SCHEME OF COURSES FOR

ME (Electronics and Communications Engineering)

First Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEC101	Discrete Time Signal Processing	3	1	2	4.5
2.	PEC102	Optical Communication Networks	3	1	2	4.5
3.	PEC103	Information and Communication Theory	3	1	0	3.5
4.	PEC104	Antenna Systems	3	0	2	4.0
5.	PEC105	Advanced Communication Systems	3	1	2	4.5
		Total	**15**	**4**	**8**	**21.0**

Second Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PVL202	Embedded Systems	3	0	2	4.0
2.	PEC201	RF Devices and Circuits	3	1	0	3.5
3.	PEC202	Advanced Wireless Communication Systems	3	1	2	4.5
4.	PCS203	Soft Computing	3	1	2	4.5
5		Elective – I	3	0	0	3.0
		Total	**15**	**3**	**6**	**19.5**

Third Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.		Elective – II	3	0	0	3.0
2.		Elective – III	3	1	2	4.5
3.	PEC391	Seminar				4.0
4.	PEC091	Thesis (starts)				-
		Total	**6**	**1**	**2**	**11.5**

Fourth Semester

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEC091	Thesis (Contd …)				**-**

Total Credits: 52

Approved by the Senate in its 70th meeting held on May 25,2009

List of Electives

Elective–I

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEC211	Passive Optical Networks	3	0	0	3.0
2.	PEC212	Audio and Speech Processing	3	0	0	3.0
3.	PEC213	Advanced Wireless Networks	3	0	0	3.0
4.	PEC214	Fractional Transforms and Applications	3	0	0	3.0
5.	PVL203	VLSI Signal Processing	3	0	0	3.0
6.	PEC215	Detection and Estimation Theory	3	0	0	3.0
7.	PEC216	Advanced Computer Networks and Protocols	3	0	0	3.0
8.	PEC217	Microstrip Antennas	3	0	0	3.0

Elective–II

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEC321	Advanced Optical Technologies	3	0	0	3.0
2.	PEC322	Video and Image Processing	3	0	0	3.0
3.	PEC323	Error Coding Theory	3	0	0	3.0
4.	PVL102	IC Fabrication Technology	3	0	0	3.0
5.	PEC324	Space-Time Wireless Communication	3	0	0	3.0
6.	PEC325	Wireless Broadband Networks	3	0	0	3.0
7.	PEC326	Optoelectronics	3	0	0	3.0

Electives–III

S. No.	Course No.	Course Name	L	T	P	Cr
1.	PEC331	IP over WDM	3	1	2	4.5
2.	PEC332	Adaptive Signal Processing	3	1	2	4.5
3.	PVL103	Digital VLSI Design	3	1	2	4.5
4.	PEC333	Wireless Sensor Networks	3	1	2	4.5
5.	PEC334	Space-Time Coding for Wireless Communication	3	1	2	4.5
6.	PEC335	Next Generation Wireless Systems and Networks	3	1	2	4.5
7.	PEC336	Digital Signal Processors	3	1	2	4.5
8.	PVL105	Logic Synthesis using HDLs	3	1	2	4.5

PEC101 DISCRETE TIME SIGNAL PROCESSING

L	T	P	Cr
3	1	2	4.5

Prerequisite(s): None

Introduction: Review of Z transforms, Continuous and discrete time Fourier series and Fourier Transforms, Sampling Theorem, Discrete Fourier Transform, Divide and Conquer Algorithm, Decimation-in-Time and Decimation-in-Frequency FFT Algorithms, Hilberts transforms, Discrete cosine transforms.

Design of digital filters: Design of FIR Filters, Symmetrical, Asymmetrical FIR Filters, Window Methods - Rectangular, Triangular, Hamming, Hanning, Blackman, Kaiser Window etc, IIR filters using pole zero placement, impulse invariant, bilinear transformation and matched Z-transformation method, Realizations for FIR and IIR digital filters.

Multirate Signal Processing: Introduction, Concepts of multirate signal processing, Decimation and Interpolation by Integer factors, Sampling rate conversion by rational factors, efficient polyphase structures, design of phase shifters, Implementation of sampling rate conversion, Multistage Implementation, Applications of multirate signal processing, Digital filter banks, Two Channel and M-Channel filter bank, Wavelets.

Estimation and Prediction: Random signal, Correlation function and Power spectra, Innovations Representation, Linear prediction, forward and backward linear prediction, Levinson-Durbin Algorithm, Schur algorithm.

Adaptive Filters: Concept of Adaptive filters, Basic Wiener filter Theory, LMS adaptive algorithm, Recursive Least Square algorithm, Applications of adaptive filters,

Power Spectrum Estimation: Estimation of spectra from finite-duration observation of Signals, Non-parametric and parametric methods for power Spectrum estimation, Filter bank methods, Eigen analysis algorithms for spectrum estimation.

DSP Processors: Architecture and instruction set of TMS320C54X DSP Chips, some example programs.

Laboratory Work

Calculation of Z, Fourier transform, Design of FIR and IIR filters, Multirate signal processing, realization of prediction, Adaptive Filters. Some example programs using TMS320C5402.

Recommended Books

1. *Proakis, J.G., and Manolakis, D.G., Digital Signal Processing principles, Algorithms and Applications, Dorling Kingsley (2008).*
2. *Schilling, Rober J., and Harris, Sandra L., Fundamentals of Digital Signal Processing, Thomson (2007).*
3. *Oppenheim, A.V., and Schafer, R.W., Discrete-Time Signal Processing, Pearson (2006) 2nd ed.*

4. *Ifeachor, Emmanuuel C., and Jervis, Barrie W., Digital Signal Processing: A practical Approach, Dorling Kingsley (2008) 2nd ed.*
5. *Andreas, Antoniou, Digital Signal Processing: Signals, Systems and Filter, TATA McGraw-Hill (2004).*

PEC102 OPTICAL COMMUNICATION NETWORKS

L	T	P	Cr
3	1	2	4.5

Prerequisite(s): None

Optical Networking: Principles and Challenges: Wavelength-Division Multiplexing (WDM) WDM Networking Evolution, WDM Network Constructions, WDM Economics.

Enabling Technologies: Building Blocks Optical Fiber, Optical Transmission in Fiber Optical Transmitters, Optical Receivers and Filters, Optical Amplifiers, Switching Elements, Wavelength Conversion, Designing WDM networks, Experimental WDM Lightwave Networks.

Single-Hop Networks: A Passive-Star-Based Local Lightwave Network, Characteristics of a Single-Hop System, Experimental WDM Systems, Other Non-Pretransmission Coordination Protocols, Pretransmission Coordination Protocols, Special Case: Linear Bus with Attempt-and-Defer Nodes, Introduction, Rainbow Protocol, Model.

Multihop Networks: Characteristics of a Multihop System, Topological Optimization Studies, Regular Structures, Near-Optimal Node Placement on Regular Structures, Shared-Channel Multihop Systems, Introduction to GEMNET.

Channel-Sharing and Multicasting: Introduction, Background, Shared-Channel Multihop GEMNET, Performance Evaluation, Illustrative Examples: Unicast Traffic, Illustrative Examples: Multicast Traffic.

Elements of Virtual Topology Design: Introduction, System Architecture, Formulation of the Optimization Problem, Algorithms, Experimental Results -Physical Topology as Virtual Topology (No WDM), Multiple Point-to-Point Links (No WRS), Arbitrary Virtual Topology (Full WDM), Comparisons, Effect of Nodal Degree and Wavelength, Network Design: Resource Budgeting and Cost Model, Virtual Topology Reconfiguration.

Routing and Wavelength Assignment: Introduction, Problem Formulation, Illustrative Examples - Static Lightpath Establishment (SLE), Dynamic Lightpath Establishment (DLE), Introduction, Basics of Wavelength Conversion, Network Design, Control, and Management Issues, Benefit Analysis, Benefits of Sparse Conversion, Circuit-Switched Approaches, Packet-Switched Approaches, Reconfiguration in WDM Networks, WDM Network Control and Management, Amplification-Related Issues, Systems Design Considerations.

Multiwavelength Ring Networks: Introduction, System Architecture and Assumptions (Model), Illustrative Examples, Optimization Criteria, Flow-Based Algorithms, delay-Based Algorithms, Illustrative Examples-Network Description, Delay vs. N Characteristics, Delay vs. Throughput Characteristics, Two or Greater Partitions.

All-Optical Cycle Elimination: Introduction, Wavelength Crossconnect Switches, Network Assumptions, Overview of Solution and Algorithms, Details of Algorithms, Illustrative Examples-Dynamic Analysis, Static Analysis.

Optimizing Amplifier Placements in an Optical LAN/MAN: Introduction to Network

Environment, Solution Approach, Solver Strategies, Amplifier-Placement Module, Open Problems-Switched Networks, Gain Model.

Optical TDM and CDM Networks: Optical TDM Networks, Optical CDMA Networks.

Laboratory Work

Basic optical communication link experiments, DWDM experiments, Amplifier, Splicing, and OTDR experiment, System design and performance analysis using simulation tools.

Recommended Books

1. *Murthy, C. Siva Ram, Mohan Gurusamy, WDM Optical Networks: Concepts, Design, and Algorithms, Prentice Hall of India (2001).*
2. *Maier, Marti, Optical Switching Networks, Cambridge University Press (2008).*
3. *Sivalingam, Krishna M., Subramaniam, Suresh, Emerging Optical Networks Technologies: Architectures, Protocols, and Performance, Springer (2004).*
4. *Mukherjee, Biswanath, Optical WDM Networks, Springer (2006).*

PEC103 INFORMATION AND COMMUNICATION THEORY

L	T	P	Cr
3	1	0	3.5

Prerequisite(s): None

Probability and Induction: Axioms of Probability, Set Theory, Probability Space, Conditional Probability, Repeated Trials, Combined Experiments, Bernoulli Trials, Bernoulli's Theorem, and Games of Chance, Concept of a Random Variables, Distribution and Density, Function Specific Random Variables, Conditional Distributions, Binomial Random Variables, Functions of One Random Variable, its Distribution, Mean and Variance, Moments, Characteristic Functions; Bivariate Distributions, Two Functions of Two Random Variables, Joint Moments, Joint Characteristic Functions, Conditional Distributions, Conditional Expected Values, Normality, Stochastic Convergence and Center Limit Theorem.

Estimation and Hypothesis Testing: Time and Ensemble Averages, Covariance and Correction Functions. Simple binary hypothesis tests, Decision Criteria, Neyman pearson tests, Bayes Criteria, Multiple Hypothesis testing, Composite hypothesis testing, Asymptotic Error rate of LRT for simple hypothesis testing.

