NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

SCHEME OF INSTRUCTION AND SYLLABI

M.Tech. – Advanced Communication Systems

Effective from 2021-22

NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

VISION

Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION

- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

VISION

Create an Educational environment to prepare the students to meet the challenges of modern electronics and communication Industry through state of art technical knowledge and innovative approaches.

MISSION

- To create learning, Development and testing environment to meet ever challenging needs of the Electronic Industry.
- To create entrepreneurial environment and industry interaction for mutual benefit.
- To be a global partner in training human resources in the field of chip design, instrumentation and networking.
- To associate with international reputed institution for academic excellence and collaborative research.

Department of Electronics and Communication Engineering

Brief about the Department:

The Department of Electronics and Communication Engineering is one of the country's larger ECE Departments among all NITs in India and one of the largest departments of the National Institute of Technology, Warangal (NITW). The ECE Department at NITW has been an international reputation of excellence in teaching, research and service. With excellent laboratory facilities and dedicated faculty, the department of ECE offers broad range of programs that include undergraduate (B.Tech) and post graduate (M.Tech) in Embedded Systems & Intelligent Instrumentation, VLSI System design, Communication Systems and research (Ph.D) programs. Some of the recent sponsored project undertaken by the department includes Radar Emitter Identification using Neural Networks sponsored by DLRL, Hyderabad and Special Manpower Development in VLSI sponsored by MIT-Govt. of India.

List of Programs offered by the Department:

Program	Title of the Program
B.Tech.	Electronics and Communication Engineering (ECE)
M.Tech.	Electronic Instrumentation & Embedded Systems (EI & ES)
	VLSI System Design (VLSI)
	Advanced Communication Systems (ACS)
Ph.D.	Electronics and Communication Engineering (ECE)

Note: Refer to the following weblink for Rules and Regulations of M.Tech. program:
https://www.nitw.ac.in/main/MTechProgram/rulesandregulations/

NOTE: Refer to the following link for the guidelines to prepare dissertation report:
https://www.nitw.ac.in/main/PGForms/NITW/

M.Tech. – Advanced Communication Systems (ACS)

PROGRAM EDUCATIONAL OBJECTIVES

PEO	PROGRAM EDUCATIONAL OBJECTIVES (PEOs)
PEO1	Conceptualize and prescribe the design flow of a communication system for a given application.
PEO2	Analyze, model, design and prototype the communication systems and networks with security features to meet the specifications
PEO3	Choose economical the coding techniques and safety measures to improve the performance by considering the most appropriate models for the available channel.
PEO4	Select the modern engineering tools to innovatively solve the problems in the design and operation of communication systems and networks.
PEO5	Pursue life-long learning as a means of enhancing the knowledge base and skills necessary to serve the engineering and scientific community.
PEO6	Contribute as an individual or a member of a team in product oriented research and demonstrate leadership skills

Mapping of Mission statements with program educational objectives

Mission	**PEO1**	**PEO2**	**PEO3**	**PE04**	**PEO5**	**PE06**
To create learning, Development and testing environment to meet ever challenging needs of the Electronic Industry.	3	3	3	3		
To create entrepreneurial environment and industry interaction for mutual benefit.	1	2	2	3		
To be a global partner in training human resources in the field of chip design, instrumentation and networking.		1	1	3	2	3
To associate with international reputed institution for academic excellence and collaborative research.				2	3	3

1-Slightly;   2-Moderately;   3-Substantially

M.Tech –Advanced Communication Systems

Program Outcomes (POs)

At the end of the program, the student will be able to:

POs	Program Outcomes (POs)
PO1	Engage in critical thinking and pursue investigations/ research and development to solve practical problems.
PO2	Communicate effectively, write and present technical reports on complex engineering activities by interacting with the engineering fraternity and with society at large.
PO3	Demonstrate higher level of professional skills to tackle multidisciplinary and complex problems related to Advanced Communication Systems.
PO4	Identify modulation and demodulation techniques, coding and decoding scheme for the design of a transmitter and receiver.
PO5	Indicate the modern data communication and networking concepts and features to be incorporated for secured data transfer as per societal needs.
PO6	Analyse and evaluate a wireless communication link or network and indicate performance enhancement methods.

Mapping of POs and PEOs

PEO	PO1	PO2	PO3	PO4	PO5	PO6
PEO1	3	3	1	3	2	3
PEO 2	3	3	2	3	2	3
PEO 3	1	3	2	3	3	1
PEO 4	1	3	2	3	3	2
PEO 5	1	2	2	2	2	2
PEO 6	1	1	3	1	2	3

1*: Slightly* *2: Moderately* 3: Substantially

SCHEME OF INSTRUCTION

M.Tech. (Advanced Communication Systems) Course Structure

I – Year: I – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	EC5301	Detection and Estimation Theory	3	0	0	3	PCC
2	EC5302	Advanced Digital Communications	3	0	0	3	PCC
3	EC5303	RF Engineering	3	0	0	3	PCC
4	EC5304	Mathematical Foundations for Communication Engineers	3	0	0	3	PCC
5		Elective-I	3	0	0	3	PEC
6		Elective-II	3	0	0	3	PEC
7	EC5305	Digital Communication Lab	0	0	4	2	PCC
8	EC5306	RF Engineering Lab	0	0	4	2	PCC
9	EC5348	Seminar	0	0	2	1	SEM
		Total	**18**	**0**	**10**	**23**	

I – Year: II – Semester

S.No.	Course Code	Course Title	L	T	P	Credits	Cat. Code
1	EC5351	Advanced Wireless Communication	3	0	0	3	PCC
2	EC5352	Mobile Networks	3	0	0	3	PCC
3	EC5353	Advanced Communication Networks	3	0	0	3	PCC
4		Elective-III	3	0	0	3	PEC
5		Elective-IV	3	0	0	3	PEC
6		Elective-V	3	0	0	3	PEC
7	EC5354	Wireless Communication Lab	0	0	4	2	PCC
8	EC5355	Networks Lab	0	0	4	2	PCC
9	EC5398	Seminar	0	0	2	1	SEM
		Total	**18**	**0**	**10**	**23**	

Note: PCC – Professional Core Courses
PEC – Professional Elective Courses

SCHEME OF INSTRUCTION

M.Tech. (Advanced Communication Systems) Course Structure

II – Year: I – Semester

S.No.	Course Code	Course Title	Credits	Cat. Code
1.	EC6347	Comprehensive Viva	2	CVV
2.	EC6349	Dissertation-Part A	12	DW
		Total	**14**	

II – Year: II – Semester

S.No.	Course Code	Course Title	Credits	Cat. Code
1.	EC6399	Dissertation-Part B	20	DW
		Total	**20**	

Credits in Each Semester					
Cat. Code	**Sem-I**	**Sem-II**	**Sem-III**	**Sem-IV**	**Total**
PCC	16	13	00	00	29
PEC	6	9	00	00	15
CVV	0	0	02	0	02
DW	0	0	12	20	32
SEM	01	01	00	00	02
Total	**23**	**23**	**14**	**20**	**80**

Professional Elective Courses:

Semester	Elective Number	Sl. No	Course Code	Course Title
I semester	Elective-I	1.	EC5311	Wireless optical communication
		2.	EC5312	IOT and Sensor Networks
		3.	EC5313	Information theory and coding
		4.	EC5113	FPGA System Design
	Elective-II	1.	EC5314	VLSI System design
		2.	EC5315	Cyber and Network Securities
		3.	EC5316	Advanced Optimization Techniques
		4.	EC5317	Image and Video Processing
II semester	Elective-III	1.	EC5361	Cognitive radio
		2.	EC5362	Optical Networks
		3.	EC5363	RF System Design
		4.	EC5163	Embedded Real Time Operating Systems
	Elective-IV	1.	EC5364	5G communications
		2.	EC5365	Green wireless communications
		3.	EC5366	Multimedia communications
		4.	EC5166	Machine Learning for Speech and Image Processing
	Elective-V	1.	EC5367	Advanced DSP
		2.	EC5368	Smart Antennas for 5G communications
		3.	EC5369	Machine Learning for Next Generation Communication Networks
		4.	EC5172	Deep learning techniques for signal Processing

M.Tech. – Electronics and Communication Engineering

Specialization: Advanced Communication Systems (ACS)

DETAILED SYLLABUS

I – Year: I – Semester

EC5301	Detection and Estimation Theory	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Apply discrete-time and continuous-time signal theory to estimate the signal parameters.
CO2	Extract useful information from random observations in communications.
CO3	Design and analyze optimum detection schemes.
CO4	Understand different estimation schemes such as ML, LSE and MMSE estimators.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2					
CO2		2				
CO3			2			
CO4			2			

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Detection theory

Introduction: Detection Theory in Signal Processing; the Detection Problem; theathematical Detection Problem; Hierarchy of Detection Problems; Role of Asymptotics; Summary of Important PDFs (Fundamental Probability Density Functions); Monte Carlo Performance Evaluation, Number of required Monte Carlo trials.

Statistical Decision Theory: Neyman-Pearson Theorem; Receiver Operating Characteristics; Minimum Probability of Error (ML, MAP, Baye's); Multiple Hypothesis Testing.

Deterministic Signals: Matched Filters – Development of Detector, Performance of Matched Filter; Multiple Signals – Binary case, Performance of Binary Case, M-ary case.

Random Signals: Estimator-Correlator – Energy Detector; Linear Model – Rayleigh Fading Sinusoid, Incoherent FSK for a Multipath Channel; Signal Processing Example – Tapped Delay Line Channel Model.

ESTIMATION THEORY

Introduction: Estimation in Signal Processing; Mathematical Estimation Problem; Assessing Estimator Performance.

Minimum Variance Unbiased Estimation: Unbiased Estimators; Minimum Variance Criterion; Existence of the Minimum Variance Unbiased Estimator; Finding the Minimum Variance Unbiased Estimator.

Cramer-Rao Lower Bound: Estimator Accuracy Considerations; Cramer-Rao Lower Bound; General CRLB for Signals in WGN; Extension to a Vector Parameter; Signal Processing Examples – Range Estimation, Sinusoidal Parameter Estimation).

Linear Models: Definition and Properties; Linear Model Examples – Curve Fitting, Fourier Analysis, System Identification.

General Minimum Variance Unbiased Estimation: Sufficient Statistics; Finding Sufficient Statistics; Using Sufficiency to Find the MUV Estimator.

