CURRICULUM AND DETAILED SYLLABI

FOR

M.E. DEGREE (Wireless Technologies) 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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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: Wireless Technologies** **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.	18WT110	Linear Algebra and Optimization	2	1	-	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.	18WT120	RF Circuits for Wireless Systems	3	-	-	3	-
2.	18WT130	Wireless Network Technologies	3	-	-	3	-
3.	18WT210	Antennas for Wireless Applications	2	1	-	3	18WT120
4.							
THEORY CUM PRACTICAL							
1.	18WT160	Random Signal Processing	2	-	2	3	-
2.	18WT260	Wireless Digital Communications	2	-	2	3	18WT160
PRACTICAL							
1.	18WT170	RF Circuits laboratory	-	-	4	2	-
2.	18WT270	Wireless Network 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.	18WTPA0	RF Test and Measurement	3	-	-	3	-
2.	18WTPB0	EMI and EMC	3	-	-	3	-
3.	18WTPC0	RF MEMS for High Performance Passives	3	-	-	3	-
4.	18WTPD0	Radio Frequency Integrated circuits	3	-	-	3	-
5.	18WTPF0	MIMO OFDM Systems	2	1	-	3	18WT260
6.	18WTPG0	Millimeter Wave Communications	2	1	-	3	18WT260
7.	18WTPH0	5G Wireless Technologies	2	1	-	3	18WT260
8.	18WTPJ0	Cognitive Radio	2	1	-	3	18WT260

		Communications					
9.	18WTPK0	Physical Layer Security	2	1	-	3	-
10.	18WTPL0	Intelligent Video Surveillance Systems	3	-	-	3	-
11.	18WTPM0	Digital Integrated Circuit Design with HDL	3	-	-	3	-
12.	18WTPN0	VLSI for Wireless Communication	3	-	-	3	-
13.	18WTPP0	Reconfigurable Wireless Transceivers	3	-	-	3	-
14.	18WTPQ0	Internet of Things	3	-	-	3	-
15.	18WTPR0	System-on-Chip	3	-	-	3	-
16.	18WTPS0	Optical Wireless Communication	3	-	-	3	-
17.	18WTPT0	Number Theory and Cryptography	3	-	-	3	-
18.	18WTPU0	Cognitive Radio Networks	3	-	-	3	-
19.	18WTPV0	Multimedia Coding and Transmission	3	-	-	3	-
20.	18WTPW0	Machine Learning for Signal Processing	2	1	-	3	-
THEORY CUM PRACTICAL							
1.	18WTPE0	RF CAD Tools	2	-	2	3	-

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.	18WTGA1	Convex Optimization	2	-	-	2	-

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	-	-	2	-

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

S.No	Course Code	Name of the Course	**Number of Hours / Week**			Credit	Prerequisite
			L	T	P		
PRACTICAL							
1.	18WT280	Mini Project	-	-	4	2	-
2.	18WT380	Dissertation Phase I	-	-	20	10	-
3.	18WT480	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							
-	-	-	-	-	-	-	-

THIAGARAJAR COLLEGE OF ENGINEERING, MADURAI-625015

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

SCHEDULING OF COURSES

Semester	Theory					Theory Cum Practical	Laboratory	Project
I (20)	18WT110 Linear Algebra and Optimization (3)	18WT120 RF Circuits for Wireless Systems (3)	18WT130 Wireless Network Technologies (3)	18WTPx0 Prog. Elective 1 (3)	18WTPx0 Prog. Elective 2 (3)	18WT160 Random Signal Processing (3)	18WT170 RF Circuits Laboratory (2)	-
II (18)	18WT210 Antennas for Wireless Applications (3)	18WTPx0 Prog Elective 3 (3)	18WTPx0 Prog. Elective 4 (3)	-	18WT250 Research Methodology and IPR (2)	18WT260 Wireless Digital Communications (3)	18WT270 Wireless Network Laboratory (2)	18WT280 Mini Project (2)
III (15)	18WTPx0 Prog. Elective 5 (3)	-	-	-	18WTGx0 Open Elective (2)	-	-	18WT380 Dissertation Phase I (10)
IV (15)	-	-	-	-	-	-	-	18WT480 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 (Wireless Technologies)
COURSES OF STUDY

I SEMESTER
Theory:

Course Code	Name of the Course	Regulation			
		L	T	P	C
18WT110	Linear Algebra and Optimization	3	0	0	3
18WT120	RF Circuits for Wireless Systems	3	0	0	3
18WT130	Wireless Network Technologies	3	0	0	3
18WTPx0	Programme Elective 1	3	0	0	3
18WTPx0	Programme Elective 2	3	0	0	3
18WT160	Random Signal Processing	2	0	2	3

Practical

18WT170	RF Circuits Laboratory	0	0	4	2

Total Credits 20

II SEMESTER
Theory:

Course Code	Name of the Course	Regulation			
		L	T	P	C
18WT210	Antennas for Wireless Applications	2	1	0	3
18WTPx0	Programme Elective 3	3	0	0	3
18WTPx0	Programme Elective 4	3	0	0	3
18WT250	Research Methodology and IPR	2	0	0	2
18WT260	Wireless Digital Communications	2	0	2	3

Practical

18WT270	Wireless Network Laboratory	0	0	4	2
18WT280	Mini Project	0	0	4	2

Total Credits 18

III SEMESTER
Theory:

Course Code	Name of the Course	Regulation			
		L	T	P	C
18WTPx0	Programme Elective 5	3	0	0	3
18WTGx0	Open Elective	2	0	0	2

Practical

18WT380	Dissertation Phase I	0	0	20	10

Total Credits 15

IV Semester:
Practical:

Course Code	Name of the Course	Regulation			
		L	T	P	C
18WT480	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 (Wireless Technologies) Program
SCHEME OF EXAMINATIONS
(For the candidates admitted from 2018-19 onwards)

FIRST SEMESTER

Course 8code	Name of the Course	Duration of End Semester Exam\ in Hrs.	Marks			Min. Marks for Pass	
			Conti-nuous Asses-sment	End Semester Exam	Max. Marks	End Semester Exam	Total
THEORY							
18WT110	Linear Algebra and Optimization	3	50	50	100	25	50
18WT120	RF Circuits for Wireless Systems	3	50	50	100	25	50
18WT130	Wireless Network Technologies	3	50	50	100	25	50
18WTPx0	Programme Elective 1	3	50	50	100	25	50
18WTPx0	Programme Elective 2						
18WT160	Random Signal Processing	3	50	50	100	25	50
PRACTICAL							
18WT170	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	End Semester Exam	Max. Marks	End Semester Exam	Total
THEORY							
18WT210	Antennas for Wireless Applications	3	50	50	100	25	50
18WTPx0	Programme Elective 3	3	50	50	100	25	50
18WTPx0	Programme Elective 4	3	50	50	100	25	50
18WT250	Research Methodology and IPR	3	50	50	100	25	50
18WT260	Wireless Digital Communications	3	50	50	100	25	50
PRACTICAL							
18WT270	Wireless Network Laboratory	3	50	50	100	25	50
18WT280	Mini Project	-	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	
			Continuous Assessment	Terminal Exam	Max. Marks	Terminal Exam	Total
THEORY							
18WTPx0	Programme Elective 5	3	50	50	100	25	50
18WTGx0	Open Elective	3	50	50	100	25	50
PRACTICAL							
18WT380	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	
			Continuous Assessment	Terminal Exam	Max. Marks	Terminal Exam	Total
PRACTICAL							
18WT480	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.

18WT110	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

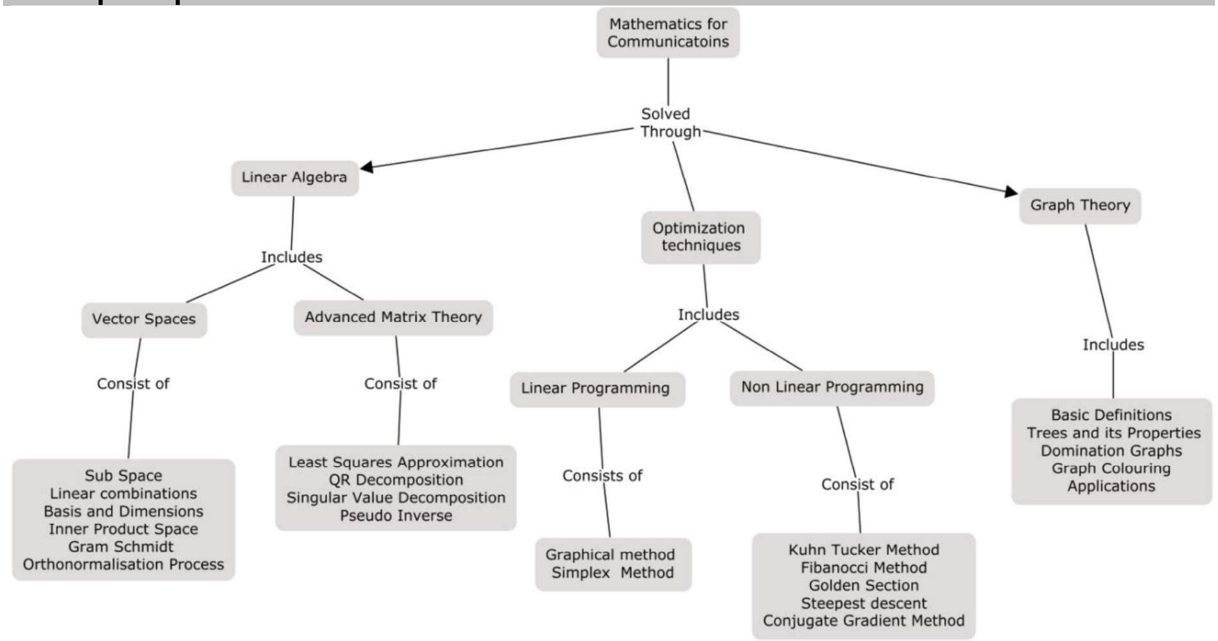
Course Outcome 6 (CO6):

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

18WT120	RF CIRCUITS FOR WIRELESS SYSTEMS

Category	L	T	P	Credit
PC	3	0	0	3

Preamble

The unprecedented success of wireless system created an unexpected demand for RF/Microwave communications engineers. This course aims to provide strong fundamentals in the field of passive and active RF/Microwave circuit design. The course begins with the study of different radio receiver architectures and the trade-off between them. Then, it focuses on the design and characterization of passive circuits such as matching circuits, couplers, power dividers and filters using scattering parameters. Active circuits such as amplifiers, mixers and oscillators are covered in the subsequent modules.

Prerequisite

Nil

Course Outcomes

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

CO1	Characterize the receiver, generate receiver specification, analyze the response	Understand
CO2	Design and analyze the behavior of lumped and distributed forms of matching circuit, coupler and power divider.	Apply
CO3	Design and analyze the response of microwave filters and resonators	Apply
CO4	Determine the stability of the given transistor using graphical aids and design stabilizing network, bias networks for linear amplifier design.	Apply
CO5	Design amplifier for maximum gain, specified gain, LNA using graphical aids.	Apply
CO6	Characterize the transistor, design matching circuit, choose the appropriate biasing network for power amplifier design.	Apply
CO7	Design and analyze the behavior of Oscillators and Mixers	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

Bloom's Category	Continuous Assessment Tests 1	2	3	Terminal Examination
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. Assume the length of a long conductor laid out on a PCB board is L=1.27cm, with Eeff=2.25. How should this conductor be treated at 10MHz, 100MHz & 1GHz?
2. Mention the process steps to calculate spurious free dynamic range of RF front end?

3. A signal has an SNR of 20dB. How much can the SNR decrease if the bandwidth is doubled, assuming the same information throughput?

Course Outcome 2 (CO2):

1. The power output (Pt) transmitted from a cellular phone is +30DBm. At the receiver the signal power (Pr) is down to 5pW. What is the attenuation of the signal path between the transmitter and receiver?
2. Distinguish the differences between homodyne and heterodyne receivers?
3. Find the order and transmission zero distribution of the two-element circuit whose values are L=15nH, C=28pF. Using a 10 Ω source and a 50 Ω load, what is the loss of the circuit at low frequencies, and what is the gain slope at the high frequencies.

Course Outcome 3 (CO3):

1. Match the 10Ω output impedance of a differential amplifier to the 100Ω input impedance of the second amplifier at 850MHz using the analytical Q-matching approach and lowpass L-C circuits.
2. Synthesize an L-C matching network to operate between two complex terminations. The source has an equivalent circuit of 5 Ω in series with the Ls=0.42nH inductance and the load consists of 50 Ω resistance in parallel with an Ll=16.5nH inductance.
3. Design a bandpass filter with a single resonant circuit for a center frequency of 500MHz and a desired 3-dB bandwidth of 50MHz. Use a 50Ω source and 50Ω load termination.
4. Design a chebyshev filter with 0.1dB equal ripple passband of 400MHz, 50Ω source and load termination with a min. number of inductors in the filter. Minimum required stopband attenuation is 40dB at 900MHz.
5. Optimize the matching circuit to match 5Ω to 50Ω at 850MHz. The octave bandwidth from 600MHz to 1200MHz with a maximum acceptable ripple of 0.2dB. Start with the single frequency matching circuit and then repeat the exercise with arbitrary component values.

Course Outcome 4 (CO4):

1. Define: unilateral figure of merit.
2. State the necessary conditions for oscillation in a one-port network.
3. Define: Noise Figure.

Course Outcome 5 (CO5):

1. Mention the design steps involved in designing low noise amplifiers.
2. Discuss the neutralization methods used for bipolar transistors.
3. Brief about the design steps involved in designing power amplifiers.

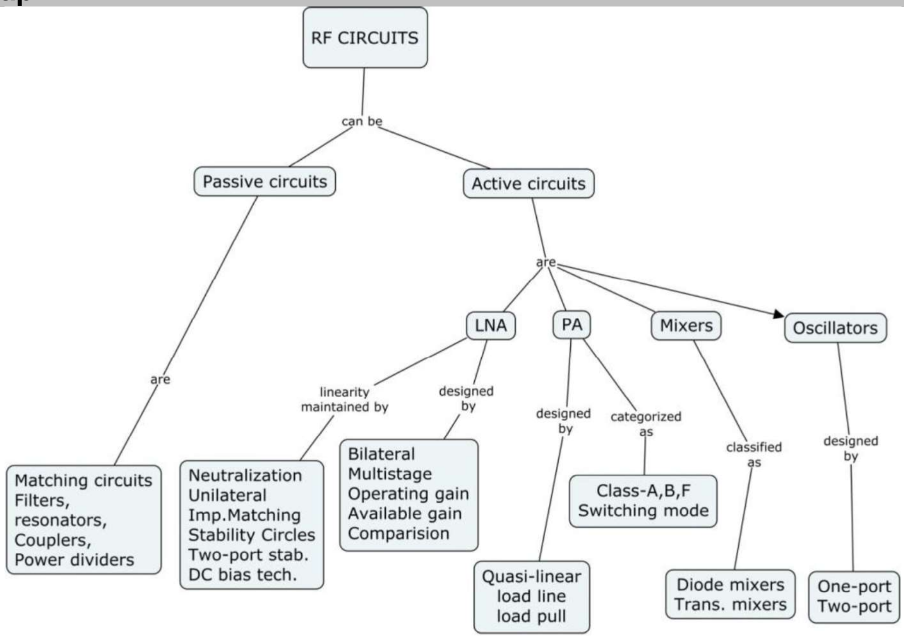
Course Outcome 6 (CO6):

1. Distinguish between bilateral and unilateral transducer gain.
2. Mention the methods to determine the stability of given RF transistor?
3. Distinguish between HBT and HEMT.

Course Outcome 7 (CO7):

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.
4. One oscillator has a Q of 5, another a Q of 50. Which oscillator reaches steady-state conditions first? Which oscillator can be quenched more quickly? Are these results intuitive? Can you think of a mechanical system that behaves the same way?
5. Derive the open-loop gain expression for the Colpitts topology. What are the conditions for startup of oscillation? At steady state, what must the load impedance equal?

Concept Map



Syllabus

The radio as typical RF system - Receiver architecture and characterization, Analysis of CDMA receiver architecture, Receiver component specification and response. **Impedance Matching Techniques –** The impedance match, Transmission zero definitions, Impedance matching - complex termination, resistive terminations, The Q-matching technique with L-C sections, Multi-section impedance matching, Matching with transmission line components on the Smith chart, Couplers and Dividers. **Filters and resonant circuits -** Filter specifications, filter types, Low frequency versus RF/MW filters, Comparison of filter responses, Lumped and distributed filter design, Network transformations, Resonators. **Linear RF Amplifier Design -** Power Gain Definition, Neutralization, Unilateral Transducer Gain, RF Oscillation, Stability Analysis, Stability Circles, Stabilizing an active two port, The dc bias techniques. **Linear and Low Noise RF Amplifiers -** Bilateral RF Amplifier Design for Maximum Small-Signal Gain, Multistage Amplifiers, Operating Gain and Available Gain design techniques, Noise in RF Circuits, Low Noise Amplifier Design, Comparison of Various Amplifier Design. **High Power RF Transistor Amplifier Design -** Nonlinear Concepts, Quasi-linear power amplifier design, Categories of Amplifiers: Class A, Class B, Class F, Switching Mode Amplifiers, Power Amplifier Design Examples: Transistor Selection, Characterization and Matching. **Oscillators and Mixers -** Principles of One-Port and Two-Port Oscillator Design, Transistor Oscillator Configuration, Oscillator Phase Noise – Design examples. Mixers, Harmonic Components in Mixers, Image Problem in Mixers, Diode Mixers - Single Ended and Balanced Mixer, Transistor Mixers, Applications of Mixers.

Reference Books

1. Les Besser and Rowan Gilmore, “Practical RF Circuit Design for Modern Wireless Systems– Passive Circuits and Systems”, Vol.I, Artech House Publishers, 2003.
2. Les Besser and Rowan Gilmore, “Practical RF Circuit Design for Modern Wireless Systems – Active Circuits and Systems”, Vol.II, Artech House Publishers, Boston, London 2003.
3. D.M.Pozar, “Microwave Engineering”, John Wiley & Sons, 2004.
4. R.E.Collin, “Foundations of Microwave Engineering”, McGraw Hill, 1995.

Course Contents and Lecture Schedule

Module No.	Topic	No.of Lectures
1.	**The radio as typical RF system**	
1.1	Receiver architecture and characterization	1
1.2	Analysis of CDMA receiver architecture, Receiver component specification and response	2
2.	**Impedance Matching Techniques**	
2.1	The impedance match, Transmission zero definitions	1
2.2	Impedance matching - complex termination, resistive terminations	1
2.3	The Q-matching technique with L-C sections, Multi-section impedance matching	2
	Matching with transmission line components on the Smith chart	1
2.4	Couplers and Dividers	2
3.	**Filters and resonant circuits**	
3.1	Filter specifications, filter types, Low frequency versus RF/MW filters, Comparison of filter responses	1
3.2	Lumped and distributed filter design	2
3.3	Network transformations, Resonators	1
4.	**Linear RF Amplifier Design**	
4.1	Power Gain Definition, Neutralization, Unilateral Transducer Gain	1
4.2	RF Oscillation, Stability Analysis	1
4.3	Stability Circles, Stabilizing an active two port	2
4.4	The dc bias techniques	1
4.5	**Linear and Low Noise RF Amplifiers -** Bilateral RF Amplifier Design for Maximum Small-Signal Gain, Multistage Amplifiers	2
4.6	Operating Gain and Available Gain design techniques	2
4.7	Noise in RF Circuits	1
4.8	Low Noise Amplifier Design, Comparison of Various Amplifier Design	1
5.	**High Power RF Transistor Amplifier Design**	
5.1	Nonlinear Concepts, Quasi-linear power amplifier design	1
5.2	Categories of Amplifiers: Class A, Class B, Class F	2
5.3	Switching Mode Amplifiers	1
5.4	Power Amplifier Design Examples: Transistor Selection, Characterization and Matching.	2
6	**Oscillators and Mixers**	
6.1	Principles of One-Port and Two-Port Oscillator Design	1
6.2	Transistor Oscillator Configuration, Oscillator Phase Noise – Design examples.	1
6.3	Mixers, Harmonic Components in Mixers, Image Problem in Mixers,	1
6.4	Diode Mixers - Single Ended and Balanced Mixer,	1
6.5	Transistor Mixers, Applications of Mixers	1

Course Designers:

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18WT130	WIRELESS NETWORK TECHNOLOGIES	Category	L	T	P	Credit
		PC	3	0	0	3

Preamble

The objective of this course is to introduce students with concepts, design issues, architectures and protocols and the state-of-the–art developments in 21st century wireless network technologies.

Prerequisite

Nil

Course Outcomes

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

CO1.	Compare adaptive and reconfigurable solutions on all layers in 4G networks with the conventional networks	Analyze
CO2.	Comprehend enabling technologies of 5G networks	Understand
CO3	Apply 5G network technologies in developing cloud networks	Apply
CO4.	Analyze energy harvesting solutions for low power devices	Analyze
CO5.	Develop automotive applications based on content centric network protocols	Apply

Mapping with Programme Outcomes

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

Assessment Pattern

Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	30	20	20	20
Apply	30	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. Classify various wireless networking scenarios in emerging wireless technologies.
2. Identify the radio technologies and service trends in future generation wireless standards.
3. State the challenges for the implementation of composite radio environment.

Course Outcome 2 (CO2):

1. Classify wireless technologies used in 5G.
2. Identify the salient features of 5G new radio.
3. State the challenges in the implementation of UDN.

Course Outcome 3 (CO3):

1. Discuss the benefits of C-RAN architecture
2. Compare network function virtualization and wireless virtualization.
3. Identify the design issues of cloud networking

Course Outcome 4 (CO4):

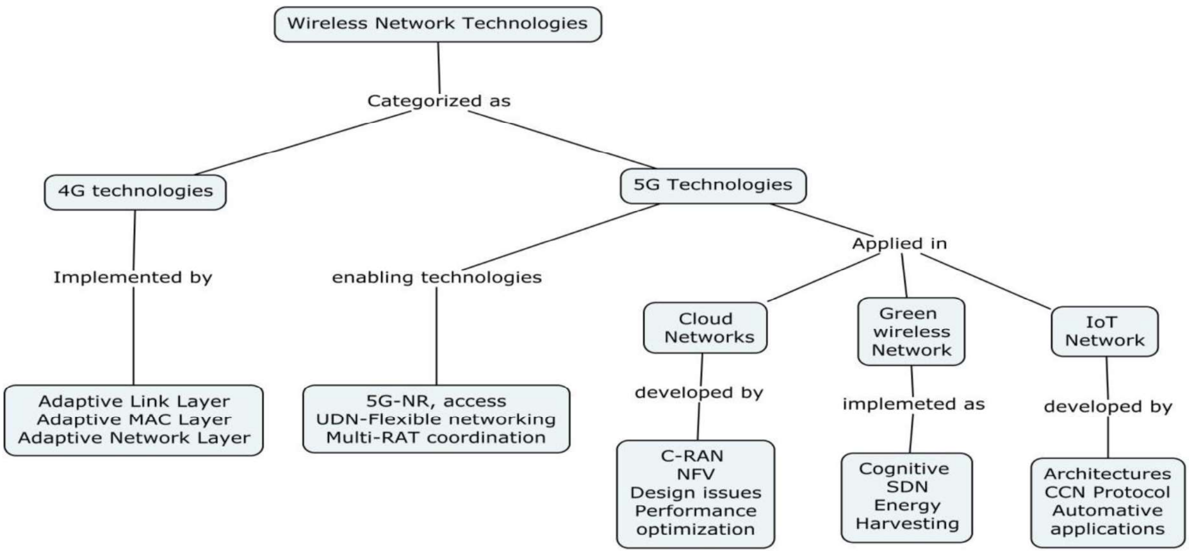
1. Discuss the role of cognitive SDN in the implementation of green wireless networks.
2. Identify the role of SDN in energy optimization of RAN.

3. Analyze the energy harvesting solutions of low power devices and sustainable M2M communication.

Course Outcome 5 (CO5):

1. Compare the architecture of NB-IoT and LTE-M.
2. Build a smart city/home solution using content centric network protocol.
3. Implement an event detection application using appropriate IoT sensors and data aggregation and fusion techniques.

Concept Map



Syllabus

4G Technologies: 4G Networks and Composite Radio Environment, Adaptive and Reconfigurable Link Layer- Adaptive Hybrid ARQ Schemes for Wireless Links, Adaptive Medium Access Control - WLAN Enhanced Distributed Coordination Function, Adaptive MAC for WLAN with Adaptive Antennas, Adaptive Network Layer- Graphs and Routing Protocols **5G Technologies:** vision and challenges, 5G NR – New Radio – air interface of 5G, radio access, Ultra-Dense Network Architecture and Technologies for 5G- Concept and Challenges of UDN, GPP HeNB Architecture, Key Technologies of UDN- Flexible Networking, Multi-RATs Coordination **Cloud Networks:** C-RAN: potentials benefits of architecture, implementation scenario, challenges and research issues, Network Virtualization - NFV, Wireless Virtualization, Cloud Networking-Architecture, Design Issues-Performance optimization, energy and cost optimization, SDN aware optimization-routing **Green Wireless Networks**- Cognitive SDN for Green Wireless Networks- Architecture and Technology, SDN-Based Energy Efficiency Optimization for RAN, Energy Harvesting and Sustainable M2M Communication in 5G Mobile Technologies- Ambient Energy Harvesting Solution for Low Power Devices **IoT Networks:** Introduction to EC-GSM-IoT. NB-IoT. and LTE-M, and their performance, content-centric networking - CCN protocol - smart city, Vehicles / Automotive Applications, Healthcare / Telemedicine / Wearable Applications, Technical Challenges for IoT and CCN, CCN-Based IoT Sensors, sensing and relaying, data control, data fusion for event detection

Reference Books

1. Savo G. Glisic, “Advanced Wireless Networks 4G Technologies”, John Wiley & Sons Ltd., 2006.
2. William Stallings, “Foundations of Modern Networking SDN, NFV, QoE, IoT, and Cloud” Pearson Education, 2015
3. Olof Liberg, Marten Sundberg, Eric Wang, Johan Bergman, and Joachim Sachs. “Cellular Internet of Things: Technologies, Standards, and Performance”, Academic Press, 2017.

