M.TECH – COMMUNICATION SYSTEMS

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Information and communication technology (ICT) has become one of the essential infrastructures for modern society and transforming the lifestyle integrated with digital devices. ICT will facilitate integrated decision making in power, transportation, sensor, healthcare, industrial automation and others. M.Tech in Communication Systems forms the fundamental premise for potpourri of computational paradigms for communication networks, energy efficient architecture and protocols aiming to deliver ubiquitous, secure and resilient next generation networks.This program also provides insights into the design aspects of wireless communication systems using computational optimization. The program by and large meets core industry requirements and facilitates required background for higher education.

Program Educational Objectives (PEOs)

- To apply mathematical foundations and advanced communication technology concepts enabling the design and analysis to meet the demands of industry, teaching and research.
- To innovate and contribute in diverse areas including Radio Frequency systems, Digital communication, Wireless networks and Computational engineering.
- To exhibit professional competence and leadership qualities with a harmonious blend of ethics leading to an integrated personality development..

Program Outcomes (POs)

PO1: An ability to independently carry out research/investigation and development work to solve practical problems.

PO2: An ability to write and present a substantial technical report/document.

PO3: Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

PO4: An ability to work in a team to take up the challenges in the field of RF systems, Digital Communication, Wireless Networks and Computational Engineering giving due consideration to societal, environmental, economical and financial factors.

PO5: An ability to maintain lifelong learning and research by way of participating in various professional activities with a higher level of commitment.

CURRICULUM

First Semester

Course Code	Type	Course	L T P	Cr
19MA602	FC	Mathematical Methods for Engineering	3 0 3	4
19CM601	FC	Signal Processing for Communications	3 0 0	3
19CM602	FC	Information Theory and Coding	3 0 0	3
19CM611	SC	Wireless Communication	3 0 3	4
19CM612	SC	Radio Frequency Transceiver System Design	3 0 3	4
19CM613	SC	Communication Systems lab	0 0 3	2
19HU601	HU	Amrita Values Program*		P/F
19HU602	HU	Career Competency I*		P/F
		Credits		**20**

* Non-credit course

Second Semester

Course Code	Type	Course	L T P	Cr
19CM614	SC	Wireless Networks and Protocols	3 0 3	4
19CM615	SC	Hardware Design with FPGA	3 0 3	4
19CM616	SC	Machine Learning for Communication Systems	3 0 0	3
19RM600	SC	Research Methodology	2 0 0	2
	E	Elective I	3 0 0	3
	E	Elective II	3 0 0	3
	E	Elective III	3 0 0	3
19CM617	SC	Modelling and Simulation of Communication Systems Lab	0 0 3	2
19HU603	HU	Career Competency II	0 0 3	1
		Credits		**25**

Third Semester

Course Code	Type	Course	L T P	Cr
19CM798	P	Dissertation		8
		Credits		**8**

Fourth Semester

Course Code	Type	Course	L T P	Cr
19CM799	P	Dissertation		12
		Credits		12
		TOTAL CREDITS (20+25+8+12)		**65**

Electives

Wireless Communication		L T P	Cr
19CM701	Millimeter Wave Communication Systems	3 0 0	3
19CM702	Multicarrier Communications	3 0 0	3
19CM703	Software Defined Radio	3 0 0	3
19CM704	Vehicular Communications and Networks	3 0 0	3
19CM705	Security for Wireless Communications	3 0 0	3
19CM706	Internet of Things	3 0 0	3
19CM707	Cooperative and Relay Communication	3 0 0	3
19CM708	Massive MIMO	3 0 0	3
19CM709	Estimation and Detection Theory	3 0 0	3
19CM710	Error Control Coding	3 0 0	3
RF Front End			
19CM711	Automotive radar	3 0 0	3
19CM712	Antenna and Array Systems Design	3 0 0	3
Communication Networks			
19CM721	Multisensor data fusion	3 0 0	3
19CM722	Stochastic Modeling and Queuing Theory	3 0 0	3
19CM723	Network Coding	3 0 0	3
19CM724	Wireless Sensor Networks	3 0 0	3
Computational Techniques			
19CM731	Convex Optimization	3 0 0	3
19CM732	Big Data Analytics	3 0 0	3
19CM733	Game Theory	3 0 0	3
Signal and Image Processing			
19CM741	Speech and Audio Processing	3 0 0	3
19CM742	Image and Video Processing	3 0 0	3

Detailed Syllabi

19MA602 MATHEMATICAL METHODS FOR ENGINEERING 3 0 3 4

Objectives:

- To introduce the mathematical methods applied for VLSI, signal processing and communication systems.
- To provide a unified applied treatment of fundamental mathematics, seasoned with demonstrations using standard tools.
- To develop contemporary techniques for applications in the diverse areas to improve the analytical skills.
- To comprehend the computational concepts learned in mathematical methods through numerical simulations and programming

Keywords:
Linear Algebra, Matrix Decompositions, Optimization, Random Process.

Contents:
Matrices and vectors – inverse and transpose – vector spaces – subspaces – linear independence – basis and dimension – orthogonal vectors and subspaces – matrix decompositions – QR decomposition- Singular value decomposition – Eigen values – Eigen vectors – Diagonalization of matrix.

Introduction to Optimization - linear optimization – unconstrained optimization – constrained optimization – nonlinear optimization.

Introduction to Probability concepts- Two dimensional jointly distributed random variables, stochastic random variables, convergence and limit theorems, multi variant probability distribution covariance, and regression models. Bayesian methods of estimation. Random process, power spectrum, discrete time process, spectrum estimation

Lab component: Gram Schmidt orthonormalization on vector spaces, Solving a system of linear equations using QR decomposition , Image compression using Singular value decomposition, Computation of basis for four fundamental subspaces for a given system, Optimization using Newton's method with line search and Broydens update.

Outcomes:
CO 1: Able to understand the mathematical methods by investigating from different perspectives.
CO 2:Able to do analytical approach towards developing mathematical models in various domains.
CO 3: Able to carry out implementation of algorithms and numerical analysis.
CO 4: Able to apply mathematical methods to practical engineering problems

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	-	3	3	3	3

CO 4	3	-	3	-	3

TEXT BOOKS/REFERENCES:

1. Gilbert Strang, *Introduction to Linear Algebra,* 5th Edition, Cambridge University Press. 2016.
2. Todd K. Moon and Wynn C. Sterling, *Mathematical Methods and Algorithms for Signal Processing*, PHI, 2000.
3. C. Bender and S. Orszag, *Advanced Mathematical Methods for Scientists and Engineers,* Springer, 1998.
4. Papoulis. A and S.U. Pillai, *Probability Random Variables and Stochastic Processes,* Fourth Edition, Mc Graw Hill, 2002.

19CM601 SIGNAL PROCESSING FOR COMMUNICATIONS 3 0 0 3

Objectives:

- To understand the signal processing techniques and transform theory in communication systems.
- To provide the design engineers with the tools necessary for efficient implementation of digital transceivers
- To focus on the multirate systems arising in the communications, especially wireless and software defined radios

Keywords:
Signals, Transforms, Multirate systems, Digital transceivers

Contents:
Discrete time signals – Hilbert spaces – Fourier analysis and LTI systems – Digital transmission systems – baseband and passband equivalents - Sampling and Discrete time systems – Numerical computation of DFT – Digital filters – design using optimization - filtering in time domain – filtering in frequency domain.

Multirate signal processing – sampling rate conversion – efficient architectures – polyphase structures – multistage implementation – cascaded-integrator-comb filters – Quadrature Mirror Filters (QMF) - Wavelet filters.

Application in communication systems – Conventional Digital down converters (DDC), Aliasing DDC, carrier acquisition and tracking – timing recovery – channel equalization – Baseband PAM transceiver - QAM transceiver.

Outcomes:
CO 1: Able to understand, design and analyze signal processing techniques for basedband communication systems
CO 2: Able to develop and implement efficient architectures for multirate systems digital RF front end systems
CO 3: Able to design and develop for signal processing problems in communications
CO 4: Able to implement solutions for spectrally efficient and reliable communication systems

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	3	3
CO 2	3	-	3	3	3
CO 3	-	3	3	3	3
CO 4	3	-	3	-	3

TEXTBOOKS/REFERENCES:

1. Fredric J Harris, *Multirate Signal Processing for Communication Systems*, Pearson Education, 2004.
2. Behrouz Farhang-Boroujeny, *Signal Processing Techniques for Software Radios*, Lulu Publishing House,
2008.
3. Paolo Prandoni, Martin Vetterli,*Signal Processing for Communications*, EPFL Press, 2008.
4. Todd K. Moon and Wynn C. Sterling, *Mathematical Methods and Algorithms for Signal Processing*, PHI,2000.

19CM602 INFORMATION THEORY AND CODING 3 0 0 3

Objectives:

- To enable the students to understand the concepts of Information theory, Shannon's source and channel coding theorem.
- To enable the students to understand the construction of Galois field, properties, encoding and decoding techniques of various linear block codes.
- To enable the students to understand the techniques of BCH, Reed Solomon, and convolutional encoding and decoding.

Keywords:
Entropy, Mutual Information, Galois field, Block codes.

Contents:

Information Theory Concepts: Entropy, Conditional entropy, Mutual information - Modelling of information sources - Source coding theorem - Source coding algorithms - Modelling of communication channels - Channel capacity- Channel coding theorem.

Binary field arithmetic: Construction, and basic properties of Galois field GF(2^m), Linear Block codes: structure - matrix description, standard array and syndrome table decoding-Cyclic codes: Encoding and decoding.

