

Proposed Revised Curriculum

for

M. Tech Program

in

Radio Frequency Design and Technology (RFDT)

**Centre for Applied Research in Electronics
Indian Institute of Technology, Delhi**

February 2015

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1. Introduction

The M.Tech Program on Radio Frequency Design and Technology (RFDT) was started in 2004. A comprehensive revision of the RFDT M.Tech Program has been undertaken under the ambit of the institute-wide PG Curriculum Revision exercise. The credit requirements and course curricula have been revised in accordance with the Senate recommendations (Resolution No. S/08/2014) and keeping in view the evolution of the field since the start of the Program and the feedbacks received from stake-holders from time-to-time.

The initially approved student intake of the RFDT M.Tech Program was 15 that comprised of 5 Institute Assistantships and 10 full-time Sponsored Category students from DRDO and Armed Forces. Subsequently, the intake was increased over the years. The current approved intake of students is 44 that comprises of 20 Institute Assistantships and 24 full-time Sponsored Category students that includes 10 seats under the R&T scheme and 13 seats under the PGT scheme of Ministry of Defence.

2. Credit Requirements

The total credit requirement for the RFDT M.Tech Program shall be 51. This will include 3 credits of bridge course. The semester-wise break-up is given in the Table below.

	Credits				
	Program Core	Program Elective	Open Elective	Bridge Course	Total Credits
1st Semester	8	3	-	3	14
2nd Semester	10	3	-	-	13
3rd Semester	6	6	-	-	12
4th Semester	-	12*/9**	3**	-	12
Total	24	24*/21**	3**	3	51

* For students with M.Tech Dissertation.

** For students without M.Tech Dissertation.

3. Curriculum Layout

The semester-wise curriculum layout is given in the Table below.

Semester	Program Core	Program Elective	Other Course
1	CRL711 (3-0-2) CRP718 (1-0-6)	PE-1: 3 credits	Bridge course: Any one of the following three: CRL501 (2-0-2) CRL511 (2-1-0) CRL521 (3-0-0)
2	CRL724 (3-0-0) CRL702 (2-0-4) CRD802(0-0-6)	PE-2 : 3 credits	-
3	CRD811(0-0-12)	PE3 : 3 credits PE4 : 3 credits	-
4	-	IF: B grade or better in CRD811 + CRC approval, THEN: CRD812 (0-0-24)	-
		ELSE: CRD814 (0-0-12) PE5 : 3 credits	Open Elective OE 1 : 3 credits

Note: Minimum eligibility criterion for doing CRD812 (M.Tech Project 2) in final semester leading to M.Tech with Dissertation shall be B grade in CRD811. However, additional/higher criteria may be set by CFB based on which CRC shall approve/disapprove this option for each student.

4. Lists of Courses

The lists of Program Core and Program Elective courses are given below.

Program Core Courses:

Course No.	Course Title	(L-T-P)	Credits
CRL702	Architectures and Algorithms for DSP Systems	(2-0-4)	4
CRL711	CAD of RF and Microwave Circuits	(3-0-2)	4
CRP718	RF and Microwave Measurement Lab	(1-0-6)	4
CRL724	RF and Microwave Measurements	(3-0-0)	3
CRD802	Minor Project	(0-0-6)	3
CRD811	Major Project I	(0-0-12)	6

Program Elective Courses:

Course No.	Course Title	(L-T-P)	Credits
CRL704	Sensor Array Signal Processing	(3-0-0)	3
CRL706	Selected Topics in Radars and Sonars	(3-0-0)	3
CRL707	Human & Machine Speech Communication	(3-0-0)	3
CRL708	Sonar Systems Engineering	(3-0-0)	3
CRL709	Underwater Electronic Systems	(3-0-0)	3
CRL712	RF and Microwave Active Circuits	(3-0-0)	3
CRL715	Radiating Systems for RF Communication	(3-0-0)	3
CRL722	RF and Microwave Solid State Devices	(3-0-0)	3
CRP723	Fabrication Techniques for RF and Microwave Devices	(1-0-4)	3
CRL725	Technology of RF and Microwave Solid State Devices	(3-0-0)	3
CRL726	MEMS Design and Technology	(3-0-0)	3
CRL727	Quantum Electronic Devices	(3-0-0)	3
CRL729	Sensors and Transducers	(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
CRL734	Selected Topics in RFDT-IV	(3-0-0)	3
CRS735	Independent Study	(0-3-0)	3
CRV741	Acoustic Classification using Passive Sonar	(1-0-0)	1
CRD802	Minor Project	(0-0-6)	3
CRD812	Major Project II	(0-0-24)	12
CRD814	Major Project III	(0-0-12)	6
ELL784	Introduction to Machine Learning	(3-0-0)	3
ELL711	Signal Theory	(3-0-0)	3
ELL714	Basic Information Theory	(3-0-0)	3
ELL718	Statistical Signal Processing	(3-0-0)	3
ELL7xx	MOS VLSI	(3-0-0)	3
ELL720	Advanced Digital Signal Processing	(3-0-0)	3
ELL712	Digital Communication	(3-0-0)	3
ELL719	Detection and Estimation Theory	(3-0-0)	3
ELL7xx	Parameter Estimation and Signal Identification	(3-0-0)	3
ELP725	Wireless Communication Laboratory	(0-1-4)	3
ELL8xx	CMOS RFIC Design	(3-0-0)	3
ELL725	Wireless Communication	(3-0-0)	3
ELL815	MIMO Wireless Communication	(3-0-0)	3
ELL7xx	Analog IC	(3-0-0)	3
ELL7xx	Mixed Signal IC	(3-0-0)	3

ELL7xx, ELL8xx: Course numbers of these named EE courses to be inserted up on updation.

5. Proposed New Courses

The following new courses are being proposed in the revised curriculum:

1. CRL501	Basics of Statistical Signal Analysis	(2-0-2)	Bridge Course
2. CRL511	Basics of RF and Microwaves	(2-1-0)	Bridge Course
3. CRL521	Fundamentals of Semiconductor Devices	(3-0-0)	Bridge Course
4. CRL709	Underwater Electronic Systems	(3-0-0)	Prog. Elective
5. CRL727	Introduction to Quantum Electron Devices	(3-0-0)	Prog. Elective
6. CRL729	Sensors and Transducers	(3-0-0)	Prog. Elective
7. CRL734	Selected Topics in RFDT-IV	(3-0-0)	Prog. Elective
8. CRD814	Major Project III	(0-0-12)	Prog. Elective

6. Deleted Courses

The following courses may be deleted from the existing course list:

1. CRL705 Advanced Sensor Array Signal Processing
2. CRL713 Fundamentals of RF Electronics
3. CRL720 SAW Devices
4. CRL721 Analog RF/IC Modeling
5. CRL728 RF Electronic System Design Techniques

7. Renumbered / Renamed / Superseded Courses

1. CRL706: Selected Topics in Radars and Sonars is a renumbered Program Elective course that previously existed as CRL737 with the same course title. The new number is more consistent with the numbering scheme being followed for the courses.
2. CRL708: Sonar System Engineering is a renumbered Program Elective course that previously existed as EEL765 with the same course title. The course has always been taught by CARE faculty and is attended by CARE RFDT M.Tech students.
3. CRL726: Has been renamed from “RF MEMS Design and Technology” to “MEMS Design and Technology”.

8. Course Templates

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Basics of Statistical Signal Analysis
3.	L-T-P structure	2-0-2
4.	Credits	3
5.	Course number	CRL501
6.	Status (<i>category for program</i>)	Bridge Course
7.	Pre-requisites (course no./title)	Nil
8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	10% with EEL205, 20% with EEL711, 5% with EEL731.
8.3	Supersedes any existing course	-
9.	Not allowed for (indicate program names)	-
10.	Frequency of offering	☐ Every sem ☒ 1stsem ☐ 2ndsem ☐ Either sem -
11.	Faculty who will teach the course Monika Aggarwal, Arun Kumar, R. Bahl.	
12.	Will the course require any visiting faculty? (yes/no)	No
13.	Course objectives (<i>about 50 words</i>): The course is designed to provide students with basic understanding of signal representation, linear systems, signal processing and statistical signal analysis. The basics of random variables and random processes will be explained. Hands-on skills will be developed through MATLAB based laboratory experiments in which concepts will be applied to practical engineering problems.	
14.	Course contents (<i>about 100 words</i>) (Include laboratory/Design activities): Fundamentals of signals and systems, LTI systems, convolution, Fourier transforms, Z-	

	transform, sampling and Nyquist criteria, set & probability theory, random variables, probability density / distribution functions, moments, characteristic and moment generating functions, transformation of a random variable, random process, stationarity, ergodicity.
	Lab experiments using MATLAB will be given to understand the practical aspects of these concepts.

15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1.	Review of Signals and Systems: Types of Signals, System Properties	1
2.	Linear Time Invariant Systems & Convolution	2
3.	Fourier Transforms & Properties	2
4.	Sampling and Nyquist Criteria	2
5.	Z-Transform & Properties	3
6.	Set & Probability Theory	4
7.	Random Variable and Probability Density / Distribution Functions; Examples	3
8.	Moments, Characteristic Function and Moment Generating Function, Autocorrelation function, Power Spectral Density, Properties	6
9.	Transformation of Random Variable	2
10.	Random Process, Stationarity, Ergodicity; Examples	3
COURSE TOTAL (14 times 'L')		28

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours
1	Familiarization with MATLAB, writing small programs using loops, conditional loops, functions, vectors, arrays	4
2	Implementation of LTI system, FIR filtering, IIR Filtering	4
3	DFT and its properties	4
4	LTI system in frequency domain	2
5	Modeling of probability density function of random variables	2
6	Moments evaluations: autocorrelation, cross-correlation, Power spectral density	4
7	Random process realization and study of their properties	4
8	Random signals through LTI systems	2

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses) **NA**

Module no.	Description	No. of hours
1-10	Assignments in the respective modules	42

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. A. Papoulis, S. U. Pillai, Probability, Random Variables and Stochastic Process, McGraw-Hill, 2002.
2. S. K. Mitra, Digital Signal Processing - A Computer based Approach, Tata McGraw-Hill, 4 th edition, 2010.
3. V. K. Ingle, and J. G. Proakis, Digital Signal Processing using MATLAB, Cengage Learning, 3 rd edition, 2011.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	MATLAB
20.2	Hardware	-
20.3	Teaching aides (videos, etc.)	Powerpoint presentations
20.4	Laboratory	DSP Applications Lab
20.5	Equipment	-
20.6	Classroom infrastructure	LCD projector, whiteboard.
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course(*Percent of student time with examples, if possible*)

21.1	Design-type problems	-
21.2	Open-ended problems	20% through assignments.
21.3	Project-type activity	-
21.4	Open-ended laboratory work	20% through MATLAB simulation experiments.
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics	
2.	Course Title (<i>< 45 characters</i>)	Basics of RF and Microwaves	
3.	L-T-P structure	2-0-2	
4.	Credits	3	
5.	Course number	CRL511	
6.	Status (<i>category for program</i>)	Bridge Course	
7.	Pre-requisites (course no./title)		
8.	Status vis-à-vis other courses (<i>give course number/title</i>)		
8.1	Overlap with any UG/PG course of the Dept./Centre	-	
8.2	Overlap with any UG/PG course of other Dept./Centre	-	
8.3	Supersedes any existing course	-	
9.	Not allowed for (indicate program names)	-	
10.	Frequency of offering	☐ Every sem ☒ 1stsem ☐ 2ndsem ☐ Either sem -	
11.	Faculty who will teach the course S. K. Koul, Ananjan Basu, Mahesh P. Abegaonkar		
12.	Will the course require any visiting faculty? (yes/no)	No.	
13.	Course objectives (<i>about 50 words</i>): Introduce the basic techniques required for RF and microwave engineering.		
14.	Course contents (about 100 words) (Include laboratory/design activities): Basic electromagnetics, plane waves and scattering, waveguide modes, Fourier series and transform, autocorrelation and power spectral density, holes and electrons in semiconductors, p-n junction.		