4. Harishkesh Venketraman, Trestian Ramonia, "5G Radio Access Networks: Centralized RAN, Cloud-RAN, and Virtualization of Small Cells", CRC Press, 2017
5. Constandinos X. Mavromoustakis, George Mastorakis · Jordi Mongay Batalla, "Internet of Things in 5G Mobile Technologies" Springer
6. Yin Zhang and Min Chen, "Cloud based 5G wireless networks", Springer, 2016
7. Kai Hwang, Geoffrey C. Fox and Jack J. Dongarra, "Distributed and Cloud Computing - From Parallel Processing to the Internet of Things" , Morgan Kaufman Publishers, 2012
8. Lee Chao, "Cloud Computing Networking, Theory, practice and development", CRC Press, 2016

Course Contents and Lecture Schedule

Module No.	Topic	No.of Lectures
1	**4G Technologies**	
1.1	4G Networks and Composite Radio Environment	2
1.2	Adaptive and Reconfigurable Link Layer- Adaptive Hybrid ARQ Schemes for Wireless Links	2
1.3	Adaptive Medium Access Control - WLAN Enhanced Distributed Coordination Function, Adaptive MAC for WLAN with Adaptive Antennas	2
1.4	Adaptive Network Layer- Graphs and Routing Protocols	1
2	**5G Technologies:**, ,	
2.1	vision and challenges, 5G NR – New Radio – air interface of 5G, radio access	2
2.2	Ultra-Dense Network Architecture and Technologies for 5G-	1
2.3	Concept and Challenges of UDN, GPP HeNB Architecture	1
2.4	Key Technologies of UDN- Flexible Networking,	1
2.5	Multi-RATs Coordination	2
3	**Cloud Networks:**	
3.1	C-RAN: potentials benefits of architecture, implementation scenario, challenges and research issues	1
3.2	NFV, Wireless Virtualization	1
3.3	Cloud Networking-Architecture, Design Issues	2
3.4	SDN aware optimization-routing	2
3.5	Performance optimization, energy and cost optimization,	2
4	**Green Wireless Networks**	
4.1	Cognitive SDN for Green Wireless Networks- Architecture and Technology	1
4.2	SDN-Based Energy Efficiency Optimization for RAN	2
4.3	Energy Harvesting and Sustainable M2M Communication in 5G Mobile Technologies- Ambient Energy Harvesting Solution for Low Power Devices	2
5	**IoT Networks:**, -,	
5.1	Introduction to EC-GSM-IoT. NB-IoT. and LTE-M, and their performance	2
5.2	content-centric networking - CCN protocol	1
5.3	Technical Challenges for IoT and CCN,	2
5.4	CCN-Based IoT Sensors, sensing and relaying,	2
5.5	data control, data fusion for event detection	2
Total		36

Course Designers:

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3. Dr. S. Ponmalar spmtce@tce.edu

18WT160	RANDOM SIGNAL PROCESSING	Category	L	T	P	Credit
		PC	2	0	2	3

Preamble

The objective of this course is to present introduction to the theory and applications of random and adaptive signal processing methods. This course focus on the key topics of spectral estimation, signal modeling, adaptive filtering, and array processing, whose selection was based on the grounds of theoretical value and practical importance.

Prerequisite

NIL

Course Outcomes

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

CO1. Compute statistical parameters like mean, correlation and power spectral density of a given random variable or random processes at the output of a LTI system	Apply
CO2. Analyze the power spectrum estimation using parametric and non parametric method	Analyze
CO3. Analyze the power spectrum estimation using Eigen analysis algorithms.	Analyze
CO4. Analyze analytically low order and higher order pole zero models.	Analyze
CO5. Analyze the properties of linear combiners, finite impulse response (FIR) filters, and linear predictors that are optimum for the least-squares error.	Analyze
CO6. Determine the filter coefficients and minimum error of LMS and RLS adaptive filters.	Apply
CO7. Extract information of signals collected using an array of sensors.	Analyze

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

Assessment Pattern

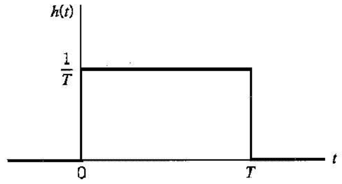
Bloom's Category	Continuous Assessment Tests				End Semester Examination
	1	2	3	Practical	
Remember	0	0	0		0
Understand	20	20	20		20
Apply	40	40	40		40
Analyze	40	40	40		40
Evaluate	0	0	0		0
Create	0	0	0		0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. The random process $X(t)$ is define by $X(t) = X\cos(2\pi f_0 t) + Y\sin(2\pi f_0 t)$ where X and Y are two zero mean independent Gaussian random variables each with variance σ^2. Find $\mu_X(t)$.
2. 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 $h(t)$ shown in Figure. 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. What is the probability density function of Y?



3. A zero-mean stationary process $X(t)$ is applied to a linear filter whose impulse response is defined by a truncated exponential: $h(t)=\begin{cases} ae^{-at}, & 0\le t\le T \\ 0, & otherwise\end{cases}$. Show that the power spectral density of the filter output $Y(t)$ is defined by $S_Y(f)=\frac{a^2}{a^2+4\pi^2 f^2}\left(1-2\exp(-aT)\cos(2\pi fT)+\exp(-2aT)\right)S_X(f)$ where $S_X(f)$ is the power spectral density of the filter input.

Course Outcome 2 (CO2):

1. The Bartlett method is used to estimate the power spectrum of a signal $x[n]$. We know that the power spectrum consists of a single peak with a 3dB bandwidthof 0.01 cycle per sample, but we do not know the location of the peak.
   i) Assuming that N is large, determine the value of $M = N/K$ so that the spectral window is narrower that the peak.
   ii) Explain why it is not advantageous to increase M beyond the value obtained in part (i)
2. Suppose we have N=1000 samples from a sample sequence of a random process.
   i) Determine the frequency resolution of the Bartlett, Welch (50 % overlap) and Blackman-Tukey methods for a quality factor Q=10.
   ii) Determine the record lengths (M) for the Bartlett, Welch (50 % overlap) and Blackman-Tukey methods.
3. Determine the mean, and the autocorrelation of the sequence $x[n]$, which is the output of a ARMA (1,1) process described by the difference equation $x[n]=0.5x[n-1]+w[n]-w[n-1]$ where $w[n]$ is a white noise process with variance σ_w^2.

Course Outcome 3 (CO3):

1. Show that the pseudospectrum for the MUSIC algorithm is equivalent to the minimum-variance spectrum in the case of an infinite signal-to-noise ratio.
2. Find a relationship between the minimum-norm pseudospectrum and the all-pole model spectrum in the case of an infinite signal-to-noise ratio.
3. For the MUSIC algorithm, we showed a means of using the MUSIC pseudospectrum to derive a polynomial that could be rooted to obtain frequency estimates, which is known as root-MUSIC. Find a similar rooting method for the minimum-norm frequency estimation procedure.

Course Outcome 4 (CO4):

1. Consider two linear random processes with systems function $H(z)=\frac{1-0.81z^{-1}-0.4z^{-2}}{(1-z^{-1})^2}$.
   i. Find a difference equation that leads to a numerically stable simulation of each process.
   ii. Generate and plot 100 samples from each process, and look for indications of nonstationarity in the obtained records.

iii. Compute and plot the second difference of (i) and the first difference of (ii). Comment about the stationary of the obtained records.

2. Show that the spectrum of any PZ model with real coefficients has zero slope at $\omega = 0$ and $\omega = \pi$.
3. Find a minimum phase model with autocorrelation $\rho(0)=1, \rho(\pm)=1, and \rho(l)=0$ for $|l| \geq 2$.

Course Outcome 5 (CO5):

1. Show that a unit vector $\mathbf{w}$ is an eigen vector of the matrix $\mathbf{H} = \mathbf{I} - 2\mathbf{w}\mathbf{w}^H$. What is the corresponding eigen value?
2. If a vector $\mathbf{z}$ is orthogonal to $\mathbf{w}$, show that $\mathbf{z}$ is an eigen vector of $\mathbf{H}$. What is the corresponding eigenvalue?
3. Solve the LS problem $\mathbf{X} = \begin{bmatrix} 1 & 2 \\ 1 & 3 \\ 1 & 2 \\ 1 & -1 \end{bmatrix}$ and $y = \begin{bmatrix} -3 \\ 10 \\ 3 \\ 6 \end{bmatrix}$ using Householder transformation.

Course Outcome 6 (CO6):

1. A stationary random signal has autocorrelation function $r_{xx}(k) = 0.25^{|k|}$ for all k. the observation signal is $y_n = x_n + v_n$ where v_n is zero mean, white noise sequence of variance 1, uncorrelated from x_n. Determine the optimal FIR Wiener filter of order $M = 1$ for estimating x_n from y_n.
2. Let $x(n)$ be a zero mean white noise sequence of unit variance. Compute the output correlation $R_{yy}(k)$ for all k of the system $y(n) = 0.25y(n-1) + x(n)$.
3. The sttepest decent algorithm becomes unstable when the step size parameter μ is assigned a negative value. Justify the validity of this statement.

Course Outcome 7 (CO7):

1. Consider a narrowband spatially propagating signal with a speed of propagation c. The signal impinges on an M=2 element ULA from an angle $\phi = 0^0$ with a spacing d between the elements. For illustration purposes, let the temporal content of the signal be a pulse.
   i) Let the time of arrival of the pulse at the first sensor be t=0. At what time does the signal arrive at the second sensor?
   ii) Do any other angles ϕ produce the same delay between the two sensors? Why?
2. The optimum beamformer weights with MVDR normalization are found by solving the following optimization

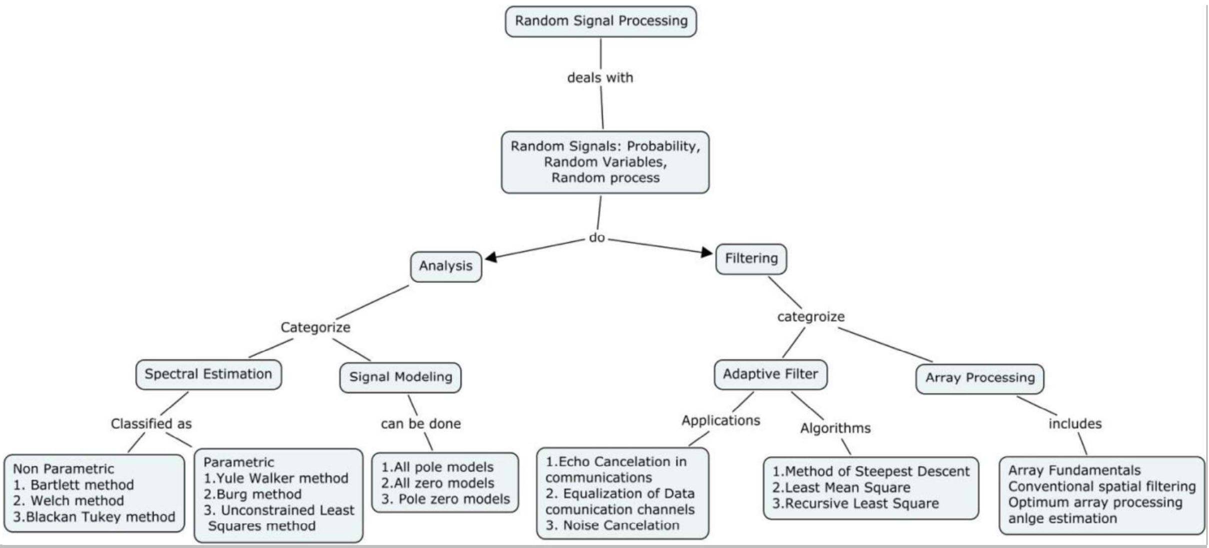
$$\min \quad P_{i+n}$$
$$\textit{subject to } \mathbf{c}^H \mathbf{v}(\varphi_s) = 1 \,.$$

   Using Lagrange multipliers, show that MVDR optimum beamformer weight vector is

$$c_0 = \frac{\mathbf{R}_{i+n}^{-1} \mathbf{v}(\varphi_s)}{\mathbf{v}^H(\varphi_s) \mathbf{R}_{i+n}^{-1} \mathbf{v}(\varphi_s)}$$

3. The frost sample by sample adaptive beamformer was derived for the MVDR beamformer. Extend the frost sample by sample adaptive beamformer for the case of multiple constraints in an LCMV adaptive beamformer

Concept Map



Syllabus

Random Signals: Probabilistic concept, random variables, statistical averages, random vector: Definitions, second order moments, linear transformations of random vectors, normal random vectors, sum of independent random number, random process: definition, stationary process, mean, correlation and covariance functions, Linear Systems with Stationary Random Inputs, Whitening and Innovations Representation. **Signal Modelling:** All pole models, all zero models, pole zero models, models with poles on the unit circle. **Parametric Estimation**- Relationships between the autocorrelation and the model parameters, Yule Walker method, Burg method, unconstrained Least squares method for the AR model parameters. **Eigen analysis algorithms for spectrum estimation**: Pisarenko Harmonic decomposition method, MUSIC, ESPRIT algorithm. **Nonparametric Estimation:** Bartlett method, Welch method, Blackman and Tukey method, performance characteristics of non parametric power spectrum estimators **Least Square filtering and prediction:** Linear Least square error estimation, least square FIR filter, linear least square signal estimation. **Adaptive filter:** Typical application of adaptive filters, principles of adaptive filter, method of steepest descent, least mean square adaptive filters, Recursive least square adaptive filter. **Array Processing:** Array fundamentals, Conventional spatial filtering, Optimum array processing, angle estimation.

List of Laboratory Experiments:

1. Generation of random signals
2. Spectrum Estimation using Parametric estimation
3. Spectrum Estimation using Non parametric estimation
4. Eigen analysis algorithms for spectrum estimation
5. Simulation of Adaptive filtering algorithms
6. Simulation of Array Processing algorithms

Reference Books

1. Dimitris G. Manolakis, Vinay K. Ingle and Stephen M. Kogon, "Statistical and Adaptive Signal Processing", Artech House, 2005.
2. John G.Proakis and Dimitris G.Manolakis, "Digital Signal Processing Principles, Algorithms and Applications", Prentice-Hall of India, Fourth Edition, 2006.
3. Simon Haykin, " Adaptive Filter Theory", Fourth Edition, Prentice Hall, 2001.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Random Signals:**	
1.1	Probabilistic concept, random variables, statistical averages	1
1.2	random vector: Definitions, second order moments, linear	1

	transformations of random vectors, normal random vectors, sum of independent random number	
1.3	random process: definition, stationary process, mean, correlation and covariance functions	1
1.4	Linear Systems with Stationary Random Inputs	1
1.5	Whitening and Innovations Representation	1
2	**Signal Modelling**	
2.1	All pole models, all zero models, pole zero models, models with poles on the unit circle.	1
3	**Parametric Estimation**	
3.1	Relationships between the autocorrelation and the model parameters	1
3.2	Yule Walker method, Burg method	1
3.3	unconstrained Least squares method for the AR model parameters.	1
4	**Eigen analysis algorithms for spectrum estimation**:	
4.1	Pisarenko Harmonic decomposition method	1
4.2	MUSIC	1
4.3	ESPRIT algorithm	1
5	**Nonparametric Estimation**	
5.1	Bartlett method, Welch method, Blackman and Tukey method	1
5.2	performance characteristics of non parameteric power spectrum estimators	1
6	**Least Square filtering and prediction**	
6.1	Linear Least square error estimation	1
6.2	least square FIR filter	1
6.3	linear least square signal estimation	1
7	**Adaptive filter**	
7.1	Typical application of adaptive filters	1
7.2	principles of adaptive filter, method of steepest descent	1
7.3	least mean square adaptive filters	1
7.4	Recursive least square adaptive filter	1
8	**Array Processing**	
8.1	Array fundamentals	1
8.2	Conventional spatial filtering	1
8.3	Optimum array processing, angle estimation	1
	Total	24

Course Designers:

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18WT170	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 WLAN application.
2. Design and Testing of LC low pass filter for WLAN application.
3. Design and Testing of Power Divider (1X4) and (4X4) for WLAN application.
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
1. Dr.K.Vasudevan kvasudevan@tce.edu

18WT210	ANTENNAS FOR WIRELESS APPLICATIONS	Category	L	T	P	Credit
		PC	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

18WT120 RF Circuits for Wireless 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

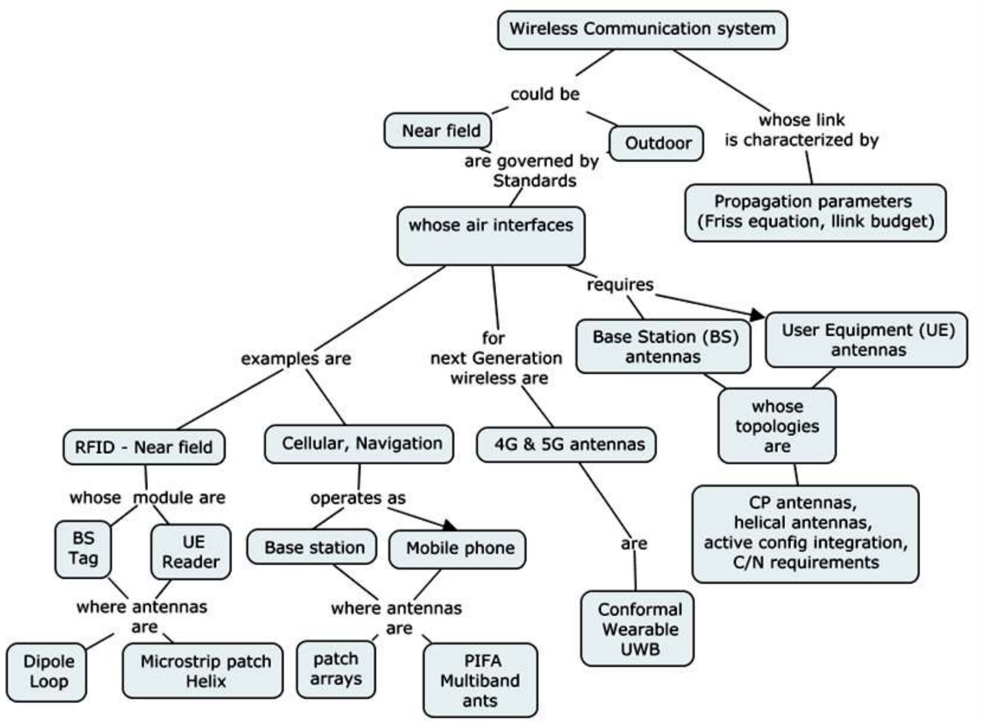
Course Outcome (CO4)

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 Rama rao, 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..	1
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	2
	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
23	Tutorial	2
	Wireless Propagation	
24	characteristics of atmosphere, its significance, propagation models, Wireless link, link budget calculations	4
25	Tutorial	3

Course Designers:

1	Dr.V.Abhaikumar	principal@tce.edu
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18WT260	WIRELESS DIGITAL COMMUNICATIONS

Category	L	T	P	Credit
PC	2	0	2	3

Preamble

The course "18WT260: Wireless Digital Communications" is offered as in the second semester in continuation with the course on "18WT160 Random Signal Processing". The objective of this course is to present the techniques in the physical layer aspects of wireless digital communications and determine and simulate the performance of Wireless systems in terms of capacity and probability of error.

Prerequisite

18WT160 Random Signal Processing

Course Outcomes

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

CO1	Characterize wireless fading channels using mathematical models.	Understand
CO2	Apply the digital modulation and demodulation techniques for wireless communication.	Apply
CO3	Apply suitable equalization techniques for wireless communications.	Apply
CO4	Analyze BER of wireless communication system with and without diversity.	Analyze
CO5	Analyze the capacity of SISO, SIMO, MISO and MIMO wireless communication systems.	Analyze
CO6	Apply the OFDM technique for wireless communication over frequency selective channels.	Apply
CO7	Simulate BER performance of digital modulation schemes in Rayleigh flat channels in SISO, SIMO, MISO, MIMO wireless communication systems and simulate BER performance of digital modulation schemes in frequency selective channels in OFDM system	Apply
CO8	Analyze outage capacity of Rayleigh flat fading channel without and with diversity using simulation.	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	L	-	-	L	-	-	-	-	-	-
CO2	S	M	L	-	L	-	-	-	-	-	-
CO3	S	M	L	-	-	-	-	-	-	-	-
CO4	S	S	L	-	L	-	-	-	-	-	-
CO5	S	S	L	-	L	-	-	-	-	-	-
CO6	S	M	L	-	L	-	-	-	-	-	-
CO7	S	L	L	-	S	L	-	-	-	-	-
CO8	S	L	L	-	S	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	20	20	20		20
Apply	60	40	40		40
Analyse	20	40	40		40
Evaluate	0	0	0		0
Create	0	0	0		0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. A Wireless channel has a multipath spread of 1msec. The total channel bandwidth at bandpass available for signal transmission is 5KHz. Determine the coherence bandwidth. Is the channel frequency selective? Justify.
2. In mobile multipath channels, if the baseband signal bandwidth is much greater than Doppler spread how do you name the channel? Why is it called so?
3. Given that the coherence bandwidth is approximated by equation $B_c = \frac{1}{5\sigma_\tau}$ show that a flat fading channel occurs when $T_s \geq 10\sigma_\tau$

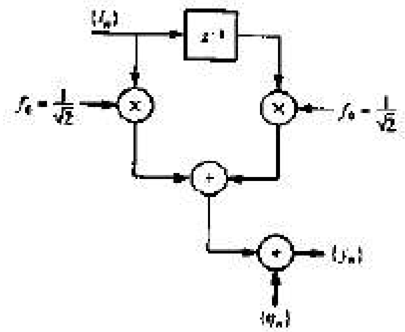
Course Outcome 2 (CO2):

1. Consider a digital communication system that uses two transmitting antennas and one receiving antenna. Let s_1 and s_2 are the symbols that are to be transmitted. The signal from the first antenna over two signal intervals is $(s_1, -s_2^*)$ and from the second antenna the transmitted signal is $(s_2, -s_1^*)$. Let (h_1, h_2) represent the complex valued channel path gains, which is assumed to be zero mean complex Gaussian with unit variance and statistically independent. (h_1, h_2) are assumed to be constant over the two signal intervals and known to the receiver. Let (n_1, n_2) represent the AWGN terms and uncorrelated.
   a. Show that the transmitted symbols s_1 and s_2 can be estimated from the received signal r_1, r_2 and achieve dual diversity reception
   b. If the symbols s_1 and s_2 are BPSK modulated, determine the probability of error.

2. For $g(t) = \sqrt{2/T_s}, 0 \leq t \leq T_s$, a rectangular pulse shape, find the average energy of 4 PAM Modulation.
3. Derive the bit error rate for BFSK Signaling scheme in frequency flat fading channels.

Course Outcome 3 (CO3):

1. 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
2. Derive the structure of a fractionally spaced equalizer when the received pulse has excess bandwidth less than 200%.
3. Determine the performance of the following types of equalizers
   a. Mean square error (MSE) criterion based infinite length Equalizer
   b. MSE based finite length equalizer

c. Decision feedback equalizer

Course Outcome 4 (CO4):

1. Consider a voice system with acceptable BER when the received signal power is at or above half its average value. If the BER is below is acceptable level for more than 120ms, users will turn off their phone. Find the range of Doppler values in a Rayleigh fading channel such that the average time duration when users have unacceptable voice quality is less than $t = 60ms$.
2. Design a digital modulation schemes which can support a BER of 10^{-2} at a SNR of 10dB Derive the probability of error of the modulation scheme.
3. 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?

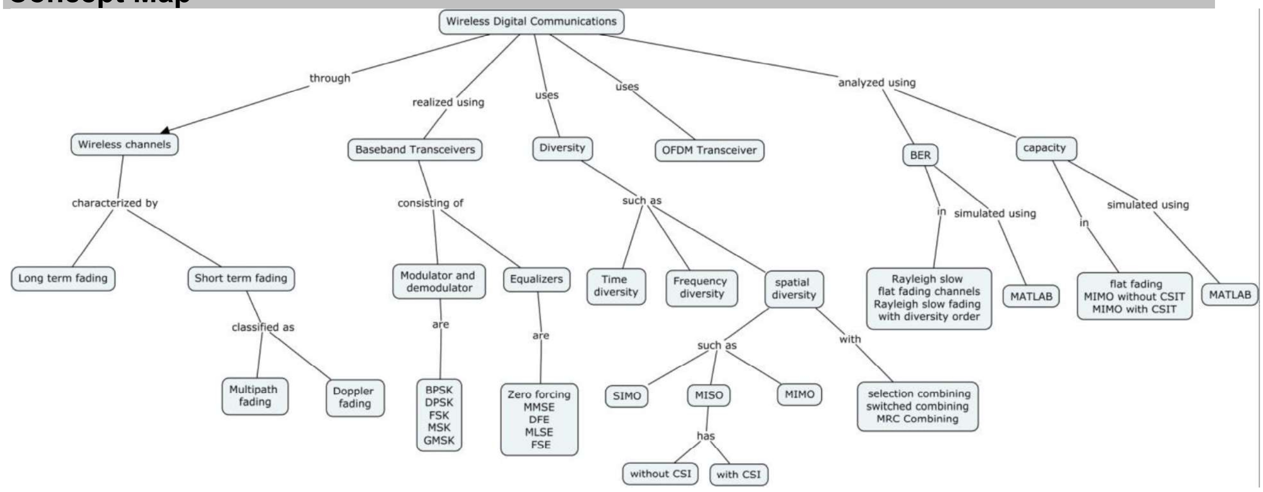
Course Outcome 5 (CO5):

1. Determine the capacity of slow fading channel and prove that the outage probability is $P_{out}(R) = \frac{2^R - 1}{SNR}$ where R is the data rate.
2. Consider a flat fading channel with i.i.d channel gain g[i] which can take on three possible values: 0.05, 0.5 and 1 with probabilities0 .1, 0.5 and 0.4. The transmit power is 10mw, the noise spectral density is $N_o=10^{-9}$W/Hz and the channel bandwidth is 30KHz. Assume the receiver has knowledge of the instantaneous value of g[i] but the transmitter does not. Find the Shannon capacity of this channel.
3. Derive expressions for the following
   a. MIMO Channel Capacity, assuming that CSI known at Transmitter.
   b. MIMO Channel Capacity, assuming that CSI unknown at Transmitter.

Course Outcome 6 (CO6):

1. What is meant by symbol timing offset in OFDM?
2. Prove that the OFDM system converts the delay spread channel into a set of parallel fading channels, using the concept of cyclic prefix.
3. Consider an OFDM system with total passband bandwidth B=1MHz assuming $\beta = \varepsilon = 0$. A Single carrier system would have symbol time $T_s = 1/B = 1\mu s$. The channel has a maximum delay spread of $T_m = 5\mu s$, so with $T_s = 1/B = 1\mu s$ and $T_m = 5\mu s$ there would clearly be severe ISI. Assume an OFDM with MQAM modulation applied to each subchannel. To keep the overhead small, the OFDM system uses N=128 subcarriers to mitigate ISI. So $T_N=NT_s$=128 micro seconds. The length of the cyclic prefix is set to $\mu = 8 > \frac{T_m}{T_s}$ to insure no ISI between OFDM symbols. For these parameters, find the sub channel bandwidth, the total transmission time associated with each OFDM symbol, the overhead of the cyclic prefix and the data rate of the system assuming M=16.