BCH codes: Code construction and Decoding of BCH codes - Reed Solomon codes: Encoding and Decoding - Convolutional codes: Encoding and Maximum Likelihood decoding.

Outcomes:
CO 1: Able to understand the Information theory concepts and apply it to perform source coding.
CO 2: Able to gain mastery over Galois field and hence apply it for coding techniques.
CO 3: Able to understand channel coding theorem and be able to select codes based on the properties of codes and perform encoding of the data to be transmitted.

CO 4: Able to apply decoding algorithms and analyze the performance of codes.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	2	-	3	1	-
CO 2	1	-	3	-	-
CO 3	2	-	3	1	-
CO 4	3	2	3	3	-

TEXT BOOKS / REFERENCES:

1. Ranjan Bose, *Information Theory, Coding and Cryptography*, Tata McGraw-Hill, Second Edition, 2002.
2. Thomas M Cover and Joy A Thomas, *Elements of Information Theory*, John Wiley, 2006.
3. Shu Lin and Daniel J.Costello, *Error Control Coding – Fundamentals and Applications*, Second Edition, Prentice-Hall, 2004.
4. Richard B. Wells, *Applied Coding and Information Theory for Engineer*, Pearson Education, LPE, First Indian Reprint, 2004.

19CM611 WIRELESS COMMUNICATION 3 0 34

Objectives:

- To provide a comprehensive introduction to the power and spectrally efficient wireless communication systems
- To facilitate the importance of resource allocation in multiuser environment using multiple access techniques.
- To provide insights into the various diversity and multiplexing techniques for the design of broadband and reliable wireless communication systems

Key words:
Fading channel, AWGN, Multiple Access, Diversity, Multiplexing, Multicarrier.

Contents:

Introduction to wireless communication and systems - Wireless channel : additive noise, interference, path loss, multipath propagation - Modulation and Demodulation: Baseband, Passband, Demodulation with noise, Demodulation with channel impairments.

Large scale channel models - Small scale fading selectivity - Small scale channel models - Channel estimation and Multiple Access techniques : Bit error rate (BER) of wireless systems, Channel estimation in wireless systems - frequency division multiple access (FDMA), time division multiple access (TDMA), code division multiple access (CDMA), space division multiple access (SDMA).

Diversity and multiplexing -Time diversity, frequency diversity and space diversity, Introduction to Multi input multi output (MIMO) communications and Multicarrier system (OFDM), Performance in respect of BER, Capacity of OFDM and MIMO.

Outcomes:
CO 1: Ability to analyze the modulation techniques in the design of communications systems
CO 2: Ability to understand the physical medium characteristics of the wireless system and analyze optimal resource utilization in the multiuser environment
CO3: Ability to understand challenges in evolving communication technology and design systems conforming to industry standards
CO4: Ability to learn and exhibit competency in the emerging trends of wireless systems

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	3	-
CO 2	2	-	3	3	-
CO 3	3	3	3	3	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:
1. Robert W. Heath Jr, *Introduction to Wireless Digital Communication: A Signal Processing Perspective*, Prentice Hall, First Edition, 2017
2. Aditya K. Jagannatham, *Principles of Modern Wireless Communication Systems,* McGraw-Hill Education, 2016.
3. Andrea Goldsmith, *Wireless Communications*, Cambridge University Press, 2006
4.David Tse and Pramod Vishwanath, *Fundamentals of Wireless Communication*, Cambridge University Press, July 2005.

19CM612 RADIO FREQUENCY TRANSCEIVER SYSTEM DESIGN 3 0 3 4

Objectives:

- To understand and study the concepts of design and working of passive components and systems in RF- Front-end sections of wireless communication and simulate using electromagnetic tools for performance analysis
- To understand RF front end architectures, system parameters and its relations with transmission characteristics
- To motivate and create expertise in the design aspect of radio frequency circuits and systems for wireless and strategic applications.

Key words:

Noise figure, carrier to noise ratio, dynamic range, microstrip, stripline, coplanar, coupler, scattering, free space path loss, link margin, effective isotropic radiated power

Contents:

RF Passive components and electromagnetic simulations: Overview of RF Front-end systems, Substrate and selection, Microstrip line, Strip line, coplanar line, bend lines, Slot line, coupled line, capacitor, Inductor, resister, terminations, Attenuators, Resonators, Directional coupler, Ring coupler, branch-line coupler, power dividers and combiners. Design of matching lines, resonators.

Planar Antenna Design and electromagnetic simulation: Microstrip antenna radiation mechanism, Rectangular, circular, annular ring, feed, circularly polarized excitations, antenna array design, corporate feed design, Wideband antennas, Helical antenna design, Impedance matching techniques. Case studies on antenna systems for wireless technologies

RF system characteristics: Noise in RF systems, Noise figure, cascaded noise figure, sensitivity, dynamic range, nonlinear effects, gain compression, inter-modulation, cross-modulation, harmonic distortion, Effective Isotropic radiated power, power density, Friss link margin, carrier to noise ratio, overview on low noise block, case studies on latest wireless communication links

Lab Component: Electromagnetic simulation of microstrip line, stripline and coplanar lines, bend lines, resonator, directional couplers, ring coupler, power divider, rectangular microstrip antenna, 2x2 antenna array design,.

Outcomes:
CO1: Understanding the working principles of radio frequency components and antennas for wireless communication systems
CO2: Enabling to provide design solutions in RF domain and understand the engineering aspect of components in wireless technologies.
CO3: Enable the expertise and analytical skills in the radio frequency circuits applied in system level approach with selected applications
CO4: Motivating to pursue research and development activities in the RF systems area.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	-	2	3
CO 2	3	-	-	2	-
CO 3	3	3	3	3	2
CO4	3	3	3	3	3

TEXT BOOKS / REFERENCES:

1. Inder J. Bahl, Maurizio Bozzi, Ramesh Garg, *Microstrip Lines and Slotlines*, Third Edition
2. ISBN: 9781608075355, Third Edition 2013
3. Ludwig R, Bogdanov G, *RF Circuit Design, Theory and Applications*, Pearson Education Inc, Second Edition, 2013.
4. Behzad Razavi, *RF microelectronics*, Pearson, 2014.
5. Pozar D M, *Microwave Engineering*, John Wiley & sons Pvt Ltd, Third Edition, 2007.

19CM613COMMUNICATION SYSYEMS LAB 0 0 3 2

Objectives:
- To provide a comprehensive introduction to the study of signal processing techniques in Communication systems.
- To address implementation concerns and architectures in signal processing algorithms for digital transceivers
- To facilitate design of advanced and customized signal processing routines for challenges in design of communication systems.

Keywords:

Transforms, Filters, Multirate , digital transceivers

Contents:
(Preferred Python)

1. Sampling – low pass and band limited
2. Numerical computation of DFT
3. Design and analysis of digital filters – optimization approach
4. Interpolation and decimation – time and frequency domain analysis
5. Fractional rate conversion
6. Realization of resampling filters
7. Polypohase and CIC structures
8. Wavelet using resampling filters
9. Carrier acquisition and tracking
10. Timing recovery
11. Channel equalization
12. QAM transceiver

Outcomes:
CO 1: Able to understand and analyze the modern signal processing techniques.
CO 2: Able to develop signal processing algorithms for specific and domain based applications.

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	3	-
CO 2	-	3	3	3	3

TEXT BOOKS / REFERENCES:

1. Fredric J Harris, *Multirate Signal Processing for Communication Systems*, Pearson Education, 2004.
2. Behrouz Farhang-Boroujeny, *Signal Processing Techniques for Software Radios*, Lulu Publishing House, 2008.
3. Paolo Prandoni, Martin Vetterli,*Signal Processing for Communications*, EPFL Press, 2008.

19CM614 WIRELESS NETWORKS AND PROTOCOLS 3 0 3 4

Objectives:
- To provide insights into the architectures of wireless local, personal and wide area networks and the wireless protocols currently used in practice at various networking layers.
- To teach the mathematics, algorithms and engineering practices applied for the design and operation of wireless networks.
- To understand and compare the performance of network protocols and algorithms by computer simulation.

.

Keywords:
802.11 WLAN, ZigBee, Bluetooth, LTE.

Contents:

History, evolution and trends; Layering and Standards: Fundamental principles of network layering, TCP/IP reference model; Physical and Medium Access Control Layers: Review of wireless channel characteristics and PHY layer techniques to combat channel impairments, Centralized access methods (TDMA, FDMA, CDMA, OFDMA), Reservation and polling, Distributed random access methods (ALOHA, CSMA/CA);

Graph-based algorithms for routing and topology control in wireless networks; Network and Transport Layer protocols; Wireless Local Area Networks: IEEE 802.11 WLANs, MAC and PHY layer variants; Wireless Personal Area Networks: Bluetooth (IEEE 802.15.1), ZigBee (IEEE 802.15.4);

Wireless Body Area Networks: IEEE 802.15.6 WBANs; Wireless Wide Area Networks: Cellular networks (2G, 3G, 4G, 5G), LTE, LTE-A; Introduction to Internet of Things (IoT) architectures and protocols.

Lab component: Simulation of wireless local, personal and wide area networks using NS, OMNET++ and SimuLTE.

