M.TECH – COMMUNICATION ENGINEERING AND SIGNAL PROCESSING

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Communication Engineering and Signal Processing applications have been rapidly growing and evolving over the past few years. Ubiquitous communication is becoming a necessity for the society. The proposed M.Tech. Program is designed to offer not only in-depth theoretical knowledge in the areas of Communication Engineering, Signal Processing, and Wireless Networks, but also system modeling and integration aspects emphasizing overall system behavioural studies in a laboratory. Such courses are unique and fall in-line with the requirements from the industries. At the end of the programme the student would acquire the ability to identify pressing research issues and research directions in Communications, Signal Processing, and Wireless Networks.

Programme Outcomes

- Creation of expertise and work force in the communication engineering domain to deal with design, development, analysis, testing and evaluation of the critical aspects of system design and its core concepts to cater to the requirements of the industry and academia.
- Facilitate research opportunities in the communication engineering domain aimed at developing state-of the art technologies with value based social responsibility.
- Developing professional competence in communication engineering domain and leadership qualities with a harmonious blend of ethics leading to an integrated personality development.

CURRICULUM

First Semester

Course Code	Type	Course	L T P	Cr
18MA602	FC	Mathematical Methods for Engineering *(Common for Communication Engineering & Signal Processing and Biomedical Engineering, VLSI Design)*	3 0 2	4
18CE601	FC	Signal Processing *(Common for Communication Engineering & Signal Processing and Biomedical Engineering)*	3 1 0	4
18CE602	FC	Digital Communications	3 0 0	3
18CE611	SC	Coding Theory	3 0 0	3
18CE612	SC	RF Circuits and Systems	3 0 0	3
18RM600	SC	Research Methodology	2 0 0	2
18CE631	SC	Communication Engineering Lab	0 0 4	2
18HU601	HU	Amrita Values Program*		P/F
18HU602	HU	Career Competency I*		P/F
		Credits		**21**

* **Non-credit course**

Second Semester

Course Code	Type	Course	L T P	Cr
18CE613	SC	Modeling and Simulation of Communication Systems	2 0 2	3
18CE614	SC	Wireless Communication	3 0 2	4
18CE615	SC	Estimation and Detection Theory	3 1 0	4
	E	Fractal Elective 1	1 0 0	1
	E	Fractal Elective 2	1 0 0	1
	E	Fractal Elective 3	1 0 0	1
	E	Live-in Lab / Elective 1	3 0 0	3
	E	Elective 2 / Open Elective**	3 0 0	3
18CE632	SC	Computational Programming Lab	0 0 4	2
18HU603	HU	Career Competency II	0 0 2	1
		Credits		**23**

****Courses can also be taken from other departments**

Third Semester

Course Code	Type	Course	L T P	Cr
18CE798	P	Dissertation		10

Fourth Semester

Course Code	Type	Course	L T P	Cr
18CE799	P	Dissertation		10
		TOTAL CREDITS (21+23+10+10)		**64**

L- Lecture; T-Tutorial; P-Practical

FC- Foundation Core; SC- Subject Core; E-Electives; P- Dissertation; P/F- Pass/Fail

List of Courses

Foundation Core

Course Code	Course	L T P	Cr
18MA602	Mathematical Methods for Engineering	3 0 2	4
18CE601	Signal Processing	3 1 0	4
18CE602	Digital Communication	3 0 0	3

Subject Core

Course Code	Course	L T P	Cr
18CE611	Coding Theory	3 0 0	3
18CE612	RF Circuits and Systems	3 0 0	3
18CE613	Modeling and Simulation of Communication Systems	2 0 2	3
18CE614	Wireless Communication	3 0 2	4
18CE615	Estimation and Detection Theory	3 1 0	4
18CE631	Communication Engineering Lab	0 0 4	2
18CE632	Computational Programming Lab	0 0 4	2
18RM600	Research Methodology	2 0 0	2

Elective Courses

Wireless Communication		**L T P**	**Cr**
18CE701	Millimeter Wave Communication Systems	3 0 0	3
18CE702	Multicarrier Communications	3 0 0	3
18CE703	Software Defined Radio	3 0 0	3
18CE704	Vehicular Communications and Networks	3 0 0	3
18CE705	Security for Wireless Communications	3 0 0	3
RF Front End			
18CE711	Radar Systems	3 0 0	3
18CE712	Satellite Communication System Design	3 0 0	3
18CE713	Antenna Design	3 0 0	3
Communication Networks			
18CE721	Wireless Networks and Protocols	3 0 0	3
18CE722	Stochastic Modeling and Queuing Theory	3 0 0	3
Computational Techniques			
18CE731	Machine Learning	3 0 0	3
18CE732	Convex Optimization	3 0 0	3
Signal and Image Processing			
18CE741	Speech and Audio Processing	3 0 0	3
18CE742	Array Signal Processing	3 0 0	3
18CE743	Multirate Signal Processing for Communication Systems	3 0 0	3
18CE744	Image and Video Processing	3 0 0	3

Fractal Elective Courses

Course Code	**Course**	**L T P**	**Cr**
Wireless Communication			
18CE751	Internet of Things with Wireless Technology	1 0 0	1
18CE752	Cooperative and Relay Communication	1 0 0	1
18CE753	Massive MIMO	1 0 0	1
18CE754	Adaptive Coding and Modulation	1 0 0	1
Communication Networks			
18CE755	Delay Tolerant Network	1 0 0	1

18CE756	Network Coding	1 0 0	1
18CE757	Wireless Sensor Networks	1 0 0	1
Computational Techniques			
18CE758	Compressed Sensing	1 0 0	1
18CE759	Big Data Analytics	1 0 0	1
18CE760	Game Theory	1 0 0	1
Signal and Image Processing			
18CE761	Complex Systems Analysis	1 0 0	1
Project Management			
18CE762	Principle of Project Management	1 0 0	1

Project Work

Course Code	**Course**	**L T P**	**Cr**
18CE798	Dissertation		10
18CE799	Dissertation		10

18MA602 MATHEMATICAL METHODS FOR ENGINEERING 3 0 2 4

(Common for Communication Engineering & Signal Processing, Biomedical Engineering & VLSI)

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:

- Understanding the mathematical methods and applying it to practical problems by investigating from different perspectives.
- Enabling an analytical approach towards developing mathematical models in various domains.
- To develop competency in implementation of algorithms and numerical analysis.

TEXT BOOKS/REFERENCES:

1. Gilbert Strang, *Linear Algebra and its Applications*, Fourth Edition, Cambridge University Press. 2009.

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.

