Centre for Applied Research in Electronics
Indian Institute of Technology Delhi

Report for Internal Review

IIT Delhi, Hauz Khas, New Delhi – 110016.

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Contents

I. Introduction to CARE

A. Evolution: The Centre for Applied Research in Electronics (CARE) started as The School for Radar Studies (SRS) in 1971, with an initial grant from the Radar and Communication Project Office, Ministry of Defence. The objective was to establish a Centre of excellence for coordinated research and manpower training in specific areas of interest to Defence. The initially identified areas were Radar Signal Processing and Phased Array Techniques. The scope of R&D was soon broadened to encompass the areas of Signal Processing, Microwaves, and Microelectronics.

B. Founding Objectives: The vision of the School was expanded when it was renamed as the Centre for Applied Research in Electronics in 1977 with the founding objectives:

i) To conduct technological research in selected thrust areas of national importance,

ii) To design and develop application specific advanced components / subsystems,

iii) To provide manpower training in specialized areas.

C. Research and Technology Development Emphasis: Several goal-oriented programs were initially taken up in these areas. These included Underwater Electronics, Railway Electronics, Electronic Phase Shifters, SAW devices, MOS Technology, VLSI Design and Millimeter Wave Integrated Circuits. Subsequently, new R&D programs were initiated in the areas of Non-Destructive Testing and Characterization, Micro-Electro-Mechanical Systems (MEMS) including Millimeter Wave MEMS, Speech Signal Processing, and SAW based systems.

Several sponsored research projects of great national importance under the above programs have been successfully completed for user organizations such as DRDO, Navy, ISRO, BARC, and DOE (now MCIT). A key aspect of these projects has been the technology intensive and hardware development nature of work involved leading to many technology and know-how transfers of international quality. In this process, strong R&D linkages have been established over the years with several organizations of national importance as well as industries.

D. State-of-the-art Laboratory Infrastructure: CARE has developed well-equipped laboratory facilities over the years in its major research areas and has consistently upgraded them due to the emphasis on advanced and contemporary experimental research and technology development work. Some of the research laboratories are: i) Microwaves Lab, ii) MEMS-CAD Lab, iii) Underwater Electronics Lab, iv) Speech and Audio Processing Lab, v) Digital Signal Processing Lab, vi) Microelectronics Lab, and vii) Non-Destructive Systems Lab. The bulk of the funding for the laboratory infrastructure has been possible through sponsored research projects.

E. Specialized Manpower Training: An M.Tech Program for defence sponsored officers and DRDO scientists was initiated in the 1970s. Under this program, the Centre has been continually providing specialized post-graduate level training in Underwater Signal Processing to Naval officers. In 2004, the Centre started its own unique M.Tech Program in Radio Frequency Design and Technology (RFDT) with an aim to provide strong foundations in various technology and signal processing aspects important to RF electronics systems. The curriculum provides flexibility to cater to specific requirements of sponsored M.Tech candidates from the Navy and DRDO. Outside of Departments, CARE was the first Centre that was permitted to run an M.Tech program on its own. In addition, CARE has its own vibrant PhD program.

F. External References to CARE's Work: The contribution of CARE to national development goals, in particular, in strategic electronics related to Microwaves and Underwater Electronics is acknowledged externally.

i) The book "Power to Firepower – An Illustrated History of the Electrical Branch" to commemorate 50 years of the Electrical Branch of the Navy in 2007 mentions **CARE IIT Delhi's contribution in developing indigenous underwater electronics technologies.**

ii) Former President Abdul Kalam states in his book "Wings of Fire" (1999) that "In yet another example of creating a synergy of scientific talent, Prof. Bharati Bhatt of IIT Delhi, working with the Solid Physics Laboratory (SPL) and Central Electronics Limited (CEL), **broke the monopoly of the western countries by developing ferrite phase shifters for use in the multi-function, multi-tasking 3-D Phased Array Radar for surveillance, tracking and guidance of Akash."**

iii) A weekly TV series **"A Question of Science"** is being telecast from **8th January 2014 on Doordarshan National Network at 9 am every Wednesday.** The first episode of the series on 8th January was - **Acoustics Technology in Conservation of Ganges River Dolphin.** This program shows how Sonar technology for Naval applications pioneered at CARE has been adapted for passive acoustic surveillance of blind Ganges River dolphins with the aim to help in conservation of this National Aquatic Mammal. This program explains in a layman's way how the technology has been deployed and highlights the successful inter-disciplinary collaboration between technologists of IIT Delhi and University of Tokyo, with field assistance provided by biologists of WWF-India.

II. Responses to the Detailed Questionnaire

1. Curriculum

1.1. List of degree programmes offered - UG + PG - and enrollment.

CARE offers the following degree programmes of its own:

i) Master of Technology in Radio Frequency Design and Technology (RFDT),
ii) PhD.

CARE also participates in the following industry-sponsored inter-disciplinary M.Tech degree programme jointly with EE and CSE departments:

iii) Master of Technology in VLSI Design Tools and Technology (VDTT). It is a wholly industry sponsored Masters programme running since 1996.

Outside of Departments, *CARE was the first Centre in IIT Delhi to be allowed to run a Master's Programme on its own*, namely the RFDT M.Tech Programme since 2004.

CARE offers PhD in the areas of Microwaves, Signal Processing, and Microelectronics.

M.Tech in RFDT:
The sanctioned number of students in M.Tech RFDT has increased from 15 in 2004 (5 Institute Assistantships, 10 Sponsored category students from Indian Navy officers of Electrical Branch and Scientists from DRDO Laboratories through R&T and PGT schemes) to 40 in 2011 (20 Institute Assistantships, 10 each in Sponsored category from Indian Navy and DRDO) and has since remained at 40.

The enrollment in M.Tech RFDT since 2008 batch is as follows:

i)	2008 batch: 22;	Institute Assistantship: 9;	Sponsored: 13.
ii)	2009 batch: 32;	Institute Assistantship: 13;	Sponsored: 19.
iii)	2010 batch: 21;	Institute Assistantship: 10;	Sponsored: 11.
iv)	2011 batch: 32;	Institute Assistantship: 19;	Sponsored: 13.
v)	2012 batch: 36;	Institute Assistantship: 16;	Sponsored: 20.
vi)	2013 batch: 30;	Institute Assistantship: 18;	Sponsored: 12.

PhD:
PhD admission interviews are held twice a year in May and December. The number of enrolled PhD students yearly since 2008 is as follows:

i)	July 2008:	21.
ii)	July 2009:	29.
iii)	July 2010:	31.
iv)	July 2011:	38.
v)	July 2012:	39.
vi)	July 2013:	37.

Inter-disciplinary M.Tech in VDTT:

The program is fully industry sponsored with the number of students admitted being equal to the number of fellowships available from the industry each year. The students do their course work at IIT Delhi, and in the final semester they work on an industry specified project at the sponsor's site (in India or abroad) that accounts for their Master's thesis.

- Students are selected based on their GATE score and internal selection procedures of IIT Delhi. Subsequently, short-listed candidates are interviewed by the sponsoring industries. Final assignment of students to industries is based on the student's prioritization of the industries and the student's performance in the interviews.
- Employees of the sponsoring organization can be admitted subject to their performance in the selection interview. These candidates are not paid Institute assistantship.

i)	2008 batch: 6;	Institute Assistantship: 4;	Part-time: 2.
ii)	2009 batch: 6;	Institute Assistantship: 4;	Part-time: 2.
iii)	2010 batch: 13;	Institute Assistantship: 9;	Part-time: 4.
iv)	2011 batch: 10;	Institute Assistantship: 10;	Part-time: 0.
v)	2012 batch: 20;	Institute Assistantship: 17;	Part-time: 3.
vi)	2013 batch: 13;	Institute Assistantship: 10;	Part-time: 3.

1.2. Consistency of curricula with academic vision of the department.

The purpose of the proposed M.Tech. program in *RF Design and Technology (RFDT)* is to provide a strong foundation in the various engineering aspects important to RF electronic systems. To-date, there is no such comprehensive M.Tech degree program in this area in any of the educational institutions within the country. The course contents are designed to provide a good grounding in radio-frequency and signal processing techniques that are also commonly applied in related areas such as underwater communications. *Flexibility has been provided in the course-work to cater for special needs of users such as the Navy and DRDO in Microwave and RF design technologies, radar, sonar, communication applications, and underwater signal processing.*

The revolution in Wireless Communication and Information Technology, in the country today, is riding mainly on software expertise. Insufficient design education and hardware exposure is creating a vacuum on the technological front. There is a strong need for hardcore RF engineers who are equipped with design know-how as well as practical knowledge to implement the circuits. The M. Tech programme provides a strong fillip to this national requirement.

The field of RF has undergone a paradigm shift in recent years. From being a technology that had its utilization mainly in Telecommunications and Radar applications, it is today the forefront technology for a myriad of Wireless Applications. As a consequence, recent years have seen rapid changes in RF techniques as well as technology. This trend is continuing, enabling the use of increasingly higher RF frequencies with their inherent advantages of smaller size components and larger bandwidth. In particular, the use of planar circuit architecture and integration using silicon micro-machining technology has opened up new opportunities in terms of reduction in weight, volume, power consumption as well as extension of operating frequencies. In keeping with the advances in technology, the design approach is also undergoing a rapid change through improved digital signal processing (DSP) techniques and CAD tools. Thus the scope of RF Design Techniques and Technology, which until a decade or so ago, was confined to HF to UHF frequency bands (that is, up to about 1 GHz), has expanded to encompass the microwave frequency band. The expansion and merging of RF technology with Microwave Integrated Circuit (MIC) techniques has widened the scope for high performance products based on Microwave Integrated Circuits, Monolithic Microwave Integrated Circuits (MMIC), Micro-Electro-Mechanical Systems (MEMS) and planar antennas. Thus, the growth of RF Technology driven by the needs of Wireless Communication and its expansion into microwave frequencies will have a major impact on radar and communication applications in the space and defence arenas.

The curricula matches very well with the academic goals of CARE, which is to provide learning in applied electronics area through advanced and specialized course-work and hands-on training experience in state-of-the-art laboratories.

This program, covering four semesters, is structured to provide a strong foundation in the various engineering aspects of modern RF and microwave electronic systems. The students are exposed to the latest design tools and practical examples. The major projects in the third and fourth semesters will be primarily hardware and application oriented so as to give hands-on experience in the design, fabrication and measurements. With this training, which is a balance of theoretical knowledge and practical experience, graduates of this program will be able to contribute meaningfully to Industries and also R&D organizations involved in futuristic development programs in the area. The employment potential is quite wide, covering commercial, space as well as defence arenas.

The RFDT M.Tech programme has a large number of specialized courses and laboratories for this purpose. It draws upon the faculty expertise in the three areas of applied research in CARE viz. Microwaves, Microelectronics, and Signal Processing. It also matches with the R&D goals of the centre.

1.3. Quality of programmes:

(a) Periodicity of curriculum review UG and PG (*relevant documents*)

CARE has undertaken an exercise for curriculum review of the RFDT M.Tech programme in 2010-11. The recommendations of the review committee are waiting to be put up for approval to the Institute after new guidelines on the structure of M.Tech programmes are formulated. Currently, an Institute-level exercise to restructure M.Tech programmes is on-going. It is expected that a new PG curricula shall be in place for the 2014-15 academic year. **Copy of RFDT M.Tech curriculum review committee recommendations is placed at Annexure – 1.**

(b) **Mechanism for review at UG and PG level (*relevant documents*)**

The review of courses offered by CARE is undertaken in two ways:

i) Class-committee meetings held in the middle of each semester. **Minutes of class-committee meetings are included in Annexure - 2.** Special PG-level courses desired by students have been floated under one of the three "Selected Topics in RFDT" course numbers.

ii) Review of feedback forms filled by students for each course at the end of the semester by Head / Head and M.Tech Coordinator.

(c) **Coursework for each UG, PG, and PhD programme - Core/ Elective.**

The semester-wise credit requirement for M.Tech in RFDT is given in the table below.

	Credits				
	Core Course	**Program Elective**	**Open Elective**	**Project**	**Total**
I - Semester	13	6	-	-	19
II -Semester	10	6	3	-	19
III-Semester	0	3	3	6	12
IV -Semester		-	-	12	12
Total	23	15	6	18	62

The list of Core courses and Programme elective courses for RFDT M.Tech are given in the table below, along with their L-T-P (Lecture-Tutorial-Practical) contact hours and credits. The course numbers beginning with "C" are offered by CARE while those beginning with "E" are offered through Electrical Engineering department. All the courses are open to undergraduate students also subject to course-specific pre-requisites. **The course-work for each course is given in Annexure - 3.**

Course No.	Course Title	L-T-P	Credits
	Core Courses		
CRL702	Architectures and Algorithms for DSP systems	(2-0-4)	4
CRL711	CAD of RF and Microwave Circuits	(3-0-2)	4
CRL713	Fundamentals of RF Electronics	(2-0-2)	3

CRP718	RF and Microwave Measurement lab	(0-0-6)	3
CRP723	Fabrication Technique for RF and Microwave Devices	(1-0-4)	3
CRL724	RF and Microwave Measurement System Techniques	(3-0-0)	3
CRD811	Major Project -I	(0-0-12)	6
CRD812	Major Project - II	(0-0-24)	12
EEL762	Digital Communication	(3-0-0)	3
Program Elective Courses			
CRL704	Sensor Array Signal Processing	(3-0-0)	3
CRL705	Advances Sensor Array Signal Processing	(3-0-0)	3
CRL707	Human & Machine Speech Communication	(3-0-0)	3
CRL712	RF and Microwave Active Circuits	(3-0-0)	3
CRL715	Radiating Systems for RF Communication	(3-0-0)	3
CRL720	SAW Devices and Application	(3-0-0)	3
CRL721	Analog/RF IC Modelling and Design	(2-0-2)	3
CRL722	RF and Microwave Solid State Devices	(3-0-0)	3
CRL725	Technology of RF and Microwave Solid State Devices	(3-0-0)	3
CRL726	RF MEMS Design and Technology	(3-0-0)	3
CRL728	RF Electronic System Design Techniques	(3-0-0)	3
CRL731	Selected Topics in RFDT-I	(3-0-0)	3
CRL732	Selected Topics in RFDT-II	(3-0-0)	3
CRL733	Selected Topics in RFDT-III	(3-0-0)	3
CRS735	Independent Study	(0-3-0)	3
CRL737	Selected Topics in Radars and Sonars	(3-0-0)	3
CRD802	Minor Project	(0-0-6)	3
EEL731	Digital Signal Processing	(3-0-0)	3
EEL765	Sonar System Engineering	(3-0-0)	3
EEL711	Signal Theory	(3-0-0)	3
EEL768	Detection and Estimation	(3-0-0)	3
IDL712	Electronic Techniques for Signal Conditioning and Interfacing	(3-0-0)	3

(d) Pre- PhD courses offered (*in last 5 yrs*.)

All courses offered by CARE are open to PhD students, several of which are advanced PG level courses. There are no specific Pre-PhD courses offered.

(e) New Advanced Master/ Pre- PhD courses introduced in last 5 yrs.

1. CRL731	Selected Topics in RFDT-1 related to Underwater Imaging and Navigation, since 2008, by Prof. R. Bahl.
2. CRL733	Selected Topics in RFDT-3: Non-linear RF circuit analysis and RF power amplifiers have been taught under CRL733 (Selected

	Topics) for the last 3 years.
3. CRL711	CAD of Microwave Theory and Integrated Circuits (UG/PG) [In this course starting from the basics of passive Microwave Integrated circuits, we cover actual design of selected devices. Students validate the text book designs using CAD software. The course has a laboratory component as well and the students actually fabricate Microwave Integrated circuits and characterize these on modern microwave measurement systems. The course mainly focuses on passive microwave Integrated Circuits]
4. CRL712	RF and Microwave Active Circuits (PG) [In this course starting from the basics of active Microwave Integrated circuits, we cover actual design of selected devices such as amplifiers, oscillators, phase shifters, switches, mixers etc. Students validate the text-book designs using CAD software. The course mainly focuses on active microwave Integrated Circuits. The students learn how to design and develop sub-system level Microwave Integrated Circuits at the end of this course.]
5. CRL728	Selected Topics in RF Electronic System Design (PG) [The course was introduced to expose students to design and development of a complete RF system. We start with basic subsystems and systematically demonstrate the integration techniques for system development. The students learn how to design and develop system level Microwave Integrated Circuits at the end of this course.]
6. CRL724	Sensors, Transducers and RF Measurement Techniques (PG) [Theory of sensors and transducers is introduced in this course. In addition, various techniques of carrying out measurements at RF and Microwave frequencies are taught to students. Theory of spectrum and network analyzers including calibration techniques are also discussed in this course.]
7. CRL718	RF and Microwave Measurements Laboratory (PG) [The laboratory course is to teach students about different measurement techniques available at RF frequencies. Students will actually perform experiments on developing equivalent circuit models based on S-parameter measurements, S-parameter measurements of typical microwave components, calibration techniques, measuring of phase noise of oscillators and antenna characterization including pattern measurements.]

(f) Overlap between courses (c), (d) & (e), including opening latter to UG.

All CARE courses are PG level courses which are open to UG and PhD students also subject to any course specific pre-requisites.

(g) Seminar series (weekly/regular) held each semester (*provide list*).

A bi-weekly seminar series of PhD scholars of CARE was started in the 2nd semester of 2010-11, and continued in the 2nd semester of 2011-12. **The list of students who presented in this duration is given in Annexure - 4.** The CARE Seminar Series has been started again in Nov. 2013.

h) PLACEMENT DETAIL - On -Campus (data for last 5 years)

Prog. Type	Prog. Name	No. of graduating students	No. of core companies that asked for prog. by name (+)	No. of student selected (+)	No. of non- core companies that recruited students (++)	No. of student placed in non-core companies (++)	No. of students not placed at graduation time
M.Tech	Radio Frequency Design and Technology	108 (34 GATE Entry + 74 Sponsored Students from Navy and DRDO Labs)	• Cypress Semiconductor Pvt Ltd • KLA-Tencor Software India Pvt Ltd • Rambus Chip Technologies Pvt Ltd • IBM India Pvt Ltd – ISL • Galgotias University • Conexant • NXP • Beceem • Texas Instruments • Power wave • Tejas networks • TSMC • Rambus • Data patterns • Sasken • Nvidia	Data regarding number of GATE entry students selected in respective companies is not available from Placement Cell.	• Infosys Limited	The number is small (less than 5). Exact data is not available from Placement Cell.	Only 2-3 students over the last 5 years have not been placed by graduation time.

i) Relevance of UG and PG programmes to recruiters, potential and on-campus recruiters.

RELEVANCE OF UG AND PG PROGRAMMES TO RECRUITERS ***(data for last 5 years)***

Prog. Type	**Prog. Name**	**No. of graduating students**	**Give details of surveys done (Names of the recruiters)**
M.Tech	Radio Frequency Design and Technology	108 (34 GATE entry and 74 sponsored)	i) Cypress Semiconductor Bangalore ii) Rajiv Gandhi University of Knowledge Technologies Hyderabad iii) LRDE, DRDO Bangalore iv) NVIDIA Bangalore

*= Give name of programme

Survey details: Department to design a questionnaire and seek inputs from a large no. of companies.

Possible questions:

Main attributes expected in a UG/PG graduate, prioritized

Adequacy of core courses

Depth and rigour of core courses

Adequacy of elective courses

Past experience with graduates

Communication skills

j) Benchmarking of curriculum

A. Benchmarking for Master of Technology in Radio Frequency Design and Technology

Institute / Parameters	RFDT M.Tech, CARE, IIT Delhi	EE Dept., IIT Kanpur	ECE Dept., IIT Kharagpur	Chalmers University of Technology, Sweden	Korea Advanced Institute of Science & Technology (KAIST)
Minimum no. course credits required for M. Tech/ M.S.	44	24	50	90	21
PG thesis credit requirement	18	28	40	30	12
Core credits (theory+ lab+thesis)	41	NA	69	37.5	30
Elective Credits	21	NA	21	52.5	3
Core credits as % of total credits	66	NA	77	31	91
Minimum no. of course required	14	6	17	14	7
Minimum CGPA Requirement to complete M.Tech	6/10	6.5/10	6/10	3/5	2.5/4.3
Thesis requirement	Yes	Yes	Yes	Yes	NA
Lab Details					
Simulators available	Agilent ADS, Microwave office AWR, CST MWS, Ansoft HFSS, CoventorWare, Cadence Spectre, RTS Empire, LabVIEW, CCS,	IE3D, WIPLD, Ansoft HFSS, Agilent ADS, CCS, Altium	Ensemble 4.1, IE3D 7, Fidelity 2.0, Tanner Tool, Compilers and simulators for TMS320c54, TMS320c6x, TMS320c80	Ansoft HFSS, Microwave office AWR, WIPL-D	Cadence Virtuosos, Allegro SPB 15.4, Mentor Graphics Calibre, Synopsis HSPICE, Ansoft HFSS,

	COMSOL Multiphysics, BIST, Coware SPD.				Ansoft link 3.0, Ansoft Designer 3.0, CST MWS, CST EMS, Agilent ADS
Measurement Instruments / Facilities	National Instruments Data Acquisition systems, Texas Instruments Digital Starter Kits for TMS320C5510 DSP, VNA (upto 110 GHz), Spectrum analyzer (upto 40GHz), Power meters (upto 40 GHz), Microwave Signal Sources (upto 20 GHz), Probe station interfaced with automatic Network analyzer, Digital signal analyzer(25 GHz), nondestructive characterization for thermal, acoustic, optical and magnetic system, Anechoic Chamber(up to 18 GHz)	Spectrum Analyzer (9 KHz upto 40 GHz),VNA (up to 20 GHz), Dielectric Probe Kit, 50 GHz PNA, Analog signal generator 20 GHz, Power meter, Noise Figure Meter, Anechoic Chamber (1-26 GHz)	Anechoic Chamber, antenna test range, Microelectronics and MEMS lab, Microwave lab, Microwave measurement lab,	G-band RF probes 140 - 220 GHz, Anechoic Chamber(26 GHz), VNA(30 GHz 1 THz), Sweep Generator (500 MHz 30 GHz), Thermal imaging and microscope thermal probe station, Spectrum Analyzer 50 GHz, Signal Generator 67 GHz,	Wide Dynamic Range Probing Station, VNA (50 GHz), DSO(0-20GHz), Spectrum Analyzer (50 GHz), High Frequency Noise Measurement System, Low Temperature Probe Station
Fabrication	MMIC	Fabricatio	Printed circuits	Nanofabricatio	Device

Facilities	fabrication, MEMS and SAW processing facilities, SOI CMOS fabrication technology for prototyping devices	n facilities for single sided, double sided and multilaye r PCB	lab	n, Microwave fabrication	fabrication, modelling and parameter extraction, MMIC fabrication

Definition of credit

	IIT Delhi	**IIT Kanpur**	**IIT Kharagpur**	**Chalmers**	**Kaist**
1 lecture credit	1 hr. lecture/week for 1 sem	40 min. lecture/week for 1 sem	1 hr. lecture/week for 1 sem	7.5 credits per course in three months with 6hours class per week	1 hr. lecture/week for 1 sem
1 lab credit	2 hr. lab/week	1 lab session/week	1.5 hr. lab/week	1.5 credit for 12 lab sessions in 3 months	3 hr. lab/week

B. Benchmarking for PhD in Applied Research in Electronics

Parameter	CARE	IIT Kanpur	IIT Kharagpur	Korea Advanced Institute Of Science and Technology	Chalmers University of Technology
Course requirement	Min 2 courses min 7.5/10 CGPA	Min 4 courses min 7/10 CGPA	Min 3 courses	**10 credit points compulsory+27 course points+30 points for thesis	*40 course credits (6 points compulsory) +120pts for thesis
Comprehensive exam	Written and Oral	Written and Oral	Written and Oral	written	NA
Inter-disciplinary courses	Communication skills	Seminar required	--------	Ethics+safety, scientific writing+leadership skills	Project management, IPR, academic writing
Teaching Assistance	8 hours/ week	8 hours/ week	Satisfactory report from supervisor	Essential, details unavailable	20% of total working hours
Requirement of publishing a paper	Informally at least 1 essential, no official rule	Essential, however numbers not specified	Essential, however numbers not specified	Essential, however numbers not specified	Essential, however numbers not specified
Univ. exchange program	Not compulsory	Not compulsory	Not compulsory	Preferred and encouraged highly	Preferred and encouraged highly

*- 1 credit point corresponds to 1hr/week for 12 weeks, 40 credits are total credits to be earned in four years

**- 1 credit is normally earned by attending one hour of lecture per week for the entire semester. Research credits are normally earned by conducting thesis research and attending seminars and lab experiments. 1 research credit is equivalent to three hours of research work per week for the entire semester.

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2. Teaching Environment

2.1. Student-teacher ratio separately and total for UG, PG and PhD (based on gross numbers and on class size basis)

i) Gross numbers registered in CARE: Student-teacher ratio based on total students enrolled in CARE: 10.4

1. For UG students: 0
2. For M.Tech students: 6.6
3. For PhD students: 3.8

ii) Class-size basis: In the 2 semesters 2013-14, CARE faculty taught 22 courses with total enrollment of 756 students. **The average number of students taught per CARE faculty per semester is 37.8.**

iii) Out of the 756 students, the number of UG students is approximately 200, while the remaining students are enrolled in M.Tech or PhD.

2.2. No. of students graduated in each programme, incl. PhD (data for 5 yrs).

S. No.	Year	M. Tech in RFDT	PhD
1.	2009	10	3
2.	2010	21	-
3.	2011	29	2
4.	2012	18	2
5.	2013	27	6

2.3. Student-T.A. (or student-hours/T.A.) ratio.

All M.Tech students with Institute Assistantship (from 2nd semester onwards) and full-time PhD students with assistantships are assigned to faculty or courses/labs for TA duties. The students are expected to spend 8 hours per week towards TA duty as per Institute norms.

The course contact hours for M.Tech RFDT students is 20.75 hours/week (29 hours of lectures, and 54 hours of labs and project) averaged over all the semesters. Thus, the student-hours/TA ratio for M.Tech students is 2.6.

PhD students after completion of their course requirement work towards their thesis for which they do not have formal contact hours. Hence, the ratio is not applicable for such students.

2.4. No. of skilled technical staff.

CARE has 6 skilled technical staff – Senior Technical Superintendent: 2; Technical Superintendent: 3; Senior Mechanic: 1.

2.5. Gross laboratory space; break-up of lab space for core UG/PG teaching.

The total laboratory space in CARE is 13,858 sq. ft. consisting of 9695 sq. ft. of Research lab space and 4163 sq. ft. of Teaching lab space.

There are no exclusive teaching laboratories, these being part of research laboratories. All the labs are for PG courses. The teaching lab space has been computed by considering half the space of all the dual-use labs.

CARE has the following labs:

i) Non-destructive Systems Lab,
ii) Microelectronics Lab 1
iii) Microelectronics Lab 2,
iv) MEMS SAW Process Lab,
v) First Reduction Camera Room,
vi) CARE Computing Lab & NPMASS Lab,
vii) DSP Applications Lab,
viii) Digital Signal Processing Lab,
ix) Speech and Audio Processing Lab,
x) Underwater and Air Acoustics Lab,
xi) Microwave Labs 1, 2 & 3,
xii) Measurement Lab,
xiii) MEMS CAD Lab,
xiv) Microwave Component Machining Lab,
xv) Radio Amplifiers and Power Transceiver Lab,
xvi) CARE Workshop.

2.6. Laboratory modernization performed in last 5 years for (i) UG core, (ii) PG core, (iii) elective courses (attach data before and after modernization).

CARE laboratories are used for both research and teaching courses. The modernization done in the last 5 years in specific labs is indicated in the table below.

Area	**Courses using labs**	**Laboratories**	**Modernization in last 5 years**	**Pre-existing major equipments**
Signal Processing	CRL702, CRL707, CRP718, CRD811, CRD812.	➢ Underwater and Air Acoustics Lab	• A major new facility, Acoustic Anechoic Chamber, has been installed in 2013. • Desktop PC (2) • NI Integrated data acquisition system; NI PXIE-8130 TURION 64x2, 2.3 GHz high BW controller, WIN VISTA (1) • Keltron Power	PC (3) Underwater Tank facility (Other pre-existing equipment have been written-off as they have served their purposes.)

			Amplifier- (3) • Switch-Preamplifier Unit • Tri-axial Accelerometer (3) • B&K Power Amplifier (1) • Neptune Underwater Acoustic Hydrophone (3)	
		➢ DSP Applications Lab,	Desktop PC (20) Printer (1) TMS320VC5510 DSP Starter Kit (10) NI Integrated data acquisition system; NI PXIE-8130 TURION 64x2, 2.3 GHz high BW controller, WIN VISTA Cambridge Audio 740A Integrated Power Amplifier (1) Panasonic Toughbook CF-19 (1) TMS320VC5510 DSP Starter kit (10) LabView Academic Software Glass tank for underwater experiments	Desktop PC (5) Printer (2) TMS320VC5510 DSP Starter kit (10) Aplab 20 MHz Function Generator (10) Tektronix Oscilloscope TDS 2002 (5) Creative Speaker (5) Power Supply Elnova Model E-61 (10) UPS 10 KVA (1)
		➢ Digital Signal Processing Lab,	Desktop PC (7) DSP Hardware platform consisting of 5 PCBs (6 set) USB JTAB Emulator OMAP-L138 kit Evaluation Module (2) CCS Software	Printer HP2015D (1) Scanner Scanjet 4670 (1) UPS 5KVA
		➢ Speech and Audio Processing Lab.	Cambridge Audio 650A Integrated Power Amplifier (1) Cambridge Audio 650C CD Player (1) Ultragain Pro Preamplifier MIC 2200 (4) Ultragain Pro 8-channel A/D & D/A converter ADA 8000 (2) Sennheiser Mic MKH 8020 (4) Tannoy Speakers (2) Elac Speakers (2)	Desktop PC (2) Printer (1) Recording & Playback setup (1)

			M-Audio speakers (2) Ifinity wireless speaker 80W (2) Amphony digital wireless Audio transmitter (2) Amphony digital stereo Audio Amplifiers (2) Desktop PC (4) High quality Sennheiser Headphone (5) Bose Noise cancelling Headphone (1)	
Microwaves	CRL711, CRP718, EEP307, EEP719, CRD811, CRD812.	➢ Microwave Lab ➢ Microwave Component Machining Lab	We use microwave measurement laboratory for characterizing the devices, Photolithography room for printing the circuits, coordinator graph room for mask making and anechoic Chamber for pattern measurements. We have added the following equipment for modernization. **Vector Network Analyzers** Agilent E5071B (300KHz – 8.5 GHz) Agilent PNA – N5227A (10 MHz – 67 GHz) Agilent PNA – E8364C (10 MHz– 50 GHz) Agilent PNA – E8361C (10MHz – 110 GHz) **Portable VNAs** Agilent FieldFox (up to 6 GHz) –[2 is Nos.] Agilent FieldFox (up to 26.5 GHz) –[1 Nos] R&S Portable VNA (up to 6 GHz) – [2 Nos.] Anritsu Portable VNA (up to 6 GHz) **Spectrum Analyzer** Agilent 8564EC (9KHz-40GHz) Anritsu M52719B (9KHz – 20 GHz) R &S (9 KHz-3 GHz) **Signal Source**	Vector Network Analyzers Agilent E5071B (300KHz – 8.5 GHz) R&S, ZVB 20 (upto 20 GHz) Portable VNAs None Spectrum Analyzer Agilent 8564EC (9KHz-40GHz) R &S (9 KHz-3 GHz) Signal Source HP Swept source Antenna None Microwave Oscilloscope None Probe station 40 GHz on wafer probe Station – Cascade Microtech Miscellaneous Dicing Saw System – 5200 AREMCO

			Anritsu NG36J4B (2- 40 GHz) Hittite Microwave Source (10MHz- 20 GHz, 200mW, synthesized) [3Nos.] **Antenna** Anechoic chamber with automatic measurement setup (up to 18 GHz) **Microwave Oscilloscope** Agilent 92504A – DSO 80 GSa/S (25 GHz) **Probe station** 110 GHz on wafer probe Station – Cascade Microtech 40 GHz on wafer probe Station – Cascade Microtech On chip Antenna Pattern Measurement setup **Miscellaneous** Quasi Optical Dielectric measurement system, 40-60GHz Agilent 81133A Function generator (up to 3 GHz) Dicing Saw System – 5200 AREMCO	
		➢ RF Amplifier and Power Transceiver Lab	This is a new lab developed in 2013. The major equipments include: 1. Agilent power supplies (Model U8002A) (Quantities: 3): 2. Rohde & Schwarz (Model NRVS) (Quantity: 1) 3. Rohde & Schwarz (Model FS300) (Quantity: 1) 4. Hittite Signal Generator (HMC T21000) (Quantity: 1) 5. Agilent DSO1012A Oscilloscope (Quantity: 1).	-
Microelectronics	CRL724, CRP723, CRD811, CRD812.	➢ Microelectronics Fabrication Lab	The major facilities are older than 5 years and are maintained mostly using indigenous vendors.	• Clean/Chemical Bench • Oxidation Furnace • Diffusion Furnace • Wafer Polishing Machine • Laminar flow Bench

				• Spin Coater (3) • Anodic Bonding System • Mask Aligner and Exposure System (Canon, SET and K&S) • Oven • Flatness Measurement System • Thermal evaporation (Varian and Vacuum Equipment Co) • RF Sputtering System (Alcatel-1, Alcatel -2, Vacuum Equipment Co. and APT) • Reactive Ion Etching • Probe Station • Microscopes • 1st Reduction Camera
		➢ MEMS SAW Process Lab	This is a new lab developed in 2013. The major equipments include: 1. Mask aligner, 2. Chemical fumehood, 3. Compressor dry air unit, 4. Xeon server, 5. Prebake postbake ovens, 6. Clean room benches, 7. Spin coater, 8. Carl Zeiss microscope, 9. Laminar flow benches, 10. Network analyzer, oscilloscope, spares & support, 11. 20 KVA online UPS, 12. Data acquisition card.	-
		➢ Non-destructive Systems Lab	• Uncooled Infrared Camera • Magneto-optic Kerr effect setup	• Cooled IR camera • Mirage setup • Laser heterodyne probe
Common Labs & Facilities		➢ CARE Computing Lab	* Desktop PCs: 13 nos. * Dell Power Edge R-710 * Server: 2 nos.	Desktop PCs: 10 nos. IBM server: 1 no. Printers: 2 nos.

			* Laserjet Printer: 2 nos.	
		➢ NPMASS Lab	* Desktop PCs: 11 nos. * HP Workstation: 2 nos. The software available on the servers in NPMASS lab are: i) Coventor Ware 2010, ii) COMSOL version 4.3, iii) Intellisuite.	-
		➢ CARE Workshop	-	1. Lathe machine 2. Four jaw chucks 3. Dividing head attachment 4. Vertical milling machine 5. Drilling machine – pillar type 6. Drilling machine – bench type 7. Power saw machine. 8. Polish slip set. 9. Hacksaw m/c. 10. HMT milling machine. 11. Outside Micrometer. 12. Dial indicating Micrometer. 13. Angle cutter. 14. Bench grinder. 15. Portable grinder. 16. Vernier height gauge. 17. UPS. 18. Collect set. 19. Chuck. 20. Radious cutter. 21. Quick change toolset. 22. Carbide insert holder. 23. Screw cutting attachment. 24. Indexing attachment. 25. Mill arbor cutter. 26. Rotating Vice Base. 27. Right angle attachment. 28. Right angle tail stock. 29. Insert fly cutter. 30. Digital vernier caliper. 31. Flexible arm. 32. Rigid arm. 33. Surface plate.

				34. Combination set. 35. Parallex Bar. 36. Thru chuck. 37. Rotary table.

1. Non-Destructive Testing Lab:

i. Non – Destructive System Laboratory

ii. Materials Characterization using Infrared Thermography

iii. InfraRed Thermography System

2. Microelectronics Lab 1:

i. Class 100 Yellow Room

ii. Class 10 Room for Diffusion & Oxidation

iii. Probe Station

iv. Sputtering In- House

v. Sputtering – Alcatel

vi. Reactive Ion Etching

vii. Thermal Evaporation -1

viii. Thermal Evaporation – 2

3. Microelectronics Lab 2

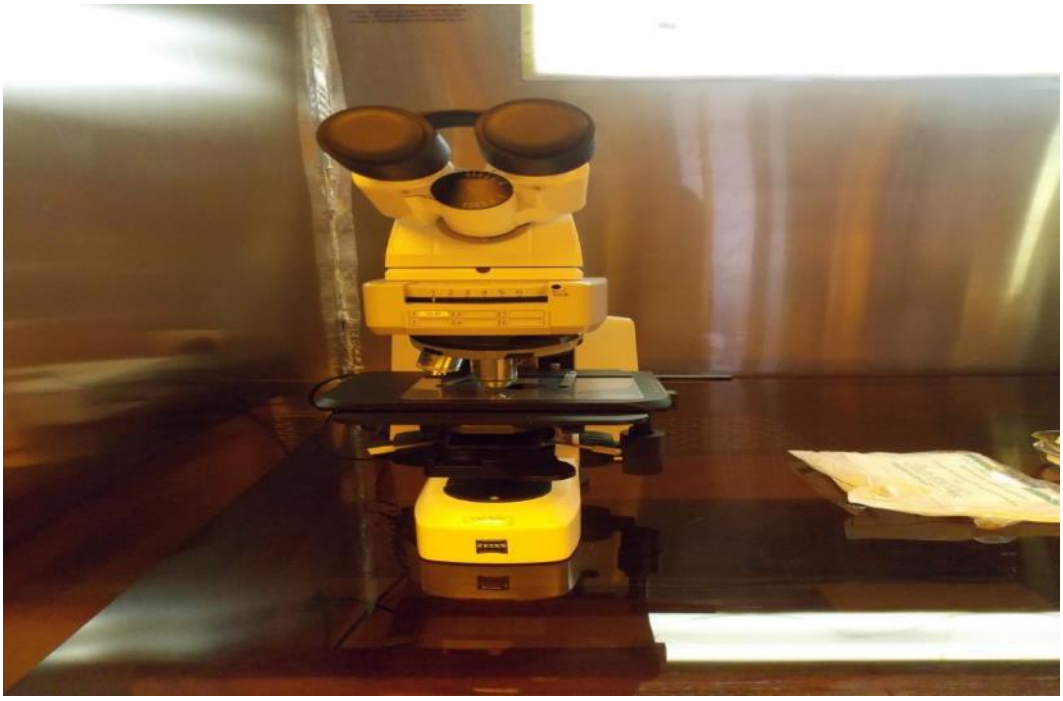
[redacted]

[redacted]

iii. Furnace

4.MEMS SAW Process Lab

i. Spin Coating Unit

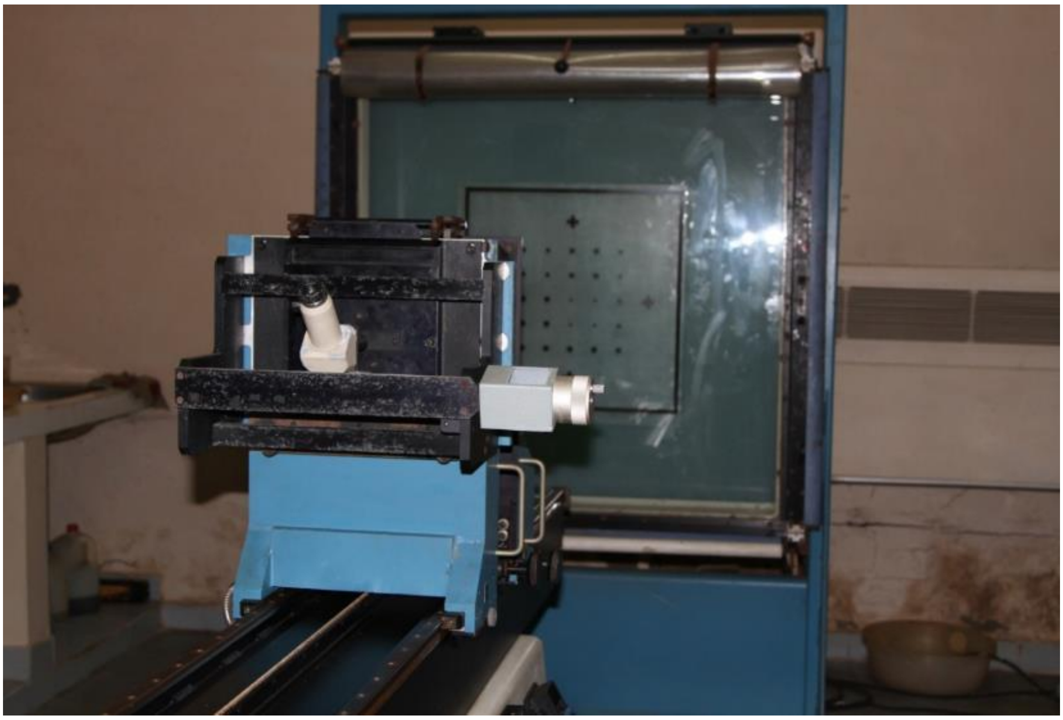


ii. Optical Microscope

iii. Mask Aligner

iv. Clean Bench Yellow Room

4. First Reduction Camera Room



i. First Reduction Camera

ii. Screen: First Reduction camera

6. CARE Computing Lab

i. CARE Computing Lab

ii. CARE Computing Lab

iii. National MEMS Resource Center supported by NPMASS

7. DSP Applications Lab

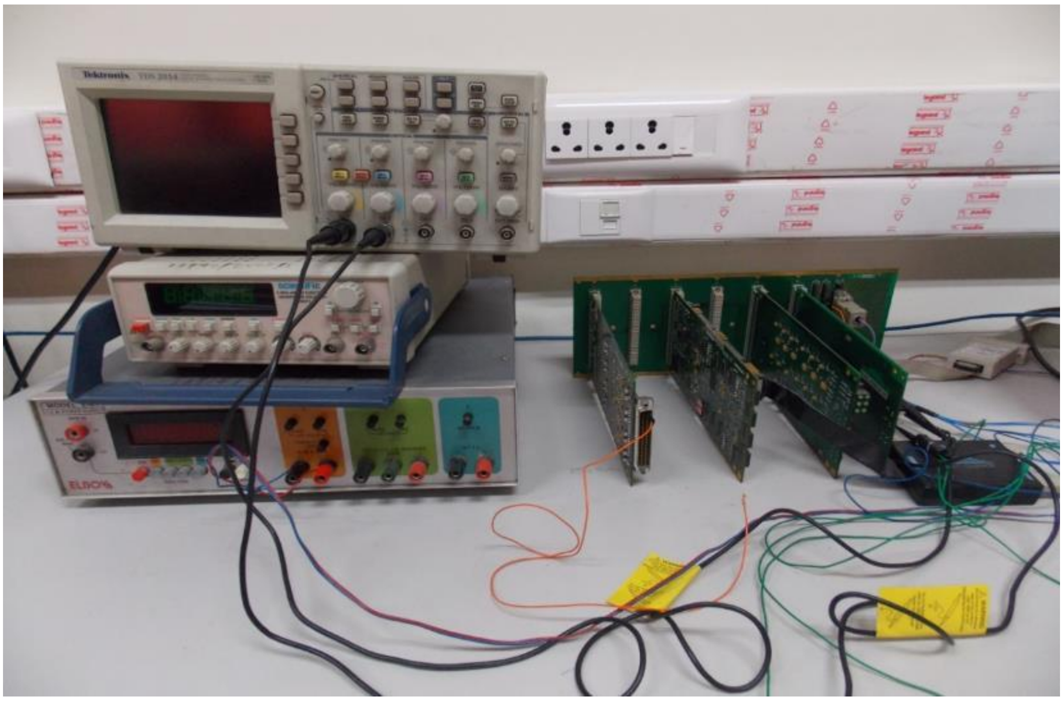
i. DSP Application Lab

ii. Signal Processing Lab


iii. Signal Processing Lab

8. DSP Lab

i. DSP Lab



ii. DSP hardware platform consisting of five PCBs designed at CARE

9. <u>Speech and Audio Processing Lab</u>

i. Speech & Audio Processing Lab

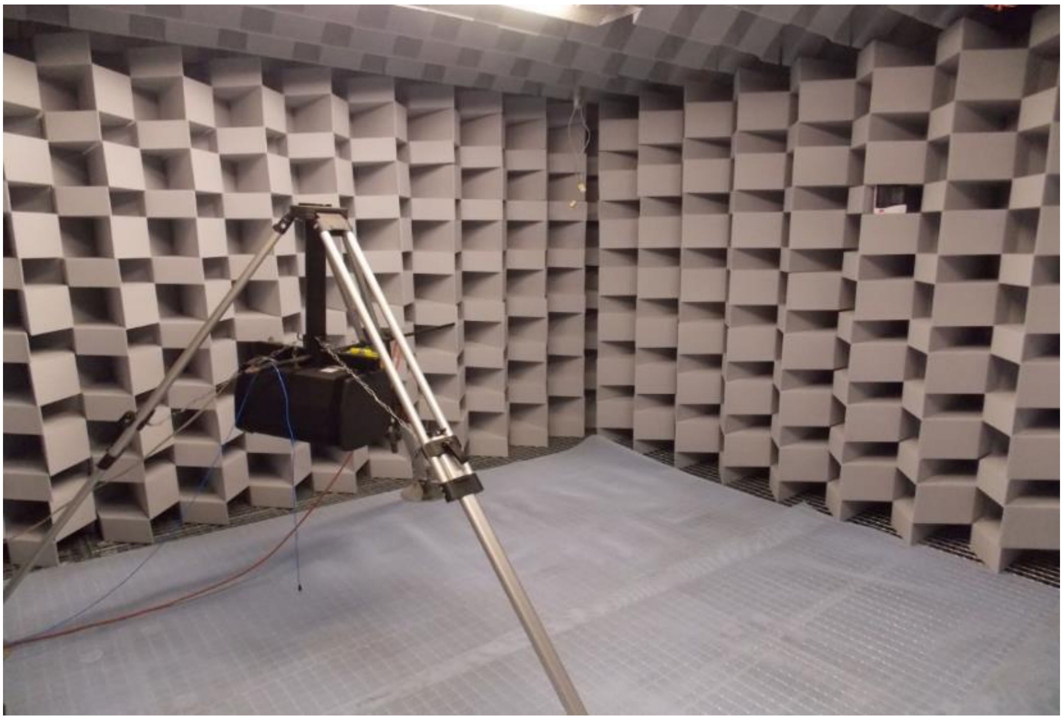
ii. Speech & Audio Processing Lab

iii. Audio Recording & Processing Setup (speech & audio processing lab)

10. Underwater and Air Acoustics Lab

i. Glass Tank for Underwater Acoustic Experiments

ii. Underwater Acoustic tank facility



iii. Anechoic Chamber for acoustic signal characterization & equipment calibration

iv. NI PXI system

v. Keltron Power Amplifier Pre-Amp setup with NI PCI card

11. <u>Microwave Lab-1</u>

i. RF & Microwave Laboratory

ii. Fabricated Microwave & Millimeter Wave Devices

iii. General Measurement setup having Agilent VNA upto 26.5GHz, Agilent spectrum Analyzer upto 40GHz and power supplies

<u>**Microwave Lab-2**</u>

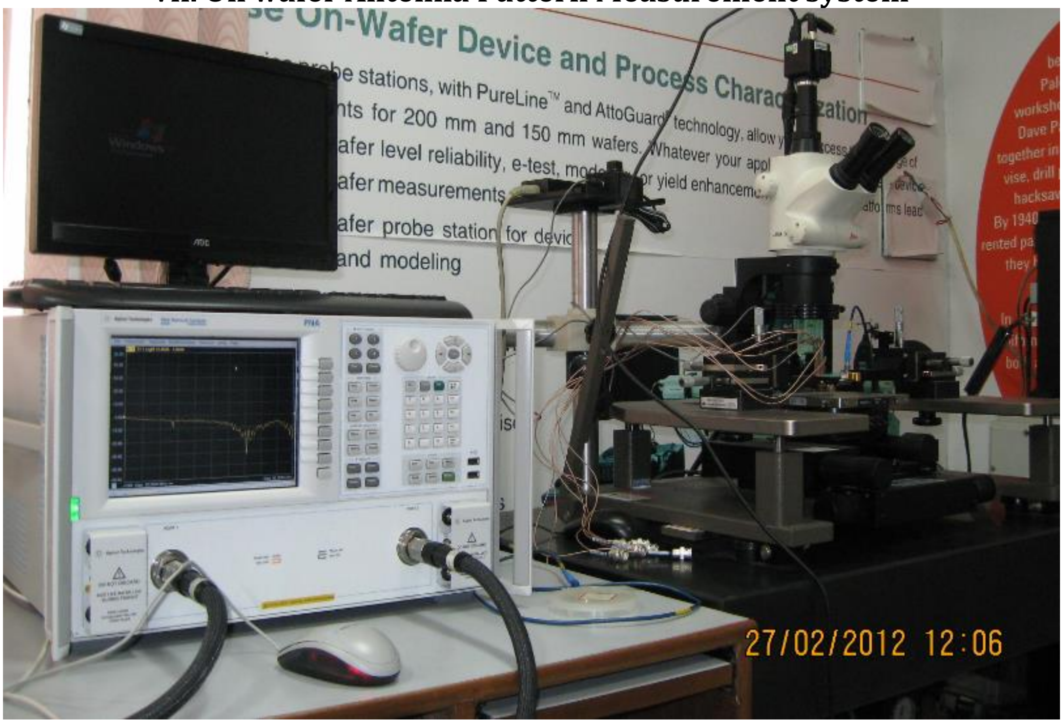
iii. RF Microwave & Millimeter wave Characterization lab with all facilities upto 110GHz.

iv. 110GHz VNA with Probe Station

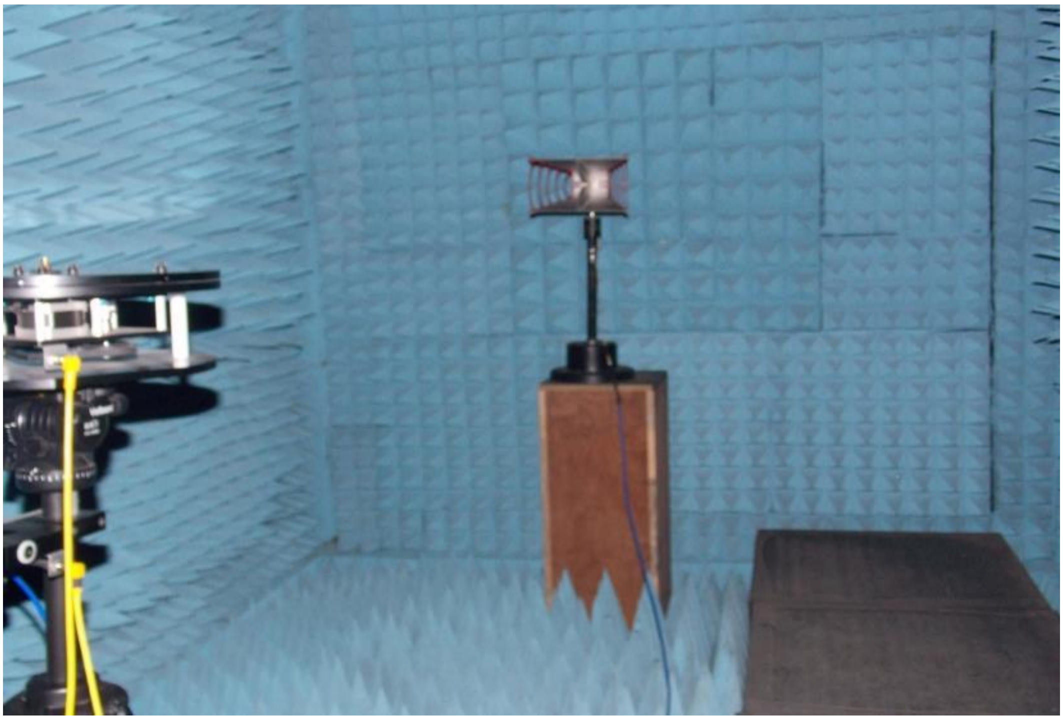
v. Agilent Infiniium 25GHz DSO- X 92504

vi. On wafer Antenna Pattern Measurement system

vii. On wafer Antenna Pattern Measurement system

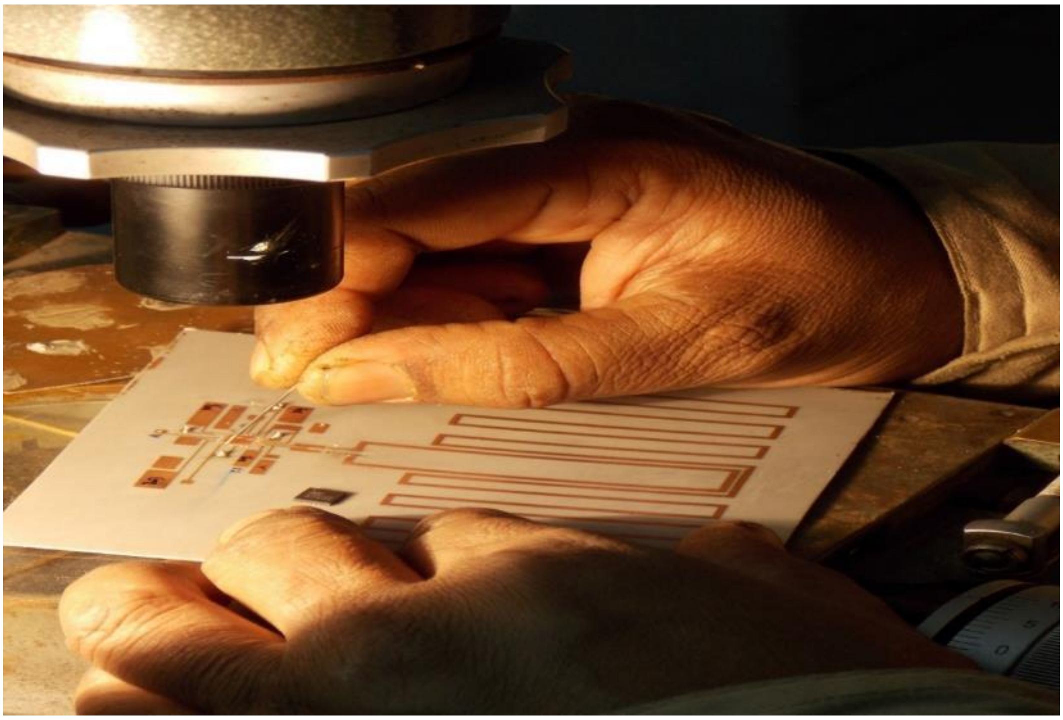


viii. Agilent 50GHz VNA with Probe station



ix.Anechoic Chamber for measuring Antenna Patterns

x. Photolithography Setup



xi. Microwave Soldering Station

xii. Wire Bonding Machine

xiii. Dicing Saw System

Microwave Lab-3

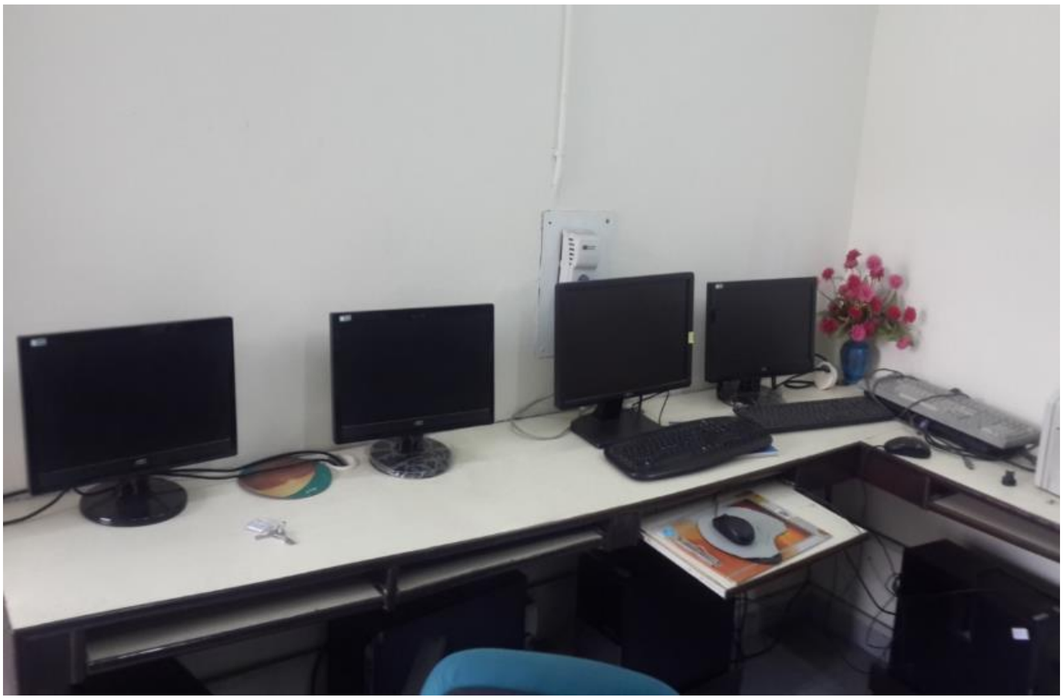
xiv. Microwave lab – CAD

xv. Sputtering Unit

xvi. Photolithography setup

12. MEMS CAD Lab

xvii. MEMS CAD



13. Microwave Component Machining Lab

15. Radio Amplifiers and Power Transceiver lab

i. Radio Amplifiers and Power Transceiver lab

ii. Measurement setup for Characterizing Power Amplifier: Power and Drain efficiency

iii. Measurement setup characterizing for Non-Linearity & Digital Pre-Distortion

16. <u>Workshop</u>

i. Workshop

ii. Lathe Machine

iii. Four Jaw Chucks

iv. Dividing Head Attachment

v. Vertical Milling Machine

vi. Drilling Machine – Pillar Type

vii. Drilling Machine – Bench Type

viii. Power Saw Machine

2.7. Course files for each course for last 5 years.

Course information for the following courses taught by CARE faculty are given in Annexure – 5:

S. No.	Course Nos.
1.	CRL715, CRL724, EEL713, EEL207, EEL338, EEP307.
2.	CRL712, CRL713, CRL724.
3.	CRL711.
4.	EEL713.
5.	CRL702, CRL704, CRL707.
6.	EEL205, CRL732.
7.	CRL731, EEL765.
8.	CRP723.
9.	CRL726.