Stochastic Processes: Systems with Stochastic Inputs, Power Spectrum, Random Walks and Poisson Points, Cyclostationary Processes, Bandlimited Processes and Sampling Theory, Deterministic Signals in Noise Bispectra and System Identification, Poisson Sum Formula, Schwarz Inequality Problems, Spectral Representation of Random Processes, Factorization and Innovations, Finite-Order Systems and State Variables, Karhunen–Lo`eve Expansions, Ergodicity, Extrapolating Spectra and Youla's Parametrization, Minimum-Phase Functions, All-Pass Functions, Mean Square Estimation, Entropy, Maximum Entropy Method, Markov Chains, Higher Transition Probabilities and Chapman – Kolmogorov Equation, Stationary Distributions and Limiting Probabilities, Transient States and Absorption Probabilities, Branching Processes, Mixed Type Population of Constant Size, Structure of Periodic Chains.

Queueing Systems: Characteristics of Queueing Process, birth-death process, arrival and service, steady state solution; M/G/1 and G/M/1, occupancy distribution, renewal theory, waiting time and busy period, Series Queues, Jackson Networks, Cyclic Queues. Little's theorem, modeling and analysis of M/M-/- queues, Burke's Theorem, Reversibility, Queues with vacations, Work conservation principle, Priority queues, Queues served in cyclic order, Fluid-flow and diffusion approximations.

Statistical Modeling of Noise: Probability density of a jointly-Gaussian random vector, Fourier transforms for joint densities, Wide-sense stationary (WSS) processes, Poisson process noise, sources of noise in communication systems, shot noise, resistor noise, calculation of noise in linear systems, noise bandwidth, noise temperature, noise in two-port networks, noise-figure, cascaded stages, signal in presence of AWGN, narrow band noise and colored noise.

Information Theory: Unit of information, rate of information, joint entropy and conditional entropy, mutual information, Shannon-Hartley Theorem, bandwidth SNR trade off, channel capacity calculations of different channels, Source Coding- Coding efficiency, Shannon-Fano coding, Huffman coding, Lempel-Ziv adaptive coding.

Recommended Books

1. *Papoulis, Athanasios, Probability Random Variables and Stochastic Processes, McGraw-Hill (2008).*
2. *Daigle, John N., Queuing Theory with Applications to Packet Telecommunication, Springer (2004).*
3. *Peebles, P.Z., Probability, Random Variables, and Random Signal Principles, Tata McGraw-Hill (2008).*
4. *Bertsekas, Dimitri P. and Gallager, Robert G., Data Networks, Prentice Hall (1992).*
5. *Larson, A., and Schubert, B.O., Stochastic Processes, vol. I and II, Holden-Day (1979).*
6. *Gardener, W., Stochastic Processes, McGraw Hill (1986).*

PEC104 ANTENNA SYSTEMS

L	T	P	Cr
3	0	2	4.0

Prerequisite(s): None

Review of Radiation Principles: Review of vector algebra, Basic Antenna Concepts and parameters, Potential functions and the Electromagnetic field, Alternating current element, Power Radiated by a current element, Applications to short antennas, Assumed current distributions, Radiation from a quarter-wave monopole or half wave dipole, Near and far fields.

Thin Linear Antennas and Arrays: Short Electric dipole, Thin linear antenna, Radiation resistance of antennas, Radiation resistance at a point which is not a current maximum, Fields of a thin linear antenna with a uniform travelling wave, Array parameters, Half-power beamwidth Mathematics of linear array, Antenna element spacing without grating lobes, Linear broadside array with non uniform distributions, Gain of regularly spaced planar arrays with $d = \lambda/2$, Tchebyscheff Array antennas, Reduction of sidelobes by tapering, Circular array, Phase and amplitude errors.

Secondary Sources and Aperture Antennas: Magnetic currents, Duality, Images of electric and magnetic currents, electric and magnetic currents as sheet sources, Impressed and induced current sources, Induction and equivalence theorems, field of a secondary or Huygens source, Radiation from open end of a coaxial line, Radiation through an aperture in conducting screen, slot antenna.

Broadband and Frequency Independent Antennas: Broadband Antennas, The frequency-independent concept: Rumseys Principle, Frequency-independent planar log-spiral antennas, Frequency-independent conical-spiral Antenna, log periodic antenna, Reflector antennas.

Pattern Synthesis: Approximate far field pattern of line source, Synthesis of line sources, Fourier transform method of line sources, Antenna as a filter, Laplace transform method, Woodwards synthesis method, Optimization methods, Synthesis of Planar rectangular source, Synthesis of planar circular source, Low sidelobe synthesis.

Effect of Mutual Coupling on Antennas: Accounting for mutual effects for dipole array-compensation using open-circuit voltages, compensation using the minimum norm formulation, Effect of mutual coupling- Constant Jammers, Constant Signal, Compensation of mutual coupling- Constant Jammers, Constant Signal, Result of different elevation angle.

Applications and Numerical Techniques: Different types of antennas for applications in communication systems. Antennas for space communication, Numerical techniques in antenna design.

Adaptive Array Concept: Motivation of using Adaptive Arrays, Adaptive Array problem statement, Signal Environment, Array Element Spacing considerations, Array Performance, concept of optimum Array Processing, Recursive Methods for Adaptive Error Processing.

Laboratory Work

Practicals related to Antenna Techniques using Software and Hardware.

Recommended Books

1. *Balanis, C., Antennas, John Wiley and sons (2007) 3rd ed.*
2. *Milligan, Thomas A., Modern Antenna Design 2nd edition, IEEE press, Wiley Interscience (2005).*
3. *Neelakanta, Perambur S., and Chatterjee, Rajeswari, Antennas for Information Super Skyways: An Exposition on Outdoor and Indoor Wireless Antennas, Research Studies Press Ltd. (2004).*
4. *Godara, Lal Chand, Smart Antennas, CRC Press (2004).*
5. *Munk, Ben A., Finite Antenna Arrays and FSS, John Wiley and Sons (2003).*
6. *Rogstad, David H., Alexander Mileant, Pham and Timothy T., Antenna Arraying Techniques in the Deep Space Network, JPL Publication (2003).*

PEC105 ADVANCED COMMUNICATION SYSTEMS

L	T	P	Cr
3	1	2	4.5

Prerequisite(s): None

Introduction: Introduction to analog and digital communication systems, baseband, bandpass and equivalent lowpass signal representations, concept of pre-envelop and Hilbert transform, representation of bandpass stochastic processes, concept of sampling and reconstruction of signal, introduction to oversampling, sigma-delta A/D converter, PCM, DPCM and ADPCM systems, memoryless modulation methods, linear modulation with memory, nonlinear modulation methods with memory, power spectra of CPFSK and CPM signals, Comparison of QPSK, MSK and GMSK.

Optimum Receivers for AWGN Channels: Correlation demodulator, Matched filter demodulator, optimum detector, maximum likelihood sequence detector, A symbol by symbol MAP detector for signals, Probability of error calculations for,"binary modulation, M-ary orthogonal signals, biorthogonal signals, simplex signals, M-ary binary coded signals, M-ary PAM, M-ary PSK, DPSK, QAM," optimum demodulation and detection of CPM, optimum receiver design for signals with random phases, comparison of coherent and non-coherent receivers.

Carrier and Symbol Synchronization: Likelihood function, carrier recovery and symbol synchronization in signal demodulation, ML carrier phase estimation, PLL, decision directed loops and non-decision directed loops, ML timing estimation, non-decision directed timing estimation, joint estimation of carrier phase and symbol timing.

Signal Design for Band Limited Channels: Characterization of band limited channels, design of band limited signals for no ISI, Design of band limited signals with controlled ISI, data detection for controlled ISI, signal design for channels with distortion, probability of error for detection of PAM with zero ISI and with partial response signals, modulation codes for spectrum shaping.

Communication through Band Limited Linear Filter Channels: ML receiver for channels with ISI and AWGN, discrete time model for channel with ISI, Viterbi algorithm for discrete time white noise filter model, Performance of MLSE for channels with ISI, linear equalization – peak distortion criterion, MSE criterion and its performance, fractionally spaced equalizers, decision feedback equalization – coefficient optimization, performance characteristics.

Satellite Communication Systems: Basic Transmission Theory, System Noise Temperature and G/T Ratio, Design Of Down Links, Domestic Satellite Systems Using Small Earth Stations, Uplink Design, Design Of Satellite Link For Specified (C/N), VSAT.

Selected Areas in Communication: Introduction to MIMO, CDMA, MC-CDMA, OFDM, BLAST and Ultra-wideband systems, Modern Coding Techniques – block coding, convolution coding, Turbo coding, STBC, STTC, soft-decoding, hard-decoding and Viterbi decoder.

Laboratory Work

Practicals based upon hardware using communication kits and simulation with the help of simulation packages.

Recommended Books

1.Proakis, John G., Digital Communications, McGraw-Hill (2000).

2.Haykin, Simon, Digital Communications, Wiley (2007).

3.Haykin, Simon, Communication Systems, Wiley (2009).

4.Proakis, John G. and Masoud, Salehi, Communication Systems Engineering, Prentice Hall (2001).

Approved by the Senate in its 70th meeting held on May 25,2009

PEC201 RF DEVICES AND CIRCUITS

L	T	P	Cr
3	1	0	3.5

Prerequisite(s): None

Schottky Barrier Diode: S.B. diode theory, Surface states, noise-temperature ratio, Its use as a Mixer and Detector.

Varacter Diode: Diode theory, operation and frequency response.

The PIN Diode: p-I-n structure, device theory, Application of p-i-n diode as a switch and limiter.

The IMPATT Diode: IMPATT theory, negative resistance, Output frequency and power, IMPATT mountings.

The TRAPPAT Diode: The TRAPPAT structure and operation, Output waveforms, power and frequency.

The GUNN Oscillator: Gunn Effect, different modes of operation, GUNN and LSA in Particular, output and frequency.

Tunnel Diode: Diode structure, (V-I) characteristics, Operation as a MW generator.

Step Recovery Diode: SRD device structure and operation, SRD as a harmonic generator.

Microwave Transistor: Device geometry, cutoff frequency and operation, MESFET, HEMT.

Semiconductor Heterojunctions: Basic device model, (V-I) characteristics, Heterojunction diodes, transistors and lasers.

Fundamentals of Power Semiconductor devices: Introduction, SiC Material properties, polytypes, comparison of electrical properties of polytypes; Transport physics of SiC power devices, Breakdown voltage, SiC Schottky Rectifiers, SiC Metal-Semiconductor Field Effect Transistors (DIMOSFET and LDMOSFET).

