14.21mm×0.5mm.

E. ***RING COUPLED RECTANGULAR MICROSTRIP ANTENNA STACKED ON RING COUPLED RECTANGULAR MICROSTRIP ANTENNA WITH U-SLOT ON RING AND PATCH (ANTENNA -3).***

Fig. 5 depicts the schematic of ring coupled rectangular microstrip antenna stacked on ring coupled rectangular microstrip antenna with U-slot on ring and patch.

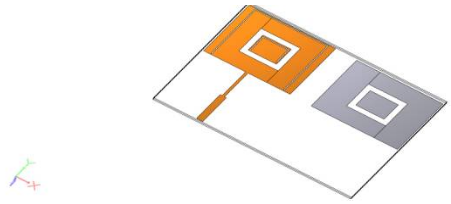

Fig. 5. Ring coupled rectangular microstrip antenna stacked on Ring coupled rectangular microstrip antenna with U-slot on ring and patch (RCRMAURP-RCRMA).

In this configuration, ring coupled rectangular microstrip antenna with U-slot on patch and ring is the bottom antenna and ring coupled rectangular microstrip antenna is the parasitic element placed on top of the bottom antenna. The length and width of the left part and right part of the U-slot on patch are 10.41mm and 0.5mm.The dimensions of the centre part of the U-slot are 14.21mm×0.5mm. The length and width of the left and right parts of the U-slot on ring are equal to 35.2mm and 0.5mm.The dimensions of the centre part of the U-slot are 45.2mm×0.5mm.The left and right parts of the U-slot are at a distance of 3.5mm from the sides of the rectangular patch.

IV. FABRICATED ANTENNAS AND RESULTS

Fig. 6, 7, 8 and 9 depict the photographs of the fabricated antennas.

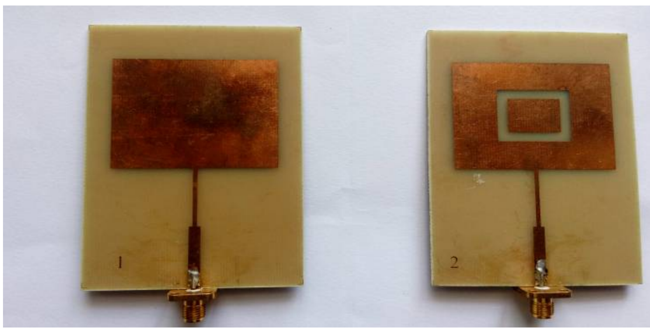

Fig. 6. Photograph of the fabricated antennas – RMA, RCRMA.

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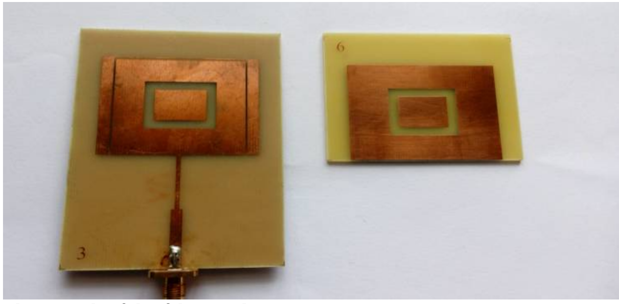

Fig. 7. Photograph of the fabricated Antenna – 1 (RCRMAUR- RCRMA).

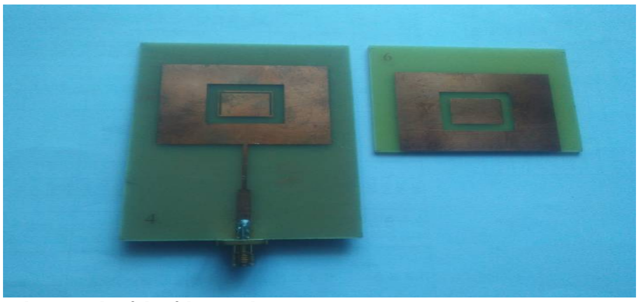

Fig. 8. Photograph of the fabricated Antenna – 2 (RCRMAUP- RCRMA).