Best Linear Unbiased Estimators: Definition of the BLUE; Finding the BLUE.

Maximum Likelihood Estimation: Example – DC Level in WGN; Finding the MLE; Properties of the MLE; MLE for Transformed Parameters.

Least Squares Estimation: The Least Squares Approach; Linear Least Squares; Order-Recursive Least Squares.

The Bayesian Philosophy: Prior Knowledge and Estimation, Nuisance parameters

General Bayesian Estimators: Risk Function; Minimum Mean Square Error Estimators; Maximum A Posteriori Estimators.

Kalman Filters and Wiener Filters: Introduction, Summary, Dynamic signal models, Scalar Kalman filter, Kalman versus Wiener filter.

Text Books:

1. **Steven M. Kay,** "Fundamentals of Statistical signal processing, volume-1: Estimation theory". Prentice Hall 2011.
2. **Steven M. Kay,** "Fundamentals of Statistical signal processing, volume-2: Detection theory". Prentice Hall 2011.
3. **Harry L. Van Trees**, "Detection, Estimation, and Modulation Theory, Part I," John Wiley & Sons, Inc. 2011.
4. **A. Papolis and S. Unnikrishna Pillai**, "Probability, Random Variables and stochastic processes, 4e". The McGraw-Hill 2010.

EC5302	**Advanced Digital Communications**	**Credits 3-0-0: 3**

Course Outcomes:

At the end of the course, the student will be able to

CO1	Design optimum receivers for digital modulation techniques
CO2	Compare the various modulation schemes from the point of view of bandwidth, circuit complexity and noise performance.
CO3	Determine the probability of error for a given scheme
CO4	Design an equalizer in the context of band-limited linear filter channels

Course Articulation Matrix:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1			2		
CO2					2	
CO3					2	
CO4						2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Elements of a Digital Communication System, mathematical models for communication channels, Communication channels and their characteristics. Representation of bandpass signals and system, Signal space representations.

Representation of digitally modulated signals, Memoryless modulation methods-Pulse Amplitude Modulation, Phase Modulation schemes, Quadrature Amplitude Modulation, Multi dimensional signaling - Spectral characteristics of Digitally modulated signals .

Optimum receiver for signals corrupted by AWGN, Performance of the optimum receiver for memoryless modulation, Optimum receiver for CPM signals and signals with random phase in AWGN channel.

Signal parameter estimation, Carrier phase estimation, Symbol timing estimation, Joint estimation of carrier phase and symbol timing, Performance characteristics of ML estimators.

Characterization of band-limited channels, Signal design for band-limited channels, Probability of error in detection of PAM, Modulation codes for spectrum shaping.

Optimum Receiver for channels with ISI and AWGN, Linear equalization, Decision feedback equalization, Reduced complexity ML detectors, Iterative equalization and decoding-Turbo equalization.

Multicarrier Systems: Multi Carrier Communications, Orthogonal Frequency Division Multiplexing(OFDM), Modulation and Demodulation of OFDM system, Algorithm implementation IFFT/FFT of OFDM, Peak to average Power Ratio in multi carrier Modulation

Textbooks:

1. J.G. PROAKIS, ' Digital communications' , MGH, 4th edition, 2001

2. Upamanyu Madhow, 'Fundamentals of Digital Communication', Cambridge University Press

3. Michael Rice, Digital Communications: A Discrete-Time Approach, Prentice Hall,

EC5303	RF Engineering	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Simulate passive circuits in microstrip line technology
CO2	Design microstrip lowpass, high pass, bandpass and bandstop filters.
CO3	Design microstrip based couplers and power dividers
CO4	Ability to use and measure S-parameters using microwave instruments

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2	2		
CO2			2	2		
CO3			2	2		
CO4			2	2		

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

UNIT 1 SCATTERING PARAMETERS

Scattering and chain scattering matrices, Generalized scattering matrix, Analysis of two port Networks, scattering matrix, representation of microwave components (directional coupler, circulators, hybrids, and isolators).

UNIT 2 PLANAR TRANSMISSION LINE

Microstrip lines: Geometry of microstrip, quasi-TEM mode of propagation, Static-TEM parameters, Characteristic impedance, effective permittivity, synthesis formulae, analysis formulae, dispersion in microstrip.

UNIT 3 HIGH FREQUENCY FILTER DESIGN

Filter design using Insertion loss method, characterization by power loss ratio, Maximally flat low pass filter, Equal-ripple low pass filter, Filter transformations: impedance and frequency scaling, bandpass and bandstop transformations, Filter implementation: Richard's transformation, Kuroda's identities.

UNIT 4 POWER DIVIDERS AND DIRECTIONAL COUPLERS

Basic properties of dividers and Couplers. Even mode and odd mode analysis, Wilkinson power divider, quadrature hybrid, and coupled line directional coupler.

UNIT 5 MICROWAVE MEASUREMENT SYSTEMS

Instrumentation concepts and measurement techniques in Spectrum analyzer, Signal generator, Vector network analyzer, and Noise figure analyzers.

REFERENCES

1. D. M. Pozar, Microwave Engineering, 3rd Edition, John Wiley & Sons.

2. R. Sorrentino and G. Bianchi, Microwave and RF Engineering, John Wiley & Sons.

3. Reinhold Ludwig and Gene Bogdanvov, ―RF Circuit Design – Theory and Application, 2nd Edition, Pearson, 2012.

4. E.da Silva, ―High Frequency and Microwave Engineering, Butterworth Heinmann publications, Oxford, 2001.

5. T. C. Edwards, Foundations of Interconnects and Microstrip lines, John Wiley & Sons.

EC5304	Mathematical Foundations for Communication Engineers	Credits 3-0-0: 3

Pre-requisites:

Course Outcomes:
At the end of the course, the student will be able to

CO1	Understand the mathematical concepts related to probability theory and random processes
CO2	Formulate and solve communication problems involving random processes
CO3	Understand the fundamental concepts in vector spaces, linear operators, matrices
CO4	Apply the concepts of inner product spaces to orthogonality and approximation problems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2					
CO2		2				
CO3			2			
CO4				2		1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

PROBABILITY AND RANDOM VARIABLES: Meaning of probability, Axioms of Probability, Conditional Probability, Concept of a Random Variable, Expected values for discrete and continuous random variables, Function of one Random Variable, Two Random variables, conditional probability density functions.

RANDOM PROCESSES: Classification, Auto Correlation, Cross Correlation, Stationary and wide sense stationary random process, Gaussian random process, Poisson random process.

LINEAR ALGEBRA: Vector spaces, Linear combination of vectors, Linear dependence, Basis and dimensions, finite dimensional vector spaces, Linear Transformations.
Norms and normed vector spaces, Inner products and inner product spaces.

LINEAR OPERATORS AND MATRIX INVERSES: Matrix factorizations, LU factorization, unitary matrices and QR factorization. Eigen values and Eigen vectors, Linear dependence of Eigen vectors, diagonalization of matrix. Singular value decomposition, pseudo inverses and the SVD.

TEXT BOOKS:

[1]. A. Papoulis and S. Unnikrishnan Pillai, ``Probability, Random Variables and Stochastic Processes," Fourth Edition, McGraw Hill. (Indian Edition is available).
[2]. Gibert Strang," Linear Algebra and its applications", Thomson Learning Inc, 4th Edition.

REFERENCES:

[1]. H.Stark and J. Woods, 'Probability and Random Processes with Applications to Signal Processing," Third Edition, Pearson Education. (Indian Edition is available).
[2]Steven M. Kay, " Intuitive Probability and Random Process using Matlab", Springer Publications.
[3]. Todd K Moon, Wynn C. Stirling" Mathematical Methods and Algorithms for Signal Processing, Prentice Hall.

EC5305	Digital Communication Lab	Credits 0-0-4: 2

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the different line codes and infer the quality of the received signal using eye diagram
CO2	Appreciate the principle of generation and detection of BPSK, DPSK, DEPSK, MSK, GFSK, GMSK signals.
CO3	Appreciate the principle of generation and detection of QPSK, DQPSK signals.
CO4	Generate and detect rate ½ convolutional code
CO5	Use a software tool to generate time domain and frequency domain descriptions of various binary digital modulation schemes.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2			
CO2				2		
CO3					2	
CO4						2
CO5			2			

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Detailed Syllabus

Hardware related experiments:

1. Sampling and reconstruction of low pass signals

2. Time Division Multiplexing

3. BPSK/DPSK generation & detection

4. QPSK/OQPSK generation &detection

5. 8-QAM generation & detection

6.FSK generation and detection

Simulation based experiments: (Matlab/Labview simulation)

1. Sampling & reconstruction of low pass signals

2. BPSK Modulation & detection

3. BER of BPSK in AWGN channel
4. QPSK generation & detection
5. BER of QPSK in AWGN channel
6. QAM generation & detection
7. 16 QAM constellation diagram
8. Generation of Nyquist-I pulse
9. Designing an equalizer in the context of baseband binary data transmission
10. OFDM generation and detection

(Any of the 5 `Hardware related experiments' and 5 more `Simulation based experiments' are performed by all the students of M.Tech. batch).

EC5306	**RF Engineering Lab**	**Credits 0-0-4: 2**

Course Outcomes:

At the end of the course, the student will be able to

CO1	Design of distributed microstrip filters
CO2	Design of microstrip couplers, power dividers and hybrids
CO3	Design of microwave active devices, oscillators and amplifiers
CO4	Fabrication and measurement of Microwave passive and active components

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2	2		
CO2			2	2		
CO3			2	2		
CO4			2	2		

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Virtual Lab

Design and simulation of a 50 Ohm microstrip line using AWR/Keysight ADS/Ansys HFSS.
Design and simulation of microstrip low pass filter using AWR/Keysight ADS/Ansys HFSS (using stubs and stepped impedance filter).
Design and simulation of microstip bandpass filter using AWR/Keysight ADS/Ansys HFSS.
Design and simulation of microstrip branch line coupler using AWR/Keysight ADS/Ansys HFSS.
Design and simulation of microstrip coupled line coupler using AWR/Keysight ADS/Ansys HFSS.
Design and simulation of Wilkinson power divider using AWR/Keysight ADS/Ansys HFSS.
Design and simulation of low noise amplifier using AWR/Keysight ADS/Ansys HFSS.
Design and simulation of an oscillator using AWR/Keysight ADS/Ansys HFSS.