2.8. Study materials (monographs, notes, books, videos, web- based materials, etc.) prepared, course-wise.

Study material for the following courses will be made available in hard-copy to the review committee members during the evaluation process:

S. No.	Course Nos.
1.	CRL715.
2.	CRL712, CRL724.
3.	CRL711.
4.	EEL713.
5.	CRL702, CRL707.
6.	CRL732.
7.	EEL765.
8.	CRP723.
9.	CRL726.

2.9. Research and Innovation in teaching-learning processes.

Faculty have used the following strategies in teaching-learning processes:

S. No.	Strategies
1.	i) In CRL707, Human and Machine Speech Communication course, students do practical assignments with real speech signals. This includes i) implementation of ITU-T P.563 Speech Quality Evaluation algorithm and using it for evaluation of speech quality for various kinds of degradations, ii) LPC-10 vocoder speech coder for classic speech coding methodology, iii) temporal, spectral, and time-frequency analysis of speech. ii) In CRL707, Human and Machine Speech Communication

	course, students develop an isolated word recognition engine using open source tools. They record words that are used for testing the performance, while the training of Hidden Markov Models is done with recordings done by other students of the class. iii) In CRL707, Human and Machine Speech Communication course, students write and present a term paper on different research aspects of current interest. iv) In CRL707, Human and Machine Speech Communication course, there is extensive use of multimedia in the lectures that included audio demonstrations, real-time computations, and graphical displays. v) In CRL702, Architectures and Algorithms for DSP Systems, students do an independent project in groups of two, on the TMS320C55xx DSP Kit in which they demonstrate real-time signal processing using assembly language programming and at least one peripheral interface device.
2.	Always motivated students to solve some problems of practical purpose. CRL704 students demonstrated the beamforming in Open house'11 focusing music in one direction only. CRL704 students also designed a basic package to predict the batsman rating in IPL using AR model.
3.	Seminar presentations on the ongoing research areas related to course content have been introduced in the curriculum. The instructor provided reference material and each student has to present an individual topic related to the course content (especially applications of the topics under the course). This generates interest and awareness among students in the applications of the course under study. This also introduces an interactive forum between students and teacher in order to understand their strength and weakness in understanding the subject. Overall, it will develop more interest among students in the subject.
4.	1. Introduced antenna pattern measurements in an anechoic chamber (EEP719, CRP718), 2. Introduced Mini-projects (EEP307), 3. Introduced Virtual-Lab (EEP307) as an aid for better understanding of the experiments.
5.	Developed software to facilitate mask-making in laboratory course.
6.	1. Awarding one mark for asking question in the class. This has enhanced the interactive approach with the students during teaching. 2. Introduction of seminars which helps understanding of

	the course in finer details. This also enhances of selecting a good M. Tech Project for keeping the continuity of the subject. 3. Changed the examination pattern. In the new pattern adopted, there are typically 15 questions testing the basic concepts. This also facilitates to cover more course content in the examination and reduces the vulnerability of students for course preparedness.
7.	A seminar presentation by each student on related research areas of the course (CRL724: RF & µwave Measurement System Techniques) was introduced at the inception of the MTech program. To introduce interaction and participation, part weightage is given to questions based on the various presentations. Overall learning, group discussion as well presentation skills are enhanced.
8.	Courses CRL 711 and CRL 712: I have introduced practical aspects of design and development of Microwave passive and active circuits in these courses. I solve several problems in the class and later ask students to solve many more practical problems by giving them 6-7 tutorial sheets. Most of the problems are done using first principles and this gives better insight of the subject to students. The textbook designs are validated by students using CAD tools and later fabricated as part of the laboratory portion of the course. The reasons for differences between theoretical and practical results is explained to the students and techniques to incorporate corrections that helps to make devices work to the specifications are taught to the students. [This approach has been very well appreciated by the students - based on the feedback received]

2.10. No. of students (UG and PG separately) who have spent at least a semester at another university/institute (overseas or Indian).

i) 8 UG students of other universities have spent a regular semester in CARE in the last 5 years doing their Major Project.

ii) Approximately 40 UG students of other universities have spent a summer semester doing 2-month internship in CARE in the last 5 years.

2.11. No. of students from overseas universities who have taken classes, done project work or internship, UG & PG separately, in the department.

Foreign students have enrolled in following courses taught by CARE faculty (12 nos.):

i) EEL207: 4.

ii) EEL338: 1.
iii) EEL713: 1.
iv) CRL725: 1.
v) CRL722: 5.

2.12. Course feedback.

The students for each course give the course feedback on-line. The quantitative feedback for each course is an average number out of a maximum of 5. Students evaluate faculty and give scores ranging from 1 to 5 on 22 different parameters.

Over the last 4 semesters (2011-12/2nd semester to 2013-14/1st semester), the average feedback score for 32 CARE courses is 4.16.

2.13. Industry experts who have delivered lecture(s), seminars, discussion as part of a core/elective course - UG & PG separately.

1. Dr. Ashish Verma, Senior Manager, Speech Research, IBM India Research Lab, New Delhi, for demonstration lecture in CRL707 – Human and Machine Speech Communication.
2. There is an active lecture scheme under IEEE-MTTS, and many Distinguished Lecturers have given talks in the RF/Microwaves/Antennas area.

2.14. Industry exposure to students - course related visits to factories, sites, industry exhibitions, field trips, etc. - UG and PG separately.

1. **Signal Processing:** M.Tech and PhD students have visited:
   i) National Physical Oceanographic Laboratory, DRDO, Kochi,
   ii) Underwater Acoustic Test Facility, Idduki,
   iii) Ganges river site, Narora, UP,
   for underwater communications experiments.
   iv) Snow and Avalanche Study Establishment, DRDO, Manali and Dhundi, Himachal Pradesh, for field experiments in snow using acoustic measurements.

2. **Microelectronics:** PhD students have visited Bharat Heavy Electricals Limited Amorphous Silicon Solar Cell Centre, near Delhi.

3. **Microwaves:**

i) **Srujana Kagatia -**	Visited CMET Pune to carry out work on LTCC circuits as part of her Ph.D.
ii) **Sukomal Dey-**	Visited Astra Microwave Private Limited to carry out measurements on RF MEMS as part of his Ph.D.
iii)**Preeti Sharma-**	Visited Astra Microwave Private Limited to carry out measurements on RF MEMS and fabrication of circuits as part of his Ph.D.

iv) **Pushpendra Kumar - Singh** Visited Astra Microwave Private Limited to fabricate circuits as part of his M.Tech Thesis.

v) **Vikas Kumar Kaushal-** Visited Astra Microwave Private Limited to fabricate circuits as part of his M.Tech Thesis.

vi) **V.G Kiran -** Visited Astra Microwave Private Limited to carry out bonding of devices and fabrication of some components of 17 GHz TR Module

vii) **P.Srinivasa -** Visited LRDE Bangalore and Astra Microwave Products Limited to carry out fabrication of MIC Phase shifters at C- band

viii) **Manjushree Tamang -** Visited LRDE Bangalore and Astra Microwave to carry out fabrication and measurements on Integrated antennas.

3. Research

3.1. No. of Masters and PhD students supported – (i) by Institute Assistantship, (ii) on sponsored projects / consultancies, (iii) other sources, and (iv) sponsored by external organizations.

S. No.	Category of students	Sanctioned	In-place
1.	RFDT M.Tech students with Institute Assistantship	20	18 (2013 batch) 16 (2012 batch)
2.	RFDT M.Tech students sponsored under PGT scheme for Defence officers and PGT scheme for DRDO scientists	20	12 (2013 batch) 20 (2012 batch)
3.	PhD scholars with Institute Assistantship	18	16 (Jan 2014)
4.	PhD scholars – On sponsored projects	*	2 (Jan 2014)
5.	PhD scholars – Sponsored by external organizations (part-time)	*	15 (Jan 2014)
6.	PhD scholars – Supported by other sources eg. CSIR, QIP.	*	4 (Jan 2014)
7.	PhD scholars – Foreign Nation	*	1 (Jan 2014)

* There is no individual sanctioned limit for the number of PhD scholars in these categories, except for the total limit for all categories of PhD scholars including Institute Assistantships to 60 (i.e. 5 times the number of sanctioned faculty strength of the Centre).

3.2 No. of PhDs enrolled, graduated per faculty for last 5 years.

Currently enrolled no. of PhD per faculty: 3.8
No. PhD graduated per faculty over last 5 years: 1.4

S. No.	Year	Enrolled	Graduated
1.	2008-09	21	4: Ravindra Singh, Preeti Sharma, Vivekanand Bhatt, Arnab Das.
2.	2009-10	29	0
3.	2010-11	31	0
4.	2011-12	38	4: S. S. Lokesh, Mithilesh Kumar, Krishnendu Chatterjee, Smita Chugh.
5.	2012-13	39	6: Atul Vir Singh, Manoj Singh Parihar, Sandeep Chaturvedi, Hardik Pandya, Uday Dadwal, Mohini Gupta.
6.	2013-14	38	-

3.3 Areas of research (e.g. areas listed in Prospectus, and others) by (i) Volume (quantifiable parameters), (ii) Breadth, and (iii) Years these have been research areas.

Data for last 5 and 10 years - The figures for 10 years is given in brackets.

S.No.	Name of research area (list from Prospectus + any other)	Faculty Involved (Nos.)	PhDs		Journal papers	Conference papers	Sponsored projects (Nos. & value in Rs. lakhs)		Industry consultancies (Nos. & value in Rs. lakhs)		Listed in Prospectus Since
			Completed	On-going	Nos.	Nos.	Completed	In progress	Completed	In progress	(*give year*)
1.	Signal Processing: Underwater Acoustics, Speech Processing, Signal Processing for Communications.	3	2 (5)	13	22 (32)	36 (77)	14 nos., 390.44 Lakhs (18 nos, 484.30 Lakhs)	3 nos., 218.97 Lakhs	14 nos., 67.17 Lakhs (17 nos., 82.24 Lakhs)	2 nos. 74.00	Last 10 years
2.	Microwaves: Microwave and Millimeter wave ICs and circuits, RF MEMS, EBG structures, Microwave antenna, RF Power Amplifiers and Transmitters.	4	4 (6)	13	33 (49)	65 (118)	22 nos., 912.0 Lakhs (42 nos., 1140.00 Lakhs)	13 nos., 902.00 Lakhs	9 nos., 32.5 Lakhs. 17 nos.	-	Last 10 years
3.	Microelectronics: Silicon micromachining and MEMS sensors, nano-structured materials, Non-destructive characterization techniques.	6*	8 (14)	12	50 (109)	58 (149)	20 nos., 781 Lakhs (25 nos., 1306.3 Lakhs)	5 nos., 398.07 Lakhs	8 nos., 41.70 (18 nos., 92.06)	-	Last 10 years

* Including 1 retired in 2009, 2 resigned in 2011 and 2013 respectively.

3.4 Publications per faculty (average per year for last five years) in academic journals.

Academic Year	# of journal publications per faculty	Remarks
2009	2.4	No. of journal publications per faculty per year averaged over last 5 years = 2.1.
2010	1.3	
2011	2.0	
2012	1.5	
2013	2.8	

The complete list of journal and conference publications of all CARE faculty for the previous 10 years (since 2003 onwards) is given in Annexure – 6.

3.5 Publications (journal and conference) total and per (a) PhD student, (b) Masters student, (c) UG student.

S. No.	Type of publication	Last 5 years	Last 10 years
1.	No. of journal publications	105	190
2.	No. of conference publications	159	344
	Total no. of papers published	**264**	**534**

Academic Year	# of journal and conference publications	# of publications with PhD students	# of publications with M.Tech students
2009	70	39	7
2010	35	18	5
2011	65	38	13
2012	36	23	4
2013	52	37	5
2014	3 (till Jan)	3	0

3.6 Best papers in last 5 years: (i) Individual best 3, (ii) department/centre best 10; and brief justifications.

List of Individual best 3 papers:

Faculty	Best 3 papers
R. Bahl	1. Ryo Hirotsu, Masao Yanagisawa, Tamaki Ura, Masao Sakata, and Harumi Sugimatsu, Junichi Kojima, Rajendar Bahl, “Localization of sperm whales in a group using clicks received at two separated short baseline arrays,” J. Acoust. Soc. Am. **127** (1), January 2010, pp 133-147.

	Several clicking and diving sperm whales were localized by triangulation using two separated SBL arrays. This required classification of overlapping clicks from several whales and co-registration of the clicks at both arrays before triangulation. It was a unique and pioneering experiment at sea. 2. Rinki Gupta, Arun Kumar, Rajendar Bahl, "Estimation of instantaneous frequencies using iterative empirical mode decomposition," *Signal, Image and Video Processing*, Springer, (doi:10.1007/s11760-012-0305-5) published online 24 March 2012. *The paper gives a novel method for time-frequency representations using instantaneous frequencies. Thus, the advantages of instantaneous frequency over Fourier frequency representation are translated to time-frequency analysis.* 3. A. Das, A. Kumar, R. Bahl, "Marine vessel classification based on passive sonar data: the cepstrum-based approach," *IET Radar, Sonar and Navigation,* vol. 7, issue 1, pp. 87-93, Jan 2013. *The paper gives a method based on cepstrum deconvolution to improve the performance of marine vessel classification from the radiated noise of ships and submarines. This is a difficult practical problem and the improvement provided by the proposed method is significant in its usefulness.*
Arun Kumar	1. S. S. Lokesh, A. Kumar and M. Agarwal, "Structure of an optimum linear precoder and its application to ML equalizer," IEEE Transactions on Signal Processing, vol. 56, issue 8, pp. 3690 - 3701, Aug 2008. *The structure of optimum precoder for rotational Invariant (invariant to rotation in output constellation) performance measure has been given. It has been further shown that many criteria of optimum equalizers (such as minimum BER, Minimum MSE, ML), maximization of channel capacity and minimization distance belong to this category. This unification of the different criteria into a single category leads to useful insight.* 2. H. Choudhary, R. Bahl, A. Kumar, "Passive acoustic localization using blind Gauss Markov estimate with spectral estimation at each sensor," IET Radar, Sonar, and Navigation, vol. 7, issue 7, pp. 800-807, Aug. 2013. *The paper uses blind Gauss Markov estimation procedure along with estimation of power spectral density at the receiving sensors to provide improved time-delay estimates leading to improved localization of radiating acoustic sources*. 3. Rajesh Dubey and Arun Kumar, "Non-intrusive speech quality

	assessment using several combinations of auditory features," Intl. Journal of Speech Technology, Springer, vol. 16, issue 1, pp. 89-101, March 2013. *The paper gives an algorithm for the objective evaluation of perceived speech quality that correlates much better with subjective evaluation scores compared to the currently used ITU-T Recommendation P.563 for this purpose.*
M. Agarwal	1. Sharbari Banerjee • Monika Agrawal, "A Simple Analytical Design Approach to Space TimeTrellis Codes, " accepted Wireless Personal Communication, Elsevier Sept 2013. (Here we have suggested a totally new method for designing MIMO Trellis codes.) 2. A. Goel, P. Gupta and M. Agrawal, "Generalized M-2M mapping for SLM and PTS based OFDM Systems without Side-Information" accepted Wireless Personal Communication, Elsevier June 2013. (A method for PAPR reduction without side information, therefore improves the data rate.) 3. S. Banerjee, M. Agrawal, "A Time Reversal Technique for minimizing Equalizer complexity in High Rate Multi-antenna UWA Link," National Conference on Communications, 2013.
S. K. Koul	1. Sukomal Dey and **Shiban K Koul**, Design and development of a CPW-based 5-bit switched line phase shifter using inline metal contact MEMS series switches for 17.25 GHz transmit/receive module application, Journal of Micromechanics and Micro-engineering, Vol. 24, No. 1, 24th January 2014, 015005(24 pages). *[starting from the basic theory, the paper gives design details, simulation results, actual phase shifter bit design and development of final integrated phase shifter. The work reports smallest size high performance phase shifter in MEMS technology available worldwide for practical transmit/receive applications]* 2. Sukomal Dey and **Shiban K Koul**, Design and development of a surface micro-machined push-pull-type true-time-delay phase shifter on an alumina substrate for Ka-band T/R module application, Journal of Micromechanics and Micro-engineering, Vol. 22, No. 12, 24th October, 2012, pp. 125006-125025(20). *[A totally new concept of realizing true-time delay phase shifter utilizing push-pull type MEMS switches is described in this paper. Complete ananlysis, design details, simulation results and*

	measured data on actual fabricated MEMS phase shifters are included in this paper. The fabricated devices reported can be directly used in building practical T/R modules for phased arrays] 3. Lalithendra Kurra, Mahesh P. Abegaonkar, Ananjan Basu and **Shiban K Koul**, A Compact Uni-Planar EBG Structure and its application in Band-Notched UWB Filter, International Journal of Microwave and Wireless Technologies , Vol.5, No.4, pp. 491–498, August 2013. *[Design and development of novel compact uni-planar EBG structure is described in this paper. Utilization of the same in practical application is demonstrated here. As an example, band notched UWB filter is fabricated and characterization. The results presented can be utilized to built variety of novel components at RF and Microwave Frequencies]*
Ananjan Basu	1. 'Circuits And Active Antennas For Ultra-Wide Band Pulse Generation And Transmission', Mithilesh Kumar , Ananjan Basu and Shiban K Koul, *Progress in Electromagnetic Research B* #23, page 251-272, July 2010. *[simplest circuit, also compatible with CMOS-RFIC/MMIC demonstrated for UWB pulse generation]* 2. 'Efficient Spurious Rejection and Null-steering Using Slot Antennas', Manoj S Parihar , Ananjan Basu and Shiban K Koul, *IEEE Antennas And Wireless Propagation Letters*, vol.10, pp 207-210, Mar 2011. *[the concept of null-steering was demonstrated in a practical way for the first time]* 3. 'Transient Response of Injection-Locked Active Antenna Arrays' Lakshminarayana S. Modur, Ananjan Basu, and Shiban Kishen Koul, *IEEE Antennas And Wireless Propagation Letters*, Vol. 9, June 2010, pp 546-549. *[one of the few papers to address transient response of active antennas till now]*
B. S. Panwar	1. J K Kaushik, V R Balakrishnan, B S Panwar, and R Muralidharan, "On the Origin of Kink Effect in Current-Voltage Characteristics of AlGaN/GaN High Electron Mobility Transistors", IEEE Trans. Electron Devices, Vol. 60, pp.351-57, 2013. 2. Pradeep Kumar Rathore, Pratyush Varshney, Sunil Prasad and **B.S. Panwar**, "Theoretical Modeling, Simulation and Optimization of Double Cavity Vacuum Sealed Piezoresistive Pressure Sensor", Sensor Review Vol. 33, pp. 352-362, 2013.

	3. Janesh K. Kaushik, V R Balakrishan, R Muralidharan, and B S Panwar "Inverse temperature dependence of reverse gate leakage current in AlGaN/GaN HEMT", Semiconductor Science and Technology, Vol. 28, pp.2013-2018, 2012.
S. Chandra	1. "Piezoresistive Pressure Sensor Using Low-Temperature Aluminium Induced Crystallization of Sputter-Deposited Amorphous Silicon Film", Ruchi Tiwari and Sudhir Chandra, *Journal of Micromechanics and Microengineering*, 23 (2013) 095020 (9pp) doi:10.1088/0960-1317/23/9/095020. 2. "Integration of ZnO Nanostructures with MEMS for Ethanol Sensor", H. J. Pandya, Sudhir Chandra and A. L. Vyas, *Sensor and Actuator B*, vol. 161, pp. 923– 928, 2012 3. "Mechanical and Structural Properties of RF Magnetron Sputter Deposited Silicon Carbide Films for MEMS Applications", Atul Vir Singh, Sudhir Chandra, Sushil Kumar and G. Bose, *Journal of Micromechanics and Microengineering*, 22 (2012) 025010 *a. In Publications 1 and 2 as listed above, complete devices have been fabricated and tested in Microelectronics Lab of CARE (including mask making).* *b. The work is published in reputed journals of our research field.*
Suneet Tuli	1. K. Chatterjee and S. Tuli, "Image enhancement in transient lock-in thermography through time series reconstruction and spatial slope correction," IEEE Transactions on Instrumentation and Measurement, Vol. 61, Issue 4, April 2012. *The technique proposed is of relevance and practical importance to industry. Together with the paper below it gives a novel algorithm and technique to enhance thermal images for sub-surface defect detection.* 2. Krishnendu Chatterjee & Suneet Tuli, "Prediction of blind frequency in lock-in thermography using electro-thermal model based numerical simulation", J. Appl. Phys. 114, 174905 (2013). *GE is negotiatiating purchase of the simulation software developed and described by way of this publication due to industrial relevance in thermal non-destructive characterization.* 3. P Tyagi, L I Giri, S Tuli and R Srivastava, "Elucidation on Joule heating and its consequences on the performance of organic light emitting diodes", J, Appl. Phys., 115 (3), 034518 (2014)
Karun Rawat	1. K. Rawat, F.M. Ghannouchi, "Design methodology for dual-band Doherty power amplifier with performance enhancement using dual-Band offset lines," in IEEE Trans.

	Industrial Electronics, vol. 59, no. 12, Dec 2012, pages: 4831-4842. (Total Citation 14, 7/year) 2. K. Rawat, F.M. Ghannouchi, "A Design Methodology for Miniaturized Power Dividers using Periodically Loaded Slow Wave Structure with Dual Band Applications," in IEEE Transactions on Microwave theory and Techniques , vol. 57, no. 12, part 2, Dec 2009, pages: 3380-3388.(Total citation: 18, 3.6/year) 3. M. Rawat, K. Rawat, F.M. Ghannouchi, "Adaptive Digital Predistortion of Wireless Power Amplifiers/Transmitters Using Dynamic Real-Valued Focused Time-Delay Line Neural Networks," in journal IEEE Transactions on Microwave theory and Techniques, vol.58 , no.1, Jan 2010, pages: 95-104.(Total citation: 46, 11.5/year)
M. Abegaonkar	1. Lalithendra Kurra, **Mahesh P. Abegaonkar**, A. Basu, S.K. Koul, "A Harmonic Suppressed Bandpass Filter using Planar EBG and its application in Diplexer", *IEEE Microwave and Wireless Components Letters,* **(in press) 2014.** *A novel design of a compact bandpass filter and diplexer using planar EBG structure is presented. The main advantages over the reported structures are: compact size and harmonic suppression.* 2. Pooja Prakash, **Mahesh P. Abegaonkar**, A. Basu, S.K. Koul, "Gain Enhancement of a CPW-fed Monopole Antenna Using Dual-band Polarization-insensitive AMC Structure", *IEEE Antennas and Wireless Propagation Letters,* 12(1), pp. 1315-1318, Dec. **2013** *A simple polarization-insensitive Artificial Magnetic Conductor (AMC) structure is reported as a back-plane for antennas. It is verified experimentally that gain of a simple microstrip monopole can be enhanced by about 10 dB. This method has a lot of potential for application in communications.* 3. Ankush Gupta, **Mahesh P. Abegaonkar**, A. Basu, S.K. Koul, "Simplified Design of a Tunable High Impedance Surface and Its Application to Dual-band Microstrip Antenna", *Progress in Electromagnetics Research (PIER)-C*, Vol. 43, page 231-246, **2013**. *A tunable high-impedance surface (HIS) is reported for applications in dual-band antennas. Unlike the reported tunable HIS structures which employ large number of varactors, the present structure relies only on two varactors for tunability. This results in significant reduction in structure and overall cost.*

List of 10 best papers of the Centre:

S.No.	Paper details
1.	Design and development of a surface micro-machined push-pull-type true-time-delay phase shifter on an alumina substrate for Ka-band T/R module application - Sukomal Dey and Shiban K Koul, Journal of Micromechanics and Micro-engineering, Vol. 22, No. 12, 24th October, 2012, pp. 125006-125025(20). *A totally new concept of realizing true-time delay phase shifter utilizing push-pull type MEMS switches is described in this paper. Complete analysis, design details, simulation results and measured data on actual fabricated MEMS phase shifters are included in this paper. The fabricated devices reported can be directly used in building practical T/R modules for phased arrays. This is also a current National requirement for military applications.*
2.	Efficient Spurious Rejection and Null-steering Using Slot Antennas - Manoj S Parihar, Ananjan Basu and Shiban K Koul, IEEE Antennas And Wireless Propagation Letters, vol.10, pp 207-210, Mar 2011. *One of the latest developments in the field of antennas is the concept of 'null-steering' (beam steering is of course very well-known). Null steering has been investigated from a theoretical and signal-processing point-of-view by several researchers. It was demonstrated in a practical way for the first time in this work.*
3.	Transient Response of Injection-Locked Active Antenna Arrays - Lakshminarayana S. Modur, Ananjan Basu, and Shiban Kishen Koul, IEEE Antennas And Wireless Propagation Letters, Vol. 9, June 2010, pp 546-549. *Microwave circuits and antennas are combined to realize an 'active antenna (oscillator type)' which can actually be a complete transmitter. This is one of the few papers to address transient response of active antennas – traditionally antennas are discussed purely in the frequency domain.*
4.	A Compact Uni-Planar EBG Structure and its application in Band-Notched UWB Filter- Lalithendra Kurra, Mahesh P. Abegaonkar, Ananjan Basu and Shiban K Koul, International Journal of Microwave and Wireless Technologies , Vol.5, No.4, pp. 491–498, August 2013. *Design and development of novel compact uni-planar EBG structure is described in this paper. Utilization of the same in practical application is demonstrated here. As an example, band notched UWB filter is fabricated and characterization. The results presented can be utilized to built variety of novel components at RF and Microwave Frequencies. This activity explores the still-growing area of 'EBG structures' and is among the first papers to introduce electronic tuning in planar EBG structures.*

5.	S. S. Lokesh, A. Kumar and M. Agarwal, "Structure of an optimum linear precoder and its application to ML equalizer," IEEE Transactions on Signal Processing, vol. 56, issue 8, pp. 3690 - 3701, Aug 2008. *The structure of optimum precoder for rotational Invariant (invariant to rotation in output constellation) performance measure has been given. It has been further shown that many criteria of optimum equalizers (such as minimum BER, Minimum MSE, ML), maximization of channel capacity and minimization distance belong to this category. This unification of the different criteria into a single category leads to useful insight.*
6.	H. Choudhary, R. Bahl, A. Kumar, "Passive acoustic localization using blind Gauss Markov estimate with spectral estimation at each sensor," IET Radar, Sonar, and Navigation, vol. 7, issue 7, pp. 800-807, Aug. 2013. *The paper uses blind Gauss Markov estimation procedure along with estimation of power spectral density at the receiving sensors to provide improved time-delay estimates leading to improved localization of radiating acoustic sources*.
7.	Ryo Hirotsu, Masao Yanagisawa, Tamaki Ura, Masao Sakata, and Harumi Sugimatsu, Junichi Kojima, Rajendar Bahl, “Localization of sperm whales in a group using clicks received at two separated short baseline arrays,” J. Acoust. Soc. Am. **127** (1), January 2010, pp 133-147. *Several clicking and diving sperm whales were localized by triangulation using two separated SBL arrays. This required classification of overlapping clicks from several whales and co-registration of the clicks at both arrays before triangulation. It was a unique and pioneering experiment at sea.*
8.	Krishnendu Chatterjee and Suneet Tuli, “Image enhancement in transient lock-in thermography through time series reconstruction and spatial slope correction,” IEEE Transactions on Instrumentation and Measurement, vol. 61, no. 4, April 2012. *The technique proposed is of relevance and practical importance to industry. Together with the paper below it gives a novel algorithm and technique to enhance thermal images for sub-surface defect detection.*
9.	"Piezoresistive Pressure Sensor Using Low-Temperature Aluminium Induced Crystallization of Sputter-Deposited Amorphous Silicon Film", Ruchi Tiwari and Sudhir Chandra, *Journal of Micromechanics and Microengineering*, 23 (2013) 095020 (9pp) doi:10.1088/0960-1317/23/9/095020. *Complete device has been fabricated and tested in Microelectronics Lab of CARE (including mask making).*
10.	J. K. Kaushik, V R Balakrishnan, B S Panwar, and R Muralidharan, “On the Origin of Kink Effect in Current-Voltage Characteristics of AlGaN/GaN High Electron Mobility Transistors”, IEEE Trans. Electron Devices, Vol. 60,

	pp.351-57, 2013.

3.7 Average citation per department/center.

Average citation per CARE faculty = 295.

3.8 Changes, modifications, etc. done to improve the quality of (i) M.Tech, and (ii) PhD graduates.

1. Suneet Tuli: As a founding philosophy of the Centre the emphasis has been on applied research and this is evident in our PhDs also. The level and quality of work has also been kept very high. Consequently two PhDs in the past 10 years have been awarded the Best Industrially relevant PhDs by FITT.

2. R. Bahl: Exposure to deal with real-world problems and testing algorithms using actual data. Example: avalanche localization using infrasound. Where actual data is not available for various reasons, students are taught how to simulate realistic effects in data generation. Example: target echoes from submarines in multipath environment.

3. Arun Kumar: Emphasis on applied research work by giving real-world projects and problems to students to work on, which are obtained by engaging with various user organizations. We are also developing sophisticated simulators of real-world scenarios so that extensive testing in controlled conditions can be done, eg. underwater radiating acoustic sources, channel propagation, scaled models for infrasound detection and localization etc.

4. S. Chandra: The focus of our Centre is on "Applied Research" in identified focused areas. Keeping that as guiding philosophy, the work carried out by M. Tech. and Ph.D. students is oriented towards the above stated philosophy.

5. S. K. Koul: I have introduced more practical aspects in the course curriculum. In addition, the tutorial sheets that highlight real life design problems are given to students for solving.

3.9 Sponsored projects – (i) individually, (ii) with another faculty of the group/section of the department, (iii) with another faculty of the department but from another group/section of the department, (iv) with another faculty of another dept. /centre.

The number and value of sponsored projects including CARS and technology development projects that fall in the above four categories since year 2003 are as follows:

i) 17 nos., Rupees 904.52 lakhs.
ii) 41 nos., Rupees 2017.62 lakhs.
iii) 7 nos., Rupees 1007.66 lakhs.
iv) 20 nos., Rupees 1495.48 lakhs.

The complete list of research and consultancy projects done since 2000 is given in Annexure – 7.

3.10 Industry consultancies.

38 projects with a value of Rs. 206.80 Lakhs have been done since year 2003. These projects mostly fall in the second category (with another faculty of the group in the department).

3.11 New areas of research which are different from the faculty's PhD thesis area.

1. R. Bahl: Main area has been Signal Processing, new interests developed in: Marine mammal bio-acoustics, infrasound based localization, low-power DSP hardware design, underwater communication, vector sensor design.

2. Arun Kumar: New areas of R&D: Underwater Acoustics: Passive detection and classification of radiating targets, underwater communication, acoustic vector sensor design and signal processing; Speech Processing: Auditory signal processing and modeling, objective evaluation of perceived speech quality, voice personality transformation, speech synthesis in Hindi, spoken term detection; Air Acoustics: Infrasonics based snow avalanche detection and localization, acoustic methods for determination of snow water equivalent.

3. Monika Agarwal: Underwater acoustic communications, communication systems, estimation and detection.

4. Ananjan Basu: Microwave imaging, Automated wideband signal detection, Magnetic effects in microwave circuits, RFIC.

5. S. K. Koul: RF MEMS, Micromachined Circuits, Active Antennas, RFICs.

6. Mahesh Abegaonkar: Printed antennas: Wideband, multiband, reconfigurable and tunable, UWB; Active Antennas: Reconfigurable; Periodic Structures: Electromagnetic Band Gap (EBG), High Impedance Surfaces (HIS) and Artificial Magnetic Conductors (AMC); RFID: Long-range tags for Electronic Toll Collection, Reader antennas at UHF.

7. B. S. Panwar: Wide band energy harvesting using MEMS Structures, System – on – Chip (SoC) for health care and biomolecular analysis, Identification and characterization GSM and LCD noise in mobile phones, Signal processing approach for detection, estimation and diagnostics of biological signal, Integration of MEMS devices with CMOS process for real time signal analysis.

8. S. Chandra: Microfluidic devices for bio-sensors, especially for detection of trace amount of pesticides and toxins in milk. (in collaboration with BITS-Pilani, K K Birla Campus, Goa, through a Sponsored Multi-Institutional Project). This area is significantly different from the research topics of my Ph.D. students.

9. Suneet Tuli: (New Areas of R&D) Non-destructive characterisation techniques and systems mainly Thermal-Optical and Acoustic based, have been initiated. Of late the focus is on Infrared Thermography Systems for sub-surface defect

detection. Expertise encompasses modeling, simulation, hardware, signal and image processing for complete system development.

10. Karun Rawat: RF Modulators, RF MEMS.

3.12 Methodology for (i) identifying obsolescence in research areas, and (ii) identification of new areas of future research.

Faculty have given the following methodologies:

1. The broad area of signal processing continues to be a rich research area. With advent of more powerful processors, we keep shifting our emphasis on meeting difficult real-world challenges with focus on need-based and application oriented research. Example: underwater communication between mobile platforms in high multipath environment.

2. Digital signal processing offers immense scope for applied research to develop solutions for real-world problems. Such problems are identified through extensive reading of technical and scientific journals and interacting with users of DSP technology in the field to assess challenging technical requirements.

3. (i) Interaction with counterparts from other countries and participations in International conferences and symposia. (ii) Close interaction with industry, DRDO, Space agencies in India and IEEE technical committee meetings globally

4. Close interaction with research institutions in India and abroad, and regularly organizing and participating in IEEE events.

5. IEEE Spectrum for recent research directions, IEEE Transaction issues in the area, Attending international conferences, Visiting multinational companies in USA and Canada finding the current interest of the companies, Interaction and collaboration with the top 10 academic institutions (Stanford, Harvard both the universities. in USA, TuDelft in Netherlands, Macmaster in Canada).

6. Through intense interaction and discussions with research partners; sponsoring agencies, participation in workshops, conferences and other technical meetings.

7. When the underlying philosophy is on applied R&D and funds are accordingly being generated, obsolescence is eliminated and new challenges are taken up automatically.

8. Publication trends in major publications and patents; interaction with researchers and industry at various international conferences.

9. (i) identifying obsolescence in research areas: Comparing our ongoing research work with the current state of art broadcasted in public domain such as news forums, published journals, conferences, patents etc.
(ii) identification of new areas of future research:
(a) Literature review especially magazine/featured articles about current state of art.

(b) Attending conferences, industry exhibitions etc. and interacting with Industry people and reading technical news/forums such as business wire and vertical news etc.
(c) Visiting labs in developed countries such as USA and Canada to visualize their focus areas.
(d) Participating in students challenge competitions.

3.13 Number of large interdisciplinary projects (within department's areas, and across the institute).

Multi-institutional:
3 projects have been completed or are in progress with total funding of Rs. 3.06 Crores in collaboration with Cochin University of Science & Technology, BITS Goa, and GTB Hospital, Delhi.

Across the institute:

7 projects have been completed or are in progress with total funding of Rs. 11.96 Crores. The collaborators are from Dept. of Electrical Engineering, Computer Science & Engineering, Physics, Centre for Polymer Science & Engineering, Textile Technology, and Mechanical Engineering.

Within department's areas:

4 projects have been completed or are in progress with total funding of Rs. 8.79 Crores, between Microwaves and Microelectronics areas and Microwaves and Signal Processing areas.

4. Innovation, Design and Development

4.1. No. of students who have been funded for innovating (TePP, PRISM, etc.)

One Dual degree, Student Undergraduate Research Award – Institute R&D Unit, 2007).

4.2. Technology & know-how developed:

S.No.	Year	Faculty	Item
			1. RF and Microwaves
1.	2013	S. K. Koul	Some Novel RF MEMS Switches and Phase Shifters at Ku-band Frequencies using Alumina Substrate to Astra Microwave Products Limited [S.K.Koul-2013] [Under National Program on Smart materials (NPMASS), we developed several key RF MEMS components of a T/R Module at Ku and Ka-bands. The components developed include SPST, SPDT, SP4T, Distributed MEMS Phase Shifters and Tuneable Filters on Quartz wafer and SPST, SPDT, Switched Line MEMS Phase Shifters on Silicon wafers. The devices were actually fabricated and tested for their performance. Complete technology of RF MEMS on Quartz, Silicon and Alumina has been demonstrated]
2.	2013	S. K. Koul	RF MEMS SPST, SPDT, Switched Line MEMS Phase Shifters at Ku-band Frequencies using Silicon Substrate to Astra Microwave Products Limited.
3.	2013	S. K. Koul	RF MEMS SPST, SPDT, SP4T, Distributed MEMS Phase Shifters and Tuneable Filters at K and Ku-band Frequencies using Quartz Substrate to Astra Microwave Products Limited.
4.	2013	S. K. Koul	RF MEMS SPST, and SPDT Switches (both Series and Shunt type) to Solid State Physics Laboratory, Delhi [S.K.Koul-2013]. [As part of CARS project, starting from basic theory, complete design and development of RF MEMS SPST and SPDT switches was carried out at CARE, IIT Delhi. The designs and the layout on the wafer were submitted to SSPL for fabrication at SITAR]
	2013	S. K. Koul	S-band Microstrip and Antenna Trainer Kit and 14

			Experiments developed on N 9923-A handheld Network Analyzer to Agilent Technologies Private Limited.
5.	2013	S. K. Koul	S-band Antenna and Microstrip Trainer Kit and 13 Experiments developed on Anritsu Handheld Network Analyze to Meera Agencies, Gurgaon. [Specialized Microstrip and Antenna trainer Kits along with instructional manual of 14 experiments on Agilent Field fox Network Analyzer and 13 experiments on Anritsu handheld network analyzer at S-band GHz were developed and these have been licensed to M/S Agilent and M/S Anritsu for marketing. *These trainer kits are now being used in several colleges and universities in India to impart practical training to students in the area of RF and Microwave Engineering.*]
6.	2012	S. K. Koul	J-band Microstrip and Antenna Trainer Kit to Microwave Technologies Incorporated, Ghaziabad [S.K.Koul-2012] [Technology of Microwave and Antenna educational trainer Kits at 2.45 GHz, 5.6 GHz, 7 GHz and 10 GHz were developed and these have been licensed to private companies for production. *These trainer kits are now being used in several colleges and universities in India to impart practical training to students in the area of RF and Microwave Engineering*]
7.	2009	S. K. Koul	Balanced mixer- in the frequency bands 18-26.5 GHz, 26.5 GHz-40 GHz, 18-40 GHz and Programmable Attenuator in the frequency band 18-40 GHz to DLRL, Hyderabad. [As part of a technology development project, balanced mixer utilizing novel baluns were developed in the frequency bands 18-26.5 GHz, 26.5 GHz-40 GHz, 18-40 GHz for EW application. In additional technology of programmable attenuators was also developed for operation in 18-40 GHz frequency band. Several devices were actually fabricated and tested to verify the design methodology used. As these items fall under the category of Strategic Electronics, it was difficult for DLRL to procure these items. Complete know how was developed for fabricating these devices in large numbers.]
8.	2008	S. K. Koul & A. Basu	Band pass filters, 3-dB coupler and balanced Mixer at 140 GHz to DEAL Dehradun. [Technology Development of millimeter wave components at 140 GHz was taken up first time in the country at CARE, IIT Delhi. Utilizing a special

			transmission media- grooved suspended stripline, design and development of specific components 3-dB coupler, band pass filter and balanced mixer at 140 GHz was carried out. These components were fabricated at DEAL Dehradun using the masks developed at IIT and characterized. The technology was completely developed in house making the country self-reliant in this area].
9.	2008	S. K. Koul	S-band Antenna Trainer Kit to Vidyut Yantra Modi Nagar, Ghaziabad.
10.	2006	S. K. Koul & A. Basu	X-band Antenna Trainer Kit to SICO Ghaziabad.
11.	2006	S. K. Koul & A. Basu	C-band Microstrip Trainer Kit to SICO Ghaziabad
12.	2004	S. K. Koul & A. Basu	VCO, DRO and Low Noise Amplifiers at Ka-band to DEAL Dehradun. [Design and development of voltage controlled oscillators (VCO), low noise amplifiers (LNA) and Dielectric resonator oscillators (DRO) was carried out at 35 GHz for target specifications given by DEAL. As these items fall under the category of Strategic Electronics, it was difficult for DEAL to procure these items. Complete know how was developed for fabricating these devices in large numbers. Detailed documents giving details of know how developed for production of these components was prepared. Microstrip technology using Alumina substrate was used in developing this technology.]
13.	1994	S. K. Koul and B. Bhat	Toroidal non-reciprocal phase shifter to Central Electronics Limited, Ghaziabad for Defence production.
14.	1990	B. Bhat & S. K. Koul	Balanced Mixer at Ka-band to Defense Electronics Applications Laboratory, Dehradun. [Balanced mixers at Ka-band were developed using a novel technology consisting of combination of Fin line, suspended stripline and coplanar lines. After complete characterization and checking of repeatability of the performance, know how document was prepared for subsequent production]
15.	1989	B. Bhat, S. K. Koul, R. Mongia	X-band Dual Mode Phase Shifters to Central Electronics Limited, Ghaziabad for Defence production.
16.	1989	B. Bhat, S. K. Koul, R. Mongia	C-band Dual Mode Phase Shifters to Central Electronics Limited, Ghaziabad for Defence production.
17.	1985	B. Bhat,	Twin-toroid ferrite phase shifter with Integrated Driver

		S. K. Koul, D. T. Shahani	to DTSR, DRDO. [Staring from basic theory, complete technology of four types of phase shifters-namely, Dual mode at X- and C-bands, twin toroid and toroidal phase shifters was developed in house for the first time in the country. Production versions of these phase shifters were fabricated and large numbers fabricated and tested over a wide range of frequencies, temperatures etc. Driver circuit along with testing software was also developed. Complete know how was documented for production of these phase control modules (phase shifter with integrated driver and antenna elements)]
18.	1984	B. Bhat, S. K. Koul, R. Mongai	2-8 GHz Directional couplers to ITI Bangalore [B.Bhat, S.K.Koul and R.Mongai-1984] [Directional couplers of different coupling values in the band 2-8 GHz using stripline (edge-coupled and broadside coupled technology was developed and several devices fabricated and completed characterized. Know document was prepared along with mask details for production]
2. Signal Processing			
19.	2013	Arun Kumar	Objective Evaluation of Perceived Speech Quality using Non-Intrusive Method: The method and software for objective evaluation of perceptual speech quality when the original clean speech is not available have been developed. The algorithm provides performance advantages over the ITU-T P.563 Recommendation (standardized in 2003) and other later proposed algorithms.
20.	2012	Arun Kumar, I. N. Kar, R. Bahl	Method and Software for Development, implementation, and performance comparison of estimation methods for bearings-only tracking. Ministry of Defence, in Sept 2012.
21.	2012	Arun Kumar, R. Bahl, M. Agarwal.	Method and Software for GMSK Modulation, Impulse Noise Suppression and LDPC Coding for VLF Communication, to DEAL, DRDO, Dehradun. The data rates have been increased from the existing 200 bps to 400, 600 and 800 bps.
22.	2012	Arun Kumar, R. Bahl, M. Agarwal.	Compact Low-power Digital Signal Processing hardware, handed over to Directorate of Weapons Equipment, Indian Navy.

23.	2011	R. Bahl, Arun Kumar, M. Agarwal.	UDA – Software for underwater domain awareness – Prediction of detection ranges for own passive sonar for active emissions of enemy sonars using ray models, to WESEE, MoD, New Delhi.
24.	2011	Arun Kumar, R. Bahl, M. Agarwal.	RAS – Real-time Audio Simulator for Generation of Acoustic Signatures of Ships and Submarines across a Time-Varying Bounded Underwater Channel, to WESEE, Ministry of Defence, New Delhi.
25.	2010	Arun Kumar, R. Bahl, M. Agarwal.	Real-time DSP software for detection of underwater targets using passive sonar, to Directorate of Weapons Equipment, Indian Navy.
26.	2009	Arun Kumar, R. Bahl	Flex-UT: Software for flexible pattern recognition of ultrasonic signals. The software tests for defects in welded joints and structures. Feb 2009. Transferred to Mitsubishi Heavy Industries Ltd., Japan.
27.	2008	Arun Kumar, R. Bahl	Signal Enhancement and Analysis Software: Software for the enhancement of ship's radiated signal and its analysis for finding quadratic phase coupling between tonal frequencies and estimating its coupling strength. The software was installed at the Underwater Ranges, Goa, and was also submitted to NSTL Vishakhapatnam.
28.	2006	Arun Kumar, R. Bahl, M. Agarwal.	PASCAL (Passive Sonar Classification): Method and software developed for underwater target classification, based on propulsion type, using passive sonar. The technology transfer was done to the Ministry of Defence, in May 2006. A feasibility study for integration of the Classifier on the HDW submarine was also done.
29.	2006	Arun Kumar, R. Bahl, M. Agarwal.	ARGUS: Method and software for platform classification using multiple sensor data and data fusion. Technology transfer to the Ministry of Defence, was done in September 2006.
30.	2006	Arun Kumar, R. K. Patney	Objective Evaluation of Perceived Wideband Speech Quality using Non-Intrusive Method: Method and software for the objective evaluation of perceptual wideband speech quality that provides performance advantages over the ITU-T P.862.2 Recommendation (standardized in 2005). The method uses the Multi-Resolution Auditory Model (MRAM) developed by the group.
31.	2006	Arun Kumar, R. Bahl	Statistical Scenario Analysis (SSA) Software Package: An algorithm has been designed in detail for statistical modeling of the motion of entities (source and target ships, torpedoes etc.) in the ocean, and evaluating the

			probability of hit between entities in war-gaming scenarios. The SSA software generates probabilistic models of motion dynamics of various entities, and computes the probability of hit between various entities under different scenario hypothesis (maneuvers etc). The SSA forms the core engine of GUI based software developed by Macmet Technologies Ltd. for simulating war-game requirements of the Navy. The corresponding software was licensed to Macmet Technologies Ltd., Bangalore, in 2006.
32.	2005	Arun Kumar	Voice Conversion using Voice Fonts: Method and software for representing the speaker individuality features of a person's voice using the paradigm of "voice fonts" defined by us, and converting speech spoken by a "source" speaker to appear as if it has been spoken by another "target" speaker, using the method of "voice fonts".
33.	2003 -04	R. Bahl	Developed algorithms for ***Classification and Tracking of Sperm Whales from their Click Sounds***. (2003-2004): Joint work at University of Tokyo as Guest Professor. Conducted field experiments off Ogasawara Islands in Pacific Ocean for passive tracking multiple diving whales.
34.	2002 -03	R. Bahl	Techniques for ***Automatic Recognition of Humpback Whales from their Songs***. Joint work at University of Tokyo as Guest Professor.
35.	2002	R. Bahl and Arun Kumar	Proposed design of a ***Low-Power DSP System for Underwater Acoustic Networks***.
36.	2002	R. Bahl, Arun Kumar	Design and Software Simulator for Underwater Local Area Network Protocols for (a) Ship-to-ship communications, and (b) Underwater Buoy Network Communication. The technology was transferred to the Directorate of Weapons Equipment - Naval Headquarters, in Nov. 2002.
37.	2000	Arun Kumar	Low Complexity 7 KHz Band Speech and Audio Coder at 16, 24 and 32 Kbps. The algorithm design and C-code implementation of encoder and decoder were developed. The subjective quality of decoded speech and audio was evaluated and found to improve up on other state-of-the-art coders available. The technology was transferred to SASKEN Communication Technologies Ltd., Bangalore in 2000.
38.	1999	R. Bahl	Designed a unique ***Autonomous Humpback Whale Song Tracking Sonar***. Joint work at University of Tokyo as

			Visiting Researcher.
39.	1996	R. Bahl	Developed techniques for ***Object Visualisation using Imaging Sonars***. (1996) Extracted object surface features and shape reconstruction from sparse acoustic images.
40.	1995	R. Bahl	Developed nation's first ***CAD Software Package for High-Resolution Imaging Sonars*** that simulates acoustic images of 3-D scenarios, and a ***SAR Simulation Tool.***
41.	1988	R. Bahl	Designed a ***Hybrid Low-noise Wide-band Preamplifier*** accepted by ***Loughborough University, UK.*** (1988). The amplifier was used for implementing compact imaging Sonars.
42.	1981	R. Bahl	Designed a geographically accurate display for ***SEAVISION Sonar, UK.*** The display is designed for a sector-scanning Sonar used for imaging of sea bottom.
43.	1976	R. Bahl	Designed and tested a ***Speech Scrambler:*** know-how handed over to NRDC. The time-domain scrambler using pseudo-random codes provided tactical-level speech secrecy over a telephone network.
3. Microelectronics and Non-destructive Characterization			
44.	2013	Suneet Tuli	Multi-Technique Thermal Imaging System for sub-surface defect detection (2013), Transfer under negotiation with GE.
45.	2013	Sudhir Chandra	A Micro Well Chip Device for High Throughput Screening of Pesticide Residues in Milk. Devices and the ultrasensitive analysis of pesticide residues meeting stringent EU standard (6-400 ng/L) in milk matrix has been developed. A complete set up consisting of the basic device, liquid handling system, optical measurements and a computerized control unit is proposed to be developed through an equipment manufacturer. The unit will be a useful tool for certification of milk (for pesticides) at accredited milk testing Labs. An Indian Patent Application (No: 933/MUM/2012) and a PCT application have been filed while an **Australian Innovation Patent (# 2013100381) has been granted, on 19th April 2013** on this work.
46.	2013	Sudhir Chandra	A new microfluidic device having inter-digited electrodes (IDE) array for measuring impedance of liquids in very minute volumes (micro liter). This has been envisaged as a portable device for screening of

			milk at remotely located Collection Centres. Two different versions of this device have been developed. In one of these, the silicon-to-glass anodic bonding has been used while the other has a polymer for fluidic confinement. An Indian Patent Application has been filed (Application No. 1203/MUM/2013, filed on March 28, 2013) and a PCT filing is in progress
46.	2009	Suneet Tuli	One Frequency modulated thermal wave imaging system (heating system along with hardware and software), transferred on purchase to Advanced Systems Laboratory, Hyderabad.
47.	1998	Suneet Tuli and A. B. Bhattacharya	Software for the design and simulation and layout of a Reflective Dot Array SAW Filter, transferred to Space Applications Centre, Ahmedabad
48.	1995	A. B. Bhattacharya and Suneet Tuli	Two design, simulation and layout software packages, named MECSIM and MASKSAW, transferred on purchase to ITI Bangalore
49.	1995	A. B. Bhattacharya and Suneet Tuli	Microelectronics Educational Kits (set of 10 experiments), Technology transferred to M/s. ROMTEK, New Delhi

4.3. Technology transferred:

Total number of technology transfers: 64:

i) Signal Processing (Underwater Electronics): 22,
ii) Microwaves: 30,
iii) Microelectronics including NDT: 12.

Signal Processing:

1. Method and Software for **target motion analysis of non-maneuvering radiating underwater targets using bearings-only tracking**, to Weapons and System Engineering Establishment (WESEE), Ministry of Defence, Sept 2012.
2. Method and Software for GMSK Modulation, Impulse Noise Suppression and LDPC Coding for **VLF Communication**, to DEAL, DRDO, Dehradun, for up-gradation of Indian Navy's VLF Communication System, Jan 2012.
3. Compact **Low-power Digital Signal Processing hardware**, handed over to Directorate of Weapons Equipment, Indian Navy, May 2012.
4. UDA – **Software for underwater domain awareness** – Prediction of detection ranges for own passive sonar for active emissions of enemy sonars using ray models, to WESEE, MoD, New Delhi, 2011.
5. RAS – **Real-time Audi Simulator** for Generation of Acoustic Signatures of Ships and Submarines across a Time-Varying Bounded Underwater Channel, to WESEE, Ministry of Defence, New Delhi, 2010.

6. Real-time DSP software for **detection of underwater targets using passive sonar**, to Directorate of Weapons Equipment, Indian Navy, May 2010.
7. Flex-UT: Software for flexible pattern recognition of ultrasonic signals: Transferred to Mitsubishi Heavy Industries Ltd., Japan, 2009.
8. HosaStation: **Software for higher order spectral analysis**: Transferred to NSTL, DRDO, Visakhapatnam, 2008.
9. **Signal Enhancement and Analysis Software**: Software for the enhancement of ship's radiated signal and its analysis for finding quadratic phase coupling between tonal frequencies and estimating its coupling strength. The software was installed at the Underwater Ranges, Goa, and was also submitted to NSTL Vishakhapatnam, 2008.
10. PASCAL Software: Method and Software developed for **Underwater Classification using Passive Sonar**: Transferred to MoD, 2006.
11. ARGUS Software: Method and Software for **platform classification using multiple sensor data**: Transferred to MoD, 2006.
12. Statistical Signal Analysis Software: Method and Software for **statistical analysis for the detection of targets by Sonar**: Licensed to M/s MACMET through FITT, 2006.
13. Validation of Software implementation of **underwater radiated noise synthesis at source and across a channel**: offered to NODPAC, Kochi unit of Navy, 2005.
14. Hardware design and fabrication of Multi-DSP based low power signal processor module: Transferred to Navy, Sept 2003.
15. Simulations Software for **7 KHz Audio Encoding & Decoding** to SASKEN, Bangalore, 2000.
16. **3-D Imaging Sonar** hardware and design documents: Handed over to NSTL, Visakhapatnam, MoD, 1999.
17. Improving the S/N Ratio of Sonar System to ENVIROTECH, 1999.
18. Hardware and Software for **Test Signal Generator for Sonars**: Handed over to NSTL, Visakhapatnam, MoD, 1997.
19. System design of a compact ***State-of-art MSK Modem*** for VLF Communication. (1985) The modem was designed for DEAL Dehradun, DRDO, for one-way digital RF communication with submerged submarines and Naval platforms.
20. Designed ***country's first Compact Multiplexed Multichannel Sonar System*** with proven superior performance in actual sea-trials: knowhow transferred to Industry. (1984) The Indian Navy accepted the enhanced performance of the Sonar against the existing foreign Sonar on anti-submarine frigates.
21. Designed and field-tested a Digital Control System for ***Landing Aid on Aircraft Carrier: NRDC Invention Award***. (1982) Provided three complete units with spares and training of Naval personnel for maintenance and operation. Deployed on INS Vikrant until its retirement from service.
22. Digital Axle Counter for Fail-Safe Railway Signal Processing used in Railways to Indian Railways: ***NRDC Award (1978)***

Microwaves:

23. Some Novel RF MEMS Switches and Phase Shifters at Ku-band Frequencies using Alumina Substrate to Astra Microwave Products Limited [S.K.Koul-2013]**.**
    [SPST, SPDT, SP4T, Distributed MEMS Phase Shifters and Tuneable Filters on Quartz wafer and SPST, SPDT, Switched Line MEMS Phase Shifters on Silicon wafers with and without packaging given to Astra Microwave Products Limited for use in T/R modules. About 350 packaged 5-bit RF MEMS phase shifters and 50 each of other components have actually been given to Astra Microwave Products Limited under a joint Industry/Academia project.]

24. RF MEMS SPST, SPDT, Switched Line MEMS Phase Shifters at Ku-band Frequencies using Silicon Substrate to Astra Microwave Products Limited [S.K.Koul-2013].
25. RF MEMS SPST, SPDT, SP4T, Distributed MEMS Phase Shifters and Tuneable Filters at K and Ku-band Frequencies using Quartz Substrate to Astra Microwave Products Limited [S.K.Koul-2013].
26. RF MEMS SPST, and SPDT Switches (both Series and Shunt type) to Solid State Physics Laboratory, Delhi [S.K.Koul-2013].
27. S-band Microstrip and Antenna Trainer Kit and 14 Experiments developed on N 9923-A handheld Network Analyzer to Agilent Technologies Private Limited [S.K.Koul-2013]

    [Design document and masks for fabricating SPST and SPDT switches of both series and shunt type transferred to SSPL Delhi].
28. S-band Antenna and Microstrip Trainer Kit and 13 Experiments developed on Anritsu Handheld Network Analyze to Meera Agencies, Gurgaon [S.K.Koul-2013]

    [Educational material in the form of a manual to be used by students and teachers to conduct UG/PG laboratory in the area of Microwave Integrated Circuits and Antennas along with trainer kits given to M/S Agilent and M/S Anritsu for production and marketing].
29. J-band Microstrip and Antenna Trainer Kit to Microwave Technologies Incorporated, Ghaziabad [S.K.Koul-2012]

    [Technology of Microwave and Antenna educational trainer Kits at 2.45 GHz, 5.6 GHz, 7 GHz and 10 GHz transferred to companies listed above for mass production and marketing to colleges and universities in India for the benefit of Microwave Community]
30. Balanced mixer- in the frequency bands 18-26.5 GHz, 26.5 GHz-40 GHz, 18-40 GHz and Programmable Attenuator in the frequency band 18-40 GHz to DLRL, Hyderabad [S.K.Koul-2009].
31. [Know how documents along with 2 pieces of final components- 18-26.5 GHz, 26.5-40 GHz and 18-40 GHz balanced mixers and 18-40 GHz programmable attenuator transferred to DLRL as part of Technology Demonstration Project].
32. UHF RFID Tags for Electronic Toll Collection – 2008-09 – Mitsubishi Heavy Industries, Japan – A long range UHF RFID system with a read range of 11 meters was developed and tested. This was transferred to Mitsubishi Heavy Industries, Japan.
33. Design, Development and Evaluation of 900 MHz RFID Antenna and Package for On-Board Unit of ERP/ETC System (2008), Mitsubishi Heavy Industries, Japan. Developed antennas for 900 MHz RFID tags for Electronic Toll Collection System. Maximum read-range achieved is 11 meters.
34. Design and Development of Antenna Array with 8 elements (elevation) $\times$ 16 elements (azimuthal) for airborne applications, (2008), Centre for Airborne Studies (CABS), DRDO, Govt. of India. Design and development of an end-fire array for airborne applications. Successfully completed. Design document submitted to funding agency.
35. S-band Antenna Trainer Kit to Vidyut Yantra Modi Nagar, Ghaziabad [S.K.Koul-2008]
36. Band pass filters, 3-dB coupler and balanced Mixer at 140 GHz to DEAL Dehradun [S.K.Koul and Ananjan Basu-2008]

    [Design document and masks for mass production of specific components 3-dB coupler, band pass filter and balanced mixer at 140 GHz was transferred to DEAL Dehradun].
37. Studies on Some Parts of C-band Rotary Field Phase Shifter, (2007), Solid State Physics Laboratory (SSPL), DRDO, Govt. of India. Design optimization of a C-band

rotary phase shifter including materials and dimensions. Successfully completed. Design document submitted to SSPL.

