CURRICULUM AND DETAILED SYLLABI

FOR

FIRST AND SECOND SEMESTER

M.E. (Communication Systems) DEGREE PROGRAMME

FOR THE STUDENTS ADMITTED FROM THE

ACADEMIC YEAR 2026-27 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.

M.E. (Communication Systems) Degree Programme

Credit Distribution and Scheduling of Courses

For the students admitted from the Academic Year 2026–27 onwards

1. CREDIT DISTRIBUTION

Sl. No.	Category	Credits
A	Foundation Course (FC)	03
B	Program Core Courses (PCC)	22
C	Program Elective Courses (PEC)	18
D	Research Methodology and IPR Course (RMC)	03
E	Employability Enhancement Course (EEC)	27
F	*Value Added Courses (VAC) - (Non-Credit and not included in CGPA) (04 credits)*	–
***Minimum Credits to be earned for the award of the Degree**		**73**

* *From A to E and the successful completion of F*

2. SCHEDULING OF COURSES

Sem	Theory / Theory cum Practical / Practical						Value Added Courses (Non-Credit)	Employability Enhancement Courses	Credits
	1	2	3	4	5	6	7	8	
I	26PCFA0 Linear Algebra and Optimization Techniques (FC-3)	26PCCA0 Baseband Communication (PCC-3)	26PCCB0 Cellular Networks (PCC-3)	26PCCC0 RF and Microwave Circuits (PCC-3)	26PCXY0 PEC-1 (3)	26PCCD0 RF Citcuits Laboratory (PCC-2)			17
II	26PZRA0 Research Methodology and IPR (RMC-3)	26PCCE0 Wireless Channel Modelling and MIMO Systems (PCC-3)	26PCCF0 FPGA Architecture and Applications (PCC-3)	26PCCG0 RF Front-End Systems (PCC-3)	26PCXY0 PEC-2 (3)	26PCCH0 SDR for Wireless Communication Laboratory (PCC-2)	26PZVA0 VAC-1 (2)	26PCEA0 Mini Project (3)	20
III	26PCXY0 PEC-3 (3)	26PCXY0 PEC-4 (3)	26PCXY0 PEC-5 (3)	26PCXY0 PEC-6 (3)			26PZVB0 VAC-2 (2)	26PCEB0 Project I (9)	21
IV								26PCEC0 Project II (15)	15
								Total Credits	**73**

Note: *FC – Foundation Course | PCC – Program Core Course | PEC – Program Elective Course | RMC – Research Methodology Course | VAC – Value Added Course*

3. PROGRAM ELECTIVE COURSES:

No.	Course Code	Course Name	No.	Course Code	Course Name
1.	26PCPA0	Computer Vision and IoT	2.	26PCPB0	Hyperspectral Imaging and Intelligent Analysis
3.	22PCPC0	Machine Learning for Communication	4.	26PCPD0	Radar Systems
5.	26PCPE0	Digital Integrated Circuits	6.	26PCPF0	Industrial IoT
7.	26PCPG0	Computer Network Security	8.	26PCPH0	Array Signal Processing
9.	26PCPJ0	Physical Layer LTE Systems	10.	26PCPK0	Intelligent Video Surveillance Systems
11.	26PCPL0	Machine Learning for Visual Recognition	12.	26PCPM0	Medical Imaging and Classification
13.	26PCPN0	Analog Integrated Circuits	14.	26PCPP0	Solid State Device Modeling and Simulation
15.	26PCPQ0	Biomedical Signal Processing	16.	26PCPR0	Nano MOSFET Modeling
17.	26PCPS0	Energy Harvesting In Wireless Sensor Networks	18.	26PCPT0	Image Systems Engineering

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015
M.E (Communication Systems) Degree Programme
COURSES OF STUDY
(For the students admitted in the Academic Year 2026-27 onwards)

FIRST SEMESTER

Course Code	Name of the Course	Category	No. of Hours / Week			Credits
			L	T	P	
THEORY						
26PCFA0	Linear Algebra and Optimization Techniques	FC	2	1	-	3
26PCCA0	Baseband Communication	PCC	2	1	-	3
26PCCB0	Cellular Networks	PCC	3	-	-	3
26PCCC0	RF and Microwave Circuits	PCC	2	1	-	3
26PCPX0	Programme Elective 1	PEC	3	-	-	3
PRACTICAL						
26PCCD0	RF Circuits Laboratory	PCC	-	-	4	2
Total						**17**

SECOND SEMESTER

Course Code	Name of the Course	Category	No. of Hours / Week			Credits
			L	T	P	
THEORY						
26PZRA0	Research Methodology and IPR	RMC	3	-	-	3
26PCCE0	Wireless Channel Modelling and MIMO Systems	PCC	3	-	-	3
26PCCF0	FPGA Architecture and Applications	PCC	3	-	-	3
26PCCG0	RF Front-End Systems	PCC	2	1	-	3
26PCXY0	Program Elective 2	PEC	3	-	-	3
PRACTICAL						
26PCCH0	SDR for Wireless Communication Laboratory	PCC	-	-	4	2
PROJECT						
24EC280	Mini Project	EEC	-	-	6	3
AUDIT COURSE						
26PZVA0	Value Added Course 1	VAC	2	-	-	0
Total			**15**	**4**	**5**	**20**

L : Lecture
T : Tutorial
P : Practical

Note:
1 Hour Lecture is equivalent to 1 credit
1 Hour Tutorial is equivalent to 1 credit
2 Hours Practical is equivalent to 1 credit

THIAGARAJAR COLLEGE OF ENGINEERING: MADURAI – 625 015
M.E (Communication Systems) Degree Programme
SCHEME OF EXAMINATIONS
(For the candidates admitted from 2026-27 onwards)

FIRST 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							
26PCFA0	Linear Algebra and Optimization Techniques	3	40	60	100	27	50
26PCCA0	Baseband Communication	3	40	60	100	27	50
26PCCB0	Cellular Networks	3	40	60	100	27	50
26PCCC0	RF and Microwave Circuits	3	40	60	100	27	50
26PCPX0	Programme Elective 1	3	40	60	100	27	50
PRACTICAL							
26PCCD0	RF Circuits Laboratory	3	60	40	100	18	50

SECOND 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							
26PZRA0	Research Methodology and IPR	3	40	60	100	27	50
26PCCE0	Wireless Channel Modelling and MIMO Systems	3	40	60	100	27	50
26PCCF0	FPGA Architecture and Applications	3	40	60	100	27	50
26PCCG0	RF Front-End Systems	3	40	60	100	27	50
26PCXY0	Program Elective 2	3	40	60	100	27	50
PRACTICAL							
26PCCH0	SDR for Wireless Communication Laboratory	3	60	40	100	18	50
PROJECT							
24EC280	Mini Project	-	60	40	100	18	50
AUDIT COURSE							
26PZVA0	Value Added Course 1	3	100	-	100	-	50

26PCFA0	LINEAR ALGEBRA AND OPTIMIZATION TECHNIQUES	Category	L	T	P	Credits
		FC	2	1	0	3

Preamble

Linear Algebra, Optimization and Graph Methods establishes the rigorous mathematical foundation essential for advanced research and system design in communication engineering, integrating vector space theory, matrix decompositions, and spectral analysis with constrained and unconstrained optimization techniques. These mathematical tools directly underpin critical applications such as MIMO signal processing, compressed sensing, and machine learning-based communications. Graph-theoretic methods further extend the course's relevance to network topology analysis, routing algorithms, and resource allocation in modern communication infrastructures.

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Apply vector space concepts such as subspaces, linear independence, basis, dimension, and orthogonality to perform Gram-Schmidt orthogonalization for solving mathematical problems.	TPS3	PO1 – S PO2 – M PO3 – L	20%	SDG4	2
CO2	Apply eigenvalues, eigenvectors, and matrix diagonalization techniques to compute least squares approximation solutions for mathematical problems.	TPS3	PO1 – S PO2 – M PO3 – L	15%	SDG4	2
CO3	Apply Singular Value Decomposition, QR decomposition, and pseudo-inverse methods to solve mathematical problems involving linear systems.	TPS3	PO1 – S PO2 – M PO3 – L	15%	SDG4	2
CO4	Apply graphical and Simplex methods to	TPS3	PO1 – S PO2 – M PO3 – L	15%	SDG4	2

	formulate and solve linear programming problems.					
CO5	Apply optimality conditions and iterative search techniques including Fibonacci method, Golden Section method, Steepest Descent method, and Conjugate Gradient method to solve unconstrained nonlinear programming problems.	TPS3	PO1 – S PO2 – M PO3 – L	20%	SDG4	2
CO6	Apply Lagrange Multiplier method and Kuhn–Tucker (KKT) conditions to solve equality-constrained and inequality-constrained nonlinear programming problems.	TPS3	PO1 – S PO2 – M PO3 – L	15%	SDG4	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	40	40	-	-	20
CO2	30	30	-	-	15
CO3	30	30	-	-	15
CO4	-	-	30	30	15
CO5	-	-	40	40	20
CO6	-	-	30	30	15
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Vector Spaces:

Definition and examples – Subspaces – Linear independence – Basis and dimension – Orthogonality of Vectors and Subspaces – Gram-Schmidt orthogonalization.

Advanced Matrix Theory:

Least squares approximation –Eigenvalues and eigenvectors – Diagonalization.

Matrix Decompositions:

Singular Value Decomposition – QR decomposition – Pseudo inverse.

Linear Programming:

Introduction - Formulation of linear programming problem -Graphical method – Simplex method with slack variables.

Nonlinear Programming:

Unconstrained Optimization: Introduction - optimality conditions - method overview - Fibonacci method - Golden section method – Steepest descent method – Conjugate gradient method.

Constrained Optimization: Multivariable Optimization with Equality constrains- Lagrange Multipliers Method - Multivariable optimization with inequality constrains- Kuhn-Tucker conditions.

6. Learning Resources

6.1 Text Book

1. Gilbert Strang, "Introduction to Linear Algebra", Sixth Edition, Wellesley-Cambridge Press, 2023.
   Vector Spaces: 3.1, 3.4, 4.1, 4.4
   Advanced Matrix theory: 4.3, 6.1, 6.2
   Matrix Decompositions: 7.1, 4.4, 4.5
2. Singiresu S. Rao, "Engineering Optimization: Theory and Practice", Fifth Edition, John Wiley and Sons, 2019.
   Linear Programming: 3.1, 3.2, 3.3, 3.4, 3.5, 3.9
   Nonlinear Programming: 5.1, 5.7, 5.8, 6.9, 6.10, 7.20, 7.21

6.2 Reference Books & Web resources

1. Steven J. Leon and Lisette de Pillis, "Linear Algebra with Applications", Tenth Edition, Pearson Education, 2021
2. Stephen Boyd and Lieven Vandenberghe, "Convex Optimization", First Edition, Cambridge University Press, 2004.
3. https://ocw.mit.edu/courses/18-06sc-linear-algebra-fall-2011/pages/positive-definite-matrices-and-applications/singular-value-decomposition/ .

7. Course Contents and Lecture Schedule

Module No.	Topics	No. of Periods
1	**Vector Spaces (7 hours)**	
1.1	Definition and examples of vector spaces	1
1.2	Subspaces	1
	Tutorial	1
1.3	Linear independence, Basis and dimension	1
1.4	Orthogonality of Vectors and Subspaces	1
	Tutorial	1
1.5	Gram–Schmidt orthogonalization	1
2	**Advanced Matrix Theory (6 hours)**	

2.1	Least squares approximation	1
	Tutorial	1
2.2	Eigenvalues and eigenvectors	2
	Tutorial	1
2.3	Diagonalization	1
3	**Matrix Decompositions (5 hours)**	
3.1	Singular Value Decomposition	1
	Tutorial	1
3.2	QR decomposition	1
3.3	Pseudo inverse	1
	Tutorial	1
4	**Linear Programming (6 hours)**	
4.1	Formulation of linear programming problems	1
4.2	Graphical method	1
	Tutorial	1
4.3	Simplex method with slack variables	2
	Tutorial	1
5	**Nonlinear Programming (12 hours)**	
5.1	Fibonacci method	1
5.2	Golden section method	1
	Tutorial	1
5.3	Steepest descent method	1
5.4	Conjugate gradient method	1
	Tutorial	1
5.5	Lagrange Multipliers Method	2
	Tutorial	1
5.6	Kuhn-Tucker conditions	2
	Tutorial	1
	Total	**36 Hrs**

8. Course Designer(s):

1. Mr. R. Suresh Kannan, Assistant Professor, Department of Mathematics — rskmat@tce.edu
2. Dr. S.P. Suriyaprabha, Assistant Professor, Department of Mathematics — spsmat@tce.edu
3. Dr. L. Muthusubramanian, Assistant Professor, Department of Mathematics — lmsmat@tce.edu
4. Dr. S. Suriyakala, Assistant Professor, Department of Mathematics — ssamat@tce.edu

26PCCA0	BASEBAND COMMUNICATION SYSTEMS	Category	L	T	P	Credits
		PCC	2	1	0	3

Preamble

This course introduces the principles of baseband communication systems, covering signal representation, information theory, digital transmission, channel coding, receiver design, and channel equalization. It enables students to analyze and design reliable communication systems for modern digital networks.

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Apply signal theory concepts to model communication systems.	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG 9	2
CO2	Apply information theory and channel coding principles for reliable data transmission.	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG 9	2
CO3	Analyze digital transmission techniques over additive white Gaussian noise channels using signal space representation, digital modulation schemes, optimum receiver design, and error probability performance evaluation.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	20	SDG 9	2
CO4	Apply pulse-shaping and bandlimited transmission concepts to evaluate digital communication systems over AWGN channels.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	2
CO5	Apply transmitter and receiver filtering and channel equalization techniques to mitigate channel impairments.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	2
CO6	Apply receiver design concepts to solve communication receiver problems presented in case studies.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30	30			10
CO2	30	30			10
CO3	40	40			20
CO4			30	30	20
CO5			30	30	20
CO6			40	40	20
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Module1:

Signal Theory:

Probability and Random Variables, Random Processes, Random Processes in the Frequency Domain, Gaussian and White Processes, Bandlimited Processes and Sampling

Module 2:

Information Theory and Channel Coding:

Modeling of Information Sources, review of source coding, Modeling of Communication Channels, Channel Capacity, Linear Block Codes, LDPC

Module 3:

Digital Transmission Through the Additive White Gaussian Noise Channel

Geometric Representation of Signal Waveforms, Pulse Amplitude Modulation, Two-dimensional Signal Waveforms: Amplitude Shift Keying, Frequency Shift Keying, Phase Shift Keying, Quadrature Phase Shift Keying, Quadrature Amplitude Modulation, Multidimensional Signal Waveforms:16 QAM,24 QAM,M-ary FSK Optimum Receiver for Digitally Modulated Signals in Additive White Gaussian Noise, Probability of Error for Signal Detection in Additive White Gaussian Noise

Module 4:

Signal design for Bandlimited AWGN Channels:

Digital Transmission through Bandlimited Channels, The Power Spectrum of Digitally Modulated Signals, Signal Design for Bandlimited Channels

Module 5: Receiver design for bandlimited channels:

Design of Transmitting and Receiving Filters for a Known Channel, Channel Equalization, Case studies: IEEE 802.15.4 Zigbee receiver, Ethernet, Wi-Fi, Bluetooth, CAN bus, USB

Learning Resources

6.1 Text Book

- Bernard Sklar: “Digital Communications: Fundamentals and Applications”, 2nd Edition, Prentice Hall, 2001.

6.2 Reference Books & Web resources

- John G. Proakis, “Digital Communications”, McGraw Hill International Edition, Fourth Edition, 2001.
- John R Barry, Edward Lee and David G. Messerschmitt, “Digital Communication”, 3rd Edition. Springer, 2003.
- John G. Proakis , Masoud Salehi, “Communication Systems Engineering”, Prentice Hall, 2nd Edition, 2002
- H Simon Haykin, “Digital Communications”, John Wiley & Sons Pvt. Ltd., 2001.

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	Signal Theory:Probability and Random Variables, Random Processes	2
1	Random Processes in the Frequency Domain, Gaussian and White Processes	2
1	Bandlimited Processes and Sampling	2
2	Information Theory and Channel Coding:Modeling of Information Sources	2
2	review of source coding, Modeling of Communication Channels	2
2	Channel Capacity, Linear Block Codes, LDPC	2
3	Digital Transmission Through the Additive White Gaussian Noise Channel:Geometric Representation of Signal Waveforms, Pulse Amplitude Modulation	1
3	Two-dimensional Signal Waveforms:Amplitude Shift Keying,Frequency Shift Keying,Phase Shift Keying	1
3	Quadrature Phase Shift Keying,Quadrature Amplitude Modulation	1
3	Multidimensional Signal Waveforms:16 QAM,24 QAM,Mary FSK	2
3	Optimum Receiver for Digitally Modulated Signals in Additive White Gaussian Noise	2
3	Probability of Error for Signal Detection in Additive White Gaussian Noise	1
4	Signal design for Bandlimited AWGN Channels:Digital Transmission through Bandlimited Channels	3
4	The Power Spectrum of Digitally Modulated Signals	3
4	Signal Design for Bandlimited Channels	2
5	Receiver design for bandlimited channels:Design of Transmitting and Receiving Filters for a Known Channel	3
5	Channel Equalization	3
5	Case studies:IEEE 802.15.4 Zigbee receiver,Ethernet,Wi-Fi,Bluetooth,CAN bus,USB	2
5	Total Periods	36

Course Designer(s):

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Dr.P.G.S.Velmurugan, Associate Professor, pgsvels@tce.edu

26PCCB0	CELLULAR NETWORKS	Category	L	T	P	Credits
		PCC	3	0	0	3

Preamble

This course introduces the evolution of cellular networks from 1G to advanced 5G communication systems. It covers LTE and 5G architectures, protocols, mobility management, and security mechanisms. The course emphasizes key 5G features such as service-based architecture, network slicing, virtualization, scalability, and resilience. It also explores 5G-enabled IoT, cloud computing, edge computing, and network function virtualization. Additionally, the course presents AI and Machine Learning techniques for network optimization, QoS/QoE enhancement, Edge AI, and Federated Learning.

Prerequisite

NIL

Course Outcome

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

CO#	Course Outcomes	TPS Level	PO Addressed	CO Weigh tage	SDG addressed	SDG Level
CO1	Apply the fundamental principles of cellular networks to analyze cell planning, handoff, and capacity improvement in mobile communication scenarios.	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG 9	2
CO2	Analyze Service-Based Architecture and message-based communication in 5G core	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	2
CO3	Apply distributed mobility management functions of next generation mobile networks heterogeneous 5G environments	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG 9	2
CO4	Apply 5G protocol stack concepts to analyze signaling and data communication and 5G Enable Internet of Things	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG 9	2
CO5	Apply the techniques of network function virtualization in 5G enabled IoT and 5G core call flow	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	2
CO6	Apply AI-native 6G	TPS3	PO1 – S	15	SDG 9	2

	architecture for intelligent network operation.		PO2 – M PO3 – L			

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30	30	0	0	15
CO2	40	40	0	0	20
CO3	30	30	0	0	15
CO4	0	0	30	30	15
CO5	0	0	40	40	20
CO6	0	0	30	30	15
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Generation of Cellular Network: Principles of Cellular Networks, First- Generation Analog, Second- Generation TDMA Second- Generation CDMA Third- Generation Systems Fourth Generation Systems and LTE- LTE Architecture, Evolved Packet Core LTE Resource Management, LTE Channel Structure and Protocols
5G Architecture overview: Overview, 5G—A new era of connectivity, the road to 5G network deployments Service-based architecture (SBA), Messaging services, Support for devices connected over non-3GPP access networks, Network slicing, Roaming, Key EPC functions, (Enhanced) Dedicated Core Networks ((e)DECOR),
Mobility Management: Establishing connectivity, Reachability, Additional MM related concepts, N2 management, Interworking with EPC, Security - Network access security, Network domain security, User domain security.
5G Protocols: Protocols, 5G non-access stratum (5G NAS), NG application protocol (NGAP), Hypertext transfer protocol (HTTP), Transport layer security (TLS), Packet forwarding control protocol (PFCP), GPRS tunneling protocol for the User Plane (GTP-U), Extensible Authentication Protocol (EAP), IP security (IPSec), Stream Control Transmission Protocol (SCTP), Generic routing encapsulation.
Basic 5G core call flow - Attach, Detach, Handover, Paging, Flexibility, Scalability, Resilience, Virtualization, Security achieved.
5G Enabled Internet of Things: 5G cloud, Mobile and Edge computing for IoT Network function virtualization based IoT in 5G network, 5G small cells
AI: AI& ML for Network Optimization, QoS & QoE Optimization, Edge AI and federated Learning

Learning Resources

6.1 Text Book

1. Stefan Rommer, Peter Hedman, Magnus Olsson, Lars Frid, Shabnam Sultana, Catherine Mulligan, “5G Core Networks”, Academic Press, 2024.

