CURRICULUM AND DETAILED SYLLABI

FOR

M.E. DEGREE (Communication Systems) PROGRAM

FOR THE STUDENTS ADMITTED FROM THE

ACADEMIC YEAR 2018-19 ONWARDS

THIAGARAJAR COLLEGE OF ENGINEERING
(A Government Aided Autonomous Institution affiliated to Anna University)
MADURAI – 625 015, TAMILNADU

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Passed in Board of Studies Meeting on 14.07.2018 Approved in 56th Academic Council Meeting on 21.07.2018

Vision

To empower the Electronics and Communication Engineering students with technological excellence, professional commitment and social responsibility

Mission

- Attaining academic excellence in Electronics and Communication Engineering through dedication to duty, innovation in learning and research, state of art laboratories and industry driven skill development.
- Establishing suitable environment for the students to develop professionalism and face life challenges with ethical integrity.
- Nurturing the students to understand the societal needs and equip them with technical expertise to provide appropriate solutions.
- Providing breeding ground to obtain entrepreneurial skills and leadership qualities for self and societal growth.

Programme Educational Objectives

I. Graduates will be capable of developing and providing optimal solutions to subsystems like RF, baseband of modern communication systems and networks.
II. Graduates will be capable of carrying out multidisciplinary scientific research in allied areas of Communication Engineering through advanced research, personal success and life long learning.
III. Graduates will be able to identify and analyze societal problem and can provide technological solutions in a cost effective manner.
   – These objectives will be evidenced by professional visibility (publications, presentations, inventions, patents and awards), entrepreneurial activities, international activities (participation in international conferences, collaborative research and employment abroad)

Program Outcomes

1. Scholarship of Knowledge
Acquire in-depth knowledge of specific discipline or professional area, including wider and global perspective, with an ability to discriminate, evaluate, analyse and synthesise existing and new knowledge, and integration of the same for enhancement of knowledge.

2. Critical Thinking
Analyse complex engineering problems critically, apply independent judgement for synthesising information to make intellectual and/or creative advances for conducting research in a wider theoretical, practical and policy context.

3. Problem Solving
Think laterally and originally, conceptualise and solve engineering problems, evaluate a wide range of potential solutions for those problems and arrive at feasible, optimal solutions after considering public health and safety, cultural, societal and environmental factors in the core area of expertise.

4. Research Skill

Extract information pertinent to unfamiliar problems through literature survey and experiment, apply appropriate research methodologies, techniques and tools, design, conduct experiment, analyze and interpret data , demonstrate higher order skill and view things in a broader perspective, contribute individually/in group(s) to the development of scientific/technological knowledge in one or more domains of engineering.

5. Usage of modern tools

Create, select, learn and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling, to complex engineering activities with an understanding of the limitations.

6. Collaborative and Multidisciplinary work

Possess knowledge and understanding of group dynamics, recognize opportunities and contribute positively to collaborative-multidisciplinary scientific research, demonstrate a capacity for self-management and teamwork, decision-making based on open-mindedness, objectivity and rational analysis in order to achieve common goals and further the learning of themselves as well as others.

7. Project Management and Finance

Demonstrate knowledge and understanding of engineering and management principles and apply the same to one's own work, as a member and leader in a team, manage projects efficiently in respective disciplines and multidisciplinary environments after considerisation of economical and financial factors.

8. Communication

Communicate with the engineering community, and with society at large, regarding complex engineering activities confidently and effectively, such as, being able to comprehend and write effective reports and design documentation by adhering to appropriate standards, make effective presentations, and give and receive clear instructions.

9. Life-long Learning

Recognize the need for, and have the preparation and ability to engage in life-long learning independently, with a high level of enthusiasm and commitment to improve knowledge and competence continuously.

10. Ethical Practices and Social Responsibility

Acquire professional and intellectual integrity, professional code of conduct, ethics of research and scholarship, consideration of the impact of research outcomes on professional practices and an understanding of responsibility to contribute to the community for sustainable development of society.

11. Independent and Reflective Learning

Observe and examine critically the outcomes of one's actions and make corrective measures subsequently, and learn from mistakes without depending on external feedback.

THIAGARAJAR COLLEGE OF ENGINEERING, MADURAI-625015

M.E./M.Tech Programme Structure (CBCS)

CREDIT DISTRIBUTION:

S.No	Category		Credits
A.	**Foundation Course**		**3 - 6**
B.	**Programme Core Courses***		**19 – 25**
C.	**Elective Courses**		**17 – 23**
	a.	Programme Elective	15 – 21
	b.	Open Elective	2 – 6
D.	**Common Core Course**		**2**
E.	**Mini Project and Dissertation**		**27**
F	**Value Added Courses (Not to be included in CGPA) – Mandatory**		**4**
	Minimum Credits to be earned for the award of the degree		**68** (from A to E) and 4 (from F)

* Theory Cum Practical (TCP) and Laboratory courses are Mandatory in the Programme Core Courses.

Credit Details:

Theory	3 Credits
Theory Cum Practical (TCP)	3 Credits
Lab	2 Credits
Open Elective	2 Credits
Mini Project	2 Credits
Dissertation Phase I	10 Credits
Dissertation Phase II	15 Credits
Common Core (Research Methodology and IPR)	2 Credits

CATEGORIZATION OF COURSES
(CHOICE BASED CREDIT SYSTEM)

Degree: M.E **Programme: Communication Systems** **Batch: 2018-19**

A. **Foundation Courses:** **Total Credits to be earned: (3 -6)**

S.No	Course Code	Name of the Course	Number of Hours / Week			Credit	Prerequisite
			L	T	P		
THEORY							
1.	18CN110	Linear Algebra and Optimization	3	-	-	3	-

B. **Core courses** **Credits to be earned: (19-25)**

S.No	Course Code	Name of the Course	Number of Hours / Week			Credit	Prerequisite
			L	T	P		
THEORY							
1.	18CN120	RF Circuits for Communication Systems	3	-	-	3	-
2.	18CN130	Wireless Cellular Networks	3	-	-	3	-
3.	18CN210	Baseband Wireless Communication Systems	2	1	-	3	18CN160
THEORY CUM PRACTICAL							
1.	18CN160	Communication System Engineering	2	-	2	3	-
2.	18CN260	RF- Front End Systems	2	-	2	3	18CN120
PRACTICAL							
1.	18CN170	RF Circuits Laboratory	-	-	4	2	-
2.	18CN270	Baseband Communications Laboratory	-	-	4	2	-

* 2 hours/week is allotted for off-class practical work

C. **Elective Courses:** **(17 -23)**

a. **Programme Elective** **Credits to be earned: (15-21)**

S.No	Course Code	Name of the Course	Number of Hours / Week			Credit	Prerequisite
			L	T	P		
1.	18CNPA0	Array Signal Processing	2	1	-	3	-
2.	18CNPB0	Digital Speech Processing	2	1	-	3	-
3.	18CNPC0	Radar Systems	2	1	-	3	-
4.	18CNPD0	Physical Layer LTE Systems	2	1	-	3	-
5.	18CNPE0	RF Test and Measurement	3	-	-	3	-
6.	18CNPF0	EMI and EMC	3	-	-	3	-
7.	18CNPG0	RF MEMS For High Performance Passives	3	-	-	3	-
8.	18CNPH0	Radio Frequency Integrated Circuits	3	-	-	3	-
9.	18CNPJ0	Antennas for Wireless	2	1	-	3	18CN120

		Applications					
10.	18CNPK0	Image Systems Engineering	3	-	-	3	-
11.	18CNPL0	Machine Learning for Visual Recognition	3	-	-	3	-
12.	18CNPM0	Intelligent Video Surveillance Systems	3	-	-	3	-
13.	18CNPN0	Medical Imaging and Classification	3	-	-	3	-
14.	18CNPP0	Remote Sensing Data Analytics	3	-	-	3	-
15.	18CNPQ0	Digital Integrated Circuits	3	-	-	3	-
16.	18CNPR0	Analog Integrated Circuits	3	-	-	3	-
17.	18CNPS0	Internet of Things	3	-	-	3	-
18.	18CNPT0	System-on-Chip	3	-	-	3	-
19.	18CNPU0	Optical Communication Systems					
20.	18CNPV0	Number Theory and Cryptography	3	-	-	3	-
21.	18CNPW0	Reconfigurable Wireless Transceivers	3	-	-	3	-
22.	18CNPX0	RF CAD Tools	3	-	-	3	-
23.	18CNPY0	Machine Learning for Signal Processing	2	1	-	3	-
THEORY CUM PRACTICAL							
1.	18CNPX0	RF CAD Tools	2	-	2	3	-
PRACTICAL							
1.	-	-	-	-	-	-	-

b. Open Elective **Credits to be earned: (02-06)**

S.No	Course Code	Name of the Course	Number of Hours / Week			Credit	Prerequisite
			L	T	P		
THEORY							
1.	18CNGA0	Convex Optimization for Communications	2	-	-	2	-
2.	18CNGB0	Operations Research	2	-	-	3	-
3.	18CNGC0	Business Analytics	2	-	-	3	-
THEORY CUM PRACTICAL							
-	-	-	-	-	-	-	-
PRACTICAL							
-	-	-	-	-	-	-	-

D. **Common Core Course** **Credits to be earned: 02**

S.No	Course Code	Name of the Course	Number of Hours / Week			Credit	Prerequisite
			L	T	P		
THEORY							
1.	18PG250	Research Methodology and IPR	2	0	0	2	-

E. **Miniproject and Dissertation** **Credits to be earned: 27**

S.No	Course	Name of the Course	Number of Hours	Credit	Prerequisite

	Code		/ Week				
			L	T	P		
THEORY							
1.	18CN280	Mini Project	-	-	4	2	-
2.	18CN380	Dissertation Phase I	-	-	20	10	-
3.	18CN480	Dissertation Phase II	-	-	30	15	-

F. **Value Added Courses** **Credits to be earned: 04**

S.No	Course Code	Name of the Course	Number of Hours / Week			Credit	Prerequisite
			L	T	P		
THEORY							
1.	18PGAA0	Professional Authoring	2	0	0	2	-
2.	18PGAB0	Value Education	2	0	0	2	-
THEORY CUM PRACTICAL							
-	-	-	-	-	-	-	-
PRACTICAL							
-	-	-	-	-	-	-	-

THIAGARAJAR COLLEGE OF ENGINEERING, MADURAI-625015

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

SCHEDULING OF COURSES

Semester	Theory					Theory Cum Practical	Laboratory	Project
I (20)	18CN110 Linear Algebra and Optimization (3)	18CN120 RF Circuits for Communication Systems (3)	18CN130 Wireless Cellular Networks (3)	18XXPX0 Prog. Elective 1 (3)	18CNPX0 Prog. Elective 2 (3)	18CN160 Communication System Engineering (3)	18CN170 RF Circuits Laboratory (2)	-
II (18)	18CN210 Baseband Wireless Communication Systems (3)	18CNPX0 Prog. Elective 3 (3)	18CN PX0 Prog. Elective 4 (3)	-	18PG250 Research Methodology and IPR (2)	18CN260 RF Frontend Systems (3)	18CN270 Baseband Communications Laboratory (2)	18CN280 Mini Project (2)
III (15)	18CNPX0 Prog. Elective 5 (3)	-	-	-	18CNGX0 Open Elective (2)	-	-	18CN380 Dissertation Phase I (10)
IV (15)	-	-	-	-	-	-	-	18CN480 Dissertation Phase II (15)

A student has to complete 2 audit courses of 24 hours duration. The courses will normally be conducted on week-ends.

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015
(An Autonomous Institution Affiliated to Anna University)
CURRICULUM
(For the Students admitted from the academic year 2018- 19)

Name of the Degree: ME (Communication Systems)
COURSES OF STUDY

I SEMESTER
Theory:

Course Code	Name of the Course	Regulation			
		L	T	P	C
18CN110	Linear Algebra and Optimization	3	0	0	3
18CN120	RF Circuits for Communication Systems	3	0	0	3
18CN130	Wireless Cellular Networks	3	0	0	3
18CNPX0	Programme Elective 1	3	0	0	3
18CNPX0	Programme Elective 2	3	0	0	3
18CN160	Communication System Engineering	2	0	2	3

Practical

18CN170	RF Circuits Laboratory	0	0	4	2

Total Credits 20

II SEMESTER
Theory:

Course Code	Name of the Course	Regulation			
		L	T	P	C
18CN210	Baseband Wireless Communication System	2	1	0	3
18CNPX0	Programme Elective 3	3	0	0	3
18CNPX0	Programme Elective 4	3	0	0	3
18PG250	Research Methodology and IPR	2	0	0	2
18CN260	RF Frontend Systems	2	0	2	3

Practical

18CN270	Baseband Communications Laboratory	0	0	4	2
18CN280	MIniproject	0	0	4	2

Total Credits 18

III SEMESTER
Theory:

Course Code	Name of the Course	Regulation			
		L	T	P	C
18CNPX0	Programme Elective 5	3	0	0	3
18CNGX0	Open Elective	2	0	0	2

Practical

18CN380	Dissertation Phase I	0	0	20	10

Total Credits 15

IV Semester:
Practical:

Course Code	Name of the Course	Regulation			
		L	T	P	C
18CN480	Dissertation Phase II	0	0	30	15

Total Credits 15

Minimum Number of credits to be earned for the award of degree: 68

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015
M.E Degree (Communication Systems) Program
SCHEME OF EXAMINATIONS
(For the candidates admitted from 2018-19 onwards)

FIRST SEMESTER

Course code	Name of the Course	Duration of End Semester Exam\ in Hrs.	Marks			Min. Marks for Pass	
			Conti-nuous Asses-sment	Termi-nal Exam	Max. Marks	Termi-nal Exam	Total
THEORY							
18CN110	Linear Algebra and Optimization	3	50	50	100	25	50
18CN120	RF Circuits for Communication Systems	3	50	50	100	25	50
18CN130	Wireless Cellular Networks	3	50	50	100	25	50
18CNPX0	Programme Elective 1	3	50	50	100	25	50
18CNPX0	Programme Elective 2	3	50	50	100	25	50
18CN160	Communication System Engineering	3	50	50	100	25	50
PRACTICAL							
18CN170	RF Circuits Laboratory	3	50	50	100	25	50

SECOND SEMESTER

Course code	Name of the Course	Duration of End Semester Exam\ in Hrs.	Marks			Min. Marks for Pass	
			Conti-nuous Asses-sment	Termi-nal Exam	Max. Marks	Termi-nal Exam	Total
THEORY							
18CN210	Baseband Wireless Communication System	3	50	50	100	25	50
18CNPX0	Programme Elective 3	3	50	50	100	25	50
18CNPX0	Programme Elective 4	3	50	50	100	25	50
18PG250	Research Methodology and IPR	3	50	50	100	25	50
18CN260	RF Frontend Systems	3	50	50	100	25	50
PRACTICAL							
18CN270	RF Systems Laboratory	3	50	50	100	25	50

THIRD SEMESTER

Course code	Name of the Course	Duration of End Semester Exam\ in Hrs.	Marks			Min. Marks for Pass	
			Conti-nuous Assess-ment	Termi-nal Exam	Max. Marks	Termi-nal Exam	Total
THEORY							
18CNPX0	Programme Elective 5	3	50	50	100	25	50
18CNGX0	Open Elective	3	50	50	100	25	50
PRACTICAL							
18CN380	Dissertation Phase I	-	50	50	100	50	100

FOURTH SEMESTER

Course code	Name of the Course	Duration of End Semester Exam\ in Hrs.	Marks			Min. Marks for Pass	
			Conti-nuous Asses-sment	Termi-nal Exam	Max. Marks	Termi-nal Exam	Total
PRACTICAL							
18CN480	Dissertation Phase II	-	50	50	100	50	100

* Continuous Assessment evaluation pattern will differ from course to course and for different tests. This will have to be declared in advance to students. The department will put a process in place to ensure that the actual test paper follow the declared pattern.

** End Semester Examination will be conducted for maximum marks of 100 and subsequently be reduced to 50 marks for the award of End Semester Examination marks.

18CN110	LINEAR ALGEBRA AND OPTIMIZATION	Category	L	T	P	Credit
		FC	3	0	0	3

Preamble

An engineering PG student needs to have some basic mathematical tools and techniques to apply in diverse applications in Engineering. This emphasizes the development of rigorous logical thinking and analytical skills of the student and appraises him the complete procedure for solving different kinds of problems that occur in engineering. Based on this, the course aims at giving adequate exposure in Linear Algebra to find the singular value decomposition and Pseudo inverse of the matrix, linear Programming problem, nonlinear programming problem and graph theory.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Predict orthonormal basis	Apply
CO2. Decompose a given matrix using QR and SVD methods	Apply
CO3. Apply linear programming techniques to optimize problems arising in communication engineering	Apply
CO4 Determine the optimum values of non-linear programming problems using Kuhn tucker conditions, elimination method.	Apply
CO5. Determine the optimum values of non-linear programming problems using search methods.	Apply
CO6. Explain the types of graphs, domination and colouring.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S	S	M	-	-	-	M	-	-	-
CO2.	S	S	S	M	-	-	-	M	-	-	-
CO3.	S	S	S	M	-	-	-	M	-	-	-
CO4.	S	S	S	M	-	-	-	M	-	-	-
CO5.	S	S	S	M	-	-	-	M	-	-	-
CO6.	S	S	S	M	-	-	-	M	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	10	10	0	0
Understand	30	30	30	30
Apply	60	60	70	70
Analyze	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Estimate the dimension of the row space of the matrix $A = \begin{pmatrix} 1 & -2 & 3 \\ 2 & -5 & 1 \\ 1 & -4 & -7 \end{pmatrix}$
2. Show that $\left\{ \frac{(1,1,1)^T}{\sqrt{3}}, \frac{(2,1,-3)^T}{\sqrt{14}}, \frac{(4,-5,1)^T}{\sqrt{42}} \right\}$ is an orthonormal set in R^3
3. Estimate the best quadratic least square fit to the data

x	0	3	6
y	1	4	5

4. Consider the vector space $C[-1, 1]$ with inner product defined by $< f, g >= \int_{-1}^{1} f(x)g(x)dx$ Calculate orthonormal basis for subspace spanned by $\{ 1, x, x^2 \}$

Course Outcome 2 (CO2):

1. Determine the singular value decomposition of i) $\begin{pmatrix} 1 & 2 \\ 1 & 1 \\ 1 & 3 \end{pmatrix}$ ii) $\begin{bmatrix} 1 & 1 & 3 \\ 1 & 1 & 3 \end{bmatrix}$
2. construct QR decomposition of the matrix i) $\begin{pmatrix} -4 & 2 & 2 \\ 3 & -3 & 3 \\ 6 & 6 & 0 \end{pmatrix}$ ii) $\begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix}$

Course Outcome 3 (CO3):

1. Solve the following using simplex method:
   Maximize Z = $45x_1+80x_2$ subject to $5x_1+20x_2 \le 400$; $10x_1+15x_2 \le 450$: $x_1, x_2 \ge 0$
2. Use Graphical method to solve the LPP
   Maximize Z = $5x_1+x_2$ subject to $5x_1+2x_2 \le 20$; $x_1+3x_2 \le 50$: $x_1, x_2 \ge 0$

Course Outcome 4 (CO4):

1. Determine the maximum value of the non-linear programming problem using Kuhn-tucker conditions, Max Z = $8x_1+10x_2-x_1^2-x_2^2$
   Subject to $3x_1+2x_2 \le 6$; $x_1, x_2 \ge 0$
2. Calculate the minimum value of f(x) = x(1.5-x) in the interval [0,3] with n=6 by Fibonacci method and golden section method.

Course Outcome 5 (CO5):

1. Calculate the minimum of $f(x_1, x_2) = x_1 - x_2 + 2\ x_1^2 + 2x_1x_2 + x_2^2$, starting from the origin, using conjugate gradient method.
2. Calculate the minimum of $f(x_1, x_2) = x_1 - x_2 + 8\ x_1^2 + 2x_1x_2$, starting from the origin, using the steepest descent method

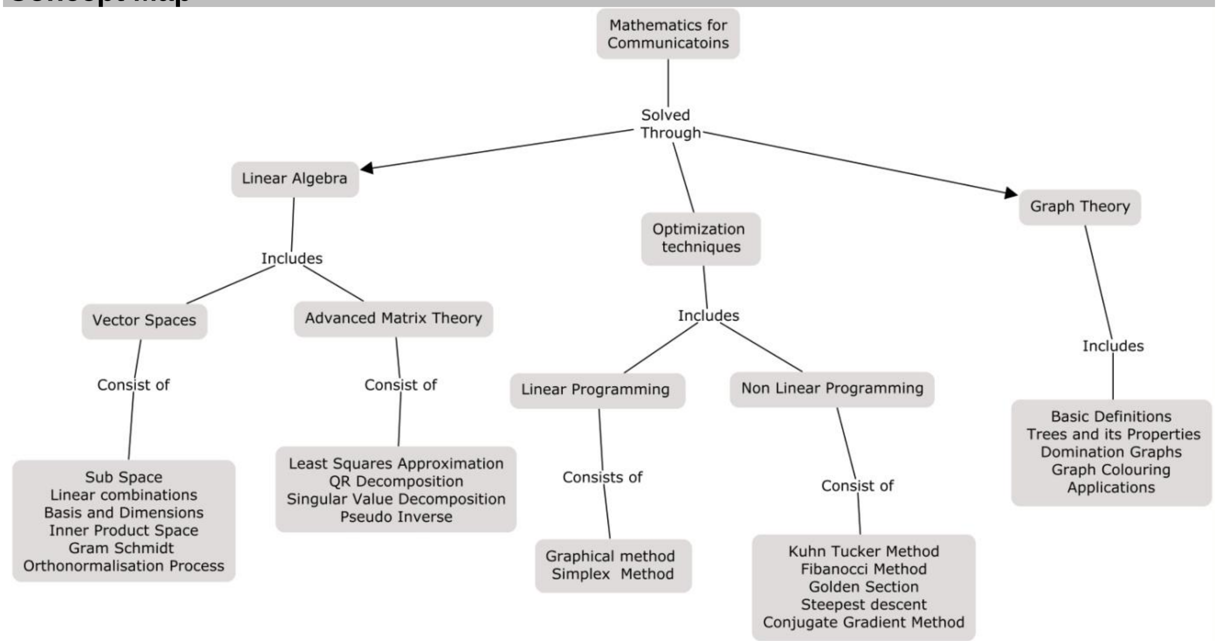
Course Outcome 6 (CO6):

1. Construct a connected and disconnected graph with 10 vertices
2. Examine the graph whose adjacency matrix is given below to see if is connected.

$$\begin{pmatrix} 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 \\ 1 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 \end{pmatrix}$$

3. Compute the domination number, independence number & Chromatic number for the following graphs. i. Peterson graph ii. Complete graph iii. Path on 'n ' vertices

Concept Map



Syllabus

Vector spaces: Definition and examples-subspaces-Linear independence-Basis and dimension - Inner product spaces- Orthonormal sets-Gram-Schmidt orthogonalization process-Generalized Eigen vectors. **Advanced Matrix Theory:** Least Square approximation - QR decomposition - Singular Value Decomposition – Pseudo inverse, Applications**. Linear programming**: Graphical solution, Simplex method. **Nonlinear programming**: Kuhn Tucker conditions, Elimination methods, Fibonacci, Golden section. Direct search method, steepest descent method, Conjugate gradient method. **Graph Theory:** Basic definitions in graphs, Walk, path, circuits, isomorphism, Connected and disconnected graph, Properties of trees, Adjacency matrix and its properties , incidence matrix and its properties, Chromatic number, domination number, Applications.

Reference Books

1. Gilbert Strang, "Introduction to Linear Algebra", Third edition, Wellesley, Cambridge Press, 2003
2. S.S. Rao, "Optimization", Wiley Eastern Limited, New Delhi-1990.
3. Steven J. Leon, "Linear Algebra with Applications", Macmillan publishing company, New York, 1990.
4. K.V. Mittal," Theory of Optimization", Wiley Eastern Limited, New Delhi,1988
5. Narsingh Deo, Graph Theory: With Application to Engineering and Computer Science, Prentice Hall of India, 2013

Course Contents and Lecture Schedule

Sl No	Topics	No. of Periods
	Vector Spaces and Orthogonality	
1.1	Vector spaces: axioms; properties examples of vector spaces	1
1.2	Sub-spaces: Null space of matrix examples	1
1.3	Linear combinations; span of a set properties; Examples, Linear independence and dependence-definition	2
1.4	Basis and dimension; properties; examples	1
1.5	Inner product space, normed linear space	1
1.6	Orthogonal bases: Gram Schmidt orthonormalisation process	2
	Advanced Matrix Theory	
2.1	Least Square approximation	2
2.2	QR decomposition	`2
2.3	Singular Value Decomposition – Pseudo inverse	3
2.4	Applications	1
	Linear programming	
3.1	Linear programming-Formulation, Canonical and standard forms	2
3.2	Graphical solution	2
3.3	Simplex method	2
	Nonlinear Programming	
4.1	Non-linear programming- Kuhn Tucker conditions	2
4.2	Non-linear programming(one dimensional minimization methods): Unimodal functions	1
4.3	Fibonacci method, Golden section method	2
4.4	Steepest descent	2
4.5	Conjugate gradient method	1
	Graph Theory	
5.1	Basic definitions in graphs, Walk, path, circuits	1
5.2	Isomorphism, Connected and disconnected graph	1
5.3	Properties of trees	1
5.4	Adjacency matrix and its properties , incidence matrix and its properties	1
5.5	Chromatic number, domination number, Applications	2

Course Designers:

1. Dr.G.Jothilakshmi gjlmat@tce.edu
2. Dr.A.P.Pushpalatha appmat@tce.edu

18CN120	RF CIRCUITS FOR COMMUNICATION SYSTEMS	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

The objective of this course is to provide strong fundamentals in the field of RF passive and active circuit design. Both circuit and system level perspectives are well addressed. The passive circuits such as transmission lines, matching circuits, filters, couplers and power dividers are covered in the first three modules. The active circuits such as amplifiers, oscillators and mixers are covered in the subsequent modules. A general overview of receiver architectures, receiver component specifications, response and characterization are given in last module. The passive and active devices are characterized using scattering parameters.

Prerequisite

NIL.

Course Outcomes

On the successful completion of the course students will be able to

CO1	Characterize the behavior of lumped component at RF/Microwave frequencies	Understand
CO2	Characterize the reciprocal networks, lossless networks in terms of S-Parameters	Apply
CO3	Design and analyze the response of planar transmission lines, matching networks, couplers, power dividers and filters	Apply
CO4	Determine the stability of the given transistor using graphical aids and design matching network for amplifier design.	Apply
CO5	Design amplifier for maximum gain, specified gain, LNA using graphical aids.	Apply
CO6	Design and analyze the behavior of Oscillators and Mixers	Apply
CO7	Characterize the receiver, generate receiver specification, analyze the response	Apply

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	L	L	-	-	-	-	-	-	-	-
CO2	s	L	L	-	-	-	-	-	-	-	-
CO3	S	M	M	L	M	-	M	L	-	-	-
CO4	S	M	M	L	M	-	M	L	-	-	-
CO5	S	M	M	L	M	-	M	L	-	-	-
CO6	s	M	M	L	M	-	M	L	-	-	-
CO7	S	L	L	-	L	-	-	M	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	20	20	20
Apply	80	80	80	80
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Mention the frequency range of Ka and Ku band.
2. List out the applications of microwaves.
3. Discuss the equivalent circuit model of inductor and capacitor at microwave frequencies.

Course Outcome 2 (CO2):

1. Show that the admittance matrix of a lossless N-port network has purely imaginary elements.
2. Does a nonreciprocal lossless network always have a purely imaginary impedance matrix?
3. Show that it is impossible to construct a three-port network that is lossless, reciprocal, and matched at all ports. Is it possible to construct a nonreciprocal three-port network that is lossless and matchedat all ports?

Course Outcome 3 (CO3):

1. A 20 dBm power source is connected to the input of a directional coupler having a coupling factor of 20 dB, a directivity of 35 dB, and an insertion loss of 0.5 dB. If all ports are matched, find the output powers (in dBm) at the through, coupled, and isolated ports.
2. Derive the scattering matrix for quadrature hybrid coupler through odd-even mode analysis.
3. Mention the design steps involved in the stepped impedance filter design.

Course Outcome 4 (CO4):

1. Define: unilateral figure of merit.
2. Discuss the different methods used to determine the stability of given transisitor.
3. State the necessary conditions for oscillation in a one-port network.

Course Outcome 5 (CO5):

1. Mention the methods used for neutralization in bipolar transistors.
2. Brief about the design steps involved in designing low noise amplifiers.
3. Discuss the drawbacks of cascading impedance-matched stages.

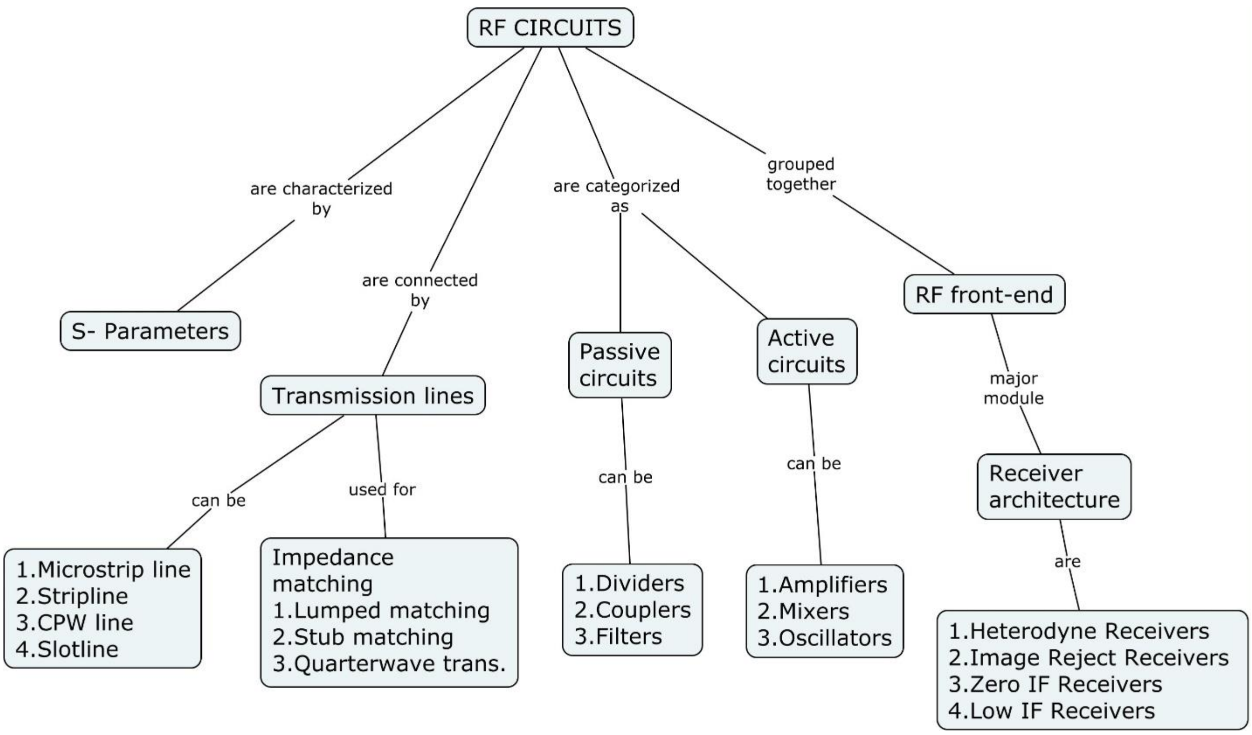
Course Outcome 6 (CO6):

1. Compute the highest and lowest gains by using the unilateral assumption for an Infineon BFP640 bipolar device. Measured S-parameters (2v, 20mA) at 900 MHz are given as: S_{11}=0.4, S_{21}=20.7, S_{12}=0.029, S_{22}=0.54.
2. Design an amplifier stage for G_{UMAX} with the BFP 405 device at 880 MHz, without any added stabilization, using ideal lumped matching elements. What are the gain, input and output reflection coefficient magnitudes of the amplifier with (a) $|S_{12}|$set to zero and (b) using the actual S_{12} of the device? How does the value of G_{UMAX} compare with the computed MSG of the device?
3. Consider a 50-Ω cable, LNA and another amplifier are cascaded together. Their gain and Noise figures are G1=-3dB, NF1=3dB; G2=-20dB, NF2=1.5dB; G3=13dB, NF3=4dB. Compute the overall noise figure.

Course Outcome 7 (CO7):

1. Discuss the issues in direct conversion receivers.
2. Mention the need for image reject receivers.
3. Discuss the differences between Low IF and Zero IF receivers.

Concept Map



Syllabus

Introduction – RF spectrum bands, Reason for using RF/Microwaves, RF and Microwave Circuit design considerations, RF/Microwave versus low AC signals, Lumped component at RF/Microwave frequencies, Applications. **Circuit representation of RF/Microwave two-port networks -** Impedance and Equivalent Voltages and Currents, Impedance and Admittance Matrices, The Scattering Matrix, Reciprocal Networks and Lossless Networks, The Transmission (ABCD) Matrix. **Planar transmission Lines –** Design of Microstrip line, Stripline, CPW line, slotline. **Impedance matching -** Matching with lumped elements, Stub matching- Single and double stub using Smith chart solutions, Quarter wave transformer. **Couplers and Dividers -** Basic Properties of Dividers and Couplers, The T-Junction PowerDivider, The Wilkinson Power Divider, The Quadrature (90°) Hybrid, The 180° Hybrid. **Filters -** Periodic structures, Insertion loss method, maximally flat low pass filter, stepped impedance low pass filter, filter transformation, filter implementation. **Amplifier -** Two-Port Power Gains, Stability, Single-Stage Transistor Amplifier Design – Design for Maximum Gain, Constant-Gain Circles and Design for Specified Gain, Low-Noise Amplifier Design. **Oscillators and Mixers –** Principles of One-Port and Two-Port Oscillator Design, Transistor Oscillator Configuration, Oscillator Phase Noise. Mixers, Harmonic Components in Mixers, Image Problem in Mixers, Diode Mixers – Single Ended and Balanced Mixer, Transistor Mixers, Applications of Mixers. **Receiver Architectures -** Heterodyne Receivers, Image Reject Receivers, Zero IF Receivers, Low IF Receivers, Issues in Direct Conversion Receivers, Architecture Comparison and Trade-off.

Reference Books

1. M.M.Radmanesh,“RF & Microwave Electronics Illustrated”, Pearson Education, 2015.
2. Joy Laskar, BabakMatinpour, Sudipto Chakraborty, “Modern Receiver Front-Ends: Systems, Circuits, and Integration”, John Wiley & Sons, 2004.
3. D.M.Pozar, “Microwave Engineering.”, John Wiley & sons, Inc., 2006.
4. Robert E.Colin, “Foundations for Microwave Engineering”, 2ed, McGraw Hill, 2001.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Introduction**	
1.1	RF spectrum bands, Reason for using RF/Microwaves, RF and Microwave Circuit design considerations	1
1.2	RF/Microwave versus low AC signals, Lumped component at RF/Microwave frequencies, Applications	2
2.	**Circuit representation of RF/Microwave two-port networks**	
2.1	Impedance and Equivalent Voltages and Currents	1
2.2	Impedance and Admittance Matrices	1
2.3	The Scattering Matrix - Reciprocal Networks and Lossless Networks	2
2.4	The Transmission (ABCD) Matrix	1
2.5	Planar transmission Lines -Design of Microstrip line, Stripline, CPW line, slotline	2
3.	**Impedance matching**	
3.1	Matching with lumped elements	1
3.2	Stub matching- Single and double stub using Smith chart solutions, Quarter wave transformer	3
4.	**Couplers and Dividers**	
4.1	Basic Properties of Dividers and Couplers	1
4.2	The T-Junction PowerDivider, The Wilkinson Power Divider	1
4.3	The Quadrature (90°) Hybrid, The 180° Hybrid	2
4.4	**Filters -** Periodic structures, Insertion loss method, maximally flat low pass filter	1
4.5	Stepped impedance low pass filter, filter transformation, filter implementation	2
5.	**Amplifier**- Two-Port Power Gains, Stability	2
5.1	Single-Stage Transistor Amplifier Design – Design for Maximum Gain, Constant-Gain Circles and Design for Specified Gain	2
5.2	Low-Noise Amplifier Design	2
5.3	**Oscillators and Mixers –** Principles of One-Port and Two-Port Oscillator Design	1
5.4	Transistor Oscillator Configuration, Oscillator Phase Noise	2
5.5	Mixers, Harmonic Components in Mixers, Image Problem in Mixers	1
5.6	Diode Mixers – Single Ended and Balanced Mixer	1
5.7	Transistor Mixers, Applications of Mixers	1
6.	**Receiver Architectures**	
6.1	Heterodyne Receivers, Image Reject Receivers	1
6.2	Zero IF Receivers, Low IF Receivers	1
6.3	Issues in Direct Conversion Receivers, Architecture Comparison and Trade-off	1

Course Designers:

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18CN130	WIRELESS CELLULAR NETWORKS	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

The objective of this course is to introduce the students with a comprehensive understanding of current and 5G wireless communication systems like LTE, LTE-A, SDN, CRAN, Massive MIMO, D2D, mathematical models, requirements, issues and performance analysis of future wireless cellular networks.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	List and compare the performance of different channel models adopted in 5G wireless systems.	Understand
CO2.	Determine the performance of channel parameter extraction algorithms implemented in SDN.	Apply
CO3	Compute the statistical parameters of Cloud RAN.	Apply
CO4.	Analyze the performance of D2D according to the specific services.	Analyze
CO5.	Investigate the Expected Intercell Interference in Massive MIMO	Analyze
CO6.	Analyze the deployment strategies adopted in outdoor 5G	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	L	-	-	-	-	-	-	M	L	-	L
CO2	M	L	-	L	L	-	-	M	L	-	L
CO3	S	M	L	M	M	L	-	M	-	-	-
CO4	S	M	L	M	M	L	-	M	L	-	L
CO5	S	S	L	M	L	L	-	M	L	-	L
CO6	S	S	L	M	L	L	-	M	L	-	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	10	10	0	0
Understand	30	10	20	20
Apply	60	60	60	60
Analyse	0	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Determine the challenges posed by these 5G wireless systems?
2. Enlist the Ongoing 5G wireless channel measurement techniques?
3. Compare and contrast the five commonly used channel modeling methods?
4. Compare 1G, 2G, 2.5G, 3G, 3.5G, 4G, and 5G Technologies

Course Outcome 2 (CO2):

1. Compute the Channel Capacity of Multiuser MIMO System?
2. Illustrate the principles in DAS?
3. Select the channel parameter extraction algorithm suitable for mm Wave application scenarios?
4. Describe the architecture of LTE –A system?

5. Explain the key technology options adopted in Device-to-device (D2D) communications

Course Outcome 3 (CO3):

1. Analyze the Performance of macro cellular densification from outdoor and indoor receiver's perspective in terms of (a) Average network spectral efficiency and (b) network energy efficiency, versus cell density.
2. Examine the Performance of D2D in the proximity communication scenario?
3. Investigate how transport traffic from the small cell at the edge to the core of a mobile Network is managed by the mobile operators when planning small cells in HetNets.
4. Compare the performance of Different channel models incorporated in 5G wireless System?

Course Outcome 4 (CO4):

1. Analyze the Fronthaul-based C-RAN scenario for interference management in a multitier infrastructure network?
2. Estimate the signal-to-interference ratio (SIR) at the m^{th} receiver point (Γm) in single path multiple access (SPMA)?
3. Compute array factor for antenna elements arranged around a circular ring (UCA)and array factor for (ULA).

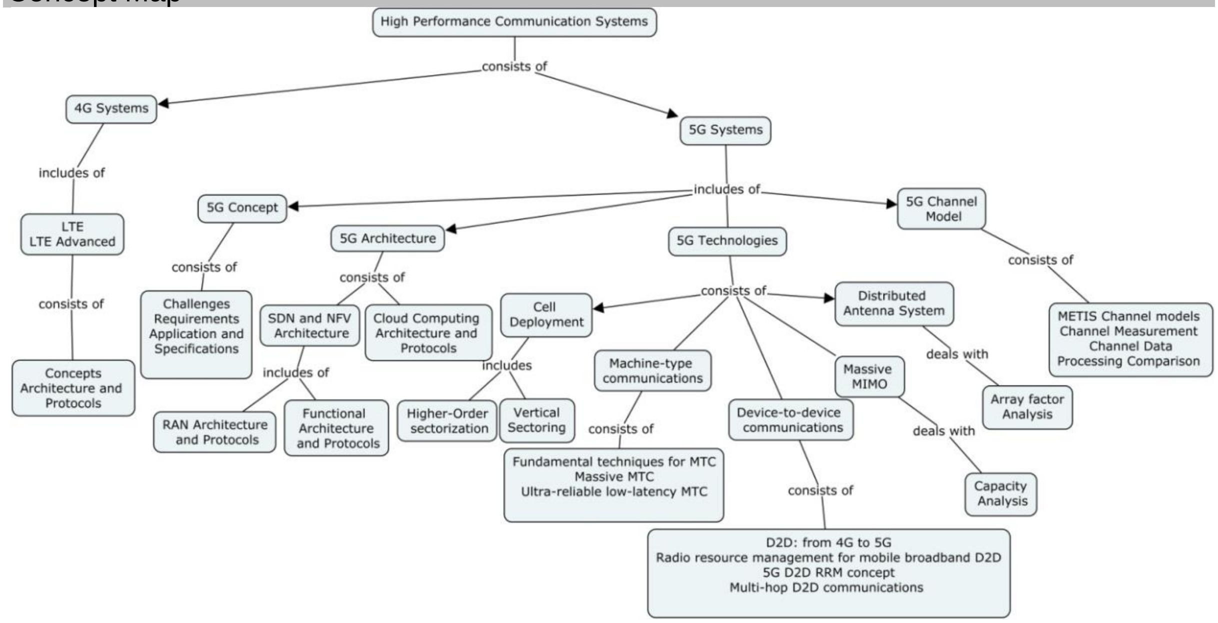
Course Outcome 5 (CO5):

1. Compare the traditional wide beam antenna and SPMA in terms of. (a) Cell coverage with traditional wide beam antenna and (b) demonstration of service provision with state-of-the-art needle beams?
2. Compute the Packet Error Loss Rate for M2M Services?
3. Investigate the software evaluation methods suitable for mm wave communication wireless scenario?

Course Outcome 6 (CO6):

1. Compare the performance of Mobile small cells with imperfect backhaul for ubiquitous high-speed data services on demand reference scenario for C-RAN along with one benchmark scenario?
2. Analyze the Performance of different deployment strategies for outdoor and indoor users in a suburban environment with different wall penetration losses and compute the following parameters. (a) Cell-edge coverage conditions, (b) cell-edge cell spectral efficiency, (c) average network area spectral efficiency, and (d) network energy efficiency?
3. Estimate the Noise Floor (Background Noise) Level and the Expected Intercell Interference of C-RAN?

Concept Map



Syllabus

4G Systems - LTE Overview, Architecture, Protocols of LTE and LTE-Advanced, **5G Systems: 5G Concept**- Challenges, Requirements, Applications and Specifications, **5G Architecture -** SDN and NFV Architecture, RAN architecture and Protocols, - Functional architecture and Protocols, Cloud-RAN, Cloud Computing architecture and Protocols, Narrow band IOT for 5G, **5G Technologies – Cell Deployment**: Higher-Order sectorization, Vertical Sectoring**, Machine Type Communication (MTC)**: Fundamental techniques for MTC, Massive MTC, Ultra-reliable low-latency MTC, **Device-to-device (D2D) communications:** D2D: from 4G to 5G, Radio resource management for mobile broadband D2D, 5G D2D RRM concept, Multi-hop D2D Communications for proximity and emergency Services, Performance of D2D communications in the proximity communications scenario, Multi-operator D2D communication, **Massive multiple-input multiple-output (MIMO) systems**: Introduction, Capacity Analysis, **Analysis of Distributed Antenna System, 5G Channel Model:** Modeling requirements and scenarios, Channel model requirements and Measurements, Propagation scenarios, METIS channel models, Map-based model , Stochastic model, Comparison of Models.

Reference Books

1. Afif Osseiran, Jose F, Monserrat and Patrick Marsch, “5G Mobile and Wireless Communications Technology”, Cambridge University Press June 2016.
2. Erik Dahlman, Stefan Parkvall and Johan Skold, 4G, LTE-Advanced Pro and The Road to 5G”, Academic Press 2016.
3. Vincent W. S. Wong, Robert Schober, Erlangen-Nürnberg, Derrick Wing Kwan Ng, Li-Chun Wang, “Key Technologies for 5G Wireless Systems”, Cambridge University Press 2017.
4. Fei Hu, “Opportunities in 5G Networks”, CRC press 2016.
5. Hrishikesh Venkatarman and Ramona Trestian, “5G Radio Access Networks:Centralized RAN, Cloud-RAN,and Virtualization of Small Cells”, CRC press 2017.
6. Yang Yang, Jing Xu, Guang Shi, Cheng-Xiang Wang, “5G Wireless Systems Simulation and Evaluation Techniques”, Springer International Publishing AG 2018.
7. Sassan Ahmadil, “LTE-Advanced: A Practical Systems Approach To Understanding 3gpp LTE Releases 10 And 11 Radio Access Technologies”, Academic Press 2013

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**4G Systems**	
1.1	LTE Overview, Architecture	2
1.2	Protocols of LTE and LTE-Advanced	3
2	**5G Concept**	
2.1	Challenges, Requirements, Applications and Specifications	2
3	**5G Architecture**	
3.1	SDN and NFV Architecture	3
3.2	RAN architecture and Protocols, Functional architecture and Protocols	3
3.3	Cloud Computing architecture and Protocols	3
4	**5G Technologies**	
4.1	**Cell Deployment**: Higher-Order sectorization, Vertical Sectoring	2
4.2	**Device-to-device (D2D) communications:** D2D: from 4G to 5G, Radio resource management for mobile broadband D2D, 5G D2D RRM concept	3
4.2.1	Multi-hop D2D Communications for proximity and emergency	2

	Services, Multi-operator D2D communication	
4.2.2	Performance of D2D communications in the proximity communications scenario	2
4.3	**Massive multiple-input multiple-output (MIMO) systems**: Introduction, Capacity Analysis,	3
4.4	**Analysis of Distributed Antenna System**	2
5	**5G Channel Model**	
5.1	Modeling requirements and scenarios, Channel model requirements and Measurements	2
5.2	Propagation scenarios, METIS channel models, Map-based model	2
5.3	Stochastic model, Comparison of Models,	2
Total		36

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18CN160	COMMUNICATION SYSTEM ENGINEERING

Category	L	T	P	Credit
PC	2	0	2	3

Preamble

The objective of this course concentrates on the techniques that are intended in designing communication system and determine their performances in terms of standard performance metrics.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Determine the performance of analog modulation schemes in the presence of additive white Gaussian noise.	Apply
CO2. Determine the capacity of AWGN channels	Apply
CO3. Characterization of baseband modulation transmitters and receivers and design of pulse shapes for band limited channels.	Apply
CO4. Analyze optimum receivers for demodulation and detection.	Analyze
CO5. Analyze the bit error rate performance of digital communication system in AWGN.	Analyze
CO6. Analyze the performance of different error control coding schemes for the reliable transmission of digital information over the channel.	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S	S	L	-	-	-	-	-	-	-
CO2.	S	S	S	L	-	-	-	-	-	-	-
CO3.	S	S	S	L	-	-	-	M	M	-	-
CO4.	S	M	M	M	-	L	-	M	M	M	-
CO5.	S	M	M	M	L	L	-	M	M	M	-
CO6.	S	M	M	M	L	M	L	M	M	M	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	0	0	20
Apply	80	60	60	40
Analyse	0	40	40	40
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. A Stationary Gaussian process, x(t) with zero mean and power spectral density, $S_x(f)$ is applied to a linear filter whose impulse response, $h(t)=\begin{cases}\frac{1}{T} & 0\le t\le T\\ 0 & elsewhere\end{cases}$. A sample, Y is taken of the random process at the filter output at time, T.
   (i) Determine the mean and variance of "Y"
   (ii) Find the Probability density function.