Experimentation

Measurement of passive components using Vector Network Analyzer, Spectrum Analyzer and Signal Generator.
Fabrication and testing of microstrip low pass and bandpass filter.
Fabrication and testing of a microstip branch line coupler and Wilkinson power divider.
Fabrication and testing of a low noise amplifier.
Fabrication and testing of an oscillator.

Professional Elective Courses:

Elective-I

EC5311	Wireless Optical Communication	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Learn the principles of wireless optical communication (WOC) and the light transmission through the air, it must contend with a complex and not always predictable channel - the atmosphere.
CO2	Understand about the modulation and demodulation techniques used in WOC systems
CO3	Expose atmospheric/free-space channel characterization with different atmospheric conditions
CO4	Design transmitter and receiver for WOC link and analyse the link feasibility interms of error performance and channel capacity.

Course Articulation Matrix:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2				
CO2				3		
CO3	1		2		2	
CO4					1	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to wireless optical communication (WOC), wireless optical channels: atmospheric channel, underwater optical channel, atmospheric losses, weather condition influence, atmospheric turbulence effects i.e. scintillation, beam spreading, etc. wireless optical communication application areas, WOC challenges.

Optical sources and detectors: LED structure, planar and dome LED, LED efficiencies, LASER diode, Modes and Threshold conditions, structure of common Laser Types: Fabry–Perot Laser, distributed feedback Laser. PIN Photo detector, avalanche photo diode, photo detection noises, comparison of photo detectors.

Channel modeling: linear time invariant model, channel transfer function, models of turbulence induced fading such aslog-normal turbulence model, exponential, K distribution, gammagammadistribution,indoor optical wireless communication channel: LOS propagation model, Non-LOS propagation model, spherical model.

Modulation techniques: analogue intensity modulation, digital baseband modulation techniques: baseband modulations, on–off keying, error performance on Gaussian channels, power efficiency, BW efficiency, bit versus symbol error rates, different modulation schemes such as M-PPM, DPPM, DAPPM schemes, subcarrier modulation, optical polarization shift keying: binary PolSK, bit error rate analysis.

Detection techniques: direct detection optical receivers, PIN/APD, coherent techniques i.e. homodyne and heterodyne, bit error rate evaluation in presence of atmospheric turbulence, spatial diversity receivers, effect of turbulence and weather conditions i.e. drizzle, haze fog on error performance and channel capacity.

References:

1. Z.Ghassemlooy, W.Popoola, S.Rajbhandari, Optical Wireless Communications, CRC Press,2013.
2. Gerd Keiser, Optical Fiber Communication, 4th Edition, Tata McGraw-Hill Ltd., 2008 (Indian Edition).
3. L.C.Andrews, R.L.Phillips, Laser Beam Propagation through Random Media, SPIE Press,USA, 2005.

EC5312	IOT and Sensor Networks	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand IOT design requirements
CO2	Compare various technologies and protocols
CO3	Study Cloud storage and intelligent analytics
CO4	Analyze security requirements along with threat model

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3					
CO2		2				3
CO3				3		
CO4					3	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Architectures: IoT and the connected world, Architecture of IoT, Security issues, Opportunities for IoT

Relavance of Internet to network of Things, network management, security, mobility and longevity, desirable features of a distributed architecture for a system of things

Technologies: Wireless protocols, Connectivity options, Low-power design, range extension techniques, data-intensive IoT, MAC and routing aspects.

Data storage and analysis: Managing high rate sensor data, Processing data streams, Data consistency in an intermittently connected or disconnected environment,

Identifying outliers and anomalies

Security in IOT: Threat models, Defensive strategies and examples

Cloud Computing: Introduction, Types of Cloud Computing, Cloud Computing: A Paradigm Shift? Price and Value Models, Security and Governance, IAAS AND PAAS, SAAS, AWS, Azure, IBM Watson

Reference Books:

1. Adrian McEwen, Hakim Cassimally, “Designing the Internet of Things”, Wiley 2013

2. Naveen Balani, “Enterprise IoT”, CreateSpace Independent Publishing Platform 2016

3. NAYAN B. RUPARELIA, “Cloud Computing”, MIT Press 2016

EC5313	Information Theory and Coding	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the major classes of error detecting and error correcting codes and how they are used in practice.
CO2	Specify specific error detecting and error correcting codes in a precise mathematical manner.
CO3	Develop and execute encoding and decoding algorithms associated with the major classes of error detecting and error correcting codes.
CO4	Construct codes capable of correcting a specified number of errors

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1			2		
CO2					2	
CO3					2	
CO4						2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Entropy, Relative Entropy, Mutual Information Inequalities, Entropy rate. Asymptotic Equipartition Property (AEP): Consequences of the AEP, Typical Sequences, Shannon McMillan Breiman Theorem.

Channel capacity: Discrete Memory less Channel, Joint Typicality, Channel Coding Theorem and its converse, Feedback capacity, Source Channel Separation Theorem. Differential Entropy: Definition, Properties. Gaussian Channel: Definition, Parallel Gaussian Channels, Channels with Colored Gaussian Noise, Gaussian Channels with Feedback, Limits to Communication.

Linear Block Codes: Groups, Fields and Vector Spaces, Construction of Galois Fields of Prime Order Syndrome Error Detection, Standard Array and Syndrome Decoding, Hamming Codes, LDPC Codes.

Cyclic Codes: Polynomial Polynomial Representation of Codewords, Generator Polynomial, Systematic Codes, Generator Matrix, Syndrome Calculation and Error Detection, Decoding of Cyclic Codes, Meggit decoder, BCH codes, generator polynomials with minimal polynomials, BCH decoding, non BCH codes(RS codes), RS decoding.

Convolutional Codes: Convolutional Encoder Representation, Tree, Trellis, and State Diagrams, Distance Properties of Convolutional Codes, Punctured Convolutional Codes and Rate Compatible Schemes, Decoding of Convolutional Codes: Maximum Likelihood Detection, The Viterbi Algorithm

Textbooks:

1.T.M. Cover and J.A. Thomas, *Elements of Information Theory*, John Wiley & Sons.

2. Todd K. Moon, Error Correction coding, John Wiley, 2005

3. Shu lin/ Daniel J.Costello Jr., Error Control Coding, Prentice Hall series in computer applications in electrical engineering series (2/e) 2005.

4. Ranjan Bose, Information Theory, coding and cryptography (2/e), McGraw Hill.

EC5113	FPGA System Design	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student will be able to:

CO1	Understand FPGA design flow.
CO2	Understand the building blocks of commercially available FPGA/CPLDs
CO3	Develop VHDL/Verilog models and synthesize targeting for Vertex, Spartan FPGAs
CO4	Develop parameterized library cells and implement system designs using parameterized cells

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1					1	
CO2					3	
CO3					2	1
CO4					2	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

INTRODUCTION TO FPGAs: Evolution of programmable devices, FPGA Design flow, Applications of FPGA.

DESIGN EXAMPLES USING PLDs: Design of Universal block, Memory, Floating point multiplier, Barrel shifter.

FPGAs/CPLDs: Programming Technologies, Commercially available FPGAs: Xilinx's Vertex and Spartan, Actel's FPGA, Altera's FPGA/CPLD, Building blocks of FPGAs/CPLDs, Configurable Logic block functionality, Routing structures, Input/output Block, Impact of logic block functionality on FPGA performance, Model for measuring delay.

CASE STUDY – Applications using Kintex-7, Virtex-7, Artix-7

Text Books:

1. John V. Old Field, Richrad C. Dorf, Field Programmable Gate Arrays, Wiley, 2008.
2. Data sheets of Artix-7, Kintex-7, Virtex-7
3.Stephen D. Brown, Robert J. Francis, Jonathan Rose, ZvonkoG. Vranesic, Field Programmable Gate Arrays, 2nd Edition, Springer, 1992.

Elective-II

EC5314	VLSI System Design	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Model the behaviour of a MOS Transistor
CO2	Understanding CMOS Inverter
CO3	Design combinational and sequential circuits using CMOS gates
CO4	Identify the sources of power dissipation in a CMOS circuit.
CO5	Analyze SRAM cell and memory arrays

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2	2		
CO2			2			
CO3			2	2		
CO4			2			
CO5						2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

MOS Transistors, CMOS Logic, CMOS Fabrication and Layout, Design Partitioning, Fabrication, Packaging, and Testing, MOS transistor Theory, Long Channel I-V Characteristics, C-V Characteristics, Non-Ideal I-V Effects, DC Transfer Characteristics. The CMOS Inverter:

The Static CMOS Inverter -An Intuitive Perspective, Evaluating the Robustness of the CMOS Inverter: The Static Behavior, Performance of CMOS Inverter: The Dynamic Behavior.

CMOS Processing Technology, CMOS Technologies, Layout Design Rules, CMOS Process Enhancements, Technology-Related CAD Issues, Manufacturing Issues, Circuit Simulation- A SPICE Tutorial, Device Models, Device Characterization, Circuit Characterization, Interconnect Simulation. Combinational Circuit Design, Circuit Families, Silicon-On-Insulator Circuit Design, Sub Threshold Circuit Design, Sequential Circuit Design, Circuit Design of Latches and Flip-Flops, Static Sequencing Element Methodology, Sequencing Dynamic Circuits, Synchronizers, Wave Pipelining.

Power, Sources of Power Dissipation, Dynamic Power, Static Power, Energy-Delay Optimization, Low Power Architectures, Robustness, Variability, Reliability, Scaling, Statistical Analysis of Variability, Variation-Tolerant Design. Delay, Transient Response, RC

Delay Model, Linear Delay Model, Logical Effort of Paths, Timing Analysis Delay Models, Datapath Subsystems,Addition/Subtraction, One/Zero Detectors, Comparators, Counters, Boolean Logical Operations, Coding, Shifters, Multiplication.

Array Subsystems, SRAM, DRAM, Read-Only Memory, Serial Access Memories, Content-Addressable Memory, Programmable Logic Arrays, Robust Memory Design, Special-Purpose Subsystems.

CMOS Testing-The need for testing, Manufacturing test principles, Design strategies for test, Chip level test techniques, System level test techniques, Layout design for improved testability.

Text Books:

1. CMOS VLSI Design – A Circuits and Systems Perspective, Neil H.E. Weste, David Harris, Ayan Banerjee, , 3rd Edition, Pearson Education, 2006.

