Course Structure: Communication System Engineering

Date: 2nd November 2016

Course Curriculum: Semester I

Sl. No.		Course Number	Course Title	L	T	P	C
1	Core	EE530	Advanced Digital Communication	3	0	0	6
2		EE534	Wireless Communications	3	0	0	6
3		EE532	Optical Communication	3	0	0	6
4	Elective	EE5XX	Elective-I	3	0	0	6
5		EE5XX	Elective-II	3	0	0	6
6		EE541	Communication System Engineering Lab – I	0	0	3	3
7		HS5XX	HSS Elective	2	0	0	4
Total				15	0	7	37

Course Curriculum: Semester II

Sl. No.		Course Number	Course Title	L	T	P	C
1	Core	EE560	Information Theory and Coding	3	0	0	6
2		EE535	Communication Networks	3	0	0	6
3	Elective	EE5XX	Elective-I	3	0	0	6
4		EE5XX	Elective-II	3	0	0	6
5		EE5XX	Elective-III	3	0	0	6
6		EE542	Communication System Engineering Lab – II	0	0	3	3
7		EE591	Seminar	0	0	0	4
Total				15	0	7	37

Course Curriculum: Semester III

Sl. No.	Course Number	Course Title	L	T	P	C
1	EE595	Project Part-I				24
Total						24

Course Curriculum: Semester IV

Sl. No.	Course Number	Course Title	L	T	P	C
1	EE596	Project Part-II				24
Total						24

Total Credit: 37+37+24+24=122

Elective Courses

1. Semester-I

1. EE540 Radio Frequency Integrated Circuits
2. EE520 Advanced Digital Signal Processing
3. EE537 Optical Networks
4. EE563 VLSI Architectural Design and Implementation
5. EE564 Teletraffic Engineering
6. EE538 Satellite Communication
7. EE525 Digital Image Processing

+ Relevant Electives from Other/EE Departments

Elective Courses

2. Semester-II

1. EE522 Multi-rate Signal Processing
2. EE521 Statistical Signal Processing for Communication
3. EE561 Antenna Theory and Design
4. EE562 Embedded Computing Systems and Interfacing
5. EE539 Multimedia Communication
6. EE508 Intelligent Visual Surveillance Systems
7. EE524 Random Process and Estimation Theory
8. EE526 Digital Video Processing
9. EE527 Pattern Recognition and Applications
10. EE565 Telecommunication Management
11. EE523 Advanced Bio-Medical Signal Processing

+ Relevant Electives from Other/EE Departments

Laboratory

1. Semester-I

EE541 Communication System Engineering Lab – I

Areas includes

a. Digital Communication
b. Wireless Communication
c. VLSI systems
d. Digital Signal Processing
e. RF Integrated Circuit

2. Semester –II

EE542 Communication System Engineering Lab – II

Areas includes

a. Digital Communication
b. Wireless Communication
c. Networking
d. Embedded Systems
e. Digital Signal Processing
f. Optical Communication

Course Details:

EE530 ADVANCED DIGITAL COMMUNICATION 3 0 0 6

Mathematical Preliminaries. Communication Channel Models. Channel capacity. Source Coding: Fixed and Variable Length Codes, Kraft Inequality, Huffman Algorithm. Deterministic and Random Signal: Bandpass & Lowpass Signals, Signal Space Concepts, Orthogonal Representation of Signals, Gram-Schmidt Procedure. Digital Modulation Schemes: Binary and Advanced Digital Modulation: CPFSK, GMSK, QPSK/DQPSK/M-ary QAM. Optimum Receiver in Presence of Additive White Gaussian Noise: Coherent versus Non-coherent Detection, Binary Signal Detection in AWGN, M-ary Signal Detection in AWGN. Receiver Synchronization. Channel Coding: Linear Block Codes, Cyclic Codes, Convolutional Codes, Turbo and LDPC codes, Trellis Based Codes: Viterbi Decoding. Adaptive Equalization: LMS, MLSD, Kalman Filter, Blind Equalization. Spread Spectrum Communication: Direct Sequence Spread Spectrum Signals, Frequency-Hopped Spread Spectrum Signals. Multichannel Digital Communication: Orthogonal Frequency Division Multiplexing. Concepts of Multiuser Communication and Multiple Antenna Systems: CDMA, MIMO, Multiuser MIMO systems.

Texts/References:

1. J. G. Proakis, M. Salehi, Digital Communications, McGraw Hill, 5th Edition, 2008.
2. R. G. Gallager, Principles of Digital Communication, Cambridge University Press, 2009
3. P. B Crilly, A. B. Carlson, Communication Systems, Tata McGraw-Hill Education, 5th Edition, 2011.
4. U. Madhow, Fundamentals of Digital Communication, Cambridge University Press, 2008
5. S. Haykin, Digital Communications, Wiley-India, 2011
6. J.M Wozencraft, I.M. Jacobs, Principles of Communication Engineering, John Wiley, 1965.
7. I. A. Glover, P. M. Grant, Digital Communications, Pearson, 5th Impression, 2012.
8. P. Z. Peeples, Digital Communication Systems, Prentice Hall International, 1987.

EE534 WIRELESS COMMUNICATION 3 0 0 6

Random Signal Theory: Joint Probability, Statistical independence, Cumulative Distribution function and Probability Density function, Error function, Rayleigh and Gaussian Probability Density, Stationary and Ergodic Process, Power Spectral Density of digital data.

Base band Data Transmission: Base band Signal receiver, Probability of error, Optimum filter, Matched filter, Coherent reception, ISI and Turbo Equalization. Digital Modulation Techniques: Performance Analysis of BPSK, DPSK, QPSK, Mary PSK, BFSK, M-ary FSK, MSK, QAM, OFDM for wireless transmission.