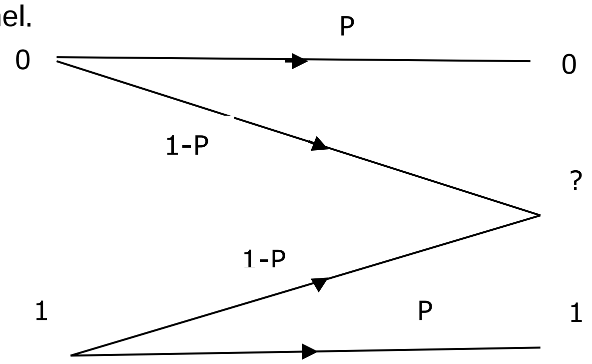
2. The signal applied to the non – linear device is relatively weak, such that it can be represented by a square law: $v_2(t) = a_1 v_1(t) + a_2 v_1^2(t)$, where a_1, a_2 are constants. $v_1(t)$ is the input voltage and $v_2(t)$ is the output voltage. The input voltage is defined by $v_1(t) = A_c.\cos(2\pi f_c t) + m(t)$, where m(t) is a message signal and $A_c.\cos(2\pi f_c t)$ is a carrier wave.
   - (i) Evaluate the output voltage $v_2(t)$.
   - (ii) Specify the frequency response that the tuned circuit must satisfy in order to generate an AM signal with f_c as the carrier frequency.
   - (iii) What is the amplitude sensitivity of this AM signal?
3. The single tone modulating signal, $m(t) = A_m.\cos(2\pi f_m t)$ is used to generate the VSB signal,

$$s(t) = (1/2).a.A_m.A_c.\cos[2\pi(f_c + f_m)t] + (1/2).A_m.A_c(1-a).\cos[2\pi(f_c - f_m)t],$$

where, ‘a’ is a constant, less than unity, representing the attenuation of the upper side frequency.
   - (a) Find the Quadrature component of the VSB signal s(t).
   - (b) The VSB signal, plus the carrier $A_c.\cos(2\pi f_c t)$, is passed through an envelope detector. Determine the distortion produced by the Quadrature component.
   - (c) What is the value of constant, ‘a’ for which this distortion reaches its worst possible condition.

Course Outcome 2 (CO2):

1. Prove that the upper bound on capacity, C_{max}= 1.44(S/N_o).
2. Show that the maximum differential entropy of a random variable which has Gaussian probability density function with zero mean and variance, σ^2 is h(X) = (1/2).$\log_2(2\pi e\,\sigma^2)$.
3. The binary erasure channel is described in the following figure. The inputs are labeled as “0” and “1” and the outputs are labeled as “0”,”1” and “?”. Find the capacity of the channel.



Course Outcome 3 (CO3):

1. Derive an expression for the power spectral density of the linearly modulated Signals with memory.
2. State and prove Nyquist Criterion for Distortionless Baseband transmission.
3. Derive an expression for power spectral density of linearly modulated signals without memory

Course Outcome 4 (CO4):

1. A binary digital communication system employs the signals

$$s_0(t) = -A, \quad 0 \le t \le T$$

$$s_1(t) = A, \quad 0 \le t \le T$$

for transmitting the information. This is called on-off signaling. The demodulator cross correlates the received signal $r(t)$ with $s(t)$ and samples the output of the correlator at t+T. Design an optimum detector for an AWGN channel and the optimum threshold, assuming that the signals are equally probable.

2. A BPSK signal is applied to a correlation demodulator supplied with a phase reference that lies within ϕ radians of the exact carrier phase. Determine the effect of the phase error ϕ on the average probability of error of the system.
3. Two quadrature carriers $\cos(2\pi f_c t)$ and $\sin(2\pi f_c t)$ are used to transmit digital information through an AWGN channel at two different data rates, 10kbits/s and 100kbits/s. Determine the relative amplitudes of the signals for the two carriers so that the Signal to Noise Ratio (SNR) for the two channels is identical.

Course Outcome 5 (CO5):

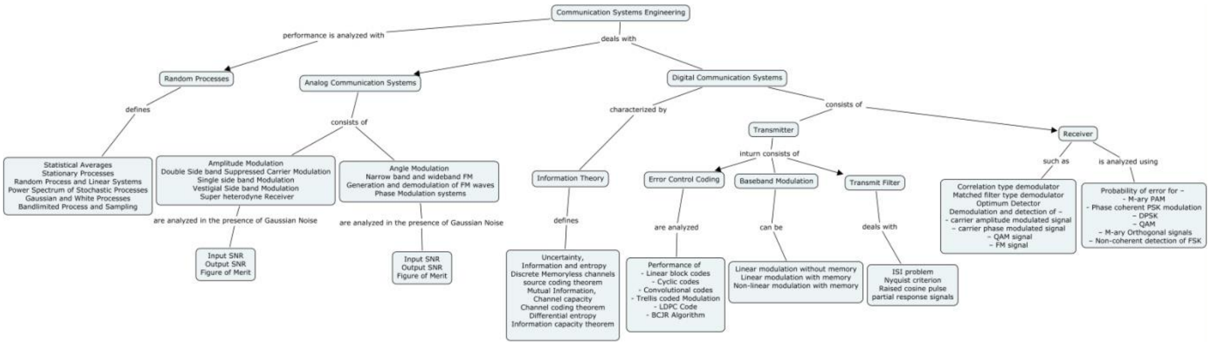
1. Derive the probability of error expression for (a) Phase coherent Binary PSK modulation (b) M'ary PAM modulation schemes.
2. (a) A Satellite in synchronous orbit is used to communicate with an earth station at a distance of 40,000 kM. The satellite with a gain of 15 dB under transmitter power of 3W. The earth station uses 10m parabolic antenna with an efficiency of 0.6. The received band is at f = 10GHz. Determine the received power level at the output of the receiver antenna

   (b). Derive an expression for the probability of error of PSK system.
3. A binary antipodal signal is transmitted over a nonideal bandlimited channel which introduces ISI over two adjacent symbols. For an isolated transmitted signal pulse s(t), the noise free output of the demodulator is $\sqrt{E_b}$ at $t = T$, $\sqrt{E_b}/4$ at $t = 2T$ and zero for $t = kT, k > 2$, where E_b is the signal energy and T is the signaling interval. Determine the average probability of error, assuming that the two signals are equally probable and additive noise is white and Gaussian.

Course Outcome 6 (CO6):

1. Consider a (7,4) cyclic code with generator polynomial $g(X) = 1 + X^2 + X^3$.
   (i) Draw the encoder and syndrome calculator
   (ii) Obtain the code words for the messages a.1101 b. 1011
   (iii) Calculate the syndrome calculator output when the codeword of the message 1101 is applied a. With out erro b. the least significant bit (LSB) is in error.
2. Find the transfer function of a rate ½ , constraint length 3, Convolutional encoder with generator sequences $g^{(1)}$ = (1,0,1), $g^{(2)}$ = (1,1,0) and $g^{(3)}$ = (1,1,1).
3. A sequence detector of 3 symbols a_o, a_1, a_2, from the binary alphabet [+1,-1] with apriori probabilities satisfying $P_{AO}(1)$ = 2.$P_{A1}(1)$=(1/2) is transmitted across an ISI channel With transfer function H(Z) = $(1-Z^{-1})$. Use the BCJR algorithm to find the aposteriori log – likelihood ratio $\lambda_0, \lambda_1, \lambda_2,$ when the observation after an AWGN channel with real variance σ^2=0.5 is Y=[Y_0, Y_1, Y_2, Y_3]=[1, 0, -1, 0]. Assume that the ideal symbol is -1 and that the state is constrained to be idle at times k=0 and k=3.

Concept Map



Syllabus

Random Processes: Statistical Averages, Stationary Processes, Random Process and linear systems, Power Spectrum of stochastic process, Gaussian and white processes, Bandlimited Processes and Sampling. **Analog Communication Systems:** Amplitude Modulation, Double Side band Suppressed Carrier Modulation, Single side band Modulation, Vestigial Side band Modulation, Super heterodyne Receiver, Frequency Division Multiplexing, Angle Modulation Systems: Narrow band and wideband FM, Generation and demodulation of FM waves, Phase Modulation systems, Noise Analysis.
Information Theory: Uncertainty, Information and entropy, source coding theorem, Discrete Memoryless channels, Mutual Information, Channel capacity, Channel coding theorem, Differential entropy, Information capacity theorem. **Baseband Modulation:** Linear modulation with memory and without memory, Non-linear modulation with memory. **Transmit Filter:** Inter Symbol Interference problem, Nyquist criterion, Raised cosine pulse, partial response signals. **Optimum Receiver with AWGN:** Correlation type demodulator, Matched filter type demodulator, Optimum detector, Demodulation and detection of – carrier amplitude modulated signal – carrier phase modulated signal – QAM signal – FM signal. **Probability of error for signal detection in AWGN:** Probability of error for – M-ary PAM – phase coherent PSK modulation – DPSK – QAM – M-ary Orthogonal signals – Non-coherent detection of FSK. **Performance of Error control coding:** Linear block codes, cyclic codes, convolutional codes, Trellis coded Modulation, LDPC Code, BCJR Algorithm.

List of Experiments:

1. Simulation of standard discrete time signals
2. Generation of Random Samples and correlated Random Samples
3. Source Coding Techniques
    a. Huffman Coding
    b. Lempel-Ziv Algorithm
4. Error Control Coding (Linear Block Code, Cyclic Code, Convolutional Code)
5. Generation and detection of binary digital modulation techniques
6. BER performance Analysis of Binary digital Modulation Techniques in AWGN Environment (Binary Phase Shift Keying, Amplitude Shift Keying, Frequency Shift Keying)
7. Scrambler and Descrambler
8. Generation of Minimum Shift Keying Signal

Reference Books

1. John G.Proakis, Masoud Salchi “Communication Systems Engineering”, Prentice Hall 2nd edition, 2002.
2. Simon Haykin and Michael Moher, “Communication systems” John Wiley & Sons, Fifth Edition, 2016

3. John G. Proakis: “Digital Communications”, McGraw Hill International Edition, Fourth Edition, 2001.
4. John R Barry, Edward Lee and David G. Messerschmitt: “Digital Communication”, 3rd Edition. Springer, 2003.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Random Processes:**	
1.1	Statistical Averages, Stationary Processes	1
1.2	Random Process and linear systems – Power Spectrum of stochastic process, Gaussian and white processes – Bandlimited Processes and Sampling	1
2	**Analog Communication Systems:**	
2.1	Amplitude Modulation – Double Side band Suppressed Carrier Modulation, Single side band Modulation, Vestigial Side band Modulation.	1
2.2	Angle Modulation Systems - Narrow band and wideband FM, Generation and demodulation of FM waves, Phase Modulation systems.	1
2.3	Noise Analysis – AM-DSBFC, AM-DSBSC and FM	1
3	**Information Theory:**	
3.1	Uncertainty, Information and entropy	1
3.2	Discrete Memoryless channels, source coding theorem	1
3.3	Mutual Information, Channel capacity, Channel coding theorem	1
3.4	Differential entropy- Information capacity theorem	1
4	**Baseband Modulation:**	
4.1	Linear modulation with memory, and without memory	1
4.2	Non-linear modulation with memory	1
5	**Transmit Filter:**	
5.1	Inter Symbol Interference problem – Nyquist criterion	1
5.2	Raised cosine pulse - partial response signals	1
6	**Optimum Receiver with AWGN:**	
6.1	Correlation type demodulator	1
6.2	Matched filter type demodulator, Optimum detector	1
6.3	Demodulation and detection of – carrier amplitude modulated signal	1
6.4	Demodulation and detection of – carrier phase modulated signal	1
6.5	Demodulation and detection of – QAM signal, FM signal	1
7	**Probability of error for signal detection in AWGN:**	
7.1	Probability of error for – M-ary PAM, phase coherent PSK modulation	1
7.2	Probability of error for – DPSK, QAM	1
7.3	Probability of error for – M-ary Orthogonal signals	1
7.4	Probability of error for – Non-coherent detection of FSK.	1
8	**Performance of Error control coding:**	
8.1	convolutional codes, LDPC Code	1
8.2	BCJR Algorithm	1
	Total	24

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18CN170	RF CIRCUITS LABORATORY

Category	L	T	P	Credit
PC	0	0	4	2

Preamble

The unprecedented success of wireless communications created an unexpected demand for RF/Microwave communications engineers. This laboratory course aims to provide technological skills needed in the field of modern RF circuit design. This course focuses on the design, simulation, characterization and testing of RF Passive circuits.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1.Design and Test the matching network, low pass filter and power divider for different wireless air interface standards	Apply
CO2. Perform the RF signal measurements	Apply
CO3. Design and validate LNA for the given application	Apply
CO4. Design and validate down-converter for the given application	Apply
CO5.Customize the RFID application based on requirements of the retailer	Apply
CO6. Fabricate and Test the RF passive devices	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	L	L	S	-	-	-	L	-	-
CO2	S	M	L	L	S	-	-	-	L	-	-
CO3	S	M	L	L	S	-	-	-	L	-	-
CO4	S	M	L	L	S	-	-	-	L	-	-
CO5	S	M	L	L	S	-	-	-	L	-	-
CO6	S	M	L	L	-	-	L	-	L	-	-

S- Strong; M-Medium; L-Low

List of experiments

1. Design and Testing of matching networks for ISM band.
2. Design and Testing of LC low pass filter for ISM band.
3. Design and Testing of Power Divider (1X4) and (4X4) for ISM band.
4. RF signal measurements – Channel power, SNR, Phase measurement of WLAN radio.
5. Design, Simulation and Validation of LNA for GPS applications.
6. Design and Validation of Down-Converter module for Radar receiver.
7. RFID customization for retailer applications.
8. Fabrication of RF passive devices.

Course Designers:

1. Dr.S.Kanthamani skmece@tce.edu
2. Dr.K.Vasudevan kvasudevan@tce.edu

18CN210	BASEBAND WIRELESS COMMUNICATION SYSTEMS	Category	L	T	P	Credit
		PC	2	1	0	3

Preamble

The course "18CN210: Baseband Wireless Communication systems" is offered in the second semester in continuation with the course on "Communication system engineering". The objective of this course is to present the techniques in the physical layer aspects of Baseband wireless communication systems and determine the performance of Wireless systems in terms of capacity and probability of error.

Prerequisite

18CN160 Communications Systems Engineering

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Apply suitable receiver structure (MLSE, Equalizer and Adaptive Equalizer) for ISI free transmission in wireline channels.	Apply
CO2	Characterize wireless fading channels in terms of small and large scale fading models.	Analyze
CO3	Analyze BER of wireless communication system with and without diversity.	Analyze
CO4	Analyze the capacity of SISO, SIMO, MISO and MIMO wireless communication systems.	Analyze
CO5	Apply OFDM technique for transmission through frequency selective channel.	Apply
CO6	Develop mathematical model in multiple access scheme for multiuser systems.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	M	M	L	-	-	-	L	-	-
CO2	S	M	S	M	M	-	-	-	L	-	-
CO3	S	M	S	M	M	-	-	-	L	-	-
CO4	S	M	S	M	M	-	-	-	L	-	-
CO5	S	M	S	M	M	-	-	-	L	-	-
CO6	S	M	S	M	M	-	-	-	L	-	-

S- Strong; M-Medium; L-Low

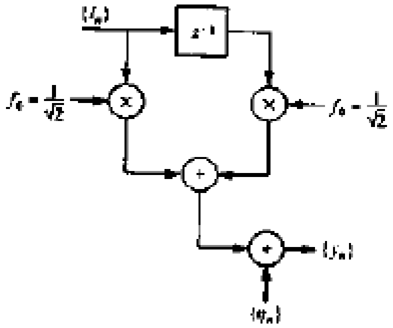
Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	10	0	0	0
Understand	10	20	10	10
Apply	60	60	60	60
Analyse	20	20	30	30
Evaluate	0	0	0	0
Create	0	0	0	0

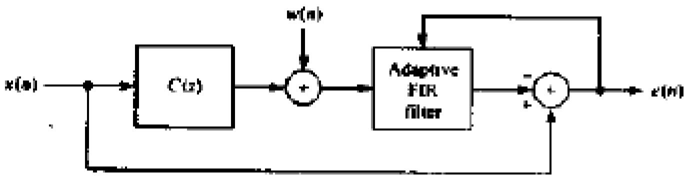
Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Compare the use of LMS and RLS algorithm in adaptive equalization.
2. Consider a discrete time equivalent channel shown in figure1. The information sequence $\{I_k\}$ is binary $\{\pm 1\}$ and uncorrelated. The additive noise is white and real valued with variance 0.1. The received sequence is processed by a linear three tap equalizer on the



basis of MSE criterion
   a. Determine the optimum coefficients of the equalizer
   b. Determine the minimum MSE and output SNR of the three tap equalizer.
   c. Suppose the channel is equalized by a DFE having a two tap feedforward filter and one tap feedback filter, on the basis of MSE criterion, determine the optimum coefficients and output SNR
3. Consider the adaptive FIR filter as shown in figure. The system $C(z)$ is characterized by the system function $C(z) = \dfrac{1}{1-0.9z^{-1}}$. Determine the optimum coefficients of the adaptive transversal FIR filter ($B(z) = b_0 + b_1 z^{-1}$) that minimize the mean square error. The additive noise is white with variance of 0.1.



Course Outcome 2 (CO2):

1. Determine the maximum spectral frequencies received from a stationary GSM transmitter that has a center frequency of exactly 1950.000000 MHz, assuming that the receiver is traveling at a speed of a. 100 km/hr, b. 5 km/hr.
2. A multipath fading channel has a multipath spread of $1m\sec$, the total channel bandwidth at bandpass available for signal transmission is 2kHz. Is the channel frequency selective?
3. Consider a channel with delay spread. The transmitted signal after scattering arrives at the receiver at two different delays τ_1 and τ_2. We assume that the channel is time-invariant. The baseband channel impulse response is given by $h(\tau) = \gamma_1\delta(t-\tau_1) + \gamma_2\delta(t-\tau_2)$, where γ_i (*i* = 1, 2) are the complex scatterer amplitudes of the scatterers located at delays τ_i (*i* = 1, 2) respectively. Further $E(\gamma_i) = 0$ with $E\left(|\gamma_i|^2\right) = 1$.
   a. Calculate the frequency response of the channel, *H*(*f*).
   b. Determine the coherence bandwidth of the channel for $\tau_1 = 1\mu s$ and $\tau_2 = 2\mu s$.

Course Outcome 3 (CO3):

1. Assume uncoded 4-QAM transmission over an i.i.d. Rayleigh flat fading MISO channel with $M_T = 4$.
   a. Derive a closed form BER expression over the channel assuming transmit-MRC.
   b. What is the corresponding upper-bound on symbol error rate for a SIMO channel with $M_R = 4$? Which channel (SIMO or MISO) performs better, why?
      The received signal model in wireless communication system is given by $y = hx + n$, where magnitude of h is Rayleigh distributed , x is a unit energy BPSK symbol and n is complex Gaussian noise with variance σ_n^2. Derive the probability of occurrence for deep fade event.
2. The received signal model in wireless communication system is given by $y = hx + n$, where magnitude of h is Rayleigh distributed , x is a unit energy BPSK symbol and n is complex Gaussian noise with variance σ_n^2. Derive the probability of occurrence for deep fade event.
3. Derive the bit error rate analysis of MISO system when channel state information is unknown in the system and also mention the array and diversity gain of the system.

Course Outcome 4 (CO4):

1. Consider a SIMO system with L receive antennas. Independent complex Gaussian noise with variance N_0 corrupts the signal at receive antenna. The transmit signal has a power constraint of P. Compute the capacity of this system, assuming that the gain between the transmit antenna and each of the receive antenna is 1.
2. Derive an expression for the capacity of the following systems
   a. SIMO system assuming that the channel is known at Receiver
   b. MISO system assuming that the channel is known at transmitter
   c. MISO system assuming that channel is unknown at the transmitter
3. Draw the capacity regions for MIMO Multi Access Channel (MAC) with joint decoding.

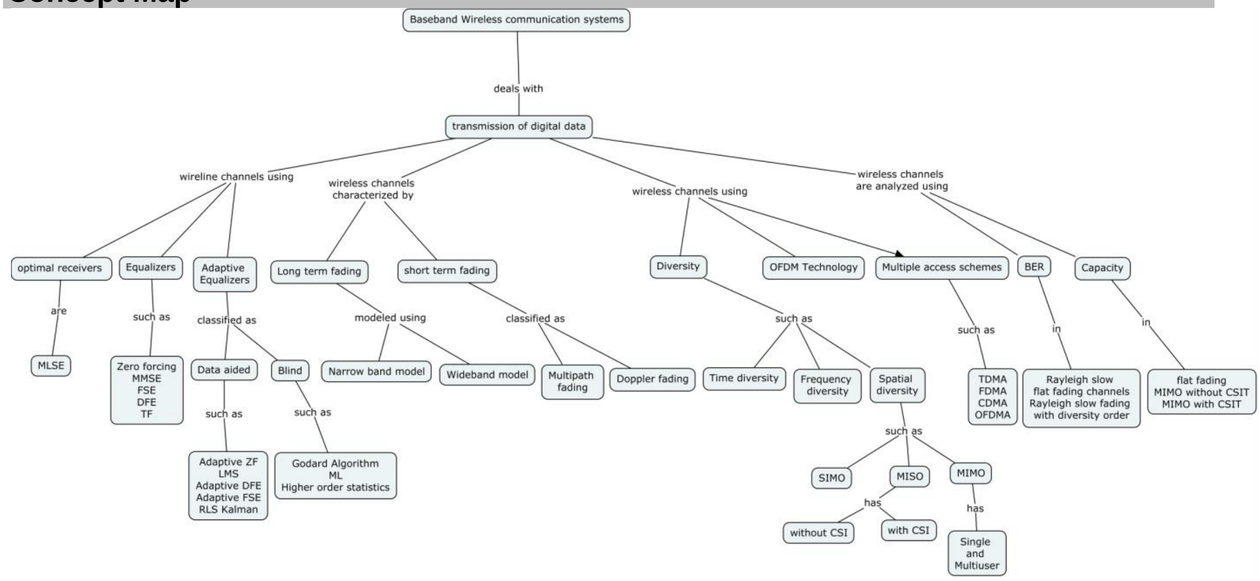
Course Outcome 5 (CO5):

1. Prove that the OFDM system converts the delay spread channel into a set of parallel fading channels, using the concept of cyclic prefix.
2. It is known that OFDM system converts a frequency selective fading channel into a set of parallel flat fading channel. Justify this statement with the assumption that the data $\tilde{s} = [1, -1, 1, -1]$ is to be transmitted through a frequency selective fading channel $g = [0.5, 0.25]$.
3. What is meant by Carrier Frequency offset in OFDM?

Course Outcome 6 (CO6):

1. A total of 30 equal power users are to share a common communication channel by CDMA. Each user transmits information at a rate of 10kbits/s via DSSS and binary PSK. Determine the minimum chip rate to obtain the bit error probability of 10^{-6}.
2. Distinguish between Cochannel Interference (CCI) characteristics for TDMA and CDMA systems.
3. Compare OFDMA and SC-FDMA Modulation schemes used in LTE Standards.

Concept Map



Syllabus

Wireline channels: Optimal receivers: Maximum Likelihood Sequence Estimation **Equalizers:** Zero forcing, Minimum Mean Square Error, Fractionally spaced Equalizer, Decision Feedback Equalizer, TF **Adaptive Equalizers:** Data aided: Adaptive ZF,LMS, Adaptive LMS, Adaptive FSE,RLS, Kalman Blind: Godard Algorithm, ML, Higher order statistics **Wireless channels:** Diversity:Time diversity,Frequency diversity, Spatial Diversity: SIMO,MISO,MIMO, single user and Multi user **OFDM Technology:**Multicarrier communications **Multiple Access schemes:** TDMA,FDMA,CDMA,OFDMA **Bit Error Rate Analysis:** Rayleigh slow flat fading channels, Rayleigh slow fading with diversity order **Capacity Analysis:** flat fading, MIMO without CSIT, MIMO with CSIT

Reference Books

1. John G Proakis, Masoud Salehi," Digital Communications", Fifth Edition, Mc Grawhill Education,2007
2. Andrea Goldsmith, " Wireless Communications", Cambridge University Press, 2005
3. Theddore S.Rappaport, " Wreless Communications: Principles and Practice", Second Edition, PHI,2006
4. David Tse and Pramod Viswanath, "Fundamentals of Wireless Communications", Cambridge University Press, 2005 (First Asian Edition, 2006)
5. A. Paulraj, R. Nabar and D Gore, "Introduction to Space-Time Wireless Communications", Cambridge University Press, 2003.
6. Andreas F.Molisch, " Wireless Communications", Second Edition, John Wiley and sons Limited, 2011.

Course Contents and Lecture Schedule

S.No	Topic	No. of Lectures
1.	**Wireline Channels**	
1.1	Optimal receivers: Maximum Likelihood Sequence Estimation	2
2	**Equalizers**	
2.1	Zero forcing	2
2.2	Minimum Mean Square Error	1
2.3	Fractionally spaced Equalizer	1

2.4	Decision Feedback Equalizer	2
2.5	TF	2
3	**Adaptive Equalizers**	
3.1	Data aided: Adaptive ZF	1
3.2	LMS	1
3.3	Adaptive LMS	1
3.4	Adaptive FSE	1
3.5	RLS	1
3.6	Kalman	3
3.7	Blind: Godard Algorithm	1
3.8	ML	1
3.9	Higher order statistics	1
4	**Wireless channels**	
4.1	Diversity:Time diversity	1
4.2	Frequency diversity	1
4.3	Spatial Diversity	1
4.4	SIMO	1
4.5	MISO	1
4.6	MIMO	2
4.7	single user and Multi user	1
5	**OFDM Technology**	
5.1	Multicarrier Modulation	2
6	**Multiple Access schemes**	
6.1	TDMA	1
6.2	FDMA	1
6.3	CDMA	1
6.4	OFDMA	2
7	**Bit Error Rate Analysis**	
7.1	Rayleigh slow flat fading channels,	2
7.2	Rayleigh slow fading with diversity order	2
8	**Capacity Analysis**	
8.1	flat fading	2
8.2	MIMO without CSIT	2
8.3	MIMO with CSIT	2
Total		46

Course Designers:

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3.	Dr.G.Ananthi	gananthi@tce.edu

18PG250	RESEARCH METHODOLOGY AND IPR	Category	L	T	P	Credit
		CC	2	0	0	2

Preamble

The course on the Research Methodology and IPR is offered as common Core course. The objective of this course is to understand and analyze Research Methodology and IPR protection.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

1. Understand research problem formulation.
2. Analyze research related information
3. Follow research ethics
4. Understand that today's world is controlled by Computer, Information Technology, but tomorrow world will be ruled by ideas, concept, and creativity.
5. Understanding that when IPR would take such important place in growth of individuals & nation, it is needless to emphasis the need of information about Intellectual Property Right to be promoted among students in general & engineering in particular.
6. Understand that IPR protection provides an incentive to inventors for further research work and investment in R&D, which leads to creation of new and better products, and in turn brings about, economic growth and social benefits.

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	20	20	20	20
Understand	40	40	40	40
Apply	40	40	40	40
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Syllabus

Module 1: Meaning of research problem, Sources of research problem, Criteria, Characteristics of a good research problem, Errors in selecting a research problem, Scope and objectives of research problem, Approaches of investigation of solutions for research problem, data collection, analysis, interpretation, Necessary instrumentations

Module 2: Effective literature studies approaches, analysis Plagiarism, Research ethics

Module 3: Effective technical writing, how to write report, Paper Developing a Research Proposal, Format of research proposal, a presentation and assessment by a review committee

Module 4: Nature of Intellectual Property: Patents, Designs, Trade and Copyright, Process of Patenting and Development: technological research, innovation, patenting, development. International Scenario: International cooperation on Intellectual Property. Procedure for grants of patents, Patenting under PCT.

Module 5: Patent Rights: Scope of Patent Rights. Licensing and transfer of technology. Patent information and databases. Geographical Indications.

Module 6: New Developments in IPR: Administration of Patent System. New developments in IPR; IPR of Biological Systems, Computer Software etc. Traditional knowledge Case Studies, IPR and IITs

Reference Books

1. Stuart Melville and Wayne Goddard, "Research methodology: an introduction for science & engineering students'" 2nd Edition,
2. "Research Methodology: A Step by Step Guide for beginners"
3. Halbert, "Resisting Intellectual Property", Taylor & Francis Ltd ,2007.
4. Mayall, "Industrial Design", McGraw Hill, 1992.
5. Niebel, "Product Design", McGraw Hill, 1974.
6. Asimov, "Introduction to Design", Prentice Hall, 1962.
7. Robert P. Merges, Peter S. Menell, Mark A. Lemley, " Intellectual Property in New Technological Age", 2016.
8. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008

Course Designers:

1. Adapted from AICTE Model Curriculum for Postgraduate Degree Courses in Engineering & Technology, Volume-I, January 2018.

18CN260	RF FRONTEND SYSTEMS	Category	L	T	P	Credit
		PC	2	0	2	3

Preamble

The research and developments in the area of RF and microwave technologies have progressed significantly In recent years due to the growing demand for applicability in wireless communication technologies. In the modern era of electronic developments, design of wireless handsets is an example of integration of many diverse skill sets. This course presents overview of receiver architectures, types and RF front end design. This course also presents characterization and testing of RF front end modules, integration and its applications such as Cellular and RADAR communication systems.

Prerequisite

18CN120 RF Circuits for communication systems

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Explain the general structure of a wireless receiver, its operation and parameters	Understand
CO2. Explain different receiver architectures and design issues involved	Apply
CO3. Design, integrate RF modules and characterize with test procedure	Apply
CO4. Design the antennas for the given specification and applications & obtain parameters	Apply
CO5. Test and evaluate the characteristics of RF front end modules	Evaluate

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
1.	S	M	M	-	-	-	-	-	-	-	-
2.	S	M	M	M	-	-	-	-	-	-	-
3.	M	M	S	S	M	L	-	M	L	L	L
4.	M	M	M	M	S	L	-	M	L	L	L
5.	M	M	M	M	M	M	-	M	M	L	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	20	20	20
Apply	80	80	80	80
Analyze	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What are the basic components of receiver front-end?
2.What is needed in the receiver front-end?
3. Draw the block diagram of simple receiver.
4.What is meant by LO leakage?

5.What is needed in the receiver front-end?

Course Outcome 2 (CO2):

1. Consider a 50Ω cable, LNA and another amplifier are cascaded together. Their gain and Noise figures are G1= -3dB, NF1= 3dB; G2= -20dB, NF2= 1.5dB; G3=13dB, NF3= 4dB. Compute the overall noise figure.

2. An RF input signal at 900MHz is down- converted in a mixer to an IF frequency of 80MHz. What are the two possible LO frequencies, and the corresponding image frequencies?

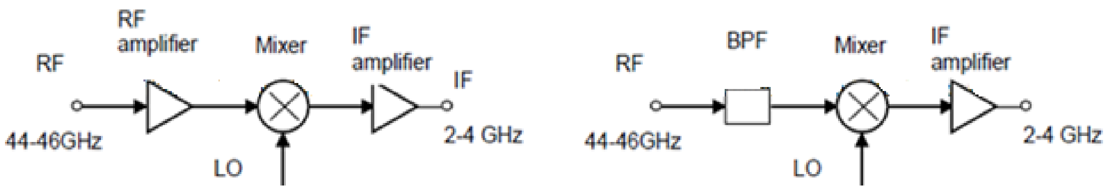
3.A double sideband signal of the form $V_{RF}(t) = V_{RF}[\cos(\omega_{Lo} - \omega_{IF})\,t + \cos(\omega_{Lo} + \omega_{IF})\,t]$ is applied to a mixer an voltage $v_{Lo}(t) = V_{Lo}\,cos\omega_{Lo}t$. Derive the output of the mixer after low pass filtering.

4.Compare the performance of different receivers.

5.What are the impact of noise in the down conversion receiver

Course Outcome 3 (CO3):

1. An amplifier uses a transistor having the following s parameters ($Z_o = 50\Omega$):
   $S_{11} = 0.61\angle -170^o$, $S_{12} = 0.06\angle 70^o$, $S_{21} = 2.3\angle 80^o$, $S_{22} = 0.72\angle -25^o$. The input of the transistor is connected to a source with $V_s = 2V(peak)$ and $Z_s = 25\Omega$ and then output of the transistor is connected to a load of $Z_L = 100\Omega$. What is the power gain, the available power gain, the transducer power gain and the unilateral transducer power gain.
2. A GaAs FET has the following scattering and noise parameters at 6GHz($Z_o = 50\Omega$):
   $S_{11} = 0.61\angle -60^o, S_{12} = 0^o$, $S_{21} = 2.0\angle 81^o$, $S_{22} = 0.72\angle -60^o$, $F_{min} = 2dB$, $\Gamma_{out} = 0.62\angle 100^o$ and $R_N = 20\Omega$. Design an amplifier to have a gain of 6dB and the minimum noise figure possible with this gain. Use open shunt stubs in the matching sections.
3. Two satellite receiver systems have the following specifications for their components:
   RF Amplifier :F=5dB, G=10Db; Mixer:$L_c = 5dB$; IF Amplifier=2dB, G=15 dB;
   Bandpass filter:$I_L = 2dB$
   Compare the two systems in terms of overall gain and noise values.



Course Outcome 4 (CO4):

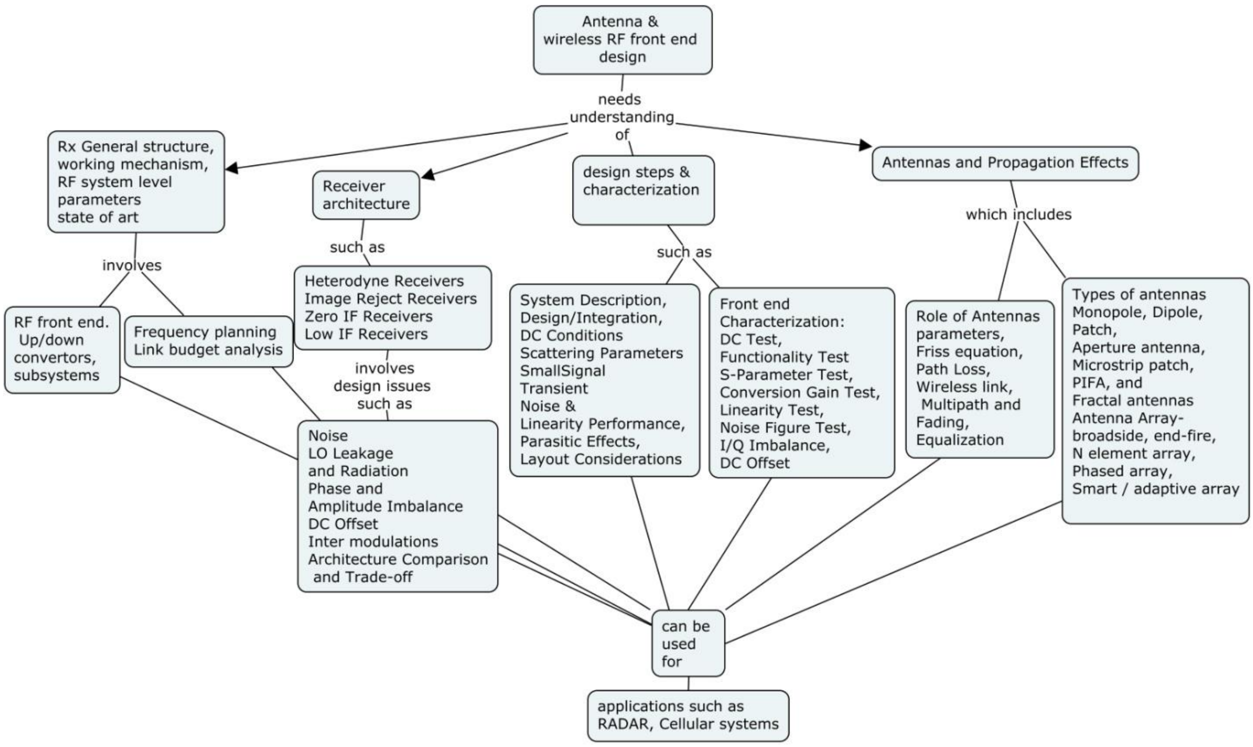
1. Design and develop a wide band antenna suitable for blue tooth communication with the substrate having Dielectric constant 4.6, thickness - 0.3 mm.
2. Design a 4 element array of λ/2 spacing between elements. The radiation pattern is to have maximum in the direction perpendicular to the array axis.
3. Design a compact microstrip antenna resonating at the frequency of 2.4GHz
4. Design a planar inverted F antenna operating in Cellular GSM lower band
5. Design of patch antenna on a multilayer substrate having effective dielectric constant of 5.5 and 2.2

Course Outcome 5 (CO5):

1. Why microstrip antennas are preferred for space applications?

2. What wireless antenna can be used to cover a small campus area of a few buildings?
3. Evaluate the performance of PC card antenna and INF antenna in a laptop prototype.
4. Explain the Significance Of Noise And Dynamic Range In The Radar Design?
5. Test and evaluate the performance of a given up down convertor.

Concept Map



Syllabus

Wireless System: General Architecture, RF front end, Up/Down Convertors, Working mechanism, RF subsystems and operation.

RF system level parameters: Frequency Planning: Blockers, Spurs and Desensing, Transmitter Leakage, LO Leakage and Interference, Image, Half IF, Linearity, Noise, Signal-to-Noise Ratio, Receiver Gain

RF Receiver Architectures: Heterodyne Receivers, Image Reject Receivers, Zero IF Receivers, Low IF Receivers, Issues in Direct Conversion Receivers, Noise, LO Leakage and Radiation, Phase and Amplitude Imbalance, DC Offset, Inter modulations, Architecture Comparison and Trade-off

RF front end Design and Characterization:

System Description and Calculations, Design and Integration of Building Blocks, DC Conditions Scattering Parameters, Small-Signal Performance, Transient Performance, Noise Performance, Linearity Performance, Parasitic Effects, Process Variation, Layout Considerations, Front end Characterization**:** DC Test, Functionality Test, S-Parameter Test, Conversion Gain Test, Linearity Test, Noise Figure Test, I/Q Imbalance, DC Offset

Antennas and Propagation Effects: Role of Antennas in RF front ends, Antenna parameters, Friss equation, Path Loss, Wireless link, Multipath and Fading, Equalization Types of antennas: Monopole, Dipole, Patch, Aperture antenna, PIFA, and Fractal antennas Antenna Array- broadside, end-fire, N element array, Phased array, Smart array

Applications: Radar range Equation, Radar system: block diagram, FMCW radar, Millimeter wave radar, GSM /CDMA System Architecture, Wireless link, Link budget and power Calculations

List of Laboratory Experiments:

Testing and evaluation of

1. Receiver characteristics such as conversion gain, linearity and noise figure
2. Characterization of RF building blocks
3. Characteristics of up/down convertors
4. Radiation characteristics of antenna
5. Range of wireless link and budget

Reference Books

1.Joy Laskar, Babak Matinpour,Sudipto Chakraborty, Modern Receiver Front-ends- systems, design and integration, a john wiley & sons, inc., publication, 2004
2.David M Pozar: Microwave and RF design of WIreless systems, John Wiley and Sons, 2001.
3.Les Besser and Rowan Gilmore, " Practical RF Circuit Design for Modern Wireless Systems- Passive Circuits and Systems", Vol.1, Artech house Publishers, Boston, London 2008.
4.Matthew M Radmanesh," Radio frequency and Microwave Electronics illustrated", Pearson Education Asia 2001.
5. Laboratory manual on “RF system design and testing” I

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Wireless System**	
1.1	**Wireless System**: General Architecture, RF front end	2
1.2	Up/Down Convertors, Working mechanism	1
1.3	RF subsystems and operation	1
1.4	RF system level parameters	1
1.5	Frequency Planning:	1
1.6	Blockers, Spurs and Desensing	1
1.7	Transmitter Leakage, LO Leakage and Interference, Image, Half IF	2
1.8	Linearity, Noise	1
1.9	Signal-to-Noise Ratio, Receiver Gain	2
2	**RF Receiver Architectures**:	
2.1	Heterodyne Receivers, Image Reject Receivers	1
2.2	Zero IF Receivers, Low IF Receivers	2
2.3	Issues in Direct Conversion Receivers, Noise	2
2.4	LO Leakage and Radiation, Phase and Amplitude Imbalance,	1
2.5	DC Offset, Inter modulations	1
2.6	Architecture Comparison and Trade-off	
3	**RF front end Design and Characterization:**	
3.1	System Description and Calculations	2
3.2	Design and Integration of Building Blocks,	2
3.3	DC Conditions Scattering Parameters	1
3.4	Small-Signal Performance, Transient Performance,	2
3.5	Noise Performance, Linearity Performance, Parasitic Effects,	2
3.6	Process Variation, Layout Considerations,	1
3.7	Front end Characterization**:** DC Test, Functionality Test, S-Parameter Test,	2
3.8	Conversion Gain Test, Linearity Test, Noise Figure Test, I/Q Imbalance, DC Offset	2

4	**Antennas and Propagation Effects:**	
4.1	Role of Antennas in RF front ends, Antenna parameters,	2
4.2	Friss equation, Path Loss, multipath and Fading, Equalization	2
4.3	Types of antennas: Monopole, Dipole, Patch, Aperture antenna, , Planar Inverted F antenna (PIFA), and Fractal antennas	4
5	**Applications:**	
5.1	Radar range Equation, Radar system: block diagram,	1
5.2	FMCW radar, Millimeter wave radar	2
5.3	GSM /CDMA System Architecture	2
5.4	Wireless link, Link budget and power Calculations	2

Course Designers:

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18CN270	BASEBAND COMMUNICATIONS LABORATORY	Category	L	T	P	Credit
		PC	0	0	4	2

Preamble

This laboratory supplements the theory cum practical course (18CN160 Communication System Engineering) assist the students in obtaining a better understanding of the operation of different modules of baseband communication systems and to provide experience in analyzing and test of baseband communication systems using simulation software as well as lab instruments

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Generate standard discrete time signals, correlated and uncorrelated random processes	Apply
CO2	Simulate the source coding and channel coding techniques	Apply
CO3	Simulate the BER performance of Binary digital modulation techniques in AWGN channel	Apply
CO4	Design, construct and test a scrambler and descrambler with given polynomial	Apply
CO5	Simulate BER performance of digital modulation schemes in Rayleigh flat channels in SISO, SIMO, MISO and MIMO wireless communication systems.	Analyze
CO6	Analyze outage capacity of Rayleigh flat fading channel without and with diversity using simulation.	Analyze
CO7	Determine BER of BPSK scheme using USRP	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	L	-	-	-	-	L	-	-	-
CO2	S	M	L	-	-	-	-	L	-	-	-
CO3	S	M	-	-	L	-	-	L	-	-	-
CO4	S	S	M	-	L	-	-	L	-	-	-
CO5	S	S	-	-	L	-	-	L	-	-	-
CO6	S	S	L	-	L	-	-	L	-	-	-
CO7	S	M	-	-	M	-	-	L	-	-	-

S- Strong; M-Medium; L-Low

List of Experiments

1. Simulation of standard discrete time signals
2. Generation of Random Samples and correlated Random Samples
3. Source Coding Techniques
   a. Huffman Coding
   b. Lempel-Ziv Algorithm
4. Error Control Coding (Linear Block Code, Cyclic Code, Convolutional Code)
5. Generation and detection of binary digital modulation techniques
6. BER performance Analysis of Binary digital Modulation Techniques in AWGN Environment (Binary Phase Shift Keying, Amplitude Shift Keying, Frequency Shift Keying)
7. Scrambler and Descrambler
8. Generation of Minimum Shift Keying Signal
9. Simulation of BER performance of PSK in Rayleigh frequency flat, slow fading channels
10. Simulation of BER performance of PSK scheme in Rayleigh frequency flat, slow fading channels with L^{th} order receive diversity.
11. Simulation of BER performance of PSK scheme in Rayleigh frequency flat, slow fading channels with Transmit diversity
12. Simulation of BER performance of PSK scheme in 2x2 spatial multiplexing system in Rayleigh frequency flat, slow fading channels.
13. Outage capacity analysis of Rayleigh flat fading channel.
14. Outage capacity analysis of Rayleigh flat fading channel with L^{th} order diversity
15. Determine BER of PSK scheme using USRP.

Course Designers:

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18CN380/18CN480	DISSERTATION PHASE I / DISSERTATION PHASE II

Course Outcomes:

At the end of this course, students will be able to

- Ability to synthesize knowledge and skills previously gained and applied to an in-depth study and execution of new technical problem.
- Capable to select from different methodologies, methods and forms of analysis to produce a suitable research design, and justify their design.
- Ability to present the findings of their technical solution in a written report.
- Presenting the work in International/ National conference or reputed journals.

Syllabus Contents:

The dissertation / project topic should be selected / chosen to ensure the satisfaction of the urgent need to establish a direct link between education, national development and productivity and thus reduce the gap between the world of work and the world of study.
The dissertation should have the following

- Relevance to social needs of society
- Relevance to value addition to existing facilities in the institute
- Relevance to industry need
- Problems of national importance
- Research and development in various domain

The student should complete the following:

- Literature survey Problem Definition
- Motivation for study and Objectives
- Preliminary design / feasibility / modular approaches
- Implementation and Verification
- Report and presentation

The dissertation stage II is based on a report prepared by the students on dissertation allotted to them. It may be based on:

- Experimental verification / Proof of concept.
- Design, fabrication, testing of Communication System.
- The viva-voce examination will be based on the above report and work.

Guidelines for Dissertation Phase – I and II at M. Tech. (Electronics):

- As per the AICTE directives, the dissertation is a yearlong activity, to be carried out and evaluated in two phases i.e. Phase – I: July to December and Phase – II: January to June.

- The dissertation may be carried out preferably in-house i.e. department's laboratories and centers OR in industry allotted through department's T & P coordinator.

- After multiple interactions with guide and based on comprehensive literature survey, the student shall identify the domain and define dissertation objectives. The referred literature should preferably include IEEE/IET/IETE/Springer/Science Direct/ACM journals in the areas of Computing and Processing (Hardware and Software), Circuits-Devices and Systems, Communication-Networking and Security, Robotics and Control Systems, Signal Processing and Analysis and any other related domain. In case of Industry sponsored projects, the relevant application notes, while papers, product catalogues should be referred and reported.

- Student is expected to detail out specifications, methodology, resources required, critical issues involved in design and implementation and phase wise work distribution, and submit the proposal within a month from the date of registration.

- Phase – I Deliverables:
    - A document report comprising of summary of literature survey, detailed objectives, project specifications, paper and/or computer aided design, proof of concept/functionality, part results, A record of continuous progress.
- Phase – I Evaluation:
    - A committee comprising of guides of respective specialization shall assess the progress/performance of the student based on report, presentation and Q & A. In case of unsatisfactory performance, committee may recommend repeating the Phase-I work.

- During phase – II, student is expected to exert on design, development and testing of the proposed work as per the schedule. Accomplished results/contributions/innovations should be published in terms of research papers in reputed journals and reviewed focused conferences OR IP/Patents.