Concept Map



Syllabus

Wireless Channels: Long term fading, Short term fading: Multipath fading, Doppler fading, Tapped delay line model **Baseband Transceivers:** Modulator and demodulator: BPSK,DPSK, FSK,MSK,GMSK **Equalizers:** Maximum Likelihood Sequence Estimator, Zero forcing, Minimum Mean Square Error, Decision Feedback Equalizer, Fractionally spaced Equalizer **Diversity:** Time diversity, Frequency diversity, Spatial Diversity: SIMO,MISO, MIMO, Selection combining, Switched combining, Maximal Ratio Combining - Multiuser **OFDM Transceiver:** Implementation of transceiver over frequency selective channels **Bit Error Rate Analysis:** Rayleigh slow flat fading channels, Rayleigh slow fading with diversity **Capacity Analysis:** SISO Flat fading, MIMO without CSIT, MIMO with CSIT

List of Laboratory Experiments:

1. Simulation of BER performance of PSK in Rayleigh frequency flat, slow fading channels
2. Simulation of BER performance of PSK scheme in Rayleigh frequency flat, slow fading channels with L^{th} order receive diversity.
3. Simulation of BER performance of PSK scheme in Rayleigh frequency flat, slow fading channels with Transmit diversity
4. Simulation of BER performance of PSK scheme in 2x2 spatial multiplexing system in Rayleigh frequency flat, slow fading channels.
5. Simulation of BER performance of OFDM system in Rayleigh frequency selective fading channels
6. Outage capacity analysis of Rayleigh flat fading channel
7. Outage capacity analysis of Rayleigh flat fading channel with L^{th} order diversity

Reference Books

1. Andreas F.Molisch, “Wireless Communications”, Second Edition, John Wiley and sons Limited, 2011.
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. John G. Proakis, “Digital Communications”, McGraw Hill, 2000.

Course Contents and Lecture Schedule

S.No.	Topic	No.of Lectures
1.	**Wireless Channels**	
1.1	Long term fading	1
1.2	Short term fading - Multipath fading, Doppler Fading	1
1.3	Tapped delay line model	1
2	**Baseband Transceivers**	
2.1	Modulator and demodulator: BPSK	1
2.2	DPSK	1
2.3	FSK	1
2.4	MSK	1
2.5	GMSK	1
3	**Equalizers**	
3.1	Maximum Likelihood Sequence Estimator	1
3.2	Zero forcing	1
3.3	Minimum Mean Square Error	1
3.4	Decision Feedback Equalizer	1
3.5	Fractionally spaced Equalizer	1
4	**Diversity**	
4.1	Time diversity and Frequency diversity	1
4.2	Spatial Diversity – SIMO, MISO, Alamouti ST code, MIMO	2
4.3	Selection combining and switched combining	1
4.4	Maximal Ratio Combining	1
5	**OFDM Transceiver**	
5.1	Implementation of transceiver over frequency selective channels	1
7	**Bit Error Rate Analysis**	
7.1	BPSK in Rayleigh slow flat fading channels	1
7.2	BPSK in Rayleigh slow flat fading channels with diversity	1
8	**Capacity Analysis**	
8.1	Flat fading channel	1
8.2	MIMO without CSIT	1
8.3	MIMO with CSIT	1
Total		24

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.

18WT270	WIRELESS NETWORK LABORATORY	Category	L	T	P	Credit
		PC	0	0	4	2

Preamble

The goals of this course are to supplement the theory course '18WT130 Wireless Network Technologies' and to assist the students in obtaining a better understanding of the operation of different protocols in wireless environment by giving hands on programming and lab activities to the students using simulation software.

Prerequisite

NIL

Course Outcomes

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

CO1	Analyze the performance of MAC protocols	Analyze
CO2	Analyze wireless routing protocols for various network scenarios	Analyze
CO3	Analyze the energy management of Wireless Sensor Networks	Analyze
CO4	Design and setup VANET using simulators	Apply
CO5	Design and setup IoT using simulators	Apply
CO6	Design and setup Cognitive Radio Network using simulators	Apply

Mapping with Programme Outcomes

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

S- Strong; M-Medium; L-Low

List of Experiments

8. Modeling and simulating simple networks
    - Creating a Network scenario
    - Configuring nodes and links
    - Modeling Traffic
    - Analyzing Packet and event traces
9. Performance analysis of Wireless Local Area Networks
    - Channel selection and packet collision in WLAN
    - Capacity estimate of WLAN
    - Analyze the performance of a MANET running CSMA/CA (802.11b) in MAC
    - Analyze the performance of 802.11g as the number of nodes are increased
    - Compare and analyze the performance of a mixed 802.11g/b network
    - CSMA/CA implementation
10. Implementing wired and wireless routing protocols
    - AODV
    - DSDV
    - DSR
11. Simulating a Wireless Sensor Network
    - Analyze the performance of energy management clustering techniques
    - Implement different routing protocols to select the network path with its optimum energy and cost during data transfer
12. Simulating a VANET
    - Implement IEEE 802.11p protocol

- Interface SUMO with simulator

13. Study the working behaviour of IoT using Network Simulator
    - Creating network scenario
    - Implementing RPL protocol in IoT
14. Simulating Cognitive Radio Network
    - Creating network scenario with primary and secondary nodes
    - Implementing resource allocation among nodes

Course Designers:

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18WT380/18WT480	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

18WTPA0	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?

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.

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.

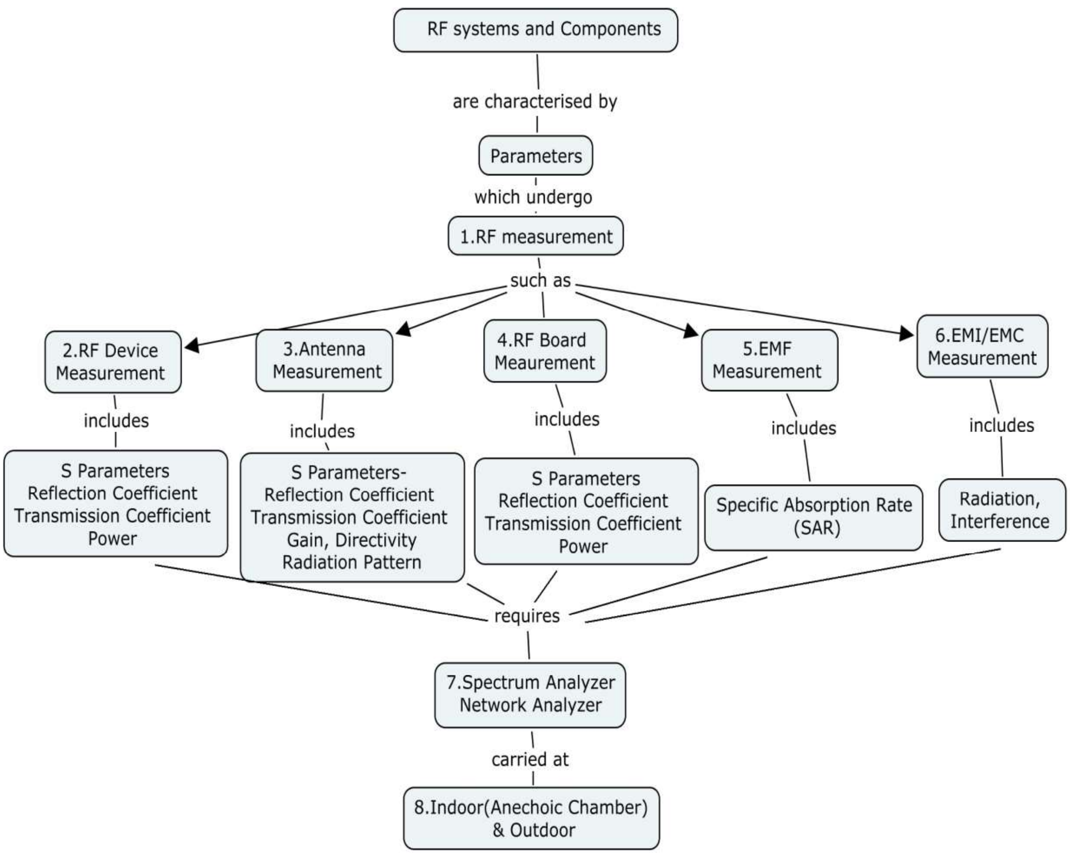
Course Outcome 4 (CO4):

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?
3. 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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18WTPB0	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

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 ofthe 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).
2. Design the DM filter using the following components: Two capacitors ($0.2\mu H$ each with a selfresonant frequency of 5 MHz) and one inductor ($5\mu F$ 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.

3. 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?

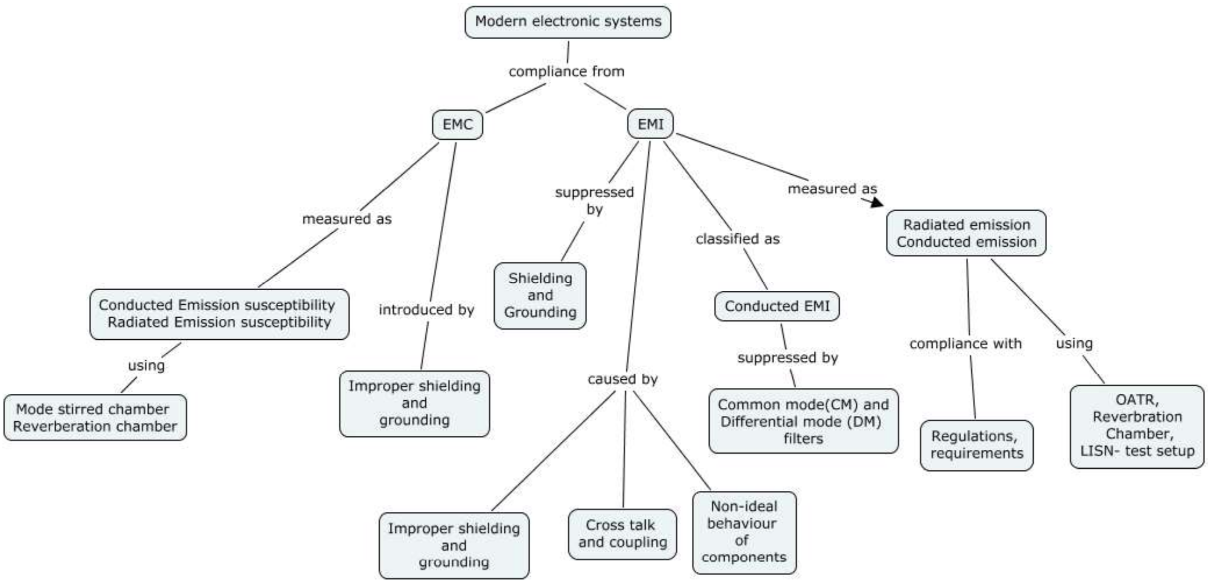
Frequency in MHz	Electric Field Limit at 10 m in dB µV/m
30-230	30
230-1000	37

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 emission, conducted emission	2
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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18WTPC0	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, $t_d = 1500\,A^0$.

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.

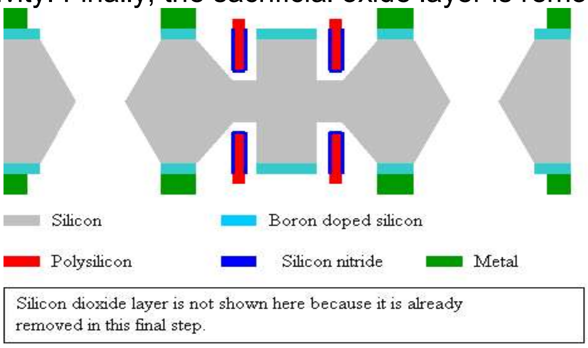
Course Outcome 7 (CO7):

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.

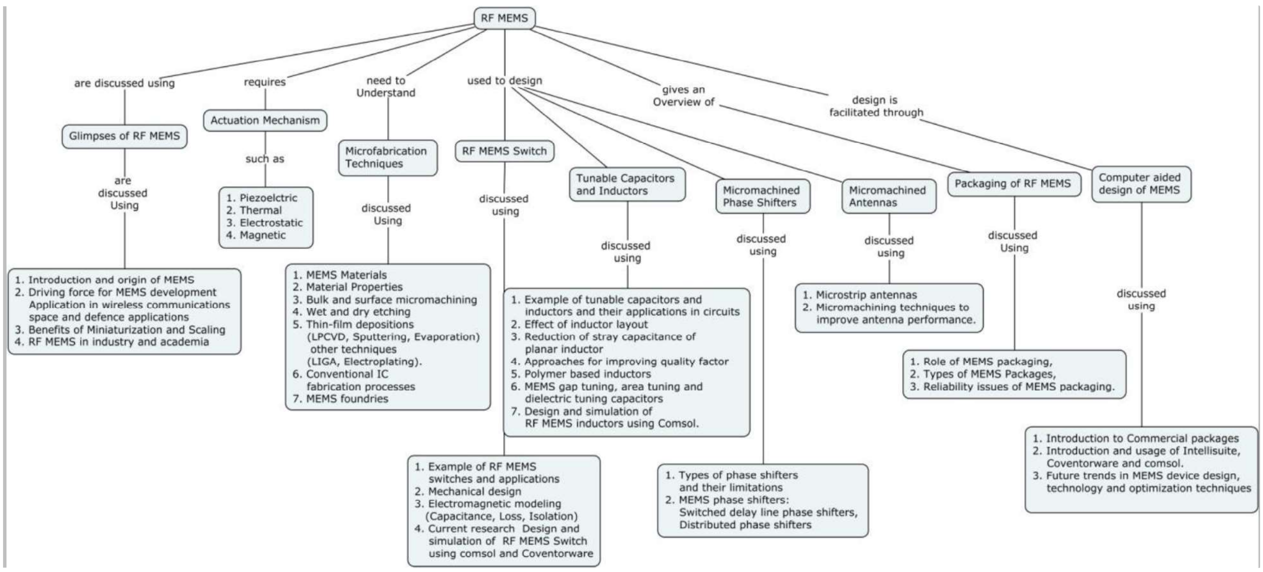
   In order to microfabricate a micromachined accelerometer, combinations of bulk and surface micromachining techniques are used. The process has seven masks and involves double-sided processing utilizing silicon dioxide as a sacrificial layer. The device structure is defined by anisotropic etching at the 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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18WTPD0	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 oscillators	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

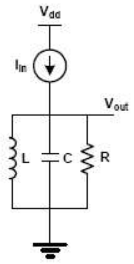
Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	20	0	0	0
Apply	80	80	60	60
Analyse	0	20	40	40
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Give any one expression for Q and state its units.

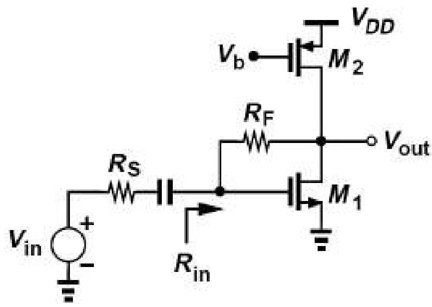
2. List out the various circuit level parameters used in RFIC.
3. Determine the quality factor of the tank with respect to R, C, and L.



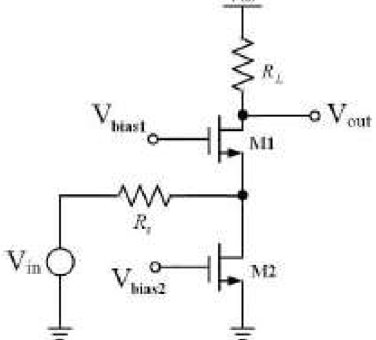
Course Outcome 2 (CO2):
1. Distinguish between a heterodyne receiver and homodyne receiver.
2. Define: ACPR.
3. Mention few packages available for RFICs

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



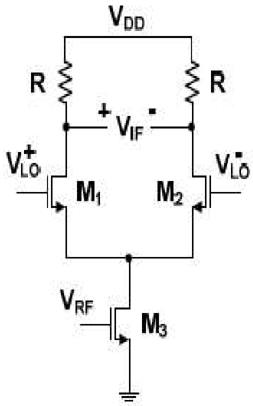
   a. Determine the input impedance (R_{in}) of the LNA.
   b. Calculate the voltage gain of the LNA (i.e.V_{out} / V_{in}) after matching if R_F = 25R_s.
   c. Derive an expression for the output noise of the LNA contributed by R_s after matching. Assume $R_F \geq R_s$.
3. Consider the wideband common-gate 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.

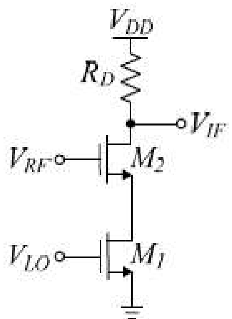
Course Outcome 5 (CO5):

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 .



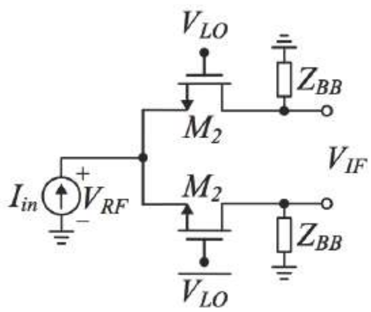
   (a) Derive an expression for the conversion gain of this mixer.
   (b) Derive an expression for the noise figure of this mixer. Assume the switching transistors do not generate noise. The total noise is contributed by transistor M3, load resistors R and source resistor R_s connected to the RF input (is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



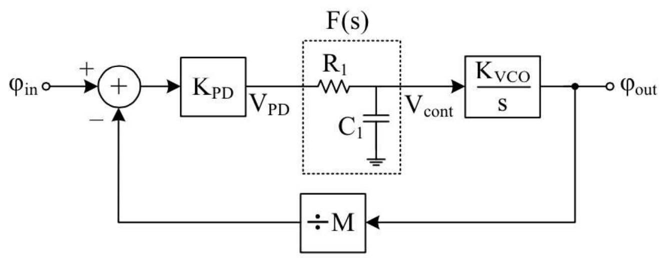
   (a) Assume that *M*1 is an ideal switch. Determine all the frequency components which appear at the mixer IF port.
   (b) Assume when *M*1 is on, it has an on-resistance of *R*on1. Compute the voltage conversion gain of the circuit. Assume *M*2 does not enter the triode region and denote its transconductance 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).

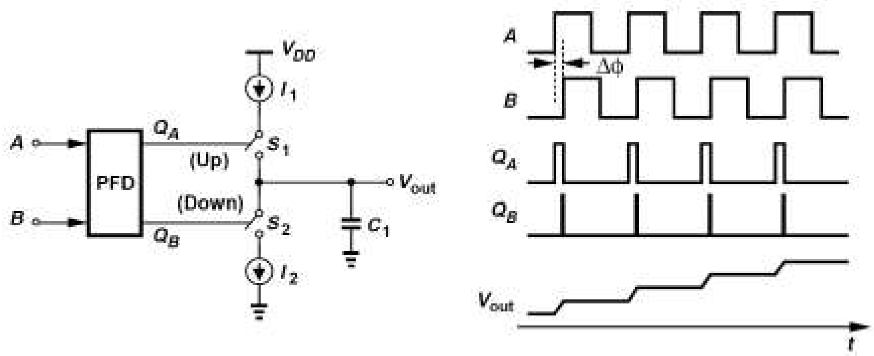


Course Outcome 6 (CO6):

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.



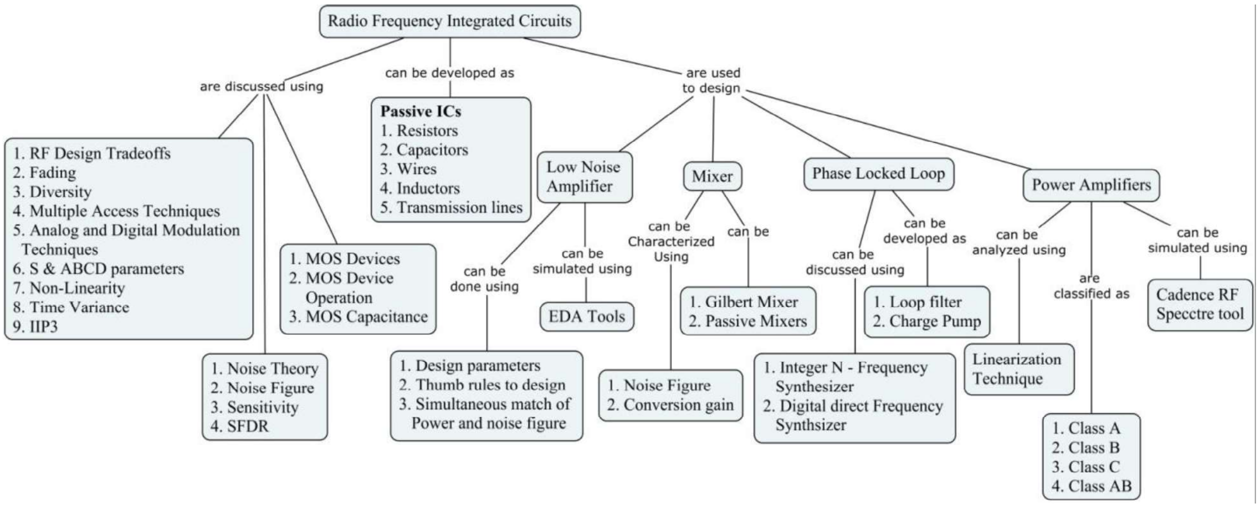
Course Outcome 7 (CO7):

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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18WTPE0	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.

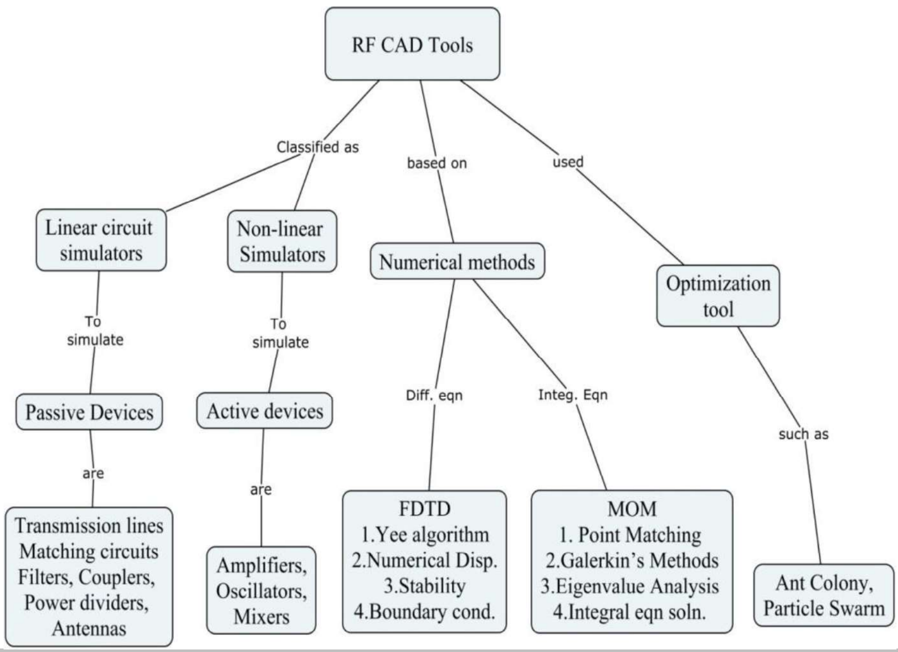
Course Outcome 2 (CO2):
1. Discuss in detail about the process flow of non-linear circuit simulations.
2. Illustrate the different types of time-domain methods used in the EM simulators.
3. Compare the merits and demerits of time- and frequency-domain methods.

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 Δx and Numerical Dispersion, Time Step Δt 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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18WTPF0	MIMO OFDM SYSTEMS

Category	L	T	P	Credit
PE	2	1	0	3

Preamble

High data rate wireless systems with very small symbol periods usually face unacceptable Inter-symbol interference (ISI) originated from multipath propagation and inherent delay spread. Orthogonal frequency division multiplexing (OFDM) is a multicarrier based technique for mitigating ISI to improve capacity in the wireless system with spectral efficiency. On the other hand, MIMO systems have rising attention of the wireless academic community and industry because their promise to increase the capacity and performance with acceptable bit error rate (BER) proportionally with the number of antennas. MIMO OFDM is an attractive air interface solution for next generation wireless local area networks and wireless metropolitan area networks and fourth generation mobile cellular wireless systems.

Prerequisite

18WT260 Wireless Digital Communications

Course Outcomes

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

CO1.	Describe the concept of MIMO OFDM Wireless Communication System.	Understand
CO2.	Determine impulse response coefficients from the power delay profiles of the SISO, SIMO, MISO and MIMO channels.	Apply
CO3.	Determine the capacity and bit error rate of MIMO OFDM system for a given power delay profile of the MIMO channel.	Apply
CO4.	Estimate the MIMO channel impulse response using least square , MMSE and robust MMSE estimation algorithms.	Analyze
CO5.	Estimate and correct the frequency offset and timing offset in the signal received at the MIMO OFDM receiver.	Analyze
CO6.	Analyze the performance of MIMO OFDM physical channel in WiMAX /LTE wireless standards.	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO8.	M	L	-	-	-	-	-	-	-	-	-
CO9.	S	M	L	L	-	-	-	-	-	-	-
CO10.	S	M	L	L	L	-	-	L	-	-	-
CO11.	S	S	M	L	L	-	-	-	-	-	-
CO12.	S	S	M	L	L	-	-	-	-	-	-
CO13.	S	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	40
Analyse	0	20	20	40
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Define Doppler spread.
2. Draw the block diagram of OFDM communication system.

3. Write the signal model for OFDM system with 2 transmit antennas and two receiving antennas.

Course Outcome 2 (CO2):

1. Explain the meaning of following
   a. The channel is frequency non selective
   b. The channel is frequency selective
   c. The channel is slowly fading
2. A scattering function for a fading channel is given by S(τ, λ) = 1 if 0 ≤ τ ≤ 50 μs and |λ| < 5 Hz, and it is zero otherwise.
   a. What is the multipath intensity profile of the channel? What is its Doppler power spectrum?
   b. What are the multipath delay spread, Doppler spread, coherence time and coherence bandwidth of the channel?
   c. Can we design a digital communication system such that this channel can be viewed as a slow frequency flat fading channel? If so, what should the symbol period be selected as?
3. Consider a deterministic MIMO channel (with AWGN) described by

$$H = \begin{bmatrix} j & 1-j & 1 & -0.5 \\ -0.3 & 0.4+0.1j & 1-j & j \\ 0.2j & 0 & -0.5+0.5j & 1 \\ 1 & -j & 1 & 1 \\ -j & 0.6+0.5j & 2 & -1 \end{bmatrix}$$

   Using the singular value decomposition, determine the equivalent representation with parallel channels.