15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Maxwell's equations	4
2	Plane waves	4
3	Reflection and refraction	4
4	Waveguide	4
5	Fourier techniques	4
6	Random signals	4
7	Basics of semiconductors	2
8	The p-n junction	2
COURSE TOTAL (14 times 'L')		28

16. Brief description of tutorial activities: NA.

Module no.	Description	No. of hours

17. Brief description of laboratory activities:

Module no.	Description	No. of hours
1.	Examples in electromagnetics	12
2.	Examples in signal processing	12
3.	Examples in semiconductor theory	4

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Assignment on electromagnetics	8
2	Assignment on signal processing	8

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. David Cheng, Field and Wave Electromagnetics, Pearson, 2011.
2. Oppenheim, Willsky and Nawab, Signals and Systems, Pearson 2014.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	NIL
20.2	Hardware	NIL
20.3	Teaching aides (videos, etc.)	NIL
20.4	Laboratory	NIL
20.5	Equipment	NIL
20.6	Classroom infrastructure	LCD Projector and whiteboard.
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course (*Percent of student time with examples, if possible*)

21.1	Design-type problems	NIL
21.2	Open-ended problems	NIL
21.3	Project-type activity	NIL
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Fundamentals of Semiconductor Devices
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL521
6.	Status (<i>category for program</i>)	Bridge Course

7.	Pre-requisites (<i>course no./title</i>)	None
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (<i>indicate program names</i>)	-
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10.	Frequency of offering	☐ Every sem ☒ 1st sem ☐ 2nd sem ☐ Either sem -
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11.	Faculty who will teach the course: Sudhir Chandra, Samaresh Das.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): The objective of this background course is to teach the students the fundamentals of semiconductor materials and solid state devices. It is expected that after completing this course, the students will be well prepared to study and understand advanced solid state RF devices in a follow up course.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Si Crystal structure, crystal planes and directions, band formation in semiconductors, direct and indirect gap semiconductors, <i>E-k</i> diagram, concept of "hole" as charge particle, effective mass, carrier mobility, life time of carriers, recombination, doping of
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	semiconductors, drift and diffusion currents in semiconductors, metal-semiconductor junctions, ohmic and non-ohmic contacts, Schottky diode, abrupt p-n junction, energy-band diagram, junction under zero-bias, forward bias and reverse bias; current calculations, break-down in p-n junction, diffused p-n junction; bipolar transistor: theory and operation; theory of MOS FET, ideal MOSFET, threshold voltage, sub-threshold conduction in MOSFET, C-V characteristics of MOS capacitor, short-channel effects.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Si Crystal structure, crystal planes and directions, atomic density in crystal planes,	2
2	Band formation in semiconductors, Fermi distribution and Fermi level, direct and indirect gap semiconductors, $E-k$ diagram, concept of "hole" as charge particle, effective mass, carrier mobility, density of state in conduction and valence band, charge carrier calculations	5
3	Life time of carriers, recombination, semiconductor under non equilibrium	3
4	Doping of semiconductors, drift and diffusion currents in semiconductors, solid state diffusion, ion implantation, characterization of diffused and implanted layer	6
5	Metal-semiconductor junctions, ohmic and rectifying contacts, Schottky diode,	3
6	Abrupt p-n junction, energy-band diagram, junction under zero-bias, forward bias and reverse bias; current calculations, break-down in p-n junction, diffused p-n junction	6
7	bipolar transistor: theory and operation, double diffused bipolar transistors	4
8	Theory of MOSFET, ideal MOSFET, threshold voltage calculation, sub-threshold conduction in MOSFET, three-terminal I-V characteristics, introduction to depletion-enhancement mode devices, CMOS, self-aligned MOSFET process.	8
9	C-V characteristics of MOS capacitor	3
10	Short-channel effects in MOSFET, LDD structures	2
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses) NA

Module no.	Description	No. of hours

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Donald A Neamen, Semiconductor Physics and Devices Basic Principles, Third Edition, Tata McGraw Hill 2003.
2. Ben G Streetman and Sanjay Banerjee, Solid State Electronic Devices, Fifth Edition Pearson Education, 2003.
3. M S Tyagi Introduction to Semiconductor Materials and Devices, John Wiley & Sons, 1991.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	NIL
20.2	Hardware	NIL
20.3	Teaching aides (videos, etc.)	NIL
20.4	Laboratory	NIL
20.5	Equipment	NIL
20.6	Classroom infrastructure	Black board, overhead projector
20.7	Site visits	NIL
20.8	Others (please specify)	NIL

21. Design content of the course (*Percent of student time with examples, if possible*)

21.1	Design-type problems	NIL
21.2	Open-ended problems	NIL
21.3	Project-type activity	NIL
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Architectures and Algorithms for DSP Systems
3.	L-T-P structure	2-0-4
4.	Credits	4
5.	Course number	CRL702
6.	Status (<i>category for program</i>)	Program Core

7.	Pre-requisites (course no./title)	EEL205 - Signals and Systems (or equivalent).
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Arun Kumar, R. Bahl, Monika Agarwal.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): This course will provide students with an in-depth understanding of DSP processor architectures and implementation of efficient algorithms in the assembly programming language for performing real-time signal processing in DSP systems. The course will enable students to design diverse DSP systems such as modems, radars, sonars, surveillance and target tracking systems, digital speech, audio, image and video processing systems, mobile communication systems etc.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Lectures Introduction – DSP Tasks and Applications, Real-time Signal Processing, Representation
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	of DSP algorithms; Number Representations and Arithmetic Operations - Fixed point and floating point representations and arithmetic operations; Q notation; Digital Signal Processor Architectures – CPU, Peripherals; Specific DSP processor architecture; DSP Instruction Set and Assembly Language Programming – Instruction types; Parallel programming; Pipelining; Efficient programming; DSP Algorithms and their Efficient Implementation - a) Linear filtering; b) FFT and spectrum analysis; c) Scalar and vector quantization, source coding, linear prediction coding; d) Function generation; Software Design for Low Power Consumption. The DSP architecture and assembly language programming will be studied in lectures and laboratory with reference to a specific DSP processor. Laboratory 1. Basic DSP algorithms using MATLAB, 2. Familiarization with DSP kit, 3. Real-time filtering, 4. PN Sequence generation, 5. FFT, 6. Lab project.
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15. Lecture Outline *(with topics and number of lectures)*

Module no.	Topic	No. of hours
1.	Introduction – DSP Tasks and Applications, Real-time Signal Processing, Representation of DSP algorithms.	4
2.	Number Representations and Arithmetic Operations - Fixed point and floating point representations; Extended precision; Q notation; Fixed-point and floating-point arithmetic operations.	3
3.	Digital Signal Processor Architectures – CPU, DMA, Codec, Serial and parallel data communication; Memories; Interrupts; Peripheral interfacing; Specific DSP processor architecture.	5
4.	DSP Instruction Set and Assembly Language Programming – Instruction types; Data addressing modes; Parallel programming; Pipelining; Efficient DSP programming techniques.	6
5.	DSP Algorithms and their Efficient Implementation - a) Linear filtering in time and frequency domains; b) FFT and spectrum analysis; c) Scalar and vector quantization, source coding, linear prediction coding; d) Function generation and pseudo-random number sequence generation.	8
6.	Software Design for Low Power Consumption – Sources of energy consumption in a DSP processor; Methods for power audit of a program; Programming techniques for low energy consumption.	2
COURSE TOTAL <i>(14 times 'L')</i>		28

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities:

Module no.	Description	No. of hours
1.	Basic DSP algorithms using MATLAB.	8
2.	Familiarization with DSP kit (1): Mathematical operations and Q-format.	4
3.	Familiarization with DSP kit (2): ADC and DAC; Simple real-time operations; Aliasing.	4
4.	Real-time FIR filtering.	4
5.	PN sequence generation.	4
6.	Fast Fourier Transform.	8
7.	Lab project requiring implementation of efficient real-time digital signal processing task on DSP kit.	16

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1.	Survey of diverse DSP applications	2
2.	Assignment on number representation and arithmetic operation	2
4.	Study from DSP processor instruction set manual and assignments requiring efficient program writing	8
5.	Assignments	6
6.	Assignment	2
-	Lab experiments 1-6 preparation	18
-	Lab project study from journal papers and preparation of efficient program	12