2. Principles of CMOS VLSI DESIGN:A Systems Perspective, Neil H. E. Weste , Kamran Eshraghian, 2nd Edition., Pearson Education, 2006.

Reference Books:

1. Jan M RABAEY, Digital Integrated Circuits, 2nd Edition, Pearson Education, 2003.
2. Douglas A. Pucknell, Kamran Eshraghian, Basic VLSI Design, 3rd Edition., PHI,1994.

EC5315	Cyber and Network Securities	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Have a fundamental understanding of the objectives of cryptography and network security.
CO2	Apply mathematical foundations to solve security problems in system and communication networks
CO3	Become familiar with the cryptographic techniques that provide information and network security
CO4	Be able to evaluate the security of communication systems

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3				
CO2	3					
CO3		1				
CO4		2				

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Cyber Security: Security requirements and attacks, CIA model, Symmetric ciphers, AES, Block cipher operation, PRBS generation and stream ciphers, Asymmetric ciphers, PKC and RSA, ECC, Data Integrity Algorithms, Hash functions, Digital signatures, User authentication, digital envelope.

Network Security and Internet Applications: Security Requirements and Attacks, Confidentiality with Conventional Encryption, Secure Socket Layer and Transport Layer Security, IPv4 and IPv6 Security, Wi-Fi Protected Access. transport level security, WLAN security, E-mail security, Malicious software, firewalls.

P2P network security: Introduction and Applications of P2P Networks, Centralized Directory, Query Flooding, Distributed Hash Table, Attacks on P2P Networks, Distributed Denial-of-Service, Poisoning the Network, Privacy and Identity, Blocking of P2P Traffic, Securing P2P Networks, Encrypting P2P Traffic, Anonymous P2P.

Reading:

1. William Stallings, Cryptography and Network Security, Pearson, 2011.

2. Bruice Schneier, Applied Cryptography, 2nd Edition, Wiley India Pvt. Ltd. 2009.

3. Jie Wang, Zachary A. Kissel, Introduction to Network Security, Wiley India Pvt. Ltd. 2015.

EC5316	**Advanced Optimization Techniques**	**Credits 3-0-0: 3**

Course Outcomes:

At the end of the course, the student will be able to

CO1	Ability to formulate mathematical models of real world problems
CO2	Understand the major limitations and capabilities of deterministic operations
CO3	Handle, solve and analyze problems using linear programming and other mathematical programming algorithms.
CO4	Solve various multivariable optimization problems.
CO5	Use search techniques methods to find optimal solutions of Non-Linear Problems

Course Articulation Matrix:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3					
CO2			3			
CO3						3
CO4	3					
CO5	3					

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Statement of an optimization problem, Classification of optimization problems, Overview of various optimization Techniques, Classical optimization techniques: Single variable optimization, Multivariable optimization, Unconstrained optimization and Constrained optimization**.**

Genetic algorithm (GA): Fundamentals of Genetic algorithm, History, Basic concepts, working principle, Encoding, Design of Fitness function, Reproduction, Crossover, Mutation operator in GA, Applications of GA for standard Bench mark test functions Fundamentals.

Swarm intelligence: Main inspiration source, Basic particle swarm optimization, Initialization techniques, Theoretical investigations and parameter selection, Design of PSO algorithm using computational statistics, Termination conditions, Application of PSO, Standard test function optimization, new modifications of PSO.

Differential Evolution: Classical differential evolution- An outline, Mutation, cross over, new modifications of DE.

Teaching Learning Based Optimization (TLBO), Applications of TLBO for standard Bench mark test functions, Case studies Basic Steps in Differential Evolution algorithm

Wavelet Mutation:

Basic Wavelet Theory, wavelet theory in mutation operation, Wavelet Mutation (WM) to improve further the optimization performance of Evolutionary Optimization Techniques through mutation.

Hybridization: Hybridization of GA, PSO, DE etc.

Reference Books:

1. S Rajasekharan, G.A Vijaya Lakshmi Pai, Neural Networks, Fuzzy logic, and Genetic algorithms, Synthesis and Applications, Prentice hall of India, 2007
2. K. Deb,"Optimization for Engineering DesignAlgorithms and Examples",Prentice-Hall of India Pvt. Ltd., New Delhi, 1995.
3. D.K. Pratihar, "Soft Computing" ,Narosa Publishing House, New Delhi, 2008
4. Milani Mitchel, An introduction to Genetic algorithms, MIT Press, 1998.
5. Richard W Daniels, An Introduction to Numerical Methods and Optimization Techniques, Elsevier North Holland Inc
6. AE Eiben and J.E Smith, Introduction to Evolutionary Computing, Springer 2010

EC5317	Image and Video Processing	Credits 3-0-0: 3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Interpret, Analyze, model and Process the Image data using appropriate methods, algorithms
CO2	Interpret, Analyze, model and Process the Video data using appropriate methods, algorithms
CO3	Specify and design optimal image and video processing techniques for the given Imaging problem to efficiently use the available hardware and software tools.
CO4	Apply suitable tools to simulate and demonstrate the working of image processing systems as per the application needs.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2				
CO2	3	2				
CO3	1	2	2			
CO4	1	2		2		2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Image Processing Overview: Image Sensing and Acquisition, Digital Image Representation, Basic Relationships between Pixels, Image Enhancement, Intensity Transformations and Spatial Filtering, Histogram Processing, Smoothing Spatial Filters, Sharpening Spatial Filters.

Image Segmentation: Point, Line, and Edge Detection, First order derivative, Prewitt and Sobel operators, Second order derivative – LoG, DoG, Canny Operator, Edge linking, Hough Transform, Thresholding – Global, Adaptive, Otsu's Method, Region Growing, Region Splitting and Merging Algorithms.

Image Representation and Description: Chain codes, Signatures, Boundary Descriptors, Shape numbers, Fourier Descriptors, Statistical moments, Regional Descriptors – Topological, Texture, Principal Component Analysis.

Object Recognition and Applications: Feature extraction, Histogram based features, intensity features, color features, Patterns and Pattern Classes, Types of classification algorithms, Minimum distance classifier, Correlation based classifier, Bayes classifier, Image Processing Applications - Biometric Authentication, Character Recognition, Remote Sensing.

Video Sampling and Indexing: Digital Video, Video Transmission, Spatiotemporal Sampling Structures, Sampling Structure Conversion, Image and Video Indexing and Retrieval

Video Enhancement: Introduction, Spatio Temporal Noise Filtering, Linear Filters, Order-Statistic Filters.

Motion Detection and Estimation: Hypothesis Testing, Markov Random Fields, MAP Estimation, Motion Detection, Motion Estimation, Motion Models, Region of Support, Estimation Criteria, Search Strategies, Practical Motion Estimation Algorithms, Global Motion Estimation, Block Matching, Phase Correlation.

Video Compression: Introduction, Application Requirements, Digital Video Signals and Formats, Digital Video Formats, Video Compression Techniques, Entropy and Predictive Coding, Block Transform Coding--The Discrete Cosine Transform, Motion Compensation and Estimation, Video Encoding Standards and H.261, spatial subband/wavelet transform (SWT), Motion Estimation, MC Temporal Filtering, Lifting Implementation, Directional IBLOCKs, Scalable Motion Vector Coding, Alphabet General Partition of Motion Vector Symbols, EZBC Coder, MPEG-1 Video Coding Standard, MPEG-1 Video Coding vs. H.261 MPEG-1 Video Structure, Summary of the Major Differences between MPEG-1 Video and H.261 Coders, MPEG-4: Technical Description, Embedded Video Codec Design Requirements and Constraints, Embedded Video Codec Design Flow.

Text Books:

1. Rafael C. Gonzalez and Richard E. Woods, "Digital Image Processing", 4th Edition, - Pearson Education, 2015.

2. **ALAN C BOVIK,** "Hand Book of Image and Video Processing", 2nd Edition, Elsevier Academic Press, 2005.

Reference Books:

1. **Rafael C. Gonzalez, Richard E. Woods, and Steven L. Eddins**, "Digital Image Processing Using MATLAB", 2nd Edition, Tata McGraw Hill Publication, 2010.

2. **Oge Marques**, "Practical Image And Video Processing Using Matlab", John Wiley & Sons, Inc., 2011.

3. **Ranjan Parekh**, "Fundamentals Of Image, Audio, And Video Processing Using Matlab® With Applications To Pattern Recognition", CRC Press, 2021.

I – Year: II – Semester

EC5351	Advanced Wireless Communication	Credits 3-0-0:3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Model the wireless channel to estimate the path loss
CO2	Evaluate the performance of digital modulation techniques over wireless channels using software and hardware techniques
CO3	Suggest the possible techniques to improve the performance of wireless systems using modern tools
CO4	Identify the advantages of multicarrier modulation

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1			2		
CO2					2	
CO3					2	
CO4						2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

WIRELESS CHANNELS: Radio wave propagation, Physical modeling for wireless channels, Path loss and Shadowing, outage probability under path loss and shadowing, time and frequency coherence, Statistical multipath channel models, narrowband fading models, wideband fading models, Discrete-time model, Space-time channel models.

CAPACITY OF WIRELESS CHANNELS:AWGN channel capacity, capacity of flat fading channels, channel distribution Information known at transmitter or receiver and both capacity comparisons, Capacity of frequency selective fading channels-time invariant- time variant.

PERFORMANCE OF DIGITAL MODULATION OVER WIRELESS CHANNELS: SNR and bit/symbol energy, error probability for BPSK, QPSK, MPSK, MPAM, MQAM , Index Modulation over fading channels. Error probability for FSK and CPFSK, error probability approximation for coherent modulations and differential modulation, Q-function representation, outage probability, average probability of error, inter symbol interference.

DIVERSITY: Receiver diversity: selection combining (SC), threshold combining, maximal ratio combining (MRC), equal gain combining (EGC), transmitter diversity: channel known at the transmitter, channel unknown at the transmitter, Alamouti scheme, moment generating functions(MGF) in diversity analysis ,diversity analysis using MGF for SC-EGC-MRC, diversity analysis for non-coherent and differentially coherent modulation.

EQUALIZATION: equalizer noise enhancement, equalizer types, zero forcing equalizer, MMSE equalizer, maximum likelihood sequence estimation, decision feedback equalization, adaptive equalizers.