18CE601 SIGNAL PROCESSING 3 1 0 4

(Common for Communication Engineering & Signal Processing, Biomedical Engineering)

Objectives:

- To bring the students coming with different backgrounds to a common minimum level of understanding of signal processing, systems, time, frequency and time-frequency transformation techniques

Keywords: Transform processing, Filters, Multi-rate signal processing, Wavelet transform

Contents:

Review of signal processing and digital filters - Introduction to Transforms: DFT- DCT- Properties of DFT – FFT - FIR and IIR filter design techniques and filter structures.

Introduction to multi-rate digital signal processing – the effect of up-sampling and down sampling of the signal – applications of multi-rate signal processing – sub- band coding - Significance of joint time -frequency domains.

Short Time Fourier Transform (STFT),Continuous wavelet transforms (CWT) – DWT – Time-frequency tiling - Scaling and Wavelet Functions – Filter Banks.

Outcome:

- To make the students confident in programming and experiment with various signal processing algorithms
- To prepare them do a term work on a selected application of signal processing. Students are encouraged to take the term work based on research papers on topics not discussed in class but related to topics discussed in class

TEXT BOOKS/REFERENCES:

1. John G Proakis and Dimitris.G.Manolakis, *Digital Signal Processing, Principles, Algorithms, Applications*, Fifth Edition, Prentice Hall India Incorporation, 2003.
2. N. Ahmed and K. R. Rao, *Orthogonal Transforms for Digital Signal Processing*, Springer, 1975.
3. Soman K. P. and Ramachandran K. I, *Insight into Wavelets from Theory to Practice*, Prentice Hall, 2004.
4. Raghuveer M Rao and Ajit S Bopardikar, *Wavelet Transforms*, Addison Wesley, 1998.

18CE602 DIGITAL COMMUNICATIONS 3 0 0 3

Objectives:

- To understand the design of spectrally and power efficient modulation techniques in existing and evolving communication systems.

- To analyze error performance of a digital communication system in presence of noise.
- To understand the implementation issues with respect to carrier and symbol synchronization.

Keywords: Coherent Modulation and demodulation techniques, Error probability, Carrier and Symbol Synchronization

Contents:

Digital modulation techniques - Review of digital communication systems, modulation techniques, Advanceddigital modulation and Detection-Baseband and Pass band modulation techniques-- Phase Shift Keying, M-ary PSK, Quadrature Amplitude Modulation, FSK, MSK, GMSK.

Detection techniques - Correlator - Matched Filter - Decision Regions and the Maximum Likelihood Decision CriterionPerformance of Digital Modulation over Wireless Channels-AWGN Channels Signal-to-Noise Power Ratio and Bit/Symbol Energy, Error Probability for BPSK and QPSK, Error Probability for MPSK, Error Probability for MPAM and MQAM, Error Probability for FSK and MSK

Synchronization - Signal Parameter Estimation - Carrier Phase Estimation -Symbol timing Estimation.

Outcomes:

- To design power efficient and spectral efficient modulation and demodulation techniques
- Helps in rapid prototyping of communication system addressing real-time issues like phase offset and symbol synchronization.

TEXT BOOKS/REFERENCES:

1. John Proakis and MasoudSalehi, *Digital Communications*, Fifth Edition, McGraw-Hill Publications, 2007.

2. Simon S Haykins, *Digital Communication Systems*, Wiley Publication, 2013.

3 Robert G. Gallager, *Principles of Digital Communication*, 2nd edition, Cambridge University Press, 2012.

4. Andrea Goldsmith, *Wireless Communications*, Cambridge University press, 2006

5. UpamanyaMadhow, *Fundamentals of Digital Communication*, Cambridge University press, 2008.

18CE611 CODING THEORY 3 0 0 3

Objectives:

• To enable the students to understand the properties, encoding and decoding techniques of various error control codes

• To introduce the state-of-the-art error control codes

Keywords: Minimum distance, Block codes, Interleaver, Performance analysis, Tanner graphs

Contents:

Computations using Galois field arithmetic – Review of Linear Block codes– BCH codes: Code construction– Decoding of BCH codes - Interleaved codes - Cyclic Product codes – Reed Solomon codes.

Encoding and Decoding - Trellises for Linear Block Codes – Optimum decoding of Convolutional codes: Soft Output Viterbi algorithm (SOVA), BCJR algorithm - single level and multilevel concatenated codes.

Turbo codes- Design and properties of Turbo codes, Iterative decoding of Turbo codes - LDPC codes: Construction of LDPC codes, Bit flipping, Sum product and Min sum decoding algorithms. Polar codes – Properties, Encoding and Decoding of polar codes.

Outcome:

Ability to select codes, implementation of encoding and decoding algorithms and analysis of the performance of codes for various applications

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.

4. Richard B. Wells, *Applied Coding and Information Theory for Engineer*, Pearson Education, LPE, First Indian Reprint, 2004.

5. W.C. Huffman and V. Pless, *Fundamentals of Error-Correcting Code*, Cambridge, 2003.

18CE612 RF CIRCUITS AND SYSTEMS 3-0-0-3

Objectives:

- To understand various linear, non-linear building blocks in RF systems from a system perspective of wireless and communication systems.
- To understand RF front end architectures, system parameters and essentials of Antennas, Transmission lines, Filters, RF amplifiers, RF oscillators and Mixers.
- To motivate and create expertise in the design aspect of radio frequency circuits and systems for wireless and strategic applications.

Keywords: Radio front end architectures, interconnects and transmission-lines, antennas, filters, RF amplifiers, Low Noise Amplifier, Power Amplifier, Mixers, RF Oscillators, RF impairments in systems, Applications.

Contents:

Radio receiver and transmitter front end architectures – Tuned – Heterodyne – Direct conversion architectures–comparison–sensitivity–noise figure–dynamic range. Transmission

lines for RF integrated circuits–microstripline–coplanar waveguide (CPW)– RF filters– S-parameters–derivation of two port gain parameters.

Antennas – Gain – radiation pattern – beam-width – return-loss – bandwidth - examples of high gain and low gain antennas – microstrip antennas – Array antennas – Phased array antennas.

Amplifier design concepts – stability analysis and stability circles - Low noise amplifier (LNA)– sources of noise – behavioral model of LNA – design of LNA using two port S-parameter of biased transistor –system aspects of power amplifiers– power added efficiency– nonlinear effects–gain compression–inter-modulation–cross-modulation–harmonic distortion. Local oscillators – phase noise.Mixers–specifications.Applications – functional descriptions of Global Positioning Systems (GPS) - Direct broadcasting satellite systems (DBS) - Radio Frequency Identification (RFID)-Mobile communications.