Propagation & Fading: Propagation path loss, Free-space propagation model, Outdoor propagation models (Okumura model & Hata model), Indoor propagation models (Partition Losses in the same floor and between floors), Multipath fading, time dispersive and frequency dispersive channels, delay spread and coherence bandwidth, LCR and ADF.

Mobile Radio Interferences & System Capacity: Co-channel Interference and System Capacity, Channel planning for Wireless Systems, Adjacent channel interferences, Power control for reducing interference, Inter-symbol Interference; The Cellular Concept: Frequency Assignment and Channel Assignment, Frequency Reuse, Handoff, Sectoring, Microcell zone, Spectral efficiency,

Multiple Access techniques: FDMA, TDMA, CDMA, OFDMA, OFDM-CDMA, MIMO-OFDM and QOS issues.

Multiuser Detection: Linear and Non-Linear Multiuser Detectors, BER Analysis, Turbo Multiuser Receiver, Iterative Interference Cancellation, Capacity Analysis, BER Analysis, Multiuser Detection for 4G wireless Systems.

Texts/References:

1. D. Tse, P. Viswanath, Fundamentals of Wireless Communications, Cambridge Press, (2005)
2. G. L. Stuber, Principles of Mobile Communication, Kluwer Acdemic, (1996)
3. J. G. Proakis, Digital Communications, McGraw-Hill, (1995)
4. T. S. Rappaport, Wireless Communications: Principles and Practice, Prentice Hall, (1996)
5. A. J. Viterbi, CDMA Systems: Principles of Spread Spectrum Communication, Addison Wesley, (1995)
6. S. Verdu, Multiuser Detection, Cambridge University Press, (1998)
7. H. Wymeersch, Iterative Receiver Design, Cambridge University Press, (2007)

EE532 OPTICAL COMMUNICATION 3 0 0 6

Optical Fiber Characteristics: Loss, Group velocity dispersion (GVD) (2nd order GVD and 3rd order GVD), Polarization mode dispersion. Fiber Nonlinearity: Self phase modulation (SPM). Pulse Propagation through Optical Fiber: Nonlinear Schrödinger equation, split step Fourier method. Optical Sources and Detectors: LED, LD, DFB-laser, PIN photodetector, APD. Multiplexing Techniques: WDM, OFDM, Optical CDMA. Optical System Performance Metrics: Eye opening penalty, Q, BER, OSNR. Link Analysis: Single channel point to point, WDM point-to-point. Nonlinearity in WDM and High Bit Rate Systems: XPM, FWM, IFWM, IXPM. Optical Amplifier: Erbium doped fiber amplifier, Semiconductor optical amplifier (SOA), Stimulated Raman scattering, Stimulated

Brillouin scattering, Distributed Raman amplifier (DRA). Optically Amplified Systems. Active and Passive Optical Components and Sub-Systems: Coupler, MUX/DEMUX, OADM, ROADM, Filter, FBG, CFBG, MZI, EAM, AWG, DGE, GVD and PMD equalizer, Wavelength converter, Power equalizer, 2R and 3R all-optical regenerator, Optical switches, Nonlinear optical loop mirror (NOLM). Dispersion and Nonlinearity Management: Dispersion map, Advanced modulation formats, Optical equalization, Electronic equalization, Error correction codes, Optical phase conjugation, Coherent detection. Optical Network Design Strategies based on Physical Parameters. Passive Optical Network (PON): Structure, Components. Introduction on Silicon on Insulator: Passive and Active devices.

Texts/References:

1. Rajiv Ramaswami, Kumar N. Sivarajan, Galen Hajime Sasaki, Optical Networks: A Practical Perspective, Elsevier direct, 2009.
2. Govind P. Agrawal, Nonlinear fiber optics, 4th Edition, Academic Press.
3. Govind P. Agrawal, Fiber-optic communication systems, 3rd Edition, Wiley India Pvt Ltd, 2007.
4. Milorad Cvijetic, Optical transmission systems engineering, Artech House Publishers, 2004.
5. Ashwin Gumaste, Tony Antony, DWDM network designs and engineering solutions, Cisco Press, 2002.
6. Pallab Bhattacharya, Semiconductor optoelectronic devices, 2nd Edition, Phi Learning.

Further Reading:

1. Raman Kashyap, Fiber Bragg gratings, Academic Press, 1999.
2. Takanori Ōkoshi, Kazurō Kikuchi, Coherent optical fiber communications, Springer, 2001.
3. Keang-Po Ho, Phase-modulated optical communication systems, Springer, 2005.
4. Cedric F. Lam, Passive optical networks: principles and practice, Academic Press, 2007.
5. Graham T. Reed, Andrew P. Knights, Silicon photonics: an introduction, Wiley, 2004.
6. Mohammed N. Islam, Raman amplifiers for telecommunications, Springer, 2003.
7. Emmanuel Desurvire, Erbium-doped fiber amplifiers: principles and applications, Wiley-Interscience, 2002.
8. Michael J. Connelly, Semiconductor optical amplifiers, Springer, 2002.
9. Paras N. Prasad, Nanophotonics, Wiley-Interscience, 2004.
10. Sergey V. Gaponenko, Introduction to Nanophotonics, Cambridge University Press, 2010.
11. William Shieh, Ivan Djordjevic, OFDM for optical communications, Academic Press, 2009.

EE560 **INFORMATION THEORY AND CODING** **3 0 0 6**

The concept of Amount of Information, Average Information, Entropy, Information rate, Shannon's Theorem, Channel Capacity, Capacity of a Gaussian Channel, Bandwidth- S/N Trade-off. Channel Capacity & Coding: Introduction to Channel Capacity & Coding, Channel Models, Channel Capacity Theorem, Shannon Limit.

Error Control Coding: Introduction, Forward & Backward error Correction, Hamming Weight and Hamming Distance, Linear Block Codes, Encoding and decoding of Linear Block-codes, Parity Check Matrix, Syndrome Decoding, Hamming Codes.