Course Outcome 3 (CO3):

1. Consider a fixed physical environment and a corresponding flat fading MIMO channel. Now, suppose we double the transmit power constraint and the bandwidth. Argue that the capacity of the MIMO channel with receiver CSI exactly doubles. This scaling is consistent with that in the single antenna AWGN channel.
2. Design a MIMO-OFDM system that achieves an overall rate of 3 Mbps over a bandwidth of 200 kHz. Assume that Nt = 2, multipath spread Tm = 1 ms and Doppler spread BD = 10 Hz. Specify the OFDM symbol duration, the number of subcarriers, the length of cyclic prefix, and the modulation scheme used.
3. Assume that two-branch diversity with BPSK modulation is used to transmit digital data. The received signals through the two diversity branches are given by,

$$y_i = \sqrt{\rho}h_i x + n_i \quad i = 1,2$$

   where y_i is the received signal, x is the transmitted signal (where $x = \pm$ with equal probability), and n_i is a zero mean (white) Gaussian noise with variance 1/2. Assume that the joint probability mass function of h_1 and h_2 is given by,

$$p_{h_1,h_2}(h_1,h_2) = \begin{cases} 0.1 & if \; h_1 = h_2 = 1, \\ 0.1 & if \; h_1 = 1, h_2 = 2, \\ 0.1 & if \; h_1 = 2, h_2 = 1, \\ 0.7 & if \; h_1 = 2, h_2 = 2 \end{cases}$$

   a. What is the probability of bit error if maximal ratio combining is used at the receiver?
   b. What is the probability of bit error if selection combining is used?

Course Outcome 4 (CO4):

1. Distinguish between block type and comb type pilot structures used for channel estimation.
2. In which systems, channel reciprocity becomes useful information.
3. Estimate the channel coefficients using LS estimator in MIMO OFDM system in Rayleigh frequency selective fading channel.
4. Derive MMSE estimator for determining channel coefficients in MIMO OFDM system.

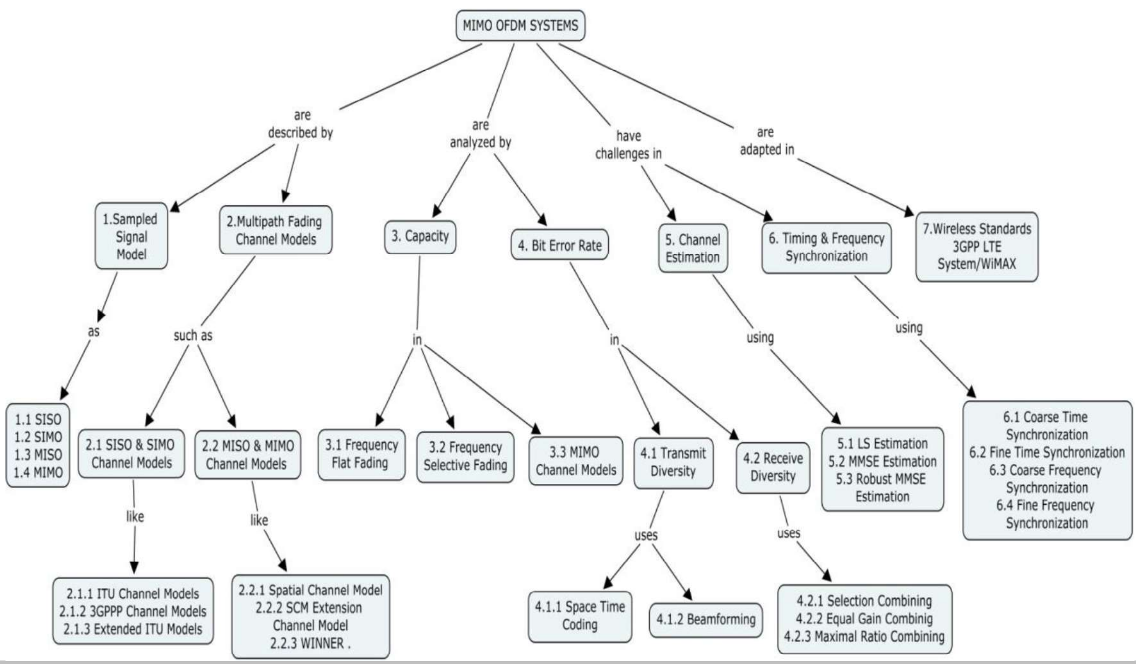
Course Outcome 5 (CO5):

1. List the two major deleterious effects caused by frequency offset in OFDM system.
2. How are the repetitive symbols used in estimating the symbol timing offset in OFDM System?
3. In OFDM system, carrier frequency offset is caused by Doppler shift. Analyse the effects of OFDM symbol in the following cases
   i. Integer Carrier Frequency Offset
   ii. Fractional Carrier Frequency Offset

Course Outcome 6 (CO6):

1. List the physical signals and physical channels in LTE downlink.
2. Consider a multicarrier LTE system with a total pass band bandwidth of 10MHz. Suppose the system operates in a city with channel delay spread Tm=20μs.How many sub channels are needed to obtain approximately flat-fading in each sub channel?
3. Consider a downlink LTE system with two antenna ports in eNodeB and one antenna in UE. The eNodeB uses transmit diversity scheme
   a. Derive an optimal receiver structure for this case
   b. Analyse the error performance

Concept Map



Syllabus

Sampled Signal Model: Signal model for SISO, SIMO , MISO and MIMO **Multipath Fading Channel Models**: ITU Channel Models, 3GPPP Channel Models , Extended ITU Models, Spatial Channel Model , SCM Extension Channel Model, WINNER Channel Model **Capacity Analysis:** Capacity in Frequency Flat Fading channel , Capacity in Frequency Selective Fading Channel **Bit Error Rate Analysis:** BER Analysis for Space Time Coding, Transmit Beamforming , Receiver Selection Combining, Receiver Equal Combining, Receiver Maximal Ratio Combining **Channel Estimation :** LS Estimation, MMSE Estimation, Robust MMSE Estimation **Timing & Frequency Synchronization :** Coarse Time Synchronization, Fine Time Synchronization, Coarse Frequency Synchronization, Fine Frequency Synchronization **Wireless Standards:** 3GPP LTE System, WiMAX

Reference Books

1. Paulraj, R. Nabar and D Gore, "Introduction to Space-Time Wireless Communications", Cambridge University Press, 2003.
2. David Tse and Pramod Viswanath, "Fundamentals of Wireless Communications", Cambridge University Press, 2005 (First Asian Edition, 2006)
3. Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, " MIMO OFDM Wireless Communications with Matlab" John Wiley & sons(Asia) pte Ltd, 2010
4. Lajos Hanzo, Yosef (Jos) Akhtman Li Wang, Ming Jiang "MIMO-OFDM for LTE, Wi-Fi and WiMAX ", John Wiley & Sons Ltd, 2011
5. Tolga M. Duman, Ali Ghrayeb "Coding for MIMO Communication Systems" John Wiley & Sons Ltd, 2007,
6. Ezio Biglieri, Robert Calderbank, Anthony Constantinides, Andrea Goldsmith, Arogyaswami Paulraj, "MIMO Wireless communications" Cambridge University press, 2007

Course Contents and Lecture Schedule

S No.	Topic	No. of Lectures/Tutorial
1	**Sampled Signal Model**	
1.1	Signal model for SISO, SIMO	1
1.2	Signal model for MISO, MIMO	2
2	**Multipath Fading Channel Models**	
2.1	SISO & SIMO Channel Models - ITU Channel Models	1
2.2	3GPPP Channel Models, Extended ITU Models	2
2.3	MISO & MIMO Channel Models – Spatial Channel Model, SCM Extension Channel Model	2
2.4	WINNER Channel Model	1
3	**Capacity Analysis**	
3.1	Capacity in Frequency Flat Fading channel	2
3.2	Capacity in Frequency Selective Fading channel	2
4	**Bit Error Rate Analysis**	
4.1	BER Analysis for Space Time Coding, Transmit Beamforming	3
4.2	Receiver Selection Combining, Receiver Equal Combining	2
	Receiver Maximal Ratio Combining	2
5	**Channel Estimation**	
5.1	LS Estimation	2
5.2	MMSE Estimation	2
5.3	Robust MMSE Estimation	2
6	**Timing & Frequency Synchronization**	
6.1	Coarse Time Synchronization,	2
6.2	Fine Time Synchronization	1
6.3	Coarse Frequency Synchronization,	2
6.4	Fine Frequency Synchronization	1
7	**Wireless Standards**	
7.1	3GPP LTE System	2
7.2	WiMAX	2
	Total	36

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18WTPG0	MILLIMETER WAVE COMMUNICATIONS	Category	L	T	P	Credit
		PE	2	1	0	3

Preamble

The objective of this course to provide a solid foundation in mmWave fundamentals, including channel propagation, communication theory and array of antennas. Due to the huge availability of spectrum in 30-100 GHz bands, millimeter wave communication will be the next frontier in wireless technology. Mm-wave communications systems promise to alleviate the spectrum crunch and be a major part of future WLAN as well as cellular systems. This course includes a systematic overview of the foundations and key developments of emerging millimeter wave wireless communications.

Prerequisite

18WT260 Wireless Digital Communications (TCP)

Course Outcomes

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

CO1. Describe the characteristics of mmWave and determine the large scale and small scale effects of mmWave propagation channel.	Understand
CO2. Determine the strong reflection path through beam steering/ beamforming algorithms in mmWave communication system.	Apply
CO3. Apply suitable digital modulation technique that improves the performance of mmWave communication system.	Apply
CO4. Analyze the available diversity schemes to improve the performance of mmWave communication system.	Analyze
CO5. Compare the performance of single carrier frequency domain equalizer with OFDM technology for ISI mitigation.	Analyze
CO6. Describe the mmWave physical layer IEEE standard 802.15.3c	Understand

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	M	-	-	-	-	-	-	-	-	-	-
CO2.	S	M	-	-	-	-	-	-	-	-	-
CO3.	S	M	L	L	M	-	-	-	-	-	-
CO4.	S	S	M	L	L	-	-	-	-	-	-
CO5.	S	S	M	L	L	-	-	-	-	-	-
CO6.	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	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. Describe the propagation characteristics and channel performance of millimetre waves.
2. Describe the outdoor and indoor channel models for mmWave communication system.
3. List the applications of millimeter wave communication.

Course Outcome 2 (CO2):

1. Write the difference between HDR link and LDR link.
2. Mention the beam steering algorithm to realize spatial diversity, whereby several pairs of sharp-beam antennas from the transmitter and the receiver are used to build up several independent wireless paths.
3. Apply suitable beamforming algorithm to improve the performance mmWave communication system.

Course Outcome 3 (CO3):

1. Derive the probability of error expression for OOK modulation technique.
2. Explain modulator and demodulator of DQPSK technique.
3. Analyze the performance of spatial modulation applied to millimeter wave communication.

Course Outcome 4 (CO4):

1. Explain the potential effects of MIMO mmWave communication.
2. Anlayze performance of mmWave communication in terms of achievable diversity gain and reduced power consumption with spatial diversity, frequency diversity and combination of both.
3. Anlayze performance of mmWave communication in terms of achievable diversity gain and reduced power consumption with spatial diversity, time diversity and combination of both.

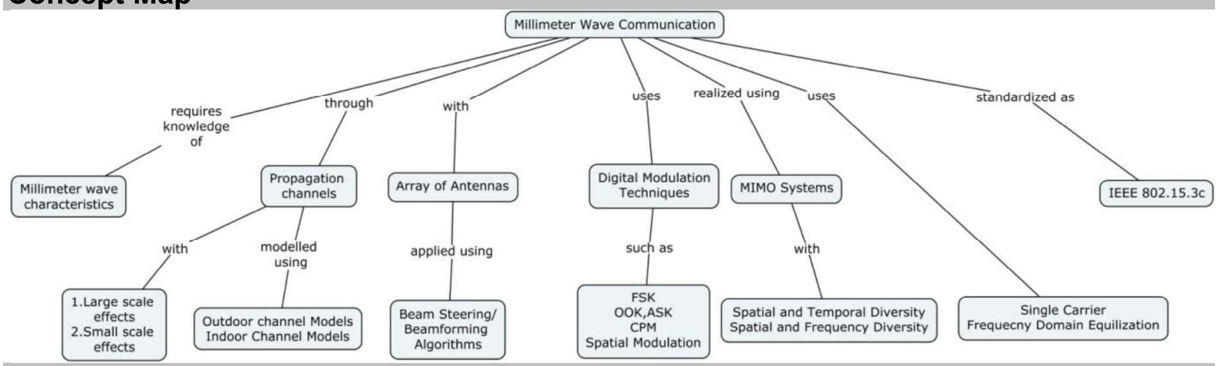
Course Outcome 5 (CO5):

1. Write the advantages of using SC-FDE for mmWave Communication systems.
2. Derive the adaptive channel estimation algorithm for mmWave Communication system that uses SC-FDE.
3. Analyze the performance of SC-FDE in mitigating ISI with OFDM technology.

Course Outcome 6 (CO6)

1. List the four physical modes supported by IEEE802.15.3c.
2. Draw block schematic of physical layer of IEEE 802.15.3c
3. Derive the bit error rate of $\pi/2$ QPSK modulation technique supported by IEEE 802.15.3c.

Concept Map



Syllabus

Introduction: Millimeter Wave Characteristics – Channel Performance at 60 GHz **Radio Wave Propagation for Mm Wave:** Large – Scale Propagation Channel effects – Log-distance path loss models, Small –Scale channel effects, Spatial Characterization of Multipath and Beam Combining, Angle Spread and Multipath Angle of Arrival, Outdoor Channel Models, Indoor channel models. **Array of Antennas:** The Need for Beam-Steering/Beam-Forming, Advanced Beam Steering Technology, Advanced Antenna ID Technology, Beam Forming Technology. **mmWave Digital Modulation Techniques:** Frequency Shift Keying (FSK), On-Off ,Amplitude Shift Keying (OOK,ASK), Spatial Modulation **mmWave MIMOSystems:** Spatial Diversity of Antenna Arrays, Spatial and

Temporal Diversity, Spatial and Frequency Diversity, Dynamic Spatial, Frequency and Modulation Allocation **Single-Carrier Frequency Domain Equalization:** Advantages of SC-FDE over OFDM for Millimeter Wave Systems, Adaptive Channel Estimation, Frequency Domain Equalization, Decision Feedback Equalization, **mmWave Standardization:** IEEE 802.15.3c.

Reference Books

1. Kao-Cheng Huang, Zhaocheng Wang, "Millimeter Wave Communication Systems", John Wiley & Sons, 2011.
2. Theodore S.Rappaport, Robert W.Heath Jr., Robert C.Danniels, Jaes N. Murdock, "Millimeter Wave Wireless Communications", Prentice Hall Professional's Communications Engineering Emerging Technologies series – Pearson Education, Inc., 2015.
3. Su-Khiong Yong, Pengfei Xia, Alberto valdes-Garcia,"60GHz Technology for Gbps WLAN and WPAN : From Theory to Practice" John Wiley & Sons, 2011

Course Contents and Lecture Schedule

S No.	Topic	No. of Lectures
1	**INTRODUCTION**	
1.1	Millimeter Wave Characteristics	2
1.2	Channel Performance at 60 GHz	1
2	**Radio Wave Propagation for Mm Wave**	
2.1	Large Scale Propagation Channel effects – Log distance path loss models	2
2.2	Small Scale channel effects	2
2.3	Spatial Characterization of Multipath and Beam Combining	1
2.4	Angle Spread and Multipath Angle of Arrival	1
2.5	Outdoor Channel Models	1
2.6	Indoor channel models	1
3	**Array of Antennas**	
3.1	Need for Beam-Steering/Beam-Forming	1
3.2	Beam Steering for mmWave Adaptive Antenna Array	2
3.3	Antenna Array Beamforming Algorithms	2
4	**mmWave Digital Modulation Techniques:**	
4.1	Frequency Shift Keying (FSK)	1
4.2	On-Off ,Amplitude Shift Keying (OOK,ASK)	2
4.3	Spatial Modulation	2
5	**mmWave MIMOSystems:**	
5.1	Spatial Diversity of Antenna Arrays	2
5.2	Spatial and Temporal Diversity	2
5.3	Spatial and Frequency Diversity	2
5.4	Dynamic Spatial, Frequency and Modulation Allocation	1
6	**Single-Carrier Frequency Domain Equalization:**	
6.1	Advantages of SC-FDE over OFDM for Millimeter Wave Systems	1
6.2	Adaptive Channel Estimation	1
6.3	Frequency Domain Equalization	2
6.4	Decision Feedback Equalization	2
7	**mmWave Standardization:**	
7.1	IEEE 802.15.3c	2
	Total	36

Course Designers:

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18WTPH0	5G WIRELESS TECHNOLOGIES	Category	L	T	P	Credit
		PE	2	1	0	3

Preamble

The objective of this course is to present the recent advanced physical layer technologies of wireless communications such as massive MIMO, mmwave communications, relaying and network coding and describe their applications such as machine type communications, device to device communications and coordinated multipoint transmissions.

Prerequisite

18WT260 Wireless Digital Communications

Course Outcomes

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

CO1	Describe the requirements of 5G systems and its applications.	Understand
CO2	Describe the salient features of Millimeter wave communication.	Understand
CO3	Apply suitable pilot sequence and resource allocation method for massive MIMO system.	Apply
CO4	Identify and apply suitable radio access schemes for 5G wireless communication.	Apply
CO5	Analyze the BER performance of wireless communication using relays.	Analyze
CO6	Analyze the capacity performance of wireless communication using relays.	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO 10	PO 11
CO1	S	L	-	-	L	-	-	-	-	-	-
CO2	S	M	L	-	L	-	-	-	-	-	-
CO3	S	M	L	-	-	-	-	-	-	-	-
CO4	S	S	L	-	L	-	-	-	-	-	-
CO5	S	S	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	40	20	10	10
Apply	60	60	60	60
Analyse	0	20	30	30
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Describe the key performance indicators in 5G.
2. Describe the four key system concepts required to provide the efficiency, scalability and versatility to address the wide range of requirements in 5G.
3. Describe the applications of 5G wireless communication.

Course Outcome 2 (CO2):

1. Explore the characteristics of channel encountered by millimetre wave communication system.
2. Explain the MIMO architecture for mmWave communications.
3. Explain the method of single user hybrid precoding with switches.

Course Outcome 3 (CO3):

1. Derive the capacity of uplink and downlink multiuser MIMO system.
2. Apply pilot power control method to mitigate pilot contamination in massive MIMO systems.
3. Formulate the resource allocation problem of a massive MIMO system using optimization framework.

Course Outcome 4 (CO4):

1. An FDMA system using frequency modulation accommodates a total of N=100 mobile users assigned to a particular cell. The largest frequency component of the speech signal is W=3.4kHz. Using Carson's rule, determine the bandwidth of the uplink and downlink of the system for each the following deviations: a)D=1 b)D=2 c)D=3
2. Describe the filter bank multicarrier for massive MIMO systems.
3. Compare the capacity regions of different multiple access schemes for the uplink and downlink massive MIMO system.

Course Outcome 5 (CO5):

1. Explain the concept of PLNC based bidirectional relay network.
2. Derive the expression for multivariate Gaussian distribution.
3. Suppose $\mathbf{X}$ is four- variate Gaussian with $\mu_X = \begin{bmatrix} 2 \\ 1 \\ 2 \\ 1 \end{bmatrix}$ and $\Sigma_{\mathbf{X}} = \begin{bmatrix} 6 & 2 & 1 & 3 \\ 2 & 4 & 2 & 3 \\ 1 & 2 & 1 & 2 \\ 3 & 3 & 2 & 4 \end{bmatrix}$

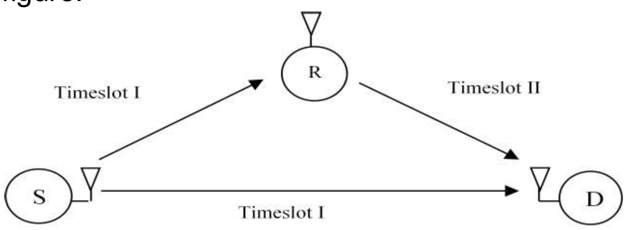
   Let $= \begin{bmatrix} X_1 \\ X_2 \end{bmatrix}$, $\mathbf{X}_2 = \begin{bmatrix} X_3 \\ X_4 \end{bmatrix}$

   a. Find the distribution of $\mathbf{X}_1$.

   b. Find the distribution of $\mathbf{Y} = \begin{bmatrix} 2X_1 \\ X_2 + X_3 \\ X_3 + 2X_4 \end{bmatrix}$

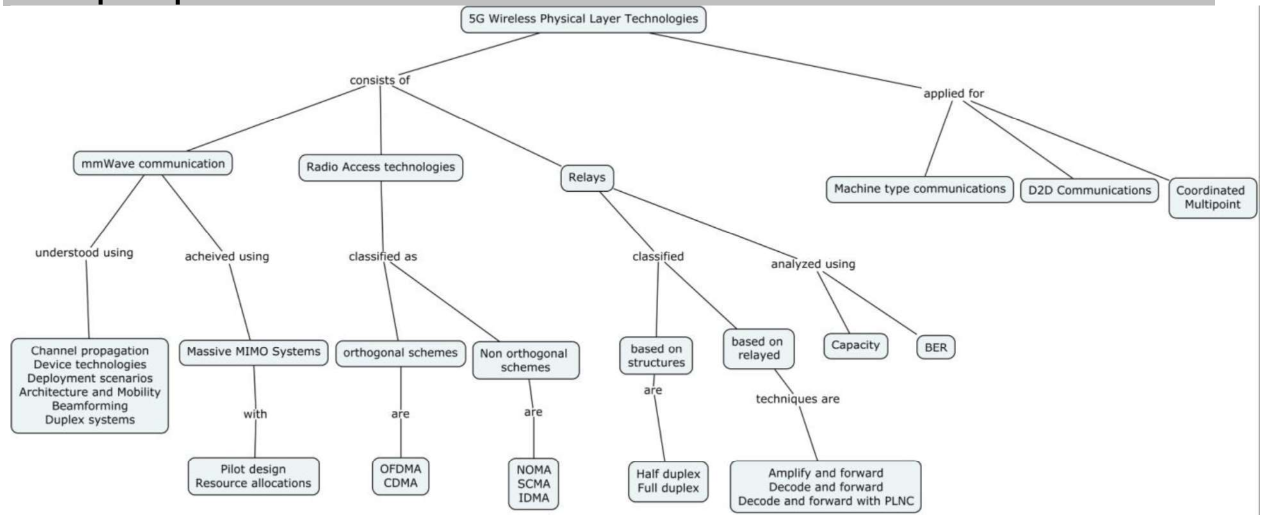
Course Outcome 6 (CO6):

1. Derive the outage capacity for the given amplify and forward relay network as shown in the figure.



2. Derive the outage capacity for a SISO wireless communication system in Rayleigh fading environment.
3. Derive the outage capacity for a PLNC based decode and forward relay network.

Concept Map



Syllabus

Introduction: 5G System Concept **mmWave Communications:** Channel Propagation, Device technologies, Deployment Scenarios, Architecture and mobility, Beamforming, Duplex systems **Massive MIMO:** Theoretical Background, Pilot design, Resource Allocation **Radio Access Technologies:** Orthogonal Schemes: OFDMA and CDMA, Non-orthogonal schemes: NOMA, SCMA and IDMA **Relaying:** Half duplex relaying, Full duplex relaying, Amplify and forward relaying, Decode and forward relaying, Decode and forward relaying with PLNC, BER Analysis, Capacity Analysis **Applications of 5G Physical Layer Technologies:** Machine type communications, D2D communications and Coordinated Multipoint Transmissions

References

1. Afif Osseiran, Jose F . Monserrat and Patrick Marsch, “5G Mobile and Wireless Communications Technology”, Cambridge University Press, 2016.
2. Robert W. Heath Jr., Nuria González-Prelcic, Sundeep Rangan, Wonil Roh,and Akbar M. Sayeed,” An Overview of Signal Processing Techniques for Millimeter Wave MIMO Systems” IEEE Journal of Selected Topics in Signal Processing, Vol. 10, No. 3, April 2016
3. MinChul Ju and Il-Min Kim, “Error Performance Analysis of BPSK Modulation in Physical-Layer Network-Coded Bidirectional Relay Networks”, IEEE Transactions on Communications, Vol. 58, No. 10, October 2010.
4. Shengli Zhang, Soung-Chang Liew, Patrick P.Lam, “Physical Layer Network Coding” Mobicom ‘06, Proceeding of the 12th International Conference on Mobile Computing and Networking, pp.358-365, Los Angeles, CA, USA, Sep.23-29,2006.

Course Contents and Lecture Schedule

S. No.	Topic	No.of Lectures
1.	**Introduction**	
1.1	5G System Concept	1
2	**mmWave Communications**	
2.1	Channel Propagation	2
2.2	Device technologies and Deployment Scenarios	1
2.3	Architecture and mobility	1
2.4	Beamforming	2
2.5	Duplex systems	1
3	**Massive MIMO**	
3.1	Theoretical Background	1

3.2	Pilot Design	2
3.3	Resource Allocation	2
4	**Radio Access Technologies**	
4.1	Orthogonal Frequency Division Multiple Access (OFDMA)	2
4.2	Code Division Multiple Access (CDMA)	1
4.3	Non-orthogonal multiple access (NOMA)	2
4.4	Sparse code multiple access (SCMA)	1
4.5	Interleave division multiple access (IDMA)	1
5	**Relaying**	
5.1	Half duplex relaying	1
5.2	Full duplex relaying	2
5.3	Amplify and forward relaying	2
5.4	Decode and forward relaying	2
5.5	Decode and forward relaying with PLNC	2
5.6	BER Analysis	2
5.7	Capacity Analysis	2
6	**Applications of 5G Physical Layer Technologies**	
6.1	Machine type communications	1
6.2	D2D communications	1
6.3	Coordinated Multipoint Transmissions	1
Total		36

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18WTPJ0	COGNITIVE RADIO COMMUNICATIONS	Category	L	T	P	Credit
		PE	2	1	0	3

Preamble

This course highlights the central role of cognitive radio in wireless communications. The course presents a comprehensive overview of wireless communication theory involved in designing/implementing cognitive radio systems.