.**REFERENCE BOOKS:**

1]. Andrea goldsmith, `Wireless Communication`, South Asia Edition 2015, Cambridge University Press

[2].Theodore S. Rappaport, 'Wireless Communications Principles and Practice," Third Edition, Pearson Education. (Indian Edition is available).

[3]David Tse, Pramod Viswanath, "Fundamentals of Wireless Communication", Cambridge University Press

[4]. Todd K Moon, Wynn C. Stirling" Mathematical Methods and Algorithms for Signal Processing, Prentice Hall

EC5352	Mobile Networks	Credits 3-0-0:3

Course Outcomes:
At the end of the course, the student will be able to

CO1	Assess the wireless network performance and trade-offs
CO2	To understand the various technologies in wireless networks.
CO3	Suggest the architectures for wireless wide area networks
CO4	Handle the planning and design issues for Adhoc wireless networks

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		3	3	3	3
CO2	3		3	3	3	3
CO3	3		3	3	3	3
CO4	3		3	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Wireless Area Networks :
WPAN: System model - protocol stack of IEEE 802.15; Bluetooth: Network architecture - operation- specification and application models; Radio Frequency Identification (RFID): Types and specifications; ZIGBEE and WBAN: Standard and architecture; WLAN: Network architecture - protocol stack of IEEE 802.11 - physical layer and MAC layer mechanism (CSMA/CA and WiFi MAC overview; Wide bandwidth channel access techniques (802.11n/ac) ; Energy efficiency and rate control); WiMAX: BWA(Broadband Wireless Access) - issues and challenges of WiMAX - network architecture - protocol stack of IEEE 802.16 - differences between IEEE 802.11 and IEEE 802.16

WIRELESS WIDE AREA NETWORKS: GSM, 3G wireless systems : Concept of Spread Spectrum - System Processing Gain - Direct-Sequence Spread Spectrum - Frequency-Hopping Spread Spectrum Systems - Requirements of Spreading Codes- evolution of IS 95 to CDMA 2000- Downlink (Forward) (BS to MS) - Uplink (Reverse) (MS to BS) - Power Control in CDMA –WCDMA.

Wireless Internet
IP for wireless domain - mobile IP - IPv6 advancements –IPV6 network layer in the internet; mobility management functions - location management - registration and handoffs; TCP in wireless domain: TCP over wireless - types - mobile transaction - impact of mobility; Wireless security and standards.

Wideband Wireless Technologies
UWB Radio Communication: Fundamentals of UWB - major issues - operation of UWB systems - comparisons with other technologies - advantages and disadvantages

Adhoc wireless networks: Characteristics of Adhoc Networks, Classifications of MAC Protocols - Table driven and Source initiated On Demand routing protocols, DSDV, AODV, DSR and Hybrid Protocols.

Fourth Generation Systems and New Wireless Technologies- 4G Vision - 4G Features and Challenges - Applications of 4G; 4G Technologies - LTE FDD vs TDD comparison; frame structure and its characteristics; Smart Antenna Techniques - OFDM-MIMO Systems - Adaptive Modulation and Coding with Time-Slot Scheduler - Bell Labs Layered Space Time (BLAST) System - Software-Defined Radio - Cognitive Radio.

TEXTBOOKS:

1) Theodore Rappaport —Wireless Communication, Prentice Hall, 2nd Edition.
2) William Stallings —Wireless Communications and Networks, Prentice Hall.
3) Schwartz —Mobile Wireless Communications, Cambridge University Press.
4) Mark and Zhuang —Wireless Communications and Networking, Prentice Hall.
5) Vijay Garg K, “Wireless Communications and Networks”, 2nd Edition, Morgan Kaufmann Publishers (Elsevier), 2007.
6) Clint Smith and Daniel Collins, “3G Wireless Networks”, 2nd Edition, Tata McGraw Hill, 2007.
7) AmitabhaGhosh and RapeepatRatasuk, “Essentials of LTE and LTE-A,” Cambridge University Press, 2011.
8) Dharma Prakash Agrawal and Qing-An Zeng, "Introduction to wireless mobile systems" Thomson India, 2007.
9) Siva Ram Murthy C and Manoj B S, “Ad Hoc Wireless Networks: Architectures and Protocols”, Prentice Hall, 2004.

Hyperlink:

1. http://doktora.kirbas.com/Kitaplar/Wireless%20Networking%20Complete.pdf
2. www.tutorialspoint.com/wimax/
3. http://www.infotech.monash.edu.au/units/archive/2012/s2/fit5083.html
4. http://www.utdallas.edu/~venky/

EC5353	Advanced Communication Networks	Credits 3-0-0:3

Pre-requisites: None

Course Outcomes:
At the end of the course, the student will be able to

CO1	Understand fundamental underlying principles of communication networking and functionality of layered network architecture and protocol standards
CO2	Apply mathematical foundations to solve computational problems in communication networks
CO3	Understand ethical, legal, security, and social issues related to communication networks
CO4	Identify and understand various techniques and modes of transmission, data link protocols, multi-channel access protocols, routing and congestion in network layer with routing algorithms and IPV6 addressing scheme

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3				
CO2	3					
CO3		1				
CO4		2				

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Basics of Data Communications for networking; Packet switching, Store-&-Forward operation; Layered network architecture, Overview of TCP/IP operation.

Data Link Layer: Framing; error control, error detection, parity checks, Internet Checksum and Cyclic Redundancy Codes for error detection; Flow control, ARQ strategies and their performance analysis using different distributions; HDLC protocol. Media Access Control (MAC): MAC for wired and wireless Local Area Networks (LAN), Pure and Slotted ALOHA, CSMA, CSMA/CD, IEEE 802.3; ETHERNET, Fast ETHERNET, Gigabit ETHERNET; IEEE 802.11 WiFi MAC protocol, CSMA/CA; IEEE 802.16 WiMAX. Network Layer:

Network layer: Internet Protocol, IPv6, ARP, DHCP, ICMP, Routing algorithms: Basic graph theoretic concepts, spanning tree, Shortest path routing, distance vector routing, link state routing, RIP, OSPF, Inter-domain routing. Subnetting, Classless addressing, Network Address Translation.

Fundamentals of Queuing Theory: Simple queuing models, M/M/- Queues, M/G/1/ Queues, queues with blocking, priority queues, vacation systems, discrete time queues.

Transport Layer: UDP, segment structure and operation; TCP, segment structure and operation. Reliable stream service, congestion control and connection management.

Selected Application Layer Protocols: Web and HTTP, electronic mail (SMTP), file transfer protocol (FTP), Domain Name Service (DNS). Real-Time Traffic, Voice Over IP and Multimedia.

Design issues in protocols at different layers, Session, Presentation, and Application Layers. Examples: DNS, SMTP, IMAP, HTTP, etc

Wireless Communication Networks: Wireless networks (WiFi (802.11), Bluetooth, WiMax.) and mobility supports, MAC protocol, routing, AODV, group communication, multicast.

Broadband Networks: ATM, Frame relay and Gigabit Ethernet. Traffic Management in ATM networks.

Text Books:

1. D. Bertsekas and R. Gallagar, Data Networks, 2/e, PHI, 1992.

2. J.F. Kurose and K. W. Ross: Computer Networking, A Top-Down Approach, 4/e, Pearson/Addison Wesley, 2008.

3. BEHROUZ A. FOROUZAN, Data Communications and Networking, 2nd Edition, Tata McGraw-Hill, New Delhi, 2003

4. DOUGLAS E COMER, Computer Networks and Internet, Pearson Education Asia, 2000.

5. A. Leon-Garcia and I. Widjaja: Communication Networks; 2/e, McGraw Hill, 2004.

6. A. S. Tanenbaum, Computer Networks, 4/e, PHI, 2000. 7. W. Stallings, Data and Computer Communication, 7/e, Prentice-Hall, 2004.

EC5354	**Wireless Communication Lab**	**Credits** **0-0-4 :2**

Course Outcomes:

At the end of the course, the student will be able to

CO1	Estimate the path loss
CO2	Calculate the uplink and downlink SNR .
CO3	Assess the effects of flat and frequency fading
CO4	Design, implement, and distribute stand-alone applications using LabVIEW

Course Articulation Matrix:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	1					
CO2	1	1				
CO3		2				
CO4			2			2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

VIRTUAL LAB

1. Introduction to the labview
2. Baseband QAM Modulation and Detection design
3. Performance of Baseband QAM/QPSK Under AWGN Channel
4. STO estimation-maximum energy for QAM/QPSK modulation
5. Implementation of channel estimation for multipath environment
6. Frame detection and CFO estimation using Frank sequence
7. Multitap indirect channel equalization
8. Multitap direct channel equalization
9. OFDM modulation and demodulation and single tap equalization
10. Preamble aided synchronization for OFDM system

EC5355	Networks Lab	Credits 0-0-4:2

Course Outcomes:

At the end of the course, the student will be able to

CO1	Implement discrete event simulations on OMNET++
CO2	Design different traffic sources corresponding to end-user services.
CO3	Evaluate the effect of queueing and different line-rates, and observe their effects on end-to-end delay.
CO4	Implement wired and wireless access control protocols.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1				2	
CO2	2		3		2	
CO3				2	2	
CO4		2		2	1	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

- Overview of the OMNET++ discrete event simulator, creating modules, generating and handling messages.
- Creating a tree type wired access network, with an optical line terminal and optical network unit modules, with round robin scheduling for media access control.
- Creating Pareto based ON OFF traffic sources.
- Implementation of the multi-point control protocol in an optical access network.
- Implementation of a long-reach passive optical network.
- Implementation of a token ring, SONET, and RPR.
- Implementation of a wireless mesh network with multiple hosts and interference with INET module.
- Implementation of CSMA with acknowledgements.
- Implementation of ad-hoc routing.
- Implementation of obstacles and realistic radio models with INET module.

Text Books:

1. Queuing systems, Vol 1, Wiley-Interscience; 1st edition - Leonard Kleinrock
2. Wireless communications, Cambridge University Press, India, 2nd edition - Andrea Goldsmith

Professional Elective Courses:

Elective-III

EC5361	Cognitive Radio	Credits 3-0-0:3

Course Outcomes:

At the end of the course, the student will be able to

CO1	An understanding on cognitive radio components, functions and capabilities.
CO2	An ability to evaluate different spectrum sensing mechanisms in cognitive radio.
CO3	An ability to analyze the spectrum management functions using cognitive radio systems and cognitive radio networks.
CO4	An understanding on software defined radio architecture and design principles.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1					2	
CO2			2			
CO3			2			
CO4					2	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Unit 1: Introduction to Cognitive Radios: Digital dividend, cognitive radio (CR) architecture, functions of cognitive radio, dynamic spectrum access (DSA), components of cognitive radio, spectrum sensing, spectrum analysis and decision, potential applications of cognitive radio.