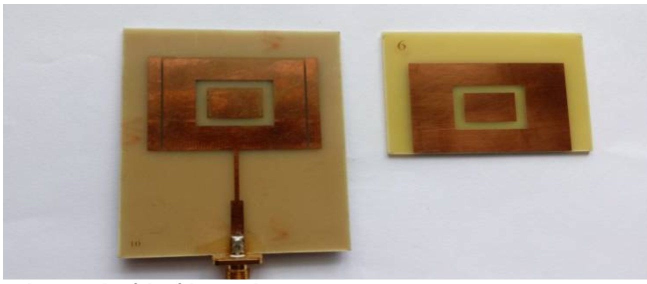

Fig. 9. Photograph of the fabricated Antenna - 3 (RCRMAURP- RCRMA).

The various characteristics of the antennas designed in section 2 are studied. The simulated and measured return loss characteristics of the above mentioned antennas are shown in Fig. 10, 11, 12, 13 and 14 respectively. The values of resonant frequency, return loss and bandwidth are calculated using these figures.

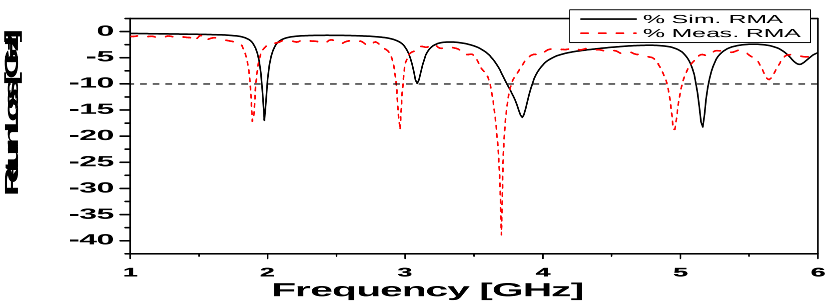

Fig. 10. Plot of return loss versus frequency of RMA.

The antenna RMA is resonating at 1.88 GHz with a return loss -17.09 dB. The antenna possesses a bandwidth of 50 MHz.

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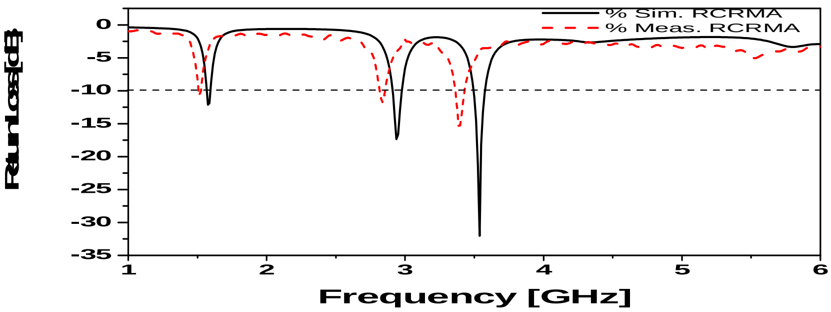

Fig. 11. Plot of return loss versus frequency of RCRMA.

The antenna RCRMA is resonating at the fundamental frequency of 1.575 GHz with return loss of -12.18 dB. Harmonic frequencies are obtained at 2.93 and 3.539 GHz. Measured bandwidth at the fundamental frequency is 40 MHz. The overall bandwidth percentage is 6.35%.

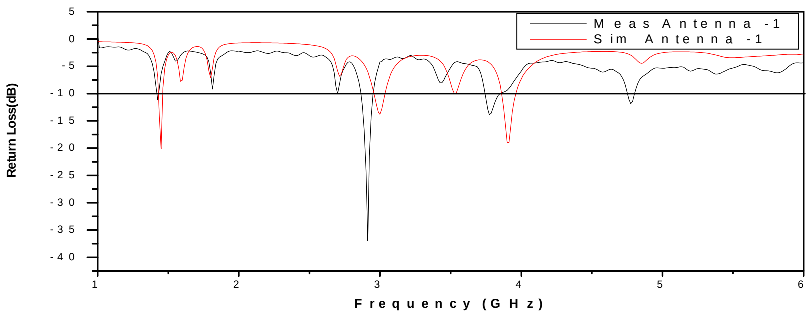

Fig. 12. Plot of return loss versus frequency of Antenna – 1.