Prerequisite

18WT260 Wireless Digital Communications

Course Outcomes

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

CO1. Describe the cognitive radio approach for better utilization of spectrum resources.	Understand
CO2. Investigate the constraints and properties of digital communication system for cognitive radio.	Apply
CO3. Apply various detection algorithms to detect the presence of primary users.	Apply
CO4. Apply spectrum sharing techniques to achieve simultaneous usage of radio frequency band in a specific geographical area.	Apply
CO5. Analyze the performance of the cooperative communication in cognitive radio	Analyze
CO6. Analyze the performance of cognitive radio in 5G wireless technologies	Analyze

Mapping with Programme Outcomes

Cos	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1.	S	L	-	-	-	-	-	-	-	-	-
CO2.	S	M	M	-	-	-	-	-	-	-	-
CO3.	S	M	M	-	-	-	-	-	-	-	-
CO4.	S	M	M	-	-	-	-	-	-	-	-
CO5.	S	S	M	M	L	-	-	M	M	M	-
CO6.	S	S	M	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	20	10	10
Apply	80	50	60	60
Analyse	0	30	30	30
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Is spectrum scarce or plentiful? Explain your answer.
2. What is TV white space? Why has it become so important in the context of cognitive radio systems?
3. What are the three ways of cognitively determining the availability of spectrum for use by a cognitive radio system? What are the advantages and disadvantages of each approach?

Course Outcome 2 (CO2):

1. Suppose a primary user is using 4-QAM with *d*2min= 0.1 J and a center frequency at *f*. The noise spectral density *N*0 is measured to be 1 mW/Hz. If a secondary user comes in and the combined spectral density of noise and the secondary user at *f* increases to 3 mW/Hz, what is the increase in upper bound of the probability of error of the primary user in terms of decibels?
2. Plot the capacity of an additive white Gaussian noise channel with a bandwidth of *W* = 3000 Hz as a function of *P/N*0 for values of *P/N*0 between −20 dB and 30 dB. Plot the capacity of an additive white Gaussian noise channel with *P/N*0 = 25 dB as a function of *W*. In particular, what is the channel capacity when *W* increases indefinitely?
3. An analog signal is sampled, quantized, and encoded into a binary PCM wave. The number of representation levels used is 128. A synchronizing pulse is added at the end of each code word representing a sample of the analog signal. The resulting PCM wave is transmitted over a channel of bandwidth 12 kHz using a quaternary PAM system with raised cosine spectrum. The roll-off factor is unity.
    a. Find the rate (b/s) at which information is transmitted through the channel.
    b. Find the rate at which the analog signal is sampled. What is the maximum possible value for the highest frequency component of the analog signal?

Course Outcome 3 (CO3):

1. Suppose that the signal vector is zero-mean Gaussian but has time-varying variance given by $\sigma_s^2(n)$. Simplify the LLR to show that the optimal detector is a weighted energy detector.
2. Consider the detection problem.
   $$H_0: \; x(n) = w(n), \quad n = 0,1,...N-1$$
   $$H_1: \; x(n) = A + w(n), \quad n = 0,1,...N-1$$
   where $w(n)$ is zero mean, white, wide sense stationary Gaussian random variables with variance σ^2.
    a. Obtain the decision rule to determine which hypothesis is true.
    b. Derive expressions for Probability of false alarm P_{FA} and Probability of detection P_D. If $P_{FA} = 10^{-4}$, Determine P_D.
3. Suppose that the signal vector $\mathbf{s} = \left[s(1), s(2), ..., s(N)\right]^T$ has covariance matrix $\sum_s$. Use the eigenvalue decomposition of $\sum_s = V\Lambda_s V^T$ and simplify the LLF. Show that the LLF can be interpreted as a two-step process: the signal is pre-whitened by projecting it onto the eigenvector matrix V^T; the resulting output is passed through a weighted energy detector, $\tilde{z} = \sum_{n=1}^{N} w(n)\left|\tilde{y}(n)\right|^2$ where $\tilde{\mathbf{y}} = \mathbf{V}^T\mathbf{y}$

Course Outcome 4 (CO4):

1. Providing one example of each, compare the licensed and unlicensed spectrum sharing approaches. What are the main advantages and disadvantages of each paradigm?
2. A biomedical manufacturing company is developing a health monitoring system (HMS) composed of two parts. The first part is a network of sensors attached to the patient's body; communication among the sensors is done using a propitiatory wireless personal area network (WPAN) technology. The gathered information is then conveyed via a second part, a low-power WLAN installed in the patient's room, itself connected to the Internet via an asynchronous digital subscriber line (ADSL) modem.
    a. Given the high cost of acquiring a licensed band for such a system, the manufacturer is looking at spectrum sharing solutions for both WPAN network connectivity (Case 1), and WPAN to WLAN communications via a WLAN gateway on one of the WPAN sensors (Case 2). Which spectrum sharing approach might best serve the purpose of each case, and why?

3. In the opportunistic spectrum hole approach, assume that the total transmit power for the cognitive MC-CDMA technology is fixed at *P*Total, that *Eb* denotes the transmitted energy per symbol, and without the presence of any primary signal in the channel, and that *S*_ subcarriers are used in the MC-CDMA system. If it is instead assumed that there are *M* primary signals in the channel, what is the amplitude of the up-conversion signal over *S* subchannels necessary for the transmitted cognitive MC-CDMA to successfully operate at the upper limit of its transmission power specification shown in Figure.1. For simplicity, assume that all subchannels have the same bandwidth and transmitted amplitude.

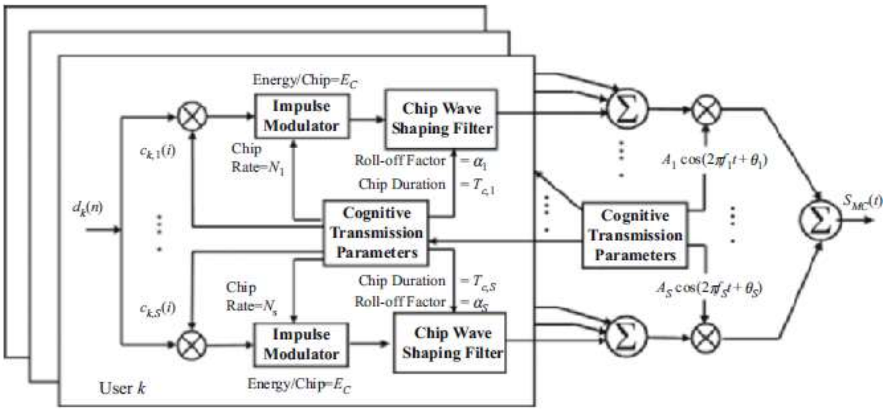


Figure.1

Course Outcome 5 (CO5):

1 List four optimization problems where power and time are allocated to achieve optimum performance. Discuss different scenarios where these optimization problems could be applicable.

2 Show that the best position for the relay in the linear channel of Figure 2. to minimize power consumption is in the middle between the source and the destination.

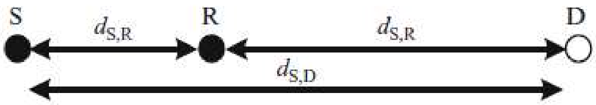


Figure.2

3 What are the three types of spectrum holes? Explain how multihop relaying could be useful for secondary users exploiting a gray hole.

Course Outcome 6 (CO6):

1. Analyze the outage performance of full duplex bidirectional relay system in the presence of eaves dropper as shown in Figure 3.

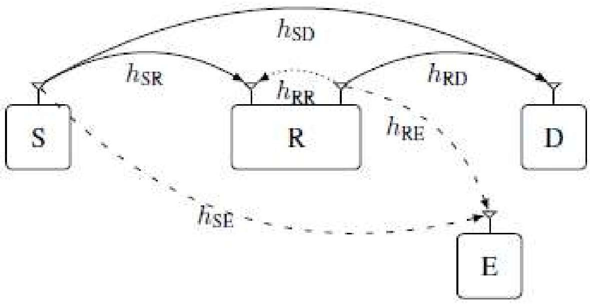
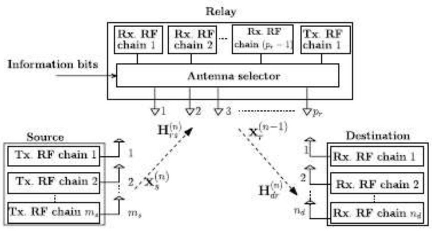
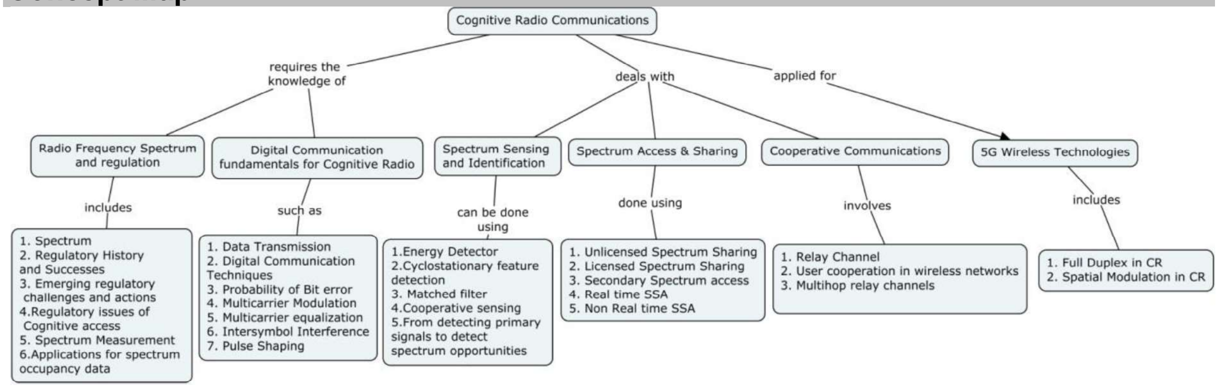


Figure.3

2. Analyze the outage performance of full duplex bidirectional relay system in the absence of eaves dropper as shown in Figure 3.
3. Analyze the outage performance of Spatial modulation in Full duplex relaying shown in Figure 4.



Concept Map



Syllabus

Radio frequency spectrum and regulation: Spectrum: Nature's Communication Highway, Regulatory History and Successes, Emerging Regulatory Challenges and Actions, Regulatory Issues of Cognitive Access, Spectrum Measurements and Usage, Applications for Spectrum Occupancy Data

Digital communication fundamentals for cognitive radio: Data Transmission, Digital Modulation Techniques, Probability of Bit Error, Multicarrier Modulation, Multicarrier Equalization Techniques, Intersymbol Interference, Pulse Shaping

Spectrum sensing and identification: Primary Signal Detection: Energy Detector, Cyclostationary Feature Detector, Matched Filter, Cooperative Sensing, From Detecting Primary Signals to Detecting Spectrum Opportunities

Spectrum access and sharing: Unlicensed Spectrum Sharing, Licensed Spectrum Sharing, Secondary Spectrum Access, Real-Time SSA, Non-Real-Time SSA

Cooperative communications: Introduction: Diversity, user cooperation and cognitive systems, relay channels, user cooperation in wireless networks, multihop relay channels.

5G Wireless Technologies: Performance analysis of Full Duplex relay in Cognitive radio, and Performance of spatial modulation in Cognitive radio.

Reference Books

1. Alexander M.Wyglinski, Maziar Nekovee**,** and Y. Thomas Hou, "Cognitive Radio Communications and Networks Principles and Practice", Elsevier Inc., 2010.
2. Bruce A. Fette, "Cognitive Radio Technology" Elsevier Inc., 2006
3. Hüseyin Arslan, "Cognitive Radio, Software Defined Radio, and adaptive wireless systems", Springer., 2007.

Course Contents and Lecture Schedule

S.No.	Topic	No. of Lectures
1	**Radio frequency spectrum and regulation**	
1.1	Spectrum: Nature's Communication Highway, Regulatory History and Successes,	1
1.2	Emerging Regulatory Challenges and Actions, Regulatory Issues of Cognitive Access	1
1.3	Spectrum Measurements and Usage, Applications for Spectrum Occupancy Data	1

2	**Digital communication fundamentals for cognitive radio**	
2.1	Data Transmission, Digital Modulation Techniques	1
2.2	Probability of Bit Error	2
2.3	Multicarrier Modulation	2
2.4	Multicarrier Equalization Techniques	2
2.5	Intersymbol Interference	1
2.6	Pulse Shaping	1
3	**Spectrum sensing and identification**	
3.1	Primary Signal Detection: Energy Detector	2
3.2	Cyclostationary Feature Detector	1
3.3	Matched Filter	2
3.4	Cooperative Sensing	1
3.5	From Detecting Primary Signals to Detecting Spectrum Opportunities	2
4	**Spectrum access and sharing**	
4.1	Unlicensed Spectrum Sharing	
4.1	Licensed Spectrum Sharing	1
4.1	Secondary Spectrum Access	1
4.2	Real-Time SSA	1
4.3	Non-Real-Time SSA	1
5	**Cooperative communications**	
5.1	Introduction: Diversity, user cooperation and cognitive systems	1
5.2	Relay channels,	1
5.3	User cooperation in wireless networks	2
5.4	Multihop relay channels.	2
6.	**5G Wireless Technologies**	
6.1	Performance analysis of Full Duplex relay in Cognitive radio,	3
6.2	Performance of spatial modulation in Cognitive radio.	3
	Total	36

Course Designers:

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18WTPK0	PHYSICAL LAYER SECURITY

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

The objective of this course concentrates on basic concepts, recent advancements, and open issues in providing communication security at the physical layer. It includes a systematic overview of the foundations and key developments of physical layer security.

Prerequisite

NIL

Course Outcomes

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

CO1	Understand the information theoretic secrecy.	Understand
CO2	Understand the importance of signal processing algorithm for enhanced physical layer security.	Understand
CO3	Determine the secrecy of wireless communication through channel estimation. Generate the security keys from wireless channels with one relay and multiple relays.	Apply
CO4	Determine the achievable secrecy through discussion and jamming in two way Gaussian wiretap channels..	Apply
CO5	Formulate and solve optimization problem of resource allocation in OFDMA networks simultaneously providing secure communications.	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	-	-	-	-	-	-	-
CO4	S	M	M	M	-	L	-	-	-	-	-
CO5	S	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	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. If the transmitter does not have any CSI, both reliability and security need to be assessed in terms of outage. How do you define outage probability?
2. **Derive the secrecy capacity of the Gaussian MIMO WTC System.**
3. Describe the role of CSI in physical layer security.

Course Outcome 2 (CO2):

1. Give the significance of Secret-key generation from channel intrinsic randomness.
2. What is meant by wiretap code? How do you generate secrecy code from it?
3. Draw the channel model for secrecy key generation.

Course Outcome 3 (CO3):

1. Derive the normalized MSE of DCE via multistage feedback and re-training

2. Derive the closed form expression for outage probability for the cooperative jamming scheme when there is an external eavesdropper.
3. For any given targeted data rate R, prove that the outage probability of the achievable secrecy rate for the addressed transmission protocol approaches zero $P\left(\left[I_{2\to1}^{M}-I_{2\to1}^{E}\right]^{+}<R\right)\to 0$ for $K\to\infty$ and $\rho\to\infty$

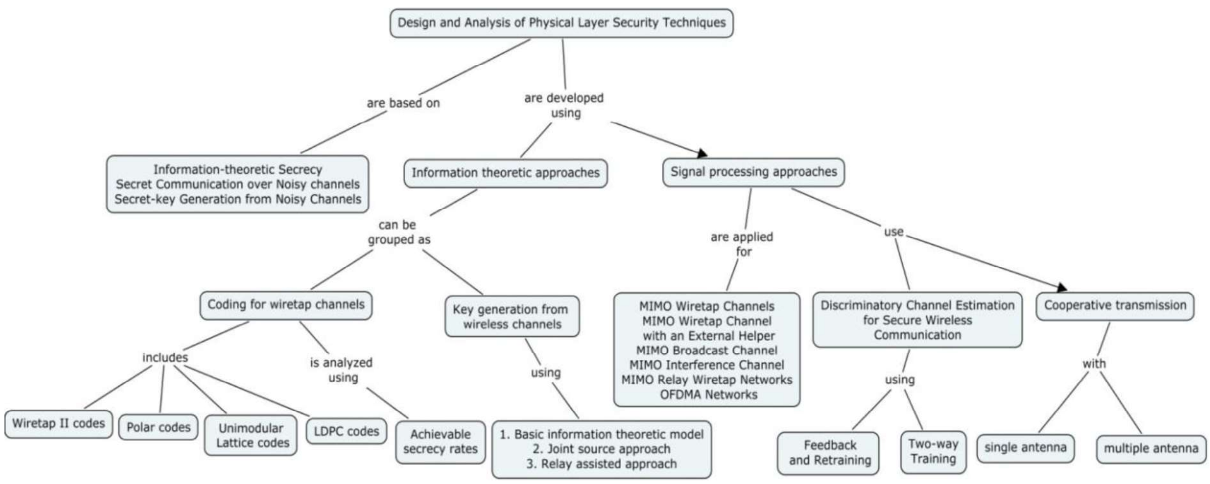
Course Outcome 4 (CO4):

1. Compare the achievable rate in MIMO relay secrecy communication scenario when CSI of eavesdropper is known and when CSI of eaves dropper is not known.
2. Compare the achievable rate in MIMO wiretap channel with and without relay.
3. Explain the role of external helper in improving secrecy in MIMO wiretap channel.

Course Outcome 5 (CO5):

1. Find an optimal power and subcarrier allocation policy to maximize the long-term aggregate information rate of all NUs while maintaining a target average secrecy rate of each individual SU under a total power constraint.
2. Among the training-based approaches for key generation, describe the algorithm that generates a key with the largest possible key rate and prove the optimality of the algorithm.
3. Among the training-based approaches for key generation, describe the algorithm that generates a key with the largest possible key rate and prove the optimality of the algorithm.

Concept Map



Syllabus

Introduction: Information Theoretic Secrecy, Secret communication over noisy channels, secret key generation from noisy channels **Information theoretic approaches** Coding for the wiretap channel II, Wiretap coding with polar codes, Coding for Gaussian wiretap channel, LDPC codes for Gaussian wiretap channel, Security Key Generation from Wireless Channels: Information-theoretic Models for Key Generation, Basic Approaches for Key Generation via Wireless Networks, A Joint Source-Channel Key Agreement Protocol, Relay-assisted Key Generation with a Public Channel **Secrecy with Feedback:** The Gaussian Two-way Wiretap Channel, Achieving Secrecy Using Public Discussion, Achieving Secrecy Using Cooperative Jamming, Achieving Secrecy through Discussion and Jamming **Signal Processing Approaches:** Signal processing aspects of physical layer security, MIMO Wiretap Channel with an External Helper, security in MIMO Broadcast Channel, MIMO Interference Channel, Basic concepts of Discriminatory Channel Estimation, DCE via Feedback and Retraining, Discriminatory Channel Estimation via Two-way Training **Physical Layer Security in OFDMA Networks** Secure OFDM networks, Basics of Resource Allocation for Secret Communication **Cooperative Transmissions to Secrecy**

Communications Cooperative transmission with a Single Antenna, MIMO relay secrecy communications scenario

Reference Books

1. Xiangyun Zhou, Lingyang Song and Yan Zhang, ”Physical Layer Security in Wireless Communications” CRC Press, 2014.
2. R.Liu and W.Trappe, ”Securing Wireless Communications at the Physical Layer”, Springer, 2010.
3. Malthiew Block and Joao Barros, “Physical Layer Security; from information theory to security Engineering” Cambridge University Press, 2011.
4. Wen, Hong, “Physical layer approaches for securing wireless communication systems” Springer 2003.

Course Contents and Lecture Schedule

S.No	Topics	No. of Lectures
1.	**Introduction**	
1.1	Information Theoretic Secrecy	2
1.2	Secret communication over noisy channels	1
1.3	secret key generation from noisy channels	2
2	**Information theoretic approaches**	
2.1	Coding for the wiretap channel II	1
2.2	Wiretap coding with polar codes	1
2.3	Coding for Gaussian wiretap channel	2
2.4	LDPC codes for Gaussian wiretap channel	1
2.5	Information-theoretic Models for Key Generation	1
2.6	Basic Approaches for Key Generation via Wireless Networks	1
2.7	A Joint Source-Channel Key Agreement Protocol	2
2.8	Relay-assisted Key Generation with a Public Channel	2
3	**Secrecy with Feedback**	
3.1	The Gaussian Two-way Wiretap Channel	2
3.2	Achieving Secrecy Using Public Discussion	1
3.3	Achieving Secrecy Using Cooperative Jamming	1
3.4	Achieving Secrecy through Discussion and Jamming	1
4	**Signal Processing Approaches**	
4.1	Signal processing aspects of physical layer security	2
4.2	MIMO Wiretap Channel with an External Helper	1
4.3	security in MIMO Broadcast Channel	1
4.4	MIMO Interference Channel	2
4.5	Basic concepts of Discriminatory Channel Estimation	1
4.2	DCE via Feedback and Retraining	1
4.6	Discriminatory Channel Estimation via Two-way Training	1
5	**Physical Layer Security in OFDMA Networks**	
5.1	Secure OFDM networks	2

5.2	Basics of Resource Allocation for Secret Communication	1
6	**Cooperative Transmissions to Secrecy Communications**	
6.1	Cooperative transmission with a Single Antenna	2
6.2	MIMO relay secrecy communications scenario	1
	Total	36

Course Designers:

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3. Dr.V.N.Senthilkumaran vnsenthilkumaran@tce.edu

18WTPL0	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	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. 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. 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

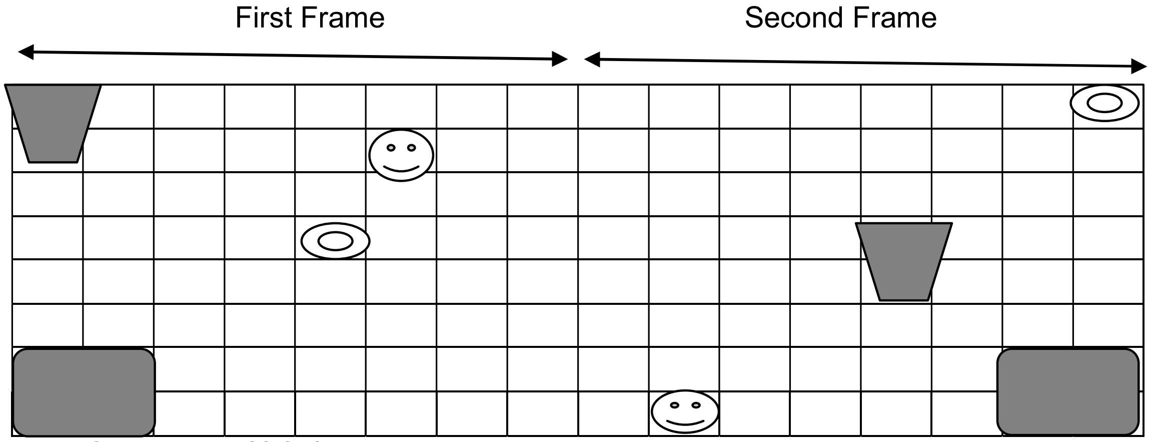
Frame2

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".

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. 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.

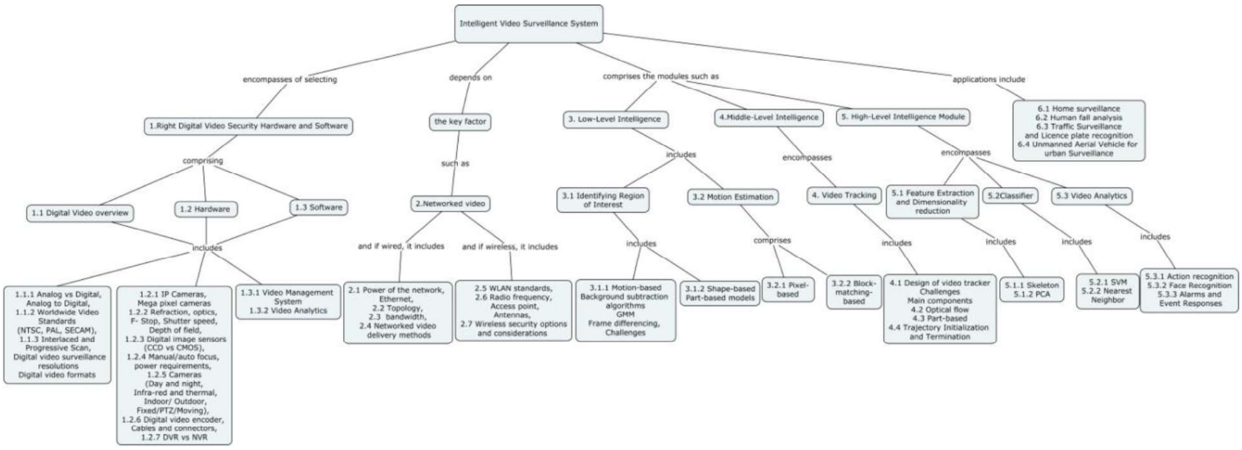
Course Outcome 5 (CO5):

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.

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.

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

1. Anthony C Caputo, "Digital Video Surveillance and security", Second Edition, Elsevier Inc, 2014.
2. Huihuan Qian, Xinyu Wu, Yangsheng Xu, ""Intelligent surveillance System", Springer, 2011.
3. Emilio Maggio and Andrea Cavallaro, "Video Tracking – Theory and Practice", John Wiley and Sons pvt Ltd, 2011.
4. Yunqian Ma, Gang Qian, Intelligent Video Surveillance -Systems and Technology", CRC Press, Taylor and Fracis Group, ISBN: 9781439813287, 2009.
5. Al Bovik, "Essential Guide to Video Processing", Academic Press, ISBN 978-0-12-37445, 2009.
6. 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
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

Module No.	Topic	No. of Lectures
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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18WTPM0	DIGITAL INTEGRATED CIRCUIT DESIGN WITH HDL	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

Digital hardware design in industry is increasingly dependent on Hardware Description Languages (HDLs) for implementing complex digital systems. Many universities have incorporated Hardware Description Language in their curriculum. The course '18WT160: Digital Integrated Circuit Design with HDL' is offered in the first semester of the Post Graduate Programme. This course needs basic knowledge of digital circuits as pre-requisite. This course introduces digital systems design concepts. This course describes the different ways of coding the building blocks of the digital circuits and systems. Further, it also aims at the design and optimization of combinational and sequential logic circuits along with the testing strategies for the digital circuits. At the same time, the concepts and methods of digital system design techniques discussed in the class may be applied through hands on projects. The analysis of the results of logic and timing simulations may be used to debug digital systems.