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1) Sen M. Kuo and W. S. Gan, Real-Time Digital Signal Processing – Fundamentals, Implementations and Applications, Wiley, 2013. 2) T. B. Welch, C. H. G. Wright, and M. G. Morrow, Real-time Digital Signal Processing – From MATLAB to C with the TMS320C6x DSPs, CRC Press, 2nd edition, 2011. 3) Richard E. Blahut, Fast Algorithms for Signal Processing, Cambridge University Press, 2010. 4) DSP Processor specific architecture and instruction set manuals.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	MATLAB, DSP Processor specific Compiler/Assembler.
20.2	Hardware	DSP Processor kit.
20.3	Teaching aides (videos, etc.)	Powerpoint presentations.
20.4	Laboratory	DSP Applications Lab.
20.5	Equipment	Function generator, Oscilloscope, Loudspeaker, Microphone.
20.6	Classroom infrastructure	LCD Projector, Whiteboard.
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	10% in writing efficient assembly language programs.
21.2	Open-ended problems	10% in solving assignment problems.
21.3	Project-type activity	20% in lab project.
21.4	Open-ended laboratory work	20% in lab experiments.
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Sensor Array Signal Processing
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL704
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	1. CRL501 – Basics of Statistical Signal Analysis (or equivalent course). 2. EEL205 - Signals and Systems (or equivalent course).
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	20% with EEL718 - Statistical Signal Processing
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Monika Agarwal, Arun Kumar, R. Bahl.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): The course will provide students with a comprehensive understanding of the key topics in the theory of sensor array signal processing that finds extensive use in distributed sensor networks, wireless communications, radars, sonars, astronomy, ultrasound imaging, spatial signal enhancement, blind source separation etc. The course will focus on the representation and modeling of space-time signals, spectral estimation, temporal and spectral domain beamforming, optimum beamforming techniques and adaptive beamforming. The course will equip students to pursue research in the field and also	
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	design sensor array signal processing systems for diverse applications.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Representation of space - time signals: Coordinate systems; propagating waves; wave number-frequency space; arrays and apertures; space-time random processes and their characterization; Signal modeling and optimal filters: AR, MA, ARMA models; Autocorrelation and power spectral density; linear MMSE estimator; optimum filters; Power spectrum estimation: Non-parametric and parametric methods; Arrays and spatial filters: Frequency-wavenumber response and beam patterns; ULA; Performance measures; Synthesis of linear arrays and apertures: Spectral weighting; array polynomials; pattern sampling in wavenumber space, minimum beamwidth for specified sidelobe levels, broadband arrays; Optimum beamforming: MVDR beamformers; MMSE beamformers; Eigenvector beamformers; Adaptive beamforming: Least mean squares algorithms; Recursive least squares; Generalized sidelobe canceler; Array geometries in higher dimensions: Rectangular arrays; Circular arrays; Spherical arrays; Cylindrical arrays.
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15. Lecture Outline*(with topics and number of lectures)*

Module no.	Topic	No. of hours
1.	Representation of space - time signals: Coordinate systems; propagating waves; wave number-frequency space; arrays and apertures; space-time random processes and their characterization; noise assumptions.	6
2.	Signal modeling and optimal filters: Auto-regressive (AR), Moving average (MA), ARMA models; Autocorrelation and power spectral density of random processes; linear minimum mean square and linear least squares error estimator; solution of normal equations; optimum filters; matched filters.	6
3.	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.	6
4.	Arrays and spatial filters: Frequency-wavenumber response and beam patterns, uniform linear arrays, uniform weighted linear arrays, array steering, array performance measures: directivity, array gain, linear apertures.	5
5.	Synthesis of linear arrays and apertures: Spectral weighting, array polynomials, pattern sampling in wavenumber space, minimum beamwidth for specified sidelobe levels, broadband arrays.	5
6.	Optimum beamforming: MVDR beamformers, MMSE beamformers, Eigenvector beamformers.	5
7.	Adaptive beamforming: Least mean squares algorithms, Recursive	5

	least squares; Generalized sidelobe canceler.	
8.	Array geometries in higher dimensions: Rectangular arrays; Circular arrays; Spherical arrays; Cylindrical arrays.	4
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1-8	Assignments	36
	Term-paper / Presentation on any advanced algorithm etc.	6

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1) Harry L. Van Trees, Optimum Array Processing, Part IV of Detection, Estimation and Modulation Theory, John Wiley, 2002.
2) S. Theodoridis and R. Chellapa, Academic Press Library in Signal Processing, Vol. 3: Statistical and Array Signal Processing, Academic Press, 2013.
3) D. G. Manolakis, V. K. Ingle and S. M. Kogon, Statistical and Adaptive Signal Processing: Spectral Estimation, Signal Modeling, Adaptive Filtering and Array Processing, Artech House, 2005.
4) S. Haykin and K. J. Ray Liu, Handbook on Array Processing and Sensor Networks, Wiley-IEEE Press, 2010.
5) Prabhakar S. Naidu, Sensor Array Signal Processing, CRC Press, 2000.

20. Resources required for the course (itemized & student access requirements, if any)

20.1	Software	MATLAB
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20.2	Hardware	-
20.3	Teaching aides (videos, etc.)	Powerpoint presentations
20.4	Laboratory	-
20.5	Equipment	-
20.6	Classroom infrastructure	LCD Projector
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	10% in design of sensor array with given specifications.
21.2	Open-ended problems	30% in solving assignment problems.
21.3	Project-type activity	-
21.4	Open-ended laboratory work	-
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Selected Topics in Radars and Sonars
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL706
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	EEL205 – Signals and Systems or equivalent.
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	10% with CRL708 10% with CRL709
8.3	Supersedes any existing course	CRL737

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Arun Kumar, R. Bahl, Monika Agarwal, S. K. Koul, Ananjan Basu.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): This is primarily a systems oriented course that will familiarize students with practical techniques and applications in the fields of Radar and Sonar. It will be particularly useful for practicing engineers who work with Radars or Sonars.
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14.	Course contents (about 100 words) (Include laboratory/design activities): The Radar and Sonar Equations: Basic System Parameters; Radar and Sonar Applications; Signal Design for range and Doppler resolution: Ambiguity functions, waveforms for
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	CTFM/FMCW, MTI Radar, Pulse Doppler Radar; Detection theory for target extraction from clutter/reverberation and noise (clutter/reverberation modeling); Synthetic Aperture Radar/Sonar; Target Tracking: active/passive, Monopulse Radar; Modern Techniques: thru-the-wall imaging, multi-static systems.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1.	The Radar and Sonar Equations: Basic System Parameters; Radar and Sonar Applications	8
2.	Signal Design for range and Doppler resolution: Ambiguity functions, waveforms for CTFM/FMCW, MTI Radar, Pulse Doppler Radar	6
3.	Detection theory for target extraction from clutter/reverberation and noise (clutter/reverberation modeling)	8
4.	Synthetic Aperture Radar/Sonar	6
5.	Target Tracking: active/passive, Monopulse Radar	8
6.	Modern Techniques: thru-the-wall imaging, multi-static systems	6
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1-6	Assignments	32
	Term-paper / Presentation on any advanced algorithm etc.	10

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- 1) M. I. Skolnik, "Introduction to Radar Systems", Tata McGraw-Hill, 2003.
- 2) F. E. Nathanson, J. P. Reilly, M. N. Cohen, "Radar Design Principles", SciTech Pub, 2nd Edition, 2006.
- 3) A. D. Waite, Sonar for Practicing Engineers, John Wiley 2001.
- 4) A. W. Rihaczek, Principles of High Resolution Radar, Peninsula Publishing, 1985.
- 5) Papers from IEE/IET/IEEE journals.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	MATLAB
20.2	Hardware	-
20.3	Teaching aides (videos, etc.)	Powerpoint presentations.
20.4	Laboratory	-
20.5	Equipment	-
20.6	Classroom infrastructure	LCD Projector and white board.
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course (*Percent of student time with examples, if possible*)

21.1	Design-type problems	10% in design of sensor array with given specifications.
21.2	Open-ended problems	30% in solving assignment problems.
21.3	Project-type activity	-
21.4	Open-ended laboratory work	-
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Human and Machine Speech Communication
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL707
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	EEL205 - Signals and Systems (or equivalent).
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Arun Kumar
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): The course will provide understanding of digital speech processing techniques for human and machine communications using voice. It will equip students to pursue research and technology development work in speech recognition, speaker recognition, text-to-speech synthesis, speech coding, speech signal enhancement, speech quality evaluation etc. The course will also provide an overview of speech science topics, speech signal analysis techniques, and auditory perception for a well-rounded understanding of the subject.	
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14.	Course contents (about 100 words) (Include laboratory/design activities): Overview of human and machine speech communication: Applications; Speech signal	
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	measurement and representation. Speech science topics: Speech production and phonetics: Speech production mechanism; Articulatory and acoustic phonetics; Speech production model; International Phonetic Alphabet; Phonetic transcription; Hearing and perception. Speech signal analysis: Time domain analysis; Spectrum domain analysis; Spectrogram; Cepstrum domain analysis; Pitch estimation; Voicing analysis; Linear prediction analysis. Engineering applications: Speech coding; Speech quality assessment: Subjective and objective evaluation of quality; Automatic speech recognition: HMM; Language models; Keyword spotting; Text-to-speech synthesis: Concatenative and HMM speech synthesis; Prosody modification. The course will include audio demonstrations and require students to do practical exercises with recorded speech signals. An isolated word speech recognizer using open source resources shall be designed.
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15. Lecture Outline*(with topics and number of lectures)*

Module no.	Topic	No. of hours
1.	Overview of human and machine speech communication: Applications; Speech signal measurement and representation.	3
2.	Speech production and phonetics: Speech production mechanism; Articulatory and acoustic phonetics; Speech production model; International Phonetic Alphabet; Phonetic transcription.	7
3.	Hearing and perception: Sound perception; Auditory masking; Critical bands.	3
4.	Speech signal analysis: Time domain analysis; Spectrum domain analysis; Spectrogram; Cepstrum domain analysis; Pitch estimation; Voicing analysis.	5
5.	Linear prediction analysis: Autocorrelation and covariance methods; Levinson-Durbin algorithm; Line spectral frequencies; Inverse filtering.	5
6.	Speech quality assessment: Subjective and objective measures of quality.	3
7.	Speech coding: Standards; PCM; ADPCM; CELP; MELP.	6
8.	Speech recognition by machine: HMM; Recognition methods; Language models; Keyword spotting.	6
9.	Text-to-speech synthesis: Concatenative and HMM based speech synthesis; Harmonic plus noise model; Prosody modification.	4
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1.	Study of important developments; Assignment on speech signal measurements.	2
2.	Assignments on phonetic transcription, articulatory and acoustic phonetics.	5
3.	Understanding auditory phenomena from audio demonstrations.	3
4.	Assignments on recorded speech signal analysis.	6
5.	Assignment on linear prediction analysis of recorded speech.	4
6.	Assignment on noisy and distorted speech quality evaluation using ITU-T standard.	3
7.	Assignment on speech coding.	4
8.	Assignment on design of isolated word speech recognizer using open source codes.	6
9.	Perception based evaluation of different types of speech synthesis methods.	3
	Term paper on state-of-the-art algorithm on any one application.	6

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. L. R. Rabiner and R. W. Schafer, Theory and Applications of Digital Speech Processing, Prentice Hall, 1st edition, 2010. 2. D. O'Shaughnessy, Speech Communications: Human and Machine, IEEE Press, 2000. 3. J. Benesty, 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. Kondo, Digital Speech – Coding for Low Bit Rate Communication Systems, John Wiley, 2nd edition, 2004.
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20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	MATLAB.
20.2	Hardware	-
20.3	Teaching aides (videos,	Powerpoint presentations, Audio

	etc.)	demonstrations.
20.4	Laboratory	Low ambient noise recording facility.
20.5	Equipment	Loudspeaker, headphones, microphones for audio recording and playback.
20.6	Classroom infrastructure	LCD Projector and whiteboard.
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	15% (Example: design of isolated word speech recognizer)
21.2	Open-ended problems	30% (MATLAB assignments using speech recordings).
21.3	Project-type activity	-
21.4	Open-ended laboratory work	-
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Sonar System Engineering
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL708
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	-
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	EEL765

