Annexure – IX

PONDICHERRY UNIVERSITY
PONDICHERRY – 605 014

EXECUTIVE SUMMARY/FINAL REPORT OF THE WORK DONE ON THE PROJECT

1. TITLE OF THE PROJECT : **Development of Compact MIMO Antennas with Reduced Coupling and Correlation**

2. NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR: **Dr. R. Nakkeeran**
Associate Professor
Department of Electronics Engineering
School of Engineering and Technology
Pondicherry University
Pondicherry – 605 014.

3. NAME AND ADDRESS OF THE INSTITUTION : **Department of Electronics Engineering**
School of Engineering and Technology
Pondicherry University
Pondicherry – 605 014.

4. UGC APPROVAL LETTER NO. AND DATE : **F. No. 43-286/2014 (SR) dated 23.07.2015**

5. DATE OF IMPLEMENTATION : **01.07.2015**

6. TENURE OF THE PROJECT : **Three Years**

7. TOTAL GRANT ALLOCATED : **Rs. 10,83,000**

8. TOTAL GRANT RECEIVED : **Rs. 10,53,000**

9. FINAL EXPENDITURE : **Rs. 10,56,220**

10. TITLE OF THE PROJECT : **Development of Compact MIMO Antennas with Reduced Coupling and Correlation**

11. OBJECTIVES OF THE PROJECT:

To investigate, design and develop compact Multiple Input Multiple Output (MIMO) antennas with multiband operation, low mutual coupling and reduced correlation

12. WHETHER OBJECTIVES WERE ACHIEVED : **Yes**

13. ACHIEVEMENTS FROM THE PROJECT :

- MIMO antennas have been proposed with more isolation (> -20 dB) considering modified and improved planar antennas as an elemental one
- One of the PhD Scholars made one chapter of the Thesis by analyzing the impact of cross polarization in the lower order MIMO antenna.
- Six M.Tech level projects have been completed from this topic and many contributory papers have been published both in journals and conferences
- Various MIMO antennas have been developed
- Cross field techniques were introduced
- Also, various designs of complementary split ring resonator with slot cut in patch antenna have been analyzed, and novel folded and unfolded monopole MIMO antennas were also designed and developed. Defected Ground Structures (DGS) were considered to suppress the propagation of the surface wave and various ground plane structures were analyzed so as to realize compact MIMO antenna
- Decoupling elements are analyzed to enhance the isolation between the various MIMO antennas

14. SUMMARY OF THE FINDINGS : The design and development of compact MIMO antennas were carried out as detailed below:

- ❖ Modified and improved Planar Antennas were considered to design the MIMO antennas,
  - In order to achieve mutual coupling less than -20 dB, mutual coupling reduction techniques were introduced
  - In addition, various designs of complementary split ring resonator with slot cut in patch antenna were analyzed
- ❖ Novel folded and unfolded monopole MIMO antennas were also designed and developed
  - Understood that high isolation in the monopole design could be obtained by introducing shorting strip, isolation stub, etching slots and transmission lines
  - Further, various feed structures were investigated for wideband operation
- ❖ In order to reduce the mutual coupling with MIMO antennas, Defected Ground Structures (DGS) were considered to suppress the propagation of the surface wave
  - Various ground plane structures were analyzed to realize compact MIMO antenna
  - Decoupling elements were analyzed to enhance the isolation between the various MIMO antennas
- ❖ Several functional features of the antenna such as impedance bandwidth, radiation patterns, radiation efficiency, electric current distributions and gain have been investigated in detail for the designed MIMO antennas

15. CONTRIBUTION TO THE SOCIETY:

- Through implementation of this project, the concept of isolation / mutual coupling in MIMO antennas is disseminated to many scholars and students over the period
- Skilled human resources in this area are developed

16. WHETHER ANY PH.D. ENROLLED/PRODUCED OUT OF THE PROJECT

List of Academic Projects carried out of the Sanctioned MRP Project

S. No.	Year	Title of the Project	Name of the Student	Degree	Status
1.	2013-2016	Study and Development of Femtocell Base Station Antennas (one chapter only)	Mr. G. Idayachandran	PhD	Completed
2.	2015-2016	Design of Multiband MIMO Antenna for Wireless Applications	Mr. Swagath Babu	M.Tech	Completed
3.	2015-2016	Design and Analysis of a 4x4 MIMO Antenna for UWB Applications	Mr. Bodavula Krishna Teja	M.Tech	Completed
4.	2015-2016	Design of UWB MIMO Antenna with Band Notch Characteristics	Mr. Ankit Kumar Verma	M.Tech	Completed
5.	2015-2016	Design of a Compact UWB MIMO Antenna with Enhanced Isolation	Mr. Nrusingha Charan Pradhan	M.Tech	Completed
6.	2016-2017	Design of Compound Reconfigurable Antennas	Mr. P. Ranjith	M.Tech	Completed