Recommended Books

1. *Baliga, B. Jayant, Silicon Carbide Power Devices, World Scientific Publishing Company (2006).*
2. *Sze, S.M., Physics of Semiconductor Devices, John Wiley and Sons (2008).*
3. *Gupta, K.C., Microwaves, New Age International (2002).*
4. *Liao, S.Y., Microwave Devices and Circuits, Pearson Education (2006).*
5. *Dutta, A.K., Semiconductor Devices and Circuits, Oxford University Press (2008).*
6. *Baliga, B. Jayant, Fundamentals of Power Semiconductor Devices, Springer (2008).*

PEC202 ADVANCED WIRELESS COMMUNICATION SYSTEMS

L	T	P	Cr
3	1	2	4.5

Prerequisite(s): PEC105 Advanced Communications Systems

Overview of Wireless Communications: Cellular Telephone Systems, Wireless LANs, Broadband Wireless access, Paging Systems, Satellite Networks, Bluetooth, Ultra wideband, Spectrum Allocations for Systems, Cellular System Fundamentals, Channel Reuse, SIR and User Capacity, Orthogonal Systems Non-Orthogonal Systems Interference Reduction Techniques, Dynamic Channel Assignment, Shannon Capacity of Cellular Systems, Area Spectral Efficiency.

Path Loss and Shadowing: Radio Wave Propagation, Free-Space Path Loss, Ray Tracing, Two-Ray Model, Ten-Ray Model (Dielectric Canyon), General Ray Tracing, Empirical Path Loss Models, Okumura Model, Hata Model, COST231 Piecewise Linear Model, Indoor Attenuation, Combined Path Loss and Shadowing, Outage Probability, Cell Coverage Area.

Statistical Multipath Channel Models: Time-Varying Channel Impulse Response, Autocorrelation, Cross Correlation, and Power Spectral Density Level Crossing Rate and Average Fade Duration, Finite State Markov Channels, Wide band Fading Models, Power Delay Profile, Coherence Bandwidth, Doppler and Channel Coherence Time, Transforms for Autocorrelation and Scattering Functions, Discrete-Time Model, Space-Time Channel Models.

Capacity of Wireless Channels: Capacity in AWGN, Capacity of Flat-Fading Channels, Channel and System Model, Channel Distribution Information (CDI) Known, Channel Side Information at Receiver, Channel Side Information at Transmitter and Receiver, Capacity with Receiver Diversity, Capacity Comparisons, Capacity of Frequency-Selective Fading Channels,

Performance of Digital Modulation over Wireless Channels: Signal Space Analysis, Receiver Structure and Sufficient Statistics, Decision Regions and the Maximum Likelihood Criterion, Union Bound, ML Phase and timing Estimation. Error Probability for BPSK QPSK, MPSK, MPAM, MQAM, FSK and CPFSK, Error Probability for Differential Modulation, Alternate Q Function Representation, Outage Probability, Moment Generating Function Combined Outage and Average Error Probability, Inter symbol Interference.

Diversity: Receiver Diversity, System Model, Combining techniques Transmitter Diversity, Channel Known and unknown at Transmitter, Moment Generating Functions in Diversity Analysis for MRC, EGC, SC, Non-coherent and Differentially Coherent Modulation.

Coding for Wireless Channels: Code Design, Hard Decision Decoding (HDD), Probability of Error for HDD and SDD in AWGN, Code Characterization, ML Decoding, State Diagrams and Transfer Functions, Error Probability for Convolutional Codes, Concatenated Codes, Turbo Codes, Low Density Parity Check Codes, Coded Modulation, Coding and Interleaving for Fading Channels, Protection Codes, Joint Source and Channel Coding.

Adaptive Modulation and Coding: Adaptive Transmission System, Adaptive Techniques, Variable Rate Techniques, Variable-Power, Error Probability, Coding, Hybrid Techniques and Rate techniques, Variable-Power MQAM, Adaptive Rate and Power Schemes, Channel Inversion

with Fixed Rate, Discrete Rate Adaptation, General M-ary Modulations, Continuous and Discrete Rate Adaptation, Adaptive Techniques in Combined Fast and Slow Fading.

.

Multicarrier Modulation: Data Transmission using Multiple Carriers, Overlapping Sub channels, Mitigation of Sub carrier Fading, Discrete Implementation of Multi-carrier, Cyclic Prefix, OFDM, Matrix Representation of OFDM, Vector Coding, PAR, Frequency and Timing Offset, Multi-user Channels, Multiple Access, Downlink Channel Capacity, Uplink Channel Capacity, Capacity in AWGN, Fading, and with Multiple Antennas.

Recommended Books

1. *Goldsmith, Andrea, Wireless Communications, Cambridge University Press (2005).*
2. *Tse, David and Viswanath, Pramod, Fundamentals of Wireless Communication, Cambridge University Press (2006).*
3. *Rappaport, T.S., Wireless Communications, Pearson Education (2007) 2nd ed.*
4. *Paulraj, Arogyaswami, Gore, Dhananjay and Nabar, Rohit, Introduction to Space-Time Wireless Communications, Cambridge University Press (2008).*

PEC211 PASSIVE OPTICAL NETWORKS

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): None

Architecture Of Future Access Networks: Multiplexing Level, WDM – Passive Optical Network, Wavelength Allocation Strategies, Dynamic Network Reconfiguration Using Flexible WDM**,** Static WDM PONs, Wavelength Routed PON, Reconfigurable WDM PONs, Wavelength Broadcast-and-Select Access Network, Wavelength Routing Access Network, Geographical, Optical and Virtual Topologies: Star, Tree, Bus, Ring and Combined, Compatibility with Radio Applications UWB, UMTS, Wi-Fi, Radio-Over-Fibre, Next Generation G/E-PON Standards Development Process.

Components for Future Access Networks: Tuneable Optical Network Unit, Fast-Tunable Laser at the Optical Line Terminal, Arrayed Waveguide Gratings, Reflective Receivers and Modulators, Colourless ONT.

Enhanced Transmission Techniques: Advanced Functionalities in PONs, Bidirectional Single Fibre Transmission with Colourless, Optical Network Unit, Remodulation by Using Reflective Semiconductor Optical Amplifiers, Fabry Perot Injection Locking with High Bandwidth and Low Optical Power for Locking, Characterization of Rayleigh Backscattering, Strategies to Mitigate Rayleigh Backscattering, ASK-ASK Configuration Using Time Division Multiplexing, FSK-ASK Configuration Using Modulation Format Multiplexing, Subcarrier Multiplexing by Electrical Frequency Multiplexing. Rayleigh Scattering Reduction by Means of Optical Frequency Dithering, Spectral Slicing, Alternative Modulation Formats to NRZ ASK, Bidirectional Very High Rate DSL Transmission Over PON, Active and Remotely-Pumped Optical Amplification, Variable Splitter, Variable Multiplexer.

Network Protection: Protection Schemes, Reliability Performance Evaluation.

Traffic Studies: Dynamic Bandwidth Allocation, QoS and Priorization in TDMA PONs, WDMA/TDMA Medium Access Control, Access Protocols for WDM Rings with QoS Support, Efficient Support for Multicast and Peer-to-Peer Traffic.

Metro-Access Convergence: Core-Metro-Access Efficient Interfacing, Optical Burst Switching in Access, Sardana Network: An Example of Metro-Access Convergence.

Economic Models: WDM/TDM PON, Long Reach PONs, Long Term Dynamic WDM/TDM-PON Cost Comparison.

Recommended Books

1. *Josep, Prat, Next-Generation FTTH Passive Optical Networks, Spinger (2008).*
2. *Dhaini, Ahmad R., Next-Generation Passive Optical Networks, VDM Verlag (2008).*
3. *Kramer, Glen and Kramer, Glen, Ethernet Passive Optical Networks**,** McGraw-Hill (2005).*
4. *Lam, Cedric F. (Editor), Passive Optical Networks: Principles and Practice, Academic Press (2007).*

PEC212 AUDIO AND SPEECH PROCESSING

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): None

Introduction: Review of digital signal and systems, transform representation of signal and systems, Sampling Theorem, Digital filters and filter banks.

Digital Models for Speech signals: Speech production and acoustic tube modeling, acoustic phonetics, anatomy and physiology of the vocal tract and ear, hearing and perception.

Digital Representation: Linear quantization, companding, optimum quantization, pulse code modulation (PCM), effects of channel errors, vector quantization (VQ), adaptive quantization, differential PCM, APCM *vs.* ADPCM, delta modulation, adaptive delta modulation, and CVSD.

Digital Vocoders: Linear predictive coding (LPC), hybrid coders: voice excited vocoders, voice excited linear predictor, and residual excited linear predictor (RELP).

Speech Recognition: Isolated word recognition, continuous speech recognition, speaker (in) dependent, measures and distances (articulation index, log spectral distortion, Itakura-Saito, cepstral distance), dynamic time warping (DTW), HMM, HMM networks, Viterbi algorithm, discrete and continuous observation density HMMs.

Speaker recognition: speaker verification/authentication *vs.* peaker identification, closed *vs.* open set, feature vectors (*e.g*., line spectrum pair and cepstrum), pattern matching (*e.g.,* DTW, VQ, HMM), hypothesis testing, and errors.

Advanced Topics: Emerging speech coding standards (*e.g*., 2400 bps MELP), Internet phone, voice and multimedia applications.

Recommended Books

1. *Deller, J., Proakis, J. and Hansen, J., Discrete-Time Processing of Speech Signals, IEEE (1993).*
2. *Rabiner, L. and Schafer, R., Digital Processing of Speech Signals. Signal Processing, Prentice-Hall (1978).*
3. *Borden, G. and Harris, K., Speech Science Primer, 2nd Edition, Williams and Wilkins (2006).*
4. *Furui, S., Digital Speech Processing, Synthesis and Recognition, CRC (2001).*
5. *Owens, F. J, Signal Processing of Speech, McGraw-Hill (1993).*
6. *Parsons, T., Voice and Speech Processing: Communications and Signal Processing, McGraw-Hill (1986).*

PEC213 ADVANCED WIRELESS NETWORKS

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): None

Fundamentals: 4G Networks and Composite Radio Environment, Protocol Boosters, Hybrid 4G Wireless Network Protocols, Green Wireless Networks, Physical Layer and Multiple Access, Multicarrier CDMA, Ultrawide Band Signal, MIMO Channels and Space Time Coding

Channel Modeling for 4G: Macrocellular Environments, Urban Spatial Radio Channels in Macro/MicroCell Environment, MIMO Channels in Micro- and PicoCell Environment, Outdoor Mobile Channel, Microcell Channel, Wireless MIMO LAN Environments, Indoor WLAN Channel, Indoor WLAN Channel, UWB Channel Model.