Outcomes:

CO 1: Ability to understand and describe the basic theories, principles, technologies, standards and system architecture of wireless networks

CO 2: Ability to evaluate and compare wireless access technologies, and design algorithms for various applications

CO 3: Ability to simulate wireless network scenarios and analyze the performance by post-processing of simulation traces

CO 4: Gain professional skills through mini projects.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	-	3	3	3	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:

1. Eldad Perahia, and Robert Stacey, *Next generation wireless LANs*, Cambridge university press, 2013.
2. Sauter, Martin, *From GSM to LTE-advanced Pro and 5G: An introduction to mobile networks and mobile broadband*, John Wiley & Sons, 2017.
3. Xiao, Yang, and Yi Pan, eds., *Emerging wireless LANs, wireless PANs, and wireless MANs: IEEE 802.11, IEEE 802.15, 802.16 wireless standard family*, Vol. 57. John Wiley & Sons, 2009.
4. Arie Koster and Xavier Muñoz, eds., *Graphs and algorithms in communication networks: studies in broadband, optical, wireless and ad hoc networks*, Springer Science & Business Media, 2009.

19CM615 HARDWARE DESIGN WITH FPGA 3 0 3 4

Objectives:

- To enable the students to understand the Verilog modeling concepts.
- To enable the students to understand the FPGA architecture and design flow.

- To enable the students to understand the high level synthesis flow and implement DSP and digital communication blocks in FPGA.

Keywords:
Verilog HDL, FPGA, Synthesis.

Contents:

Modeling of combinational and sequential building blocks using Verilog: data flow modeling - behavioral modeling - structural modeling – Timing and delays - State machine - Case study of processor.

Spartan-7 FPGA Family: Scheme outline, Overview of Clocking, Block RAM, Configurable Logic Blocks, Memory Controller, Transceiver, Configuration, DSP slices, Clock Management, SERDES, Embedded Processor. Design Flow.

Introduction to high level synthesis (HLS) flow for FPGA- Applications: Design of FIR Filters and IIR Filters - DFT and FFT Algorithms - Error Control coders - Channel estimation algorithms.

Outcomes:
CO 1: Able to understand modeling using Verilog HDL.
CO 2: Able to apply the modeling concepts to gain mastery over HDL simulation of logic circuits.
CO 3: Able to understand FPGA architecture and design flow.
CO 4: Able to use HLS flow for FPGA for implementing DSP and digital communication blocks.

Lab Component: Simulation of Combinational and sequential logic using data flow modeling, behavioral modeling, structural modeling -Modeling, synthesis and Implementation of DSP and digital communication algorithms.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	-	-	3	1	-
CO 2	-	-	3	1	-
CO 3	3	-	3	1	-
CO 4	3	3	3	3	-

TEXT BOOKS / REFERENCES:

1. Ciletti, Michael D,*Advanced digital design with the verilog HDL*, Prentice Hall of India, 2003.
2. Uwe Meyer Baese, *Digital Signal Processing with Field Programmable Gate Arrays*, Springer, 2014.
3. User guides for different blocks of FPGA from Xilinx.
4. System Generator for DSP Xilinx User Guide.

19CM616MACHINE LEARNING FOR COMMUNICATION SYSTEMS
3 0 03

Objectives:

- To understand classification techniques used in machine learning
- To efficiently solve real time problems using machine learning algorithms
- To apply the machine learning algorithms for communication system applications

Keywords :
Neural networks, Support Vector Machines (SVM), Auto encoders, Communication systems

Contents :

Introduction to mixture models and EM, K-means clustering, mixture of Gaussians - Maximum likelihood and EM for Gaussian mixtures - Neural networks - network training - local quadratic approximation - use of gradient information - gradient descent optimization; error back propagation - Bayesian neural networks - Support vector machines-SVM formulation with two variables - Lagrangian dual - L1 SVM with soft margin (linear Kernel) - L2 norm linear SVM - Non-linear SVM and Kernel trick - SVM formulation of non-linear Kernels with soft margin (L1 norm, and L2 norm) - Introduction to support vector regression - one class SVM

The Jacobian matrix - Hessian matrix and diagonal approximation - Regularization in neural networks - mixture density neural networks - Introduction to deep learning neural networks - Theoretical advantages of deep architectures - Neural networks for deep architectures - Deep generative architectures - Convolution neural networks (CNN) - Auto encoders - Restricted Boltzmann machines - Variants of RBMs and auto encoders.

Applications in communication systems – Signal Detection – Channel Encoding and Decoding – Channel estimation, Prediction and Compression – End – to – End communication – Resource allocation

Outcomes:

CO 1 : Ability to understand classification techniques used in machine learning
CO 2 : Ability to design deep and CNN architectures for various applications
CO 3 : Ability to use machine learning algorithms for communication system applications
CO 4 : Ability to identify challenges in evolving machine learning concepts conforming to industry standards

CO - PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	-
CO 2	3	-	3	3	-
CO 3	3	3	-	-	3
CO 4	3	3	3	3	3

TEXT BOOKS / REFERENCES:

1. Christopher Bishop, *Pattern Recognition and Machine Learning*, First Edition, Springer, 2016.
2. K. P. Soman, R. Loganathan, and V. Ajay, *Machine Learning with SVM and Kernel Methods*, First Edition, PHI Learning Private Ltd., New Delhi, 2011.
3. Yoshua Bengio, *Learning Deep Architectures for AI,Foundations and Trends in Machine Learning*, First Edition, Now Publishers Inc, 2009.
4. https://www.comsoc.org/publications/best-readings/machine-learning-communications

19RM600 RESEARCH METHODOLOGY 2-0-0-2

Objectives:

- To enable defining and formulating research approaches towards obtaining solutions to practical problems
- To facilitate development of scientific oral and written communication skills.
- To comprehend the concepts behind adhering to scientific ethics and values.

Keywords:
Research Classification; Research Design; Communication; Scientific Ethics

Contents:

Meaning of Research, Types of Research, Research Process, Problem definition, Objectives of Research,Research Questions, Research design, Approaches to Research, Quantitative vs. Qualitative Approach,Understanding Theory, Building and Validating Theoretical Models, Exploratory vs. ConfirmatoryResearch, Experimental vs Theoretical Research, Importance of reasoning in research.

Problem Formulation, Understanding Modeling & Simulation, Conducting Literature Review,Referencing, Information Sources, Information Retrieval, Role of libraries in Information Retrieval,Tools for identifying literatures, Indexing and abstracting services, Citation indexes

Experimental Research: Cause effect relationship, Development of Hypothesis, Measurement SystemsAnalysis, Error Propagation, Validity of experiments, Statistical Design of Experiments, FieldExperiments, Data/Variable Types & Classification, Data collection, Numerical and Graphical DataAnalysis: Sampling, Observation, Surveys, Inferential Statistics, and Interpretation of Results

Preparation of Dissertation and Research Papers, Tables and illustrations, Guidelines for writing the abstract,introduction, methodology, results and discussion, conclusion sections of a manuscript. References,Citation and listing system of documents

Intellectual property rights (IPR) - patents-copyrights-Trademarks-Industrial design geographical indication. Ethics of Research- Scientific Misconduct- Forms of Scientific Misconduct.Plagiarism, Unscientific practices in thesis work, Ethics in science

Outcomes:
CO 1: Understand and apply some basic concepts of research and its methodologies
CO 2: Able to select and define appropriate research problem and parameters

CO 3: Demonstrate skills to draft a research paper (develop scientific writing skills)
CO 4: Comprehend the ethical practices in conducting research and dissemination of results in different forms.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	-	-
CO 2	3	3	3	-	-
CO 3	3	3	3	-	3
CO 4	-	-	-	-	3

TEXT BOOKS/ REFERENCES:

1. Bordens, K. S. and Abbott, B. B., "Research Design and Methods – A Process Approach", 8th Edition, McGraw-Hill, 2011
2. C. R. Kothari, "Research Methodology – Methods and Techniques", 2nd Edition, New Age International Publishers
3. Davis, M., Davis K., and Dunagan M., "Scientific Papers and Presentations", 3rd Edition, Elsevier Inc.
4. Michael P. Marder," Research Methods for Science", Cambridge University Press, 2011
5. T. Ramappa, "Intellectual Property Rights Under WTO", S. Chand, 2008
6. Robert P. Merges, Peter S. Menell, Mark A. Lemley, "Intellectual Property in New Technological Age". Aspen Law & Business; 6th Edition July 2012
7. Tony Greenfield and Sue Greener., *Research Methods for Postgraduates*, 3rd Edition, John Wiley & Sons, Ltd. 2016.

19CM617MODELING AND SIMULATION OF COMMUNICATION SYSTEMS LAB 0 0 3 2

Objectives:

- To comprehend system aspects of modern communication systems through modeling and simulation.
- To simulate and predict the behavior of broadband and high data rate intractable communication systems.
- To analyze the tradeoff between design constraints and sub-system parameters.

Keywords:
Digital transceivers, Power efficiency, Spectral efficiency, System behavior predictions,

Contents:

1. Deterministic and stochastic simulations
2. Modeling of errors due to sampling and quantization– choice of simulation sampling frequency
3. Sampling and generation of low pass and band limited signals
4. Baseband representation of linear and non-linear band pass signals and systems– time varying systems
5. Simulation of random process and noise sources
6. Pulse shaping and matched filter – impairments and phase effects

7. QAM transceiver
8. BER simulation and analysis using Monte Carlo techniques
9. Simulation of nonlinear and time varying systems
10. Case studies of simulation of M-PSK systems with amplitude and phase noise
11. Simulation of CDMA and OFDM systems.
12. Receiver sensitivity and link margin
13. Non-linear effects in RF front end of communication systems

Outcomes:

CO 1: Able to develop mathematical models based on theoretical foundations for communication engineering problems

CO 2: Able to do analyze tradeoffs of various subsystem parameters

CO 3: Able to do mathematically model complex intractable systems with non-linearity

CO 4: Able to perform simulation and validation of communication systems

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	-	3
CO 2	3	3	3	-	3
CO 3	3	3	3	-	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:

1. W. H. Tranter, K. S. Shanmugan, T. S. Rappaport and K. L. Kosbar, *Principles of Communication Systems Simulation with Wireless Applications*, Prentice Hall, 2003.