38. C-band VCO to SICO Ghaziabad [S.K.Koul and Ananjan Basu-2006]
39. C-band Microstrip Trainer Kit to SICO Ghaziabad [S.K.Koul-2005]
40. VCO, DRO and Low Noise Amplifiers at Ka-band to DEAL Dehradun [S.K.Koul and Ananjan Basu-2004]
    [Know how documents along with 5 pieces of final components- VCO, DRO and low noise amplifiers at 35 GHz transferred to DEAL as part of Technology Demonstration Project]
41. Millimeter wave Finline Software (1998), Center for Defence Electronics Application Laboratory (DEAL), DRDO, India.
42. Ka-band Millimeter wave IC Components (1998), DRDO, India.
43. X-band Twin Toroid Phase Shifter (1998), DRDO, India.
44. Millimeter Wave Balanced Mixer (1996), Center for Defence Electronics Application Laboratory (DEAL), DRDO, India.
45. X- and C-band Dual Mode Electronically Variable Ferrite Phase Shifters: ***NRDC Award*** (1996), DRDO, India.
46. Toroidal non-reciprocal phase shifter to Central Electronics Limited, Ghaziabad for Defence production [S.K.Koul and B.Bhat-1994].
47. Balanced Mixer at Ka-band to Defense Electronics Applications Laboratory, Dehradun [B.Bhat and S.K.Koul-1990].
    [Know how document along with fabricated mixers and masks transferred to DEAL Dehradun]
48. X-band Dual Mode Phase Shifters to Central Electronics Limited, Ghaziabad for Defence production [B.Bhat, S.K.Koul, R.Mongia-1989]
49. C-band Dual Mode Phase Shifters to Central Electronics Limited, Ghaziabad for Defence production [B.Bhat, S.K.Koul, R.Mongia-1989]
50. Twin-toroid ferrite phase shifter with Integrated Driver to DTSR, DRDO [B.Bhat, S.K.Koul and D.T.Shahani-1985]
    [A set of know how documents giving design details, assembly procedure, driver circuit interface, mechanical drawings, assembly procedures, software for automatic testing and bill of material along with several phase shifters of each type transferred to DRDO. Out of these, both X-and C-band dual mode phase shifters have been mass produced by Central Electronics Limited for use in Rajendra Radar. The country has become self reliant in this important technology].
51. 2-8 GHz Directional couplers to ITI Bangalore [B.Bhat, S.K.Koul and R.Mongai-1984]
    [Know document along with several directional couplers giving loose as well as tight coupling and masks transferred to ITI Bangalore].
52. Electrical Design of VLF Antenna (1991), Indian Navy.

Microelectronics:

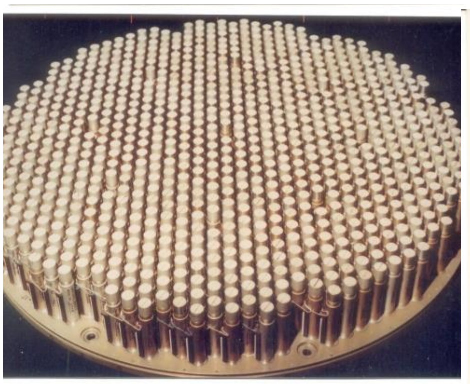
53. Multi-Technique Thermal Imaging System for sub-surface defect detection (2013), Transfer under negotiation with GE.
54. One Frequency modulated thermal wave imaging system (heating system along with hardware and software), 2009, transferred on purchase to Advanced Systems Laboratory, Hyderabad.
55. Frequency modulating heat sources for thermal NDT of composites, 2009, ASL.
56. Software for the design and simulation and layout of a Reflective Dot Array SAW Filter, transferred to Space Applications Centre, Ahmedabad (97-98).
57. Resonator Based SAW Filter Design Techniques, 1998, COM-DEV.

58. Microelectronics Educational Kits (set of 10 experiments), Technology transferred to M/s. ROMTEK, New Delhi (1996).
59. Software for the design and simulation and layout of a Reflective Dot Array SAW Filter, transferred to Space Applications Centre, Ahmedabad (1998)
60. CAD Tools for Low Loss SAW Filter Design, 1999, MOTOROLA.
61. Resonator Based SAW Filter Design Techniques, 1998, COM-DEV.
62. Pulse Compression Filter with Mil Specs. , 1985, DRDO, India.
63. Micropower CMOS Hearing Aid Design, 1997, SCL, India.
64. 5 Micron Analog Cells for Analog/Digital Gate Array, 1995, SCL, India.

Showcase of Technologies, Know-How, and Training Material developed in CARE
1. Microwaves

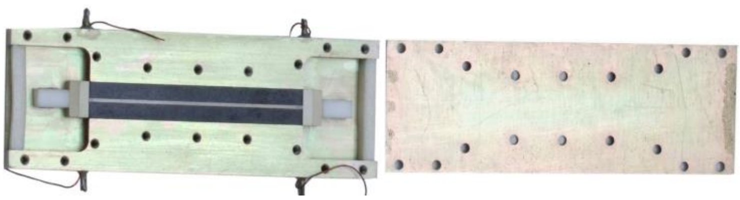
C-band ferrite Phase Shifter

X-band ferrite Phase Shifter

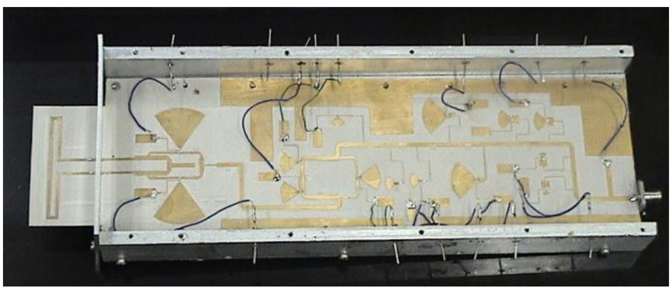


Array assembly

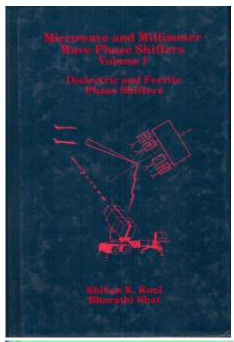
Complete Radar using Indigenous Phase Shifters

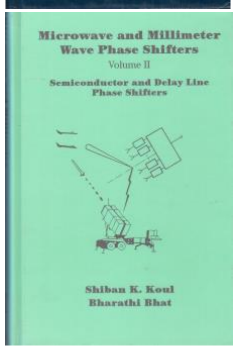


Twin Toroid Ferrite Phase Shifter



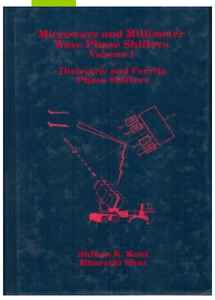
6-bit p-i-n diode phase shifter with integrated dipole antenna

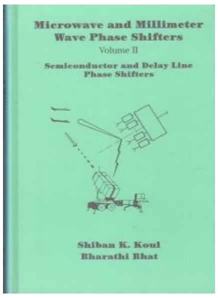


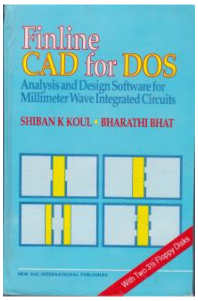


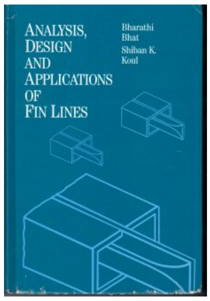
Showcase of Technologies, Know-How, and Training Material developed in CARE

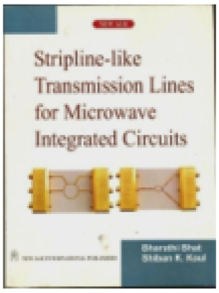
1. Microwaves

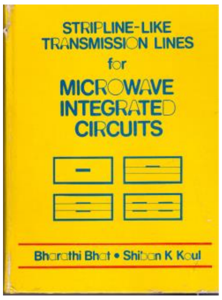


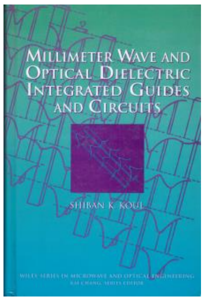


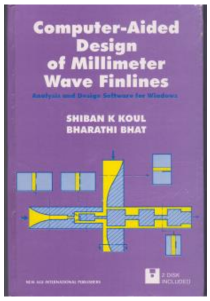


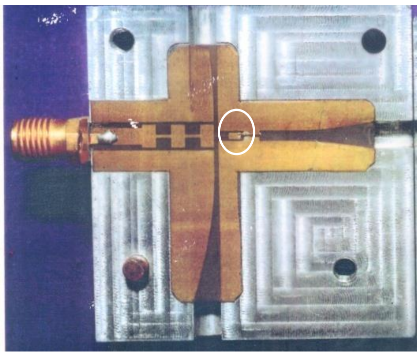


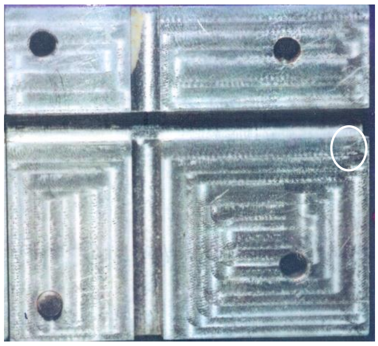






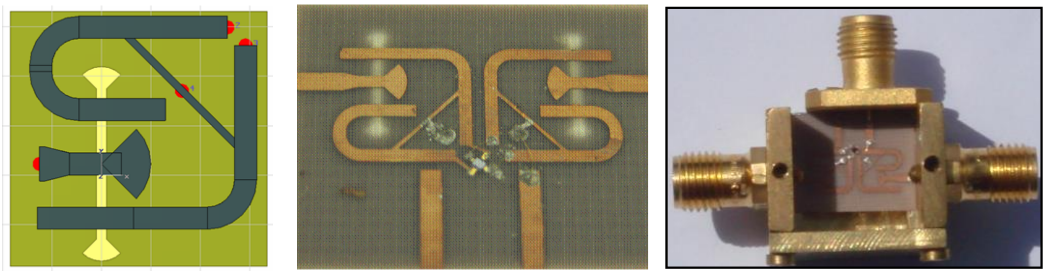






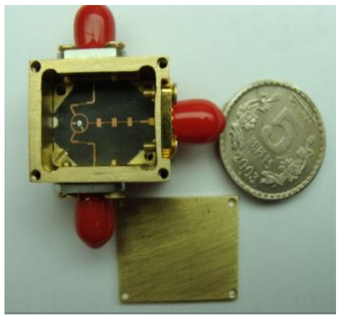
Balanced Mixer at 35 GHz

Showcase of Technologies, Know-How, and Training Material developed in CARE
1. Microwaves

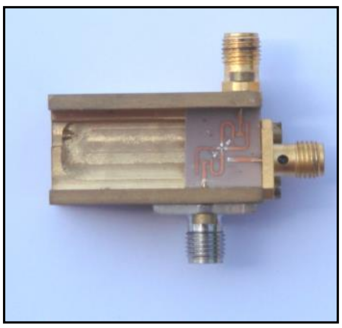


18-40 GHz Mixer using novel slot-line to microstrip balun

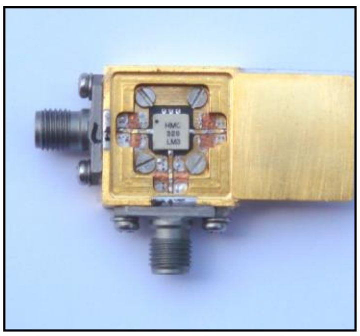
18-26 GHz Mixer



26-40 GHz Mixer



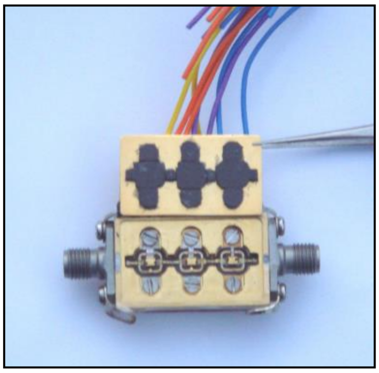
18-40 GHz Mixer



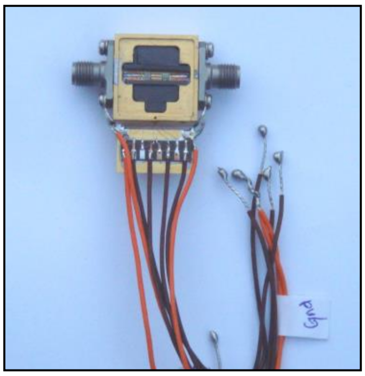
18-40 GHz Mixer

Showcase of Technologies, Know-How, and Training Material developed in CARE

1. Microwaves

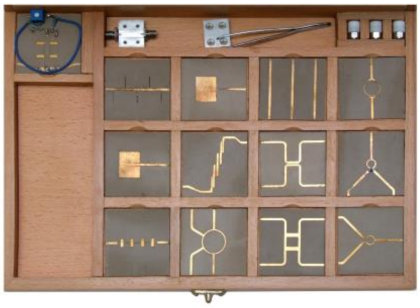


10-60 dB Switched bit attenuator
18-40 GHz



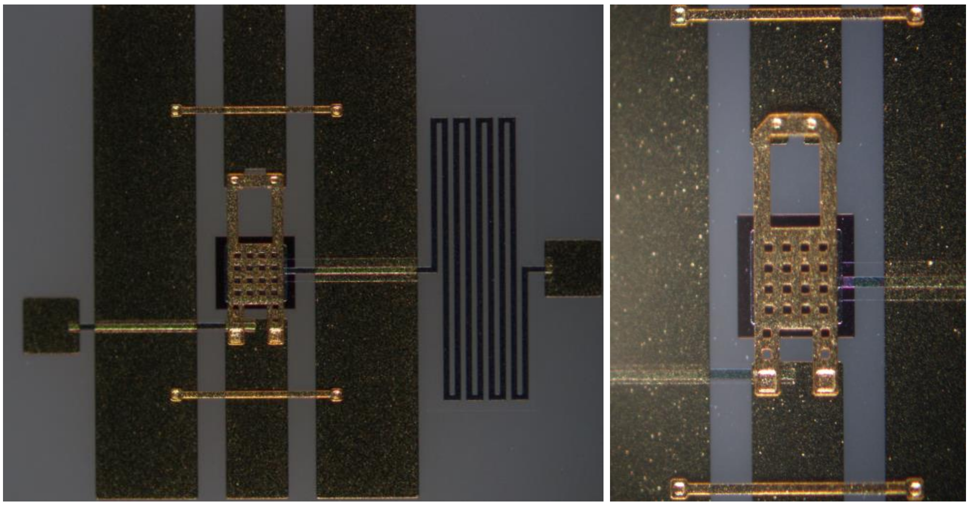
10-60 dB Cascaded coplanar Voltage
Variable attenuator 18-40 GHz

Microstrip Trainer Kit

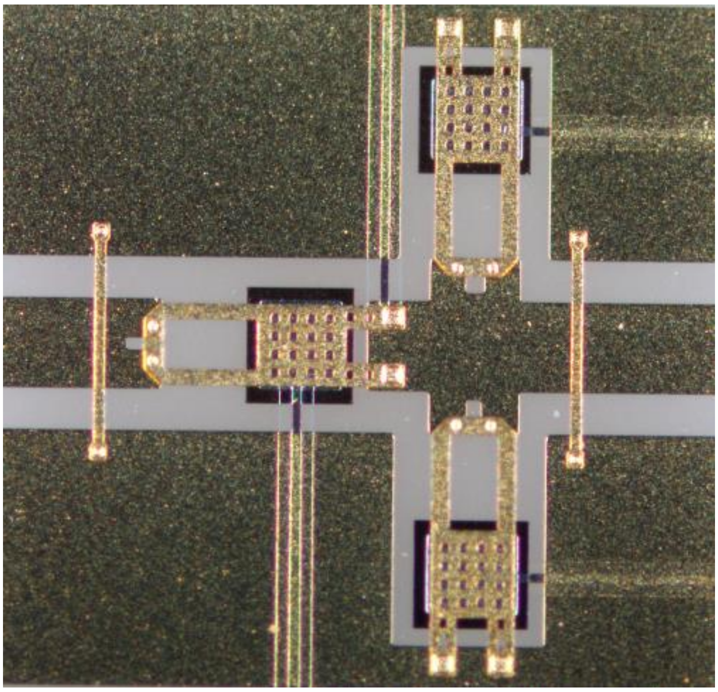


Antenna Trainer Kit

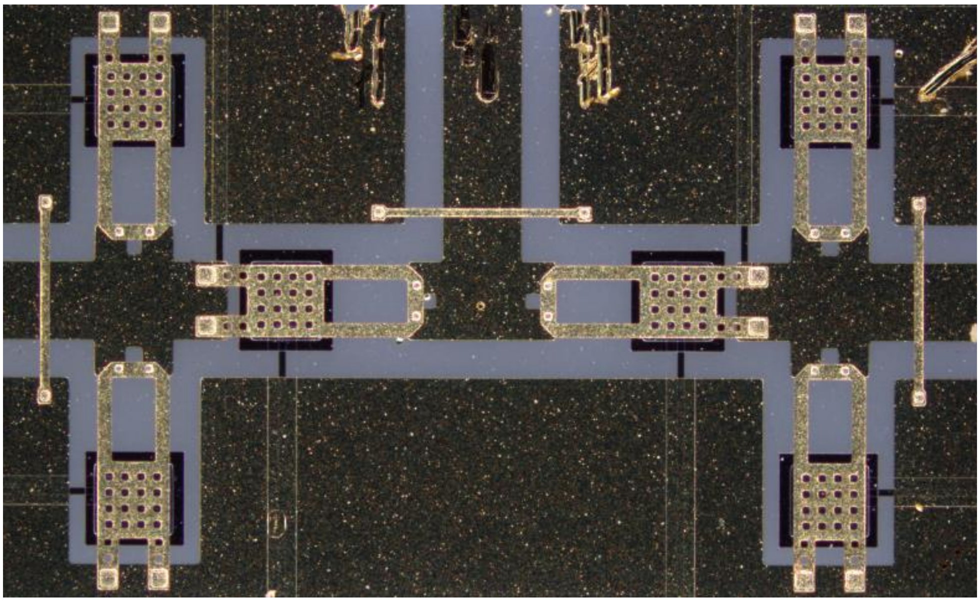
DC-Contact RF MEMS switch



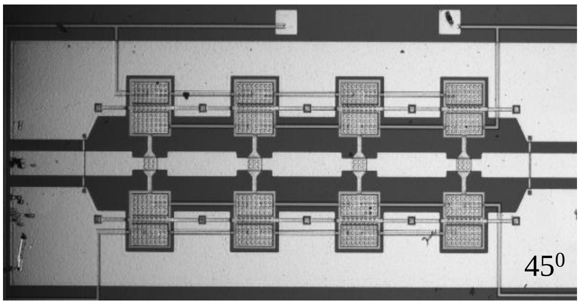
DC-Contact High Isolation RF MEMS Switch

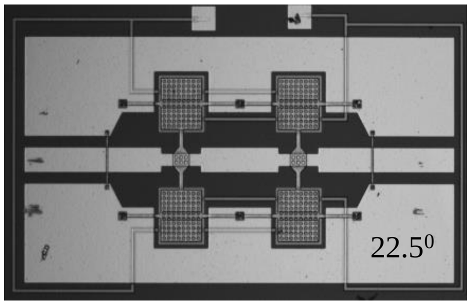


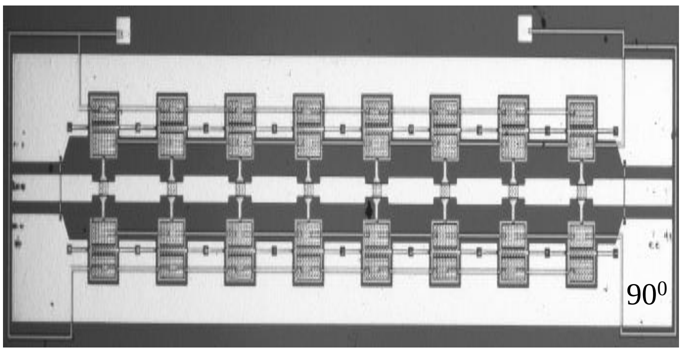
High Isolation SPDT RF MEMS Switch

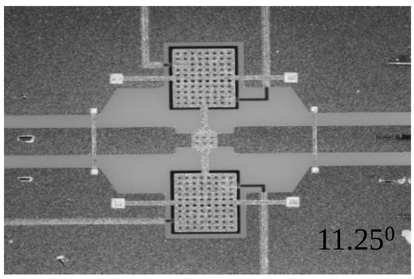


RF MEMS DMTL Phase Shifter

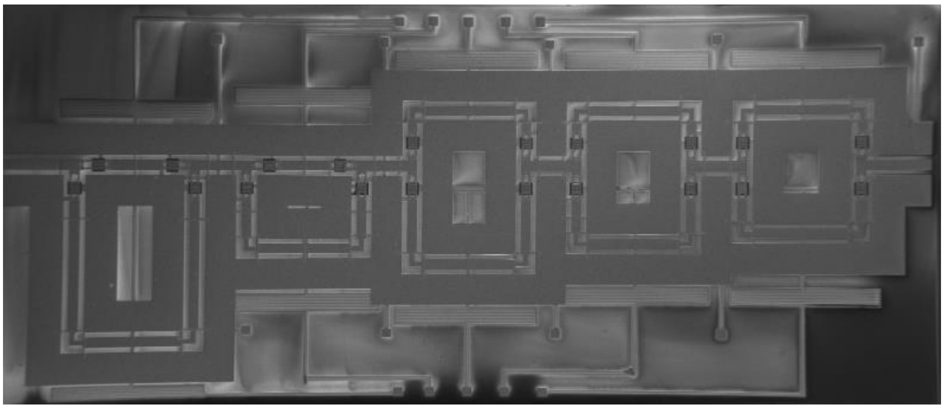




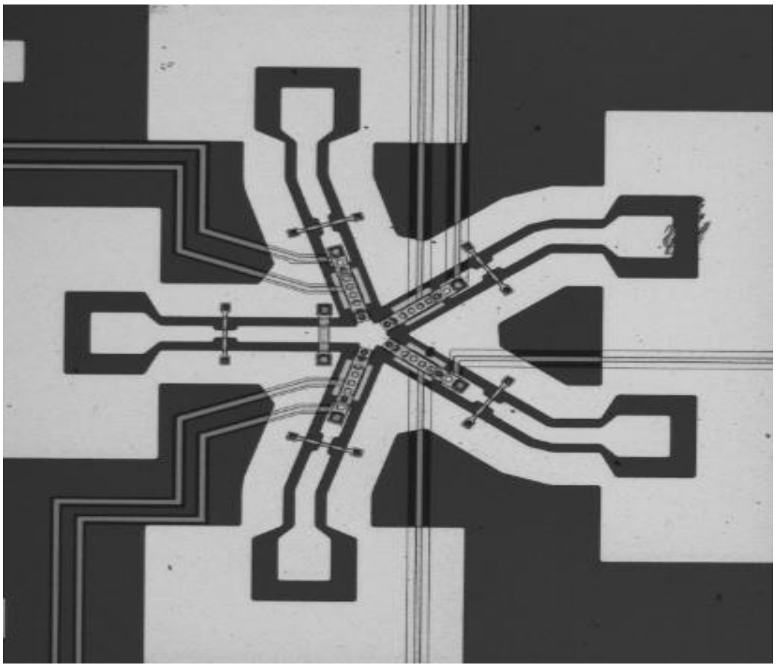




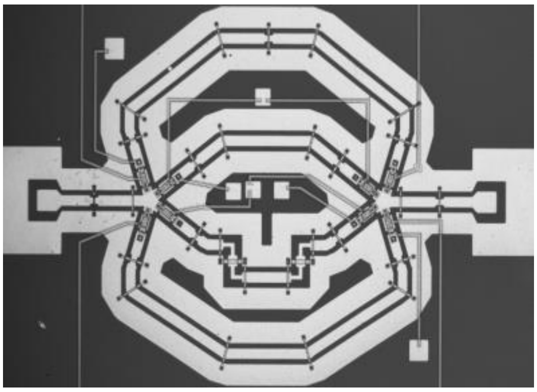
RF MEMS 5-bit Switched-line phase shifter

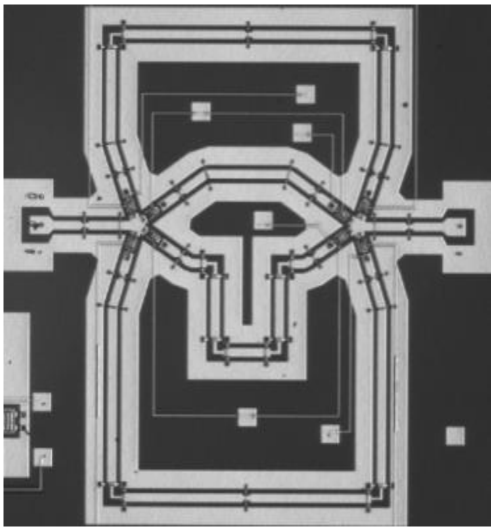


RF MEMS based SP4T switch

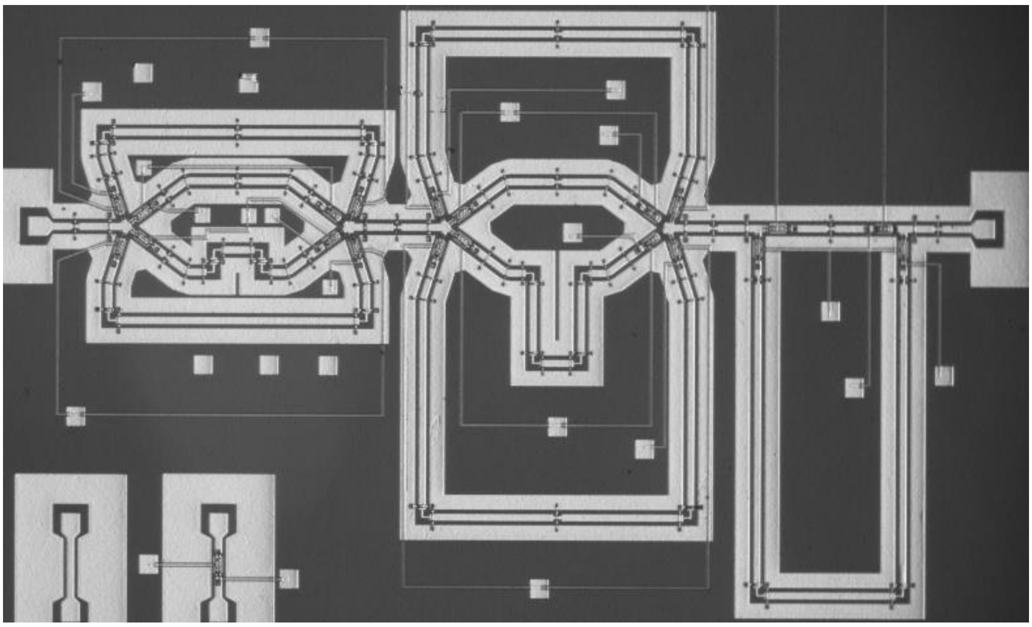


RF MEMS based 2-bit phase shifter using SP4T switch





RF MEMS based 5-bit phase shifter using SP4T and SPDT switches



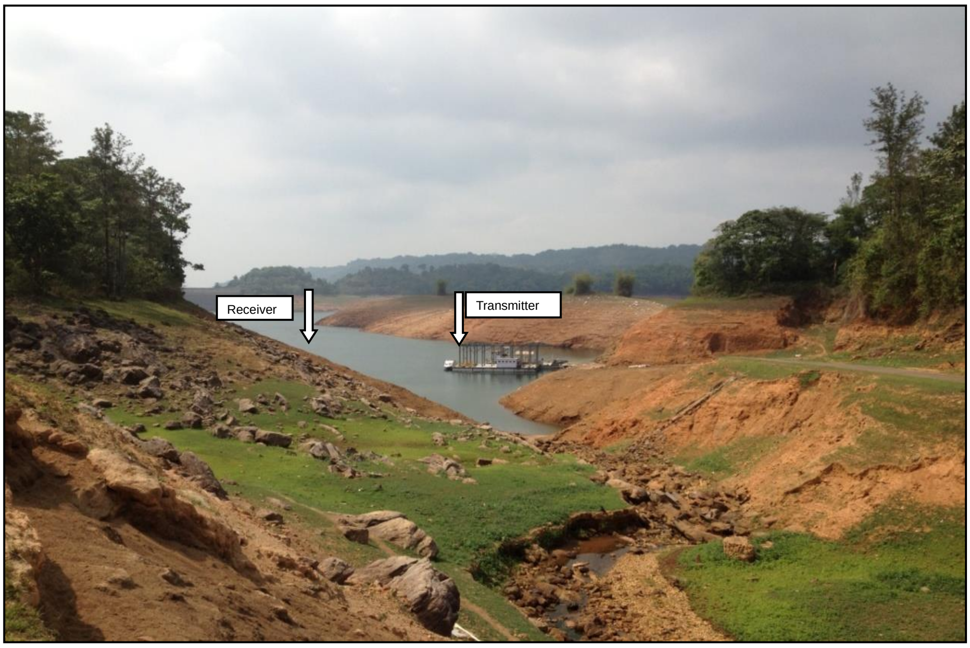
Showcase of Technologies, Know-How, and Training Material developed in CARE
2. Signal Processing

Acoustic Reflectometry System developed in CARE in use in field studies at Dhundi, Feb 2013

Acoustic Reflectometry System developed in CARE in use in field studies at Dhundi for determination of structure of snow layers and determination of snow water equivalent

Infrasonic sensor mounted on the structure forming part of a 4-sensor array placed 50 m horizontally apart in planar geometry for measurement of infrasound signature of snow avalanche for their detection and localization – in collaboration with SASE, DRDO, Feb. 2013.

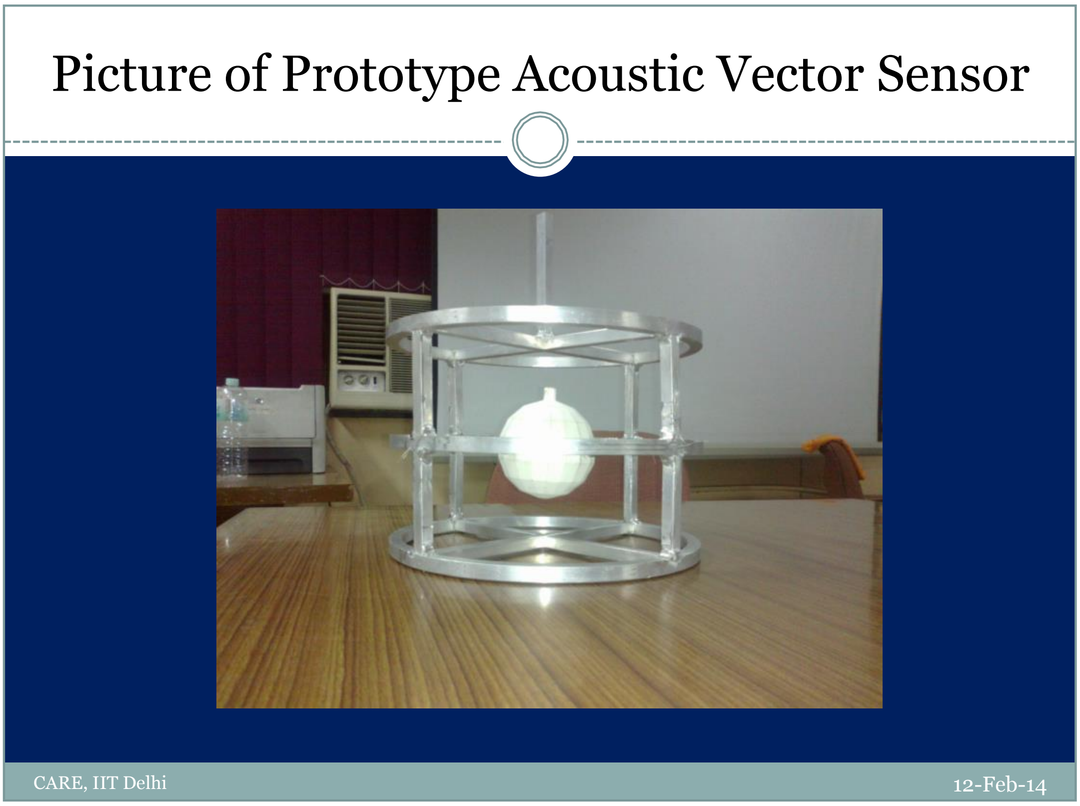
TRIALS AT U.A.R.F., Idduki May 2012



Trials of TRM and MIMO-OFDM based underwater acoustic communications at the Underwater Acoustic Research Facility, Idduki, Kerala, by CARE, IIT Delhi team, May 2012.

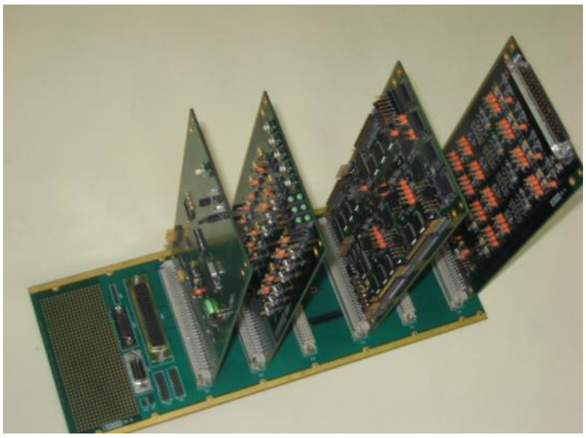
Equipment used for TRM and MIMO-OFDM based underwater communication experiments at Idduki, Kerala, May 2012.

Underwater Acoustic MIMO-OFDM experiments at Ganges River, Narora, UP in April 2013.



Prototype Underwater Acoustic Vector sensor comprising of a tri-axial accelerometer and a pressure hydrophone for localization of a radiating underwater source – designed and developed in CARE, April 2013.

Low Power Multi-DSP Acoustic Signal Processing Module



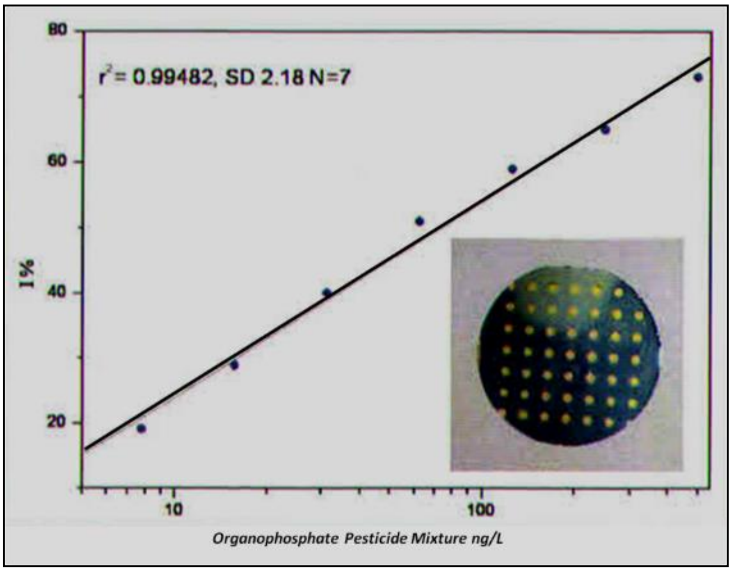
- GENERAL PURPOSE DESIGN
  - NETWORK CONTROL UNIT
  - NETWORK NODE
  - ACTIVE / PASSIVE SONAR
  - MODEM
- LOW POWER CONSUMPTION
- SCALABLE ARCHITECTURE
- FAULT TOLERANT DESIGN
- BUILT-IN SELF TEST FACILITY
- REMOTE HEALTH MONITORING
- REMOTE SYSTEM CONTROL

Low power Multi-DSP Acoustic Signal Processing Module based on 4 PCBs and back-plane, designed and developed in CARE, IIT Delhi.

Personal Navigation System without GPS using Wearable Device: Tracking the motion of a human being using MEMS based sensors including tri-axial accelerometer, gyroscope, digital compass and pressure sensor. Green track shows the actual path taken by a human being walking, and the red track shows the estimate in real-time. The wearable hardware and algorithms were developed in CARE, IIT Delhi, and is the subject of 3 patents filed simultaneously in US and India.

Showcase of Technologies, Know-How, and Training Material developed in CARE
3. Microelectronics

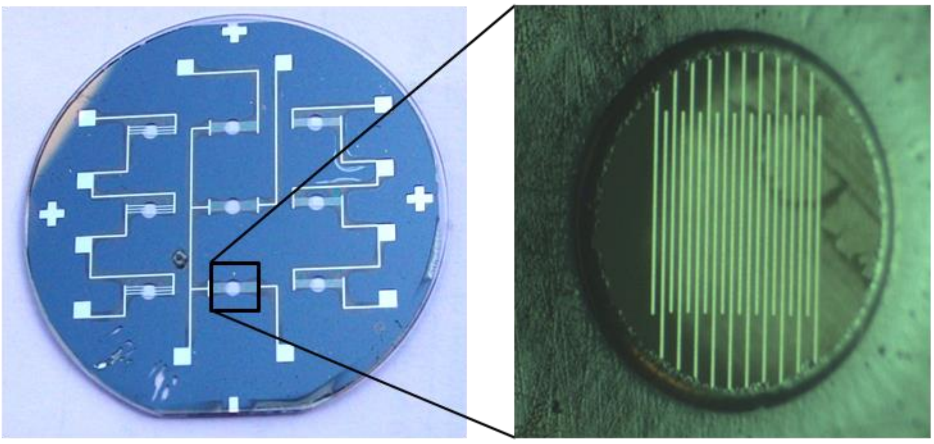
1. A Micro Well Chip Device for High Throughput Screening of Pesticide Residues in Milk. The Fig. shows the Si-wafer containing the devices and the ultrasensitive analysis of pesticide residues meeting stringent EU standard (6-400 ng/L) in milk matrix. A complete set up consisting of the basic device, liquid handling system, optical measurements and a computerized control unit is proposed to be developed through an equipment manufacturer. The unit will be a useful tool for certification of milk (for pesticides) at accredited milk testing Labs.



This work was jointly carried out at CARE, IIT Delhi (Prof. Sudhir Chandra and his students) and BITS-Pilani, K K Birla campus Goa (Prof. Sunil Bhand and his team) under a Project funded by National Agriculture Innovation Project (NAIP), ICAR (Indian Council of Agriculture Research).

An Indian Patent Application (No: 933/MUM/2012) and a PCT application have been filed while an **Australian Innovation Patent (# 2013100381) has been granted, on 19th April 2013** on this work.

2. A new microfluidic device having inter digited electrodes (IDE) array for measuring impedance of liquids in very minute volumes (micro liter). This has been envisaged as a portable device for screening of milk at remotely located Collection Centres. Two different versions of this device have been developed. In one of these, the silicon-to-glass anodic bonding has been used while the other has a polymer for fluidic confinement.

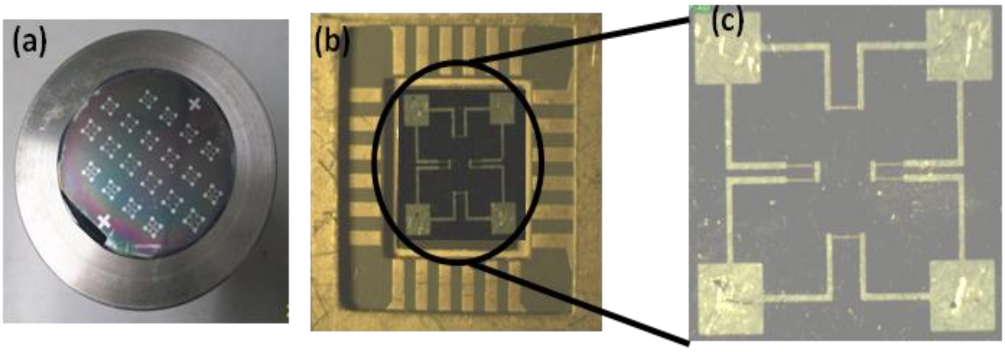


This work was jointly carried out at CARE, IIT Delhi (Prof. Sudhir Chandra and his students) and BITS-Pilani, K K Birla campus Goa (Prof. Sunil Bhand and his team) under a Project funded by National Agriculture Innovation Project (NAIP), ICAR (Indian Council of Agriculture Research).

An Indian Patent Application has been filed (Application No. 1203/MUM/2013, filed on March 28, 2013) and a PCT filing is in progress.

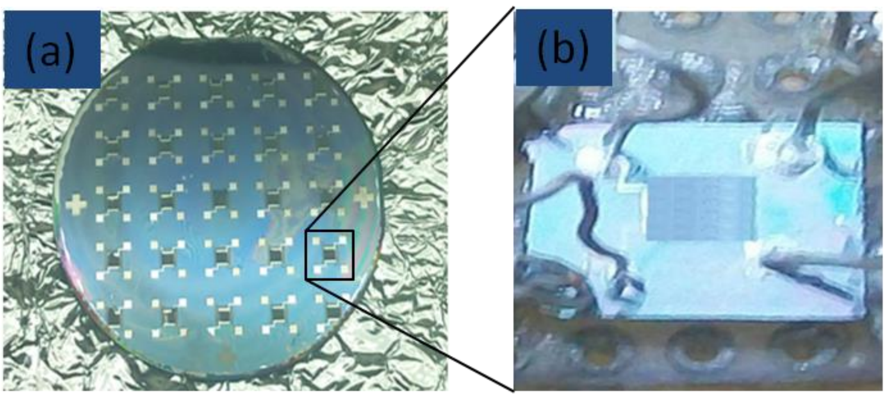
The Fig. shows (i) a 3 x 3 array made on a 2-inch silicon wafer and (ii) close-up view of the IDE electrodes having line width and gap of 30 micron.

3. A pressure sensor using aluminum-induced crystallization of sputter-deposited amorphous silicon. The Fig shows (a) optical image of a 2-inch diameter silicon wafer having an array of the devices and mounted on a substrate holder for measurements (b) a single chip diced from the wafer and mounted on a header and (c) zoomed image of a single device showing four piezoresistors connected in Wheatstone bridge configuration.



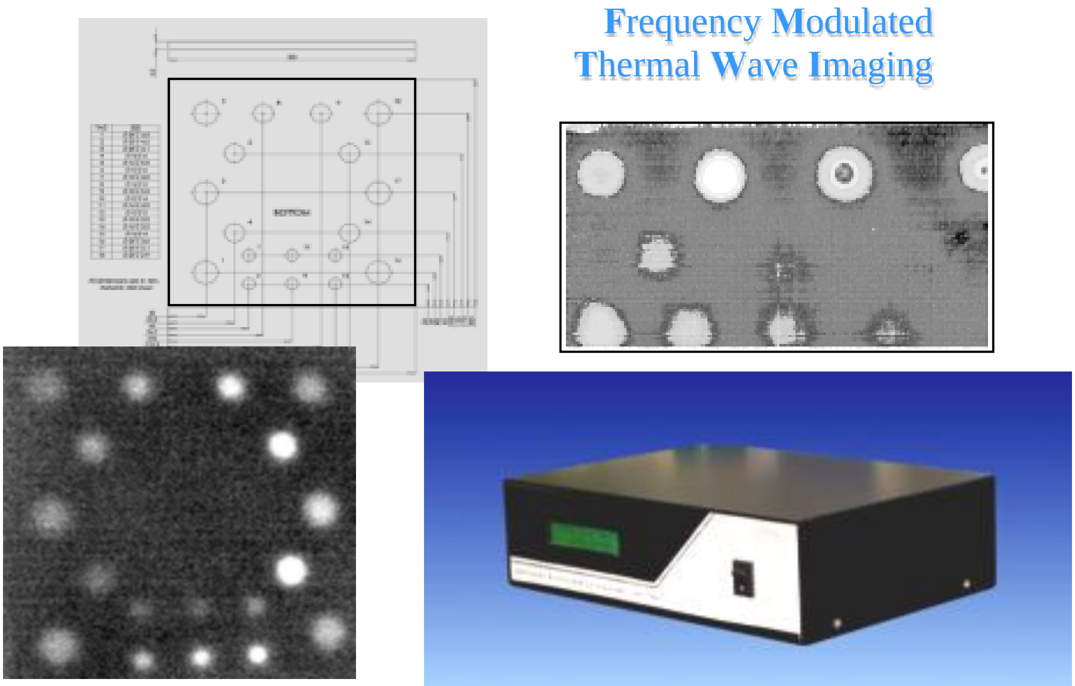
The work was carried out by a Ph.D. student and has been published in Journal of Micromechanics and Microengineering (JMM).

4 Optical photograph showing a completely processed 2-inch diameter silicon wafer containing an array of sensors for VOC (volatile organic compounds) monitoring. The device is realized by integrating nanostructured ZnO with MEMS processing.



The work was carried out by a Ph.D. student and has been published in Sensors and Actuators B (Chemical).

Technologies Developed



Frequecy modulated thermal wave imaging principle and device developed in CARE, IIT Delhi.

4.4. Number of patents filed and patent granted as a fraction of patents field.

i) Number of patents filed: 25.
(S. K. Koul: 7; M. Abegaonkar: 1; S. Chandra: 11; A. Kumar: 3; S. Tuli: 3).

iii) Number of patents granted: 11.
(S. K. Koul: 6; S. Chandra: 5).

iv) Number of copyrights filed: 4.
(S. K. Koul: 4).

iv) Number of copyrights granted: 4.
(S. K. Koul: 4).

4.5. Innovations of products, processes, designs etc. in the department.

Many of the items in 4.3 above (Technologies and Know-how developed) will fall under this heading as well. These have not been duplicated here.

S. No.	Faculty	Item
1.	S. Chandra	My sponsored project deliverables and research interests required a few very expensive equipments such as: (i) Front-to-back Mask Aligner, (ii) Glass-to-silicon Anodic Bonding System, (iii) Chemical Mechanical Planarization (CMP) system and (iv) Deep Reactive Ion Etching (DRIE) system. While the first three equipments from standard manufacturer cost about Rs. 1 crore each, the DRIE system costs upward of Rs. 2.5 crore. For the first three equipments as listed above, a low-cost solution to demonstrate "proof of concept" and make prototype devices was worked out and implemented with support from local manufacturer. An Indian Patent was also filed and granted recently on one of these. Using these indigenously developed equipments, several prototype devices have been made and delivered to the sponsoring agency (BARC). These have been extensively used by several Ph.D. and M. Tech. students and resulted in several quality publications in highly reputed Journals.
2.	S. Chandra	For the deep reactive ion etching, a improved process has been configured recently using the existing RIE system in the Lab to obtain substantially significant etch rates in silicon. Using the modified process, prototype microfluidic devices have been made for an sponsored project and work has also been submitted to an International Conference, to be held in April 2014, in France.

3.	S. Chandra	Several very expensive equipments in the Microelectronics Lab are more than 25 years old with no support from original equipment manufacturer (example: RIE system, RF sputtering system and mask aligner). These have been kept operational through indigenous modifications (e.g. RF magnetron sputtering target holder, Alcatel sputtering systems etc.), and repairs using locally developed skills of vendors. In the absence of these innovations, it would have been almost impossible to sustain the research in the area of micro-fabrication and Microelectronics.
4.	S. K. Koul and Sukomal Dey	Novel RF MEMS Switches and Phase Shifters at Ku-band Frequencies using Alumina Substrate that are small in size and results in improved performance.
5.	S. K. Koul and Ananjan Basu	Novel Design of a Balanced Mixer at 140 GHz using asymmetric grooved Suspended line utilizing 2-mil Quartz substrate.
6.	S. K. Koul, Ananjan Basu, A. Mittal	Novel Balun Design using slotline-microstrip transition for 18-40 GHz balanced mixers.
7.	S. K. Koul	Microstrip and Antenna Trainer Kit for Education.
8.	S.K.Koul, B.Bhat and Ajay Poddar	Novel technique of using evanescent guide for making a cost effective, repeatable and stable Gunn oscillator using suspended stripline.
9.	S.K.Koul and B.Bhat	Use of Window-cut resonator to improve selectivity of a conventional millimeter wave band pass filter realized by using bilateral fin line.
10.	S.K.Koul and B.Bhat	Ring structure having mean circumferential length of 4.5 wavelengths for realizing a fin line hybrid, which reduces fabrication complexities and hence is suitable for large scale production.
11.	S.K.Koul, Ananjan Basu and N.Pathak	A back-to-back suspended stripline to non-radiative dielectric guide transition that is easy to fabricate and delivers superior wideband performance at millimeter wave frequencies.

4.6. Availability and access to students' workshops, "tinkering laboratories" so that they may pursue their own ideas.

The students' hobby laboratories/clubs are operated centrally by the Board of Student Welfare of IIT Delhi.

4.7. No. of students / teams who have competed in national / international competitions and outcome.

1. S. Banerjee, M. Agrawal , "Time Reversal Precoder: An Efficient Tool for more Reliable Underwater Acoustic Communication" IEEE Oceans 2012 Conference, Korea. *Sharbari Banerjee received 3rd prize for the paper at the IEEE Oceans 2012 student paper competition.*

2. S. Banerjee, M. Agrawal, "Underwater Acoustic Noise with Generalized Gaussian Statistics: Effects on Error Performance," IEEE Oceans 2013 Conference, Norway. *Sharbari Banerjee received student travel grant from to attend and present the paper.*

3. Mithilesh Kumar, IEEE International Conference on Antennas Propagation and Systems, Dec 2009, Malayasia, *Best Student Paper Award*.

4. Ritabrata Bhattacharya, Robin Gupta, 'Low-Noise Amplifier Design Competition' International Microwave Symposium 2011, Baltimore USA.

5. H.J. Pandya and S. Chandra, **"**Zinc Oxide Nanostructures By Oxidation Of Zinc Films Deposited on Oxidized Silicon Substrate", ISSMD Vadodara, January 2011. *Best poster paper award.*

6. K Chatterjee, Suneet Tuli, S Pickering and D P Almond, National Symposium on Non-Destructive Evaluation, Kolkata, 2008, *Best Paper Award*.

7. Vijay Gupta, *Recipient of INAE best undergraduate innovation potential project award* -2001.

8. Vijay Gupta and Sumit Sinha, *Recipient of Motorola Award* -2001.

9. Vinod Kumar Singh, *Recipient of the INAE best project award in the M.Tech Category*-2002.

10. Preeti Sharma, *MEMS design scholarship by Coventorware and MANCEF, USA to work on RF and optical MEMS integration and packaging at system-level architecture and Devices include Ka-band micro-machined transmission lines, antennas, filters, resonators and switches*, 2004.

11. Nagendra Pathak, *Recipient of the IETE Research fellowship Award*-2004 &2006.

12. Manish, Hitesh Harnal, Meet Kanodia and Nishant, *Recipient of SURA Award* -2006.

13. Preeti Sharma, *Platinum Award-first Prize, for best paper presented at the IEEE International RF and Microwave Conference , Malaysia,* 12-14th September 2006.

14. Hitesh Harnal, *Recipient of IEEE MTT-S UG Project Scholarship Award*- 2007.

15. Balamurali Rama Bhat, *Recipient of Second Prize at the Agilent Engineering and Technology Awards*-2007.

16. Preeti Sharma, *Recipient of the IETE Research fellowship Award*- 2006 & 2007.

17. Manoj Parihar, *Recipient of the IETE Research fellowship Award*-2007.

18. Preeti Sharma, *R.S.Varma Memorial Award, for best paper presented at the 14th Intenational Conference on Computational, Mathematical and Statistical Methods, IIT Madras*, 6-8th January 2007.

19. Preeti Sharma, *Science Day Award, IIT Delhi*, 2008.

20. Mithilesh Kumar, *Best Student Paper Platinum Award, 2009 IEEE International Conference on Antennas, Propagation and Systems, INAS-2009 Malaysia*, 3-5th Dec.2009.

21. Sukomal Dey, *Recipient of PG award (2nd Place) by Institute of Smart Materials and Systems* , Bangalore,2012.
22. A.Sanyal, *Recipient of the M.N.Saha Memorial Award from IETE*-2013.

5. R&D Environment

5.1. No. of post-doctoral scholars hired in the department / centre and their durations, from (i) abroad, (ii) on project, and (iii) others, and outcomes.

a) No. of post-doctoral scholars: Nil. The provision to hire post-doctoral scholars has been made by the Institute in October 2013 and 1 position has been allocated to CARE. We have submitted an advertisement inviting applications.

b) No. of DST INSPIRE Faculty for duration of 5 years: One (since January 2013).

5.2. No. of foreign students enrolled in (i) Masters, and (ii) PhD programmes.

Master of Technology in RFDT: Nil.
PhD: 1 (from Ethiopia).

5.3. No. of Indian and foreign faculty / researchers who have spent a sabbatical in the department.

One (Associate Professor and Head, Mandalay Technological University, Myanmar: 1 month).

5.4. Sabbatical taken by faculty and where spent.

Four sabbaticals have been taken by currently in-position faculty of CARE:

R. Bahl:
1. Awarded NRC Associateship at US Naval Post Graduate School, Monterey, CA, USA: 1 year 1989-90
2. Guest Professor: University of Tokyo, Japan: 2 years 2002-2004.

S. Chandra:
1. Extra Ordinary Leave for 1 year in 1998-99 (kind of sabbatical leave but without pay from IIT Delhi) to work at R&D Centre, HOYA Corporation, Tokyo, Japan.

S. K. Koul [1996-1997]: On sabbatical leave to National University of Singapore.

5.5. Number of seminars (education and research separately) given by the faculty:
(i) in the department,
(ii) in other departments,
(iii) at other institutions.

The list is combined for education and research type seminars since Aug. 2008.

Faculty	In the department	In other departments	At other institutions
R. Bahl	5	3	14
S. Chandra	-	-	20
A. Kumar	4	6	23

M. Agarwal	-	-	4
K. Rawat	1	-	1
S. K. Koul	-	-	68 (30 research & 38 education)
M. Abegaonkar	-	-	30
B. S. Panwar	-	2	-
S. Tuli	1	1	15

5.6. No. of faculty / researchers / scholars invited by the department for giving (i) seminars, (ii) spending at least a week in the department.

Faculty/researchers invited by the Centre for giving seminars in last 5 years: 20. The list includes:

i) Prof. Thomas Lee: Stanford University,
ii) Prof. Donhee Ham: Harvard University,
iii) Prof. Sylvain Ballandras: Femto-ST, Besancon France,
iv) Prof. Satish Sharma: Univ. of Regina Canada,
v) Prof. Baron Thomas: Femto-ST Besancon France,
vi) Prof. James Miller: University of Rhode Island,
vii) Dr. James Rautio: Founder, Sonnet Software Inc.,
viii) Dr. R Muralidharan, Director, SSPL, DRDO.
ix) Prof Darryl Almond, University of Bath, UK (2006, 2007, 2008)
x) Dr. Simon Pickering, University of Bath, UK (2007, 2008)

5.7. No. of faculty / researchers who visited the department on their initiative for giving (i) seminars, (ii) spending at least a week in the department.

Faculty / researchers who visited the Cetnre on their own initiative for giving seminars in last 5 years: 22.

The list includes:

1. Zhining Chen: National University of Singapore.
2. Levent Gurel: Bilkent University.
3. Ajay Poddar: Synergy Microwave Corp., USA.
4. Ulrich Rohde: Synergy Microwave Corp., USA.
5. Dominique Schreurs: Katholieke University, Belgium.
6. Nemai Karmakar: Monash University, Australia.
7. Jeffory Pawlan: Pawlan Communications, USA.

5.8. Adequacy of research infrastructure.

Overall research infrastructure is excellent. It is a very important aspect related to CARE’s applied R&D thrust. Recent new infrastructure development include the setting up of MEMS SAW Process laboratory, and Acoustic Anechoic chamber facility.

The research infrastructure in the Microwave Group is of world standard. Excellent facilities exist to carry out both basic and advanced Research. The existing facilities include: software tools-ADS, CST Microwave Studio, MEMS Design Tools, Cadence tools, Empro etc; Network Analyzers (110 GHz, 67 GHz, 50 GHz, 26.5 GHz, 20 GHz, 6 GHz), Spectrum analyzers, 25 GHz DSO, Signal sources, antenna pattern measurement setup, probe stations at 110 GHz and at 40 GHz, bonders and photolithography facility.

The research infrastructure in Signal Processing area is unique in an academic environment in the country in terms of Underwater Tank facility and state-of-the-art Acoustic Anechoic Chamber.

Some aspects of research infrastructure that require near-term attention include the following:

i) Some additional instruments are required for Centre's upcoming focus in RF/DSP co-design approach. These instruments are identified and research proposal seeking the possible grant for purchasing these instruments is already initiated.
ii) Backup power in Microelectronics labs,
iii) Absence of lifts on the Blocks,
iv) Stream-lined procurement of gases,
v) Safety related issues in handling, storing and disposing of chemicals and gases. (Some initiatives have now been taken, very recently),
vi) Long delays in Lab renovations, when requested.

5.9. Adequacy of technical staff – existing numbers and competency areas; competency areas in which there is a shortage.

The Centre's thrust on doing applied research work reflects in the large number of research laboratories (15 nos). Several of these laboratories are also used as teaching labs for the RFDT M.Tech courses. Currently, the Centre has 6 permanent technical staff from the Institute. Out of these, 2 staff shall be retiring within the next 1 year.

The technical staff strength is inadequate to manage the specialized laboratories both administratively and technically. Currently, the technical staff strength of an academic unit is allotted by the Institute on proportional basis of faculty strength. There is a need to have an additional minimum of 3 long-term technical staff appointees (1 each in Signal Processing, Microwaves, Microelectronics) for our specialized laboratories that require training for extended period before such staff can be productive to full potential, keeping in view the retirements of 2 technical staff within the next 1 year.

5.10. Work space available for (a) Masters students, (b) PhD students, (c) Project staff, (d) Post doctoral scholars.

Just adequate work-space is available for persons in the respective categories.

5.11. No. of national conference / workshops / seminars attended by PhD students *(total and per student for 5 years).*

An average of 2 National Conferences / Workshops / Symposia are attended by PhD students over the last 5 years.