Outcomes:

- Understanding the basic design principles of radio frequency components and systems leading to the design of wireless communication systems
- Enable expertise in the area of RF front-end design for strategic applications
- Motivating to pursue research and development activities in the RF systems area.

TEXT BOOKS / REFERENCES:

1. BehzadRazavi, *RF microelectronics*, Pearson, 2014.
2. Ludwig R, Bogdanov G, *RF Circuit Design, Theory and Applications*, Pearson Education Inc, Second Edition, 2013.
3. Pozar D M, *Microwave Engineering*, John Wiley & sons Pvt Ltd, Third Edition, 2007.
4. Cheng, D K, *Field and Wave Electromagnetics*, Pearson education Inc, Second edition, 2008.

18CE631 COMMUNICATION ENGINEERING LAB 0 0 4 2

Objectives:

- To comprehend the communication engineering concepts through numerical simulations and programming

Contents:

(Preferred: GNU Radio)

1. Introduction to Software Defined Radio and GNU Radio
2. Pseudorandom sequence generator and analysis
3. Digital ModulationTechniques
4. Detection Techniques
5. Bit error rate analysis of modulation schemes in AWGN channels.
6. Frequency division multiplexing
7. Channel coding and decoding
8. Filter Design

Outcomes:

- Ability to designand analyze digital communication techniques and systems.

18CE613 MODELING AND SIMULATION OF COMMUNICATION SYSTEMS

2 0 2 3

Objectives:

• To comprehend system aspects of modern communication systems through modeling and simulation

• To analyze and predict the behavior of broadband and high data rate intractable communication systems

Keywords: Power efficiency, Spectral efficiency, System behavior predictions, Baseband simulation, Channel models

Contents:

Introduction, evolution of communication systems in terms spectral efficiency– challenges in design and optimization– overview of deterministic and stochastic simulations– tractable and intractable systems– role of simulations for link budgeting– implementation and behavior predictions

Simulation methodology—basic steps and aspects of simulation—simulation errors due to sampling and quantization– choice of simulation sampling frequency—baseband representation of linear and non-linear band pass signals and systems– time varying systems— modeling of system building blocks such as filters, linear and nonlinear amplifiers with internal noise, modeling oscillator phase noise

Simulation of random process and noise sources—post processing of data and waveforms– generation of eye-diagrams– spectrum and scatter-plots—BER simulations using Monte Carlo techniques—introduction to simulation of nonlinear and time varying systems—models of waveform channels– guided and unguided channels, radio channels, multi-path– and fading channel—introduction to discrete channel models—case studies of simulation of M-PSK systems with amplitude and phase noise– simulation of power amplifier nonlinearity for CDMA- simulation of OFDM systems.

Outcome:

• Enable students to be industry ready Engineers and Researchers

• Enable students to do calculations and tradeoffs of various subsystem parameters

• Enable students to do modeling and simulations of complex intractable systems with non-linearities

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

18CE614 WIRELESS COMMUNICATION 3 0 2 4

Objectives:

- To introduce the wireless and cellular concepts with emphasis on the channel models and their parameters.
- 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 high speed and reliable wireless communication systems

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

Contents:

Introduction to Wireless and Cellular Communication- Overview of cellular system, Introduction and evolution of 2G, 3G and 4G wireless systems and standards, cellular service progression. Wireless and Mobile Channel: Basics of wireless channel modelling, Path loss and Shadowing models, Statistical fading models, Narrow band and wideband fading models, Rayleigh fading channels, Ricean model; Jakes model for wireless communication, Mobile radio channel –large scale fading, small scale fading, Doppler spread and coherent time, delay spread and coherent bandwidth.

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), Highlight of Performance in respect of BER, Capacity of OFDM and MIMO.

Lab component: Fading Channel modeling and parameter analysis, Channel estimation, MIMO.

Outcomes:

- Design of communication systems comprehending real-time issues
- To identify challenges in evolving communication technology and design systems conforming to industry standards

TEXT BOOKS/REFERENCES:

1. Aditya K. Jagannatham, *Principles of Modern Wireless Communication Systems* McGraw-Hill Education, 2016.

2. Andrea Goldsmith, *Wireless Communications*, Cambridge University Press, 2006

3.David Tse and PramodVishwanath, *Fundamentals of Wireless Communication*, Cambridge University Press, July 2005.

4. Simon Haykin and Michael Moher, *Modern Wireless Communications*, Pearson Education, 2007.

5.G.L Stuber, *Principles of Mobile Communications*, Second Edition, Kluwer Academic Publishers, 2001.

18CE615 ESTIMATION AND DETECTION THEORY 3 1 0 4

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: Random processes, Estimation, Detection, Hypothesis testing, Likelihood, Bayesian

Contents:

Review of probability and random processes: Introduction and applications of statistical estimation and detection 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, minimax and Neyman-Pearson detection; Composite hypothesis testing, GLRT; Sequential detection; Performance analysis; Signal detection in continuous time, KL theorem; Detection of random signals in Gaussian noise.

Outcome:

- The students understand real applications of statistical decision theory for communication and signal processing
- The students gain confidence by applying various estimation and detection techniques to complete project assignments wherein they solve mini problems in communication and/or signal processing

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, 2ndEd., John Wiley, 2013.
4. E. L. Lehman, *Testing Statistical Hypothesis*, John Wiley, 1986.

5. M. D. Srinath, P. K. Rajasekaran and R. Vishwanathan, *An Introduction to Statistical Signal Processing with Applications*, Prentice-Hall, 1996.
6. A. Papoulis, *Probability, Random Variables, and Stochastic Processes*, McGraw-Hill International Edition.

18CE632 COMPUTATIONAL PROGRAMMING LAB 0 0 4 2

Objectives:

- To provide a comprehensive introduction to the study of computer algorithms.
- To address implementation concerns of the algorithms for communication systems.
- To facilitate design of advanced and customized algorithms for engineering applications.

Keywords: Data structures, sorting, search, dynamic programming

Contents: (Preferred Python)

1. Complexity of algorithms
2. Probabilistic Analysis and Randomized Algorithms
3. Sorting
    - Heap Sort
    - Quick Sort
    - Sorting in linear time
4. Data structures
    - Elementary data structures
    - Hash tables
    - Binary search trees
5. Algorithms
    - Dynamic programming
    - Greedy algorithms

Outcomes:

- Understand and analyze the modern computer algorithms.
- Develop algorithms for specific and domain based applications.