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course R. Bahl, Arun Kumar, Monika Aggarwal
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): 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.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Introduction to Sonar applications, Units, Sonar Equations and their limitations, Propagation of sound, Transmission loss, Ambient Noise, Spatial Correlation, Directivity Index, Array Gain, Beam-
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	patterns, Projector Source level, Reverberation, Scattering by targets, echo formation, Radiated Noise and Self Noise, Transmission and Reception modes, Dynamic Range Compression and Normalisation, Receiver Beamforming techniques, Sidelobe nulling, Detection Performance issues, Performance prediction, Sonar System Design examples
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction to Sonar applications, Units Sonar Equations and their limitations Propagation of sound Transmission loss	10
2	Ambient Noise, Spatial Correlation Directivity Index, Array Gain, Beam-patterns Projector Source level	10
3	Reverberation Scattering by targets, echo formation Radiated Noise and Self Noise	8
4	Transmission and Reception modes Dynamic Range Compression and Normalisation Receiver Beamforming techniques, Sidelobe nulling	7
5	Detection Performance issues Performance prediction	5
6	Sonar System Design examples	2
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Assignments on Sonar Equation, Transmission Loss, Transducers	6
2	Assignments on Array Gain, Beam-pattern	8

3	Assignments on Echo, Target strength, Reverberation	6
4	Assignments on Beam-forming, Sidelobe nulling	6
5	Assignments on Sonar detection and Performance evaluation	8
6	Assignments on Sonar System Design	8
	Total	42

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1.	R.J. Urick, Principles of Underwater Sound, McGraw Hill Book Company, 3rd Ed 1983
2.	W.S. Burdic, Underwater Acoustic System Analysis, Peninsula Publishing, 2nd Ed 2003
3.	A.D. Waite, Sonar for Practising Engineers, Wiley, 3rd Ed 2002
4.	A.A. Winder, "Sonar System Technology", IEEE Transactions on Sonics & Ultrasonics, Vol SU-22, No 5, pp 291-332, Sept 1975
5.	Selected papers from: Journal of Acoustical Society of America (JASA)
6.	Selected papers from: IEEE Journal of Oceanic Engineering
7.	Selected papers from: IEE/IET Proceedings

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	MATLAB
20.2	Hardware	-
20.3	Teaching aides (videos, etc.)	PowerPoint presentations
20.4	Laboratory	-
20.5	Equipment	-
20.6	Classroom infrastructure	LCD projector/ Monitor
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	20 (example: calculation of Sonar parameters)
21.2	Open-ended problems	20 (example: effect of noise on detection)
21.3	Project-type activity	-
21.4	Open-ended laboratory work	-
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Underwater Electronic Systems
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL709
6.	Status (<i>category for program</i>)	Program elective

7.	Pre-requisites (course no./title)	-
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course R. Bahl, Arun Kumar, Monika Aggarwal
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): System design issues related to a variety of Underwater electronic systems such as underwater imaging systems, navigation systems, Positioning and Localization systems, underwater communication.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Introduction to High Resolution Underwater Imaging Applications, Sidescan Sonar principles, Sector Scan Sonar Principles: Principle of within-pulse scanning, role of grating lobe in sector coverage, Swept -frequency delay line scanning technique, Time-Delay-Integrate scanning technique, Modulation Scanning Technique:
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	Multi-stage scanning, Spatial DFT-based imaging technique, True Phase-Shift beamforming: Near-field focusing, Hilbert-transform based implementation, Synthetic Aperture Sonar: range migration issue, PRF limits, swath coverage, real beam pattern effects, tow-body precision issues, CTFM Sonar, Dual Demodulation CTFM Sonar Phase-Difference based SAS, Radial Projection method of imaging, Monopulse technique, Navigation: Doppler Log, JANUS system, Localization: LBL (Long baseline), SBL (Short baseline), SSBL/USBL (super/ultra short baseline), requirements of tracking and positioning systems, hyperbolic and spherical-based localization using pingers and transponders, Passive Inverse Synthetic Aperture for localizing radiated tonals from moving platforms, Underwater Acoustic Communication Modems and their applications.
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15. Lecture Outline*(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Introduction to High Resolution Underwater Imaging Applications, Sidescan Sonar principles, Sector Scan Sonar Principles: Principle of within-pulse scanning, role of grating lobe in sector coverage Swept -frequency delay line scanning technique Time-Delay-Integrate scanning technique Modulation Scanning Technique: Multi-stage scanning, Spatial DFT-based imaging technique True Phase-Shift beamforming: Near-field focusing, Hilbert-transform based implementation	12
2	Synthetic Aperture Sonar: range migration issue, PRF limits, swath coverage, real beam pattern effects, tow-body precision issues CTFM Sonar, Dual Demodulation CTFM Sonar Phase-Difference based SAS, Radial Projection method of imaging, Monopulse imaging technique	12
3	Navigation: Doppler Log, JANUS system Localization: LBL (Long baseline), SBL (Short baseline), SSBL/USBL (super/ultra short baseline), requirements of tracking and positioning systems, hyperbolic and spherical-based localization using pingers and transponders, Passive Inverse Synthetic Aperture for localizing radiated tonals from moving platforms	6
4	Underwater Acoustic Communication Modems and their applications	12
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Assignments on Scanning Sonars	10
2	Assignments on Synthetic Aperture Sonars, CTFM Sonar, Radial Projection and Monopulse imaging	12
3	Assignments on Navigation and Localization systems	8
4	Assignments on Underwater Communication	12
	Total	42

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

Course Notes (softcopy) Selected papers from: IEE/IET proceedings Selected papers from: IEEE Journal of Oceanic Engg Selected papers from: JASA Acoustical Imaging, Proceedings of The International Symposium on Acoustical Imaging, Plenum Press
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20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	MATLAB
20.2	Hardware	-
20.3	Teaching aides (videos, etc.)	PowerPoint presentations
20.4	Laboratory	-
20.5	Equipment	-

20.6	Classroom infrastructure	LCD projector/ Display
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	20
21.2	Open-ended problems	20
21.3	Project-type activity	-
21.4	Open-ended laboratory work	-
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	CAD OF RF AND MICROWAVE CIRCUITS
3.	L-T-P structure	3-0-2
4.	Credits	4
5.	Course number	CRL711
6.	Status (<i>category for program</i>)	Core Course

7.	Pre-requisites (course no./title)	Course on Basic Electromagnetics like EEL207
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	15% with EEL713, 15% with EEP719.
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☒ 1stsem ☐ 2ndsem ☐ Either sem -
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11.	Faculty who will teach the course S. K. Koul, Ananjan Basu, Mahesh P. Abegaonkar.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): 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.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Review of basic microwave theory: Transmission lines-concepts of characteristics impedance, reflection coefficient, standing and propagating waves, equivalent circuit. Smith chart, Network analysis: Z, ABCD, Y, T, S-parameters, Impedance matching
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	technique, Implementation using simulators. Planar transmission lines. Filters- lumped as well as distributed element realization, Implementation using simulators. Directional couplers and Power divider. Familiarization of photolithography process, mask making using intellicad and measurement using Automatic Network Analyzer in the laboratory classes. Design, optimization, fabrication and testing of Microstrip components and determining equivalent circuits
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15. Lecture Outline*(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Review of basic microwave theory: Transmission lines-concepts of characteristics impedance, reflection coefficient, standing and propagating waves, equivalent circuit.	4
2	Smith chart, Network analysis: Z, ABCD, Y, T, S-parameters, Impedance matching technique, Implementation using simulators.	8
3	Planar transmission lines: stripline, microstrip line and suspended strip line, coupled lines- quasi-static analysis.	6
4	Low pass, band pass, high pass and band stop filters- lumped as well as distributed element realization, Implementation using simulators.	8
5	Directional coupler- Hybrid branch line, rat race and parallel coupled types, implementation using simulators.	8
6	Power divider- design and Implementation using simulator.	2
7	Active circuit- Phase shifter, Mixer.	4
8	Introduction to High frequency structure simulator/ CST studio.	2
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA.

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours
1	Fabrication of Microwave Integrated Circuit- Microstrip Transmission Line. Familiarization of Photolithography process, mask making using intellicad, measurement using network analyzer.	8
2	Measuring Characteristics of an inductor/capacitor and determining equivalent circuits	4

3	Design of Low Pass Filter and its optimization using serenade software. Realization of the Low pass filter in microstrip and testing on Automatic Network Analyzer.	8
4	Design of a Branch Line coupler and its simulation using CST studio. Realization of the branch line coupler in microstrip and testing on Automatic Network Analyzer.	8

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Assignments consists of problems related to transmission line concepts	2
2	Assignment on single stub matching, double stub matching and LC matching using Smith Chart. Problems related to S-parameters.	4
3	Assignment consisting of simple derivation related to coupled lines and analysis of transmission lines.	1
4	Assignment on problems related to design of Low pass filters and verifying their response using serenade software.	4
5	Assignment on problems related to branch line coupler, parallel line coupler and verifying them in serenade software.	4
6	Problems related to power divider.	1
7	CST Microwave Studio Manual	2

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. D. M. Pozar, Microwave Engineering, Wiley, 2011.
2. B. Bhat and S. K. Koul, Strip line Like Transmission Lines for Microwave Integrated Circuits, New Age Intl. Pvt Ltd., 2007.
3. Agilent Technologies Application Notes.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	Serenade Software, CST microwave Studio
20.2	Hardware	Dielectric Laminates and Chemicals for Photolithography Process.
20.3	Teaching aides (videos, etc.)	Power Point Presentations
20.4	Laboratory	Photolithography LAB, Microwave Measurement LAB.
20.5	Equipment	Network Analyzer

20.6	Classroom infrastructure	LCD Projector
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	25% of time in designing of Low Pass Filter, Branch Line Coupler, Power divider, parallel line coupler, Phase shifters.
21.2	Open-ended problems	25 % time in solving numerical problems and smith chart problems.
21.3	Project-type activity	
21.4	Open-ended laboratory work	20 % of time in Laboratory work in fabrication and measurement.
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	RF AND MICROWAVE ACTIVE CIRCUITS
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL712
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	Course on Basic Electromagnetics like EEL207, CRL711 preferred
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☒ 2ndsem ☐ Either sem -
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11.	Faculty who will teach the course S. K. Koul, Ananjan Basu, Mahesh P. Abegaonkar.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): Provide understanding of the operation of active microwave components, and equip the student with the tools for analyzing and designing such components, utilizing CAD tools if desirable.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Microwave Amplifier theory and design. Theory and design of microwave phase shifters, switches and attenuator. Analysis of microwave mixers.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Generalized S-parameters	6
2	Microwave amplifier layout and stability	6
3	High gain and low noise designs	8
4	Microwave switch and attenuator – diode and FET based	8
5	Microwave phase shifter circuits	8
6	Mixer analysis	6
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Assignment on S-parameter	12
2	Assignment on amplifier design	12
3	Assignment on control circuits	12