6.2 Reference Books & Web resources

1. Yulei Wu, Haojun Huang, Cheng-Xiang Wang, Yi Pan(edited),”5G Enabled Internet of Things”, CRC Press, 2019.
2. Saad Z. Asif, “5G Mobile Communications Concepts and Technologies”, CRC Press, 2022.

3. Cory Beard, William Stallings, "Wireless Communication Networks and Systems", Pearson, 2016.
4. Jonathan Rodriguez, Fundamental of 5G Mobile Network, Wiley, 2015.

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	Principles of Cellular Networks, First- Generation Analog, Second- Generation TDMA Second- Generation CDMA Third- Generation Systems LTE Channel Structure and Protocols	2
	Fourth Generation Systems and LTE- LTE Architecture, Evolved Packet Core LTE Resource Management,	2
	LTE Channel Structure and Protocols	2
2	Overview, 5G—A new era of connectivity, the road to 5G network deployments Service-based architecture (SBA),	2
	Messaging services, Support for devices connected over non-3GPP access networks	2
	Network slicing, Roaming, Key EPC functions	2
	(Enhanced) Dedicated Core Networks ((e)DECOR),	2
3	Establishing connectivity, Reachability	1
	Additional MM related concepts, N2 management	1
	Interworking with EPC, Security - Network access security	1
	Network domain security, User domain security	1
4	Protocols, 5G non-access stratum (5G NAS), NG application protocol (NGAP),	2
	Hypertext transfer protocol (HTTP), Transport layer security (TLS),	1
	Packet forwarding control protocol (PFCP), GPRS tunneling protocol for the User Plane (GTP-U),	1
	Extensible Authentication Protocol (EAP), IP security (IPSec), Stream Control Transmission Protocol (SCTP), Generic routing encapsulation	1
5	Attach, Detach, Handover, Paging,	1
	Flexibility, Scalability, Resilience, Virtualization, Security achieved	2
6	5G cloud, Mobile and Edge computing for IoT	2
	Network function virtualization based IoT in 5G network,	2
	5G small cells	1
7	AI& ML for Network Optimization,	2
	QoS & QoE Optimization	2
	Edge AI and federated Learning	1
	Total Periods	**36**

8. Course Designer(s):

- Dr. M. S. K. Manikandan, Professor, manimsk@tce.edu
- Dr. E. Murugavalli, Assistant Professor, murugavalli@tce.edu

26PCCC0	RF AND MICROWAVE CIRCUITS	Category	L	T	P	Credits
		PCC	2	1	0	3

Preamble

The objective of this course is to provide strong fundamentals in the field of RF passive and active circuit design. Design of passive circuits such as transmission lines, matching circuits, filters, couplers and power dividers are covered. Gaining knowledge in active circuit design is also covered. The passive and active devices are characterized using scattering parameters.

Prerequisite

1. Engineering Electromagnetic Fields

Course Outcomes

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

No.	Course Outcome	TPS Level	PO's Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Characterize a microwave network using Z, Y ,ABCD and S parameters	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG9, SDG 11	2
CO2	Learn the basics of transmission lines and design a planar transmission line.	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG9, SDG 11	2
CO3	Apply impedance matching techniques for microwave circuits	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG9, SDG 11	3
CO4	Design passive microwave couplers such as Branch line and Rat-Race coupler	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG9, SDG 11	3
CO5	Design passive microwave circuits such as power divider and filter	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG9, SDG 11	3
CO6	Design microwave amplifiers for maximum gain and specified gain	TPS3	PO1 – S PO2 – M PO3 – L	30	SDG9, SDG 11	3

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30	100			10
CO2	30				15
CO3	40				20
CO4			20	100	15
CO5			20		10
CO6			60		30
Total	100	100	100	100	100

Syllabus

RF/Microwave two-port networks: RF/Microwave versus low AC signals, Equivalent Voltages and Currents, Impedance and Admittance Matrices, Transmission (ABCD) Matrix, Scattering Matrix, Reciprocal Networks and Lossless Networks.
Planar Transmission Lines: Types of Transmission Lines- Microstrip, Slot, CPW, Parameters, Design of Micro strip line for RF applications
Impedance matching: Matching with lumped elements, Stub matching- Single using Smith chart solutions, Quarter wave transformer.
Couplers and Dividers: Basic Properties of Dividers and Couplers, T-Junction Power Divider, Quadrature (90°) Hybrid, The 180° Hybrid.
Filters: Insertion loss method, maximally flat low pass filter, stepped impedance low pass filter, filter transformation.
Amplifier: Two-Port Power Gains, Stability, Single-Stage Transistor Amplifier Design – Design for Maximum Gain, Constant-Gain Circles and Design for Specified Gain.

Learning Resources

6.1 Text Book

- David M. Pozar, *Microwave Engineering*, 4th Edition, Wiley, 2012.
- Robert E. Collin, *Foundations for Microwave Engineering*, 2nd Edition, Wiley-IEEE Press, 2001

6.2 Reference Books&Web resources

- Samuel Y. Liao, *Microwave Devices and Circuits*, 3rd Edition, Prentice Hall, 1990.
- Reinhold Ludwig and Pavel Bretchko, *RF Circuit Design: Theory and Applications*, 2nd Edition, Pearson Education, 2009.
- Guillermo Gonzalez, *Microwave Transistor Amplifiers: Analysis and Design*, 2nd Edition, Prentice Hall, 1997.
- Kai Chang, *RF and Microwave Wireless Systems*, 1st Edition, Wiley, 2000.
- Behzad Razavi, *RF Microelectronics*, 2nd Edition, Prentice Hall / Pearson, 2011.

Course Contents and Lecture Schedule

Module No.	Topic	No of Periods
1.	**RF/Microwave two-port networks**	
1.1	RF/Microwave versus low AC signals, Equivalent Voltages and Currents	2
1.2	Impedance and Admittance Matrices	1
1.3	Transmission (ABCD) Matrix	2
1.4	Scattering Matrix, Reciprocal Networks and Lossless Networks	2
2.	**Planar Transmission Lines**	
2.1	Types of Transmission Lines- Microstrip, Slot, CPW, Parameters	2
2.2	Design of Micro strip line for RF applications	2
3.	**Impedance matching**	
3.1	Matching with lumped elements	2
3.2	Stub matching- Single stub using Smith chart solutions	3
3.3	Quarter wave transformer	1
4.	**Couplers and Dividers**	
4.1	Basic Properties of Dividers and Couplers	1
4.2	The T-Junction PowerDivider	1

4.3	The Quadrature (90°) Hybrid, The 180° Hybrid	3
4.4	**Filters**	
	Insertion loss method, maximally flat low pass filter	1
4.5	Stepped impedance low pass filter, filter transformation	2
5.	**Amplifier**	
5.1	Two-Port Power Gains	1
5.2	Stability concepts	2
5.3	Single-Stage Transistor Amplifier Design – Design for Maximum Gain,	2
5.4	Constant-Gain Circles	2
5.5	Design for Specified Gain	2

Course Designer(s):

1. Dr. S.Kanthamani, Professor, skmece@tce.edu
2. Dr. B.Manimegalai, Professor, naveenmega@tce.edu

26PCCD0	RF CIRCUITS LABORATORY	Category	L	T	P	Credits
		PCC	0	0	4	2

1. Preamble

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.

2.Prerequisite

Nil

3.Course Outcomes

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

COs	Course Outcome 1 (CO1)	TCE Proficiency Scale	PO Addressed	SDG Addressed	SDG Level
CO1	Design and experimentally evaluate Planar Transmission lines	TPS 3	PO1 – S PO2 – M PO3 – L	SDG 9, 11	2
CO2	Design and simulate impedance matching networks	TPS 3	PO1 – S PO2 – M PO3 – L	SDG 9, 11	2
CO3	Design and simulate RF Passive components for any application	TPS 3	PO1 – S PO2 – M PO3 – L	SDG9, 11	2
CO4	Test RF passive components	TPS 4	PO1 – S PO2 – S PO3 – M PO4 – L	SDG 9,11	2
CO5	Perform the RF signal measurements	TPS 4	PO1 – S PO2 – S PO3 – M PO4 – L	SDG 9,11	2
CO6	Prototype and test RF passive devices for wireless communication systems	TPS 4	PO1 – S PO2 – S PO3 – M PO4 – L	SDG 9,11	3

4.Assessment Pattern: Cognitive Domain

Type of Assessment	Component	Marks	Remarks
Continuous Assessment	In-lab	75	Conducted throughout the semester
Model Test	In -Lab	25	Mid/End semester internal test
Total Internal Marks		**100**	
End Semester Examination	CO1- CO6	100	As directed by COE or as per curriculum

5.List of Experiments with CO Mapping

Sl. No.	Name of the Experiment	Level of Experiment	Objective(s)	COs Addressed

1.	Design, Simulation and Testing of Planar Transmission lines	**1**	Instrumentation, Experimentation	CO1
2.	Design ,simulation of Impedance Matching Networks	**1**	Instrumentation, Experimentation,	CO2
3.	Design and Performance analysis of maximally flat Low -Pass Filters	**1**	Instrumentation, Experimentation	CO3-CO4
4.	Design and Characterization of Wilkinson Power Dividers	**1**	Instrumentation, Experimentation	CO3-CO4
5.	RF signal measurements – Channel power, SNR, Phase measurement using Spectrum Analyser.	**2**	Instrumentation, Experimentation	CO5
6.	Fabrication and Experimental verification of Microwave passive Components using Network Analyser	**3**	Instrumentation, Experimentation	CO6

6.Course Designer(s):

1. Dr. S. Kanthamani, Professor, skmece@tce.edu
2. Dr. B. Manimegalai, Professor, naveenmega@tce.edu

26PZRA0	RESEARCH METHODOLOGY AND IPR	Category	L	T	P	Credits
		RMC	3	0	0	3

Preamble

The course aims to provide postgraduate engineering students with comprehensive knowledge of research methodology, scientific writing, ethical research practices, AI-assisted research tools, and Intellectual Property Rights (IPR). The course enables students to formulate research problems, perform literature analysis using modern databases and AI tools, prepare scholarly publications, and understand patenting and technology transfer mechanisms.

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Formulate and analyse engineering research problems	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG 9	2
CO2	Conduct literature review using conventional databases and AI-assisted research tools.	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG 9/4	2
CO3	Apply ethical practices, plagiarism control, and responsible AI usage in research.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	20	SDG 9	2
CO4	Prepare technical reports, research proposals, journal manuscripts, and scholarly publications.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	2
CO5	Understand Intellectual Property Rights, patent filing procedures, and technology transfer mechanisms.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	2
CO6	Utilize AI tools effectively for academic research, innovation, and scientific publication support.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30	30			10
CO2	30	30			10
CO3	40	40			20
CO4			30	30	20
CO5			30	30	20
CO6			40	40	20
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Module1: Research Problem Formulation and Research Design:
Meaning and characteristics of research problems – Identification of research gaps – Sources of research problems – Objectives and scope of research – Research methodology and research process – Approaches to investigation and solution formulation – Data collection, analysis, and interpretation methods – Experimental design and validation techniques.

Module 2: Literature Review and AI-Assisted Research Tools:
Research databases and indexing systems: Scopus, Web of Science, Google Scholar, IEEE Xplore, ScienceDirect – Literature survey techniques – Systematic literature review – Bibliometric analysis – AI-assisted literature review tools: Semantic Scholar, Research Rabbit, Connected Papers, Consensus – Research trend analysis and identification of research gaps.

Module 3: Research Ethics, Plagiarism and Responsible AI:
Research ethics and integrity – Ethical issues in engineering research – Plagiarism detection and prevention – Citation and referencing standards – Responsible usage of Generative AI tools in research – Bias, hallucination, and limitations of AI-generated content – Data privacy and academic integrity.

Module 4: Technical Writing and Scholarly Publication:
Technical report writing – Research proposal preparation – Journal manuscript writing – Structure of research papers – Abstract, introduction, methodology, results, discussion, and conclusion writing – Conference papers and thesis preparation – Journal selection criteria – Impact factor, citation metrics, h-index, indexing databases – Peer review process and publication ethics.

Module 5: Intellectual Property Rights and Patenting:
Introduction to Intellectual Property Rights – Patents, copyrights, trademarks, industrial designs, and geographical indications – Patent drafting and filing procedures – Patent databases and patent search – New IPR Developments in India- Technology transfer and commercialization – Innovation management and startup ecosystem.

Module 6: AI Tools for Research and Innovation:
Citation and reference management tools – AI tools for data analysis and visualization – AI applications in research proposal preparation, journal publication support, patent prior-art search, patent drafting, and patent analytics.

Learning Resources

6.1 Reference Books & Web resources

- C.R. Kothari and Gaurav Garg, Research Methodology: Methods and Techniques, 4th Edition, New Age International Publishers, 2019.
- Ranjit Kumar, Research Methodology: A Step-by-Step Guide for Beginners, 5th Edition, SAGE Publications, 2019.
- Barbara Gastel and Robert A. Day, How to Write and Publish a Scientific Paper, 9th Edition, Greenwood Publishers, 2022.
- Deborah E. Bouchoux, Intellectual Property: The Law of Trademarks, Copyrights, Patents, and Trade Secrets, 5th Edition, Cengage Learning, 2017.
- Stuart Melville and Wayne Goddard, Research Methodology: An Introduction for Science and Engineering Students, Juta Academic Publishers, 2004.
- Robert P. Merges, Peter S. Menell, and Mark A. Lemley, Intellectual Property in the New Technological Age, 2023 Edition, Clausen Group Publishers, 2023.
- Patrick Dunleavy, Authoring a PhD: How to Plan, Draft, Write and Finish a Doctoral Thesis or Dissertation, Palgrave Macmillan, 2003.
- Booth, Colomb, and Williams, The Craft of Research, 4th Edition, University of Chicago Press, 2016.

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	**Research Problem Formulation and Research Design:** Meaning and characteristics of research problems	1
1	Identification of research gaps – Sources of research problems – Objectives and scope of research	1
1	Research methodology and research process – Approaches to investigation and solution formulation	1
1	Data collection, analysis, and interpretation methods – Experimental design and validation techniques	1
2	**Literature Review and AI-Assisted Research Tools:** Research databases and indexing systems: Scopus, Web of Science, Google Scholar, IEEE Xplore, ScienceDirect	1
2	Literature survey techniques – Systematic literature review – Bibliometric analysis	2
2	AI-assisted literature review tools: Semantic Scholar, Research Rabbit, Connected Papers, Consensus	1
2	Research trend analysis and identification of research gaps.	1
3	**Research Ethics, Plagiarism and Responsible AI:** Research ethics and integrity - Ethical issues in engineering research	1
3	Plagiarism detection and prevention – Citation and referencing standards	2
3	Responsible usage of Generative AI tools in research – Bias, hallucination, and limitations of AI-generated content	2
3	Data privacy and academic integrity.	1
4	**Technical Writing and Scholarly Publication:** Technical report writing – Research proposal preparation – Journal manuscript writing	2
4	Structure of research papers – Abstract, introduction, methodology, results, discussion, and conclusion writing	2
4	Conference papers and thesis preparation	2
4	Journal selection criteria – Impact factor, citation metrics, h-index, indexing databases – Peer review process and publication ethics.	2
5	**Intellectual Property Rights and Patenting:** Introduction to Intellectual Property Rights – Patents, copyrights, trademarks, industrial designs, and geographical indications	2
5	Patent drafting and filing procedures - Patent databases and patent search	3
5	New IPR Developments in India- Technology transfer and commercialization – Innovation management and startup ecosystem.	2
6	**AI Tools for Research and Innovation:** Citation and reference management tools – AI tools for data analysis and visualization	2
6	AI applications in research proposal preparation, journal publication support	2
6	patent prior-art search, patent drafting, and patent analytics.	2
	Total Periods	**36**

8. Course Designer(s):

Dr. B. Sathya Bama, Professor, sbece@tce.edu

26PCCE0	WIRELESS CHANNEL MODELLING AND MIMO SYSTEMS	Category	L	T	P	Credits
		PCC	3	0	0	3

Preamble

The rapid proliferation of wireless communication technologies spanning 5G, 6G, IoT, and intelligent networks has made a rigorous understanding of wireless channel behavior and multi-antenna systems indispensable for modern communication engineers. This course, Wireless Channel Modelling and MIMO Systems, equips students with a strong theoretical and analytical foundation in wireless channel characterization and advanced transmission strategies.

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Apply wireless propagation and statistical fading channel models to characterize wireless communication channels under different propagation environments.	TPS3	PO1 – S PO2 – M PO3 – L	10 %	SDG 9	2
CO2	Evaluate the BER performance of SISO, SIMO, MISO, and MIMO systems using diversity techniques.	TPS3	PO1 – S PO2 – M PO3 – L	20 %	SDG 9	3
CO3	Compute the channel capacity of SIMO, MISO, and MIMO communication systems under varying power and bandwidth constraints	TPS3	PO1 – S PO2 – M PO3 – L	10 %	SDG 9	3
CO4	Analyze the outage performance of SISO, SIMO, MISO, and MIMO channels under fading conditions.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	20 %	SDG 9, SDG 11	4
CO5	Analyze SIMO, MISO, and MIMO communication systems using antenna array principles and line-of-sight channel models.	TPS3	PO1 – S PO2 – M PO3 – L	20 %	SDG 9, SDG 11	3
CO6	Implement OFDM-based wireless communication systems and apply frequency-domain link adaptation techniques for	TPS3	PO1 – S PO2 – M PO3 – L	20 %	SDG 9	3

	performance enhancement.					

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30	30			10
CO2	40	40			20
CO3	30	30			10
CO4			40	40	20
CO5			30	30	20
CO6			30	30	20
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Module1:
Fading Wireless Channels
Radio wave propagation, Ray tracing, two ray ground reflection model, signal modelling: statistical multipath channel model: time varying channel impulse response, narrowband fading models, wideband fading models, Basics of multipath propagation and Rayleigh fading, slow and fast fading versus the channel coherence time, Link budget analysis.
Module 2:
Performance analysis of SISO, SIMO, MISO and MIMO Systems
Diversity gain, Coding gain, receive antenna diversity, transmit antenna diversity, Diversity order and channel variability, BER performance of SISO, SIMO, MISO and MIMO systems.
Module 3:
Capacity of point to point MIMO Channels
Impact of power and bandwidth on the capacity, Capacity of SIMO channels, Capacity of MISO channels, capacity of MIMO channels, Outage performance of SISO, SIMO, MISO, and MIMO channels.
Module 4:
Line of Sight
Basic properties of antenna arrays, modeling of LoS SIMO, MISO and MIMO channels. Three-dimensional far field channel modelling
Module 5: Space Time OFDM
Single-Carrier vs. Multi-Carrier Transmission, Basic Principle of OFDM, BER of OFDM Scheme, Water-Filling Algorithm for Frequency-Domain Link Adaptation

Learning Resources

6.1 Text Book

- David Tse and Pramod Viswanath, “Fundamentals of Wireless Communications”, Cambridge University Press, First Asian Edition, 2006.
- Emil Bjornson and Ozlem Tugfe Demir, “Introduction to Multiple Antenna Communications and Reconfigurable Surfaces” now Publisher Inc, 2024.
- Paulraj, R. Nabar and D Gore, “Introduction to Space-Time Wireless Communications”, Cambridge University Press, 2003.