Prerequisite

Nil

Course Outcomes

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

CO1. Describe Hardware Description Language and FPGA Implementation process flow	Understand
CO2. Design Combinational and sequential building block using HDL	Apply
CO3. Design and analyze synchronous sequential logic circuits for a given specifications	Analyze
CO4 Design and analyze asynchronous sequential logic circuits for a given specifications	Analyze
CO5 Design and Simulation of building blocks for digital systems	Apply
CO6. Apply electronic design automation software to implement combinational and sequential digital systems in PLDs.	Apply

Mapping with Programme Outcomes

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

Assessment Pattern

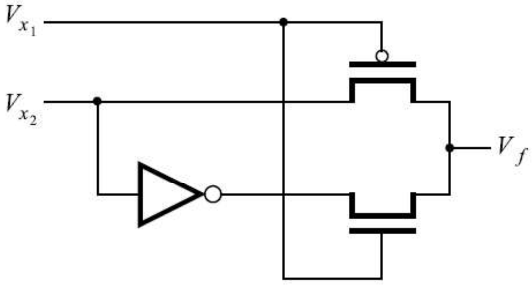
Bloom's Category	Continuous Assessment Tests			End Semester Examination
	1	2	3	
Remember	0	0	0	0
Understand	40	20	20	20
Apply	30	50	40	40
Analyse	30	30	40	40
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Write VHDL code to implement the function *f (x*1*, x*2*, x*3*)* = *m(*0, 1, 3*,* 4*,* 5*,* 6*)*.

2. What logic gate is realized by the circuit given below Does this circuit suffer from any major drawbacks?



3. Define Synthesis in HDL

Course Outcome 2 (CO2):

1. Design an 16-to-1 multiplexer using 4-to-1 multiplexer in VHDL
2. Illustrate conditional signal assignment using priority encoder
3. Write VHDL code for 4-to-16 decoder using generate statement

Course Outcome 3 (CO3):

1. Design a sequential circuit that has two inputs, w1 and w2 and an output z. Its function is to compare the input sequences on the two inputs. If w1=w2 during any four consecutive clock cycles, the circuit produces z=1; otherwise, z=0.
2. Design a three-bit counter like circuit controlled by the input w. If w=1, then the counter adds 2 to its contents, wrapping around if the count reaches 8 or 9. If w=1 then the counter subtracts 1 from its contends, acting as a normal down-counter. Use D flip flop in the circuit.
3. Draw the state diagram for an FSM that has an input w and an output z. The machine has to generate z=1 when the previous four values of w were 1001 or 1111; otherwise, z=0. Overlapping input patterns are allowed.

Course Outcome 4 (CO4):

1. Design a control mechanism for Vending machine that accepts nickels and dimes. It dispenses merchandise when 20 cents is deposited; it does not give change if 25 cents is deposited.
2. Design a system controller for the pop machine that will direct the control of the coin receiver, coin changer and pop drop mechanics while dispensing soda pop at 30 Rs per can and making the proper change retrieval for the following coin sequences of 5 and 10.
3. Design and evaluate a full adder circuit expressed having inputs A, B, C by introducing stuck at fault 0 at “B” signal using signature analysis.

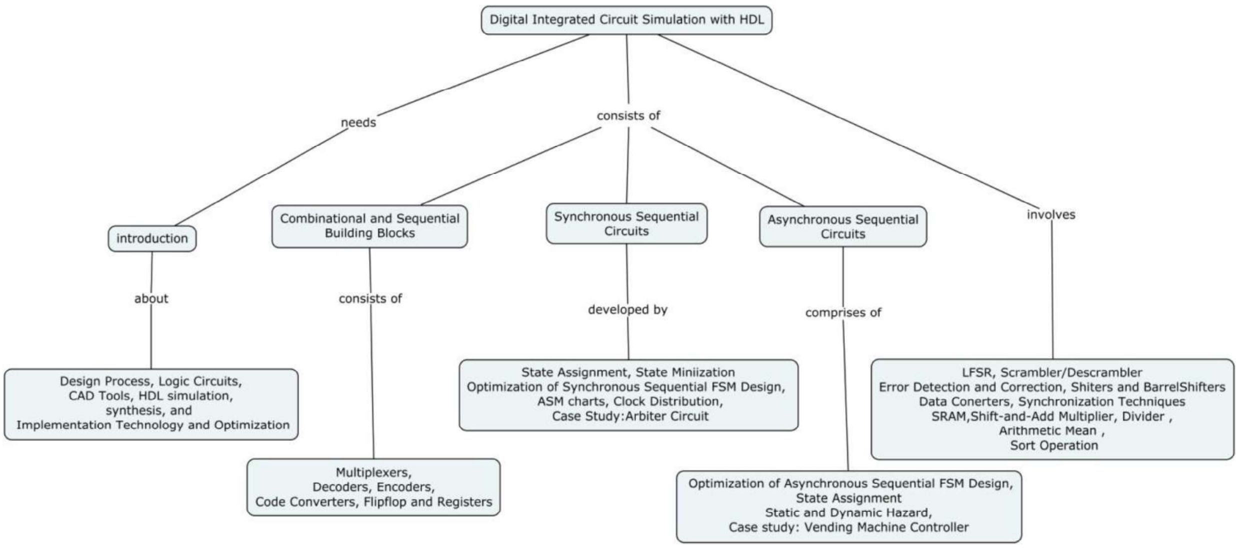
Course Outcome 5 (CO5):

1. Design a circuit that finds the *log*2 of an operand that is stored in an *n*-bit register. Show all steps in the design process and state any assumptions made. Give HDL code that describes your circuit.
2. The circuit gives a shift register in which the parallel-load control input is independent of the enable input. Show a different shift register circuit in which the parallel-load operation can be performed only when the enable input is also asserted.
3. For the *divider* subcircuit, use a shift operation that divides by four, instead of using the divider circuit designed uses an adder to compute the sum of the contents

Course Outcome6 (CO6):

1. Assume that the exclusive –OR gate has propagation delay of 10ns and that the AND or OR gates have a propagation delay of 5ns. Calculate the total propagation delay time of a four-bit carry look ahead adder?
2. Find a hazard free minimum cost implementation of the function
   a. F(x1,...x4)=m(0,4,11,13)+D(2,3,5,10)
3. Show that how the function f(w1,w2,w3)=Σm(1,2,3,4,5,6) can be implemented using 3-8 binary decoder and an OR gate.

Concept Map



Syllabus

Introduction: Design Process, Logic Circuits, CAD Tools, HDL simulation, synthesis, Implementation Technology and Optimization, **Combinational and Sequential Building Blocks:** Multiplexers, Decoders, Encoders, Code Converters, Flip Flops, Registers **Synchronous Sequential Circuits:** State Assignment problem, State Minimization, Optimization of Synchronous Sequential FSM Design, ASM charts, Arbiter Circuit, **Asynchronous Sequential Circuits:** Optimization of Asynchronous Sequential FSM Design, State Assignments, Static and Dynamic Hazard, Case study: Vending Machine Controller, **Digital System Design**- Building Blocks: Linear Feedback Shift Register, Cyclic Redundancy Check, Shifters and Barrel Shifters, Data Converters, Synchronization Techniques, Throughput, Latency, Static Random Access Memory (SRAM) Blocks in PLDs, Shift-and-Add Multiplier, Divider ,Arithmetic Mean , Sort operation.

Reference Books

1. Stephen Brown and Zvonko Vranesic, “Fundamentals of Digital Logic Design with VHDL design”, Tata McGraw hill, Third edition, 2009
2. Kishore Misra, “Advanced Chip Design, Practical Examples in Verilog” ,Create Space Independent Publishing Platform, 2013
3. Ronald Mehler, ”Digital Integrated Circuit Design Using Verilog and SystemVerilog”, Newnes ,2015
4. Michael John Sebastian Smith, “ Application Specific Integrated Circuits”, Addison Wesley, Ninth Indian Reprint, 2004
5. William I. Fletcher, “An Engineering Approach to Digital Design”, EEE, Fourth Indian Reprint, 1996

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**Introduction**	
1.1	Design Process	1
1.2	Logic Circuits & CAD Tools	1
1.3	VHDL Simulation & synthesis	1
1.4	Implementation Technology and Optimisation	1
2	**Combinational and Sequential Building Blocks**	
2.1	Multiplexers &Code Converters	1
2.2	Decoders & Encoders	1

2.3	Flip Flops	1
2.4	Shift Registers	2
3.	**Synchronous Sequential Circuits**	
3.1	State Assignment & State Minimization	2
3.2	Optimization of Synchronous Sequential FSM Design	2
3.3	ASM charts	1
3.4	Case Study: Arbiter Circuit	1
4	**Asynchronous Sequential Circuits**	
4.1	Optimization of Asynchronous Sequential FSM Design	2
4.2	State Assignments	1
4.3	Static and Dynamic Hazard	1
4.4	Case study: Vending Machine Controller	2
5	**Digital System Design**	
5.1	Linear Feed Back Shift Registers	2
5.2	Cyclic Redundancy Check	2
5.3	Shifters and Barrel Shifters	1
5.4	Data Converters	2
5.5	Synchronization Techniques	2
5.6	Throughput & Latency	1
5.7	Static Random Access Memory (SRAM) Blocks in PLDs	1
5.8	Shift-and-Add Multiplier	1
5.9	Divider	1
5.10	Arithmetic Mean , Sort Operation	2

Course Designers:

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18WTPN0	VLSI FOR WIRELESS COMMUNICATION	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

This course aims at studying the design concepts of low noise amplifiers, studying the various types of mixers designed for wireless communication, designing frequency synthesizers, data converters, adaptive filters, equalizers and transceivers. Further, it also aims at understanding the design concepts of CDMA in wireless communication and VLSI architecture for multiuser wireless systems.

Prerequisite

Nil

Course Outcomes

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

CO1	Discuss the front end and filters inside receiver architecture	Apply
CO2	Design of Low noise amplifiers, AGC amplifiers and power amplifiers	Apply
CO3	Design and study of Active mixers for wireless communication	Analyze
CO4	Design and study of Passive mixers for wireless communication	Analyze
CO5	Design of Frequency synthesizers	Apply
CO6	Design of sub-components such as data converters, filters and equalizers	Apply

Mapping with Programme Outcomes

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

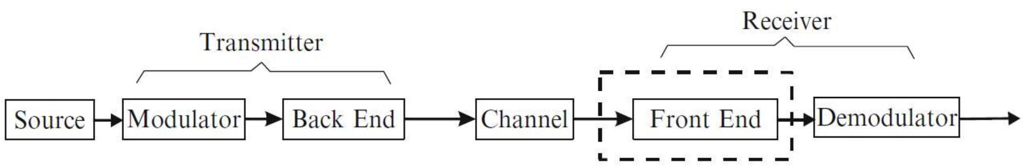
Assessment Pattern

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

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Calculate the SNR at the input of the demodulator shown in figure below. Assume no front end is used and the only AWGN in the channel comes from a 50 ohms input resistance.



2. Assume that we use a fixed intermediate frequency 10 MHz and a variable local oscillator frequency. Draw the frequency spectrum, including all relevant frequencies, when received signal frequency is 894 and 824 MHz. Repeat the case for fixed intermediate frequency of 100 MHz. Also determine the image frequency.

3. Assume that we use a variable intermediate frequency and a fixed local oscillator frequency. Again, draw the spectrum when received signal frequency is 894 and 824 MHz. Repeat the case for local oscillator frequency of 850 MHz. Also determine the image frequency.

Course Outcome 2 (CO2):

1. Identify the type of feedback of the differential wideband LNA shown in figure Figure CO2.1.

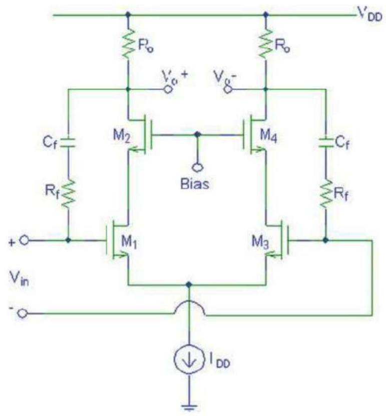


Figure CO2.1

2. Develop the single-ended portion only of this circuit shown in Figure CO2.1, without feedback elements R_f , C_f
3. Implement the narrowband LNA in Figure CO2.3 using another active device to replace M_1 . This active device's small-signal representation should have a voltage controlled voltage source.

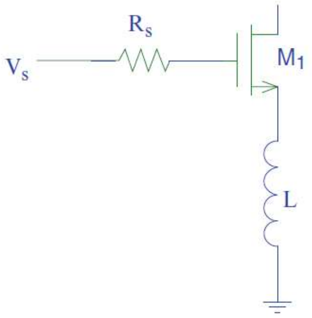


Figure CO2.3

Course Outcome 3 (CO):

1. Show mathematically that the mixer output current shown in Figure CO3.1 is balanced and does not contain any RF feedthrough.

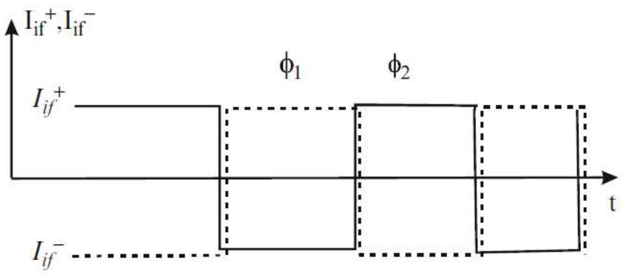


Figure CO3.1

2. A Gilbert mixer operates under the following condition: Vov = 0.387 V, A_{rf} = $A_{interference}$ = 0.316 V. Assuming that the LO is not switching, find the mixer's distortion behavior: HD_3 , IM_3 , IIP_3.
3. Consider a Gilbert mixer with IIP_3 = 5 dBm, Power = 10 mW, V_{DD} = 3.3 V, K' = 100 μA/V^2. Assume that LO is not switching. Calculate W/L.

Course Outcome 4 (CO4):

1. Compare the differences between the unbalance switching mixer and switching mixer with IF amplifier.

2. Draw the conversion gain model for the unbalanced switching mixer and derive the expression for conversion gain.
3. Consider design parameter R = 50 Ω, V_{ov} = 4V, L = 1 µm, K' = 100µA/V^2 , C_{db} is assume to be a linear capacitor with C_{jsw} = 0 and Cj = 2 fF/ µm^2 , with its area = W x drain height. Assume drain height = 6 µm. Design a mixer to operate at f_{rf} = 1.9 GHz with third order intercept point IIP_3 of +35dBm using low frequency analysis.

Course Outcome 5 (CO5):

1. Consider the divider circuit given in Figure CO.5.1. Draw the waveform along the signal path at different nodes for MC =0 to show the divider action. Also calculate the total division ratio.

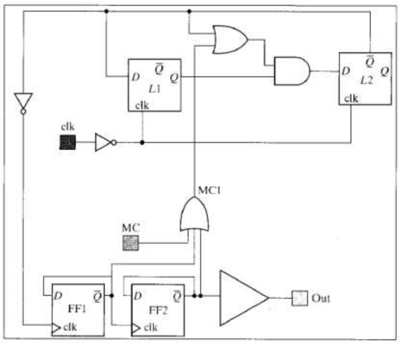


Figure CO 5.1

2. Consider the Colpitts oscillator circuit given in Figure CO 5.2 having a BJT biased at I_C=1 mA, R_L=2KΩ, C_1= 5.26 pF(with Q=100). Calculate the value of C_2 and L to operate at ω_0=1.9 X10^9 rad/S.

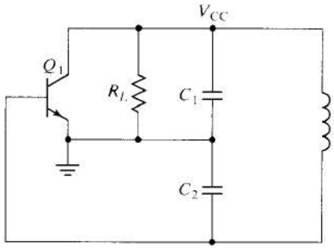


Figure CO 5.2

3. Determine the range of frequency generated for a change in control voltage Vc= 0.1 V to 1 V for the VCO shown in Figure CO 5.3.

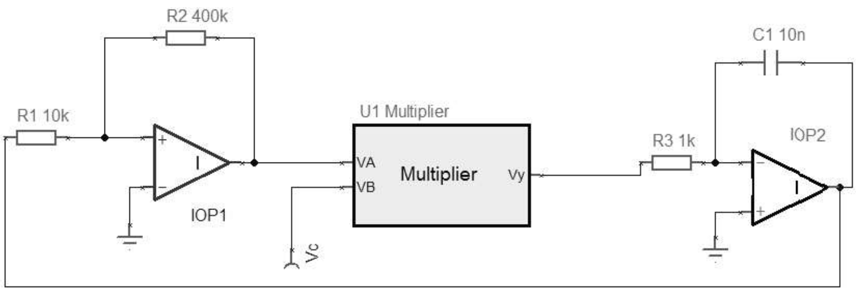


Figure CO 5.3

Course Outcome 6 (CO6):

1. Investigate the time domain response of a sigma delta modulator of a first-order sigma-delta modulator with a 2-bit internal quantizer. Assume that the input V_{in} consists of a ramp that goes from 0 to Full Scale voltage in 50 clock cycles (assume Full Scale voltage = 1 V). Plot V_{out} for these 50 clock cycles.
2. Investigate the time domain response of a sigma delta modulator of a second-order sigma-delta modulator with a 1-bit internal quantizer. Assume that the input V_{in} consists of a ramp that goes from 0 to Full Scale voltage in 50 clock cycles (assume Full Scale voltage = 1 V). Plot V_{out} for these 50 clock cycles.
3. Find the signal transfer function (STF) and noise transfer function (NTF) of a modified second-order sigma-delta modulator. This modulator has a loop filter in the forward and feedback path (shown in Figure CO5.2). Note that X(z) is the input and Y(z) is the output.

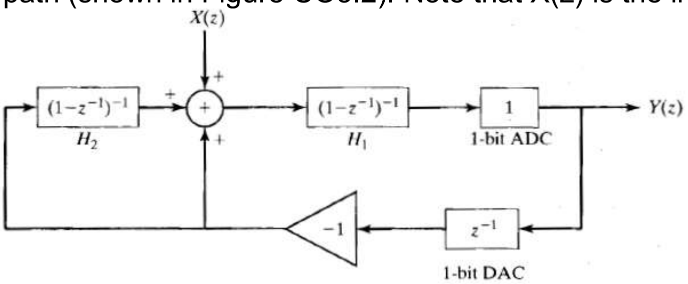
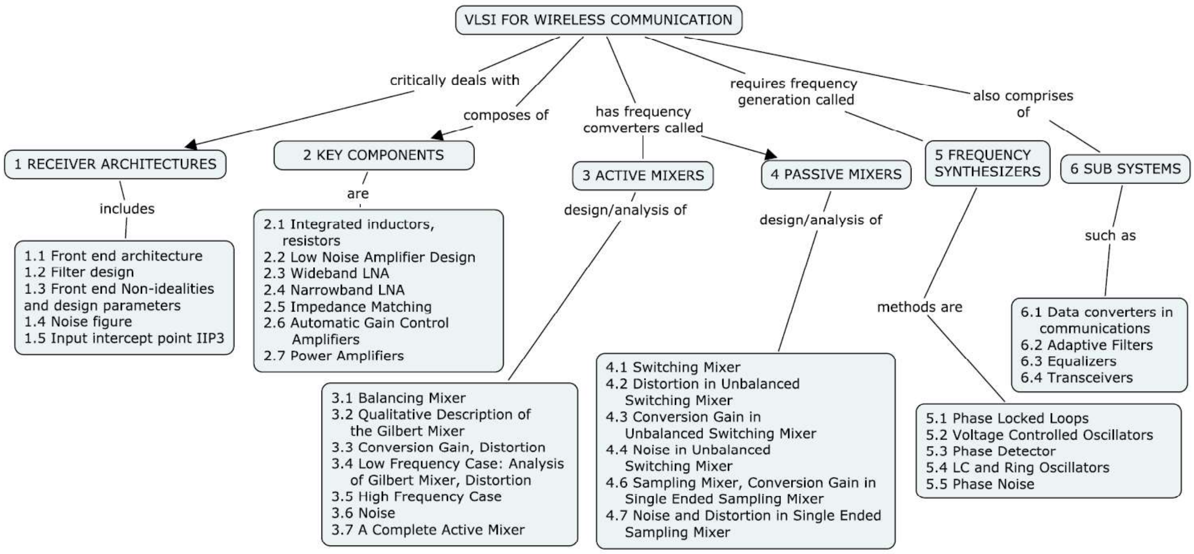


Figure CO5.2

Concept Map



Syllabus

RECEIVER ARCHITECTURES: Front end architecture, Filter design, Front end Non-idealities and design parameters, Noise figure, Input intercept point IIP3. **KEY COMPONENTS**: Integrated inductors, resistors, Low Noise Amplifier Design, Wideband LNA, Design Narrowband LNA, Impedance Matching, Automatic Gain Control Amplifiers, Power Amplifiers. **ACTIVE MIXERS**: Balancing Mixer, Qualitative Description of the Gilbert Mixer, Conversion Gain, Distortion , Low Frequency Case: Analysis of Gilbert Mixer, Distortion, High Frequency Case, Noise, A Complete Active Mixer. **PASSIVE MIXERS**: Switching Mixer, Distortion in Unbalanced Switching Mixer, Conversion Gain in Unbalanced Switching Mixer, Noise in Unbalanced Switching Mixer, Sampling Mixer, Conversion Gain in Single Ended Sampling Mixer, Noise and Distortion in Single Ended Sampling Mixer. **FREQUENCY SYNTHESIZERS**: Phase Locked Loops, Voltage Controlled Oscillators, Phase Detector, Frequency Dividers, LC and Ring Oscillators, Phase Noise. **SUB SYSTEMS**: Data converters in communications, adaptive Filters, equalizers and transceivers.

Reference Books

1. B.Razavi ,"RF Microelectronics" , Prentice-Hall ,1998.
2. Bosco H Leung "VLSI for Wireless Communication", Pearson Education, 2002.
3. Thomas H.Lee, "The Design of CMOS Radio –Frequency Integrated Circuits', Cambridge University Press ,2003.
4. Emad N Farag and Mohamed I Elmasry, "Mixed Signal VLSI Wireless Design - Circuits and Systems", Kluwer Academic Publishers, 2000.
5. Phillip E.Allen, Douglas R.Holberg, "CMOS Analog Circuit Design", Third edition, Oxford University Press, 2011.
6. Behzad Razavi, "Design of Analog CMOS Integrated Circuits" McGraw-Hill, 1999.
7. J. Crols and M. Steyaert, "CMOS Wireless Transceiver Design," Boston, Kluwer Academic Publication, 1997.

Course Contents and Lecture Schedule

No.	Topic	No. of Lectures
1	**RECEIVER ARCHITECTURES**	
1.1	Front end architecture	1
1.2	Filter design	1
1.3	Front end Non-idealities and design parameters	1
1.4	Noise figure	1
1.5	Input intercept point IIP3	1
2	**KEY COMPONENTS**	
2.1	Integrated inductors, resistors	1
2.2	Low Noise Amplifier Design	2
2.3	Wideband LNA	1
2.4	Narrowband LNA	1
2.5	Impedance Matching	1
2.6	Automatic Gain Control Amplifiers	1
2.7	Power Amplifiers	1
3	**ACTIVE MIXERS**	
3.1	Balancing Mixer	1
3.2	Qualitative Description of the Gilbert Mixer	1
3.3	Conversion Gain, Distortion	1
3.4	Low Frequency Case: Analysis of Gilbert Mixer, Distortion	1
3.5	High Frequency Case	1
3.6	Noise	1
3.7	A Complete Active Mixer	1
4	**PASSIVE MIXERS**	
4.1	Switching Mixer	1
4.2	Distortion in Unbalanced Switching Mixer	1
4.3	Conversion Gain in Unbalanced Switching Mixer	1
4.4	Noise in Unbalanced Switching Mixer	1
4.6	Sampling Mixer, Conversion Gain in Single Ended Sampling Mixer	1
4.7	Noise and Distortion in Single Ended Sampling Mixer	1
5	**FREQUENCY SYNTHESIZERS**	
5.1	Phase Locked Loops	1
5.2	Voltage Controlled Oscillators	1
5.3	Phase Detector	1
5.4	LC and Ring Oscillators	1
5.5	Phase Noise	1
6	**SUB SYSTEMS**	

6.1	Data converters in communications	2
6.2	Adaptive Filters	1
6.3	Equalizers	1
6.4	Transceivers	1
	Total Hours	36

Course Designers:

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18WTPP0	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?

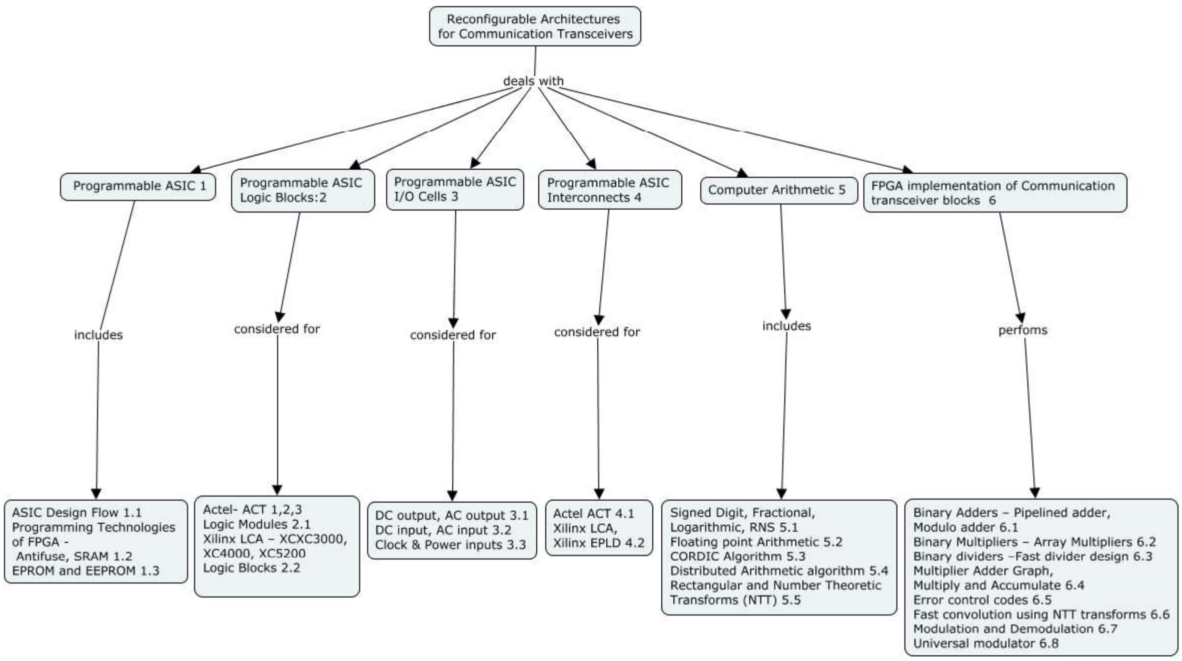
Course Outcome 4 (CO4):

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:

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18WTPQ0	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. Explain the challenges in building IOT.
3. How the functions of IOT are classified in various domain specific?

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.