Adaptive and Reconfigurable Link Layer: Link Layer Capacity of Adaptive Air Interfaces, Adaptive Transmission in *Ad Hoc* Networks, Adaptive Hybrid ARQ Schemes for Wireless Links, Stochastic Learning Link Layer Protocol, Adaptive Medium Access Control: WLAN Enhanced Distributed Coordination Function Adaptive MAC for WLAN with Adaptive Antennas, MAC for Wireless Sensor Networks, MAC for *Ad Hoc* Networks, Teletraffic Modeling and Analysis.

Adaptive Network and TCP Layer: Graphs and Routing Protocols, Graph Theory, Routing with Topology Aggregation, Network and Aggregation Models, Effective Capacity, TCP Operation and Performance, TCP for Mobile Cellular Networks, Random Early Detection Gateways for Congestion Avoidance TCP for Mobile *Ad Hoc* Networks, A Cross-Layer Architecture for Video Delivery,

Mobility and Resource Management: Prioritized Handoff, Cell Residing Time Distribution, Mobility Prediction in Pico- and Micro-Cellular Networks, Channel Assignment Schemes, Resource Management in 4G. Mobile Agent-based Resource Management, Joint Data Rate and Power Management, Dynamic Spectra Sharing in Wireless Networks,

Security: Authentication, Security Architecture, Security Management in GSM Networks, Security Management in UMTS, Security Architecture for UMTS/WLAN Interworking, Security in *Ad Hoc* Networks, Security in Sensor Networks.

Network Deployment and Management: Cellular Systems with Overlapping Coverage, Multitier Wireless Cellular Networks, Local Multipoint Distribution Service., Self-organization in 4G Networks, Simple Network Management Protocol, Distributed Network Management. Mobile Agent-based Network Management, *Ad Hoc* Network Management. Quality-of-Service Management: Blind QoS Assessment System, QoS Provisioning in WLAN. Dynamic Scheduling on RLC/MAC Layer, QoS in OFDMA-based Broadband Wireless Access Systems,

***Ad Hoc* and Sensor Networks:** Routing Protocols, Hybrid Routing Protocol, Scalable Routing Strategies, Multipath Routing, Clustering Protocols. Cashing Schemes for Routing, Distributed QoS Routing, Sensor Networks Parameters, Sensor Networks Architecture. Mobile Sensor Networks Deployment, Directed Diffusion, Aggregation in Wireless Sensor Networks, Boundary Estimation, Optimal Transmission Radius in Sensor Networks, Data Funneling

Active Networks: Programmable Networks Reference Models, Programmable 4G Mobile Network Architecture, Cognitive Packet Networks, Game Theory Models in Cognitive Radio Networks, Biologically Inspired Networks. Energy-efficient Wireless Networks: Energy Cost Function, Minimum Energy Routing, Maximizing Network Lifetime, Energy-efficient MAC in Sensor Networks.

Network Information Theory: Effective Capacity of Advanced Cellular Networks, Capacity of *Ad Hoc* Networks. Information Theory and Network Architectures, Cooperative Transmission in Wireless Multihop *Ad Hoc* Networks, Network Coding, Capacity of Wireless Networks Using MIMO Technology, Capacity of Sensor Networks with Many-to-One Transmissions.

Recommended Books

1. *Lewis, Barry D., Davis, Peter T., Wireless Networks for Dummies, John Wiley and sons (2004).*
2. *Chen, Hsiao-Hwa and Guizani, Mohsen, Next Generation Wireless Systems and Networks, John Wiley and Sons (2006).*
3. *Glisic, Savo G., Advanced Wireless Networks, John Wiley and Sons (2006).*
4. *Rappaport, T.S., Wireless Communications, Pearson Education (2007 2nd ed).*
5. *Zheng, Jun and Jamalipour, Abbas, Wireless Sensor Networks: A Networking Perspective, Wiley-IEEE Press (2009).*

PEC214 FRACTIONAL TRANSFORMS AND APPLICATIONS

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): None

Introduction: Fractional operations and the fractional Fourier transform, Applications of the fractional Fourier transform, Signals, Systems, Representations and transformations, Operators, The Fourier transform, Some important operators, Uncertainty relations, Time-frequency and space-frequency representations, The Wigner distribution and the ambiguity function, Linear canonical transforms.

The Fractional Fourier Transform: Fractional operations, Definitions of the fractional Fourier transform, Eigenvalues and Eigenfunctions, Transforms of some common functions, Properties, Rotations and projections in the time-frequency plane, Fractional Fourier domains, Chirp bases and chirp transforms, Relationships with the Wigner distribution and the ambiguity function Two-dimensional fractional Fourier transforms, Applications of the fractional Fourier transform.

The Discrete Fractional Fourier Transform: Discrete Hermite-Gaussian functions, The discrete fractional Fourier transform, Definition in hyperdifference form, Higher-order discrete analogs, Discrete computation of the fractional Fourier transform.

The Fractional Fourier Transform in Optics: General fractional Fourier transform relations in free space, Fractional Fourier transformation in quadratic graded-index media, Hermite-Gaussian expansion approach, First-order optical systems, Fourier optical systems, Locations of fractional Fourier transform planes, Wavefield reconstruction, phase retrieval, and phase-space tomography, Applications of the transform to wave and beam propagation.

Applications to Signal Processing: Optimal Wiener filtering in fractional Fourier domains, Multi-stage, multi-channel, and generalized filtering configurations, Applications of fractional Fourier domain filtering, Convolution and filtering in fractional Fourier domains, Repeated filtering in the ordinary time and frequency domains, Multiplexing in fractional Fourier domains, Fractional correlation, Controllable shift-invariance, Performance measures for fractional correlation, Fractional joint-transform correlators, Adaptive windowed fractional Fourier transforms, Applications with different orders in the two dimensions

Other fractional Transforms: Fractional sine and Cosine transforms, fractional Hartley Transforms, fractional Wavelet Transforms and their applications in one and two dimensional Signal processing.

Recommended Books

1. *Ozaktas, Haldun M., Zalevsky, Zeev, and Kutay, M. Alper, The Fractional Fourier Transform with Applications in Optics and Signal Processing, John Wiley and Sons (2001).*
2. *IEEE and Elsevier Papers.*

PEC215 DETECTION AND ESTIMATION THEORY

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): PEC103 Information and Communication Theory

Representations of Random Processes: Orthogonal Representations, Random Process Characterization, Homogeneous Integral Equations and Eigenfunctions, Rational Spectra, Bandlimited Spectra, Nonstationary Processes, White Noise Processes, Optimum Linear Filter, Properties of Eigenfunctions and Eigenvalues.

Detection and Estimation of Signal: Linear Estimation, Nonlinear Estimation, Known Signals in White Gaussian Noise, Detection and Estimation in Nonwhite Gaussian Noise, Whitening Approach, Karhunen-Loeve Expansion, Sufficient Statistics, Integral Equations, Sensitivity**,** Random Phase Angles, Random Amplitude and Phase, Multiple Channels, Multiple Parameter Estimation in AWGN Channel, No-Memory Modulation Systems, Modulation Systems with Memory, Lower Bound on Mean-Square Estimation Error, Multidimensional Waveform Estimation, Bound on the Error Matrix, Nonrandom Waveform Estimation, Solution of Wiener-Hopf Equation, Unrealizable Filters, Optimum Feedback Systems, Kalman-Bucy Filters, Differential Equation Representation of Linear Systems.

Detection of Gaussian Signals in White Gaussian Noise: Optimum Receivers, Canonical Realization: Estimator-Correlator, Filter-Correlator Receiver, Filter-Squarer-Integrator (FSI) Receiver, Long Observation Time, Simple General Binary Problem, Separable Kernel Model, Time Diversity, Frequency Diversity, Low-Energy-Coherence (LEC) Case, Suboptimum Receivers, Adaptive Receivers, Parameter Estimation Model, Estimator Structure, Derivation of the Likelihood Function, Maximum Likelihood and Maximum A-Posteriori Probability Equations, Composite-Hypothesis Tests.

Detection of Slowly Fluctuating Point Targets: Model of a Slowly Fluctuating Point Target, White Bandpass Noise, Colored Bandpass Noise, Colored Noise with a Finite State Representation, Performance of the Optimum Estimator, Local Accuracy, Global Accuracy, Properties of Time-Frequency Autocorrelation Functions and Ambiguity Functions.

Doppler-Spread Targets and Channels: Model for Doppler-Spread Target (or Channel), Detection of Doppler-Spread Targets, Likelihood Ratio Test, Canonical Receiver Realizations, Performance of the Optimum Receiver, Communication Over Doppler-Spread Channels, Performance Bounds for Optimized Binary Systems, Doppler-Spread Target, Detection of Range-Spread Targets, Time-Frequency Duality, Dual Targets and Channels, Model for a Doubly-Spread Target, Differential-Equation Model for a Doubly-Spread Target (or Channel), Detection in the Presence of Reverberation or Clutter (Resolution in a Dense Environment), Detection of Doubly-Spread Targets and Communication over Doubly-Spread Channels, Approximate Models for Doubly-Spread Targets and Doubly-Spread Channels, Binary Communication over Doubly-Spread Channels, Detection under LEC Conditions, Parameter Estimation for Doubly-Spread Targets, Estimation under LEC Conditions, Amplitude Estimation, Estimation of Mean Range and Doppler.

Recommended Books

1. *Trees, Harry L. Van, Detection, Estimation and Modulation Theory, Part I, John Wiley and Sons (2001).*

2. *Trees, Harry L. Van, Detection, Estimation and Modulation Theory, Part III, John Wiley and Sons (2002).*
3. *Haykin, Simon S., Adaptive Filter Theory, Prentice Hall (2008). 4th ed.*
4. *Papoulis, Athanasios, Probability Random Variables and Stochastic Processes, McGraw-Hill (2008).*

PEC216 ADVANCED COMPUTER NETWORKS and PROTOCOLS

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): None

Review of Network Fundamentals: Network Systems and the Internet, Network Systems Engineering, Packet Processing, Network Speed, A conventional computer system, Fetch-Store paradigm, Network Interface Card functionality, Onboard Address Recognition, Packet Buffering, Promiscuous Mode, IP Datagram, Fragmentation, Reassembly, Forwarding, TCP Splicing.

Internetworking: Motivation, Concept, Goals, IP addressing, Address Binding with ARP, IP Datagram, Encapsulation IP Fragmentation and Reassembly, ICMP, TCP, UDP concept and datagram protocols, Remote Login, Introduction to Protocol Specification, Validation and Testing.