TEXT BOOK / REFERENCE:

Thomas Cormen, "*Introduction to Algorithms*", 3rd Edition, MIT Press, 2009.

18RM600 RESEARCH METHODOLOGY 2-0-0-2

Unit I:

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. Confirmatory Research, Experimental vs Theoretical Research, Importance of reasoning in research.

Unit II:

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

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

Unit IV:
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

Unit V:
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

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; 6 edition July 2012

18CE701 MILLIMETER WAVE COMMUNICATION SYSTEMS 3 0 0 3

Objectives:

- To understand the channel behavior in mm 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.

Outcome:

- Improve the confidence in mathematical modeling and understanding of different mm wave channel models
- The ability to apply knowledge of design processes in higher frequency band of mm wave
- The ability to understand and design of mm Wave transceiver
- The ability to generate innovative design to fulfill new requirements particularly in the field of wireless communications at higher frequency in mm wave

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.

18CE702 MULTI CARRIER COMMUNICATIONS 3 0 0 3

Objectives:

- To develop mathematical theory and engineering practice of digital communications over fading channels
- To learn multi channel/carrier techniques for fading wireless channels and mobile radios
- To analyzes and design of multi-channel techniques for communication
- To understand the synchronization issues in multicarrier environment
- To understand the challenges in the design of such multicarrier 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

Outcome:

- The ability 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
- The ability to analyze the performance of multicarrier system in wireless cellular systems

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.

18CE703 SOFTWARE DEFINED RADIO 3 0 0 3

Objectives:

- To understand software radio design and implement Multirate DSP, RF front-ends, direct digital synthesis of modulated waveforms, A/D and D/A conversion
- To appreciate performance improvement with the help of smart antennas and other adaptive array algorithms

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:

1. Ability to use programmable DSP to implement software radio for wireless systems and sub-systems
2. Ability to appreciate the design flexibility in software defined radios by using software tools
3. To take up some case studies for implementation using software radio concepts

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.

18CE704 VEHICULAR COMMUNICATIONS AND NETWORKS 3 0 0 3

Objective:

- This subject will introduce students with the emerging technologies, standards and applications in vehicular communication systems
- The students will study the design considerations and challenges of vehicle - to-infrastructure and vehicle - To – vehicle communications. Theories such as vehicular mobility modelling and vehicular technologies and standards from the physical to network layers will be introduced in the course, Examples of emerging applications of

vehicular communications in Intelligent Transportation Systems will also be studied and discussed.

Keywords: Vehicular Communications, V2V, V2X, ITS, VANET, Adhoc. 802.11p.

Contents

Introduction Basic principles and challenges, past and ongoing VANET activities, Cooperative Vehicular Safety Applications Enabling technologies, cooperative system architecture, safety applications;

Vehicular Mobility Modeling Random models, flow and traffic models, behavioral models, trace and survey based models, joint transport and communication simulations; Physical Layer Consideration for Vehicular Communications Signal propagation, Doppler spread and its impact on OFDM systems

MAC Layer of Vehicular Communication Networks Proposed MAC approaches and standards , IEEE 802.11p, VANET Routing protocols Opportunistic packet forwarding, Topology based routing, geographic routing, Emerging VANET Applications Limitations, example applications, communication paradigms, message coding and composition, data aggregation, Standards and Regulations Protocol Stack, DSRC regulations and standards

Outcomes

Upon completion of the subject, students will be able to:

- Grasp the professional/academic knowledge and skills
- Understand and describe the basic theories and principles, technologies, standards, and system architecture of vehicular adhoc networks (VANET) or inter-vehicle communication networks
- Analyze, design, and evaluate vehicular communication platforms for various kinds of safety and infotainment applications

TEXT BOOKS/ REFERENCES:

There is no specific text book. However, this reference book can be referred. We will be studying the research papers.

1. **"Vehicular Networks: From Theory to Practice",** Stephan Olariu, Michele C. Weigle, CRC Press, 2014

18CE705 SECURITY FOR WIRELESS COMMUNICATIONS 3 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.

Outcome:

- Develop skills to use the tools from game theory and graph theory to analyze and design wireless networks with physical layer security considerations
- Able to explore issues and solutions in providing physical layer security in practical wireless systems

TEXTBOOKS/REFERENCES:

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

18CE711 RADAR SYSTEMS 3 0 0 3

Objectives:

- Understanding the components of a radar system and their relationship to overall system performance
- Understanding basic detection theory as applied to radar
- Understanding the concepts of the matched filter, ambiguity functions and other aspects of waveform and signal processor design

Keywords: Radar range equations, SNR, Matched filter, Doppler radars, SAR

Contents:

Radar range equation, Radar cross section-Examples of simple radar systems-analysis of SNR model for system noise-radar detection in the presence of noise- matched filter detection-target effects on detection-parametric description of antennas.

Pulsed Radars-fundamentals of range measurements -range ambiguity.Doppler radar-velocity measurements.FM-CW radars-Doppler ambiguity.

SAR-signal processing-pulse compression-azimuth signal processing- imaging- design example and system implementation issues-ambiguity functions-theorems-polarimetric radars-interferometric radars.

Outcome:

- Ability to understand the system perspective of Radar Technology

TEXT BOOKS/REFERENCES:

1. Skolnik M, *Introduction to Radar Systems*, Tata-Mcgraw Hill, 2003.

2. David K. Barton, *Modern Radar System Analysis*, Artech House, Inc., NY 1988.

3. Brookner E, *Aspects of Modern Radar*, Artech House, Inc., NY 1988.

18CE712 SATELLITE COMMUNICATION SYSTEM DESIGN 3 0 0 3

Objective:

- To understand the concepts of space missions, orbits and spacecraft systems
- To study the mechanism of guidance, controls, navigation systems and sensor technology
- To study the power communication and data handling systems, concept of small satellite requirements and design

Keywords: Spacecraft, Orbit, Launch vehicle, Navigation, EMI, EMC, Telemetry

Contents:

Space Mission Design- Introduction, Elements of a Space Mission: The mission, the spacecraft, trajectories and orbits, launch vehicles, mission operations systems, Overview of Orbit and Constellation Design: The orbit design process - Earth coverage - Simple delta-V budgets - Selecting orbits and constellations - Common Examples - The physical environment of space and spacecraft system design.

Sensors and Mechanisms- Guidance and Control- Mechanisms and Optics – kinematics - bearings and lubrication - motors and drives; mechanisms – wheels - materials.Optical mountings, alignment, and stray-light controlSensors- Guidance - Navigation and Control Systems - Optical sensor technology; ADCS sensor technology; GNC systems.