Unit 2: Spectrum Sensing: Spectrum sensing and identification, primary signal detection. energy detector, cyclostationary feature detector, matched filter, cooperative sensing, spectrum opportunity, spectrum opportunity detection, fundamental trade-offs: performance versus constraint, sensing accuracy versus sensing overhead.

Unit 3: Dynamic Spectrum Access and Management: Spectrum broker, Dynamic spectrum access architecture- centralized dynamic spectrum access, distributed dynamic spectrum access, Inter- and intra-RAN dynamic spectrum allocation, Spectrum management, Spectrum sharing, Spectrum mobility issues

Unit 4: Cognitive Radio Networks: Cognitive radio networks (CRN) architecture, terminal architecture of CRN, diversity radio access networks, routing in CRN, Control of CRN, Self-organization in mobile communication networks, security in CRN, cooperative communications, cooperative wireless networks, user cooperation and cognitive systems.

Unit 5: Software Defined Radio (SDR): Essential functions of the SDR, SDR architecture, design principles of SDR, traditional radio implemented in hardware and SDR, transmitter architecture and its issues, digital radio processing, reconfigurable wireless communication systems.

Text Books:

1. Ekram Hossain, Dusit Niyato, Zhu Han, "Dynamic Spectrum Access and Management in Cognitive Radio Networks", Cambridge University Press, 2009.
2. Kwang-Cheng Chen, Ramjee Prasad, "Cognitive radio networks", John Wiley & Sons Ltd., 2009.
3. https://www.cmsoc.org/publications/best-readings/cognitive-radio

Reference books:

1. Alexander M. Wyglinski, Maziar Nekovee, and Y. Thomas Hou, "Cognitive Radio Communications and Networks - Principles and Practice", Elsevier Inc., 2010.
2. Jeffrey H. Reed "Software Radio: A Modern Approach to radio Engineering", Pearson Education Asia.

EC5362	**Optical Networks**	**Credits 3-0-0:3**

Course Outcomes:
At the end of the course, the student will be able to

CO1	Identify the building blocks of an optical network for the given application
CO2	Recognize the trade off issues in the design of optical networks
CO3	Select the components to suit the performance in an optimized way
CO4	Manage and control the optical network following the safety norms

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	2			2
CO2	3	3	3			2
CO3	3			2	2	3
CO4	1	2	2	1		2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Optical Networking Components/Building Blocks- Optical transmitters, laser diode, tunable and fixed laser, laser characteristics, photo-detectors, optical filters, multiplexers, de-multiplexers channel/gain equalizers, optical amplifiers and its characteristics, Raman amplifier, Erbium doped fiber amplifier, Hybrid EDFA-Raman amplifiers, ROPA-Subsea amplifier, various switching elements, ROADM, OXC-WSS, CLOS architecture, MEMS, wavelength converters.

Client Layers - Introduction to SONET/SDH/OTN – Multiplexing, SONET/SDH/OTN layers, framestructure, physical layer, adaptation layers, quality of service, flow control, signaling and routing, IP – Routing and forwarding, QoS, MPLS/GMPLS,Gigabit Ethernet, problems

Industrial Optical Networks: Dense Wavelength Division Multiplied (DWDM) networks, Elastic Optical Networks (EON), Spatial Division Multiplied (SDM) networks, Passive Optical Networks (PON)-Fiber Ethernet.

Optical line system engineering- system model, power penalty, transmitter, receiver, optical fibers, linear and nonlinear impairments, optical amplifiers, crosstalk, dispersion, wavelength stabilization, spectrum equalization, repeater and amplifier spacing, overall design considerations.

Optical Network Design-Cost trade-offs, RWA/RSA/RCMSA problems, Dimensioning DWDM/EON/SDM, statistical dimensioning models, dynamic dimensioning models, machine learning oriented models, problems

Network Control and Management- control and management – network management system, optical layer services and interfacing, layers within the optical layer, multivendor interoperability, performance and fault management, configuration management, optical safety, problems.

Text Books:

1. R RAMASWAMY, KN SIVARAJAN, Optical Networks: A Practical Perspective, Elsevier, 2009.
2. JUN ZHENG, Optical WDM Networks, John Wiley, 2004.
3. Optical WDM Networks, Biswanath Mukharjee, Springer, 2006.

Reference Books:

1. The Handbook of Optical Communication Networks, MohammadIlyas, Hussein T. Mouftah, CRC Press, 2003.
2. Optical WDM Networks - Principles and Practice, Krishna M. Sivalingam, Suresh Subramaniam, Springer, 2010.
3. Next Generation Intelligent Optical Networks - From Access to Backbone, Stamatios V. Kartalopoulos, Springer, 2008

EC5363	RF System Design	Credits 3-0-0:3

Prerequisite: RF Engineering

Course Outcomes:
At the end of the course, the student will be able to

CO1	Design RF amplifier, oscillators and other related circuits.
CO2	Simulate RF Systems using modern microwave/RF design packages.
CO3	Design and evaluate RF and Microwave amplifiers and oscillators using packages.
CO4	Design a RF mixer circuit

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1						3
CO2	2			3		3
CO3	2					3
CO4						3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

UNIT 1 BASIC CONCEPTS IN RF DESIGN
Non linearity, effects of non linearity, harmonic distortion, gain compression, cross modulation, intermodulation, cascaded non-linear stages, sensitivity and dynamic range, noise.

UNIT 2 TRANSMITTER AND RECEIVER ARCHITECTURES
General considerations, basic heterodyne receivers, direction conversion receivers, Image reject receivers: Hartley receiver and Weaver receivers. Transmitter general considerations, Direct conversion transmitter and heterodyne transmitter.

UNIT 3 MICROWAVE TRANSISTOR AMPLIFIER DESIGN
Types of amplifiers, power gain equations. Stability considerations, Constant gain circles, unilateral case and bilateral case, constant noise circles, Low noise amplifier design and high power amplifier design.

UNIT 4 MICROWAVE OSCILLATOR DESIGN
One port and two port negative resistance oscillators. Oscillator’s configurations, Oscillator design using large signal measurements, Introduction to Microwave CAD Packages, Microwave integrated circuits, MIC design for lumped elements.

UNIT 5 MICROWAVE MIXER DESIGN

Basic operation of a mixer, mixer spectral products, conversion gain/loss, types of mixer circuits, Single ended mixer, single balanced mixer, Image reject mixer, and sub harmonic mixer.

REFERENCES

1. B. Razavi, RF Microelectronics, 2nd Edition, Prentice hall, 2012.
2. González, G. Microwave transistor amplifiers: analysis and design. 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, 1997.
3. Reinhold Ludwig and Gene Bogdanvov, ―RF Circuit Design – Theory and Application‖, 2nd Edition, Pearson, 2012.
4. I. Bahl and P. Bhartia, Microwave solid state circuit design, John Wiley.
5. David.M.Pozar, ―Microwave Engineering‖, John Wiley and Sons, Third Edition

EC5163	Embedded Real Time Operating Systems	Credits 3-0-0:3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Identify the functioning of embedded systems for different applications.
CO2	Develop embedded system programming skills.
CO3	Design, implement and test an embedded system.
CO4	Identify the unique characteristics of real-time embedded systems.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1					1	1
CO2			2		1	
CO3			2		1	1
CO4		2			1	

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction to Embedded Computing: Embedded systems Overview, Characteristics of embedded computing applications, Design Challenges, Common Design Metrics, Processor Technology, IC Technology, Trade-offs.

The Process of Embedded System Development: The development process, Requirements, Specification, Architecture Design, Designing Hardware and Software components, system Integration and Testing.

Hardware platforms: Types of Hardware Platforms, Single board computers, PC Add-on-cards, custom-built hardware platforms, ARM Processor, CPU performance, CPU power consumption, Bus-based computer systems, Memory devices, I/O devices ,component interfacing, Designing with microprocessors, system level performance analysis.

Program Design and Analysis: components for Embedded programs, Models of programs, Assembly, Linking, and loading, basic compilation techniques, software performance optimization ,program level energy and Power analysis, Program validation and Testing.

Real-Time Operating Systems: Architecture of the kernel, Tasks and Task Scheduler, Scheduling algorithms, Interrupt Service Routines, Semaphores, Mutex, Mailboxes, Message queues, Event Registers, Pipes, Signals, Timers, Memory management, Priority Inversion problem. Overview of off-the shelf operating systems-Micro C/OS II, VX works, RT Linux.

Text Books:

1. Wayne Wolf: Computers as Components-Principles of Embedded Computer System Design, Morgan Kaufmann Publisher-2006.
2. David E-Simon: An Embedded software Primer, Pearson Education, 2007.
3. K.V.K.K. Prasad Real-Time Systems: Concepts Design and Programming, Dreamtech Press,2005.

Elective-IV

EC5364	5G Communications	Credits 3-0-0:3

Course Outcomes:
At the end of the course, the student will be able to

CO1	Learn 5G Technology advances and their benefits
CO2	Learn the key RF, PHY, MAC and air interface changes required to support 5G
CO3	Learn Device to device communication and millimeter wave communication
CO4	Implementation options for 5G

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1			2		
CO2					2	
CO3					2	
CO4						2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Overview of 5G Broadband Wireless Communications: Evaluation of mobile technologies 1G to 4G (LTE, LTEA, LTEA Pro) , An Overview of 5G requirements, Regulations for 5G,Spectrum Analysis and Sharing for 5G.

The 5G wireless Propagation Channels: Channel modeling requirements, propagation scenarios and challenges in the 5G modeling, Channel Models for mmWave MIMO Systems.

Transmission and Design Techniques for 5G: Basic requirements of transmission over 5G, Modulation Techniques – Orthogonal frequency division multiplexing (OFDM), generalized frequency division multiplexing (GFDM), filter bank multi-carriers (FBMC) and universal filtered multi-carrier (UFMC), Multiple Accesses Techniques – orthogonal frequency division multiple accesses (OFDMA), generalized frequency division multiple accesses (GFDMA), non-orthogonal multiple accesses (NOMA).