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. S. A. Maas, Nonlinear Microwave and RF Circuits, Artech, 2003.
2. G. Gonzales, Microwave Transistor Amplifiers, Prentice Hall, 1996.
3. B.Bhat and S.K.Koul, Stripline Like Transmission Lines For Microwave Integrated Circuits – New Age Intl. Pvt Ltd., 2007.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	Serenade (free)
20.2	Hardware	NIL
20.3	Teaching aides (videos, etc.)	NIL
20.4	Laboratory	NIL
20.5	Equipment	NIL
20.6	Classroom infrastructure	LCD Projector
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course (*Percent of student time with examples, if possible*)

21.1	Design-type problems	25% on amplifier design given S-parameter from data sheet
21.2	Open-ended problems	NIL
21.3	Project-type activity	NIL
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Radiating Systems for RF Communication
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL715
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	Basic course on Electromagnetics
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	None
8.2	Overlap with any UG/PG course of other Dept./Centre	EEL760 (30%)
8.3	Supersedes any existing course	None

9.	Not allowed for (indicate program names)	NA
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course: Mahesh P. Abegaonkar, Ananjan Basu, S. K. Koul.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): To provide an understanding of the operation of microwave antennas, antenna arrays and the scattering of radiation by different types of objects.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Revision of Maxwell's equations, radiation, Poynting vector; antenna parameters like gain, radiation pattern, VSWR wire antennas – dipole monopole; antenna arrays; aperture antennas and equivalence theorems; printed antennas, scattering.
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15. Lecture Outline*(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	Antennas: radiation concepts, dipoles, monopoles	6
2	Antenna parameters (gain, efficiency etc.) – theory , comparison with simulators , and measured data for simple antennas	6
3	Analysis and synthesis of simple linear arrays. Optimizers.	6
4	Equivalence theorems and application to horns and reflectors, comparison with simulations.	8
5	Active and passive electronic scanning antennas	4
6	Microstrip and other printed antennas, analysis using equivalent circuit, numerical techniques. Broad band printed antennas, and other broad-band antennas for ESM.	6
7	Scattering by wedge, GTD, and application to short range communications.	6
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA.

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA.

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Literature survey on antennas used in mobile devices	4
2	Learn full wave EM simulation tools like HFSS or CST etc.	12
3	Assignments on wire antennas and arrays	10
4	Assignments on aperture antennas	10
5	Array design exercise	6

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

- 1) C. A. Balanis, Antenna Theory – Analysis and Design, 3rd Edition, John Wiley & Sons, 2005.
- 2) HFSS Users Manual – Agilent Technologies / Ansoft Corp.
- 3) R. A. Sainati, CAD of Microstrip Antennas for Wireless Applications, Artech, 1996.
- 4) Warren L. Stutzman, Gary A. Thiele, Antenna Theory and Design, John Wiley & Sons; 3rd Edition edition, 2012.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	CST
20.2	Hardware	-
20.3	Teaching aides (videos, etc.)	Powerpoint presentations.
20.4	Laboratory	-
20.5	Equipment	-
20.6	Classroom infrastructure	LCD Projector, whiteboard.
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course (*Percent of student time with examples, if possible*)

21.1	Design-type problems	25% synthesize an array with a given radiation pattern
21.2	Open-ended problems	-
21.3	Project-type activity	-
21.4	Open-ended laboratory work	-
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	RF AND MICROWAVE MEASUREMENT LABORATORY
3.	L-T-P structure	1-0-6
4.	Credits	4
5.	Course number	CRP718
6.	Status (<i>category for program</i>)	Program Core

7.	Pre-requisites (course no./title)	Course on Basic Electromagnetics like EEL207 Course on Signals and Systems like EEL205
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☒ 1stsem ☐ 2ndsem ☐ Either sem -
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11.	Faculty who will teach the course S. K. Koul, Ananjan Basu, Mahesh P. Abegaonkar, Arun Kumar, Monika Aggarwal, Suneet Tuli.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): 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 utilized.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Laboratory experiments based on network analyzer, spectrum analyzer, antenna pattern measurement, thermography, data acquisition and digitization.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1.	Network analyzer basics	2
2.	Spectrum analyzer basics	2
3.	RF amplifier characterization	2
4.	Anechoic chamber setup and operation	2
5.	IR camera operation and application	2
6.	Data acquisition, sampling, quantization and processing	2
7.	Labview software	2

16. Brief description of tutorial activities: NA.

Module no.	Description	No. of hours

17. Brief description of laboratory activities

Module no.	Description	No. of hours
1.	Measurement with Network analyzer	12
2.	Measurement with Spectrum analyzer	12
3.	Antenna pattern measurement	12
4.	Data acquisition, effects of variations of sampling rate and quantization	12
5.	IR source characteristics	12
6.	Thermography	12
7.	Data processing with Labview	12

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Familiarization with RF cables, anechoic chamber, RF sources	4
2	Familiarization with IR camera and sources	4
3	Familiarization with Labview software	4

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Ananjan Basu 'Introduction to Microwave Measurements' CRC Press 2014.

2. Agilent Technologies Application Notes.
3. IEEE Standards on Antennas.
4. Labview Manual.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	Labview, IR camera interface, MATLAB
20.2	Hardware	Microwave components, substrates, cables and connector
20.3	Teaching aides (videos, etc.)	Powerpoint presentations.
20.4	Laboratory	Microwave laboratory, Signal processing laboratory, Non-destructive systems laboratory
20.5	Equipment	Network and Spectrum analyzers, anechoic chamber, microwave sources, data acquisition cards, IR camera and source.
20.6	Classroom infrastructure	LCD Projector
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course (*Percent of student time with examples, if possible*)

21.1	Design-type problems	NIL
21.2	Open-ended problems	NIL
21.3	Project-type activity	NIL
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	RF and Microwave Solid State Devices
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL722
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	-
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	20% with CRL725
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem
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11.	Faculty who will teach the course Sudhir Chandra, Samaresh Das.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): The aim of this Course is to provide in-depth knowledge of semiconductor devices relevant for high frequency-microwave operation. The students will be introduced to Schottky diode followed by GaAs MESFET and HEMTs. Some silicon based devices which are relevant for high frequency application such as SOI will also be covered.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Review of basics of semiconductor devices. Schottky diode, qualitative description, junction properties, I-V characteristics in forward and reverse biased diodes, high frequency application of Schottky diode, Schottky barrier gate FET. GaAs MESFET I-V characteristics, High Electron Mobility Transistor (HEMT), Hetro-structures, SOI
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	technologies and MOSFETs, Fabrication technologies for GaAs MESFET, MBE, Ion Implantation. Pattern transfer at sub-micron level.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Review of basics of semiconductor devices. Schottky diode, qualitative description, junction properties, I-V characteristics in forward and reverse biased diodes, high frequency application of Schottky diode, Schottky barrier gate FET	6
2	GaAs MEFETs: basic device design and principle of operation, current-voltage characteristics, pinch-off voltage, mode of operation, velocity saturation effect; high frequency performance,	6
3	High Electron Mobility Transistor (HEMT): physical structure of HEMT, quantum well structures, 2D electron gas density, charge-voltage relation, current voltage characteristics, cut-off frequency,	6
4	Introduction to Varactor diode, p-i-n diode, IMPATT diode, Gunn diode, tunnel diode	3
5	Bipolar junction transistors (BJT), Hetero-junction bipolar junction transistor (HBT)	5
6	Silicon on Insulator (SOI) substrates, MOSFET in SOI, high frequency operation,	6
7	Introduction to fabrication technologies for high frequency solid state devices:	3
8	Molecular Beam Epitaxy (MBE), Ion Implantation, Liquid Phase Epitaxial (LPE),	4
9	Pattern transfer at sub micron level: deep UV lithography, e-beam lithography, X-ray lithography.	3
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Self study: p-i-n diode	9
2	Self study: IMPATT diode,	9
3	Self study: Gunn diode ,	8
4	Self study: Tunnel diode	8
5	Self study: Varactor diode	8

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Michael Shur, Physics of Semiconductor Devices, Prentice Hall, first published in 1990.
2. S S Islam Semiconductor Physics and Devices, Oxford University Press, Fifth Impression 2010.
3. S M Sze and Know K Ng, Physics of Semiconductor Devices, 3rd Edition, Wiley India Edition, 2009.

20. Resources required for the course *(itemized & student access requirements, if any)*

20.1	Software	-
20.2	Hardware	-
20.3	Teaching aides (videos, etc.)	-
20.4	Laboratory	-
20.5	Equipment	-
20.6	Classroom infrastructure	Black board, Overhead Projector
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course *(Percent of student time with examples, if possible)*

21.1	Design-type problems	-
21.2	Open-ended problems	-
21.3	Project-type activity	-
21.4	Open-ended laboratory work	-
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Fabrication Techniques for RF & Microwave Devices
3.	L-T-P structure	1-0-4
4.	Credits	3
5.	Course number	CRP723
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	None
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	No
8.2	Overlap with any UG/PG course of other Dept./Centre	No
8.3	Supersedes any existing course	No

9.	Not allowed for (indicate program names)	
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Sudhir Chandra, Samaresh Das
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): 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.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Concept of process flow in IC fabrication, representative process flow for diode/MOSFET.
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	High temperature processes;oxidation, diffusion, and annealing. Use of masks in IC fabrication, mask design and fabrication., Photolithography processes. Chemical etching processes: dry and wet etching. Vacuum and vacuum systems. Thin films in IC processing, resistive evaporation, ebeam, RF and DC sputtering processes. Concept of test chip design and process parameter extraction. Practicals: Vacuum system, Thermal evaporation, DC/RF puttering, Mask making techniques: Coordinatograph/Photo-plotter first Reduction Camera, Step and Repeat process, Photolithography process, Etching techniques, Oxidation/diffusion processes, Diode fabrication, Band Pass filter fabrication, Measurement equipment calibration.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Concept of process flow in IC fabrication, representative process flow for diode / MOSFET	2
2	High temperature processes: oxidation, diffusion, and annealing	2
3	Use of “masks” in IC fabrication, mask design and fabrication	1
4	Photolithography processes	2
5	Chemical etching processes: dry and wet etching	2
6	Vacuum and vacuum systems.	2
7	Thin films in IC processing, resistive evaporation, e-beam, RF and DC sputtering processes	2
8	Concept of test chip design and process parameter extraction	1
COURSE TOTAL (14 times 'L')		14

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities:

Module no.	Description	No. of hours
1	Micro fabrication safety	4
2	Thermal evaporation, DC/ RF sputtering	8
3	Mask making techniques: Coordinatograph / Photo-plotter First Reduction Camera, Step and Repeat process	4
4	Photolithography process	4
5	Etching techniques	4
6	Oxidation / diffusion processes	4
7	Diode and resistors fabrication and testing	8
8	MOS fabrication and testing	4

9	Measurement equipment calibration	8
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18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Details on microfabrication safety: Chemical, electrical and mechanical	4
2	Design the process module: MOS, MOSFET and JFET	10
3	Mask design: simple MOS, MOSFET and JFET process (using free software)	12
4	Pre-lab reading for that day experiments	24

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. S. M. Sze, VLSI Technology (2nd Edition), McGraw Hill, (2003).
2. James D. Plummer, Michael Deal, and Peter D. Griffin, Silicon-VLSI-Technology-Fundamentals-Practice-and-Modeling (1st edition), Prentice Hall (2009).