Power communication and Data handling systems - Power Systems - EMC and Interfacing Power Systems - Power generation – storage - regulation and monitoring. Harnesses and connectors - EMC, shielding and grounding - monitoring and protection - TT&C - RF Systems and On-Board Data Handling, Tracking – telemetry - & command systems; RF link - OBCs. Small Satellite Designs: Micro/Nano-Satellite Design Principles: Organization - the KISS principle – capabilities - technology road-map - Space Mission Design Exercise.

Outcome:

- Able to understand the Space Environment & its Effects
- Able to understand Spacecraft Platform Systems, design, satellite manufacture & Testing
- Able to understand Applications of Small, Low-Cost Satellites, space mission analysis & design

TEXTBOOKS/REFERENCES:

1. Maral and Bousquet, *Satellite Communications Systems*, Third Edition, Wiley ISBN 0-471-97166-9: 1998.

2. Jerry Jon Sellers, *Understanding Space - An Introduction to Astronautics*, McGraw Hill ISBN 0-07-057027-2: 1994.

3. Fortesque and Stark (eds), *Spacecraft Systems Engineering*, John Wiley and Sons ISBN 0-471-93451-8: 1992.

4. W.J. Larson (eds), *Space Mission Analysis & Design*, Second Edition, Kluwer Academic Publishers ISBN 0-7923-19982.

18CE713 ANTENNA DESIGN 3 0 0 3

Objectives:

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

Keywords: Radiation pattern, Microstrip, Substrate

Contents:

Review of radiation principles, Radiation from transmission lines, planar transmission lines Microstrip Radiators - Radiation Field - Surface Waves - Rectangular Microstrip Antenna-Models for Rectangular Patch Antenna

Design Considerations for Rectangular, Quarterwave shorted, Circular Disk and Ring Antennas. Microstrip Slot Antennas: Microstrip-Fed Rectangular Slot Antennas. CPW-Fed Slot Antennas. Circularly Polarized Microstrip Antennas and Techniques

Bandwidth Enhancement Techniques - Broad-Banding of Microstrip Antennas - Effect of Substrate Parameters on Bandwidth - Selection of Suitable Patch Shape - Selection of Suitable Feeding Technique.

Outcomes:

The student will be able to

- Design and analyze antenna for wireless applications
- Evaluate the antenna parameters for various applications

TEXT BOOKS / REFERENCES:

1. Ramesh Garg, P. Bhartia, InderBahl and A. Ittipiboon, *Microstrip Antenna Design Handbook*, Artech House Publishers, 2001.

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

1986.

3. Hubregt J Visser, *Antenna Theory and Applications*, Wiley, 2012.

18CE721 WIRELESS NETWORKS AND PROTOCOLS 3 0 0 3

Objectives:

- To provide insights into the architectures and protocols currently used in practice at various layers of wireless communication systems
- To develop mathematical theory of and engineering practice in wireless networks

- To learn the existing standards of WLAN and associated technologies
- To understand and compare the performance of wireless networks

Keywords:WLAN, WPAN, WSN, 802.11, Protocols, MAC Layer, Ad hoc Network, ZigBee

Contents:

Introduction to Wireless Networks and Protocols- history, standards and market issues, evolution and trends; Wireless Networks Concepts and Systems: mobility management, bandwidth and energy management, quality of service; Physical and MAC Layer Protocols: Physical layer characteristics and technologies

Centralized access methods – TDMA, FDMA, CDMA, Reservation and Polling, Random access methods – ALOHA, CSMA; Routing in Wireless Ad Hoc and Sensor Networks; Transport layer protocols; Security and Privacy; Wireless Technology and Standards:

Wireless Local Area Networks (IEEE 802.11) – MAC and PHY layer variants, 802.11p for vehicular networks, Low Power Sensor Networks – Bluetooth (IEEE 802.15.1), ZigBee (IEEE 802.15.4), Wireless Body Area Networks (IEEE 802.15.6), Wide Area Wireless Networks – cellular systems based on TDMA, CDMA and OFDM, LTE, WiMAX.

Outcome:

- Able to analyze different protocols
- Ability to design protocols at different layers in WLAN
- Ability to develop authentication and security algorithm necessary in WLAN

TEXTBOOKS/REFERENCES:

1. C. Siva Murthy and B.S. Manoj, *Ad-hoc Wireless Networks, Architectures and Protocols*, Prentice Hall, 2004.
2. Carlos de M. Cardeiro and Dharma P. Agrawal, *Ad Hoc & Sensor Networks: Theory and Applications*, World Scientific, 2006.
3. H. Karl and A. Willig, *Protocols and Architectures for Wireless Sensor Networks*, John Wiley and Sons, 2005.
4. XiangYang Li, *Wireless Ad Hoc and Sensor Networks*, Cambridge University Press, 2008.
5. Yi-Bing Lin and ImrichChlamtac, *Wireless and Mobile Network Architectures*, Wiley, 2001.
6. Chai K Toh, *Ad Hoc Mobile Wireless Networks: Protocols and Systems*, Prentice Hall, 2002.

18CE722 STOCHASTIC MODELLING AND QUEUEING THEORY 3 0 0 3

Objectives:

- To Provide a thorough understanding of the mathematical foundations of telecommunication and computer communication networks

- To teach the applications of Markov processes and queuing theory, to analyze the performance and address the design questions in circuit- and packet-switching networks

Keywords: Markov Chains, Renewal Processes, Queuing Theory, Performance Analysis, Capacity Design

Contents:

Review of Probability and Random Variables - memory less property of exponential and geometric random variables, moment generating function, Laplace-Stieljes transform (LST) of random variables; 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; Queuing Theory - common queuing 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/x), vacation models, loss networks and delay networks, multiclass queuing models with priority, open and closed networks of queues; Fluid and Gaussian approximations;

Applications to Telecommunications and Computer Communication Networks – capacity design, dynamic channel allocation and scheduling in 4G/LTE, 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).

Outcome:

After successfully finishing this course, students will

- Acquire the skill of mapping frequently occurring scenarios in telecommunication and computer networking into standard stochastic models, i.e., they will develop the ability of constructing mathematical models from the physical description of the problems
- Be able to identify appropriate solution methods in each case and physically interpret the mathematical results

TEXTBOOKS/REFERENCES:

1. Kulkarni, Vidyadhar G., *Modeling and Analysis of Stochastic Systems*, CRC Press, 2016.

2.Kumar, Anurag, *Discrete Event Stochastic Processes*, available online http://ece.iisc.ernet.in/~anurag/books/anurag/spqt.pdf

3. Bertsekas, Dimitri P., and Robert G. Gallager, *Data Networks*, Prentice-Hall International, 1987.

4. Leon-Garcia, Alberto, *Probability, Statistics, and Random Processes for Electrical Engineering*, 3rd ed. Pearson/Prentice Hall, 2008.