5.12. No. of international overseas conference / workshops / seminars attended by PhD students *(total and per student for 5 years).*

An average of 1 International overseas Conference / Workshop / Symposia is attended by PhD students over the last 5 years.

5.13. No. of M.Tech students who have continued to PhD:
(i) in same dept.,
(ii) other departments of IITD,
(iii) in India,
(iv) abroad.

The following information is since July 2008:

(i) In CARE:	5:	Pratyush Varshney, Kapil Dev Tyagi, Ashish Agarwal, Deepika Sipal, Vishal Kumar.
(ii) Other departments:	4:	Binish Fatima - EE, 3 from Physics.
(iii) In India:	3:	Anindya – IISc, Giriraj Vyas – IIT Jodhpur, Pramendra Tilanthe – RGPV Bhopal.
(iv) Abroad:	4:	Prabhu – Uppsala Univ., Meenakshi Sundaram, Srikarnt Burra.

5.14. No. of projects with co-guide from industry.

There are no projects with co-guide from industry. However, there are 4 PhD students with co-guides from DRDO and CSIR labs in the last 5 years.

5.15. No. of students who have spent time in industry as part of thesis / project work (give no. and duration).

No. of students = 10; Most of these visits were between 3 – 30 days, with the exception of 1 PhD student who spent 6 months in France.

5.16. Self-assessment reports of the departments/centres/schools if any.

Nil.

5.17. Placement of M.Tech and PhD graduates in technical careers (*as per format*).

Prog. Type	Prof. Name	No. of Graduating students (last 5 years)		Nature of job for first 2-3 years after graduation	Nature of job 5 years after graduation	% of graduates in technical line of work	% of graduates started in technical line and are managers / administrators
		GATE Entry	Sponsored				
M.Tech.	Radio Frequency Design and Technology	34	74	Technical (Industry, Naval organizations, DRDO Labs and Academia) and Higher Education	Information from significant number of students is not available 5 years after graduation	100%	All GATE entry graduates we know are in technical line. However, Navy officers progress towards managerial / administrative positions in the technical branch as they rise in rank.
PhD	Specializations: i)Microelectronics, ii) Signal Processing, iii) Microwaves, iv) Non-destructive characterization.	17 (last 7 years)		Technical (Industry, Naval organization, DRDO Labs, Academia)	Technical	100%	All are in technical line including academia. They are not full-time managers/administrators.

5.18. Inter-disciplinary work:

(i) joint thesis guidance by faculty across groups within a department, or across departments /centres,

No. of joint PhD & MS-R thesis guidance across groups within a department, or across departments/centres since 2008:

PhD: 10;
MS-R: 2;
M.Tech: 10.

(ii) Proposals submitted and funded – PI/Co-PI and their group / department affiliations.

No. of interdisciplinary projects since 2008: Ten (10).

1. Bio-molecular sensing: with EE department.
2. Large scale data processing and visualization: with CSE department.
3. Airtel-IITD centre for excellence in telecom: with EE department.
4. Sonic characterization of marine species: with Cochin University of Science and Technology, Kochi.
5. Performance evaluation and optimization of opto-mechanical sensing and related technologies: with Physics department.
6. An ultra low-cost Microwave imaging system using active RFID for surveillance applications: with EE department.
7. Wafer bonding and layer transfer for novel engineered substrates: with Physics department.
8. Design and development of prototype micro-fluidic MEMS: with Physics department, Mechanical Engineering, Chemical Engineering, Instrument Design & Development Centre.
9. Intelligent processing of advanced polymeric materials: with Textile Technology, Centre for Polymer Sciences, Mechanical Engineering.
10. Wireless Body Area Network for Health Monitoring, with IDDC Centre, Department of Electronics & Information Technology.

6. Outreach/External Stakeholder engagement

6.1. Educational

(a) Workshop/Short term courses - topical research for disseminating research of IITD.

Some of the workshops listed under 6.1(b) are of a dual nature and can also be considered under this heading. However, they have not been listed twice.

S. No.	Faculty	Description
1.	Karun Rawat	1. IEEE AP-MTT Chapter sponsored talk on: " Techniques in Multi-band/Multi-standard Doherty Power Amplifiers for Wireless Transmitters" at Ohio state University, Columbus, Ohio, USA.
2.	Mahesh Abegaonkar	1. Several talks on antennas and electromagnetic band gap (EBG) structures.
3.	Sudhir Chandra	Under IIT Delhi-BARC MoU(analogous to a sponsored Project), two Workshop were conducted which was open to all students and faculty of IIT Delhi, 1. “Microfluidic Devices Using MEMS Technology" March 30-31, 2009. 2. “MEMS Technologies and Applications”, July 5-6, 2010.
4.	S. K. Koul, Ananjan Basu	1. *IEEE Sponsored workshop on MIC, MMIC and RF MEMS Components and Circuit Design*, Department of Electronics Communication Engineering, Institute of Engineering & Technology, Alwar, Rajasthan, India, Oct. 24, 2008. *2. Half day Pre-conference Tutorial* , Advances in RF MEMS and Nanotechnology , IETE Conference on RF and Wireless-2008 (ICON RFW-08), Bangalore, India, April 24,2008. 3. RF&Microwave Activity, CARE at Agilent Technologies, Manesar, Nov 24, 2011. 4. UWB and Reconfigurable Antennas at IISc Bangalore, Jan 28, 2012. 5. IEEE-MTTS Colloquium on Microwave and Millimetre-wave Integrated Circuits, New Delhi, Oct 5, 2012.

(b) Workshop/Short term courses - educational methods (teaching, learning resources, pedagogy).

S. No.	Faculty	Description
1.	S. K. Koul	1. Given 30 educational talks as IEEE MTT-S Distinguished Microwave Lecturer on " Circuit to System Level Microwave Education".

		2. MEMS Design Using Comsol and Intellisuite, IIT Delhi, 7-10th April 2010. 3. MEMS Design Using Coventorware, IIT Delhi, 6-7th March 2010.
2.	Karun Rawat	1. IEEE AP-MTT Chapter sponsored talk on: "Techniques in Multi-band/Multi-standard Doherty Power Amplifiers for Wireless Transmitters" at Ohio State University, Columbus, Ohio, USA.
3.	Mahesh Abegaonkar	1. Around 20 workshops to popularize Virtual Labs in various institutes across India.
4.	S. K. Koul, A. Basu, M. Abegaonkar.	Short Course on RF and Microwave Circuit Design – I for Engineers from Shyam Telecom Ltd., 12-16 May 2008, CARE, IIT Delhi.
5.	S. K. Koul, A. Basu, M. Abegaonkar.	Simulation, fabrication and Characterization of RF and Microwave Components, IIT Delhi, 30-31st, October. 2009
6.	Ananjan Basu	1. Multiport parameters Directional Couplers and Power Dividers, IET Alwar Dec 16 2009. 2. RF Circuit Design, GITS Udaipur, Dec 20, 2009.
7.	Monika Agarwal	1. "Advances in Signal Processing & its Applications"* at UIET, Kurukshetra from on 15th –27th July, 2013. 2. "Recent Advances in Signal Processing & Communication," July 2008.
8.	R. Bahl, Arun Kumar	1. Advanced Short Course on Passive Underwater Surveillance 6th – 10th Sept. 2010 at CARE, IIT Delhi. Attended by Naval Officers, DRDO Scientists and Engineers from industry. 2. CEP Course on Autonomous Underwater Acoustic Surveillance – 17th – 19th Jan 2013. Organized at INS Valsura, Jamnagar for Naval officers. 3. CEP Course on Autonomous Underwater Acoustic Surveillance - 22nd March 2011 – 24th March 2011. Organized at INS Valsura, Jamnagar for Naval officers. 4. CEP Course on Underwater Superiority – 29th Jan – 31st Jan 2010. Organized at INS Valsura, Jamnagar for Naval officers.
9.	Suneet Tuli	▪ Suneet Tuli, "Active Thermography and its Applications" Training programme on Infrared Thermography at The National Productivity Council, New Delhi on February 16-17, 2012. ▪ Suneet Tuli, "Sub-surface Thermal Imaging of Bamboo and Bamboo-Glue Interface" WOOD NDT 2011 at University of West Hungary, Sopron - 17th International Non- Destructive Testing and Evaluation of Wood Symposium on September 14-16, 2011. ▪ Suneet Tuli, "Frequency Modulated Thermal Wave Imaging" QNDE 2011 Conference at University of Vermont, Burlington, USA on July 17-22, 2011. ▪ Suneet Tuli, "Applications of Passive and Active Infrared Thermography" at Power Management

		Institute, Noida on Aug 16, 2010. ▪ Suneet Tuli, "Applications of Numerical Simulations and Modelling In Thermography", Pre-conference Workshop on Digital Imaging NDE at NDE 2010, Kolkata on Dec 8, 2010. ▪ Suneet Tuli, "Thermographic Techniques for Laser Diagnostics", CEP Course on Laser Diagnostics at LASTEC, New Delhi on Feb 18, 2011. ▪ Suneet Tuli, "Understanding Computers and Softwares", Orientation Programme for Women Scientists organised by Technology Information, Forecasting & Assessment Council (TIFAC) at Patent Facilitating Centre (PFC), department of Science & Technology on 18 May, 2010. ▪ Suneet Tuli, " Waves and Electronics", Annual Science Association Festival at SriVenkateshwara College, University of Delhi, 19-20 November, 2009. ▪ Suneet Tuli, "Infrared Thermography For Condition Monitoring Status And Advances", a 2-day National Conference on 'Condition Monitoring Of Machinery & Equipment', Organized by Condition Monitoring Society Of India (CMSI), 4-5 December, 2009, Vishakhapatnam ▪ Suneet Tuli, "Thermal Imaging Technology *for* Diagnostics: Modeling, Simulation, Signal Processing, System Development *and* Applications", Satyabhama University, IETE and EME Chennai, 5-7 Sept. 2008. 1. Suneet Tuli, "NDE by Thermal Imaging", ASL Hyderabad, 12-14 Dec. 2007.

(c) Learning, research material on the website.

S. No.	Faculty	Description
1.	S. K. Koul	Distinguished Microwave Lecturers: http://www.mtt.org/dmls.html
2.	Mahesh Abegaonkar	The virtual labs are available on website: http://www.vlab.co.in. Particular virtual labs developed are at: a. Virtual Engineering Electromagnetics Lab: http://iitd.vlab.co.in/?sub=65&brch=180 b. Virtual Microwave and Antenna Lab.: http://iitd.vlab.co.in/?sub=65&brch=183

(d) Science and Technology for public information - on website.

S. No.	Faculty	Description
1.	R. Bahl	Weekly TV series **"A Question of Science"** is being telecast from **8th January 2014 on Doordarshan**

		National Network at 9 am every Wednesday. The first episode of the series on 8th January was - **Acoustics Technology in Conservation of Ganges River Dolphin.** This program shows how Sonar technology for Naval applications pioneered at CARE has been adapted for passive acoustic surveillance of blind Ganges River dolphins with the aim to help in conservation of this National Aquatic Mammal. This program explains in a layman's way how the technology has been deployed and highlights the successful inter-disciplinary collaboration between technologists of IIT Delhi and University of Tokyo, with field assistance provided by biologists of WWF-India.
2.	S. Chandra	The information about the NAIP ICAR sponsored project on testing of milk is available on NAIP website.
3.	For CARE activities	CARE website: care.iitd.ac.in

(e) Courses taught to students of other IITs/NITS/other Institutions.

S. No.	Faculty	Description
1.	Monika Agarwal	1. Taught EEL101: Fundamentals of Electrical Engineering (3-0-2) (2008-9) to IIT Ropar students at IIT Delhi campus for 1 semester. Number of students was 60. 2. Taught EEL101: Fundamentals of Electrical Engineering (3-0-2) (2009-10) at IIT Ropar for 1 semester. Number of students was 60.
2.	B. S. Panwar	Taught UG Analog Electronics course to IIT Ropar students in 2nd semester 2009-2010. The class strength was 52.
3.	S. Chandra	A part of course on IC Technology was taught at IIIT, Gwalior, 2008, 40 hours of lectures.

(f) Courses taught via NKN.

S. No.	Faculty	Description
1.	Arun Kumar	Twice taught one-semester course “Architectures and Algorithms for DSP Systems,” in the IITD-Addis Ababa Institute of Technology, M.Sc. Electronics Program via 2-way video link. The course was taught from March to August 2012 and October 2010 to March 2011 and included 5 day visits for student interactions related to the course.

(g) Courses developed for NPTEL.

NIL.

(h) Books, monographs, study material made available to other institutions.

S. No.	Faculty	Description
1.	S. K. Koul	The following books have been made available to many institution across the country and outside as well: 1. **S.K.Koul**, Millimeter Wave and Optical Dielectric Integrated Guides and Circuits, (563 Pages) John Wiley and Sons, NY, USA, April 1997. 2. **S.K.Koul** and B.Bhat, Computer-Aided Design of Millimeter Wave Fin lines- Analysis and Design Software for Windows, (250 pages and two 3.5" diskettes), New Age Publishers, New Delhi, January 1997. 3. **S.K.Koul** and B.Bhat, FINLINE CAD FOR DOS-Analysis and design software for Millimeter Wave Integrated Circuits, (200 pages and two 3.5" diskettes), New Age Publishers, New Delhi, Sept.1996. 4. **S.K.Koul** and B.Bhat, Microwave and Millimeter Wave Phase Shifters, *Volume* II- Semiconductor and Delay Line Phase Shifters, (300 Pages), Artech House (Mass.), USA, March 1992. 5. **S.K.Koul** and B.Bhat, Microwave and Millimeter Wave Phase Shifters, *Volume* I - Dielectric and Ferrite Phase Shifters (390 Pages), Artech House (Mass.), USA, Sept.1991. 6. B.Bhat and **S.K.Koul**, Stripline-like Transmission Lines for Microwave Integrated Circuits (697 pages), Wiley Eastern Pvt. Ltd, India and John Wiley, NY, USA, 1989. 7. B.Bhat and **S.K.Koul**, Analysis, Design and Applications of Fin-lines, (475 pages), Artech House (Mass.), USA, 1987.
2.	Arun Kumar	Lecture-wise study material including video of lectures for one-semester course “Architectures and Algorithms for DSP Systems,” taught in the IITD-Addis Ababa Institute of Technology, M.Sc. Electronics

		Program via 2-way video link.

(i) Experiments developed and made available to other Institutions.

S. No.	Faculty	Description
1.	S. K. Koul	Taken the initiative to set up Low Cost RF and Microwave Component Characterization facility at different Engineering Colleges (done at 3 colleges so far) . *These laboratories are developed around portable network analyzer. 14 experiments are included on three basic printed transmission lines, asymmetrical as well as symmetrical stub line low pass filter having sharp cut-off characteristics, and various other passive components for microwave applications. The low cost laboratory setup including the components developed is self-contained and is useful for conducting laboratory experiments as part of a microwave or wireless communication laboratory for undergraduate/post-graduate students.)* In addition to setting up of the laboratories , I developed four trainer kits- namely Microstrip Trainer Kit and the Printed Antenna Trainer Kit to impart practical training to students. U*sing these kit, students can carry out experiments on microstrip transmission line, passive components (directional couplers, ring resonators, filters etc), active circuits (amplifiers), basic patch antennas of different shapes, array antennas, printed dipole antenna, printed Yagi antenna, aperture coupled antenna, leaky wave antennas and reconfigurable antennas.* ***About 400 such trainer kits have so far been sold in the last 4 years to Engineering colleges and Universities in India and Abroad***).
2.	Arun Kumar	Five experiments on Texas Instruments TMS320C5510 fixed-point Digital Signal Processor simulator were given as part one-semester course “Architectures and Algorithms for DSP Systems,” taught in the IITD-Addis Ababa Institute of Technology, M.Sc. Electronics Program via 2-way video link.

(j) Seminars live/via NKN, web to other institution in India/abroad.

S. No.	Faculty	Description
1.	Arun Kumar	90-minute lecture on “Overview of speech processing and coding” via 2-way video link from IIT Delhi to

		Dayalbagh University, Agra, on 4 occasions.

(k) **Reach out to schools, NCERT, KVs, etc. (e.g. K-12 programmes).**

S. No.	Faculty	Description
1.	R. Bahl	1. Invited talk at DST-Inspire Science Camp for Schools, IIT Delhi, 2012, and lab visit by school students to Underwater Electronics Lab.

(l) **Mentoring of other institutions, e.g. new IITs, NITs, universities, etc. including faculty mentoring, curriculum development, laboratory development. etc.**

S. No.	Faculty	Description
1.	S. Chandra	Close interaction and mentoring of faculty of few engineering colleges located in Maharashtra through BARC initiative. The colleges include: MGM College of Engineering and Technology, Navi-Mumbai, Engineering College, Pandarpur.
2.	Arun Kumar	Summer Faculty Research Fellow (SFRF) Program of IIT Delhi. Five faculty of other Institutions have been mentored for 6-weeks duration in summer of 2011, 2012, 2013.
3.	Mahesh Abegaonkar	Summer Faculty Research Fellow (SFRF) Program of IIT Delhi. Nine faculty of other Institutions have been mentored for 6-weeks duration in summer of 2009, 2010, 2011, 2012, 2013.
4.	S. K. Koul	Setup advanced RF and Microwave laboratories at IET Alwar, GITS Udaipur and Techno India NJR Institute in Udaipur.

6.2. Industry collaboration

(a) **No. of students (PhD. / Masters) directly linked to industry funded projects.**

Number of PhD students working on industry funded projects: 9.
Number of Masters students working on industry funded projects: 14; 11 in Signal Processing and 3 in Microwaves area.

(b) **No. of industry staff/ engineers who have taken a regular course(s) for entire semester.**

Ten (10) industry staff/engineers have taken a regular course for entire semester.

(c) **Technology transfer to companies, entrepreneurs, local and other governments/government agencies, NGOs (separately).**

The list of technologies transferred is given in Section 4.3.

(d) **Continuing education/courses for industry.**
The list of courses is given in 6.1(b) above.

(e) **Faculty secondment to industry.**

Nil.

(f) **Research projects undertaken with industry as partners.**

S. No.	Area	Description
1.	Signal Processing	1. Active sonar classifier, with Bharat Electronics Limited, Bangalore, 2009. 2. Flexible pattern recognition for ultrasonic signals, Mitsubishi Heavy Industries, Japan, 2007-2009. 3. Formulating realistic criteria for the detection of targets by sonar, with MACMET Technologies, Bangalore for NSTL, DRDO, Visakhapatnam, 2005-2006.
2.	Microwaves	1. RF MEMS Phase Shifters, SPST, SPDT switches & tunable filters with Astra Microwave Products Ltd., 2010-2013.
3.	Microelectronics	1. Characterization and optimization of solar cell fabrication process, BHEL, 2006-2008.

(g) **Laboratories, equipment, etc. provided by industry for use in UG/PG teaching laboratories and student projects.**

S. No.	Area	Description
1.	Signal Processing	1. TMS320C5510 DSP Starter Kits 20 nos. from Texas Instruments, Bangalore, 2004.
2.	Microwaves	1. HFSS and ADS Softwares, Agilent Technologies, 2000. 2. Wire bonder from LRDE (DRDO) – loan for 9 years. 3. Field Fox Network Analyzer, 2013. Donated by M/S

		Agilent Technologies Private Limited. 4. E8900PS ADS Premier Bundled Package- 5 Licenses and EmPro- 1 License by M/S Agilent Technologies Private Limited. 5. Ansoft HFSS with Optimeterics- 2 licenses by M/S Ansoft Corporation, Singapore. 6. E8900PS ADS Premier Bundled Package- 5 Node locked Licenses by M/S Agilent Technologies Private Limited.

(h) **Seminars/workshops held with industry by the department.**

S. No.	Area	Description
1.	Microwaves	1. Accelerating Design Cycles and Time to Market with Agilent EEsof EDA –Agilent Technologies and CARE, IIT Delhi, 2005. 2. IEEE Sponsored workshop on MIC, MMIC and RF MEMS Components and Circuit Design, Department of Electronics Communication Engineering, Institute of Engineering & Technology, Alwar, Rajasthan, India, Oct. 24, 2008. 3. RF and Microwave Circuit Design Course conducted for Shyam Telecom Pvt. Ltd., IIT Delhi, India, May 13, 2008. 4. Half day Pre-conference Tutorial , Advances in RF MEMS and Nanotechnology , IETE Conference on RF and Wireless-2008 (ICON RFW-08), Bangalore, India, April 24,2008.

6.3. Professional

(a) **Service as Board, Senate, Selection committee member at other IITs, NITs and Universities.**

S. No.	Faculty	Service Description
1.	S. K. Koul	1. Member Board of Governors, NIT Srinagar, 2004-2011. 2. Member Academic Council, DIAT, Pune, 2005-2008. 3. Selection Committee Member at IIT Mumbai, IIT Kanpur, Osmania University, Mata Vashno Devi university, NIT Jalandhar, NSIT, DTU, IIT Roorkee, IIIT Guawhati. 4. Member Council for Academic Affairs, NSIT Delhi, 2006
2.	R. Bahl	Selection committee at ISM Dhanbad, NIT Jamshedpur.
3.	Arun Kumar	Member of Assessment Board for promotion of DRDO

		and DIT-MCIT scientists.

(b) **Service as Ph.D. thesis examiner at other institutions.**

S. No.	Faculty	Institutions
1.	R. Bahl	Andhra University, IISc Bangalore.
2.	Arun Kumar	IIT Bombay, IIT Kharagpur, IIT Kanpur, IIT Madras, IIT Guwahati, Goa University, CUSAT University, Dayalbagh University, MNIT, Jaipur.
3.	S. Chandra	IIT Madras, Pune University, IIT Kharagpur, IIIT Jabalpur.
4.	S. K. Koul	Ph.D Thesis Examiner at IIT Mumbai, IIT Guawhati, IIT Kharagpur. Ph.D Thesis Examiner at - SRM University, UP-TECH, BITS -MESRA, LNMIT JAIPUR, Osmania University.
5.	M. Abegaonkar	Dr. Dadasaheb Ambedkar Technological University, Lonere, Swami Ramanand Tirth Marathwada University, Nanded.

(c) **Service as technical expert on committee - MHRD, DST, DSIR, DRDO, Pan-IIT initiative, other ministries, state and local government.**

S. No.	Faculty	Description
1.	R. Bahl	Various DRDO lab projects: SASE, DEAL, NSTL, NPOL.
2.	Arun Kumar	1. Member, Working Group on Technology Development for Indian Languages, DEITY, MCIT, 2012 onwards. 2. Served as Chairman of the Monitoring and Advisory Committee (MAC) of CSIR's networked projects on "Electronics for Societal Purposes" for the 10th five year plan 2003-2007. There were 15 projects of 8 CSIR Labs with financial outlay of Rs. 24.40 crores which were evaluated. 3. Member of Peer Review Committee of "Underwater Sensor Networks Technology" of the DRDO.
3.	Monika Agarwal	DIT.
4.	S. K. Koul	1. National Member, URSI, Commission-C, 2006-2012

		2. Member, National Committee of COSPAR-URSI-SCOSTEP, 2006-2012 3. Member, Board for Smart Materials (B-Smart), ADA, Bangalore, since 2008. 4. Steering Committee Member, Young Engineers Award Committee, Indian National Academy of Engineers (INAE), 1994-1996. 5. Member, Appellate Committee of AICTE, 2005,2012-2014 6. Member Expert Advisory committee, UGC Nominee under Special Assistance Programme, 2005 7. Expert Member Assessment Board, DRDO,2005-2007 8. Membership Assessment Committee, RAB, CSIR, 2006 9. Member Design Review Committee, Project Midas, DLRL, 2006-2010 10. Member Project and Review Committee, Development of 40 GHz MMIC Technology, SSPL, 2007-2010 11. Member Project Design Review, Combat Identification of Friend or Foe, DEAL, 2008 12. Member Project and Review Committee, Development of C-band Rotary Field phase shifter, SSPL, 2007-2009 13. Member Project Design Review Millimeter Wave Transmitter-Receiver, Sameer Kolkata (2009) 14. Member Executive Board, SSPL on Development of MEMS Technology, SSPL (2009-2012) 15. Member Microwave Tube Research and Development Centre (MTDRC) Bangalore Research Council 16. Member Defense Electronics Application Laboratory (DEAL), Dehradun Research Council 17. Member Re-visit committee , Recruitment and Assessment Centre (RAC), Ministry of Defense, Delhi

		18. Member Mentor Council for Electronics and hardware sector, Ministry of Labour and Employment, Government of India 19. Chairman of project review and Steering Committee of the Project " Design and Characterization of CMOS based Millimeter-Wave Components for 60-GHz Integrated Broadband Transceivers, Ministry of Communication and Information Technology
5.	M. Abegaonkar	1. Recruitment and Assessment Centre, DRDO. 2. Discipline-wise National Coordinator (E&CE), Virtual Labs, MHRD, during Sept. 2010 to Aug. 2013. This was a responsibility in the overall Virtual Labs project. The Virtual Labs were developed in different phases during 2009-2013 by faculty members from different institutes.
6.	Suneet Tuli	1. Reviewer, Journal of Quantitative Infrared Thermography. 2. Reviewer, IETE Journals. 3. Book review: NCUTE. 4. Member, Core Group of Experts (Thermal Imaging), Indian Army 5. Member, Technical Advisory Committee on Facility for IR Detectors, DRDO 6. Chairman, DSIR Committee on Building Capacities for Consultancy Development & Knowledge Management with Partner Institutions 7. Invited Member, Academic Council, Shri Mata Vaishno Devi University 8. Member, Board of Examiners, Indian Institution of Industrial Engineers 9. Life Member Indian Society for NDT (ISNT) 10. Chairman Conference on Rotating Equipment 2004, Kuala Lumpur (Malaysia) 11. Member, National Advisory Committee: NCTP'07: 4th National Conference on Thermo Physical Properties, Kollam, September 20-22,2007. 12. Member, National Advisory Committee, NCTP Conference, October 7-9, 2009. 13. Member, Examination Committee & Selection Committee for TIFAC Women Scientist Scholarship Scheme. 14. Reviewer (Project Proposals): Various Govt. agencies: DRDO, CCRH, DeiTY. 15. Editor (Instrumentation & Measurement), IETE Journal of Research 16. Member, Selection Committee for NTPC Executives

		(2007, 2008, 2009) 17. Member, Selection Committee for Faculty, Thapar University, Patiala. 18. Evaluation of M.S. Thesis, IIT Madras. 19. Member – Integrated Coastal Surveillance System (ICSS), Peer Review Committee, DRDO 20. Member – Executive Board Meeting Committee for Projects TALAS (Thermal Imagers for Applications over Land and Sea) and MRSS (Mid Range Surveillance System with Fused Imagery in SWIR, MWIR and LWIR Band) – IRDE, Dehradun 21. Member – Peer Review Committee Meeting of the Project "Laser Target Designator with Thermal Imager for Air Force" - IRDE, Dehradun 22. Session Chair (Thermography) at the Annual National Conferences in NDE (2009 onwards).
7.	Vikram Kumar	1. Chairman, Working Group on Nanotechnology, Dept. of Electronics and Information Technology (DeitY). 2. Chairman, Solar Energy Expert Group on Enabling R&D (SEER), DST 3. Chairman, PAC on Energy, Materials Science & Engineering for International Cooperation Programmes of the DST. 4. Chairman, R&D Sectoral Project Appraisal Committee (RDSPAC) on Photovoltaic Technology, MNRE 5. Member, RD&D Project Appraisal Committee (RDPAC), MNRE 6. Member, Fellowship Management Committee of National Solar Science Fellows Programme, MNRE 7. Indian Co-Chair for the India – EU Thematic Group on Energy, DST International Cooperation

(d) **Technical expert on policy, regulatory, law, standard committees.**

S. No.	Faculty	Description
1.	R. Bahl	1. Co-chair, Underwater Research Advisory Committee (UWRAC) at Naval Headquarters. UWRAC is a committee consisting of CARE faculty members in the Underwater Electronics / Signal Processing area, and Naval Officers of concerned Directorates, to co-ordinate R&D requirements of Indian Navy in Underwater Electronics and award sponsored projects to CARE appropriately.

2.	Arun Kumar	1. Member, Underwater Research Advisory Committee (UWRAC) at Naval Headquarters. UWRAC is a committee consisting of CARE faculty members in the Underwater Electronics / Signal Processing area, and Naval Officers of concerned Directorates, to co-ordinate R&D requirements of Indian Navy in Underwater Electronics and award sponsored projects to CARE appropriately.
3.	S. K Koul	1. Member, Board of Directors of Electronics Sector Skills Council of India (ESSCI), Since 2003.

(e) Member of Board/Advisory Board of public and private sector corporations.

S. No.	Faculty	Description
1.	S. K. Koul	▪ Chairman, Astra Microwave Products Limited, Hyderabad, Since 2009. ▪ Member, Board for Smart Materials (B-Smart), ADA, Bangalore. ▪ Independent Director, Astra Microwave Products Limited, Hyderabad, Since 2004.
2.	R. Bahl	Non-executive member of Board of Directors of Delsig Systems Pvt. Ltd.
3.	Arun Kumar	• Non-executive member of Board of Directors of Delsig Systems Pvt. Ltd. • Non-executive member of Board of Directors of Voxomos Systems Pvt. Ltd.

(f) Positions (e.g. Director, Vice-Chancellor, etc.) held by faculty on lien.

Nil.

(g) Miscellaneous

S. No.	Faculty	Description
1.	Suneet Tuli	1. Dean (R & D) at IITD (2012-present) 2. Associate Dean (Industrial R&D) at IIT Delhi (2005 - 2009) 3. Member (Ex-Officio), IRD Board (2005 -) 4. Member, Managing Committee for Evaluating proposals for Ministry of Small and Medium Enterprise, Govt. of India (MSME) Scheme for Entrepreneurial and Managerial Development of

		Small and Medium Enterprises (SMEs) through Incubators. 5. Proctorial Team Vice-Chairman (2005) and member (2001-05) 6. Chairman, Holistic Health Committee (HHC), (2008 - 10) 7. Convocation: Member Standing Committee (2004) and member VIP reception (2000-05) 8. Member PEC, Interdisciplinary MTech Programme-Power Generation Technology (NTPC Sponsored) 9. Member, Technopreneur Promotion Programme (TePP) Monitoring Committee (TMC) for FITT (2007-) 10. Mentor, Tepp Projects (FITT related) 11. Chairman, Summer Undergraduate Research Award (SURA) Proposals/Projects Evaluation Committee 12. Member, Technology Development Project Initiation Award for Students (TDP-IAS) Proposal Evaluation Committee (2009) 13. Member, Student-Teacher Interaction Committee (STIC), (2008-09) 14. Member Commercial Establishment Monitoring Committee (CEMC) 15. JEE & GATE regular participation, JEE 2008 : Institute Representative, Palampur (HP). 16. SRC's of Research Scholars in EE, Civil Engineering, CARE,CBME, Physics and Textiles. 17. Convener, Reception Committee for Convocation 2009. 18. Member – IRD Board for 2010-2011 19. Member – FITT Committee 20. Evaluation of TEPP proposals (FITT related) 21. Member – Management Committee of the Benevolent Fund Scheme for academic year 2010-2011. 22. Member – PAC for the period 01-09-2010 to 31-08-2011 for Mtech & Research Programme in VLSI Design, Tools and Technology (VDTT) 23. Member – PAC for the period 01-09-2010 to 31-08-2011 for Mtech & Research Programme in Opto Electronics & Optical Communication 24. Member – PAC for the period 01-09-2010 to 31-08-2011 for MTech & Research Programme in Instrument Technology
2.	S. K. Koul	1) General Chair, International Microwave and Radio Frequency Conference (IMaRC-2013), New Delhi, India. 2) TPC Member Asia Pacific Microwave Conference,

		Yokohama, Japan (2010). 3) Reviewer for EuMC-2011, ISAP-2011 and COMCAS-2011. 4) Elected Administrative Committee Member (AdCom), IEEE, Microwave Theory and Techniques Society, USA, 2010-2015. 5) Member MTT-6 Technical committee on Millimeter wave Integrated Circuits, Microwave Theory and Techniques Society, USA, Since 2010. 6) Member MTT-21 Technical committee on Radio Frequency MEMS, IEEE, Microwave Theory and Techniques Society, USA, Since 2010. 7) Member India Initiative team, IEEE, Microwave Theory and Techniques Society, USA, Since 2010. 8) IEEE Distinguished Speaker Bureau lecturer, IEEE, Microwave Theory and Techniques Society, USA, Since 2010. 9) Vice Chair of Membership and Geographical Activities, IEEE, Microwave Theory and Techniques Society, USA, Since 2011. 10) Vice Co-coordinator Asia Pacific Region R-10, IEEE, Microwave Theory and Techniques Society, USA, Since 2010. 11) Chairman, IEEE Microwave Theory and Techniques Chapter, Delhi Section, 2008-2011. 12) Chairman, IEEE Electron Devices and Microwave Theory and Techniques joint Chapter, India Council, 1988,1989,1992, 13) 1993,1994,1995 14) Chairman Fellow and awards nomination committee, IEEE Delhi Section, 2010. 15) IEEE MTT-S representative, Society Partnership Group (SPG) under the IEEE/UN Foundation Humanitarian Technology Challenge, 2010. 16) International Steering Committee Member, Asia Pacific Microwave Conference, Since 2007. 17) Editor-in-Chief, IETE Journal of Research, Since

		2008. 18) Honorary editor- IETE Journal of Research, 2006-2008. 19) Honorary editor-Electro-magnetics, IETE Journal of Research,2000-2006. 20) General Advisory Committee Member, Micro and Nano Technology Foundation (MANCEF), USA, Since 2002. 21) Chief Delegate Representing India, Micro-machined Summit Consortium Europe, Since 2004. 22) Member Editorial Board, Microwave & Optical Technology Letters, John Wiley, USA, Since 2000. 23) Member Editorial Board, International Journal of RF and Microwave Computer-Aided Engineering, John Wiley, USA,2005-2008. 24) Associate Editor, International Journal of Microwave and Wireless Technologies, since 2011. 25) Technical Programme Committee Member, National Conference on RF and Baseband Systems for Wireless Applications, Thiagarajar College of Engineering, Madurai, 2005. 26) National Advisory Committee member, International Microwave Conference on Microwaves and Optoelectronics (ICMO-2007), Aurangabad, 2007. 27) Advisory Committee Member, International Symposium on Microwaves-2008, Bangalore, 2008. 28) Advisory Committee Member, IETE Conference on RF and Wireless (ICON RFW-08),Bangalore , 2008 29) National Advisory Committee member, Recent Advances in Electronic, Telecommunication and Computing Control Technologies, NCET-CCT 2010, Jaipur, India. 30) National Advisory Committee member, IEEE

		National Conference on Advanced Communication Technologies and Applications, NCACA-2009, Udaipur, India. 31) National Advisory Committee member, International Microwave Conference on Microwaves and Optoelectronics (ICMO-2007), Aurangabad, India ,2007.
3.	R. Bahl	1) Member, Ocean Acoustics Panel, NIOT, Chennai. (visited 7 Aug 2013). 2) Member, Committee on Faculty Affairs (up to Nov 2013). 3) TPC member, **International Conference on Signal Processing and Communication**, JIIT Noida, Dec 12-14, 2013 4) Vice Chairman, National Organizing Committee for UT Workshop 2013. 5) Member, Advisory Committee SYMPOL 2013 6) Member, Technical Program Committee SYMPOL 2013 7) Chairman, EWC: 01 Sept 13 - 31 Aug 14 8) IITD Rep at CENJOWS Defence-Academia meeting in ICT area, 25 Sept 2013 9) Member: Institute Committee for qualifying service of Dr KD Sharma 10) Member, Computer users' Committee, 01 Sept 2013 - 31 Aug 2014 11) Expert: IITD-IPR Standing Committee, 90th meeting 26 Dec 2013. 12) Member, Committee on Faculty Affairs. 13) Vice Chairman, IEEE OES India Chapter, Year 2012. 14) Member, Assessment committee for confirmation of faculty of Physics Dept, Jan 2013. 15) Member, International Advisory Board UT'13 International Symposium on Underwater Technology, March 5-8, 2013, Tokyo. 16) Member, Institute Assessment Committee for HAG Scale, June 2013. 17) Vice Chairman, National Organizing Committee for UT Workshop 2013. 18) Member, Ocean Acoustics Panel, NIOT, Chennai
4.	Arun Kumar	1) Member, Technical Program Committee of Intl. Symposium on Ocean Electronics, SYMPOL, 2013. 2) Member, Technical Program Committee of International Conference on Signal Processing, Communication and Control, held at Jaypee University of Information Technology, Waknaghat,

		between 15th and 17th March 2012. 3) Advisor for project on the development of auditory screening device for infants under the Stanford India Biodesign Program between Stanford University Medical School, AIIMS, and IIT Delhi. 4) Member of IIT Delhi delegation to explore the feasibility of setting up of IIT-like institute in Mauritius at the invitation of the Mauritian government. A feasibility report was prepared upon return that has since been accepted by the Mauritius government for implementation with IIT Delhi's assistance. 5) Reviewer of project proposals submitted for TePP (Technoprenurship Promotion Program) funding to DSIR, Ministry of Science and Technology. 6) Member, Underwater Research Advisory Committee (UWRAC). UWRAC is a committee consisting of CARE faculty members in the Underwater Electronics / Signal Processing area, and Naval Officers of concerned Directorates, to co-ordinate R&D requirements of Indian Navy in Underwater Electronics. 7) Member of Peer Review Committee of Integrated Sonar Suite (ISS) for Indian Naval Ships being developed by NPOL, DRDO, Kochi. 8) Member, Assessment Board, DRDO and DIT-MCIT. 9) Member, Executive Committee of IEEE Oceanic Engineering Society, India Chapter. 10) Member of the Progress Monitoring Committee of Virtual Labs Projects in Electronics and Communications for about 15 projects being executed by different Institutions, 2011-2013. 11) Reviewer of paper manuscripts submitted to the following: i) National Conference on Communications, (several years), ii) Defence Science Journal, iii) Applied Acoustics, Elsevier, iv) IEEE Intl. Conf. on Communications (ICC), v) IEEE Intl. Conf. on Signal Processing & Communications (SPCOM), vi) IEEE Intl. Conf. on Signal Processing, vii) Communications & Control (ISPCC), IEEE Transactions on Audio, Speech and Language Processing, vii) Pattern Recognition and Machine Intelligence. 12) Chaired Technical Paper presentation sessions in the following: i) National Workshop on Underwater Acoustics, Bangalore, May 2013, ii) Intl. Symposium on Underwater Technology, Tokyo, March 2013. 13) Editor for Communications area for the IETE Journal of Research since 2008. 14) Member of Advisory Committee of FITT. 15) Member of the Program Executive Committee of

		VDTT M.Tech Program of IIT Delhi. 16) Technical Expert in IITD – IPR Standing Committee Meetings for evaluation of patent applications for submission.

6.4. Contribution to national development goals

(a) Projects undertaken and their outcome.

The contribution of CARE to national development goals, in particular, in strategic electronics related to Microwaves and Underwater Electronics is acknowledged externally.

i) The book "Power to Firepower – An Illustrated History of the Electrical Branch" to commemorate 50 years of the Electrical Branch of the Navy in 2007 mentions CARE IIT Delhi's contribution in developing indigenous underwater electronics technologies.

ii) Former President Abdul Kalam states in his book "Wings of Fire" (1999) that "In yet another example of creating a synergy of scientific talent, Prof. Bharati Bhatt of IIT Delhi, working with the Solid Physics Laboratory (SPL) and Central Electronics Limited (CEL), broke the monopoly of the western countries by developing ferrite phase shifters for use in the multi-function, multi-tasking 3-D Phased Array Radar for surveillance, tracking and guidance of Akash."

iii) A weekly TV series "A Question of Science" is being telecast from 8th January 2014 on Doordarshan National Network at 9 am every Wednesday. The first episode of the series on 8th January was - Acoustics Technology in Conservation of Ganges River Dolphin. This program shows how Sonar technology for Naval applications pioneered at CARE has been adapted for passive acoustic surveillance of blind Ganges River dolphins with the aim to help in conservation of this National Aquatic Mammal. This program explains in a layman's way how the technology has been deployed and highlights the successful inter-disciplinary collaboration between technologists of IIT Delhi and University of Tokyo, with field assistance provided by biologists of WWF-India.

S. No.	Area	Description
1.	Microwaves	**1.** Development of toroidal phase shifter with integrated driver for phased arrays at X-band," from *Directorate of Training and Sponsored Research, DRDO,* Rs. 18.34 Lakhs, 1979-1985. (S.K.Koul, B. Bhat and D. T. Shahani) **2.** Development and performance evaluation of batch produced toroidal phase shifters with integrated drivers, from *Directorate of Training and Sponsored Research, DRDO,* Rs. 16.30 Lakhs, 1981-1985. (S.K.Koul, B. Bhat and D. T. Shahani)

		3. Development of X-band twin-toroid phase shifter, *from Directorate of Training and Sponsored Research, DRDO,* Rs. 56.75 Lakhs, 1989-1994. (S.K.Koul, B.Bhat) **4.** Development of C-band dual-mode reciprocal ferrite phase shifter, *from Directorate of Training and Sponsored Research, DRDO,* Rs. 28.82 Lakhs, 1984-1989. (S.K.Koul, B.Bhat and R.K.Mongia) **5.** Development of a laboratory model of dual -mode ferrite phase shifter for airborne applications, from *Directorate of Training and Sponsored Research, DRDO,* Rs. 35.32 Lakhs, 1982-1988. (S.K.Koul, B.Bhat and R.K.Mongia) [Complete technology of toroidal phase shifter, twin-toroid phase shifter and dual mode phase shifters at C- and X-bands was developed under the Projects listed at S.Nos. 1-5. This technology was transferred to Central Electronics Limited in Sahibabad, UP for production and supply to DRDO for phased array program. This technology development has made the country self reliant in developing indigenous phased array- Rajendra Radar]. **6.** Millimeter wave integrated circuit technology with applications to radar and communications from *Directorate of Training and Sponsored Research, DRDO*, Rs. 17.60 Lakhs, 1979-1985. (S.K.Koul, B.Bhat) **7.** Adaptable microwave and millimeter wave receiver components using suspended substrate planar technology, from *Directorate of Training and Sponsored Research, DRDO,* Rs. 37.763 Lakhs, 1995 –1998. (S.K.Koul, B.Bhat) **8.** Development of millimeter wave integrated circuit components for Ka-band, from *Directorate of Training and Sponsored Research, DRDO,* Rs. 76.67 Lakhs, 1990-1994. (S.K.Koul, B.Bhat) **9.** Development of Millimeter Wave Components using Dielectric Integrated Guides, from *Directorate of Training and Sponsored Research, DRDO,* Rs. 61.71 Lakhs, 1999–2003. (S.K.Koul, B.Bhat and Ananjan Basu) [Under the projects listed at S. No's 6-9, we

		developed complete technology of fabricating millimeter wave receiver components first time in the country. This technology was transferred to DRDO for their missile program. This technology development has made the country self reliant in developing millimeter wave components and subsystems for indigenous missile systems- AKASH and NAG] **10.** Millimeter Wave Antenna Using MEMS, from *Aeronautical Development Establishment, Bangalore,* Rs. 11.5 Lakhs, 2002-2003. (S.K.Koul, Ananjan Basu) **11.** Design and Development of MEMS based Millimeter wave Active Antenna, from *Aeronautical Development Establishment, Bangalore,* Rs. 22.425 Lakhs, 2003-2004. (S.K.Koul, Ananjan Basu) **12.** Design and Fabrication of 8x8 Array of Micro-machined Patch Antenna and Development of Fabrication Technology Compatible with MEMS Foundry at SCL, from *Aeronautical Development Establishment, Bangalore,* Rs. 15.41 Lakhs, 2004-2005. (S.K.Koul,Ananjan Basu) **13.** Design & fabrication of 2x2-element Active Antenna Array, from *Aeronautical Development Establishment, Bangalore,* Rs. 11.16 Lakhs, 2005-2006. (S.K.Koul, Ananjan Basu) **14.** National MEMS Resource Centre at IIT Delhi, *from National Programme on Micro and Smart Systems (NPMASS), Bangalore*, Rs 49.889 Lakhs, 2009-2014. (S.K.Koul) **15.** RF, Microwave and Millimeter Wave MEMS Characterization, *from National Programme on Micro and Smart Systems (NPMASS), Bangalore*, Rs 485.10 Lakhs, 2009-2013. (S.K.Koul, Suneet Tuli, Sudhir Chandra, Ananjan Basu and M. Abegaonkar) [Under the projects listed at S. No's 10-15, we developed complete technology of designing and fabricating high performance components and antenna systems using Micromachining Technology. We also established National MEMS design Centre and state-of-the art Characterization facilities in CARE for MEMS device characterization. Several high performance components have been developed and technology given to DRDO

		laboratories as part of the projects. This was the first initiative in the country to develop novel microwave and millimeter wave devices and subsystems utilizing MEMS technology] **16.** Feasibility Study of RF MEMS Phase Shifter, *from Research Center Imarat, Hyderabad,* Rs. 10.00 Lakhs, 2003-2004. (S.K.Koul) **17.** Design and Development of MEMS Antenna 2X2 Sub-array, *from Solid State Physics Laboratory, Delhi,* Rs. 4.75 Lakhs, 2003-2004. (S.K.Koul) **18.** Design data on Discontinuities involved in Membrane Microstrip and Coplanar Lines, *from Solid State Physics Laboratory, Delhi,* Rs. 4.80 Lakhs, 2003-2004. (S.K.Koul) **19.** Feasibility Study on Applications of RF MEMS to Microwave Phase Shifters, *from Electronics & Radar Development Establishment (LRDE) Bangalore,* Rs. 8.20 Lakhs, 2003-2005. (S.K.Koul) **20.** Study of RF MEMS Phase Shifter and Switch using GaAs, *from Research Center Imarat, Hyderabad,* Rs. 9.00 Lakhs, 2005-2006. (S.K.Koul) **21.** Design, Simulation and Characterization of GaAs based Coplanar Structures and air bridges using GATECH Process, *from Research Center Imarat, Hyderabad,* Rs. 40.00 Lakhs, 2006-2008. (S.K.Koul) **22.** Design and Development of Unit Cell Model for a single bit phase shifter using measured data from GAETE, *from Research Center Imarat, Hyderabad,* Rs. 10.00 Lakhs, 2008-2009. (S.K.Koul) **23.** Design of RF MEMS Switches, SPST Shunt Switch, SPST Series Switch, Phase Shifter, Tunable Filter from industry*,* Rs. 211.9015 Lakhs, 2011 -2014. (S.K.Koul) **24.** Design and Development of MEMS based Phase Shifter and SPDT Switch-A Joint Project proposal, *from National Programme on Micro and Smart Systems (NPMASS), Bangalore,* Rs. 224.39 Lakhs, 2009-2014. (S.K.Koul) **25.** Design and Characterization of SPST Shunt Switch, SPST Series Switch and SPDT Switch (PH-II), *from industry,* Rs. 114.80 Lakhs, 2012 -2013. (S.K.Koul)

		[Under the projects listed at S. No's 16-32, starting from the feasibility study; we developed complete process and technology of novel MEMS components for strategic applications. We demonstrated the first working RF MEMS switch on GaAs utilizing indigenous foundry GATECH. Next, we worked closely with DRDO laboratories and Industry to develop fully packaged RF MEMS components for Transmit/ Receive Module Systems required for Defence applications. Several high performance components that include RF MEMS switches, phase shifters and tunable filters have been demonstrated. We have recently supplied 400 such units in packaged form to M/S Astra Microwave Products Limited for use in building indigenous Transmit/Receive Module for DRDO. The work carried out for more than 1 decade has made country self reliant in the strategic are of RF MEMS]. **26.** Development of Software for Designing Filters in Suspended Stripline and Fin-line", *from Defence Electronics Applications Laboratory, Dehradun,* Rs. 4.00 Lakhs, 2003. (S.K.Koul, Ananjan Basu) **27.** Development of Software Packages, CAD Data and Hardware for LNA, DRO, and VCO: Phase-I, II, III, *from Defence Electronics Application Laboratory, Dehradun,* Rs. 24.2 Lakhs, 2001-2003. (S.K.Koul, Ananjan Basu) **28.** Design of Suspended Stripline Based Components at 140 GHz, *from Defence Electronics Application Laboratory, Dehradun,* Rs. 33.06 Lakhs, 2006-2008. (S.K.Koul) [Under the projects listed at S. No's 33-35, we developed indigenous technology for designing and fabricating Low noise amplifiers, Dielectric resonator oscillator and Voltage controlled oscillator for a strategic DRDO project. 10 units of each component at 35 GHz were delivered to DEAL Dehradun as part of the technology development project. In addition to this, design and development of novel components for indigenous imaging radar at 140 GHz were also developed and technology transferred to DEAL. Technology at these frequencies is unavailable due to application in strategic areas.]

		29. Design and Development of 18-40 GHz Double balanced Mixer, *from Defence Electronics Research Lab., Hyderabad*, Rs 10.0 Lakhs, 2008-2009. (S.K.Koul, Ananjan Basu) **30.** Design and Development of 18-26.5 GHz Mixer, *from Defence Electronics Research Lab., Hyderabad*, Rs 10.0 Lakhs, 2008-2009. (S.K.Koul, Ananjan Basu) **31.** Design and Development of 26.5-40 GHz Mixer, *from Defence Electronics Research Lab., Hyderabad*, Rs 10.0 Lakhs, 2008-2009. (S.K.Koul, Ananjan Basu) **32.** Design and Development of a Programmable Attenuator in the 18-40 GHz band, *from Defence Electronics Research Lab., Hyderabad*, Rs 10.0 Lakhs, 2008-2009. (S.K.Koul and M. P. Abegaonkar) **33.** Modeling of Suspended Stripline Discontinuities at Millimeter Wave Frequency, *from Defence Electronics Research Lab., Hyderabad*, Rs 8.0 Lakhs, 2008-2009. (S.K.Koul and M. P. Abegaonkar) **34.** Thermal Modeling of Switches and Power Module, *from Defence Electronics Research Lab., Hyderabad*, Rs 8.0 Lakhs, 2008-2009. (S.K.Koul) [Under the projects listed at S. No's 36-41, we developed indigenous technology for designing and fabricating components operating over wider frequency bands centered at millimeter wave frequencies. Such components are extremely useful in building Electronic Warfare (EW) systems. Several high performance components operating over frequency band 18-40 GHz for indigenous EW systems were developed and technology transferred to DLRL. Technology at these frequencies is unavailable due to application in strategic areas.] **35.** Design and Development of Antenna Array with 8 elements (elevation) x 16 elements (azimuth)", *from Centre for Airborne Studies, Bangalore*, Rs 9.5 Lakhs, 2006-2007. (S.K.Koul, Ananjan Basu, M. P. Abegaonkar) **36.** Design and Development of a Scanning Array of Efficient Radiating Elements to be Integrated with High Power Phase Shifter, *from Electronics & Radar*

		Development Establishment (LRDE) Bangalore, Rs. 10.0 Lakhs, 2007-2009. (S.K.Koul) **37.** Design and Development of a High Power Phase Shifter, *from Electronics & Radar Development Establishment (LRDE) Bangalore,* Rs. 10.0 Lakhs, 2007-2009. (S.K.Koul) [Under the projects listed at S. No's 42-44, we carried out design and development of high power phase shifter including efficient integrated antenna for indigenous radar system being developed by LRDE Bangalore. In addition, we did design and development of a scaled model of antenna array with 8 elements (elevation) x 16 elements (azimuth). The results are currently being used by CABS in complete AWACS system development] **38.** Technology Development cum Transfer Project on Microwave Integrated Circuits Kit *from Scientific Instruments Co. Ltd, Sahibabad,* Rs. 5.00 Lakhs, 2004-2005. (S.K.Koul) **39.** Technology Development of Antenna Trainer Kit Phase-I, II and III *from Scientific Instruments Co. Ltd,* Rs. 7.50 Lakhs, 2005-2006. (S.K.Koul, Ananjan Basu) **40.** Technology Development of C-band Source and Detector from *Scientific Instruments Co. Ltd, Sahibabad,* Rs. 3.50 Lakhs, 2005-2006. (S.K.Koul , Ananjan Basu) **41.** Design and Development of active Microwave Integrated Circuit Trainer Kit, *from Scientific Instruments Co. Ltd, Sahibabad,* Rs. 5.00 Lakhs, 2008-2010. (S.K.Koul) **42.** Computer Aided Design of Components at Microwave Frequencies, from *Scientific Instruments Co. Ltd, Sahibabad,* Rs. 5.00 Lakhs, 2008-2010.(S.K.Koul, M.P. Abegaonkar, Ananjan Basu) **43.** Development of Practical Oriented Teaching Manual and set of MIC devices, *from Meera Agencies Private Limited, Gurgaon* , Rs 1.95 Lakhs, 2011. (S.K.Koul) **44.** Development of Practical Oriented Laboratory Manual for Agilent Model N 9923-A handheld

Network Analyzer (6 GHz) along with a set of 10 devices (PH-1), *from Agilent Technologies Private Limited*, Rs 2.75 Lakhs, 2011-2012. (S.K.Koul)

45. Design and Development of MIC and Antenna Trainer Kit at J-Band, *from Microwave Technologies Incorporated, Ghaziabad,* Rs 5.0 Lakhs, 2011-2012. (S.K.Koul)

46. RF Kit Consisting of 10 devices including Manual for N99230A handheld Network Analyzer (PH-III), *from Agilent Technologies Private Limited* , Rs 5.0 Lakhs, 2013-2014. (S.K.Koul)

47. RF Kit consisting of 10 devices including Manual for N99230A handheld Network Analyzer (PH-II), *from Agilent Technologies Private Limited* Rs 10.0 Lakhs, 2013. (S.K.Koul)

[Under the projects listed at S. No's 45-54, we developed low cost trainer kits for imparting practical education to students and faculty in the area of RF and Microwave Engineering. Technology of these kits has been transferred to several industries and more than 500 Kits are already in use in various Engineering Institutes throughout the country].

48. Setting up of RF Characterization Laboratory and Development of Microwave Integrated Circuit Components, *from Techno India NJR Institute of Technology, Udaipur*, Rs 15.90 Lakhs, 2011-2012. (S.K.Koul)

49. Development of RF Components and Setting up of RF Laboratory, *from IET, Alwar*, Rs 14.95 Lakhs, 2009-2010. (S.K.Koul)

50. Development of RF Components and Setting up of RF Laboratory, *from GITS, Udaipur*, Rs 14.95 Lakhs, 2009-2010. (S.K.Koul)

[Setting up of RF and Microwave Laboratory is very expensive using standard fabrication and test equipment. This is one of the reasons why RF and Microwave Engineering area is not popular at undergraduate level in various Engineering Institutes. Under the projects listed at S.No's 55-57, we set up low cost laboratories for imparting practical training to students at select institutes. These laboratories are currently being used to

		impart practical education to students and faculty in the area of RF and Microwave Engineering]
2.	Signal Processing	1. 16-pt FFT Processor for Pulse Doppler Radar applications, Underwater Data Telemetry Link, 1970s. 2. Axle Counter for Railway Signaling, 1970s, 3. DLMS: Light Beam Stabilization System to assist landing on Aircraft Carrier: Installed on INS Vikrant during 1980's 4. ODS: Technology developed: Omni-Directional Sonar for submarine detection. Knowhow transferred to KELTRON, 1986, 5. HRS: Technology developed for High Resolution Sonar for underwater imaging, 1987. 6. SOBID: Multi-beam Imaging Robotic Sonar for automatic target detection, classification and parameter estimation by torpedo. Prototype delivered to NSTL, 1999. 7. MSK Modem: Developed prototype for VLF communication modem and handed over to DEAL, 1986. 8. Collaborative project with Univ of Tokyo for long-term underwater acoustic monitoring of Ganges dolphin, India's National Aquatic Animal: in progress since 2009. 9. Method and Software for Development, implementation, and performance comparison of estimation methods for bearings-only tracking. The software is used to track the motion parameters of a non-maneuvering radiating underwater target such as ships and submarines from their bearings measurements. Delivered to Weapons and System Engineering Establishment (WESEE), Ministry of Defence, in Sept 2012. 10. Method and Software for GMSK Modulation, Impulse Noise Suppression and LDPC Coding for VLF Communication, to DEAL, DRDO, Dehradun, for up-gradation of Indian Navy's VLF Communication System. The data rates have been increased from the existing 200 bps to 400, 600 and 800 bps, 2012.

		11. Compact Low-power Digital Signal Processing hardware, handed over to Directorate of Weapons Equipment, Indian Navy, 2012. 12. UDA – Software for underwater domain awareness – Prediction of detection ranges for own passive sonar for active emissions of enemy sonars using ray models, to WESEE, MoD, New Delhi, 2011. 13. RAS – Real-time Audio Simulator for Generation of Acoustic Signatures of Ships and Submarines across a Time-Varying Bounded Underwater Channel, to WESEE, Ministry of Defence, New Delhi, 2011. 14. Real-time DSP software for detection of underwater targets using passive sonar, to Directorate of Weapons Equipment, Indian Navy, 2010. 15. Signal Enhancement and Analysis Software: Software for the enhancement of ship's radiated signal and its analysis for finding quadratic phase coupling between tonal frequencies and estimating its coupling strength. The software was installed at the Underwater Ranges, Goa, and was also submitted to NSTL Vishakhapatnam, 2008. 16. PASCAL (Passive Sonar Classification): Method and software developed for underwater target classification, based on propulsion type, using passive sonar. The technology transfer was done to the Ministry of Defence, in May 2006. A feasibility study for integration of the Classifier on submarine platform was also done, 2006. 17. ARGUS: Method and software for platform classification using multiple sensor data and data fusion. Technology transfer to the Ministry of Defence, New Delhi, in September 2006. 18. Statistical Scenario Analysis (SSA) Software Package: An algorithm has been designed in detail for statistical modeling of the motion of entities (source and target ships, torpedoes etc.) in the ocean, and evaluating the probability of hit between entities in war-gaming scenarios. The SSA software generates probabilistic models of motion dynamics of various entities, and computes the probability of hit between various entities under different scenario hypothesis (maneuvers etc). The SSA forms the core engine of GUI based software

		developed by Macmet Technologies Ltd. for simulating war-game requirements of the Navy. The corresponding software was licensed to Macmet Technologies Ltd., Bangalore, in 2006. 19. Design and Software Simulator for Underwater Local Area Network Protocols for (a) Ship-to-ship communications, and (b) Underwater Buoy Network Communication. The technology was transferred to the Directorate of Weapons Equipment - Naval Headquarters, in Nov. 2002. 20. Developed nation's first ***CAD Software Package for High-Resolution Imaging Sonars*** that simulates acoustic images of 3-D scenarios, and a ***SAR Simulation Tool, 1995.***
2.	Microelectronics	1. IIT Delhi (CARE) is a partner of a consortium consisting of BITS, Pilani K K Birla Campus-Goa, National Dairy Research Institute NDRI) and Punjabi University Patiala who are jointly and collectively working on a **National Agriculture Innovation Project (NAIP), Indian Council of Agriculture Research** to develop technologies for testing of milk for trace amount of pesticides, toxins, heavy metals and bacterial contamination. India is the largest milk manufacturing country in the World. Recently established Food Safety and Standard Authority of India (FSSAI) This is a World Bank funded / monitored project The Microelectronics Group, CARE has played a critical role in developing microfluidic based devices-chips using Microelectronics and MEMS technologies for the partners for use in developing the relevant sensors. Several Indian and International Patent applications have been filed and the technology is validated on thousands of milk samples in the Lab environment. A complete prototype system consisting of sensor array chip (made at IIT Delhi) incorporating self assembled monolayers (developed at BITS Goa), optical readout hardware etc. is functional and a more professional unit is being developed through involvement of a private sector manufacturing Co. This system when developed and tested fully is likely to be used at Referral Lab for milk testing being set up at NDRI Karnal. A field portable device is also under development (patent has been filed) for use at milk collection centres for quick screening of milk samples for toxins.