Cyclic Codes: Introduction, Method for generating Cyclic Codes, Matrix description of Cyclic codes, Burst error correction, Cyclic redundancy check (CRC) codes, Circuit implementation of cyclic codes.

Convolutional and Turbo Codes: Introduction, Polynomial description of Convolutional Codes, Generating function, Matrix description of Convolutional Codes, Viterbi Decoding of Convolutional codes, Turbo Codes, Turbo Encoder and Decoder.

Introduction to Image Compression, The JPEG standard for lossless and Lossy Image Compression & Decompression, Video Compression and Transmission Standards for Wireless Channels.

Texts/References:

1. R. Bose, Information Theory and applications, 2nd Edition, TMH, (2008)
2. J. G. Proakis, Digital Communications, McGraw-Hill, (1995)
3. D. Tse, P. Viswanath, Fundamentals of Wireless Communications, Cambridge Press, (2005)

EE535 **COMMUNICATION NETWORKS** **3 0 0 6**

Introduction; Protocol hierarchies: OSI and TCP/IP reference models; Physical layer: Transmission media and topology, circuit switching and packet switching, Telephone network; Data link layer: Framing, error control, simplex stop and wait, sliding window protocol, SONET/SDH, ISDN switches, Medium access protocols: Aloha, slotted aloha, CSMA, CSMA CD, and collision - free protocols, FDDI, token ring, wireless LAN protocol, IEEE standard 802 for LANs and MANs, Bridges, Network layer: Routing algorithms, IP protocol, ICMP, ARP, RARP, Mobile IP; Transport layer: Establishing and releasing connection, TCP and UDP, Sockets interface, sockets programming; Application Layer: SNMP, Authentication, Encryption, electronic mail, WWW; Admission control in Internet, Concept of Effective bandwidth, Measurement based admission control, Differentiated Services in Internet; MPLS

switching, MPLS architecture and framework. MPLS Protocols. Traffic engineering issues in MPLS, Lamda Switching, DWDM Networks.

Texts:

1. W. Stallings, Data and Computer Communications, 7th Ed, Prentice Hall, 2004.
2. Alberto Leon Garcia, I. Widjaja, Communication Networks, 2nd Ed., Tata McGraw Hill, 2010

References:

1. J. F. Kurose and K. W. Ross, Computer networking: A Top-down Approach Featuring the Internet, 3rd Ed, Addison-Wesley, 2005.
2. A. S. Tenenbaum, Computer Networks, 4th Ed, Prentice Hall PTR, 2003.
3. B. A. Forouzan, Data Communications and Networking, 3rd Ed, McGraw Hill, 2004.
4. T. Ramteke, Networks, 2nd Ed, Prentice Hall, 2001.
5. G. Held, Ethernet Networks: Design, Implementation, Operation, Management, 4th Ed, John Wiley & Sons, 2002.
6. Stevens, D.L. et al., TCP/IP Illustrated, Volumes I, II and III, Addison Wesley, 1996.

EE540 RADIO FREQUENCY INTEGRATED CIRCUITS 3 0 0 6 Prerequisite: Basic Electronics and Basic Electromagnetic Engineering

Introduction to RF and Wireless technology; Basic concepts in RF & Wireless Integrated Circuits Design; Receiver and Transmitter Architectures.

Low Noise RF Amplifiers – Electrical Noises, Two port Noise theory, LNA characteristic parameters and basic topologies, Input impedance and Noise Figure of amplifiers, Differential and Broadband Amplifier, Stability;

Mixers – Mixer Operation and linearity, Passive and Active Mixers, Single & Double-Balanced Mixers, Conversion Gain and Port-to-Port Feedthrough (or leakage), Image Reject and Single Sideband Mixers, Noise in Mixers;

Oscillators – Oscillator as a Feedback System, Negative Resistance Oscillator, Colpitts, Hartley, Clapp, Pierce crystal Oscillators, Quadrature Oscillators, Voltage Controlled-Oscillator, Phase Noise in Oscillators;

Frequency Synthesizers – Phase Locked Loop (PLL), Analysis of PLL Synthesizers, Phase Noise in PLL Synthesis, PLL Frequency Synthesizers, Integer-N and Fractional-N PLL Synthesizers, PLL System Frequency Response and Bandwidth;

RF Power Amplifiers – Efficiency, Analysis of Basic Classes – A, AB, B, C, Class B Push-Pull Arrangements, Switch mode Classes – D, E, F Amplifiers, Doherty Power Amplifier, Linearization Techniques.

Texts:

1. Thomas H Lee, The Design of CMOS Radio Frequency Integrated Circuits, Cambridge University Press
2. Behzad Razavi, RF MicroElectronics, 2/e, Pearson India.
3. David M Pozar, Microwave and RF Design of Wireless Systems, John Wiley and Sons
4. Steven Cripps, RF Power amplifier for wireless communications, Artech House
5. Herbert Krauss, Charles Bostian, and Frederick Raab, Solide state radio engineering, John Wiley and Sons

References:

1. Guillermo Gonzalez, Microwave Transistor Amplifier- Analysis and Design, Prentice Hall, New Jersey.
2. Richard C-H Li, RF Circuits Design, John Wiley
3. John W M Rogers and Calvin Plett, Radio Frequency Circuit Design, Artech House, Boston.
4. Les Besser and Rowan Gilmore, Practical RF Circuit Design for Modern Wireless Systems, vol. 2, Artech House, Boston

EE520 ADVANCED DIGITAL SIGNAL PROCESSING 3 0 0 6

Discrete Time Signals: Sequences; representation of signals on orthogonal basis; Sampling and Reconstruction of signals;

Discrete systems: attributes, Z-Transform, Analysis of LSI systems, Frequency Analysis, Inverse Systems, Discrete Fourier Transform (DFT), Fast Fourier Transform algorithm, Implementation of Discrete Time Systems.