2. G. Rubino and B. Tuffin, *Rare Event Simulation Using Monte Carlo Methods*, John Wiley and Sons, 2009.

3. M. Schiff, *Introduction to Communication Systems Simulation*, Artech House, 2006.

4. C. B. Rorabaugh, *Simulating Wireless Communication Systems: Practical Models in C,* Prentice Hall, 2004

Electives

19CM701 MILLIMETER WAVE COMMUNICATION SYSTEMS 3 0 0 3

Objectives:

- To understand the channel behavior in millimeter wave communication systems
- To develop mathematical theory and engineering practice of wireless communication in higher frequency of mm wave
- To understand diversity and interpretation of capacity calculations
- To learn the transceiver architecture in mm wave communication range
- To understand beam steering and beam forming techniques in multi antenna array

Keywords:

Millimeter wave, 60GHz, MIMO, Diversity

Contents:

Millimeter Wave (MMW) characteristics - 60GHz MMW Case Study and Technical Challenges - Channel performance at 60 GHz - ITU Indoor Path Loss Model - Log Distance Path Loss Model - Link Budget- Development of MMW standards - Coexistence With Wireless Backhaul.

Modulation Schemes for MMW communications- PSK - OFDM. MMW Transceiver architecture- MMW Antennas- Path Loss and Antenna Directivity - Antenna Beam width - Beam steering Antenna- Need for MIMO – Channel Capacity of SISO and MIMO Systems - Water-filling algorithm

Spatial Diversity of Antenna Arrays - Multiple Antennas - Multiple Transceivers - Noise Coupling in a MIMO System - Potential Benefits of Advanced Diversity for MMW- Spatial And Temporal Diversity - Spatial and Frequency Diversity - Dynamic Spatial, Frequency and Modulation Allocation - Advanced Beam steering and Beam forming -The Need for Beam steering/Beam forming.

Outcomes

CO 1: Able to develop channel models for millimeter wave systems

CO 2:Able to apply single carrier , multicarrier modulation techniques , MIMO techniques in design of high data rate systems

CO 3:Able to understand the diversity and beamforming techniques and their use in millimeter wave systems.

CO4: Ability to learn and exhibit competency in the field of communication

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	-	3	3	3	3
CO 4	3	-	3	3	3

TEXT BOOKS/REFERENCES:

1. Kao- Cheng Huang and Zhoacheng Wang, *Millimeter Wave Communication Systems*, Wiley IEEE Press, 2011.

2. Theodore S.Rappaport, Robert W. Heath Jr. Robert C. Daniels and James N. Murdock, *Millimeter Wave Wireless Communication*, Prentice Hall, 2014.

3. John S. Seybold, *Introduction to RF Propagation*, John Wiley and Sons, 2005. *Millimeter*

4. Chia-Chin Chong, Kiyoshi Hamaguchi, Peter F. M. Smulders an d Su-Khion g, *Millimeter-Wave* Wireless *Communication Systems*: *Theory and Applications*, Hindawi PublishingCorporation, 2007.

19CM702MULTICARRIER COMMUNICATIONS 3 0 0 3

Objectives:

- To apply knowledge of design processes in multicarrier systems
- To generate innovative designs to fulfill new needs, particularly in the fields of broadband networks and mobile/wireless communication systems
- To analyze the performance of multicarrier system in wireless cellular systems

Keywords:

Multicarrier communications, OFDM, MIMO, Synchronizations, PAPR

Contents:

Introduction- High Rate Wireless Applications - Single-Carrier vs. Multi-Carrier

Transmission -Introduction to OFDM - Basic Principle of OFDM - Modeling of OFDM for Time-Varying Random Channel- Appropriate Channel Model for OFDM Systems - Impairments of Wireless Channels to OFDM Signals - Application to Millimeter-Wave Radio Channels

Coded OFDM Multiple Access Extensions of OFDM– Multiband OFDM- MIMO OFDM - Performance Optimization - Channel Partitioning - Synchronization - Timing Offset Estimation - Frequency Offset Estimation -Synchronization in Cellular Systems

Channel Estimation - Pilot Structure - Training Symbol-Based Channel Estimation - DFT-Based Channel Estimation - Decision-Directed Channel Estimation -PAPR Reduction- Inter-Cell Interference Mitigation Techniques

Outcomes:
CO 1: Able to develop mathematical theory and engineering practice of digital communications over fading channels
CO 2: Able to perform analysis and design of multi-channel techniques for communication
CO 3: Able to develop solution to challenges like synchronization, estimation and detection in multicarrier systems
CO 4: Able to evaluate solutions in communication system prespective

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	-	3	3	3	3
CO 4	3	-	3	-	3

TEXT BOOKS/REFERENCES:
1. Ye (Geoffrey) Li and Gordon L. Stuber, *Orthogonal Frequency Division Multiplexing forWireless Communications*, Springer, 2006.
2. Ramjee Prasad, *OFDM for Wireless Communications Systems*, Artech House, 2004
3. Bahai, Saltzberg and Ergen, *Multi-Carrier Digital Communications, Theory andApplications of OFDM*, Second Edition, Springer, 2004.
4. Henrik Schulze and Christian Lueders, *Theory and Applications of OFDM and CDMAWideband Wireless Communications*, John Wiley and Sons, 2005.

19CM703 SOFTWARE DEFINED RADIO 3 0 0 3

Objectives:
• To introduce the concept of design of communication systems on reprogrammable and reconfigurable hardware platform.
• To impart the use of multirate signal processing in efficient filter design for communication applications
• To introduce different architectures and tools in software defined radio for design of communication subsystems

Keywords:
Digital filtering, multirate signal processing, Direct Digital Synthesis, USRP

Contents:

Introduction to software-defined radio - Review of telecommunication concepts and systems - Analog and Digital Communication System - Front-end RF system - Link Budgets, noise, C/N and S/N ratios - Digital filtering - Signal recovery - Baseband and Band pass Sampling - Complete SDR systems - Future trends in SDR.

Multirate signal processing - Sample Rate conversion principles - Efficient Structures for Decimation and Interpolation Filters – Polyphase filters – Digital Filters Banks– Arbitrary sampling rate conversion – CIC Filter - Analog to Digital and Digital to Analog converters for SDR.

Hardware and Software Architecture for SDR: Universal Software Radio Peripheral, bladeRF, RTL-SDR, HackRF, WebSDR

Outcome:

CO 1:Able to use programmable DSP to implement software radio for wireless systems and sub-systems

CO 2: Able to appreciate the design flexibility in software defined radios by using software tools CO 3: Able to take up some case studies for implementation using software radio concepts

CO 4: Able to learn and exhibit competency in the emerging trends of wireless systems

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	-	3	3	3	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:

1. Jeffrey H Reed, *Software Radio: A Modern Approach to Radio Engineering*, Prentice Hall PTR, 2002.

2. Johnson, C.R. and W.A. Sethares, *Telecommunication Breakdown: Concepts ofCommunication Transmitted via Software-Defined Radio*, Pearson Prentice Hall, 2004.

3. Tony J. Rouphael, *RF and Digital Signal Processing for Software-Defined Radio: A Multi-Standard Multi-Mode Approach*, Elsevier Inc., 2009.

4. Walter Tuttlebee, *Software Defined Radio: Origins, Drivers and International Perspectives*, John Wiley and Sons Ltd, 2002.

19CM704 VEHICULAR COMMUNICATIONS AND NETWORKS 3 0 0 3

Objectives:

- To introduce students with the emerging technologies, standards and applications in the area of vehicular communication systems and networks.
- To make the students appreciate the challenges and design considerations of vehicle-to-anything (V2X) communications at various networking layers.
- To teach how to simulate various aspects of a vehicular communication network and investigate and compare the performances of various solutions.

.

Keywords:

V2X, DSRC, WAVE, 802.11p.

Contents:

Applications of V2X: Safety vs. non-safety; Use cases: Traffic information systems, Safety-critical applications; Mapping service requirements to communication technologies; Layering and Standards: Fundamental principles of layering, DSRC/WAVE, ETSI ITS-G5 and ARIB architectures; DSRC standard: Channelization, SAE J2735 message set dictionary, Basic Safety Message, IEEE 1609 WAVE multi-channel operation, IEEE 802.11p MAC and PHY;

Vehicular channel characteristics: Pathloss, Shadowing and Small-scale fading, Delay spread and Doppler spread, Coherence bandwidth and coherence time, Impact of channel impairments on system design; Techniques for combating channel impairments; Digital modulation schemes in 802.11p; Design of OFDM parameters in 802.11p (symbol time, sub-carrier spacing, pilot spacing); Transmit power control and transmit masks;

Routing in VANETs: Flooding and the 'Broadcast Storm Problem'; Traditional MANET routing: Topology based / table-driven routing protocols, Proactive (DSDV) vs. Reactive / On-demand (DSR, AODV, DYMO) routing protocols; Geographic routing protocols; Beaconing; DTN and peer-to-peer ideas for VANET routing; Vehicular network simulations using VEINS: Mobility models, Traffic flow models.