(b) **Policy inputs- implications, visible impacts on society.**

NIL.

(c) **Entrepreneurship development.**

S. No.	Faculty	Description
1.	S. Chandra	Two small-scale industries have benefitted from interactions for developing low-cost components / equipments for use in Microfabrication Laboratory especially for Institutions and Colleges.
2.	Ananjan Basu	One graduate of IIT Delhi worked on the training kits developed and transferred to SICO. This got him interested in the field of RF and microwave, and he now runs his own successful company (Apexplus Technologies) developing RF sub-systems.
3.	S. K. Koul	I did motivate students (Hitesh Harnal (UG-2007), Abhishesk Kumbhat (MS(R)-2004) and Balamurali Bhat (M.Tech-2007) to start a company in the area of RF. The company was launched but did not kickstart.

6.5. Alumni engagement

(a) **Regular interactions/ engagement with alumni and outcomes.**

S. No.	Faculty	Description
1.	Karun Rawat	Working with Gowrish B., M.Tech pass-out 2013, who is currently working in Cypress Semiconductor Technologies India Pvt. Ltd., Bangalore. The main engagement is in terms of brain storming and technical paper writing related to the industrial problem of Cyprus semiconductors ltd.
2.	Ananjan Basu	1. Shashank Mutha (B.Tech ,TT, IITD) – started his own company (Apexplus), and I have been informally giving him advice on microwave components for the last ~2 years.
3.	S. K. Koul	I have been regularly interacting with some alumni. The outcome has been joint R&D work with Synergy Microwave USA, GATECH Hyderabad and Cypress, India. The outcome of these interactions has resulted in joint publications and currently we are in the process of filing joint patent applications.
4.	-	Mithilesh Kumar (Ph.D, CARE) – Deeply involved in IEEE-MTTS Delhi Chapter activities.

5.	-	Vikas Sharma (B.Tech, ME, IITD) – Runs his own Software Company, and is involved with a number of on-going research projects at IIT Delhi. A software for microwave imaging has been developed by him as part of an on-going research project.

(b) **Contribution from alumni.**

S. No.	Name	Description
1.	Ajay Poddar (PG-1997)	Has been supplying microwave devices, connectors, substrates and books to the RF and Microwave Group for student use since 1998.
2.	Hitesh Harnal (UG-2007)	Contributed US$ 5000.00 as travel grant for M.Tech, MS® and Ph.D students enrolled in RF and Microwave Area.

6.6. Recognitions and Awards

(a) **Award to faculty.**

S. No.	Faculty	Description
1.	R. Bahl	1. Commendation Medal by the Chief of Naval Staff, 2006. 2. NRDC Meritorious Invention Award, 1982. 3. Senior Research Associateship Award of the US Academy of Sciences, National Research Council.
2.	S. K. Koul	1. **IEEE MTT-S Distinguished Educator Award-2014**, IEEE, USA,2014, for Outstanding Achievements as an Educator, Mentor, and Role Model of Microwave Engineers and Engineering Students. 2. **M.N.Saha Memorial Award-2013**, Institution of Electronics and Telecommunication Engineering, Delhi, **2013,** for the best application oriented paper. [Jointly with A.Sanyal, A.Basu and M.Abegaonkar] 3. **Award for Special recognition of Contributions** made to the growth of Smart

		Materials Technology, **2012**, by the Institute of Smart Materials and Systems (ISSS) Bangalore. 4. **Excellence in Teaching Award** , Indian Institute of Technology Delhi, **2012**, for the course CRL-713 taught in 1st semester 2011-12. 5. **Shiksha Ratan Puraskar**, India International Friendship Society, New Delhi, **2011**- for meritorious services, outstanding performance and remarkable role. 6. **Shri Om Prakash Bhasin Award**, Om Prakash Bhasin Foundation, New Delhi, **2009** - for contributions to the field of Electronics and Information Technology. 7. **Certificate of Appreciation**, Institution of Electrical and Electronics Engineering (IEEE), USA, **2008-2010**- for notable services and contributions towards advancement of IEEE and its Engineering Professions. 8. **DRDO Award for Academic Excellence-1998**, Defence Research and Development organization (DRDO), **1999** - for pioneering and outstanding contributions in design and development of phase control modules for Rajendra Radars. [Jointly with B. Bhat] 9. **18th Ram Lal Wadhwa Gold Medal -1995,** Institution of Electronics and Telecommunication Engineers (IETE), **1996 -** for outstanding contributions in the field of electronics and Telecommunication engineering during the last 10 years. 10. **Vasavik Industrial Research Award-1994,** Vividhlaxi Audyogik Samshodhan Vikas Kendra**, 2001**- for Development of Ka-band millimeter wave components and Ferrite Phase shifters for Defense applications. [Jointly with B. Bhat] 11. **Certificate of Appreciation**- Institution of Electrical and Electronics Engineering

		(IEEE), USA, **1995**- for contributions made as Chapter Chairman-India. 12. **Certificate of Appreciation**- Institution of Electrical and Electronics Engineering (IEEE), USA, **1994**- for contributions made as Chapter Chairman-India. 13. **Certificate of Recognition**- Institution of Electrical and Electronics Engineering (IEEE), USA, **1993**- for contributions made as Chapter Chairman-India. 14. **Certificate of Recognition**- Institution of Electrical and Electronics Engineering (IEEE), USA, **1992**- for contributions made as Chapter Chairman-India. 15. **Certificate of Recognition**- Institution of Electrical and Electronics Engineering (IEEE), USA, **1991**- for contributions made as Chapter Chairman-India. 16. **NRDC Invention Award-** National Research Development Corporation (NRDC), New Delhi, **1991**, for the Development of Ferrite Phase shifter technology: (a) Non-reciprocal toroidal phase shifter and (b) Reciprocal dual mode phase shifter. [Jointly with B. Bhat] 17. **Certificate Recognizing Valued Services and Contributions** - Institution of Electrical and Electronics Engineering (IEEE), USA, **1988-89**- for contributions made as Chapter Chairman-India. 18. **Certificate of Recognition**- Institution of Electrical and Electronics Engineering (IEEE), USA, **1987-88**- for contributions made as Chapter Chairman-India. 19. **INSA Medal for Young Scientists-1986**, Indian National Science Academy (INSA), New Delhi, **1987**, for innovative analysis of microstrip-like transmission lines. 20. **URSI Young Scientist Award -1987**, International Union of Radio Science (URSI), New Delhi, **1987**, Award Presented during

		the general Assembly of International Union of Radio Science held in Tel Aviv, Israel. 21. **S.K.Mitra Memorial Award-1986**, Institution of Electronics and Telecommunication Engineering, Delhi, **1988,** for the best research oriented paper. Jointly with B. Bhat] 22. **Consolation Postgraduate Prize**, The Institution of Electrical Electronics Engineers, Inc., **1981**, for the paper " Low loss structures for microwave and millimeter wave Integrated circuit application" 23. **Institution Gold Medal**, Institution of Engineers India, **1976**, for securing highest marks amongst all branches in Engineering
3.	Monika Agarwal	1. URSI Young Scientist Award. 2. INAE Young Engineer Award.
4.	S. Chandra	1. Excellence in Teaching Award, 2011.
5.	Mahesh Abegaonkar	1. Indian National Academy of Engineering INAE Young Associate, 2013. 2. IETE – M N Saha Memorial Award for Best Application Oriented Paper. (*A Planar End-fire Array in S-band for Airborne Applications – Abhijit Sanyal, S.K. Koul, Ananjan Basu, Mahesh Abegaonkar, Suma Varughese, P.B. Venkatesh Rao*). 2013 3. YOUNG ENGINEER AWARD IN THE FIELD OF RF & MICROWAVE ENGINEERING, Indian National Academy of Engineering (INAE), 2008. 4. Short-listed for Asia-Pacific Microwave Conference (APMC) 2008 Prize at the APMC2008, Hong Kong, 16-19 Dec. 2008. 5. Received Best Paper from IEEE MTT/ED India Chapter at the International Conference on Microwaves and Optoelectronics (ICMO), held at Aurangabad (India) during 17-20 Dec. 2007. 6. Post-Doc Fellowship under Brain-Korea 21 Program (Govt. of Republic of Korea): May 2002 – Jan 2005. 7. Senior Research Fellow: Council of Scientific and Industrial Research (CSIR), Govt. of India.1998-2001. 8. Received Consolation Prize at 7th National Seminar on Physics and Technology of Sensors (NSPTS-7), for Best Industry Oriented Research

		Work, 2000. 9. Received Consolation Prize for Best Poster in "Susamwad": A Research Students Seminar, held on the occasion of Golden Jubilee of Pune University, in Physical Sciences Group, Nov. 1998. 10. Late Prof. M.R. Bhiday Award for Best Industry Oriented Research work, presented at Raman Memorial Conference'97, held at Pune University in 1997.
6.	Arun Kumar	1. Young Scientist Award of Intl. Union of Radio Science, 2002.
7.	Vikram Kumar	1. ISA Technomentor Award, 2011. 2. MRSI Distinguished Materials Scientist of the Year Award, 2012

(b) **Fellows of academies, INAE, etc.**

S. No.	Faculty	Description
1.	S. K. Koul	**1. Fellow IEEE**, Institution of Electrical and Electronics Engineering (IEEE), USA, **2010 -** for contributions to analysis and design of Microwave and millimeter wave components and circuits. **2. Fellow INAE**, Indian National Academy of Engineering, **1994.** **3. Fellow IETE**, The Institution of Electronics and Telecommunication Engineers, **1991**
1.	R. Bahl	1. Fellow, IETE.

7. Governance

7.1. Governance

(a) Organization structure- their autonomy/ terms of reference.

The Centre is structured into three groups according to areas of academic specialization. The number of regular faculty members in each group is indicated in brackets along-side.

1. Signal Processing (3).
2. Microwaves (4).
3. Microelectronics (3).

There is a Group In-charge for each group. The groups are responsible for:

i) Formulation of teaching courses in the respective areas, and assignment of Instructors for teaching the courses every semester.
ii) Infrastructure development and maintenance of laboratories in the respective areas.
iii) Formulation of the group's vision for academic and sponsored research, training activities, creation of facilities and new faculty recruitment and realization of the same.

(b) Planning documents developed by the department - space, faculty, staff related.

The following documents have been developed. These are attached in Annexures 8 and 9.

1. Space utilization document **(Annexure – 8).**
2. Centre's vision document **(Annexure – 9).**

The vision document is comprehensive and articulates the new faculty requirements in the different areas.

(c) Records of discussions within the department - internal documents (meeting minutes, position papers, discussion papers, concept papers, etc.)

The Minutes of Meetings of the following Committees of the Centre from September 2009 can be downloaded from the
http://care.iitd.ac.in/protected/Minutes_CFB_CRC_PFC.pdf

i) Centre's Faculty Board (CFB).
ii) Centre's Research Committee (CRC).
iii) Professorial Committee.

The discussions pertaining to the development of Centre's vision were held in CFB meetings.

(d) **Physical resources - percentage utilization for UG, PG core and electives teaching separately, UG and PG student projects, Ph.D. student research. Projection for future.**

CARE labs are used either exclusively for research purposes including PG projects and PhD research or for both research and teaching PG courses. There are no exclusive teaching laboratories. The total laboratory space in CARE is 13,858 sq. ft. consisting of 9695 sq. ft. of Research lab space (70%) and 4163 sq. ft. of Teaching lab space (30%). The teaching lab space has been calculated from the concerned labs based on 1:1 basis between teaching and research lab space.

(e) **Financial resources - (i) funds provided to the department, (ii) processes of distribution, (iii) funding for focus areas, (iv) funding for UG and PG core teaching laboratories. Outcomes of funds utilization, and effect on department strategy.**

i)

Year	**Funds provided by IIT (Rs.)**		**Funds generated by faculty through projects (Rs.)**
	Non-Plan	**Plan**	
2008-2009	6,06,000	23,66,000	
2009-2010	10,59,000	24,43,000	
2010-2011	9,00,000	32,00,000	
2011-2012	7,00,000	62,00,000	
2012-2013	9,00,000	1,49,50,000	
2013-2014	20,00,000	1,26,00,000	
Sub-total	61,65,000	4,17,59,000	
Total	**4,79,24,000**		**31,72,97,000**

From the above table, it can be seen that over the last 6 years, **87% of the funds have been generated through externally funded projects of faculty while 13% of the funds have been provided by IIT.** The facilities in CARE labs have been developed substantially from sponsored project funds.

ii) Funds are sought from IIT based on a review of requirements projected by faculty at the beginning of every financial year. The funds allocated by IIT are distributed proportionately to the three groups based on the projected requirements.

iii) The funding sought from IIT are for the focus areas of research of the Centre along with requirements for teaching laboratories.

iv) It is not feasible to separate the funding for teaching from that for research since there are no exclusive teaching labs in CARE. The facilities in the research labs are also used for teaching courses.

It is the constant endeavor of faculty to modernize the labs which is a continuous process. CARE labs provide state-of-the-art facilities for teaching and applied research.

(f) **Delegation of decision making within department/centre. List the processes and structures for financial and academic management and the methodology for their review.**

The Centre has 3 groups: Signal Processing, Microwaves, and Microelectronics. Academic and financial proposals are discussed in the respective groups and then considered for approval or recommendation in the Centre's Faculty Board or Centre's Research Committee.

7.2. Department management and operations

(a) **Organization structure - mandates, flexibility, etc.**

As mentioned in 7.1 (a), the Centre is structured into three groups according to areas of academic specialization.

a. Signal Processing.
b. Microwaves.
c. Microelectronics.

There is a Group In-charge for each group who is generally the senior-most person of the group. There is complete freedom for faculty to collaborate with other groups in the Centre / other departments / other institutions in pursuing their research and academic objectives.

(b) **Processes for curriculum planning.**

a. The Centre has one PG program of its own, namely the Radio Frequency Design and Technology (RFDT) M.Tech Program that was started in 2004. At that time, feedback for the course was taken from external experts from academia, industry and government labs.

b. New courses have been floated under the 3 Selected Topics in RFDT courses from time-to-time based on interest amongst significant number of students. The interest in new courses is discussed in the Class-Committee meeting with the students that is held in the middle of each semester.

c. CARE has undertaken an exercise for curriculum review of the RFDT M.Tech programme in 2010-11. The recommendations of the review committee are waiting to be put up for approval to the Institute after new guidelines on the structure of M.Tech programmes are formulated. Currently, an Institute-level exercise to restructure M.Tech programmes is on-going. It is expected that a new PG curricula shall be in place for the 2014-15 academic year.

(c) **Processes and methods for teaching resources management.**

Faculty of CARE teaches courses of RFDT M.Tech program. They also contribute to teaching UG and PG courses, mostly in the Electrical Engineering Department. Course allocation is done in the Centre's Faculty Board meeting every semester.

(d) **Guest faculty, affiliation for teaching core, elective UG & PG courses.**

There is no guest faculty involved in teaching CARE courses.

(e) **Faculty short-listing criteria.**

The faculty short-listing criteria of CARE are over and above the Institute minimum short-listing criteria. The consolidated faculty short-listing criteria is given below.

Short-listing criteria used by department/Centre/School
IIT Delhi, Department/Centre/School **Centre for Applied Research in Electronics**

Institute-level short-listing criteria for faculty positions:

MINIMUM SHORT-LISTING CRITERIA FOR AN ASSISTANT PROFESSOR:

1. Ph.D. with 3 years experience (excluding the experience gained while pursuing Ph.D.),
2. First class or equivalent grade in preceding degree in respective discipline, with a consistently good academic record,
3. Potential for very good teaching,
4. Maximum age is 35 years for male and 38years for female candidates (to be relaxed by 5 years in case of persons with physical disability, SC and ST), and
5. At least 4 refereed conference/journal papers (of which at least 2 should be in reputed journals).

MINIMUM SHORT-LISTING CRITERIA FOR AN ASSOCIATE PROFESSOR:

6. Ph.D. with 6 years experience (excluding the experience gained while pursuing Ph.D.) of which at least 3 years should be as Assistant Professor or equivalent,
7. First class or equivalent grade in preceding degree in respective discipline, with a consistently good academic record,
8. Should have demonstrated capability for good teaching,
9. At least 10 refereed conference/journal papers (of which at least 4 should be in reputed journals, out of which at least 2 in last 3 years), and
10. Completed at least one sponsored R&D or consulting project as a PI, or completed two sponsored R&D or consulting projects as a co-PI**.**

MINIMUM SHORT-LISTING CRITERIA FOR A PROFESSOR:

11. Ph.D. with 10 years experience (excluding the experience gained while pursuing Ph.D.) of which either.
    1. At least 4 years should be as Associate Professor or equivalent, or
    2. At least 8 years should be as Assistant Professor or equivalent (in case of Institutions where the post of Associate Professor or equivalent does not exist),
12. First class or equivalent grade in preceding degree in respective discipline, with a consistently good academic record,
13. Should have demonstrated excellence in teaching.
14. At least 20 refereed conference/journal papers (of which at least 8 should be in reputed journals, out of which at least 3 in last 4 years),
15. Should have guided independently at least one Ph.D. student, or have guided at least two Ph.D. students jointly with other faculty/researchers, and
16. Completed:
    i) One sponsored R&D or consulting project as a PI, and
    ii) One more sponsored R&D or consulting project as a PI, or two sponsored R&D or consulting projects as a co-PI.

Additional criteria for CARE:

In addition to Institute-level short-listing criteria for faculty positions, following additional criteria must be satisfied for positions in CARE.

1. Assistant Professor
i) Area of expertise should be relevant to CARE.
ii) 1st class from Bachelor's degree onwards.
iii) Potential for very good applied research and development work.
iv) At least 1 paper in reputed journal should be in the last 3 years.

2. Associate Professor
i) Area of expertise should be relevant to CARE.
ii) 1st class from Bachelor's degree onwards.
iii) Should have guided at least 1 PhD student either singly/jointly OR should have additional 2 papers in reputed journals.
iv) Should have demonstrated capability in execution of sponsored projects and involvement in development of laboratory infrastructure.

3. Professor
i) Area of expertise should be relevant to CARE.
ii) 1st class from Bachelor's degree onwards.
iii) Should have demonstrated excellence in delivery of sponsored projects and development of laboratory infrastructure.

(f) **How collectiveness of the faculty has enhanced academic output and enhanced quality, etc.**

Significant part of the research work is done through faculty collaborations both within and across the groups. This is necessary because the research work is mostly of an applied nature that demands pooling of the complimentary skills of different faculty to achieve an objective. The collaborative efforts of CARE faculty have helped achieve higher research goals that are not generally possible working individually. The collective approach is also exhibited in the large percentage of PhD students having joint supervisors.

(g) **Nature, quantum and quality of support from secretarial staff, stores and inventory management, purchases, ambience, etc.**

CARE has one secretarial staff and one store-keeper. The quantum and quality of support are just adequate for the respective work.

Secretarial support encompasses regular work in Head's office including drafting of letters on the computer, overseeing office staff work etc. The task of the store-keeper is important because of the large number of laboratories in the Centre. The nature of work includes maintenance of computerized inventory, administrative work for purchases, write-off of old unserviceable equipment etc.

7.3. Faculty

(a) **Faculty profile, and a critique of the same.**

CARE has 10 faculty in regular positions (7 Professors, 1 Associate Professor, 2 Assistant Professors), 1 DST Inspire Faculty, and 1 Emeritus Professor. Their brief profile is given below.

Prof. Arun Kumar (Head CARE) did his B.Tech, M.Tech and PhD, all in Electrical Engineering, from the Indian Institute of Technology, Kanpur. His doctoral thesis was titled "Nonlinear dynamical analysis and predictive coding of speech". He was a Visiting Researcher at the University of California, Santa Barbara, from 1994 to 1996, prior to joining the Indian Institute of Technology, Delhi in 1997. He is a recipient of the Young Scientist Award of the International Union of Radio Science (URSI)

Prof. Sudhir Chandra obtained M.Sc. (Physics) from Bareily College, Bareily (Agra University) in 1970, M.Tech in Solid State Physics from IIT Delhi in 1972 and Ph.D. in the area of Microelectronics in 1980 from IIT Delhi. He contributed significantly in Planning and establishing Microelectronics Laboratory at CARE IIT Delhi. He joined CARE as project scientist in 1977 and became a faculty member in 1981. He is currently working on silicon micromachining devices.

Prof. Shiban K. Koul received B.E. degree in Electrical Engineering from the Regional Engineering College, Srinagar in 1977 and M.Tech and PhD degrees in Microwave Engineering from the Indian Institute of Technology, Delhi, India in 1979 and 1983, respectively.

His research interests include: RF MEMS, Device modelling, Millimeter wave IC design and Reconfigurable microwave circuits including antennas. He is also the Chairman of M/S Astra Microwave Pvt. Ltd, a major private company involved in the Development of RF and Microwave systems in India. He is author/co-author of 235 Research Papers and 7 state-of-the art books. He has successfully completed 25 major sponsored projects, 50 consultancy projects and 35 Technology Development Projects. He holds 7 patents and 4 copyrights.

Prof. Koul is a Fellow of the IEEE, USA, Fellow of the Indian National Academy of Engineering (INAE) India and Fellow of the Institution of Electronics and Telecommunication Engineers (IETE) India, He has received a Gold Medal from the Institution of Electrical and Electronics Engineers Calcutta (1977); Indian National Science Academy (INSA) Young Scientist Award (1986); International Union of Radio Science (URSI) Young Scientist Award (1987); the top Invention Award (1991) of the National Research Development Council for his contributions to the indigenous development of ferrite phase shifter technology; VASVIK Award (1994) for the development of Ka- band components and phase shifters; Ram Lal Wadhwa Gold Medal (1995) from the Institution of Electronics and Communication Engineers (IETE); Academic Excellence award (1998) from the Indian Government for his pioneering contributions to phase control modules for the Rajendra Radar, Shri Om Prakash Bhasin Award (2009) in the field of Electronics and Information Technology, and a teaching excellence award (2012) from IIT Delhi. Prof. Koul is a distinguished IEEE Microwave Theory and Techniques Lecturer for the years 2012-2014. He is also recipient of IEEE Distinguished Educator award in year 2014.

Prof. Rajendar Bahl has a B.Tech (Honours) in Electronics and Electrical Communication Engineering from IIT Kharagpur (1974) and Ph.D (EE) from IIT Delhi (1982). He has been a past Head of the Centre during 1996-99. He has participated in various national bodies of the Department of Electronics, Ministry of Information Technology, and the Defence Research & Development Organisation. He was jointly awarded the 1982Invention Award of the National Research & Development Corporation for the indigenous development of a Digital Control System. He won a Senior Fellowship award of the US National Research Council during 1989-90 at the Naval Postgraduate School, Monterey. He has also been a Visiting Professor in the field of bio-acoustics at the Institute of Industrial Science, University of Tokyo, Japan during 2002-2004. His major expertise is in sonar design and he has implemented a number of projects in this area.

Prof. B. S. Panwar joined as a faculty at Indian Institute of Technology Delhi – India in 1981. Prof. Panwar has published more than 60 papers in the international journals and conference with good citation index. Prof. Panwar is recipient of International IBM Faculty Award, Adjunct Professor at University of Regina, Saskatchewan Canada, recipient of mobility exchange grant of Canadian International Development Agency, and a senior member of IEEE. He is reviewer of IEEE transaction on UFFC, Electron Devices, Evolutionary Computation, Applied Physics etc. Prof. Panwar has been consultant Motorola USA, Phase Devices U.K., Biomorphic USA, and is presently consultant to Honeywell Technologies Bangalore-India, Akshi Gurgaon - India and, Maxim Semiconductor USA. He has delivered lectures at University of Regina, McMaster Canada, Delft Institute of Microelectronics and Sub-micron Technology. Prof. Panwar has an ongoing collaborative research program at FEMTO, Besancon – France on wireless network sensors.

Prof. Panwar has been involved in initiating a graduate programme on RF Design and Technology, and coordinated this programme. He has taught courses on Fundamentals of RF Electronics, Signals and Systems, Electronic Circuits, Analog and digital Integrated Circuits, Measurement and Instrumentation with student strength varying from 15 to 110. He had an active participation in the multi-disciplinary program on VLSI Design Tools and Technology at IIT Delhi, and coordinated this programme which was sponsored by leading multinational companies such as Philips Semiconductor, Texas Instruments, Nokia, Cypress, Analog Devices. He has also been instrumental in providing vision and direction on the computerization of administrative and academic functionalities at IIT Delhi. As the Head of Administrative Computerization and support services he has been instrumental in launching a new Web-based Academic system with a very high level of complexity on the academic registration process, course offering/allocation, on line grade submission etc.

Prof. Panwar also nucleated an interdisciplinary team to address the project requirement of Motorola, USA on the design and technology development for low loss Surface Acoustic Wave (SAW) filters for mobile communication. He has successfully completed research and development projects exceeding 10 million US dollar and consultancy assignments more than 1 million US Dollars. Prof. Panwar has kept himself updated on the front-end research through participation in international symposia and conferences. In the recent past he has chaired the IEEE sponsored conference on Integrated Circuit.

Prof. Suneet Tuli received his B.E.(Hons)degree in Electrical & Electronic Engg. from the Birla Institute of Technology and Science, Pilani (1982) and M.Tech and Ph.D from the Indian Institute of Technology, Delhi in 1987 and 1995,respectively. He joined CARE as project scientist in 1984 and became a faculty member in 1986. He has been a major participant in setting up of a non-destructive thermal-acoustic-optical laboratory in particular and developing Surface Acoustic Wave CAD environment in general. He has been the recipient of a French Fellowship in 1987 and worked at the University of P.et. M. Curie, Paris on generation and detection of micro acoustic waves in solids.

In 2003, Dr. Tuli received the 10th IETE Professor K. Sreenivasan Memorial Award in recognition of his distinguished contributions in the field of "Teaching Electronics & Telecommunication Engineering in the broadest sense".

Prof. Ananjan Basu did his B.Tech and M.Tech from IIT Delhi in 1991 and 1993 respectively. He completed Ph.D from University of California, Los Angeles in 1998. He was a visiting faculty member in C.A.R.E I.I.T.Delhi from 1/1999 to 4/2000 and became assistant professor in 4/2000.

Dr. Monika Aggarwal was born in Dehra Dun, India. She received the B.Tech. degree in Electrical Engineering and the M.Tech. degree in Electronics and Communication Engineering from the Regional Engineering College, Kurukshetra, India, and the Ph. D. degree from the Indian Institute of Technology, New Delhi, India, in 1993, 1995, and 2000, respectively. She was employed with Hughes Software Systems (HSS), Gurgaon, India from 1999 to 2002. During 2001 she was a visiting researcher in the Dept. of Systems and Control, Uppsala University, Uppsala, Sweden. She joined C.A.R.E, I.I.T Delhi as Asst.Professor in Jan.2003.

Dr.Mahesh Abegaonkar completed his M.Sc. in Physics from BAM University, Aurangabad, Maharashtra in 1995 and Ph.D. in Physics from Department of Physics, University of Pune, Pune, Maharashtra in 2002. He has worked with Kyungpook National University, Daegu, South Korea as a Post-Doctoral Researcher and Assistant Professor during2002-2004. He joined CARE, IIT Delhi as an Assistant Professor in Feb. 2005.

Dr. Karun Rawat received his PhD. degree in Electrical Engineering from University of Calgary,Canadain 2012. He is currently Assistant Professor in Centre for Applied Research in Electronics, IIT Delhi. He is senior member of IEEE. Before this, he worked as scientist in the Space Applications Center, Indian Space Research Organization (ISRO) Ahmedabad, from 2003–2007, where he was involved in the design and development of microwave receivers for remote sensing applications. After that, he joined the iRadio Laboratory of the Schulich School of Engineering, University of Calgary, where he worked as a student research assistant and later Post-doctoral research fellow under the research grant of iCORE and CRC chair, Alberta, Canada. His research involvement has resulted in more than 24 publications in journals and conferences with 15 in IEEE society. Due to his active research activities and publications, he has been recipient of research production award for the three consecutive years from 2009-2012 by University of Calgary. Under his leadership, University of Calgary team won first prize as well as the best design award in the 3rd Annual Smart Radio Challenge 2010 conducted by Wireless Innovation forum while competing against five universities from U.S. and Japan.

Dr. Saakshi Dhanekar (Inspire Faculty) completed her Ph.D. in Electronics from Nano-Sensor Research Laboratory, F/o Engg. and Technology, Jamia Millia Islamia (Central University), New Delhi, India in January 2012. She worked as Assistant Professor at Amity Institute of Nanotechnology, Amity University, Noida, India from August 2011 till December 2012. She was awarded a 5 year project from Department of Science and Technology, Ministry of Science and Technology, Govt. of India under INSPIRE Faculty Scheme. She joined CARE, IIT Delhi in January 2013 as INSPIRE Faculty and is presently implementing her project based on detection of bacteria using nanomaterials for safe drinking water

Prof. Vikram Kumar (Emeritus Professor jointly with Physics Department) is well known in the area of semiconductor materials characterization and device technology.
His early work on ultra thin oxide MOS structures is cited widely. His extensive work towards the understanding of electronic defects and interface states in silicon, III-V and II-VI semiconductors lead to the prestigious **Shanti Swarup Bhatnagar Award** in 1992.
As the **Director** of the **Solid State Physics Laboratory**, he has contributed towards the development of technology of materials and devices some of which reached production stage. His team developed the technology of 0.7m gate ion implanted MESFET and 0.5m pseudomorphic HEMT using MBE grown strained layer AlGaAs/InGaAs/GaAs structures. He led the team for setting up GaAs Enabling Technology Centre (GAETEC) foundry for pilot production of monolithic microwave integrated circuits (MMIC) that is supplying devices to various users including defence and space. His team has also developed the technology for growth of single crystals of CdZnTe and GaAs and supplied device quality wafers. He also contributed to the development HgCdTe based PV and PC infra-red detectors. Under his **directorship, NPL** underwent international peer review to fulfil the requirements of BIPM mutual recognition arrangement (MRA). Kumar is currently working in the area of polymer electronics. At NPL he initiated programmes on silicon and organic solar cells. In particular, he has been modelling carrier transport in organic materials.

He has been contributing to the development of science and technology in India as member of several nationally important committees. He played a key role in starting the National Programme on Smart Materials, and as Chairman of the committee for development of devices, has guided the development of MEMS technology in India. He is a fellow of the NASc, INAE and IETE in addition to being a member of several professional societies.

The following 5 faculty members of CARE are also Associate Faculty members of Bharti School of Telecommunication Technology and Management: i) S. K. Koul, ii) Ananjan Basu, iii) Monika Agarwal, iv) Mahesh Abegaonkar, v) Karun Rawat.

(b) **Diversity in faculty profile by: (i) gender, (ii) category, (iii) region, (iv) Ph.D. institution, (v) post- doctoral institution worked in, (vi) organizations/industry worked in, (vii) employment prior to joining the department.**

CARE currently has 10 faculty in regular positions. The sanctioned strength is 16. One new faculty has been offered appointment at the Assistant Professor level in the Microelectronics area. The diversity in faculty profile under the respective heads is given in the table below.

S. No.	Item	Description
i)	Gender	Nine male and one female.
ii)	Category	All faculty belong to the general category.
iii)	Region	Uttar Pradesh: 3; West Bengal: 1; Haryana: 1; Delhi: 2; Jammu & Kashmir: 1; Uttarakhand: 1; Maharashtra: 1;
iv)	PhD Institution	IIT Delhi: 6; IIT Kanpur: 1; University of Pune: 1; University of California, Los Angeles, USA: 1; University of Calgary, Canada: 1;
v)	Post-Doctoral Institution worked in	a. Ananjan Basu: University of California, Los Angeles, USA. b. Arun Kumar: University of California, Santa Barbara, USA. c. Karun Rawat: University of Calgary, Canada. d. Mahesh Abegaonkar: Kyungpook National University, South Korea. e.
vi)	Organizations / Industry worked in	i. Ananjan Basu: IIT Delhi (before PhD); University of California, Los Angeles, USA. ii. Arun Kumar: University of California, Santa Barbara, USA. iii. R. Bahl: i) University of Technology, Loughborough, UK (7 + 3 months) ; ii) US Naval Postgraduate School, Monterey, CA, USA (1 year); iii) University of Tokyo, JAPAN (2 years + several summer visits upto 2 month each time). 4. Mahesh Abegaonkar: University of Pune. 5. B. S. Panwar: Aligarh Muslim University, SITM Lucknow (on leave from IIT Delhi for six months) and IIT Delhi.
vii)	Employment prior to joining the Centre	1. Ananjan Basu: IIT Delhi; University of California, Los Angeles, USA. 2. Arun Kumar: University of California, Santa

		Barbara, USA. 3. Karun Rawat: University of Calgary, Canada. 4. Mahesh Abegaonkar: Kyungpook National University, South Korea. 5. S. K. Koul: Nil. 6. R. Bahl: Nil – Working since 1974 at SRS – predecessor of CARE.

(c) **Procedure for faculty searches.**

Applications are accepted throughout the year across IIT for Assistant Professor position, in addition to the regular newspaper advertisements that appear every 18 months. CARE has put a permanent call for applications on its website. In addition, CARE faculty interacts with potential candidates and senior colleagues in international conferences. CARE faculty has written to their contacts in foreign universities and research labs and other acquaintances asking for potential candidates to submit resumes.

(d) **Result of faculty searches - area-wise, number of applicants, short-listed and offered a position, their education qualification, and experience.**

The statistics since June 2012 is given in the table below.

	Microwaves	Signal Processing	Microelectronics
Number of applicants	108 (combined in all 3 areas)		
Number of shortlisted applicants	3	0	4
Number offered position	1	0	1
Educational Qualification	PhD	-	PhD
Experience	Post-doctoral	-	Post-doctoral

(e) **Success in recruitment (data for last 5 yrs.) and offers that the person has from other IITs/IISc/TIFR.**

Two new faculty members have been recruited at the Assistant Professor level in the last 5 years. Offers have been made in 2013 and 2014. One of them joined while the other is expected to join in a few months after completing current assignment. CARE has been extremely selective in offering faculty positions. Candidates are rigorously evaluated for their deep interest and expertise in doing goal oriented applied research involving laboratory based experimental and hardware development work.

(f) **Faculty lost to other institution post selection.**

Nil.

(g) **Faculty time utilization - in class, in meeting, project management, Ph.D. guidance, Master project guidance, UG project guidance.**

On an average, faculty time in CARE is utilized according to the following:

i) Classes: 25%.
ii) M.Tech and PhD research guidance: 35%.
iii) Management of funded projects: 30%.
iv) UG student project guidance: 5%.
v) External work including administration: 5%.

(h) **Level of harmony amongst department faculty.**

There is excellent harmony amongst faculty of CARE. This can also be gauged from the very large number of joint research activities including sponsored projects and Masters and PhD thesis supervision, both within the academic groups and across groups leading to multi-disciplinary nature of work.

7.4. Students

(a) **Criteria for short-listing and selecting students for admission to Master's and Ph.D. programmes of past 5 years.**

i) **M.Tech in Radio Frequency Design and Technology:**

Total sanctioned strength = 40 consisting of 10 GATE entry seats (10 for General category, 5 for OBC, 3 for SC and 2 for ST category students) and 20 sponsored category students including10 for Naval officers, and 10 for DRDO scientists.

Short-listing of GATE entry students:

The criteria for short-listing of GATE entry students for the last 5 years are given in the table below. The short-listed candidates appear for an interview that is conducted over 2 days involving all faculty members of the Centre.

Selection of GATE entry students:

The final selection of short-listed GATE entry students is based on ranks obtained in the respective category (General, OBC non-creamy layer, SC, ST) on the basis of total marks that include 70% weightage to GATE score and 30% weightage to the interview marks.

Selection of Navy and DRDO sponsored students:

Short-listing of candidates is done by the respective organizations based on the minimum short-listing criteria of IIT Delhi. A committee comprising of faculty members of CARE and DRDO/Navy representatives interviews the short-listed candidates. The interviews are held in April every year at the Recruitment and Assessment Centre, DRDO, Delhi.

Short-listing Criteria for RFDT M.Tech Admissions from 2009 to 2013.

The short-listing criteria for call for interviews for M.Tech admissions (Full time with Assistantship) in RFDT (CRF programme code) in CARE for the respective years 2009 onwards are given below.

Candidates must satisfy the minimum qualification criteria of the Institute as given in the Information Brochure. Additionally, candidates must have the minimum GATE score in the allowed disciplines according to the following:

Category	2009-10	2010-11	2011-12	2012-13	2013-14
General	558	674	655	685	675
Non-creamy layer OBC	538	611	600	620	605
SC	242	436	400	450	450
ST	242	310	320	400	400
PH	242	310	350	450	450

ii) PhD Programme in Applied Research in Electronics:

The PhD selections are scheduled twice a year in May and December. For QIP scholars, the selections are held in Jan/Feb. In addition, PhD applications are received throughout the year and if sufficient number of applications is received, then they are short-listed for interviews at other times also.

The short-listing criteria for PhD applicants for the two scheduled selections in May and December are given in the succeeding tables from 2009 onwards.

CARE IIT Delhi

April 29th, 2009

Sub: Short-listing criteria for call for interviews of PhD applicants for 2009-2010/I.

Criteria	**Discipline-wise**	**GEN**		**OBC**		**SC/ST**		**PH**		**Qualifying Exam**
GATE	EC/EE/Phy/ Instrumentation	450		405		350		350		M.Sc/B.Tech
		*A	*B	*A	*B	*A	*B	*A	*B	
Degree Requirements	% Aggregate	72	60	65	60	60	60	60	60	M.Tech/M.Sc
		78	60	72	60	70	60	70	60	B.Tech
	CGPA	7.75	6.75	7.00	6.75	6.75	6.75	6.75	6.75	M.Tech/M.Sc
		8.75	6.75	7.75	6.75	7.50	6.75	7.50	6.75	B.Tech

***A: In the qualifying exam (M.Tech / B.Tech / M.Sc).**
***B: In previous exams (B.Tech / B.Sc / 10+2 as applicable) from 10+2 stage.**
Candidates with CSIR are shortlisted with 70% (7.5) marks in Qualifing exam.

CARE IIT Delhi

Nov 25th, 2009

Sub: Short-listing criteria for call for interviews of PhD applicants for 2009-2010/II.

Criteria	Discipline-wise	GEN		OBC		SC/ST		PH		Qualifying Exam
GATE	EC/EE/Phy/ Instrumentation	450		405		350		350		M.Sc/B.Tech
		*A	*B	*A	*B	*A	*B	*A	*B	
Degree Requirements	% Aggregate	72	60	65	60	60	60	60	60	M.Tech/M.Sc
		78	60	72	60	70	60	70	60	B.Tech
	CGPA	7.75	6.75	7.00	6.75	6.75	6.75	6.75	6.75	M.Tech/M.Sc
		8.75	6.75	7.75	6.75	7.50	6.75	7.50	6.75	B.Tech

***A: In the qualifying exam (M.Tech / B.Tech / M.Sc).**
***B: In previous exams (B.Tech / B.Sc / 10+2 as applicable) from 10+2 stage.**
Candidates with CSIR are shortlisted with 70% (7.5) marks in Qualifing exam.

CARE IIT Delhi

April 30th, 2010

Sub: Short-listing criteria for call for interviews of PhD applicants for 2010-2011/I.

Candidates must satisfy the minimum qualification criteria of the Institute as given in the Information Brochure. Additionally, candidates must fulfill the following minimum criteria in terms of aggregate marks / cumulative grade point average out of 10:

	GE				OBC				SC/ST/PH			
	Qualifying Degree	Previous Degree	GATE	CSIR	Qualifying Degree	Previous Degree	GATE	CSIR	Qualifying Degree	Previous Degree	GATE	CSIR
M.Tech with B.Tech	75/8.0	70/7.5	-	-	70/7.5	65/7.25	-	-	65/7.25	60/6.75	-	-
M.Tech with M.Sc	75/8	70/7.5	-	-	70/7.5	65/7.25	-	-	65/7.25	60/6.75	-	-
B.Tech with GATE	80/9	70/7.5	674	-	75/8	65/7.25	611	-	70/7.5	60/6.75	436	-
M.Sc with GATE	80/9	70/7.5	674	-	75/8	65/7.25	611	-	70/7.5	60/6.75	436	-
M.Sc with CSIR	80/9	70/7.5	-	Q	75/8	65/7.25	-	Q	70/7.5	60/6.75	-	Q

CARE IIT Delhi

Nov 29th, 2010

Sub: Short-listing criteria for call for interviews of PhD applicants for 2nd semester 2010-2011/II.

Candidates must satisfy the minimum qualification criteria of the Institute as given in the Information Brochure. Additionally, candidates must fulfill the following short-listing criteria in terms of aggregate marks / cumulative grade point average out of 10 and GATE/ CSIR requirements

	GE				OBC				SC/ST/PH			
	Qualifying Degree %marks/ CG(10)	**Previous Degree** %marks/ CG(10)	**GATE score**	**CSIR**	**Qualifying Degree** %marks/ CG(10)	**Previous Degree** %marks/ CG(10)	**GATE score**	**CSIR**	**Qualifying Degree** %marks/ CG(10)	**Previous Degree** %marks/ CG(10)	**GATE score**	**CSIR**
M.Tech with B.Tech	**72/8.0**	**69/7.4**	**-**	**-**	**70/7.5**	**65/7.25**	**-**	**-**	**64/7.2**	**60/6.75**	**-**	**-**
M.Tech with M.Sc	**72/8.0**	**69/7.4**	**-**	**-**	**70/7.5**	**65/7.25**	**-**	**-**	**64/7.2**	**60/6.75**	**-**	**-**
B.Tech with GATE	**80/9.0**	**69/7.4**	**674**	**-**	**72/8.0**	**65/7.25**	**611**	**-**	**70/7.5**	**60/6.75**	**436**	**-**
M.Sc with GATE	**80/9.0**	**69/7.4**	**674**	**-**	**72/8.0**	**65/7.25**	**611**	**-**	**70/7.5**	**60/6.75**	**436**	**-**
M.Sc with CSIR	**80/9.0**	**69/7.4**	**-**	**Qualified**	**72/8.0**	**65/7.25**	**-**	**Qualified**	**70/7.5**	**60/6.75**	**-**	**Qualified**

Interview/written test is scheduled on Dec 14th, 2010(Tuesday) at 9:00 AM in the office of Head CARE, Block III Room no. 218

CARE IIT Delhi

May 4th, 2011

Sub: Short-listing criteria for call for interviews of PhD applicants for 2011-2012/I.

Candidates must satisfy the minimum qualification criteria of the Institute as given in the Information Brochure. Additionally, candidates must fulfill the following short-listing criteria in terms of aggregate marks / cumulative grade point average out of 10 and GATE/ CSIR requirements

	GE				OBC				SC/ST/PH			
	Qualifying Degree %marks/ CG(10)	**Previous Degree** %marks/ CG(10)	**GATE score**	**CSIR**	**Qualifying Degree** %marks/ CG(10)	**Previous Degree** %marks/ CG(10)	**GATE score**	**CSIR**	**Qualifying Degree** %marks/ CG(10)	**Previous Degree** %marks/ CG(10)	**GATE score**	**CSIR**
M.Tech with B.Tech	**72/8.0**	**60/6.75**	**-**	**-**	**68/7.25**	**60/6.75**	**-**	**-**	**63/7.0**	**60/6.75**	**-**	**-**
M.Tech with M.Sc	**72/8.0**	**60/6.75**	**-**	**-**	**68/7.25**	**60/6.75**	**-**	**-**	**63/7.0**	**60/6.75**	**-**	**-**
B.Tech with GATE	**80/9.0**	**60/6.75**	**674**	**-**	**75/8.25**	**60/6.75**	**611**	**-**	**70/7.5**	**60/6.75**	**436**	**-**
M.Sc with GATE	**72/8.0**	**60/6.75**	**674**	**-**	**68/7.25**	**60/6.75**	**611**	**-**	**63/7.0**	**60/6.75**	**436**	**-**
M.Sc with CSIR	**72/8.0**	**60/6.75**	**-**	**Qualified**	**68/7.25**	**60/6.75**	**-**	**Qualified**	**63/7.0**	**60/6.75**	**-**	**Qualified**

CARE| IIT Delhi

Dec 1, 2011

Sub: Short-listing criteria for call for interviews of PhD applicants for 2011-2012/II.

Candidates must satisfy the minimum qualification criteria of the Institute as given in the Information Brochure. Also, they must have earned a B.Tech or B.Sc degree. Additionally, candidates must fulfill the following short-listing criteria in terms of aggregate marks / cumulative grade point average out of 10 and GATE/ CSIR requirements

	GE				OBC				SC/ST/PH			
	Qualifying Degree %marks/ CG(10)	**Previous Degrees & 10+2** %marks/ CG(10)	**GATE score**	**CSIR**	**Qualifying Degree** %marks/ CG(10)	**Previous Degrees & 10+2** %marks/ CG(10)	**GATE score**	**CSIR**	**Qualifying Degree** %marks/ CG(10)	**Previous Degrees &10+2** %marks/ CG(10)	**GATE score**	**CSIR**
M.Tech with B.Tech	**72/8.0**	**60/6.75**	-	-	**68/7.25**	**60/6.75**	-	-	**63/7.0**	**60/6.75**	-	-
M.Tech with M.Sc	**72/8.0**	**60/6.75**	-	-	**68/7.25**	**60/6.75**	-	-	**63/7.0**	**60/6.75**	-	-
B.Tech with GATE	**80/9.0**	**60/6.75**	**674**	-	**75/8.25**	**60/6.75**	**611**	-	**70/7.5**	**60/6.75**	**436**	-
M.Sc with GATE	**72/8.0**	**60/6.75**	**674**	-	**68/7.25**	**60/6.75**	**611**	-	**63/7.0**	**60/6.75**	**436**	-
M.Sc with CSIR	**72/8.0**	**60/6.75**	-	**Qualified**	**68/7.25**	**60/6.75**	-	**Qualified**	**63/7.0**	**60/6.75**	-	**Qualified**

[N.B. In case a candidate has completed a Master's Degree program shorter than 2 years, shortlisting/admission will be provisional until ratified by the Institute authorities].

Interview/written test is scheduled on Dec 14, 2011 (Wed) 9:00 AM in the office of Head CARE, Block III Room no. 218

CARE IIT Delhi

May 7, 2012

Sub: Short-listing criteria for call for interviews of PhD applicants for 2012-2013/ sem I.

Candidates must satisfy the minimum qualification criteria of the Institute as given in the Information Brochure. Also, they must have earned a B.Tech or B.Sc degree. In all cases, the qualifying degree should be relevant to Electronics. Additionally, candidates must fulfill the following short-listing criteria in terms of aggregate marks / cumulative grade point average out of 10 and GATE/ CSIR / UGC requirements

	GE				OBC				SC/ST/PH			
	Qualifying Degree %marks/ CG(10)	**Previous Degrees & 10+2** %marks/ CG(10)	**GATE score**	**CSIR/ UGC**	**Qualifying Degree** %marks/ CG(10)	**Previous Degrees & 10+2** %marks/ CG(10)	**GATE score**	**CSIR/ UGC**	**Qualifying Degree** %marks/ CG(10)	**Previous Degrees &10+2** %marks/ CG(10)	**GATE score**	**CSIR/ UGC**
M.Tech with B.Tech	**72/8.0**	**60/6.75**	-	-	**68/7.25**	**60/6.75**	-	-	**63/7.0**	**60/6.75**	-	-
M.Tech with M.Sc	**72/8.0**	**60/6.75**	-	-	**68/7.25**	**60/6.75**	-	-	**63/7.0**	**60/6.75**	-	-
B.Tech with GATE	**80/9.0**	**60/6.75**	**674**	-	**75/8.25**	**60/6.75**	**611**	-	**70/7.5**	**60/6.75**	**436**	-
M.Sc with GATE	**72/8.0**	**60/6.75**	**674**	-	**68/7.25**	**60/6.75**	**611**	-	**63/7.0**	**60/6.75**	**436**	-
M.Sc with CSIR	**72/8.0**	**60/6.75**	-	**Qualified**	**68/7.25**	**60/6.75**	-	**Qualified**	**63/7.0**	**60/6.75**	-	**Qualified**

[N.B. In case a candidate has completed a Master's Degree program shorter than 2 years, shortlisting/admission will be provisional until ratified by the Institute authorities].

Interview/written test is scheduled on May 21, 2012 (Mon) 9:00 AM in the office of Head CARE, Block III Room no. 218.

In case a candidate sees a mistake in applying these criteria in the lists on the IITD web-site, he may contact ananjan@care.iitd.ernet.in.

CARE IIT Delhi

Nov 30, 2012

Sub: Short-listing criteria for call for interviews of PhD applicants for 2012-2013/ sem II.

Candidates must satisfy the minimum qualification criteria of the Institute as given in the Information Brochure. Also, they must have earned a B.Tech or B.Sc degree. In all cases, the qualifying degree should be relevant to Electronics. Additionally, candidates must fulfill the following short-listing criteria in terms of aggregate marks / cumulative grade point average out of 10 and GATE/ CSIR / UGC requirements

	GE				OBC				SC/ST/PH			
	Qualifying Degree %marks/ CG(10)	**Previous Degrees & 10+2** %marks/ CG(10)	**GATE score**	**CSIR/ UGC**	**Qualifying Degree** %marks/ CG(10)	**Previous Degrees & 10+2** %marks/ CG(10)	**GATE score**	**CSIR/ UGC**	**Qualifying Degree** %marks/ CG(10)	**Previous Degrees &10+2** %marks/ CG(10)	**GATE score**	**CSIR/ UGC**
M.Tech with B.Tech	**72/8.0**	**60/6.75**	-	-	**68/7.25**	**60/6.75**	-	-	**63/7.0**	**60/6.75**	-	-
M.Tech with M.Sc	**72/8.0**	**60/6.75**	-	-	**68/7.25**	**60/6.75**	-	-	**63/7.0**	**60/6.75**	-	-
B.Tech with GATE	**80/9.0**	**60/6.75**	**674**	-	**75/8.25**	**60/6.75**	**611**	-	**70/7.5**	**60/6.75**	**436**	-
M.Sc with GATE	**72/8.0**	**60/6.75**	**674**	-	**68/7.25**	**60/6.75**	**611**	-	**63/7.0**	**60/6.75**	**436**	-
M.Sc with CSIR	**72/8.0**	**60/6.75**	-	**Qualified**	**68/7.25**	**60/6.75**	-	**Qualified**	**63/7.0**	**60/6.75**	-	**Qualified**

[N.B. In case a candidate has completed a Master's Degree program shorter than 2 years, shortlisting/admission will be provisional until ratified by the Institute authorities].

Interview/written test is scheduled on Dec 7, 2012 (Fri) 9:00 AM in the office of Head CARE, Block III Room no. 218.

In case a candidate sees a mistake in applying these criteria in the lists on the IITD web-site, he may contact ananjan@care.iitd.ernet.in.

CARE IIT Delhi

May 10, 2013

Sub: Short-listing criteria for call for interviews of PhD applicants for 2013-2014/ sem I.

Candidates must satisfy the minimum qualification criteria of the Institute as given in the Information Brochure (available from www.iitd.ac.in). Also, they must have earned a B.Tech or B.Sc degree. In all cases, the qualifying degree should be relevant to Electronics. Additionally, candidates must fulfill the short-listing criteria in terms of aggregate marks / cumulative grade point average out of 10 and GATE/ CSIR / UGC requirements :

	GE				**OBC**				**SC/ST/PH**			
	Qualifying Degree %marks/ CG(10) ≥	**Previous Degrees & 10+2** %marks/ CG(10) ≥	**GATE score ≥**	**CSIR/ UGC**	**Qualifying Degree** %marks/ CG(10) ≥	**Previous Degrees & 10+2** %marks/ CG(10) ≥	**GATE score ≥**	**CSIR/ UGC**	**Qualifying Degree** %marks/ CG(10) ≥	**Previous Degrees &10+2** %marks/ CG(10) ≥	**GATE score ≥**	**CSIR/ UGC**
M.Tech with B.Tech	**72/8.0**	**60/6.75**	-	-	**68/7.25**	**60/6.75**	-	-	**63/7.0**	**60/6.75**	-	-
M.Tech with M.Sc	**72/8.0**	**60/6.75**	-	-	**68/7.25**	**60/6.75**	-	-	**63/7.0**	**60/6.75**	-	-
B.Tech with GATE	**80/9.0**	**60/6.75**	**660**	-	**75/8.25**	**60/6.75**	**611**	-	**70/7.5**	**60/6.75**	**436**	-
B.Tech with CSIR	**80/9.0**	**60/6.75**	-	**Qualified**	**75/8.25**	**60/6.75**	-	**Qualified**	**70/7.5**	**60/6.75**	-	**Qualified**
M.Sc with GATE	**72/8.0**	**60/6.75**	**660**	-	**68/7.25**	**60/6.75**	**611**	-	**63/7.0**	**60/6.75**	**436**	-
M.Sc with CSIR	**72/8.0**	**60/6.75**	-	**Qualified**	**68/7.25**	**60/6.75**	-	**Qualified**	**63/7.0**	**60/6.75**	-	**Qualified**

[N.B. In case a candidate has completed a Master's Degree program shorter than 2 years, shortlisting/admission will be provisional until ratified by the Institute authorities].

Interview/written test is scheduled on May 22 (Wed) 9:00 AM in the office of Head CARE, Block III Room no. 218.

In case a candidate sees a mistake in applying these criteria in the lists on the IITD web-site, he/she may contact ananjan@care.iitd.ernet.in.

CARE IIT Delhi

Nov 20th, 2013

Sub: Short-listing criteria for call for interviews of PhD applicants for 2013-2014/II.

Candidates must satisfy the minimum qualification criteria of the Institute as given in the Information Brochure. Additionally, candidates must fulfill the following short-listing criteria in terms of aggregate marks / cumulative grade point average out of 10 and GATE/ CSIR requirements

	GE				OBC				SC/ST/PH			
	Qualifying Degree %marks/ CG(10)	**Previous Degree** %marks/ CG(10)	**GATE score**	**CSIR**	**Qualifying Degree** %marks/ CG(10)	**Previous Degree** %marks/ CG(10)	**GATE score**	**CSIR**	**Qualifying Degree** %marks/ CG(10)	**Previous Degree** %marks/ CG(10)	**GATE score**	**CSIR**
M.Tech with B.Tech	**72/8.0**	**60/6.75**	**-**	**-**	**68/7.25**	**60/6.75**	**-**	**-**	**63/7.0**	**60/6.75**	**-**	**-**
M.Tech with M.Sc	**72/8.0**	**60/6.75**	**-**	**-**	**68/7.25**	**60/6.75**	**-**	**-**	**63/7.0**	**60/6.75**	**-**	**-**
B.Tech with GATE	**80/9.0**	**60/6.75**	**660**	**-**	**75/8.25**	**60/6.75**	**611**	**-**	**70/7.5**	**60/6.75**	**436**	**-**
B.Tech with CSIR	**80/9.0**	**60/6.75**	**-**	**Qualified**	**75/8.25**	**60/6.75**	**-**	**Qualified**	**70/7.5**	**60/6.75**	**-**	**Qualified**
M.Sc with GATE	**72/8.0**	**60/6.75**	**660**	**-**	**68/7.25**	**60/6.75**	**611**	**-**	**63/7.0**	**60/6.75**	**436**	**-**
M.Sc with CSIR	**72/8.0**	**60/6.75**	**-**	**Qualified**	**68/7.25**	**60/6.75**	**-**	**Qualified**	**63/7.0**	**60/6.75**	**-**	**Qualified**

Interview/written test is scheduled on Dec 9th, 2013(Monday) 9:00 AM in the office of Head CARE, Block III Room no. 215

In case a candidate sees a mistake in applying these criteria in the lists on the IITD web-site, he/she may contact maggarwal@care.iitd.ernet.in.

(b) **Facilities provided to students and their maintenance/management system.**

PhD students are provided with sitting space mostly in the labs where they work or separately if necessary. M.Tech students also have sitting space in their respective labs in the second year when they do their Major Projects. All students have access to the labs beyond office hours. Faculty members ensure that the students have access to all material and equipment needed to do their research work. The lab requirements are also discussed with M.Tech students during class-committee meetings.

(c) **Mentoring seminars/sessions held for Ph.D. students for prospective faculty careers.**

No formal collective mentoring has been done for PhD students for prospective faculty careers at the Centre level.

8. Benchmarking

8.1. Identify departments/centres within IITD as peers.

CARE has over the last 4 decades established a unique role within academic institutions in India in developing technologies for specialized high-end national strategic electronics requirements. In the strictest sense, there is no peer for CARE amongst academic departments / centres in academic institutions within the country with the same mandate, unlike for core departments that are present in every technical institute in the country.

However, in terms of broad areas of R&D and manpower training, the closest peer will be the Electrical Engineering department within IITD.

8.2. Identify departments/centres/schools/divisions from other IITs, NITs, IISc, private universities as peers and reasons/criteria there for.

The comment of 8.1 above holds here too. Again, in terms of broad areas of R&D and manpower training, the closest peers will be the Electrical Engineering department of other IITs. In the niche area of Underwater Signal Processing, there is no other equivalent research group with similar research and manpower training objectives.