18CE731 MACHINE LEARNING 3 0 0 3

Objectives:

- To strengthen the expertise of the students in machine learning algorithms

Keywords:GMM, HMM, SVM, Neural networks, Auto encoders, Restricted Boltzman machine

Contents:

Introduction to mixture models and EM, K-means clustering, mixture of Gaussians– maximum likelihood and EM for Gaussian mixtures, Bayesian neural networks. Introduction to linear algebra- theory of optimization-unconstrained optimization– sufficient condition for optimality-optimization with constraints-introduction to Lagrangian multipliers-Kuhn Tucker conditions-Lagrangian function for optimization with equality and inequality constraints-Lagrangian duality

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 – Neural networks-network training–local quadratic approximation-use of gradient information – gradient descent optimization; error back propagation – The Jacobian matrix – Hessian matrix and diagonal approximation

Regularization in neural networks – mixture density neural networks - convolutional networks – Introduction to deep learning neural networks – Theoretical advantages of deep architectures - Neural networks for deep architectures – Deep generative architectures – Convolution neural networks – Auto encoders – Restricted Boltzmann machines – Variants of RBMs and auto encoders.

Outcome:

- Training the students on the state-of-the-art machine learning algorithms
- Prepare them to apply these algorithms for their further study/research

TEXTBOOK/REFERENCES:

1. Christopher Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006.
2. Bernard Scholkopf and Alexander J Smola, *Learning with Kernel*, MIT Press, London, England, 2002.
3. K. P. Soman, R. Loganathan, and V. Ajay, *Machine Learning with SVM and KernelMethods*, PHI Learning Private Ltd., New Delhi.2011.
4. YoshuaBengio, *Learning Deep Architectures for AI, Foundations and Trends in MachineLearning,* Vol. 2, Now Publishers Inc.

18CE732 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

Outcome:

- Develop a working knowledge of convex optimization, i.e., to develop the skills and background needed to recognize, formulate, and solve convex optimization problems
- Design sophisticated algorithms based on Convex Optimization for applications in communication and signal processing

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.

18CE741 SPEECH AND AUDIO PROCESSING 3 0 0 3

Objectives:

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

Keywords: Speech signal analysis, Speech recognition, Speaker recognition, Language modeling, Feature extraction

Contents:

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

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

analysis - speech signal modeling

Principles of speech recognition- Hidden Markov models (HMM) for acoustic modeling - observation probability and model parameters - HMM as probabilistic automata Viterbi algorithm – Language models – n-gram language modeling and difficulties with the evaluation 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

Outcome:

- Enables to develop a speech/speaker recognition system
- Enables to analyze the speech signal in both time and frequency domain

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: Principles andPractice*, Prentice Hall Inc, 2008.
4. B. Gold and N. Morgan, *Speech and Audio Signal Processing: Processing and Perceptionof Speech and Music*, Wiley, 2000.
5. Xuedong Huang, Alex Acero and Hsiao-Wuen Hon, *Spoken Language Processing, A Guideto Theory, Algorithm and System Development*, Prentice Hall Inc, New Jersey, USA, 2000.

18CE742 ARRAY SIGNAL PROCESSING 3-0-0-3

Objectives:

- To familiarize with spatial signals
- To introduce the concept behind sensor arrays
- To familiarize with spatial frequency
- To introduce different methods for direction of arrival estimation

Keywords:

Spatial frequency, Sensor arrays, Planar array, Random array, Aliasing

Contents:

Spatial Signals - Signals in space and time-spatial frequency-direction Vs. frequency-wave fields-far fields and near fields signals

Sensor Arrays - spatial sampling-Nyquist criterion-sensor arrays-uniform linear arrays-planar and random arrays-array transfer (steering) vector-array steering vector for ULA-broadband arrays

Spatial frequency- aliasing in spatial frequency domain

Outcome:

- Gain knowledge about the efficient use of different signal processing and optimization techniques in adaptive arrays
- Equip students to design and develop more efficient practical systems to meet the future requirements using adaptive arrays. spatula frequency transform-spatial spectrum-spatial domain filtering-beam forming-spatially white signal-Direction of arrival estimation: non parametric methods-beam forming and capon methods-resolution of beam forming methods-subspace methods-MUSIC-minimum Norm and ESPRIP techniques-spatial smoothing

TEXT BOOKS / REFERENCES:

1. Don H Johnson and Dan E. Dudgeon, *Array Signal Processing: Concepts&Techniques*, Prentice Hall, 1993.
2. PetreStoica and Randolph L. Moses, *Spectral Analysis of Signals,* Prentice Hall, 2005
3. Bass J, McPheeters C, Finnigan J and Rodriguez E. *Array Signal Processing* [Connexions Web site]. February 8, 2005.

18CE743 MULTIRATE SIGNAL PROCESSING FOR COMMUNICATION SYSTEMS 3 0 0 3

Objectives:

- To understand the signal processing algorithms, filter design methods, and signal processing techniques
- 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: Multirate systems, Resampling, Polyphase architectures, Digital up-conversion, Digital Down-conversion, CIC filters

Contents:

Fundamentals of Multirate Signal Processing – Nyquist and Square root Nyquist Filter– Systems using resampling filter. Quadrature Mirror Filters (QMF): Theory and Application - Wavelet for multirate signal processing.

Polyphase FIR filter – Resampling Filter - Half-band Filters – Dyadic filter – Arbitrary Sampling Rate Conversion. Recursive polyphase filter – Cascade Integrator Comb Filter (CIC) - Cascade and multiple stage filters

Application in communication systems – Conventional Digital down converters (DDC), Aliasing DDC, Timing recovery in digital demodulation, Carrier recovery and phase recovery.

Outcome:

- Ability to design a resampling architecture for digital RF front end systems
- Ability to design efficient filter implementations for baseband transceivers
- Ability to design multirate systems for carrier, phase and timing recovery for

communication receivers

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. Vaidyanathan P P, *Multirate Systems and Filter Banks*, Prentice Hall Inc., 1993.
4. N. J. Fliege, *Multirate Digital Signal Processing - Multirate Systems, Filter Banks andWavelets*, John Wiley, 1994.
5. Omid S. Jahromi, *Multirate Statistical Signal Processing*, Springer, 2007.