6.2 Reference Books & Web resources

- Andrea Goldsmith, “Wireless Communications”, Cambridge University Press, 2005.

- Yong Soo Cho, Jaekwon Kim, Won Young Yang, Chung G. Kang, MIMO-OFDM Wireless Communication with MATLAB, Wiley, John Wiley & Sons (Asia) Pvt Ltd, 2010.
- Theodore S.Rappaport, “Wireless Communications Principles and Practice”, Pearson Education, Second Edition, 2001.
- Aditya. K. Jegannatham, “Principles of Modern Wireless Communication Systems”,Tata McGraw Hill, 2016.
- https://nptel.ac.in/courses/117104115
- https://archive.nptel.ac.in/courses/108/106/106106167

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1.	Radio wave propagation, Ray tracing, two ray ground reflection model, signal modelling	2
1.	discrete statistical multipath channel model: time varying channel impulse response, narrowband fading models, wideband fading models	1
1.	Basics of multipath propagation and Rayleigh fading, slow and fast fading versus the channel coherence time,	2
1.	Link budget analysis	1
2.	Diversity gain, Coding gain	2
2.	receive antenna diversity	2
2.	transmit antenna diversity	1
2.	Diversity order and channel variability,	1
2.	BER performance of SISO, SIMO, MISO and MIMO systems.	2
3.	Impact of power and bandwidth on the capacity	1
3.	Capacity of SIMO channels	1
3.	Capacity of MISO channels	2
3.	capacity of MIMO channels	2
3.	Outage performance of SISO, SIMO, MISO, and MIMO channels	2
4.	Basic properties of antenna arrays	2
4.	modeling of LoS SIMO, MISO and MIMO channels.	2
4.	Three-dimensional far field channel modelling	2
5.	Single-Carrier vs. Multi-Carrier Transmission	2
5.	Basic Principle of OFDM	2
5.	BER of OFDM Scheme	2
5.	Water-Filling Algorithm for Frequency-Domain Link Adaptation	2
Total		**36**

Course Designer(s):

1. Dr.M.N.Suresh – Associate Professor, mnsece@tce.edu
2. Dr.K.Rajeswari - Associate Professor, rajeswari@tce.edu
3. Dr.G.Ananthi – Associate Professor, gananthi@tce.edu
4. Dr.P.G.S.Velmurugan – Associate Professor, pgsvels@tce.edu

26PCCF0	FPGA ARCHITECTURE AND APPLICATIONS	Category	L	T	P	Credits
		PCC	3	0	0	3

Preamble

This course provides a comprehensive understanding of FPGA and ASIC design methodologies, covering HDL-based design flows, programmable logic architectures, and modern FPGA technologies. It explores FPGA logic blocks, interconnect structures, clocking resources, and programmable I/O architectures used in contemporary digital systems. The syllabus emphasizes advanced computer arithmetic and high-speed arithmetic units for efficient signal processing and hardware acceleration. It also introduces FPGA design optimization, high-level synthesis, timing closure, power management, and reconfigurable computing techniques for developing high-performance digital systems.

Prerequisite

NIL

Course Outcomes

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

CO	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG Addressed	SDG Level
CO1	Describe the ASIC/FPGA design flow using HDL methodology and differentiate programming technologies Anti-fuse, SRAM, EPROM, EEPROM and Flash in terms of LUT-based synthesis	2	PO1 – S PO2 – M	20	4, 9	1
CO2	Compare logic block architectures of Actel ACT 1/2/3, Xilinx LCA (XC3000/ XC4000/ XC5200) and modern ALMs with fracturable LUTs	3	PO1 – S PO2 – M PO3 – L	20	9	1
CO3	Explain DC/AC I/O buffer structures, clock distribution, power input architectures and differentiate Actel ACT vs Xilinx LCA/EPLD interconnect schemes	3	PO1 – S PO2 – M PO3 – L	10	9	1
CO4	Analyze signed digit, fractional, logarithmic, RNS, fixed/floating-point arithmetic, CORDIC pipelines and Distributed Arithmetic with respect to FPGA architectures	3	PO1 – S PO2 – M PO3 – L	20	9	1
CO5	Implement pipelined adders, Wallace tree multipliers, fast dividers, MAC engines and FFT/NTT butterfly architectures on FPGA	3	PO1 – S PO2 – M PO3 – L	20	9	1

CO6	Apply timing analysis, timing closure, clock gating, power optimization, HLS directives and partial/dynamic reconfiguration for efficient FPGA design	3	PO1 – S PO2 – M PO3 – L	10	7, 9	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	40	40			20
CO2	40	40			20
CO3	20	20			10
CO4			40	40	20
CO5			40	40	20
CO6			20	20	10
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

FPGA and ASIC Design Fundamentals: ASIC & FPGA Design Flow using HDL - based Methodology - FPGA Programming Technologies - Antifuse, SRAM - based FPGAs - EPROM, EEPROM and Flash-based FPGA Architectures - LUT - based Logic Synthesis and Technology Mapping.

FPGA Logic Block Architectures: Actel ACT 1, ACT 2 and ACT 3 Logic Module Architectures - Xilinx LCA – XC3000, XC4000 and XC5200 Architectures - Modern FPGA Logic: ALMs and Fracturable LUTs.

Programmable I/O, Clocking and Interconnect: DC and AC Output / Input Buffer Architectures - Clock Distribution and Power Input Architectures - Actel ACT and Xilinx LCA Routing Architectures - Xilinx EPLD Interconnect – Comparison with FPGA.

Computer Arithmetic Architectures: Signed Digit, Fractional, Logarithmic and RNS Arithmetic - Fixed Point and Floating-Point Arithmetic Architectures - CORDIC Architectures for Signal Processing - Distributed Arithmetic based FPGA Architectures.

High-Speed Arithmetic Units: Pipelined and Modulo Adder Architectures - Array and High - Speed Multiplier Architectures - High - Speed Divider Architectures - Multiply - Accumulate (MAC) and Multiplier Adder Graph - FFT and Number Theoretic Transform (NTT) Architectures.

FPGA Design Optimization and Reconfigurable Computing: Timing Analysis, Constraints and Timing Closure - Power Optimization Techniques for FPGA - High - Level Synthesis (HLS) – Vitis HLS Overview - Partial and Dynamic Reconfiguration on FPGA.

Learning Resources

6.1 Text Book

- S.D. Brown, R.J. Francis, J. Rose and Z.G. Vranesic, Field-Programmable Gate Arrays, 1st Edition, Kluwer Academic Publishers, 1992.
- W.Wolf,FPGA-BasedSystemDesign,1stEdition,PrenticeHall/Pearson,2004.

6.2 Reference Books&Web resources

- D. Harris and S. Harris, “Digital Design and Computer Architecture: RISC-V Edition”, 1st Edition, Morgan Kaufmann, 2021.
- M.Parhami, “Computer Arithmetic: Algorithms and Hardware Designs”, 2nd Edition, Oxford University Press, 2010
- P.P.Chu, “FPGA Prototyping by Verilog Examples: Xilinx Micro Blaze MCS SoC Edition”, 2nd Edition, Wiley, 2018
- Xilinx/AMD – Vivado Design Suite User Guide, UG901, v2023.2, AMDInc.,2023

- Intel FPGA – Quartus Prime Pro Edition Design Software Handbook, v23.1, Intel Corporation, 2023

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	**FPGA and ASIC Design Fundamentals**	
	ASIC & FPGA Design Flow using HDL - based Methodology	1
	FPGA Programming Technologies - Anti fuses	1
	FPGA Programming Technologies SRAM - based	1
	FPGA Programming Technologies EPROM, EEPROM and Flash-based	1
	FPGA Architectures - LUT - based Logic Synthesis	1
	Technology Mapping.	1
2	**FPGA Logic Block Architectures**	
	Actel ACT 1, ACT 2 and ACT 3 Logic Module Architectures	1
	Xilinx LCA – XC3000	1
	XC4000	1
	XC5200 Architectures	1
	Modern FPGA Logic: ALMs	1
	Fracturable LUTs.	1
3	**Programmable I/O, Clocking and Interconnect**	
	DC and AC I/O Buffer Architectures	1
	Clock Distribution	1
	Power Input Architectures	1
	Actel ACT Routing Architectures	1
	Xilinx LCA Routing Architectures	1
	Xilinx EPLD Interconnect – Comparison with FPGA	1
4	**Computer Arithmetic Architectures**	
	Signed Digit	1
	Fractional and Logarithmic	1
	RNS Arithmetic	1
	Fixed Point Architectures	1
	Floating-Point Arithmetic Architectures	1
	CORDIC Architectures for Signal Processing	1
	Distributed Arithmetic based FPGA Architectures	1
5	**High-Speed Arithmetic Units**	
	Pipelined and Modulo Adder Architectures	1
	Array and High-Speed Multiplier Architectures	1
	High-Speed Divider Architectures	1
	Multiply-Accumulate (MAC)	1
	Multiplier Adder Graph-FFT	1
	Number Theoretic Transform (NTT) Architectures	1
6	**FPGA Design Optimization and Reconfigurable Computing**	
	Timing Analysis, Constraints	1
	Timing Closure	1
	Power Optimization Techniques for FPGA	1
	High- Level Synthesis (HLS) – Vitis HLS Overview	1
	Partial and Dynamic Reconfiguration on FPGA.	1
	Total Periods	36

Course Designer(s):

Dr. V. Vinoth thyagarajan, Associate Professor, vvkece@tce.edu
Dr. V. R. Venkatasubramani, Associate Professor, venthiru@tce.edu

26PCCG0	RF FRONT END SYSTEMS	Category	L	T	P	Credits
		PCC	2	1	0	3

Preamble

To provide a cohesive overview of the fundamental concepts required for the design and analysis of RF stages of a modern wireless system. This course presents overview of receiver architectures, various RF front end modules in the modern wireless systems and design specifications of the various RF systems. This course helps to understand the design principles of active RF circuits like LNA, Mixers and Oscillators. This course also presents characterization, testing of RF front end modules and integration.

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Explain the fundamentals of RF communication systems and emerging technologies.	TPS2	PO1 – M PO2 – L	10	SDG9	1
CO2	Design the RF front-end modules such as LNA , mixers and Oscillators	TPS3	PO1 – S PO2 – M PO3 – L	30	SDG9	1
CO3	Explain and compute the performance of various types of receiver architectures in terms of noise figure and gain	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG9	1
CO4	Apply antenna and propagation concepts to estimate wireless path loss using the Friis transmission equation.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG9	2
CO5	Summarize the characterization procedures of RF front-end circuits	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG9	2
CO6	Use RF measurement instruments to obtain wireless system characteristics and receiver performance	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG9	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	10	100			10
CO2	60				30
CO3	30				20
CO4			60	100	20
CO5			30		10
CO6			10		10
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Introduction to Wireless Systems Overview of wireless communication systems, architecture of radio transceivers, Principle, Classification, Cellular, Terahertz, 5G/6G wireless networks and emerging applications.
RF Front end building Blocks RF frontend subsystems and components, Low Noise Amplifiers (LNA), Noise figure, gain, Inter modulation distortion, Mixers and its characteristics, RF Filters and types, Frequency Synthesizers, Phase Locked Loop (PLL), RF Oscillators - one port negative resistance oscillators, Voltage controlled oscillator.
Receiver Architectures and Antennas - Super heterodyne, image reject type, Zero-IF receiver, low-IF receivers, characteristics- sensitivity and selectivity, Noise Figure and gain, comparison of architectures, performance trade-offs. Antenna parameters, wire and planar antennas, Radiation characteristics, wave propagation mechanisms, free-space path loss and Friis transmission equation. Design of antennas.
RF front end Characterization Integration of Building Blocks, DC Conditions, Scattering Parameters, Small-Signal and Transient Performance, Noise performance, Linearity, Front end Characterization: DC Test, Functionality Test, S-Parameter Test, Conversion Gain Test, Linearity Test, Noise Figure, Test, I/Q Imbalance, DC Offset.
Testing and Measurements- RF measurement techniques and instrumentation, Vector Network Analyzer (VNA), Spectrum Analyzer, receiver dynamic range measurements, over-the-air (OTA) testing of wireless systems, measurements in anechoic chambers.

Learning Resources

6.1.Text Book

- Joy Laskar, BabakMatinpour,Sudipto Chakraborty, Modern Receiver Front-ends- systems, design and integration, a john wiley& sons, inc., publication, 2004
- Ibrahim A. Haroun,, “Essentials of RF Front-end Design and Testing, A Practical Guide for Wireless Systems” Wiley IEEE Press 2024
- Behzad Razavi, *RF Microelectronics*, 2nd Edition, Prentice Hall / Pearson, 2011.

6.2.Reference Books & Web Resources

- David M Pozar: Microwave and RF design of WIreless systems, John Wiley and Sons, 2001.
- Les Besser and Rowan Gilmore, " Practical RF Circuit Design for Modern Wireless Systems- Passive Circuits and Systems", Vol.1, Artech house Publishers, Boston, London 2008.

Course Contents and Lecture Schedule

Module No.	Topic	No. of periods
1	**Introduction to Wireless Systems**	
1.1	Overview of wireless communication systems	0.5
1.2	Architecture of radio transceivers	0.5
1.3	Principle, Classification	0.5
1.4	Cellular, Terahertz, 5G/6G wireless networks and emerging applications	0.5
2	**RF Front end building Blocks**	
2.1	RF front end subsystems and components	1
2.2	Low Noise Amplifiers (LNA),Noise figure, Inter modulation distortion, gain	2
2.3	Mixers and its characteristics	2
2.4	RF Filters and types	1
2.5	Frequency Synthesizers, Phase Locked Loop(PLL)	1
2.6	RF Oscillators - one port negative resistance oscillators	2
2.7	Voltage controlled oscillator	1
3	**Receiver Architectures and Antennas**	
3.1	Super heterodyne, image reject type, Zero-IF receiver, low-IF receivers	1
3.2	Characteristics- sensitivity and selectivity, Noise Figure and gain	1
3.3	Comparison of architectures, performance trade-offs.	1
3.4	Antenna parameters	3
3.5	wire and planar antennas	2
3.6	Radiation characteristics	1
3.7	wave propagation mechanisms	1
3.8	free-space path loss and Friis transmission equation.	2
3.9	Design of antennas	3
4	**RF front end Characterization**	
4.1	Integration of Building Blocks, DC Conditions,	0.5
4.2	Scattering Parameters, Small-Signal and Transient Performance	0.5
4.3	Noise performance, Linearity	1
4.4	Front end Characterization: DC Test, Functionality Test	0.5
4.5	S-Parameter Test, Conversion Gain Test	0.5
4.6	Linearity Test, Noise Figure, Test	0.5
4.7	I/Q Imbalance, DC Offset	0.5
5	**Testing and Measurements**	
5.1	RF measurement techniques and instrumentation	1
5.2	Vector Network Analyzer (VNA)	1
5.3	Spectrum Analyzer	1
5.4	Receiver dynamic range measurements, over-the-air (OTA) testing of wireless systems	1
5.5	Measurements in anechoic chambers	1

Course Designer(s):

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26PCCH0	SDR FOR WIRELESS COMMUNICATION LABORATORY	Category	L	T	P	Credits
		PCC	0	0	4	2

1. Preamble

This laboratory course provides hands-on experience in implementing and analyzing wireless communication systems using Software Defined Radio (SDR) platforms. Students will perform real-time experiments on signal generation, modulation, synchronization, channel estimation, and spectrum analysis to understand practical wireless communication concepts. The course bridges theoretical foundations and real-world implementation, enabling learners to develop SDR-based communication applications and prototypes.

2. Prerequisite

NIL

3. Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Generate and analyze random, sinusoidal, and multi-tone signals using SDR platforms and spectrum analysis tools.	TPS3	PO1 – S PO2 – M PO3 – L	20 %	SDG 9	2
CO2	Implement digital modulation and demodulation techniques and evaluate their performance using BER measurements.	TPS3	PO1 – S PO2 – M PO3 – L	20 %	SDG 9	2
CO3	Apply pulse shaping, matched filtering, and synchronization techniques in SDR-based communication systems.	TPS3	PO1 – S PO2 – M PO3 – L	20 %	SDG 9	2
CO4	Perform channel estimation, equalization, and frequency offset correction for reliable wireless communication	TPS3	PO1 – S PO2 – M PO3 – L	20 %	SDG 9	2
CO5	Develop and demonstrate SDR-based wireless communication applications for text, audio, spectrum sensing, and IoT communication systems	TPS6	PO1 – S PO2 – S PO3 – M PO4 – M PO5 – S PO8 – M PO11 – L	20 %	SDG 4 & SDG9	2

4. Assessment Pattern: Cognitive Domain

Type of Assessment	Component	Marks	Remarks
Continuous Assessment	Pre-lab, In-lab, Post-lab	75	Conducted throughout the semester
Model Test	CO-wise (Cognitive, Psychomotor, Affective)	25	Mid/End semester internal test
Total Internal Marks		**100**	
End Semester Examination	CO-wise (Cognitive, Psychomotor, Affective)	100	As directed by COE or as per curriculum

5. List of Experiments with CO Mapping

S. No	Name of the experiment	Level of the experiment	Objectives	COs addressed
1.	Random signal generation, noise characterization, and spectrum analysis	Level 1	Models, Experimentation, Data Analysis, Communication	CO1
2.	Complex baseband representation and IQ imbalance	Level 1	Models, Experimentation, Data Analysis, Communication	CO1
3.	Single tone and multi-tone generation and detection using SDR	Level 1	Models, Experimentation, Data Analysis, Communication	CO1
4.	Modulation, demodulation and BER measurement using SDR	Level 1	Models, Experimentation, Data Analysis, Communication, Creativity	CO2
5.	Pulse shaping and matched filtering using SDR	Level 1	Models, Experimentation, Data Analysis, Communication, Creativity	CO3
6.	Timing and carrier frequency synchronization using SDR	Level 1	Models, Experimentation, Data Analysis, Communication, Creativity	CO3
7.	Channel estimation and equalization using SDR	Level 1	Models, Experimentation, Data Analysis, Communication, Creativity	CO4
8.	Frame detection & frequency offset correction	Level 1	Models, Experimentation, Data Analysis, Communication, Creativity	CO4
9.	Text/audio transmission and reception using SDR.	Level 3	Design, Communication, Creativity, Ethics & Integrity	CO5
10.	Wi-Fi/ZigBee signal analysis using SDR	Level 3	Design, Communication, Creativity, Ethics & Integrity	CO5
11.	Spectrum Sensing and Occupancy Detection for Cognitive Radio	Level 3	Design, Communication, Creativity, Ethics & Integrity	CO5

6. Course Designer(s):

- Dr.M.N.Suresh – Associate Professor, mnsece@tce.edu
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26PCPA0	COMPUTER VISION AND IOT	Category	L	T	P	Credits	TE Type
		PEC	2	0	2	3	TCP-T

Preamble

This course focuses on the integration of Computer Vision and the Internet of Things (IoT) to design and develop intelligent, connected systems. It introduces the fundamental concepts of image formation, feature extraction, object recognition, and machine learning techniques for vision-based applications. The course also covers IoT architecture, sensors, communication protocols, cloud connectivity, and edge computing technologies. Through practical experiments and application-oriented learning, students gain the skills required to develop smart solutions for surveillance, agriculture, healthcare, and industrial automation, enabling real-time monitoring, analysis, and decision-making in diverse domains.