Network Standards and Standard Organizations: Proprietary, Open and De-facto Standards, International Network Standard Organizations, Internet Centralization Registration Authorities, Modern hierarchy of registration authority, RFC categories, The Internet Standardization Process.

TCP/IP Network Interface Layer Protocol: TCP/IP Serial Internet Protocols, Point to Point Protocols, PPP core protocol, PPP Feature Protocols, PPP Protocol Frame Formats, ARP and RARP Protocol, IPv4 and IPv6, IP Network Address Translation Protocol, ICMP Protocols and IPv6 Neighbor Discovery Protocol.

Routing and Application Layer Protocols: Communication Protocols, Connection Oriented, Connection Less, Working with Network Layer and Transport Layer, Routing Information Protocol (RIP. RIP-2, and RIPng), Border Gateway Protocol, User Datagram protocol, SMTP and FTP protocols, TFTP Protocols, Hypertext Transfer Protocols.

Recommended Books

1. *Farrel, A., The Internet and Its Protocols - A Comparative Approach, Morgan Kaufmann (2004).*
2. *Puzmanová, R., Routing and Switching - Time of Convergence, Addison-Wesley (2001).*
3. *Tanenbaum, A.S., Computer Networks, 4th Edition, Prentice Hall (2007).*
4. *Hunt, C., TCP/IP Network Administration, 3rd Edition, O'Reilly Media (2002).*
5. *Keshav, S., An Engineering Approach to Computer Networking, Addison-Wesley (1997).*

PEC217 MICROSTRIP ANTENNAS

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): PEC104 Antenna Systems

Microstrip lines: Introduction of Planar Transmission Structures, Microstrip Field Configuration, Microstrip Dispersion Models, Microstrip Transitions, Microstrip measurement, Methods of Full wave Analysis, Analysis of an Open Microstrip, Analysis of an Enclosed Microstrip, Design Considerations, Suspended and Inverted Microstrip Lines, Multilayered Dielectric Microstrip, Thin Film Microstrip (TFM), Valley Microstrip Lines, Microstrip Applications.

Microstrip Antenna Arrays: Array theory, Array calculations and analysis, array architectures, corporate array design, Resonant series fed array design, series fed traveling wave array design.

Microstrip discontinuities: Introduction of Quasi-Static Analysis and Characterization, Discontinuity Capacitance Evaluation, Discontinuity Inductance Evaluation, Characterization of Various Discontinuities, Planar Waveguide Analysis, Full wave Analysis of Discontinuities, Discontinuity Measurements.

Slotline: Introduction of Slotlines, Slotline Analysis, Design Considerations, Slotline Discontinuities, Slotline Transitions, Slotline Applications.

Coplanar lines and wave guides: Introduction of Coplanar Waveguide and Coplanar Strips, Quasi-Static Analysis, Design Considerations Losses, Effect of Tolerances, Comparison With Microstrip Line and Slotline, Transitions, Discontinuities in Coplanar Waveguide, Coplanar Line Circuits.

Coupled Microstrip lines: Introduction of Coupled Microstrip Lines, General Analysis of Coupled Lines, Characteristics of Coupled Microstrip Lines, Measurements on Coupled Microstrip Lines, Design Considerations for Coupled Microstrip Lines, Coupled Multi conductor Microstrip Lines, Discontinuities in Coupled Microstrip Lines.

Microstrip circuit design: impedance transformers, filters, isolators and phase shifters.

Laboratory

Circuit are designed by IE3D and HFSS ANSOFT software.

Recommended Books

1. *Gupta, K.C. and Garg, Ramesh, Microstrip lines and slot lines, Artech house (1996) 2nd ed.*
2. *Sainiti, Robert A., CAD of Microstrip Antenna for Wireless Applications, Artech House (1996).*
3. *Lu, Wong Kim, Planar antennas for Wireless applications, John Wiley and Sons (2003).*
4. *Simons, Rainee N., Coplanar Waveguide Circuits, Components, and Systems, John Wiley and Sons (2001).*

PEC321 ADVANCED OPTICAL TECHNOLOGIES

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): None

Specialty Fibers for Optical Communication: Introduction, Dispersion Compensation Fibers, Polarization Maintaining And Single Polarization Fibers, Nonlinear Fibers Double-Clad Fibers For Fiber Lasers And Amplifiers By Ovd, Microstructured Optical Fibers.

High-Speed Low-Chirp Semiconductor Lasers: Introduction, Fundamental Dc Properties of Long-Wavelength Qw Lasers, High-Speed Direct Modulation Of Strained Qw Lasers, Quantum Dot Lasers, Long-Wavelength Vcsels, Wavelength Integration And Control, Plasmonic Vcsels, Optical Signal Processing Based On Vcsel Technologies, And Vcsel-Based Slow Light Devices.

Telecom Optical Amplifiers: Power Photonics, single-mode fiber 980-NM pumps, Materials for 980-nm Pump Diodes, Optical Beam Narrow Stripe Technology, Output Power Scaling, Spectral Stability, Packaging, Failure Rate.

Ultra High-Speed Laser Modulation By Injection: Introduction, basic principle of oil, modulation properties of oil VCSELS, RF link gain enhancement of oil VCSELS, nonlinearity and dynamic range of oil VCSELS, applications, passive optical networks, metropolitan area networks, analog optical communications.

Recent Developments In High-Speed Optical Modulators: 1ntroduction, principles and mechanisms of external optical modulation, high-speed modulation, and modulators based on phase changes and interference, intensity modulators based on absorption changes, traveling-wave electroabsorption modulators (EAMS), high-efficiency modulators for 100 gb/s and beyond novel types of modulators.

Advances In Photodetectors: Waveguide Photodiodes, Balanced Receivers, High-Power Photodetectors, Avalanche Photodiodes.

Planar Lightwave Circuits In Fiber-Optic Communications: Introduction, Basic Waveguide Theory And Materials, Passive Optical Filtering, Demodulating, And Demultiplexing Devices, Inter-Signal Control Devices, Intra-Signal Control Devices.

Silicon Photonics: Introduction, Soi Wafer Technology, High-Index-Contrast Waveguide Types And Performance On Soi, Input–Output Coupling, Passive Waveguide Devices And Resonators, Active Modulation Silicon Photonics, Germanium Photodetectors And Photoreceivers For Integrated Silicon Photonics, Cmos Integration and Integated Silicon Photonics, Nonlinear Effects, Applications.

Microelectromechanical Systems For Lightwave Communication: Introduction, Optical Switches And Crossconnects, Wavelength-Selective MEMS Components, Transform Spectrometers, Diffractive Spectrometers And Spectral Synthesis, Tunable Lasers, Other Optical MEMS Devices, Emerging MEMS Technologies and Applications.

Recommended Books

1. *Kaminow, Ivan P., Li, Tingye, Willner, Alan E., Optical Fiber Telecommunications V.A., Components and Subsystems, Elsevier (2008).*
2. *Kaminow, Ivan P., Li, Tingye and Willner, Alan E., Optical Fiber Telecommunications V.B., Systems and Networks, Academic Press (2008) 5th ed.*
3. *Goleniewski, Lillian, Jarrett Kitty Wilson, Telecommunications Essentials: The Complete Global Source, 2nd Edition, Addison Wesley Professional (2006).*
4. *Lee, Chi H., Thompson and Brian J., Optical Science and Engineering, CRC (2007).*

PEC322 VIDEO AND IMAGE PROCESSING

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): None

Introduction: Digital image representation, fundamental steps in image processing, elements of digital image processing systems digitization.

Digital Image fundamentals: A Simple Image Model, Sampling and Quantization, Relationship between Pixel, Image Formats, Image Transforms.

Image Enhancement: Histogram processing, image subtraction, image averaging, smoothing filters, sharpening filters, enhancement in frequency and spatial domain, low pass filtering, high pass filtering.

Image Compression: Fundamentals, Image Compression Models, Elements of Information Theory, Error-Free Compression, Lossy Compression, Recent Image Compression Standards.

Video Fundamentals and Compression: Introduction to Digital Video, Spatial and Temporal Redundancy, Entropy Coding, Motion Estimation, I, B, P Pictures, Generic Inter-Frame Video Codec, Recent Video Compression Standards.

Recent Trends in Image and Video Coding: Video Surveillance, Video Coding for Broadcasting Applications, Content based Video Databases.

Recommended Books

1. *Gonzalez, R.C., and Woods, R.E., Digital Image Processing, Dorling Kingsley (2009) 3rd ed.*
2. *Jain A.K., Fundamentals of Digital Image Processing, Prentice Hall (2007).*
3. *`Tekalp A.M., Digital Video Processing, Prentice Hall (1995).*
4. *Ghanbari M., Standard Codecs: Image Compression to Advanced Video Coding, IET Press (2003).*
5. *Sonka M., Image Processing and Machine Vision, Prentice Hall (2007) 3rd ed.*
6. *Wang Y., Ostermann J., and Zhang Y., Video Processing and Communications, Prentice Hall (2001).*

PEC323 ERROR CODING THEORY

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): None

Introduction: Error Correcting codes, basic concepts, Block codes, Convolutional codes, Hamming distance, Hamming sphere, Error correcting capability,

Linear Block Codes: Introduction, Generator and Parity check matrices, Encoding and decoding of linear block codes, Weight distribution and error performance, Hard decision decoding of linear block codes, Hamming, Golay and Reed-Muller Codes, Binary cyclic codes, General decoding of cyclic codes, BCH codes, Polynomial codes, Decoding of binary BCH codes, Weight distribution and error performance, Non-binary BCH codes, Reed-Solomon (RS) codes, RS codes as polynomial codes, Encoding and Decoding of RS codes.

Binary Convolutional Codes: Introduction, Basic structure, Connections with block codes, Weight enumeration and performance bounds, Decoding with Viterbi algorithm, Maximum likelihood decoding and Hamming metrics, Implementation issues, Punctured convolutional codes, Modifying the codes, Different techniques, Combining codes, Product of codes, Concatenated codes.

Soft Decision Decoding: Binary transmission over AWGN channels, Viterbi algorithm with Euclidean distances, Decoding binary linear codes with a trellis, The Chase algorithm, Ordered Statistics decoding, Generalized minimum distance decoding, List decoding, Soft-output algorithms, Soft-output Viterbi algorithm, Maximum-a-posteriori algorithm, Msx-log-MAP algorithm, Soft-output OSD algorithm.

Iteratively Decodable Codes: Iterative decoding, Product codes, Serial Concatenation Codes, Parallel Concatenation codes, Turbo Codes, Log-likelihood ratio, Encoding and decoding of Turbo codes, Low density parity check (LDPC) codes, Tanner Graphs, The bit-flip algorithm, Belief propagation, Message passing, Trellis coded modulation, Mapping, Interleaving techniques.