Fig. 12 depicts that antenna -1 is resonating at 1.42, 2.91, 3.77 and 4.78 GHz respectively. The bandwidths measured are 30, 90, 120 and 60 MHz. The antenna – 1 yields an overall bandwidth of 9.635%.

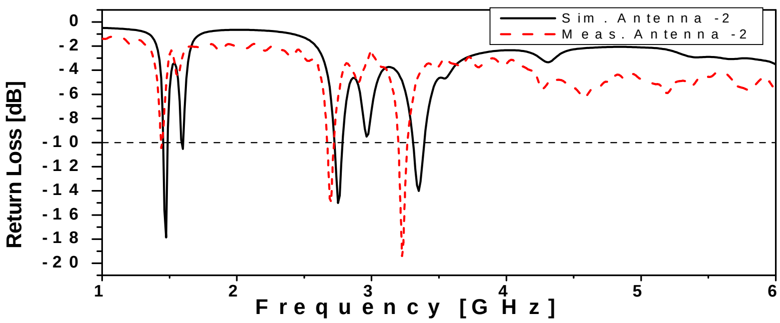

Fig. 13. Plot of return loss versus frequency of Antenna - 2.

From Fig. 13, antenna-2 is resonating at four frequencies 1.43, 2.69 and 3.22 GHz respectively. The return loss at the fundamental resonant frequency is -10.8 dB yielding an overall bandwidth of 8.194 %.

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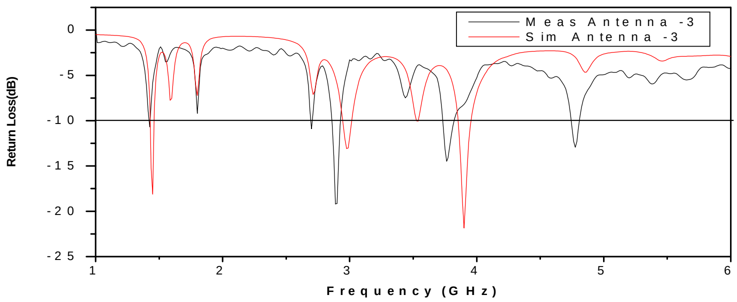

Fig. 14. Plot of return loss versus frequency of Antenna - 3.

Fig. 14 shows that the fundamental resonant frequency of antenna -3 is 1.277 GHz. The harmonics are at 2.129, 2.262, 2.836 and 4.035 GHz respectively. The bandwidths measured at these frequencies are 14, 22, 44, 65 and 87 MHz respectively. The overall bandwidth is equal to 8.521%.

Table 2 summarizes the simulated and measured results and table 3 the measured results of size reduction.

Table 2: Simulated and measured results.

Configuration of the antenna	Simulated results				Measured results			
	Resonant frequency (GHz)	Return Loss (dB)	Bandwidth (MHz)	Overall bandwidth (%)	Resonant frequency(GHz)	Return Loss (dB)	Bandwidth (MHz)	Overall bandwidth (%)
RMA	1.97	-16.99	48	2.420	1.88	-17.09	50	2.64
RCRMA	1.575 2.93 3.53	-12.18 -17.37 -32.16	52 92 110	9.530	1.51 2.83 3.39	-10.76 -11.74 -15.36	40 40 80	6.35
Antenna – 1 (RCRMAUR–RCRMA)	1.45 2.99 3.91 ---	-20.08 -13.78 -19.00 ---	44 92 101 ---	8.682	1.42 2.91 3.77 4.78	-11.28 -37.11 -13.95 -11.95	30 90 120 60	9.635
Antenna – 2 (RCRMAUP–RCRMA)	1.47 2.74 5.35	-17.62 -14.98 -14.02	61 70 83	8.251	1.43 2.69 3.22	-10.80 -16.54 -20.11	40 70 90	8.194
Antenna – 3 (RCRMAURP–RCRMA)	1.44 --- --- 2.97 3.89	-18.02 --- --- -13.48 -21.86	39 --- --- 73 100	7.712	1.27 2.12 2.26 2.83 4.03	-10.70 -10.86 -19.13 -14.44 -12.86	14 22 44 65 87	8.521