Design of FIR Digital filters: Window method, Park-McClellan's method.

Design of IIR Digital Filters: Butterworth, Chebyshev and Elliptic Approximations; Lowpass, Bandpass, Bandstop and High pass filters.

Effect of finite register length in FIR filter design

Parametric and non-parametric spectral estimation: Introduction to multi-rate signal processing. Application of DSP to Speech and Radar signal processing.

Texts/ References:

1. A.V. Oppenheim and Schafer, Discrete Time Signal Processing, Prentice Hall, 1989.

2. S. K. Mitra, Digital Signal Processing: A computer-Based Approach, 3/e, TMcHl, 2006.
3. John G. Proakis and D. G. Manolakis, Digital Signal Processing: Principle, Algorithms and Applications, Prentice Hall, 1997.
4. L.R. Rabiner and B. Gold, Theory and Application of Digital Signal Processing, Prentice Hall, 1992.
5. J.R. Johnson, Introduction to Digital Signal Processing, Prentice Hall, 1992.
6. D. J. DeFatta, J. G. Lucas and W. S. Hodgkiss, Digital Signal Processing, J Wiley and Sons, Singapore, 1988.

EE537 OPTICAL NETWORKS 3 0 0 6

Overview of optical communication system; Switching techniques: Circuit switched paradigm, Packet switched paradigm; Client layer: SONET/SDH, IP, MPLS, GMPLS; WDM network elements: Optical line terminals, Optical add/drop multiplexers, Optical crossconnects; WDM network design: Traffic models, Static and dynamic traffic grooming techniques; Formulation of network optimization problem: linear, Integer, Mixed integer linear programming problem, Lightpath topology design, Routing and wavelength assignment problem, NP-Completeness, Heuristic solution; Survivability in WDM networks, 1+1, 1:1, 1: N protection, Dynamic Restoration; Optical Packet Switching: Slotted networks, Unslotted networks, Packet format, Contention resolution in OPS networks, Optical buffering; Optical Access Networks: Passive Optical Network standards, Ethernet PON, WDM PON access network, architecture, PON transreceivers, Upstream and downstream transmission, Bandwidth allocation algorithm.

Texts/References:

1. Rajiv Ramaswami, Kumar N. Sivarajan and Galen H. Sasaki, Optical Networks; A Practical Perspective, Elsevier, 3rd Edition, 2010.
2. Biswanath Mukherjee, Optical WDM Networks, Springer, 2006.
3. Cedric F. Lam, Passive Optical Networks: Principles and Practice, Elsevier, 2007.
4. Jun Zheng, Hussein T. Mouftah, Optical WDM Networks: Concepts and Design Principles, Wiley-interscience, 2004.
5. C. Siva Ram Murthy, WDM Optical Networks: Concepts, Design and Algorithms, PHI Learning, 2001.
6. Pin-han Ho, Hussein T. Mouftah, Optical Networks: Architecture And Survivability, Kluwer Academic Publishers, 2010.
7. Ashwin Gumaste, Tony Antony, DWDM network designs and engineering solutions, Cisco Press, 2002

EE563 VLSI ARCHITECTURAL DESIGN AND IMPLEMENTATION 3 0 0 6

Introduction: Digital Systems and its applications to Signal Processing and Communication Systems; Digital Systems on hardware. Design and Implementation Challenges: Timing, Area, power issues in Digital Systems; Design and implementation Methodologies (Full custom and Semicustom): Design Flow, Design Optimization, Design Implementation using PLD, FPGA and ASIC; Architectural mapping with examples: Data path, Control path Synthesis; Control Strategies: Hardware implementation of various control structures; Micro-program control techniques; Introduction to Digital System Design and verification using HDL, FSM Architecture and Implementation with example, Semiconductor Memory and Peripheral Architectures.
Computer arithmetic Architectures and complexity analysis: Fast Adder/Subtractors, Sequential and Array multipliers and dividers, square root, Absolute Difference Value, Floating Point arithmetic.

Hardware architecture design and performance analysis: Sequential/Folding architectures; bit and word serial architecture; pipelined/unfolding Architecture; parallel and Systolic Array architecture with examples; Throughput and Latency analysis;

Basic Hardware Architectures for Digital Signal and Communication Systems: CORDIC, FFT/IFFT, DCT, DWT, DHT, LFSR, FIFO, CRC, RS Encoder and Decoder Architectures, Digital Filter Architectures.
Introduction to Mixed Signal Architectures: ADC, DAC and DPLL
Introduction to VLSI Chip testing and validation Architectures: Introduction to Chip Fault Model, conventional chip testing and validation methodologies, DFT Architecture, BIST Architecture.

Texts/References:

1. Architectures for Digital Signal Processing, Peter Pirsch, John Willy & sons.
2. Digital VLSI Systems design, S. Ramachandran, Springer
3. VLSI Digital Signal Processing Systems: Design and Implementation, K. K. Parhi, A Wiley-Interscience publications.
4. Computer Arithmetic: Algorithm and Hardware Design, Behrooz Parhami, Oxford University Press.
5. Real World FPGA Design with Verilog, Ken Coffman, Prentice Hall.
6. Application Specific Integrated Circuit, Michael John Sebastian Smith, Addison Wesley.
7. VerilogHDL: A Guide to Digital Design and Synthesis, S. Palnitkar, Pearson.

EE564 **TELETRAFFIC ENGINEERING** **3 0 0 6**

Review of essential probability theory: Exponential, Poisson, Binomial distributions; Queuing Theory and Traffic Models: Markovian, Non-Markovian, Multicast Input, Erlang's Formula, Networks of Queues; Performance Analysis of Different Types of Networks: Blocking Probability, Congestion, Delay etc.; Traffic Shaping, Policing Priorities and QoS Issues; Simulation and Numerical Techniques; Dimensioning of Telecom Networks; Application in Circuit and Packet Switched Networks.