Recommended Books

1. *Morelos-Zaragoza R.H., The Art of Error-Correcting Codes, John Wiley and Sons (2006) 2nd ed.*
2. *Neubauer A., Freudenberger J. and Kuhn V., Coding Theory: Algorithms, Architectures, and Applications, John Wiley and Sons (2007).*
3. *Pretzel, O., Error-correcting Codes and Finite Fields, St. Martins (2003).*
4. *Hamming, R.W., Coding and Information Theory, Prentice Hall (1992).*

PEC324 SPACETIME WIRELESS COMMUNICATION

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): PEC104 Antenna Systems
PEC202 Advanced Wireless Communications

Introduction: MIMO wireless communication, MIMO channel and signal model, A fundamental trade-off, MIMO transceiver design, MIMO in wireless networks, MIMO in wireless standards, Organization of the book and future challenges.

ST Propagation: Wireless channel, path loss, fading, scattering model in macrocells, channel as a ST random field, scattering functions, polarization and field diverse channels, antenna array topology, degenerate channels, reciprocity and its implications.

ST Channel and Signal Models: SISO channel, SIMO channel, MISO channel and MIMO channel, physical scattering model for ST channel, Extended channel models, Statistical properties of **H,** channel measurements and test channels, sampled signal model, ST multiuser and ST intereference channel, ST channel estimation.

Capacity of ST Channels; Capacity of frequency flat faded deterministic MIMO channels, channel unknown to transmitter, channel known to transmitter, capacity of random MIMO channels, Influence of Ricean fading, fading correlation XPD and degeneration on MIMO capacity, capacity of frequency selective MIMO channels.

Spatial Diversity: Diversity gain, receive antenna diversity, transmit antenna diversity, diversity order and channel variability, diversity performance in extended channels, combined space and path diversity, Indirect transmit diversity.

Capacity Limits of MIMO Systems: Mutual information and Shannon capacity, Single-user MIMO, Multi-user MIMO, Multi-cell MIMO, MIMO for ad hoc networks.

ST Coding without Channel Knowledge at Transmitter: coding and interleaving architecture, ST coding for flat added channels, ST coding for frequency selective channels.

Precoding Design: Transmit channel side information, Information-theoretic foundation for exploiting CSIT, A transmitter structure, Precoding design criteria, Linear precoder designs, Precoder performance results and discussion, Applications in practical systems.

ST Receivers: Receivers SISO, SIMO, MIMO, Iterative MIMO receivers, Reception of uncoded signals, Factor graphs and iterative processing, MIMO receivers for uncoded signals, MIMO receivers for coded signals, Some iterative receivers.

Exploiting Channel Knowledge at Transmitter: Linear pre-filtering, optimal pre filtering at maximum rate, optimal pre-filtering for error rate minimization, selection at transmitter, exploiting imperfect channel knowledge.

MIMO-Multiuser: MIMO MAC, MIMO BC, outage performance of MIMO-MU.

ST Co-Channel Interference Mitigation: CCI characteristics, Signal models, CCI mitigation on receive SIMO, CCI mitigating on receivers for MIMO, CCI mitigation on transmit for MISO, joint encoding and decoding.

Recommended Books

1. *Paulraj, Arogyaswami, Gore, Dhananjay and Nabar, Rohit, Introduction to Space-Time Wireless Communications, Cambridge University Press (2008).*
2. *Biglieri, Ezio, Calderbank, Robert, Constantinides, Anthony, Goldsmith, Andrea, Arogyaswami, Paulraj, and Poor, H. Vincent, MIMO Wireless Communications, Cambridge University Press (2007).*
3. *Oestges, Claude and Bruno Clerckx, MIMO Wireless Communications: From Real-World Propagation to Space-Time Code Design, AP Press (2009).*
4. *Bölcskei, H., ETH Zürich, Switzerland, Gesbert, D. and Papadias, C. B., Space-Time Wireless Systems: From Array Processing to MIMO Communications, Cambridge University Press (2008).*

PEC325 WIRELESS BROADBAND NETWORKS

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): PEC202 Advanced Wireless Communications

Review Basics of Probability, Random Variables, Random Processes, and Queueing Systems: Probability, Random Variables, Poisson Random Process, Birth-Death Processes, Basic Queueing Systems.

Enabling Technologies For Wireless Broadband Networks: Orthogonal Frequency-Division Multiplexing and Other Block-Based Transmissions: Block-based Transmissions, Orthogonal Frequency-Division Multiplexing Systems, Single-Carrier Cyclic Prefix Systems, OFDMA, IFDMA, SC-FDMA, CP-based CDMA Systems, Receiver Design.

Multi-Input, Multioutput Antenna Systems: MIMO System Model, Channel Capacity, Diversity, Diversity and Spatial Multiplexing Gain, SIMO Systems, MISO Systems, Space-Time Coding, MIMO Transceiver Design, SVD-Based Eigen-Beamforming, MIMO for Frequency-Selective Fading Channels, Cyclic Delay Diversity. Ultrawideband: Time-Hopping UltraWideband, Direct Sequence Ultrawideband, MultiBand, Other Types of UWB.

Routing Protocols For Multihop Wireless Broadband Networks: Multihop Wireless Broadband Networks: Mesh Networks, Importance of Routing Protocols,Routing Metrics, Classification of Routing Protocols, MANET Routing Protocols; Radio Resource Management for Wireless Broadband Networks:, Packet Scheduling, Admission Control. Quality of Service for Multimedia Services: Traffic Models, Quality of Service in Wireless Systems, Outage Probability for Video Services in a Multirate DS-CDMA System.

Modem Design: Basic Modulation Techniques, Theoretical Limits and Practical Impairments, Traditional Modems for Wide-Area Wireless Networks, Other Aspects of Modem Implementation. Broadband Modem Technologies: Effects of Frequency-Selective Multipath Fading, Discrete Multipath Fading Channel Model, Adaptive Discrete Matched Filter, Adaptive Equalization, Sectored Antennas, Multi-carrier, OFDM, and Frequency Diversity, MIMO in Frequency-Selective Fading.

Systems for Wireless Broadband Networks: Long-Term-Evolution Cellular Networks.: Network Architecture, Physical Layer, Avoidance MAC, Polling MAC, Reservation MAC, Energy-Efficient MAC, Multi-Channel MAC, Directional-Antenna MAC, MultiHop Saturated Throughput of IEEE 802.11 MAC, Mobility Resource Management: Types of Handoffs, Handoff Strategies, Channel Assignment Schemes, Location Management, Mobile IP, Cellular IP, HAWAII.. Radio Resource Management, Security, Quality of Service, Applications

Wireless Broadband Networking with WiMAX: WiMAX Overview, Competing Technologies, Overview of the Physical Layer, PMP Mode, Mesh Mode, Multihop Relay Mode.

Wireless Local Area Networks: Network Architectures, Physical Layer of IEEE 802.11n, Medium Access Control, Mobility Resource Management; Quality of Service, Applications.

Wireless Personal Area Networks: Network Architecture, Physical Layer, Medium Access Control, Mobility Resource Management, Routing, Quality of Service, Applications.

Convergence of Networks: GPP/WLAN Interworking, IEEE 802.11u Interworking with External Networks, LAN/WLAN/WiMax/3G Interworking Based on IEEE 802.21 Media-Independent Handoff, Future Cellular/WiMax/WLAN/WPAN Interworking, Analytical Model for Cellular/WLAN Interworking.

Recommended Books

1. *Wong, David T., Kong, Peng-Yong, Liang, Ying-Chang and Chua, Kee C., Wireless Broadband Networks, John Wiley and sons (2009).*
2. *Pahlavan, Kaveh and Levesque, Allen H., Wireless Information Networks, 2nd Edition, John Wiley and Sons (2005).*
3. *Goldsmith, Andrea, Wireless Communications, Cambridge University Press (2007).*
4. *Geier, Jim, Wireless Networks first-step, Cisco Press (2004).*

PEC326 OPTOELECTRONICS

L	T	P	Cr
3	0	0	3.0

Prerequisite(s): None

Light: Nature of light, Wave nature of light, Optical components, Light sources-blackbody radiation, Units of light.

Elements of solid-state physics: Review of some quantum mechanical concepts, Energy bands in solids, Electrical conductivity, semiconductors, carrier concentration, Work function, Excess carriers in semiconductors, junctions, and quantum well.

Modulation of light: Elliptical polarization, Birefringence, optical activity, Electro-optic effect, Kerr modulators, Scanning and switching, Magneto optic devices, Acousto-optic effect, Quantum well modulators, nonlinear optics.

Display Devices: Luminescence, Photoluminescence, Cathodoluminescence, Cathode ray tube, Electro luminescence, Injection luminescence and light emitting diodes, Plasma displays, Display brightness, LCD, Numeric displays.

Lasers: Emission and absorption of radiation, Einstein relations, Absorption of radiation, Population inversion, Optical feedback, Threshold conditions-laser losses, Line shape function, population inversion and pumping threshold conditions, Laser modes, Classes of Laser, Single mode operation, Frequency stabilization, Mode locking, Q switching, Laser applications, Measurement of distance, Holography, High energy applications of lasers.

Photo detectors: Detector performance parameters, Thermal detectors, Photon devices.

Fiber Optical Waveguides: Total internal reflection, Planar dielectric waveguide, Optical fiber waveguide, Losses in fibers, Optical fiber connectors, Measurement of fiber characteristics, Fiber material and manufacture, Fiber cables.

Optical Communication Systems: Modulation schemes, Free space communication, Fiber optical communication systems, Integrated optics.

Non-Communications Applications of fibers: Optical fiber sensors, Light guiding fibers.

Recommended Books

1. *Wilson, John and Hawkes, John, Optoelectronics: An Introduction, Prentice Hall (2003) 2nd ed.*
2. *Kasap, S.O., Optoelectronics and Photonics: Principles and Practices, Prentice Hall (2001).*
3. *Keiser, G, Optical Fiber Communication, Tata McGraw Hill (2007).*
4. *Senior, John M., Optical Fiber Communication, Dorling Kindersley (2008) 2nd ed.*

PEC331 IP OVER WDM

L	T	P	Cr
3	1	2	4.5

Prerequisite(s): None

Protocol Design Concepts: Capacity, Interface Speeds, and Protocols, TCP/IP, and the Network Layer, Protocols and Layering , Internet Protocol Design: The End-to-End Principle, Transport Layer and TCP, Service Models at the Transport Layer, UDP and Connectionless Transport, TCP and Connection-Oriented Transport, Network Layer, Network Service Models, Internet Protocol and Fragmentation/Reassembly, Routing in the Internet, Asynchronous Transfer Mode, IP over ATM , IP Switching, QoS, Integrated Services, and Differentiated Services, Integrated Services and RSVP, Differentiated Services, Multiprotocol Label Switching, Labels, Route Selection.