8.3. Identify departments/centres from institution in other countries as peers.

The following peers have been identified from other countries in the respective research areas:

i) Signal Processing: University of Tokyo, Japan.
ii) Microwaves: Monash University: Microwave, antennas, RFID and Sensors group.

8.4. Define parameters for benchmarking (i) research, (ii) curriculum - separately for UG, Masters and Ph.D. programmes, (iii) teaching-learning processes.

Research benchmarking has been done based on the following parameters:

i) Projects and technologies developed / transferred.
ii) State-of-the-art and special facilities.
iii) Collaborations with users, industries, across institutions, across countries.
iv) Niche areas nationally recognized.
v) Faculty, student, staff numbers, external funding, prominence, awards etc.

8.5. Perform benchmarking and report the analysis/finding for the last 5 (or 10) years.

Benchmarking comparisons for Microwaves and Signal Processing groups are given in the tables below.

Benchmarking of Signal Processing Group

Peer Institution	Projects & Technologies developed/delivered	Special facilities	Collaboration with users, industry, across depts, across univs, across countries	Niche areas nationally recognised	Faculty number, student number, external funding, prominence, awards etc
Signal Processing Group, CARE	Sonar systems, Low Power DSP platform for acoustic signal processing on manned / unmanned platforms, Underwater communication systems, Underwater Acoustic Vector Sensors, Passive Sonar algorithms for detection and classification of radiating targets, Radiated Noise simulation packages and underwater domain awarness software for manpower training and algorithm development applications, Bearings-only target motion analysis for non-maneuvering and maneuvering underwater targets, Voice conversion from source to target speaker, Single-ended non-intrusive speech quality evaluation algorithms, Spoken term detection methods.	Water Tank, Miniature water tank for sonar trainer experiments, Air Acoustic Anechoic chamber, Hydrophones, Underwater projectors, Power amplifiers, multi-channel pre-amplifiers, National Instruments chassis for multi-channel data acquisition, High quality microphones and headphones, loudspeakers, Infrasonic microphone and signal conditioning unit, DSP kits, Softwares including Code Composer Studio, and Labview.	Directorate of Weapons Equipment – Indian Navy, WESEE – MoD, Bharat Electronics Limited, Cochin University of Science and Technology, Ministry of Earth Sciences, DRDO labs – Naval Science and Technological Lab, Visakhapatnam, Snow and Avalanche Study Establishment, Chandigarh, DEAL Dehradun; WWF-India, University of Tokyo Japan, Mitsubhishi Heavy Industries, Japan, SiRF USA; Voxomos Systems Pvt. Ltd.	Acoustic Signal Processing: Underwater and Air Acoustics, Speech Signal Processing, Marine Mammal Acoustics.	03 active full time faculty: NRDC Invention Award, Navy Commendation Medal, Young Engr/Scientist Award, URSI Young Scientist Award. 6 yr average external funding: Rs. 584 lakhs = Rs 32.4 Lakhs/full time faculty/year. 4 yr average total staff-students = 22. 3(Faculty)+2(Staff)+7(MTech)+10 PhD

Within IITD:					
Other IITs etc.					
Other countries: Underwater Technology Research Center, University of Tokyo, Japan	Security Sonar, Bathymetry, Sea Surface Microwave Remote Sensing, Hydroelastic behaviour of floating structures, EIA for marine utilization, AUVs and applications for surveys and imaging	Water tank for acoustics and AUV testing, Deep Sea Pressure test chamber	JAMSTEC, Port & Airport Res Inst, NMRI + **Univs**: Kyoto, Hiroshima, Kyushu Inst, Marine S&T, Doshisha, Japan Coast Guard academy, JCG, CRIEPI **Industry**: KDDI, Toyo Corp, Hitachi, Kokusai Kogyo Co, NTT, Izu Mito sea Paradise **USA**: Univ of Hawaii, MBARI, Reson, Sound Metrics Corp **Europe**: EPFL, Swiss Federal Inst of Aquatic S&T **Asia**: CDA Odisha, IIT Delhi, KAIST, KORDI, Mulawarman Univ, NTU, POSTECH, Seoul Univ, WWF-	Underwater Acoustic systems, Ocean Env Engg, Marine Ecosystem Engg, Underwater Platform systems	(2013-14) 04 active full-time highly awarded and recognized+2 full-time Project faculty 4 yr average external funding: ~250 Million Yen ~ 15 crore INR = Rs 2.5 crore/full time faculty/annum 4 yr average total Faculty + staff+students = 55

			India		

Benchmarking of Microwave Group

Institution	Projects &Technologies developed/delivered	Special facilities	Collaboration with users, industry, across depts, across univs, across countries	Niche areas nationally recognised	Faculty number, student number, external funding, prominence, awards etc
MW Group, CARE	Non-radiative dielectric guide components , Micromachined Antenna array, Micromachined Active Antenna, Broadband mixer, MEMS phase shifter, Airborne phased array radar element with integrated antenna, Microstrip Trainer Kit, Antenna Trainer Kit, Dual-mode ferrite phase shifter, Twin-toroid phase shifter. An Ultra-low Cost Microwave Imaging System Using Active RFID for Surveillance Applications, Filter Design Software, Design and Development of Antenna Array with 8	Anechoic chamber for antenna testing and characterization,VNAs up to 110 GHz .Spectrum Analyzers up to 40 GHz.Microwave Signal Source up to 20 GHz,Mask making facility with coordinatograph,MIC fabrication facility, On wafer Device and Process characterization facility, 200 mm Probing system for submicron probing.Digital Storage Oscilloscope up to 40 GHz, On-chip Antenna Measurement Facility, Quasi-Optical table with 67 GHZ VNA for Dielectric Constant Measurement.Advanced	Agilent Technologies, Applied Nanostructures USA, Femto, CNRS France, Lockheed Semiconductor USA, MEMS Cap. USA, Mitsubishi Japan, Maxim Semiconductor USA, NXP Semiconductors, Netherlands, SiRF Technology USA Astra Microwave, Bharat Electronics Ltd. DRDO, GATEEC Hyderabad, Honeywell Bangalore, Indian Navy, NPMASS, Space Application Centre, Ahmedabad, Tektronix	Microwave and millimetre wave engineering, antennas in integrated systems , RF MEMS	4 faculty, 2 Staff + 18 MTech + 8 PhD: Distinguished Microwave Lecturer (DML),IEEE MTT, IEEE Fellow, Shri Om PrakashBhasin Award in the field of Electronics, INAE Young Engineer Award, IEEE Distinguished educator award,DRDOaward for academic excellence,IETE Ram LalWadhwa Award, IETE Prof. K SREENIVASAN Award, NRDC invention Award,IETES.K.Mittraaward,ShriHari Ohm PreritVikramSarbhai Research Award

	elements (elevation) x 16 elements (azimuthal), C-Band Source and Detector, Ka-band Filters	RF, MEMS and EM simulation Tools viz. Ansoft HFSS, Agilent ADS, CST Studio			
Within IITD:					
IIT Kanpur, EE department, RF microwave and photonics	Multi-Layer Multi-Permittivity Dielectric Antenna for Wideband Applications, Development of 3D Multipacting Analysis Code for RF Couplers, Analysis of Wideband Printed Dipole Antennas, Fiber-optic entangled photon pair generation for generation for quantum key distribution quantum optics, Fully automated Trackside Bogie Monitoring System for measuring i) angle-of-attack using laser range finder based system, ii) lateral and vertical rail forces, Location sensing	Agilent Advanced Design System (ADS) Ansoft High Frequency Structure Simulator (HFSS) ,Agilent Spectrum Analyzer 8564EC: 9 KHz upto 40 GHz AR/RF Microwave Power Amplifier, 100A-250A, 100 Watt CW, 10kHz Â-250MHz,Digital Oscilloscope, Dielectric Probe Kit, Vector Network Analyserupto 50 GHz, Noise Figure Meter, Power Meter, signal sources upto 20GHz, shielded anechoic chamber, 10 Gbps,External Mach-Zehnder Optical Modulator, 40 Gbps	University of Manchester, SAC Ahmedabad,UKIREI/ British Council,MHRD, ChatrapatiShahuMaharaj Medical University, , College of Military Engineering, Pune	Microwave and millimetre wave engineering, dielectric antennas in integrated systems, Fibre Optics and Photonics	4 yr average total staff+students= 9 Faculty + 15 MTech + 33 PhD CST University Publication Award External funding : Not available

	simulator for indoor environments, File Tracking System using RFID, on-chip transceiver design, Brihaspati-2: SCORM packager and SCORM runtime, ERP pilot project, Development of Dielectric Resonators for Applications to Microwave Systems.	DQPSK Optical Modulator, Ps-pulsed laser source at 980nm, 1550nm, and 400nm, Agilent 86142B Optical Spectrum Analyzer, nano fabrication facility			
Other countries: Monash Microwave, Antennas, RFIDS and sensors group	Electronically controlled phased array antenna for (RFID) applications, Microwave Medical Devices for Imaging of Pediatric Cancer Patients, Printable Multi-Bit Radio Frequency Identification for Banknotes, Smart Information Management of Partial Discharge in Switchyards using Smart Antennas, Back-scatter based RFID system	Agilent VNA Upto 67 GHz,spectrum analyser upto 26GHz,anechoic chamber, milling machine, 55GHz signal generator, ADS and CST software	Industries: Securancy International Private limited,SATNET, SP AusNet, Express Promotions,Regni,PacSat,Griffith University, La Trobe University, University of South Carolina, University of South Australia, Deakin University, Multimedia Victoria, Massey University	Development of conventional and chipless RFID Systems for identification and tracking, RF sensor technology development for condition monitoring of goods and human beings	Member of editorial board of 6 refereed international journals, senior member IEEE, Highly cited research, Published edited 6 books 4 yr average total staff-students= 1(F)+19Post Graduates External Funding ~ Rs 8 Crores for last 4 years

	capable of reading multiple chipless tags for regional and suburban libraries, Wireless Battery Operated Orthopaedic Pin for Bone Healing and Growth Therapy for Children,Chipless RFID for Barcode Replacement, Improved Wireless Communications for Rural and Regional Australia, Smart Antennas for Mobile Communications, Phase Array for Satellite Communications, Chipless RFID Reader on Conveyer Belt, ARC Linkage Project: Radio Frequency Wireless Monitoring in Sleep Apnoea				

9. Feedback systems and results

9.1. System for feedback from UG student and its results.

Not applicable, as CARE does not have its own UG program.

9.2. System for feedback from PG, Master's and Ph.D. students and their outcome.

Feedback is obtained from Masters students in two forms:

1. Class-committee meetings held at the middle of each semester. The actionable points are followed up.
2. Online feedback from all students in a class. Head or a committee comprising of Head and M.Tech coordinator reviews the feedback. In case of any shortfall, the concerned faculty is asked to take corrective measures.

9.3. System for feedback from recruiters (i) on-campus, (ii) off-campus - separately for UG, and PG graduates; and the result.

Feedback was obtained from recruiters of RFDT M.Tech students, by sending a questionnaire with quantitative evaluation of 5 points as listed below.

9.4. Mechanism of obtaining industry feedback and the findings.

Quantitative feedback was obtained from industries (private and public) that have recruited our graduates in the past. The details of the quantitative feedback obtained from 4 industries are given in the table below:

S. No.	Question	Points Scored (1 indicating poor and 5 indicating excellent)
1.	Past experience with graduates	4.25
2.	Communication skills	3.75
3.	Team skills	3.75
4.	Ability to learn independently	4.75
5.	Correlation between CGPA and on-job performance	4.00

9.5. Alumni feedback mechanism and its outcome.

A large number of alumni were contacted for feedback. However, only 5 responded. The outcome is as follows:

S. No.	Question	Points Scored (1 indicating poor and 5 indicating excellent)

1.	Adequacy of core courses	3.6
2.	Depth and rigour of core courses	3.8
3.	Adequacy of electives	3.6

9.6. Placement records – PhD, M.Tech and B.Tech

The placement details of M.Tech students are given in 1.3 (h). For PhD students, the information is given below.

S. No.	Student's Name	Year of defence	Placement Details
1	Tanmay Roy	2004	Commander, Indian Navy; Currently with Centena.
2	Prem Pal	2004	Assistant Professor, IIT Hyderabad.
3	Nagendra P. Pathak	2005	IIIT Jabalpur, now as Associate Professor in IIT Roorkee.
4	Ashish Verma	2006	Senior Manager, IBM Research, New Delhi.
5	Jyoti Prakash Kar	2006	Post-doctoral fellow, Korea; Currently Assistant Professor, NIT Rourkela.
6	Rajesh Gupta	2006	Assistant Professor, IIT Bombay.
7	Ravibabu M.	2007	Assistant Professor, IIT, Ropar.
8	Abhijit Karmakar	2007	Scientist E, CEERI, Pilani.
9	Arnab Das	2009	Commander, Indian Navy.
10	Vivekanand Bhatt	2009	BARC; Scientist D, R&DE, DRDO.
11	S. S. Lokesh	2011	Senior DSP Engineer, Marvell Semiconductors
12	Mithilesh Kumar	2011	Assistant Professor, Rajasthan Technical University, Kota.
13	Krishnendu Chatterjee	2012	Head, R&D, Quazar Technologies, New Dehi.
14	Manoj Singh Parihar	2013	Assistant Professor, IIIT Jabalpur
15	Sandeep Chaturvedi	2013	Gatec, Hyderabad.
16	Atul Vir Singh	2013	Assistant Professor, Shiv Nadar University.
17	Hardik J Pandya	2013	Post-doc at University of Maryland, USA.
18	Rajesh Kumar Dubey	Submitted Dec 2013	Assistant Professor, Jaypee Univeristy of Information Technology.
19	Mahur Dev Upadhyay	Submitted July 2013	Assistant Professor, Shiv Nadar University.

10.Vision for next 5-10 years

10.1. Goals and benchmarking for future in relation to (i) curricula, (ii) research, (iii) outreach, (iv) processes for regular internal assessment.

The Centre's goals are articulated in the CARE Vision Document, April 2013. The essential vision is reproduced from the document.

> *"The Centre derives immense pride from the several unique achievements of the past that have been well recognized.* ***Its model of focused, goal-oriented applied research and specialized manpower training has been useful in serving several important national requirements over the past four decades.*** *This successful backdrop provides the pedestal for preparingthe Centre's vision for the future.*
>
> *CARE shall focus on research, development, and specialized manpower training activities in electronics technologies for strategic needs of the nation and societal benefits.*
>
> *CARE shall intensively do* ***focused, goal-oriented research of an applied nature*** *in the areas of Microwaves, Signal Processing, and Microelectronics for the development of advanced electronics technologies of relevance. For this, it shall maintain and endeavor to enhance close interactions with user organizations in the strategic sectors of defence and space, R&D based industries, and national and international research institutions. The Centre will also explore methods to recruit post-doctoral researchers to provide further thrust to its high-end research activities.*
>
> *The Centre shall endeavor to* ***enhance the scope of postgraduate training*** *through its M.Tech program on Radio Frequency Design and Technology* ***by providing avenues for rigorous specialization in sub-streams of Signal Processing, Microwaves and RF, and Microelectronics.*** *It is expected that a reorganized course structure will motivate the bright students to pursue PhD in these areas and consider research as a career option."*

Goals of CARE regarding curricula, research and outreach are articulated in items 10.2, 3, 4, 5, 6 and 12 below.

Benchmarking:
(i) Curricula: The Radio Frequency Design and Technology (RFDT) M.Tech program of CARE is unique in terms of syllabus. However, individual courses can be benchmarked with other institutions offering same or similar courses at the PG level.

(ii) Research: CARE guiding philosophy is to do "applied research in electronics" for strategic needs and for societal benefits. Its performance in research should be benchmarked with the number of state-of-the-art technologies developed for national requirements in the core areas of expertise of the Centre. A related criteria is the total number and value of sponsored projects of national relevance exected in the Centre over 5-10 years. Another relevant criterion is the number of publications in journals and conferences per faculty.

(iii) Outreach: a) Number of students and faculty of other colleges who are given the opportunity to work in CARE for 2-6 months durations under SFRF and other programs, b) Number of workshops organized, c) Educational material developed for the benefit of students and teachers of other colleges.

(iv) Processes for regular internal assessment: The achievements in teaching, research including technology development shall be assessed at regular intervals against the projections made in this document.

10.2. Vision of curricula and teaching-learning processes - UG, PG, and Ph.D.; innovations proposed.

CARE runs a unique M.Tech program in Radio Frequency Design and Technology (RFDT) since 2004 with a current sanctioned strength of 40 which includes 20 candidates with Institute Assistantship, and 10 sponsored candidates each from the Defence forces, and DRDO laboratories. In addition, it has its own PhD program with about 40 enrolled research scholars at present.

The RFDT M.Tech program shall be updated to reflect the revised provisions for Masters programs that has reduced the minimum credit requirements of core courses and increased the requirements of program electives. Currently, CARE is ready with such a proposal for such changes and is waiting for the Institute's initiation of the PG curriculum revision process. Efforts shall be made to introduce in-depth specialization courses with the aim to motivate more students to pursue PhD in these areas and consider research as a career option.

10.3. Areas identified for improvement in (i) curriculum (ii) teaching - learning processes.

Students coming for Masters have varying background depths due to the varying quality of undergraduate education across colleges in the country. As a result, a significant part of the courses has to be devoted to developing the requisite background that should ideally be covered in undergraduate courses. This restricts the level of specialized or advanced material that can be taught in the PG courses. There is discussion at the Institute level related to PG curriculum revision in which this issue is being attempted to be resolved through means such as extra courses, self-learning material etc. so that the level of PG courses can be raised.

The teaching-learning process in both M.Tech and PhD in CARE is significantly based on lab practice. The skills developed by students of CARE are unique in this regard. Laboratory modernization in CARE is a continuous process and efforts in this regard shall continue vigorously.

10.4. New Areas for research and Masters programme, and industry participation in these.

The vision for research in the three groups in CARE is articulated below as was identified in CARE's Vision document prepared in April 2013. Most of the research in CARE is aligned with the high-end requirements of users such as defence, DRDO labs, ISRO etc. Since the requirements are typically in the form of concrete deliverables such as Microwave components, MEMS devices and sensors, Signal Processing based Electronics systems and real-time software etc. the association with industry/users is very close during the execution of the projects.

A. Microwaves: The research program in focus shall be the development of state-of-the-art microwave components and sub-systems up to 100 GHz. Specific topics of thrust being considered for the near future include:

1. RFIC development (priority area designated by MCIT). This is a new direction for the group, and it is expected that in about 5 years, expertise shall be developed for designing practically useful components such as frequency synthesizers, down-converters, and transmitter front-ends in CMOS-RFIC for the microwave and lower-millimeter-wave frequencies.

2. Development of microwave components and systems with focus on components for pulsed signals, imaging and surveillance. It is expected that in the next 5 years, the group will be able to demonstrate a prototype microwave imaging system and a wide-band electro-magnetic signal detection and analysis system.

3. Study of transient effects in microwave components and components using magnetic effects. This is an academic research topic with potential applications in Ultra-Wideband systems (specially for military and security applications), and miniature short-range radar.

4. Component development for specific users (mainly DRDO) has been an on-going activity, and will continue to be so.

B. Signal Processing: The research program of focus shall be the development of technologies based onacoustic signal processing including underwater acoustics, air acoustics, acoustics in other media such as solids, sediment and snow, bio-acoustics, and speech and audio. It shall encompass the development of DSP algorithms, hardware prototypes, and specialized software, and involve laboratory and field experiments. The specific topics of thrust envisioned for the next few years are based on requirements expressed by users including Naval units, DRDO and industries, and our own projections. The topics include:

1. Underwater acoustic surveillance algorithms and systems: Target localization and classification for active and passive sonar for networked observatories, Target motion analysis for tracking using passive sonar.

2. Acoustics based source localization: Infrasound based localization of snow avalanches, algorithms for precise source localization.

3. Passive acoustic vector sensor system: Signal processing and hardware system development for co-located particle velocity and pressure measurement based passive source localization.

4. Signal processing for communications: Efficient acoustic communication techniques.

5. Acoustic stratigraphy: Algorithms and portable hardware system development for analysis of layered snow media for the determination of snow water equivalent for forecasting applications.

6. Passive acoustic monitoring of wildlife and habitats: Marine mammal classification and monitoring systems for requirements in various applications.

7. Human and machine speech communication technologies: keywords spotting in speech, voice personality transformation, objective speech quality evaluation, text-to-speech synthesis in Indian languages.

C. Microelectronics: The Microelectronics Group in CARE shall focus on research in applied electronics with particular emphasis on wafer-level processing and integration for semiconductor devices. The process and fabrication lab shall form the core of the Microelectronics stream within both the M.Tech and Ph.D. programmes run by the Centre. This lab will have minimal overlap and will be complementary to other such facilities within IIT Delhi. It is envisaged that the lab will serve the interests of the Microelectronics group for both research and teaching with general-purpose equipment while more expensive facilities could be housed as central facilities. Another aspect of continuing interest to the group is the development of non-destructive characterization techniques in the electrical, thermal, magnetic, and optical domains for the characterization of materials and devices.

The group will strive to build a strong faculty proficient in various processing techniques, device design and measurements for doing experimental research in related fields of nanoelectronics, microelectronics, MEMS, microfluidics, biosensors, and nano-fabrication techniques. The specific research topics in coming years include:

1. Microdevices for detection of pesticides and antibiotics in milk and other food items such as fruit juice and edible oils.

2. Microfluidic devices such as micromixers for strategic applications.

3. Development of instrumentation systems based on non-destructive characterization techniques for various applications including those identified by the industry.

4. Bio-signal detection, analysis and diagnostics.

5. MEMS for energy harvesting application.

6. GaN based semiconductor device fabrication and characterization.

In the area of **Thermal Non-destructive characterization**, the group in the Centre has a pre-eminent position in the country. It is also recognized internationally for the new concept and patented technique of frequency modulated thermal wave imaging (FMTWI). Though 4 PhDs have contributed till now, the goal is to develop a low-power mobile system for sub-surface defect characterization. This would be of immense use to industry and is in keeping with the Centre's vision of applied R&D.

10.5. Projections for (i) funded projects, (ii) journal publications.

(i) Funded projects: One major funded project per faculty with significant deliverables meeting national requirements in electronics for strategic / societal applications.
(ii) Journal publications: An average of 5 publications per faculty per year in reputed journals and conferences of which at least 2 shall be in reputed journals.

10.6. Projected graduation numbers - Ph.D., M.Tech, and B.Tech.

PhD: An average of 0.8 per faculty per year.
M.Tech: An average of 35 students per year.
B. Tech: Centre's do not have B.Tech programs of their own.

10.7. Projected faculty profile, and areas for recruitment of faculty.

CARE currently has 10 faculty members, 1 Emeritus Professor jointly with Physics Department and 1 DST Inspire faculty. The sanctioned faculty strength of CARE is 16. The number of faculty members in the research areas of Microwaves, Signal Processing and Microelectronics are 4, 3, and 4 respectively. It is strongly felt that the optimum number of faculty in each area should be 5 so that more forceful impact can be made in meeting national requirements and international presence.

The Signal Processing group has operated with faculty strength of 3 for the past several years. This is a bare minimum level to meet ongoing commitments on a modest scale only. There is tremendous scope and opportunity to take on more challenging tasks to meet national needs. Attempts are being made to have faculty strength of around 5 to be able to make a more forceful impact.

The Microelectronics group presently has three faculty members working in separate aspects of materials, processing, device design, and measurements. In view of superannuations in the next 2-3 years, there is an immediate need to recruit about 3 young faculty members in order to reach and maintain strength of at least 5. These five faculty members would be roughly complementary to each other but with the main emphasis on processing and experimental device realization.

10.8. Projection for future benchmarking (for comparison after 5 years) - institution in India and abroad, and parameters for future comparison.

The most important aspect of future benchmarking should be in terms of state-of-the-art technologies developed that serve important national requirements. This is the uniqueness of CARE in which it has excelled over the years.

Future benchmarking paramters may include: i) New areas of R&D initiated, ii) No. of technologies developed / delivered, iii) No. of publications in journals and conferences per faculty, iv) No. of PhDs and Masters students graduated per faculty.

Institutions for comparison may be IIT Kanpur for curriculum and teaching/learning purposes. For research, it can be IIT Kanpur and Monash University for Microwaves & RF area and University of Tokyo for Underwater Acosutics/Signal Processing area.

10.9. Infrastructure and governance - limiting factors that affect achievement of benchmarking and methods to overcome these.

i) A significant portion of faculty time is spent on various administrative work including purchases, functioning of labs, student admission processes etc. Faculty must be free of several such routine administrative work in order to concentrate on high quality research. However, high quality administrative / secretarial support is not available on long-term basis. The institute may make available such support staff. Some efforts regarding technical support in labs through high value M.Tech assistantships has been started recently.

ii) There is a need for uninterrupted power supply for running of critical facilities in Microelectronics labs. This has been a long-standing requirement and various efforts through the years have not led to a satisfactory solution. This affects the functional efficiency of the labs.

iii) The time taken for renovation of labs is inordinately long. Again, this requires extensive faculty time for coordination of related activities, monitoring of quality of work etc. due to the poor quality of support from the staff of concerned central units. The Institute should work out out-sourcing to professional agencies with good track record for doing such jobs.

10.10. Working with other department/centres and institution in teaching and research.

CARE faculty collaborates with faculty of other departments, notably Electrical Engineering, Physics and Textile Engineering departments, on research and sponsored projects. Five of CARE’s faculty members are associated with the Bharati School of Telecommunications: i) Prof. S. K. Koul, ii) Prof. Ananjan Basu, iii) Dr. Mahesh Abegaonkar, iv) Dr. Karun Rawat, and v) Dr. Monika Agarwal. With the central Nanoscale Research Facility coming up in IITD, there shall be further collaborations with more departments for the fabrication of specialized use nanoscale sensors etc. Such cross-departmental collaborations shall continue on need basis to gainfully use the complementary expertise within the institute to achieve concrete research and project goals.

CARE faculty also work on multi-institutional collaborations in R&D such as with BITS, Goa Campus, Cochin University of Science and Technology, Kochi, University of Tokyo. There will be efforts to enhance cooperation with IGCAR Kalpakkam, GE, IRDE Dehradun, NTPC in the area of Non-destructive Characterization. Such collaborations shall be encouraged to achieve objectives of large multi-disciplinary projects.

CARE faculty contributes to teaching in other departments, notably Electrical Engineering, Physics and Textile Engineering departments. Its faculty teaches both PG courses and large undergraduate classes in the Electrical Engineering department, such as EEL101 – Introduction to Electronics, EEL205 – Signals and Systems, EEL204 – Analog Electronics. The same shall continue in future also.

10.11. New initiative that the department/center will undertake.

1. Thrust on identified new and prioritized research areas given above.
2. Recruitment of new faculty particularly in the Microelectronics area is an immediate priority. Renovation of Microelectronics labs for teaching and research facilities that is complementary to the new Nanoscale Research Facility being built in IITD.

10.12. Outreach goals and anticipated limitation in the attainment of these.

i) CARE faculty train several UG students of other institutions every year through 2-month summer internships. In addition, some UG students of other institutions do their six-month final semester projects in CARE as registered visiting students.

ii) CARE faculty participates actively in the Summer Faculty Research Fellowship Program in which 5-6 teachers of other institutions spend a minimum of 6 weeks in the summer of every year in the Centre to participate in on-going research work of the Centre and learn about approaches to doing high-quality research and also technical aspects of respective areas. This has been a very successful program wherein the some of the teachers have subsequently come back on study-leave from the respective institutions to pursue PhD in CARE.

iii) CARE faculty participates in giving lectures in the faculty development programs that run from time-to-time in other institutions.

iv) Specialized Microstrip and Antenna trainer Kits along with instructional manual of 14 experiments on Agilent Field fox Network Analyzer and 13 experiments on Anritsu handheld network analyzer at S-band GHz were developed and these have been licensed to M/S Agilent and M/S Anritsu for marketing. *These trainer kits are now being used in several colleges and universities in India to impart practical training to students in the area of RF and Microwave Engineering.*

It is expected that the interactions with faculty and students of other institutions in the above forms shall continue in an intensive manner as at present. We do not see any limitations in this regard.

10.13. Mechanisms for effective changes based on feedback received and development and implementation of corrective measures.

To be filled post-internal review.

10.14. Questions to which the department seeks answers from the Review Committee.

CARE's unique guiding objectives since inception have been:

i) To conduct technological research in selected thrust areas of national importance,
ii) To design and develop application specific advanced components / subsystems for strategic requirements,
iii) To provide manpower training in specialized areas.

CARE has largely excelled in the above objectives, and in the process developed sophisticated indigenous technologies that are in use in the field and have served several national strategic electronics requirements, particularly when foreign countries deny these advanced technologies. In the process, CARE has trained its students in the skills of doing hardcore technology work that is not very common in the country. This situation continues to exist in a major way in the country and CARE faculty is regularly requested by the armed forces, DRDO and other organizations to solve technologically complex challenges.

Advanced technology development work requires almost full-time focus of its faculty, and sometimes there are constraints on publishing or patenting due to their confidential nature etc. However, in an academic institution, there is also a requirement to do open-ended fundamental research leading to excellent journal publications, which is a different objective that also requires undivided attention.

For Centres such as CARE, what is the advice of the Review Committee regarding the relative weightage to be given to the development of advanced technologies for national strategic requirements vs. doing open-ended research resulting in publications?

11.Information for Public domain

11.1. Minutes of all meetings.

The Minutes of Meetings of the following Committees of the Centre are public information:

i) Centre's Faculty Board (CFB),
ii) Centre's Research Committee (CRC),
iii) Professorial Committee.

A copy of the minutes of all meetings of the above committees from September 2009 till January 2014 can be downloaded from the *http://care.iitd.ac.in/protected/Minutes_CFB_CRC_PFC.pdf* **.**

11.2. All reports archived in the central/department/centre libraries.

All M.Tech and PhD theses of CARE are archived in the Central Library. The list of Masters Project of all students of RFDT for last 5 years and PhD theses supervised by CARE faculty in the last 10 years is given below.

PhD Thesis supervised by CARE faculty in last 10 years

S. No.	Student's Name	Year of defence	Thesis Title / Area	Supervisors	Remarks
1	Tanmay Roy	2004	Bispectrum phase based extraction of target parameters using passive sonar	Arun Kumar and R. Bahl	
2	Prem Pal	2004	Some Novel Processes and Techniques for MEMS Design, Fabrication and Characterization	Sudhir Chandra and Suneet Tuli	FITT IIT Delhi award for best PhD thesis relevant to industry
3	Nagendra P. Pathak	2005	Linear And Non-Linear Millimetre Wave Circuit Elements Using Non-Radiative Dielectric Wave Guide	S. K. Koul and Ananjan Basu	
4	Ashish Verma	2006	Voice fonts framework for individuality representation and transformation	Arun Kumar	
5	Jyoti Prakash Kar	2006	Growth and characterization of AlN films	Suneet Tuli and G. Bose	

			and devices		
6	Gagan Mohan Khanduri	2006	Si-Ge Heterojunction Transistors	B. S. Panwar	
7	Priyanka	2006	Low Loss SAW Filter Realization by Infinite Impulse Response Design Techniques	B. S. Panwar and S. D. Joshi	
8	Rajesh Gupta	2006	An electro-thermal approach to active thermography	Suneet Tuli	
9	Ravibabu M.	2007	Propagation and processing of thermal waves for non-destructive characterisation	Suneet Tuli	
10	Abhijit Karmakar	2007	A multi-resolution auditory model and its application to objective evaluation of subjective speech quality	Arun Kumar and R. K. Patney (EE)	
11	Ravindra Singh	2008	Preparation and Characterization of Piezoelectric/Ferroelectric Thin Films for MEMS	Sudhir Chandra and T C Goel (Physics)	
12	Arnab Das	2009	Classification of marine vessels using passive sonar	Arun Kumar and R. Bahl	
13	Preeti Sharma	2009	Studies on Micromachined Structures for RF Application	S K Koul and Sudhir Chandra	
14	Vivekanand Bhatt	2009	Investigation of RF Sputtered Films for Rapid Prototyping of Micro-Electro-Mechanical-Systems (MEMS)”	Sudhir Chandra	
15	S. S. Lokesh	2011	Pre-coding techniques for communication systems	Arun Kumar and Monika Agarwal	
16	Mithilesh Kumar	2011	Active Antenna And Circuits For UWB Transceivers	S. K. Koul and Ananjan Basu	
17	Krishnendu Chatterjee	2012	Development of simulator and image processing tools for multi-technique thermography	Suneet Tuli	FITT IIT Delhi award for best PhD thesis relevant to industry
18	Smita Chugh (nee Gupta)	2012	Strategizing an eco friendly rural housing alternative using bamboo parabolic	Suneet Tuli and P. Sudhakar	

			infill arches as load bearing elements		
19	Manoj Singh Parihar	2013	Novel Reconfigurable Printed Antennas	S. K. Koul and Ananjan Basu	
20	Sandeep Chaturvedi	2013	Modeling of packages for MMICs and MEMS	S. K. Koul	
21	Atul Vir Singh	2013	Investigation of Sputter Deposited Silicon Carbide and Aluminum Nitride Films for MEMS Technologies	Sudhir Chandra and G. Bose (retired from CARE in 2009)	
22	Uday Dadwal	2013	Investigation of Blistering and Exfoliation Phenomena in Hydrogen Implanted Semiconductors for Potential Layer Transfer Applications	Sudhir Chandra and Rajendra Singh (Physics Deptt.)	
23	Hardik J Pandya	2013	Novel Techniques For MEMS-Based VOC Sensors Using Nanostructured Metal Oxides	Sudhir Chandra and A. L. Vyas, (IDDC)	
24	Mohini Gupta	2013	Optical techniques for bio-molecular sensing	Manish Sharma	
25	Sachin Pathak	Submitted in late 2013	Magnetic Materials for GHz Frequency Devices	Manish Sharma	
26	Rajesh Kumar Dubey	Submitted Dec 2013	Non-intrusive objective speech quality assessment using features at single and multiple time scales	Arun Kumar	
27	Ruchi Tiwari	Submitted Dec 2013	Sputter deposition of dielectric and semi-conducting thin films for MEMS prototyping	Sudhir Chandra	

CARE M.Tech. Projects since 2009

S. No.	Name of the student	Year	Thesis Title	Supervisors	Remarks
1.	V. Siva Prasad	2009	Design of tag and reader antennas for long range RFID applications	S.K. Koul, M. P. Abegaonkar	
2.	Sankarsan Padhy	2009	Studies of RADAR Cross Section prediction, measurement and reduction techniques	A. Basu, M.P. Abegaonkar	
3.	Lt Cdr Anurag Mittal	2009	Design of 18 – 40 GHz Broadband Double Balanced Mixer	S. K. Koul, Ananjan Basu	
4.	Lt. Cdr. Abhijit Sanyal	2009	S-band End fire array	S. K. Koul, Ananjan Basu, M.P. Abegaonkar	IETE Best Application Oriented Paper 2013
5.	Prasun Chongder	2009	Microwave/Millimeter wave Device Modeling and Non-linear Circuit Design	S.K. Koul, A. Basu	
6.	Amarendra Kumar	2009	Passive sonar classification algorithm (Pascal) and dimensionality reduction of feature vector	A. Kumar, M. Aggarwal	
7.	Amarendra Kumar	2009	Realization of underwater acoustic modem	A. Kumar, M. Aggarwal	
8.	M. V. Dora	2009	Realization of low power DSP hardware platform with BIST and development of applications	A. Kumar, R. Bahl	
9.	Sharad Bhadula	2009	Active sonar classifier: Geometric simulation of echo formulation using ray theory	A. Kumar, R. Bahl	
10	Ruchita Gomkale	2009	Separation of singing voice from music	A. Kumar	
11.	Vishwajeet Malshe	2010	LTCC based reconfigurable antennas and arrays	S.K. Koul, A. Basu	
12.	Ashutosh Sharma	2010	Reconfigurable antennas using tunable EBG structures	S.K. Koul, M. P. Abegaonkar	
13.	Rakhi Kumari	2010	Packaged MEMS phase shifter	S.K. Koul, A. Basu	
14	Saurabh Dwivedi	2010	Reconfigurable passive circuits using RF MEMS on microwave laminates.	S.K. Koul, M. P. Abegaonkar,	
15.	Kiran V.G.	2010	T/R Module at 17 GHz using indigenous MMICs	S.K. Koul, M. P. Abegaonkar	
16.	Kinjal Patel	2010	VCO using broadband amplifier and MEMS switches	M. P. Abegaonkar, A. Basu	
17.	Pramod Kumar	2010	Polarization reconfigurable active	M. P.	Paper in

			antenna	Abegaonkar, A. Basu	APMC 2010
18.	Surendra Jain	2010	MEMS based conformal antennas	S.K. Koul, A. Basu	Paper in APMC 2010
19.	Sahebgowda Patil	2010	Development of interface and driver for external flash memory with TMS320C5510 DSP Processor	A. Kumar, R. Bahl	
20.	Gunjan Pant	2010	Active sonar classifier: realistic echo formulation and HMM based classifier design	A. Kumar, R. Bahl	
21.	Hari Parameswaran	2010	Spatial mapping of radiated tonals from moving source using passive inverse synthetic aperture	A. Kumar, R. Bahl	Paper in UT-13, Tokyo Japan.
22.	Gaurav Sharma	2010	Built-in self test implementation for low power DSP hardware platform	A. Kumar, R. Bahl	
23.	Kapil Sharma	2010	Realization of underwater acoustic modem	AK, MA	
24.	Sukriti Ranjan	2010	Simulation studies on passive array signal	A. KumarM. Aggarwal	
25.	Sunil Prasad	2011	MEMS Inductor	S.K. Koul, M. P. Abegaonkar	
26.	Vanparia Kashyap C.	2011	**??**	S. Chandra, S.K. Koul	
27.	S Harprit Singh	2011	DRA EBG Antenna	S.K. Koul, M. P. Abegaonkar	
28.	Robin Gupta	2011	CMOS LNA/PA	S.K. Koul, A. Basu	IMS Student Design Competition 2012
29.	Amit Kumar	2011	Uniplanar millimeter wave circuits	S.K. Koul, M. P. Abegaonkar	
30.	Hemprasad Ghanta	2011	Fractal Antennas	M. P. Abegaonkar, A. Basu	
31.	Rajesh Kumar Jain	2011	Transceiver Design	S.K. Koul, A. Basu	
32.	Vishal Kumar	2011	PCB MEMS	A. Basu, V. Rana	
33.	Vikas	2011	**??**	S. Chandra	
34.	C. Parthiban	2011	**??**	S. Chandra	
35.	Pramod Dhande	2011	Quad-band Reconfigurable Antenna	M. P. Abegaonkar, A. Basu	Paper in ISAP 2011
36.	Takeshore	2011	Antenna array on large platforms	S.K. Koul, A. Basu	
37.	Praveen Latwal	2011	UWB Radar	M. P. Abegaonkar, A. Basu	

38.	Ankush Gupta	2011	Tunable antenna using EBG	S.K. Koul, M. P. Abegaonkar	PIERS Paper 2013
39.	Stephen P. Ranjan	2011	Reconfigurable Quad-band Filter	S.K. Koul, M. P. Abegaonkar	Paper in preparation for IETE Jr. of Research
40.	Gaurav Mittal	2011	VCO	S.K. Koul, A. Basu	
41.	Archana Ahirwar	2011	MEMS Phase Shifter	S.K. Koul, A. Basu	
42.	Srikanta Monal	2011	Transceiver Design	S.K. Koul, A. Basu	
43.	Subashish Basak	2011	Microwave Subsystems	S.K. Koul, A. Basu	Paper
44.	Kapil Dev Tyagi	2011	Calibration of underwater sensors and materials	AK, MA	
45.	Vikram Gupta	2011	Language independent audio search	A. Kumar	
46.	Chandra Shekhar Agan	2011	Underwater acoustic vector sensors	A. Kumar, M. Aggarwal	
47.	Anindya Gupta	2011	LDPC codes for VLF communication	A. Kumar, R. Bahl	
48.	Mrinal Sinha	2011	Implementation of system controller functions on compact low power multi-DSP hardware platform	A. Kumar, R. Bahl	Awarded IIT Alumni First Prize in I^2 Tech Open House 2011, and FITT Best Industry relevant M.Tech Project 2011.
49.	Shekhar Nayak	2011	Text-to-speech synthesis modules for Hindi	A. Kumar, M. Aggarwal	
50.	Ashutosh Sharma	2011	Study of generation of planar wavefront in the near field	A. Kumar, R. Bahl	
51.	Manish Kumar	2011	Configuration of DAQ systems for signal processing functions on compact low power DSP hardware	A. Kumar, R. Bahl	
52.	Ritesh Suri	2011	Active sonar classifier - realistic echo formulation and HMM based classifier design	A. Kumar, R. Bahl	
53.	Amol Gupta	2011	Magnetic sensor testing for inertial navigation	A. Kumar, M. Sharma	
54.	Ashish Singh	2012	Reconfigurable CMOS Radio Frequency Integrated Circuit	S.K. Koul, A. Basu	
55.	Anil Chepalla	2012	W-band (75-110 GHz) millimeter wave receiver components	S.K. Koul, A. Basu	
56.	Ajoy Kr. Mondal	2012	Substrate Integrated Waveguide	S.K. Koul, A.	

			Subsystem	Basu	
57.	Mohit	2012	Reconfigurable Electronic Band Gap (EBG) based Components	S.K. Koul, A. Basu	
58.	H. Gopala Krishnan	2012	Design and Development of Ultra wide band Transceiver	S.K. Koul, A. Basu	
59.	Manu Paliwal	2012	Antennas Array using Electronic Band Gap (EBG) Structures	S.K. Koul, A. Basu	
60.	Ashwani Kumar	2012	**??**	**??**	
61.	Srikanth Bura	2012	Short Range FMCW Radar	S.K. Koul, A. Basu	
62.	Giriraj Vyas	2012	EBG Structures using Metal Nanowire Arrays	M. P. Abegaonkar, M. Sharma	
63.	Yugandhar b.	2012	X-band receiver	S.K. Koul, A. Basu	
64.	Aditya Malik	2012	Underwater acoustic modem implementation using MIMO-OFDM technology	A. Kumar, R. Bahl	
65.	Sunil Kumar Sharma	2012	Implementation of applications for battery operated sonar on low-power DSP hardware platform	A. Kumar, R. Bahl	
66.	Anup Singh	2012	Algorithm design and system implementation of underwater acoustic vector sensor	A. Kumar, R. Bahl	
67.	Akshay Prabhu	2012	Active sonar classifier design and implementation	A. Kumar, R. Bahl	
68.	Pooja Rathi	2012	Design and development of scaled model of avalanche detection and localization system using infrasonics	A. Kumar, R. Bahl	
69.	Kanike Pratap	2012	Development of underwater sonar applications on OMAP processor	A. Kumar, R. Bahl	
70.	Ayush Khandelwal	2012	Simulator for imaging sonar	A. Kumar, R. Bahl	
71.	Pradeep Kumar D.	2012	Underwater acoustic communication using OFDM	A. Kumar, R. Bahl	
72.	Gowrish B.	2013	60 GHz NRD Guide Transceiver	S.K. Koul, A. Basu	Paper
73.	Vinay J. M.	2013	60 GHz CMOS RFIC	S.K. Koul, A. Basu	
74.	LT CDR Harshavardhan	2013	Substrate Integrated Waveguide Subsystem design and Fabrication	S.K. Koul, M. P. Abegaonkar	
75.	Sushobhit Gangwar	2013	Broadband Balun design and its application	S.K. Koul, M. P. Abegaonkar	
76.	Sangeeta Singh	2013	Reconfigurable antennas Design and development	M. P. Abegaonkar, A. Basu	IEEE AP-S Paper 2013
77.	Meetesh Gupta	2013	MEMS based VCO	S.K. Koul, M. P. Abegaonkar	

78.	Savita	2013	Energy harvesting	S.K. Koul, M. P. Abegaonkar	
79.	Pushpendra Kumar Singh	2013	MEMS based Phase shifter	S.K. Koul, A. Basu	
80.	Rethish Rajan	2013	Non-reciprocal device(35GHz circulator in NRD guide)	M. P. Abegaonkar, A. Basu	
81.	Vikas Kumar Kaushal	2013	MEMS based Tunable filters	S.K. Koul, M. P. Abegaonkar	
82.	Soumen Das	2013	L-band Antenna array application	M. P. Abegaonkar, A. Basu	
83.	Tripta Gupta	2013	EMI / EMC analysis of commonly used circuits on multilayer PCB	S.K. Koul, A. Basu	
84.	Parvinder Singh	2013	Broadband LNA development	S.K. Koul, A. Basu	
85.	D. Sukhvir Singh	2013	Broadband RFIC VCO	S.K. Koul, A. Basu	
86.	LT CDR Sandeep Dillip Nair	2013	W-band planar circuits	S.K. Koul, A. Basu	
87.	Deepika Sipal	2013	Reconfigurable UWB antenna design and development	M. P. Abegaonkar, A. Basu	Paper in preparation
88.	Srinu Buddarapu	2013	EMI / EMC Analysis of complex systems including electronic and mechanical parts	S.K. Koul, A. Basu	
89.	Rahul Kumar	2013	RF Class E Power Power Amplifier	S.K. Koul, A. Basu	
90.	Suman Lata	2013	Wideband Antenna Arrays	M. P. Abegaonkar, A. Basu	
91.	Prasoon Kumar	2013		S. Chandra	
92.	Arpit Goyal	2013	Hidden Markov Model based text-to-speech synthesis for Hindi	Arun Kumar	
93.	Akshay Kumar	2013	Emotional speech synthesis	Arun Kumar	
94.	K. A. Vikas	2013	Echo modeling and simulator development for imaging sonar	Arun Kumar, R. Bahl	
95.	Joseph Chacko	2013	Development of RTOS and applications on low power acoustic signal processing platform	Arun Kumar, R. Bahl	
96.	Ashish Mallik	2013	High speed underwater acoustic communication using MIMO-OFDM technology	Arun Kumar, R. Bahl	
97.	S. M. Muneeb Aatif	2013	Acoustic vector sensor system and algorithm development	Arun Kumar, R. Bahl	
98.	Ashutosh Sharma	2013	Active sonar classifier design and implementation	Arun Kumar, R. Bahl	
99.	Hemant	2013	Design and development of compact	Arun Kumar,	

	Chauhan		sonar signal processor- Based on OMAP L138	R. Bahl	
100	Baiju M. Nair	2013	Simulation and optimization of plane waves using Near Field arbitrary placed sensors	Arun Kumar, R. Bahl	
101	Rohit Agarwal	2013	Design and Development of Snow Avalanche Detection and Localization System with Field and Laboratory Experiments	Arun Kumar, R. Bahl	

11.3. Past vision documents, review documents, Standing Review Committee documents.

Vision document of CARE prepared in 2013 is attached in **Annexure – 9**.

11.4. Any other documents developed by the department, a group/section of the department/centre.

Other documents include Technical Reports of all Sponsored and Consultancy Projects that are available with the respective Project Investigators / Consultant-Incharge.

11.5. Feedback documentation and action taken on the same, and its outcome.

ANNEXURE – 1

Recommendations of RFDT M.Tech Curriculum Review Committee

CARE

RFDT M.Tech Restructuring: Committee's Recommendations (Sept 2011)

Proposed list of core and program electives for semester 1-3 for the three specialization streams in RFDT.

Stream	Semester I	Semester II	Semester III
Signal Processing stream	**1. CRL711 (4)** **2. CRL722 (3)** 3. EEL762 (3) 4. EEL711 (3) 5. One of CRL715/CRL713/ EEL731 (3) 16 credits	**1. CRL702 (4)** **2. CRL724 (3)** 3. CRL704 (3) 4. EEL765/EEL768 (3) 5. CRD860 (3) 6. Open Elective – 1 (3) 19 credits	1. CRL731/CRL707 (3) 2. CRS735/CRL705 (3) 3. Open Elective - 2 (3) 4. Major Project - 1 (6) 15 credits
Microwaves stream	**1. CRL711 (4)** **2. CRL722 (3)** 3. CRL715 (3) 4. Two of CRP723/EEL762/ CRL713 (3+3) 16 credits	**1. CRL702 (4)** **2. CRL724 (3)** 3. CRL712 (3) 4. CRP718 (3) 5. CRL725/CRL721/ EEL838/EEL834 (3) 6. Open Elective - 1 (3) 19 credits	1. Two of: CRL726/EEV838/ IDL712 / CRL737/EEL834 (3+3) 2. Open Elective – 2 (3) 3. Major Project - 1 (6) 15 credits
Microelectronics stream	**1. CRL711 (4)** **2. CRL722 (3)** 3. CRP723 (3) 4. Two of CRL715/EEL762/ CRL713 (3+3) 16 credits	**1. CRL702 (4)** **2. CRL724 (3)** 3. CRL725 (3) 4. CRD802/EEL838/ EEL834 (3) 5. CRL721 (3) 6. Open Elective - 1 (3) 19 credits	1. Two of: CRL726/CRL728/ CRL732/EEL838/EEL834 (3+3) 2. Open Elective - 2 (3) 3. Major Project - 1 (6) 15 credits

Core courses are shown in bold. Others are Program Elective Courses. Credits for each course are given in brackets.

Notes:

1. CRL713 will in future focus on basics of analog electronics (device equivalent circuits, emitter-coupled pair, current mirror etc.) Signal Processing and Microwaves related basic topics may be covered in CRL702 and CRL711 respectively, if required.

2. Streams will be nominally decided at admission. A Microwave/Microelectronics student who opts for Program Elective set (CRL715,CRP723,CRL713) cannot switch to Signal Processing stream electives. Otherwise a change to Signal Processing stream may be allowed at the end of semester I, in which case one or more of EEL762/CRL733e/EEL731 will have to be done in semester III.

3. Signal Processing stream student can switch to Microwaves/Microelectronics stream electives after semester I, in which case CRL715 will have to be done in semester III
4. Signal Processing student can switch to Microelectronics after semester I, in which case CRL713/CRP723 will have to be done in semester III.
5. EEL838 (CMOS RF IC Design) - right now incorrectly numbered EEV838 in the prospectus, and EEL834 (VLSI design) may be included as new courses in Program Elective list.

ANNEXURE – 2

Minutes of Class Committee Meetings

Annexure - 2

- CARE –

Date: 26th Feb., 2010

Sub: Minutes of the Class Committee meeting

The class committee meeting of 2008 and 2009 entry students of the RFDT M. Tech. Programme in CARE was held o 25th Feb.,2010 at 1100 Hrs in the CARE committee room. The following emerged during the meeting.

1. The students were of the opinion that more transparency may be brought in the M. Tech. project evaluation process, which will provide the distribution of the marks under different categories such as; quality of report, presentation/communication skills, knowledge gained, sincerity, quality and quantity of the work and distribution of the marks between the project reader, supervisor marks, external examiner marks and weightage given to mid-semester and final presentation of the project.
2. The students were of the opinion that there should review meeting of the projects in the group floating the projects. This practice is already being followed in some of the streams and Head CARE agreed to adopt this practice to enhance the teacher student interaction and improving the quality of work.
3. The students were of the opinion that the courses on “Fabrication Techniques for RF & Microwave Techniques CRP-723”, and “Technology of RF and Microwave Solid State Devices - CRL 725” be offered in the same semester. This will assist in having better understanding of theory and correlating theory with the experiment. The Head CARE agreed to review the case of offering the course in the same semester.
4. The students brought in the issue relating to the placement procedure followed by the placement cell where the M. Tech. students of RFDT programme gets the last priority with the industries. This is primarily on account of the fact that the RFDT programme is listed last in the short listing process. The better idea could be that short listing of the depts.. and centre be on the basis of expertise being developed.

(B. S. Panwar)

CARE, IIT Delhi

24th Sept. 2010

Sub: Minutes of Class Committee Meeting with RFDT M.Tech students.

1. The Class Committee Meeting with RFDT M.Tech students was held on 21st Sept. 2010 at 1500 hrs for 2009 batch and 1530 hrs for 2010 batch. It was attended by Prof. Suneet Tuli, Prof. Arun Kumar and students of the respective batches.

Meeting with 2009 batch students

2. Students brought out the problem of placement that companies which interview EE department students do not automatically consider RFDT students although the matter has been taken up with Placement Office on several occasions. It was resolved that the relevant companies shall be apprised of the RFDT M.Tech Program directly before they come for placement interviews to IIT Delhi.

Action: Dr. Ananjan Basu

3. Comments were invited regarding syllabi of RFDT courses. The following observations were made by the students:
   (i) There should be a full course on MEMS.
   (ii) The course CRL733 (Selected Topics in RFDT – III) can include design aspects of RF MEMS.
   (iii) Some students opined that CRL713 (Fundamentals of RF Electronics) and CRL715 (Radiating Systems for RF Communications) have a significant overlap with UG curricula, while others felt that the review of UG topics is quite useful.
   (iv) Relevant topics from analog electronics can be included in CRL713 which is an important background for EEL838 (CMOS of RF IC Design).
   (v) CRP723 (Fabrication techniques for RF and Microwave Devices) is a core laboratory course in the 1st semester while the corresponding theory course CRL725 (Technology of RF and Microwave Solid State Devices) is a program elective and is slotted in the 2nd semester. The two courses can be floated concurrently in one semester.

Action: Prof R. Bahl – Chairman, M.Tech Review Committee,
and respective Course Coordinators.

Meeting with 2010 batch students

4. Students brought out issues related to computers and the printer in CCL. It was resolved that a meeting with CCL Faculty In-charge will be scheduled to comprehensively address the issues of CCL.

Action: Dr. Ananjan Basu

5. Some students had to appear for 3 Minor exams on a single day. It was informed that a request can be made to the course coordinator in advance to arrange for rescheduling a Minor exam.

Action: Concerned students and RFDT Course Coordinators

6. The books used for the courses were generally not available from Central Library. It was mentioned that cheaply priced Indian edition text-books can be purchased by the

students and course coordinators shall make available other reference material wherever required.

Action: RFDT Course Coordinators

Arun Kumar

CARE, IIT Delhi

7th March 2011

Sub: Minutes of Class Committee Meeting with RFDT M.Tech students.

1. The Class Committee Meeting with RFDT M.Tech students was held on 21st February 2011 at 1200 hrs for 2009 batch and on 24th February 2011 1200 hrs for 2011 batch. It was attended by Prof. Suneet Tuli, Prof. Arun Kumar and students of the respective batches.

Meeting with 2009 batch students

2. Students brought out that the Internet quota of 500 MB/week allotted to M. Tech students is less considering that they have to download papers etc. for courses and projects. It was observed that this is an Institute-wide policy. The requirement of more quota is likely to be in exceptional cases wherein student's supervisors can be requested to download the required material.

3. Students observed that companies coming for placement interviews to campus need to be made more aware of the RFDT M.Tech program.

   Action: Dr. Ananjan Basu

4. There is a conflict in the course slot in which Analog IC course is offered by EE department, with another course of RFDT. This shall be resolved in the next year's course slotting so that more students can credit the Analog IC course.

   Action: Dr. Monika Agarwal

Meeting with 2010 batch students

5. Students mentioned that a heavy-duty printer can be installed in CCL to cater to the large number of students using the lab.

   Action: Dr. Ananjan Basu

6. There were no comments regarding the courses being done by the students in the current semester.

Arun Kumar

CARE, IIT Delhi

15th March 2013

Sub: Minutes of Class Committee Meeting with RFDT M.Tech students.

1. The students pointed out that there was some difference between the topics covered in the lectures in CRL724 and the Minor I examination questions in the same course. Other than this, the students felt that the course-work was progressing smoothly.

   Action Prof Suneet Tuli

2. The students from DRDO/Navy emphasized the difficulties caused by lack of accommodation on campus. Several possibilities to mitigate this were discussed – it was felt that the possibility of IIT Delhi arranging rented accommodation off-campus, to be paid for by the Navy (or other MoD branch) was worth exploring.

   Action : Head, CARE

3. The placement process was discussed and it was concluded that placement options beyond campus interviews should be pursued more aggressively.

   Action : Dr Mahesh Abegaonkar

Ananjan Basu

(M.Tech co-ordinator)

CARE, IIT Delhi

27th Sept 2013

Sub: Minutes of Class Committee Meeting with RFDT M.Tech students.

[A- course specific feedback]

1. Students felt that their skills in probability theory should be brushed for EEL762. Some extra practice sessions after minor 2 would be useful

   Action : Prof Arun Kumar

2. Students felt that some of the topics dealing with basic theory of RF devices from currently taught CRL733 (Selected Topics – currently covering physics of RF devices like HEMT and HBT) should be taught in CRL722.

   Action : Prof S Chandra

[B – general suggestions]

3. Students felt that the lab course EEP776 (Wireless Communication lab) is important for the RFDT program and should be core.

4. Students suggested that the courses should have more application-oriented content and should expose them to the latest developments in the relevant field.

5. Students suggested that all or most of the core courses should be covered in the first semester.

6. Students felt that CRP723 (Fabrication Techniques for RF & Microwave Devices) and EEL762 (digital communication) should not be core.

7. Students felt that 'Analog IC' (EEL782) should be taught in both semesters to make it available all students who opt for it.

8. Students felt that there should be greater exposure to 'Matlab' before using it in courses such as CRL702.

Ananjan Basu

(M.Tech co-ordinator)

ANNEXURE - 3

M. Tech in Radio Frequency Design and Technology (RFDT)

Syllabus for each Course

Annexure - 3

CRL 702 - Architectures and Algorithms for DSP Systems

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1. Course Structure and Credits: L-T-P (2-0-4); Credits: 4
2. Status of Course: Core course
3. Prerequisites for the Course: None
4. Course Objective and Contents:

Objective

The objective of this course is to comprehensively introduce Master's level students to design techniques and methodologies for digital signal processing systems. Theory classes and laboratory sessions will be held in parallel to equip students with the fundamental aspects of DSP chips and their usage in practice. Students will be exposed to:

(a) state-of-the art programmable digital signal processor architecture and its assembly language programming,

(b) standard algorithms used for processing digital signals and their optimal implementation techniques and,

(c) analysis and optimisation methods for DSP algorithms and systems.

The course will enable students to design diverse DSP systems such as modems, acoustic beam formers, digital speech, audio, image and video compression systems, wireless and mobile communication systems etc.