17. NO. OF PUBLICATIONS OUT OF THE PROJECT:

Journals

1. Idayachandran Govindanarayanan and Nakkeeran Rangaswamy, "Asymmetric folded dipole antenna with high front-to-back ratio for LTE base stations," IEEE Antennas and Wireless Propagation Letters, vol. 15, pp. 869-872, Mar. 2016. ISSN: 1536-1225. (SCIE, Impact factor: 1. 579)

2. Swagath Babu M, Idayachandran G, Rajesh A, Shankar T and Nakkeeran R, "Investigation on Defected Ground-plane Structures to Improve Isolation and Correlation in Multi-Band MIMO Antenna," International Journal of Information and Computer Security (Inderscience), vol. 8, no. 3, pp. 258-271, 2016. ISSN: 1744-1773. (DOI: 10.1504/IJICS.2016.079186)

3. Idayachandran Govindanarayanan, Nakkeeran Rangaswamy and Rajesh Anbazhagan, "Design and analysis of broadband magneto-electric dipole antenna for LTE femtocell base stations," Journal of Computational Electronics (Springer), vol. 15, no. 1, pp. 200-209, Mar. 2016. ISSN: 1569-8025. (SCIE, Impact factor: 1. 52)

4. G. Idayachandran and R. Nakkeeran, "Compact magneto-electric dipole antenna for LTE femtocell base stations," Electronics Letters (IET), vol. 52, no. 8, pp. 574-576, Apr. 2016. ISSN: 1350-911X. (SCI, Impact factor: 0.93)

5. G. Idayachandran and R. Nakkeeran, "Defected Ground Magneto-Electric Dipole with Trivial Back Radiation" Progress in Electromagnetics Research C (PIER-C), VOL. 67, pp. 65-72, Sep. 2016. ISSN: 1937-8718. (Scopus Indexed).

Conferences

1. Ankit Kumar Verma, R. Nakkeeran and Rigvendra Kumar Vardhan, "Design of 2x2 Single Sided Wrench Shaped UWB MIMO Antenna with High Isolation", in the IEEE Sponsored International Conference on Circuit, Power and Computing Technologies, 18-19 March 2016, Kanyakumari, Tamilnadu, India.

2. Swagath Babu, Rajesh A, Nakkeeran R and Idayachandran G, "Design of DGS based Dual-Element Multiband (DEMB) MIMO Antenna for GPS and LTE-A Applications", IEEE International Conference on Circuit, Power and Computing Technologies, 19-20 Mar. 2015, Nagarkoil, Tamilnadu, India.

3. Swagath Babu M, Rajesh A, Nakkeeran R and Idayachandran G, "Design of Dual-Element Multi-Band MIMO Antenna for LTE-A, GPS and IEEE 802.11af Applications," IEEE International Conference on Electrical, Computer and Communication Technologies, 5-7 Mar. 2015, Coimbatore, Tamilnadu, India.

4. Swagath Babu M, Rajesh A, Shankar T, Nakkeeran R and Idayachandran G, "Design of Dual-Element Tri-Band (DETB) MIMO Antenna with Improved Isolation," IEEE 2nd International Conference on Electronics and Communication Systems, 26-27 Feb. 2015, Coimbatore, Tamilnadu, India.

5. Nrusingha Charan Pradhan, R Nakkeeran and B Krishna Teja, "Design of MIMO Antennas for Handsets", IEEE International Conference on Circuit, Power and Computing Technologies (ICCPCT), 18-19, March 2016, Kanyakumari, Tamilnadu, India.

6. P. Ranjith, R. Nakkeeran and Srinivasa rao Alluri, "Investigation on Compound Reconfigurable Solid State Planar Antenna", First International Conference on Computational and Intelligent Techniques for Automation of Engineering Systems, 30th November - 1st December 2018, Dept. of ECE, Gudlavalleru Engineering College, Gudlavalleru, AP, India.