- Phase – II Deliverables: A dissertation report as per the specified format, developed system in the form of hardware and/or software, a record of continuous progress.

- Phase – II Evaluation: Guide along with appointed external examiner shall assess the progress/performance of the student based on report, presentation and Q & A. In case of unsatisfactory performance, committee may recommend for extension or repeating the work.

18CNPA0	ARRAY SIGNAL PROCESSING	Category	L	T	P	Credit
		PE	2	1	0	3

Preamble

The objective of this course to assemble in a coherent way a variety of theoretical and practical approaches to sensor array processing problems.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explore the properties of spatiotemporal propagating signals and noise.	Apply
CO2	Determine the characteristics of apertures and find the array geometry that determines the performance characteristics of arrays.	Apply
CO3	Apply spatiotemporal filtering to separate signals according to their directions of propagation and their frequency content.	Apply
CO4	Apply suitable detection algorithm to the array's output so as not to disturb an array processing algorithm designed for some particular problem and also analyze performance of the detection based array processing algorithm.	Analyze
CO5	Determine the location and motion of identified sources using tracking algorithms.	Apply
CO6	Derive signal processing algorithms for the outputs of an array of sensors that adapt their computations to the characteristics of the observations.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	L	-	-	-	-	-	-	-	-
CO2	S	M	L	-	-	-	-	-	-	-	-
CO3	S	M	L	-	L	-	-	-	-	-	-
CO4	S	S	L	L	L	-	-	-	-	-	-
CO5	S	M	L	-	L	-	-	-	-	-	-
CO6	S	M	L	-	L	-	-	-	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	20	20	20
Apply	80	60	60	60
Analyse	0	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Derive the wave equation from Maxwell's equation.
2. Assume cosinusoid is propagating outwardly from a point (spherical symmetry). We sample the spatio temporal waveform at time $t_o : s(t_o, r) = \cos(\omega t_o - kr)/r$
   a. Find the distance between successive zeros.
   b. Find the distance between successive extrema of the propagative wave.
3. In radar, the return from a moving source experiences a Doppler shift: A sinusoid emitted from an antenna strikes the target, reflects from it, and returns to the antenna at a different frequency. How is the propagation delay between emission and return related to the target's range?

Course Outcome 2 (CO2):

1. Derive the co-array of a uniform circular aperture of Radius R. Begin by using elementary planar geometry to compute the area of overlap of two circles whose centers are separated by X.
2. Consider a compound planar aperture consisting of two square regions, one centered at $(x_o, 0)$ and the other centered at $(-x_o, 0)$. Each side measures D meters. Sketch the compound aperture and derive its aperture smoothing function.
3. For nondispersive media, temporal bandwidth determines spatial bandwidth. What happens when the medium is dispersive?

Course Outcome 3 (CO3):

1. Consider a simple beamformer for a two sensor array having an output given by $z(t) = y(t+\Delta) - y(t-\Delta)$. Show that the energy E_z in $z(t)$ as measured over the interval $0 \le t \le T$ is maximized when $\Delta = 0$. $E_z = \int_0^T z^2(t)dt$
2. Consider an array of seven sensors located at $(x, y) = (-1,-1), (1,-1), (-2,0), (0,0), (2,0), (-1,1), (1,1)$. Compute the array pattern as a function of k_x, k_y, k_z
3. Situations do occur in which frequency domain beamformers have distinct advantages over their time domain counterparts and vice versa. For example, let's explore the relative merits of each implementation when the array lies in a dispersive medium. Assuming that the signal is monochromatic, show that either implementation suffices. How are the sensor delays related to propagation direction?

Course Outcome 4 (CO4):

1. The two hypotheses describe different equivariance statistical models for the observations
$$H_o : p_y(y) = \frac{1}{\sqrt{2}} e^{-\sqrt{2}|y|}$$
$$H_1 : p_y(y) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}y^2}$$
   Find the likelihood ratio test. Compute the decision regions for various values of the threshold in the likelihood ratio test.
2. One observation of the random variable y is obtained. This random variable is either uniformly distributed between -1 and +1 or expressed as the sum of statistically independent random variables, each of which is also uniformly distributed between -1 and +1. Suppose there are two terms in the aforementioned sum. Assuming that the two hypotheses are equally likely, find the minimum probability of error decision rule.

3. The additive noise in a detection problem consists of a sequence of statistically independent Laplacian random variables. The probability density of $n(l)$ is therefore $p_{n(l)}(n) = \frac{1}{2} e^{-|n|}$. The two possible signals are constant throughout the observation interval, equaling either +1 or -1. Find the optimum decision rule that could be used on a single value of the observation signal.

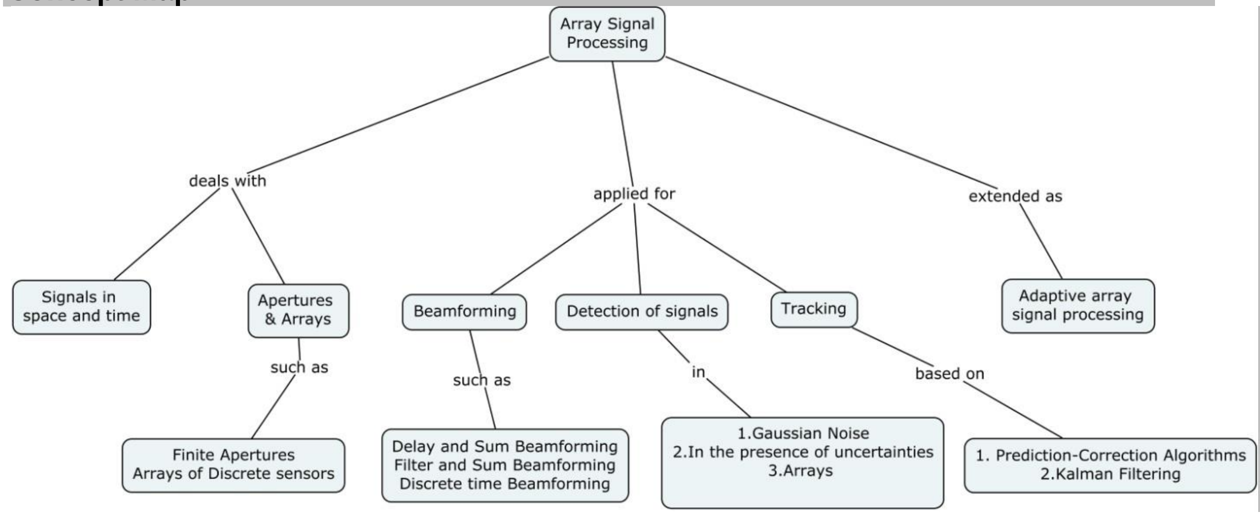
Course Outcome 5 (CO5):

1. We can use the Cramer Rao bound to determine how well an unbiased two array tracking algorithm can perform in a single source problem. Assume two linear arrays spatially separated along their axes in the x direction produce statistically independent, Gaussian distributed angular measurements. Find the conditional joint distribution of the measurements given the source's true Cartesian position.
2. Assume array A is located at the origin of a spatial coordinate system and array B is located at $(\bar{x}_x, \bar{x}_y) = (100,0)$. Two sources move parallel to each other in the x direction with common speed s=20, which has units of distance/snapshot. At snapshot $l = 0$, source 1 is located at $(10,100)$ and source 2 at $(10,150)$. Determine how each array's angular measurements change over the first five snapshots.
3. In problems in which the sources distance from the tracking array varies considerably and the speed of propagation is relatively small, the sources position may be significantly different by the time the radiation has propagated to the array. How is measured azimuth at time t related to source position relative to the array and propagation delay?

Course Outcome 6 (CO6):

1. Consider a regular linear array. The field is known to contain a single narrowband signal plus spatially white Gaussian noise. Sensor outputs are sampled and a length D snapshot collected. The snapshot encompasses many cycles of the sinusoid. Find the maximum likelihood estimate for the signal's amplitude.
2. For analytic simplicity, a two point amplitude constrained minimum variance algorithm for the single signal white noise case. The constraints are placed symmetrically about the assumed propagation direction. Analytically express the algorithm's steered response in terms of the inverse correlation matrix and the two signal vectors that define the constraint directions.
3. When we have a rectangular array geometry, we need to find both the elevation and azimuth angles to determine the direction of propagation. Assuming the source to be narrowband and the array to have an equal number of sensors along each side in the (x, y)plane, we seek the maximum likelihood estimate of the signal's direction of propagation. Express the normalized signal vector in terms of elevation and azimuth angles and in terms of the intersensor delays Δ_x, Δ_y.

Concept Map



Syllabus

Signals in space and time: Co-ordinate systems, propagating waves, Dispersion and attenuation, Refraction and Diffraction, Wavenumber-Frequency Space Random Fields. Signal and Noise Assumptions **Apertures and Arrays:** Finite Continuous Apertures, Spatial Sampling, Arrays of Discrete Sensors **Beamforming:** Delay-and-Sum Beamforming, Space-Time Filtering, Filter-and-Sum Beamforming, Frequency-Domain Beamforming, Array Gain, Resolution, Sampling in Time, Discrete-Time Beamforming, Averaging in Time and Space **Detection Theory:** Elementary Hypothesis Testing Hypothesis Testing in Presence of Unknowns, Detection of Signals in Gaussian Noise, Detection in Presence of Uncertainties, Detection-Based Array Processing Algorithms **Tracking:** Source Motion Models, Single-Array Location Estimate Properties, Prediction-Correction Algorithms, Tracking Based on Kalman Filtering, Multiarray Tracking in Clutter **Adaptive Array Processing:** Signal Parameter Estimation, Constrained Optimization Methods, Eigenanalysis Methods, Robust Adaptive Array Processing, Dynamic Adaptive Methods

Reference Books

1. Don H.Johnson, Dan E.Judgeon, “Array signal processing: concepts and techniques”, First edition, Prentice hall signal processing series,
2. Harry L. Van Trees, “Optimum Array Processing,” John Wiley & Sons, 2004
3. Prabhakar S. Naidu, Sensor Array Signal Processing,CRC Press,2000
4. Pillai, S. Unnikrishna, Array Signal Processing,Springer,1989

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1.	**Signals in space and time**	
1.1	Co-ordinate systems	1
1.2	propagating waves, Dispersion and attenuation	1
1.3	Refraction and Diffraction	1
1.4	Wavenumber-Frequency Space Random Fields	2
1.5	Signal and Noise Assumptions	1
2	**Apertures and Arrays**	
2.1	Finite Continuous Apertures	1
2.2	Spatial Sampling, Arrays of Discrete Sensors	2
3	**Beamforming**	
3.1	Delay-and-Sum Beamforming	1
3.2	Space-Time Filtering	1
3.3	Filter-and-Sum Beamforming, Frequency-Domain Beamforming	2

3.4	Array Gain, Resolution, Sampling in Time	1
3.5	Discrete-Time Beamforming, Averaging in Time and Space	1
4	**Detection Theory**	
4.1	Elementary Hypothesis Testing Hypothesis Testing in Presence of Unknowns	1
4.2	Detection of Signals in Gaussian Noise	1
4.3	Detection in Presence of Uncertainties	2
4.4	Detection-Based Array Processing Algorithms	2
5	**Tracking**	
5.1	Source Motion Models	1
5.2	Single-Array Location Estimate Properties	2
5.3	Prediction-Correction Algorithms	1
5.4	Tracking Based on Kalman Filtering	3
5.5	Multiarray Tracking in Clutter	1
6	**Adaptive Array Processing**	
6.1	Signal Parameter Estimation	1
6.2	Constrained Optimization Methods	1
6.3	Eigenanalysis Methods	1
6.4	Robust Adaptive Array Processing	2
6.5	Dynamic Adaptive Methods	2
Total		36

Course Designers:

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18CNPB0	DIGITAL SPEECH PROCESSING	Category	L	T	P	Credit
		PE	2	1	0	3

Preamble

This course highlights the central role of DSP techniques in modern speech communication research and applications. The course presents a comprehensive overview of digital speech processing that ranges from the basic nature of the speech signal, through a variety of methods of representing speech in digital form, to applications in voice communication and automatic synthesis and recognition of speech.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1.Describe the speech production model and characterize the speech sounds.	Understand
CO2. Extract the feature such as Linear Prediction, Homomorphic and frequency domain pitch of a speech sounds.	Apply
CO3. Apply the coding techniques such as LPC, CELP for communication applications	Apply
CO4. Apply spectral subtraction, cepstral subtraction and wiener filtering for speech enhancement	Apply
CO5. Apply spectral features and non spectral features for speaker recognition using MDC, VQ, GMM	Apply
CO6. Explain the principle of text to speech coding synthesis and speech recognition	Understand

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	-	-	-	-	-	-	-	-	-	-
CO2.	S	M	M	L	-	-	-	-	-	-	-
CO3.	S	S	M	L	-	-	-	-	-	-	-
CO4.	S	S	M	L	L	-	-	M	M	L	-
CO5.	S	S	M	L	L	-	-	M	M	L	-
CO6.	S	S	M	L	L	-	-	M	M	L	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	20	20	20
Apply	80	80	80	80
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. There are a variety of ways of classifying speech sounds into distinctive sounds (i.e., phonemes).These methods fall under the study of articulatory phonetics and acoustic phonetics.

   a. List the procedures used for distinguishing speech sounds in both areas of study.

b. Describe the articulatory and acoustic differences and similarities between the voiced fricative $|Z|$,as in “azure,” and the unvoiced fricative $|S|$,as in “she.”

2. Based on the spectrogram, propose a method for measuring a speaker’s rate of articulation. Hint: Consider the difference in spectral magnitudes in time, integrate this difference across frequency, and form a speaking rate metric.
3. Propose a simplified mathematical model of an unvoiced plosive, accounting for the burst after the opening of the oral tract closure and aspiration noise prior to the onset of voicing. Model the burst as an impulse $\delta[n]$ and aspiration as a noise sequence $q[n]$.Assume a linear time-varying oral tract.

Course Outcome 2 (CO2):

1. Consider the problem of estimating zeros of the numerator polynomial of a rational z-transform model. Develop a method of “inverse linear prediction” by converting zero estimation to pole estimation.
2. Consider a speech or audio signal $x[n] = e[n]f[n]$ with “envelope” $e[n]$ and “fine structure” $f[n]$.The envelope (assumed positive) represents a slowly time-varying volume fluctuation and the fine structure represents the underlying speech events (Fig)

   (a) Design a homomorphic system for multiplicatively combined signals that maps the time-domain envelope and fine structure components of $x[n]$ to additively combined signals. In your design, consider the presence of zero crossings in $f[n]$, but assume that $f[n]$ never equals zero exactly. Hint: Use the magnitude of $x[n]$ and save the sign information.

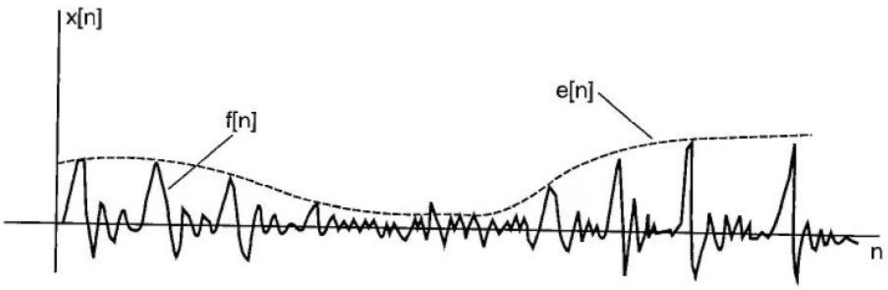


Fig. Acoustic signal with time-varying envelope

3. Consider applying sinewave analysis/synthesis to slowing down the articulation rate of a speaker by a factor of two. The goal is to perform the modification without loss in phase coherence.

   (a) Using the baseline analysis/synthesis system, if analysis is performed with a 10-ms frame interval,what is the corresponding synthesis frame interval over which amplitude and phase interpolation is performed?

   (b) Explain your method of doing sinewave amplitude interpolation across the center of two consecutive frames.

Course Outcome 3 (CO3):

1. Consider a 4-level quantizer. Suppose that values of a sequence $x[n]$ fall within the range [0,1] but rarely fall between $X_3 = \frac{1}{2}$ and $X_4 = 1$. Propose a nonuniform quantization scheme, not necessarily optimal in a least-squared-error sense, that reduces theleast-squared error relative to that of a uniform quantization scheme.
2. Let x denote the signal sample whose pdf $p_x(x)$ is given by

$$p_x(x) = \begin{cases} 1 & \frac{-1}{2} \leq x \leq \frac{1}{2} \\ 0 & otherwise \end{cases}$$

   1. Suppose we assign only one reconstruction level to x. We denote the reconstruction level by $\hat{x}$. We want to minimize $E\{(x-\hat{x})^2\}$. Determine $\hat{x}$. How many bits are required to represent the reconstruction level?

3. Let x denote the random variable whose pdf $p_x(x)$ is given in Fig. A symmetric quantizer is defined such that if it has a reconstruction level of r, then it also has a reconstruction level of –r. Given 1 bit to quantize the random variable x, determine the symmetric minimum mean-squared-error quantizer. What is the corresponding mean-squared-error?

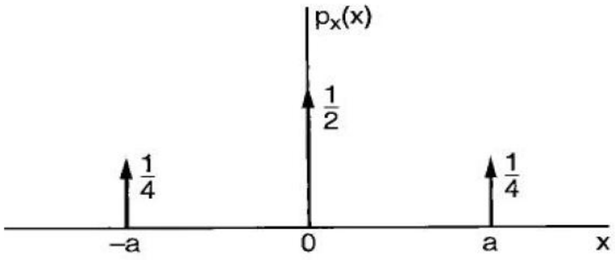


Fig. Symmetric probability density function of random variable x.

Course Outcome 4 (CO4):

1. Suppose a speech waveform is modeled with vocal tract poles and zeros, and consider the problem of estimating the speech in the presence of additive noise. Maximize the a posterior probability density $\left(\underline{a}, \underline{b}, \underline{x}/\underline{y}\right)$. The vectors $\underline{a}$ and $\underline{b}$ represent (for each analysis frame) the clean and noisy speech, respectively.
2. Consider a filter bank $h_k[n] = w[n]e^{jkn\frac{2\pi}{N}}$ that meets the FBS CONSTRAINT. In this problem, you develop a single noise suppression filter, applied to all N channel outputs for a noisy input $y[n] = x[n] + b[n]$. Assume the object random process $x[n]$ uncorrelated with the background noise random process $b[n]$. Specifically, find the optimal noise suppression filter $h_s[n]$ that minimizes the error criterion.
$$E\left[\sum_{K=0}^{N-1}\{\, h_s[n] * (h_k[n] * y[n]) - (h_k[n] * x[n])\}^2\right].$$
Express your solution in terms of the object and background spectra $S_x(\omega)$ and $S_b(\omega)$,respectively. Explain intuitively the difference between your solution and the standard wiener filter.
3. Consider a signal $y[n]$ of the form $y[n] = x[n] * g[n]$ where $g[n]$ represents a linear time-invariant distortion of a desired signal $x[n]$, In this problem you explore different formulations of the STFT of $y[n]$.
   a. Given $y[n] = x[n] * g[n]$, show that $\mathrm{y}(n,\omega) = \left(g[n]e^{-j\omega n}\right) * \mathrm{X}(n,\omega)$

   where the above convolution is performed with respect to the time variable n. Then argue that the two block diagrams are equivalent.

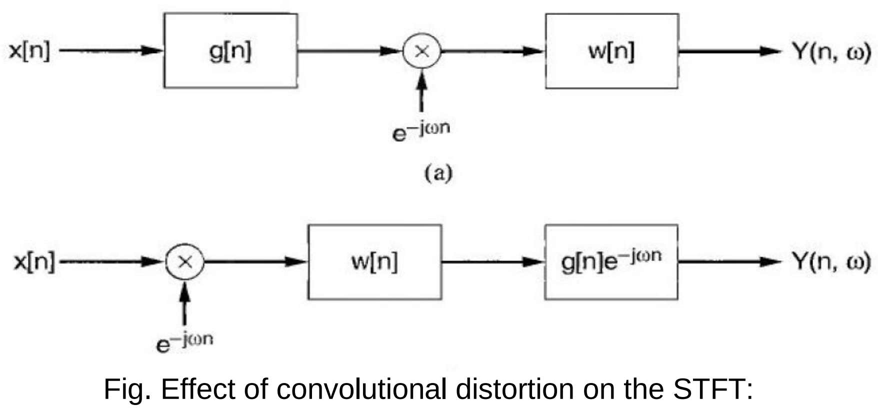


Fig. Effect of convolutional distortion on the STFT:
(a) filter-bank interpretation;
(b) Equivalence to (a)

b. Rewrite the STFT of $y[n]$ as

$$y(n,\omega) = \sum_{m=-\infty}^{\infty} x[m]\, e^{-j\omega n} \sum_{r=-\infty}^{\infty} \omega[n-m-r]\, g[r] e^{-j\omega r}$$

and argue that if the window $\omega[n]$ is long and smooth relative to the impulse response $g[n]$ so that $\omega[n]$ is approximately constant over the duration of $g[n]$, then $\omega[n-m]g[m] \approx \omega[n]g[m]$. from which it follows that $y(n.\omega) \approx X(n.\omega)G(\omega)$i.e., the convolutional distortion results in approximately a multiplicative modification $G(\omega)$ to the STFT of $x[n]$. Discuss practical conditions under which this approximation may not be valid.

Course Outcome 5 (CO5):

1. Show that when each individual Gaussian mixture component of the GMM in Equ

$$p(\underline{x}/\lambda) = \sum_{i=1}^{I} p_i\, b_i(\underline{x})$$

Integrates to unity, then the constraint $\sum_{i=1}^{I} p_i = 1$ ensures that the mixture density represents a true pdf,i.e.,the mixture density itself integrates to unity. The scalars p_i are the mixture weights.

2. Design a GMM-based handset recognition system that detects when an utterance is generated from a high-quality electret handset or a low-quality carbon-buttton handset. Assume you are given a training set consisting of a large set of electret and carbon-button handset utterances. *Hint:* use the same methodology applied in the design of a GMM –based speaker recognition system
3. An important problem in speaker verification is detecting the presence of a target speaker within a multi-speaker conversation. In this problem you are asked to develop a method to determine where the target speaker is present within such an utterance. Assume that a GMM target model λ_c and a GMM background model $\lambda_{\bar{C}}$ have been estimated using clean, undistorted training data.

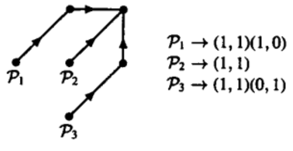
a. Suppose you estimate a feature vector $\underline{x}_n$ at some frame rate over a multi-speaker utterance where n here denotes the frame index, you can then compute a likelihood score for each frame as $\Lambda(\underline{x}_n)$=log$[p(\underline{x}_n/\lambda_C)]$- log$[p(\underline{x}_n/\lambda_{\bar{C}})]$ and compare this against a threshold. Explain why this approach to speaker tracking is unreliable. Assume that there is no channel mismatch between the training and test data so that channel compensation is not needed.

Course Outcome 6 (CO6):

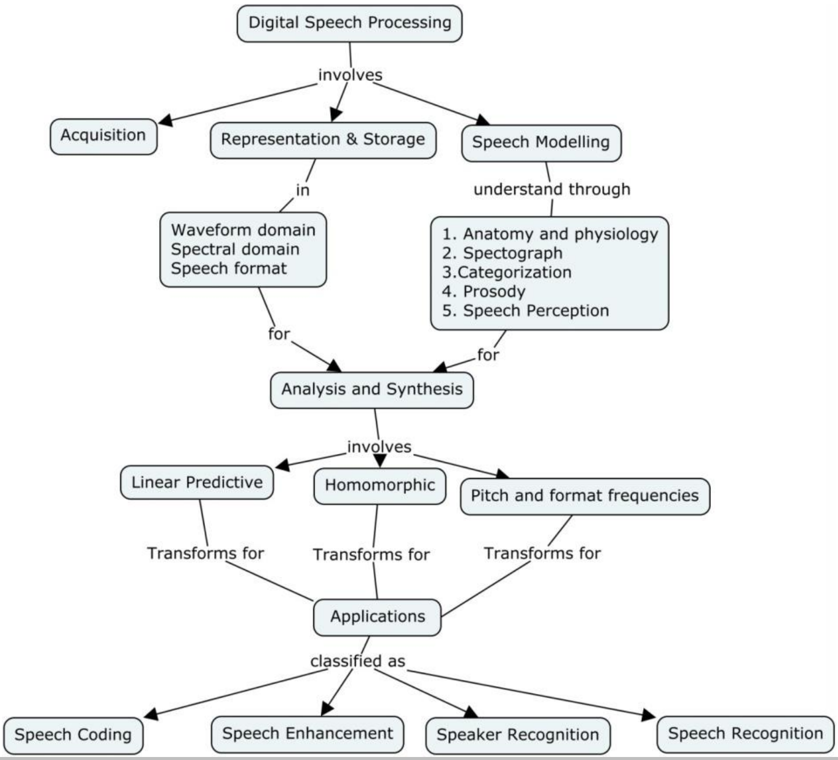
1. Derive the zero mean property of the log spectrum of a minimum phase all pole model:

$$\int_{-\pi}^{\pi} \log \frac{1}{\left|A\left(e^{j\omega}\right)\right|^2} \frac{d\omega}{2\pi} = 0\,.$$

2. Show that the L_1 spectral distortion measure $\left(d_1\right)^1 = \int_0^{2\pi} \left|\log S(\omega) - \log S^{'}(\omega)\right| \frac{d\omega}{2\pi}$ obeys the mathematical properties of distance metrics, namely:
   c. It is positive definite
   d. It is symmetric
   e. It satisfies the triangular inequlality.
3. Consider Type II local continuity constraints, Find the sequence of path moves that match the sample path shown below:



Concept Map



Syllabus

Digital Speech Processing: Introduction: Acquisition, representation and storage.
Speech Modelling: Anatomy and physiology of speech production, spectrographic analysis of speech, categorization of speech sounds, prosody, speech perception
Linear Prediction analysis of speech signals: Formulation, error minimization, autocorrelation method, time domain, frequency domain, synthesis based on all pole model, pole zero estimation
Homomorphic Signal Processing: Homomorphic systems for convolution, complex spectrum of speech like sequences, spectral root homomorphic filtering, short time homomorphic analysis of periodic sequences, short time speech analysis, analysis and synthesis structures.
Frequency Domain Pitch Estimation: A correlation based pitch estimator, pitch estimation based on a comb filter, pitch estimation based on harmonic sinewave model, Glottal onset estimation, multi band pitch and voicing estimation.
Speech Coding: Scalar quantization, vector quantization, frequency domain coding, model based coding, LPC residual coding
Speech Enhancement: Wiener filtering, enhancement based on auditory masking, temporal processing in a time frequency space.
Speaker Recognition: spectral features of speaker recognition, speaker recognition algorithms, non spectral features in speaker recognition, speaker recognition from coded speech
Speech Recognition: speech detection, distortion measures: mathematical and perceptual considerations, spectral distortion measures.

Reference Books

1. Thomas. F.Quatieri, "Discrete Time Speech Signal Processing Principles and Practice" Prentice Hall, 2002.
2. L. R. Rabiner and R. W. Schafer, " Introduction to Digital Speech Processing", now Publishers Inc.,2007
3. J. L. Flanagan," Speech Analysis, Synthesis and Perception". Springer-Verlag,1972
4. L. R. Rabiner and B. H. Juang, "Fundamentals of Speech Recognition". Prentice-Hall Inc., 1993.

5. J. H. Schroeter, "Basic principles of speech synthesis," Springer Handbook of Speech Processing, Springer- Verlag, 2006.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1.	**Digital Speech Processing**	
1.1	Introduction: Acquisition, representation and storage.	1
2.	**Speech Modelling**	
2.1	Anatomy and physiology of speech production	1
2.2	spectrographic analysis of speech	1
2.3	categorization of speech sounds, prosody	1
2.4	speech perception	1
3.	**Linear Prediction analysis of speech signals**	
3.1	Formulation, error minimization	1
3.2	autocorrelation method	1
3.3	time domain, frequency domain,	1
3.4	synthesis based on all pole model, pole zero estimation	2
4.	**Homomorphic Signal Processing**	
4.1	Homomorphic systems for convolution,	1
4.1	complex spectrum of speech like sequences,	1
4.2	spectral root homomorphic filtering,	1
4.3	short time homomorphic analysis of periodic sequences	1
4.4	short time speech analysis	1
4.5	analysis and synthesis structures	1
5.	**Frequency Domain Pitch Estimation**	
5.1	A correlation based pitch estimator	1
5.2	pitch estimation based on a comb filter	1
5.3	pitch estimation based on harmonic sinewave model	1
5.4	Glottal onset estimation	1
5.5	multi band pitch and voicing estimation	1
6.	**Speech Coding**	
6.1	Scalar quantization, vector quantization	1
6.2	frequency domain coding	1
6.3	model based coding	2
6.4	LPC residual coding	2
7.	**Speech Enhancement**	
7.1	Wiener filtering	1
7.2	enhancement based on auditory masking	1
7.3	temporal processing in a time frequency space	1
8.	**Speaker Recognition**	
8.1	spectral features of speaker recognition speaker recognition algorithms	1
8.2	non spectral features in speaker recognition	1
8.3	speaker recognition from coded speech	1
9.	**Speech Recognition**	
9.1	speech detection	1
9.2	distortion measures: mathematical and perceptual considerations	1
9.3	spectral distortion measures	1
	Total	36

Course Designers:

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18CNPC0	RADAR SYSTEMS	Category	L	T	P	Credit
		PE	2	1	0	3

Preamble

This course provides in-depth coverage of fundamental topics in radar signal processing from a digital signal processing perspective. The techniques of linear systems, filtering, sampling, and Fourier analysis techniques and interpretations are used in this course to provide a unified approach in improving probability of detection and Signal to interference ratio.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Identify the concepts of radar measurements, radar functions and range equation	Understand
CO2. Apply the clutter model in radar environment	Apply
CO3. Apply the detection rules/tests such as Neyman-Pearson principle, Likelihood ratio test for RADAR signal processing.	Apply
CO4. Apply CFAR detector to improve the detection performance of Radar.	Apply
CO5. Process slow time data in a given range bin to analyze the Doppler content of the signal.	Apply
CO6. Analyze various waveform modulations used in modern radar	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	L	-	-	-	-	-	-	-	-	-
CO2	S	M	-	-	-	-	-	-	-	-	-
CO3	S	M	L	L	M	-	-	-	-	-	-
CO4	S	M	-	-	M	-	-	-	-	-	-
CO5	S	S	M	L	M	-	-	-	-	-	-
CO6	S	M	M	-	M	-	-	-	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	20	20	20
Apply	80	60	60	60
Analyse	0	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1(CO1):

1. Find an expression for the range of a target in kilometres (km) for a reflected signal that returns to the radar ΔT μs after being transmitted.
2. A radar systems provides 18 dB SNR for a target having an RCS of 1 square meter at a range of 50 km. Ignoring the effects of atmospheric propagation loss, determine the range at which the SNR be 18 dB if the target RCS is reduced to:
   a. 0.5 square meters
   b. 0.1 square meters.
3. A system has a single pulse SNR of 13 dB for a given target at a given range. Determine the integrated SNR if 20 pulses are coherently processed.

Course Outcome 2 (CO2):

1. A radar has a pulse length of $\tau = 10\mu s$, an azimuth beamwidth $\theta_3 = 3^\circ$, and an elevation beamwidth $\phi_3 = 3^\circ$. At what grazing angle δ does the transition occur between the pulse limited and beam limited ground clutter cases when the nominal range to the ground is $R = 10$ km?
2. Consider two radar targets with polarization scattering matrices $\mathbf{S}_1$ and $\mathbf{S}_2$ as follows: $\mathbf{S}_1 = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \mathbf{S}_2 = \begin{bmatrix} 1 & j \\ -j & -1 \end{bmatrix}$ where $j = \sqrt{-1}$. Compute the parallel/cross-polarization ratio and the vertical/horizontal polarization ratio for each target. Which ratio could be used to discriminate between the two targets?
3. Show that the Weibull distribution reduces to the exponential distribution when b=1 and to the Rayleigh distribution when b=2.

Course Outcome 3 (CO3)

1. We observe the IID samples $x(n)$ for $n = 0,1,....N-1$ from the Rayleigh PDF $p(x[n]) = \frac{x[n]}{\sigma^2}\exp\left(-\frac{1}{2}\frac{x^2[n]}{\sigma^2}\right)$. Derive the NP test for the hypothesis testing problem

   $H_0 : \sigma^2 = \sigma_0^2$

   $H_1 : \sigma^2 = \sigma_1^2 > \sigma_0^2$
2. Consider the detection problem

   $H_0 : x(n) = 1 + w(n), \quad n = 0,1,...N-1$

   $H_1 : x(n) = -1 + w(n), \quad n = 0,1,...N-1$

   w(n) is WGN with variance σ^2 and is independent of the signal. Apply NP detector to decide H_1. Find the Probability of error.
3. Consider the detection of a signal $s[n]$ embedded in WGN with variance σ^2 based on the observed samples $x[n]$ for $n = 0,1,\ldots,2N-1$. The signal is given by $s[n] = \begin{cases} A & n = 0,1,\ldots,N-1 \\ 0 & n = N, N+1,\ldots,2N-1 \end{cases}$ under H_0 and by $s[n] = \begin{cases} A & n = 0,1,\ldots,N-1 \\ 2A & n = N, N+1,\ldots,2N-1 \end{cases}$ under H_1. Assume that A>0.
   a. Determine the NP detector
   b. Determine the probability of detection $P_{D.}$ In what way, instruction alignment unit supports program sequencer?

Course Outcome 4 (CO4):

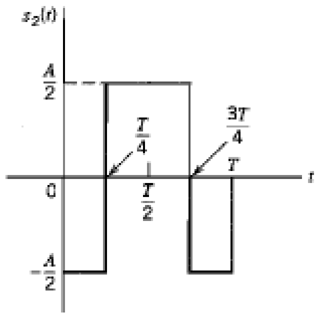
1. The Neyman-Pearson threshold is set to achieve a $P_{FA} = 10^{-6}$. The interference power level changes by 6 dB. What is the new P_{FA} if the threshold remains unchanged?
2. Calculate the average P_D for a CA-CFAR with $N = 20$ and $P_{FA} = 10^{-4}$ in a homogenous environment. Assume the target in the CUT has SINR=22 dB.
3. For a CA-CFAR, calculate the SINR required to achieve a $P_D = 0.95$, with $N = 16$ and $P_{FA} = 10^{-4}$ in a homogeneous environment.

Course Outcome 5 (CO5):

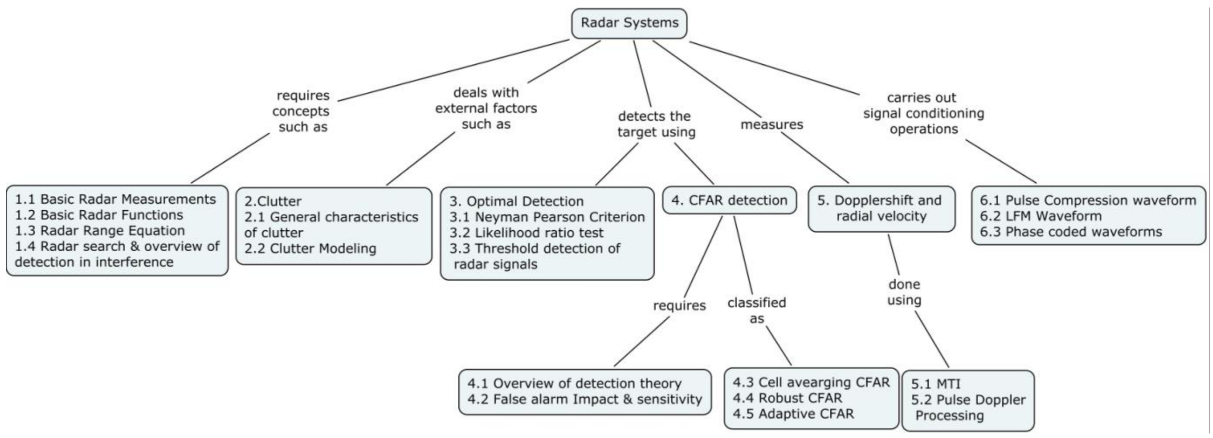
1. In terms of the radar wavelength λ, what is the two way range change between pulses when the target Doppler shift equals the blind speed f_b?
2. Consider a pulse to pulse staggered PRF system using a series of P=3 PRFs, namely, [10 kHz, 12 kHz, 15kHz].
   a. What is the first blind Doppler frequency of a constant PRF system having the same average PRI as the staggered system?
3. Discuss the threshold settings in two parameters CFAR and distributed CFAR.

Course Outcome 6 (CO6):

1. Determine the autocorrelation function of the 11-length Barker sequence
2. Determine the matched filter output for Frank code with M=2.
3. Consider the signal shown in figure
   a. Determine the impulse response of the matched filter
   b. Plot the matched filter output as a function of time. What is the peak value at the output?



Concept Map



Syllabus

Radar: Radar concept, basic radar measurements, basic radar functions, radar range equation: Amplitude model, simple point target radar range equation, distributed target radar range equation, noise model and signal to noise ratio, search mode fundamentals, overview of detection fundamentals

Characteristics of Clutter: General characteristics of clutter and clutter modelling

Threshold detection of radar targets: Detection strategies for multiple measurements, Introduction to optimal detection: Hypothesis testing and Neyman-Pearson criterion, statistical models for noise and target RCS in radar, threshold detection of radar signals.

Constant False Alarm Rate Detectors: Overview of detection theory, false alarm impact and sensitivity, CFAR detectors, Cell averaging CFAR, robust CFARs, adaptive CFARs.

Doppler Processing: Review of Doppler shift and pulsed radar data, Pulsed radar Doppler data acquisition and characteristics, Moving Target Indication, Pulse Doppler Processing.

Fundamentals of Pulse compression waveforms: Pulse compression waveforms, Linear Frequency Modulated Waveforms, Phase coded waveforms.

Reference Books

1. Mark A.Richards, James A.Scheer, William A.Holm," Principles of Modern RADAR", Yesdee Publishing Pvt Ltd, 1st Edition, 2012.
2. Mark A.Richards, "Fundamentals of Radar Signal Processing", Tata McGraw Hill, 1st Edition, 2005.
3. Steven M.Kay, "Fundamentals of Statistical Signal Processing", Vol II Detection Theory, Prentice Hall Inc, 1998.
4. Nathanson, F.E, "Radar Design Principles, second edition, McGraw-Hill, New York, 1991.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Radar:**	
1.1	Radar concept, basic radar measurements,	1
1.2	Basic radar functions	1
1.3	Radar range equation: Amplitude model	1
1.4	simple point target radar range equation	1
1.5	distributed target radar range equation	1
1.6	noise model and signal to noise ratio	1
1.7	search mode fundamentals	1
1.8	overview of detection fundamentals	1
2	**Characteristics of Clutter:**	
2.1	General characteristics of clutter and clutter modelling	1
2.2	Clutter modelling	1
2.3	Tutorial	1
3	**Threshold detection of radar targets:**	
3.1	Detection strategies for multiple measurements,	1
3.2	Introduction to optimal detection: Hypothesis testing and Neyman-Pearson criterion,	1
3.3	statistical models for noise and target RCS in radar,	1
3.4	Threshold detection of radar signals.	1
3.5	Tutorial	1
4	**Constant False Alarm Rate Detectors:**	
4.1	Overview of detection theory	1

4.2	false alarm impact and sensitivity	2
4.3	CFAR detectors, Cell averaging CFAR	1
4.4	robust CFARs,	2
4.5	Adaptive CFARs.	2
4.6	Tutorial	1
5	**Doppler Processing:**	
5.1	Review of Doppler shift and pulsed radar data	1
5.2	Pulsed radar Doppler data acquisition and characteristics	2
5.3	Moving Target Indication	2
5.4	Pulse Doppler Processing	1
5.5	Tutorial	1
6	**Fundamentals of Pulse compression waveforms:**	
6.1	Pulse compression waveforms	1
6.2	Linear Frequency Modulated Waveforms	1
6.3	Phase coded waveforms	1
6.4	Tutorial	1
	Total	36

Course Designers:

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18CNPD0	PHYSICAL LAYER LTE SYSTEMS	Category	L	T	P	Credit
		PE	2	1	0	3

Preamble

The course on the physical layer Long Term Evolution (LTE) systems is offered as an elective course in continuation with the course on "Wireless Digital Communications". LTE is a standard for wireless communication of high-speed data for mobile phones and data terminals. The objective of this course is to present the techniques for the design of physical layer LTE systems and determine its performance.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Describe the FDD and TDD frame formats, physical signals and channels of downlink and uplink LTE systems.	Understand
CO2	Carry out the cell search using synchronization signals in LTE downlink and determine the channel frequency response using reference signals in downlink and uplink of LTE systems.	Apply
CO3	Characterize the modulation schemes such as OFDM,OFDMA and SC-FDMA schemes and describe the single user and multi user techniques in LTE downlink and uplink systems.	Apply
CO4	Determine the bit error rate and outage probability performances of LTE downlink and uplink channels.	Apply
CO5	Design LTE downlink and uplink receiver.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	-	-	-	-	-	-	-	-	L	-
CO2	S	L	M	M	M	L	L	M	-	-	-
CO3	S	-	-	-	M	-	L	M	-	L	-
CO4	S	-	-	-	M	-	L	M	-	-	-
CO5	S	M	M	M	M	M	L	M	L	L	L

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	20	20	20
Apply	80	80	80	80
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List the physical control channels in LTE downlink systems
2. List out the features of downlink LTE System.
3. Define cyclic delay diversity.

Course Outcome 2 (CO2):

1. Name the signals transmitted on each downlink component carrier for cell search and define their structure.

2. Describe the basic cell-search procedure used in LTE.
3. Obtain the shift register implementation of scrambling sequence generator using the polynomial $g(x) = 1 + x + x^3$

Course Outcome 3 (CO3):

1. Distinguish between OFDM and SC-FDMA
2. Compute and compare the autocorrelation amplitudes for PN sequence and Zadoff-Chu sequence at a zero time lag.
3. Compute the autocorrelation profile of Zadoff-Chu sequence assuming that the frequency offset is 7.5 kHz and the root indexes are 25, 29 and 34.

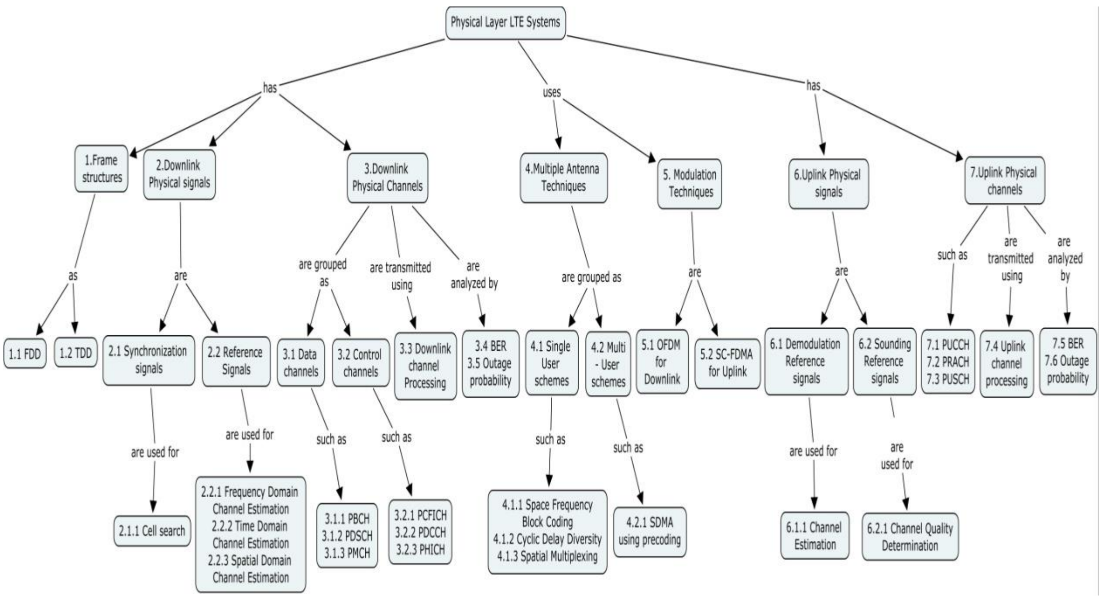
Course Outcome 4 (CO4):

1. Compute PRACH sub-carrier spacing for $800\mu s$ interval.
2. Determine the pairwise probability of PCFICH channel assuming that CFI can take values between 1 and 4.
3. Construct convolutional encoder used in LTE with m=6,n=3,k=1 and rate 1/3 for the generator polynomials $g_o = \{1011011\}, g_1 = \{1111001\}, g_2 = \{1110101\}$

Course Outcome 5 (CO5):

1. Design a transceiver for Physical Control Format Indicator Channel (PCFICH).
2. Design a transceiver for Physical Hybrid ARQ Indicator Channel (PHICH).
3. Design a transceiver for Physical Downlink Control Channel (PDCCH).