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TCE Proficiency Scale	PO Addressed	CO Weightage	SDG Addressed	SDG Level
CO1	Utilize camera parameters, perspective projection, and 3D–2D transformations to solve computer vision problems	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9, SDG 11	2
CO2	Apply image processing techniques for object detection and recognition	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9, SDG 11	2
CO3	Apply machine learning techniques to process and interpret visual data	TPS4	PO1 – S PO2 – M PO3 – L	10	SDG 9, SDG 11	2
CO4	Implement IoT-based applications using sensors and embedded devices	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9, SDG 11	2
CO5	Implement computer vision algorithms with IoT platforms for real-time monitoring	TPS3	PO1 – S PO2 – S PO3 – M PO4 – L	10	SDG 9, SDG 11	2
CO6	Demonstrate the smart systems for healthcare, agriculture, and surveillance using Computer Vision and IoT	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 3, SDG4, SDG 9, SDG 11	2

Assessment Pattern

CO	Theory		Practical		Terminal Exam (Theory)
	CAT1	CAT2	OCR/Continuous Assessment	Model Test CO-wise	
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30		20	20	10
CO2	70		20	20	20
CO3		30	20	20	20
CO4		20	20	20	20
CO5		20	10	10	20
CO6		30	10	10	10
Total	100	100	100	100	100

Assessment Pattern: Practical Component

Type of Assessment	Component	Marks	Remarks
Continuous Assessment	Pre-lab, In-lab, Post-lab	75	Conducted throughout the semester
Model Test	CO-wise (Cognitive, Psychomotor, Affective)	25	Rubrics covering all Domains of learning
Total Internal Marks		**100**	
End Semester Examination	CO-wise (Cognitive, Psychomotor, Affective)	100	Rubrics covering all Domains of learning

Syllabus

Computer Vision Fundamentals
Introduction to Computer Vision, Digital Image Representation, Image Formation Process, Camera Models, Camera Intrinsic and Extrinsic Parameters, Perspective Projection.

Image Processing Techniques
Image Enhancement, Filtering Techniques, Edge Detection, Image Segmentation.

Feature Extraction and Object Recognition
Feature Detection and Description, Harris Corner Detection, Scale Invariant Feature Transform (SIFT), Histogram of Oriented Gradients (HOG), Feature Matching, RANSAC, Performance Evaluation Metrics, Object Detection, Object Tracking, Pattern Recognition Techniques.

Machine Learning for Vision Applications
Introduction to Machine Learning, Convolutional Neural Networks (CNNs), Image Classification.

Internet of Things Fundamentals
IoT Architecture, Sensors and Actuators, Embedded Systems, Smart Sensors, Cloud Integration.

IoT Communication and Data Management
Wi-Fi, Bluetooth, ZigBee, MQTT, HTTP Protocols, Data Transmission, Security and Privacy in IoT Systems, Real-Time Data Analytics, Visualization Dashboards.

Vision-Enabled IoT Systems
Vision Sensors and Smart Cameras, Edge Computing Concepts, Integration of Computer Vision and IoT, Smart Surveillance Systems, Smart Agriculture, Healthcare Monitoring, Industrial Automation.

Practical: (Using Python)

1. Basic Image Processing Operations using Python and OpenCV.
2. Image Enhancement and Filtering Techniques.
3. Edge Detection and Image Segmentation.
4. Feature Detection and Matching using Harris Corner Detector, SIFT or ORB.
5. Object Detection and Tracking using OpenCV.
6. Image Classification using a Pre-trained CNN Model.
7. Sensor Interfacing and Data Acquisition using IoT Devices.
8. Cloud-Based Monitoring and Data Visualization for IoT Applications.
9. Mini Project: Development of a Vision-Based IoT System using an Edge Device.

Text Book

- Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer, 2022.
- Adrian Rosebrock, "Practical Python and OpenCV", PyImageSearch, 2021.
- Arshdeep Bahga and Vijay Madisetti, "Internet of Things: A Hands-On Approach", Universities Press, 2015

Reference Books & web resources

- Rafael C. Gonzalez and Richard E. Woods, "Digital Image Processing", Pearson, 2018.
- Jan Erik Solem, "Programming Computer Vision with Python", O'Reilly Media, 2012.
- Olivier Hersent, David Boswarthick, and Omar Elloumi, "The Internet of Things", Wiley, 2012.
- https://nptel.ac.in/courses/106105216 - Computer Vision NPTEL course by Prof. Jayanta Mukhopadhyay, IIT Kharagpur,
- https://www.tensorflow.org

SDG Alignment

Activities aligned with SDGs addressed:

1. SDG 3 - Development of computer vision and IoT-based healthcare monitoring systems for patient observation and smart surveillance systems for public safety and emergency response.
2. SDG 4 – Provides hands-on learning experiences in Computer Vision, IoT, Machine Learning, and Edge Computing through laboratory experiments and mini projects.
3. SDG 9 - Development of intelligent monitoring and predictive systems for industrial processes using sensors and machine learning techniques. Foster innovation through the integration of embedded systems, communication protocols, cloud computing, and edge analytics.
4. SDG 11 –Implement IoT-enabled solutions for smart surveillance, traffic monitoring, public infrastructure management, and environmental observation.

Course Contents and Lecture Schedule

Module No	Topics	No of Periods	**Course Outcomes**
1	**Computer Vision**	1	CO1
1.1	Image formation		CO1
1.2	Camera intrinsic and extrinsic parameters		CO1
1.3	3D-2D Transformations	1	CO1
1.4	Euler Angle		CO1
1.5	Rotation Matrices		CO1
1.6	Translation	1	CO1
1.7	Perspective Projection		CO1
2	**Image Processing Techniques**	1	CO2
2.1	Image Enhancement		CO2
2.2	Filtering Techniques		CO2
2.3	Edge Detection	1	CO2
2.3	Image Segmentation		CO2

3	**Feature Extraction and Object Recognition**	1	CO2
3.1	Feature detectors and descriptors		CO2
3.2	Harris corner detection –		CO2
3.3	Scale Invariant Feature Transform (SIFT),	2	CO2
3.4	Histogram of Oriented Gradients (HOG)		CO2
3.5	Local Binary Pattern (LBP)	1	CO2
3.6	Feature matching		CO2
3.7	RANSAC		
3.8	Performance Evaluation Metric		CO2
3.9	Case study: Object Detection	1	CO2
3.10	Case study: Object tracking		CO2
3.11	Case study: Pattern recognition techniques		CO2
4	**Machine Learning for Vision Applications:**	1	CO3
4.1	Introduction to machine learning		CO3
4.2	CNN basics	1	CO3
4.3	Image classification	1	CO3
5	**Internet of Things Fundamentals**	1	CO4
5.1	IoT architecture		CO4
5.2	Sensors and actuators	1	CO4
5.3	Embedded systems		CO4
5.4	Communication protocols	1	CO4
5.5	Cloud integration		CO4
6	**IoT Communication and Data Management**	1	CO4
6.1	Wi-Fi		CO4
6.2	Bluetooth		CO4
6.3	ZigBee	1	CO4
6.4	MQTT		CO4
6.5	HTTP protocols	1	CO4
6.6	Data transmission and security in IoT systems		CO4
6.7	Edge computing concepts.		CO4
6.8	Real-time data analytics	1	CO4
6.9	Visualization dashboards		CO4
7	**Vision enabled IoT Systems**	1	CO5, CO6
7.1	Vision Sensors and Smart Cameras		CO5, CO6
7.2	Edge Computing Concepts		CO5, CO6
7.3	Integration of Computer Vision and IoT.	1	CO5, CO6
7.4	Smart Surveillance Systems		CO6
7.5	Smart Agriculture,	2	CO6
7.6	Healthcare Monitoring		CO6
7.7	Industrial Automation		CO6
	Total Periods	**24**	

List of Experiments with CO Mapping

Sl. No.	Name of the Experiment	Level of Experiment	Objective(s)	COs Addressed
1.	Basic Image Processing Operations using Python and OpenCV.	1	3-Experimentation	CO1
2.	Image Enhancement and Filtering Techniques.	1	3-Experimentation	CO1

3.	Edge Detection and Image Segmentation.	1	3-Experimentation	CO2
4.	Feature Detection and Matching using Harris Corner Detector, SIFT or ORB.	1	3-Experimentation	CO2
5.	Object Detection and Tracking using OpenCV.	2	3-Experimentation	CO3
6.	Image Classification using a Pre-trained CNN Model.	2	3-Experimentation	CO3
7.	Sensor Interfacing and Data Acquisition using IoT Devices.	2	3-Experimentation	CO5, CO6
8.	Cloud-Based Monitoring and Data Visualization for IoT Applications.	2	5-Design	CO1 - CO6

Course Designer(s):

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26PCPB0	HYPERSPECTRAL IMAGING AND INTELLIGENT ANALYSIS	Category	L	T	P	Credits
		PEC	3	0	0	3

Preamble

This course aims at understanding the characteristics of Hyperspectral Imaging data and applying suitable coding techniques to efficiently analyse and classify the HSI data in real-time applications with case studies.

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Characterize the hyperspectral Image data in EM Spectrum with its performance measures.	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG 9	2
CO2	Enhance the hyper data using preprocessing methods such as noise reduction techniques.	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG 9	2
CO3	Measure and extract the spectral features from HSI data using various spectral indices.	TPS4	PO1 – S PO2 – M PO3 – L	20	SDG 9	2
CO4	Recognize and classify the objects from the image using ML algorithms.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	2
CO5	Apply recent deep learning concepts such as CNN, RNN with hyperspectral data.	TPS3	PO1 – S PO2 – L PO3 – M	20	SDG 9	2
CO6	Analyse different real-time applications with case studies	TPS3	PO1 – S PO2 – S PO3 – M PO4 – M PO6 – L	20	SDG 9, SDG 12/13	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30	30			10
CO2	30	30			10
CO3	40	40			20
CO4			30	30	20
CO5			30	30	20
CO6			40	40	20
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Module1:

Fundamentals of Hyperspectral Imaging:

Electromagnetic Spectrum – Near-Infrared Imaging and Spectroscopy – Spatial, Spectral and Radiometric Resolution – Components of Hyperspectral Imaging Systems – Hyperspectral Data Acquisition – Hypercube Representation – Reflectance – Transmittance – Pixel Bit Depth.

Module 2:

Hyperspectral Image Preprocessing:

Image Acquisition – Calibration – Atmospheric Correction – Noise Reduction – Dimensionality Reduction – Band Selection – Spectral Mapping – Pixel Purity Index (PPI) – Minimum Noise Fraction (MNF).

Module 3:

Spectral Feature Extraction and Analysis:

Spectral Similarity Measures – Spectral Discriminability Measures – Spectral Indices – Endmember Extraction – Spectral Unmixing – Spatial-Spectral Feature Extraction.

Module 4:

Multivariate Analysis and Machine Learning:

Principal Component Analysis (PCA) – Partial Least Squares Discriminant Analysis (PLS-DA) – Classical Least Squares (CLS) – Support Vector Machines (SVM) – k-Nearest Neighbour (k-NN) – Random Forest – Gradient Boosting.

Module 5:

Deep Learning for Hyperspectral Imaging:

Sub-pixel Mapping – 1D CNN – 2D CNN – 3D CNN – Vision Transformers for Hyperspectral Image Classification.

Module 6:

Applications of Hyperspectral Imaging:

Remote Sensing – Material Characterization and Chemical Composition Analysis – Food Quality Inspection and Processing – Biomedical Imaging – Case Studies using Public Hyperspectral Datasets.

Learning Resources

6.1 Text Book

- Hans F.Grahn, Paul Geladi, “Techniques and Applications of Hyperspectral Image Analysis”, 1st Edition, 2007, John Wiley & Sons Inc

6.2 Reference Books & Web resources

- Bosoon Park, Renfu Lu, “Hyperspectral Imaging Technology in Food and Agriculture”, Springer – Food Engineering Series
- Chein I Chang, “ Hyperspectral Imaging Techniques for Spectral Detection and Classification”, Springer Science+Business Media, LLC
- Saurabh Prasad, Jocelyn Chanussot Hyperspectral Image Analysis: Advances in Machine Learning and Signal Processing (Advances in Computer Vision and Pattern Recognition), 1st Edition, 2020, Springer
- Annamalai Manickavasagan Hemantha Jayasuriya, “Imaging with Electromagnetic Spectrum – Applications in Food and Agriculture”, Springer
- Prasad S. Thenkabail, John G. Lyon, Alfredo Huete , “Hyperspectral Indices and Image Classifications for Agriculture and Vegetation” CRC Press, Taylor and Francis Group.
- N.C.Basantia, Leo M.L.Nollet, Mohammed Kamruzzaman, “Hyperspectral Imaging Analysis and Applications for Food Quality” 1st Edition, 2018 CRC Press, Taylor and Francis Group.

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	**Fundamentals of Hyperspectral Imaging:** Electromagnetic Spectrum – Near-Infrared Imaging and Spectroscopy	1
1	Spatial, Spectral and Radiometric Resolution	1
1	Components of Hyperspectral Imaging Systems – Hyperspectral Data Acquisition - Hypercube Representation`	1
1	Reflectance – Transmittance – Pixel Bit Depth	1
2	**Hyperspectral Image Preprocessing:** Image Acquisition – Calibration - Atmospheric Correction	1
2	Noise Reduction – Dimensionality Reduction	2
2	Band Selection – Spectral Mapping – Pixel Purity Index (PPI) – Minimum Noise Fraction (MNF).	2
3	**Spectral Feature Extraction and Analysis:** Spectral Similarity Measures	1
3	Spectral Discriminability Measures – Spectral Indices	2
3	Endmember Extraction – Spectral Unmixing	2
3	Spatial-Spectral Feature Extraction	1
4	**Multivariate Analysis and Machine Learning:** Principal Component Analysis (PCA)	2
4	Partial Least Squares Discriminant Analysis (PLS-DA) – Classical Least Squares (CLS)	2
4	Support Vector Machines (SVM)	1
4	k-Nearest Neighbour (k-NN) – Random Forest	2
4	Gradient Boosting	1
5	**Deep Learning for Hyperspectral Imaging:** Sub-pixel Mapping	1
5	1D CNN – 2D CNN	2
5	3D CNN	2
5	Vision Transformers for Hyperspectral Image Classification	2
6	**Applications of Hyperspectral Imaging:** Remote Sensing	2
6	Material Characterization and Chemical Composition Analysis	1
6	Food Quality Inspection and Processing – Biomedical Imaging	2
6	Case Studies using Public Hyperspectral Datasets	1
	Total Periods	**36**

Course Designer(s):

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Dr. B. Sathya Bama, Professor, sbece@tce.edu

22PCPC0	MACHINE LEARNING FOR COMMUNICATION	Category	L	T	P	Credits	TE Type
		PEC	2	0	2	3	TCP-P

Preamble

This course introduces machine learning techniques in wireless communication systems, including supervised, semi-supervised, unsupervised, and transfer learning approaches. It covers dataset preparation using single-carrier, OFDM, MIMO, and OTFS systems for tasks such as modulation classification, decoding, beamforming, and spectrum sensing. It also focuses on AI-driven methods for parameter estimation, synchronization, and resource management in next-generation wireless networks.

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TCE Proficiency Scale	PO Addressed	CO Weightage	SDG Addressed	SDG Level
CO1	Apply supervised, semi-supervised, and unsupervised machine learning techniques, and transfer learning models to solve wireless communication problems.	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG 9	2
CO2	Prepare datasets using single-carrier, OFDM, MIMO, and OTFS systems for wireless communication analysis	TPS3	PO1 – S PO2 – M PO3 – L PO5 - S	20	SDG 9	2
CO3	Apply machine learning techniques to perform modulation classification, LDPC code decoding, beamforming, and spectrum sensing in wireless communications	TPS3	PO1 – S PO2 – M PO3 – L PO5 – S	20	SDG 9	2
CO4	Use AI/ML methods for parameter estimation in wireless communication systems	TPS3	PO1 – S PO2 – M PO3 – L PO5 – S	15	SDG 9 SDG 11	2
CO5	Apply AI/ML methods for synchronization in wireless communication systems	TPS3	PO1 – S PO2 – M PO3 – L PO5 – S	15	SDG 9	2
CO6	Use AI/ML methods to improve resource allocation, spectrum sharing, and power control in wireless systems	TPS3	PO1 – S PO2 – M PO3 – L PO5 – S	20	SDG 9 SDG 11	2

Assessment Pattern

CO	Theory		Practical		Terminal Exam - Practical
	CAT1	CAT2	OCR/Continuous Assessment	Model Test CO-wise	
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	20	-	10	10	100
CO2	40	-	20	20	
CO3	40	-	20	20	
CO4	-	30	15	15	
CO5	-	30	15	15	
CO6	-	40	20	20	
Total	100	100	100	100	100

Assessment Pattern: Practical Component

Type of Assessment	Component	Marks	Remarks
Continuous Assessment	Pre-lab, In-lab, Post-lab	75	Conducted throughout the semester
Model Test	CO-wise (Cognitive, Psychomotor, Affective)	25	Rubrics covering all Domains of learning
Total Internal Marks		**100**	
End Semester Examination	CO-wise (Cognitive, Psychomotor, Affective)	100	Rubrics covering all Domains of learning

Syllabus

Module 1:
Introduction to Machine Learning - Overview of supervised, semi supervised and unsupervised, Regression Model, SVM, KNN, CNN, RNN, LSTM, Transfer learning
Module 2:
Wireless Techniques and Dataset Creation - Overview of Single-Carrier, OFDM, MIMO, and OTFS Systems and Their Dataset Creation
Module 3:
AI/ML-Based Wireless Signal Processing - Modulation classification, LDPC code decoding, Beamforming (based on 3GPP Standard), and Spectrum sensing
Module 4:
AI/ML Based Signal Estimation and Detection - AL/ML based Parameter estimation, channel estimation, symbol rate estimation, STO and CFO estimation.
Module 5:
AI/ML Based Resource allocation - Resource allocation, Spectrum sharing, Power allocation.

Text Book

- Phil Kim, MATLAB Deep Learning With Machine Learning, Neural Networks and Artificial Intelligence, Apress, 2017.
- Goodfellow, Y. Bengio, and A. Courville, Deep Learning, MIT Press, 2016
- F.-L. Luo, Machine Learning for Future Wireless Communications, Wiley-IEEE Press, 2020

Reference Books & web resources

- Y. C. Eldar, A. Goldsmith, D. Gündüz, and H. V. Poor, Machine Learning and Wireless Communications, Cambridge University Press, 1st edition, 2022.

- R. He and Z. Ding, Applications of Machine Learning in Wireless Communications. London, U.K.: The Institution of Engineering and Technology, 2019.
- M. Viswanathan, Digital Modulations using Python. Independently published, 2019.