Texts:

1. Donald Gross, Carl M. Harris, Fundamentals of Queuing Theory, 3rd Ed, Wiley.
2. Thomas G. Robertazzi, Computer Networks and Systems: Queueing Theory and Performance Evaluation, Springer-Verlag, 2000.

References:

1. Peryton Z. Peebles, Probablity, Random Variables and Random Signal Properties, 4th Ed, Tata McGraw-Hill.
2. Yue, Wuyi; Takahashi, Yutaka; Takagi, Hideaki, Advances in Queuing Theory and Network Application, 2009, Springer.

EE538 **SATELLITE COMMUNICATION** **3 0 0 6**

Introduction to Satellite Communications: Origin, History, Current Technology State and Overview of Satellite System Engineering. Orbital Aspects of Earth Satellites: Orbital Mechanics and Orbital Elements, Azimuth and Elevation, Coverage Angle and Slant Range, Placement of a Satellite in a Geostationary Orbit.

Satellite Link Design: Basic Radio Transmission Theory, System Noise Temperature and G/T Ratio, Uplink and Downlink Design, Interference Analysis, Carrier-to-Noise plus Interference Ratio, Interference to and from Adjacent Satellite Systems, Terrestrial Interference, Cross-polarization Interference, Intermodulation Interference, Design of Satellite Links for Specified Carrier-to-Noise plus Interference Ratio, Digital Satellite Link.

Propagation on Satellite-Earth Paths and Its Influence on Link Design: Absorbitive Attenuation Noise by Atmospheric Gases, Rain Attenuation, Noise due to Rain, Rain Depolarization, Tropospheric Multipath and Scintillation Effects.

Multiple Access Techniques in Satellite Communications: Frequency Division Multiple Access, FDMA, SCPC, MCPC. Time Division Multiple Access, TDMA: random (ALOHA, S-ALOHA) and time synchronized access. Code Division Multiple Access, CDMA, Fixed and On-demand Assignment.

Satellite Networking: Advantages and Disadvantages of Multibeam Satellites, Interconnection by Transponder Hopping, Interconnection by On-board Switching, Interconnection by Beam Scanning, On-Board Processing, Intersatellite Links.

Types of Satellite Networks: Fixed Point Satellite Network, INTELSAT, Mobile Satellite Network, INMARSAT, Low Earth Orbit and Medium Earth Orbit Satellite Systems, Very Small Aperture Terminal (VSAT) Network, Direct Broadcast Satellite Systems, Global Positioning System.

Texts:

1. Digital Satellite Communications, 2/e, McGraw-Hill, 1990.Tri T. Ha
2. Satellite Communications, John Willey and Sons, 2000T. Pratt, C.W. Bostian
3. Satellite Communications Systems Engineering, Pearson Education, 2/e; 2003 W.L. Prichard, H.G. Suyderhoud and R.A. Nelson

EE 525 **Digital Image Processing** **3 0 0 6**

Introduction to Digital Image Processing & Applications, Sampling, Quantization, Basic Relationship between Pixels, Imaging Geometry, Image Transforms, Image Enhancement, Image Restoration, Image Segmentation, Morphological Image Processing, Shape Representation and Description, Object Recognition and Image Understanding, Texture Image Analysis, Motion Picture Analysis, Image Data Compression.

Texts/References:

1. Rafael C. Gonzalez and Richard E. Woods, Digital Image Processing, Pearson
2. Milan Sonka, Vaclav Hlavac and Roger Boyle, Image Processing, Analysis and Machine Vision, Springer
3. Anil K. Jain, Fundamentals of Digital Image Processing, Prentice Hall

EE522 **MULTI-RATE SIGNAL PROCESSING** **3 0 0 6**

Digital FIR filter design, Filter specifications, ideal filters; Equi-ripple filters; Windowing and the Gibbs phenomenon; The Remez Algorithm, Digital IIR filter design, Bilinear transformation. Half-band and M-band filters. Fundamentals of Multi-rate Systems.

Down sampling and Decimation. Upsampling and interpolation. Commutativity of up sampling and down sampling, noble identities, inter-connection of building blocks. Polyphase filters for sample rate conversion. Applications of multi-rate systems. Nyquist Filter and square-root Nyquist filter. Systems using re-sampling filters, Re-sampling filters: Interpolators, Interpolator architecture, band-pass interpolator, rational ratio sampling, arbitrary re-sampling ratio, Farrow filter. Cascade Integrator Comb (CIC) filters. Filter Banks, Perfect Reconstruction Filter Banks, Quadrature Mirror Filter Banks, DFT Filter Banks, Cosine Modulated Filter Banks. Transmultiplexers. Digital down converter. Aliasing digital down converter. Timing recovery of digital modulator. Modem carrier recovery. Interpolated shaping filter. Digitally controlled sampled data delay. FM receiver and Demodulator.

Texts/References:

1. Fredric J Harris, "Multirate Signal Processing for Communication Systems", Pearson Education, 2007.
2. P.P. Vaidyanathan, "Multirate Systems and Filter Banks", Pearson Education, 2004.
3. Mitra S K, "Digital Signal Processing, A Computer Approach", 3/e, TMH, 2006.
4. Emmanuel C. Ifeachor and Barrie W. Jervis, "Digital Signal Processing: A practical Approach", 2/e, Pearson Education, 2002.
5. N. J. Fliege, "Multirate Digital Signal Processing", John Wiley & Sons,1995.