Outcomes:

CO 1: Ability to understand and describe the basic theories, principles, technologies, standards and system architecture of vehicular networks.
CO 2: Ability to analyze, design, and evaluate vehicular communication technologies for various kinds of safety and infotainment applications.
CO 3: Ability to evaluate and compare vehicular routing and information dissemination protocols.
CO 4: Gain professional skills through mini projects.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	3	3	3	3	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:

1. Christophe Sommer and Falko Dressler, *Vehicular Networking*, Cambridge University Press, 2014.
2. Hannes Hartenstein and Kenneth Laberteaux (eds.), *VANET Vehicular Applications and Inter-networking Technologies*, John Wiley & Sons, 2009.
3. Claudia Campolo, Antonella Molinaro and Riccardo Scopigno, *Vehicular ad hoc Networks: Standards, Solutions, and Research*, Springer, 2015.
4. Andrea Goldsmith, *Wireless Communications*, Cambridge University Press, 2005.

19CM705 SECURITY FOR WIRELESS COMMUNICATIONS3 0 0 3

Objectives:

- To introduce the key concepts and analytical models of physical layer security in both single-user and multi-user communication systems
- To apply signal processing techniques to design physical layer security enhancements

Keywords:
Physical layer security, secret key, cryptography, secrecy capacity

Contents:
Fundamentals of Physical layer security – Information theoretic secrecy metrics – channel models - Secret Communication - Coding for Security - Asymptotic Analysis - Key Generation from wireless channels

Key agreement techniques - Secrecy With Feedback - Achieving Secrecy through Discussion and Jamming. MIMO Signal Processing Algorithms for Enhanced Physical Layer Security - Secrecy Performance Metrics -Physical Layer Security in OFDMA Networks -Power Allocation Law for Secrecy - Multiple Eavesdroppers

Resource Allocation for Physical Layer Security in OFDMA Networks- Application of Cooperative Transmissions to Secrecy Communications - Stochastic Geometry Approaches to Secrecy in Large Wireless Networks.

Outcomes:
CO 1: Able to analyze the performance of secrecy schemes and impact of attacks
CO 2: Able to use the tools from game theory and graph theory to analyze and design wireless networks with physical layer security considerations
CO 3: Able to explore issues and solutions in providing physical layer security in practical wireless systems
CO 4: Able to implement secure communication systems

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	-	3	3	3	3
CO 4	3	-	3	-	3

TEXTBOOKS/REFERENCES:

1. Xiangyun Zhou, Lingyang Song and Yan Zhang, *Physical Layer Security in WirelessCommunications*, CRC Press, 2013.
2. Lidong Chen and Guang Gong, *Communication System Security*, Chapman and Hall/CRC, 2012

19CM706 INTERNET OF THINGS 3 0 0 3

Objectives:
- To introduce students with the emerging technologies, standards and applications of Internet of Things.
- To make the students appreciate the challenges and design considerations of Internet of Things.

- To understand how different access technologies and protocols can be made to work together towards building an IoT network.
- To gain experience of building IoT systems by hands-on-projects.

Keywords:
IoT, 6LoWPAN, CoAP, MQTT.

Contents:
What is IoT? IoT network architecture; Constrained devices and networks; Sensors, actuators and smart objects; Sensor networks and protocols; Communication criteria for choosing between access technologies; Building small IoT Projects with Arduino;

IoT Access Technologies: IEEE 1901.2a, IEEE 802.15.4/e/g, IEEE 802.11ah, LoRaWAN, NB-IoT and other LTE variations; IoT Network Layer: Adoption vs. adaptation of IP for IoT, IP versions, 6LoWPAN, Mesh addressing, Mesh-under vs. mesh-over routing, 6TiSCH, RPL;

IoT Transport and Application Layers: CoAP, MQTT; IoT Applications and Use Cases; Hardware prototyping of IoT use cases.

Outcomes:
CO 1: Ability to understand IoT architectures, communication technologies and protocols.
CO 2: Ability to evaluate and compare access technologies for IoT applications.
CO 3: Ability to design and develop IoT applications using off-the-shelf wireless technology.
CO 4: Gain professional skills through mini projects.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	3	3	3	3	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:

1. Hanes, David, Gonzalo Salgueiro, Patrick Grossetete, Robert Barton, and Jerome Henry, *IoT fundamentals: Networking technologies, protocols, and use cases for the internet of things*, Cisco Press, 2017.
2. Houda Labiod, Hossam Afifi, and Costantino De Santis, *Wi-Fi, Bluetooth, Zigbee and WiMAX*, Springer, 2007.
3. Javed, Adeel, *Building Arduino projects for the Internet of Things: experiments with real-world applications*, Apress, 2016.
4. Waher, Peter, Pradeeka Seneviratne, Brian Russell, and Drew Van Duren, *IoT: Building Arduino-Based Projects*, Packt Publishing Ltd., 2016.

19CM707 COOPERATIVE AND RELAY COMMUNICATION 3-0-0-3

Objectives:
- To provide the fundamental concepts of cooperative and relay communication in wireless networks

- To impart the design principles in cooperative and relay system.
- To facilitate the design of distributed communication in wireless system

Keywords:
Cooperative communication, relay communication, multihop.

Contents:
Overview of cooperative and relay communication - Brief history of cooperative and relay Channels - Standardization of cooperative communication and relay technology - Review of wireless communications and MIMO techniques

Two user cooperative transmission schemes - Decode and forward - Amplify and forward Coded cooperation - Compress and forward relaying schemes - Channel estimation in single relay schemes

Cooperative transmission schemes with multiple relays - Orthogonal cooperation - Transmit beamforming - Selective relaying - Distributed space-time coding- Channel estimation in multirelay systems - Multihop cooperative transmissions.

Outcomes:
CO 1: Ability to design cooperative, relay and multihop communication in wireless networks
CO 2: Ability to analyze different relay techniques suitable for modern wireless systems.
CO 3: Ability to evaluate the performance of relay based systems over conventional wireless systems
CO 4: Ability to learn and understand power efficient system in futuristic wireless systems

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3		3	3	3
CO 2	-	-	3	3	3
CO 3	3	3	3	3	3
CO 4	3	3	3	3	3

TEXTBOOKS/ REFERENCES:
1. Y.-W. Peter Hong, Wan-Jen Huang, C.-C. Jay Kuo, *Cooperative Communications and Networking: Technologies and System Design*, Springer
2. Murat Oysal, *Cooperative Communications for Improved Wireless Network for virtual antenna array signals* by, information science reference. *Transmission: framework*

19CM708 MASSIVE MIMO 3 0 0 3

Objectives:
- To learn the basic Massive MIMO concept, results and properties.
- To provides a clean introduction to the theoretical tools that are suitable for analyzing the Massive MIMO performance.
- To carry develop advanced Massive MIMO techniques and algorithms

Keywords:

Massive MIMO, precoding, Markov chain Monte Carlo

Contents

Introduction – multi antenna channels – Large MIMO systems – opportunities – challenges – MIMO encoding – spatial multiplexing – space time coding – spatial modulation

MIMO detection – Linear detection – LR aided detection – sphere decoding – detection based on local search – probabilistic data association – message passing on graphical models – factor graphs

Markov chain Monte Carlo – Channel estimation – iterative channel estimation - MIMO Precoding – multi cell prrecoding – multiuser precoding - Channel Models – Analytical channel model – standard channel model – antenna arrays– Large MIMO Testbeds

Outcome:

CO 1: To understand and analyze Massive MIMO systems with baseband signal processing aspects.
CO 2: Model and simulate a massive MIMO system and develop an experimental test bed.
CO 3: To acquire the skill set needed to analyze complex wireless communication systems
CO 4: To put knowledge into practice design massive MIMO communication system

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	-	3	3	3	3
CO 4	3	-	3	3	3

TEXT BOOKS /REFERENCES:

1. A. Chockalingam & B. Sundar Rajan, *Large MIMO Systems*, Cambridge University Press, 2014.
2. T.L.Marzetta, E.G.Larsson, Hong Yang, H.Q.Ngo, *Foundations of Massive MIMO*, Cambridge University Press, 2017.
3. Emil Björnson, Jakob Hoydis and Luca Sanguinetti (2017), *Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency*, Foundations and Trends® in Signal Processing, 2017.

19CM709 ESTIMATION AND DETECTION THEORY 3 0 0 3

Objectives:

- To introduce the fundamental principles of decision making under uncertainty.
- To make the students appreciate how practical problems in communication and signal processing are formulated and solved using the classical and Bayesian approaches.
- To boost the mindset of application-oriented learning of random process theory through programming assignments.

Keywords:

Unbiased, Likelihood, Bayesian, Hypothesis testing.

Contents:
Review of probability and random processes; Applications of statistical estimation and detection techniques in communication and signal processing; Classical estimation: bias and variance, Cramer-Rao lower bound, Sufficient statistic, MVUE, Fischer-Neyman factorization theorem, Rao-Blackwell theorem;

Maximum likelihood estimation, Linear models, BLUE, Least squares; Consistency, efficiency and asymptotics; Bayesian estimation: MMSE and MAP estimation; Kalman and Weiner filtering; Detection theory: Bayesian and Neyman-Pearson detection;

Minimax Detection, Composite hypothesis testing, GLRT; Sequential detection; Performance analysis by Monte Carlo method; Signal detection in continuous time, Karhunen–Loève (KL) theorem; Detection of random signals in Gaussian noise.