Device-to-device (D2D) and machine-to-machine (M2M) type communications – Extension of 4G D2D standardization to 5G, radio resource management for mobile broadband D2D, multi-hop and multi-operator D2D communications.

Millimeter-wave Communications – spectrum regulations, deployment scenarios, beam-forming, physical layer techniques, interference and mobility management, Massive MIMO propagation channel models, Channel Estimation in Massive MIMO, Massive MIMO with Imperfect CSI, Multi-Cell Massive MIMO, Pilot Contamination, Spatial Modulation (SM),

Textbooks:

1. Martin Sauter "From GSM From GSM to LTE–Advanced Pro and 5G: An Introduction to Mobile Networks and Mobile Broadband", Wiley-Blackwell.
2. Afif Osseiran, Jose.F.Monserrat, Patrick Marsch, "Fundamentals of 5G Mobile Networks" , Cambridge University Press.
3. Athanasios G.Kanatos, Konstantina S.Nikita, Panagiotis Mathiopoulos, "New Directions in Wireless Communication Systems from Mobile to 5G", CRC Press.
4. Theodore S.Rappaport, Robert W.Heath, Robert C.Danials, James N.Murdock "Millimeter Wave Wireless Communications", Prentice Hall Communications.

References

1. Jonathan Rodriguez, "Fundamentals of 5G Mobile Networks", John Wiley & Sons.
2. Amitabha Ghosh and Rapeepat Ratasuk "Essentials of LTE and LTE-A", Cambridge University Press.

EC5365	**Green Wireless Communications**	**Credits** 3-0-0:3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Recognize the challenges in energy efficiency and spectral efficiency for digital data transmission
CO2	Suggest the methods to manage the dynamic loads of mobile communications for energy saving
CO3	Indicate the design practices for power minimization at cellular base station
CO4	Practise cell deployment strategies for efficient network management

Course Articulation Matrix:

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3		3	3	3	3
CO2	3		3	3	3	3
CO3	3		3	3	3	3
CO4	3		3	3	3	3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

1. Green Wireless Communications :
Introduction - Effective Capacity and Energy Per Information Bit - Variable-Rate/Variable-Power and Variable-Rate/Fixed-Power Transmissions - Fixed-Rate/Fixed-Power Transmissions - Transmissions over Imperfectly-Known Wireless Channels - Energy Efficiency in the Low-Power Regime - Energy Efficiency in the Wideband Regime

2. Energy Efficiency-Spectral Efficiency Trade-off in Cellular Systems :
Spectral Efficiency; Energy Efficiency; Energy Efficiency-Spectral Efficiency Trade-Off; Idealistic vs. Realistic Power Consumption Model ; MIMO vs. SISO: An Energy Efficiency Analysis ; Power Model Implications

3. Energy Savings for Mobile Communication Networks through Dynamic Spectrum and Traffic Load Management :
Dynamic Spectrum and Traffic Load Management ; Power Saving by Dynamically Powering Down Radio Network Equipment ; Power Saving by Propagation Improvement ; Power Saving by Channel Bandwidth Increase or Better Balancing Performance Assessment ; Power Saving by Propagation Improvement.

4. Minimizing Power Consumption to Achieve More Efficient Green Cellular Radio Base Station Designs :Explosive Traffic Growth - Cellular Scenarios - Energy Metrics; Energy Reduction Techniques for High Traffic Load Scenarios; Energy Reduction Techniques for Low Traffic Load Scenarios, Other Energy Reduction Techniques.

Green Wireless Access Networks :Energy Efficiency and Network Technologies ; Cell Deployment Strategies; Relaying Techniques; Base Station Coordination and Cooperation ; Adaptive Network Reconfiguration ; Radio Resource Management; Future Architectures ; Green Ad Hoc and Sensor Networks; Energy Harvesting Techniques.

5. Fundamental Technologies implementing Smart cities :Criteria for smart cities, Ubiquitous computing, Big Data, Networking, Internet of Things, Cloud computing, Service-oriented architectures, Cyber security architectures.

Reference Books:

1. Green Communications: Theoretical Fundamentals, Algorithms, and Applications
Jinsong Wu, SundeepRangan, Honggang Zhang
2. Green Communications and Networking :F. Richard Yu, Xi Zhang, Victor C.M. Leung ; CRC press, 2012.
3. Carlo Ratti and Matthew Claudel, ―The City of Tomorrow: Sensors, Networks, Hackers, and
the Future of Urban Life (The Future Series)‖, Yale University Press.
4. Stephen Goldsmith, Susan Crawford, ―The Responsive City: Engaging Communities through Data-Smart Governance‖, 1st Edition Jossey Bass – Wiley.
5. EkramHossain, Vijay Bhargava K and Gerhard Fettweis P, "Green Radio Communication Networks", Cambridge University Press, New York, 2012.
6. Mazin Al Noor, "Green Radio Communication Networks Applying Radio-Over-Fibre Technology for Wireless Access", GRINVerlag, 2012.
7. Mohammad Obaidat S, AlaganAnpalagan and Isaac Woungang, "Handbook of Green Information and Communication Systems", 1st Edition, Academic Press, 2012.
8. Jinsong Wu, SundeepRangan and Honggang Zhang, "Green Communications: Theoretical Fundamentals, Algorithms and Applications", CRC Press, 2016.
9. Ramjee Prasad, Shingo Ohmori and Dina Simunic, "Towards Green ICT", River Publishers, 2010.

Hyperlinks:

1. http://www.comsoc.org/webcasts/view/wireless-green-networking
2. http://home.ku.edu.tr/~nwcl/green.html
3. http://mypage.zju.edu.cn/en/honggangzhang/607861.html

EC5366	Multimedia Communications	Credits 3-0-0:3

Prerequisites:
1) Communications.
2) Image processing.
3) Audio and video signals.

Course Outcomes:
At the end of the course, the student will be able to

CO1	Understand the audio, video and text interaction
CO2	Explain various audio, video and joint coding techniques
CO3	Understand multimedia communication standards
CO4	Identify the requirements of real time multimedia transfer on IP networks

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	2	1	1
CO2	1	2	1	3	2	2
CO3	1	2	3	1	2	2
CO4	3	2	2	2	2	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Chapter 1
Introduction and tools used for MM content development , Media interaction, Biomodality of human speech, Lip reading, speech driven talking heads, Lip synchronisation, Lip tracking

Chapter 2
Biomodal person verification, Joint AV coding, Multimedia processing, Challenges in MM processing, Perceptual coding of Digital Audio, CBIR

Chapter 3
Introduction to audio, Image, video coding, Water marking techniques, Storage and retrieval issues, Multimedia processors

Chapter 4
Distributed MM systems, Multimedia OS, Multimedia communication standards, MPEG approach, ITU-T standards for audio visual, video and speech coding

Chapter 5
Real time multimedia across Internet, packet audio/video multimedia transport across IP/ATM Network, Wireless multimedia, mobile multimedia access for internet, multimedia PCS

Text Book:

1. Multimedia Communication Systems: Techniques and Standards, KR RAO et al, Pearson, 2002.
2. Insight into Mobile Multimedia Communication : D. BULL et al, Academic Press, 1999
3. Multimedia Systems Design : PK ANDLEIGH , K. THAKKAR, PHI,2002
4. Multimedia-Making it Work, TAY VAUGHAN,5/e, TMH, 2001

EC5166	Machine Learning for Speech and Image Processing	Credits 3-0-0:3

Prerequisite: None

Course Outcomes: At the end of the course the student will be able to:

CO1	Differentiate various learning approaches,and interpret the concepts of supervised & unsupervised,reinforcement learning schemes
CO2	Analyzing supervised and unsupervised machine learning algorithms for classification
CO3	Analyze the pre-processing techniques and machine learning applications in the areas of signal processing.
CO4	Analyze the pre-processing techniques and machine learning applications in the areas of Image Processing
CO5	Understand the deep learning basics for image processing and classification

Mapping of COs and POs:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	**1**					
CO2	**1**		**3**			
C03		**2**				
CO4		**2**				
C05	**1**		**2**			

Detailed Syllabus

Introduction to Machine Learning

Introduction to Machine Learning, Examples of Machine Learning applications- Learning associations, Overview of Unsupervised Learning, Reinforcement Learning, Supervised learning- Input representation, Hypothesis class, Version space, Vapnik- Chervonenkis (VC) Dimension, PAC Learning

Machine Learning Algorithms

Supervised Learning - Linear Regression, , K-NN classifier, Decision Trees, Naïve Bayes, Support Vector Machines, Logistic Regression analysis, Unsupervised Learning – Clustering, K-means Clustering, Hierarchical Clustering, Dimensionality reduction, PCA(Principal Component Analysis), Ensemble Learning , Reinforcement Learning

ML for Signal Processing and Feature Extraction

Introduction to real world signals, Stochastic Signals, Frequency-Domain Analysis, Short-Time Fourier Transform; Spectral Estimation -The Periodogram , Time-Series Analysis Methods, Case study: Application of Machine Learning algorithms for signal analysis and classification signals (Biomedical signals/Communication signal analysis)

Fundamentals of Image Processing and Feature Extraction

Basic Image Manipulation- Image Filtering, Linearity and Convolution, Edge detection, Hough Transform, Frequency Analysis, Feature Recognition - Finding Interest points, Harris Detector Algorithm, Matching Interest Points, Error Functions, RANSAC algorithm.

Deep Learning Approach for Image Processing

Introduction , Artificial neurons, Activation function, Perceptron Algorithm, Multilayer Perceptron (Neural Networks), comparison of ML & Deep Neural Network, fundamentals of Artificial Neural networks ,Characteristics of ANN, Backpropagation, Building blocks of Convolutional Neural Networks , Case Study: Implementation of Deep Learning methods for image classification.

Reading:

1. Christopher M. Bishop, " Pattern Recognition and Machine Learning ", Springer, 2006.
2. R. O. Duda, P. E. Hart , " Pattern Classification ", WILEY, (2001).