EE521 STATISTICAL SIGNAL PROCESSING FOR COMMUNICATION 3 0 0 6

Fundamentals of detection and estimation theory. Optimal combining: single-signal , Array signal processing and smart antenna. Optimal combining: multiple-signal. Multiple signal detection in vector space – MIMO detection. Fundamentals of wireless communication: channel and fading, capacity, access methods, multiplexing and diversity. Hidden Markov Model and Particle Filter methods: application to wireless localization. Estimation of delays and synchronization. Multiple antennas and array processing. Subspace methods in space/time or doubly-space/time (MIMO) processing. Block-processing: equalization, precoding/decoding for MIMO systems. Channel aware scheduling for multiuser/multi-antenna systems. Cooperation/competition/synchronization in wireless sensor networks. Algorithms for MIMO Wireless Communication, Compressed Sensing. Position location and navigation for indoor enclosed spaces. MIMO Radar signal processing. Spectrum sensing in Cognitive Radio. Signal Processing using the LSF Model of sequences. MIMO detection with successive interference cancellation. Lattice-reduction aided MIMO detection. Analysis of LR based MIMO detection. Coding and decoding of information using position of pulses (annihilating filter approach); Avoiding interference with GPS (spectral mask and periodogram estimation); Spectrum estimation for classical radio transmissions (estimating frequencies of a harmonic signal). Microphone array signal processing. Echo cancellation: Adaptive filtering (least mean squares and recursive least squares).

Texts/References:

1. Optimal Combining and Detection: Statistical Signal Processing for Communications, J. Choi, Cambridge, 2009.
2. An Introduction to Statistical Signal Processing, R. M. Gray, L. D. Davisson, Cambridge, 2010.
3. Fundamentals of Statistical Signal Processing, Volume III: Practical Algorithm Development, S. Kay, Prentice Hall, 2012.
4. Adaptive Signal Processing in Wireless Communications, Mohamed Ibnkahla, CRC Press, 2009

EE561 ANTENNA THEORY AND DESIGN 3 0 0 6 Prerequisite: EE341 – Electromagnetic Theory and Applications or any other course with similar content

Antenna fundamentals and definitions; Radiation integral and Auxiliary Potential Functions, Reaction and reciprocity theorems; Wire antennas – infinitesimal dipole, small dipole, finite length dipole, half wave dipole and loop antennas; Antenna arrays – two element array, N-element linear array, planar array and circular array; Antenna Synthesis – continuous source, Schelkunoff polynomial method, Fourier transform method, Woodward-Lawson method, Taylor –Line source; Integral equation techniques and its application to wire antenna and scatterer; Aperture antennas; Travelling wave antenna; Broadband antennas and Matching techniques; Microstrip antenna; Reflector antenna; Antenna measurements.

Text:

1. C A Balanis, Antenna Theory: Analysis and Design, John Wiley & Sons, India

References:

2. R E Collin, Antennas and Radiowave Propagation, McGraw-Hill Education
3. R S Elliott, Antenna Theory and Design, Wiley India Pvt.
4. J D Kraus, Antennas, Tata-McGraw-Hill
5. Warren L. Stutzman, Gary A. Thiele, Antenna Theory and Design, John Wiley & Sons

EE562 **EMBEDDED COMPUTING SYSTEMS AND INTERFACING** **3 0 0 6**

Introduction to Embedded Systems: Introduction to Embedded Systems, Embedded System Applications, Block diagram of embedded systems, Trends in Embedded Industry, Introduction to Embedded system Models and Architectures, Embedded System development cycle, Challenges for Embedded system Design, Evolution of computing systems and applications, Introduction to Processor Architectures, Evolution of Embedded Bus protocols and Architectures, Introduction to I/O interfacing techniques in Embedded platform.

Embedded Processor and applications: ARM Architecture, ARM organization and Implementation, Instruction Set, programming model, Addressing Mode, Assembly and high level language programming, Embedded C and UML, Interrupt Controller, Architectural support for System Development, ARM Processor Core, Memory Hierarchy and organization, Introduction to Embedded OS and RTOS, Introduction to Embedded ARM applications, Embedded I/O Interfacing controllers and Devices.

FPGA platform Embedded System: Introduction to reconfigurable devices, Advanced FPGA Architectures, IP Cores: Processor, Memory, IOs. Design and Implementation techniques using FPGA platform: Integrated Software environment, System design: Hardware and Software design, Partitioning, Spatial design, Case Studies: FPGA platform for Communication Systems.

Introduction to Embedded Device and Drivers for Communication Systems: serial and parallel communication bus, SPI, I2C, CAN, USB, Ethernet, Bluetooth, GPS, RFID, Wi-Fi.

Texts/References:

1. Introduction to Embedded Systems, Shibu K V, Tata McGraw Hill Publications
2. Embedded Systems: Architecture, Programming and Design, Raj Kamal, McGraw Hill Publications.
3. Embedded Systems Architecture, Tammy Noergaard, Newnes, Elsevier.
4. Embedded Microcomputer Systems and Real Time Interfacing, J. W. Valvano, Cengage Learning.
5. ARM System-On-Chip Architecture, Steve Furber, Pearson publication.
6. ARM System Developer's Guide: Designing and Optimizing System Software, Andrew N. Sloss, Dominic Symes, Chris Wright. Morgan Kaufmann Publisher, Elsevier.
7. Embedded Systems Design with Platform FPGA, Ron Sass and Andrew G. Schmidt, Morgan Kaufmann Publisher, Elsevier.
8. FPGA- Based System Design, Wayne Wolf, Pearson Publisher.

EE539 **MULTIMEDIA COMMUNICATION** **3 0 0 6**

Introduction to Multimedia System: Architecture and components, Multimedia distributed processing model, Synchronization, Orchestration and Quality of Service (QOS) architecture.

Audio and Speech: Data acquisition, Sampling and Quantization, Human Speech production mechanism, Digital model of speech production, Analysis and synthesis, Psycho-acoustics, low bit rate speech compression, MPEG audio compression.