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	none
20.2	Hardware	Computer
20.3	Teaching aides (videos, etc.)	none
20.4	Laboratory	Microelectronics Laboratory CARE
20.5	Equipment	Diffusion and Oxidation Furnaces, Reduction Camera, Optical Lithography system, DC and RF sputtering, Thermal evaporation, RIE, Microscope, semiconductor parameter analyzer.
20.6	Classroom infrastructure	Whiteboard
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course(*Percent of student time with examples, if possible*)

21.1	Design-type problems	-
21.2	Open-ended problems	-
21.3	Project-type activity	20%

21.4	Open-ended laboratory work	20%
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics	
2.	Course Title (<i>< 45 characters</i>)	RF AND MICROWAVE MEASUREMENTS	
3.	L-T-P structure	3-0-0	
4.	Credits	3	
5.	Course number	CRL724	
6.	Status (<i>category for program</i>)	Program Core	

7.	Pre-requisites (course no./title)	Course on Basic Electromagnetics like EEL207	
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)		
8.1	Overlap with any UG/PG course of the Dept./Centre	-	
8.2	Overlap with any UG/PG course of other Dept./Centre	-	
8.3	Supersedes any existing course	-	

9.	Not allowed for (indicate program names)	
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☒ 2ndsem ☐ Either sem -	
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11.	Faculty who will teach the course S. K. Koul, Ananjan Basu, Mahesh P. Abegaonkar.		
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): To introduce students to the basic techniques of modern RF and microwave measurements.		
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14.	Course contents (about 100 words) (Include laboratory/design activities): Theory of operation of network analyzer, and spectrum analyzer. VNA calibration, synthesized signal generation, noise measurement, measurement of antenna properties.		
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Review of S-parameters	4
2	Scalar S-parameter measurement	6
3	Vector S-parameter measurement	6
4	Spectrum analysis	6
5	Microwave Signal Generation	6
6	Noise Measurement	6
7	Antenna Measurements	8
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA.

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA.

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Assignments on S-parameter	4
2	Assignments on network analysis	8
3	Understanding the operation and calibration of VNA from user manual.	8
4	Assignments on noise measurement techniques	8

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Ananjan Basu 'Introduction to Microwave Measurements' CRC Press 2014.
2. Agilent Technologies Application Notes.
3. IEEE Standards on Antennas.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	NIL
20.2	Hardware	NIL
20.3	Teaching aides (videos, etc.)	NIL
20.4	Laboratory	NIL
20.5	Equipment	NIL
20.6	Classroom infrastructure	LCD Projector
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course(*Percent of student time with examples, if possible*)

21.1	Design-type problems	NIL
21.2	Open-ended problems	NIL
21.3	Project-type activity	NIL
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Technology of RF and Microwave Solid state Devices
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL725
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	None
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	15% with CRL722
8.2	Overlap with any UG/PG course of other Dept./Centre	20% with EEL784 (IC Technology) and PHL704 (Semiconductor Device Technology)
8.3	Supersedes any existing course	No

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Sudhir Chandra and Samaresh Das
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): 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.
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14.	Course contents (about 100 words) (Include laboratory/design activities): 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. 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. Fine line lithography process: optical lithography, x-ray and e-beam lithography, lift-off techniques. Wet and plasma assisted etching techniques, RIE, RIBE. Introduction to Ion Implantation, Molecular Beam Epitaxy. Chemical Vapour Deposition (epitaxial growth, polycrystalline, silicon, dielectric films, flow pressure and plasma chemical deposition), Atomic layer deposition. GaAs MESFET technology.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction semiconductor device technology: History and current technology	1
2	Process sequence development: Diode, JFET, MOS and MOSFET	5
3	Oxidation	2
4	Diffusion, and Ion Implantation	5
5	Mask making, Fine line lithography process: optical lithography, x-ray and e-beam lithography, lift-off techniques.	4
6	Techniques of metallization: Introduction to vacuum systems. Sputtering (DC,RF and magnetron), e-beam evaporation for ohmic and Schottky.	6
7	Molecular Beam Epitaxy, Chemical Vapour Deposition (epitaxial growth, polycrystalline, silicon, dielectric films, flow pressure and plasma chemical deposition), Atomic layer deposition.	6
8	Contact formation, silicides for gate and interconnect.	3
9	Wet and plasma assisted etching techniques, RIE, RIBE.	4
10	Interconnect	2
11	GaAs MESFET technology.	4
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Study of Silica to silicon wafer growth	6
2	Study of Group III-V semiconductor crystals growth	6
3	Study of Advanced lithography to make quantum devices	6
4	Assignments	20
6	Term paper	12

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. James D. Plummer, Michael Deal, and Peter D. Griffin, Silicon-VLSI-Technology-Fundamentals-Practice-and-Modeling (1st edition), Prentice Hall (2009).
2. S. M. Sze, VLSI Technology (2nd Edition), McGraw Hill, (2003).
3. W-K. Chen and W-K. Chen, VLSI Technology (1st Edition), CRC Press (2007).
4. R. W. Johnson, A. Hultqvist, S. F. Bent, A brief review of atomic layer deposition: from fundamentals to applications, Materials Today, 17, 26 (2014).

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	none
20.2	Hardware	none
20.3	Teaching aides (videos, etc.)	Videos and power point presentation
20.4	Laboratory	none
20.5	Equipment	none
20.6	Classroom infrastructure	Black board and Overhead Projector
20.7	Site visits	none
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	15%
21.2	Open-ended problems	25%
21.3	Project-type activity	none
21.4	Open-ended laboratory work	none
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics	
2.	Course Title (<i>< 45 characters</i>)	MEMS Design and Technology	
3.	L-T-P structure	3-0-0	
4.	Credits	3	
5.	Course number	CRL726	
6.	Status (<i>category for program</i>)	Program Elective	
7.	Pre-requisites (course no./title)	-	
8.	Status vis-à-vis other courses (<i>give course number/title</i>)		
8.1	Overlap with any UG/PG course of the Dept./Centre	20% with CRL725	
8.2	Overlap with any UG/PG course of other Dept./Centre	-	
8.3	Supersedes any existing course	-	
9.	Not allowed for (indicate program names)		
10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem	
11.	Faculty who will teach the course Sudhir Chandra, Samaresh Das, S K Koul.		
12.	Will the course require any visiting faculty? (yes/no)	No	
13.	Course objectives (<i>about 50 words</i>): The objective of this Course is to introduce the students the field of Micro-Electro-Mechanical-Systems (MEMS). The Course will cover two different aspects of MEMS namely the working principles and design of various MEMS components especially for RF use and the technology used for their fabrication.		
14.	Course contents (about 100 words) (Include laboratory/design activities): Introduction, origin and driving force for MEMS; extension of IC technologies for MEMS fabrication, major technologies for MEMSL: bulk and surface micromachining, LIGA process anisotropic etching of silicon, piezoresistive -piezoelectric effect, piezoresistive		

	silicon based pressure sensor, capacitive pressure sensor, RF switch design, fabrication and characterization, actuation in MEMS, MEMS accelerometer design, fabrication, vibration sensor, energy harvesting devices, piezoelectric materials for MEMS, MEMS based RF and microwave circuits
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1	Introduction, origin and driving force for MEMS	3
2	Silicon as mechanical material for MEMS	2
3	Introduction to bulk and surface micromachining technologies	3
4	Silicon anisotropic etching for MEMS microstructures, development of diaphragms and cantilevers for MEMS using anisotropic etching, etch-stop techniques,	6
5	MEMS specific fabrication technologies: front-to-back alignment, convex corner in anisotropic etching and compensation techniques, anodic bonding, packaging of MEMS, MEMS prototyping	8
6	Piezoelectric effect in Si, pressure sensor using piezoresistive effect in Si, capacitive pressure sensor,	4
7	RF Switch in surface micromachining, shunt and series configurations, turn-on voltage, insertion loss, doubly supported beam for RF switch,	4
9	MEMS inductor,	2
10	Accelerometer in MEMS	4
11	Optical MEMS	2
12	Miscellaneous MEMS devices	4
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours
	NIL	

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Self study: MEMS Micromachined microphones	11
2	Self study: Comb drive for resonators	11
3	Self study: Electromagnetic modeling of MEMS switch	11
4	Self study: Microfluidic MEMS and Bio MEMS	11

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Gabriel M Rebeiz, RF MEMS: Theory, Design and Technology; Wiley, 2003
2. Nadim Maluf, An Introduction to Microelectromechanical Systems Engineering, Artech House, 2000
3. Ljubisa Ristic, Sensor Technology and Devices, Artech House, 1994
4. S. M. Sze, Semiconductor Sensors, John Wiley & Sons, 1994

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	-
20.2	Hardware	-
20.3	Teaching aides (videos, etc.)	Powerpoint presentations
20.4	Laboratory	-
20.5	Equipment	-
20.6	Classroom infrastructure	LCD Projector, Whiteboard
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course(*Percent of student time with examples, if possible*)

21.1	Design-type problems	Nil
21.2	Open-ended problems	Nil
21.3	Project-type activity	Nil
21.4	Open-ended laboratory work	Nil
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Introduction to Quantum Electron Devices
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL 727
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	Basic course on Semiconductor Devices
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	No
8.2	Overlap with any UG/PG course of other Dept./Centre	No
8.3	Supersedes any existing course	No

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Samaresh Das
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): To provide the student with a basic understanding of the electronic quantum devices for future generation systems and subsystems. Such components may be based on superconductivity, quantum mechanical tunneling, and charge transport in low-dimensional nano-scale systems.
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14.	Course contents (<i>about 100 words</i>) (Include laboratory/design activities): The foundation of quantum electronics; Nanoscale resistors: quantum resistance, quantum conductance; Scattering at quantum levels: quantum contacts, quantum interference, Andrev scattering, spin-dependent scattering; Coulomb blockade, Resonant tunneling,
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	Quantum capacitance, Single electron and tom transistors: coulomb blockade memory and logic devices, single electron invertors; Electron transport through single molecule: molecular transistors, memories and switches; Spinning of electron: spin valve and transistors, Sub-band quantum devices: quantum wells, wires an dots, sub band infrared and terahertz detectors; Quantum bit: quantum computers, different types of qubit, initialization, quantum manipulation, readout, charge qubit, phase and flux qubit, spin qubit.
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15. Lecture Outline*(with topics and number of lectures)*