Concept Map



Syllabus

Frame structure: Frequency Division Duplexing, Time Division Duplexing **Downlink Physical signals:** Synchronization signals, Cell Search, Reference signals: Frequency Domain, Time domain and Spatial Domain channel estimations, **Downlink Physical channels:** Data channels-PBCH,PDSCH,PMCH, Control channels: PCFICH, PDCCH, PHICH, Downlink channel processing, BER and Outage probability, **Multiple Antenna Techniques:** Single user systems: Space Frequency Block coding, Cyclic Delay Diversity, Spatial Multiplexing, Multi user systems: Space Division Multiple Access(SDMA) using precoding, **Modulation Techniques:** OFDM for downlink, SC-FDMA for uplink, **Uplink Physical signals:** Demodulation Reference signals, channel Estimation, Sounding Reference signals, Channel Quality Determination, **Uplink Physical channels:** PUCCH,PRACH, PUSCH, Uplink channel processing, BER and Outage probability, **Power control, scheduling and interference handling, LTE Advanced-** Career aggregation, Downlink Multiantenna enhancements, Uplink Multiantenna techniques, Heterogeneous networks, Relays,HSPA Evolution

Reference Books

1. Harri Holma and Antti Toskala, "LTE for UMTS Evolution to LTE-Advanced," John Wiley &Sons Limited, 2011.
2. Erik Dahlman and Stefan Parkvall. "4G: LTE/LTE-Advanced for Mobile Broadband," Academic Press is an imprint of Elsevier,2011.
3. 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation", 2011
4. 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding". 2011
5. 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures". 2011
6. Stefania Sesia, Issam Toufik, Matthew Baker, "LTE-The UMTS Long Term Evolution From theory to practice, John Wiley & Sons Ltd., 2009.
7. David Tse and Pramod Viswanath, "Fundamentals of Wireless Communications", Cambridge University Press, 2005 (First Asian Edition, 2006)
8. Andrea Goldsmith, " Wireless Communications", Cambridge University Press, 2005
9. A.Paulraj, R. Nabar and D Gore, "Introduction to Space-Time Wireless Communications", Cambridge University Press, 2003.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Frame structure**	
1.1	Frequency Division Duplexing, Time Division Duplexing	1
2	**Downlink Physical signals:**	
2.1	Synchronization signals	1
2.1.1	Cell Search	1
2.2	Reference signals	1
2.2.1	Frequency Domain channel estimation	1
2.2.2	Time domain channel estimation	1
2.2.3	Spatial domain channel estimation	1
3	**Downlink Physical channels**	
3.1	Data channels	1
3.1.1	PBCH – Physical Broadcast Channel	1
3.1.2	PDSCH – Physical Downlink Shared Channel	1
3.1.3	PMCH – Physical Multicast Channel	1
3.2	Control channels	1
3.2.1	PCFICH – Physical Control Format Indicator Channel	1
3.2.2	PDCCH – Physical Downlink Control Channel	1
3.2.3	PHICH – Physical Hybrid ARQ Channel	1
3.3	Downlink channel processing	1
3.4	BER Analysis/ Outage probability Analysis of Downlink physical Channels	1
4	**Multiple Antenna Techniques:**	
4.1	Single user systems:	1
4.1.1	Space Frequency Block coding	1
4.1.2	Cyclic Delay Diversity	1
4.1.3	Spatial Multiplexing	1
4.2	Multi user systems:	1
4.2.1	Space Division Multiple Access(SDMA) using precoding	1
5	**Modulation Techniques**	

5.1	OFDM	1
5.2	SC-FDMA	1
6	**Uplink Physical signals**	
6.1	Demodulation Reference signals	1
6.1.1	channel Estimation	1
6.2	Sounding Reference signals	1
6.2.1	Channel Quality Determination	1
7	**Uplink Physical channels**	
7.1	PUCCH – Physical Uplink Control Channel	1
7.2	PRACH – Physical Random Access Channel	1
7.3	PUSCH – Physical Uplink Shared Channel	1
7.4	Uplink channel processing	1
7.5	BER Analysis/ Outage probability Analysis of Uplink physical Channels	1
8	**Power control, scheduling and interference handling**	1
9	**LTE Advanced**	1
TOTAL		36

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18CNPE0	RF TEST AND MEASUREMENT	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

RF and wireless communication is becoming the standard in everyday devices design. In addition, the convergence of technologies has increased opportunities and challenges in the field of RF testing and measurements. The purpose of this course is to expose the students to the basics of traditional RF measurement techniques applied to RF components, antenna and Electromagnetic Interference and Compatibility. One of the main competencies that a present day RF and microwave measurement engineer has to posses is the capability to understand the RF parameters suitability of RF equipment for respective RF test and measurements. This course presents the fundamentals of RF and microwave power measurements, which tends to be timeless, and the modern RF measurement techniques and test equipment which represents the current state-of-the-art.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explain the basics of RF measurement and related parameters associated with the sample such as transmission line, RF components and EMI/EMC	Apply
CO2	Explain the measurement techniques and procedure	Apply
CO3	Experience testing of RF components/ systems and measurement of electromagnetic emission	Apply
CO4	Test, analyze and validate the performance of RF components and systems	Analyze
CO5	Analyze the issues with EMI/EMC through RF testing	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11
CO1	S	M	L	L	L	-	-	L	M	L	-
CO2	S	M	L	L	L	-	-	L	L	L	L
CO3	S	M	L	L	L	-	-	-	L	L	-
CO4	S	S	M	L	-	-	L	L	-	L	-
CO5	S	S	M	L	-	-	-	L	L	L	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	10	0	0	0
Understand	30	20	20	20
Apply	60	50	60	60
Analyse	0	30	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. State the basic principle involved in RF measurement

2. Name some of the standard connectors used in RF testing
3. What are scattering parameters?
4. List some of the power measurement technique.
5. State the effects of environment on cellular phone?
6. State the need for compatibility test?

Course Outcome 2 (CO2):

1. Obtain the S parameter of hybrid coupler.
2. How do you measure Z0 in a printed transmission line fabricated on an ideal dielectric?
3. Compare network analyzer with spectrum analyzer.
4. What are the mandatory requirements for measuring far field pattern of an antenna?
5. What are the effects of electromagnetic interference?
6. Explain the working principle of Spectrum analyzer

Course Outcome 3 (CO3):

1. A 50-V signal generator is attached to a signal measurer whose input impedance is 25V. The dial on the signal generator indicates that it is putting out a level of -20 dBm. Determine the voltage at the input to the signal measurer in dBmV.
2. Convert the following dimensions to those indicated: (i) 30 miles to km (ii) 1 ft to mils (iii) 100 yds to meters (iv) 1 mm to mils, (v) 235 dBm to V (vi) 200A to db
3. The gains of antennas (Tx and Rx) of a microwave link operating at 10GHz are 40db each. Calculate the path loss for a transmitted power of 10W and a path distance of 80Km.
4. While measuring the gain of a horn antenna, the gain of the oscillator was set for 9GHz frequency and the attenuation inserted was found to be 9.8db. Determine the gain of the horn antenna provided the distance between the two horns was 35cm.

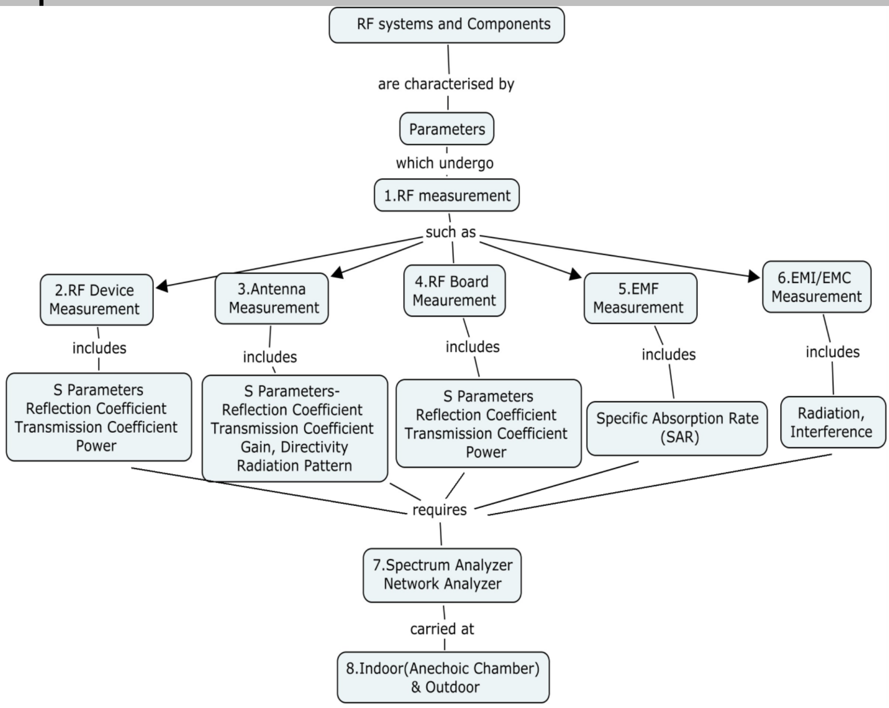
Course Outcome 4 (CO4):

1. A 50V receiver is attached to an antenna via 200 m of RG58U coaxial cable. The receiver indicates a level of -20 dBm at 200 MHz. Determine the voltage at the base of the antenna in dBmV and in V if the cable loss at 200 MHz is 8 dB/100 ft.
2. Compute the reflection loss and absorption loss for a 20-mil steel (SAE 1045) barrier at 10 kHz, 100 kHz, and 1 MHz for a near-field electric source that is a distance of 5 cm from the shield.
3. Construct and compare in-circuit probing and high impedance probing method using network analyzer

Course Outcome 5 (CO5):

1. Compare and contrast the different emission measurement techniques
2. To minimize ground noise voltage, what term of Eq.3-2 do we usually control: a. In the case of a low-frequency circuit? b. In the case of a high-frequency circuit? If a small circular and a small rectangular loop both have the same area and carry the same current at the same frequency, which will produce the greater radiated emission?

Concept Map



Syllabus

Introduction: RF Systems and components – Need for Characterization, evaluation and Certification. RF measurement, Measurement Parameters- S parameters, power. **RF equipment for Measurement**: Spectrum Analyzer- Principle, Measurement procedure, Network Analyzer- Principle, Measurement procedure, Calibration. **RF Device Measurement:** S parameters for Devices - transmission lines, coupler, filters, circulators, resonator, antenna etc. Measurement with Network Analyzer. **Antenna Measurement: Reflection coefficient, Return loss of different antennas,** Measurement with Spectrum and Network Analyzer, Gain Measurement, Radiation pattern measurement in both Indoor and Anechoic chamber, Test ranges. **RF Board Measurement:** Filter, coupler measurement, Amplifier testing, gain, phase noise and Noise margin measurement, Power measurement. **EMF Measurement:** Some International Precautionary Exposure Guidelines, EMF Measurement System, RF Exposure Measurements & Testing, Mobile phone SAR Measurements. **EMI/EMC Measurement:** Sources of EMI, conducted and radiated EMI, transient EMI, EMI- EMC definitions and units of parameters. EMI Coupling Principles: conducted, radiated and transient coupling, common impedance ground coupling, Common mode and differential mode coupling, near field cable to cable coupling, power main and power supply coupling. EMI Units of specifications, Civilian standards & Military standards. Limits

Reference Books

1. D. Pozar, “Microwave Engineering”, Wiley, 3rd ed., 2007
2. IET Electrical Measurement Series, “Microwave Measurements” 3rd Edition
3. Agilent"s, “Fundamentals of RF and Microwave Power Measurements”
4. John D. Kraus, “Antennas for all applications”, Tata McGraw Hill ,2002
5. V.P.Kodali, "Engineering EMC Principles, Measurements and Technologies", IEEE Press, 1996
6. Clayton R.Paul, “Introduction to Electromagnetic Compatibility” A John Wiley & Sons, Inc. Publication, 2006
7. http://edocs.soco.agilent.com

Course Contents and Lecture Schedule

Module No.	Topic	No.of Lectures
1	**Introduction**	
1.1	RF Systems and components	1
1.2	Need for Characterization, evaluation and Certification.	1
1.3	RF measurement	2
1.4	Measurement Parameters- S parameters	1
1.5	Power measurement	1
2	**RF equipment for Measurement**	
2.1	Spectrum Analyzer- Principle	1
2.2	Measurement procedure	2
2.3	Network Analyzer- Principle	1
2.4	Measurement procedure, Calibration.	2
3	**RF Device Measurement**	
3.1	S parameters for Devices - transmission lines	1
3.2	Coupler, filters Measurement with Network Analyzer.	1
3.3	Circulators, resonator Measurement with Network Analyzer.	1
4	**Antenna Measurement**	
4.1	Return loss Measurement with Spectrum and Network Analyzer,	1
4.2	Gain Measurement	1
4.3	Radiation pattern measurement (Indoor)	1
4.4	Measurement in Anechoic chamber,	1
4.5	Test ranges	1
	Filtering & decoupling	2
5	**RF Board Measurement**	
5.1	Filter, coupler measurement	1
5.2	Amplifier testing	1
5.3	Gain, phase noise measurement,	1
5.4	Noise margin measurement	0.5
5.5	Power measurement	0.5
6	**EMF Measurement**	
6.1	Some International Precautionary Exposure Guidelines,	2
6.2	EMF Measurement System,	1
6.3	RF Exposure Measurements & Testing	1
6.4	Mobile phone SAR Measurements	1
7	**EMI/EMC Measurement**	
7.1	Sources of EMI, conducted and radiated EMI,	1
7.2	Transient EMI, EMI- EMC definitions and units of parameters.	1
7.3	EMI Coupling Principles: conducted, radiated and transient coupling	2
7.4	common impedance ground coupling, Common mode and differential mode coupling	1
7.5	near field cable to cable coupling, power main and power supply coupling	1
7.6	EMI Units of specifications, Civilian standards & Military standards. Limits	1
7.1	Sources of EMI, conducted and radiated EMI,	1
Total		36

Course Designers:

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18CNPF0	EMI AND EMC	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

This course aims at understanding the sources of EMI/EMC and estimation, standards, Filters to remove noise and EMI/EMC measurement for compliances.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Apply the effects of EMI-EMC and their sources, the standards and estimate the non ideal behaviour of passives at high frequencies	Apply
CO2	Synthesize EMI rejection filters for a particular application	Analyze
CO3	Calculate the effects of shielding and grounding in a circuit environment	Apply
CO4	Determine the cross talk effects in time and frequency domain	Apply
CO5	Evaluate EMI/EMC through measurement	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11
CO1	S	M	L	L	-	L	-	-	M	L	-
CO2	S	S	M	L	L	L	-	L	L	L	L
CO3	S	M	L	L	L	-	-	-	L	L	-
CO4	S	M	L	-	L	-	L	L	-	L	-
CO5	S	S	M	L	L	-	-	L	L	L	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	10	10	0	0
Understand	30	20	20	20
Apply	60	50	60	60
Analyse	0	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. What do you mean by EMI and EMC?
2. Enumerate at least three sources of EMI
3. Name three International standards for EMI-EMC
4. Write the International standards of EMI- EMC for the following: (1)Electric Motor, (2) PCB, (3) SMPS,(4) Antenna Tower with Antenna
5. What are the needs for modelling the passive devices at high frequencies

Course Outcome 2 (CO2)

1. A differential-mode (DM) filter is needed to attenuate noise emission from an uninterruptable power supply (UPS). The equivalent DM noise source impedance of the UPS can be modelled as a resistance of 2 Ω in series with an inductance of $5\mu H$. The UPS is connected to a Line Impedance Stabilization Network (LISN).

Design the DM filter using the following components: Two capacitors (0.2μH each with a selfresonant frequency of 5 MHz) and one inductor (5μF with a self-resonant frequency
of 2 MHz).
Draw the full circuit with your designed filter. (a)If the filter has two capacitors only, what is the filter attenuation at 200 kHz, 10 MHz and 100 MHz, respectively?
(b) Determine the filter attenuation of the filter designed in part (b) at 100 kHz, 1 MHz and 10 MHz.

2. Design a second order common-mode (CM) filter to attenuate the CM conducted noise generated by a switched mode power supply (SMPS). The SMPS is powered through a line impedance stabilization network (LISN). The equivalent CM noise source impedance of the SMPS can be modelled as a capacitor of 1000 pF. The CM circuit has to be realized by two capacitors of value2000 P.F with self resonance frequency of 5 MHz and one inductor with inductance of 1mH with self resonance frequency of 10 MHz.

Course Outcome 3 (CO3)

1. A mirocontroller is kept inside painted shielded chamber 25cm X 20cm X 10 cm with the painting thickness of 60 μm with conductivity and permeability are 5× 107 S/m and 6π × 10−7 H/m respectively. The cross section of the chamber has a slot of 2 mm width with 15 cm length to insert the microcontroller. Considering the microcontroller acts as a loop antenna and the distance between the card and the paint is about 8 cm determine the shielding effectiveness (SE) of the coating between 100 MHz to 800 MHz and determine the frequencies at which the SE deteriorates.
2. A power supply board is placed near an tarpaulin shed with aluminium coating The conductivity of Aluminium is 3.55 × 107 S/m. Assuming the tarpaulin shed is much bigger than the power board and assuming the power board acts as circular loop antenna, determine the shielding effectiveness The effect of the tarpaulin plastic can be ignored in all the calculations.

Course Outcome 4 (CO4)

1. A two-layer printed circuit board (PCB). A voltage regulator (VR) provides DC power to an integrated circuit(IC) through the power and ground planes of the PCB. When the IC is in operation, it draws the current from the capacitor in saw tooth form with amplitude of 100 mA , with rising edge of 2 nS and period 20nS. Assume that the capacitor is ideal and its capacitance is large enough to supply the current to the IC. (a) Will the PCB comply with CISPR 22 Class B limit as given in Table. Justify your answer by calculating and plotting the radiated electric field spectrum against the limit up to 1 GHz. (b) What is the purpose of adding the capacitor next to the IC?

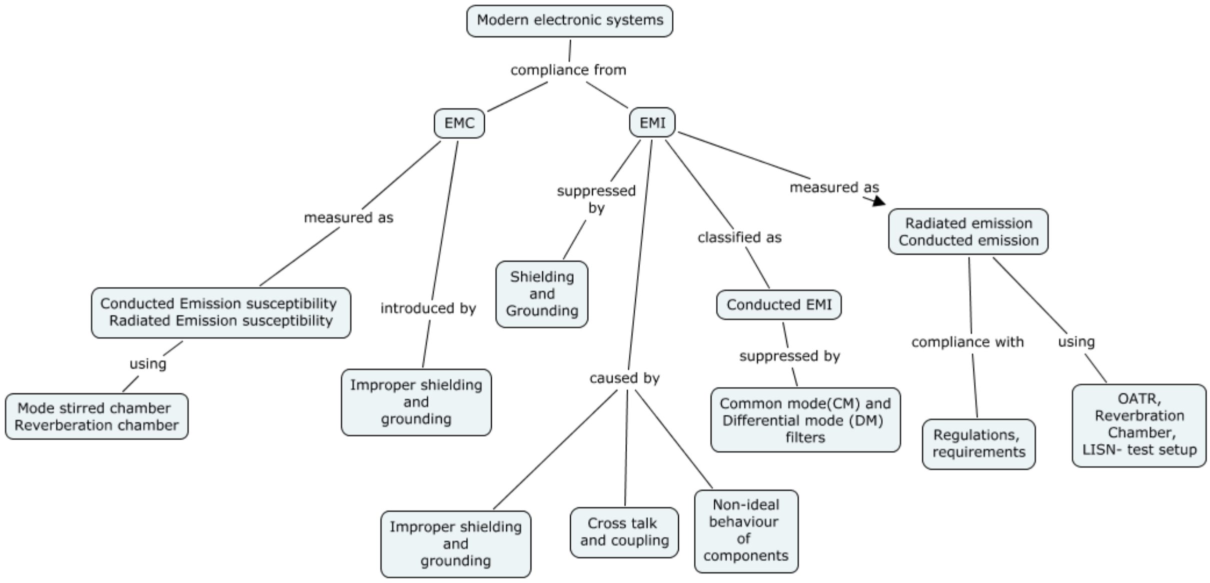
Frequency in MHz	Electric Field Limit at 10 m in dB μV/m
30-230	30
230-1000	37

2. A dipole as a transmitting antenna and a circularly polarized patch receiving antenna are separated by a distance D and a height H, The patch antenna is tilted by an angle α from the vertical axis.
(a) Show that the polarization mismatch loss (PML) is given by: PML (dB) = 20 log [cos ($\alpha - \beta$)] −3, where $\beta = tan{-1}$ (H/D).
(b) Given that D = 10 m and H = 1.2 m, determine the tilt angle α that will result in minimum PML. Compute the PML under this condition.

Course Outcome 5 (CO5)

1. Compare and contrast various EMI measurement set up with respect to their size, design complexity and versatility.
2. What are the measurement set up to measure Conducted emission and radiation emission

Concept Map



Syllabus

Introduction to EMI - Definitions, Different Sources of EMI(Electro-magnetic Interference), Electro-static discharge(ESD),Electro-magnetic pulse(EMP),Lightning, Mechanism of transferring Electro-magnetic Energy: Radiated emission, radiated susceptibility, conducted emission, conducted susceptibility, Differential & common mode currents.
Introduction to EMC - Concepts of EMC, EMC units.
EMC Requirements for Electronic Systems - World regulatory bodies- FCC, CISPR etc. Class-A devices, class-B devices, Regulations of the bodies on EMC issues.
Different Mitigation Techniques for preventing EMI - Grounding: Fundamental grounding concepts, Floating ground, Single-point and Multi-point ground, advantages & disadvantages of different grounding processes. **Shielding**: Basic concepts of shielding, Different types of shielding, Shielding effectiveness (S.E), S.E of a conducting barrier to a normal incident plane wave, multiple reflection within a shield, mechanism of attenuation provided by shield, shielding against magnetic field & Electric field, S.E for Electronic metal & Magnetic metal, Skin-depth, S.E for far-field sources, shield seams. Cross-talks and Coupling, Measurement set for measuring Cross-talk. Filtering and decoupling.

Reference Books

1. Clayton R. Paul, Introduction to Electromagnetic Compatibility, 2nd Edition, Wiley Interscience, 2006
2. V.P.Kodali, Engineering Electromagnetic Compatibility, Principles, Measurements, and Technologies, IEEE Press,1996
3. Henry W Ott, Electromagnetic Compatability Engineering, John Wiley& Sons, 2009
4. Christos Christopoulos, Principles and Techniques of Electromagnetic Compatibility, Second Edition, CRC Press, Taylor & Francis Group
5. EMI/EMC Computational modeling Hand Book- by Archambelt

Course Contents and Lecture Schedule

Module No.	Topic	No.of Lectures
1	**Introduction to EMI**	1
1.1	Definitions, Different Sources of EMI(Electro-magnetic Interference)	2
1.2	Electro-static discharge(ESD)	2
1.3	Electro-magnetic pulse(EMP), Lightning,	2
1.4	**Mechanism of transferring Electro-magnetic Energy:** Radiated	2

	emission, conducted emission	
1.5	radiated susceptibility, conducted susceptibility	2
1.6	Differential & common mode currents	2
2	**Introduction to EMC** - Concepts of EMC, EMC units	2
3	**EMC requirements for electronic systems**	
3.1	World regulatory bodies- FCC, CISPR etc	3
3.2	Class-A devices, class-B devices	2
3.3	Regulations of the bodies on EMC issues	1
4	**Different Mitigation Techniques For preventing EMI**	1
4.1	**Grounding**: Fundamental grounding concepts, Floating ground	2
4.2	Single-point & Multi-point ground, advantages & disadvantages of different grounding processes	1
4.3	**Shielding**: Basic concepts of shielding, Different types of shielding	1
4.4	Shielding effectiveness(S.E),S.E of a conducting barrier to a normal incident plane wave,	2
4.5	multiple reflection within a shield, mechanism of attenuation provided by shield	1
4.6	shielding against magnetic field & Electric field, S.E for Electronic metal & Magnetic metal,	1
4.7	Skin-depth,S.E for far-field sources, shield seams.	2
4.8	Cross-talks & Coupling, Measurement set for measuring Cross-talk	2
4.9	Filtering & decoupling	2

Course Designers:

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18CNPG0	RF MEMS FOR HIGH PERFORMANCE PASSIVES	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

MEMS has been identified as one of the most promising technologies for the 21st Century and has the potential to revolutionize both industrial and consumer products by combining silicon-based microelectronics with micromachining technology. The performance of current RF (Radio Frequency) systems can be enhanced by replacing critical components by their MEMS counterparts (Micro Electro Mechanical systems).This course starts with the glimpses of MEMS covering the introduction and origin of MEMS, driving force for MEMS development, commercial applications, fabrication process and packaging techniques. The latter half of the course will be devoted to provide a thumb rule in designing, modeling various RF MEMS components such as switches, capacitors, phase shifters, micromachined Transmission lines and antennas. They are also exposed to the MEMS CAD tools available in the Design center. Special weight is given to design circuits and do simulation with Comsol, Intellisuite and Coventoreware.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Design and analyse different RF MEMS Switch circuits	Analyse
CO2	Summarize the Concept of miniaturization, need for MEMS in various applications, concepts of various actuation mechanisms and also the need for packaging techniques of MEMS devices	Understand
CO3	Design and analyze different types of RF MEMS capacitors and inductors.	Analyse
CO4	Design RF MEMS phase shifters for phased array applications.	Apply
CO5	Design and summarize the need for micromachining techniques to antennas	Apply
CO6	Summarize various micro fabrication techniques	Analyse
CO7	Analyse the RF MEMS components using MEMS CAD Tools	Analyse

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	S	M	L	L	-	-	L	-	L	-
CO2	L	L	L	-	-	-	-	-	-	-	-
CO3	S	S	M	L	L	-	-	L	-	L	-
CO4	S	M	L	L	L	-	-	L	-	L	-
CO5	S	M	L	-	L	-	-	L	-	-	-
CO6	L	L	L	-	-	-	-	-	-	-	-
CO7	S	S	M	L	L	-	-	L	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	40	0	20	20
Apply	40	80	50	60
Analyse	20	20	30	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Design a RF MEMS shunt switch with an equivalent circuit approach operating at a frequency of 40 GHz.
2. i) Applying the concepts of direct analogy between electrical and mechanical domains Convert the mechanical model of a RF MEMS shunt switch to electrical model.
   ii) Derive the expression for pull down voltage of a switch.
3. With the help of an equivalent circuit model design a MEMS capacitive switch with the following specifications: f = 36 GHz, Length of the membrane (L) = 300 μm, $wxW = 40*100\ \mu m^2$, g = 4 μm, t = 2 μm, $t_d = 1500A^0, \varepsilon_r = 7.6$

Course Outcome 2 (CO2):

1. Tabulate the direct analogy of electrical and mechanical domains.
2. Classify MEMS packages. Based on the need for packaging of MEMS devices classify and differentiate various packaging methodologies.
3. Mention few MEMS softwares?

Course Outcome 3 (CO3):

1. Applying the various actuation mechanisms, discuss how MEMS capacitors can be realized?
2. List the ways of designing RF MEMS capacitors and explain the draw backs present in two plate system. How three plate system provides better capacitance ratio.
3. How a planar inductor can be modeled and designed? Explain the various design issues for enhancing the performance of the MEMS inductors.

Course Outcome 4 (CO4):

1. Determine the Bragg frequency and the phase shift per unit length of a DMTL phase shifter at a frequency of 10 GHZ.
2. Design a DMTL phase shifter using LC model with the following design specifications.
   f = 30 GHz, Length of the membrane (L) = 300 μm, $wxW = 40*100\ \mu m^2$,g=4 μm,
   t = 2 μm, $Z_0 = 100$ ohms, $Z_{lu} = 60$ ohms, z_{ld} = 42 ohms, $t_d = 1500A^0$.

Course Outcome 5 (CO5):

1. How radiation occurs from microstrip antennas. Comment on the various choices of micromachining techniques for realizing microstrip antennas.
2. What do you mean by reconfigurability?.How micromachining technique could be applied to build a Vee antenna for beam steering and beam shaping?
3. Design a patch antenna (w, L, Δ*l*, ϵ_{eff}, Q_c, Q_d) with the following specifications:
   ϵ_r = 4.3, h=1.8mm, f=5.6GHz

Course Outcome 6 (CO6):

1. What is PVD and CVD?
2. What do you mean by top to bottom design approach?
3. a)Classify the materials used for MEMS fabrication.
   b) List the properties of silicon nitride.

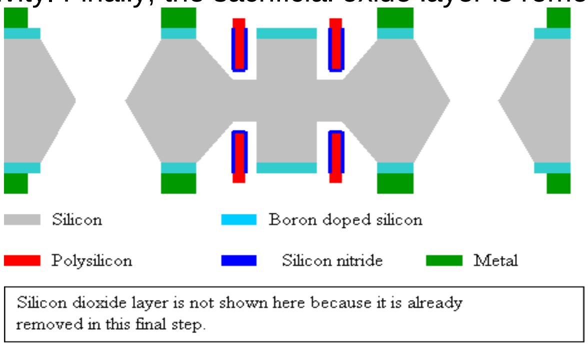
Course Outcome 7 (CO7):

1. Compare and contrast the usage of Intellisuite and Coventorware MEMS CAD tools.
2. List the important features of Coventorware MEMS CAD tool.
3. Given the following description of a micromachined accelerometer, draw the step-by-step process flow with cross-section diagrams. For your convenience, the cross-section of the final device is also given below.

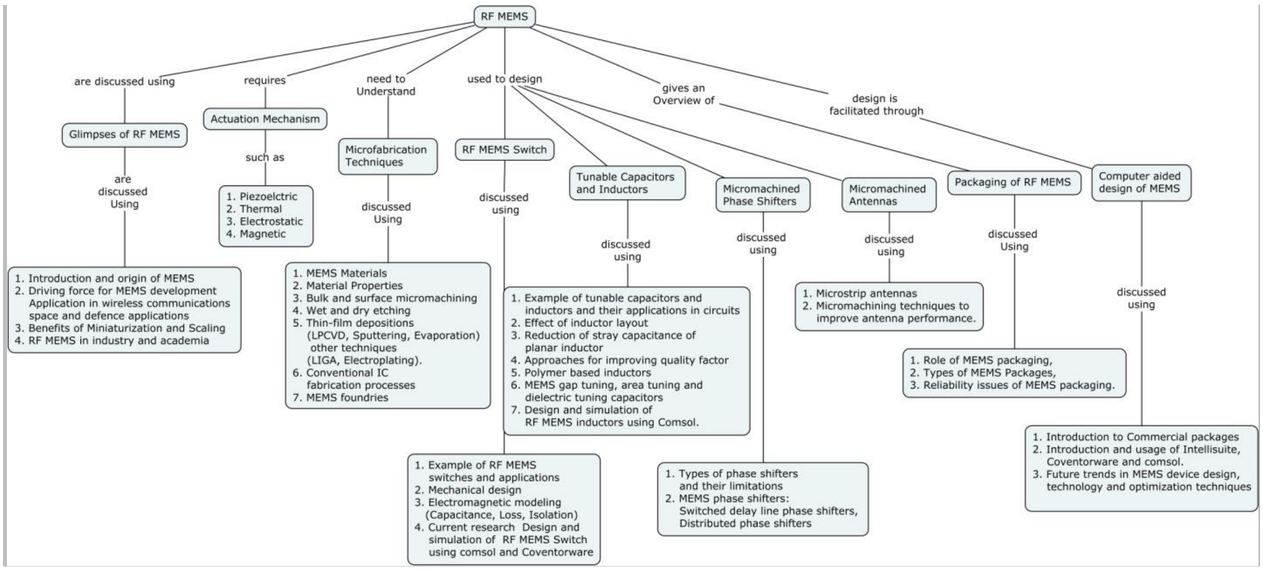
   In order to microfabricate a micromachined accelerometer, combinations of bulk and surface micromachining techniques are used. The process has seven masks and involves double-sided processing utilizing silicon dioxide as a sacrificial layer. The device structure is defined by anisotropic etching at the end of the process.

   The process begins with a shallow p++ boron diffusion, defining the proof-mass and supporting rim, on a <100> silicon wafer that is polished on both the sides. Then, 60 um deep trenches are DRIE etched in the silicon and are used later to form the vertical electrodes. The trenches are then refilled completely with a combination of LPCVD silicon dioxide (sacrificial layer), silicon nitride, and doped polysilicon. The polysilicon trench refilling is used to form vertical sense/drive electrodes and high aspect ratio springs to support the proof mass. After polysilicon deposition, annealing is followed to alleviate any compressive stress in the polysilicon.

Next, the polysilicon and nitride films are etched using RIE and another LPCVD silicon dioxide (capping oxide) is deposited. The oxide is patterned to form contact openings to the bulk silicon for the subsequent etch in the EDP. Then, contact metal is electroplated. To minimize the etch-time in the EDP and help undercut the electrodes by the etchant, some of the single-crystal silicon is etched by DRIE. After the DRIE, EDP etch is followed not only to release the proof mass and the supporting rim but also to etch the unnecessary silicon around the sense/drive electrodes. This step is important to achieve high-sensitivity. Finally, the sacrificial oxide layer is removed by etching in HF.



Concept Map



Syllabus

Glimpses of MEMS: Introduction and origin of MEMS, driving force for MEMS development Application in wireless communications, space and defence applications, Benefits of Miniaturization and Scaling, RF MEMS in industry and academia.

Actuation Mechanisms in MEMS: Piezoelectric, Electrostatic, Thermal and Magnetic

Micro fabrication Techniques: MEMS Materials, Material Properties, Bulk and surface micromachining, Wet and dry etching Thin-film depositions (LPCVD, Sputtering, Evaporation), other techniques (LIGA, Electroplating). Conventional IC fabrication processes, MEMS foundries

RF MEMS Switch: Example of RF MEMS switches and applications, Mechanical design, Electromagnetic modeling (Capacitance, Loss, Isolation), Current research Design and simulation of RF MEMS Switch using Comsol and Coventorware.
Tunable Capacitors and Inductors: Example of tunable capacitors and inductors and their applications in circuits, Effect of inductor layout, reduction of stray capacitance of planar inductor, Approaches for improving quality factor, Polymer based inductors, MEMS gap tuning, area tuning and dielectric tuning capacitors, Design and simulation of RF MEMS inductors using Comsol.
Micromachined phase shifters: Types of phase shifters and their limitations, MEMS phase shifters: Switched delay line phase shifters, Distributed phase shifters.
Micromachined antennas: Microstrip antennas, Micromachining techniques to improve antenna performance.
Packaging of RF MEMS : Role of MEMS packaging, Types of MEMS Packages, Reliability issues of MEMS packaging.
Computer aided design of MEMS: Introduction to Commercial packages, Introduction and usage of Intellisuite, Coventorware and comsol. Future trends in MEMS device design, technology and optimization techniques.

Reference Books

1. http://care.iitd.ac.in/People/Faculty/bspanwar/teaching.html
2. http://nptel.ac.in/courses
3. http://www.mecheng.iisc.ernet.in/~suresh/memscourse/pcontent.html
4. Vijay K Varadhan ,K.J.Vinoy "RF MEMS and their Applications", John Wiley & Sons, 1998.
5. K.J Vinoy, K.N Bhat, V.K Aatre "Micro and Smart Systems", John Wiley & Sons, 2010

Course Contents and Lecture Schedule

Module No	Topic	No. of Lectures
1.	**Glimpses of MEMS**	
1.1	Introduction and origin of MEMS	1
1.2	Driving force for MEMS development Application in wireless communications, space and defence applications	1
1.3	Benefits of Miniaturization and Scaling	0.5
1.4	RF MEMS in industry and academia	0.5
2.	**Actuation Mechanisms in MEMS**	
2.1	Piezoelectric	0.5
2.2	Electrostatic	0.5
2.3	Thermal	0.25
2.4	Magnetic	0.25
3.	**Micro fabrication Techniques**	
3.1	MEMS Materials	0.5
3.2	Material Properties	0.5
3.3	Bulk and surface micromachining	0.5
3.4	Wet and dry etching	0.5
3.5	Thin-film depositions (LPCVD, Sputtering, Evaporation), other techniques (LIGA, Electroplating)	0.5
3.6	Conventional IC fabrication processes	0.5
3.7	MEMS foundries	0.5
4.	**RF MEMS Switch**	
4.1	Example of RF MEMS switches and applications	1
4.2	Mechanical design	1

4.3	Electromagnetic modeling (Capacitance, Loss, Isolation)	1
4.4	Current research Design and simulation of RF MEMS Switch	3
5.	**Tunable Capacitors and Inductors**	
5.1	Example of tunable capacitors and inductors and their	1
5.2	Effect of inductor layout	1
5.3	Reduction of stray capacitance of planar inductor	0.5
5.4	Approaches for improving quality factor	0.5
5.5	Polymer based inductors	0.5
5.6	MEMS gap tuning, Area tuning and dielectric tuning capacitors	1
5.7	Design and simulation of RF MEMS inductors using Comsol	3
6	**Micromachined phase shifters**	
6.1	Types of phase shifters and their limitations	1
6.2	MEMS phase shifters: Switched delay line phase shifters,	2
7	**Micromachined antennas**	
7.1	Microstrip antennas	1
7.2	Micromachining techniques to improve antenna performance	2
8	**Packaging of RF MEMS**	
8.1	Role of MEMS packaging	1
8.2	Types of MEMS Packages	1
8.3	Reliability issues of MEMS packaging.	0.5
	Computer aided design of MEMS	
9.1	Introduction to Commercial packages	1
9.2	Introduction and usage of Intellisuite, Coventorware and Comsol	6
9.3	Future trends in MEMS device design	1
9.4	Technology and optimization techniques	0.5
	Total	38

Course Designers:

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18CNPH0	RADIO FREQUENCY INTEGRATED CIRCUITS

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

This course will cover the design and analysis of Radio frequency integrated circuits (RFICs) for communications. We will begin with an overview of RF and wireless technology, and cover some fundamental concepts in RF design such as nonlinearity, noise, sensitivity, and dynamic range. Following this we will discuss transceiver architectures (Heterodyne, Direct Conversion, etc.), and review modulation and upconversion concepts. The latter half of the course will be devoted to a provide thumb rule in designing each of the blocks in the transceiver architectures such as Low Noise Amplifiers, Mixers, Frequency Synthesizers and Power Amplifiers. They are also required to design circuits and do simulation with Cadence SpectreRF. By taking this course, students can make good preparations for their research in relevant areas.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Calculate noise (amplitude and phase), linearity, and dynamic range performance	Apply
CO2. Discuss transceiver architectures relevant to current wireless communications	Understand
CO3. Design monolithic inductors and capacitors for integrated amplifiers and	Apply
CO4. Design and Implementation of Low Noise Amplifier based on foundry models for Wireless Communication Systems	Apply
CO5. Design and analyse different RF mixer circuit based on noise figure, conversion	Analyse
CO6. Design and analyse different types of Phase Locked Loops	Analyse
CO7. Design and analyze different Power amplifiers	Analyse

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	L	-	-	-	-	L	L	L	-
CO2	L	L	L	-	-	-	-	-	-	-	-
CO3	S	M	L	-	L	-	-	L	-	-	-
CO4	S	M	L	-	L	-	-	L	-	-	-
CO5	S	S	M	L	-	L	-	L	L	-	-
CO6	S	S	M	L	-	L	-	L	L	-	-
CO7	S	S	M	L	-	L	-	L	L	-	-

S- Strong; M-Medium; L-Low

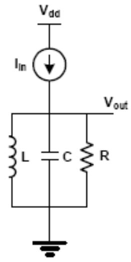
Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	0	0	0
Apply	80	80	60	60
Analyse	0	20	40	40
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Give any one expression for Q and state its units.
2. List out the various circuit level parameters used in RFIC.
3. Determine the quality factor of the tank with respect to R, C, and L.



Course Outcome 2 (CO2):

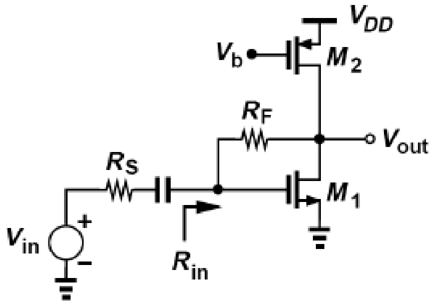
1. Distinguish between a heterodyne receiver and homodyne receiver.
2. Define: ACPR.
3. Mention few packages available for RFICs

Course Outcome 3 (CO3):

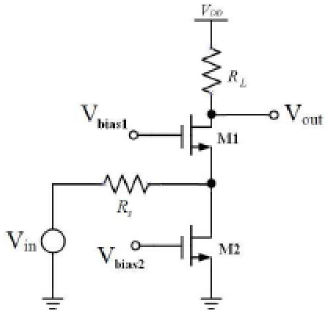
1. Explain the different choices of realization of RF inductors and capacitors in CMOS technology. Why these are different in compared to the conventional lumped component inductors and capacitors?
2. How can you design a monolithic capacitor?
3. Draw the schematics of a monolithic inductor. Mention few procedures available to design a effective layout

Course Outcome 4 (CO4):

1. Draw the circuit diagram of a typical inductor degenerated MOSFET LNA.
2. A common-source low noise amplifier (LNA) with feedback is shown in Fig. is the input source resistance. Assume that the transistors are long-channel devices and



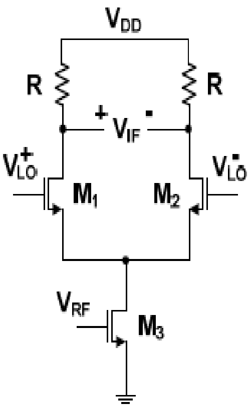
   a. Determine the input impedance (R_{in}) of the LNA.
   b. Calculate the voltage gain of the LNA (i.e.V_{out} / V_{in}) after matching if $R_F = 25R_S$.
   c. Derive an expression for the output noise of the LNA contributed by R_s after matching. Assume $R_F \geq R_S$.
3. Consider the wideband common-gate low noise amplifier (LNA) shown in Figure is the input source resistance. Assume that the transistors are long-channel devices with . Also assume that γ*body effect* = 0.



a. Calculate the input impedance of the LNA. Assume that we can neglect all parasitic associated with the transistors.
b. Derive an expression for the noise figure of the LNA. Only consider the thermal noise sources and ignore the gate noise of the transistors. Also assume that is a noiseless resistor.

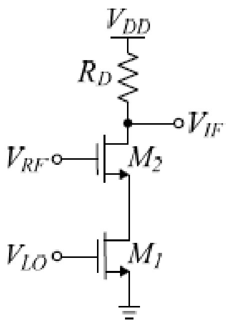
Course Outcome 5 (CO5):

1. A single-balanced mixer is shown in Fig. Assume that the switching transistors M1 and M2 are ideal switches with zero on-resistance and .



(a) Derive an expression for the conversion gain of this mixer.
(b) Derive an expression for the noise figure of this mixer. Assume the switching transistors do not generate noise. The total noise is contributed by transistor M3, load resistors R and source resistor R_s connected to the RF input (is not shown in the figure). Consider only the thermal noise sources and ignore the gate noise of the transistor.

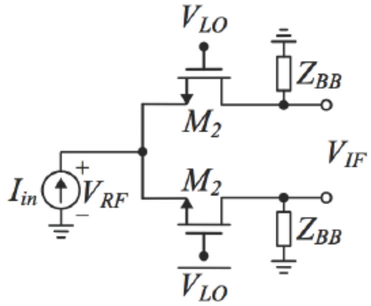
2. The circuit shown in Fig. is a dual-gate mixer used in traditional microwave design. Assume abrupt edges and a 50% duty cycle for the LO, and neglect channel-length modulation and body effect.



(a) Assume that *M*1 is an ideal switch. Determine all the frequency components which appear at the mixer IF port.

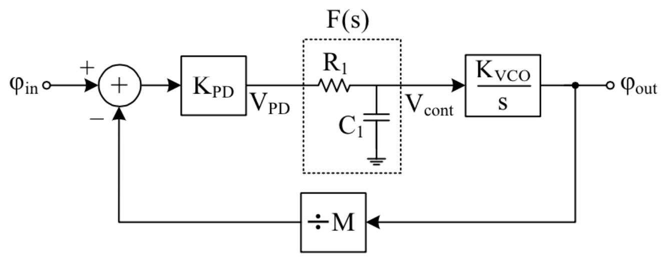
(b) Assume when *M*1 is on, it has an on-resistance of *R*on1. Compute the voltage conversion gain of the circuit. Assume *M*2 does not enter the triode region and denote its transconductance by *gm*2.
(c) Assume that *M*1 is an ideal switch (noise contribution is zero). Derive the expression for the noise figure of the mixer.

3. Prove that the voltage conversion gain of a sampling mixer approaches 6 dB as the width of the LO pulses tends to zero (i.e., as the hold time approaches the LO period).

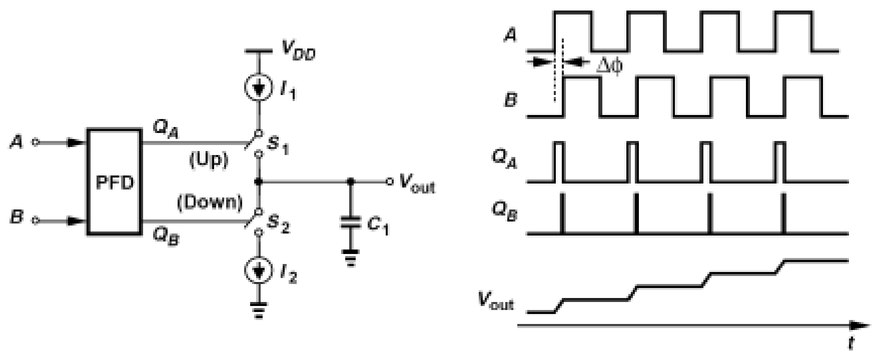


Course Outcome 6 (CO6):

1. For the frequency-multiplying PLL shown below, determine the:
   a. closed-loop transfer function
   b. damping factor ζ
   c. natural frequency ωn
   d. loop bandwidth



2. Explain how a type-I PLL operates as a FSK demodulator, if the VCO control voltage is considered as the output.
3. Figure show the waveforms of PFD and charge pump in a type-II PLL. Using this figure, determine the transfer function of this combination.



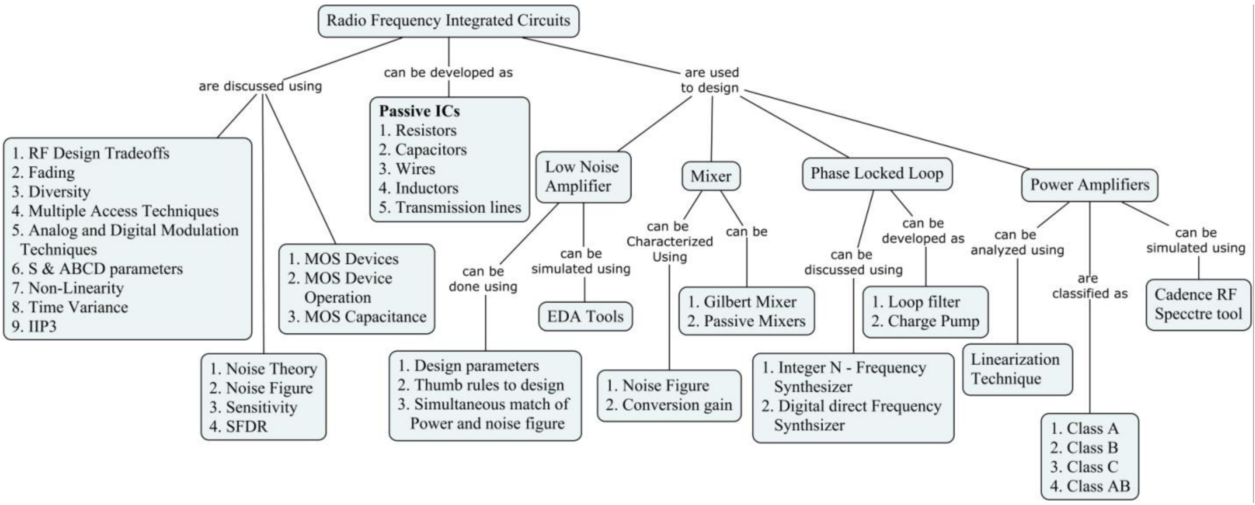
Course Outcome 7 (CO7):

1. The following table lists three different properties for the A, B, C, D, and E power amplifier classes and their typical values. Identify the power amplifier class for each column.

Maximum drain efficiency [%]	100	78.5	100	50	100
Peak drain voltage [*V_{DD}]	2	2	1	2	3.6
Normalized power output capability [Pout/(max V and I)]	0.125	0.125	0.32	0.125	0.098
Power Amplifer Class					

2. How would you select the gate-bias Vg,bias for a class-AB power amplifier?
3. What are the performance trade-offs when choosing this Vg,bias-value?

Concept Map



Syllabus

Introduction: RF Design Tradeoffs, Fading, Diversity, Multiple access techniques, Analog and Digital modulation, S and ABCD parameters, Non linearity, Time variance,IIP3(different expressions and Calculations),Transceiver architecture.

Noise in RF Circuits: Classical two port noise theory, Thermal noise, flicker noise review, Noise figure, Noise figure of cascaded systems, sensitivity, SFDR.

Passive IC components: Resistors, capacitors, Wires, Inductors and Transmission lines, skin depth concepts **Review of MOS devices**: Device Overview, MOS Device operation, MOS capacitances. **Low Noise amplifier**: Design parameters, Thumb rules to design, simultaneous match of Power and noise figure. Design of Low noise amplifier using EDA tools **Mixers**: Mixer fundamentals, Mixer non idealities, Two and Three port mixers, Gilbert Mixers, Passive mixers **Phase- Locked Loop**: PLL basics, Loop filters and Charge pumps, Integer-N frequency synthesizers, Direct Digital Frequency synthesizers. **Power Amplifier**: Classes of power amplifiers, Stability of feedback systems, Gain and phase margin, Root-locus techniques, Design of Power amplifier using CADENCE spectre tool.