Electro-optic and Wavelength Conversion: Enabling Technologies, Wavelength-Converter Design, Wavelength-Convertible Switch Design, Network Design, Control, and Management Issues, Network Design, Network Control, Network Management.

Terabit Switching and Routing Network Elements: Transparent Terabit Switching and Routing, Opaque Terabit Switching and Routing, Modular Structure and Greater Granularity, Scalability, Multiple Protocol Interfaces, Architectures and Functionalities, Buffering Scheme, Switching Fabric, IP-Based IPI and OPI, IP-Based Electronic Controller, Multiprotocol Label Switching.

Optical Network Engineering: Optical Network Architecture, Optical Network and Traffic Engineering, Routing and Wavelength Assignment, Optical Network Design and Capacity Planning, Physical Topology Design, Virtual Topology Design, Design of Survivable Optical Networks, Dynamic Light path Provisioning and Restoration, Route Computation, Wavelength Assignment, Performance of Dynamic RWA Algorithms, Control Plane Issues and Standardization Activities.

Traffic Management for IP-over-WDM Networks: Network Scenario, Traffic Management in IP Networks, Self-Similarity, Demand Analysis, Connection-Level Analysis, IP Traffic Management in IP-over-WDM Network, End-to-End Issues, Performance Evaluation of File Transfer (WWW), Services over WDM Networks.

IP- and Wavelength-Routing Networks: Internet Protocol and Routing, Routing in Datagram Network, Wavelength-Routing Networks, Layered Graph Approach for RWA, VWP Approach for Design of WDM Networks, MPLS/MPlS/GMPLS, IP-over-WDM Integration, Interconnection Models, Integrated Dynamic IP and Wavelength Routing, Network Model, Waveband Routing in Optical Networks, Additional Issues in Optical Routing.

Internetworking Optical Internet and Optical Burst Switching: Overview of Optical Burst Switching, QoS Provisioning with OBS, Survivability Issue in OBS Network, IP-over-WDM Control and Signaling, Network Control, Engineering Control Plane, MPlS/GMPLS Control Plane for Optical Networks, Signaling Protocol, Optical Internetworking and Signaling, Across the Network Boundary, Sample IP-Centric Control Plane for Optical Networks.

Survivability in IP-over-WDM Networks: IP-over-WDM Architecture, Survivability Strategies, Survivable Routing Algorithms, Survivability Layer Considerations, Fault Detection and Notification, Signaling Protocol Mechanism, Survivability in Future IP-over-Optical Networks.

Optical Internetworking Models and Standards Directions: Intelligent Optical Network, Internetworking Models to Support, Optical Layer Intelligence, Overlay Model, Static Overlay Model, Dynamic Overlay Model, Peer Model, Optical Internetworking and Ethernet Standards, Gigabit Ethernet.

Laboratory Work

System design and performance analysis using simulation tools.

Recommended Books

1. *Liu, Kelvin H., IP Over WDM, Wiley (2002).*
2. *Dixit, Sudhir, IP over WDM: Building the Next Generation Optical Internet, Wiley Interscience (2003).*
3. *Serrat, Joan and Galis, Alex, Deploying and Managing IP over WDM networks, Artech House (2003).*

PEC332 ADAPTIVE SIGNAL PROCESSING

L	T	P	Cr
3	1	2	4.5

Prerequisite(s): PEC101 Discrete Time Signal Processing,
PEC103 Information and Communication Theory

Signals and Systems: System theory, stochastic processes Gauss Markov model, Representation of stochastic processes, likelihood and sufficiency, Hypothesis testing, decision criteria, multiple measurements.

Estimation Theory: Estimation of parameters, random parameters, Bayes Estimates, estimation of non random parameters, properties of estimators, Linear Estimation of signals, prediction, filtering, smoothing, correlation cancellation, Power Spectrum Estimation-Parametric and Maximum Entropy Methods.

Estimation of Waveforms: Linear, MMSE estimation of waveforms, estimation of stationary processes: Wiener filter, Estimation of non stationary processes: Kalman filter, Non linear estimation.

Prediction: Forward and backward linear prediction, Levinson-Durben algorithm, Schurr algorithm, properties of linear prediction error filters, AR- Lattice and ARMA Lattice Ladder filters, Wiener filters for prediction.

System Modeling and Identification: System identification based on FIR (MA), All Pole (AR), Pole Zero (ARMA) system models, Least square linear prediction filter, FIR least squares inverse filter, predictive de convolution, Matrix formulation for least squares estimation: Cholesky decomposition, LDU decomposition, QRD decomposition, Grahm - Schmidt orthogonalization, Givens rotation, Householder reflection, SVD.

Adaptive Filtering: Least square method for tapped-delay line structures. Least Mean Squares (LMS) and Recursive Least Squares (RLS) algorithms and their convergence performance, IIR adaptive filtering and Transform domain adaptive filtering, introduction of different types of LMS, RLS and Kalman filters and their relationship with each other.

Adaptive Equalization: Optimal Zero-Forcing and MMSE Equalization, Generalized Equalization Methods, Fractionally Spaced Equalizer, Transversal Filter Equalizers, ISI and ADFE and Error Propagation.

Nonstationary Signal Analysis: Time frequency analysis, Cohen class distribution, Wigner-Ville Distribution, Wavelet Analysis.

Applications: Noise and echo cancellation, Parameters estimation in Radar systems, Dynamic target tracking, Application to pattern classification and system identification, channel identification and equalization, Generalized inverses, regularization of ill-posed problems. Interpolation and approximation by least squares and minimax error criteria, Optimization techniques for linear and nonlinear problems, Model order selection, MUSIC, ESPRIT algorithms, Signal Analysis with Higher order Spectra, array processing, Beam forming, time-delay estimation, successive and parallel interference cancellers.

Laboratory Work

Practicals based upon hardware using communication kits and simulation with the help of simulation packages.

Recommended Books

1. *Haykin, Simon S., Adaptive filter theory, Dorling Kingsley (2008).*
2. *Honig, Michael L., David G., Messerschmitt, Adaptive Filters: Structures Algorithms and Applications, Springer (1984).*
3. *Trees, Harry L. Van, Optimum Array Processing, Detection, Estimation, and Modulation Theory, Part IV, John Wiley and Sons (2002).*
4. *Adams, Peter F., Cowan, Colin F. N. and Grant, Peter M., Adaptive Filters, Prentice-Hall (1985).*
5. *Sayeed, Zulfiquar, Adaptive Coding and Transmitter Diversity for Slow Fading Channels, University of Pennsylvania (1996).*

PEC333 WIRELESS SENSOR NETWORKS

L	T	P	Cr
3	1	2	4.5

Prerequisite(s): PEC104 Antenna Systems
PEC202 Advanced Wireless Communications

Introduction: The vision of Ambient Intelligence., Application examples, Types of applications, Challenges for WSNs, Why are sensor networks different?, Enabling technologies.

ARCHITECTURES

Single Node Architecture: Hardware components, Energy consumption of sensor nodes, Operating systems and execution environments, Some examples of sensor nodes, Conclusion.

Network Architecture: Sensor network scenarios, Optimization goals and figures of merit, Design principles for WSNs, Service interfaces of WSNs, Gateway concepts, Conclusion.

COMMUNICATION PROTOCOLS

Physical Layer: Introduction, Wireless channel and communication fundamentals, Physical layer and transceiver design considerations in WSNs.

MAC Protocols: Fundamentals of (wireless) MAC protocols, Low duty cycle protocols and wakeup concepts, Contention-based protocols, Schedule-based protocols, The IEEE 802.15.4 MAC protocol, How about IEEE 802.11 and Bluetooth.

Link Layer Protocols: Fundamentals: Tasks and requirements, Error control, Framing, Link management, Summary.

Naming and Addressing: Fundamentals, Address and name management in wireless sensor networks, Assignment of MAC addresses, Distributed assignment of locally unique addresses, Content-based and geographic addressing.

Time Synchronization: Introduction to the time synchronization problem, Protocols based on sender/receiver synchronization, Protocols based on receiver/receiver synchronization,

Localization and Positioning: Properties of positioning, Possible approaches, Mathematical basics for the lateration problem, Single-hop localization, Positioning in multi-hop environments, Impact of anchor placement.

Topology Control: Motivation and basic ideas, Flat network topologies, Hierarchical networks by dominating sets, Hierarchical networks by clustering, Combining hierarchical topologies and power control, Adaptive node activity.

Routing Protocols: The many faces of forwarding and routing, Geometric routing, Routing with virtual coordinates, Gossiping and agent-based unicast forwarding, Energy-efficient unicast, Broadcast and multicast, Geographic routing, Mobile nodes.

Data-Centric and Content-based Networking: Introduction, Data-centric routing, Data aggregation, Data-centric storage, Conclusions.

Transport Layer and Quality of Service: The transport layer and QoS in wireless sensor networks, Coverage and deployment, Reliable data transport, Block delivery, Congestion control and rate control.

Advanced Application Support: Advanced in-network processing, Security, Application-specific support.

Laboratory Work

Experiments related to wireless sensor networks.

Recommended Books

1. *Karl, Holger and Andreas, Willig, Protocols and Architectures for Wireless Sensor Networks, John Wiley and sons (2005).*
2. *Xiaoyan, Cheng Maggie and Li, Deying, Advances in Wireless Ad Hoc and Sensor Networks Series, Springer (2008).*
3. *Sohraby, Kazem, Minoli, Daniel and Taieb Znati, Wireless Sensor Networks: Technology, Protocols, and Applications, John Wiley and Sons (2007).*
4. *Swami, Ananthram, Qing, Zhao, Hong, Yao-Win, and Lang Tong (editors), Wireless Sensor Networks: Signal Processing and Communications, Wiley (2007).*
5. *Rappaport, T.S., Wireless Communications, Prentice hall of India (2003) 2nd ed.*
6. *Jun, Zheng and Jamalipour, Abbas, Wireless Sensor Networks: A Networking Perspective, Wiley-IEEE Press (2009).*

PEC334 SPACETIME CODING FOR WIRELESS COMMUNICATION

L	T	P	Cr
3	1	2	4.5

Prerequisite(s): PEC104 Antenna Systems
PEC202 Advanced Wireless Communications,

MIMO Information Theory: Entropy and Mutual Information, Capacity of the MIMO Channel, Channel Capacity for Informed Transmitters, Erogodic Channel Capacity The Ratio Between IT and UT Channel Capacities, Outage Capacity.