Module no.	Topic	No. of hours
1	General Introduction: The foundation of quantum electronics: Illustrated historical presentation of new concepts and recent experiments	2
2	Nanoscale Resistors: Generalized Ohm's law, The Quantum of resistance-2D, 1D, 0D, quantum conductance.	4
3	Scattering: Wave properties of electron, Quantum contacts, quantum interference, Andrev scattering, spin-dependent scattering	6
4	Coulomb blockade-Charge quantization and charging energy, Resonant tunneling, 2d ballistic tunneling	4
5	Quantum capacitance	1
6	Single electron Transistors: Metal and semiconductor, Single atom devices, coulomb blockade memory and logic devices, Single electron Invertors; Single molecule electron devices: Electron transport through single molecule, molecular transistors, memories and switches.	6
7	Spinning of Electron: Spin valve, Spin transistors: Closer to an all-electric device	4
8	Sub-band quantum devices: Sub-band for quantum wells, wires an dots, Sub-band infrared and Terahertz detectors.	5
9	Qubits: Quantum computers, different types of qubit, initialization, quantum manipulation, readout Charge qubit: Super conductor and semiconductor charge qubit devices Phase and flux qubit Spin qubit	10
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1	Review of quantum mechanics	8
3	Simulation on single electron transistors	10
5	Assignments	20
6	Term paper	12

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Supriya Datta, Quantum Transport Atom to Transistor, Cambridge University Press, 2013.
2. F. Henneberger, and O. Benson, Semiconductor Quantum Bits, Pan Stanford Publishing, 2008.
3. Y. Nazarov and Y. Blanter, Quantum Transport: Introduction to Nanoscience, Cambridge University Press, 2009.
4. Floris A. Zwanenburg, Andrew S. Dzurak, Andrea Morello, Michelle Y. Simmons, Lloyd C. L. Hollenberg, Gerhard Klimeck, Sven Rogge, Susan N. Coppersmith, and Mark A. Eriksso, Silicon quantum electronics, Rev. Mod. Phys. 85, 961, 2013.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	SIMON 2.0 Educational
20.2	Hardware	none
20.3	Teaching aides (videos, etc.)	Videos and power point presentation
20.4	Laboratory	none
20.5	Equipment	none
20.6	Classroom infrastructure	Black board and Overhead Projector
20.7	Site visits	none
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	15%
21.2	Open-ended problems	20%
21.3	Project-type activity	none
21.4	Open-ended laboratory work	none
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Sensors and Transducers
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL729
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	None
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	CRL724 - 10%
8.2	Overlap with any UG/PG course of other Dept./Centre	IDL711 - 10%
8.3	Supersedes any existing course	No

9.	Not allowed for (indicate program names)	NA
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course: Mahesh P. Abegaonkar, Suneet Tuli
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): The objective of this course is to acquaint Master's students with the various kinds of sensors and transducers.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Introduction to sensors and transducers, basic parameters and principles and applications of various sensors and transducers in characterization of materials, devices, circuits and systems; Acoustic and Ultrasonic sensors and transducers; Magnetic and Electrical sensors and transducers; Thermal sensors and transducers; Radiation including Optical sensors and transducers; Smart Sensors for characterization of RF materials, devices, circuits and
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	systems; Mechanical and Thermal Engineering issues for RF Modules / Instruments; Typical applications and use of transducers in systems/instruments.
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15. Lecture Outline(with topics and number of lectures)

Module no.	Topic	No. of hours
1.	Introduction to sensors and transducers, basic parameters and principles and applications of various sensors and transducers in characterization of materials, devices, circuits and systems.	4
2.	Acoustic and Ultrasonic sensors and transducers.	6
3.	Magnetic and Electrical sensors and transducers	8
4.	Thermal sensors and transducers	6
5.	Radiation including Optical sensors and transducers	6
6.	Smart Sensors for characterization of RF materials, devices, circuits and systems	4
7.	Mechanical and Thermal Engineering issues for RF Modules / Instruments	4
8.	Typical applications and use of transducers in systems/instruments	4
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
1.	Explore various sensors used in day-to-day life and their specifications	6
2.	Basics of Acoustic Waves	6
3.	Basics of Ultrasonics	6
4.	Revision of EM theory	6
5.	Basics of Heat propagation	6
6.	Revision of basics of Optics	6

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1. Kourosh Kalantar-zadeh, Sensors: An Introductory Course, Springer Science & Business Media, 2013.
2. Ramon Pallas-Areny and John G. Webster, Sensors and Signal Conditioning, Wiley India Pvt Ltd; Second edition (Paperback), 2012.
3. D. Patranabis, SENSORS AND TRANSDUCERS, PHI, 2003.
4. Jacob Fraden, Handbook of Modern Sensors: Physics, Designs, and Applications, Springer Science & Business Media, 2010.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	None
20.2	Hardware	None
20.3	Teaching aides (videos, etc.)	None
20.4	Laboratory	None
20.5	Equipment	None
20.6	Classroom infrastructure	White-board, white-board markers, LCD Projector, desktop computer
20.7	Site visits	None
20.8	Others (please specify)	None

21. Design content of the course(*Percent of student time with examples, if possible*)

21.1	Design-type problems	25 %
21.2	Open-ended problems	50%
21.3	Project-type activity	-
21.4	Open-ended laboratory work	-
21.5	Presentations	25 %

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Selected Topics in RFDT - I
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL731
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	To be specified by course instructor as per course contents.
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Will depend on the topics.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): Impart specialized skills.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Advanced course on selected topics of relevance to the RFDT M.Tech Program.
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15. Lecture Outline(*with topics and number of lectures*)

Module no.	Topic	No. of hours
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	As per requirements – to be specified by course instructor	
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	As per requirements of the selected topics in the course.	42

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be announced by Course Instructor as per requirements of the topics in the course.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	Will depend on the course topics.
20.2	Hardware	Will depend on the course topics.
20.3	Teaching aides (videos, etc.)	Powerpoint presentations.
20.4	Laboratory	Nil
20.5	Equipment	Will depend on the course topics.
20.6	Classroom infrastructure	LCD Projector, White board.
20.7	Site visits	Nil
20.8	Others (please specify)	Nil

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	Will depend on the course topics.
21.2	Open-ended problems	Will depend on the course topics.
21.3	Project-type activity	Will depend on the course topics.
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Selected Topics in RFDT - II
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL732
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (<i>course no./title</i>)	To be specified by course instructor as per course contents.
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (<i>indicate program names</i>)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Will depend on the topics.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): Impart specialized skills.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Advanced course on selected topics of relevance to the RFDT M.Tech Program.
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15. Lecture Outline(*with topics and number of lectures*)

Module no.	Topic	No. of hours
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	As per requirements – to be specified by course instructor	
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	As per requirements of the selected topics in the course.	42

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be announced by Course Instructor as per requirements of the topics in the course.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	Will depend on the course topics.
20.2	Hardware	Will depend on the course topics.
20.3	Teaching aides (videos, etc.)	Powerpoint presentations.
20.4	Laboratory	Nil
20.5	Equipment	Will depend on the course topics.
20.6	Classroom infrastructure	LCD Projector, White board.
20.7	Site visits	Nil
20.8	Others (please specify)	Nil

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	Will depend on the course topics.
21.2	Open-ended problems	Will depend on the course topics.
21.3	Project-type activity	Will depend on the course topics.
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Selected Topics in RFDT - III
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL733
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (<i>course no./title</i>)	To be specified by course instructor as per course contents.
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (<i>indicate program names</i>)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Will depend on the topics.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): Impart specialized skills.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Advanced course on selected topics of relevance to the RFDT M.Tech Program.
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15. Lecture Outline(*with topics and number of lectures*)

Module no.	Topic	No. of hours
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	As per requirements – to be specified by course instructor	
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	As per requirements of the selected topics in the course.	42

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be announced by Course Instructor as per requirements of the topics in the course.

20. Resources required for the course (itemized & student access requirements, if any)

20.1	Software	Will depend on the course topics.
20.2	Hardware	Will depend on the course topics.
20.3	Teaching aides (videos, etc.)	Powerpoint presentations.
20.4	Laboratory	Nil
20.5	Equipment	Will depend on the course topics.
20.6	Classroom infrastructure	LCD Projector, White board.
20.7	Site visits	Nil
20.8	Others (please specify)	Nil

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	Will depend on the course topics.
21.2	Open-ended problems	Will depend on the course topics.
21.3	Project-type activity	Will depend on the course topics.
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Selected Topics in RFDT - IV
3.	L-T-P structure	3-0-0
4.	Credits	3
5.	Course number	CRL734
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (<i>course no./title</i>)	To be specified by course instructor as per course contents.
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (<i>indicate program names</i>)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Will depend on the topics.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): Impart specialized skills.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Advanced course on selected topics of relevance to the RFDT M.Tech Program.
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15. Lecture Outline(*with topics and number of lectures*)

Module no.	Topic	No. of hours
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	As per requirements – to be specified by course instructor	
COURSE TOTAL (14 times 'L')		42

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	As per requirements of the selected topics in the course.	42

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be announced by Course Instructor as per requirements of the topics in the course.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	Will depend on the course topics.
20.2	Hardware	Will depend on the course topics.
20.3	Teaching aides (videos, etc.)	Powerpoint presentations.
20.4	Laboratory	Nil
20.5	Equipment	Will depend on the course topics.
20.6	Classroom infrastructure	LCD Projector, White board.
20.7	Site visits	Nil
20.8	Others (please specify)	Nil

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	Will depend on the course topics.
21.2	Open-ended problems	Will depend on the course topics.
21.3	Project-type activity	Will depend on the course topics.
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Independent Study
3.	L-T-P structure	0-3-0
4.	Credits	3
5.	Course number	CRS735
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	To be specified by the course instructor as per course contents.
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course Will depend on the topics.
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12.	Will the course require any visiting faculty? (yes/no)	No
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13.	Course objectives (<i>about 50 words</i>): Impart specialized skills through independent study by the student.
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14.	Course contents (about 100 words) (Include laboratory/design activities): Advanced course on selected topics of relevance to the RFDT M.Tech Program.
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15. Lecture Outline(*with topics and number of lectures*) NA

Module no.	Topic	No. of hours
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COURSE TOTAL (14 times 'L')		

16. Brief description of tutorial activities:

Module no.	Description	No. of hours
	Will depend on the topics for independent study in the course	42

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	As per requirements of the selected independent study topics in the course.	42

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be announced by Course Instructor as per requirements of the topics in the course.