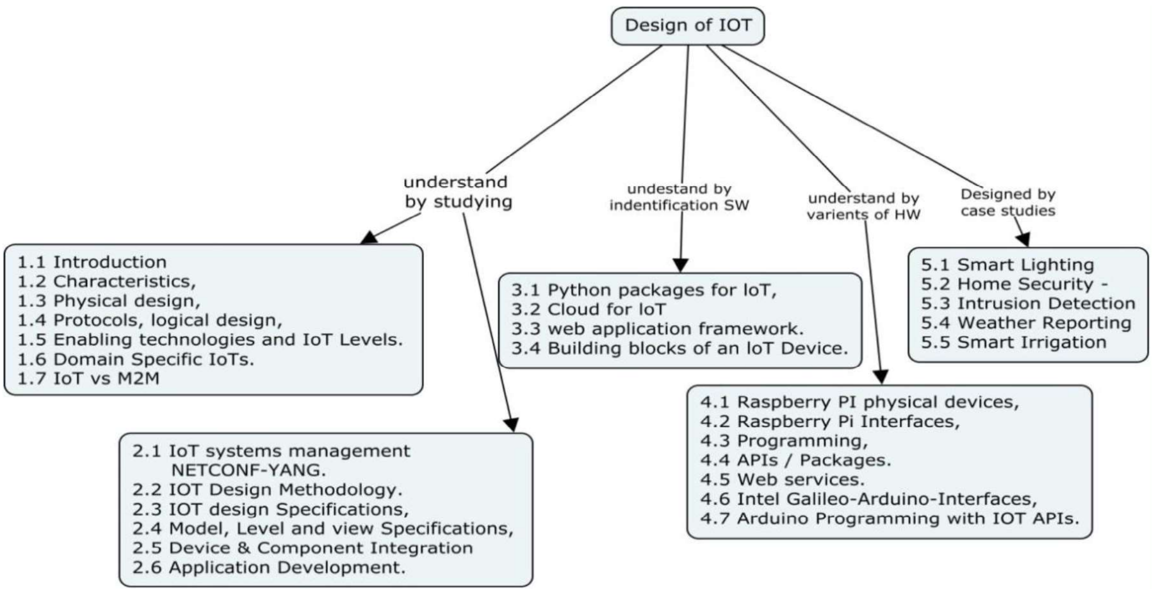
Course Outcome 3 (CO3):
1. Demonstrate the layers of an IoT framwork.
2. Demonstrate the use of sensor in an IoT.
3. Show and illustrate the components in the framework of IoT

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

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. Examine the developed software frame work for IoT physical design for the specific domain in terms of execution speed.
3. Investigate the embedded the software into the hardware with various API use in given scenario

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 hardware to implement an 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

Reference Books

1. ARM University Program – Learning material on Internet 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", Arshdeep Bahga, Vijay Madisetti, Universities Press, 2015
4. Peter Waher "Learning Internet of Things", Packt Publishing, UK, 2015.

5. Miguel de Sousa", Internet of Things with Intel Galileo" ",Packt Publishing, UK, 2015.
6. Marco Schwartz, "Internet of Things with the Arduino", Packt Publishing, 2014
7. Adrian McEwen, Hakim Cassimally "Designing the Internet of Things", Wiley Publishing, 2015

Course Designer:

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

18WTPR0	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?

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.

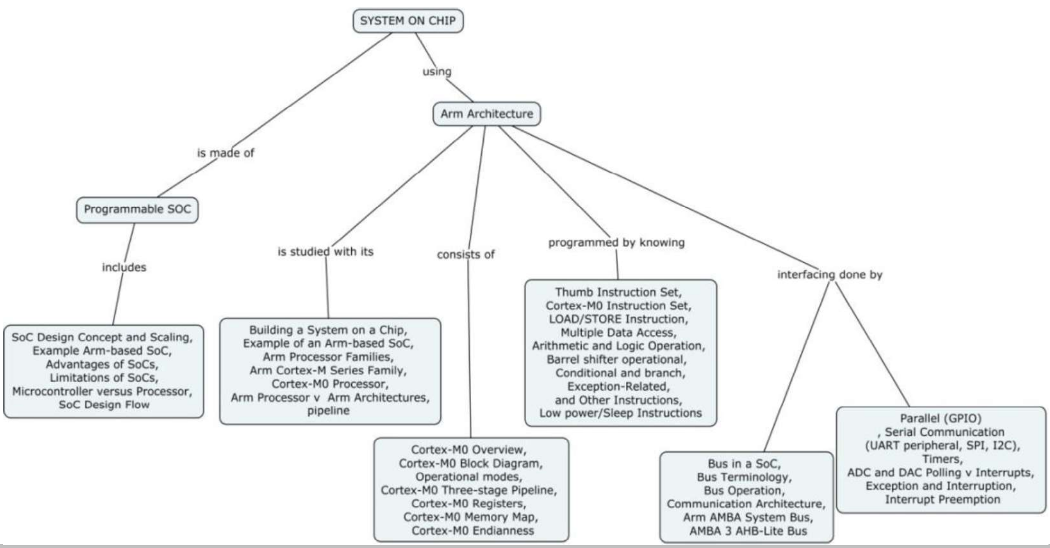
Course Outcome 3 (CO3):
1. Demonstrate the ARM architecture feature.
2. Demonstrate the use of ARM thumb instructions.
3. Show and illustrate the functional components in the ARM core

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

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

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 instructions, 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 Designer:

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

18WTPS0	OPTICAL WIRELESS COMMUNICATION	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

The future 5G networks will be heterogeneous, hosting a variety of technologies and devices. Inevitable heterogeneity of such networks motivates to consider optical wireless communications (OWC) as a promising technology to coexist with the already matured RF wireless systems. This course addresses the system model, channel modelling, modulation techniques and performance analysis of indoor/outdoor optical wireless communication.

Prerequisite

NIL

Course Outcomes

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

CO1	Comprehend the need for optical wireless communication systems with applications.	Understand
CO2	Apply suitable indoor/outdoor channel modelling algorithms to implement efficient optical wireless systems.	Apply
CO3	Compare the impact of different analog and digital modulation schemes on the performance of indoor/outdoor optical wireless systems	Analyze
CO4	Analyze the performance of indoor and outdoor optical wireless system with atmospheric turbulence.	Analyze
CO5	Apply suitable channel model and modulation techniques to enhance the performance of visible light communication system	Apply
CO6	Analyze an optical wireless communication Link using power budget/rise time budget.	Analyze

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	L	L	L	L	L	-	L	-	-	-
CO2	S	M	M	L	M	L	-	M	-	M	-
CO3	S	S	M	L	M	L	-	M	-	M	-
CO4	S	S	M	L	M	L	-	M	-	M	-
CO5	S	M	M	L	M	L	-	M		M	-
CO6	S	S	M	L	M	L	-	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	40	40	20	20
Apply	30	30	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. Discuss about the access technologies for last mile link.
2. What are the merits and demerits of optical wireless communication?
3. Explain about the link configuration of OWC system.

Course Outcome 2 (CO2):

1. Determine the impulse response of a line of sight optical wireless system.

2. Compute the attenuation coefficient against the visibility range V.
3. Derive an expression for RMS delay spread for a diffuse indoor system using ceiling bounce model.

Course Outcome 3 (CO3):

1. Analyze the performance of the OOK modulation scheme with RZ and NRZ signal format.
2. Show that the power efficiency of pulse position modulation scheme is better than other schemes.
3. Compare and contrast the performance of optical wireless system with OOK and PPM modulation scheme.

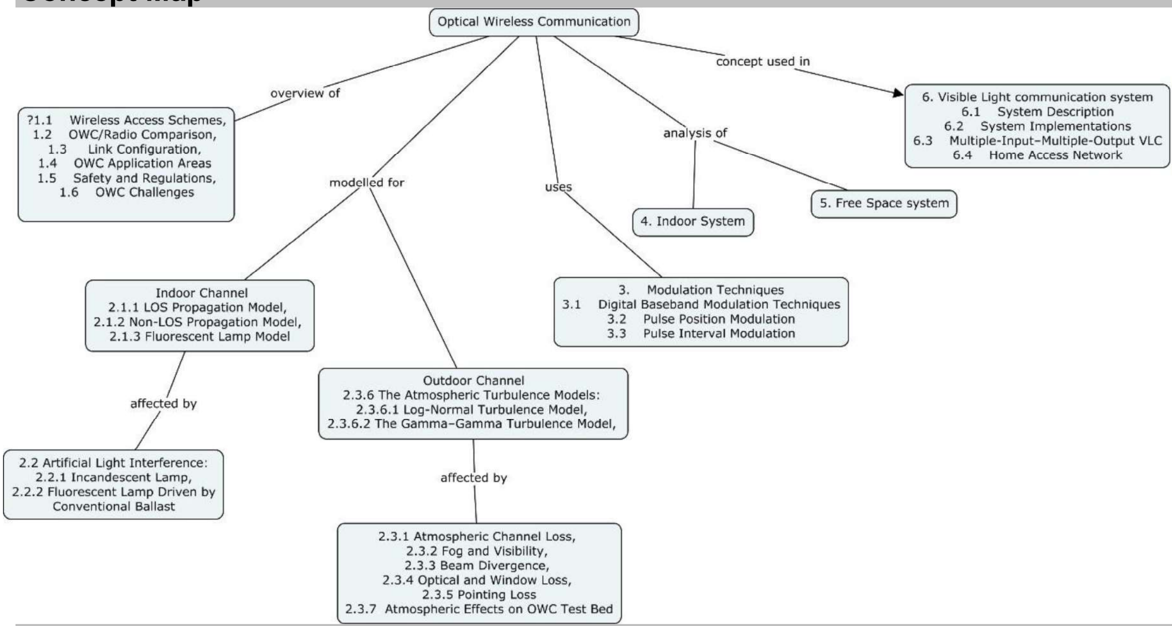
Course Outcome 4 (CO4):

1. Analyse the effect of ambient light source on the link performance of indoor wireless system.
2. How does fluorescent light interference affect the OOK-NRZ modulation optical signal?
3. How does the effect of scintillation affect the bit error rate performance of outdoor wireless system?

Course Outcome 5 (CO5):

1. Derive an expression for signal to noise ratio of OOK based visible light communication system.
2. How does multilevel PPM scheme utilized in visible light system?

Concept Map



Syllabus

Introduction to Optical Wireless Communication Systems: Wireless Access Schemes,OWC/Radio Comparison, Link Configuration, OWC Application Areas, Safety and Regulations, OWC Challenges, **OpticalSources:** Laser, LED, **Optical Detectors:** PIN and Avalanche photodiode

Channel Modelling: Indoor Channel: LOS Propagation Model, Non-LOS Propagation Model **Outdoor Channel:** Atmospheric Channel Loss, Fog and Visibility, Beam Divergence, Optical and Window Loss, Pointing Loss

Modulation Techniques: Digital Baseband Modulation Techniques, Pulse Position Modulation, Pulse Interval Modulation,Multilevel DPIM, Comparisons of Baseband Modulation Schemes

System Performance Analysis: Indoor - Effect of Ambient Light Sources on Indoor OWC Link Performance, Effect of FILI without Electrical High-Pass Filtering,Link Performance for Multipath Propagation, Mitigation Techniques: Filtering, Equalization

FSO Link Performance under the Effect of Atmospheric Turbulence:On–Off Keying: OOK in a Poisson Atmospheric Optical Channel, OOK in a Gaussian Atmospheric

Optical Channel - **Pulse Position Modulation**
Visible Light Communications: Introduction, **System Description**: VLC System Model, SNR analysis, Channel Delay Spread, **System Implementations:** Bit Angle Modulation, Pulse Modulation Schemes, **Multiple-Input–Multiple-Output VLC**, **Home Access Network**
Design of Optical Wireless CommunicationLink : Power budgetanalysis

Reference Books

1. Z. Ghassemlooy, W. Popoola, S. Rajbhandari, “Optical Wireless Communications: System and Channel Modelling with MATLAB®”, CRC press, 2013.
2. Roberto Ramirez-Iniguez, Sevia M. Idrus, Ziran Sun, “ Optical Wireless Communications: IR for Wireless Connectivity”, CRC press, 2008
3. ZabihGhassemlooy, Luis Nero Alves, Stanislav Zvánovec, Mohammad-Ali Khalighi, “Visible Light Communications: Theory and Applications”, CRC Press, 2013

Course Contents and Lecture Schedule

Topics	Sub topics	No. of Lectures
1.	**Introduction to Optical Wireless Communication Systems:**	
1.1 1.2 1.3 1.4 1.5 1.6	Wireless Access Schemes, OWC/Radio Comparison, Link Configuration, OWC Application Areas Safety and Regulations, OWC Challenges	2
1.7 1.8	Optical Sources: Laser, LED Optical Detectors: PIN and Avalanche photodiode	2
2	**Channel Modelling:**	
2.1 2.1.1 2.1.2	Indoor Optical Wireless Communication Channel: LOS Propagation Model, Non-LOS Propagation Model	2
2.2	Artificial Light Interference:	1
2.3 2.3.1 2.3.2 2.3.3 2.3.4 2.3.5	Outdoor Channel: Atmospheric Channel Loss, Fog and Visibility, Beam Divergence, Optical and Window Loss, Pointing Loss,	2
3	**Modulation Techniques:**	
3.1	Digital Baseband Modulation Techniques	1
3.2	Pulse Position Modulation	2
3.3	Pulse Interval Modulation	2
3.4	Comparisons of Baseband Modulation Schemes	2
4	**System Performance Analysis: Indoor**	
4.1	Effect of Ambient Light Sources on Indoor OWC Link Performance,	2
4.2	Effect of FLI without Electrical High-Pass Filtering	2
4.3	Link Performance for Multipath Propagation	2
4.4	Mitigation Techniques: Filtering, Equalization	2
5	**System Performance Analysis: Free space**	
5.1 5.1.1	**Link Performance under the Effect of Atmospheric Turbulence:** On–Off Keying: OOK in a Poisson Atmospheric Optical Channel, OOK in a Gaussian Atmospheric Optical Channel	2
5.1.2	Pulse Position Modulation	2

6	**Visible Light communication system**	
6.1	System Description: VLC System Model, SNR analysis, Channel Delay Spread,	2
6.2	System Implementations: Bit Angle Modulation, Pulse Modulation Schemes	2
6.3	Multiple-Input–Multiple-Output VLC,	1
6.4	Home Access Network	1
7.	**Design of Optical wireless Communication**	2
	Total Number of Hours	36

Course Designers:

1. Dr. S.Ponmalar spmece@tce.edu
2. Dr. E. Murugavalli murugavalli@tce.edu

18WTPT0	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

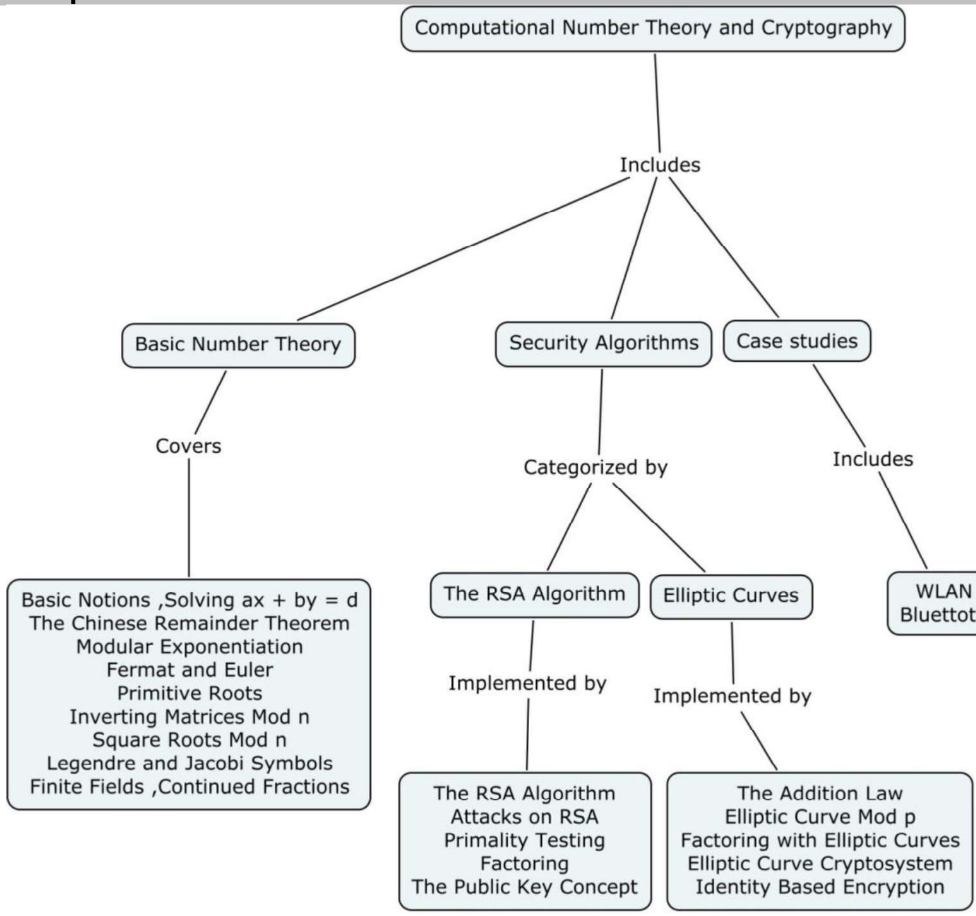
1. Show that if P=(x,0) is a point on a elliptic curve, then 2P=∞
2. Show that if P,Q are points on an elliptic curve then
   P+Q+R=$\infty \Leftrightarrow$ P,Q, R are collinear
3. a. List the points on the elliptic curve $E = y^2 \equiv x^3 - 2$ (mod 7)
   b. Find the sum (3,2)+(5,5) on E
   c. Find 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

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	Topics	No of
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:

Dr.M.S.K. Manikandan manimsk@tce.edu

18WTPU0	COGNITIVE RADIO NETWORKS	Category	L	T	P	Credit
		PE	3	0	0	3

Preamble

This course presents the state-of-the-art in the field of Software defined and Cognitive Radio Systems. The course will enable the students to learn about the architecture, design methodologies, spectrum sensing and management techniques used in emerging wireless applications.

Prerequisite

Nil

Course Outcomes:

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

CO1.	Inspect the Challenges in Software defined radio/ cognitive radio and technologies	Understand
CO2.	Analyze the performance of cognitive radio networks	Analyze
CO3	Analyze the performance of Spectrum Underlay/ Spectrum Overlay methodologies in Cognitive Radio Networks	Analyze
CO4.	Examine the techniques that detect the spectrum holes in cognitive radio.	Analyze
CO5.	Assess the performance of the Single and multiple user Power Control solutions adopted in CR networks	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

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	20	20
Apply	40	40	40	40
Analyse	30	30	40	40
Evaluate	0	0	0	0
Create	0	0	0	0

Course Level Assessment Questions

Course Outcome 1 (CO1):

1. Sort out the design tools available for SDR
2. Categorize the requirements of cognitive radio
3. Point out the spectrum access problems in cognitive radio

Course Outcome 2 (CO2):

1. Compare software architecture with cognitive radio architecture
2. Determine the spectrum capacity of an unlicensed user when it receives a signal power of 40 dB while sensing 20 MHz wide bandwidth in a Gaussian channel with a noise power of 5dB.
3. Compare the benefits of tit-for tat gaming model with Nash equilibrium model for spectrum pricing strategy.

Course Outcome 3 (CO3):

1. State the role of Software tunable smart antennas in cognitive systems.

2. In cognitive radio network calculate the outage probability and interference if the base station transmits signal power at 20 dB along with noise power 5 dB at 800 MHz. Assume the user is at a distance of 20 km. Assume maximum propagation distance r_{max}=40.
3. Design a typical Digital front end for SDR transmitter.

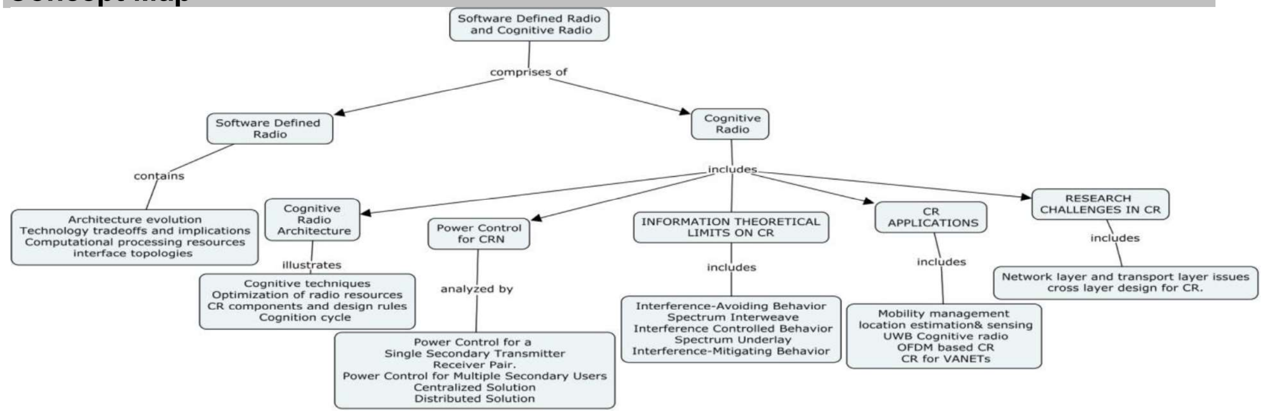
Course Outcome 4 (CO4):

1. Give the goal of spectrum adaptation. Explain any one spectrum adaptation technique.
2. Assess the better solution offered by UWB cognitive radio.
3. Explain how Cramer Rao bound estimates bounding criteria for any unbiased estimator?

Course Outcome 5 (CO5):

1. Write a technical note on cognitive radio based location estimation
2. Assess the performance of an OFDM based CR in health monitoring applications.
3. Illustrate the benefits of intelligent algorithms in learning and adapting wireless transmission according to the ambient radio environment.

Concept Map



Syllabus

SOFTWARE DEFINED RADIO AND ITS ARCHITECTURE:
Definitions and potential benefits, software radio architecture evolution, technology tradeoffs and architecture implications. Essential functions of the software radio, basic SDR, hardware architecture, Computational processing resources, software architecture, top level component interfaces, interface topologies among plug and play modules. **COGNITIVE RADIOS AND ITS ARCHITECTURE:** Marking radio self-aware, cognitive techniques – position awareness, environment awareness in cognitive radios, optimization of radio resources, Artificial Intelligence Techniques, Cognitive Radio – functions, components and design rules, Cognition cycle – orient, plan, decide and act phases, Inference Hierarchy, Architecture maps, Building the Cognitive Radio Architecture on Software defined Radio Architecture. **Power Control for Cognitive Radio Networks:** Power Control for a Single Secondary Transmitter–Receiver Pair. Power Control for Multiple Secondary Users- Centralized Solution, Distributed Solution, **INFORMATION THEORETICAL LIMITS ON CR NETWORKS:** Types of Cognitive Behavior, Interference-Avoiding Behavior: Spectrum Interweave, Interference Controlled Behavior: Spectrum Underlay, Underlay in Small Networks: Achievable Rates, Underlay in Large Networks: Scaling Laws, Interference-Mitigating Behavior: Spectrum Overlay, Opportunistic Interference Cancellation, Asymmetrically Cooperating Cognitive Radio Channels. **COGNITIVE RADIO APPLICATIONS: Cognitive radios** in wireless communication, Mobility management, location estimation& sensing, UWB Cognitive radio, OFDM based CR, CR for VANETs, **RESEARCH CHALLENGES IN COGNITIVE RADIO:** Network layer and transport layer issues, cross layer design for cognitive radio networks.

Reference Books

1. Alexander M. Wyglinski, Maziar Nekovee, And Y. Thomas Hou, “ Cognitive Radio Communications And Networks - Principles And Practice”, Elsevier Inc. , 2010.

2. Kwang-Cheng Chen and Ramjee Prasad, “Cognitive Radio Networks” , John Wiley & Sons, Ltd, 2009.
3. Khattab, Ahmed, Perkins, Dmitri, Bayoumi, Magdy, “Cognitive Radio Networks - From Theory to Practice”, Springer Series: Analog Circuits and Signal Processing, 2009.
4. J. Mitola, “ Cognitive Radio: An Integrated Agent Architecture for software defined radio”, Doctor of Technology thesis, Royal Inst. Technology, Sweden 2000.
5. Simon Haykin, “Cognitive Radio: Brain –empowered wireless communications”, IEEE Journal on selected areas in communications, Feb 2005.
6. Ian F. Akyildiz, Won – Yeol Lee, Mehmet C. Vuran, Shantidev Mohanty, “ NeXt generation / dynamic spectrum access / cognitive radio wireless networks: A Survey Elsevier Computer Networks, May 2006.
7. Jeffrey Hugh Reed, “Software Radio: A Modern Approach to Radio Engineering,” Prentice Hall Professional, 2002.
8. Paul Burns, “Software Defined Radio for 3G,” Artech House, 2002.
9. K.J. Rayliu, A.K. Sadek, Weifeng Su & Andres Kwasinski, “Cooperative Communications and Networking”, Cambridge University Press, 2009.
10. Kwang-Cheng Chen and Ramjee Prasad, “Cognitive Radio Networks”, John Wiley & Sons, 2009.

Course Contents and Lecture Schedule

Module No.	Topic	No. of Lectures
1	**Software Defined Radio and its Architecture**	
1.1	Definitions and potential benefits, software radio architecture evolution, technology tradeoffs and architecture implications	2
1.2	Essential functions of the software radio, basic SDR, hardware architecture, Computational processing resources	2
1.3	Software architecture, top level component interfaces, interface topologies among plug and play modules	2
2	**Cognitive Radios and its Architecture**	
2.1	Marking radio self-aware, cognitive techniques – position awareness, environment awareness	1
2.2	Optimization of radio resources, Artificial Intelligence Techniques, Cognitive Radio – functions, components and design rules	2
2.3	Cognition cycle – orient, plan, decide and act phases, Inference Hierarchy	2
2.4	Architecture maps, Building the Cognitive Radio Architecture on Software defined Radio Architecture	2
3	**Power Control for Cognitive Radio Networks**	
3.1	Power Control for a Single Secondary Transmitter–Receiver Pair	2
3.2	Power Control for Multiple Secondary Users- Centralized Solution, Distributed Solution	2
3.3	Case Study	2
4	**Information Theoretical Limits on CR Networks**	
4.1	Types of Cognitive Behavior, Interference-Avoiding Behavior: Spectrum Interweave	2
4.2	Interference Controlled Behavior: Spectrum Underlay, Underlay in Small Networks: Achievable Rates, Underlay in Large Networks: Scaling Laws	3
4.3	Interference-Mitigating Behavior: Spectrum Overlay, Opportunistic Interference Cancellation, Asymmetrically Cooperating Cognitive Radio Channels.	3
5	**Cognitive Radio Applications**	

5.1	Cognitive radios in wireless communication	1
5.2	Mobility management, location estimation& sensing, UWB Cognitive radio	2
5.3	OFDM based CR, CR for VANETs	2
6	**Research Challenges in Cognitive Radio**	
6.1	Network layer and transport layer issues	2
6.2	Cross layer design for cognitive radio networks	2
	Total	36

Course Designer:

Dr.T.Aruna taece@tce.edu

18WTPV0	MULTIMEDIA CODING AND TRANSMISSION

Category	L	T	P	Credit
PE	3	0	0	3

Preamble

Since multimedia data are often of bulky size, they have to be effectively compressed to be stored on storage media and transmitted over bandwidth-limited networks. While multimedia coding defines representations of different types of digital information such as audio, speech, image and video, it becomes the foundation of managing and processing these digital data. Therefore, it becomes more and more important to have an in-depth understanding on how multimedia coding works, not only for developers, but also for users of these systems.This course aims at understanding characteristics of various multimedia signals and design a suitable coding/compression technique to efficiently represent and transmit the data.