Outcomes:
CO 1: Ability to understand the fundamental principles behind frequently applied estimation and detection techniques in communication systems and signal processing.
CO 2: Ability to select and apply appropriate estimation and detection techniques for problems arising in communication systems and signal processing.
CO 3: Ability to implement in software commonly used estimation and detection techniques and investigate their performance for real applications.
CO 4: Gain professional skills through mini projects.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	3	3	3	3	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:
1. H. V. Poor, *An Introduction to Signal Detection and Estimation*, 2nd Ed., Springer-Verlag, 1994.
2. S.M. Kay, *Fundamentals of Statistical Signal Processing*, Volume I and II, Prentice Hall Inc., 1998.
3. H. L. Van Trees, *Detection, Estimation and Modulation Theory, Part 1*, 2nd Ed., John Wiley, 2013.
4. M. D. Srinath, P. K. Rajasekaran and R. Vishwanathan, *An Introduction to Statistical Signal Processing with Applications*, Prentice-Hall, 1996.

19CM710 ERROR CONTROL CODING 3 0 0 3

Objectives:
- To enable the students to understand the properties, encoding and decoding techniques of Turbo codes.

- To enable the students to understand the properties, encoding and decoding techniques of LDPC codes.
- To enable the students to understand the properties, encoding and decoding techniques of Polar codes.

Keywords:
MAP algorithm, Tanner graph, Performance analysis.

Contents:
Turbo codes: Introduction to Turbo codes-Design and properties of Turbo convolutional codes- Iterative decoding of Turbo codes- Turbo product codes -Encoding and decoding.
Low-Density Parity- Check codes: Introduction to LDPC codes- Construction of LDPC codes- Decoding of LDPC codes.
Polar codes – Properties, Encoding and Decoding of polar codes - Case study of practical applications of Block codes and Convolutional codes.

Outcomes:
CO 1: Able to encode and decode Turbo convolutional codes and Turbo product codes.
CO 2: Able to apply LDPC decoding algorithms and analyze the performance of the code.
CO 3: Able to understand the improvement in error control performance using strong codes and their iterative soft decoding techniques.
CO 4: Able to apply the concepts of encoding and decoding algorithms to real time problems.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	1	-
CO 2	3	-	3	1	-
CO 3	3	2	3	1	-
CO 4	3	2	3	3	-

TEXT BOOKS / REFERENCES:
1. Shu Lin and Daniel J.Costello, *Error Control Coding – Fundamentals and Applications*, Second Edition, Prentice-Hall, 2004.
2. Tom Richardson and RudigerUrbanke, *Modern Coding Theory*, Cambridge University Press, 2008. 3. Richard E. Blahut, *Algebraic Codes for Data Transmission*, Cambridge University Press, 2003.
3. Todd K.Moom, *Error Correction Coding- Mathematical methods and algorithms*, Wiley,2006.
4. Richard B. Wells, *Applied Coding and Information Theory for Engineer*, Pearson Education, LPE, First Indian Reprint, 2004.

19CM711 AUTOMOTIVE RADAR 3 0 0 3

Objectives:
- Understanding the components of a radar system and their relationship to overall system performance

- Understanding the classification of various types of radars
- Understanding the principles of operation of automotive and other types of radars.

Keywords:
Radar range equations, SNR, Doppler radars, Automotive, SAR

Contents:
Radar Principles: Frequency of operation, Radar range equation, Radar cross section-Radar echo, Prediction of radar range, Antenna systems, Loss factors, Jamming and clutter, Receiver and Transmitter parameters, Types of radar principles and operation, Phased array antenna radars, Analog and Digital beamforming radars
Automotive Radars: Classification of automotive radars, frequency of operations, Long range and short-range radar operations, Technical specifications, Direction of arrival estimation, case studies on various automotive radars and performance analysis
Radars for strategic applications: Principles of air-traffic controllers, satellite communication and launch vehicle radars for Telemetry, tracking and tele command systems, Case studies on various types of radars in strategic domains.

Outcome:
CO1: Ability to understand the principles of operation of radars
CO2: Enable and the system level design aspects components for radars
CO3: Understand the principles of radars used in various applications
CO4: Enable the research aptitude of radar principles and applying in project works

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	-	3	3
CO 2	3	3	3	3	3
CO 3	2	-	1	2	-
CO4	3	3	3	3	-

TEXT BOOKS/REFERENCES:
1.Skolnik M, *Introduction to Radar Systems*, Tata-Mcgraw Hill, 2003.
2. Kai Chang, *RF and Microwave Wireless Systems*., John Wiley & Sons, Inc. 2000
3.David K. Barton, *Modern Radar System Analysis*, Artech House,Inc., NY 1988.
4.http://www.iet.unipi.it/m.greco/esami_lab/Radar/automotive_radar.pdf

19CM712 ANTENNA AND ARRAY SYSTEMS DESIGN 3 0 0 3

Objectives:
- To understand the radiation concepts for antenna systems
- To design, develop and analyze specific antenna and array systems for various applications
- To motivate for pursuing project and research in the antenna domain

Keywords:
Radiation pattern, Microstrip, Substrate

Contents

Design and electromagnetic analysis of antenna systems: Antenna parameters, analysis of performance, types of antenna systems, wire antennas, printed dipole, helical antenna, microstrip rectangular and annular ring antenna, Feed techniques, feed systems for circular polarization, Axial ratio, Bandwidth enhancement, Case studies on antenna design for selected applications and electromagnetic simulation studies.

Design of Array antenna systems: Principle of array operation, array factor, radiation pattern analysis, side-lobe suppression techniques, element spacing, gain computation, microstrip array, helical array, feed techniques, impedance matching planar feed techniques, corporate feed techniques, multi-layer antenna array and feed systems, Electromagnetic simulations of array antenna systems

Phased and active array antenna: Principles of phased array techniques, monopulse comparator, monopulse using planar hybrid system, determination of angle of arrival, beamforming principles, principle of analog and digital beamforming techniques, RF Front-End integrated array antenna systems, Gain and pattern analysis, case studies on analog and digital beamforming antenna arrays.

Outcomes:

The student will be able to

CO1: Design and analyze various types of antenna systems and study using electromagnetic simulation

CO2: Provide end-to-end solutions in the antenna design aspects and able to choose the suitable configurations

CO3: Apply the design and analysis aspects of antennas in research and support the industrial requirements

CO4: Ability to provide solutions for wireless connectivity in the RF front-end domain.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	2	3	3	3
CO 2	3	1	2	3	-
CO 3	3	1	2	3	-
CO4	-	-	3	3	3

TEXT BOOKS / REFERENCES:

1.Constantine A. Balanis, *Antenna Theory: Analysis and Design*, 4th Edition, Wiley and Sons, ISBN: 978-1-118-64206-1 February 2016

2. J R James and P S Hall, *Microstrip Antenna: Theory and Design*, Peter Peregrinus Ltd,1986.

3. Hubregt J Visser, A*ntenna Theory and Applications*, Wiley, 201

19CM721 MULTI-SENSOR DATA FUSION 3 0 0 3

Objectives:

• To provide a thorough understanding of the mathematical foundations of data fusion methods.
• To apply appropriate data fusion methods to problems in communication and signal processing.
• To gain hands-on experience of implementing data fusion algorithms.

Keywords:
Bayesian methods, Feature vector, ANFIS, Decision fusion.

Contents:
Introduction to data fusion process: Data fusion models, Configurations and architectures; Probabilistic Data Fusion: Maximum Likelihood, Bayesian, and Maximum Entropy methods; Recursive Bayesian methods for estimation and data fusion: Kalman filter theory, Kalman filter as a natural data-level fuser;

Data fusion by nonlinear Kalman filtering; Information filtering; H_∞ filtering; Multiple hypothesis filtering: Data fusion with missing measurements; Possibility theory and Dempster-Shafer Method; Fuzzy Logic based Decision Fusion: Type 1 and Type 2 Fuzzy logic, Adaptive Neuro-Fuzzy Inference System (ANFIS);

Decision Theory based Fusion: Bayesian decision theory, Decision making with multiple information sources, Fuzzy approach, Decision making based on voting; Performance Evaluation of Data Fusion systems: Monte Carlo methods.

Outcomes:
CO 1: Ability to understand and appreciate the benefits and shortcomings of various data fusion algorithms.
CO 2: Ability to select and apply appropriate data fusion techniques to problems in communication and signal processing.
CO 3: Ability of numerically implementing data fusion algorithms accounting for computational issues.
CO 4: Gain professional skills through mini projects.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	3	3	3	3	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:

1. Jitendra R Raol, *Data Fusion Mathematics: Theory and Practice*, CRC Press, 2016.
2. David L. Hall, *Mathematical Techniques in Multisensor Data Fusion*, Artech House, Boston, 1992.
3. Lawrence A. Klein, *Sensor and Data Fusion: A Tool for Information Assessment and Decision Making*, 2nd Ed., SPIE Press, 2012.
4. H. B. Mitchell, *Data Fusion: Concepts and Ideas*, Springer-Verlag, 2012.

19CM722 STOCHASTIC MODELLING AND QUEUING THEORY 3 0 0 3

Objectives:

- To provide a thorough understanding of the mathematical foundations of telecommunication and computer communication networks.
- To teach the application of Markov processes and queueing theory to analyze the performance of and address the design questions in circuit- and packet-switching networks.
- To gain hands-on experience of discrete-event simulations of queueing systems.

Keywords:
Markov Chains, Renewal Processes, Queueing Theory, Performance Analysis.