Reference Books

1. http://www.ee.iitm.ac.in/~ani/2013/ee6240/lectures.html
2. http://nptel.ac.in/courses/117102012
3. http://www.ece.utah.edu/~ccharles/ece6730
4. Behzad Razavi, RF Microelectronics, 2nd Ed., Prentice Hall, Reprint 2012.
5. Thomas. H. Lee, The Design of CMOS Radio Frequency Integrated Circuits, Cambridge,U.K., Cambridge University Press, 2004
6. John W.M.Rogers and Calvin Plett, “Radio Frequency Integrated Circuit Design”, 2nd Edition,Artech House, Norwood, 2010.

Course Contents and Lecture Schedule

Module No	Topic	No. of Lectures
1.	**Introduction**	
1.1	RF Design Tradeoffs	1
1.2	Fading	0.5
1.3	Diversity	0.5
1.4	Multiple access techniques	0.5
1.5	Analog and Digital modulation	0.5
1.6	S and ABCD parameters	0.5
1.7	Non linearity	1
1.8	Time variance	0.5
1.9	IIP3(different expressions and Calculations)	1
1.10	Transceiver architecture	1
2.	**Noise in RF Circuits**	
2.1	Classical two port noise theory	0.5
2.2	Thermal noise	0.5
2.3	Flicker noise review	0.5
2.4	Noise figure	0.5
2.5	Noise figure of cascaded systems	2
2.6	Sensitivity	0.5
2.7	SFDR	0.5
3.	**Passive IC components**	
3.1	Resistors	0.5
3.2	Capacitors	1
3.3	Wires	0.5
3.4	Inductors and Transmission lines	1
3.5	Skin depth concepts	1
4.	**Review of MOS devices**	
4.1	Device Overview	0.5
4.2	MOS Device operation	0.5
4.3	MOS capacitances.	1
5.	**Low Noise amplifier**	
5.1	Design Parameters	1
5.2	Thumb rules to design	1
5.3	Simultaneous match of Power and noise figure	1
5.4	Design of Low noise amplifier using EDA tools	1
6.	**Mixers**	
6.1	Mixer fundamentals	1
6.2	Mixer non idealities	1
6.3	Two and Three port Mixers	1
6.4	Gilbert Mixers	1
6.5	Passive mixers	1
7.	**Phase- Looked Loop**	
7.1	PLL basics	1
7.2	Loop filters and Charge pumps	1
7.3	Integer-N frequency synthesizers	1
7.4	Direct Digital Frequency synthesizers	1

8	**Power Amplifier**	1
8.1	Classes of power amplifiers	1
8.2	Stability of feedback systems	1
8.3	Gain and phase margin	1
8.4	Root-locus techniques	1
8.5	Design of Power amplifier using CADENCE spectre tool	1
	Total	36

Course Designers:

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18CNPJ0	ANTENNAS FOR WIRELESS APPLICATIONS	Category	L	T	P	Credit
		PE	2	1	0	3

Preamble

Recent advances in cellular and navigation communication systems demands development of small antennas that can be embedded into the base station and user equipments. Furthermore, the development of new services and radio technologies demand for low cost, light weight, miniaturized, efficient antennas for wireless system. One of the main competencies that a present day antenna engineer has to posses is the capability to design antennas for wireless devices that have good bandwidth, gain and radiation characteristics.

This subject is essential to understand the need for designing broadband and miniaturized antennas for wireless applications such as Radio frequency identification, cellular, navigation and next generation wireless applications. This course presents various types of antenna geometry suitable for the above mentioned wireless devices, the issues in respect of their design and development.

One of the main competencies that a present day communication engineer has to acquire is the capability to design antennas for wireless applications that provide easy integration with good performance.

Prerequisite

18CN120 RF Circuits for Communication Systems

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Explain the requirements of an antenna for wireless applications in terms its parameters	Understand
CO2. Identify and apply antenna design techniques for applications such as RFID and cellular, navigation and next wireless generation	Apply
CO3. Simulate the radiation pattern of antennas using EM CAD simulator software-ADS	Apply
CO4. Develop prototype of a designed antenna & Measure its parameters	Evaluate
CO5. Calculate the wireless link budget for specific application	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	L	-	-	-	-	-	-	-	-
CO2	S	M	L	-	-	-	-	-	-	-	-
CO3	S	M	M	M	M	-	-	-	-	-	-
CO4	S	M	M	M	M	-	-	-	-	-	-
CO5	S	M	M	L	M	L	M	-	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	30	30	30	30
Apply	70	70	70	70
Analyze	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome (CO1)

1. What are the features of 4G wireless systems?
2. Explain the spectrum allocation for various wireless applications.

3. List some of the antennas used for near field communication

Course Outcome (CO2)

1. What are the effects of environment on RFID Tag antenna?
2. What are the effects of user on the mobile unit performance?
3. Why monopole antennas are preferred for wireless communication ?

Course Outcome (CO3)

1. Design and simulate wireless antenna to work at 1.7GHz
2. Design and simulate planar inverted F antenna operating in Cellular GSM lower band.
3. Suggest a suitable planar antenna system for the given specification:
   Center Frequency - 5GHz
   Dielectric constant – 3.38
   Thickness - 1.52mm
   VSWR - 2:1
   Bandwidth > 500MHz

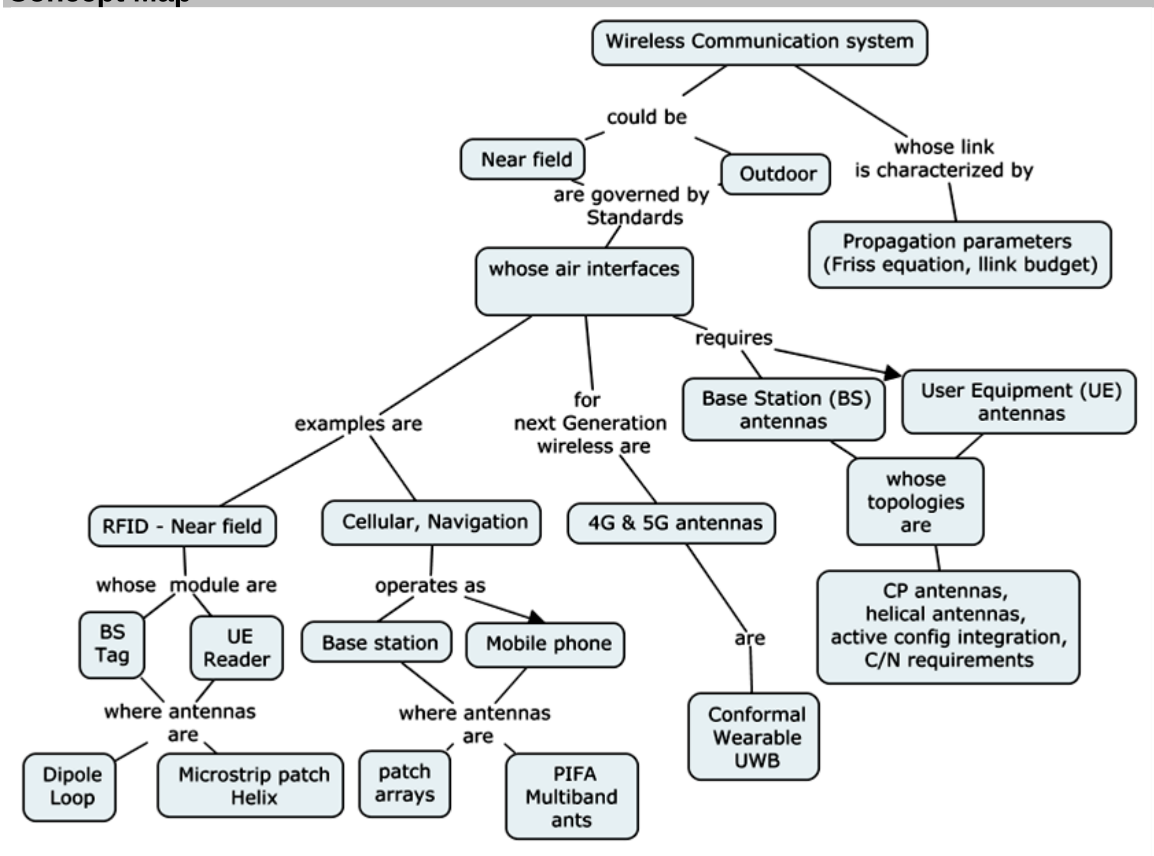
Course Outcome (CO4)

1. Propose simulation steps to facilitate the design of patch antenna on a multilayer substrate having effective dielectric constant of 5.5.
2. Develop prototype of an antenna operating in lower GSM band.
3. Test and measure the parameters of given antenna operating at 3GHz.

Course Outcome (CO5)

1. The output power of a 900MHz mobile phone base station transmitter is 100w. It is connected to an antenna having a gain of 15.Calculate the power delivered to the receiver kept at a distance of 25km. Gain of the receiver antenna is 20.
2. Derive Friss transmission formula for a given wireless link
3. If a transmitting dipole antenna sends out a wave of 25kw power, calculate the field strength at the a distance of 30km away from the transmitter.

Concept Map



Syllabus

Introduction: Evolution of wireless communications, Key terms and concepts, Wireless systems and standards – Applications, Air interface- Near field, Indoor, Outdoor, Requirements of antenna for above applications, Base station (BS) and User equipment (UE) antennas

RFID Antennas: RFID Regulations, frequencies and Standardization, Reader Air interface parameters-. Types of readers - Handheld, Fixed, high power. Reader antennas- gain, bandwidth and polarization, Microstrip patch, pillar antennas and design.

RFID Tag Antennas: Tag architecture- Tag, clip type, Types of Tag- Dipole, loop, design considerations, Radio Link, Parameters, Effect of Environment on RFID Tag Antennas. Design of reader and tag antennas.

Cellular antennas: Cellular applications, Performance Requirements, Mode of operation, Base station antenna- specifications and challenges, topologies, Electrically Small Antennas, Topologies- Patch arrays,. User equipment- antenna design challenges, Multiband PIFA, SAR

Antennas for Navigation: Adaptive GPS Antennas , Ground Plane, Aircraft Fuselage, and Other Platform Effects on GPS Antennas, Multiband, Handset, and Active GNSS Antennas, topologies, CP patch antennas, Helix, Active antenna and Integration.

Practical Design- Simulations using CST MW studio, prototyping and Measurements.

Next Generation Wireless Antennas: 4G & 5G communication, challenges, form factor and broadband performance, Conformal, wearable and UWB antennas, Artificial intelligence and machine learning approach for designing antennas.

Wireless Propagation : characteristics of atmosphere, its significance**,** propagation models, Wireless link, link budget calculations

Reference Books:

1. Kin Lu Wong "Planar antennas for wireless communications" her John Wiley and Sons Ltd Publishers, 2003
2. John D.Kraus, Ronald J.Marhefka "Antennas for all Applications" Fourth Edition, Tata McGraw- Hill, 2006.
3. Zhi Ning Chen, "Antennas for Portable devices" Wiley Publishers, 2007
4. V.Daniel Hunt, Albert Puglia, Mike Puglia, 'A Guide to Radio Frequency Identification', Wiley Interscience, A John Wiley & sons inc., publications 2007
5. B Ramarao, W.Kunysz, R Fante, K.McDonald, 'GPS/GNSS Antennas', Artech House, 2013.
6. Q.J. Zhang, K.C.Gupta, "Neural Networks for RF and Microwave Design", Artech House Publishers, 2000.
7. http://www.tranzeo.com

Course Contents and Lecture Schedule

Module No	Topics	No. of Lectures
	Introduction:,	
1	Evolution of wireless communications, Key terms and concepts,	2
2	Wireless systems and standards – Applications,	2
3	Air interface- Near field, Indoor, Outdoor	2
4	Requirements of antenna for above applications, Base station (BS) and User equipment (UE) antennas	1
5	Tutorial	3
	Near field applications:	
6.	RFID Frequency, Regulations and Standardization , spectrum allocation	2
1.	RFID Reader: Air interface parameters- power, data rate, Types of readers- Handheld, Fixed, high power	2
2.	Reader antennas- Specifications- gain, bandwidth and polarization	1

3.	Microstrip patch, loop..	2
4.	Types of Tag- Dipole , loop, design considerations	1
5.	Radio Link, Parameters, Effect of Environment on RFID Tag Antennas. Design of reader and tag antennas.	2
6.	Tutorial	3
	Cellular antennas:	
14	Cellular applications, Performance Requirements, Mode of operation,	2
15	Base station antenna- specifications and challenges, topologies,	1
16	Electrically Small Antennas, Topologies- Patch arrays, Beam tilting, null fill.	2
17	User equipment- antenna design challenges,	1
18	Multiband PIFA, SAR, Practical Design- Simulations	2
19	Tutorial	2
	Antennas for next Generation wireless Applications:	
20	4G & 5G communication	2
21	Conformal, wearable and UWB antenna	2
22	Artificial intelligence and machine learning approach for designing antennas	2
22	Tutorial	2
	Wireless Propagation	
23	characteristics of atmosphere, its significance, propagation models, Wireless link, link budget calculations	4
24	Tutorial	3

Course Designers:

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18CNPK0	IMAGE SYSTEMS ENGINEERING	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The purpose of this course is to provide the basic concepts and methodologies for Digital Image Processing in three different levels. At the lowest level, the course introduces the terminology of image processing, different imaging technologies and the algorithms deal directly with the raw pixel values. In the middle level, it addresses the Quality improvement techniques like enhancement and restoration approaches, segmentation and image representation techniques for analysis purpose. At the highest level, it addresses the classification using statistical decision making and it includes the image processing applications with few case studies.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Enhance and Restore images in spatial as well as frequency domains	Apply
CO2. Segment given images in terms of edge, threshold and region	Apply
CO3. Apply morphological operations like dilation, erosion, opening and closing on given images	Apply
CO4. Represent , recognize and classify objects from the given images	Apply
CO5. Apply compression techniques to various imaging modalities	Apply
CO6. Analyze different case studies like Face image feature extraction, video Motion imaging, watermarking.	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
1.	S	M	M	M	M	M	L	L	-	M	-
2.	S	M	M	M	M	M	L	L	-	M	M
3.	M	L	L	L	S	L	L	L	-	M	L
4.	L	L	S	M	L	L	M	L	M	M	M
5.	M	M	L	S	M	M	M	M	M	M	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's category	Continuous Assessment Tests			End Semester Examinations
	1	2	3	
Remember	10	10	10	10
Understand	10	10	10	10
Apply	60	60	60	60
Analyze	0	0	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

COURSE OUTCOME 1(CO1):

1. List the properties of first and second order derivatives.
2. Give the PDF of Erlang noise and sketch the PDF.
3. Explain sharpening in frequency domain filters.
4. Consider two 8-bit images whose gray levels span the full range from 1 to 255. Will reversal of the order of the images yield a different result?
5. For a 5 bit input matrix perform histogram equalization.

10	10	15	0	0
5	0	10	10	15
15	15	2	0	10
5	5	0	10	30

6. Find the filter output using Alpha trimmed mean filter for the following matrix.
Assume d=10.

5	10	15	20	5
10	10	15	20	5
5	10	20	5	5
20	15	15	10	0
15	0	5	15	20

7. Suppose that you form a low pass spatial filter that averages the four immediate neighbors of a point (x, y) but excludes the point itself.
   a) Find the equivalent filter H(u, v) in the frequency domain.
   b) Show that your result is low pass filter.

COURSE OUTCOME 2(CO2):

1. Write the masks to detect horizontal and vertical lines in an image
2. State convolution and correlation.
3. A binary image contains straight lines oriented horizontally, vertically, at 45^o and -45^o. Give a set of 3X3 masks that can be used to detect one pixel long breaks in these lines. Assume that the gray level of the line is 1 and that the gray level of the background is 0.
4. With reference to this equation

$$\nabla^2 h(r) = -\left[\frac{r^2-\sigma^2}{\sigma^4}\right] e^{\frac{-r^2}{2\sigma^2}}$$

   a. Show that the average value of the laplacian Δ^2h=0
   b. Prove that the average value of any image convolved with this operator is also zero.

COURSE OUTCOME 3(CO3):

1. (i) Give a morphological algorithm for converting an 8-connected binary boundary to an m-connected boundary. you may assume that the boundary is fully connected.
   a. Does the operation of your algorithm require more than one iteration with each Structuring element? Explain your reasoning.
   b. Is the performance of your algorithm independent of the order in which the Structuring elements are applied? if your answer is yes, prove it. otherwise give an example that illustrates the dependence of your procedure on the order of application of the structuring elements.

2.Erode the region consisting of 1's in the following image using the operator

2	3

.The '*' denotes the region of the operator.

0	0	1	0	0	0
0	1	1	1	0	0
0	1	0	1	1	0

COURSE OUTCOME 4(CO4):

1. Differentiate KNN Decision making and Bayesian Decision making?
2. The Bayes decision functions $d_j(x)=p(x/\omega_j)p(\omega_j)$, j=1,2,…W, were derived using a 0-1 loss function. Prove that these decision functions minimize the probability of error.(Hint: The probability of error p(e) is 1-p(c) where p(c) is the probability of being correct. For pattern vector x belonging to class ω_j $p(c/x)=p(\omega_j/x)$. Find p(c) and show that p(c) is maximum (p(e) is minimum when $p(x/\omega_j)$ $p(\omega_j)$is maximum)
3. Specify the structure and weights of a neural network capable of performing exactly the same function as a minimum distance classifier for two pattern class in N-dimensional place. Obtain the signatures for a pentagon and a rectangle.
4. What is the use of Bayesian Decision Making?
5. Specify the structure and weights of a neural network capable of performing exactly the same function as a bayes classifier for two pattern classes in n-dimensional space. The classes are Gaussian with different means but equal covariance matrices.
6. Explain the system flow for the character recognition.

COURSE OUTCOME 5(CO5):

1. Define Bit Plane Coding.
2. Explain how the lossless compression is done using bit plane coding.
3. Consider the simple 4 x 8, 8-bit image:

21	21	95	95	169	169	243	243
21	21	95	95	169	169	243	243
21	21	95	95	169	169	243	243
21	21	95	95	169	169	243	243

   a. Compress the image using Huffman coding
   b. Compute the compression achieved and the effectiveness of the Huffman coding.
4. Consider the following 8 x 8 subimage:

52	55	61	66	70	61	64	73
63	59	66	90	109	85	69	72
62	59	68	113	144	104	66	73
63	58	71	122	154	106	70	69
67	61	68	104	126	88	68	70
79	65	60	70	77	63	58	75
85	71	64	59	55	61	65	83
87	79	69	68	65	76	78	94

a.

Compute compression and reconstruction using JPEG baseline standard.

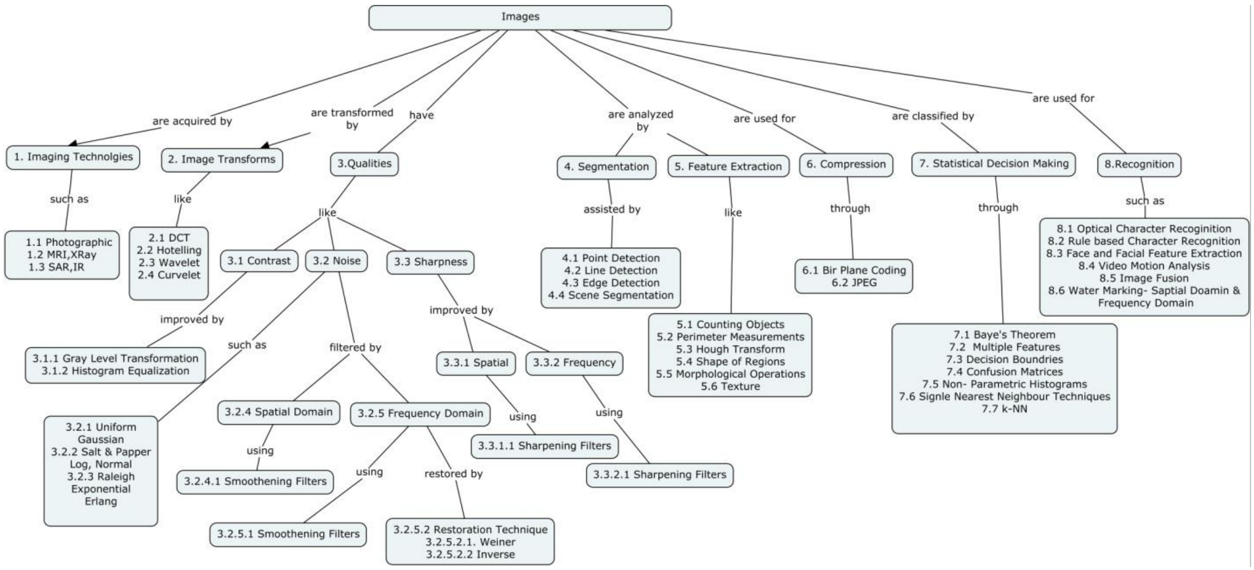
COURSE OUTCOME 6(CO6):

1. You are contracted to design a image processing system for detecting imperfection on the inside of certain solid plastic wafers. The wafers are examine using an X-ray imaging system which yields 8-bit images of 512×512 resolution. In the absence of

imperfection the images appear “bland” having a mean gray level of 100 and variance 400.The imperfection appear as blob like regions in which 70% of the pixels have excursion in intensity of 50 gray levels or less about a mean of 100.A wafer is considered defective such a region occupies an area exceeding 20 ×20 pixels in size. Propose a system based on texture analysis.

2. Evaluate the performance of spatial domain and frequency domain Watermarking
3. Analyze the various steps involved to extract facial features for recognizing

Concept Map



Syllabus

Imaging Fundamentals: Introduction to Imaging Technologies-Photographic- X-Ray-MRI-SAR-IR imaging–Image Representations- Image Transforms- DCT- Hotelling- Wavelet–Curvelet. **Image Quality Enhancement***:* contrast- noise- Sharpness –Gray level Transformation – Histogram processing –Spatial Domain spatial filtering – smoothing, sharpening filters- Frequency Domain Smoothing, sharpening **Image Restoration Techniques** – Inverse-Wiener **Processing and Analyzing Images***:* Point Detection- Line Detection – Edge Detection – Scene Segmentation and labeling – Counting objects – Perimeter measurement- Hough Transform – Shape of Regions- Morphological operations – Texture **Image Compression:**Bit plane coding,JPEG, **Statistical Decision Making:** Bayes Theorem – Multiple features- Decision Boundaries- Confusion matrices- Non parametric Histogram-Single nearest neighbor technique-K-NN **Imaging Applications:** System design**-** Optical character Recognition- Rule based Character Recognition- Face and Facial feature Extraction - Video motion Analysis- Image Fusion- Watermarking – spatial & frequency domain..

Reference Books

1. Rafael.C.Gonzalez and Richard.E. Woods, “Digital Image Processing”, 4th edition, Pearson/Prentice Hall Education, 2018
2. Earl Gose, Richard Johnson Baugh, “Pattern Recognition and Image analysis”, Prentice Hall India Pvt Ltd, 2006
3. William.K.Pratt, “Digital Image Processing”, 4th edition, A John Wiley and Publications,2007.
4. G.W.Awcock & R.Thomas, “Applied Image Processing” McGraw-Hill Inc.1996.
5. Frank.Y.Shih, “Image Processing and Pattern Recognition Fundamentals and Techniques”, A John Wiley & sons publication,2010.

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1.	**Introduction to Imaging Technologies**	
1.1	Photographic	1
1.2	X-Ray, MRI,	1
1.3	SAR, IR, Image Representations	1
2.0	**Image Transforms**	
2.1	Discrete CosineTransform	1
2.2	Hotelling	1
2.3	Wavelet	1
2.4	Curvelet	1
3.0	**Qualities**	
3.1	contrast	1
3.1.1	Gray level Transformation	1
3.1.2	Histogram Processing	1
3.2	Noise	
3.2.1 3.2.2 3.2.3	Uniform, Gaussian, Salt & pepper , Log normal, Rayleigh , Exponential ,Erlang	1
3.2.4	Spatial domain	
3.2.4.1	Smoothing filter	1
3.2.5	Frequency domain	
3.2.5.1	Smoothing filter	1
3.2.5.2	Restoration Techniques	1
3.2.5.2.1, 3.2.5.2.2	Wiener and Inverse	1
3.3	Sharpness	1
3.3.1	Spatial domain	
3.3.1.1	Sharpening filters	1
3.3.2	Frequency domain	
3.3.2.1	Sharpening filters	1
4.0	**Segmentation**	
4.1 4.2	Point detection Line detection	1
4.3	Edge detection	1
4.4	Scene Segmentation and labelling	1
5.0	**Feature Extraction**	
5.1	Counting objects	1
5.2	perimeter measurement	1
5.3,5.4	Hough transforms, shape of regions	1
5.5	morphological operations	1
5.6	Texture	1
6.0	**Image Compression**	
6.1	Bit Plane Coding	1
6.2	JPEG	1
7.0	**Statistical decision making**	
7.1	Bayes' theorem	1
7.2	multiple features	1
7.3	decision boundaries	1
7.4	confusion matrices	1

No.	Topic	No. of Lectures
7.5	Non-parametric-Histogram,	2
7.6	single nearest neighbor techniques	1
7.7	k-NN	1
8.0	**Applications**	
8.1	Optical character Recognition	1
8.2	Rule based Character Recognition	1
8.3	Face and Facial feature Extraction	1
8.4	Video motion Analysis	1
8.5	Image Fusion	1
8.6	Watermarking – spatial domain & Frequency domain	1

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18CNPL0	MACHINE LEARNING FOR VISUAL RECOGNITION	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The goal of "Machine learning for visual recognition" course is to develop the theoretical and algorithmic basis by which useful information about the world can be automatically extracted and visualized from a single image or a set of images. Since images are two-dimensional projections of the three-dimensional world, knowledge about the objects in the scene and projection geometry is required for low-level vision process. In mid-level, it describes that how the feature points are detected, matched and the alignment of matched feature points. Subsequently, it deals various clustering and segmentation algorithms to obtain meaningful segments for further analysis. The higher-level vision encompasses object recognition and categorization which includes various classifiers. Finally, it explores applications such as scene recognition, pedesterian detection, activity recognition and face recognition.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Illustrate the relationship between world coordinates and image coordinates and image formation using projective geometry.	Apply
CO2.	Select appropriate feature detection and matching method to recover transformation parameters based on matched points for feature alignment.	Analyze
CO3.	Examine segmentation algorithms such as meanshift, graph-based and active contours to find the correlation for grouping the meaningful segments.	Apply
CO4.	Investigate machine learning algorithms such as K Nearest Neighbor, Bag of words and Convolutional Neural Network for object recognition and categorization.	Analyze
CO5.	Identify the low, mid and high level methods for the exemplar computational visual recognition applications such as scene recognition, pedestrian detection, activity recognition and face recognition.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	L	L	L	L	-	-	-	L	-	-
CO2	S	M	M	M	L	L	-	-	M	-	-
CO3	M	M	L	L	L	-	-	-	M	L	-
CO4	M	L	L	M	L	-	-	-	M	-	-
CO5	M	L	L	M	M	L	-	M	M	M	-
	M	M	L	L	M	L	L	-	M	L	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's category	Continuous Assessment Tests			End Semester Examinations
	1	2	3	
Remember	10	10	0	0
Understand	30	10	10	10
Apply	40	60	50	50
Analyze	20	20	40	40
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define specular aberration.
2. How an image is formed through pin hole projection
3. Illustrate the planar projective transformation that describes the relationship between (X,Y) and (u,v)? Give your answer using homogeneous coordinates.
4. An ideal pinhole camera has focal length 5mm. Each pixel is 0.02 mm · 0.02 mm and the image principal point is at pixel (500, 500). Pixel coordinates start at (0, 0) in the upper-left corner of the image. Obtain the 3 · 3 camera calibration matrix, **K**, for this camera configuration.
5. Assuming the world coordinate frame is aligned with the camera coordinate frame (i.e., their origins are the same and their axes are aligned), and the origins are at the camera's pinhole, obtain the 3 x 4 matrix that represents the extrinsic, rigidbody transformation between the camera coordinate system and the world coordinate system.

Course Outcome 2 (CO2):

1. Develop an algorithm to stich two sample images of the mural in the geology museum which are taken by moving a handheld camera in a freeform motion.
2. Use SIFT features and propose solution for matching and alignment Describe how the *RANSAC* algorithm could be used to detect the orientation of the plane in the scene from the scene points.
3. Develop an algorithm using Harris corner detection and describe one feature alignment technique for the two matched points captured in our TCE Dome.
4. Illustrate various matching strategies and error rates. Compare the results by fixing the false positive rates.

Course Outcome 3 (CO3):

1. Prove that, in the absence of external forces, a snake will always shrink to a smallcircle and eventually a single point, regardless of whether first- or second order smoothness (or some combination) is used. Also, illustrate how active contour models are used for object detection as a geodesic computation approach.
2. Illustrate Graph cut algorithm to segment moving object from the static background.
3. Develop an algorithm to group the scattered regions in a SAR image using meanshift clustering algorithm for urban surveillance applications.
4. Illustrate region based segmentation for pedestrian and vehicle classification.

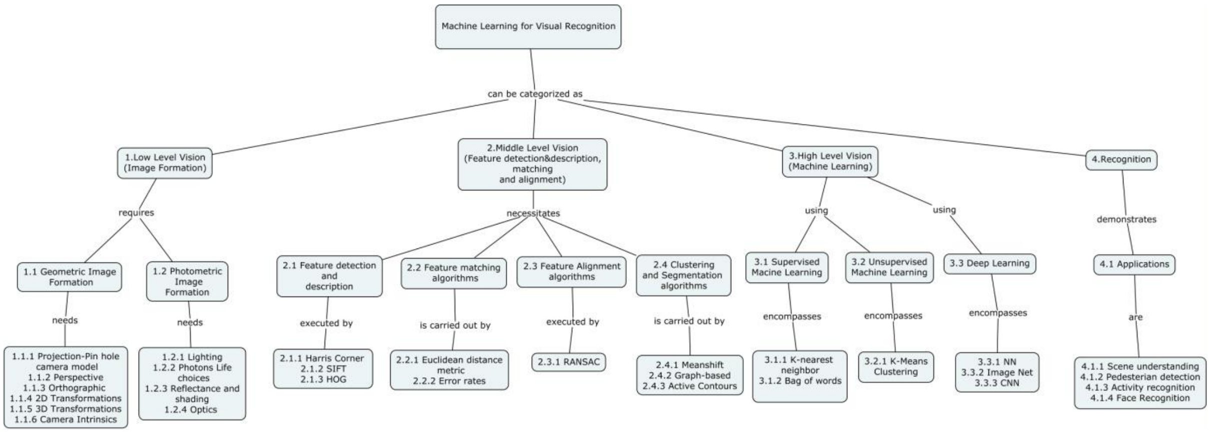
Course Outcome 4 (CO4):

1. Select a classifier to recognize the detected object is car or a human being when this frame is captured by a single static camera. Write the complexities for such classification for the given scenario.
2. Illustarte bag of words technique to recognize the scene as indoor or outdoor.
3. Demonstrate the training and testing process by convolutional neural networks to recognize the face in the given image.
4. Illustrate K nearest neighbor classifier to categorize the objects in the given image.

Course Outcome 5 (CO5):

1. Illustrate the algorithm to identify the important similarities of objects within a category.
2. Develop an algorithm to recognize objects based on shape in a clutterd environment, for example an office table comprises of penstand, stapler, cup and water bottle etc.
3. Illustrate scene understanding for an indoor scenario, for example one laboratory of your department with main components.
4. Develop a face recognition system using PCA subspace approach for authentication system to enter into the restricted zone.

Concept Map



Syllabus

Machine Learning for Visual Recognition- Introduction- computer vision applications-**Low Level Vision – Image formation**-**Geometric image formation**- Projection-Pinhole-perspective-orthographic-2D Transformations- 3D Transformations-camera intrinsics-**Photometric image formation**- Photon's life choices-Lighting-reflectance and shading-optics

Middle Level Vision- Feature detection, matching and alignment- Feature detectors and descriptors**-** Harris corner detection- Scale Invariant Feature Transform (SIFT)- Histogram of Oriented Gradients (HOG)-Feature matching algorithms- Euclidean distance metric-Error rates-Feature alignment algorithms- Random Sample Consensus (RANSAC)-**Clustering and Segmentation-** Meanshift Clustering –Graph-based segmentation-Active contours

High Level Vision-**Classifiers**-**Machine Learning:** Supervised-K-nearest neighbor-Bag of words-Unsupervised-K-Means Clustering-**Deep Learning:** Neural networks-Image Net-Convolutional Neural Networks

Recognition:Applications- Scene recognition using bag of words- Pedesterian detection using part based models-Activity recognition-Face recognition using Convolutional Neural Networks

Reference Books and Resources

1. R Szeliski, "Computer vision: algorithms and applications", Springer Science & Business Media, 2010.
2. David A. Forsyth, Jean Ponce, "Computer Vision – A Modern Approach", Prentice Hall, ISBN: 0130851981, 2003.
3. Richard Hartley and Andrew Zisserman, "Multiple View Geometry in Computer Vision", Second Edition, Cambridge University Press, March 2004.
4. Al Bovik, "Handbook of Image & Video Processing", Academic Press, ISBN: 0121197905, 2000.
5. Ragav VenRagav Venkatesan and Baoxin Li, "Convolutional Neural Networks in Visual Computing A Concise Guide", CRC Press, Taylor and Francis Group, LCCN 2017029154| ISBN 9781498770392 (hardback : alk. paper) |ISBN 9781315154282 (ebook), 2017.
6. Prince, S.J.D, "Computer Vision: Models, Learning, and Inference", Cambridge University Press, 2012.
7. http://www.ius.cs.cmu.edu/demos/facedemo.html

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Machine Learning for Visual Recognition- Introduction to computer vision course, Course objectives and outcomes, Concept Map - Low Level Vision: Introduction to Computer vision and its applications, Image Formation**	1

No.	Topic	No. of Lectures
1.1	**Geometric Image Formation**	1
1.1.1	Projection-Pinhole camera model	1
1.1.2	Perspective	1
1.1.3	orthographic	
1.1.4	2D Transformations	2
1.1.5	3D Transformations	2
1.1.6	Camera intrinsics	1
1.2	**Photometric Image Formation**	
1.2.1	Lighting	1
1.2.2	Photon's life choices	
1.2.3	Reflectance and shading	1
1.2.4	Optics	
2	**Middle Level Vision:**	
2.1	**Feature detectors and descriptors**	
2.1.1	Harris corner detection	2
2.1.2	Scale Invariant Featyre Transform (SIFT)	2
2.1.3	Histogram of Oriented Gradients (HOG)	1
2.2	**Feature matching algorithms**	
2.2.1	Euclidean distance metric	1
2.2.2	Error rates	1
2.3	**Feature alignment algorithms**	
2.3.1	Random Sample Consensus (RANSAC)	2
2.4	**Clustering and Segmentation**	
2.4.1	Meanshift Clustering	1
2.4.2	Graph based segmentation	1
2.4.3	Active contours	1
3.	**High Level Vision: Machine Learning Algorithms**	
3.1	**Supervised Machine Learning Calssifiers**	
3.1.1	K-nearest neighbor	1
3.1.2	Bag of words	1
3.2	**Unsupervised Machine Learning Calssifiers**	
3.2.1	K-Means Clustering	1
3.3	**Deep Learning**	
3.3.1	Neural Networks	2
3.3.2	Image Net	1
3.3.3	Convolutional Neural Networks	2
4	**Recognition: Applications**	1
4.1	Scene recognition using bag of words	1
4.2	Pedesterian detection using part based models	1
4.3	Activity Recognition	1
4.4	Face Recognition using Convolutional Neural Networks	1
	Total Number of Hours	36

Course Designer:

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18CNPM0	INTELLIGENT VIDEO SURVEILLANCE SYSTEMS	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The purpose of this course is to provide an insight into theoretical foundations and techniques in developing intelligent video surveillance system. It emphasizes the selection of the appropriate equipment including hardware and software and storage devices and encompasses the essential topics such as networked video, wireless networked video and bandwidth. Further, it covers the low-level intelligence modules such as motion segmentation and tracking and high-level intelligence modules such as action and face recognition. These topics comprise the formal problem formulation, typical challenges which make the processes difficult and computational principles of state-of-the-art algorithms. Finally, it concludes with design of an intelligent video surveillance system for exemplar security applications as case studies including home surveillance, Human fall analysis, Traffic surveillance, License plate recognition and object detection and tracking from a moving platform for urban surveillance (UAV).

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1.	Select the suitable equipment including hardware and software for the real-life functioning of intelligent video surveillance system.	Apply
CO2.	Explain the network topology, bandwidth and environment for networking equipment for a video surveillance system.	Understand
CO3	Investigate motion and shape-based motion segmentation methods and motion estimation algorithms for low-level intelligence modules of an intelligent video surveillance system conducted in a static camera environment.	Analyse
CO4.	Examine object tracking algorithms for low-level intelligence modules of an intelligent video surveillance system conducted in a static camera environment.	Apply
CO5.	Illustrate high-level intelligence modules conducted in static camera environment such as simple action, activity recognition of a single or multiple persons, comprising feature extraction and classification algorithms.	Apply
CO6.	Identify an intelligent surveillance system for the exemplar application scenarios such as, home surveillance system for human fall analysis, Traffic surveillance and object detection and tracking from a moving platform for urban surveillance (UAV).	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	M	L	L	L	L	L	M	L	L	L
CO2	L	-	L	L	-	-	L	-	-	-	-
CO3	S	M	L	M	L	M	L	L	-	L	-
CO4	M	M	-	M	-	-	-	-	-	-	-
CO5	M	M	L	M	L	L	-	L	L	L	-
CO6	M	L	L	M	L	M	L	M	L	M	L
	M	M	L	M	L	L	L	L	L	L	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	10	10	0	0
Understand	30	10	10	10
Apply	60	60	60	60
Analyse	0	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Select suitable cameras from the following list and match it with respective location for the given application scenario. **Multi-Specialty Hospital (Multi-Storey building)**
   Justify your selection with specifications.

S.No	Cameras	Locations
1	Fixed/PTZ/Moving	Individual Patient Rooms/ Doctor Cabins
2	Bullet camera	Operation Theatre
3	Thermal camera	Underground parking lot
4	IR Camera	Visiting Hall/Reception
5	Covert Camera	Lifts
6	Dome camera	Food court (kitchen vs Dining)
7	Indoor/Outdoor Camera	Corridors
8	Day/Night camera	Entrance

2. Describe the difference between progressive and interlaced scan. What is the advantage and disadvantage of interlaced scan compared with progressive scan, when the line rate per second (lines/s) is the same? Describe progressive content on progressive display, interlaced on Progressive display vice versa.
3. Compare different type of sensors such as indoor vs outdoor, Thermal vs infrared.
4. The figure below show two interlaced video frames.
   Generate the field data associated with each frame.
   Deinterlace field 1 of frame 2 using field averaging. Write down the deinterlaced field.
   Now try line averaging. Write down the deinterlaced field.
   Now try field and line averaging. Write down the deinterlaced field.
   For this simple example, which method is better?

50	50	100
50	50	50
100	150	150
100	150	50
150	100	150

Frame1

100	50	50
100	50	50
100	150	150
100	150	150
100	150	100

Frame2

5. If a video file is captured in PAL standard with the following specifications:
   1. Duration=10 secs
   Frame rate=25 fps
   Frame size=640 by 480
   Colour resolution=2 bytes
   2. Sampling rate/Frequency =44.1KHz

3. Sound resolution-8bit
4. Channel-Stereo

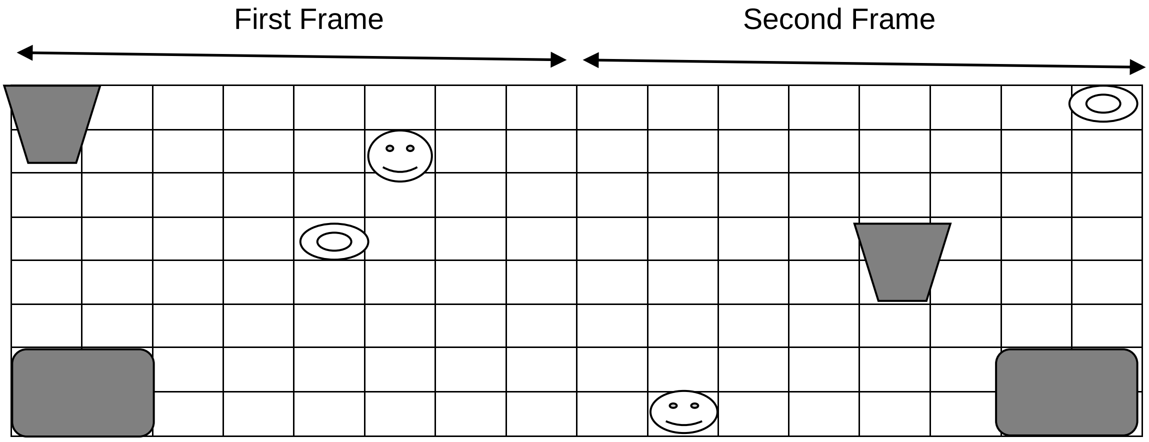
Obtain the video file size.

Course Outcome 2 (CO2):

1. Existing Network topology and bandwidth are key factors to be considered while designing any surveillance system. Justify your answer. Illustrate the procedure to develop networking for college premises by considering these factors.
2. Illustrate the use of having video surveillance or additional digital security if cutting power will shut it all down?
3. Demonstrate the surveillance scenario where wireless will be suitable and can be replaced "wired".
4. Illustrate SSID and determine the rules and considerations for wireless security.

Course Outcome 3 (CO3):

1. Illustrate different background subtraction algorithms with some examples to give solutions for global illumination changes, sudden illumination changes, shadows, camouflage and repositioning of static background objects. Also, justify whether moving objects present in the scene will impact foreground segmentation. Design and analyze the suitable algorithm for multiple target tracking.
2. Illustrate how Mubarak shah's background subtraction algorithm gives solutions for global illumination changes, initialization of background model with moving objects present in the scene and repositioning of static background objects.
3. Describe an algorithm to differentiate car and an individual human being for traffic surveillance application.
4. For the following frames, obtain the motion vector for the motion compensated prediction. Obtain the motion vector for the following four objects. Consider First 8X8 as Frame I and second 8X8 as Frame II.



Course Outcome 4 (CO4):

1. Illustrate the challenges when a video tracker tracks multiple people using a fixed camera where temporal variations of the target appearance is possible.
2. Compare automatic and interactive tracking.
3. Illustrate trajectory initialization and termination procedure using part-based model's responses to track students in a college corridor view even they are partially occluded.
4. Demonstrate how data association using affinity measure of detection responses obtained from part-models are used to label a person captured in two different intervals are same.

Course Outcome 5 (CO5):

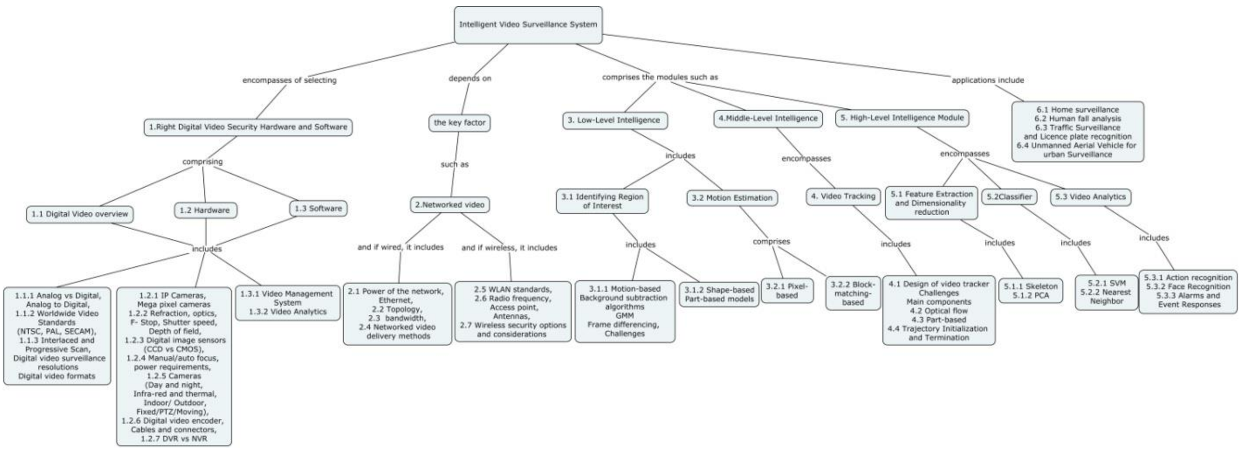
1. Describe action, activity and event.
2. Illustrate feature selection for a person is doing abnormal activity in the case of street surveillance application where he snatched the chain of an old lady and ran. Assume it is captured in one of the CCTV camera in that street.

3. Develop a surveillance algorithm to classify a bowler's performance after shoulder tendonitis as normal or abnormal for the selection procedure. Examine the features, and apply the selected features as input to classifier.
4. Illustrate how nearest neighbor classifier classifies the action as normal or abnormal. Apply skeleton feature extraction and PCA dimensionality reduction. Given that normal actions are walking and running and abnormal actions are waving hands and jumping.

Course Outcome 6 (CO6):

1. Illustrate how unmanned aerial vehicles are helpful in urban surveillance applications.
2. Illustrate how SVM classifier classifies the moving object as car vs human being. In what way it is useful for a parking lot system. Examine the features, and apply the selected
features as input to classifier.
3. Develop a surveillance algorithm to alarm your parents at office, when your grandmother/father fall on the ground unexpectedly at home. Provide the details of such surveillance system which includes camera specifications, number of cameras and the proposed algorithm. Assume the number of rooms and area of the home as your own.
4. Illustrate how SVM classifier is used for finding suspects. In what way it is useful in a ATMs. Analyze the feature extraction techniques which will be suitable to recognize the face even it is partially occluded. Apply those selected features as input to the classifier.