18CE744 IMAGE AND VIDEO PROCESSING 3 0 0 3

Objectives:

- To efficiently solve real time problems using the image processing algorithms
- To provide deep understanding of two dimensional, three dimensional transforms and video processing concepts
- To strengthen the research skills of students in image and video processing

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 transforms– DCT –DWT- Application to images -2D Hadamard Transform, Walsh Transform, KLT

Application to images – Modes of Image acquisition in various fields -Filtering in Spatial and Frequency domain- Color Image Processing - Image Segmentation - Image Compression

Video processing concepts and Standards – Interframe and Intraframe coding-Digital Video Compression – Applications of image processing algorithms in various fields.

Outcome:

• Students will have expertise in developing programming skills to implement image and video processing algorithms

• Do a term work on a selected application of image/video processing, with minimum support from the faculty. Objective is to support the students to be placed in core companies.

TEXTBOOKS/REFERENCES:

1. Rafael C. Gonzalez, *Digital Image Processing*, Third Edition, PHI Private Limited, New Delhi, 2008.
2. John W. Wood, *Multidimensional Signal, Image, Video Processing and Coding*, Elsevier,

2006.

3. A K Jain, *Fundamentals of Image Processing*, Prentice Hall, 2001.

4. Wiliam K Pratt, *Digital Image Processing*, Third Edition, Prentice Hall, 2007

FRACTAL ELECTIVES

18CE751 INTERNET OF THINGS WITH WIRELESS TECHNOLOGY 1 0 0 1

Objectives:

- To understand how different wireless technologies used and influences the IoT
- To understand the design and various use cases with some of the technologies.

Keywords: IoT, Wireless technologies for IoT, NBIoT

Contents:

Cellular and wireless technologies for IoT, Designing and developing IoT applications, Integrating different technologies and software, 5G wireless technology and IoT, Narrow band IoT.

Outcomes:

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

- Design and develop IoT applications using wireless technology
- Understand the concept of narrow band IoT

TEXTBOOKS/REFERENCES

1. Cellular Internet of Things: Technologies, Standards, and PerformanceBy OlofLiberg, Marten Sundberg, Eric Wang, Johan Bergman, Joachim Sachs, Elsevier
2. Designing the Internet of ThingsBy Adrian McEwen, Hakim Cassimally, Wiley

18CE752 COOPERATIVE AND RELAY COMMUNICATION 1 0 0 1

Objectives:

- To understand the concept of cooperative and relay communication in wireless networks
- To analyze the performance of a system which use the cooperative and relay concept

Keywords: Cooperative communication, relay communication, multihope.

Contents:

Overview of cooperative and relay communication, two user cooperative transmission scheme, decode and forward, amplify and forward; cooperative transmission schemes with multiple relays and multihop communications.

Outcomes:

- Able to understand and appreciate cooperative, relay and multihope communication in wireless networks

- Able to analyze different methods/schemes used in these techniques.

TEXTBOOKS/ REFERENCES:

1. By 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*

18CE753 MASSIVE MIMO 1 0 0 1

Objectives:

- To carry out effective system performance analyses and develop advanced Massive MIMO techniques and algorithms

Contents:

Introduction - Large MIMO systems - MIMO encoding - MIMO detection - probabilistic data association - message passing and graphical models - Channel estimation - Precoding - MIMO channel models - Large MIMO test beds

Outcomes:

- Model and simulate a massive MIMO system and develop an experimental test bed.
- To put knowledge into practice and acquire the skill set needed to design and analyze complex wireless communication systems

TEXTBOOKS/ REFERENCES

1. A. Chockalingam& B. SundarRajan, " Large MIMO Systems", Cambridge University Press, 2014.

18CE754 ADAPTIVE CODING AND MODULATION 1 0 0 1

Objectives:

- To understand the concepts for the applicability of coding in practical wireless systems.

Contents:

Introduction to coded modulation-coding and Information theory-Set partition coding-continuous phase modulation coding-PRS coded modulation-Trellis coding on fading channels.

Outcomes:

- Equip the students to apply coding theory concepts to real time applications.

TEXTBOOKS/REFERENCES:

1. John B Anderson, Arne Svensson, *Coded modulationsystems*,Kluwer Academic publishers,2003.
2. Roman Rafi, Rafi Us Shan,*Adaptive coding and modulation: (for 3G systems)*,VDM VerlagDr.Muller , 2010.

18CE755 DELAY TOLERANT NETWORKS 1 0 0 1

Objectives:

- To introduce the concepts of delay and disruption tolerant networking and illustrate the applications of DTNs to wireless networks

Contents:

History and Early Applications: DakNet, ZebraNet; Layered Architecture: The Bundle Layer; Mobility Models: exponential and power law mobility models, human mobility model; DTN Routing: opportunistic routing, single copy vs. multicopy routing, epidemic, probabilistic, geographic and social-based routing protocols; Deep-Space and Satellite Applications; Terrestrial Applications: data dissemination, delay tolerant social networks; vehicular DTNs, airborne networks; mobile robots, applications in data centre and mobile peer-to-peer networks; Underwater Applications; Performance Analysis and Optimization

Outcomes:

- Students will be able to model and analyze several communication scenarios with disruption applying the delay tolerant framework

TEXTBOOKS/REFERENCES:

1. LongxiangGao, Shui Yu, Tom H. Luan Wanlei Zhou, *Delay Tolerant Networks*, Springer, 2015.
2. Athanasios Vasilakos, Yan Zhang, ThrasyvoulosSpyropoulos, *Delay Tolerant Networks: Protocols and Applications*, CRC Press, Taylor & Francis Group, 2012.
3. J. J. P. C. Rodrigues (Ed.),*Advances in Delay Tolerant Networks (DTNs): Architecture and Enhanced Performance*, Woodhead Publishing, Elsevier, 2015.

18CE756 NETWORK CODING 1 0 0 1

Objectives:

- To introduce the concepts network coding and illustrate its applications to wireless networks

Contents:

Theorems of Network Multicast: min-cut max-flow theorem; the main theorem of network coding; Theoretical Frameworks: algebraic, combinatorial, information-theoretic and linear programming frameworks; Throughput Benefits; Network Code Design for Multicasting; Networks with Delays and Cycles; Applications: gossip algorithms for information dissemination, content distribution, applications in wireless networks and security

Outcomes:

- Students will be able to demonstrate the improvement in performance of wireless networks due to network coding

TEXT BOOKS/ REFERENCES:

1. Christina Fragouli and EminaSoljanin, *Network Coding Fundamentals*, Foundations and

Trends in Networking, now Publishers Inc, 2007.
2. Christina Fragouli and EminaSoljanin, *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.