Images and Video: Image acquisition and representation, Composite video signal NTSC, PAL and SECAM video standards, Bilevel image compression standards: ITU (formerly CCITT) Group III and IV standards, JPEG image compression standards, MPEG video compression standards.

Multimedia Communication: Fundamentals of data communication and networking, Bandwidth requirements of different media, Real time constraints: Audio latency, Video data rate, multimedia over LAN and WAN, Multimedia conferencing.

Hypermedia presentation: Authoring and Publishing, Linear and non-linear presentation, Structuring Information, Different approaches of authoring hypermedia documents, Hyper-media data models and standards.

Multimedia Information Systems: Operating system support for continuous media applications: limitations is usual OS, New OS support, Media stream protocol, file system support for continuous media, data models for multimedia and hypermedia information, content based retrieval of unstructured data.

Texts/ References:

1. Ralf Steinmetz and Klara Nahrstedt, Multimedia Systems, Springer.
2. J. D. Gibson, Multimedia Communications: Directions and Innovations, Springer.
3. K. Sayood, Introduction to Data Compression, Morgan-Kaufmann.
4. A. Puri and T. Chen, Multimedia Systems, Standards, and Networks, Marcel Dekker.
5. Iain E.G. Richardson, H.264 and MPEG-4 Video Compression, John Wiley.
6. Borivoje Furht, Handbook of Multimedia Computing, CRC Press.

EE508 **INTELLIGENT VISUAL SURVEILLANCE SYSTEMS** **3 0 0 6**

Basics of Image and Video Processing: Introduction to Image Processing methods, Image Transforms, Color spaces, An overview of Video Compression Standards: H. 261, H. 263, MPEG-1, MPEG-2, MPEG-4, MPEG-7, and MPEG-21, Video shot boundary detection.

Motion Analysis: Real versus apparent motion, Optical Flow Methods, Block Based Methods, Pel Recursive Methods, Mesh-based methods, Region-based (parametric), motion modeling, Categorization of motion segmentation technique.
Object Classification and Tracking- Shape based object classification, motion based object classification, Haar like feature based object detection, Viola Jones object detection framework, Multiclass classifier boosting.
Multi-Object Tracking- Video monitoring for detection and tracking of multiple interacting objects, Classification of multiple interacting objects from video, Region-based Tracking, Contour-based Tracking, Feature-based Tracking, Model-based Tracking, Hybrid Tracking, Particle filter based object tracking, Mean Shift based tracking.
Human Activity Recognition Techniques- Template based activity recognition, Hidden Markov Models (HMMs), Dynamic Time Warping (DTM), Finite-State Machine (FSM), Nondeterministic-Finite-State Automaton (NFA), Time-Delay Neural Network (TDNN), and Syntactic/Grammatical Techniques.
Camera Network Calibration - Types of CCTV (closed circuit television) camera- PTZ (pan-tilt zoom) camera, IR (Infrared) camera, IP (Internet Protocal) camera, wireless security camera, Multiple view geometry, camera network calibration, PTZ camera calibration, camera placement, smart imagers and smart cameras.
Security and Privacy of visual surveillance- Reliable visual data protection technique without sacrificing perceptual utility, secure authentication and privacy of visual surveillance.
Implementation of algorithms based on OpenCV (or Matlab) is covered in the course.

Texts:

1. Murat A. Tekalp, "Digital Video Processing", Prentice Hall, 1995.
2. Y. Ma and G. Qian (Ed.), "Intelligent Video Surveillance: Systems and Technology", CRC Press, 2009.
3. H. Aghajan and A. Cavallaro (Ed.), Multi-Camera Network: Principles and Applications", Elsevier, 2009.
4. A senior (Ed.), "Privacy Protection in Video Surveillance", Elsevier, 2009

Reference:

1. Dr. Richard Szeliski, "Computer Vision: Algorithms and Applications", Springer Publication, 2010

EE524 RANDOM PROCESS AND ESTIMATION THEORY 3 0 0 6

Concept of stationarity (strict-sense stationary, wide-sense stationary, etc.); periodic and cyclostationary processes; auto-correlation; cross-correlation; spectral densities; linear systems with random process inputs; matched filter; ergodicity; mean-square stochastic continuity and calculus.Special random processes :Gaussian process, Poisson counting process, shot-noise process, renewal process , Markov process, Wiener process. Spectral representation of random processes: Karhunen-Lo`eve expansion, Fourier series, sampling theorem. Sequences and Stochastic Convergence: Convergence with probability one, convergence in probability, laws of large numbers, mean-square convergence; convergence in distribution; central limit theorem; Martingale sequence and Martingale convergence theorem.Estimation and Filtering: Bayesian estimation (MMSE, MAP); Fisher estimation (MLE); Sufficient statistics; the exponential family of distributeons; information inequality; minimum variance unbiased estimates; Rao-Blackwell Theorem and Lehmann-Scheff e Theorem; orthogonality principle; Wiener-Hopf equation; Wiener filtering, Kalman filtering. Signal Detection: Binary hypothesis testing; Bayesian, minimax, Neyman-Pearson detection; nonparametric detection (sign detector).

Texts/ References:

1. Simon Haykin, Adaptive Filter Theory, 3rd Edition. Upper Saddle River, NJ: Prentice-Hall, 1996.
2. Simon Haykin, Ed. Advances in Spectrum Analysis and Array Processing , Vols. I & II. Upper Saddle River, NJ: Prentice-Hall, 1991.
3. Steven M. Kay, Fundamentals of Statistical Signal Processing – Estimation Theory , Vol. I. Pearson.
4. Steven M. Kay, Fundamentals of Statistical Signal Processing – Detection Theory , Vol. II. Pearson.
5. Steven M. Kay, Modern Spectral Estimation . Upper Saddle River, NJ: Prentice-Hall, 1988.
6. Henry Stark and John W. Woods, Probability, Random Processes and Estimation Theory , 3rd Edition. Upper Saddle River, NJ: Prentice Hall, 2002.
7. H.L. Van Trees, Detection, Estimation, and Modulation Theory , Part I. New York, NY: John Wiley & Sons, Inc., 1971.
8. Andrew J. Viterbi, CDMA, Principles of Spread Spectrum Communication . Reading, MA: Addison-Wesley, 1996.