Contents:
Selected Topics in Probability and Random Variables: Memoryless property of exponential and geometric random variables, Moment generating function, Laplace-Stieljes transform (LST) of random variables; Selected Topics in Stochastic Processes: Stationarity, Ergodicity, Independence, Correlation; Stationary increment and independent increment Processes: Bernoulli trials, Poisson processes, Gaussian processes;

Markov Processes: Discrete time Markov chains (DTMCs), Continuous time Markov chains (CTMCs), Recurrence, Transience, Stability; Renewal Processes and Markov Renewal Processes; Queueing Theory: Common queueing models (M/M/1, M/M/1/K, M/M/K/K, M/G/1, M/G/1/K, G/M/1, Geo/Geo/1, M/G/∞), Vacation models, Loss networks and delay networks, Multiclass queueing models with priority, Open and closed networks of queues; Fluid and Gaussian approximations;

Discrete-Event Simulation of Queueing Systems; Applications to Telecommunications and Computer Communication Networks: Capacity design, Dynamic channel allocation and scheduling in cellular, TCP/IP networks and telecommunication switching, Throughput and delay analysis in wireless local area networks (WLANs), Coverage analysis in wireless sensor networks (WSNs), Spreading of computer virus and messages in intermittently connected networks (ICNs/DTNs).

Outcomes:
CO 1: Able to map frequently occurring scenarios in telecommunication and computer networking into standard stochastic models, i.e., able to construct mathematical models from the physical description of the problems.
CO 2: Able to identify appropriate solution methods in each case and physically interpret the mathematical results.
CO 3: Able to analyze and compare the performance of queueing systems by discrete-event simulations.
CO 4: Gain professional skills through mini projects.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3

CO 3	3	3	3	3	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:

1. Vidyadhar G. Kulkarni, *Modeling and Analysis of Stochastic Systems*, CRC Press, 2016.
2. Anurag Kumar, *Discrete Event Stochastic Processes*, available online http://ece.iisc.ernet.in/~anurag/books/anurag/spqt.pdf
3. Dimitri P. Bertsekas, and Robert G. Gallager, *Data Networks*, Prentice-Hall International, 1987.
4. Alberto Leon-Garcia, *Probability, Statistics, and Random Processes for Electrical Engineering*, 3rd ed. Pearson/Prentice Hall, 2008.

19CM723 NETWORK CODING 3 0 0 3

Objectives:

- To introduce the fundamental concepts and theorems of network coding and illustrate its applications to wireless networks.
- To demonstrate the application of network coding mathematics and algorithms for solving several important problems in communication networks, e.g., throughput maximization, reliable communication over erasure channels, robust storage and distribution of content.
- To gain hands-on experience of implementing network coding techniques and algorithms.

Keywords:

Min-cut max-flow theorem, Network multicasting, Gossip algorithms, Erasure correction.

Contents:

Theorems of network multicast: min-cut max-flow theorem; distributed protocol for the min-cut max-flow theorem; the main theorem of network coding; Theoretical frameworks for network coding: algebraic, combinatorial, information-theoretic and linear programming frameworks; Throughput benefits of network coding;

Network code design for multicasting: centralized and decentralized algorithms; Networks with delays and cycles; Applications of network coding; Collecting coupons and linear combinations; Network coding over random graphs; Gossip algorithms for information dissemination; Content distribution;

Applications of network coding in wireless networks and security: energy efficiency, fairness and delay, adaptability to dynamically changing networks, physical layer network coding, applications to sensor networks; Benefits for network coding with multiple unicast sessions; Network coding for erasure channels.

Outcomes:

CO 1: Ability to understand and apply the fundamental concepts of network coding for network design and optimization.

CO 2: Ability to design distributed algorithms for multicasting and information dissemination using network coding.

CO 3: Ability to quantify the improvement in performance of wireless networks due to network coding.

CO 4: Gain professional skills through mini projects.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	3	3	3	3	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:

1. Christina Fragouli and Emina Soljanin, *Network Coding Fundamentals*, Foundations and Trends in Networking, now Publishers Inc, 2007.
2. Christina Fragouli and Emina Soljanin, *Network Coding Applications*, Foundations and Trends in Networking, now Publishers Inc, 2007.
3. Raymond Yeung, S.-Y.R. Li, N. Cai, Z. Zhang, *Network Coding Theory*, Foundations and Trends in Communications and Information Theory, now Publishers Inc, 2006.
4. Tracey Ho and Desmond S. Lun, *Network Coding: An Introduction*, Cambridge University Press, 2008.

19CM724 WIRELESS SENSOR NETWORKS 3 0 0 3

Objectives:

- To understand the theoretical aspects of wireless sensor networks with focus on signal processing and communication perspectives
- To apply the ideas and illustrations from distributed signal processing, communications and cross-layer optimization to design of Wireless sensor network.
- To design wireless sensor network for specific applications.

Keywords:
Localization, Routing, Sensor fusion, Ad-Hoc networks, Energy Efficiency.

Contents:
Introduction - Fundamental Properties and Limits: Information-theoretic Bounds on Sensor Network Performance - Network Information Processing in Wireless Sensor Networks - Sensing Capacity of Sensor Networks - Law of Sensor Network Lifetime and Its Applications –

Signal Processing for Sensor Networks: Detection in Sensor Networks - Distributed Estimation Under Bandwidth and Energy Constraints - Distributed Learning in Wireless Sensor Networks - Graphical Models and Fusion in Sensor Networks - Communications, Networking and Cross-Layered Designs: Randomized

Cooperative Transmission in Large-Scale Sensor Networks.
Application Dependent Shortest Path Routing in Ad-Hoc Sensor Networks - Data-Centric and Cooperative MAC Protocols for Sensor Networks -Game Theoretic Activation and Transmission Scheduling in Unattended GroundSensor Networks: A Correlated Equilibrium Approach

Outcomes:

CO 1: Able to conceptualize WSNs from different angles

CO 2: Able to design large-scale sensor networks with constraints and perform parametric analysis

CO 3: Able to customize the network for specific applications of application-specific WSNs

CO 4: Able to perform distributed signal processing, communication algorithms and novel cross-layer design paradigms.

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	-	3	3	3	3
CO 4	-	3	3	3	3

TEXT BOOKS /REFERENCES:

1. Ananthram Swami, Qing Zhao, Yao-Win Hong, & Lang Tong, "*Wireless Sensor Networks: Signal Processing and Communications*" Wiley Inc, 2007.

2. **Holger** Karl, &Andreas **Willig** "*Protocols and Architectures for Wireless Sensor Networks*", Wiley Inc, 2005.

3. Azzedine Boukerche, "*Handbook of Algorithms for Wireless Networking and Mobile Computing*", Chapman & Hall/CRC, 2006

4. Nirupama Bulusu and Sanjay Jha, "*Wireless Sensor Networks : A systems perspective*", Artech House, August 2005.

19CM731 CONVEX OPTIMIZATION 3 0 0 3

Objectives:

• To efficiently solve mathematical optimization problems which arise in a variety of applications

• To discover/identify various applications in areas such as, estimation and signal processing, communications and networks, electronic circuit design, data analysis and modeling, statistics, automatic control systems and finance

Keywords:

Linear Programming, Quadratic Programming, Semi definite programming, Interior Point methods, KKT conditions

Contents:

Introduction - linear algebra fundamentals - Solving linear equations with factored matrices - Block elimination and Schur complements - Convex sets - Convex functions - examples

Classes of Convex Problems - Linear optimization problems - Quadratic optimization problems - Geometric programming - Vector optimization -Reformulating a Problem in Convex Form

Lagrange Duality Theory and KKT Optimality Conditions - Interior-point methods- Primal and Dual Decompositions-Applications

Outcomes:
CO 1: Able to recognize, formulate, and analyze convex optimization problems
CO 2: Able to design sophisticated algorithms based on convex Optimization for applications in communication and signal processing
CO 3: Able to solve convex problems using computationally efficient techniques.
CO 4: Able to evaluate computational aspects of convex optimization techniques

CO-PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	-	3
CO 2	3	-	3	3	3
CO 3	3	-	3	-	3
CO 4	3	3	3	-	3

TEXTBOOKS/REFERENCES:
1. Stephen Boyd and LievenVandenberghe, *Convex Optimization*, Cambridge University Press, 2004.
2. Daniel Palomar, *Convex Optimization in Signal Processing and Communications*, Cambridge University Press, 2009.
3. Dimitri P Bertsekas, *Convex Optimization Theory*, Athena Scientific, 2009.

19CM732 BIG DATA ANALYTICS 3 0 0 3

Objectives:
- To introduce big data concepts with emphasis on the Hadoop ecosystem.
- To enable efficient design and deployment of an HDFS based system.
- To provide insights into the applicability of various techniques for analyzing big data.

Keywords:
Hadoop, HDFS, MapReduce, Spark, MLLib

Contents:
Introduction: Data Storage and Analysis, a Brief History of Apache Hadoop and the Hadoop Ecosystem. MapReduce: Map and Reduce, Data Flow, Combiner Functions, Running a Distributed MapReduce Job, Hadoop Streaming, Hadoop Pipes.

The Hadoop Distributed Filesystem (HDFS): The Design of HDFS, Blocks, Namenodes and Datanodes, HDFS Federation, HDFS High-Availability. Basic Filesystem Operations: Hadoop Filesystems, Interfaces. Data flow: file read and write, Hadoop archives. Hadoop I/O: Data Integrity, Compression, Serialization, File-Based Data Structures.Developing a MapReduce Application: The Configuration API, Configuring the Development Environment, Writing a Unit Test, Running Locally, Running on a Cluster, Tuning a Job, MapReduce Workflows.

SPARK: Spark Jobs and APIs, Spark 2.0 architecture. Resilient Distributed Datasets (RDDs): Internal workings, Creating RDDs, Global versus local scope, Transformations, Actions. DataFrames: Python to RDD communications, Speeding up PySpark with DataFrames, Creating DataFrames, Simple DataFrame queries, Interoperating with RDDs. Querying with the DataFrame API, Querying with SQL. MLLib: Overview, Loading and transforming data, ML Package: Overview and examples, Parameter hyper-tuning.