The performances of the five antennas are compared on the basis of resonant frequency, return loss, bandwidth and size reduction. The size reduction of the corresponding antennas has been calculated based on the measured values of the

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resonant frequency. Among the five antennas, ring coupled rectangular microstrip antenna stacked on ring coupled rectangular microstrip antenna with U-slot on ring provides the best results in terms of bandwidth of 9.635%. From figures 10 and 11, rectangular microstrip antenna and ring coupled rectangular microstrip antenna are resonating at frequencies of 1.88 and 1.51GHz respectively. The virtual size reduction yielded by antenna-3 is 18.862%, highest compared to other designed antennas.

Table 3: Measured results of size reduction.

Configuration of the antenna	Size reduction (%)
RMA	0
RCRMA	3.925
Antenna – 1 (RCRMAUR – RCRMA)	9.794
Antenna – 2 (RCRMAUP – RCRMA)	9.144
Antenna – 3 (RCRMAURP – RCRMA)	18.862

The results discussed above can be justified as below. With the introduction of U-slot, the length of the current path increases thereby causing a decrease in the resonant frequency, which results in the virtual decrease in the size of the antenna. Combination of U-slot, ring coupled rectangular microstrip antenna and stacking produce multiple resonances which leads to increase in overall bandwidth.

V. CONCLUSION

The above mentioned antennas have been designed and fabricated at a frequency of 2GHz with a good return loss. The antennas have been compared on various parameters to judge their performance. The results depict that the introduction of ring coupling and U- slot results in the decrease of resonant frequency of the antenna and subsequently causes size reduction. Wide band and multiple band responses have been demonstrated using the technique of stacking .The bandwidth of the conventional microstrip antenna has been enhanced by 7%. A minimum of three resonances have been obtained. As a result the performance of the conventional microstrip antenna has been improved. The results obtained satisfy the needs of wireless communications.

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BIOGRAPHY

Vani R.M received her B.E. in Electrical and Electronics from B.I.E.T, Davangere and M. Tech in Industrial Electronics from S.J.C.E. Mysore, Karnataka. She has received her Ph.D in Applied Electronics from Gulbarga University, Gulbarga, India, in the year 2005. She is working as Professor & Head, University Science Instrumentation Centre, Gulbarga University, Gulbarga. She has more than 100 research publications in national and international reputed journals/Conference proceedings. She has presented many research papers in National/ International conferences in India and abroad. She has guided many Ph.D and M.Phil students. She has conducted several courses, workshops and symposiums for the benefit of university faculty and PG students. Her areas of interest are microwave antennas, compact and broadband antennas, Embedded controllers and Wireless communication. She has completed one UGC major research project.

Inamdar S.R received his B. Sc and M. Sc Physics in the year 1981 and 1983. He has received his Ph. D in the year 1990. Currently he is working as Professor in the department of Physics, Karnatak University, Dharwad, Karnataka. He has 50 research publications in National/International reputed journals. He has presented more than 65 research papers in National/International conferences. He has guided many Ph.D and M.Phil students. He has completed 7 major research projects funded by UGC, CSIR and BRNS.

Prahlada Rao K received his M.E from RMIT University, Australia and B.E from Osmania University, India. Currently he is pursuing his Ph. D in the field of microwave antennas from the department of Applied Electronics, Gulbarga University, Gulbarga. He has 3 research publications in international conferences and 1 in international journal. His areas of research interests include Microstrip patch antennas and arrays, Electromagnetic Band Gap Structures, Defective Ground Structures

P. V. Hunagund, received his M. Sc and Ph. D from the Dept. of Applied Electronics, Gulbarga University, Gulbarga, in the year 1982 and 1992 respectively. He is working as professor and chairman of Applied Electronics department, Gulbarga University, Gulbarga. He has more than 125 research publications in national and international reputed journals, more than 100 research publications in national and international symposium/Conferences. He has presented many research papers in National/International conferences in India and abroad. He has guided many Ph. D and M. Phil students. He has completed three major research projects funded by AICTE, DST and UGC New Delhi.