Contents (28 Lectures)

- Introduction to Digital Signal Processing Systems (DSP tasks; DSP processors and embodiments; Representation of DSP algorithms – block diagram, signal flow graph, data flow graph, dependence graph) (3L)

- Numeric Representation and Arithmetic Operation Formats (Fixed point and floating point representations; Extended precision; Floating point emulation; Q notation; Fixed point and floating point arithmetic operations) (2L)

- Architecture of Programmable Digital Signal Processors (Central processing unit - Data and program memory features; Peripheral interfacing; Execution control) (5L)

- Digital Signal Processor specific Assembly Language Programming (3L)

(Instruction types; Addressing modes. Assembly language programming for specific fixed / floating point DSP processor; Pipelining)

- DSP Algorithms (Convolution and FFT; Methods for generation of elementary functions; Pseudo-random number generation) (4L)

- Analysis and Optimization of DSP Algorithms and Systems (Loop bound and iteration bound; Retiming transformation; Unfolding transformation from data flow graph - Folding transformation; Performance optimization using pipelining and/or parallel processing) (7L)

- Software Design for Low Power (Sources of power consumption in a programmable DSP; Software power estimation; Software optimization techniques for low power) (4L)

Laboratory: 12 Turns

- Familiarization with assembly language programming tools of chosen DSP Processor (1 Turn)

- Number representation formats and arithmetic operations (1 Turn)

- Basic DSP operations: Filtering, FFT (4 Turns)

- Random number and other function generation algorithms (2 Turns)

- Lab Project (4 Turns)

CRL 704 – Sensor Array Signal Processing

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1. Course Structure and Credits: L-T-P (3-0-0); Credits: 3
2. Status of Course: Program Elective
3. Prerequisites for the Course: Signal Theory (or equivalent course)
4. Course Objective and Contents:

Objective

This course will provide Master's level students with a comprehensive unified coverage of the key topics in the theory of sensor array signal processing. The course will focus on representation and modeling of space-time signals, spectral estimation, adaptive filtering, signal shaping for transmission and array signal processing aspects. The course will equip students to design sensor array signal processing systems for diverse applications.

Contents

42 Lectures

- Representation of Space - Time Signals (Coordinate systems; propagating waves; wave number-frequency space; random fields; noise assumptions) (3L)
- Signal Modeling and Optimal Filters (Auto-regressive (AR), Moving average (MA), ARMA models; Autocorrelation and power spectral density (PSD) of random processes; linear minimum mean square and linear least squares error estimator; solution of normal equations; optimum filters; matched filters) (7L)
- Adaptive Filter Theory (Motivation and applications; method of steepest descent; Least mean squares adaptive filters; recursive least squares adaptive filters; Convergence issues and performance analysis) (6L)
- Power Spectrum Estimation (Nonparametric methods: Estimation of autocorrelation function and PSD using periodogram; Blackman-Tukey and Welch-Bartlett methods; Parametric methods: Model and model order selection; PSD estimation using rational spectral models; MUSIC; ESPRIT.) (9L)
- Signal Shaping for Transmission (Representation of band pass signals;

band pass sampling theorem; Complex Envelope; Ambiguity function and its properties; Considerations in signal shaping.) (6L)

- Array Processing (Array signal modeling; sensor array: geometries; spatial sampling; beam forming - spatial and space-time filtering; array aperture; delay and sum beam forming; filter and sum beam forming; frequency domain beam forming; optimum beam forming: MVDR beam former, Generalized side-lobe canceller; Adaptive beam forming) (11L)

CRL 705 - Advanced Sensor Array Signal Processing

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1. Course Structure and Credits: L-T-P (3-0-0); Credits: 3
2. Status of Course: Program Elective
3. Prerequisites for the Course: Sensor Array Signal Processing
4. Course Objective and Contents:

Objective

This course will provide Master's level students with detailed coverage of sensor array signal processing. This advanced course will help students in understanding the various concepts of the state of art problems of the direction of arrivals estimation, beamforming, detection of sources and array design. The course will equip the students to do research and system design projects in this area.

Contents

42 Lectures

- Introduction: Motivating examples, history of array signal processing, wave propagation, mathematical model, basic notations, assumptions and problem formulation (2L)
- DOA Estimation Problem: Basic estimation methods, beamforming techniques, subspace techniques, ML techniques (Deterministic and stochastic), some special techniques for ULAs, coherent, wideband, nearfield, spread etc. sources (16L)
- Beamforming: Classical methods, Subspace techniques, space time beamforming. Special techniques for ULA, wideband etc. sources. (10L)
- Detection of number of signals Classical methods, subspace methods. (4L)
- Array design techniques (6L)
- Special topics (4L)

CRL 707 – Human and Machine Speech Communication

1.	Course Structure and Credits:	L-T-P (3-0-0);	Credits: 3
2.	Status of Course:	Program Elective	
3.	Prerequisites for the Course:	First course on DSP	
4.	Course Objective and Contents:		

Objective

The objective of this course is to introduce Master's level students to digital speech processing techniques for human and machine communications. Wireless communications is heavily dependent on advanced speech coding techniques for basic voice communications purposes. Furthermore emerging applications of voice based interactions with computers require an understanding of speech recognition, speech synthesis, speaker recognition etc. These topics will be studied in the course. Further, the course will provide a comprehensive overview of speech science topics, speech signal analysis techniques, auditory perception and speech quality evaluation techniques to form a complete insight into the subject of human and machine communications via speech.

Contents

42 Lectures

- Introduction (Human-machine speech communications aspects; speech chain; digital representations of speech; intensity level of sound) (2L)
- Speech production (Anatomy and physiology of speech organs; articulatory phonetics; acoustic phonetics; phonetic transcription; universal speech production model) (4L)
- Speech signal analysis (Time domain methods; Frequency domain methods; Pitch estimation; Spectrogram analysis; Cepstrum analysis;) (5L)
- Linear prediction coding (Least squares autocorrelation and covariance methods; Line spectral frequencies) (3L)
- Psychoacoustics and auditory perception (Hearing; critical bands; phenomena of masking; Mel scale; perceptually important features of speech; prosodic features) (3L)

- Speech signal coding (Speech coder attributes; Coding rates; PCM; ADPCM; CELP; Harmonic coding of speech; Coding standards) (8L)

- Evaluation of speech quality (Dependencies of quality; Objective and subjective quality evaluation measures; Objective evaluation of subjective quality) (2L)

- Speech synthesis (Limited and unrestricted text to speech synthesis; Articulatory synthesis; Concatenative synthesis; Incorporation of prosody) (3L)

- Automatic speech recognition (Pattern recognition approach; Dynamic time warping; Feature extraction; HMM; Language models) (8L)

- Speaker recognition (Verification vs. recognition; recognition techniques; features that distinguish speakers) (4L)

CRL 711 – CAD of RF and Microwave Circuits

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1. Course Structure and credits: L-T-P (3-0-2); 4 Credits
2. Status of course: Core course
3. Pre-requisites for course: Course on Basic Electromagnetics
4. Course Objective and Contents:

Objective

To provide understanding of the operation of linear passive microwave components, and equip the students with the tools for analyzing and designing such components. At the end of the course, the student should be able to design microwave components using industry standard CAD tools.

Contents

42 lectures

- Review of basic microwave theory: Transmission Lines and waveguides – Concepts of characteristic impedance, reflection coefficient, standing and propagating waves. Modes and evanescent waves (4L)
- Network analysis: S, Z and other multi-port parameters, impedance matching and tuning. Implementation in simulators. (8L)
- Planar transmission lines: Quasi-static analysis, full wave analysis, and numerical techniques. (6L)
- Discontinuities, equivalent circuits, use of simulators. (5L)
- Simple printed couplers, filters, power dividers (8L)
- Implementation with lumped elements at RF (5L)
- Simulation of structures on HFSS, and optimization. (6L)

Laboratory: 10 Turns

- Design and fabrication of band pass filter using SERENADE (2 Turns)

- Design and fabrication of Wilkinson power divider using SERENADE (2 Turns)
- Design and fabrication of ring coupler using SERENADE (2 Turns)
- Design and fabrication of NRD guide band pass filter using HFSS (4 Turns)

CRL712 – RF and Microwave Active Circuits

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1. Course Structure and Credits: L-T-P (3-0-0); Credits: 3

2. Status of Course: Program Elective

3. Pre-requisites for Course: Course on Basic Electromagnetics, a. (CRL711 preferable)

4. Course Objective and Contents:

Objective

Provide understanding of the operation of active microwave components, and equip the student with the tools for analyzing and designing such components, particularly non-linear ones, utilizing CAD tools if desirable.

Contents

42 Lectures

• Small signal amplifiers – low noise, maximum gain, stability	(9L)
• Broad band amplifiers – matching circuits, travelling wave amplifiers	(9L)
• Power amplifiers – Efficiency, CAD, device modeling, measurement	(9L)
• Mixers – Single ended, balanced, double balanced, different configurations for microstrip, waveguide etc., noise properties, simulation using harmonic balance.	(9L)
• Oscillators – various configurations depending on active device, stability and noise, resonators, VCO, transient analysis using SPICE, harmonic balance analysis, frequency synthesis using DDS, PLL.	(6L)

CRL 713- Fundamentals of RF Electronics

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1. Course Structure and Credits: L-T-P (2-0-2); Credits: 3
2. Status of Course: Core Course
3. Prerequisites for the Course: None
4. Course Objective and Contents:

Objective

The objective of this course is to introduce the basic concepts of signal processing, microelectronic devices and microwave lumped and distributed circuit elements. The course will cover the techniques of frequency conversion, Modulation, digital signaling, and discrete time signal processing techniques, DC and low frequency concepts in the modeling of microelectronic devices, two port representation of RF / microwave networks, scattering parameters etc.

Contents

28 Lectures

- Mathematical foundation in understanding of signals, microwave circuits, and devices: (5L)

  Phasor diagrams, duality, superposition, miller, Thevenin and Norton Theorems, instantaneous, average, complex powers their representation nomenclature, Fourier series, Laplace, Fourier and Z transforms, convolution, correlation and basic properties of Fourier transforms, transmission line theory, T and Π equivalent circuit, behavior of transmission line at radio frequency. Physics and operation of bipolar, and MOS structures.

- DC and Low Frequency Circuit Concepts: (5L)

  BJT Biasing, mode of operation small signal AC analysis, FET circuits at DC, AC analysis, first and second order AC models of FETs, high frequency models of BJT and FETs, single pole approximation, differential amplifiers, and frequency response

- Circuit Representation of Two Port RF/ Microwave Networks: (3L)

Impedance, Admittance, Hybrid, Transmission line Parameters, Transmission Matrix, Generalized S parameters, Reciprocal Networks, Loss less Networks, Signal flow graphs and its Applications.

- Gain Consideration in amplifiers, Impedance Matching and Network Selection: (4L)

  Power gain concept, mismatch factor, return loss, input / output VSWR, maximum gain, constant gain design, figure of merit, matching network design using lumped and distributed elements, stability considerations in active networks.

- Base-band and Pulse Signaling: (4L)

  Sampling, quantizing and encoding, digital signal formats: binary coding, differential coding, bit synchronization, multilevel signaling, intersymbol interference, differential pulse code modulation, delta modulation time division multiplexing, pulse time, pulse width, pulse position modulation

- Amplitude and Frequency Modulation (3L)

  Amplitude modulation, Double sideband suppressed carrier, Asymmetric sideband signals, phase/frequency modulation, narrowband angle modulation, wideband frequency modulation

- Band pass Digital Signaling (4L)

  Binary signaling (OOK, BPSK, DPSK), multilevel signaling (QPSK, MPSK, QAM), minimum-shift keying (MSK) and comparison of band pass digital signaling systems, band pass sampling, filtering and linear distortion.

Laboratory: 12 Turns

- Design, simulation (P spice), realization, and characterization of high gain differential amplifier used in the first stage of an operational amplifier. This will involve design and simulation of a current source, extraction spice parameters, gain characterization etc. (4 Turns)

- Comparison of coding schemes, self-correcting codes, assembly language programming, operating a system in a closed loop for investigating the matched filtering performance, detecting the signal in a noisy environment. The already developed modules for SODAR and the new two systems being developed for RF Identification will (4 Turns) be used for this experiment.

- Design, fabrication and characterization of an RF antenna (4 Turns)

CRL 715 - Radiating Systems for RF Communication

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1. Course Structure and Credits: L-T-P (3-0-0); Credits: 3
2. Status of course: Program Elective
3. Pre-requisites for course: Basic course on Electromagnetics
4. Course Objective and Contents:

Objective

To provide an understanding of the operation of microwave antennas, and the scattering of radiation by different types of objects.

Contents

42 lectures

- Antennas: radiation concepts, dipoles, monopoles (6L)
- Antenna parameters (gain, efficiency etc.) – theory, comparison with simulators , and measured data for simple antennas (6L)
- Analysis and synthesis of simple linear arrays. Optimizers. (6L)
- Equivalence theorems and application to horns and reflectors, comparison with simulations. (8L)
- Active and passive electronic scanning antennas (4L)
- Microstrip and other printed antennas, analysis using equivalent circuit, numerical techniques. Broad band printed antennas, and other broad-band antennas for ESM. (6L)
- Scattering by wedge, GTD, and application to short-range communications. (6L)

CRP 718 - RF and Microwave Measurement Laboratory

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1. Course Structure and Credits: L-T-P (0-0-6); Credits: 3
2. Status of Course: Core Laboratory
3. Prerequisites for the Course: None.
4. Course Objective and Contents:

Objective

The objective of this course is to provide Master's students with hands-on exposure to measurement techniques in the RF and Microwave domain, and with the various kinds of sensors and transducers utilised thereof.

Contents

Laboratory: 10 Turns

- Experiments based on measurement and instrumentation techniques using: (5 Turns)

  oscilloscopes, spectrum analyzers, network analyzers, lock-in-amplifiers, waveform generators, bit-error rate and S/N measurement, antenna characterization, telemetry, data recorders and display, etc.

- Experiments based on various sensors used in characterization of RF materials, devices, circuits and systems: (5 Turns)

  acoustic, ultrasonic, magnetic, electrical, thermal, optical, radiation, and smart sensors, etc.

CRL721 – Analog/RF IC Modeling and Design

1.	Course Structure and Credits:	L-T-P (2-0-2),	Credits: 3
2.	Status of the Course:	Program Elective	
3.	Prerequisite of the Course:	None	
4.	Course Objective and Contents		

Objective

The course will provide an exposure on the design and modeling of Silicon and SiGe bipolar, CMOS and HBT's, and sub-micron phenomena. The course will also build up the background on the building blocks of RF receivers and discuss the design limitations. The techniques of RF communications, their limitations and the basic receiver architectures will be covered in the course.

Contents

28 Lectures

- Amplifier fundamentals in CMOS, Bipolar and BiCMOS technologies (3L)
- SiGe – Heterojunction Bipolar Transistors for RF applications and their noise performance (3L)
- Trans-receiver building blocks for CMOS, Bipolar and BiCMOS (3L)
- Low voltage, Low noise, Low power techniques in RF CMOS sub micron design (4L)
- Receiver Architecture, RF / Base band filtering and compensation (3L)
- LNA's and VCOs at RF – Design and Limitations (3L)
- Direct conversion, Image rejection, sub sampling, mobile and cellular communication (5L)
- Multimode, multi-band communications 3G communication (4L)

Laboratory: 12 Turns

- Design and characterization of a high gain (20,000) differential Amplifier (2 Turns)
- Design and Simulation of high gain high frequency SiGe Double Hetero structures Transistors (2 Turns)
- Characterization and simulation of a communication link (2 Turns)
- Coding schemes, self correcting codes and auto-correlation process (2 Turns)
- Design and characterization of an integrated transmit receive module (2 Turns)
- Sampling, sub sampling, band pass sampling and spectrum characetrization (2 Turns)

CRL722 – RF and Microwave Solid State Devices

1.	Course Structure and Credits:	L-T-P (3-0-0);	3 Credits
2.	Status of Course:	Program Elective	
3.	Prerequisite for the Course:	None	
4.	Course Objective and Contents		

Objective

The objective of this course is to introduce the Master's level students to the semiconductor devices used in RF and microwave circuits and systems. The course aims to provide sound knowledge in the area of semiconductor devices relevant to RF and microwave applications.

Contents

42 Lectures

- Review of basic concepts in semiconductor device operation: energy-band diagram, drift and diffusion currents, generation recombination, excess carriers, and p-n junction theory (9L)
-
- Schottky barrier diode: formation of metal-semiconductor barrier, Schottky-Mott theory and modification, metal-semiconductor interface, silicides-Si interface, effect of interface states, current flow through barrier, forward and reverse bias I-V, C-V characteristics, measurement of barrier height. Schottky diode device structures and technology. Ohmic contact formation (4L)
-
- Varactor diode, equivalent circuit, C-V characteristics for linearly graded, abrupt, and hyper abrupt p-n junctions, cut-off frequency (4L)
- P-I-N diode general considerations, I-V and C-V characteristics (4L)
- IMPATT diode, principle of operation, small signal impedance, power conversion efficiency, diode structure and fabrication (4L)
- Transferred electron devices, differential negative resistance effect, Gunn diode (4L)
- GaAs MESFETs, basic device structure, theory of operation, equivalent circuit and analysis (4L)
- Silicon MOSFETs: brief review of MOSFET theory, design and operation, high frequency structures, SOI based MOSFETs (5L)
- Passive components in RF technology (inductors, capacitors), MMICs (4L)

CRP723 – Fabrication Techniques for RF & Microwave Devices

1.	Course Structure and Credit:	L-T-P (1-0-4); Credits:3
2.	Status of Course:	Core Course
3.	Prerequisite for the Course:	None
4.	Course Objective and Contents:	

Objective

The objective of this course is to provide the students basic background in microelectronics device fabrication techniques and hands-on practical training in Integrated Circuit fabrication relevant to RF and microwave devices. It is proposed to cover vacuum systems and metallization technologies, photolithography and etching processes, mask making techniques, and process integration aspects. It is also proposed to introduce the concepts of test chip design and characterization.

Contents

14 Lectures

- Concept of process flow in IC fabrication, representative process flow for diode / MOSFET (2L)
- High temperature processes: oxidation, diffusion, and annealing (2L)
- Use of "masks" in IC fabrication, mask design and fabrication (1L)
- Photolithography processes (2L)
- Chemical etching processes: dry and wet etching (2L)
- Vacuum and vacuum systems (2L)
- Thin films in IC processing, resistive evaporation, e-beam, RF and DC sputtering processes (2L)
- Concept of test chip design and process parameter extraction (1L)

Laboratory: 12 Turns (4 hours duration)

- Vacuum systems. (1 Turn)
- Thermal evaporation, DC/ RF sputtering (2 Turns)
- Mask making techniques: Coordinatograph / Photo-plotter First Reduction Camera, Step and Repeat process (1 Turn)
- Photolithography process (1 Turn)
- Etching techniques (1 Turn)
- Oxidation / diffusion processes (1 Turn)
- Diode fabrication (2 Turns)
- Band Pass filter fabrication (1 Turn)
- Measurement equipment calibration (2 Turns)

CRL724 – RF and Microwave Measurement System Techniques

1.	Course Structure and Credits:	L-T-P (3-0-0); Credits: 3
2.	Status of Course:	Core Course
3.	Prerequisites for the Course:	None
4.	Course Objective and Contents:	

Objective

The objective of this course is to acquaint Master's students with measurement techniques instruments and systems in the RF and microwave domain, and with the various kinds of sensors and transducers utilised in characterisation of RF materials, devices, circuits and systems.

Contents

42 Lectures

- Review of measurement and instrumentation basics (6L)
- Principles and applications of various sensors used in characterization of RF materials, devices, circuits and systems: acoustic, ultrasonic, magnetic, electrical, thermal, optical, radiation, and smart sensors. (7L)
- Mechanical and thermal engineering issues for RF modules/ instruments (3L)
- Instrumentation concepts and measurement techniques in:
  Oscilloscopes (3L)
  Spectrum analyzers (3L)
  Network analyzers (3L)
  Lock-in-amplifiers (3L)
  Waveform generators (3L)
  Bit-error rate measurement (2L)
  S/N measurement (2L)
  Telemetry (2L)
  Data recording and display (2L)
- Recent advances in RF and Microwave Measurement Techniques (3L)

CRL725 – Technology of RF and Microwave Solid state Devices

1. Course Structure and Credits: L-T-P (3-0-0); Credits: 3
2. Status of Course: Program Elective
3. Prerequisite for the Course: None
4. Course Objective and Contents:

Objective

The purpose of this course is to provide the students sound knowledge related to the fabrication aspects of RF and Microwave devices. It is expected that the students taking this M.Tech course will come from varied background. For this reason, it is proposed to provide basics of semiconductor technology in the first few lectures before moving on to the technologies more relevant to RF and Microwave devices.

Contents

42 Lectures

- Review of semiconductor device processing technologies: process sequence development for a representative MOS technology, overview of oxidation, diffusion, mask making, pattern transfer, etching, metallization etc., process integration (9L)
- Techniques of metallization: Introduction to vacuum systems. Sputtering (DC, RF and magnetron), e-beam evaporation for ohmic and Schottky contact formation, silicides for gate and interconnect. (6L)
- Fine line lithography process: optical lithography, x-ray and e-beam lithography, lift-off techniques (4L)
- Wet and plasma assisted etching techniques, RIE, RIBE (4L)
- Introduction to Ion Implantation, Molecular Beam Epitaxy (4L)
- Chemical Vapour Deposition (epitaxial growth, polycrystalline silicon, dielectric films, low pressure and plasma chemical deposition) (5L)
- GaAs MESFET technology (5L)
- Introduction to MEMS technology (5L)

CRL 726 – RF MEMS Design and Technology

1. Course Structure and Credits: L-T-P (3-0-0); Credits:3

2. Status of Course: Program Elective

3. Prerequisite for the Course: None

4. Course Objective and Contents:

Objective

The objective of this course is to introduce the M.Tech. students to the emerging area of Microelectromechanical Systems (MEMS) as applied to Radio Frequency (RF) and Microwave Systems. The subject is interdisciplinary in nature as it encompasses topics from integrated circuit fabrication technology, mechanical and material science and engineering and RF/microwave electronics and communication systems. It is widely believed that MEMS will revolutionize the wireless and satellite communication.

Contents

42 Lectures

- Introduction and origin of MEMS, driving force for MEMS development, fabrication process (2L)
- MEMS fabrication technologies: Conventional IC fabrication processes, bulk micro machining, surface micro machining, LIGA process, anodic and fusion bonding, packaging techniques for MEMS (8L)
- Sensors: classification and terminology of sensors, evolution of semiconductor sensors, sensor characterization, basic concepts of acoustic, mechanical, magnetic, radiation, thermal sensors and integrated sensors (5L)
- Actuation in MEMS devices, electrostatic actuation, parallel plate capacitor-cantilever beam based movement, comb-drive structures (5L)
- The MEM switch: cantilever based MEM switch, membrane based switch design, microwave, material and mechanical considerations (5L)
- The MEMS switch: cantilever based MEMS switch, membrane based switch design, microwave, material and mechanical considerations (5L)
- Microwave transmission lines, membrane supported micro-strip line, coplanar waveguide, micro-machined waveguides, inductors, capacitors and tunable capacitors (6L)

- MEMS based RF and microwave circuits: phase shifters, resonators, filters, oscillators (6L)

CRL 728 - RF Electronic System Design Techniques

1.	Course Structure and Credits:	L-T-P (3-0-0) ; Credits: 3
2.	Status of the Course:	Program Elective
3.	Prerequisite of the Course	None
4.	Course Objective and Contents	

Objective

The objective of the course is to introduce to the students on the design RF Systems, mode of communications at RF, basic building blocks of an RF system and protocols for the communications at RF. The course will also cover the architecture of existing RF system in context with the specification, performance and functionality of the system. The use of blue tooth technique, CDMA, wireless connectivity and other techniques of RF communication will be covered.

Contents

42 Lectures

- Economics of Wireless and Fixed Communication Systems (2L)
- Building Blocks of RF Systems, super component design (4L)
- Spread Spectrum Communication and Channel Modeling (4L)
- Advanced Receiver Algorithms (4L)
- Reed Solomon codes and Modulation (3L)
- Wireless Application Protocols (3L)
- WAP Services and Applications (4L)
- Personal Communication Systems and Global Positioning Systems (4L)
- CDMA and Bluetooth System Simulation (4L)
- Systems on Chip (4L)
- 3 G systems (6L)

CRL731 – Selected Topics in RFDT - I

1.	Course Structure and Credits:	L-T-P (3-0-0); Credits: 3
2.	Status of Course:	Program Elective
3.	Prerequisite for the Course:	As per course contents
4.	Course Objective and Contents:	As per requirements of students

CRL732 – Selected Topics in RFDT- II

1.	Course Structure and Credits:	L-T-P (3-0-0); Credits: 3
2.	Status of Course:	Program Elective
3.	Prerequisite for the Course:	As per course contents
4.	Course Objective and Contents:	As per requirements of students

CRL733 – Selected Topics in RFDT- III

1.	Course Structure and Credits:	L-T-P (3-0-0); Credits: 3
2.	Status of Course:	Program Elective
3.	Prerequisite for the Course:	As per course contents
4.	Course Objective and Contents:	As per requirements of students

CRS735 –Independent Study

1.	Course Structure and Credits:	L-T-P (0-3-0); Credits: 3
2.	Status of Course:	Program Elective
3.	Prerequisite for the Course:	As per course contents
4.	Course Objective and Contents:	As per requirements of students

CRL 737 – Selected Topics in Radars and Sonars

1.	Course Structure and Credits:	L-T-P (3-0-0); Credits: 3
2.	Status of Course:	Program Elective
3.	Prerequisites for the Course:	None
4.	Course Objective and Contents:	

Objective

This is primarily a systems oriented course that will familiarize students with practical applications in the fields of Radar and Sonar. It will be particularly useful for practicing engineers who work with radars or sonars.

Contents

42 Lectures

- The Radar and Sonar Equations: Basic System Parameters; Radar and Sonar Applications (4L)
- High resolution imaging sonars: Sidelook sonar, Sector-scan sonar, Modulation scanning techniques, synthetic aperture sonar, CTFM/FMCW principle. (14L)
- Modern Navigation and positioning techniques. (3L)
- The Doppler Effect, FM-CW Radar, MTI Radar, Pulse Doppler Radar, tracking and Monopulse radar. (11L)
- Scattering and radar cross-section, radar clutter and combating clutter. (10L)

CRD802 –Minor Project

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1. Course Structure and Credits: L-T-P (0-0-6); Credits: 3
2. Status of Course: Program Elective
3. Prerequisite for the Course: As per course contents
4. Course Objective and Contents: As per requirements of students

CRD811 –Major Project -I

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1. Course Structure and Credits: L-T-P (0-0-12); Credits: 6
2. Status of Course: Core Course
3. Prerequisite for the Course: As per course contents
4. Course Objective and Contents: As per requirements of students

CRD812 –Major Project - II

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1. Course Structure and Credits: L-T-P (0-0-24); Credits: 12
2. Status of Course: Core Course
3. Prerequisite for the Course: As per course contents
4. Course Objective and Contents: As per requirements of students

RFDT M.TECH COURSES FROM OTHER DEPARTMENTS AND CENTRES

- **Core Course**

  EEL 762 Digital Communication

- **Program Elective Courses**

  EEL 731 Digital Signal Processing

  EEL765 Sonar System Engineering

  EEL711 Signal Theory

  EEL768 Detection and Estimation

  IDL712 Electronic Techniques for Signal Conditioning and Interfacing

ANNEXURE – 4

CARE SEMINAR SERIES

Annexure - 4

CARE Seminar Series

S. No.	Name	Topic	Date
1	Krishnendu Chatterjee	Sub-surface Imaging Using Thermal Waves	28-Jan-2010
2	Rajesh Kumar Dubey	Speech Quality Estimation Techniques	11-Feb-2010
3	Atul Vir Singh	Micro-Electro-Mechanical Systems: An Introduction with Examples	25-Feb-2010
4	Manoj Singh Parihar	Novel Reconfigurable Printed Antennas	11-Mar-2010
5	Lokesh S.S.	Precoding Techniques for Communication Systems	25-Mar-2010
6	Madhur Deo Upadhyay	Active Antenna for RF Systems	8-Apr-2010
7	Mithilesh Kumar	Active Antenna & Circuits for UWB Transceivers	22-Apr-2010
8	Hemalata Choudhary	Passive Acoustic Localization of Transient Signal Source using Narrow Aperture Array	13-Apr-2011
9	Mohini Gupta	Optical Techniques for Bio-Molecular Sensing	28-Apr-2011
10	Sachin Pathak	Study on magnetization dynamics in electrodeposited magnetic nanostructures	5-May-2011
11	Rinki Gupta	Estimation of Instantaneous Frequency and its Applications	19-Jan-2012
12	Ruchi Tiwari	Anodic Bonding for MEMS Application	9-Feb-2012
13	Neetu Agarwal	Electronic Transport in Graphene Based Devices	15-Mar-2012
14	Neetu Agrawal	Electron optics with Dirac fermions: Electron transport in mono- and bi- layer graphene through various scalar and vector potential barriers	13-Nov-2013
15	Akula Rajani	Snow Avalanches Modeling, Detection And Localization	13-Nov-2013
16	Rajesh Dubey	Non-intrusive Objective Speech Quality Evaluation using Features at Multiple Time Scales	20-Nov-2013
17	Ruchi Tiwari	Piezoresistive pressure sensor using low-temperature aluminium induced crystallization of sputter-deposited amorphous silicon film	27-Nov-2013
18	Anima Johari	Synthesis and study of structural, optical and gas sensing properties of tin oxide (SnO_2)	11-Dec-2013

		nanostructures	
19	Pradeep Rathore	CMOS Compatible MEMS Structures for Pressure Sensing	18-Dec-2013
20	Pratyush Varshney	Theoretical Modelling, Design principles and Simulation of Surface Acoustic Wave Resonators and Filters	23-Jan-2014
21	Lalithendra Kurra	Reconfigurable and tunable electromagnetic bandgap structures	30-Jan-2014
22	Ritabrata Bhattacharya	Reconfigurable and Broadband CMOS RF ICs	12-feb-2014

ANNEXURE – 5

COURSE FILES

Course Files

The course information for the following courses are given in the succeeding pages:

S. No.	Instructor	Course Nos.
1.	Mahesh Abegaonkar	CRL715, CRL724, EEL713, EEL207, EEL338, EEP307.
2.	Ananjan Basu	CRL712, CRL713, CRL724.
3.	S. K. Koul	CRL711.
4.	Karun Rawat	EEL713.
5.	Arun Kumar	CRL702, CRL704, CRL707.
6.	Monika Agarwal	EEL205, CRL732.
7.	R. Bahl	CRL731, EEL765.
8.	Sudhir Chandra	CRP723.
9.	B. S. Panwar	CRL726.

1. Mahesh Abegaonkar:

Course	Years	Course Contents (General)
CRL715	2005-06, 2006-07, 2007-08, 2008-09, 2009-10, 2011-12, 2012-13, 2013-14	**Contents:** Revision: Maxwell's equations and Plane waves: **Minor – I;** Antenna Parameters: **Minor – I**Wire Antennas: **Minor – I;** Aperture Antennas: **Minor – II;** Antenna Arrays: **Minor – II;** Microstrip Antennas: **Major;** Antennas for modern communication systems: Broadband, high gain, compact, conformal, active antennas, Multi-band antennas, Reconfigurable antennas: **Major;** Student Seminars: **Major** **Evaluation:** Minor – I: 20% (Topics covered till Minor-I); Minor – II:20% (Topics covered after Minor-I till Minor-II); Major: 40% (Complete syllabus with 30% marks for topics covered till Minor-II); Assignments:10% (Typically 4-5 assignments); Seminar: 10% (Seminar topics to be chosen by students and approved by me)
CRL724	2011-12	**Contents:** Review of Measurement and Instrumentation basics; Types of Measuring Systems and their Specifications; Transducers, Sensors and Actuators: - Classification - state description; Principles & Applications of Transducers in Characterization of RF Materials, Devices & Circuits: acoustic, ultrasonic, magnetic, electrical, thermal, optical, radiation; Digital Storage Oscilloscopes: Signal Sources; Spectrum Analyzers; Network Analyzersl; Waveguide Measurements; Miscellaneous **Evaluation:** Minors: (2 x 20 = 40 marks); Presentations/Assignments: (30 marks); Major: (30 marks)
EEL713	2011-12, 2012-13	**Contents:** Revision of Maxwell's equations and Plane waves, Transmission Lines, Low pass filters, Bandpass filters, Directional couplers, Power dividers, Microstrip antenna. **Evaluation:** Minors: (2x20) 40 Marks, Major: 45 marks; Assignments: 15 Marks
EEL207	2008-09, 2009-10, 2010-11	**Contents:** Transmission lines, Maxwell's equations, Plane waves, Waveguides, Antennas **Evaluation:** Minors: (2x25) 50 marks; Quizzes:15 Marks; Major: 30 Marks and Attendance 5 marks
EEL338	2007-08, 2008-09	**Contents:** Revision of Maxwell's equations and Plane waves, Antenna Parameters, Wire Antennas**;** Aperture Antennas**;** Antenna Arrays**;** Microstrip Antennas**;** **Evaluation:** Minors: (2x30) 60 Marks, Major: 25 marks; Assignments: 15 Marks
EEP307	2005-06, 2006-07, 2007-08, 2008-09, 2009-10, 2010-11, 2011-12, 2012-13, 2013-14	**Contents:** Measurement of VSWR on line with different loads, Determination of unknown impedance, Relationship between wavelength in free space and waveguide, Expts. on Transmission lines, Antenna Radiation Pattern measurement, Gunn Oscillator, Expts. on optical fibre, Mini-projects. **Evaluation:** Reports: 10%, Vivas: 40%; Lab test: 25%, Mini-project: 25%

2. Ananjan Basu

CRL 712 – RF and Microwave Active Circuits, 2011-12, sem 2.
Instructor : Dr. A. Basu , C.A.R.E.
Office : III-323 (Microwave Lab, C.A.R.E.) ,
Ph : 1110 / 6210 , E-mail : ananjan_b@yahoo.com

Topics:
1. Review of S-parameters and Smith Chart.
2. Basic theory of Schottky and p-i-n diodes, MESFET, HEMT,HBT.
3. Amplifier design – bias, stability, high gain, low noise, broad-band.
4. Diode-based attenuators, switches and phase shifters.
5. Mixers (time permitting).

References:
1. Microwave Engineering – David Pozar
2. Solid-state Microwave Amplifier Design – T.T.Ha
3. Microwave Transistor Amplifiers – G.Gonzalez.
4. B.Bhat & S.K.Koul, 'Stripline Like Transmission Lines for Microwave Integrated Circuits'.

Grading (tentative) :
Minor Tests : 25% + 25%.
Major Test : 35%.
Assignments : 15%.

Centre for Applied Research in Electronics
EEL713 – Microwave Theory and Circuits (2010-11, Sem 1)
Instructor : Ananjan Basu, Rm.III-319, Ph : 1110/6210
E-mail : ananjan_b@yahoo.com

Topics

1. Transmission line theory (distributed L-C model, propagation constant , reflection coefficient , lossy lines, ABCD parameters , distributed circuits , VSWR and related measurements).

2. S-parameters and related introductory multi-port network theory.

3. Plane waves in lossy and lossless media, polarization. Reflection and refraction (lossless media).

4. Rectangular metal waveguide (modes, fields, currents, loss, dispersion).

5. Surface waves, propagation in dielectric slab and related guides.

6. Impedance matching and Smith Chart.

Evaluation (tentative):

Minor I : 25%
Minor II : 25%
Major : 35%
Assignment / quiz : 15%.

Books
Microwave Engineering – D.M.Pozar.

CRL 724 – RF and Microwave Measurement System Techniques (part 2)

Topics

1. Network Analysis, including slotted waveguides.

2. Spectrum Analyzer

3. Frequency Synthesis

4. Noise Measurements

5. Antenna Measurements, field probes.

Books

1. G.F. Engen – Microwave Circuit Theory and Foundations of Microwave Metrology [advanced theory of reflectometry, network analysis and calibration, and noise]
2. Sucher and Fox – Microwave Measurements (?) Vol 1 [slotted line related]
3. Application notes (IEEE Standards, Agilent). [spectrum analyzer, basics of VNA calibrations, Gigatronics synthesizer, VNA block diagram]

4. Karun Rawat:

Course Content of EEL 713 (taken in Electrical Engineering):

i) Course Content: Syllabus is divided into five modules
MODULE # 1: Maxwell's Equations, Plane waves in dielectric and conducting media, Energy and power. (approx. 8 lectures)

MODULE # 2: Transmission lines and Waveguides: Closed and Dielectric Guides, planar Transmission Lines and Optical fibers. (approx. 8 lectures)

MODULE #3: Network Analysis, Scattering matrix and other parameters, signal flow graphs and network representation.(approx. 11 lectures)

MODULE # 4: Impedance Matching and Tuning (approx. 8 lectures)

MODULE # 5: Analysis of planar transmission lines. Analysis and design of passive components. (approx. 11 lectures)

ii) Minor and Major Exams:
(a) 2 Minor exams and
(b)1 Major Exams
iii) Quizzes: None
iv) lab experiment hand-outs for each course taught year-wise: None
v) any other item deemed under course-file.
(a) 4 Assignments
(b) Seminars presentation by each student.

5. Arun Kumar

CARE, IIT Delhi

CRL702 Architectures and Algorithms for DSP Systems 2012-13/II

1. Contents

Lectures

1. Introduction – DSP Tasks and Applications, Real Time Signal Processing.
2. Number Representations and Arithmetic Operations.
3. Digital Signal Processor Architectures – Ref. TMS320C55xx.
4. DSP Instruction Set and Programming – Ref. TMS320C55xx.
5. DSP Algorithms and their Efficient Implementation.
    a. Linear filtering in time and frequency domains;
    b. FFT and spectrum analysis;
    c. Quantization and coding, linear prediction coding;
    d. Function generation and pseudo-random number sequence generation.
6. Software Design for Low Power Consumption.

Lab Experiments

Labs will be done in groups of 2 students each. Experiment 2 onwards will be done on TMS320C55xx DSP Starter Kit (DSK) in the assembly language of the processor.

1. Basic DSP using MATLAB.
2. Familiarization with DSK 1; Mathematical operations and Q-format.
3. Familiarization with DSK 2; ADC and DAC; Simple real-time operations; Aliasing.
4. Real-time FIR filtering.
5. Fast Fourier Transform.

Lab Project

You will be required to do a lab project on the TMS320C55xx DSK for the remaining lab sessions after completing the above experiments.

2. References

i. TMS320C55x Manuals – a) CPU Reference Guide – spru371d.pdf, b) Algebraic Instruction Set Reference Guide – spru375e.pdf, c) Code Composer Studio Getting Started Guide – spru509c.pdf, d) Assembly Language Tools – User's Guide – spru280.pdf.

ii. Sen M. Kuo and Woon-Seng Chen, Digital Signal Processors – Architectures, Implementations and Applications, Prentice Hall, 2005.

3. Evaluation: Minor Exams (2): 15% each; Major Exam: 35%; Lab Experiments: 15%; Lab Project: 20%.

4. Attendance Policy: In case attendance is below 75%, 1 grade less than the actual grade earned shall be awarded.

CARE IIT Delhi
CRL704 Sensor Array Signal Processing
2012-13 / 1st Semester

Contents

7. Introduction to the course.
8. Review of related background topics:

- Linear signal models,
- Optimum linear filtering,
- Power spectrum estimation.

9. Arrays and spatial filters: Frequency-wavenumber response and beam patterns, uniform linear arrays, uniform weighted linear arrays, array steering, array performance measures, linear apertures.
10. Linear arrays and apertures: Spectral weighting, Array polynomials, pattern sampling.
11. Characterization of space-time processes.
12. Optimum beamforming: MVDR, MMSE, Eigenvector beamformers.

Pre-requisites

Formal course-work in the following:

1. Signals and Systems / Digital Signal Processing.
2. Probability and Statistics.

Text

iii. D. Manolakis, V. Ingle, and S. M. Kogon, “Statistical and Adaptive Signal Processing,” Artech House, 2005.
iv. Harry L. Van Trees, “Optimum Array Processing - Part IV of Detection, Estimation and Modulation Theory,” Wiley Interscience, 2002.

References

1. Prabhakar S. Naidu, "Sensor Array Signal Processing," CRC Press, 2000.

Evaluation

Minor Exams (2): 20% each; Major Exam: 45%; Assignments / Quizzes: 15%.

Attendance Policy

If the attendance is below 75%, then one grade less shall be awarded.

Centre for Applied Research in Electronics
CRL707 - Human and Machine Speech Communication (2013-14/I)

Course Outline

a. **Overview of speech communication:** Applications; Speech signal measurement and representation.
b. **Speech production and phonetics:** Speech production mechanism; Articulatory and acoustic phonetics; Speech production model; International Phonetic Alphabet; Phonetic transcription.
c. **Speech signal analysis:** Time domain analysis; Spectral domain analysis; Spectrogram; Cepstral domain analysis; Pitch estimation; Voicing analysis.
d. **Linear prediction analysis:** Autocorrelation and covariance methods; Levinson-Durbin algorithm; Line spectral frequencies; Inverse filtering.
e. **Hearing and perception:** Sound perception; Auditory masking; Critical bands.
f. **Speech coding:** Standards; PCM; ADPCM; Vocoder; MELP; CELP; VoIP.
g. **Speech quality assessment:** Subjective & objective measures of speech quality.
h. **Automatic speech recognition:** HMM; Recognition methods; Language models.
i. **Text-to-speech synthesis:** Concatenative and HMM based speech synthesis; Harmonic plus noise model; Prosody modification.

Evaluation & Attendance Policy

1st Minor: 20%; 2nd Minor: 20%; Major: 45%; Assignments: 15%.
In case attendance is < 75% attendance, one grade less than academically obtained grade shall be awarded.

References

1. D. O'Shaughnessy, Speech Communications: Human and Machine, IEEE Press, 2000.
2. L. R. Rabiner and R. W. Schafer, Digital Processing of Speech Signals, Prentice Hall, 1978.
3. J. Benetsy, M. M. Sondhi and Y. Huang, Springer Handbook of Speech Processing, Springer Verlag, 2008.
4. L. R. Rabiner and B. –H. Juang, Fundamentals of Speech Recognition, Prentice Hall, 1993.
5. A. M. Kondoz, Digital Speech – Coding for Low Bit Rate Communication Systems, John Wiley, 2nd ed., 2004.
6. Additional papers and hand-outs shall be given as required.

6. Dr. Monika Agarwal

EEL205 Signals & Systems
2013-14/2nd semester

- Unit 1 : Introduction to Linear Time-Invariant (LTI) systems
  - Given an arbitrary system, find out whether it is LTI or not
  - Given an LTI system and an input, find the output using convolution

- Unit 2 : LTI Systems – Stability, Infinite Impulse Response [IIR] and Finite Impulse Response [FIR]
  - Given an LTI system, determine if its stable
  - Given an LTI system, determine if its IIR or FIR

- Unit 3: Introduction to Discrete Fourier Series [DFS]
  - Given a periodic discrete-time sequence, compute its DFS
  - Given the DFS, determine the corresponding discrete-time sequence

- Unit 4 : Properties of Discrete Fourier Series
  - Given two discrete-time sequences, compute the periodic convolution using DFS

- Unit 5 : Discrete-Time Fourier Transform (DTFT)
  - Given a discrete-time signal, compute its DTFT
  - If the input and output of a discrete-time LTI system is known, find its impulse response

- Unit 6 : Z Transform
  - Given a discrete-time signal, compute its z-transform
  - Given a z-transform of the impulse response of an LTI system, determine whether it is causal and/or stable

- Unit 7 : Minimum Phase LTI Systems
  - Given the square of the magnitude of frequency response of an LTI system, determine the system function H(z) assuming that it is minimum phase.
  - Given a stable, causal LTI system, decompose it into a minimum phase system and an all pass sytem
- Unit 8 : Linear Phase LTI systems
  - Given the impulse response of an LTI system, determine whether it is a generalized linear phase system.
  - Given a FIR linear phase system, determine its type

CARE
CRL732
(2013-14)

Course Contents
Set Theory
Probability Theory : Meaning, Axiom, etc.
Random Variables : Concept, different pdfs, expectation etc.
Functions of Random Variables : One variable, two variables etc.
Random Process : Concept, examples, stationarity, ergodicity etc.
Some Random Process.

Text Book
Probability, Random Variables and Stochastic Process by A . Papoulis

Course Instructors
Prof R Bahl, CARE IIT Delhi (rbhal@care.iitd.ernet.in)
Dr. Monika Aggarwal, CARE IIT Delhi (maggarwal@care.iitd.ernet.in)

Evaluation Procedure

Minor test I	20
Minor test II	20
Quizs	15
Major	45

Note:
There will be no re-minors/re-majors unless the course coordinator is informed *prior* to the exam, and a medical certificate produced as per rules.
Attendance rules will be *strictly enforced*. If attendance is less than 75%, lower grade will be awarded.

7. R. Bahl

CRL731
Special Topics (Miscellaneous Underwater Systems)

Course Outline (lecture hours)

Introduction to High Resolution Underwater Imaging Applications (2)
Terrain mapping, Minehunting, salvage, cable laying
Sidescan Sonar principles (3)
Mapping geometry, frequency, parameters, coverage rate, limitations
Sector Scan Sonar Principles (6)
Principle of within-pulse scanning, role of grating lobe in sector coverage
Swept -frequency delay line scanning technique (1)
Time-Delay-Integrate scanning technique (1)
Modulation Scanning Technique (4)
Multi-stage scanning
Spatial DFT-based imaging technique (1)
True Phase-Shift beamforming (2)
Near-field Focusing, Hilbert-Transform based implementation
Synthetic Aperture Sonar (8)
development of concept, azimuth resolution, matched filter implementation, range migration issue, PRF limits, system design examples for swath coverage, real beam pattern effects, tow-body precision issues, Squint SAS, Spotlight SAS
CTFM Sonar (3)
Principles, Blind time management, Dual Demodulation CTFM Sonar
Phase-Difference based SAS (1)
Radial Projection method of imaging (2)
Monopulse technique
Navigation (3)
Doppler Log, JANUS system, practical issues of unknown sound speed and beam-width
Localization (5)
LBL (Long baseline), SBL (Short baseline), SSBL/USBL (super/ultra short baseline), requirements of tracking and positioning systems, Range and bearing estimation with linear arrays, hyperbolic and spherical-based localization using pingers and transponders, use of surface reflection as virtual hydrophone,

Material:
Course Notes
IEE Proc F
IEEE and JASA papers as required

Sonar System Engineering

Objective:

The objective of the course is to introduce all issues related to sonar system design: both active and passive. Special attention is placed on the basics of the propagation medium and environmental effects, target effects, and equipment effects. The effort is to enable the students to understand the interplay of environment, target and equipment parameters so that performance evaluation and design of sonar systems can be effectively carried out.

Suggested Reading/ Text Books.

1. R.J. Urick, Principles of Underwater Sound, McGraw Hill Book Company, 1983
2. W.S. Burdic, Underwater Acoustic System Analysis, Prentice-Hall Inc., 1991
3. A.A. Winder, "Sonar System Technology", IEEE Transactions on Sonics & Ultrasonics, Vol SU-22, No 5, pp 291-332, Sept 1975
4. Journal of Acoustical Society of America (JASA)
5. IEEE Journal of Oceanic Engineering
6. IEE Proceedings

Typical coverage:

i) Introduction to Sonar applications, Units
2
ii) Sonar Equations and their limitations
3
iii) Propagation of sound, transmission loss
6
iv) Ambient Noise, Spatial Coherence
3
v) Directivity Index, Array Gain, Projector Source level
4
vi) Reverberation
3
vii) Scattering by targets
2
viii) Radiated Noise and Self Noise
3
ix) Generic Sonar System
1
x) Transmission and Reception modes
2
xi) Dynamic Range Compression and Normalisation
3
xii) Receiver Beamforming techniques, Sidelobe nulling
3
xiii) Detection Performance issues
3

xiv) Performance prediction
2
xv) Sonar System Design examples
2

Distribution of marks

Minor I:	25
Minor II:	25
Assignments/Quiz:	10
Major:	40

8. Sudhir Chandra:

CRL722: Course Contents:

1. Review of semiconductor material properties, band structure, concept of "hole", effective mass, *E-k* diagram, mobility and life time of carriers, Fermi distribution, free-carrier calculation and its relation with Fermi-level location. Quasi-charge neutrality, generation of internal weak electric fields in non uniformly doped structures and in low level charge injection. 8

2. Drift and diffusion currents and governing equations, continuity equation, steady state and transient effects, generation low-level injection in forward biased p-n junction, excess carriers, diffusion length, minority and majority currents, total current in p-n recombination, charge neutrality concept. 10

3. P-N junction in equilibrium, electrostatics, built-in voltage and field across depletion region, depletion approximation, carrier profile in depletion region. 8

4. Junction breakdown, junction formation by diffusion and implantation process. 2

5. NPN and PNP transistors, various current components, emitter injection efficiency, base transport factor, common base and common current gain, correlation with physical device parameters. 5

6. MOSFET understanding through energy-band diagram, accumulation, depletion, weak inversion and strong inversion region, ideal MOSFET, non-ideality effects, calculation of depletion and inversion charge density, threshold voltage calculation, 6

7. MOS CV analysis 2

8. Hetro-structures, Schottky and Ohmic contacts, GaAs MESFET device structure and 2

CRP723

This is a 3 credit course (1-0-4) which include lecture component also. The lecture part of the Course is conducted in the Lab itself for simultaneous demonstration also. The break-up of the experiments are:

1. Lecture on Al-gate MOSFET process and Si-gate self-aligned MOSFET technology along with demonstration of chips made by these two technologies. The students gain clear understanding of the various technologies involved.
2. Wafer polishing (including CMP) and cleaning process.
3. Thermal evaporation of aluminum
4. RF sputtering of a dielectric film such as ZnO or SiO_2
5. Exposure to mask making techniques

6. Wet and dry chemical etching process
7. Thermal oxidation of silicon
8. Boron diffusion
9. Photolithography process

9. Prof. B. S. Panwar:

CR 713 - Fundamentals of RF Electronics

Course No. : CR 713 Course Title: Fundamentals of RF Electronics

Course Structure and Credits: L-T-P (2-0-2); Credits: 3

Marks Distribution:

Minor I: 15 Marks Minor II: 15 Marks Two Quizzes: 5 Marks each

Lab Experiments: 30 Marks Major Exam: 30 Marks

28 Lectures

Mathematical foundation in understanding of signals, microwave circuits, and devices : (5L)
Phasor diagrams, duality, superposition, miller, Thevenin and Norton Theorems, instantaneous, average, complex powers their representation nomenclature, Fourier series, Laplace, Fourier and Z transforms, convolution, correlation and basic properties of Fourier transforms, transmission line theory, T and Π equivalent circuit, behavior of transmission line at radio frequency. Physics and operation of bipolar, and MOS structures.

DC and Low Frequency Circuit Concepts: (5L)
BJT Biasing, mode of operation small signal AC analysis, FET circuits at DC, AC analysis, first and second order AC models of FETs, high frequency models of BJT and FETs, single pole approximation, differential amplifiers, and frequency response

Circuit Representation of Two Port RF/ Microwave Networks : (3L)
Impedance, Admittance, Hybrid, Transmission line Parameters, Transmission Matrix, Generalized S parameters, Reciprocal Networks, Loss less Networks, Signal flow graphs and its Applications.

Gain Consideration in Amplifiers Impedance Matching and Network Selection: (4L)

Power gain concept, mismatch factor, return loss, input / output VSWR, maximum gain, constant gain design, figure of merit, matching network design using lumped and distributed elements, stability considerations in active networks.

Base-band and Pulse Signaling: (4L)
Sampling, quantizing and encoding, digital signal formats: binary coding, differential coding, bit synchronization, multilevel signaling, intersymbol interference, differential pulse code modulation, delta modulation time division multiplexing, pulse time, pulse width, pulse position modulation.

Amplitude and Frequency Modulation (3L)
Amplitude modulation, Double sideband suppressed carrier, Asymmetric sideband signals, phase/frequency modulation, narrowband angle modulation, wideband frequency modulation.

Band pass Digital Signaling (4L)
Binary signaling (OOK, BPSK, DPSK), multilevel signaling (QPSK, MPSK, QAM), minimum-shift

keying (MSK) and comparison of band pass digital signaling systems, band pass sampling, filtering and linear distortion.

Lab Experiments: 12 Turns

- Design, simulation (P spice), realization, and characterization of high gain differential amplifier used in the first stage of an operational amplifier. This will involve design and simulation of a current source, extraction spice parameters, gain characterization etc. — 4 Turns
- Comparison of coding schemes, self-correcting codes, assembly language programming, operating a system in a closed loop for investigating the matched filtering performance, detecting the signal in a noisy environment. The already developed modules for SODAR and the new two systems being developed for RF Identification will be used for this experiment. — 4 Turns
- Designing and fabrication of an antenna and its characterization for return loss and scattering parameters — 4 Turns

Suggested Reading/Text Books:

1. Razavi, " RF Microelectronics", Prentice hall, 1998
2. Ziemer, Tranter and Fannin, "Signals & Systems" Pearson Education, 1998
3. David M. Pozar, "Microwave Engineering", John Wiley &Sons Inc, 2005
4. Matthew M. Radmanesh, " Radio Frequency and Microwave Electronics", Addison Wesley Longman (Singapore), 2001
5. Leon C. Couch, " Modern Communication Systems", Prentice Hall o India Prvate Limited, 1998
6. Robert C. Dixon, "Spread Spectrum Systems with Commercial Applications", John Wiley & Sons, Inc. 3rd Edition.
7. B.P. Lathi, "Modern Digital and Analog Communication System", Oxford University Press, 3rd Edition
8. Sedra and Smith, "Microelectronic Circuits", Oxford University Press, Fifth Edition.
9. Marc T. Thompson, " Intuitive Analog Circuit Design", Elsevier Publication, 2006
10. Andy Bateman, "Digital Communication", Prentice hall, 1999.
11. Chris Bowick, "RF Circuit Design", Newnes, 1982

ANNEXURE – 6

List of Journal and Conference Publications since 2000

Journal Papers

2014

1. D.Rama Krishna, V.M.Pandharipande and Shiban K Koul, "New Microstrip Patch Antenna with Polarization Diversity", Accepted for Publication in *Microwave and Optical Technology Letters* -2014.

2. Shiban K Koul and Sukomal Dey, "Radio Frequency Micro-electro- mechanical Systems- an Overview", *Journal of ISSS*, Vol. 3 No. 1, pp. 26-72, January 2014.

3. Sukomal Dey and Shiban K Koul, Design and development of a CPW-based 5-bit switched line phase shifter using inline metal contact MEMS series switches for 17.25 GHz transmit/receive module application, Journal of Micromechanics and Micro-engineering, Vol. 24, No. 1, 1st January 2014, 015005(24 pages).

4. P Tyagi, L I Giri, S Tuli and R Srivastava, "Elucidation on Joule heating and its consequences on the performance of organic light emitting diodes", J, Appl. Phys., 115 (3), 034518 (2014)

2013

5. Rajesh Dubey and Arun Kumar, "Non-intrusive speech quality assessment using several combinations of auditory features," *Intl. Journal of Speech Technology*, Springer, vol. 16, issue 1, pp. 89-101, March 2013.

6. Janesh K. Kaushik, V. Raman Balakrishnan, Brishbhan Singh Panwar, Senior Member, IEEE and Rangarajan Muralidharan, Member, IEEE, "On the Origin of Kink Effect in Current–Voltage Characteristics of AlGaN/GaN High Electron Mobility Transistors," *IEEE Trans. Electron. Devices,* Vol. 60, pp.3351-57, Oct 2013.

7. Pradeep Kumar Rathore, Pratyush Varshney, Sunil Prasad and B.S. Panwar, "Theoretical Modeling, Simulation and Optimization of Double Cavity Vacuum Sealed Piezoresistive Pressure Sensor," *Sensor Review*, Vol. 33, pp.352-362, 2013.

8. Pradeep Kumar and Brishbhan Singh Panwar, "CMOS-MEMS based Current Mirror MOSFET Embedded Pressure Sensor for Health care and Biomedical Applications,"*Advanced Material Research*, Vol. 647, pp. 315-320, 2013.

9. Arun Kumar and Rajendar Bahl, "An architecture for high data rate very low frequency communication," *Defence Science Journal*, vol. 63, no. 1, pp. 25-33, Jan 2013.

10. T. Akamatsu, T. Ura, H. Sugimatsu, R. Bahl, S. Behera, S. Pand, M. Khan, S.K. Kar, C.S. Kar, S. Kimura and Y. Sasaki-Yamamoto, "A multimodal detection model of dolphins to estimate abundance validated by field experiments," *J. Acoust. Soc. Am.* 134 (3), Pt. 2, pp 2418-2426, September 2013.

11. A.Das, A.Kumar, R.Bahl, "Marine vessel classification based on passive sonar data: the cepstrum-based approach," *IET Radar, Sonar and Navigation*, vol. 7, issue 1, pp. 87-93, Jan. 2013.

12. Ruchi Tiwari, Sudhir Chandra and B. R. Chakraborty, "Preparation, Characterization and Application of RF Sputter Deposited Boron Doped Silicon Dioxide Thin Films", *Material Science in Semiconductor Processing*, vol. 16, no. 6, pp. 2013-20, Dec. 2013.

13. Ruchi Tiwari and Sudhir Chandra, "Piezoresistive Pressure Sensor Using Low-Temperature Aluminium Induced Crystallization of Sputter-Deposited Amorphous Silicon Film", *J. Micromech. Microeng.* , vol. 23, no. 9, pp. 9, 2013. doi:10.1088/0960-1317/23/9/095020.

14. Pooja Prakash, Mahesh P. Abegaonkar, A. Basu, S.K. Koul, "Gain Enhancement of a CPW-fed Monopole Antenna Using Dual-band Polarization-insensitive AMC Structure," *Accepted for Publication in IEEE Antennas and Wireless Propagation Letters,* 2013.

15. Ankush Gupta, Mahesh P. Abegaonkar, A. Basu, S.K. Koul, "Simplified Design of a Tunable High Impedance Surface and Its Application to Dual-band Microstrip Antenna," *Progress in Electromagnetics Research (PIER)-C*, vol. 43, pp. 231-246, 2013.

16. Madhur Deo Upadhayay, A. Basu, Mahesh P. Abegaonkar, S.K. Koul, "Active Antenna Using BJT With Floating Base," *IEEE Microwave and Wireless Components Letters,* vol. 23, no. 4, pp. 202-204, Apr. 2013.