Performance Limits Of Multiple-Input Multiple-Output Wire Less Communication Systems: MIMO System Model, MIMO System Capacity Derivation, Capacity of MIMO Systems with Random Channel Coefficients Channels, Effect of System Parameters and Antenna Correlation on the Capacity of MIMO Channels, Correlation Model for LOS MIMO Channels, MIMO Correlation Fading The Effect of System Parameters on the Keyhole Propagation.

Space-Time Coding Performance Analysis And Code Design: Space-Time Coded Systems, Performance Analysis of Space-Time Codes, Error Probability on Slow and fast Fading Channels, Space-Time Code Design Criteria, Code Design Criteria for Slow and Fast Rayleigh Fading Channels, Code Performance at Low to Medium SNR Ranges.

Space-Time Block Codes: Alamouti Space-Time Code with Multiple Receive Antennas, Space-Time Block Codes (STBC), STBC for Real Signal Constellations, STBC for Complex Signal Constellations, Decoding of STBC, Performance of STBC, Effect of Imperfect Channel Estimation and Antenna Correlation on Performance.

Space-Time Trellis Codes: Encoder Structure for STTC, Generator Description, Optimal STTC Based on the Rank, Determinant and Trace Criterion, Performance Comparison for Codes Based on Different Design Criteria, The Effect of Imperfect Channel Estimation on Code Performance, Design of Space-Time Trellis Codes on Fast Fading Channels, Construction of Recursive STTC, Space-Time Turbo Trellis Codes, Comparison of ST TurboTC and STTC, Effect of Memory Order and Interleaver Size, Decoder EXIT Charts Effect of Interleaver Type.

Layered Space-Time Codes: LST Transmitters, LST Receivers, QR Decomposition Interference Minimum Mean Square Error (MMSE) Suppression Combined with Interference Cancellation, Iterative LST Receivers, An Iterative Receiver with PIC, An Iterative MMSE Receiver, Comparison of the Iterative MMSE and the Iterative PIC-DSC Receiver, Comparison of Various LST Architectures and HLST Architectures with Various Component Codes.

Differential Space-Time Block Codes: Differential Encoding, Differential Decoding, Differential STBC with Real Signal Constellations for one, two, Three and Four Transmit Antennas, Differential STBC with Complex Signal Constellations for Three and Four Transmit Antennas, Unitary Space-Time Modulation, Unitary Group Codes.

Space-Time Coding For Wideband Systems: STC in Wideband OFDM Systems, Capacity of STC-OFDM Systems, Performance of Concatenated Space-Time Codes Over OFDM Systems, Concatenated RS-STC, Concatenated CONV-STC and ST Turbo TC over OFDM Systems, Time-Switched Orthogonal Transmit Diversity (TS-OTD), Space-Time Spreading (STS), STS for

Three and Four Antennas, Space-Time Coding for CDMA Systems, Space-Time Matched Filter Detector, Space-Time MMSE Multiuser Detector, Space-Time Iterative MMSE Detector, Performance of Layered STC in CDMA Systems.

Space-Time Coding For Informed Transmitters: Information Theoretical Considerations, STBC with Linear Precoding, Quantized Feedback and Diversity, Linear Precoding for Known Fading Statistics, OSTBC with One-Bit Feedback for $nt = 2$.

Space-Time Coding In a Multiuser Environment: Statistical Properties of Multiuser Interference, OSTBC and Multiuser Interference, The Algebraic Structure of OSTBC, Suppression of Multiuser Interference in an OSTBC System.

Laboratory Work

Matlab related simulation experiments.

Recommended Books

1. *Larsson, Erik G. and Petre Stoica, Space-Time Block Coding for Wireless Communications, Cambridge University Press (2008).*
2. *David, Tse and Viswanath, Pramod, Fundamentals of Wireless Communication, Cambridge University Press (2006).*
3. *Fitzek, Frank H.P., Katz and Marcos D., Cooperation in Wireless Networks: Principles and Applications, Springer (2007) 2nd ed.*
4. *Arogyaswami., Paulraj, Gore, Dhananjay and Nabar, Rohit., Introduction to Space-Time Wireless Communications, Cambridge University Press (2008).*

PEC335 NEXT GENERATION WIRELESS SYSTEMS AND NETWORKS

L	T	P	Cr
3	1	2	4.5

Prerequisite(s): PEC105 Advanced Communication Systems
PEC202 Advanced Wireless Communications

Review: Background Knowledge, 3GMobile Cellular Standards, Wireless Networking, B3G and Emerging Wireless Technologies.

Fundamentals of Wireless Communications: Theory of Radio Communication Channels, Spread Spectrum Techniques, Multiple Access Technologies, Multiple User Signal Processing, OSI Reference Model, Switching Techniques, IP-Based Networking.

3G Mobile Cellular Technologies: CDMA2000, WCDMA, TD-SCDMA.

Wireless Data Networks: IEEE 802.11 Standards for Wireless Networks, IEEE 802.11a Supplement to 802.11 Standards, IEEE 802.11 Security, IEEE 802.15 WPAN Standards, IEEE 802.16 WMAN Standards, ETSI HIPERLAN and ETSI HIPERLAN/2 Standards, MMAC by Japan, Bluetooth Technologies.

All-IP Wireless Networking: Some Notes on 1G/2G/3G/4G Terminology, Mobile IP, IPv6 versus IPv4, Mobile IPv6, Wireless Application Protocol (WAP), IP on Mobile Ad Hoc Networks. All-IP Routing Protocols.

Architecture of B3G Wireless Systems: Spectrum Allocation and Wireless Transmission Issues, Integration ofWMAN/WLAN/WPAN andMobile Cellular, High-Speed Data, Multimode and Reconfigurable Platforms, Adhoc Mobile Networking, Networking Plan Issues, Satellite Systems in B3G Wireless, Other Challenging Issues.

Multiple Access Technologies for B3G Wireless: What B3GWireless A Feature Topic on B3GWireless, Next-Generation CDMA Technologies, Multicarrier CDMA Techniques, OFDM Techniques, Ultra-Wideband Technologies.

MIMO Systems: SIMO, MISO, and MIMO Systems, Spatial Diversity in MIMO Systems, Spacial Multiplexing in MIMO Systems, STBC-CDMA Systems, Generic STBC-CDMA System Model, Unitary Codes Based STBC-CDMA System, Complementary Coded STBC-CDMA System.
Cognitive Radio Technology: Why Cognitive Radio, History of Cognitive Radio, SDR to Cognitive Radio, Cognitive Radio for WPANs, Cognitive Radio for WLANs, Cognitive Radio for WMANs, Cognitive Radio for WWANs, Cognitive Radio for WRANs: IEEE 802.22, Challenges to Implement Cognitive Radio, Cognitive Radio Products and Applications.

E-UTRAN: 3GPP's Evolutional Path to 4G: 3GPP TSG for E-UTRAN, Origin of E-UTRAN, General Features of E-UTRAN, E-UTRAN Study Items, E-UTRAN TSGWork Plan, E-UTRAN Radio Interface Protocols, E-UTRAN Physical Layer Aspects.

Laboratory Work
Matlab related simulation experiments.

Recommended Books

1. *Chen, Hsiao-Hwa and Mohsen Guizani, Next Generation Wireless Systems and Networks John Wiley and sons (2006).*
2. *Wong, David T., Kong, Peng-Yong, Ying-Chang Liang and Chua, Kee C., Wireless Broadband networks, John Wiley and sons (2009).*
3. *Kaveh, Pahlavan and Levesque, Allen H., Wireless Information Networks, 2nd Edition, John Wiley and Sons (2005).*
4. *Glisic, Savo G., Advanced Wireless Networks: 4G Technologies, John Wiley and Sons (2006).*

PEC-336 DIGITAL SIGNAL PROCESSORS

L	T	P	Cr
3	1	2	4.5

Prerequisite(s): PEC-101 Discrete Time Signal Processing

An Introduction to DSP Processors: Advantages of DSP, characteristics of DSP systems, classes of DSP applications, DSP processor embodiment and alternatives, Fixed Vs Floating point processors, fixed point and Floating point Data Paths.

DSP Architecture: An introduction to Harvard Architecture, Differentiation between Von-Neumann and Harvard Architecture, Quantization and finite word length effects, Bus Structure, Central Processing Unit, ALU, Accumulators, Barrel Shifters, MAC unit, compare, select, and store unit (CSSU), data addressing and program memory addressing.

Memory Architecture: Memory structures, features for reducing memory access required, wait states, external memory interfaces, memory mapping, data memory, program memory and I/O memory, memory mapped registers.

Addressing: Various addressing modes - implied addressing, immediate data addressing, memory direct addressing, register direct and indirect addressing, and short addressing modes. **Instruction Set:** Instruction types, various types registers, orthogonality, assembly language and application development.

Execution Control and Pipelining: Hardware looping, interrupts, stacks, pipelining and performance, pipelining depth, interlocking, branching effects, interrupt effects, instruction pipelining.

Peripherals: Serial ports, timers, parallel ports, bit I/O port, host ports, communication ports, on-chip A/D and D/A converters, external interrupts, on chip debugging facilities, power consumption and management.

Processors: Architecture and instruction set of TMS320C3X, TMS320C5X, TMS320C6X, ADSP 21XX DSP Chips, some example programs.
Recent Trends in DSP System Design: FPGA-Based DSP System Design, advanced development tools for FPGA, Development tools for Programmable DSPs, An introduction to Code Composer Studio.

Laboratory Work

Introduction to code composer studio, Using CCS write program to compute factorial, dot product of two arrays, Generate Sine, Square and Ramp wave of varying frequency and amplitude, Design various FIR and IIR filters, Interfacing of LED, LCD, Audio and Video Devices with the DSP processor.

Recommended Books

1. *Lapsley, P., Bier, J., Shoham, A. and Lee, E.A., DSP Processor Fundamentals: Architecture and Features, IEEE Press Series on Signal Processing, IEEE (2000).*
2. *Venkataramani, B. and Bhaskar, M., Digital Signal Processor: Architecture, Programming and Applications, Tata McGraw Hill (2003).*

3. *Padmanabhan, K., Ananthi, S. and Vijayarajeswaran, R., A practical Approach to Digital Signal Processing, New Age International Pvt. Ltd (2001).*
4. *TI DSP reference set (www.ti.com).*
5. *Babast, J., Digital Signal Processing Applications using the ADSP-2100 family, PHI (1992).*