SDG Alignment

Activities aligned with SDGs addressed:

- AI-based modulation classification to improve wireless communication reliability, contributing to smart and sustainable digital infrastructure
- Develop AI-driven wireless communication models that enhance reliability, efficiency, and adaptability of next-generation digital infrastructure

Course Contents and Lecture Schedule

Module No	Topics	No of Periods	Course Outcomes
1	Overview of supervised algirithms	2	CO1
	Overview of semi supervised algorithms	1	CO1
	Overview of unsupervised algorithms	1	CO1
2	Overview of Single-Carrier systems and their dataset creation	1	CO2
	Overview of OFDM system and its dataset creation	1	CO2
	Overview of MIMO system and its dataset creation	1	CO2
	Overview of OTFS system and its dataset creation	1	CO2
3	AI/ML based Modulation classification	1	CO3
	AI/ML based LDPC code decoding	1	CO3
	AI/ML based Beamforming (based on 3GPP Standard)	1	CO3
	AI/ML based Spectrum sensing	1	CO3
4	AL/ML based Parameter estimation	2	CO4
	AL/ML based channel estimation	2	CO4
	AL/ML based symbol rate estimation	2	CO5
	AL/ML based STO estimation	1	CO5
	AL/ML based CFO estimation	1	CO5
5	Resource allocation	2	CO6
	Spectrum sharing	1	CO6
	Power allocation	1	CO6
	Total Periods	**24**	

List of Experiments with CO Mapping

Sl. No.	Name of the Experiment	Level of Experiment	Objective(s)	COs Addressed
1.	CNN-based modulation classification	TPS3	2,3,4,9,10,11	CO2
2.	DNN-based MIMO detector	TPS3	2,3,4,9,10,11	CO2
3.	ML-based LDPC decoding	TPS3	2,3,4,9,10,11	CO3
4.	Deep learning-based beamforming	TPS3	2,3,4,9,10,11	CO3
5.	AI-based channel estimation	TPS3	2,3,4,9,10,11	CO4
6.	ML-based STO/CFO estimation	TPS3	2,3,4,9,10,11	CO5
7.	Deep learning for spectrum sharing	TPS3	2,3,4,9,10,11	CO6
8.	Reinforcement learning-based power allocation	TPS3	2,3,4,9,10,11	CO6

Course Designer(s):

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26PCPD0	RADAR SYSTEMS	Category	L	T	P	Credits
		PEC	2	1	0	3

Preamble

This course introduces the fundamentals of radar systems, including range measurement, Doppler estimation, radar equations, and target detection techniques. It covers continuous-wave, pulsed, and synthetic aperture radar (SAR) systems along with their signal processing methods. This course explores the applications of radar technology in surveillance, weather monitoring, automotive safety, near-range sensing, and emerging intelligent sensing systems.

Prerequisite

Nil

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weig-htage	SDG addressed	SDG Level
CO1	Apply radar equations and radar cross-section concepts to evaluate target detection and ranging performance in radar systems.	TPS3	PO1 – S PO2 – M PO3 – L	10%	SDG 9	3
CO2	Analyze the operation and performance characteristics of Continuous Wave (CW), Linear FM CW, and Pulsed Radar systems for different sensing applications.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	20%	SDG 9	3
CO3	Analyse range and Doppler ambiguities in radar systems and evaluate their impact on target localization and velocity estimation.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	20%	SDG 9	3
CO4	Apply radar detection techniques, including probability of detection, probability of false alarm, pulse integration, and CFAR processing, to detect targets in noisy environments.	TPS3	PO1 – S PO2 – M PO3 – L	20%	SDG 9	3
CO5	Apply Synthetic Aperture Radar (SAR) geometry, radar equations, and signal processing techniques for high-resolution radar imaging applications.	TPS3	PO1 – S PO2 – M PO3 – L	15%	SDG 9	3
CO6	Apply radar-based sensing methods for surveillance, weather observation, automotive safety, and near-range sensing applications.	TPS3	PO1 – S PO2 – M PO3 – L	15%	SDG 9	3

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	20	20	-	-	10
CO2	40	40	-	-	20
CO3	40	40	-	-	20
CO4	-	-	40	40	20
CO5	-	-	30	30	15
CO6	-	-	30	30	15
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Module 1:
RADAR Fundamentals - Radar classification, range, range resolution, Doppler frequency, radar equation, radar cross section
Module 2:
Continuous wave and Pulsed radars - Functional block diagram, CW radar equation, frequency modulation, Linear FM CW radar, pulsed radar, range and Doppler ambiguities
Module 3:
Radar detection - Detection in the presence of noise, probability of false alarm, probability of detection, pulse integration, constant false alarm rate (CFAR).
Module 4:
Synthetic Aperture Radar - Introduction, Real Versus Synthetic Arrays, Side Looking SAR Geometry, SAR Design Considerations, SAR Radar Equation, SAR Signal Processing.
Module 5:
Radar Applications - Surveillance Radar, Weather Radar, Automotive Radar, Near-Range Sensing Applications (Occupant Detection, Classification, Gesture Recognition), and Emerging Radar Technologies and Trends.

Learning Resources

6.1 Text Book

- Bassem R. Mahafza, Radar Systems Analysis *and* Design *Using* MATLAB, CRC Press, 2000.
- Mark A.Richards, “Fundamentals of Radar Signal Processing”, Tata McGraw Hill, 1st Edition, 2005.

6.2 Reference Books & Web resources

- Mark A.Richards, James A.Scheer, William A.Holm,” Principles of Modern RADAR”, Scitech Publishing, 2010.
- Nathanson, F.E, “Radar Design Principles, second edition, McGraw-Hill, New York, 2nd Edition, 1991.

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	Radar classification, range, range resolution	2
	Doppler frequency, radar equation,	2
	Radar cross section	2
2	Functional block diagram of Radar, CW radar equation	1
	Frequency modulation, Linear FM CW radar	2
	Pulsed radar	1

	Range and Doppler ambiguities	4
3	Detection in the presence of noise	2
	Probability of false alarm,	2
	Probability of detection, pulse integration,	2
	Constant false alarm rate	2
4	Introduction to Synthetic RADAR	1
	Real Versus Synthetic Arrays, Side Looking SAR Geometry,	2
	SAR Design Considerations, SAR Radar Equation,	3
	SAR Signal Processing	2
5	Surveillance Radar, Weather Radar,	1
	Automotive Radar,	2
	Near-Range Sensing Applications (Occupant Detection, Classification, Gesture Recognition), and.	2
	Emerging Radar Technologies and Trends	1
	Total Periods	**36**

Course Designer(s):

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26PCPE0	DIGITAL INTEGRATED CIRCUITS	Category	L	T	P	Credits
		PEC	2	1	0	3

Preamble

Digital systems form the foundation of modern electronic devices by processing information in binary form. This course provides students with hands-on training in the design and analysis of combinational and sequential logic circuits. It emphasizes the use of Hardware Description Language (HDL) for modelling, simulating, and implementing digital logic designs on standard integrated circuits, preparing students for real-world digital system applications.

Prerequisite

Nil

Course Outcomes

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Describe and compare digital IC implementation methodologies – full custom, standard cell, array-based and FPGA-based – and evaluate design metrics of area, speed, power and reliability for technology selection.	TPS2	PO1 – M PO2 – L	10%	SDG 4	1
CO2	Analyze static CMOS, dynamic CMOS and pass transistor logic families; design latches, flip-flops and pipelined datapath structures; and evaluate timing parameters, clocking issues and metastability in sequential circuits.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	10%	SDG 4	1
CO3	Model electrical wire interconnects including RC, capacitive, resistive and inductive parasitic effects, and apply crosstalk reduction, buffering and advanced interconnect techniques to ensure signal integrity.	TPS3	PO1 – S PO2 – M PO3 – L	24%	SDG 4 SDG 8 SDG 9 SDG 17	2
CO4	Classify timing methodologies, design synchronous and self-timed/asynchronous circuits, analyze clock distribution networks and implement PLL-based clock synthesis for skew and jitter minimization.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	24%	SDG 4 SDG 8 SDG 9 SDG 17	2
CO5	Design and verify arithmetic building blocks – ripple carry and carry lookahead adders, array multipliers, barrel shifters and datapath elements – and analyze area–power–speed trade-offs using EDA simulation	TPS3	PO1 – S PO2 – M PO3 – L	12%	SDG 4 SDG 8 SDG 9 SDG 17	2

CO6	Analyze SRAM and DRAM memory core architectures, design peripheral circuits including decoders and sense amplifiers, and evaluate memory reliability, yield, fault tolerance and low-power design strategies	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	20%	SDG 4 SDG 8 SDG 9 SDG 17	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	20	20	-	-	10
CO2	30	30	-	-	10
CO3	50	50	-	-	20
CO4	-	-	30	30	20
CO5	-	-	30	30	20
CO6	-	-	40	40	20
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Digital IC Implementation Methodologies: Full Custom Design Methodology and Design Flow - Standard Cell / Semi-Custom Design Methodology - Array-Based and FPGA-Based Design Approaches - Design Metrics: Area, Speed, Power and Reliability

CMOS Logic Design and Sequential Circuits: Static CMOS Logic Families and Design Techniques - Dynamic CMOS and Pass Transistor Logic - Timing Parameters and Clocking Issues in Sequential Circuits - Latches, Flip-Flops, Dynamic Registers and Metastability - Sequential Logic Optimization using Pipelining - CMOS Inverter Characteristics and Simulation using EDA Tools.

Interconnects and Signal Integrity: Electrical Wire and RC Interconnect Models - Capacitive Effects and Coupling Capacitance - Resistive Effects and Interconnect Delay - Inductive Effects and Signal Integrity - Crosstalk Reduction, Buffering and Advanced Interconnect Techniques.

Timing and Clocking in Digital Circuits: Timing Classification and Timing Constraints - Synchronous Interconnect and Clock Distribution - Synchronous Design Methodology - Self-Timed and Asynchronous Circuit Design - Clock Synthesis, Clock Skew and PLL-Based Synchronization.

Arithmetic Circuit and Datapath Design: Ripple Carry and Carry Look-Ahead Adders - Array and Fast Multiplier Architectures - Barrel Shifters and Datapath Elements - Area–Power–Speed Trade-offs in Datapath Structures - Simulation and Verification of Arithmetic Blocks using EDA Tools.

Memory Subsystem Design: Memory Classification and Organization - SRAM / DRAM Memory Core Architecture - Decoders, Sense Amplifiers and Peripheral Circuits - Memory Reliability, Yield and Fault Tolerance - Low-Power Memory Design and Power Dissipation.

Learning Resources

6.1 Text Book

- Jan M. Rabaey, Anantha Chandrakasan and Borivoje Nikolic, Digital Integrated Circuits: A Design Perspective, 2nd Edition, Pearson Prentice Hall, 2003
- Neil H.E. Weste and David Money Harris, CMOS VLSI Design: A Circuits and Systems Perspective, 4th Edition, Addison-Wesley / Pearson, 2011

6.2 Reference Books & Web resources

- Sung-Mo Kang, Yusuf Leblebici and Chulwoo Kim, “CMOS VLSI Design: Circuit and System Perspectives”, 4th Edition, McGraw-Hill, 2015
- Kaushik Roy and Sharat C. Prasad, “Low-Power CMOS VLSI Circuit Design”, 1st Edition, Wiley-Interscience, 2000
- Wayne Wolf, “Modern VLSI Design: IP-Based Design”, 4th Edition, Prentice Hall, 2008
- Cadence Design Systems –Virtuoso Analog Design Environment User Guide, IC6.1.8, Cadence Design Systems, 2020
- Synopsys Inc. – HSPICE User Guide: Simulation and Analysis, vO-2018.09, Synopsys Inc., 2018

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	**Digital IC Implementation Methodologies**	
1.1	Full Custom Design Methodology and Design Flow	1
1.2	Standard Cell / Semi-Custom Design Methodology	1
1.3	Array-Based and FPGA-Based Design Approaches	1
1.4	Design Metrics: Area, Speed, Power and Reliability	1
2	**CMOS Logic Design and Sequential Circuits**	
2.1	Static CMOS Logic Families and Design Techniques	1
2.2	Dynamic CMOS and Pass Transistor Logic	1
2.3	Timing Parameters and Clocking Issues in Sequential Circuits	1
2.4	Latches, Flip-Flops, Dynamic Registers and Metastability	1
2.5	Sequential Logic Optimization using Pipelining	1
2.6	CMOS Inverter Characteristics and Simulation using EDA Tools.	2
3	**Interconnects and Signal Integrity**	
3.1	Electrical Wire and RC Interconnect Models	1
3.2	Capacitive Effects and Coupling Capacitance	1
3.3	Resistive Effects and Interconnect Delay	1
3.4	Inductive Effects and Signal Integrity	1
3.5	Crosstalk Reduction, Buffering	1
3.6	Advanced Interconnect Technique	1
4	**Timing and Clocking in Digital Circuits**	
4.1	Timing Classification and Timing Constraints	2
4.2	Synchronous Interconnect and Clock Distribution	1
4.3	Synchronous Design Methodology	1
4.4	Self-Timed and Asynchronous Circuit Design	1
4.5	Clock Synthesis, Clock Skew and PLL-Based Synchronization	2
5	**Arithmetic Circuit and Datapath Design**	
5.1	Ripple Carry and Carry Look-Ahead Adders	1
5.2	Array and Fast Multiplier Architectures	1
5.3	Barrel Shifters and Datapath Elements	1
5.4	Area–Power–Speed Trade-offs in Datapath Structures	1
5.5	Simulation and Verification of Arithmetic Blocks using EDA Tools	2
6	**Memory Subsystem Design**	
6.1	Memory Classification and Organization	2
6.2	SRAM / DRAM Memory Core Architecture	1
6.3	Decoders, Sense Amplifiers and Peripheral Circuits	1
6.4	Memory Reliability, Yield and Fault Tolerance	1
6.5	Low-Power Memory Design and Power Dissipation	1
	Total Hours	36

Course Designer(s):

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Dr.D.Gracia Nirmala Rani, Professor, gracia@tce.edu

26PCPF0	INDUSTRIAL IoT	Category	L	T	P	Credits
		PEC	3	0	0	3

Preamble

This course introduces the concepts of Industrial Internet of Things (IIoT) and Industry 4.0 for smart industrial automation. It covers industrial communication, cyber-physical systems, cloud and fog computing, machine learning, and cybersecurity. Students will learn IIoT architectures, protocols, and enabling technologies for connected industries. The course also explores real-world IIoT applications and case studies in smart manufacturing, healthcare, and industrial systems.

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Explain the fundamentals of IoT, IIoT, Industry 4.0 concepts, sensing and actuation, and industrial communication systems.	TPS2	PO1 – M PO2 – L	10	SDG 9	L1
CO2	Explain Cyber Physical Systems (CPS) and the role of enabling technologies such as industrial sensors, artificial intelligence, big data analytics, AR, VR, and industrial automation.	TPS2	PO1 – M PO2 – L	10	SDG 9	L1
CO3	Apply Industrial IoT architecture concepts, communication protocols, networking layers, industrial gateways, and cloud integration for industrial applications.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	L1
CO4	Apply machine learning, cloud computing, fog computing, software-defined networking, and cybersecurity concepts in Industrial IoT environments.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	L2
CO5	Apply Industrial IoT technologies to smart manufacturing, healthcare, power plants, and industrial automation systems.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	L2
CO6	Apply Industrial IoT concepts to analyze industrial case studies and propose suitable Industry 4.0 solutions for real-world applications.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	L2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30	30			10
CO2	30	30			10
CO3	40	40			20
CO4			30	30	20
CO5			30	30	20
CO6			40	40	20
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Introduction to Industry 4.0 and IIoT: Fundamentals of IoT and IIoT, sensing and actuation, industrial communication, M2M communication, Industry 4.0 concepts, smart manufacturing, and smart factories.

Cyber Physical Systems and Enabling Technologies: Cyber Physical Systems (CPS), industrial sensors, artificial intelligence, big data analytics, augmented reality (AR), virtual reality (VR), and industrial automation systems.

Industrial IoT Architecture and Communication: IIoT architecture, sensing, processing, communication and networking layers, industrial gateways, communication protocols, and cloud integration.

Industrial Analytics, Cloud, Fog and Security: Machine learning for IIoT, Hadoop framework, software defined networking (SDN), cloud and fog computing, cybersecurity, industrial network security, and secure communication frameworks.

Industrial IoT Applications and Case Studies: IIoT applications in smart factories, power plants, plant safety, UAV-based industrial systems, IoMT in healthcare, and industrial case studies.

Learning Resources

6.1 Text Book

- Sudip Misra, Anandarup Mukherjee, and Arijit Roy, Introduction to IoT, Cambridge University Press, 2021.
- Sudip Misra, Chandana Roy, and Anandarup Mukherjee, Introduction to Industrial Internet of Things and Industry 4.0, CRC Press, 2021.

6.2 Reference Books & Web resources

- Alasdair Gilchrist, Industry 4.0 – The Industrial Internet of Things, Apress, 2016.
- Arshdeep Bahga and Vijay Madisetti, Internet of Things – A Hands-on Approach, Universities Press, 2015.
- Sudip Misra, Introduction to Industry 4.0 and Industrial Internet of Things, NPTEL-SWAYAM Course, IIT Kharagpur, 2021.

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	**Introduction to Industry 4.0 and IIoT:** Fundamentals of IoT and IIoT, .	2
1	sensing and actuation, industrial communication, M2M communication,	2
1	Industry 4.0 concepts, smart manufacturing, and smart factories	3
2	**Cyber Physical Systems and Enabling Technologies:** Cyber Physical Systems (CPS), industrial sensors,	2
2	artificial intelligence, big data analytics, augmented reality (AR),	3
2	Virtual reality (VR), and industrial automation systems.	2
3	**Industrial IoT Architecture and Communication:** IIoT architecture, sensing, processing, communication and networking layers	3
3	Industrial gateways, communication protocols, and cloud integration.	4
4	**Industrial Analytics, Cloud, Fog and Security:** Machine learning for IIoT, Hadoop framework, software defined networking (SDN),	4
4	Cloud and fog computing, cybersecurity, industrial network security, and secure communication frameworks.	3
5	**Industrial IoT Applications and Case Studies**: IIoT applications in smart factories, power plants, plant safety,	4
5	UAV-based industrial systems, IoMT in healthcare, and industrial case studies.	4
	Total Periods	36

Course Designer(s):

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Mr.M.Senthilnathan, Assistant Professor, msnece@tce.edu

26PCPG0	COMPUTER NETWORK SECURITY	Category	L	T	P	Credits
		PEC	2	1	0	3

Preamble

This course introduces security principles and mechanisms for protecting modern computer networks. It deals with foundational threat models and classical cryptography through PKI, network-layer protocols, and active defence systems. Students develop both analytical and design skills required for careers in network security engineering, security architecture, and cybersecurity research.

Prerequisite

Nil

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Analyse security threats, vulnerabilities, and attack vectors in networked environments using standard security models and frameworks.	TPS4		10	SDG 9	L1
CO2	Apply symmetric cryptographic algorithms and hash functions to design secure communication channels.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	L1
CO3	Design and evaluate Public Key Infrastructure solutions incorporating asymmetric cryptography, ECC and digital certificates.	TPS3	PO1 – S PO2 – M PO3 – L	25	SDG 9	L1
CO4	Configure network security protocols including IPSec, TLS / SSL, SSH, and wireless security standards.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	L1
CO5	Design the network defence architectures employing firewalls, IDS/IPS, VPNs, and DDoS mitigation strategies.	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG 9	L2
CO6	Examine the emerging security paradigms such as Zero Trust, SDN security, IoT security.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	10	SDG 9	L2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30	30			10
CO2	30	30			20
CO3	40	40			25
CO4			30	30	20
CO5			30	30	15
CO6			40	40	10
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Foundations of Network Security: Security Goals, Attack types: Eavesdropping, MitM, Replay, IP Spoofing, Session Hijacking, DoS/DDoS, Zero-Day exploits Vulnerabilities: ARP poisoning, SYN flooding, DNS poisoning, OWASP Top 10 Cryptographic Primitives

Cryptographic Primitives: Number theory, Chinese Remainder Theorem, Symmetric encryption — DES, and AES: security analysis - Block cipher modes of operation: stream ciphers, Cryptographic hash functions: MD5, SHA-family HMAC

Public Key Infrastructure & Key Management: RSA security and attacks, Diffie-Hellman key exchange; Elliptic Curve Cryptography: ECDH; Digital signatures: RSA signatures, DSA, ECDSA; blind signatures; non-repudiation; digital envelopes; X.509 digital certificates, PKCS standards; enterprise PKI design

Network Security Protocols: IP Security, IPSec modes, ISAKMP, Perfect Forward Secrecy in IKE, Transport Layer Security: forward secrecy, SSH: Architecture; port forwarding; tunnelling; SFTP/SCP; Authentication protocols: Kerberos v5, RADIUS; Wireless & application security: WEP weaknesses; WPA2, WPA3; DNSSEC; Email security

Network Defence Mechanisms: Firewall types and design, ruleset design and optimisation; Intrusion Detection and Prevention Systems: Inline deployment; evasion and anti-evasion; SIEM integration; Security Orchestration, Virtual Private Networks, DDoS attack types and Mitigation, CDN-based defence; Honeypots and honeynets

Emerging Trends in Network Security: Cloud network security, SDN security, threats to SDN controllers; securing OpenFlow, IoT and edge security: lightweight cryptography; MQTT/CoAP security; Zero Trust Architecture, SIEM & threat intelligence.