18CE757 WIRELESS SENSOR NETWORKS 1 0 0 1

Objectives:

- To understand the theoretical aspects of wireless sensor networks with focus on signal processing and communication perspectives

Contents:

Introduction - Fundamental Properties and Limits - Network Information Processing - Sensing Capacity - Detection - Distributed Estimation - Distributed Learning - Data gathering - Graphical Models and Fusion in Sensor Networks - Communications, Networking and Cross-Layered Designs – Routing – Case Studies.

Outcomes:

- To enable state-of-the-art design of wireless sensor network with an emphasis on the large-scale sensor networks distributed signal processing, communication algorithms and novel cross-layer design paradigms.

TEXTBOOKS/REFERENCES

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

18CE758 COMPRESSED SENSING 1 0 0 1

Objectives:

- Understand the concept of compressed sensing framework and reconstruction algorithms

Contents:

Introduction to compressed sensing - sparse modelling – compressed sensing of analog signals – introduction to analysis of random matrix theory – greedy algorithms – graphical models.

Outcomes:

- Thorough understanding of compressed sensing framework.
- Design of sensing and reconstruction algorithms for inverse problems in engineering

TEXTBOOKS/REFERENCES

1. Yonina C. Eldar,GittaKutyniok "Compressed Sensing: Theory and Applications", Cambridge University Press, 2012.

18CE759 BIG DATA ANALYTICS 1 0 0 1

Objectives:

- Introduce the concepts of big data to students
- Train the students to develop and deploy MapReduce applications
- Train the students to perform data analytics on big data

Contents:

Introduction– distributed file system–Big Data and its importance, Four Vs of big data. Apache Hadoop & Hadoop EcoSystem- Features and architecture- MapReduce fundamentals-analysing data with Hadoop-Scaling out-Hadoop streaming-examples. The Hadoop Distributed Filesystem (HDFS)- HDFS Concepts- Hadoop Filesystems- Data Flow-Hadoop Archives. Hadoop I/O- Data Integrity, Compression, Serialization, File-Based Data Structures. Developing a MapReduce Application- Setting up the development environment-running locally on test data- Running on a cluster. Analyzing big data using MapReduce-linear regression models for forecasting, k-means clustering, kNN classification.

Outcomes:

- Training the students on the fundamentals of big data and its applications in data analytics
- Prepare them to apply these algorithms for their further study/research

TEXTBOOKS/REFERENCES:

1. Tom White, *Hadoop: The Definitive Guide*, 4th Ed., O′Reilly, 2015
2. Michael Manoochehri, *Data Just Right- Introduction to Large-Scale Data & Analytics*, Addison Wesley,2013
3. VigneshPrajapati, *Big Data Analytics with R and Hadoop*, Packt Publishing Ltd, 2013
4. Parag Kulkarni,SarangJoshi,Meta S. Brown, *Big Data Analytics*, PHI Learning Pvt. Ltd., 2016

18CE760 GAME THEORY 1 0 0 1

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 especially emphasizing the computational issues

Contents:

Introduction – Rational Decision making: single person decision problem-actions, outcomes and preferences – The rational choice paradigm. Games with perfect information- Nash Equilibrium- examples- Best response functions- Dominated actions-Equilibrium in a single population.Games with Imperfect Information- Bayesian Games-examples and case studies.

Outcomes:

- Apply Nash Equilibrium for engineering problems.
- Identify some applications that need aspects of Bayesian Games

- Implement a typical scenario using Game theory

TEXTBOOKS/REFERENCES:

1. Steven Tadelis, *Game Theory-An Introduction*, Princeton University Press,2013
2. M. J. Osborne, *An Introduction to Game Theory*, Oxford University Press, 2003.
3. N. Nisan, T. Roughgarden, E. Tardos, and V. V. Vazirani, *Algorithmic Game Theory*, Cambridge University Press, 2007.

18CE761 COMPLEX SYSTEMS ANALYSIS 1 0 0 1

Objectives:

- To introduce the concepts of nonlinear dynamics and chaos theory
- Understanding biomedical and communication systems as complex systems.
- Use of information science in complex system analysis and classification.

Contents:

Characteristics of nonlinear and dynamical systems-phase space analysis-periodic orbits and stability-maps and flows-chaos theory-modelling biomedical and communication systems as dynamical systems-complexity measures for signal quantification-analysis and classification of ECG and EEG signals using entropy and complexity measures.

Outcomes

- Ability to analyze traditional systems from a novel perspective
- Exposure to the state-of-the-art methods for complex system analysis
- To identify the presence of complex systems in every day signal processing applications including biomedical and communication systems.

TEXT BOOKS / REFERENCES:

1. Alligood, Kathleen T., Tim D. Sauer, and James A. Yorke. *Chaos*. Springer New York, 1996.
2. Northrop, Robert B. *Introduction to complexity and complex systems*. CRC press, 2010.
3. Recent publications on ‘Complexity measures for complex system analysis’.

18CE762 PRINCIPLE OF PROJECT MANAGEMENT 1 0 0 1

Objective:

- To understand the project management, stages in project management and planning
- To understand the risk management, scheduling and related tools

Contents:

Characteristics of projects, Definition and objectives of Project Management, Stages of Project Management, Project Planning Process, Establishing Project organization.Project Risk Management, Project scheduling and Planning Tools.

Outcomes:

- To enable planning and scheduling of a project

- To know some of the tools used in project management

TEXTBOOKS/REFERENCES:

1.Shtub, Bard and Globerson, *Project Management: Engineering, Technology, and Implementation,* PH Inc.

2. Lock, Gower, *Project Management Handbook.*

18CE798 DISSERTATION 0 0 0 10

Objectives:

- To define the problem of the proposed work.
- To apply the concepts of communication engineering and signal processing in the selected problem.
- To demonstrate the results of the design concept.

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.Communication engineering and signal processing 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:

- Creation of manpower in the communication engineering and signal processing domain and specialize in the state-of the art technology.
- Enable design aptitude and complex problem solving in the communication engineering and signal processing design aspects.
- Research publications and filing of patents.

18CE799 DISSERTATION 0 0 0 10

Objectives:

- To define the problem of the proposed work.
- To apply the concepts of communication engineering and signal processing design in the selected problem.
- To demonstrate the results of the design concept.

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.Communication engineering and signal processing 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:

- Creation of manpower in the communication engineering and signal processing domain and specialize in the state-of the art technology.
- Enable design aptitude and complex problem solving in the communication engineering and signal processing design aspects.
- Research publications and filing of patents.