Outcomes:

CO 1: Ability to design an HDFS based system

CO 2: Ability to employ MapReduce for solving big data problems

CO 3: Ability to analyse big data using Spark and ML packages.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	3	3
CO 2	3	-	3	3	-
CO 3	3	-	3	3	-

TEXT BOOKS/REFERENCES:

1. Tom White, *HADOOP: The definitive Guide*, 4th Ed., O Reilly Media, 2015.
2. Tomasz Drabas, Denny Lee, *Learning PySpark*, Packt Publishing, 2017.
3. Alex Holmes, *Hadoop in Practice*, Manning Publications, 2012.
4. Nataraj Dasgupta, *Practical Big Data Analytics*, Packt Publishing, 2018.

19CM733 GAME THEORY 3 0 0 3

Objectives:

- To formalize the notion of strategic thinking and rational choice by using the tools of game theory, and to provide insights into using game theory in modeling applications.
- To draw the connections between game theory and its applications emphasizing the computational issues.
- To gain hands-on experience by seeing game-theoretic algorithms in action.

Keywords:

Nash equilibria, best response, routing games, bargaining.

Contents:

Introduction to Game Theory; Non-cooperative games: strategic form vs. dynamic; Bayesian games: static vs. dynamic games in extensive form; Differential games: connections with optimal control theory;

Evolutionary games: evolutionarily stable strategies, replicator dynamics, reinforcement learning; Cooperative games: bargaining, coalitional games; Auction theory and mechanism design: VCG auction;

Application to Communication Networks: Applications to cellular and broadband wireless access networks, Applications to wireless local area networks, Applications to multihop networks, Applications to cooperative communication networks, Applications to Cognitive radio networks, Applications to Internet congestion control and Net Neutrality.

Outcomes:

CO 1: Ability to map communications, signal processing and networking problems into standard game-theoretic models.

CO 2: Ability to apply game-theoretic concepts to solve engineering problems and obtain insights.

CO 3: Ability to implement game-theoretic design algorithms numerically and investigate performance.
CO 4: Gain professional skills through mini projects.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	3
CO 2	3	-	3	-	3
CO 3	3	3	3	3	3
CO 4	3	3	3	3	3

TEXT BOOKS/REFERENCES:

1. M. J. Osborne, *An Introduction to Game Theory*. Oxford University Press, 2003.
2. Han, Zhu, Dusit Niyato, Walid Saad, Tamer Başar, and Are Hjørungnes, *Game theory in wireless and communication networks: theory, models, and applications.* Cambridge university press, 2012.
3. MacKenzie, Allen B., and Luiz A. DaSilva, *Game theory for wireless engineers*. Synthesis Lectures on Communications, 1, no. 1 (2006): 1-86.
4. N. Nisan, T. Roughgarden, E. Tardos, and V. V. Vazirani, *Algorithmic Game Theory*. Cambridge University Press, 2007.

19CM741 SPEECH AND AUDIO PROCESSING 3 0 0 3

Objectives:

- To help the students deepen their understanding of signal processing algorithms forspeech and audio processing
- To strengthen the research skills of students in speech processing

Keywords: Speech signal analysis, Speech recognition, Speaker recognition, Languagemodeling, Feature extraction

Contents:

Speech analysis-source filter modeling - speech sounds - lip radiation - linear prediction - lattice filters - Levinson-Durbin recursion, Feature extraction for speech processing-shortterm Fourier transform-wavelets - cepstrum, sinusoidal and harmonic representations – melfrequency cepstral coefficients (MFCC) - perceptual linear prediction (PLP) –mel filter bankenergies– use of temporal patterns (TRAPS) in speech processing

Principles of speech coding–main characteristics of a speech coder - key components of aspeech coder - from predictive coding to CELP - Improved CELP coders–wide band speechcoding, audio-visual speech coding – Speech synthesis–Linguistic processing – acousticprocessing - training models automatically – text pre-processing – grapheme to phonemeconversion – rule based and decision tree approaches – syntactic prosodic analysis – prosodicanalysis - speech signal modeling

Principles of speech recognition- Hidden Markov models (HMM) for acoustic modeling - observation probability and model parameters - HMM as probabilistic automata Viterbialgorithm – Language models – n-gram language modeling and difficulties with theevaluation of higher order n-grams and solutions – spoken language identification approaches– acoustic– phonetic – LVCSR based – Introduction to speaker recognition– DET– EER–Cost function – weighted error rate and HTER

Outcomes:
CO 1: To analyze the speech signal in both time and frequency domain
CO 2: To learn various transform coders for audio coding
CO 3: To develop a speech/speaker recognition system and language models

CO - PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	2	2
CO 2	2	2	3	3	2
CO 3	2	3	3	3	2

TEXTBOOKS/REFERENCES:
1. Joseph Mariani (Ed), *Language and Speech Processing*, John Wiley and Sons, 2009.
2. Lawrence R Rabiner and Ronald W Schafer, *Digital Processing of Speech Signals,*Pearson Education, 2003.
3.Thomas F. Quatieri Cloth, *Discrete-Time Speech Signal Processing: PrinciplesandPractice*, Prentice Hall Inc, 2008.
4. B. Gold and N. Morgan, *Speech and Audio Signal Processing: Processing andPerceptionof Speech and Music*, Wiley, 2000.
5. Xuedong Huang, Alex Acero and Hsiao-Wuen Hon, *Spoken Language Processing*, *AGuideto Theory*, *Algorithm and System Development*, Prentice Hall Inc, New Jersey, USA,2000.

19CM742 IMAGE AND VIDEO PROCESSING 3 0 0 3

Objectives:
- To provide deep understanding of two dimensional transforms and its applications in image processing
- To understand and implement image and video processing algorithms
- To efficiently solve real time problems using image and video processing algorithm**s**

Keywords:
2D and 3D Transforms, Image Filtering, Image Compression, Video processing

Contents:
Two dimensional and three dimensional signals and systems-Sampling in 2D and 3D- Two dimensional Discrete Fourier Transform (DFT) – 2D Discrete Cosine Transform - Discrete Wavelet Transform (DWT) - 2D Hadamard Transform – 2D Walsh Transform- KL Transform applications to images

Modes of Image acquisition in various fields - Filtering in Spatial and Frequency domain - Color Image Processing - Image Segmentation - Morphological Image Processing - Image Compression

Video processing concepts and Standards – Motion Estimation and Motion Compensation – Interframe and Intraframe coding - Digital Video Compression – MPEG4 standards - Applications of image processing and video processing algorithms in various fields

Outcomes:

CO 1: Ability to understand the concepts and applications of image transforms

CO 2: Ability to understand and implement algorithms used for image pre-processing, image compression and
image segmentation

CO 3: Ability to understand and implement algorithms used for video compression

CO 4: Ability to identify challenges in evolving image processing and video processing technology and design
systems conforming to industry standards

CO - PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	-	3	-	-
CO 2	3	-	3	-	-
CO 3	3	-	3	-	-
CO 4	3	3	2	2	2

TEXTBOOKS/REFERENCES:

1. Rafael C. Gonzalez, *Digital Image Processing*, Third Edition, PHI Private Limited, New Delhi, 2016.

2. John W. Wood, *Multidimensional Signal, Image, Video Processing and Coding*, Second Edition, Elsevier,
2006.

3. Anil Jain K, *Fundamentals of Digital Image Processing*, First Edition, PHI Learning Pvt. Ltd., 2015.

4. Willliam K Pratt, *Digital Image Processing*, Fourth Edition, John Wiley, 2002.

19CM798 DISSERTATION 0 0 0 8

Objectives:

- To apply the knowledge of computational and electronic concepts in wireless communication systems.
- To provide a platform for innovations in wireless communication systems.
- To identify the state-of-the-art research challenges wireless communication systems.

Contents:

Problems and concepts may be defined based on extensive literature survey by standard research articles. Significance of proposed problem and the state-of the art to be explored. Industry relevant tools may be used for demonstrating the results with physical meaning and create necessary research components. Publications in reputed journals and conferences may be considered for authenticating the results.

Outcomes:

CO 1: Design and analysis of wireless communication systems.

CO 2: Understand and apply computational optimization in wireless communication systems.

CO 3: Conduct independent research in diverse areas of wireless networks and systems.

CO 4: Design and develop next generation wireless communication systems giving due consideration to societal, environmental, economic and financial factors.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5
CO 1	3	3	3	1	3
CO 2	3	3	3	3	3
CO 3	3	3	2	2	-
CO 4	-	-	2	3	3

19CM799 DISSERTATION 0 0 0 12

Objectives:

- To apply the knowledge of computational and electronic concepts in wireless communication systems.
- To provide a platform for innovations in wireless systems.
- To identify the state-of-the-art research challenges wireless systems.

Contents:

Problems and concepts may be defined based on extensive literature survey by standard research articles. Significance of proposed problem and the state-of the art to be explored. Industry relevant tools may be used for demonstrating the results with physical meaning and create necessary research components. Publications in reputed journals and conferences may be considered for authenticating the results.

Outcomes:

CO 1: Design and analysis of wireless communication systems.

CO 2: Understand and apply computational optimization in wireless communication systems.

CO 3: Conduct independent research in diverse areas of wireless networks and systems.

CO 4: Design and develop next generation wireless communication systems giving due consideration to societal, environmental, economic and financial factors.

CO – PO Mapping:

CO/PO	PO 1	PO 2	PO 3	PO 4	PO 5

CO 1	3	3	3	1	3
CO 2	3	3	3	3	3
CO 3	3	3	2	2	-
CO 4	-	-	2	3	3