Learning Resources

6.1 Text Book

- W. Stallings — Cryptography and Network Security: Principles and Practice, 8th Ed., Pearson, 2022

6.2 Reference Books & Web resources

- C. Kaufman, R. Perlman & M. Speciner — Network Security: Private Communication in a Public World, 2nd Ed., Prentice Hall, 2002
- B. Forouzan & D. Mukhopadhyay — Cryptography and Network Security, 3rd Ed., McGraw-Hill, 2015
- J. Bishop — Computer Security: Art and Science, 2nd Ed., Addison-Wesley, 201R. Anderson — Security Engineering: A Guide to Building Dependable Distributed Systems, 3rd Ed., Wiley, 2020

- D. Boneh & V. Shoup — A Graduate Course in Applied Cryptography, v0.6, 2023
- NIST SP 800-207 — Zero Trust Architecture, 2020 | NIST SP 800-208 — PQC Migration, 2022
- Coursera — Cryptography I & II by Dan Boneh (Stanford University): coursera.org
- NPTEL — Cryptography and Network Security, IIT Kharagpur: nptel.ac.in
- NIST Computer Security Resource Centre: csrc.nist.gov

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	Foundations of Network Security: Security Goals, Attack types: Eavesdropping, MitM, Replay	1
1	IP Spoofing, Session Hijacking, DoS/DDoS, Zero-Day exploits DNS poisoning	2
1	Vulnerabilities: ARP poisoning, SYN flooding	1
1	OWASP Top 10 Cryptographic Primitives	1
2	Cryptographic Primitives: Number theory, Chinese Remainder Theorem,	2
2	Symmetric encryption — DES, and AES: security analysis	2
2	Block cipher modes of operation, stream ciphers,	1
2	Cryptographic hash functions: MD5, SHA-family HMAC	1
3	Public Key Infrastructure**:** RSA security and attacks, Diffie-Hellman key exchange	2
3	Elliptic Curve Cryptography: ECDH,	2
3	RSA signatures, DSA, ECDSA; blind signatures; non-repudiation; digital envelopes	2
3	X.509 digital certificates, PKCS standards; enterprise PKI design	1
4	Network Security Protocols: IP Security, IPSec modes, ISAKMP, Perfect Forward Secrecy in IKE,	1
4	Transport Layer Security: forward secrecy, SSH: Architecture; port forwarding; tunnelling; SFTP/SCP;	2
4	Authentication protocols: Kerberos v5, RADIUS	1
4	Wireless & application security: WEP weaknesses; WPA2, WPA3; DNSSEC; Email security	2
5	Network Defence Mechanisms: Firewall types and design, ruleset design and optimisation	2
5	Intrusion Detection and Prevention Systems: Inline deployment; evasion and anti-evasion; SIEM integration; Security Orchestration	2
5	Virtual Private Networks, DDoS attack types and Mitigation	1
5	CDN-based defence; Honeypots and honeynets	1
6	Emerging Trends in Network Security: Cloud network security	1
6	SDN security, threats to SDN controllers; securing OpenFlow	1
6	IoT and edge security: lightweight cryptography; MQTT/CoAP security	2
6	Zero Trust Architecture, SIEM & threat intelligence	2
	Total Periods	**36**

Course Designer(s):

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- Dr. V.R.Venkatasubramani, Associate Professor, venthiru@tce.edu

26PCPH0	ARRAY SIGNAL PROCESSING	Category	L	T	P	Credits
		PEC	3	0	0	3

Preamble

This course introduces the fundamental principles of array signal processing for the acquisition, detection, localization, and tracking of signals in spatially distributed sensing systems. It covers wave propagation, sensor arrays, beamforming, statistical detection theory, target tracking, and adaptive array processing techniques. The course equips students with the analytical tools required to design and evaluate advanced sensing and communication systems used in radar, sonar, wireless communications, navigation, and surveillance applications.

Prerequisite

Nil

Course Outcomes

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

No.	Course Outcome	TPS Level	CO Weightage	SDG addressed	SDG Level
CO1	Explore the properties of spatiotemporal propagating signals and noise.	TPS3	15%	SDG 9	1
CO2	Determine the characteristics of apertures and find the array geometry that determines the performance characteristics of arrays.	TPS3	15%	SDG 9	1
CO3	Apply spatiotemporal filtering to separate signals according to their directions of propagation and their frequency content.	TPS3	15%	SDG 9	2
CO4	Apply suitable detection algorithm to the array output so as not to disturb an array processing algorithm designed for some particular problem and also analyse performance of the detection based array processing algorithm.	TPS4	20%	SDG 9	2
CO5	Determine the location and motion of identified sources using tracking algorithms.	TPS3	15%	SDG 9	2
CO6	Derive signal processing algorithms for the outputs of an array of sensors that adapt their computations to the characteristics of the observations.	TPS3	20%	SDG 9	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30	30	-	-	15
CO2	40	40	-	-	15
CO3	30	30	-	-	15
CO4	-	-	35	35	20
CO5	-	-	30	30	15
CO6	-	-	35	35	20
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Module 1:
Signals in space and time - Co-ordinate systems, propagating waves, Dispersion and attenuation, Refraction and Diffraction, Wavenumber-Frequency Space Random Fields. Signal and Noise Assumptions
Module 2:
Apertures and Arrays - Finite Continuous Apertures, Spatial Sampling, Arrays of Discrete Sensors
Module 3:
Beamforming - Delay-and-Sum Beamforming, Space-Time Filtering, Filter-and-Sum Beamforming, Frequency-Domain Beamforming, Array Gain, Resolution, Sampling in Time, Discrete-Time Beamforming, Averaging in Time and Space
Module 4:
Detection Theory - Elementary Hypothesis Testing Hypothesis Testing in Presence of Unknowns, Detection of Signals in Gaussian Noise, Detection in Presence of Uncertainties, Detection-Based Array Processing Algorithms
Module 5:
Tracking - Source Motion Models, Single-Array Location Estimate Properties, Prediction-Correction Algorithms, Tracking Based on Kalman Filtering, Multiarray Tracking in Clutter
Module 6:
Adaptive Array Processing: Signal Parameter Estimation, Constrained Optimization Methods, Eigen analysis Methods, Robust Adaptive Array Processing, Dynamic Adaptive Methods

Learning Resources

6.1 Text Book

- Don H.Johnson, Dan E.Judgeon, ―Array signal processing: concepts and techniques‖, First edition, Prentice Hall signal processing series.

6.2 Reference Books & Web resources

- Harry L. Van Trees, ―Optimum Array Processing, ‖ John Wiley & Sons, 2004
- Prabhakar S. Naidu, Sensor Array Signal Processing,CRC Press,2000
- Pillai, S. Unnikrishna, Array Signal Processing, Springer,1989

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	Co-ordinate systems	1
	Propagating waves, Dispersion and attenuation	1
	Refraction and Diffraction	1
	Wavenumber-Frequency Space Random Fields	2
	Signal and Noise Assumptions	1
2	Finite Continuous Apertures	1
	Spatial Sampling, Arrays of Discrete Sensors	2
3	Delay-and-Sum Beamforming	1
	Space-Time Filtering	1
	Filter-and-Sum Beamforming, Frequency-Domain Beamforming	2
	Array Gain, Resolution, Sampling in Time	1
	Discrete-Time Beamforming, Averaging in Time and Space	1
4	Elementary Hypothesis Testing Hypothesis Testing in Presence of Unknowns	1
	Detection of Signals in Gaussian Noise	1
	Detection in Presence of Uncertainties	2

	Detection-Based Array Processing Algorithms	2
5	Source Motion Models	1
	Single-Array Location Estimate Properties	2
	Prediction-Correction Algorithms	1
	Tracking Based on Kalman Filtering	3
	Multiarray Tracking in Clutter	1
6	Signal Parameter Estimation	1
	Constrained Optimization Methods	1
	Eigen analysis Methods	1
	Robust Adaptive Array Processing	2
	Dynamic Adaptive Methods	2
	Total Periods	**36**

Course Designer(s):

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26PCPJ0	PHYSICAL LAYER LTE SYSTEMS	Category	L	T	P	Credits
		PEC	2	1	0	3

Preamble

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

Prerequisite

Baseband Communication Systems

Course Outcomes

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

No.	Course Outcome	TPS Level	CO Weightage	PO Addressed	SDG addressed	SDG Level
CO1	Describe the FDD and TDD frame formats, physical signals and channels of downlink and uplink LTE systems.	TPS2	20	PO1 – M PO2 – L	SDG 9	2
CO2	Carry out the cell search using synchronization signals in LTE downlink and determine the channel frequency response using reference signals in downlink and uplink of LTE systems.	TPS3	20	PO1 – S PO2 – M PO3 – L	SDG 9	2
CO3	Characterize the modulation schemes such as OFDM, OFDMA and SC-FDMA schemes and describe the single user and multi user techniques in LTE downlink and uplink physical layer channel processing systems.	TPS3	20	PO1 – S PO2 – M PO3 – L	SDG 9	2
CO4	Determine the bit error rate and outage probability performances of LTE downlink and uplink channels.	TPS3	20	PO1 – S PO2 – M PO3 – L	SDG 9	2
CO5	Determine the performance of LTE downlink and uplink receiver.	TPS3	20	PO1 – S PO2 – M PO3 – L	SDG 9	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	20	20			20
CO2	40	40			20
CO3	40	40			20
CO4			50	50	20
CO5			50	50	20
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Module1:

Frame structure:

Frequency Division Duplexing, Time Division Duplexing

Module 2:

Downlink Physical signals:

Synchronization signals, Cell Search, Reference signals: Frequency Domain, Time domain and Spatial Domain channel estimations

Module 3:

Downlink Physical channels:

Data channels-PBCH, PDSCH, PMCH, Control channels: PCFICH, PDCCH, PHICH, Downlink channel processing, BER and Outage probability

Module 4:

Multiple Antenna Techniques:

Single user systems: Space Frequency Block coding, Cyclic Delay Diversity, Spatial Multiplexing, Multi user systems: Space Division Multiple Access(SDMA) using precoding

Module 5: Modulation Techniques:

OFDM for downlink, SC-FDMA for uplink

Module 6: Uplink Physical signals:

Demodulation Reference signals, channel Estimation, Sounding Reference signals, Channel Quality Determination

Module 7: Uplink Physical channels:

PUCCH, PRACH, PUSCH, Uplink channel processing, BER and Outage probability

Module 8: Power control, scheduling and interference handling, LTE Advanced: Career aggregation, Downlink Multiantenna enhancements, Uplink Multiantenna techniques, Heterogeneous networks, Relays, HSPA Evolution

6. Learning Resources

6.1 Text Book

- Harri Holma and Antti Toskala, “LTE for UMTS Evolution to LTE-Advanced,” John Wiley and Sons Limited, 2011.

6.2 Reference Books & Web resources

- Erik Dahlman, Stefan Parkvall,Johan Skold, “4G-LTE-LTE-Advanced for Mobile broadband”, Elsevier,2011.
- 3GPP TS 36.211: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation", 2011
- 3GPP TS 36.212: "Evolved Universal Terrestrial Radio Access (E-UTRA); Multiplexing and channel coding". 2011
- 3GPP TS 36.213: "Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures". 2011
- Stefania Sesia, Issam Toufik, Matthew Baker, “LTE-The UMTS Long Term Evolution From theory to practice, John Wiley & Sons Ltd., 2009.

- David Tse and Pramod Viswanath, “Fundamentals of Wireless Communications”, Cambridge University Press, 2005 (First Asian Edition, 2006)
- Andrea Goldsmith, “ Wireless Communications”, Cambridge University Press, 2005
- A.Paulraj, R. Nabar and D Gore, “Introduction to Space-Time Wireless Communications”, Cambridge University Press, 2003.

7. Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	**Frame structure**	
	Frequency Division Duplexing, Time Division Duplexing	2
2	**Downlink Physical signals**	
	Synchronization signals, Cell Search	2
	Reference signals: Frequency Domain, Time domain and Spatial Domain channel estimations	2
3	**Downlink Physical channels**	
	Data channels-PBCH,PDSCH,PMCH,	2
	Control channels: PCFICH, PDCCH, PHICH,	2
	Downlink channel processing, BER and Outage probability	2
4	**Multiple Antenna Techniques**	
	Single user systems: Space Frequency Block coding, Cyclic Delay Diversity, Spatial Multiplexing,	2
	Multi user systems: Space Division Multiple Access(SDMA) using precoding	2
5	**Modulation Techniques**	
	OFDM for downlink, SC-FDMA for uplink	2
6	**Uplink Physical signals**	
	Demodulation Reference signals, channel Estimation,	2
	Sounding Reference signals, Channel Quality Determination	4
7	**Uplink Physical channels**	
	PUCCH,PRACH, PUSCH	2
	Uplink channel processing, BER and Outage probability	4
8	**Power control, scheduling and interference handling, LTE Advanced**	
	Career aggregation,Downlink Multiantenna enhancements	2
	Uplink Multiantenna techniques, Heterogeneous networks, Relays,HSPA Evolution	4
	Total Periods	36

8. Course Designer(s):

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26PCPK0	INTELLIGENT VIDEO SURVEILLANCE SYSTEM	Category	L	T	P	Credits
		PEC	3	0	0	3

Preamble

Intelligent Video Surveillance Systems integrate computer vision, networking, and artificial intelligence technologies to enable automated monitoring, analysis, and decision-making from video data. The course addresses surveillance hardware, video analytics, object tracking, activity recognition, and AI-driven security applications. It highlights the role of intelligent surveillance in smart cities, transportation systems, public safety, and urban monitoring, providing students with the knowledge required to design and evaluate modern surveillance solutions.

Prerequisite

Nil

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Apply appropriate surveillance hardware and software components for the effective deployment of intelligent video surveillance systems.	TPS3	PO1 – S PO2 – M PO3 – L	15	9	2
CO2	Explain network topology, bandwidth requirements and communication infrastructure for networked video surveillance systems.	TPS2	PO1 – M PO2 – L	10	9	2
CO3	Examine motion detection, motion segmentation and motion estimation algorithms used in low-level intelligence modules of static-camera surveillance systems.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	20	11	3
CO4	Examine object tracking algorithms and their performance in static-camera intelligent video surveillance environments.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	15	11	3
CO5	Demonstrate feature extraction and classification techniques for action, activity and face recognition in intelligent surveillance systems.	TPS3	PO1 – S PO2 – M PO3 – L	20	9	3
CO6	Apply intelligent video surveillance techniques to real-world applications such as human fall detection, traffic surveillance, license plate recognition and UAV-based urban monitoring.	TPS3	PO1 – S PO2 – M PO3 – L	20	11	3

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	40	60	-	-	15
CO2	60	40	-	-	10
CO3	-	-	50	40	20
CO4	-	-	50	60	15
CO5	-	-	-	-	20
CO6	-	-	-	-	20
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Module 1: Video Surveillance Hardware and System Components

Introduction to Intelligent Video Surveillance Systems – CCTV and IP-based surveillance systems – Analog vs Digital video – Video standards (NTSC, PAL, SECAM) – Video resolutions and formats – Cameras and image sensors (CCD, CMOS) – Optics, focal length, F-stop, shutter speed, depth of field – Day/Night, Infrared, Thermal, PTZ and Megapixel cameras – Video encoders – DVR, NVR and storage systems – Video Management Software (VMS).

Module 2: Networked Video Surveillance Systems

Fundamentals of networking for surveillance – Ethernet and IP networking – Network topologies – Bandwidth estimation and management – Networked video delivery methods – Wireless video surveillance – WLAN standards – Access points and antennas – Wireless security and privacy considerations – Edge and cloud-based surveillance architectures.

Module 3: Low-Level Video Analytics

Region of Interest (ROI) extraction – Motion detection and motion segmentation – Background subtraction techniques – Frame differencing – Gaussian Mixture Models (GMM) – Shape-based methods – Motion estimation techniques – Pixel-based motion estimation – Block matching algorithms – Challenges in dynamic environments.

Module 4: Object Tracking and Video Analysis

Video tracking fundamentals – Design and components of video trackers – Optical flow methods – Multi-object tracking – Part-based tracking – Trajectory initialization and termination – Tracking challenges under occlusion and illumination variations – Performance evaluation metrics for tracking systems.

Module 5: High-Level Intelligence and Recognition

Feature extraction techniques – Skeleton-based representation – Dimensionality reduction using PCA – Classification techniques: Nearest Neighbour and SVM – Action recognition – Activity recognition – Face recognition – Event detection and alarm generation – Introduction to AI and Deep Learning-based video analytics.

Module 6: Applications and Case Studies

Home surveillance systems – Human fall detection – Smart traffic surveillance – Automatic License Plate Recognition (ALPR) – Person and vehicle analytics – UAV-based urban surveillance – Intelligent city surveillance systems – Emerging trends in AI-powered video surveillance and smart security applications.

Learning Resources

6.1 Text Book

- Anthony C. Caputo, "Digital Video Surveillance and Security", Butterworth-Heinemann, 2nd Edition, 2014.

- Huihuan Qian, Xinyu Wu and Yangsheng Xu, "Intelligent Surveillance Systems", Springer, 1st Edition, 2011.

6.2 Reference Books & Web resources

- Emilio Maggio and Andrea Cavallaro, "Video Tracking: Theory and Practice", John Wiley & Sons, 1st Edition, 2011.
- Yunqian Ma and Gang Qian, "Intelligent Video Surveillance: Systems and Technology", CRC Press, 1st Edition, 2009.
- Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer, 2nd Edition, 2022.
- Al Bovik, "The Essential Guide to Video Processing", Academic Press, 2nd Edition, 2009.
- Omar Javed and Mubarak Shah, "Automated Multi-Camera Surveillance: Algorithms and Practice", Springer, 1st Edition, 2008.
- Mohamed Elgendy, "Deep Learning for Vision Systems", Manning Publications, 2020.

Web resources

- NPTEL – Computer Vision and Image Processing, IIT Madras.
- OpenCV Documentation – Open Source Computer Vision Library.
- Ultralytics YOLO Documentation – Object Detection and Tracking Framework.
- NVIDIA Intelligent Video Analytics Resources.

SDG-Aligned Activities

SDG 9 (Industry, Innovation and Infrastructure)
Analyze the design of a smart-city surveillance network and recommend suitable camera, storage and communication infrastructure.

SDG 11 (Sustainable Cities and Communities)
Case study on AI-based traffic surveillance for urban congestion monitoring.

SDG 3 (Good Health and Well-being)
Evaluate human fall detection techniques for elderly healthcare monitoring using surveillance videos.

Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	**Digital Video Surveillance Hardware and Software: Introduction to Intelligent Video Surveillance Systems, Course Objectives, Course Outcomes and 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, Megapixel 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 Neighbour	1
5.3	**Video Analytics:**	
5.3.1	Action recognition of a single person	1
5.3.2	Face recognition	1
5.3.3	Alarms and Event Responses	1
6	**Applications and Case study**:	
6.1	Home surveillance system	1
6.2	Human Fall Detection	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 Periods	36

Course Designer(s):

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26PCPL0	MACHINE LEARNING FOR VISUAL RECOGNITION	Category	L	T	P	Credits
		PEC	3	0	0	3

1.Preamble

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

2.Prerequisite

NIL

3.Course Outcomes

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Illustrate the relationship between world coordinates and image coordinates and image formation using projective geometry.	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG 9	1
CO2	Select appropriate feature detection and matching method to recover transformation parameters based on matched points for feature alignment.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	20	SDG 9	1
CO3	Examine segmentation algorithms such as meanshift, graph-based and active contours to find the correlation for grouping the meaningful segments.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9	1
CO4	Investigate machine learning algorithms such as K Nearest Neighbor, Bag of words and Convolutional Neural Network for object recognition and categorization.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	25	SDG 9	2
CO5	Identify the low, mid and high level methods for the exemplar computational visual recognition applications such as scene recognition, pedestrian detection, activity recognition and face recognition.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 3 and SDG 9	2

4.Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	30	30			15
CO2	35	35			20
CO3	35	35			20
CO4			40	40	25
CO5			60	60	20
Total	**100**	**100**	**100**	**100**	**100**

5.Syllabus

Machine Learning for Visual Recognition- Introduction- computer vision applications-**Low Level Vision – Image formation-Geometric image formation**- Projection-Pinhole-perspective-orthographic-2D Transformations- 3D Transformations-camera intrinsics-**Photometric image formation**- Photon's life choices-Lighting-reflectance and shading-optics
Middle Level Vision- Feature detection, matching and alignment- Feature detectors and descriptors- Harris corner detection- Scale Invariant Feature Transform (SIFT)- Histogram of Oriented Gradients (HOG)-Feature matching algorithms- Euclidean distance metric-Error rates-Feature alignment algorithms- Random Sample Consensus (RANSAC)-**Clustering and Segmentation**- Mean shift Clustering –Graph-based segmentation-Active contours
High Level Vision-Classifiers-Machine Learning: Supervised-K-nearest neighbor-Bag of words-Unsupervised-K-Means Clustering-Deep Learning: Neural networks-Image Net-Convolutional Neural Networks
Recognition: Applications- Scene recognition using bag of words- Pedesterian detection using part based models-Activity recognition-Face recognition using Convolutional Neural Networks

6. Learning Resources

6.1 Reference Books & Web resources

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

7. Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	**Machine Learning for Visual Recognition- Introduction to computer vision course, Course objectives and outcomes, Concept Map - Low Level Vision: Introduction to Computer vision and its applications, Image Formation**	
1	Geometric Image Formation	1
1	Projection-Pinhole camera model	1
1	Perspective	1
1	Orthographic	
1	2D Transformations	2
1	3D Transformations	2
1	Camera intrinsics	1
1	**Photometric Image Formation**	
1	Lighting	1
1	Photon’s life choices	
1	Reflectance and shading	1
1	Optics	
2	**Middle Level Vision:**	
2	**Feature detectors and descriptors**	
2	Harris corner detection	2
2	Scale Invariant Featyre Transform (SIFT)	2
2	Histogram of Oriented Gradients (HOG)	1
2	**Feature matching algorithms**	
2	Euclidean distance metric	1
2	Error rates	1
2	**Feature alignment algorithms**	
2	Random Sample Consensus (RANSAC)	2
2	**Clustering and Segmentation**	
2	Meanshift Clustering	1
2	Graph based segmentation	1
2	Active contours	1
3	**High Level Vision: Machine Learning Algorithms**	
3	**Supervised Machine Learning Calssifiers**	
3	K-nearest neighbor	1
3	Bag of words	1
3	**Unsupervised Machine Learning Classifiers**	
3	K-Means Clustering	1
3	**Deep Learning**	
3	Neural Networks	2
3	Image Net	1
3	Convolutional Neural Networks	2
4	**Recognition: Applications**	1
4	Scene recognition using bag of words	1
4	Pedesterian detection using part based models	1
4	Activity Recognition	1
4	Face Recognition using Convolutional Neural Networks	1
	Total Number of Hours	1
		36

8. Course Designer(s):

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26PCPN0	ANALOG INTEGRATED CIRCUITS	Category	L	T	P	Credits
		PEC	3	0	0	3

Preamble

Analog Integrated Circuits form the foundation of modern communication, sensing, biomedical and mixed-signal systems. The course introduces CMOS device modelling and the analysis and design of analog building blocks such as current mirrors, differential amplifiers, operational amplifiers and frequency compensation techniques. It bridges transistor-level circuit concepts with practical integrated circuit design methodologies used in communication and VLSI systems. This course provides the basis for advanced studies in RF ICs, data converters and mixed-signal design.

Prerequisite

Nil

Course Outcomes

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

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Explain MOS transistor characteristics and small-signal models used in analog IC design.	TPS2	PO1 – S PO2 – M	12	SDG 9	2
CO2	Solve biasing and performance parameters of current mirrors and single-stage amplifiers.	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG 9	2
CO3	Analyze differential amplifiers and operational amplifiers using CMOS design principles.	TPS3	PO1 – S PO2 – M PO3 – L	18	SDG 9	3
CO4	Apply frequency response and compensation techniques for stable amplifier operation.	TPS3	PO1 – S PO2 – S PO3 – M PO4 – L	17	SDG 9	3
CO5	Analyze switched-capacitor circuits and data converter architectures used in mixed-signal systems.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	18	SDG 9	3
CO6	Apply analog building blocks for communication and mixed-signal integrated systems.	TPS3	PO1 – S PO2 – S PO3 – M PO4 – L	20	SDG 9, SDG 11	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	32	42	-	-	18
CO2	36	28	-	-	16
CO3	32	30	-	-	18
CO4	-	-	32	30	12
CO5	-	-	36	28	12
CO6	-	-	32	42	24
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

MOS Device Fundamentals: Introduction to Analog IC Design – CMOS Fabrication Overview – MOS Transistor Operation – Regions of Operation – Threshold Voltage – Body Effect – Channel Length Modulation – Small-Signal Model – Transconductance – Output Resistance – High-Frequency Model – Frequency Response. **Current Mirrors and Single Stage Amplifiers :** Basic Current Mirror – Widlar Current Source – Wilson Current Mirror – Cascode Current Mirror – Active Loads – Common Source Amplifier – Source Follower – Common Gate Amplifier – Cascode Amplifier – Gain Enhancement – Frequency Response. **Differential Amplifiers and Operational Amplifiers:** Differential Pair Operation – Differential Gain – Common Mode Gain – CMRR – Current Mirror Loaded Differential Amplifier – Single-Stage Op-Amp – Two-Stage CMOS Op-Amp – Output Stages – Slew Rate – Gain-Bandwidth Product. **Frequency Compensation and Analog Building Blocks:**Pole-Zero Analysis – Stability Concepts – Miller Compensation – Frequency Compensation Techniques – Voltage Reference Circuits – Bandgap References – Comparators – Analog Switches – Sample-and-Hold Circuits.**Switched Capacitor Circuits and Data Converters:** Switched Capacitor Principles – Integrators – Differentiators – Switched Capacitor Filters – Noise in Analog Circuits – DAC Architectures – Flash ADC – Successive Approximation ADC – Pipeline ADC – Introduction to RF and Mixed-Signal ICs.

6. Learning Resources

6.1 Text Book

- Behzad Razavi, **"Design of Analog CMOS Integrated Circuits"**, McGraw Hill Education, Second Edition, 2017.
- Paul R. Gray, Paul J. Hurst, Stephen H. Lewis and Robert G. Meyer, **"Analysis and Design of Analog Integrated Circuits"**, Wiley, Fifth Edition, 2019.

6.2 Reference Books & Web resources

- Phillip E. Allen and Douglas R. Holberg, **"CMOS Analog Circuit Design"**, Oxford University Press, Third Edition, 2012.
- R. Jacob Baker, **"CMOS Circuit Design, Layout and Simulation"**, Wiley-IEEE Press, Fourth Edition, 2019.
- Sergio Franco, **"Design with Operational Amplifiers and Analog Integrated Circuits"**, McGraw Hill, Fourth Edition, 2015.
- Johns and Martin, **"Analog Integrated Circuit Design"**, Wiley, Second Edition, 2016.
- Sedra and Smith, **"Microelectronic Circuits"**, Oxford University Press, Eighth Edition, 2020.

7. Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1.1	Introduction and CMOS Fabrication	2
1.2	MOS Characteristics and Regions of Operation	2
1.3	Threshold Voltage and Body Effect	1
1.4	Small Signal Model	1
1.5	Channel Length Modulation and gm, ro	1
1.6	High Frequency Model and Response	2
2.1	Current Mirrors	1
2.2	Wilson and Cascode Current Mirrors	2
2.3	Common Source Amplifier	1
2.4	Source Follower and Common Gate Amplifier	2
2.5	Cascode Amplifier	2
2.6	Frequency Response	2
3.1	Differential Pair	2
3.2	CMRR and Current Mirror Loads	1
3.3	Single Stage Op-Amp	2
3.4	Two Stage Op-Amp	2
3.5	Output Stages	1
3.6	Slew Rate and GBW	1
4.1	Pole-Zero Analysis	2
4.2	Stability and Compensation	2
4.3	Miller Compensation	1
4.4	Voltage References	2
4.5	Comparators	2
4.6	Sample and Hold Circuits	1
5.1	Switched Capacitor Principles	2
5.2	Integrators and Filters	1
5.3	Noise Analysis	2
5.4	DAC Architectures	2
5.5	ADC Architectures	2
5.6	RF and Mixed Signal IC Introduction	1
	Total Hours	48

8. Course Designer(s):

Dr.N.Balamurugan, Professor, nbbalamurugan@tce.edu

26PCPPO	SOLID STATE DEVICE MODELING AND SIMULATION	Category	L	T	P	Credits
		PEC	3	0	0	3

1. Preamble
Solid State Device Modeling and Simulation addresses the physical principles, mathematical formulations, and numerical methods used for analyzing semiconductor devices. The course integrates semiconductor physics with Technology Computer Aided Design methodologies employed in modern CMOS, power devices, and nanoscale transistors. It enables students to investigate carrier transport phenomena and evaluate advanced device structures used in contemporary integrated circuit technologies.

2. Prerequisite
NIL

3. Course Outcomes
After the successful completion of the course, students will be able to:

No.	Course Outcome	TPS Level	PO Addressed	CO Weightage	SDG addressed	SDG Level
CO1	Explain semiconductor material properties and carrier transport mechanisms governing device operation.	TPS2	PO1 – M PO2 – L	10	SDG 9	1
CO2	Apply Poisson and continuity equations to determine charge transport in semiconductor devices.	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG 9	2
CO3	Solve drift-diffusion equations and evaluate mobility and recombination models.	TPS3	PO1 – S PO2 – M PO3 – L	18	SDG 9	2
CO4	Analyze PN junctions, BJTs and MOS structures using analytical models.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	18	SDG 9	2
CO5	Apply numerical techniques and TCAD methodologies for semiconductor device simulation.	TPS3	PO1 – S PO2 – M PO3 – L	19	SDG 9	2
CO6	Apply nanoscale devices and compact models used in VLSI technologies.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9, SDG 12	2

4. Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	**32**	**42**	**-**	**-**	**10**
CO2	**36**	**28**	-	-	**15**
CO3	**32**	**30**	**-**	**-**	**18**
CO4	**-**	**-**	**32**	**42**	**18**
CO5	-	-	**36**	**28**	**19**
CO6	**-**	**-**	**32**	**30**	**20**
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Semiconductor Physics Fundamentals: Energy band theory – Intrinsic and extrinsic semiconductors – Carrier concentration – Fermi level – Carrier statistics – Drift current – Diffusion current – Einstein relation – Generation and recombination mechanisms. **Transport Equations and Physical Models:** Poisson equation – Continuity equations – Boundary conditions – Drift-diffusion transport model – Mobility models – Shockley Read Hall recombination – Auger recombination – High-field effects – Velocity saturation. **Modeling of Basic Semiconductor Devices:** Differential Pair Operation – Differential Gain – Common Mode Gain – CMRR – Current Mirror Loaded Differential Amplifier – Single-Stage Op-Amp – Two-Stage CMOS Op-Amp – Output Stages – Slew Rate – Gain-Bandwidth Product.**Frequency Compensation and Analog Building Blocks:** MOS capacitor – Surface potential – Threshold voltage – Channel charge model – Long-channel MOSFET – Short-channel effects – DIBL – Velocity saturation – Subthreshold conduction circuits. **Switched Capacitor Circuits and Data Converters:** Finite difference method – Finite element method – Newton-Raphson method – Gummel iteration – Mesh generation – Process simulation – Device simulation – Sentaurus TCAD – Silvaco Atlas.

6.1 Text Book

- Mark Lundstrom and Jing Guo, *"Nanoscale Transistors Device Physics Modeling and Simulation"*, Springer, First Edition, 2021.
- Paul R Vasileska, Goodnick and Klimeck, *"Computational Electronics"*, CRC Press, Second Edition, 2022.

6.2 Reference Books & Web resources

- Yuan Taur and Tak H. Ning, *"Fundamentals of Modern VLSI Devices"*, Cambridge University Press, Third Edition, 2021.R. Jacob Baker, **"CMOS Circuit Design, Layout and Simulation"**, Wiley-IEEE Press, Fourth Edition, 2019.
- Yuan Taur and Tak H. Ning, *"Fundamentals of Modern VLSI Devices"*, Cambridge University Press, Third Edition, 2021.
- Karl Hess, *"Advanced Theory of Semiconductor Devices"*, Wiley, 2021.
- Robert F. Pierret, *"Semiconductor Device Fundamentals"*, Pearson.
- Synopsys Sentaurus TCAD User Manual.
- Silvaco Atlas Device Simulation Manual.
- NPTEL: Semiconductor Device Modeling and Simulation.
- MIT OpenCourseWare: Microelectronic Devices and Circuits.

7. Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	Semiconductor Physics Fundamentals	9
2	Transport Equations and Physical Models	9
3	Modeling of Basic Semiconductor Devices	9
4	MOS Device Modeling	10
5	Numerical Methods and TCAD Simulation	11
	Total Hours	48

Detailed Lecture Schedule

Module No	Topics	No of Periods
1.1	Energy bands and carrier concentration	1
1.2	Intrinsic and extrinsic semiconductors	1
1.3	Fermi level and carrier statistics	1
1.4	Drift current mechanism	1
1.5	Diffusion current mechanism	1
1.6	Einstein relation	1
1.7	Generation mechanisms	1
1.8	Recombination mechanisms	1
1.9	Numerical examples	1
2.1	Electrostatics and Poisson equation	1
2.2	Continuity equations	1
2.3	Boundary conditions	1
2.4	Drift-diffusion model	1
2.5	Mobility models	1
2.6	SRH recombination	1
2.7	Auger recombination	1
2.8	High-field transport	1
2.9	Velocity saturation	1
3.1	PN junction electrostatics	1
3.2	Built-in potential	1
3.3	Current-voltage characteristics	1
3.4	Junction capacitances	1
3.5	BJT operation	1
3.6	Ebers-Moll model	1
3.7	Charge control model	1
3.8	Small signal model	1
3.9	Device characteristics	1
4.1	MOS capacitor fundamentals	2
4.2	Surface potential	1
4.3	Threshold voltage	1
4.4	Channel charge model	1
4.5	Long channel MOSFET	1
4.6	Short-channel effects	1
4.7	DIBL	1
4.8	Velocity saturation	1
4.9	Subthreshold conduction	1
5.1	Finite difference method	1
5.2	Finite element method	2
5.3	Newton-Raphson method	1
5.4	Gummel iteration	1
5.5	Mesh generation	1
5.6	Process simulation	1
5.7	Device simulation	1
5.8	Sentaurus TCAD	2
5.9	Silvaco Atlas and case studies	1
	Total Hours	48

8. Course Designer(s):

Dr.N.B.Balamurugan, Professor, nbbalamurugan@tce.edu

26PCPQ0	BIOMEDICAL SIGNAL PROCESSING	Category	L	T	P	Credits
		PEC	3	0	0	3

Preamble

The objective of this course is to provide a firm foundation in cutting-edge biomedical signalling and imaging systems, including current coverage of issues that are pertinent to industry. This course focuses on biological signals, signal processing, and evaluating methods and findings in order to optimize clinical applications. It also includes automated classification and decision making approaches to aid in diagnosis.

Prerequisite

Nil

Course Outcomes

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

No.	Course Outcome	TPS Level	CO Weig-htage	SDG addressed	SDG Level
CO1	Characterize the biomedical signals in both time and frequency Domain.	TPS2	14%	SDG 3 SDG 9	1
CO2	Model the discrete biomedical signal using parametric modelling.	TPS3	14%	SDG 3 SDG 9	2
CO3	Apply periodogram techniques to analyse the biomedical signals.	TPS3	14%	SDG 3 SDG 9	2
CO4	Apply adaptive filtering techniques to cancel noise and enhance the quality of biomedical signals.	TPS3	17%	SDG 3 SDG 9	2
CO5	Detect the presence of a wavelet in a noisy biosignal using structural features and template matching techniques for monitoring and automatic classification.	TPS3	17%	SDG 3 SDG 9	2
CO6	Apply signal classification and recognition methods to address biomedical problems by analyzing signals such as EEG, ECG, PCG, EMG, and PPG.	TPS3	12%	SDG 3 SDG 9	2
CO7	Reconstruct biomedical images from CT scanners using the principles of computed tomography.	TPS3	12%	SDG 3 SDG 9	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	35	35	-	-	14
CO2	35	35	-	-	14
CO3	30	30	-	-	14
CO4	-	-	25	25	17
CO5	-	-	25	25	17
CO6	-	-	25	25	12
CO7	-	-	25	25	12
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Module 1:

SIGNAL, SYSTEM AND SPECTRUM - Characteristics of some dynamic biomedical signals, Noises- random, structured and physiological noises. Filters- IIR and FIR filters. Spectrum power spectral density function, cross-spectral density and coherence function, cepstrum and homomorphic filtering. Estimation of mean of finite time signals

Module 2:

TIME SERIES ANALYSIS AND SPECTRAL ESTIMATION - Time series analysis linear prediction models, process order estimation, non-stationary process, fixed segmentation, adaptive segmentation, application in EEG, PPG, PCG and HRV signals, model-based ECG simulator. Spectral estimation Blackman Tukey method, periodogram, and model-based estimation. Application in Heart rate variability, PCG and PPG signals

Module 3:

ADAPTIVE FILTERING AND WAVELET DETECTION: Filtering LMS adaptive filter, adaptive noise cancelling in ECG, improved adaptive filtering in FECG, EEG, PPG and other applications in Bio signals, Wavelet detection in ECG structural features, matched filtering, adaptive wavelet detection, detection of overlapping wavelets, scalogram.

Module 4:

BIOSIGNAL CLASSIFICATION AND RECOGNITION: Signal classification and recognition Statistical signal classification, linear discriminant function, direct feature selection and ordering, Back propagation neural network-based classification. Application in Normal versus Ectopic ECG beats and other biomedical applications

Module 5:

COMPUTED TOMOGRAPHY - Principles of tomography, CT Generations, Xray sources-collimation- X- Ray detectors Viewing systems spiral CT scanning Ultra fast CT scanners. Image reconstruction techniques back projection and iterative method.

Learning Resources

6.1 Text Book

- Arnon Cohen, Bio-Medical Signal Processing Vol I and Vol II, CRC Press Inc., Boca Rato, Florida 1999.