Concept Map



Syllabus

Digital video security Hardware and Software: – **Digital Video Overview:** Introduction to CCTV, Analog vs Digital, Analog to Digital, Worldwide Video Standards (NTSC, PAL, SECAM), Interlaced and Progressive Scan, Digital video surveillance resolutions, **Digital Video Hardware:** IP Cameras, Megapixel cameras, Working principle of camera, Refraction, optics, F- Stop, Shutter speed, Depth of field, Digital image sensors- CCD vs CMOS, Manual/auto focus, power requirements, Surveillance cameras: Day/night, Infra-red/thermal, Indoor/Outdoor, Fixed/PTZ/Moving, Choosing the right camera for right job, Digital video formats, Digital video encoder, Cables and connectors, Media converters, DVR vs NVR, **Software:** Video Management system software and video analytics, **Understanding Networks and Networked Video:** The power of the network, Ethernet, Setting up a star network, bandwidth, Networked video delivery methods, Wireless networked video, WLAN standards, Radio frequency, Access point, Antennas, Wireless security options and considerations **Low level Intelligence: Identifying region of interest in image**

sequences, Motion based Methods: Background subtraction**,** Challenges, **Shape based Methods:** Part-based models**, Motion estimation**: Pixel-based and block matching-based, **Middle Level Intelligence**: **Video Tracking-** Design of Video Tracker, Challenges, Main Components, Optical flow, Part-based tracking, Trajectory initialization and termination, **High Level Intelligence:** Feature extraction and Dimensionality reduction: Skeleton and PCA, Classifier: SVM, Nearest Neighbor, **Video Analytics**: Action recognition of a single person, Face recognition, Alarms and Event Responses, **Applications and Case study**: Home surveillance system, Human fall analysis, Traffic surveillance-License plate recognition, object detection and tracking from a moving platform (Unmanned Aerial Vehicle (UAV)) for urban surveillance**.**

Reference Books

8. Anthony C Caputo, "Digital Video Surveillance and security", Second Edition, Elsevier Inc, 2014.
9. Huihuan Qian, Xinyu Wu, Yangsheng Xu, ""Intelligent surveillance System", Springer, 2011.
10. Emilio Maggio and Andrea Cavallaro, "Video Tracking – Theory and Practice", John Wiley and Sons pvt Ltd, 2011.
11. Yunqian Ma, Gang Qian, Intelligent Video Surveillance -Systems and Technology", CRC Press, Taylor and Fracis Group, ISBN: 9781439813287, 2009.
12. Al Bovik, "Essential Guide to Video Processing", Academic Press, ISBN 978-0-12-37445, 2009.
13. Omar Javed and Mubarak Shah" Automated Multi camera Video Surveillance Algorithms and Practice", Springer, 2008.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Digital video Security Hardware and Software: Introduction to Intelligent Video Surveillance System course, course objectives and outcomes, Concept Map** and Introduction to CCTV	1
1.1	**Digital Video Overview:**	
1.1.1	Analog vs Digital, Analog to Digital	1
1.1.2	Worldwide Video Standards (NTSC, PAL, SECAM)	1
1.1.3	Interlaced and Progressive Scan, Digital video surveillance resolutions, Digital video formats	1
1.2	**Digital video Hardware:**	
1.2.1	IP Cameras, Mega pixel cameras	1
1.2.2	Working Principle of camera, Refraction, optics, F- Stop, Shutter speed, Depth of field	1
1.2.3	Digital image sensors- CCD vs CMOS	1
1.2.4	Manual/auto focus, power requirements, PoE	
1.2.5	Surveillance Cameras: Day/night, Infra-red/thermal, Indoor/ Outdoor and Fixed/PTZ/Moving cameras	1
1.2.6	Digital video encoder, Cables and Connectors, Media converters,	1
1.2.7	Storage devices: DVR vs NVR	
1.3	**Software:**	
1.3.1	Video Management system software	1
1.3.2	Video analytics	1

Module No.	Topic	No. of Lectures
2	**Networks and Networked Video:**	
2.1	Wired: The power of the network, Ethernet	1
2.2	Setting up a star network	1
2.3	Bandwidth	
2.4	Networked video delivery methods	1
2.5	Wireless networked video	1
2.6	WLAN standards, Radio frequency, Access point, Antennas,	
2.7	Wireless security options and considerations	1
3	**Low level Intelligence:**	
3.1	**Identifying region of interest in image sequences**	
3.1.1	**Motion-based Methods:** Background subtraction algorithms GMM and Frame differencing, Challenges,	1
3.1.2	**Shape-based Methods:** Part based models	1
3.2	**Motion estimation:**	
3.2.1	Pixel based motion estimation	1
3.2.2	Block matching based motion estimation	1
4	**Middle Level Intelligence: Video Tracking:**	
4.1	Design of Video Tracker, Challenges, Main Components	1
4.2	Optical flow	1
4.3	Part-based tracking	1
4.4	Trajectory initialization and termination	1
5	**High Level Intelligence:**	
5.1	**Feature extraction and Dimensionality reduction**	
5.1.1	Skeleton	1
5.1.2	Principal Component Analysis Transform (PCA)	1
5.2	**Classifier:**	
5.2.1	SVM	1
5.2.2	Nearest Neighbor	1
5.3	**Video Analytics:**	
5.3.1	Action recognition of a single person	1
5.3.2	Face recognition	1
5.3.3	Alarms and Event Responses	1
6	**Applications and Case study**:	
6.1	Home surveillance system	1
6.2	Human fall analysis	1
6.3	Traffic surveillance and License plate recognition	1
6.4	Object detection and tracking from a moving platform (Unmanned Aerial Vehicle (UAV)) for urban surveillance	2
	Total	36

Course Designers:

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18CNPN0	MEDICAL IMAGING AND CLASSIFICATION	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The purpose of this course is to provide the basic concepts of various medical imaging modalities and the use of analysis tools for medical image reconstruction. It involves three different levels. At the lowest level, the course introduces the terminology of medical imaging and explains how X-ray, CT, MRI and ultrasound images are generated. In the middle level, it addresses how to select the specific classification methods for extracting meaningful information from the medical imaging modalities. At highest level, it addresses how the algorithm is implemented in real life by observing some case studies and applications.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Describe the various medical imaging modalities.	Remember &Understand
CO2. Estimate dose and exposures of x-ray, and observe how these influence the imaging system usage.	Apply
CO3. Analyze about the various reconstruction techniques by solving problems.	Analyze
CO4. Apply the registration techniques and able to choose the selective classifier with respect to the problem.	Apply
CO5. Visualize and analyse the given 3-D images.	Analyze

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	L	-	L	L	-	--	-	-	-	S
CO2	M	M	L	M	L	-	-	-	M	-	M
CO3	M	L	L	M	M	L	M	L	M	M	
CO4	M	L	S	M	L	L	M	L	M	M	M
CO5	M	M	L	M	M	L	-	L	L	M	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's category	Continuous Assessment Tests			End Semester Examinations
	1	2	3	
Remember	10	10	10	10
Understand	10	10	10	10
Apply	60	60	60	60
Analyze	0	0	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

COURSE OUTCOME 1(CO1):

1. Explain photoelectric effect
2. How T1-weighted spin echo is generated in MRI.
3. Explain how B-mode images are useful in the display of moving structures
4. Mention the role of Affine transformation in medical imaging
5. Relate volume of interest with region of interest.
6. Differentiate surface rendering with volume rendering.
7.Mention the principal feature of gradient echo pulse sequence.
8.List out the properties of ultrasound waves.

COURSE OUTCOME 2(CO2):

1. A narrow beam containing 2000 mono energetic photons is reduced to 1000 photons by a slab of copper 10−2 m thick. What is the total linear attenuation coefficient of the copper slab for these photons?
2. What are the total mass (μm), atomic (μa), and electronic (μe) attenuation coefficients of the copper slab described in Example 4-4? Copper has a density of 8.9×103 kg/m3, a gram-atomic mass of 63.6, and an atomic number of 29.
3. An x-ray beam produced at 200 kVp has an HVL of 1.5mmCu. The density of copper is 8900 kg/m3
   a. What are the effective linear and mass attenuation coefficients?
   b. What is the average effective energy of the beam?
4. What is the length of the Fresnel zone for a 10-mm-diameter, 2-MHz unfocused ultrasound transducer?
5. What is the estimated focal zone length for a 2-MHz (λ = 0.075 cm) focused ultrasound transducer with an *f*-number of 8?
6. An x-ray tube emits 10^{12} photons per second in a highly collimated beam that strikes a 0.l-mm-thick radiographic screen. For purposes of this example, the beam is assumed to consist entirely of 40-keV photons. The attenuation coefficient of the screen is 23 m^{-1}, and the mass energy absorption coefficient of the screen is 5 m^{-1} for 40-keV photons. Find the total energy in keV absorbed by the screen during a 0.5-sec exposure.
7. A 210-keV photon is scattered at an angle of 80 degrees during a Compton interaction. What are the energies of the scattered photon and the Compton electron?
8. Five minutes of fluoroscopy at 4 mA and 100 kVp are to be combined with eight 0.5-second spot films at 100 kVp and 100 mA. Is the technique permissible according to the energy rating chart and the anode thermal chart for a Machlett dynamax “25” rotating anode X-ray tube.
9. Specify the structure and weights of a neural network capable of performing exactly the same function as a minimum distance classifier for two pattern class in N-dimensional place.

COURSE OUTCOME 3(CO3):

1. Consider the following image:

4	5	6	9
13	14	7	7
15	16	8	4
15	16	8	3

Apply iterative reconstruction method and obtain the resultant image.

2. What is the use of Fourier transform in image reconstruction?
3. What is central slice theorem? Explain

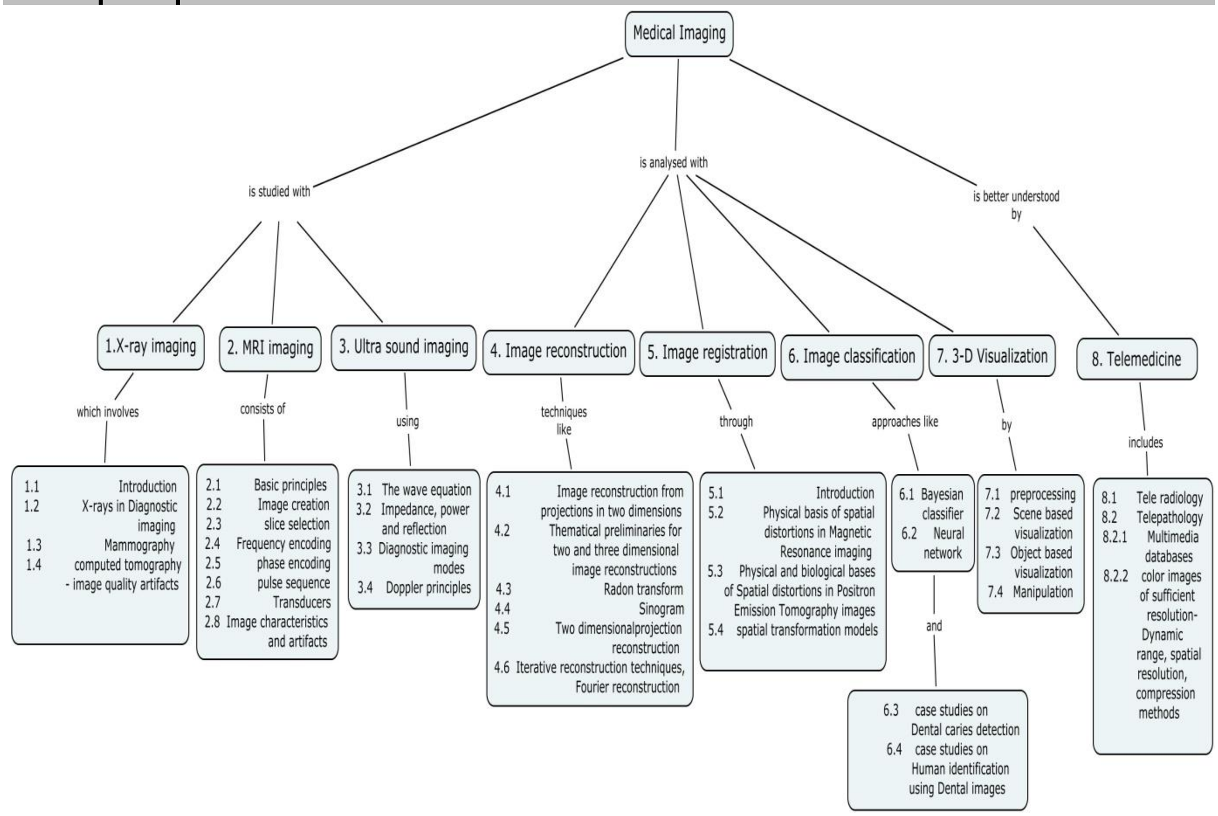
COURSE OUT COME 4(CO4):

1. Obtain the transformation matrix for the input image with the furnished details as given here: It is first rescaled by factors 3.7 along x-axis, 4.2 units along y-axis and 7.5 units along z-axis, then rotated around the x-axis by 9^0 around x-axis, 12^0 around y-axis and 2^0 around z-axis and finally translated 5 units along x, 4 units along y and 7 units along z
2. How various Spatial Transformation models are useful in Image registration?.Explain
3. The Bayes decision functions $d_j(x)=p(x/\omega_j)p(\omega_j)$, j=1,2,…W, were derived using a 0-1 loss function. Prove that these decision functions minimize the probability of error.(Hint: The probability of error p(e) is 1-p(c) where p(c) is the probability of being correct. For pattern vector x belonging to class ω_j $p(c/x)=p(\omega_j/x)$. Find p(c) and show that p(c) is maximum (p(e) is minimum when $p(x/\omega_j)\, p(\omega_j)$is maximum)
4. Design a neural net that classifies a sample as belonging to class 1 if the sample produces a positive value for $D = 34 + 8x_1 - 7x_2 + x_3$ and classifies the samples as belonging to class 0 if the sample produces a negative value for D
5. Write about affine transform in Forensic dentistry

COURSE OUT COME 5(CO5):

1. List out the 3-D imaging operations
2. Write shortly about scene based visualization and object based visualization
3. Explain the necessity of manipulation and analysis in 3D visualization

Concept Map



Syllabus

Introduction to X-Ray Imaging- Introduction to imaging modalities-X-rays in Diagnostic imaging-Mammography-Computed tomography systems – Image quality artifacts-reconstruction techniques. **Magnetic Resonance Imaging & Ultrasound Imaging** – Basic principles of nuclear magnetic resonance-Image creation-slice selection-Frequency encoding, phase encoding- pulse sequence- Transducers- Image characteristics and artifacts- **Ultrasound Imaging**- The wave equation- Impedance, power and reflection – Diagnostic imaging modes- Doppler principles. **Image Reconstruction**- Image reconstruction from projections in two dimensions- Mathematical preliminaries for two and three dimensional image reconstructions-Radon transform-Sinogram- Two dimensional projection reconstruction-Iterative reconstruction techniques-Fourier reconstruction. **Image Registration & Classification** – Introduction - Physical basis of spatial distortions in Magnetic Resonance imaging- Physical and biological bases of Spatial distortions in Positron Emission Tomography images- spatial transformation models- Bayesian classifier-Neural network **3d Visualization** – Preprocessing – Scene based visualization- Object based visualization – Manipulation – Tele medicine: Teleradiology- Telepathology: Multimedia databases- color images of sufficient resolution: Dynamic range, spatial resolution, compression methods - case studies for classification: Dental caries detection-Human identification using Dental images

Reference Books

1. William.R.Hendee and Russell Ritenour.E. Woods, “Medical Imaging Physics”, A John Wiley & sons , Inc. publications, 2002
2. Jacob Beutel and M.Sonka, “Handbook of Medical Imaging”, volume 2. “Medical Image Processing and Analysis” , SPIE press 2000
3. Issac Bankman and I.N.Bankman, “ Handbook of Medical Imaging: Processing and Analysis”, Academic press,2009
4. Atam.P.Dhawan, “Medical Image Analysis”, John Wiley and Sons ,2011
5. Zang-Hee Cho, Joie P. Jones, Manbir Singh, “Foundations of Medical Imaging”, A John Wiley & sons , Inc. publications, 1993
6. Krzysztof Iniewski, “Medical Imaging- Principles, Detectors and Electronics”, A John Wiley & sons , Inc. publications, 2009

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1.	**X-ray imaging**	
1.1	Introduction	1
1.2	X-rays in Diagnostic imaging	
1.3	Mammography	2
1.4	computed tomography, image quality artifacts	1
2.0	**MRI imaging**	
2.1	Basic principles	1
2.2	Image creation	1
2.3	slice selection	
2.4	Frequency encoding	1
2.5	phase encoding	
2.6	pulse sequence	1
2.7	Transducers	1
2.8	Image characteristics and artifacts	
3.0	**Ultra sound imaging**	
3.1	The wave equation	1

No.	Topic	No. of Lectures
3.2	Impedance, power and reflection	1
3.3	Diagnostic imaging modes	1
3.4	Doppler principles	1
4.0	**Image reconstruction**	
4.1	Image reconstruction from projections in two dimensions	1
4.2	Mathematical preliminaries for two and three dimensional image reconstructions	1
4.3	Radon transform	1
4.4	Sinogram	1
4.5	Two dimensional projection reconstruction	1
4.6	Iterative reconstruction techniques, Fourier reconstruction	2
5.0	**Image registration**	
5.1	Introduction	1
5.2	Physical basis of spatial distortions in Magnetic Resonance imaging	1
5.3	Physical and biological bases of Spatial distortions in Positron Emission Tomography images	1
5.4	spatial transformation models	1
6.0	**Image classification**	
6.1	Bayesian classifier	2
6.2	Neural network	1
6.3	Case studies on Dental caries detection	1
6.4	Case studies on Human identification using Dental images	1
7.0	**3-D Visualization**	
7.1	Preprocessing	1
7.2	Scene based visualization	
7.3	Object based visualization	1
7.4	Manipulation	1
8.0	**Telemedicine**	
8.1	Teleradiology	1
8.2	Telepathology	1
8.2.1	Multimedia databases	1
8.2.2	color images of sufficient resolution: Dynamic range, spatial resolution, compression methods	1
	Total Number of Hours	36

Course Designers:

1. Dr.A.Banumathi, au_banu@tce.edu

18CNPP0	REMOTE SENSING DATA ANALYTICS

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

This course deals with the qualitative and quantitative techniques to extract, categorize, identify and analyse the information present in remotely sensed data.

Prerequisite

NIL.

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Describe the electromagnetic remote sensing process and the platforms used for data acquisition.	Understand
CO2. Demonstrate theresolution characteristics and interpretation of different types of satellite images.	Apply
CO3. Apply Pre-processing techniques that are specifically developed for remote sensing including Geometric, radiometric corrections and satellite image enhancement techniques.	Apply
CO4. Analyze various spatial and spectral transforms on satellite images	Analyze
CO5. Perform data fusion algorithms on satellite images	Apply
CO6. Analyze various feature extraction and machine learning methods for satellite data	Analyze
CO7. Explore the concept of Big Data Analytics to Satellite data	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	L	-	-	-	-	-	L	-	-	-
CO2	M	L	-	-	-	L	-	L	-	-	-
CO3	S	M	L	-	L	L	-	L	L	-	-
CO4	S	M	L	M	M	M	-	M	L	L	-
CO5	S	M	L	M	M	M	-	M	L	M	-
CO6	S	M	L	M	M	M	-	M	L	M	-
CO7	M	L	-	L	M	L	-	L	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	20	0	0	0
Understand	20	20	20	20
Apply	60	60	60	60
Analyse	0	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1)

1. What is atmospheric window?
2. Define: spectral reflectance of earth surface features.
3. Explain the Electromagnetic Remote Sensing Process.
4. Describe the scattering mechanism in detail.

Course Outcome 2 (CO2)
1. Explain the types of resolutions of a remotely sensed data.
2. Differentiate the types of various Image resolutions.
3. Describe various remote sensing systems employed.
4. Calculate the area covered of an image of size 100X100 with a spatial resolution of 23.5 m.

Course Outcome 3 (CO3)
1. Apply the edge sharpening filter over an image size of 5*5.
2. Why do we need preprocessing for raw satellite data?
3. Consider an image with a size 5*5 and apply average filtering operation over it.
4. Apply the edge sharpening filter over an image size of 5*5.
5. Apply the histogram equalization to the following image sub scene.
   A= [54 58 64 67; 73 82 86 90; 23 39 120 27; 56 118 122 34]
6. Consider an image with Urban and Roads as major features**.** Analyze the impact of Robert and Prewitt filters on the image.

Course Outcomes 4 (CO4)
1. Expain the impact of convolution filters in satellite data analysis.
2. Prove the rotation invariance property of Fourier transform.
3. Explain how wetness and dryness are analyzed using tasseled cap transformation?
4. Explain the role of wavelet transform in satellite data
5. How do we extract features using wavelet transform. Apply the Haar wavelet transform on the following vector V = [1 3 2 4].
6. Construct an image of size 8x8 with a resolution of 5 bit. Apply the discrete wavelet transform and comment on the output.
7. Construct an image of size 4x4 with 'n' bands. Calculate the vegetation index parameters and interpret the results.
8. Construct an image with a radiometric resolution of 7-bit and of size 4x4 with three bands. Calculate the vegetation index parameters and interpret the results.
9. Consider a 4-band image with size of 4 x 4. Compute different band ratio parameters and interpret the results.

Course Outcomes 5(CO5)
1. Why do we need to fuse two satellite images?. Describe any one fusion method.
2. Explain the Deep fusion method.
3. Describe theSparse based fusion approach.
4. How will you improve the spatial and spectral information of a satellite image. What are the steps applied for the IHS based fusion.
5. How will you improve the spatial and spectral information of a satellite image. What are the steps applied for the Wavelet based fusion.

Course Outcomes 6 (CO6)
1. Consider the following image of size 4x8.Apply the k-means clustering approach to get the classified image.
   A= [54 58 64 67 11 13 15 18; 73 82 86 90 34 36 38 40 ; 23 28 20 27 67 69 71 73; 110 118 122 120 45 46 47 48]
2. Construct an image of size 5x5. Apply the opening and closing morphological operations with a square structuring element with suitable size. Comment on the output.
3. Consider the following image of size 4x4.Compute the GLCM matrix with d=1 and θ = 90

   I=[0 1 0 1;1 1 0 0; 2 0 2 2; 3 3 2 2]
4. Differentiate pixel based and texture based approaches of satellite data classification.
5. Calculate the GLCM parameters with d=1 and θ = 45 for an image with size 3*3.
6. Compute the GLCM matrix at (d=1, $\theta = 0^o$) for the following image of size 4x4 and derive the possible features from the GLCM matrix.

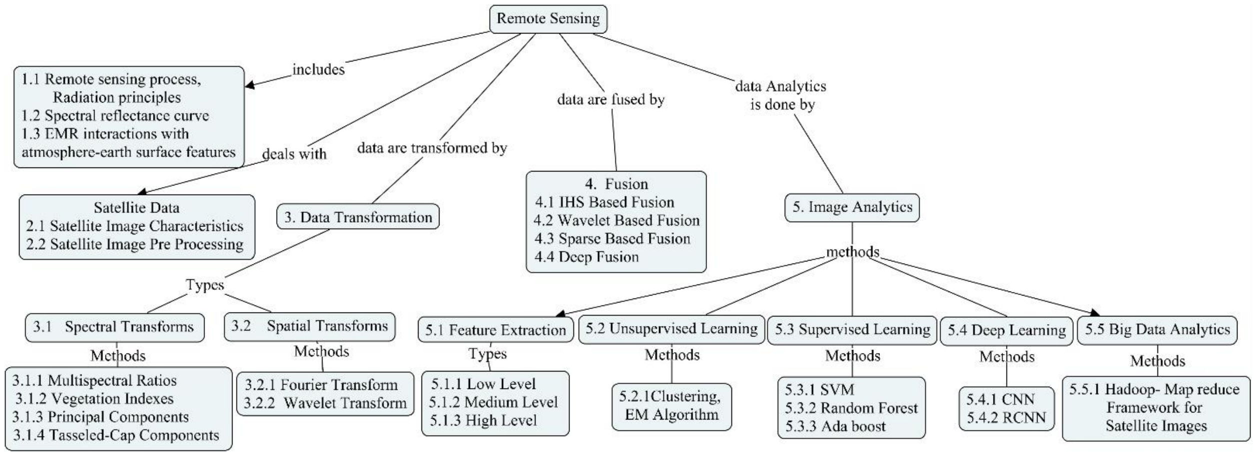
1	2	2	1

2	3	3	2
2	1	1	2
4	4	3	3

Course Outcome 7 (CO7)

1. Outline the concept of Big Data Analytics to Satellite data
2. Illustrate the use of Hadoop- Map reduce Framework for Satellite data.

Concept Map



Syllabus

Remote Sensing: Definition, Remote sensing process, Radiation principles, Spectral reflectance curve, EMR interactions with-atmosphere-earth surface features.

Satellite Data: Satellite Image Characteristics, Resolutions: Multispectral image, Thermal Image, Hyperspectral Image, Synthetic Aperture Radar& LiDAR and interpretation.Satellite Image Preprocessing: Geometric and Radiometric Correction, Radiometric and Geometric Enhancement.

Data Transformation: Spectral Transforms: Multispectral Ratios, Vegetation Indexes, Principal Components, Tasseled-Cap Components. Spatial Transforms: Fourier Transform, Wavelet Transforms,

Data Fusion: IHS based Fusion, Wavelet based fusion, Sparse based Fusion, Deep Fusion-PAN NET.

Image Analytics:Feature Extraction: Low levelFeatures - GLCM,LBP, SIFT, HOG,Mid-levelFeatures -Bag of Features, High levelFeatures - Semantics for satellite Images, Deriving Semantics using Morphology Features and Hidden Markov Model. Unsupervised Learning:Clustering, EM Algorithm. Supervised Learning:SVM Classifier, Random Forest Classifier, Ada boost Classifier.Deep Learning:CNN, RCNN. Big Data Analytics: Hadoop-Map reduce Framework for Satellite Images

Reference Books

1. Thomas M.Lillesand, Ralph W.Kiefer, “Remote Sensing And Image Interpretation”, 6th Edition, Wiley publishers,2011.
2. Robert A. Schowengerdt, Remote Sensing Models & Methods for Image Processing, 3rdEdition, 2007.
3. John R. Jensen, “ Introductory Digital Image Processing, A Remote Sensing perspective” , Pearson Education Series, 2003.
4. Rafael C.Gonzalez, Richard E.Woods, “Digital Image Processing” (3rd Edition),Prentice Hall, 2007.
5. Shai Shalev-Shwartz, Shai Ben-David,”Understanding Machine LearningFrom Theory to Algorithms”,Cambridge University press, 2014.
6. Ethem Alpaydin, “Introduction to Machine Learning, second edition”, The MIT Press, 2010.

7. Nilanjan Dey, Chintan Bhatt and Amira S. Ashour,"Big Data for Remote Sensing: Visualization, Analysis and Interpretation", Springer International Publishing, 2018.

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1.	**Remote sensing**	
1.1	Remote sensing process, Radiation principles	1
1.2	Spectral reflectance curve	1
1.3	EMR interactions with-atmosphere-earth surface features	2
2.	**Satellite Data**	
2.1	Satellite Image Characteristics- Resolutions -Multispectral image,Thermal Image, Hyperspectral Image, Synthetic Aperture Radar, & LiDAR images and interpretation	2
2.2	Satellite Image Pre Processing	
2.2.1	Geometric and Radiometric Correction	1
2.2.2	Geometric and Radiometric Enhancement	1
3.	**Data Transformation**	
3.1	Spectral Transforms	
3.1.1	Multispectral Ratios	1
3.1.2	Vegetation Indexes	
3.1.3	Principal Components	1
3.1.4	Tasseled-Cap Components	
3.2	Spatial Transforms	
3.2.1	Fourier Transform	1
3.2.2	Wavelet Transform	1
5.	**Data Fusion**	
5.1	IHS Based Fusion	1
5.2	Wavelet Based Fusion	
5.3	Sparse Based Fusion	2
5.4	Deep Fusion (PAN NET)	2
6.	**Image Analytics**	
6.1	*Feature Extraction*	
6.1.1	Low Level Features: GLCM, LBP, SIFT, HOG	2
6.1.2	Medium Level Features: Bag of Features	2
6.1.3	High Level Features	
6.1.3.1	Semantics for satellite Images	2
6.1.3.2	Deriving Semantics using Morphology Features And Hidden Markov Model	2
6.2	*Unsupervised learning*	
6.2.1	Clustering, EM Algorithm	2
6.3	*Supervised learning*	
6.3.1	SVM Classifier	2
6.3.2	Random Forest Classier	1
6.3.3	Ada Boost Classifier	1
6.4	*Deep Learning*	
6.4.1	CNN	2
6.4.2	RCNN	1
6.5	*Big Data Analytics*	
6.5.1	Hadoop- Map reduce Framework for Satellite Images	2

Course Designers:

1. Dr.R.A.Alagu Raja alaguraja@tce.edu
2. Dr. B.SathyaBamasbece@tce.edu

18CNPQ0	DIGITAL INTEGRATED CIRCUITS	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The course is designed to give the student an understanding of the different design steps required to carry out a complete digital VLSI design in silicon. This course covers fundamental concepts and structures of designing digital VLSI systems that includes CMOS devices and circuits, static and dynamic logic structures, interconnect analysis, and memory architectures. The course emphasizes design, and requires extensive use of CADENCE for circuit simulations.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Design of combinational circuits with trade-off in area, power and performance for specific applications.	Analyze
CO2	Design of sequential latches/registers with trade-off area, switching speed, energy dissipation and power for specific applications.	Analyze
CO3	Identify the parasitics and build RC model for interconnects	Analyze
CO4	Discuss ways to control the loading of data into registers based on its timing properties.	Understand
CO5	Design arithmetic building blocks including adder, multiplier and shifters	Apply
CO6	Investigate the memory array structures used in digital circuits	Analyze

Mapping with Program Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	S	M	L	M	L	-	-	-	L	L
CO2	S	S	M	L	M	L	-	M	L	-	L
CO3	S	S	M	L	L	L	L	M	L	L	L
CO4	S	S	M	L	L	-	L	M	L	L	-
CO5	S	M	M	L	M	L	L	M	M	L	-
CO6	S	S	M	L	L	-	L	M	M	L	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's category	Continuous Assessment Tests			End Semester Examinations
	1	2	3	
Remember	20	10	10	0
Understand	20	20	10	20
Apply	30	40	40	40
Analyze	30	30	40	40
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

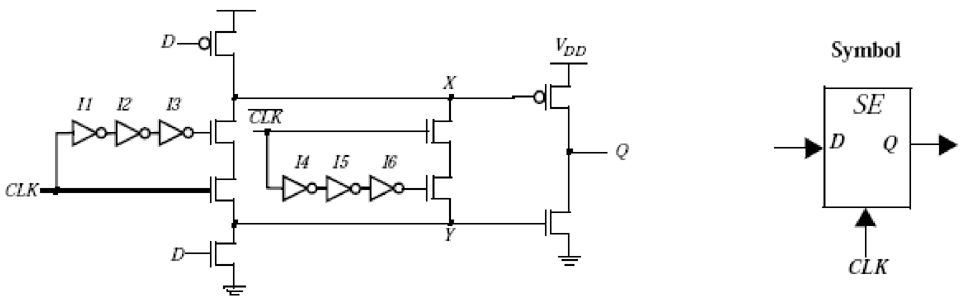
1. Implement the equation *X* = ((*A' + B'*) (*C' + D' + E'*) + *F'*) *G'* using complementary CMOS. Size the devices so that the output resistance is the same as that of an inverter with an NMOS *W/L* = 2 and PMOS *W/L* = 6. Which input pattern(s) would give the worst and best equivalent pull-up or pull-down resistance?
2. Implement the following expression in a full static CMOS logic fashion using no more than 10 transistors: *Y'* = (*A . B*) + (*A . C . E*) + (*D . E*) + (*D . C . B*)
3. Implement *F = AB'C' + A'CD* (and *F'*) in DCVSL. Assume *A*, *B*, *C*, *D,* and their complements are available as inputs. Use the minimum number of transistors.
4. Implement the function *S = ABC + AB'C' + A'B'C + A'BC'*, which gives the sum of two inputs with a carry bit, using NMOS pass transistor logic. Design a DCVSL gate which implements the same function. Assume *A*, *B*, *C*, and their complements are available as inputs.
5. Suppose we wish to implement the two logic functions given by *F = A + B + C* and *G = A + B + C + D*. Assume both true and complementary signals are available.

a. Implement these functions in dynamic CMOS as cascaded f stages so as to minimize the total transistor count.

b. Design an *np*-CMOS implementation of the same logic functions. Does this design display any of the difficulties of part (a)?

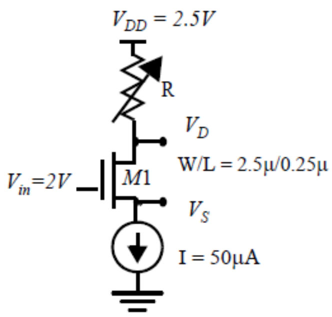
Course Outcome 2 (CO2):

1. Design a D-flipflop using static CMOS logic circuit.
2. Determine how the adoption of dual-edge registers influences the power-dissipation in the clock-distribution network.
3. Consider the following circuit. Assume that each inverter takes 1 time unit for a low-to-high or high-to-low transition. Assume that it takes 1 time unit for a pull-up path or pull-down path to pull-up or pull-down, respectively. Ignore any leakage effects. Assume VDD >> VT. Also assume that there is no skew between CLK and CLK and assume that the rise/fall times on all signals are zero.a) What is the setup time, *tsu*, hold time, *thold* and propagation delay, *tp* of this sequential building block relative to the appropriate edge(s)? Explain.



Course Outcome 4 (CO4):

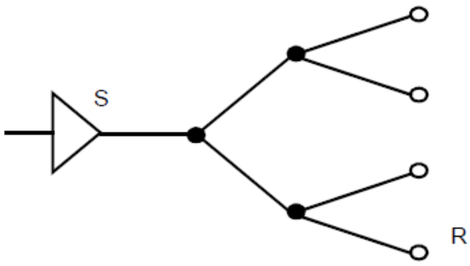
1. An NMOS device is plugged into the test configuration shown below in Figure below. The input *Vin* =2V. The current source draws a constant current of 50 μA. *R* is a variable resistor that can assume values between 10kΩ and 30 kΩ. Transistor M1 experiences short channel effects and has following transistor parameters: *k'* = 110*10-6 V/A2, VT =
0.4 , and VDSAT = 0.6V. The transistor has a W/L = 2.5μ/0.25μ. For simplicity body effect and channel length modulation can be neglected. i.e λ=0, γ=0.
   a. When *R* =10kΩ find the operation region, VD and VS.
   b. When R= 30kΩ again determine the operation region VD, VS
   c. For the case of R = 10kΩ, would VS increase or decrease if λ ≠ 0. Explain qualitatively



2. A two-stage buffer is used to drive a metal wire of 1 cm. The first inverter is of minimum size with an input capacitance Ci=10 fF and an internal propagation delay tp0=50 ps and load dependent delay of 5ps/fF. The width of the metal wire is 3.6 μm. The sheet resistance of the metal is 0.08 Ω/ , the capacitance value is 0.03 fF/μm2 and the fringing field capacitance is 0.04fF/μm.
   a. What is the propagation delay of the metal wire?
   b. Compute the optimal size of the second inverter. What is the minimum delay through the buffer?
   c. If the input to the first inverter has 25% chance of making a 0-to-1 transition, and the whole chip is running at 20MHz with a 2.5 supply voltage, then what's the power consumed by the metal wire?
3. A standard CMOS inverter drives an aluminium wire on the first metal layer. Assume R_n=4kΩ, R_p=6kΩ. Also, assume that the output capacitance of the inverter is negligible in comparison with the wire capacitance. The wire is .5um wide, and the resistivity is 0.08 Ω/cm.
   a. What is the "critical length" of the wire?
   b. What is the equivalent capacitance of a wire of this length?

Course Outcome 4(CO4):

1. Figure below shows a clock-distribution network. Each segment of the clock network (between the nodes) is 5 mm long, 3 μm wide, and is implemented in polysilicon. At each of the terminal nodes (such as *R*) resides a load capacitance of 100 fF



   c. Determine the average current of the clock driver, given a voltage swing on the clock lines of 5 V and a maximum delay of 5 nsec between clock source and destination node *R*. For this part, you may ignore the resistance and inductance of the network
   d. Determine the dominant time-constant of the clock response at node *R*.
2. What is the first thing to do if given a sequential circuit and asked to analyze its timing?

Course Outcome 5(CO5):

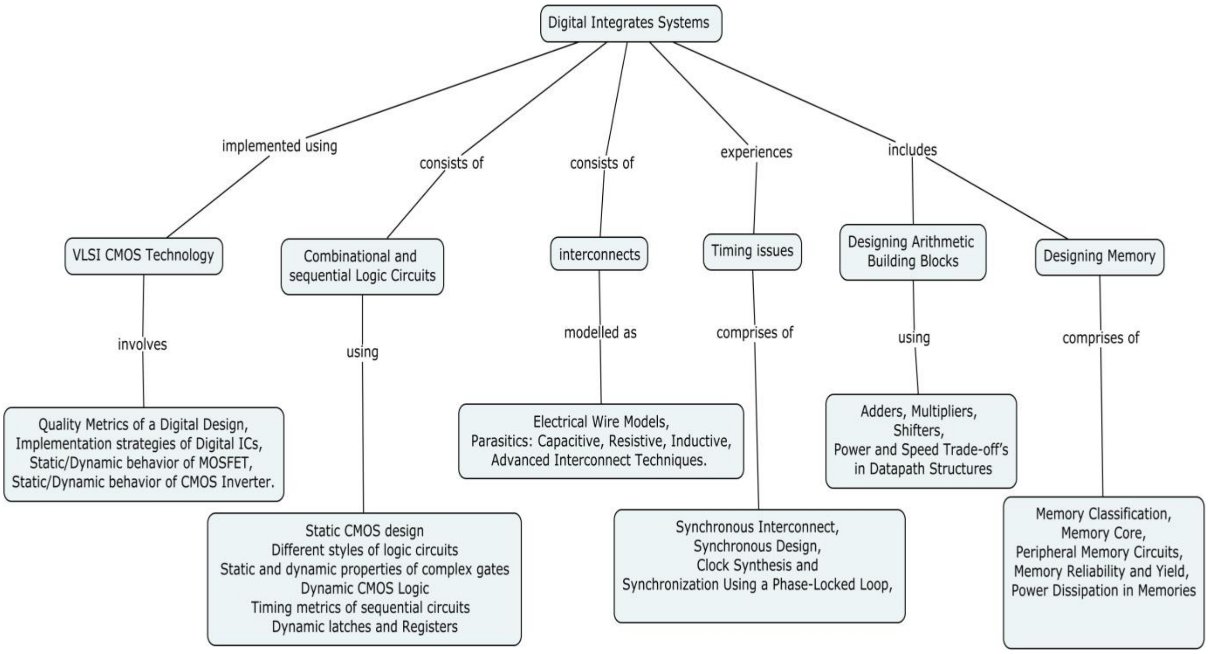
1. Design a Complimentary Static CMOS Full Adder.
2. Design a 4x4b-bit CMOS Barrel Shifter.
3. Design 4-bit CMOS carry look-ahead adder.
4. Design 8-to-1 CMOS multiplexer using 2-to-1 CMOS multiplexer.

Course Outcome 6 (CO6):

1. Design a 8x8 MOS NOR ROM.
2. Design a 4x4 MOS NAND ROM.

3. Design a 8-to-1 column decoder for accessing memory.
4. Design a 4x4 CAM memory

Concept Map



Syllabus

Implementation strategies of Digital ICs: Custom circuit Design, Cell-Based Design Methodology, and Array-Based Implementation Approaches. **Designing Combinational and Sequential Logic Circuits:** Static CMOS Logic, Dynamic CMOS Logic, Timing metrics of sequential circuits, Dynamic latches and Registers, Optimization of Sequential logic using pipelining, CMOS inverter simulation using EDA Tool. **Wire and coping with interconnect:** Interconnect Parameters, Electrical Wire Models, Capacitive, Resistive and Inductive parasitics, Advanced Interconnect Techniques. **Timing Issues in Digital Circuits:** Timing Classification of Digital Systems, Synchronous Interconnect, Synchronous Design, Self-Timed Circuit Design, Clock Synthesis and Synchronization Using a Phase-Locked Loop. **Designing Arithmetic Building Blocks:** Adders, Multipliers, Shifters, Power and Speed Trade-off's in Data path Structures, Simulation of Arithmetic blocks using EDA tool. **Designing Memory**: Memory Classification**,** Memory Core, Peripheral Memory Circuits, Memory Reliability and Yield, Power Dissipation in Memories.

Reference Books

1. Jan M. Rabaey, Anantha P. Chandrakasan, Borivoje Nikolić, "Digital Integrated Circuits: A Design Perspective", Prentice Hall, Third Edition, 2008.
2. N. Weste and K. Eshraghian, "Principles of CMOS VLSI Design: A Systems Perspective", Second Edition, Addison-Wesley, 1993, Third Impression 2010.
3. Weste Neil, David Harris, "CMOS VLSI Design: A Circuits and Systems Perspective", Fourth Edition, Addison Wesley, 2010.
4. R. Jacob Baker, "CMOS Circuit Design, Layout, and Simulation", Wiley-IEEE, Revised Second Edition, 2008.
5. John P. Uyemura, "Introduction to VLSI Circuits and Systems". John Wiley & Sons, 2002.
6. John P. Uyemura, "CMOS Logic Circuit Design". Kluwer Academic Publishers, 2001.
7. John P. Uyemura, " Chip Design for Submicron VLSI: CMOS Layout and simulation". Thomson/Nelson, 2006.
8. Pucknell, "Basic VLSI Design", Prentice Hall, 1995.
9. Wayne Wolf, "Modern VLSI Design: System On Chip", Pearson Education, 2002.

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Implementation strategies of Digital ICs**	
1.1	Custom circuit Design	1
1.2	Cell-Based Design Methodology	1
1.3	Array-Based Implementation Approaches	1
2	**Designing Combinational and Sequential Logic Circuits**	
2.1	Static CMOS design	3
2.2	Dynamic CMOS Logic	3
2.3	Timing metrics of sequential circuits	2
2.4	Dynamic latches and Registers.	3
2.5	Optimization of Sequential logic using pipelining.	2
3	**Wire and coping with interconnect**	
3.1	Electrical Wire Models	1
3.2	Capacitive Parasitics	2
3.3	Resistive Parasitics	1
3.4	Inductive Parasitics	1
3.5	Advanced Interconnect Techniques	1
4	**Timing Issues in Digital Circuits**.	
4.1	Timing Classification of Digital Systems	1
4.2	Synchronous Interconnect	2
4.3	Synchronous Design	2
4.4	Self-Timed Circuit Design	1
4.5	Clock Synthesis and Synchronization Using a Phase-Locked Loop,	2
5	**Designing Arithmetic Building Blocks**	
5.1	Adders	1
5.1	Multipliers	1
5.2	Shifters	1
5.3	Power and Speed Trade-off's in Datapath Structures	1
6	**Designing Memory**	
6.1	Memory Classification	2
6.2	Memory Core	1
6.3	Peripheral Memory Circuits	1
6.4	Memory Reliability and Yield	1
6.5	Power Dissipation in Memories	2

Course Designers:

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2. Dr.D.Gracia Nirmala Rani gracia@tce.edu

18CNPR0	ANALOG INTEGRATED CIRCUITS

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

This course needs basic knowledge of analog circuits as pre-requisite. CMOS technology as rapidly embraced the field of analog integrated circuits, providing low cost, high performance solutions and rising to dominate the market. While silicon bipolar and III-V devices still find niche applications, only CMOS processes have emerged as a viable choice for the integration of today's complex mixed signal systems. With channel lengths projected to scale down to 10nm, CMOS technology will continue to serve circuit design for probably another two decades.This course describes the analysis and design of analog CMOS integrated circuits,emphasizing fundamentals as well as new paradigms that students and practicing engineers need to master in today's industry.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Design the single stage, differential amplifiers and Current Sources for given specification	Apply
CO2. Investigate frequency and noise response of single stage and differential amplifiers	Analyse
CO3. Examine the stability and frequency compensation of amplifiers	Analyse
CO4. Design the oscillator circuits for given specifications	Apply
CO5. Evaluate the basic operation of PLL	Analyse

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S	S	M	M	L	L	L	-	-	-
CO2.	S	S	S	M	L	L	L	L	-	-	-
CO3.	S	S	S	M	L	L	L	L	-	-	-
CO4.	S	S	S	M	M	L	L	M	-	L	-
CO5.	S	S	S	M	M	L	L	M	-	L	L

Assessment Pattern

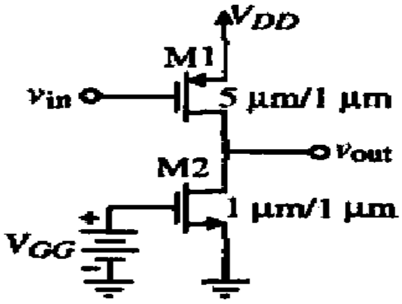
Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	10	0	0	0
Understand	10	10	10	10
Apply	30	30	40	40
Analyse	50	60	50	50
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. CMOS amplifier is shown in figure. Assume M1 and M2 operate in the saturation region.
   (a) What value of V_{GG} gives 100 µA through M1 and M2?
   (b) What is the dc value of V_{IN}?
   (c) What is the small signal voltage gain, V_{out}/V_{in}, for this amplifier?

(d) What is the -3dB frequency in hertz of this amplifier if Cgd1=Cgd2=5fF, Cbd1=Cbd2=30fF and C_L=500fF?



2. Develop the expression for V_{IC}(max) and V_{IC}(min) for the p-channel input differential amplifier.

3.Design DC current sources with current values of 10 µA and 20 µA and DC current sinks with current values of 10 µA and 40 µA . V_{DS} sat for both current sinks and sources must be less than 0.5 v. You are given one reference current source of 10 µA .V_{TN} = 1 V, V_{TP} = - 1 V, $\mu_N C_{ox}$ = 50 µA / V^2 , $\mu_P C_{ox}$ = 25 µA / V^2 , $\lambda_n = \lambda_p$ 0.1 V^{-1} at L = 1 µm.

Course Outcomes 2(CO2):

1. Find the maximum thermal noise voltage that the gate resistance of a single Mosfet can generate.
2. For a CS amplifier, derive the expression for transfer function from the small signal equivalent circuit.
3. Enumerate the difficulties in compensating two – stage CMOS Op Amps . Discuss the compensation technique using a common gate stage.

Course Outcome 3 (CO3):

1. Enumerate the difficulties in compensating two – stage CMOS Op Amps . Discuss the compensation technique using a common gate stage.
2. Compute the transfer function for the common – gate stage with parasitic capacitances, Neglecting channel – length modulation.
3. An amplifier with a forward gain of A_0 and two poles at 10 MHz and 500 MHz is placed in a unity – gain feedback loop. Calculate A_0 for a phase margin of 60^0.

Course Outcome 4(CO4):

1. A VCO senses a small sinusoidal control voltage $V_{cont} = V_m \cos \omega_m t$. Determine the output waveform and its spectrum.
2. Illustrate with neat sketches and describe in detail about the construction, working principle of LC Oscillators.
3. Determine the maximum voltage swings and the minimum supply voltage of a ring oscillator incorporating differential pairs with resistive loads , if no transistor must enter the triode region. Assume each stage experiences complete switching.
4. If each inductor in figure exhibits a series resistance of Rs, how low must Rs be to ensure the low-frequency loop gain is less than unity?

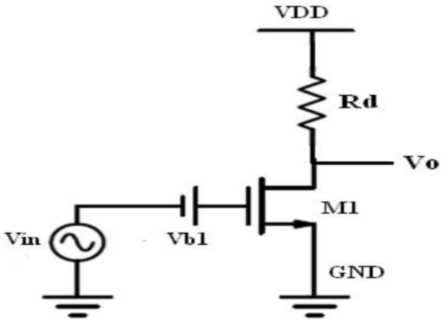
Course Outcome 5 (CO5):

1. From the circuit shown below , assume (W / L) = 50 / 0.5 , R_D = 2 kΩ , λ = 0.

(a) What is the small-signal gain if M_1 is in saturation and I_D = 1 mA ?