20. Resources required for the course (itemized & student access requirements, if any)

20.1	Software	Will depend on the course topics.
20.2	Hardware	Will depend on the course topics.
20.3	Teaching aides (videos, etc.)	-
20.4	Laboratory	-
20.5	Equipment	Will depend on the course topics.
20.6	Classroom infrastructure	-
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	Will depend on the course topics.
21.2	Open-ended problems	Will depend on the course topics.
21.3	Project-type activity	Nil
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics	
2.	Course Title (<i>< 45 characters</i>)	Acoustic Classification using Passive Sonar	
3.	L-T-P structure	1-0-0	
4.	Credits	1	
5.	Course number	CRV741	
6.	Status (<i>category for program</i>)	Program Elective	

7.	Pre-requisites (course no./title)	EEL205 – Signals and Systems or equivalent.	
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)		
8.1	Overlap with any UG/PG course of the Dept./Centre	-	
8.2	Overlap with any UG/PG course of other Dept./Centre	-	
8.3	Supersedes any existing course	-	

9.	Not allowed for (indicate program names)	-	
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -	
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11.	Faculty who will teach the course Cdr. Dr. Arnab Das.
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12.	Will the course require any visiting faculty? (yes/no)	Yes
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13.	Course objectives (<i>about 50 words</i>): This course focuses on the topic of Marine Vessel Classification using Passive Sonar. The challenges faced by a sonar designer, involved in developing underwater classification systems will be introduced and possible solutions will be discussed.
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14.	Course contents (about 100 words) (Include laboratory/design activities): The challenges faced by a sonar designer, involved in developing underwater classification systems will be introduced and possible solutions will be discussed. The radiated noise characteristics from marine vessels and the unique characteristics of the acoustic
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	signature with respect to the class of the marine platform will be presented. Recent research work has shown that classical homomorphic signal processing techniques and other channel inversion techniques can be used to significantly reduce the unwanted underwater channel distortions that otherwise affect the classifier performance drastically. The course shall provide insight into some of the methods that can improve sonar classification performance.
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15. Lecture Outline*(with topics and number of lectures)*

Module no.	Topic	No. of hours
1.	Motivation for the topic and applications	1
2.	Radiated Noise of Marine Vessels: Marine vessel design and operations. Radiated noise generation, transmission path and manifestation.	2
3.	Underwater Channel Characteristics: Multi-path and time varying channel fluctuations. Surface/bottom interactions and their impact on signal propagation. A block adaptive linear model for a time varying multi-path UW channel will be discussed.	2
4.	Feature Extraction: Features in time, spectral, and cepstral domains for radiated noise of marine vessels. Cepstral based features will be shown to be more robust to the UW channel fluctuations.	2
5.	Homomorphic Processing: Cepstral liftering that deconvolves the UW channel distortions quite well will be explained. Concept and application with signal processing advantage supported by analytical justification.	2
6.	Pattern Classification Background: Audio samples will be presented to perceptually differentiate the classes. Parametric and non-parametric pattern classification methods including Bayes' method, variations of nearest neighbor method, artificial neural networks etc.	2
7.	Passive Sonar based Classification: Marine Vessel Classification using Passive Sonar Data. Training and test data preparation. Performance evaluation of different feature sets. Effect of additive noise and different underwater channel profiles. Inferences.	3
COURSE TOTAL (14 times 'L')		14

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities: NA

Module no.	Description	No. of hours

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
2-7	Assignments / studying reference material	14

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

1) Robert J. Urick, "Principles of Underwater Sound" third edition, Peninsula Publishing, 1983.
2) R.O. Duda, P.E. Hart, D.G. Stork, "Pattern Classification", Wiley, New York, 2000.
3) Paul C. Etter, "Underwater Acoustic Modelling and Simulation" third edition, Spon Press, Taylor and Francis Group, London and New York, 2003.
4) Papers from IEE/IET/IEEE/JASA journals.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	MATLAB
20.2	Hardware	-
20.3	Teaching aides (videos, etc.)	Powerpoint presentations.
20.4	Laboratory	-
20.5	Equipment	-
20.6	Classroom infrastructure	LCD Projector and white board.
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course (*Percent of student time with examples, if possible*)

21.1	Design-type problems	20% in design of sensor array with given specifications.
21.2	Open-ended problems	-
21.3	Project-type activity	-

21.4	Open-ended laboratory work	-
21.5	Others (please specify)	-

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Minor Project
3.	L-T-P structure	0-0-6
4.	Credits	3
5.	Course number	CRD802
6.	Status (<i>category for program</i>)	Core Course

7.	Pre-requisites (course no./title)	-
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course There will be a Course Coordinator. One or more faculty members, depending on the topic, will supervise the project for each student.
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12.	Will the course require any visiting faculty? (yes/no)	No.
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13.	Course objectives (<i>about 50 words</i>): Use of acquired knowledge and skills for doing project work towards research or technology development.
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14.	Course contents (<i>about 100 words</i>) (Include laboratory/design activities): The project work shall be specific to each student.
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15. **Lecture Outline**(*with topics and number of lectures*)

Module no.	Topic	No. of hours
COURSE TOTAL (14 times 'L')		0

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities:

Module no.	Description	No. of hours
	As per requirements – to be specific for each student undertaking the course.	84

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	As per requirements of the project.	84

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be given by the project supervisor of the student.

20. Resources required for the course (itemized & student access requirements, if any)

20.1	Software	Depending on the project topic.
20.2	Hardware	Depending on the project topic.
20.3	Teaching aides (videos, etc.)	NIL
20.4	Laboratory	Depending on the project topic.
20.5	Equipment	Depending on the project topic.
20.6	Classroom infrastructure	-
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	NIL
21.2	Open-ended problems	NIL
21.3	Project-type activity	100%
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Major Project - I
3.	L-T-P structure	0-0-12
4.	Credits	6
5.	Course number	CRD811
6.	Status (<i>category for program</i>)	Program Core

7.	Pre-requisites (course no./title)	-
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course There will be a Course Coordinator. One or more faculty members, depending on the topic, will supervise the project for each student.	
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12.	Will the course require any visiting faculty? (yes/no)	No.
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13.	Course objectives (<i>about 50 words</i>): Use of acquired knowledge and skills for doing project work towards research or technology development.	
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14.	Course contents (about 100 words) (Include laboratory/design activities): The project work shall be specific to each student.	
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15. **Lecture Outline**(*with topics and number of lectures*)

Module no.	Topic	No. of hours
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COURSE TOTAL (14 times 'L')		0

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities:

Module no.	Description	No. of hours
	As per requirements – to be specific for each student undertaking the course.	168

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	As per requirements of the project.	168

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be given by the project supervisor of the student.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	Depending on the project topic.
20.2	Hardware	Depending on the project topic.
20.3	Teaching aides (videos, etc.)	NIL
20.4	Laboratory	Depending on the project topic.
20.5	Equipment	Depending on the project topic.
20.6	Classroom infrastructure	-
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	NIL
21.2	Open-ended problems	NIL
21.3	Project-type activity	100%
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Major Project - II
3.	L-T-P structure	0-0-24
4.	Credits	12
5.	Course number	CRD812
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	'B' or higher grade in CRD811 (Major Project – 1) and CRC approval.
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course There will be a Course Coordinator. One or more faculty members, depending on the topic, will supervise the project leading to dissertation for each student.	
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12.	Will the course require any visiting faculty? (yes/no)	No.
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13.	Course objectives (<i>about 50 words</i>): Use of acquired knowledge and skills for doing project work towards research or technology development and leading to a dissertation.	
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14.	Course contents (about 100 words) (Include laboratory/design activities): The project work shall be specific to each student.	
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15. Lecture Outline(*with topics and number of lectures*)

Module no.	Topic	No. of hours
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COURSE TOTAL (14 times 'L')		0

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities:

Module no.	Description	No. of hours
	As per the requirements – to be specific for each student undertaking the course.	336

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
	As per the requirements of the project.	336

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be given by the project supervisor of the student.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	Depending on the project topic.
20.2	Hardware	Depending on the project topic.
20.3	Teaching aides (videos, etc.)	NIL
20.4	Laboratory	Depending on the project topic.
20.5	Equipment	Depending on the project topic.
20.6	Classroom infrastructure	-
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	NIL
21.2	Open-ended problems	NIL
21.3	Project-type activity	100%
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)

COURSE TEMPLATE

1.	Department/Centre proposing the course	Centre for Applied Research in Electronics
2.	Course Title (<i>< 45 characters</i>)	Major Project - III
3.	L-T-P structure	0-0-12
4.	Credits	6
5.	Course number	CRD814
6.	Status (<i>category for program</i>)	Program Elective

7.	Pre-requisites (course no./title)	CRD811
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8.	Status vis-à-vis other courses (<i>give course number/title</i>)	
8.1	Overlap with any UG/PG course of the Dept./Centre	-
8.2	Overlap with any UG/PG course of other Dept./Centre	-
8.3	Supersedes any existing course	-

9.	Not allowed for (indicate program names)	-
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10.	Frequency of offering	☐ Every sem ☐ 1stsem ☐ 2ndsem ☒ Either sem -
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11.	Faculty who will teach the course There will be a Course Coordinator. One or more faculty members, depending on the topic, will supervise the project for each student.
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12.	Will the course require any visiting faculty? (yes/no)	No.
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13.	Course objectives (<i>about 50 words</i>): Use of acquired knowledge and skills for doing project work towards research or technology development.
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14.	Course contents (about 100 words) (Include laboratory/design activities): The project work shall be specific to each student.
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15. **Lecture Outline**(*with topics and number of lectures*)

Module no.	Topic	No. of hours
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COURSE TOTAL (14 times 'L')		0

16. Brief description of tutorial activities: NA

Module no.	Description	No. of hours

17. Brief description of laboratory activities:

Module no.	Description	No. of hours
-	As per the requirements – to be specific for each student undertaking the course.	168

18. Brief description of module-wise activities pertaining to self-study component (mandatory for 700 / 800 level courses)

Module no.	Description	No. of hours
-	As per the requirements of the project.	168

19. Suggested texts and reference materials

STYLE: Author name and initials, Title, Edition, Publisher, Year.

To be given by the project supervisor of the student.

20. Resources required for the course (*itemized & student access requirements, if any*)

20.1	Software	Depending on the project topic.
20.2	Hardware	Depending on the project topic.
20.3	Teaching aides (videos, etc.)	NIL
20.4	Laboratory	Depending on the project topic.
20.5	Equipment	Depending on the project topic.
20.6	Classroom infrastructure	-
20.7	Site visits	-
20.8	Others (please specify)	-

21. Design content of the course*(Percent of student time with examples, if possible)*

21.1	Design-type problems	NIL
21.2	Open-ended problems	NIL
21.3	Project-type activity	100%
21.4	Open-ended laboratory work	NIL
21.5	Others (please specify)	NIL

Date:

(Signature of the Head of the Department)