17. Lalithendra Kurra, Mahesh P. Abegaonkar, A. Basu, S.K. Koul, "A Compact Uni-Planar EBG Structure and its application in Band-Notched UWB Filter," *Int. J. of Microwave and Wireless Technologies*, 5(4), pp. 491–498, 2013.

18. Deshmukh P.S., Banerjee B.D., Mahesh P. Abegaonkar, Kanu Megha, Ahmed R.S., Tripathi A.K., Mediratta P.K., "Effect of low level microwave radiation exposure on cognitive function and oxidative stress in rats," *Indian Journal of Biochemistry and Biophysic*, vol. 50, pp. 114-119, Apr. 2013.

19. P. Deshmukh, Kanu Megha, B. D. Banerjee, R. S. Ahmed, S. Chandna, Mahesh P. Abegaonkar, Ashok Kumar Tripathi, "Detection of low level microwave radiation induced DNA damage vis-a-vis genotoxicity in brain of Fischer rats," *Toxicology International* (In Press), 2013.

20. M. Rawat, K. Rawat, and F. M. Ghannouchi, "Three-Layered Biased Memory Polynomial for Dynamic Modeling and Predistortion of Transmitters," *IEEE trans. on circuits and Systems-I*, (accepted for publication).

21. K. Rawat, M. Rawat, M.S. Hashmi, F.M. Ghannouchi, "Dual Band branch-line hybrid with distinct power division ratio at two bands," *Wiley International Journal of RF and Microwave Computer-Aided Engineering*, (accepted for publication).

22. Sharbari Banerjee, Monika Agrawal, "A Simple Analytical Design Approach to Space TimeTrellis Codes," *Wireless Personal Communication*, Elsevier, Sept 2013.

23. A. Goel, P. Gupta and M. Agrawal, "Generalized M-2M mapping for SLM and PTS based OFDM Systems without Side-Information," *Wireless Personal Communication,* Elsevier June 2013.

24. A. Goel, P. Gupta and M. Agrawal, "Joint ICI Cancellation and PAPR Reduction in OFDM Systems without Side-Information," *Wireless Personal Communication*, Elsevier, vol. 71, Issue 4, pp. 2605-2623, Aug. 2013

25. A. Goel, P. Gupta and M. Agrawal, "SER Analysis of PTS Based Techniques for PAPR Reduction in OFDM Systems," *Digital Signal Processing*, Elsevier, vol. 23, no.1, pp. 302-313, Jan. 2013.

26. D. Banerjee, S.K. Chattopadhyay, K. Chatterjee, S. Tuli, N. Jain, I. Goyal, and S. Mukhopadhyay, "Non-destructive testing of jute–polypropylene composite using frequency-modulated thermal wave imaging", *Journal of Thermoplastic Composite Materials,* doi: 0892705713486134, May 20, 2013.

27. S.G. Pickering, K. Chatterjee, D.P. Almond, S. Tuli, "LED optical excitation for the long pulse and lock-in thermographic techniques", *NDT&E International*, doi.org/10.1016/j.ndteint.2013.04.009.

28. Priyanka Tyagi, Ritu Srivastava, Arunandan Kumar, Suneet Tuli, M.N. Kamalasanan, "Study of shifting of recombination zone in multi-emissive layer organic light emitting devices and its effect on color stability", *Journal of Luminescence*, 136 (2013), 249–254.

29. Manoj Singh Parihar, Ananjan Basu and Shiban K Koul, "Transient Analysis of Reconfigurable Polarization Antenna", *International Journal of Microwave and Wireless Technologies*, Vol.5, No.4, pp. 521–527, August 2013.

30. Manoj Singh Parihar, Ananjan Basu and Shiban K Koul, "Reconfigurable Printed Antennas", *IETE Journal of Research*, Vol.59, No.4, pp. 332-340, July-August 2013.

31. Sandeep Chaturvedi and Shiban K Koul, "A Novel Low Cost Packaging for RF Applications", *Journal of Electronics Packaging*, Vol. 135, Issue 2, pp. 024501-1-3, June 2013.

32. Sandeep Chaturvedi, G.Sai Saravana, Mahadeva K Bhat, S.L.Badnikar, R.Muralidharan and Shiban K Koul, "Design and Electrical Characterization of Wafer-level Micro-package for GaAs-based RF MEMS Switches," *IETE Journal of Research*, Vol.59, No.3, pp. 201-209, May-June 2013.

33. Krishnendu Chatterjee & Suneet Tuli, “Prediction of blind frequency in lock-in thermography using electro-thermal model based numerical simulation”, J. Appl. Phys. 114, 174905 (2013).

2012

34. H. Choudhary, R. Bahl, A. Kumar, "Passive acoustic localization using blind Gauss Markov estimate with spectral estimation at each sensor," *IET Radar, Sonar and Navigation*, Sept. 2012.

35. Rinki Gupta, Arun Kumar, Rajendar Bahl, "Estimation of instantaneous frequencies using iterative empirical mode decomposition," *Signal, Image and Video Processing, Springer* [online], doi: 10.1007/s11760-012-0305-5, 24 Mar 2012.

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ANNEXURE – 7

List of Sponsored Projects (including CARS and Technology Development Projects) and Consultancy Projects done by CARE faculty since 2000

Sponsored Projects, including Technology Development Projects and CARS (Contract for Acquisition of Research Services) Projects

Details of all sponsored projects (sanctioned / completed/ in-progress) since 1.1.2000.

S.No.	Name of the Project	Total Cost In Rs. Lakhs	Duration	Sponsored by	PI / Co-PI	Comments
1.	Design and Development of Low Insertion Loss Narrow Band Surface Acoustic Wave (SAW) Filters on Quartz Substrate at VHF & UHF for Satellite Communication	22.48	2 years 2013-15	Space Application Centre (Dept. of Space)	B.S. PANWAR	RP02698
2.	Design and Development of GaN Devices based Power Amplifier, Low Noise Amplifier and SPDT Switch for T/R Module Application	99.00	1 year 2013-14	Solid State Physics Laboratory	B.S. PANWAR	RP02760
3.	Transit Tracking Pipeline safety and Human Communication	14.84	4 months 2013-14	Shastri Indo-Canadian Institute, University of Rag	B.S. PANWAR	RP02683
4.	Sonic Characterization of Marine Species	85.75	5 years 2012-17	Centre for Marine Living Resources and Ecology	RAJENDAR BAHL (PI) Monika Aggarwal ARUN KUMAR	RP02681
5.	Design and Development of Retinal Image	15.00	1 year 6 months 2012-	Telecommunications Consultants India Ltd.	MANISH SHARMA	RP02602

	Based wireless Sensor Module for affordable Mobile Healty-Care		13			
6.	Studies on Snow Acoustic Reflectometry and Development of Electronics System for Stratigraphy and Snow Water Equivalent Determination	44.22	3 years 2012-15	DRDO, Ministry of Defence	ARUN KUMAR (PI) Monika Aggarwal	RP02563
7.	CMOS Compatible MEMS Sensors for Health Care	37.51	3 years 2012-15	Department of Science & Technology (DST)	B.S. PANWAR (PI)	RP02548
8.	Ultra Low Power Fabric for Reconfigurable Processors	35.27	3 years 2011-14	Department of Science & Technology (DST)	MANISH SHARMA (CP)	RP02518
9.	Portable Wideband Detector for Electromagnetic Emissions	1,20.00	3 years w.e.f Oct. 11	M/s Bharti Airtel	Ananjan Basu (PI) Monika Aggarwal	MI00900
10.	Performance Evaluation & Optimization of Opto-mechanical sensing and related technologies	48.30	1 year 9 months	BARC	Sudhir Chandra (PI) Suneet Tuli K. Thyagarajan	RP02505
11.	Wireless Body Area Network for Health Monitoring	79.32	3 years 2011-14	Department of Information Technology	SHIBAN KISHEN KOUL (CP)	RP02491
12.	An Ultra-low Cost Microwave Imaging System using Active RFID for Survelliance Applications	96.00	2 years w.e.f. May 2011	Ministry of Information Technology	Ananjan Basu (PI) Shouribrata Chatterjee Mahesh P Abegaonkar S.K. Koul	RP02473

13.	Design and development of 5-bit RF MEMS switches, phase shifter and tunable filters	269.60	2011	DRDO & Industry sponsored	Prof S K Koul	
14.	Upgradation and Maintenance of Laboratories at CARE IIT Delhi	89.00	5 years w.e.f. 4.3.11	Directorate of Naval Training, Ministry of Defence	Arun Kumar (PI) Monika Aggarwal R Bahl	RP02450
15.	Design & Development of MIC and Antenna Trainer Kit at J-Band	5.00	2011	M/s Microwave Technologies Inc., Ghaziabad	Prof S K Koul	
16.	Development of Low-cost Organic Semiconductor Technology	9.84	3 years w.e.f. 8.10.10	DST	Vikas Rana, PI	RP02404
17.	Electron Transport in Graphene: Effect of Electromagnetic Potential Barriers, impurities and electron-electron Interactions	13.67	3 years w.e.f. 25.05.2010	Department of Science & Technology (DST)	MANISH SHARMA (CP)	RP02356
18.	Simulation studies and evaluation of infrasonic based avalanche localization system	9.92	18 months w.e.f. 24.9.10	Snow & Avalanche Study Establishment DRDO, Chandigarh	Arun Kumar (PI) R Bahl	
19.	CARS – GMSK and Impulse Radio Noise Suppression Schemes for VLF Communication	9.00	18 months w.e.f. 04.2010	Defence Electronics Applications Laboratory, Dehradun	Arun Kumar (PI), R. Bahl, M. Agarwal	
20.	CARS – LDPC	9.00	18	Defence	R. Bahl (PI),	

	Codes for VLF Communication		months w.e.f. 04.2010	Electronics Applications Laboratory, Dehradun	Arun Kumar, M. Agarwal	
21.	Design and Development of Electromagnetic Band-gap (EBG) Surfaces for Applications in Microstrip Antennas and Circuits	21.85	3 years w.e.f. 15.10.09	DST	Mahesh P Abegaonkar (PI) S.K. Koul A. Basu	RP02279
22.	Design and Development of MEMS Phase Shifter and SPDT Switch	224.39	4 years w.e.f. July 09	Industry sponsored	S.K. Koul(PI)	
23.	Network Energy Scavenging in Wireless Ad Hoc Sensors Networks.	50.68	3 years w.e.f. June 2009	Department of Science & Technology (DST)	SUNEET TULI (CP)	RP02251
24.	Investigation of TRM and MIMO-OFDM Methods for Underwater Acoustic Communications	59.80	3 years w.e.f. Sept. 2009	NIOT	Monika Aggarwal(PI) Arun Kumar R. Bahl	RP02246
25.	Virtual Engineering Electromagnetics Lab	21.50	8 months w.e.f. 2009-10	MHRD	MP Abegaonkar (PI) D. Chadha	
26.	National MEMS Resource Centre at IIT Delhi	38.73	4 years 2009-2013	ADA, Bangalore	S.K. Koul	RP02212
27.	RF, Microwave and Millimeter Wave MEMS characterization	485.00	4 years 2009-2013	ADA, NP-MASS	S.K. Koul(PI) Sudhir Chandra Mahesh P Abegaonkar Ananjan Basu Suneet Tuli	

28.	Large Scale Data Processing and Visualisation	39.74	2 years, 10 months 2008-11	Naval Research Board, Ministry of Defence	RAJENDAR BAHL (CP)	RP02162
29.	Intelligent Sensor Data Fusion for Indoor Positioning	46.077	4 years, 10 months w.e.f. 01-aug-2008	SIRF Technology	MANISH SHARMA, ARUN KUMAR, KOLIN PAUL	RP02141
30.	Airtel IIT Delhi Centre of Excellence in Telecommunication	452.00	9 years, 4 months w.e.f. 06-aug-2008	M/s Bharti Airtel	ANANJAN BASU (CP)	RP02132
31.	Wireless Network Sensors Using SAW Devices	13.42	3 years, 8 months w.e.f. 01-dec-2008	Indo-French Centre for the Promotion of Advn. Res	B.S. PANWAR (PI)	RP02116
32.	Magnetic nanoparticles as biosensors	21.00	2 years 2008	Lockheed-Martin Corp.	Manish Sharma (PI)	
33.	Development of Magnetic Materials for High-Permeability GHz-Frequency Inductors	189.60	3 years 2008-	MCIT/DOE	Manish Sharma(PI) Vikram Kumar Suneet Tuli Sudhir Chandra	
34.	Development of Biosensor and Micro-techniques for analysis of Pesticite Residues, Aflatoxin, heavy Metals and Bacterial Contemination in Milk	190.82	6 years w.e.f. 04-apr-2008	Indian Council of Agriculture Research	SUDHIR CHANDRA (PI) SHIBAN KISHEN KOUL SUNEET TULI G. BOSE	RP02083

35.	Development of a model system for quantitative microwave exposure to experimental animals for studying behavioral, biochemical, immunological and genotoxic effects	29.67	2008-11	ICMR	Mahesh P Abegaonkar (PI)	Faculty from GTB Hospital, Delhi
36.	Design and Development of a Programmable Attenuator in 18-40 GHz Band	10.0	15 months 2008-2009	DLRL Hyderabad	S.K. Koul (PI) Mahesh P Abegaonkar	
37.	Design and Development of 18-40 GHz Double Balanced Mixer	10.0	15 months 2008-2009	DLRL Hyderabad	S.K. Koul (PI) Ananjan Basu	
38.	Design and Development of 18-26.5 GHz Mixer	10.0	15 months 2008-2009	DLRL Hyderabad	S.K. Koul (PI) Ananjan Basu	
39.	Design and Development of 26.5-40 GHz Balanced Mixer	10.0	15 months 2008-2009	DLRL Hyderabad	S.K. Koul (PI) Ananjan Basu	
40.	Thermal Modeling of Switches and Power Modules	8.0	15 months 2008-2009	DLRL Hyderabad	S.K. Koul (PI)	
41.	Modeling of Suspended Sripline Discontinuities at Millimeter Wave Frequency	8.0	12 months 2008-2009	DLRL Hyderabad	S.K. Koul (PI) Mahesh P Abegaonkar	
42.	Nanomagnet Arrays for Patterned	11.98	1 y 2 m 2008-2009	US Air Force	Manish Sharma (PI) Anjan	

	Magnetic Media and Magnonic Crystal Applications				Barman	
43.	Development of Biosensor and Micro-techniques for analysis of Pesticide Residues, Aflatoxin, Heavy Metals and Bacterial Contamination in Milk	69.83	5 years 2008-2013	IARI	Sudhir Chandra (PI) S.K. Koul G. Bose Suneet Tuli	
44.	Application Specific Thermal NDE	27,39	3 yrs 2008-2011	British Council	Suneet Tuli	
45.	Design of Block Layered Space Time Codes	17.21	3 years 2007-2010	DRDO, Ministry of Defence	Monika Aggarwal (PI) R. Bahl, Aun Kumar	
46.	Quantum design evercool MPMS XL 7 as a National facility at IIT Delhi	4 crores	5 years 2007-	DST	R. Chatterjee (PI) S. Chaudhary N. Khare M. Sharma	
47.	Spin-wave and domain wall dynamics in vertical magnetic Nanowires	15.00	3 years 2008-	UKIERI-DST	Anjan Barman (PI) Manish Sharma	
48.	Dynamic Light Scattering Studies of Biofunctionalized Magnetic Nanoparticles	20 .0	3 years 2007-	Dept. of Biotechnology, MS&T	Manish Sharma (PI) Sujeet Chaudhary	
49.	Design, development & evaluation of 900 MHz RFID	12.0	8 months 2007-08	Mitsubishi Heavy Industries,Ltd.Japan	M.P. Abegaonkar (PI) S.K. Koul	

	antenna and package for on – board unit of ERP/ETC System				Ananjan Basu	
50.	Design & development of antenna array with 8 elements (elevation) x 16 elements (azimuth)	9.50	2007-10	Centre for Airborne Studies, Bangalore	Ananjan Basu(PI) S.K. Koul M.P. Abegaonkar	
51.	Studies on some parts of C-band Rotary Field Phase Shifter	9.00	2007-2010	SSPL, Delhi	S.K. Koul(PI) M.P. Abegaonkar	
52.	Wafer Bonding and Layer Transfer for Novel Engineered Substrates	10.93	3 years 2007-2010	Max Planck Institute, Germany	Rajendra Singh, (PI) Sudhir Chandra,	
53.	Water Bonding and Layer Transfer for Novel Engineered Substrates	25.50	3 years 2007-2010	DST	Rajendra Singh, (PI) Sudhir Chandra,	
54.	Design and Development of Prototype Micro-Fluidic MEMS	46.00	24 Months 2007-2009	BARC	S. Chandra (PI), G.Bose, S,Tuli, PMV Subbarao, A.Darpe, K.Thyagarajan, R.Mohan, A.L.Vyas	Faculty from M.E., Physics, Ch.E, IDDC as Co-PIs
55.	Design and Development of 26.5-40 GHz Balanced Mixer	10.00	2008	Defence Electronics Research Lab., Hyderabad	Prof S K Koul	
56.	Design and Development of 18-26.5 GHz Mixer	10.00	2008	Defence Electronics Research Lab., Hyderabad	Prof S K Koul	
57.	Design and Development of 18-40 GHz	10.00	2008	Defence Electronics Research Lab.,	Prof S K Koul	

	Double Balanced Mixer			Hyderabad		
58.	Design and Development of a Programmable Attenuator in 18-40 GHz band	10.00	2008	Defence Electronics Research Lab., Hyderabad	Prof S K Koul	
59.	Thermal Modeling of Switches and Power Modules	8.00	2008	Defence Electronics Research Lab., Hyderabad	Prof S K Koul	
60.	Modeling of Suspended Stripline Discontinuities at Millimeter Wave Frequency	8.00	2008	Defence Electronics Research Lab., Hyderabad	Prof S K Koul	
61.	Design & Development of High Power Pin Diode Phase Shifters	10.00	2008	Electronics & Radar Development Establishment, Bangalore	Prof S K Koul	
62.	Efficient Radiating Elements to be used with High Power phase shifters with good scanning properties	10.00	2008	Electronics & Radar Development Establishment, Bangalore	Prof S K Koul	
63.	Design of Silicon based Switch and Mask preparation	3.35	2008	M/s Astra Microwave Products Limited, Hyderabad	Prof S K Koul	
64.	Design & development of Unit Cell Model for a Single Bit Phase Shifter using measured data from GAETEC	10.00	2008	Research Centre Imarat (RCI), H'bad	Prof S K Koul	
65.	Design and Development of a Multi-technique	Rs.4312 000.00	09-apr-2007 31-oct-	Naval Research Board, Ministry of Defence	SUNEET TULI (PI)	RP01934

	Thermal system Including signal Processing modules for Non-destructive defect localization		2010			
66.	Studies on Some parts of C-band rotary field phase shifter	10.00	12 Months 2007-2008	SSPL, DRDO	S.K.Koul (PI) M.P.Abegaonkar	w.e.f 1.4.07 FT/05/117
67.	Design of Optimum Element for 2D Scanning Phased Array	9.50	6 Months 2007	CABS, Bangalore	M.P.Abegaonkar (PI) S.K.Koul Ananjan Basu	
68.	Design and Development of Antenna Array with 8 elements (elevation) × 16 elements (azimuth)	9.50	10 Months 2007-2008	CABS, Bangalore	Ananjan Basu (PI) M.P.Abegaonkar S.K.Koul	.
69.	Study of Different Heating and Synchronized Measurement Techniques for Infrared Thermography applied to NDE of Honeycomb-Composite Spacecraft Components	4.20	1 year 20.2.2007	Dept. of Space, ISRO Head-quarters	Suneet Tuli (PI)	
70.	Higher Order Spectrum Analysis Tools for Underwater Acoustic Signals	10.00	2007, 18 months	Naval Science and Technological Lab, Visakhapatnam	Arun Kumar (PI), R. Bahl, M. Agarwal	CARS Project
71.	Realization of prototype low power acoustic signal processor module for remote manned /	48.00	2 years 2007-10	Directorate of Weapons Equipment, Naval Headquarters	Arun Kumar (PI) R. Bahl Monika Aggarwal	

	unmanned platforms					
72.	Intelligent Processing of Advanced Polymeric Materials	130.74	4 years w.e.f. 22-mar-2006	Department of Science & Technology (DST)	SUNEET TULI	RP01836
73.	MEMS Based Micro-cantilevers for Chemical and Biochemical Sensors	24.00	2 years 6 months w.e.f. 15-nov-2005	Department of Science & Technology (DST)	SUDHIR CHANDRA (PI) SUNEET TULI G. BOSE	RP01806
74.	Design and implementation of target detection module for underwater passive surveillance	21.00	2.5 years 2006-10	Directorate of Weapons Equipment, Naval Headquarters	Arun Kumar (PI) R. Bahl Monika Agarwal	
75.	Upgradation of laboratory facilities in UWE at CARE, IIT Delhi	78.00	5 years 2006-10	Directorate of Naval Training, Naval Headquarters	Arun Kumar (PI) R. Bahl Monika Agarwal	
76.	TCS Media Laboratory: Computer vision based active surveillance	31.80	1 year 2006-07	TCS	Subahish Banerjee Prem Kalra Arun Kumar Santanu Chaudhury S. D. Joshi	Participation of Arun Kumar in CSE project
77.	Identification of coupled machinery frequencies from passive sonar data	9.50	1.5 years 2006-2008	NSTL	Arun Kumar (PI) R. Bahl Monika Agarwal	CARS project
78.	Noise filtering and spectral estimation techniques for passive sonar data	9.50	1.5 years 2006-2008	NSTL	Arun Kumar (PI) R. Bahl Monika Agarwal	CARS project

79.	Design Simulation and Characterization of GaAs based Coplanar Structures and air bridges using GATECH Process	40.00	24 Months 2006-2008	RCI, Hyderabad	S.K.Koul (PI)	Technology Development Project
80.	Design of platform classifier using multi-sensor data fusion	14.50	15 months (2005-06)	WESEE, Ministry of Defence	R. Bahl (PI) Arun Kumar Monika Agarwal	Technology transferred
81.	Installation of Anechoic Antenna Test Chamber	5.00	24 Months 2005-2007	IIT	M.P.Abegaonkar	Internal Project
82.	Design and Development of Super conducting Microwave Components	15.00	42 Months 2005-2008	MHRD	Ananjan Basu (PI) M.P.Abegaonkar	
83.	Design and Development of Antenna Array with 8 elements (elevation) x 16 elements (azimuth)	9.50	2007	Centre for AirBorne Systems (CABS), DRDO, Bangalore	Dr Ananjan Basu, Dr.M P Abegaonkar, Prof. S K Koul	
84.	Technology Development Project “Studies on some parts of C-Band Rotary Field Phase Shifter”	10.00	2007	Solid State Physical Lab.	Prof S K Koul	
85.	Installation/Up gradation of Vector Network Analyzer in Microwave Laboratory in CARE	12.00	24 Months 2005-2007	MHRD	S.K.Koul (PI) Ananjan Basu	
86.	Improvement of S&T	53.30	60 Months	DST	S.K.Koul (PI)	FIST Program

	Infrastructure in CARE		2005-2010			
87.	Design of Suspended Stripline Based Components at 140 GHz	33.06	26 Months 2005-2007	DEAL Dehradun	S.K.Koul (PI)	Technology Development Project
88.	Non-linear Modelling of PHEMT and Design of Active Mixers at K-band	9.00	18 Months 2005-2006	SSPL Delhi	S.K.Koul (PI) Ananjan Basu	
89.	E-video: Video information processing with enhanced functionality	19.56	30 months 2004-06	DST	Santanu Chaudhury Arun Kumar S. D. Joshi	Participation of Arun Kumar in EE project
90.	Design and Fabrication of 8x8 Array of Micro-machined Patch Antenna and Development of Fabrication Technology Compatible with MEMS Foundry at SCL	15.41	24 Months 2004-2006	Aeronautical Development Agency, DRDO	S.K.Koul (PI) Ananjan Basu	
91.	Design and Development of MEMS based Millimeter wave Active Antenna	22.42	18 Months 2004-2005	Aeronautical Development Agency, DRDO	S.K.Koul (PI) Ananjan Basu	
92.	Development of Catheter-End Temperature Probe for Determining Temparature Profile of Arterial Plaques	17.204	16-jan-2003 31-mar-2006	Aeronautical Development Agency	SUDHIR CHANDRA	RP01492
93.	Technology Development-cum-Transfer Project "Design,	37.50	2006	Research Center Imarat, Hyderabad	Prof S K Koul	

	Simulation and Characterization of GaAs based Coplanar Structures and Air Bridges using GATECH Process”					
94.	Design of target classification method for passive surveillance sonar	18.50	2.5 years 2003-06	Ministry of Defence	Arun Kumar (PI) R. Bahl Monika Agarwal	Technology transferred
95.	Feasibility Study of RF MEMS Phase Shifter (Phases-I, II, III)	10.00	18 Months 2003-2004	RCI, Hyderabad	S.K.Koul (PI)	
96.	Technology Development cum Transfer Project on Microwave Integrated Circuits Kit	5.00	10 Months 2003-2004	SICO, Ghaziabad	S.K.Koul (PI) Ananjan Basu	Technology transferred
97.	Design data on Discontinuities involved in Membrane Microstrip and Coplanar Lines	4.80	12 Months 2003-2004	SSPL Delhi	S.K.Koul (PI)	
98.	Installation/Up gradation of Vector Network Analyzer in Microwave Laboratory in CARE	6.00	24 Months 2003-2005	MHRD	Ananjan Basu (PI)	
99.	Novel Studies on Propagation and Signal Processing of Thermal Waves for Defect Localization with Applications to Non-destructive Characterization	47.38	2003-2007	NRB	Suneet Tuli (PI) G. Bose Arun Kumar	

100.	Network Enabled Digitized Collection in Engineering and Technology	10.00	24 Months 2002-2004	MHRD	J.Arora (PI) S.K.Koul	
101.	Millimeter Wave Antenna Using MEMS	10.50	12 Months 2002-2003	Aeronautical Development Agency, DRDO	S.K.Koul (PI) Ananjan Basu	Technology transferred
102.	IC Compatible Piezoelectric Films for Sensors	23.69	3 years 2000-2006	DRDO	Sudhir Chandra(PI) G. Bose Suneet Tuli T.C. Goel	
103.	Developing Network Enabled Digitized Collection in Biotechnology at IIT Delhi	23.58	24 Months 2001-2003	DBT	J.Arora (PI) S.K.Koul CV Ramakrishnan	
104.	Development of Software Packages, CAD Data and Hardware for LNA, DRO, and VCO: Phase-I, II, III	24.20	26 Months 2001-2003	DEAL Dehradun	S.K.Koul (PI) Ananjan Basu	
105.	Development of MEMS based Micro-switch	15.00	2 years 2001-	NPSM B-SMART	Sudhir Chandra(PI) G. Bose Suneet Tuli	
106.	Design and development of a prototype compact low-power acoustic signal processor module for remote manned / unmanned platforms	9.50	27 months 2000-2003	Directorate of Weapons Equipment, Naval Headquarters	R. Bahl (PI) Arun Kumar	Technology transferred
107.	Relays for launch vehicle using silicon	2.00	11 months 30 days	Vikram Sarabhai Space Centre (Dept. of Space)	SUDHIR CHANDRA SUNEET	RP01241

	micromachining technology (Phase-III)		w.e.f. 31-mar-2000		TULI G. BOSE	
108.	Design and development of silicon micromachined pressure sensors - phase II	4.34	1 year 4 months w.e.f. 29-mar-2000	Department of Science & Technology (DST)	B.S. PANWAR	RP01242
109.	Study for establishing a programme of excellence in underwater acoustic imaging and survey platforms	2.00	8 months 29 days w.e.f. 18-feb-2000	Ministry of Communication & Information Technology	RAJENDAR BAHL	RP01228
110.	Development of techniques for low probability of intercept secure underwater LAN links	9.00	24 months 2000-2002	Directorate of Weapons Equipment, Naval Headquarters	R. Bahl (PI) Arun Kumar	Technology transferred
111.	Study and simulation of passive surveillance techniques for autonomous platforms	9.00	24 months 2000-2002	Directorate of Weapons Equipment, Naval Headquarters	R. Bahl (PI) Arun Kumar	Technology transferred
112.	Optimized Electrical parameters for Electrically Enhanced Transdernal Drug Delivery Instruments	16.68	36 months 2000-2003	DST	S. Anand (PI) V. Koul S.K. Koul	
113.	Development of RF Identification System for Moving Vehicles	48.36	2000-2003	MIT	B.S. Panwar (PI)	
114.	Development of	61.71	48	DTSR	S.K.Koul (PI)	

	Millimeter Wave Components using Dielectric Integrated Guides		Months 1999-2003	DRDO	B.Bhat Ananjan Basu	
115.	Developing Web-based Digitized Collection for Distance and Continuing Education in Information Technology	21.30	36 Months 1999-2002	DOE	J.Arora (PI) S.K.Koul	
116.	Synchronous Thermal Wave Infra-Red Imaging for Surface and Sub-Surface Non-Destructive Characterization	18.00	3 years 1998-2001	Directorate of Training & Sponsored Research	Suneet Tuli (PI)	
117.	Avian Auditory Perception of Microwaves-Phase I	5.3	2 years 1999-2001	Aeronautics Research & Development Board	Suneet Tuli (PI) Ananjan Basu	
118.	Design & Development of Silicon Carbide Schottky Rectifiers	20.00	4 years 1999-2002	DRDO	B.S. Panwar (PI)	
119.	Development of Bulk Micro-machined Pressure Sensors	7.0	4 years 1998-2001	DST	B.S. Panwar(PI) Sudhir Chandra	

Consultancy Projects (excluding CARS): Since 2000

S.No.	Name of the Project	Total Cost In Rs. Lakhs	Duration	Sponsored by	CI / Co-CI
1.	Development of software for underwater domain awareness (UDA)-Phase-II	10.11	2012	Submarine Combat Systems Group, WESEE, New Delhi	Prof R Bahl
2.	Advice for development of long term monitoring techniques using underwater acoustic technology	3.29	2012	URA Lab., Underwater Technology Research Centre, IIS, Univ. of Tokyo	Prof R Bahl
3.	Research & Analysis of Active Image Pixel	2.724	3 months 18-sep-2012	Akshi Technologies, New Delhi	B.S. PANWAR
4.	Analysing and Determining the Resistive Property of the given Items	1.50	7 days 11-17 Sep. 2012	Subros Limited, Noida	SUNEET TULI
5.	Visit and Interaction with Electrical & Computer Engineering Students and Faculty Phase-II of (CW11800)	45.83	1 year 5 months 07-jun-2011	Addis Ababa University, Ethiopia	ARUN KUMAR
6.	Advice for development of long term monitoring techniques using underwater acoustic technology (Phase-III)	2.667	2011	Ura Lab, Underwater Tech. Research Centre, Tokyo, Japan	Prof R Bahl
7.	Development of real time platform noise simulator software using time varying underwater channel	8.00	2011	Submarine Combat Systems Group, WESEE, New Delhi	Prof Arun Kumar
8.	Development of practical oriented teaching manual and set of MIC devices	3.00	2011	Meera Agencies Pvt Ltd., Gurgaon	Prof S K Koul
9.	Development, implementation and performance comparison of estimation methods for Bearings Only Tracking	38.00	2011	Submarine Combat Systems Group, WESEE, New Delhi	Prof Arun Kumar

10.	Broadband Energy Harvesting using MEMS Structures- Ph-I	8.16	1 year 1 month 01-may-2011	Maxim Integrated Circuits, Bengalaru, Karnataka	B.S. PANWAR
11.	Development of Practical Oriented Laboratory Manual for Agilent, Model N9923 A handheld Network Analyzer (6 GHZ), along with a set of 10 devices	2.75	2011	Agilent Technologies India Pvt Ltd, New Delhi	Prof S K Koul
12.	Development of software for underwater domain awareness (UDA) for CICS	9.00	2011	Submarine Combat Systems Group, WESEE, New Delhi	Prof R Bahl
13.	HRD Program Short Course on "Underwater Superiority – Technologies for Underwater Surveillance Systems"	1.60	3 days 22-24 March 2011	CO, INS Valsure, Gujarat	R. Bahl Arun Kumar
14.	Technical & Financial Vetting----of Fire Alarm System & Public Address System for Manyavar Kanshiram Multispeciality Hospital Gr.Noida	3.33	42 days 07-feb-2011	Greater Noida Industrial Development Authority	MONIKA AGGARWAL
15.	Technical & Financial Vetting of Estimates of---- CCTV System & Access Control System for Manyavar Kanshiram Multispeciality Hospital Gr.Noida	1.117	42 days 04-feb-2011	Greater Noida Industrial Development Authority	MONIKA AGGARWAL
16.	Setting up of RF Characterization Laboratory and Development of Microwave Integrated Circuit Components	15.90	12 months w.e.f. 1.3.2011	Techno India NJR Institute of Technology, Udaipur	S.K. Koul
17.	Development of practical oriented teaching manual and set of MIC devices	1.95	3-4 months w.e.f. 31.1.2011	Meera Agencies Pvt. Ltd. Gurgaon	S.K. Koul
18.	Application and Optimization of FMTWI on	4.80	6 months w.e.f.	ASL, Hyderabad	Suneet Tuli

	Thick Composites		21.1.2011		
19.	Development of real-time platform radiated noise simulator for classifier testing using unbounded underwater channel	8.00	2010	Submarine Combat Systems Group, WESEE, New Delhi	Prof Arun Kumar
20.	Consultancy in developing long-term monitoring techniques using underwater acoustic technology (Phase-II)	2.226	2010	Institute of Industrial Science, Univ. of Tokyo, Japan	Prof R Bahl
21.	Development of practical oriented teaching manual and set of MIC devices	1.95	2010	M/s Meera Agencies Pvt Ltd., Gurgaon	Prof S K Koul
22.	Setting up of RF Characterization Laboratory and Development of Microwave Integrated Circuit Components	15.90	2010	Techno India NJR Institute of Technology, Udaipur	Prof S K Koul
23.	Design of Coaxial to Waveguide Transition	0.50	3 days w.e.f. 1.1.2010	Lambda Group, Gurgaon	S.K. Koul
24.	Target classifier using active sonar	36.00	2 years 5-Dec-2009	BEL, Bangalore	R Bahl(PI) Arun Kumar Monika Aggarwal
25.	Advice and assistance in developing long-term monitoring techniques using underwater acoustic technology	2.153	2009	Institute of Industrial Science, Univ. of Tokyo, Japan	Prof R Bahl
26.	License of Intellectual Property	0.50	2009	M/s. Vacuum Equipment Co., Noida	Prof. Sudhir Chandra
27.	CMOS Pixels Design and Simulation for Imaging Applications (Phase-II of CW09696)	6.75	1 year 02-apr-2009	Akshi Technologies	B.S. PANWAR
28.	Development and Characterization of Heat Source for Frequency Modulated Thermography	10.00	2008	Advanced Systems Laboratory (DRDO), Hyderabad	Prof. Suneet Tuli
29.	Flexible Pattern	9.29	2008,	Mitsubishi	Arun

	Recognition for Ultrasonic Signals – Step 2		6 months	Heavy Industries Ltd., Japan	Kumar(CI) R. Bahl
30.	Technical Consultancy Services on speech based recognition application	1.80	2008	M/s Tata Consultancy Servcies Limited, New Delhi	Prof Arun Kumar
31.	Design of Silicon based Switch and Mask preparation	3.35	3 months 2008	M/s Astra Microwave Products Ltd., Hyderabad	S.K. Koul
32.	Design and Development of active Microwave Integrated Circuit Trainer Kit	5.00	15 months 1.1.08	SICO, Ghaziabad	S.K. Koul (PI)
33.	Computer Aided Design of Components at Microwave Frequencies	5.00	12 months 1.1.2008	SICO, Ghaziabad	S.K. Koul (PI) Ananjan Basu Mahesh P. Abegaonkar
34.	CMOS Pixels Design and Simulation for Imaging Application	7.26	2 years 27-dec-2007	Akshi Technologies	B.S. PANWAR
35.	Flexible Pattern Recognition for Ultrasonic Signals – Step 1	3.07	2007, 3 months	Mitsubishi Heavy Industries Ltd., Japan	Arun Kumar(CI) R. Bahl
36.	Computer Aided Design of Components at Microwave Frequencies	5.00	2007	The Scientific Instrument Company Ltd., Ghaziabad	Prof S K Koul
37.	Design and Development of active Microwave Integrated Circuit Trainer Kit	5.00	2007	The Scientific Instrument Company Ltd., Ghaziabad	Prof S K Koul
38.	SAW sensor Development of Honeywell Technology Solutions Lab. Pvt. Ltd.	10.00	12 months 2007	Honeywell Technology	B.S. Panwar (CI)
39.	Consultancy on Solar Cell Processing	12.02	18 months 2006-07	BHEL	S. Chandra (CI) S. Tuli, G. Bose

40.	Feasibility of Getting Double Cantilever Test Structures Fabricated at MEMSTECH Foundry in Singapore	3.75	3 Months 2006	Astra Microwave, Hyderabad	S.K.Koul (CI)
41.	Condition Monitoring of Electronic Card Assemblies by Thermography	1.76	0.5 year 2006	NTPC	S. Tuli (CI)
42.	Simulation of Pixels for CMOS Imaging Sensors	6.86	1 year 2006-07	Biomorphic VLSI Inc. USA	B.S. Panwar (CI)
43.	Characterization and Optimization of Solar Cell Fabrication Process	10.90	10 months 03-apr-2006	B.H.E.L.	SUDHIR CHANDRA (PI) G. BOSE SUNEET TULI
44.	Formulating realistic criteria for detection of targets by sonars	9.00	1 year 2005-06	Macmet, Bangalore	A. Kumar (CI) R. Bahl
45.	Technology Development of C-band Source & Detector	3.50	6 Months 2005-2006	SICO, Ghaziabad	S.K.Koul (PI) Ananjan Basu
46.	Technology Development of Antenna Trainer Kit	7.50	12 Months 2005-2006	SICO, Ghaziabad	S.K.Koul (PI) Ananjan Basu
47.	Wireless Integrated Network Sensors	2.33	2005	Nokia, Germany	B.S. Panwar (CI)
48.	Development of Antenna Trainer Kit	7.50	2005	The Scientific Instrument Co.Ltd. (SICO), Ghaziabad	Prof S K Koul
49.	Technology Devt of C-band Source and Detector	3.50	2005	The Scientific Instrument Co.Ltd. (SICO), Ghaziabad	Prof S K Koul
50.	Modular course in DSP	3.00	1 month 2003	LRDE, Bangalore	A. Kumar (CI) S. Prakriya
51.	Development of Software for Designing Filters in Suspended Stripline and Fin-line	4.00	6 Months 2003	DEAL Dehradun	S.K.Koul (CI) A. Basu (CI)

52.	NTPC R&D: Future Strategies	6.00	1 year 2003-04	NTPC, PMI	R. Balasubramanim PMV Subbarao R.K. Pandey A. Ramnan Suneet Tuli
53.	IC Technology Teaching to Staff	0.50	2003-04	Continental Device India Ltd, New Delhi	S. Chandra (CI) G. Bose
54.	Training simulation software for naval applications	3.50	3 months 2002	Macmet, Bangalore	R. Bahl (CI) Arun Kumar
55.	SRP Software and Sonar Sound Library	3.50	21 Days 22-apr-2002	Macmet India Ltd.	RAJENDAR BAHL
56.	Telecontroller Phase-II	0.57	31 days 21-mar-2002	Third Eye Control Solutions (Pvt.) Ltd.	RAJENDAR BAHL
57.	Simulation of Microstrip/CPW structures for Dielectric Constant Measurement	1.00	12 Months 2001-2002	SSPL Delhi	S.K.Koul (CI)
58.	DSP Consultation	1.06	1 month 2000	ST Micro.	R. Bahl (CI) Arun Kumar
59.	Development of Sonar Simulation	1.00	12 months 2000-01	Macmet, Bangalore	R. Bahl (CI)
60.	Sonar Simulation Phase II	1.50	3 months 2000-01	Macmet, Bangalore	R. Bahl (CI)
61.	Telecontroller System	2.00	10 months 2000-01	TECSPL, New Delhi	R. Bahl (CI)
62.	Simulation of MMIC Structures at Millimeter Wave Frequencies	4.75	18 Months 2000-2002	SSPL Delhi	S.K.Koul (CI) A. Basu
63.	Hands-on-Training for Solar Cell Fabrication	0.25	2000-01	Garg Associates	S. Chandra (CI) G. Bose
64.	Consultancy on Development of Sonar Simulation	1.00	1 years 2 months 02-may-2000	Macmet India Limited	RAJENDAR BAHL (PI)

65.	Design of some parts of rotary field ferrite phase shifter (Parts I, II, III)	9.75	18 Months 1999-2000	SSPL Delhi	S.K.Koul (CI) B.Bhat
66.	Improving the Signal to Noise Ratio of a SODAR system	0.25	1999-2002	Envirotech, New Delhi	B.S. Panwar(CI) S.M.K. Rahman

ANNEXURE – 8

CARE Space Utilization Document 2013

Total Space of CARE: 22,540 sq. ft.

Space Measurement CARE: Ground Floor

S. No.	Room No.	Area (ft x ft = sq ft)	Use and comments	Category*
1	101 -102	24’ x 32’ = 768	CARE Committee Room	US
2	103	600	Non destructive Testing Lab (NDT)	RL
3	119	1856	Microelectronics Lab-II	RL/TL
4	120-121	1344	Under-water / Signal Processing Lab	RL
5	121 A	512	First Reduction Camera Room	RL/TL
6		12’ x 32’ = 384	IC Lab Stores (ME Group)	US
7	122	640	CARE Seminar Room	US
8	123	864	Workshop	US
9	124	12’ x 12’ = 144	Faculty Room	FS
10	125	12’ x 12’ = 144	Faculty Room – Dr. S. Dhanekar	FS

*Category abbreviations:

FS: Faculty Space
RL: Research Lab
TL: Teaching Lab
SS: Student Space
US: Utility Space

Space Measurement CARE: First Floor

S. No.	Room No.	Area (approx) ft x ft = sq ft	Use and comments	Category*
1	201	7' x 12' = 84	ME Group	SS
2	202	7' x 12' = 84	With Microwave Group	SS
3	203	7' x 12' = 84	ME Processing Group	SS
4	204	7' x 12' = 84	ME Group	SS
5	205	7' x 12' = 84	ME Group	SS
6	206	866	CARE Computing Lab	US/RL/TL
7	207	20' x 20' = 400	Radio Amplifier and Power Transceiver Lab	RL
8	211	16' x 8' = 128	Entry	US
9	211A	12' x 12" = 144	Prof. Arun Kumar	FS
10	211B1	12' x 12" = 144	Dr. Monika Aggarwal	FS
11	211B2	12' x 8'= 96	I Signal Processing Sitting Room	US/FS
12	211B3	12' x 12' = 144	II Signal Processing Sitting Room	US
13	211B4	24' x 4' = 96	Gallery Within Signal processing Lab	US
14	211B5	624	Main Lab	RL
15	211C	16' x 16'= 256	Prof. Bahl	FS
16	211D	32' x 20' = 640	DSP Application Lab	RL/TL
17	211D1	12' x 12' = 144	Sitting Room- Deputed Naval Officer	FS
18	211E	20' x 12' = 240	Speech Lab	RL
19	211F	20' x 24' = 480	Acoustics Lab	RL
20	212	12' x 16' = 192	Students of Prof. Panwar	SS/RL
21	213	12' x 16' = 192	Prof. B.S. Panwar	FS
22	214	12' x 16' = 192	Prof. Sudhir Chandra	FS
23		7.5' x 20' = 150	Entrance to CARE Office	US
24	215	24' x 20' = 480	CARE Office	US
25	216	16' x 12' = 192	CARE Stores	US
26	217	16' x 16' = 256	Prof. Vikram Kumar	FS
27	218	16' x 16' = 256	Head CARE	FS
28	219	7.5' x 12' = 90	PA to Head	US

29	220	20’ x 32’ = 640	DSP lab	RL

Space Measurement CARE: Second Floor

S. No.	Room No.	Area (approximate) ft x ft = sq ft	Use and comments	Category*
1	301A	32’ x 16’ = 512	Microwave Lab III	RL
2	301B	736	Measurement Lab	RL
3	302	12’ x 8’= 96	Ph.D. Student	SS
4	303	12’ x 16’ = 192	Prof. Suneet Tuli	FS
5	311	120	AHU III	US
6	312	Included in S.No 5	First Entrance to Micro-electronics Lab	RL
7	313	Included in S.No 5	Emergency Entrance to Microelectronics Lab	RL
8	314	12’ x 16’ = 192	AHU II	US
9	315	12’ x 8’= 96	Utility Room	US
10	316	2483	Microelectronics Lab (Total Area)	RL/TL
11	317	12’ x 12’ = 144	AHU I	US
12	318	Included in S.No 11	Microelectronics Lab (Second Entrance)	RL
13	319	12’ x 12’ = 144	Part of Microwave Lab	RL/US
14	320	20’ x 12’ = 240	Prof. S.K. Koul	FS
15	321	32’ x 20’= 640	Microwave Lab I	RL/TL
16	322 & 325	68’ x 20’ = 1360	Microwave Lab II	RL/TL
17	323	12’ x 16’ = 192	Dr. Ananjan Basu	FS
18	323A	12’ x 12’ = 144	Student Room MEMS CAD Lab	SS
19	323B	12’ x 8’= 96	Student Room MEMS CAD Lab	SS
20	323C	12’ x 8’= 96	Dr. Karun Rawat	FS
21	323D	12’ x 8’= 96	Student Room	SS
22	324	12’ x 12’ = 144	Dr. Mahesh Abegaonkar	FS
23	326	100	MW Component Machining lab	RL

ANNEXURE – 9

CARE Vision Document - April 2013

Centre for Applied Research in Electronics

Vision Document

April 2013

CARE, IIT Delhi
HauzKhas, New Delhi – 110016

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1. Introduction

A. Evolution: The Centre for Applied Research in Electronics (CARE) started as The School for Radar Studies (SRS) in 1971, with an initial grant from the Radio and Communication Project Office, Ministry of Defence. The objective was to establish a Centre of excellence for coordinated research and manpower training in specific areas of interest to Defence. The initially identified areas were Radar Signal Processing and Phased Array Techniques. The scope of R&D was soon broadened to encompass the areas of Signal Processing, Microwaves, and Microelectronics.

B. Founding Objectives: The vision of the School was expanded when it was renamed as the Centre for Applied Research in Electronics in 1977 with the founding objectives:

i) To conduct technological research in selected thrust areas of national importance,

ii) To design and develop application specific advanced components / subsystems,

iii) To provide manpower training in specialized areas.

C. Research and Technology Development Emphasis: Several goal-oriented programs were initially taken up in these areas. These included Underwater Electronics, Railway Electronics, Electronic Phase Shifters, SAW devices, MOS Technology, VLSI Design and Millimeter Wave Integrated Circuits. Subsequently, new R&D programs were initiated in the areas of Non-Destructive Testing and Characterization, Micro-Electro-Mechanical Systems (MEMS) including Millimeter Wave MEMS, Speech Signal Processing, and SAW based systems.

Several sponsored research projects of great national importance under the above programs have been successfully completed for user organizations such as DRDO, Navy, ISRO, BARC, and DOE (now MCIT). A key aspect of these projects has been the technology intensive and hardware development nature of work involved leading to many technology and know-how transfers of international quality. In this process, strong R&D linkages have been established over the years with several organizations of national importance as well as industries.

D. State-of-the-art Laboratory Infrastructure: CARE has developed well-equipped laboratory facilities over the years in its major research areas and has consistently upgraded them due to the emphasis on advanced and contemporary experimental research and technology development work. Some of the research laboratories are: i) Microwaves Lab, ii) MEMS-CAD Lab, iii) Underwater Electronics Lab, iv) Speech and Audio Processing Lab, v) Digital Signal Processing Lab, vi) Microelectronics Lab, and vii) Non-Destructive Characterization Lab. The bulk of the funding for the laboratory infrastructure has been possible through sponsored research projects.

E. Specialized Manpower Training: An M.Tech Program for defence sponsored officers and DRDO scientists was initiated in the 1970s. Under this program, the Centre has been continually providing specialized post-graduate level training in

Underwater Signal Processing to Naval officers. In 2004, the Centre started its own unique M.Tech Program in Radio Frequency Design and Technology (RFDT) with an aim to provide strong foundations in various technology and signal processing aspects important to RF electronics systems. The curriculum provides flexibility to cater to specific requirements of sponsored M.Tech candidates from the Navy and DRDO. Outside of Departments, CARE was the first Centre that was permitted to run an M.Tech program on its own. In addition, CARE has its own vibrant PhD program.

F. Scope of the Document: This document attempts to capture the vision of the Centre for the next 5 years, which is extendible to 10 years with a mid-course review. The broad objectives are presented in Section 2. The research areas, programs, and initiatives for this period are discussed in Section 3. The initiatives to be taken towards manpower training aspects are given in Section 4. In Section 5, the requirement of new faculty in the three research areas is discussed. The aspirations of the Centre are summarized in Section 5.

2. CARE's Vision Statement

The Centre derives immense pride from the several unique achievements of the past that have been well recognized. Its model of focused, goal-oriented applied research and specialized manpower training has been useful in serving several important national requirements over the past four decades. This successful backdrop provides the pedestal for preparingthe Centre's vision for the future.

CARE shall focus on research, development, and specialized manpower trainingactivities in electronics technologies for strategic needs of the nation and societal benefits.

CARE shall intensively do focused, goal-oriented research of an applied nature in the areas of Microwaves, Signal Processing, and Microelectronics forthe development of advanced electronics technologies of relevance. For this, it shall maintain and endeavor to enhance close interactions with user organizations in the strategic sectors of defence and space, R&D based industries, and national and international research institutions. The Centre will also explore methods to recruit post-doctoral researchers to provide further thrust to its high-end research activities.

The Centre shall endeavor to enhance the scope of postgraduate training through its M.Tech program on Radio Frequency Design and Technology by providing avenues for rigorous specialization in sub-streams of Signal Processing, Microwaves and RF, and Microelectronics. It is expected that a reorganized course structure will motivate the bright students to pursue PhD in these areas and consider research as a career option.

3.Research Areas, Programs, and Thrust

3.1 Background

The Centre has three research groups, namely, Microwaves, Signal Processing and Microelectronics.

A. Microwaves: The Microwaves group is well known as a leading research group in the area amongst Indian universities. The unique feature of this group are its focus on practical hardware development, which over the years has amounted to a substantial knowledge bank regarding sourcing of components, indigenous assembly, interfacing between components and instruments, and characterizing devices and components. In the process, it has established long-term relationships with companies and universities, and government organizations, particularly the DRDO.

In India, there are very few companies developing microwave components and systems, leading to an over-reliance on imports, which is particularly undesirable for products for defence uses. Hence, the Microwave group has a valuable role to play.

B. Signal Processing: The Signal Processing Group has developed a niche area in Underwater Acoustic Signal Processing over the past 35 years and has established a leadership role amongst academic institutions in this area. Several projects of great national significance have been completed and handed over to users such as the Navy, DRDO and other Ministry of Defence establishments. It is the only group in an academic institution imparting specialized post-graduate training to Naval officers in the area of Underwater Signal Processing in the country.The group has also developed major strengths in Speech Signal Processing in the past 15 years. In recent years, the group hasalso taken up research activities and sponsored projects in the broad area of Acoustic Signal Processing, including underwater acoustics, bio-acoustics, air acoustics, acoustics of layered snow media, and speech signal processing.

The role of acoustic signal processing is ever increasing in multi-disciplinary precision engineering applications and innovative technological products and solutions. The Signal Processing group aims to expand and play a significant role in this field.

C. Microelectronics: The Microelectronics activity at the Centre was pioneering in establishing capability of in-house design and fabrication of Integrated Circuits (ICs), at an academic institution in India. It was associated with all leading commercial/governmental ventures in the area, i.e., BEL, SCL, ITI, CDIL etc. It produced a generation of scientific leaders who continue to occupy roles of academic / industrial importance in India and abroad. About 50 PhDs of high international level have been produced by the group. Innovative designs, processes, and products have been produced by the group based on the concept of design to prototyping including characterization. These include Analog Cells for SCL Gate Array (1995), Surface Acoustic Wave Pulse Compression Filter for DRDO (1985), Micropower CMOS Hearing Aid (1987). Recent years, in tune with international focus, has seen the group focus on the areas of Micro-Electro-Mechanical Systems (MEMS) and nano-fabrication with application to sensors, specially bio-related.

3.2 Research Programs and Initiatives

A. Microwaves: The research program in focus shall be the development of state-of-the-art microwave components and sub-systems up to 100 GHz. Specific topics of thrust being considered for the near future include:

5. RFIC development (priority area designated by MCIT). This is a new direction for the group, and it is expected that in about 5 years, expertise shall be developed for designing practically useful components such as frequency synthesizers, down-converters, and transmitter front-ends in CMOS-RFIC for the microwave and lower-millimeter-wave frequencies.
6. Development of microwave components and systems with focus on components for pulsed signals, imaging and surveillance. It is expected that in the next 5 years, the group will be able to demonstrate a prototype microwave imaging system and a wide-band electro-magnetic signal detection and analysis system.
7. Study of transient effects in microwave components and components using magnetic effects. This is an academic research topic with potential applications in Ultra-Wideband systems (specially for military and security applications), and miniature short-range radar.
8. Component development for specific users (mainly DRDO) has been an on-going activity, and will continue to be so.

B. Signal Processing: The research program of focus shall be the development of technologies based onacoustic signal processing including underwater acoustics, air acoustics, acoustics in other media such as solids, sediment and snow, bio-acoustics, and speech and audio.It shall encompass the development of DSP algorithms, hardware prototypes, and specialized software, and involve laboratory and field experiments. The specific topics of thrust envisioned for the next few years are based on requirements expressed by users including Naval units, DRDO and industries, and our own projections. The topics include:

8. Underwater acoustic surveillance algorithms and systems: Target localization and classification for active and passive sonar for networked observatories, Target motion analysis for tracking using passive sonar.
9. Acoustics based source localization: Infrasound based localization of snow avalanches, algorithms for precise source localization.
10. Passive acoustic vector sensor system: Signal processing and hardware system development for co-located particle velocity and pressure measurement based passive source localization.
11. Signal processing for communications: Efficient acoustic communication techniques.
12. Acoustic stratigraphy: Algorithms and portable hardware system development for analysis of layered snow media for the determination of snow water equivalent for forecasting applications.
13. Passive acoustic monitoring of wildlife and habitats: Marine mammal classification and monitoring systems for requirements in various applications.

14. Human and machine speech communication technologies: keywords spotting in speech, voice personality transformation, objective speech quality evaluation, text-to-speech synthesis in Indian languages.

C. Microelectronics: The Microelectronics Group in CARE shall focus on research in applied electronics with particular emphasis on wafer-level processing and integration for semiconductor devices. The process and fabrication lab shall form the core of the Microelectronics stream within both the M.Tech and Ph.D. programmes run by the Centre. This lab will have minimal overlap and will be complementary to other such facilities within IIT Delhi. It is envisaged that the lab will serve the interests of the Microelectronics group for both research and teaching with general-purpose equipment while more expensive facilities could be housed as central facilities. Another aspect of continuing interest to the group is the development of non-destructive characterization techniques in the electrical, thermal, magnetic, and optical domains for the characterization of materials and devices.

The group will strive to build a strong faculty proficient in various processing techniques, device design and measurements for doing experimental research in related fields of nanoelectronics, microelectronics, MEMS, microfluidics, biosensors, and nano-fabrication techniques. The specific research topics in coming years include:

7. Microdevices for detection of pesticides and antibiotics in milk and other food items such as fruit juice and edible oils.
8. Microfluidic devices such as micromixers for strategic applications.
9. Graphene and novel semiconductor materials and devices.
10. Synthesis of electronic and magnetic nanostructured materials and their integration for semiconductor, MEMS and GHz-frequency applications.
11. Development of instrumentation systems based on non-destructive characterization techniques for various applications including those identified by the industry.
12. Bio-signal detection, analysis and diagnostics.
13. MEMS for energy harvesting application.

4. Specialized Manpower Training

CARE runs a unique M.Tech program in Radio Frequency Design and Technology (RFDT) since 2004 with a current sanctioned strength of 40 which includes 20 candidates with Institute Assistantship, and 10 sponsored candidates each from the Defence forces, and DRDO laboratories. In addition, it has its own PhD program with about 40 enrolled research scholars at present.

The RFDT M.Tech program shall be updated to reflect the revised provisions for Masters programs that has reduced the minimum credit requirements of core courses and increased the requirements of program electives. Efforts shall be made to introduce in-depth specialization courses with the aim to motivate more students to pursue PhD in these areas and consider research as a career option.

5. Faculty Requirement

CARE currently has 11 faculty members and 1 joint faculty member with Physics Department, the sanctioned faculty strength of CARE being 16. The number of faculty members in the research areas of Microwaves, Signal Processing and Microelectronics are 4, 3, and 4 respectively. It is strongly felt that the optimum number of faculty in each area should be 5 so that more forceful impact can be made in meeting national requirements and international presence.

The Signal Processing group has operated with faculty strength of 3 for the past several years. This is a bare minimum level to meet ongoing commitments on a modest scale only. There is tremendous scope and opportunity to take on more challenging tasks to meet national needs. Attempts are being made to have faculty strength of around 5 to be able to make a more forceful impact.

The Micro-electronics group presently has four faculty members working in separate aspects of materials, processing, device design, and measurements. In view of superannuations in the next 2-3 years, there is an immediate need to recruit about 3 young faculty members in order to reach and maintain strength of at least 5. These five faculty members would be roughly complementary to each other but with the main emphasis on processing and experimental device realization.

6. Aspirations

CARE's aspirations, expressed through the vision document, is summarized in the following:

1.1. To strive and maintain leadership in the country and increase international visibility in the focus areas through intensive goal-oriented research leading to high quality publications,

1.2. To nurture and forge stronger links with user organizations from the strategic sector in the country and industries, by taking up challenging technology development projects from them,

1.3. To have increased research collaborations with national and international institutions,

1.4. To maintain and continually upgrade the state-of-the-art laboratory facilities in the respective research areas - this shall be complemented with a large number of PhD students,

1.5. To take the M.Tech programme to the next level by i) introducing in-depth elective courses, to motivate bright students towards PhD and research, and ii) providing specialized courses for human resource development for national requirements in key areas of defence (DRDO and Services), and emerging industries.