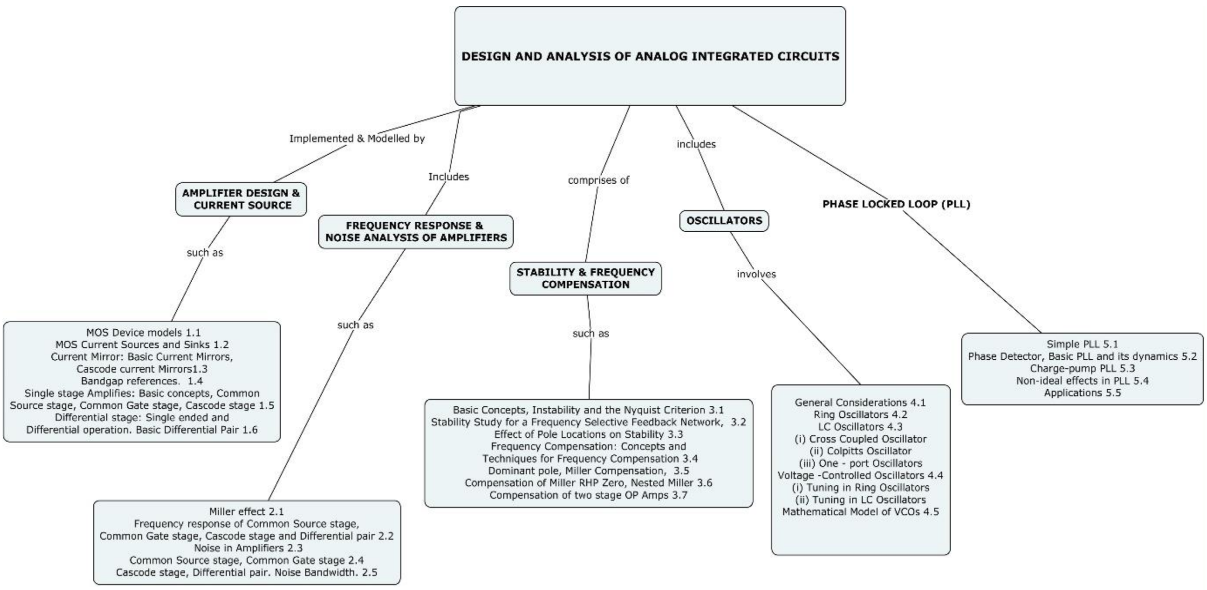
(b) What input voltage places M_1 at the edge of the triode region ? What is the small signal gain under this condition ?

(c) What input voltages drives M_1 into the triode region by 50 mV ? What is the small-signal gain under this condition ?



2. Calculate the intrinsic gain of an NMOS device and a PMOS device operating in saturation with W/L = 50/0.5 and I_D =0.5 mA. Repeat these calculations if W/L = 100/1
3. For an NMOS device operating in saturation , plot g_m , r_0 and $g_m r_0$ as the bulk voltage goes from 0 to infinity while other terminal voltages remain constant.
4.A source follower employing an NFET wit W/L = 50/0.5 and a bias current of 1 mA is driven by a source impedance of 10 kΩ. Calculate the equivalent inductance seen at the input.
5.A differential pair is driven by an ideal voltage source is required to have a total phase shift of 135^0 at the frequency where its gain drops to unity. Explain why a topology in which the load is realized by diode connected devices or current sources does not satisfy this condition.

Concept Map



Syllabus

Amplifier Design and Current source: MOSFET Device Models, Single Stage Amplifiers: Basic concepts, Common Source Stage, Common Gate Stage, Cascode Stage. Differential Stage: Single ended and Differential Operation. Basic Differential Pair. MOS Current Sources and Sinks, Current Mirror: Basic Current Mirror, Cascode Current Mirror. Band gap References. **Frequency Response and Noise Analysis of amplifiers:** Miller effect, Frequency Response of Common Source Stage, Common Gate Stage, Cascode Stage and

Differential Pair. Noise in Amplifiers:Common Source Stage, Common Gate Stage, Cascode Stage and Differential Pair. **Stability and Frequency Compensation:**Basic Concepts, Instability and the Nyquist Criterion, Stability Study for a Frequency-Selective Feedback Network, Effect of Pole Location On stability, Frequency Compensation: Concept and Technique for frequency compensation Dominant pole, Miller Compensation, Compensation of Miller RHP Zero Nested Miller, Compensation of two stage OP-amp. **Oscillator:** Ring Oscillator, LC Oscillator: Cross Oscillator, Colpits Oscillator, One-Port Oscillator. Voltage Controlled Oscillator: Tuning in Ring RC Oscillator, LC Oscillator. Mathematical Model of VCO.**PLL:** Simple PLL, Charge Pump PLL, Non-ideal Effects in PLL, Delay Locked loop, Applications.

Reference Books

1. BehzadRazavi, "Design of Analog CMOS Integrated Circuits", Tata McGraw Hill, 2013.
2. Phillip E.Allen, Douglas R.Holberg, "CMOS Analog Circuit Design", Third edition, Oxford University Press, 2011.
3. P. R. Gray, P. J. Hurst, S. H. Lewis, R. G. Meyer "Analysis and Design of Analog Integrated Circuits", Fourth Edition, Wiley-India, 2008.
4. David Johns, Ken Martin," Analog Integrated Circuit Design", Second Edition, Wiley, 2011.
5. Willey M.C. Sansen, "Analog design essentials", Springer, 2006.
6. Franco Maloberti, "Analog design for CMOS VLSI systems", Springer, 2001.
7. Kenneth Laker, Willy Sansen "Design of Analog Integrated Circuits and Systems",McGraw-Hill, 1994.

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Amplifier Design and Current source**	
1.1	MOSFET Device Models	1
1.2	Single Stage Amplifiers: Basic concepts, Common Source Stage, Common Gate Stage, Cascode Stage	1
1.3	Differential Stage: Single ended and Differential Operation. Basic Differential Pair	2
1.4	MOS Current Sources and Sinks Current Mirror: Basic Current Mirror	1
1.5	Current Mirror: Basic Current Mirror Cascode Current Mirror	2
1.6	Band gap References	1
2	**Frequency Response and Noise Analysis of amplifiers**	
2.1	Miller effect	1
2.2	Frequency Response of Common Source Stage, Common Gate Stage, Cascode Stage and Differential Pair	2
2.3	Noise in Amplifiers	1
2.4	Common Source Stage, Common Gate Stage	1
2.5	Cascode Stage and Differential Pair	2
3	**Stability and Frequency Compensation**	
3.1	Basic Concepts	1
3.2	Instability and the Nyquist Criterion	1
3.3	Stability Study for a Frequency-Selective Feedback Network	1
3.4	Effect of Pole Location On stability	1
3.5	Frequency Compensation: Concept and Technique for frequency compensation Dominant pole	1
3.6	Miller Compensation, Compensation of Miller RHP Zero Nested Miller	1
3.7	Compensation of two stage OP-amp	1

4	**Oscillator**	
4.1	Ring Oscillator	1
4.2	LC Oscillator: Cross Oscillator, Colpits Oscillator, One-Port Oscillator	2
4.3	Voltage Controlled Oscillator	1
4.4	Tuning in Ring RC Oscillator, LC Oscillator.	2
4.5	Mathematical Model of VCO	1
5	**PLL**	
5.1	Simple PLL	1
5.2	Charge-pump PLL	1
5.3	Non-ideal effects in PLL	2
5.4	Delay Locked loop	2
5.5	Applications	1
	Total Hours	36

Course Designers:

1. Dr.N.B.Balamurugan nbbalamurugan@tce.edu

18CNPS0	INTERNET OF THINGS	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Internet of Things (IoT) is presently a hot technology in the worldwide. Government, academia, and industry are involved in different aspects of research, implementation, and business with IoT. A variety of concerted endeavors by different stakeholders is to substantially speed up the establishment and sustenance of the IoT-inspired smarter planet vision in a systematic and streamlined manner. IoT-based applications such as innovative shopping system, infrastructure management in both urban and rural areas, remote health monitoring and emergency notification systems, and transportation systems, are gradually relying on IoT based systems. In worldwide academic institutions and research labs, IoT has become the subject of deeper study and intensive research to explore and experiment any IoT-associated concerns and challenges and to expound viable and venerable solutions to boost the confidence of end users.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to:

CO1	Explain the IoT functional architecture and its subsystem usage in different contexts and also where the IoT design concept fits within the broader Information and communication technology (*ICT*) industry.	Understand
CO2	Develop and establish various physical and logical device to be used in an IoT by considering its capabilities	Apply
CO3	Develop and make use various logical device with built in network API in an IoT frame work	Apply
CO4	Select and develop various network protocols used in IoT and selecting network APIs given for free IoT servers	Apply
CO5	Examining the cost effectiveness of the hardware and network platform for the design of an IOT framework for the given scenario	Analyze
CO6	In various facts, analyze the IoT system made up of sensors, wireless network connection, data analytics and display/actuators, and write the necessary control software	Analyze

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	L						M		M	
CO2	S	M	L					M		M	
CO3	M	L						M		M	
CO4	M	L						M		M	
CO5	S	M	L					M		M	
CO6	S	S	M	L	S			M		M	

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	40	0	0	10
Understand	60	40	0	20
Apply	0	60	40	40
Analyse	0	0	60	30
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):
1. Discuss the hardware and software used in IOT.
2. How the functions of IOT are classified in various domain specific?
3. Describe the design process in embedded system.

Course Outcome 2 (CO2):
1. Illustrate the selection of microcontroller for a particular application.
2. Develop an embedded application in IoT which is required for sensing any physical signal
3. Show the selection of suitable microcontroller and other peripherals for the application.
4. Illustrate the effects of proper selection of hardware for an IOT application.

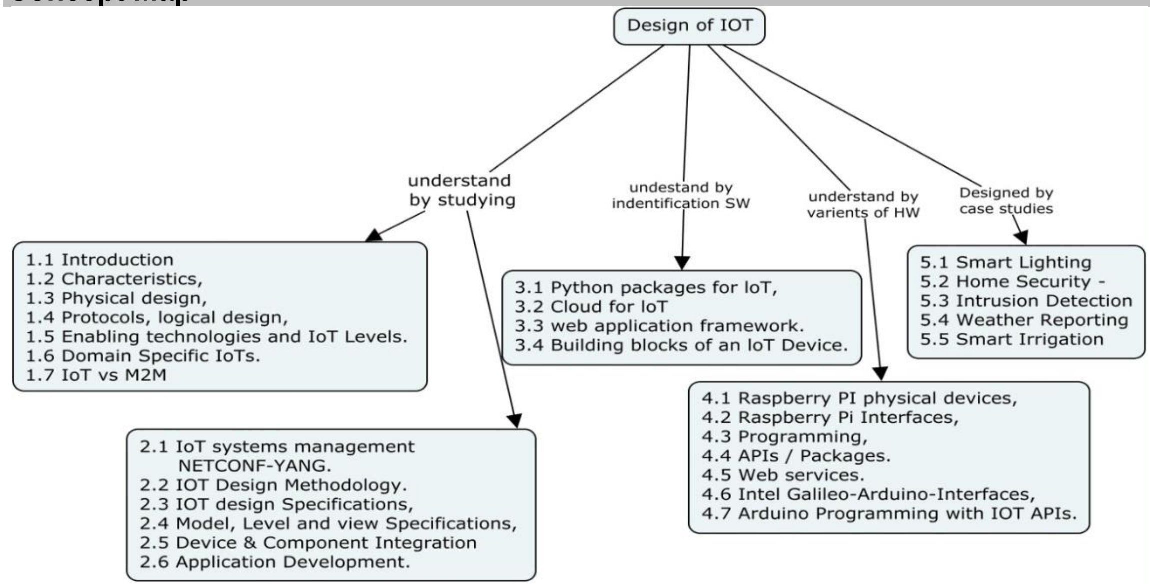
Course Outcome 3 (CO3):
1. Demonstrate the layers of an IoT framwork.
2. Show and illustrate the components in the framework of IOT
3. Demonstrate various methods to develop the flow of the program.

Course Outcome 4 (CO4):
1. Develop the hardware frame work for IOT physical design.
2. Show the method of embedding the software into the hardware with proper coding for the executional flow
3. Development of different frame work for a given scenario for the IoT

Course Outcome 5 (CO5):
1. Examine the developed hardware frame work for IOT physical design for the specific domain in terms of power consumption.
2. Investigate the embedded the software into the hardware with various API use in given scenario
3. Differentiate the functionality and its role in the integration of sub system a given scenario for the IoT

Course Outcomes 6 (C06):
1. Analyze the hardware framework in various facts of it functionality
2. Examine the requirement of the building blocks in the IoT framework in the given need.
3. Distinguish various software APIs to be used for the given hardaware to implement an IOT
4. Analyze the integration issues of sub system in a given scenario for the IoT

Concept Map



Syllabus

IOT in design: Introduction, Characteristics, Physical design, logical design, IoT enabling technologies and IoT Levels. Domain Specific IoTs. IoT vs M2M. IoT systems management with NETCONF-YANG.
IoT Design Methodology: IOT design Specifications, Model, Level and view Specifications, Device & Component Integration and Application Development.
IoT Logical Design in Python, Physical Devices and End points: Python packages of interest for IoT, hardware for IoT devices.
IoT server and cloud offering: various clouds for IoT, python web application framework.
OPEN SOURCE HARDWARE: Raspberry PI, Intel Galileo, Edition-Arduino and PSOC.
Interface with Sensors using PSoC4 BLE Platform:
Programmable Analog Blocks, Sequencing SAR ADC Block, Continuous Time Block (CTBm), Programmable Digital Blocks, Universal Digital Block, Serial Communication Block, Timer/Counter/PWM Block, Sensor-Based IoT System Design

Course Contents and Lecture Schedule

Module No	Topic	No.of Lectures
1	**INTRODUCTION TO IOT**	
1.1	Definition & Characteristics and Physical Design of IOT	1
1.2	Logical Design, Functional Blocks and Communication Models	1
1.3	Enabling Technologies, Levels & Deployment Templates	1
1.4	Domain Specific IoTs (Smart Lighting, Smart Appliances Intrusion Detection)	1
1.5	IoTand M2M-differences	1
2	**DESIGN METHODOLOGY**	
2.1	IoT systems management with NETCONF-YANG	1
2.2	IOT Design Specifications	1
2.3	Model, Level and view Specifications	1
2.4	Device & Component Integration	1
2.5	Application Development	1
3	**LOGICAL DESIGN& PHYSICAL DEVICES**	
3.1	Introduction to Python	2
3.2	Control Flow Functions Modules Packages for IOT	2
3.3	Cloud for IoT	2
3.4	Python web application framework	2
3.5	Programming, APIs / Packages	2
4	**OPEN SOURCE HARDWARE**	
4.1	Raspberry PI physical devices	1
4.2	Raspberry Pi Interfaces, Web services	2
4.3	Intel Galileo-Arduino-InterfacesProgramming with IOT APIs	2
5	**PSOC**	
5.1	Programmable Analog Blocks, Sequencing SAR ADC Block	1
5.2	Continuous Time Block (CTBm), Programmable Digital Blocks	1
5.3	Universal Digital Block, Serial Communication Block,Timer/Counter/PWM Block	2
5.4	Sensor-Based IoT System Design	2

REFERENCES

1. ARM University Program – Learning material on Intenet of thing theory and Lab

2. The Internet of Things: Enabling Technologies, Platforms, and Use Cases", by Pethuru Raj and Anupama C. Raman (CRC Press) 2017.
3. Internet of Things – A hands-on approach", ArshdeepBahga, Vijay Madisetti, Universities Press, 2015
4. Peter Waher "Learning Internet of Things",PacktPublishing,UK, 2015.
5. Miguel de Sousa",Internet of Things with Intel Galileo" ",PacktPublishing,UK, 2015.
6. Marco Schwartz, "Internet of Things with the Arduino", Packt Publishing, 2014
7. Adrian McEwen, Hakim Cassimally "Designing the Internet of Things",WileyPublishing, 2015

Course Designers:

1. Dr.K.Hariharan khh@tce.edu

18CNPT0	SYSTEM-ON-CHIP	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The revolution in mobile computing has been driven by the low power and integrated performance available in modern System-on-Chip (SoC) designs. As a result, understanding and practicing SoC Design is a crucial part of the curriculum in any Engineering department. The course aims to produce students who are capable of developing Arm Cortex-M0 and Cortex-M3 based SoCs from high level functional specifications to design, implementation and testing on real FPGA hardware using standard hardware description and software programming languages.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to:

CO1	Explain the SOC functional Blocks and its subsystem usage in different contexts and also where the SOC design concept fits.	Understand
CO2	Develop and establish a System with various physical and logical device to be used in a SOC	Apply
CO3	Illustrate the embedded system software development tools and Cortex-M programming	Apply
CO4	Select and develop various communication peripheral in a SOC and selecting those for given applications	Apply
CO5	Examining the cost effectiveness of the hardware and SOC platform for the design of a SOC for the given application	Analyze
CO6	In various facts, analyze the IoT system made up of sensors, wireless network connection, data analytics and display/actuators, and write the necessary control software	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	L	-	-	-	-	-	M	-	M	-
CO2	S	M	L	-	-	-	-	M	-	M	-
CO3	M	L	-	-	-	-	-	M	-	M	-
CO4	M	L	-	-	-	-	-	M	-	M	-
C05	S	M	L	-	-	-	-	M	-	M	-
C06	S	S	M	L	S	-	-	M	-	M	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination**
	1	2	3	
Remember	40	0	0	10
Understand	60	40	0	20
Apply	0	60	40	40
Analyse	0	0	60	30
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):
1. Discuss the selection of processor and memory in embedded application.
2. Explain the challenges in building SOC.
3. How the embedded systems using SOC are classified?
4. Describe the design process in embedded system.

Course Outcome 2 (CO2):
1. Illustrate the selection of microcontroller for a particular application.
2. Develop an embedded application using an SoC
3. Show the selection of suitable SoC and other peripherals for the application.
4. Illustrate the effects of proper selection of hardware for an Soc based application.

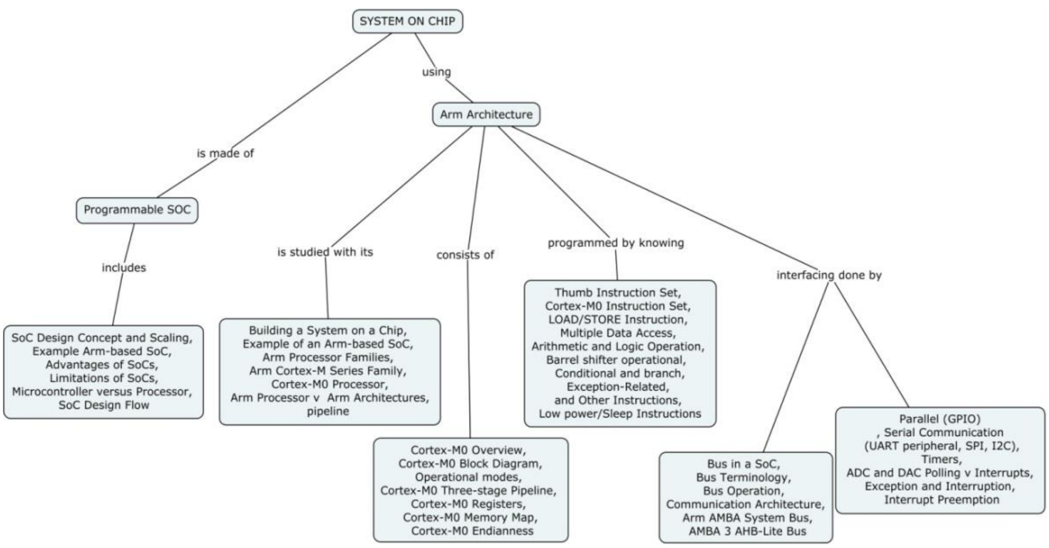
Course Outcome 3 (CO3):
1. Demonstrate the ARM architecture feature.
2. Demonstrate the use of ARM thumb instructions.
3. Show and illustrate the functional components in the ARM core
4. Demonstrate various methods to develop the arithmetic operation in ARM program.

Course Outcome 4 (CO4):
1. Demonstrate the ARM cortex M architectures and its feature.
2. Demonstrate the use of ARM Cortex M0 thumb instructions.
3. Show and illustrate the functional components in the ARM cortex M core
4. Demonstrate various methods to develop the Shifting operation in ARM program.

Course Outcome 5 (CO5):
1. Examine the developed SoC hardware frame work for embedded system design for the specific domain.
2. Examine the developed software frame work for SoC design for the specific domain in terms of execution speed.
3. Investigate the embedded the software into the hardware with various peripherals

Course Outcomes 6 (C06):
1. Analyze the FRDM-KL25Z hardware framework in various facts of it functionality
2. Examine the requirement of the peripheral blocks in the FRDM-KL25Z
3. Distinguish various peripherals to be used for the given SoC to implement an Embedded system
4. Analyze the integration issues of sub system in a given scenario for the SoC

Concept Map



Syllabus

Programmable SoCs: SoC Design Concept and Scaling, Example Arm-based SoC, Advantages of SoCs, Limitations of SoCs, Microcontroller versus Processor, SoC Design Flow.

SOC with Arm Architecture: Building a System on a Chip, Example Design of an Arm-based SoC, Arm Processor Families, Arm Cortex-M Series Family, Cortex-M0 Processor, Arm Processor v Arm Architectures, pipeline

ARM Cortex-M Architecture:
Cortex-M0 Overview, Cortex-M0 Block Diagram, Operational modes, Cortex-M0 Three-stage Pipeline, Cortex-M0 Registers, Cortex-M0 Memory Map Example, Cortex-M0 Endianness

ARM Cortex Instructions: Thumb Instruction Set, Cortex-M0 Instruction Set, Memory Access: LOAD/STORE Instruction, Multiple Data Access, Arithmetic and Logic Operation, Barrel shifter operational instrcutions, Conditional and branch instructions. Exception-Related Instructions, Other Instructions, Low power/Sleep Mode/ON-exit Instructions,

Bus Architecture: Bus in a SoCp, Bus Terminology, Bus Operation, Communication Architecture Standards, Arm AMBA System Bus and AMBA 3 AHB-Lite Bus.

Peripherals in ARM cortex- FRDM-KL25Z:
Parallel (GPIO), Serial Communication (UART peripheral, SPI, I2C), Timers, ADC and DAC Polling v Interrupts, Exception and Interruption, Interrupt Preemption

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lecture Hours
1.	**Programmable SoCs:**	
1.1	SoC Design Concept and Scaling	1
1.2	Example Arm-based SoC Limitations of SoCs, Advantages of SoCs	1
1.3	Microcontroller versus Processor SoC Design Flow	1
2	**SOC with Arm Architecture:**	
2.1	Building a System on a Chip, Example Design of an Arm-based SoC	1
2.3	Arm Processor Families, Cortex-M Series Family	1
2.4	Cortex-M0 Processor and Arm Processor v Arm Architectures	1
2.5	pipeline	1
3.	**ARM Cortex-M Architecture:**	
3.1	Cortex-M0 Overview , Cortex-M0 Block Diagram	1
3.3	Operational modes, Cortex-M0 Three-stage Pipeline, Cortex-M0 Registers	1
3.6	Cortex-M0 Memory Map, Example Cortex-M0 Endianess	1
4	**ARM Cortex Instructions:**	
4.1	Thumb Instruction Set	1
4.2	Cortex-M0 Instruction Set	1
4.3	Memory Access: LOAD/STORE Instruction	1
4.4	Multiple Data Access	1
4.5	Arithmetic and Logic Operation	1
4.5	Barrel shifter operational instrcutions	1
4.6	Conditional and branch instructions	1
4.7	Exception-Related Instructions	1
4.8	Other Instructions	1
4.9	Low power/Sleep Mode/ON-exit Instructions	1
5	**Bus Architecture:**	
5.1	Bus in a SoC, Bus Operation, Bus Terminology	1

5.4	Communication Architecture Standards	1
5.5	Arm AMBA System Bus and AMBA 3 AHB-Lite Bus	1
6	**Peripherals in ARM cortex- FRDM-KL25Z:**	
6.1	Parallel (GPIO)	1
6.2	Serial Communication (UART peripheral, SPI, I2C)	1
6.3	Timers	1
6.4	ADC and DAC	1
6.5	Polling vs Interrupts	1
6.6	Exception and Interruption	1
6.7	Interrupt Preemption	1
	Total	**36**

Reference Books

1. ARM University Program- Rapid embedded system design and programming
2. Alexander G Dean ,Embedded Systems Fundamentals with ARM Cortex-M based Microcontrollers: A Practical Approach, ARM Education Media
3. Raj Kamal, ‘Embedded Systems, Architecture, Programming and Design’, Tata McGraw-Hill, second edition 2010.
4. D.P.Kothari, Shriram K.Vasudevan, Embedded Systems, New Age International Publishers, 2012.
5. ARM Cortex M4 (TM4C123) Data sheet, Texas Instruments.

Course Designers:

1. Dr.K.Hariharan khh@tce.edu

18CNPU0	OPTICAL COMMUNICATION SYSTEMS

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

The objective of this course is to enable the students to learn about the methods of analysis, design and performance evaluation of direct detection and coherent detection optical communication system. It also provides in-depth understanding of existing and emerging optical networking technologies.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Compute the operating parameters of different types of opticaltransmitter, detector and fiberused in optical communication system.	Apply
CO2	Analyze the characteristics of direct detection receiver.	Analyze
CO3	Evaluate the performance of direct detection optical communication system.	Evaluate
CO4	Evaluate the performance of coherent detection optical communication system.	Evaluate
CO5	Apply different wavelength routing and assignment algorithms, access network architectures and packet switching techniques in designing a fiber optic communication network.	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	M	L	L	M	S	-	-	M	-	-	-
CO2	S	M	L	M	S	-	-	M	-	-	-
CO3	S	S	S	S	S	L	M	M	-	-	-
CO4	S	S	S	S	S	L	M	M	-	-	-
CO5	M	L	L	M	S	-	-	M	L	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

		1	2	3	
1	Remember	0	0	0	0
2	Understand	40	30	20	20
3	Apply	20	30	30	30
4	Analyze	20	0	20	20
5	Evaluate	20	40	30	30
6	Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1) :

1. A GaAs injection laser has an optical cavity of length 250 μm and width 100 μm.At normal operating temperature the gain factor β is 21 × 10−3 A cm−3 and the losscoefficient A per cm is 10. Determine the threshold current density and hence thethreshold current for the device. It may be assumed that the cleaved mirrors areuncoated and that the current is restricted to the optical cavity. The refractive indexof GaAs may be taken as 3.6.

2. A planar LED is fabricated from gallium arsenide which has a refractive index of 3.6.
   (a) Calculate the optical power emitted into air as a percentage of the internal optical power for the device when the transmission factor at the crystal–air interface is 0.68.
   (b) When the optical power generated internally is 50% of the electric power supplied, determine the external power efficiency.
3. An APD with a multiplication factor of 20 operates at a wavelength of 1.5 μm. Calculate the quantum efficiency and the output photocurrent from the device if its responsivity at this wavelength is 0.6 A W−1 and 1010 photons of wavelength 1.5 μm are incident upon it per second.

Course Outcome 2 (CO2):

1. A germanium APD (with x = 1) is incorporated into an optical fiber receiver witha 10 kΩ load resistance. When operated at a temperature of 120 K, the minimumphotocurrent required to give an SNR of 35 dB at the output of the receiver is foundto be a factor of 10 greater than the dark current. If the noise figure of the followingamplifier at this temperature is 1 dB and the post-detection bandwidth is 10 MHz,determine the optimum avalanche multiplication factor.
2. A digital optical fiber link employing ideal binary signalling at a rate of 50 Mbit s−1 operates at a wavelength of 1.3 μm. The detector is a germanium photodiode which
   has a quantum efficiency of 45% at this wavelength. An alarm is activated at thereceiver when the bit-error-rate drops below 10−5. Calculate the theoretical minimum
   optical power required at the photodiode in order to keep the alarm inactivated.Comment briefly on the reasons why in practice the minimum incidentoptical power would need to be significantly greater than this value.
3. Discuss the implications of the load resistance on both thermal noise and post detection bandwidth in optical fiber communication receivers.

Course Outcome 3 (CO3):

1. An optical transmission system transmits non-return-to-zero (NRZ) data at 2.488 Gbit/s on a single-mode fiber. The optical transmitter operates at 1550 nm and is carefully controlled that negligible optical power is transmitted at the “0” bits. The “0” bits and the “1” bits are assumed to be equally-probable. A PIN photo-detector is used to detect the optical signal. The quantum efficiency of the photo-detector is 0.8. Assuming the receiver circuit has an equivalent resistance of 1kΩ, the receiver bandwidth matches with the signal bandwidth, negligible dark and leakage current at the photo-detector, the operating temperature is 27^{o}C (Note that Bandwidth =1/(2×Bit Period) for NRZ)

a. Compute the signal-to-noise ratio (SNR) with a received power of -20 dBm. (i) shot noise (ii) thermal-noise dominated. Which one, (i) or (ii), is a more practical and reasonable assumption? Explain.
b. Find the minimum average optical power received at the detector in order to achieve an SNR by 20 dB by assuming the receiver is shot-noise dominated or thermal-noise dominated. Which one, (i) or (ii), is a more practical and reasonable assumption? Explain.

2. Evaluate the attenuation -limited transmission distance of the following two systems operating at 100 Mb/s:
   System one operating at 850 nm
   (a) GaAlAs laser diode: fiber coupled power 0 dBm
   (b) Silicon avalanche photodiode: -50 dBm sensitivity
   (c) Graded index fiber: 3.5 dB/km attenuation at 850 nm
   (d) 1 dB/connector connector loss

System two operating at 1300 nm
(a) InGaAsP LED: fiber coupled power -13 dBm
(b) InGaAs PIN photodiode: -38 dBm sensitivity
(c) Graded index fiber: 1.5 dB/km attenuation at 1300 nm
(d) 1 dB/connector connector loss
Allow 6 dB system margin in each case

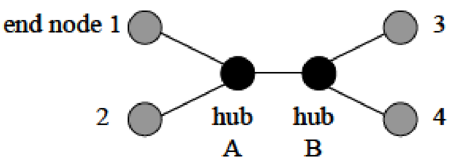
3. Discuss the major considerations in the design of digital drive circuits for:
   (a) an LED source;
   (b) an injection laser source.
   Illustrate your answer with an example of a drive circuit for each source.

Course Outcome 4 (CO4):

1. Evaluate the performance of ASK heterodyne synchronous detection and FSK heterodyne synchronous detection in terms of receiver sensitivity.
2. Calculate the absolute maximum repeater spacing that could be provided to maintain
   a BER of 10−9 within a coherent optical fiber system operating at a wavelength of1.55 μm when the fiber and splice/connector losses average out at 0.2 dB km−1, theoptical power launched into the fiber link is 2.5 mW and the transmission rates are50 Mbit s−1 and 1 Gbit s−1. For both bit rates consider the following ideal receiver types:
   (a) ASK heterodyne synchronous detection;
   (b) PSK homodyne detection.
   Evaluate the performance of both type of detectors at different transmission rate.

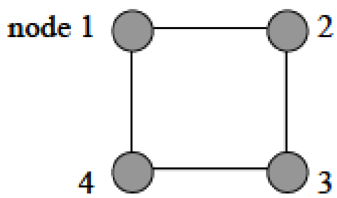
Course Outcome 5 (CO5):

1. Consider the network topology shown below. Each undirected link represents two fibers, one for the transmission in each direction. There are 4 end nodes and 2 hub nodes.



Consider the following s-d pairs each of which has 1 wavelength unit of traffic: 1-3, 1-4, 2-3, 2-4, 3-1, 3-2, 4-1, 4-2, 4-3. Specify the wavelength assignment (WA) that uses the minimum number of wavelengths.

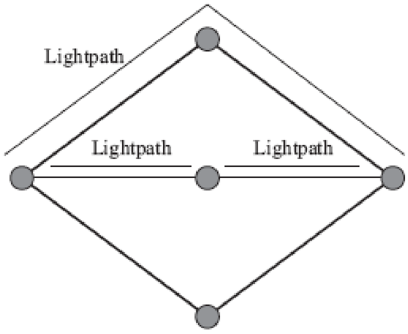
2. Consider a 4-node transparent optical network shown below. Assume that adjacent nodes are connected by two fibers, one for the transmission in each direction. In addition, assume that there are 2 wavelengths in each fiber.



Assume that calls (i.e., lightpath demands) arrive in the following sequence
2-1, 2-4, 4-3, 1-3, 2-4, … where each value pair is the s-d pair for the call. Suppose that we use fixed routing with the paths 1-4-3, 2-1, 2-1-4, and 4-3 for s-d pairs 1-3, 2-1, 2-4, and 4-3 respectively. Use the following wavelength assignment techniques to assign wavelengths. (i.e., put on λ_1, put on λ_2 , or blocked)
(*a*) First-fit WA: Assign the first possible wavelength starting from the smallest wavelength index.

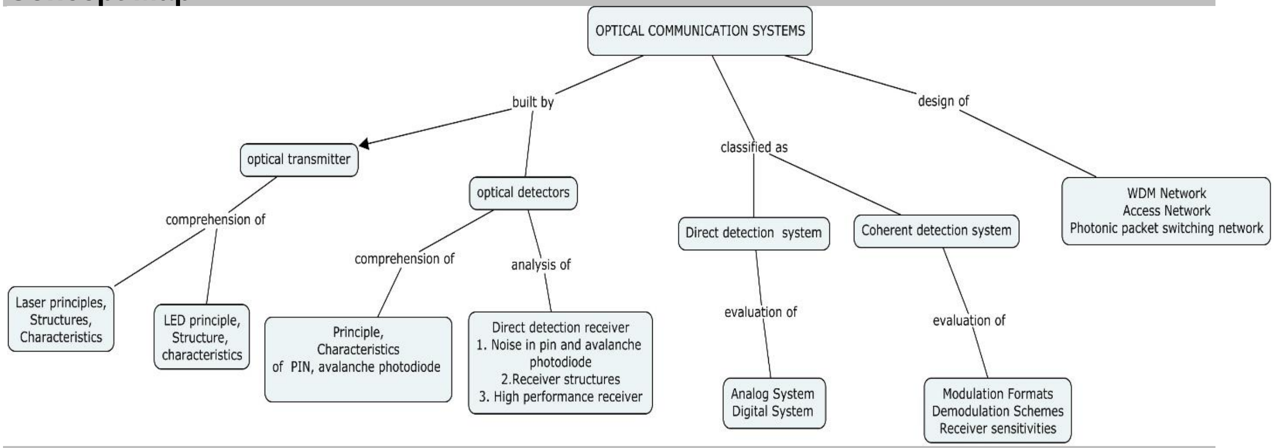
(*b*) Most-used WA: Assign the wavelength with the highest utilization (before the new call). The utilization of wavelength $\lambda i$is the number of fibers on which wavelength $\lambda i$is used.

3. Consider the network shown in Figure, with three lightpaths to be supported. Each lightpath uses one unit of capacity on each link that it traverses. How to protect all the lightpaths in case of failure.



4. Consider the RITENET architecture shown in Figure 11.10. Suppose the laser speedat the CO is limited to 155 Mb/s. The network needs to support 20 ONUs and provide each ONU with 10 Mb/s bandwidth from the CO to the ONU and 2 Mb/s from the ONU to the CO. How could you modify the architecture to support this requirement?
5. In the packet multiplexing, show that the delay encountered by pulse i, i = 1, 2, . . . , l, on passing through the k compression stages is $(2^k - i)(T - \tau)$. Using the fact that the pulses are separated by time T at the input, now show that pulse i occurs at the output at time $(2^k - 1)(T - \tau) + (i - 1)\tau$. Thus the pulses are separated by a time interval of τ at the output.

Concept Map



Syllabus

Overview of Optical Communication Systems: Motivation, Optical communication linkrequirements**Optical fibers:**Modes, Dispersion, Nonlinearities **Optical Transmitters:** Semiconductor laser – principle, characteristics and types, Light Emitting Diode-Principle, characteristics and types, **Optical Detectors:**principle – Characteristics:Quantum efficiency,Responsivity, cut off wavelength- Types: pin photodiode, avalanche photodiode,
Direct detection receiver performance: Receiver Noise: Noise in *p–i–n* photodiode receiver and Avalanche photodiode (APD) receiver, Receiver capacitance and bandwidth, Excess avalanche noise factor, Gain–bandwidth product -**Receiver structures**: Low-impedance front-end, High-impedance front-end, Transimpedance front-end – **High performance receivers**
Direct detection optical fibersystem design: Optical transmitter circuit:Source limitation, LED drive circuits, laser drive circuits **–** optical receiver Circuit:Preamplifier, Automatic gain control, Equalization – **System design consideration** – Digital system planning: optical power budget – temporal response – Analog system planning
Coherent optical fibersystem design: Coherent detection principles – **Modulation Formats:** ASK, FSK, PSK – **Demodulation Schemes:** Heterodyne Synchronous and Asynchronous detection, Homodyne detection, Intradyne detection - **Receiver sensitivities:** ASK, FSK, and PSK heterodyne detection, ASK and PSK homodyne detection, Comparison of sensitivities
Optical Network Design:SONET/SDH networks - WDM networks**:** Cost Trade off, LTD and RWA Problems - Access Networks:Network Architecture, Enhanced HFC, Fiber to the Curb (FTTC) – Optical Packet switching Network.

Reference Books

1. John M. Senior, “Optical fiber communications : Principles and practices”, 3rd ed., Prentice Hall, 2009.
2. Gerd Keiser, “Optical fiber communications”, 4th ed. McGraw Hill Int., 2008.
3. Rajiv Ramaswami, Kumar N. Sivarajan, “Optical Networks”, 3rded., Morgan Kaufmann Publishers, 2010.
4. Le Nguyen Binh, “Optical Fiber Communication Systems with MATLAB and Simulink Models”, 2nd ed., Taylor & Francis, 2015.
5. Govind P. Agarwal, “Fiber optic communication systems”, 3rd ed., John Wiley & Sons, 2002.
6. Biswanath Mukherjee, “ Optical WDM Network”, Springer, 2006

Course Contents and Lecture Schedule

Module	Titile	No. of Lectures
1.	**Introduction to Optical Communication Systems**	
1.1	Optical Finer Link- Optical fiber modes – configuration - characteristics	2
1.2	**Optical Transmitters**	

1.2.1	**Injection laser structures:** Gain-guided lasers, Index-guided lasers, Quantum-well lasers, Quantum dot lasers, Distributed feedback lasers	1
1.2.2	**Injection laser characteristics:** Threshold current temperature dependence, Dynamic response, Frequency chirp, Noise, Mode hopping, Reliability	1
1.2.3	**Light Emitting Diode:LED structures:**Superluminescent LEDs, Resonant cavity and quantum-dot LEDs	1
1.2.4	**LED characteristics:** Optical output power, Output spectrum, Modulation bandwidth, Reliability	1
1.3	**Optical Detectors:**	
1.3.1 1.3.2	Optical detection principles **Characteristics:** Quantum efficiency, Responsivity, cut off wavelength	1
1.3.3	**Detector Types:** pin photodiode, avalanche photodiode, quantum dot photodetector, phototransistors	1
2	**Direct detection receiver performance:**	
2.1	Receiver Noise:	
2.1.1	Noise in *p–i–n* photodiode receiver and Avalanche photodiode (APD) receiver	2
2.1.2	Receiver capacitance and bandwidth, excess avalanche noise factor, gain-bandwidth product	2
2.2	Receiver structure: Low-impedance front-end, High-impedance front-end, transimpedance front-end	1
2.3	High performance receivers	1
3	**Direct detection optical fiber system**	
3.1	Optical transmitter circuit	1
3.2	Optical receiver circuit	1
3.3	Digital system planning	3
3.4	Analog system planning	2
4	**Coherent detection optical fiber system**	
4.1	Coherent detection principles	1
4.2	Modulation Formats	2
4.3	Demodulation Schemes	2
4.4	Receiver sensitivities	2
5	**Optical Network Design**	
5.1	SONET/SDH Networks	2
5.2	WDM network: LTD and RWA problem	2
5.3	Access network	2
5.4	Packet switching Network	2

Course Designers:

1. Dr. S.Ponmalar spmece@tce.edu
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18CNPV0	NUMBER THEORY AND CRYPTOGRAPHY	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Computational number theory and cryptography is the discipline which studies the theoretical, practical and managerial aspects of cryptography from a mathematical point of view. The course will enable the students to familiarize the various aspects of cryptography: Overview of cryptography and its application; Basic number theory; RSA algorithms Discrete Algorithms, Elliptive curves and Study of WLAN and Bluetooth case studies.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Apply the concept of number theory for cryptography	Apply
CO2	Apply the Finite fields concepts for cryptography	Apply
CO3	Design of RSA crypto systems	Apply
CO4	Design of Elliptic crypto systems	Analyze
CO5	Study of WLAN and Bluetooth case studies	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	S	S	L	-	M	L	L	M	-	-
CO2	S	S	S	L	-	L	L	L	-	-	-
CO3.	M	M	L	L	-	L	L	L	-	-	-
CO4.	S	S	S	S	-	-	-	L	L	L	-
CO5.	L	L	L	L	-	L	L	L	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	60	40	20	20
Apply	40	60	60	60
Analyse	0	0	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1

1. a. Why is gcd(*n, n+1*) for two consecutive integers *n* and *n + 1*?
   b. Suppose x≡2 (mod 7) and x≡3 (mod 10).What is x congruent to mod 70?

2. a. Find all solutions of 12x≡28 (mod 236)
   b. Find all solutions of 12x≡30 (mod 236)

3. Use Euclidean algorithm to compute gcd (30030, 257). Using this result and the fact that 30030=2.3.5.7.11.13, show that 257 is prime. (Remark: This method of

computing one gcd, rather than doing several trial divisions (by 2, 3, 5 ...), is often faster for checking whether small primes divide a number)

4. a. Compute gcd(4883,4369)
   b. Factor 4883 and into products of prime

Course Outcome 2

1. a. Let p be prime. Show that $a^p \equiv a$ (mod p) for all a
   b. Divide 2^{10203} by 101
2. Suppose you encrypt using an affine cipher, then encrypt the encryption using another affine cipher (both are working mod 26).Is there any advantage to doing this, rather than using a single affine cipher? Why or why not?
3. Suppose we work mod 27 instead of mod 26 for affine ciphers. How many keys are possible? What if we work mod 29?
   a. Find integers x and y such that 17x + 101y=1
   b. Find 17^{-1} (mod 101)

Course Outcome 3

1. The ciphertext 5859 was obtained from the RSA algorithm using *n* =11413 and *e* = 7467. Using the factorization 11413 = 101.113.find the plaintext.
2. Suppose that there are two users on a network. Let their RSA moduli be n_1 and n_2, with n_1 not equal to n_2.If you are told that n1 and n_2 are not relatively prime, how would you break their system?
3. Suppose you encrypt messages m by computing $c \equiv m^3$ (mod 101).How do you decrypt? (That is, you want a decryption exponent d such that $c^d \equiv m$ (mod 101); note that 101 is prime).
4. Suppose that there are two users on a network. Let their RSA moduli be n_1 and n_2, with n_1 not equal to n_2.If you are told that n1 and n_2 are not relatively prime, how would you break their system?
5. The exponents e = 1 and e= 2 should not be used in RSA. Why?

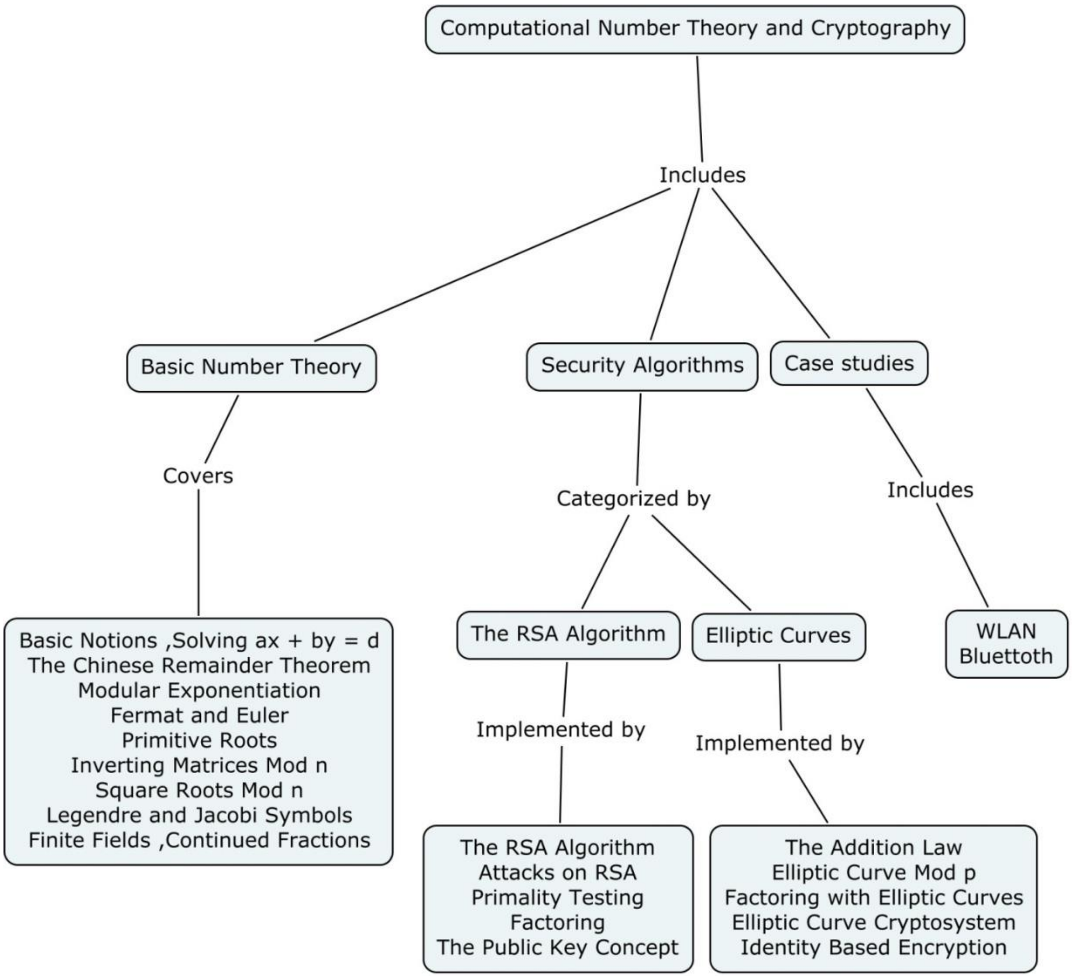
Course Outcome 4

1. Show that if P=(x,0) is a point on a elliptic curve, then 2P=∞
2. Show that if P,Q are points on an elliptic curve then
   P+Q+R=$\infty \Leftrightarrow$ P,Q, R are collinear
3. a. List the points on the elliptic curve $E = y^2 \equiv x^3 - 2$ (mod 7)
   b. Find the sum (3,2)+(5,5) on E
   c. Find the sum (3,2)+(3,2) on E
4. For $E_{11}(1,6)$, consider the point $G = (2,7)$. Compute the multiples of G from 2G
5. Does the elliptic curve equation $y^2 = x^3 - 7x + 3$ define a group over Z_{19}?

Course Outcome 5

1. Identify the security algorithms used in WLAN
2. Identify the security and authentication algorithms used in Bluetooth
3. Analyze the security algorithms for various applications

Concept Map



Syllabus

Overview of Cryptography And Its Applications –Secure Communications, Cryptographic Applications. **Classical Cryptosystems**: Shift Ciphers, Affine Ciphers , The Vigen`ere Cipher , Substitution Ciphers, **Basic Number Theory -**Basic Notions ,Solving ax + by = d, Congruence's ,The Chinese Remainder Theorem, Modular Exponentiation, Fermat and Euler ,Primitive Roots ,Inverting Matrices Mod n , Square Roots Mod n , Legendre and Jacobi Symbols , Finite Fields ,Continued Fractions. **The RSA Algorithm-** The RSA algorithm, Attacks on RSA,primality testing and Factoring. **Discrete Logarithms-**Discrete Logarithms, Computing Discrete Logs, Bit Commitment Diffie-Hellman Key Exchange, The ElGamal Public Key Cryptosystem, The RSA Algorithm, Attacks on RSA, Primality Testing, Factoring, The RSA Challenge, An Application to Treaty Verification, **Elliptic curves:** The addition law, Elliptic curves mod *p*, Factoring with elliptic curves, Elliptic curves in characteristic 2, Elliptic curve cryptosystems. **Hash Functions**-Hash Functions ,A Simple Hash Example ,The Secure Hash Algorithm , Birthday Attacks, Multicollisions ,The Random Oracle Model, Using Hash Functions to Encrypt , Computer Problems. **Case Studies**: WLAN, Bluetooth.