Signature of
Principal Investigator

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Registrar
Pondicherry University

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A: DETAILS OF PROJECT

1.	UGC Reference No. and Date	UGC MRP-MAJOR-ELEC-2013-3226 F.NO. 43-286/2014(SR)
2.	Name of the Principal Investigator	Dr. R. Nakkeeran
3.	Address with e-mail and mobile no.	Department of Electronics Engineering School of Engineering and Technology Pondicherry University Pondicherry – 605 014 nakkeeranpu@gmail.com 9443029346
4.	Department and University/College where the project has undertaken	Department of Electronics Engineering School of Engineering and Technology Pondicherry University Pondicherry – 605 014
5	Title of the Project	Development of Compact MIMO Antennas with Reduced Coupling and Correlation
6.	Date of Implementation	01.07.2015
7	Tenure of the Project	Three Years
8	Name of the Project Fellow and date of Appointment	Not Applicable
9	Grant Received	Rs. 10,53,000/.
10	Project Status	Completed

B: EVALUATION REPORT OF EXPERT MEMBERS

1.	Name of the Principal Investigator	**Dr. R. Nakkeeran**
2.	Designation	**Associate Professor**
3.	Address of Principal Investigator	**Department of Electronics Engineering** **School of Engineering and Technology** **Pondicherry University** **Pondicherry – 605 014**
4.	Whether work is focused on the title of sanctioned project	**Yes**
5	Whether original work is done	**Yes**
6.	Whether significant contribution made by Principal Investigator	**Yes**
7.	Whether proposed work have relevance to the Society/Scientific Community	**Yes**
8.	What type of contribution found in the final report: Theoretical /Practical Contribution	**Practical**
9.	Whether theoretical contributions and their results and findings are published	**Yes**
10.	Whether results and findings are significant	**Yes**
11.	Whether the significant publications are made by Principal Investigators in Peer reviewed journals	**Yes**
12.	The number of publications made by Principal Investigator in Standard reputed journal	**Five**
13.	Whether contributions made by investigator is sufficient	**Yes**
14.	The findings and results of the	**Yes**

	sanctioned projects are justifiable	
15.	Whether completed project work meet the proposed objectives	**Yes**
16.	Give your brief comments on the overall work of the project	The project has been very well executed and hardware prototypes have been fabricated. Novel techniques for coupling reduction in compact MIMO antennas have been developed. The study of the proposed MIMO antennas has formed part of a number of M.Tech thesis and one Ph.D thesis. The quality of the work is excellent, as it has been approved and published in world class journals including IEEE and IET.
17	Any specific comments	NIL
18	Indicate your overall assessment of the project : Poor/Good/Excellent Name: Signature Address of Expert: Date: Place:	EXCELLENT Dr. M. GANESH MADHAN M. Han – Professor, 24-6-19

Department of Electronics Engg

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2.	Name of the Principal Investigator	Dr. R. Nakkeeran
3.	Address with e-mail and mobile no.	Department of Electronics Engineering School of Engineering and Technology Pondicherry University Pondicherry – 605 014 nakkeeranpu@gmail.com 9443029346
4.	Department and University/College where the project has undertaken	Department of Electronics Engineering School of Engineering and Technology Pondicherry University Pondicherry – 605 014
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8	Name of the Project Fellow and date of Appointment	Not Applicable
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B: EVALUATION REPORT OF EXPERT MEMBERS

1.	Name of the Principal Investigator	**Dr. R. Nakkeeran**
2.	Designation	**Associate Professor**
3.	Address of Principal Investigator	**Department of Electronics Engineering School of Engineering and Technology Pondicherry University Pondicherry – 605 014**
4.	Whether work is focused on the title of sanctioned project	**Yes**
5	Whether original work is done	**Yes**
6.	Whether significant contribution made by Principal Investigator	**Yes**
7.	Whether proposed work have relevance to the Society/Scientific Community	**Yes**
8.	What type of contribution found in the final report: Theoretical /Practical Contribution	**Practical**
9.	Whether theoretical contributions and their results and findings are published	**Yes**
10.	Whether results and findings are significant	**Yes**
11.	Whether the significant publications are made by Principal Investigators in Peer reviewed journals	**Yes**
12.	The number of publications made by Principal Investigator in Standard reputed journal	**Five**
13.	Whether contributions made by investigator is sufficient	**Yes**
14.	The findings and results of the	**Yes**

	sanctioned projects are justifiable	
15.	Whether completed project work meet the proposed objectives	Yes
16.	Give your brief comments on the overall work of the project	The title of the project seems to be sound enough and would meet the expectations of the current scenario. Practically viable.
17	Any specific comments	Validations of findings and results are justified.
18	Indicate your overall assessment of the project : Poor/Good/Excellent Name: D. SRIRAM KUMAR Signature Address of Expert: Date: 23/05/2019 Place: NIT, TRICHY-620015	Good Dr. D. SRIRAM KUMAR Professor Department of Electronics & Communication Engineering National Institute of Technology Tiruchirappalli - 620015, Tamil Nadu, India

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