Prerequisite

Familiarity in discrete mathematics, one dimensional signal processing and image processing.

Course Outcomes

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

CO1.CharacterizeMultimedia Signals and its digital representation	Apply
CO2.Illustrate the Quantization and Coding strategies useful for Multimedia signals	Apply
CO3.Demonstrate the principles of various Image coding standards.	Apply
CO4.Analyze the performance of different video coding schemes	Analyze
CO5.Experiment various speech and audio coding standards	Analyze
CO6.Demonstrate the transmission of multimedia data including live streaming	Apply

Mapping with Programme Outcomes

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11
CO1	S	L	L	L	-	-	-	-	-	L	-
CO2	S	L	S	L	M	-	-	-	-	L	-
CO3	M	M	S	M	M	L	-	L	L	M	-
CO4	M	M	M	M	M	L	-	L	L	M	-
CO5	M	M	M	M	M	L	-	L	L	M	-
CO6	M	L	L	L	M	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	10	0	0	0
Understand	30	20	20	20
Apply	60	40	40	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. Using your own words, describe what is “multimedia”?
2. Is multimedia simply a collection of different types of media?
3. Identify three novel multimedia applications. Discuss why you think these are novel and their potential impact.
4. Discuss the relation between multimedia and hypermedia.
5. Brieflyexplainwhyweneedtobeabletohavelessthan24-bitcolorandwhythis makes for a problem. Generally, what do we need to do to adaptively transform 24-bit color values to 8-bit ones?
6. Suppose we decide to quantize an 8-bit grayscale image down to just 2 bits of accuracy. What is the simplest way to do so? What ranges of byte values in the original image are mapped to what quantized values?
7. Suppose we have available 24 bits per pixel for a color image. However, we notice that humans are more sensitive to R and G than to B—in fact, 1.5 times more sensitive to R or G than to B. How could we best make use of the bits available?
8. NTSCvideohas525linesperframeand63.6μsperline,with20linesperfield of vertical retrace and 10.9μs horizontal retrace.
    a. Where does the 63.6μs come from?
    b. Which takes more time, horizontal retrace or vertical retrace? How much more time?
9. Digital video uses chroma subsampling. What is the purpose of this? Why is it feasible?
10. Draw a diagram showing a sinusoid at 5.5 kHz, and sampling at 8 kHz (just show 8 intervalsbetween samples in your plot). Draw the alias at 2.5 kHz andshow that in the 8 sample intervals, exactly 5.5 cycles of the true signal fit into 2.5 cycles of the alias signal.

Course Outcome 2 (CO2)

1. What is the term “rate” in compression?
2. How integer arithmetic could be used to generate binary code and examine the same for the typical scenario of u(n) = 54 and l(n) = 33 with m = 6.
3. How do we start decoding in arithmetic coding process?
4. Encode the sequence with lossy differential scheme:4.2, 1.8, 6.2, 9.7, 13.2, 5.9, 8.7, 0.4
5. For an alphabet A = {a1, a2, a3} with p(a1) = 0.7, p(a2) = 0.2, p(a3) = 0.1. Design a ‘3’ bit Tunstall code.
6. Build the dictionary of diagram coding for ‘3’ letter alphabet S = {a, b, c}
7. Encode the following sequence by LZ77 approach with window = 14 , LAB = 5 a b c a r a d a b r a r r a a d r r
8. If we obtain co-efficient as 28.5, 5.8, -2.3, 1.2, -0.8, 2.1. Quantize it with flooring function.
9. Find adaptive Huffman code for {a, a, r, d, v} and continue this with the next letters in the sequence {a, r, k}, if two more alphabets (r) comes, what is the structure of the tree?
10. A source emits letters from an alphabet A = {a1, a2, a3, a4, a5} with probabilities P (a1) = 0.15, P (a2) = 0.04, P (a3) = 0.26, P (a4) = 0.05 & P (a5) = 0.5
    a. Calculate the entropy
    b. Find Huffman code
    c. Average length of the code and its redundancy
11. For an alphabet A = {a1, a2, a3, a4} with probabilities
    P (a1) = 0.1, P (a2) = 0.3, P (a3) = 0.25, P (a4) = 0.35

a. Find Huffman code and compare with the minimum variance procedure
b. Comment on the difference

Course Outcome 3 (CO3)

1. Explain the bi-level lossless compression standard.
2. Youaregivenacomputercartoonpictureandaphotograph.Ifyouhaveachoice of using either JPEG compression or GIF, which compression would you apply for these two images? Justify your answer.
3. Supposeweviewadecompressed512×512JPEGimagebutuseonlythecolor part of the stored image information, not the luminance part, to decompress. What does the 512×512 color image look like? Assume JPEG is compressed using a 4:2:0 scheme.
4. IstheJPEG2000bitstreamSNRscalable?Ifso,explainhowitisachievedusing the EBCOT algorithm.
5. Could we use wavelet-based compression in ordinary JPEG? How?

Course Outcome 4 (CO4)

1. Define the macroblock modes supported by MPEG-1
2. In block-based video coding, what takes more effort: compression or decompression? Briefly explain why.
3. Explain the facial feature animation capabilities of MPEG-4.
4. Explain MPEG-1 standard for video information.
5. B-frames provide obvious coding advantages, such as increase in SNR at low bitratesandbandwidthsavings.WhataresomeofthedisadvantagesofB-frames?
6. Draw block diagrams for an MPEG-2 encoder and decoder for (a) SNR and spatial hybrid scalability, (b) SNR and temporal hybrid scalability
7. Motion vectors can have subpixel precision. In particular, MPEG-4 allows quarter-pixel precision in the luminance VOPs. Describe an algorithm that will realize this precision.
8. What is the major motivation behind the development of MPEG-21?

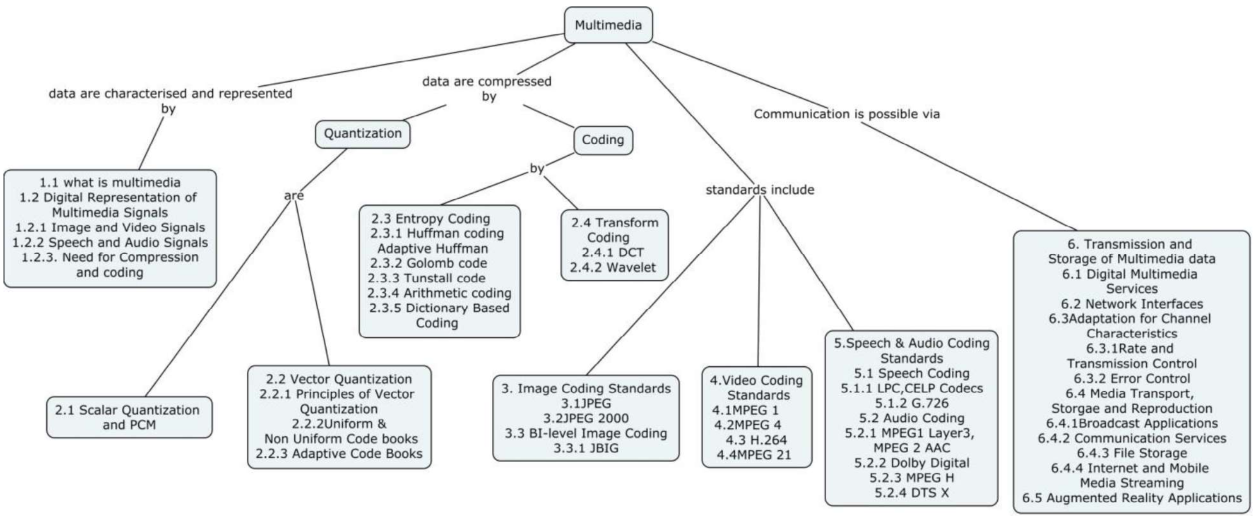
Course Outcome 5 (CO5)

1. Linear prediction analysis can be used to estimate the shape of the envelope of the short-time spectrum. Given ten LP coefficients a1,...,a10, how do we get the formant position and bandwidth?
2. Give a simple time domain method for pitch estimation based on the autocorrelation function. What problem will this simple scheme have when based on one speech frame? If we have three speech frames, including a previous frame and a future frame, how can we improve the estimation result?
3. Describe the ITU G.726 standard for ADPCM system.
4. Onthereceiverside,speechisusuallygeneratedbasedontwoframes'parameters instead of one, to avoid abrupt transitions. Give two possible methods to obtain smooth transitions. Use the LPC codec to illustrate your idea.
5. What is the compression ratio of MPEG audio if stereo audio sampled with 16 bits per sample at 48 kHz is reduced to a bitstream of 256 kbps?
6. In MPEG's polyphase filter bank, if 24 kHz is divided into 32 equal-width frequency subbands,
   a. What is the size of each subband?
   b. How many critical bands, at worst, does a subband overlap?

Course Outcome 6 (CO6)

1. Why is it necessary to introduce time stamps with different media stream.
2. Explain Rate control in multimedia transmission by quantizer step size adaptation.
3. How does cyclic intra-picture coding is carried out to avoid infinite propagation of Transmission error.
4. Briefly explain Transport stream multiplex of MPEG-2.
5. Draw the Block diagram of DVB transmitters and discuss each block in detail.

Concept Map



Syllabus

Multimedia- Digital Representation of Multimedia Signals:Image and Video Signals-Speech and Audio Signals-Need for Compression and Coding of Multimedia signals;**Quantization and coding**Scalar Quantization & PCM,Vector Quantization:Principles of Vector Quantization-Vector Quantization with uniform and non-uniform codebooks-Adaptive Code Books;Entropy Coding:Huffman Coding--Adaptive Huffman-Golomb Code-Tunstall Code-Arithmetic coding-Dictionary Based Coding; Transform Coding: DCT-Wavelet**;Image Coding Standards**JPEG-JPEG 2000-JBIG; **Video Coding Standards:**MPEG 1- MPEG 4 - H.264 - MPEG 21 **Speech and Audio Coding Standards:** LPC,CELP codecs-G.726-MPEG 1 Layer III(MP3) -MPEG 2 (AAC)-Dolby Digital- MPEG H- DTS X**;Transmission and storage of multimedia data:** Digital Multimedia Services-Network Interfaces-Adaptation for Channel Characteristics:Rate and Transmission Control-Error Control;Media Transport, Storage and Reproduction:Broadcast Applications-Communication Services-File Storage-Internet and Mobile media Streaming- Augmented Reality Applications.

Reference Books

1. Li, Ze-Nian, Mark S. Drew, and Jiangchuan Liu, “Fundamentals of multimedia” Upper Saddle River (NJ):: Pearson Prentice Hall, 2004.
2. Khalid Sayood, “Introduction to Data Compression” Fourth Edition, Morgan Kauffmann Publishers, Inc, Newnes, 2012.
3. Jens-Rainer Ohm, “Multimedia Signal Coding and Transmission”, Springer, 2015.
4. Andreas Spanias, Ted Painter, VenkatramanAtti, “Audio Signal Processing and Coding”, Wiley-Interscience, 2007.
5. David Salomon, “A Guide to Data Compression Methods” Fourth Edition Springer Science & Business Media, 2013.
6. Irina Bocharova, “Compression for Multimedia”, Cambridge University press, 2010.

Course Contents and Lecture Schedule

Module No.	Topic	No. of lectures
1.	**Multimedia:** Introduction to Multimedia, Overview of Course Outcomes and Programme Outcomes	1
1.1	What is Multimedia	
1.2	Digital Representation of Multimedia Signals	
1.2.1	Image and Video Signals	1
1.2.2	Speech and Audio Signals	
1.3	Need for Compression and Coding	1
2.	**Quantization and coding**	
2.1	Scalar Quantization & PCM	2
2.2	Vector Quantization	
2.2.1	Principles of Vector Quantization	2
2.2.2	Vector Quantization with uniform and non-uniform codebooks	1
2.2.3	Adaptive Code Books	
2.3	Entropy Coding	
2.3.1	Huffman Coding, Adaptive Huffman	2
2.3.2	Golomb Code	1
2.3.3	Tunstall Code	
2.3.4	Arithmetic coding	1
2.3.5	Dictionary Based Coding	2
2.4	Transform Coding	
2.4.1	DCT	1
2.4.2	Wavelet	1
3	**Image Coding Standards**	
3.1	JPEG	2
3.2	JPEG 2000	1
3.3	Bi-level Image Coding Standards	
3.3.1	JBIG	1
4	**Video Coding Standards**	
4.1	MPEG 1	1
4.2	MPEG 4	1
4.3	H.264	1
4.4	MPEG 21	1
5.	**Speech and Audio Coding Standards**	
5.1	Speech coding	
5.1.1	LPC,CELP codecs	1
5.1.2	G.726	1
5.2	Audio Coding	
5.2.1	MPEG 1 Layer III(MP3), MPEG 2 (AAC)	1
5.2.2	Dolby Digital,	1
5.2.3	MPEG H	1
5.2.4	DTS X	
6	**Transmission and storage of multimedia data**	
6.1	Digital Multimedia Services	1
6.2	Network Interfaces	
6.3	Adaptation for Channel Characteristics	
6.3.1	Rate and Transmission Control	1

6.3.2	Error Control	
6.4	Media Transport, Storage and Reproduction	
6.4.1	Broadcast Applications	1
6.4.2	Communication Services	1
6.4.3	File Storage	
6.4.4	Internet and Mobile media Streaming	2
6.5	Augmented Reality Applications	1

Course Designers:

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18WTPWO	MACHINE LEARNING FOR SIGNAL PROCESSING

Category	L	T	P	Credit
PE	2	1	0	3

Preamble

The course "18WT210: Machine Learning for Signal Processing" is offered as an elective course. 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.

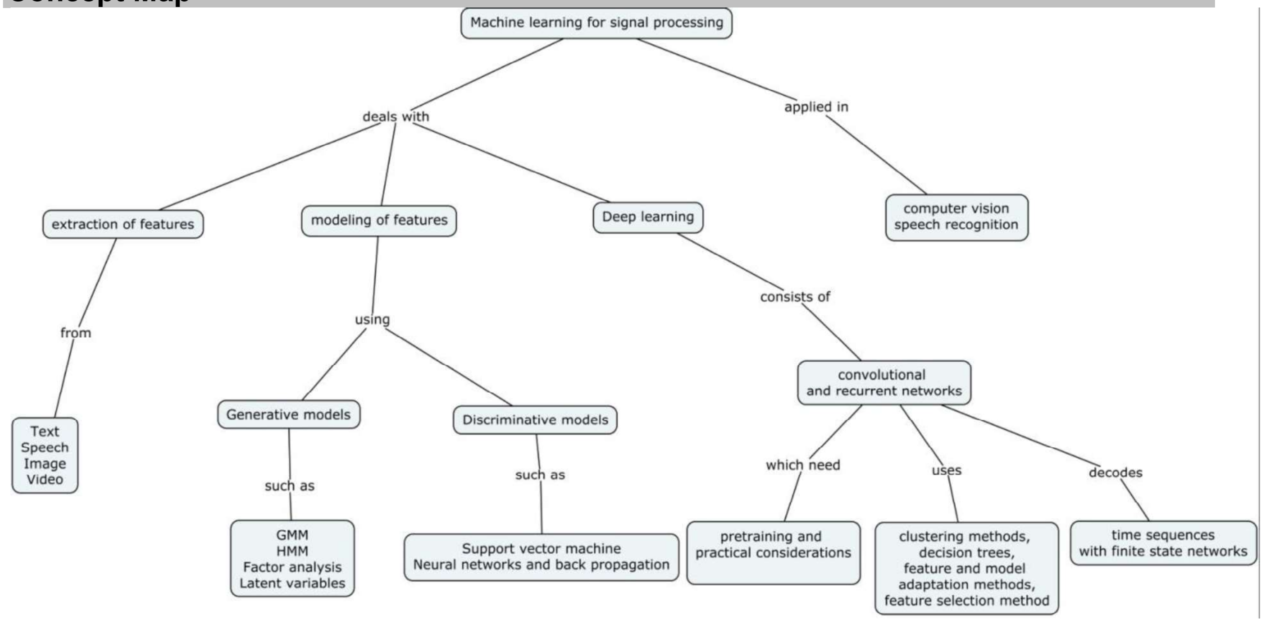
Course Outcome 5 (CO5):

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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REVISED SYLLABUS

OF

OPEN ELECTIVE

FOR

M.E. DEGREE 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)
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18CNGA1	CONVEX OPTIMIZATION	Category	L	T	P	Credit
		PE	2	0	0	2

Preamble

This course aims to give students the tools and training to recognize convex optimization problems that arise in many fields of science and engineering, 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. Formulate the primal and dual optimal solution of convex optimization problems.	Apply
CO5. Apply gradient descent method and 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	M	L	-	-	-	-	-	-	-	-	-
CO2	S	M	L	-	-	-	-	-	L	-	-
CO3	S	M	L	-	L	-	-	-	L	-	-
CO4	S	M	L	L	L	-	-	-	L	-	-
CO5	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	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. Which of the following sets are convex?
   a. A slab i.e., a set of form $\{x \in R^n / \alpha \le a^T x \le \beta\}$
   b. A rectangle i.e., a set of form $\{x \in R^n / \alpha_i \le x_i \le \beta_{i,} i = 1.....n\}$
   c. A wedge i.e., $\{x \in R^n / a_1^T x \le b_{1,} a_2^T x \le b_2\}$.
   d. The sets of points closer to a given point than a given set i.e., $\{x / \|x - x_0\|_2 \le \|x - y\| forally \in S\}$ where $S \subseteq R^n$.
   e. The set of points closer to one set than another i.e. , $\{x / dist(x,s) \le dist(x,T)\}$, where $S,T \subseteq R^n$ and 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 $\{x / \|x - a\|_2 \le \theta \|x - b\|_2\}$. You can assume $a \ne b$ and $0 \le \theta \le 1$.

2. Some sets of probability distributions. Let x be a real valued random variable with $prob(x = a_i) = p_i, i = 1,.....,n,$ where $a_1 < a_2 < ...... < a_n$. 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) $\alpha \le Ef(x) \le \beta$, 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) $prob(x > \alpha) \le \beta$

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

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

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

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

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

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

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

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 ΔT μs 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 $\text{dom}\, g = \left\{x \middle| (x, y) \in \text{dom} f \ \forall\ y \in A, \sup_{y \in A} f(x, y) < \infty \right\}$ 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 $f_1, f_2, f_3 : \left[0, \pi/2\right] \to$. 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) $\log x \le 1$

   ii) $1 - x_1 x_2 \le 0 \;\; x_1, x_2 \ge 0$

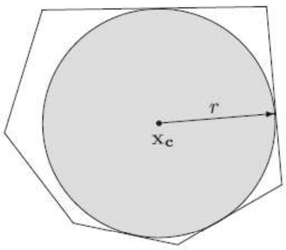
   Convert them into convex optimization problems.

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 $B(X_c, r) = \{X \| \|X - X_c\|_2 \le r\}$ and a polyhedron $\mathrm{P} = \{X | a_i^T X \le b_i, i = 1,..,m\}$.



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

Course Outcome 4 (CO4):

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 $\begin{array}{l} Gx \le h \\ Ax = b \end{array}$

   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 5 (CO5):

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 $x_1 \leq x_2$, $0 \leq x_2$, with variable $x \in R^2$?

3. Boundedness of centering problem.

   Minimize $f_0(x)$

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

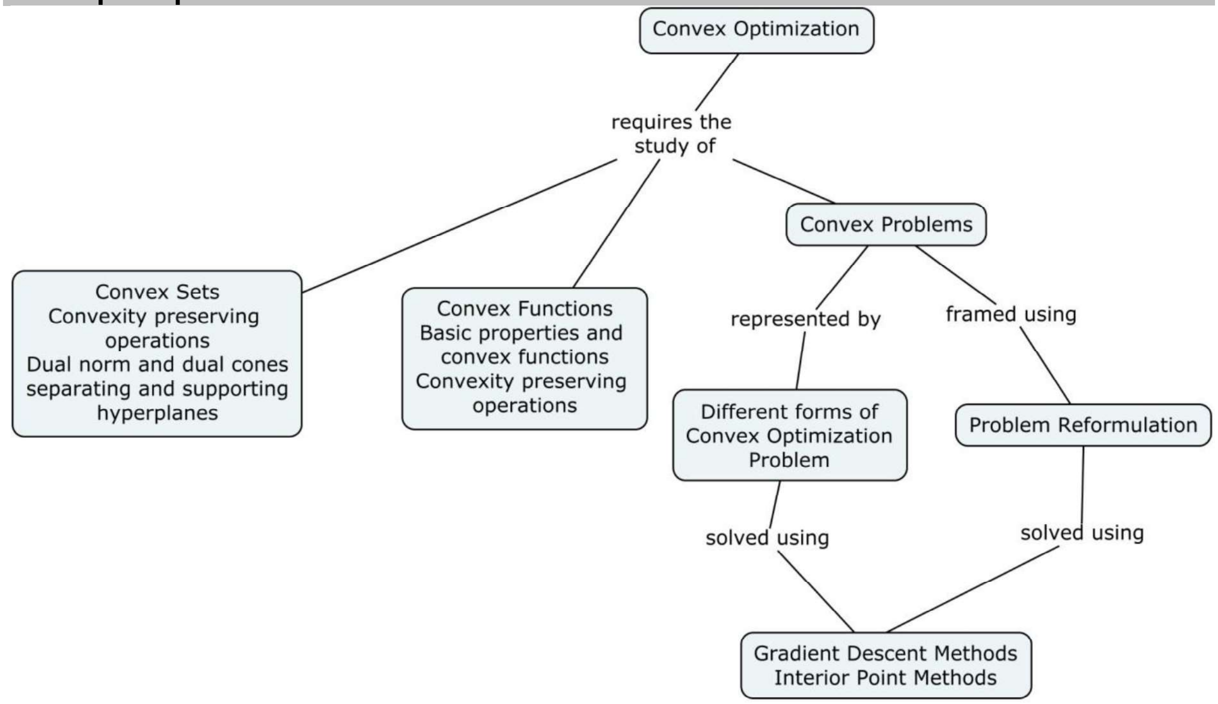
   $Ax = b$, are bounded.

   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.

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

Algorithms: Descent method, Grdient descent method and 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. Dimitri P. Bertsekas, “Convex Analysis and Optimization” Athena Scientific, 2003.

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	**Duality**	
4.1	Lagrange dual function	1
4.2	Lagrange dual problem	1
4.3	Karush–Kuhn–Tucker (KKT) optimality conditions.	2
5	**Algorithms**	
5.1	Descent Methods	1
5.2	Gradient Descent Methods	1
5.3	Interior Point Methods	1
5.4	Inequality and equality constrained convex problems	1
5.5	Barrier method	1
5.6	Primal-dual interior-point method	1
	Total	24

Course Designers:

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DETAILED SYLLABI

OF

AUDIT COURSES

FOR

M.E. DEGREE PROGRAM

FOR THE STUDENTS ADMITTED FROM THE

ACADEMIC YEAR 2018-19 ONWARDS

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Approved in 57th Academic Council Meeting on 05.01.2019

18PGAA0	PROFESSIONAL AUTHORING	Category	L	T	P	Credit
		AC	2	0	0	2

Preamble

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

1. Explain how to improve your writing skills and level of readability
2. Write each section of research paper
3. Write good quality technical paper

Syllabus

Planning and Preparation, Word Order, Breaking up long sentences, Structuring Paragraphs and Sentences, Being Concise and Removing Redundancy, Avoiding Ambiguity and Vagueness

Clarifying Who Did What, Highlighting Your Findings, Hedging and Criticising, Paraphrasing and Plagiarism, Sections of a Paper, Abstracts. Introduction

Review of the Literature, Methods, Results, Discussion, Conclusions, The Final Check.

Key skills for writing a Title, writing an Abstract, writing an Introduction, writing a Review of the Literature,

Skills for Writing the Methods, Results, Discussion and Conclusions
Useful phrases, how to ensure paper is as good as it could possibly be the first- time submission

Assessment Pattern

Abstract	:	10
Introduction	:	10
Literature Review	:	10
Research Question	:	10
Methods	:	10
Results and Discussion	:	10
Conclusions	:	10
Appropriateness of Title	:	05
Quality of the Paper and Plagiarism	:	25

References

1. Goldbort R, ‘Writing for Science’, Yale University Press, 2006
2. Day R, ‘How to Write and Publish a Scientific Paper’, Cambridge University Press, 2006
3. Highman N, ‘Handbook of Writing for the Mathematical Sciences, SIAM Highman’s book, 1998
4. Adrian Wallwork, ‘English for Writing Research Papers’, Springer New York Dordrecht Heidelberg London, 2011

18PGAB0	VALUE EDUCATION

Category	L	T	P	Credit
AC	2	0	0	2

Preamble

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

1. Experience self-development
2. Explain the importance of Human values
3. Develop the overall personality

Syllabus

Values and self-development –Social values and individual attitudes. Work ethics, Indian vision of humanism. Moral and non- moral valuation. Standards and principles, Value judgements

Importance of cultivation of values, Sense of duty. Devotion, Self-reliance. Confidence, Concentration. Truthfulness, Cleanliness, Honesty, Humanity, Power of faith, National Unity, Patriotism, Love for nature, Discipline

Personality and Behavior Development, Soul and Scientific attitude, Positive Thinking. Integrity and discipline, Punctuality, Love and Kindness, Avoid fault Thinking, Free from anger, Dignity of labour, Universal brotherhood and religious tolerance, True friendship, Happiness Vs suffering, love for truth.

Aware of self-destructive habits, Association and Cooperation, Doing best for saving nature

Character and Competence –Holy books vs Blind faith, Self-management and Good health, Science of reincarnation, Equality, Nonviolence , Humility, Role of Women, All religions and same message, Mind your Mind, Self-control, Honesty, Studying effectively

Assessment Pattern

Bloom's Category	Continuous Assessment Test	Terminal Examination
Remember	20	20
Understand	40	40
Apply	40	40
Analyse	0	0
Evaluate	0	0
Create	0	0

References

1. Chakroborty, S.K. "Values and Ethics for organizations Theory and practice", OxforUniversity Press, New Delhi