6.2 Reference Books & Web resources

- Kayvan Najarian and Robert Splinter, Biomedical Signal and Image Processing, second edition, CRC Press, Taylor & Francis Group, 2012.
- Emmanuel C. Ifeachor, Barrie W.Jervis, second edition, Digital Signal processing- A Practical Approach, Pearson Education, 2002.
- Raghuveer M. Rao and AjithS.Bopardikar, Wavelets transform Introduction to theory and its applications, Pearson Education, India 2000
- Rangaraj M. Rangayyan, 2nd edition, Biomedical Signal Analysis- Wiley- Interscience / IEEE Press, 2015.
- Willis J. Tompkins, Biomedical Digital Signal Processing, Prentice Hall of India, New Delhi, 2003.

7. Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	Characteristics of some dynamic biomedical signals	1
	Noises- random, structured and physiological noises	1
	Filters- IIR and FIR filters	1
	Spectrum power spectral density function, cross-spectral density and	1

	coherence function	
	Cepstrum and homomorphic filtering	1
	Estimation of mean of finite time signals	1
2	Time series analysis - linear prediction models, Process order estimation, non-stationary process	1
	Fixed segmentation, adaptive segmentation	1
	Application in EEG, PPG, PCG and HRV signals	1
	Model-based ECG simulator	1
	Spectral estimation Blackman Tukey method, periodogram, and model-based estimation	1
	Application in Heart rate variability, PCG and PPG signals	1
3	Filtering - LMS adaptive filter, adaptive noise cancelling in ECG	2
	Improved adaptive filtering in FECG, EEG, PPG and other applications in Bio signals	2
	Wavelet detection in ECG structural features	1
	Matched filtering	1
	Adaptive wavelet detection, detection of overlapping wavelets	1
	Scalogram	1
4	Statistical signal classification	1
	Linear discriminant function	1
	Direct feature selection and ordering,	1
	Back propagation neural network-based classification	2
	Application in Normal versus Ectopic ECG beats and	1
	Other biomedical applications involving classification & recognition	2
5	Principles of tomography	1
	CT Generations	1
	Xray sources- collimation	1
	X- Ray detectors Viewing systems	1
	Spiral CT scanning, Ultra-fast CT scanners	1
	Image reconstruction techniques	2
	Back projection and iterative method	1
	Total Periods	**36**

8. Course Designer(s):

Dr.K. Rajeswari, Associate Professor, rajeswari@tce.edu
Dr.G.Ananthi, Associate Professor, gananthi@tce

26PCPR0	NANO MOSFET MODELING	Category	L	T	P	Credits
		PEC	3	0	0	3

Preamble

Nano-scale MOSFET devices are the foundation of modern VLSI and semiconductor technologies. As CMOS technology scales below 100 nm, classical device models become inadequate due to short-channel effects, quantum confinement, ballistic transport, and leakage mechanisms. This course provides a comprehensive understanding of advanced MOSFET structures and compact modeling techniques used in nanoelectronics and integrated circuit design. Students will gain knowledge of analytical models, device simulation, and emerging transistor technologies for advanced semiconductor applications.

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TPS Level	Performance Indicator	CO Weightage	SDG addressed	SDG Level
CO1	Explain the fundamentals of MOSFET scaling and short-channel effects in nano-scale devices.	TPS2	PO1 – M PO2 – L	10	SDG 9	1
CO2	Analyze electrical characteristics and transport mechanisms in Nano MOSFETs.	TPS3	PO1 – S PO2 – M PO3 – L	15	SDG 9	2
CO3	Apply compact MOSFET models for device and circuit analysis.	TPS3	PO1 – S PO2 – M PO3 – L	18	SDG 9	2
CO4	Evaluate leakage mechanisms, quantum effects, and reliability issues in nanoscale transistors.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	18	SDG 9	2
CO5	Analyze advanced MOSFET structures such as FinFETs, SOI MOSFETs, and Multi-Gate devices.	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	19	SDG 9	2
CO6	Use simulation tools and apply modeling techniques for nanoscale transistor design and performance evaluation.	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG 9, SDG 12	2

SDG ALIGNMENT

SDG 9: Industry Innovation and Infrastructure

- Semiconductor device simulation for advanced integrated circuit technologies.
- TCAD-based design methodologies.

SDG 12: Responsible Consumption and Production

- Material optimization and low-power semiconductor devices.

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	% of Marks	% of Marks	% of Marks	% of Marks
CO1	32	42	-	-	18
CO2	36	28	-	-	16
CO3	32	32	-	-	18
CO4	-	-	32	42	12
CO5	-	-	36	28	12
CO6	-	-	32	32	24
Total	100	100	100	100	100

Syllabus

Fundamentals of MOSFET Scaling:MOSFET operation and structure – Energy band theory – Intrinsic and extrinsic semiconductors – Carrier concentration – Fermi level – Carrier statistics – Drift current – Diffusion current – Einstein relation – Scaling theory – Constant field scaling – Constant voltage scaling – Short channel effects – Threshold voltage roll-off – Drain Induced Barrier Lowering (DIBL). **Nano MOSFET Characteristics:**Carrier transport mechanisms – Drift-diffusion transport – Velocity saturation – Mobility degradation – Ballistic transport – Quasi-ballistic transport – Subthreshold conduction – Hot carrier effects – Carrier scattering mechanisms – Impact ionization – Current-voltage characteristics of nano MOSFETs.**Compact Modeling of MOSFETs:**Large signal models – Small signal models – Charge-sheet model – Threshold voltage modeling – Channel length modulation – Mobility models – BSIM models – EKV model – Parameter extraction methods – Compact model implementation and applications. **Leakage Mechanisms and Reliability:**Leakage current mechanisms – Gate oxide tunneling – Direct and Fowler–Nordheim tunneling – Junction leakage – Gate Induced Drain Leakage (GIDL) – Subthreshold leakage – Reliability issues in nano MOSFETs – Negative Bias Temperature Instability (NBTI) – Hot Carrier Injection (HCI) – Time Dependent Dielectric Breakdown (TDDB) – Oxide breakdown mechanisms.**Advanced MOSFET Structures:**Limitations of conventional MOSFETs – Silicon-on-Insulator (SOI) MOSFET – Double Gate MOSFET – FinFET architecture – Multi-Gate MOSFETs – Gate-All-Around (GAA) MOSFET – Electrostatic control in advanced devices – Performance comparison of advanced transistor architectures. **Device Simulation and Emerging Technologies:**TCAD simulation fundamentals – Device modeling and simulation techniques – Parameter extraction methods – Compact model implementation – Carbon Nanotube Field Effect Transistors (CNTFETs) – Nanowire MOSFETs – Two-dimensional material-based transistors – Emerging nanoelectronic devices – Future trends and challenges in nanoelectronics.

6.1 Text Book

- Yannis Tsividis and Colin McAndrew, Operation and Modeling of the MOS **Transistor**, Oxford University Press, 3rd Edition.
- Yuan Taur and Tak H. Ning, Fundamentals of Modern VLSI Devices, Cambridge University Press, 2nd Edition.

6.2 Reference Books & Web resources

- Chenming Hu, Modern Semiconductor Devices for Integrated Circuits, Pearson Education.

- S. M. Sze and Kwok K. Ng, Physics of Semiconductor Devices, Wiley, 3rd Edition.
- Jean-Pierre Colinge, FinFETs and Other Multi-Gate Transistors, Springer.
- Mark Lundstrom, Fundamentals of Carrier Transport, Cambridge University Press.
- Massoud Pedram and Jan Rabaey, Power Aware Design Methodologies, Springer.

Web Resources

- IEEE Xplore Digital Library
- NPTEL Courses on Nanoelectronics
- MIT OpenCourseWare – Semiconductor Devices
- Synopsys TCAD Documentation
- MOSIS Educational Resources

7. Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	Fundamentals of MOSFET Scaling and Short Channel Effects	8
2	Nano MOSFET Characteristics and Transport Mechanisms	8
3	Compact Modeling Techniques and BSIM Models	9
4	Leakage Mechanisms and Reliability Issues	8
5	Advanced MOSFET Structures and FinFETs	6
6	Device Simulation and Emerging Nano Devices	9
	Total Hours	36

Detailed Lecture Schedule

Module No	Topics	No of Periods
1.1	Introduction to MOSFET operation	3
1.2	Scaling theory	1
1.3	Constant field and constant voltage scaling	1
1.4	Short channel effects	1
1.5	Threshold voltage roll-off	1
1.6	Drain Induced Barrier Lowering (DIBL)	1
2.1	Carrier transport mechanisms	3
2.2	Velocity saturation	1
2.3	Mobility degradation	1
2.4	Ballistic transport	1
2.5	Subthreshold conduction	1
2.6	Hot carrier effects	1
3.1	Large signal and small signal models	3
3.2	Charge-sheet model	1
3.3	BSIM models	1
3.4	EKV model	1
3.5	Threshold voltage modeling	2
3.6	Channel length modulation	1
4.1	Gate oxide tunneling	1
4.2	Junction leakage	1
4.3	GIDL	1
4.4	Subthreshold leakage	1
4.5	Reliability issues	1
4.6	NBTI, HCI and oxide breakdown	3
5.1	Silicon-on-Insulator (SOI) MOSFET	1
5.2	Double gate MOSFET	1
5.3	FinFET	1
5.4	Multi-gate MOSFET	1

5.5	Gate-all-around MOSFET	1
5.6	Comparison of advanced transistor architectures	1
6.1	TCAD simulation fundamentals	3
6.2	Parameter extraction techniques	1
6.3	Compact model implementation	1
6.4	Carbon nanotube FETs (CNTFET)	1
6.5	Nanowire MOSFETs	1
6.6	Future trends in nanoelectronics	2
	Total Hours	36

8. Course Designer(s):

Dr.N.B.Balamurugan, Professor, nbbalamurugan@tce.edu

26PCPS0	ENERGY HARVESTING IN WIRELESS SENSOR NETWORKS	Category	L	T	P	Credits
		PEC	2	1	0	3

Preamble

The objective of this course concentrates on the energy harvesting techniques that are intended in designing wireless sensor networks and determining their performances in terms of standard performance metrics.

Prerequisite

Nil

Course Outcomes

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

No.	Course Outcome	TPS Level	CO Weightage	PO addressed	SDG addressed	SDG Level
CO1	Explain the principles of the wireless sensor network, architecture, and Protocol stack.	TPS3	10	PO1- S PO2 - M PO3 - L	4	2
CO2	Apply various localization techniques used in wireless sensor networks.	TPS3	20	PO1- S PO2 - M PO3 - L	4	2
CO3	Apply various sensing techniques used in wireless sensor networks.	TPS3	20	PO1- S PO2 - M PO3 - L	4	2
CO4	Determine the performance of various energy harvesting schemes in wireless sensor network.	TPS3	20	PO1- S PO2 - M PO3 - L	4	2
CO5	Apply statistical approach based on stochastic geometry to analyze the performance of energy harvesting.	TPS3	15	PO1- S PO2 - M PO3 - L	4	2
CO6	Develop simultaneous wireless information and power transfer technique from the measurement device in the sensor network.	TPS3	15	PO1- S PO2 - M PO3 - L	4	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	**% of Marks**	**% of Marks**	**% of Marks**	**% of Marks**
CO1	30	30			10
CO2	30	30			10
CO3	40	40			20
CO4			40	40	20
CO5			30	30	20
CO6			30	30	20
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

Module1:
Wireless Sensor Networks:
Architecture and Protocol stack, Hardware constraints, Fault tolerance, scalability, Network topology: Pre-deployment and Deployment Phase, Post-deployment Phase, Re-deployment Phase of Additional Nodes, Transmission Media, Power Consumption: Sensing, Data Processing, Communication

Module 2:
Localization techniques: Localization Challenges and Properties, Pre-deployment schemes, Proximity schemes, Ranging schemes: Triangulation, Trilateration, Range based Localization, Range free Localization: Hop based Localization, Point in Triangle

Module 3:
Sensing Techniques:
Types of sensors, Sensing coverage, High level sensors, Special case: The Human as a sensor, Actuators, Sensor Calibration, Detecting errors

Module 4:
Energy Harvesting:
Life time issues in the Wireless Sensor Network, Storage Capacity, Energy Harvesting Schemes: Solar, Wind, Thermal, Flow of Liquid, Acoustic Energy, Mechanical Vibrations, Ambient RF Energy, Human body, Observations on the Reviewed Energy harvesting Mechanisms

Module 5:
Simultaneous Wireless Information and Power Transfer:
Deployment of sensors/Measurement device, Data transmission and harvest energy simultaneous transmission

Module 6:
Stochastic Geometry: Point Processes as spatial models, Properties of Point Processes, Point Process transformations, Distances, Modeling Sensor nodes using Poisson Point Process, Energy harvesting analysis

6. Learning Resources

6.1 Text Book

- Faisal Karim Shaik,Sherali Zeadally, “Energy harvesting in Wireless Sensor Networks and Internet of Things”,IET Publishers,2022.

6.2 Reference Books & Web resources

- Olfa Kanoun,“Energy harvesting for Wireless Sensor Networks: technology, components and system design”, De Gruyter Oldenbourg,2019.
- Vidushi Sharma, Anuradha P,“Energy efficient Wireless Sensor Networks”,ughatCRC Press,2018.
- Anna Forster, “Introduction to Wireless Sensor Networks”,IEEE Wiley Press,2016.
- Ian F.Akyildiz,Mehmet Can Vuran, “Wireless Sensor Networks”, John Wiley and Sons Limited,2010
- Waltenegus Dargie,Christian Poellabauer, “Fundamentals of Wireless Sensor Networks,Theory and Practice”Wiley,2010.
- Feng Zhao and Leonidas Guibas, “Wireless Sensor Networks”, Morgan Kaufman Publishers, 2004.
- Anna Hac, “Wireless Sensor Network Designs”,John Wiley and Sons Limited,2003

7. Course Contents and Lecture Schedule

Module No.	Topic	No.of Periods
1	**Wireless Sensor Networks**	
1.1	Architecture and Protocol stack,	1
1.2	Hardware constraints	1
1.3	Fault tolerance, scalability	1
1.4	Network topology: Pre-deployment and Deployment Phase,	1
1.5	Post-deployment Phase, Re-deployment Phase of Additional Nodes, Transmission Media,	1
1.6	Power Consumption: Sensing, Data Processing, Communication	1
2	**Localization techniques**	
2.1	Localization Challenges and Properties	1
2.2	Pre-deployment schemes, Proximity schemes	1
2.3	Ranging schemes: Triangulation, Trilateration	1
2.4	Range based Localization	1
2.5	Range free Localization: Hop based Localization, Point in Triangle	2
3	**Sensing Techniques**	
3.1	Types of sensors	1
3.2	Sensing coverage, High level sensors	1
3.3	Special case: The Human as a sensor	1
3.4	Actuators	1
3.5	Sensor Calibration, Detecting errors	2
4	**Energy Harvesting**	
4.1	Life time issues in the Wireless Sensor Network	1
4.2	Storage Capacity	1
4.3	Solar Energy harvesting scheme	1
4.4	Wind Energy harvesting scheme	1
4.5	Thermal Energy harvesting scheme	1
4.6	Energy harvesting using Flow of Liquid	1
4.7	Acoustic Energy harvesting scheme	1
4.8	Energy harvesting using Mechanical vibrations	1
4.9	Ambient RF Energy harvesting Scheme	1
4.10	Human body Energy harvesting scheme	1
5	**Simultaneous Wireless Information and Power Transfer**	
5.1	Deployment of sensors/Measurement device	1
5.2	Data transmission and harvest energy simultaneous transmission	1
6	**Stochastic Geometry**	
6.1	Point Processes as spatial models	1
6.2	Properties of Point Processes	1
6.3	Point Process transformations	1
6.4	Distances	1
6.5	Modeling Sensor nodes using Poisson Point Process	1
6.6	Energy harvesting analysis	1
	Total Number of Hours	36

8. Course Designer(s):

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26PCPT0	IMAGE SYSTEMS ENGINEERING	Category	L	T	P	Credits
		PEC	2	1	0	3

Preamble

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

Prerequisite

NIL

Course Outcomes

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

No.	Course Outcome	TPS Level	Performance Indicator	CO Weightage	SDG addressed	SDG Level
CO1	Enhance and Restore images in spatial as well as frequency domains	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG9	2
CO2	Segment given images in terms of edge, threshold and region	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG9	2
CO3	Apply morphological operations like dilation, erosion, opening and closing on given images	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG9	2
CO4	Represent , recognize and classify objects from the given images	TPS3	PO1 – S PO2 – M PO3 – L	20	SDG9	2
CO5	Apply compression techniques to various imaging modalities	TPS3	PO1 – S PO2 – M PO3 – L	10	SDG9	2
CO6	Analyze different case studies like Face image feature extraction, video Motion imaging, watermarking	TPS4	PO1 – S PO2 – S PO3 – M PO4 – L	10	SDG4, SDG9	2

Assessment Pattern

CO	CAT1	Assignment 1	CAT2	Assignment 2	Terminal Exam
	% of Marks	**% of Marks**	**% of Marks**	**% of Marks**	**% of Marks**
CO1	40	**100**			**20**
CO2	30				**20**
CO3	30				**20**
CO4			40	**100**	**20**
CO5			20		10
CO6			40		**10**
Total	**100**	**100**	**100**	**100**	**100**

Syllabus

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

6. Learning Resources

6.1 Text Book

- Rafael.C.Gonzalez and Richard.E. Woods, “Digital Image Processing”, 4th edition, Pearson/Prentice Hall Education, 2018

6.2 Reference Books & Web resources

- Earl Gose, Richard Johnson Baugh, “Pattern Recognition and Image analysis”, Prentice Hall India Pvt Ltd, 2006
- William.K.Pratt, “Digital Image Processing”, 4th edition, A John Wiley and Publications,2007.
- G.W.Awcock & R.Thomas, “Applied Image Processing” McGraw-Hill Inc.1996.
- Frank.Y.Shih, “Image Processing and Pattern Recognition Fundamentals and Techniques”, A John Wiley & sons publication,2010.imon Haykin, “Digital Communications”, John Wiley & Sons Pvt. Ltd., 2001

7. Course Contents and Lecture Schedule

Module No	Topics	No of Periods
1	**Imaging Fundamentals:**	1
1.1	Introduction to Imaging Technologies	
1.2	Photographic	1
1.3	X-Ray	
1.4	MRI	
1.5	SAR	1
1.6	IR imaging	1
1.7	Image Representation	
2	**Image Transforms**	1
2.1	DCT	
2.2	Hotelling	1
2.3	Wavelet	1
2.4	Curvelet	1
3	**Image Quality Enhancement**:	1
3.1	Contrast	
3.2	Gray level Transformation	1
3.3	Histogram processing	1
4	**Image Restoration Techniques**:	1
4.1	Noise	
4.2	Spatial Domain spatial filtering- smoothing, sharpening filters	1

4.3	Frequency Domain filtering	1
4.4	Inverse-Wiener	1
5	**Processing and Analyzing Images**	1
5.1	Point Detection	
5.2	Line Detection	
5.3	Edge Detection	
5.4	Scene Segmentation and labelling	1
5.5	Counting objects	1
5.6	Perimeter measurement	
5.7	Hough Transform	1
5.8	Shape of Regions	1
5.9	Morphological operations	1
5.10	Texture	1
6	**Image Compression:**	1
6.1	Bit plane coding	
6.2	JPEG	1
7	**Statistical Decision Making:**	1
7.1	Bayes Theorem	
7.2	Decision Boundaries	1
7.3	SVM	1
7.4	Confusion matrices	1
7.5	Non-parametric Histogram	1
7.6	K-NN	1
8	**Imaging Applications:**	1
8.1	System design	
8.2	Optical character Recognition	
8.3	Rule based Character Recognition	1
8.4	Face and Facial feature Extraction	1
8.5	Video motion Analysis	1
8.6	Image Fusion	1
8.7	Watermarking - spatial & frequency domain	1
	Total Periods	36

8. Course Designer(s):

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