Reference Books

1. Wade Trappe, Lawrence C. Washington, "Introduction to Cryptography with Coding Theory", Pearson Education, Second Edition, 2006.
2. C E Veni Madhavan, Abhijit Das "Public Key Cryptography: Theory And Practice" Pearson Publication, 2009
3. T. H. Cormen, C. E. Leiserson, R. Rivest and C. Stein, Introduction to Algorithms, 2nd Edition, Prentice Hall, 2002.

4. Neal Koblitz, A Course in Number Theory and Cryptography, Springer-Verlag, New York, May 2001.
5. William Stallings, "Cryptography and Network Security", Pearson Education, Second Edition, 2016.

Course Contents and Lecture Schedule

Module No.	Topics	No of Lectures
1	**Basic Number Theory**	
1.1	Basic Notions ,Solving ax + by = d	1
1.2	The Chinese Remainder Theorem	2
1.3	Modular Exponentiation	2
1.4	Fermat and Euler	2
1.5	Primitive Roots	2
1.6	Inverting Matrices Mod n	2
1.7	Square Roots Mod n	1
1.8	Legendre and Jacobi Symbols	2
1.9	Finite Fields ,Continued Fractions	2
2	**The RSA Algorithm**	
2.1	The RSA Algorithm	2
2.2	Attacks on RSA	2
2.3	Primality Testing	2
2.4	Factoring	1
2.5	The Public Key Concept	1
3	**Elliptic Curves**	
3.1	The Addition Law	1
3.2	Elliptic Curve Mod p	2
3.3	Factoring with Elliptic Curves	1
3.4	Elliptic Curve Cryptosystem	2
3.5	Identity Based Encryption	2
4	**Case Studies**	
4.1	WLAN	2
4.2	Bluetooth	2
Total number of Hours		**36**

Course Designers:

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18CNPW0	RECONFIGURABLE WIRELESS TRANSCEIVERS

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

This course provides the students, the knowledge about implementation of Communication blocks on FPGA. It considers programmable ASICs analysis especially on programming technologies and structure and from various vendors. It provides both the fixed point and floating point representation of data used for implementation. It considers algorithms and techniques for the optimal way of implementing the communication system blocks efficiently on FPGA.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Explain the design flow of Programmable ASIC	Understand
CO2	Categorize the programming technologies of Programmable ASIC	Analyze
CO3	Investigate the Logic blocks, I/O cells and Interconnects of Programmable ASIC.	Analyze
CO4	Demonstrate advanced number systems, algorithms and transforms to implement communication transceiver blocks	Apply
CO5	Implementation of communication transceiver blocks using algorithms and transforms with HDL	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	S	L	-	-	-	-	-	S	-	M
CO2	S	S	-	-	-	-	-	-	M	-	M
CO3	S	S	S	S	-	S	S	S	S	S	S
CO4	S	M	S	S	S	S	S	S	S	S	S
CO5	S	S	S	S	S	S	S	S	S	S	S

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	10	10	0	0
Understand	30	10	20	20
Apply	20	40	40	40
Analyse	40	40	40	40
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. List out the sequence of steps to design an ASIC.
2. Differentiate global routing and detailed routing
3. Mention the Goals and objective of Floorplanning

Course Outcome 2 (CO2):

1. Define OTP in ASIC
2. Compare the programming technologies for Xilinx and Actel FPGA.
3. Examine the EPROM and EEPROM programming technology of an FPGA.

Course Outcome 3 (CO3):

1. Compare the architecture of ACT 1 and ACT 2 logic cell with neat diagrams.
2. Illustrate the output characteristics of totemploe buffer of programmable ASIC
3. Explain different types of I/O requirements with example?

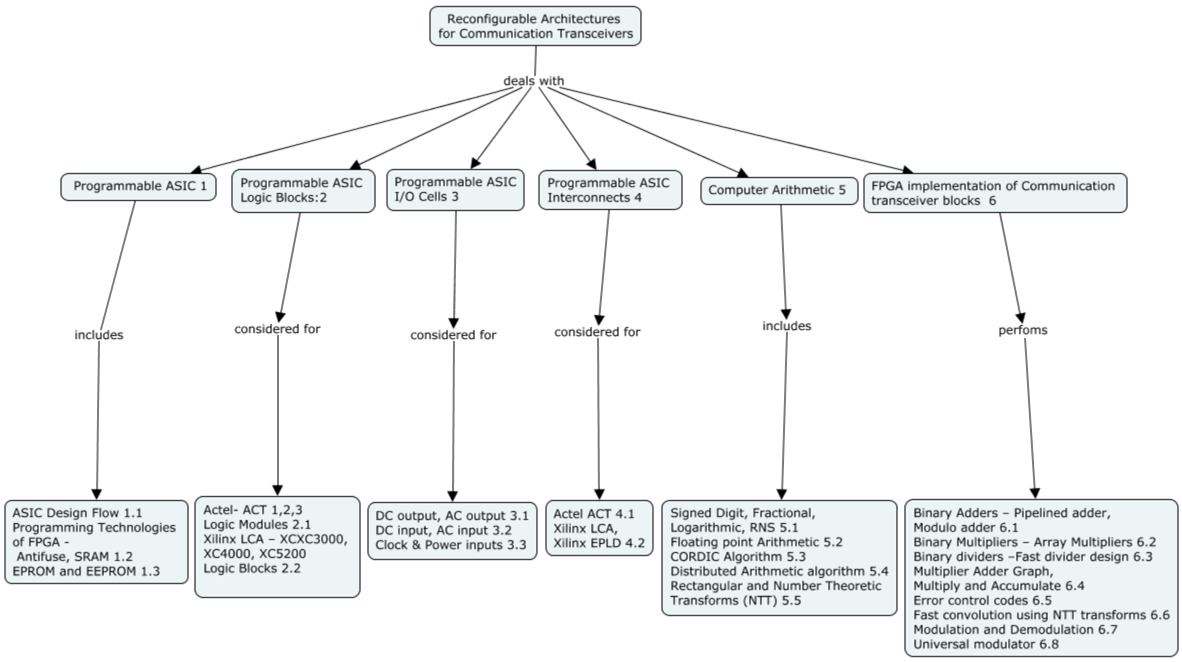
Course Outcome 4 (CO4):

1. Convert the given decimal number 15 into equivalent optimal CSD
2. Explain the function of pipelined adder with neat diagram
3. Predict equivalent CSD coding for the decimal number 15.

Course Outcome 5 (CO5):

1. Design and implement an universal modulator using HDL coding
2. Illustrate implementation of Encoder of BCH code.
3. Compute cyclic convolution of length 4 time series x(n)={1,1,0,0} and h(n)={1,0,0,1} using a Fermat NTT modulo 255.

Concept Map



Syllabus

Programmable ASIC: ASIC Design Flow, Programming Technologies of FPGA – Antifuse, SRAM, EPROM and EEPROM. **Programmable ASIC Logic Blocks:** Actel- ACT Logic Modules, Xilinx LCA Logic Blocks, **Programmable ASIC I/O Cells:** DC output, AC output, DC input, AC input, Clock & Power inputs **Programmable ASIC Interconnect:** Actel ACT, Xilinx LCA - Xilinx EPLD, **Computer Arithmetic:** Signed Digit, Fractional, Logarithmic and RNS, QRNS, Floating point, CORDIC Algorithm, Distributed Arithmetic algorithm, Rectangular and Number Theoretic Transforms (NTT) **FPGA Implementation of Communication transceiver blocks :** Binary Adders, Binary Multipliers – Array Multipliers, Binary dividers, Multiply Adder Graph, Multiply and Accumulate, Block codes and Convolution codes, Fast convolution using NTT transforms, Modulation and Demodulation, Universal modulator (AM, FM, PM).

Reference Books

1. Michael John Sebastian Smith, "Applications Specific Integrated Circuits", Pearson Education, Ninth Indian reprint,13th edition,2004.
2. Neil H.E.Weste, Eshraghian, "Principles of CMOS VLSI Design": Addison Wesley, 1999.
3. Andrew Brown, "VLSI Circuits and Systems in Silicon", McGraw Hill,1991.
4. Uwe.Meyer-Baese, "Digital Signal Processing with Field Programmable Gate Arrays", Springer, Third edition, May 2007
5. Keshab K. Parhi, "VLSI Digital Signal Processing systems, Design and implementation", Wiley, Inter Science, 1999

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Programmable ASIC**	
1.1	ASIC Design Flow	1
1.2	Programming Technologies of FPGA **-** Antifuse, SRAM	1
1.3	EPROM and EEPROM	1
2	**Programmable ASIC Logic Blocks:**	
2.1	Actel- ACT 1, ACT 2, ACT 3 Logic Modules	2
2.2	Xilinx LCA – XC3000, XC4000, XC5200 Logic Block	2
3	**Programmable ASIC I/O Cells:**	
3.1	DC output, AC output	1
3.2	DC input, AC input	1
3.3	Clock & Power inputs	1
4	**Programmable ASIC Interconnect:**	
4.1	Actel ACT	1
4.2	Xilinx LCA - Xilinx EPLD	1
5	**Computer Arithmetic**	
5.1	Signed Digit, Fractional, Logarithmic, RNS	2
5.2	Floating point Arithmetic	2
5.3	CORDIC Algorithm	2
5.4	Distributed Arithmetic algorithm	2
5.5	Rectangular and Number Theoretic Transforms (NTT)	2
6	**FPGA Implementation of Communication transceiver blocks**	
6.1	Binary Adders – Pipelined adder, Modulo adder	2
6.2	Binary Multipliers – Array Multipliers, Fast array Multipliers	2
6.3	Binary dividers –Fast divider design	1
6.4	Multiplier Adder Graph, Multiply and Accumulate.	2
6.5	Error control codes	1
6.6	Fast convolution using NTT transforms	2
6.7	Modulation and Demodulation	1
6.8	Universal modulator	2
	Total Hours	**36**

Course Designers:

1. Dr.S.Rajaram rajaram_siva@tce.edu
2. Dr.K.Kalyani kalyani@tce.edu

18CNPX0	RF CAD TOOLS	Category	L	T	P	Credit
		PE	2	0	2	3

Preamble

In today's radiofrequency and microwave communication circuits, there is an ever-increasing demand for higher integration and miniaturization. This trend leads to massive computational tasks during simulation, optimization and statistical analyses, requiring robust modeling tools so that the whole process can be achieved reliably. The course begins with the overview of linear and non-linear circuit simulation techniques. Then it will give detailed picture about the two commonly used numerical methods in the RF CAD tools such as FDTD and MOM methods. Both the two methods are covered from the general description to application level in the RF domain. The course ends with the optimization techniques such as ant colony optimization and particle swarm optimization to derive the optimal electrical parameters of the RF circuits. By taking this course, the students can gain theoretical knowledge about the backbone numerical methods, optimization tools of the recent RF CAD software's and they are encouraged to do RF passive and active circuit simulations using the CAD tools.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Summarize the synthesis and optimization techniques to solve the complex problems in the EM simulations.	Understand
CO2. Determine the suitable method for RF circuit simulation to obtain the desired results.	Apply
CO3. Analyze the EM problems in the RF circuit and apply the FDTD one-dimensional method.	Analyze
CO4. Analyze the scattering and radiation problems in the RF circuits and apply the MOM method.	Analyze
CO5. Evaluate the electrical parameters of the filters and antennas through ant colony and PSO algorithms	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	L	L	-	-	-	-	-	-	-	-
CO2	S	L	L	-	-	-	-	-	-	-	-
CO3	S	M	M	L	L	-	-	L	-	-	-
CO4	S	M	M	L	L	-	-	L	-	-	-
CO5	S	M	M	L	L	-	-	L	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests				End Semester Examination
	1	2	3	Practical	
Remember	0	0	0		0
Understand	40	0	20		20
Apply	40	80	50		60
Analyse	20	20	30		20
Evaluate	0	0	0		0
Create	0	0	0		0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Compare the differences between synthesis and optimization.
2. Discuss the different types of circuit simulation techniques.

3. Mention the impedance mapping and component tuning.

Course Outcome 2 (CO2):

1. Discuss in detail about the process flow of non-linear circuit simulations.
2. Illustrate the different types of time-domain methods used in the EM simulators.
3. Compare the merits and demerits of time- and frequency-domain methods.

Course Outcome 3 (CO3):

1. Discuss about the absorbing boundary conditions of one-dimensional FDTD method.
2. Apply the FDTD method to determine the propagation constant.
3. Illustrate the procedure to extract the frequency-domain information from the time-domain data.

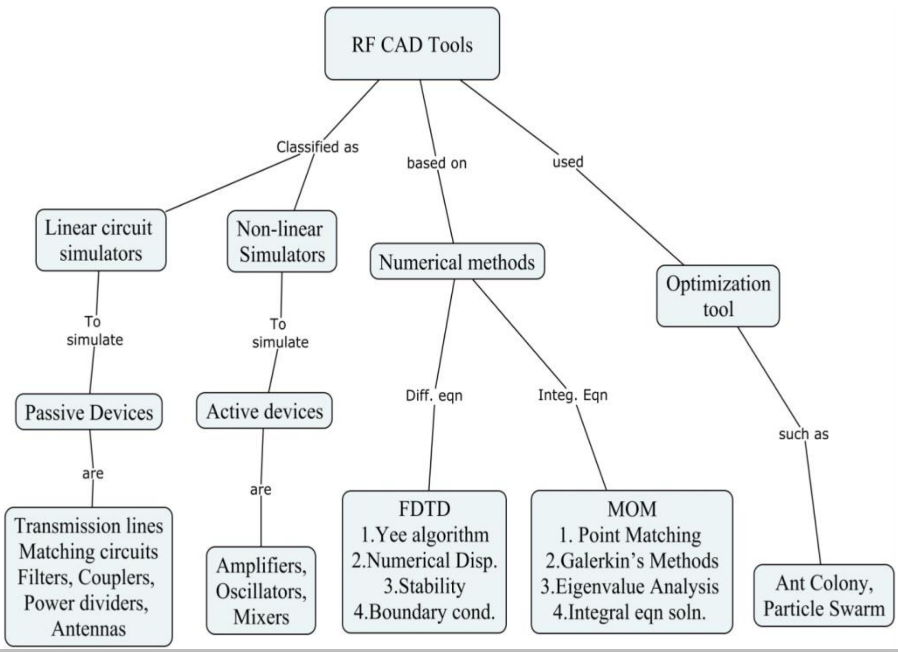
Course Outcome 4 (CO4):

1. Discuss in detail about the Point colloacation method.
2. Analyze the characteristics of a stripline using method of moments.
3. Brief about the merits and demerits of hybrid computational methods.

Course Outcome 5 (CO5):

1. Discuss in detail about the ant colony optimization method.
2. Brief about the variants of particle swarm optimization.
3. Discuss about the recent trends in the field of ant colony optimization.

Concept Map



Syllabus

Linear circuit simulation techniques - Analysis versus synthesis and optimization, Circuit simulation techniques, Impedance mapping, Component tuning, Circuit optimization, Statistical design techniques, Circuit synthesis, EM field simulation, CAD program descriptions. **Nonlinear circuit simulation techniques -** Classification of nonlinear circuit simulators- Analytical methods, Time-domain methods, Hybrid time and frequency domain techniques, Frequency domain techniques. The harmonic balance method. **Finite Difference Time Domain** – Pulse propagation in a transmission line, FDTD analysis in one dimension - Spatial Step ∆x and Numerical Dispersion, Time Step ∆t and Stability of the Solution, Source/Excitation of the Grid, Absorbing Boundary Conditions for One Dimensional. Applications of One Dimensional FDTD Analysis – Reflection at an Interface, Determination of Propagation Constant, Extraction of Frequency Domain Information from the Time Domain Data, Simulation of Lossy, Dispersive Materials. **The Method of Moments** - MoM Procedure, Point Matching and Galerkin's Methods, Eigenvalue Analysis Using MoM. Solution of Integral Equations Using MoM - Integral Equation, Static Charge Distribution on a Wire, Analysis of Strip Line, Analysis of Wire Dipole Antenna, Scattering from a Conducting

Cylinder of Infinite Length. Fast Multipole Solution Methods for MoM, Comparison between FDTD and MoM, Hybrid Computational Methods. Point Collocation method. **Optimization –** Swarm Intelligence in Optimization - Introduction - Ant Colony Optimization - The Origins of Ant Colony Optimization, Ant Colony Optimization: A General Description, Recent Trends. Particle Swarm Optimization - Particle Swarm Optimization: An Introduction, Inertia Weight, Fully Informed Particle Swarm, PSO Variants, Applications of PSO Algorithms, Recent Trends - Theoretical Work on PSO, PSO for Multiobjective Optimization, PSO for Dynamic Optimization - PSO for Constraint Handling.

Laboratory Experiments:

1. Design and simulation of Microstrip and Stripline.
2. Design and simulation of Microstrip and CPW Power Divider.
3. Design and simulation of Discrete and Microstrip Coupler Design.
4. Design and simulation of Discrete and Microstrip Filter Design.
5. Design and simulation of Microwave Amplifier.
6. Design and simulation of Power Amplifier.
7. Design and simulation of Microwave Oscillator.
8. Design and simulation of Active Mixer.
9. Design and simulation of patch antenna.
10. Design and simulation of aperture coupled antenna.

Reference Books

1. Xin-Qing Sheng, Wei Song, "Essentials of Computational Electromagnetics", John Wiley & Sons, 2012.
2. David B. Davidson, "Computational Electromagnetics for RF and Microwave Engineering", Cambridge University Press, 2011.
3. Ramesh Garg, "Analytical and Computational Methods in Electromagnetics", Artech House, Inc. 2008.
4. Christian Blum, Daniel Merkle, "Swarm Intelligence: Introduction and Applications", Springer-Verlag, 2008.
5. Daniel G. Swanson, Wolfgang J. R. Hoefer, "Microwave Circuit Modeling Using Electromagnetic Field Simulation", Artech House, Inc. 2003.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1.	**Linear circuit simulation techniques**	
1.1	Analysis versus synthesis and optimization, Circuit simulation techniques	1
1.2	Impedance mapping, Component tuning, Circuit optimization	1
1.3	Statistical design techniques, Circuit synthesis, EM field simulation, CAD program descriptions	1
2.	**Nonlinear circuit simulation techniques**	
2.1	Classification of nonlinear circuit simulators, Analytical methods	1
2.2	Time-domain methods, Hybrid time and frequency domain techniques	1
2.3	Frequency domain techniques, The harmonic balance method	1
3.	**Finite Difference Time Domain**	
3.1	Pulse propagation in a transmission line, FDTD analysis in one dimension - Spatial Step Δx and Numerical Dispersion	2
3.2	Time Step Δt and Stability of the Solution, Source/Excitation of the Grid, Absorbing Boundary Conditions for One Dimensional	1
3.3	Applications of One Dimensional FDTD Analysis – Reflection at an Interface, Determination of Propagation Constant	1
3.4	Extraction of Frequency Domain Information from the Time Domain Data, Simulation of Lossy, Dispersive Materials.	1
4.	**The Method of Moments**	

4.1	MoM Procedure, Point Matching and Galerkin's Methods, Eigenvalue Analysis Using MoM	2
4.2	Solution of Integral Equations Using MoM - Integral Equation, Static Charge Distribution on a Wire,	1
4.3	Analysis of Strip Line, Analysis of Wire Dipole Antenna	1
4.4	Fast Multipole Solution Methods for MoM, Comparison between FDTD and MoM	1
4.5	Hybrid Computational Methods, Point Collocation method	1
5.	**Optimization**	
5.1	Swarm Intelligence in Optimization - Ant Colony Optimization - The Origins of Ant Colony Optimization	2
5.2	Ant Colony Optimization: A General Description, Recent Trends	1
5.3	Particle Swarm Optimization - Particle Swarm Optimization: An Introduction, Inertia Weight, Fully Informed Particle Swarm,	2
5.4	PSO Variants, Applications of PSO Algorithms, Recent Trends	1
5.5	PSO for Multiobjective Optimization, PSO for Dynamic Optimization - PSO for Constraint Handling.	1
Theory		24
Practical		24
	Total	48

Course Designers:

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18CNPYO	MACHINE LEARNING FOR SIGNAL PROCESSING	Category	L	T	P	Credit
		PE	2	1	0	3

Preamble

The objective of this course is to develop techniques which can enable machines to understand complex real-world signals like text, speech, images, videos etc. This course will cover methods which analyze, classify and detect the underlying information modalities present in real world signals. This course consists of descriptions of signal processing tools for learning patterns in image and speech signals as the description of a class of machine learning tools which have been successfully used for these signals.

Prerequisite

Nil

Course Outcomes

On the successful completion of the course, students will be able to

CO1	Design engineering approaches to extract feature from real world signal such as text, speech, image and video.	Apply
CO2	Apply generative and discriminative models for features extracted.	Apply
CO3	Describe the working principles of CNN and RNN.	Understand
CO4	Demonstrate the usage of open source resources for CNN and RNN	Apply
CO5	Apply CNN and RNN to obtain inferences from features extracted.	Apply
CO6	Apply machine learning approaches for speech recognition and computer vision.	Apply

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	M	-	-	L	-	M	-	L	-
CO2	S	M	M	-	-	L	-	M	-	L	-
CO3	S	M	M	-	-	L	-	M	-	L	-
CO4	-	M	M	-	S	L	-	M	-	L	L
CO5	S	M	M	-	-	L	-	M	-	L	-
CO6	S	S	M	L	-	L	-	M	-	L	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	20	20	20
Apply	80	80	80	80
Analyse	0	0	0	0
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Take a word, for example, "machine." Write it ten times. Also ask a friend to write it ten times. Analyzing these twenty images, try to find features, types of strokes, curvatures, loops, how you make the dots, and so on, that discriminate your handwriting from your friend's.
2. If a face image is a 100 × 100 image, written in row-major, this is a 10,000-dimensional vector. If we shift the image one pixel to the right, this will be a very different vector in the 10,000-dimensional space. How can we build face recognizers robust to such distortions?

3. Assume we are given the task to build a system that can distinguish junk email.What is in a junk e-mail that lets us know that it is junk? How can the computer detect junk through a syntactic analysis? What would you like the computer to do if it detects a junk e-mail—delete it automatically, move it to a different file, or just highlight it on the screen?

Course Outcome 2 (CO2):

1. Assuming that the classes are normally distributed, in subset selection, when one variable is added or removed, how can the new discriminant be calculated quickly? For example, how can the new s_{new}^{-1} be calculated from s_{old}^{-1} ?
2. Draw two-class, two-dimensional data such that (a) PCA and LDA find the same direction and (b) PCA and LDA find totally different directions.
3. Using Optdigits from the UCI repository, implement PCA. For various number of eigenvectors, reconstruct the digit images and calculate the reconstruction error.

Course Outcome 3 (CO3):

1. Consider one-class SVM. Prove there are no bounded support vector when the regularization constant *C* is equal to 1.
2. Consider the SMO algorithm for classification. What is the minimum number of Lagrange multipliers which can be optimized in an iteration? Explain your answer.
3. Given the observable Markov model with three states s_1, s_2, s_3 , initial probabilities $\Pi = [0.5 \quad 0.2 \quad 0.3]^T$ and transition probabilities $A = \begin{bmatrix} 0.4 & 0.3 & 0.3 \\ 0.2 & 0.6 & 0.2 \\ 0.1 & 0.1 & 0.8 \end{bmatrix}$ Generate 3 sequences of 5 states.

Course Outcome 4 (CO4):

1. Represent python loop to do stochastic gradient descent method.
2. Generate a grid of filter response patterns in a layer.
3. Explain Numpy implementation of a simple RNN in python.

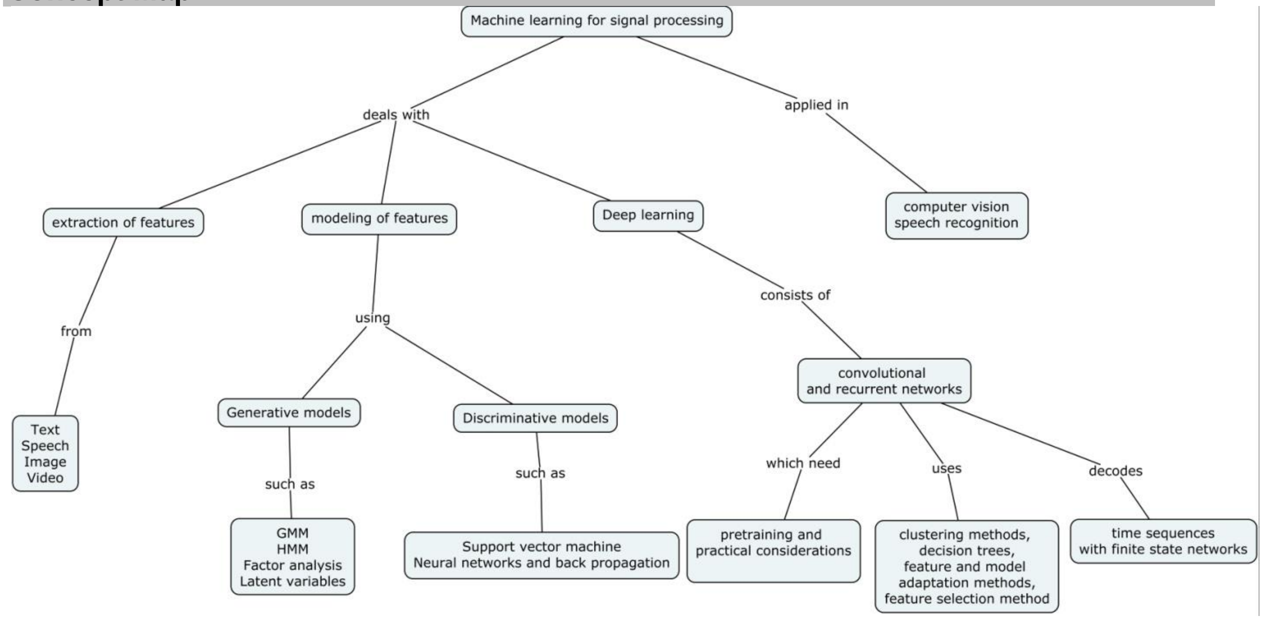
Course Outcome 5 (CO5):

1. Find the on-line gradient descent update rules for an MLP where hidden nodes have the logistic sigmoid as activation function, the output nodes have a linear activation function and the loss function is the quadratic loss.
2. Find the on-line gradient descent update rules for an MLP when the loss function is the cross-entropy.
3. Train an MLP using different initializations for the weights. Use the resulting networks to build an ensemble and measure the improvement with respect to the best and the worse single MLP.

Course Outcome 6 (CO6):

1. We can do *k*-means clustering, partition the instances, and then calculate S*i* separately in each group. Why is this not a good idea?
2. What are the similarities and differences between average-link clustering and *k*-means?
3. In hierarchical clustering, how can we have locally adaptive distances? What are the advantages and disadvantages of this?

Concept Map



Syllabus

Introduction to real world signals - text, speech, image, video **Feature extraction and front-end signal processing** - information rich representations, robustness to noise and artifacts, signal enhancement, bio inspired feature extraction Basics of pattern recognition, **Generative modelling** - Gaussian and mixture Gaussian models, hidden Markov models, factor analysis and latent variable models. **Discriminative modelling** - support vector machines, neural networks and back propagation **Introduction to deep learning** - convolutional and recurrent networks, pre-training and practical considerations in deep learning, understanding deep networks, Clustering methods and decision trees, Decoding time sequences with finite state networks, Feature and model adaptation methods. Feature selection methods. **Applications in computer vision and speech recognition.**

Reference Books

1. C.M.Bishop, "Pattern Recognition and Machine Learning", C.M. Bishop, 2nd Edition, Springer, 2011.
2. I.Goodfellow,Y.Bengio,A.Courville, "Deep Learning", MIT Press, 2016.
3. L.Rabiner and H.Juang, Prentice Hall,1993.
4. D.Yu,L.Deng, "Automatic Speech Recognition," Springer 2014.
5. Ethem Alpaydın, "Introduction to Machine learning", The MIT Press Cambridge, Massachusetts,2010
6. Michael Bowles, "Machine learning in Python: Essential techniques for predictive analysis," John Wiley and sons, 2015.

Course Contents and Lecture Schedule

S. No.	Topic	No.of Lectures
1.	**Introduction to real world signals**	
1.1	text, speech, image, video	2
2	**Feature extraction and front-end signal processing**	
2.1	information rich representations	1
2.2	robustness to noise and artifacts	1
2.3	signal enhancement	2
2.4	bio inspired feature extraction	2
2.5	Basics of pattern recognition	2
3	**Generative modelling**	

3.1	Gaussian and mixture Gaussian models	1
3.2	hidden Markov models	2
3.3	factor analysis and latent variable models	2
4	**Discriminative modelling**	
4.1	support vector machines	4
4.2	neural networks and back propagation	2
5	**Introduction to deep learning**	
5.1	convolutional and recurrent networks	2
5.2	pre-training and practical considerations in deep learning	2
5.3	understanding deep networks	2
5.4	Clustering methods and decision trees	2
5.5	Decoding time sequences with finite state networks	2
5.6	Feature and model adaptation methods	2
5.7	Feature selection methods	2
6	**Applications in computer vision and speech recognition**	1
Total		36

Course Designers:

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18CNGA0	CONVEX OPTIMIZATION FOR COMMUNICATIONS

Category	L	T	P	Credit
PE	2	1	0	3

Preamble

This course aims to give students the tools and training to recognize convex optimization problems that arise in wireless communications, presenting the basic theory, and concentrating on modeling aspects and results that are useful in applications.

Prerequisite

NIL

Course Outcomes

On the successful completion of the course, students will be able to

CO1. Interpret the convex sets, their representation and their properties	Understand
CO2. Apply various conditions to check the given function is convex or not	Apply
CO3. Formulate problems into standard convex optimization problems	Apply
CO4. Reformulate the original optimization problem in wireless communication applications into an GP, LP and QP	Apply
CO5. Reformulate the original optimization problem in wireless communication applications into an SOCP and semidefinite programme	Apply
CO6. Analyze the primal and dual optimal solution of convex optimization problems in wireless communication applications	Analyze
CO7. Apply interior point method to solve convex optimization problem	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	M	L	-	-	-	-	-	-	-	-
CO2	S	M	M	-	-	-	-	-	-	-	-
CO3	S	M	L	L	S	-	-	-	-	-	-
CO4	S	S	M	S	S	-	-	-	-	L	L
CO5	S	S	M	S	S	-	-	-	-	L	L
CO6	S	S	M	S	-	-	-	-	-	L	L
CO7	S	M	L	L	-	-	-	-	-	-	-

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	20	20	20
Apply	80	60	60	60
Analyse	0	20	20	20
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1(CO1):

1. Which of the following sets are convex?
   a. A slab i.e., a set of form $\{x \in R^n / \alpha \leq a^T x \leq \beta\}$
   b. A rectangle i.e., a set of form $\{x \in R^n / \alpha_i \leq x_i \leq \beta_{i,} i = 1....n\}$
   c. A wedge i.e., $\{x \in R^n / a_1^T x \leq b_{1,} a_2^T x \leq b_2\}$.
   d. The sets of points closer to a given point than a given set

i.e., $\{x / \|x - x_0\|_2 \leq \|x - y\| \, for all y \in S\}$ where $S \subseteq R^n$.

e. The set of points closer to one set than another i.e. , $\{x / dist(x, s) \leq dist(x, T)\}$, where $S, T \subseteq R^n$ and $\text{dist}(x, S) = \inf \{\|x - z\|_2 / z \in S\}$

f. The set $\{x / x + S_2 \subseteq S_1\}$, where $S_1, S_2 \subseteq R^n$ with S_1 convex.

g. The set of points whose distance to a does not exceed a fixed fraction θ of the distance to b i.e., the set $\{x / \|x - a\|_2 \leq \theta \|x - b\|_2\}$. You can assume $a \neq b$ and $0 \leq \theta \leq 1$.

2. Some sets of probability distributions. Let x be a real valued random variable with $prob(x = a_i) = p_i, i = 1, \ldots, n,$ where $a_1 < a_2 < \ldots < a_n$. of course $p \in R^n$ lies in the standard probability simplex $P = \{p / 1^T p = 1, p \succ 0\}$, which of the following conditions are convex in p?

   (a) $\alpha \leq Ef(x) \leq \beta$, where E f(x) is the expected value of f(x) i.e., $Ef(x) = \sum_{i=1}^{n} p_i f(a_i)$.

   (The function $f : R \to R_i isgiven$)

   (b) $prob(x > \alpha) \leq \beta$

   (c) $E|x^3| \leq \alpha E|x|$.

   (d) $Ex^2 \leq \alpha$

   (e) $Ex^2 \geq \alpha$

   (f) $Var(x) \leq \alpha$, where $Var(x) = E(x - Ex)^2$ is the variance of x

   (g) $Var(x) \geq \alpha$

   (h) $quartile(x) \geq \alpha$ where $quartile(x) = \inf \{\beta / prob(x \leq \beta) \geq 0.25\}$

   (i) $quartile(x) \leq \alpha$

2 Converse supporting hyper plane theorem. Suppose the set C is closed, has nonempty interior, and has a supporting hyperplane at every point in its boundary. Show that C is convex. Find an expression for the range of a target in kilometres (km) for a reflected signal that returns to the radar $\Delta T \ \mu s$ after being transmitted.

Course Outcome 2 (CO2):

1. Check the following functions for convexity:

   a) $f(\mathbf{x}) = e^{x_1} + x_2^2 + 5$

   b) $f(\mathbf{x}) = 3x_1^2 + 5x_1x_2 + x_2^2$

   c) $f(\mathbf{x}) = \frac{1}{4}x_1^4 - x_1^2 + x_2^2$

2. Assume that function $f_1(x)$ and $f_2(x)$ are convex and let $f(x) = \max\{f_1(x), f_2(x)\}$, show that $f(x)$ is convex function. Note: The pointwise maximum property extends to the pointwise supremum over an infinite set of convex functions. If for each $y \in A, f(x, y)$ is convex in x, then the function g, defined as $g(x) = \sup_{y \in A} f(x, y)$ is convex in x. Here the domain of g is $\text{dom}\, g = \left\{ x | (x, y) \in \text{dom}\, f \ \ \forall \ y \in A, \sup_{y \in A} f(x, y) < \infty \right\}$ Similarly, the pointwise infimum of a set of concave functions is a concave function.

3. Let $f_1(x) = 2e^{-x}, f_2(x) = |x + 3|, f_3(3) = \sin(x)$, where $f_1, f_2, f_3 : \left[0, \pi/2\right] \to \square$. Then

a. $f_1 + f_2 - 2f_3$ is a convex function

b. $-f_1 + f_3$ is a convex function

c. $-f_3 + 4f_2$ is a concave function

d. $(\ln f_1)^2 + f_2$ is a concave function

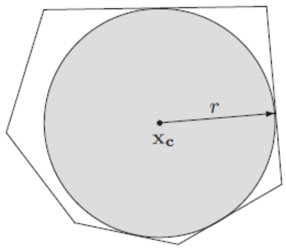
Course Outcome 3 (CO3)

1. The following inequality functions are in nonconvex form,
   i) $\log x \leq 1$
   ii) $1 - x_1 x_2 \leq 0 \; x_1, x_2 \geq 0$

   Convert them into convex optimization problems.
2. Given below is an unconstrained piecewise-linear objective function,

   $$\min_{x \in \Re^n} \max_{i=1,\ldots,m} \{a_i^T X + b_i\}$$

   Reformulate the above problem using epigraph method.
3. Consider a norm ball $B(X_c, r) = \{X \| \|X - X_c\|_2 \leq r\}$ and a polyhedron $\mathrm{P} = \{X | a_i^T X \leq b_i, i = 1,..,m\}$.

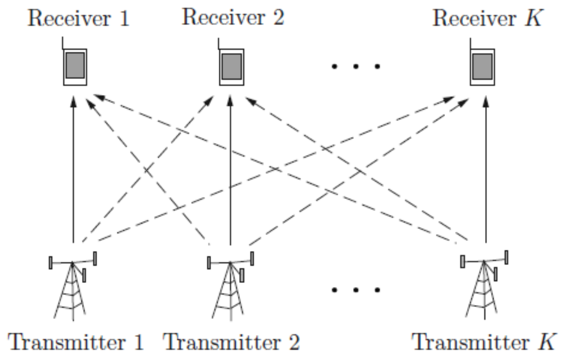


   Formulate a convex optimization problem for finding the largest ball inside the polyhedron.

Course Outcome 4 (CO4):

1. Problems involving ℓ_1 – and ℓ_∞ – norms are given below. Formulate them as LPs. Explain in detail the relation between the optimal solution of each problem and the solution of its equivalent LP.
   i) **Minimize** $\|Ax - b\|_\infty$ **(**ℓ_∞ **– norm approximation).**
   ii) **Minimize** $\|Ax - b\|_1$ **(**ℓ_1 **– norm approximation).**
   iii) **Minimize** $\|Ax - b\|_1$ **subject to** $\|x\|_\infty \leq 1$.
   iv) **Minimize** $\|x\|_1$ **subject to** $\|Ax - b\|_\infty \leq 1$.
   v) **Minimize** $\|Ax - b\|_1 + \|x\|_\infty$**.**

   where $A \in \Re^{mXn}$ **and** $b \in \Re^m$ **.**
2. Consider the scenario given in the figure below with K transmitters and K receivers. Transmitter i sends signals to receiver i and other transmitters are interferers to transmitter i.

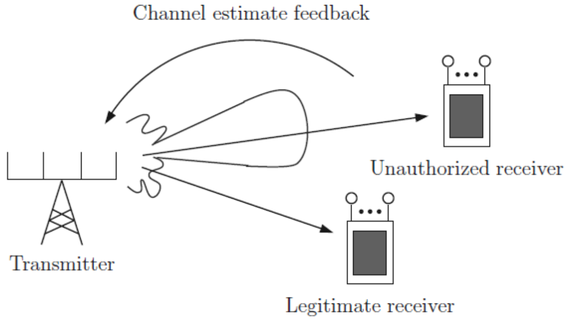


The signal-to-interference-plus-noise ratio (SINR) at receiver i is given by,

$$\gamma_i = \frac{G_{ii} p_i}{\sum_{j=1, j\neq i}^{K} G_{ij} p_j + \sigma_i^2},$$

where p_i is the power of transmitter i, G_{ij} is the channel power gain from transmitter j to receiver i and σ_i^2 is the noise power at receiver i. Formulate a convex optimization LP problem to minimize the average transmitter power, subject to constraint that all SINRs are no less than a prespecified threshold γ_0.

3. Consider the scenario as shown in figure below in designing multi stage training sequence for discriminatory channel estimation in wireless MIMO systems. This training signal design also considers artificial noise superimposed in the training signal.



A wireless MIMO system

Formulate a convex optimization problem to minimize the normalized mean-squared error of the legitimate receiver's channel estimation under the constraint on the total transmit energy and normalized mean-squared error of the unauthorized receiver's channel estimation.

Course Outcome 5 (CO5):

1. Consider the LP $\min \mathbf{c}^T\mathbf{x}$

$$\text{s.t. } \mathbf{a}_i^T\mathbf{x} \le b_i \text{ where } i = 1,2,\ldots m$$

Reformulate LP to robust linear program, which turns out to be an SOCP when there is some uncertainty in $\mathbf{a}_i$ as given below.

$$\mathbf{a}_i \in \mathbf{Y}_i, \{\bar{\mathbf{a}}_i + \mathbf{P}_i\mathbf{u} \mid \|\mathbf{u}\|_2 \le 1\}$$

where $\bar{\mathbf{a}}$ and $\mathbf{P}_i$ (perturbation matrix) are only known system parameters rather than the true system vector $\mathbf{a}_i$. 8.4.3

2. Consider the situation where there is uncertainty with true direction θ_{des}. Suppose that $\bar{\theta}_{des}$ is the given nominal arrival direction of the signal of interest and $\mathbf{a}(\bar{\theta}_{des})$ is the associated steering vector. The uncertainty effect can be modeled as $\mathbf{a}(\theta_{des}) = \mathbf{a}(\bar{\theta}_{des}) + \mathbf{u}$ where $\mathbf{u}$ is the uncertainty vector. The minimum variance beamformer design based on $\mathbf{a}(\bar{\theta}_{des})$ can be very sensitive to uncertainty in the given $\mathbf{a}(\bar{\theta}_{des})$.The robust beamforming problem is given by

$$\min \ \mathbf{w}^H \mathbf{R} \mathbf{w}$$
$$\textbf{s.t} \ \inf_{\|\mathbf{u}\|_2 \le \varepsilon} \ \mathbf{w}^H (\mathbf{a} + \mathbf{u}) \ge 1$$

Reformulate the above nonconvex problem into an SOCP problem.

3. Consider the scenario that the transmitter and the receiver have n and m antennas, respectively. We consider a spatial multiplexing system where each transmitter antenna transmits its own sequence of symbols. Assume frequency flat fading and antipodal modulation. Reformulate the MIMO ML detector problem for the above system as SDP problem.

Course Outcome 6 (CO6):

1. A simple example. Consider the optimization problem

Minimize $x^2 + 1$

Subject to $(x-2)(x-4) \le 0$, with variable $x \in R$

Analysis of primal problem: Give the feasible set, the optimal value, and the optimal solution.

2. Dual of general LP. Find the dual function of LP

Minimize $c^T x$

Subject to $\begin{matrix} Gx \le h \\ Ax = b \end{matrix}$

Give the dual problem and make the implicit equality constraints explicit.

3. Consider the QCQP

Minimize $x_1^2 + x_2^2$

Subject to $(x_1 - 1)^2 + (x_2 - 1)^2 \le 1$

$(x_1 - 1^2) + (x_2 + 1)^2 \le 1$

with variable $x \in R^2$. Sketch the feasible set and level sets of the objective. Find the optimal point x^* and optimal value p^*.

Course Outcome 7 (CO7):

1. Barrier method example. Consider the simple problem

Minimize $(x^2 + 1)$

Subject to $2 \le x \le 4$,

which has a feasible set $[2,4]$, and optimal point x^* =2. Plot f_0 and $tf_0 + \phi$, for several values of $t > o$, versus x, Label $x^*(t)$.

2. What happens if the barrier method is applied to the LP?

Minimize x_2

Subject to $x_1 \le x_2$, $0 \le x_2$, with variable $x \in R^2$?

3. Boundedness of centering problem.

Minimize $f_0(x)$

Subject to $f_i \quad (x \le 0), i = 1,.....,m$.

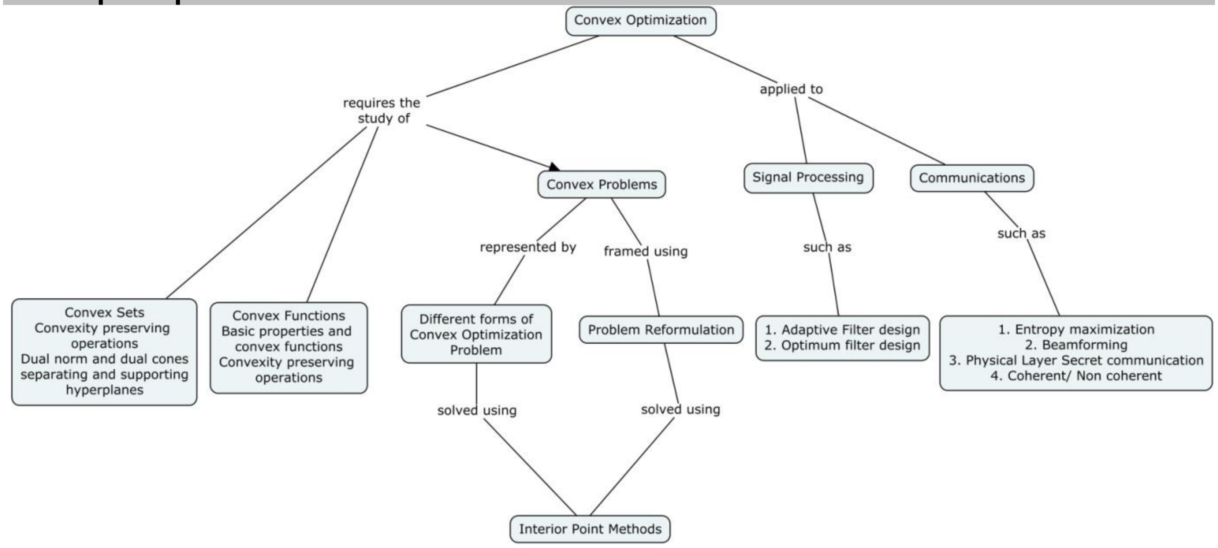
$Ax = b$, are bounded.

Show that the sublevel sets of the associated centering problem,

Minimize $tf_0 x + \phi(x)$

Subject to $Ax = b$, are bounded.

Concept Map



Syllabus

Convex Sets: Affine and convex sets, Examples of Convex sets, Operations that preserves convexity, Generalized inequalities, dual cones and generalized inequalities

Convex Functions: Basic properties and examples of convex functions, convexity preserving operations, Quasi convex functions.

Convex Optimization Problems: Optimization problems in a standard form, convex optimization problems, Equivalent representations and transforms, Quasiconvex optimization.

Geometric Programming, Linear Programming and Quadratic Programming: Introduction to GP, GP in a convex form, successive GP approximation, physical layer secret communication, examples using linear program: Diet problem, Chebyshev center, Maximization/minimization of matrix determinant, quadratic program, applications of QP and QCQP in beamformer design.

Second Order Cone Programming and Semidefinite Programming: Robust linear program, robust receive beamforming via SOCP, transmit downlink beamforming via SOCP, application of SDP in transmit beamforming.

Duality: Lagrange dual function, Lagrange dual problem, Karush–Kuhn–Tucker (KKT) optimality conditions.

Interior Point Methods: Inequality and equality constrained convex problems, Barrier method, Primal-dual interior-point method

Reference Books

1. Stephen Boyd, Lieven Vandenberghe, “Convex Optimization” Cambridge University Press, 2004.
2. Chong-Yung-Chi • Wei-Chiang Li • Chia-Hsiang Lin, “Convex Optimization for Signal Processing and Communications from fundamentals to applications”, CRC Press, 2017.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Convex Sets**	
1.1	Affine and convex sets, Examples of Convex sets	1
1.2	Operations that preserves convexity	2
1.3	Generalized inequalities	1
1.4	dual cones and generalized inequalities	1
2	**Convex Functions**	

2.1	Basic properties and examples of convex functions,	2
2.2	convexity preserving operations	1
2.3	Quasi convex functions	2
3	**Convex Optimization Problems**	
3.1	Optimization problems in a standard form, convex optimization problems,	1
3.2	Equivalent representations and transforms	2
3.3	Quasiconvex optimization	1
4	**Geometric Programming, Linear Programming and Quadratic Programming**	
4.1	Introduction to GP, GP in a convex form	1
4.2	successive GP approximation, physical layer secret communication,	2
4.3	examples using linear program: Diet problem, Chebyshev center, Maximization/minimization of matrix determinant,	2
4.4	quadratic program	1
4.5	applications of QP and QCQP in beamformer design	2
5	**Second Order Cone Programming and Semidefinite Programming:**	
5.1	Robust linear program, robust receive beamforming via SOCP,	2
5.2	transmit downlink beamforming via SOCP	2
5.3	application of SDP in transmit beamforming	2
6	**Duality**	
6.1	Lagrange dual function	1
6.2	Lagrange dual problem	1
6.3	Karush–Kuhn–Tucker (KKT) optimality conditions.	2
6.4	**Interior Point Methods**	
6.5	Inequality and equality constrained convex problems	1
6.6	Barrier method	1
6.7	Primal-dual interior-point method	2
	Total	36

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