References:

1. George Kuddrayvtsev , " Fundamentals of Computer Vision ", 2020.

Elective-V

EC5367	Advanced DSP	Credits 3-0-0:3

Course Outcomes:

At the end of the course, the student will be able to

CO1	Understand the properties, functioning of DCT, KLT and wavelet transforms for 1-D and 2-D signals.
CO2	Implement adaptive filter algorithms for applications in noise cancellation, de-convolution, enhancement and channel equalization.
CO3	Apply higher order spectra for solving Non-Gaussian, non-linear stochastic problems
CO4	Design a decimator or interpolator for the given specifications

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2					
CO2		2	1			
CO3			2			
CO4				2		

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Introduction: Review of Discrete time Signals and Systems, Discrete Time Fourier Transform, Z-Transform

Transform techniques: Discrete cosine transforms(DCTs), Discrete sine transforms(DSTs), KL transforms, Hadamard transforms, Walsh transforms and Wavelet transforms, Applications of DCTs and Wavelets.

Adaptive Filter theory: Stochastic gradient based algorithms LMS algorithm, stability analysis, Mean-squared error behavior. Convergence analysis, Normalized LMS algorithm, Gradient adaptive lattice algorithm. Prediction, filtering and smoothing, adaptive equalization, noise cancellation, blind deconvolution, adaptive IIR filters, RLS algorithms-GRLS, Gauss-Newton and RML.

Multirate signal processing: Decimation, Interpolation, polyphase filters and their structures, Subband coding of speech signals, filter banks, Quadrature mirror filters.

Optimum linear filters: Wiener filters for filtering and prediction, FIR wiener filter, orthogonality principle in LMS estimation, IIR wiener filter, state-space (Kalman) filters, Method of least squares, data windowing, principle of orthogonality, Innovation process, statement of the kalman filtering problem, Estimation of the state using innovations process, Riccati equation, filtering, kalman filter as the unifying basis for RLS filters.

Reading:

1. DSP Principles, Algorithms and Applications JG Proakis, DG Manolakis, 3rd Edition, PHI Private Ltd., 2001.
2. Adaptive Filter Theory S. Haykin, 2nd Edition, PRENTICE HALL., 2001
3. Modern Digital Signal Processing-2nd Edition, V.Udayashankara, PHI, 2012.

References:

1. Modern spectral estimation, SM Kay, PH Int, 1997
2. Advanced digital signal processing, Proakis, C. M. Rader, Fuyun, Ling CL., Mcmillan Publishing Company, NY, 1992.
3. Modern Digital signal processing An Introduction Prabhakar S. Naidu, Narosa Publishing House,2003.
4. Adaptive Signal processing B. Widrow & D. Stearns, PH Int 1987 Optimum Signal Processing; An Introduction, S.J.Orfanidis, Second Edition, McGraw Hill Book Company, 1992.

EC5368	**Smart Antennas for 5G communications**	**Credits** 3-0-0:3

Course Outcomes:
At the end of the course, the student will be able to

CO1	To Familiarize with smart and adaptive antennas.
CO2	Apply different adaptive algorithms for 5G antenna.
CO3	Understanding the concept of direction of arrival and angle of arrival
CO4	Design of antenna array architectures to meet 5G requirement.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1			2		2	1
CO2			2		1	1
CO3			3		2	1
CO4	3		3		2	1

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

5G Concepts
5G Objectives and Usage Scenarios, 5G Activities, Channel Access Method/Air Interface, 5G Policy, 5G Timelines, 4G/5G Radio Access Network, 5G system concept, LTE-Advanced, LTE-Advanced Pro, 5G NR, The 5G architecture, Spectrum Analysis and Regulations for 5G

Introduction to smart antenna
Introduction to Smart Antennas, Architecture of a Smart Antenna System: Transmitter and Receiver, Types of Smart Antennas, Benefits and Drawbacks of Smart Antennas, Applications of Smart Antennas.

Smart Antenna Configurations
Fixed Sidelobe Canceling, Retrodirective Arrays, Beamforming, Adaptive Arrays, Butler Matrix, Spatial Filtering with Beamformers, Switched Beam Systems, Multiple Fixed Beam System. Uplink Processing, Diversity Techniques, Angle Diversity, Maximum Ratio Combining, Adaptive Beamforming, Fixed Multiple Beams versus Adaptive Beamforming, Downlink Processing.

Angle-of-Arrival Estimation
Fundamentals of Matrix Algebra, Array Correlation Matrix, AOA Estimation Methods: Bartlett AOA Estimate, Capon AOA Estimate, Linear Prediction AOA Estimate, Maximum Entropy AOA Estimate, Pisarenko Harmonic Decomposition AOA Estimate, Min-Norm AOA Estimate, MUSIC AOA Estimate, ESPRIT AOA Estimate.

MIMO Antennas

Introduction, Multiple-Antenna MS Design, RAKE Receiver Size, Mutual Coupling Effects, Dual-Antenna Performance Improvements, Downlink Capacity Gains, Principles of MIMO systems: SISO, SIMO, MISO,MIMO, Hybrid antenna array for mmWave massive MIMO: Massive Hybrid Array Architectures, Hardware Design for Analog Subarray.

Text Books:

1. Ahmed El Zooghby, 'Smart Antenna Engineering', ARTECH HOUSE, INC, 2005.
2. Frank B. Gross, 'Smart antenna with MATLAB', 2nd Edition, McGraw-Hill, 2015.
3. Lal Chand Godara , "SMART ANTENNAS" , CRC PR ESS, 2004
4. Shahid Mumtaz, Jonathan Rodriguez, Linglong Dai mmWave Massive MIMO: A Paradigm for 5G

EC5369	**Machine Learning For Next Generation Communication Networks**	**Credits** **3-0-0:3**

Pre-requisites: Advanced digital communication

Course Outcomes:

At the end of the course, the student will be able to

CO1	Design machine learning algorithms for spectrum access and sharing
CO2	Design reinforcement algorithms for resource allocation
CO3	Design deep learning algorithms for optimizing coverage and channel capacity
CO4	Apply machine learning algorithms for optimizing energy efficiency, modulation, coding, channel equalization and signal detection.

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3			2	2	2
CO2	3			3	2	
CO3	3				2	
CO4	1		2	3		3

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

Machine Learning for Spectrum Access and Sharing: Online Learning Algorithms for Opportunistic Spectrum Access, Performance Measures of the Online Learning Algorithms, Random and Deterministic Approaches, The Adaptive Sequencing Rules Approach, Structure of Transmission Epochs, Learning Algorithms for Channel Allocation, Distributed Learning

Machine and Reinforcement Learning for Resource Allocation in Cognitive Radio Networks: Use of Q-Learning for Cross-layer Resource Allocation, Deep Q-Learning and Resource Allocation, Cooperative Learning and Resource Allocation, Decentralized Resource Minimization, Resource Minimization Approaches, Optimized Allocation

Deep Learning–Based Coverage and Capacity Optimization: Related Machine Learning Techniques for Autonomous Network Management, Data-Driven Base-Station Sleeping Operations by Deep Reinforcement Learning, Deep Q-Learning Preliminary and its Applications to BS Sleeping Control, Dynamic Frequency Reuse through a Multi-Agent Neural Network Approach

Machine Learning in Energy Efficiency Optimization: Self-Organizing Wireless Networks, Traffic Prediction and Machine Learning, Cognitive Radio and Machine Learning, Deep Learning, Positioning of Unmanned Aerial Vehicles, Traffic Prediction, Mobility Prediction

Machine Learning–Based Adaptive Modulation and Coding (AMC) Design: Overview of ML-Assisted AMC, k-NN-Assisted AMC, Algorithm for k-NN-Assisted AMC, Performance Analysis of k-NN-Assisted AMC System, RL-Assisted AMC

Machine Learning for Joint Channel Equalization and Signal Detection: Overview of Neural Network-Based Channel Equalization, Multilayer Perceptron-Based Equalizers, Functional Link Artificial Neutral Network-Based Equalizers, Radial Basis Function-Based Equalizers, Deep-Learning-Based Equalizers

Reading:

1. Fa-Long Luo," Machine Learning for Future Wireless Communications", John Wiley and Sons, 2020
2. Ruisi He, Z Ding, "Applications of Machine Learning in Wireless Communications", IET Telecommunication series 81.
3. K. K. Singh, A. Singh, K. Cengiz**,** Dac-Nhuong Le**,** "Machine Learning and Cognitive Computing for Mobile Communications and Wireless Networks", **Wiley 2020.**

EC5172	**Deep Learning Techniques for Signal Processing**	**Credits 3-0-0:3**

Course Outcomes: At the end of the course the student will be able to:

CO1	Understand fundamentals of Machine Learning and Deep Learning
CO2	Analyze Various Deep Learning Architectures
CO3	Analyze the deep learning methods for speech processing
CO4	Analyze the deep learning methods for Image processing
CO5	Analyze the deep learning methods for Biomedical signal processing

Mapping of COs and POs:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1		**2**		**1**		
CO2		**2**				**1**
CO3		**2**				**1**
CO4		**2**				**1**
CO5		**2**	**1**			

1 - Slightly; 2 - Moderately; 3 – Substantially

Detailed Syllabus:

Fundamentals of ML & DL: Basics of Machine Learning (ML), Supervised Learning, Unsupervised Learning, Reinforcement Learning, Introduction to Deep Learning, Perceptron Algorithm, Multilayer Perceptron (Neural Networks), , ML vs Deep Neural Networks.

Deep Learning Algorithms: Basic Building Blocks of CNN, Forward and Back propagation in CNN, Classic CNN Architectures, Modern CNN Architectures, Basic Building Blocks of RNNs, RNNs and Properties, Deep RNN Architectures.

DL in Speech Processing Applications:, A case study approach on Real time Analysis of speech Processing: - Pre-processing, Feature extraction and Implementation of Classification based on Deep learning methods

DL in Image Processing Applications:, A case study approach on Real time Analysis of Image Processing : Pre-processing, Feature extraction and Implementation of Classification based on Deep learning methods

DL in Bio-medical Signal Analysis: A case study approach on Real time Analysis of any Biomedical signals: Pre-processing, feature extraction and Implementation of Classification based on Deep learning methods.

Reading:

1. Uday Kamath • John Liu • James Whitaker, Deep Learning for NLP and Speech Recognition, Springer nature, 2019.
2. Deep Learning : Methods and Applications", Li Deng, Microsoft Technical Report.
3. "Automatic Speech Recognition - Deep learning approach" - D. Yu, L. Deng, Springer, 2014.
4. "Machine Learning for Audio, Image and Video Analysis", F. Camastra, Vinciarelli, Springer, 2007.