EE526 DIGITAL VIDEO PROCESSING 3 0 0 6

Representation of digital video: Introduction and fundamentals; Time-varying image formation models: Motion models, Geometric image formation; Spatio-temporal sampling: Sampling of analog and digital video, Two-dimensional rectangular and periodic sampling, Sampling of 3-D structures, Reconstruction from samples; Sampling structure conversion: Sampling rate change, Sampling lattice conversion; Two-Dimensional Motion Estimation: Optical flow based methods, Block-based methods, Pel-recursive methods, Bayesian methods based on Gibbs Random Fields; Image Compression: Lossless compression, DPCM, Transform coding, JPEG, Vector Quantization, Sub-band Coding; Video compression: Inter-frame compression methods (3-d waveform and motion-compensated waveform coding), Video compression standards (H.26X and MPEG-X); Applications of video processing: Video Indexing, Summarization, Browsing and Retrieval, Video Surveillance.

Text:

1. A. M. Tekalp, "Digital Video Processing", Prentice Hall.

References:

2. R. C. Gonzalez, and R. E. Woods, "Digital Image Processing", Addison-Wesley.
3. Dudgeon & Mersereau, "Multi-dimensional Digital Signal Processing", Prentice Hall.
4. C. Poynton, "A Technical Introduction to Digital Video", Wiley.
5. Y. Wang, J. Ostermann, and Y. Zhang, "Video Processing and Communications", Prentice Hall.
6. K. Castleman, "Digital Image Processing", Prentice Hall.
7. S. Mitra, "Digital Signal Processing", 2nd Edition, McGraw Hill.

EE527 Pattern Recognition and Applications 3 0 0 6

Introduction: Feature extraction and Pattern Representation, Concept of Supervised and Unsupervised Classification, Introduction to Application Areas.
Statistical Pattern Recognition: Bayes Decision Theory, Minimum Error and Minimum Risk Classifiers, Discriminant Function and Decision Boundary, Normal Density, Discriminant Function for Discrete Features, Parameter Estimation.
Dimensionality Problem: Dimensionality Reduction, Fisher Linear Discriminant and Multiple Discriminant Analysis.
Nonparametric Pattern Classification: Density Estimation, Nearest Neighbour Rule, Fuzzy Classification.
Linear Discriminant Functions: Separability, Two Category and Multi Category Classification, Linear Discriminators, Perceptron Criterion, Relaxation Procedure, Minimum Square Error Criterion, Widrow-Hoff Procedure, Ho-Kashyap Procedure, Kesler's Construction.
Neural Network Classifier: Single and Multilayer Perceptron, Back Propagation, Learning Hopfield, Network Fuzzy and Neural Network.
Time Varying Pattern Recognition: First Order Hidden Markov, Model Evaluation, Decoding Learning.
Unsupervised Classification: Clustering, Hierarchical Clustering, Graph Based Method, Sum of Squared Error Technique, Iterative Optimization.

Texts/References:

1. Richard O. Duda, Peter E. Hart and David G. Stork, Pattern Classification, John Wiley & Sons, 2001.
2. Earl Gose, Richard Johsonbaugh and Steve Jost, Pattern Recognition and Image Analysis, Prentice Hall, 1999.

EE565 TELECOMMUNICATIONS MANAGEMENT 3 0 0 6 Prerequisites: Basic knowledge of wireless/wire line telecom switching and transmission technologies.

Introduction to telecom scenario:- Acts and regulations covering telecom services, DOT,TRAI and TDSAT – their roles, Telecom growth, FDI policies in services, manufacturing.
Licensing policies of various telecom services and OTT services, Active and passive sharing of infrastructure.
Technologies trends and forecast for broadband, wireless and other services: Technologies, support, price, security, obsolescence and up gradation and their impact on business.
Business models: managed services, managed capacity revenue models.
Spectrum management: Frequency bands and their deployments, auction methodology, spectrum planning
A business case study

Texts/References:

1. The Telecom Revolution in India: Technology, Regulation and Policy by Varadharajan Sridhar, Oxford Press
2. ITA 1885, TRAI Act 1997, National Telecom Policy 2015.
3. Telecommunication Management by Nolan Vincent Jones. Virtualbookworm.com publishing Aug 5 2004

EE523 ADVANCED BIO-MEDICAL SIGNAL PROCESSING 3 0 0 6

Introduction of Biomedical Signals: Nervous system, Neuron anatomy, Basic Electrophysiology, Biomedical signal's origin and dynamic characteristics, biomedical signal acquisition and processing, Different transforms techniques.
The Electrical Activity of Heart: Heart Rhythms, Components of ECG signal, Heart beat Morphologies, Noise and Artifacts, Muscle Noise Filtering, QRS Detection Algorithm, ECG compression techniques (Direct Time Domain (TP, AZTECH, CORTES, SAPA, Entropy

Coding), Frequency Domain (DFT, DCT, DWT, KLT, Walsh Transform), Parameter Extraction: Heart rate variability, acquisition and RR Interval conditioning, Spectral analysis of heart rate variability.

The Electrical Activity of Brain: Electroencephalogram, Types of artifacts and characteristics, Filtration techniques using FIR and IIR filters, Independent component analysis, Nonparametric and Model-based spectral analysis, Joint Time-Frequency Analysis, Event Related Potential, Noise reduction by Ensemble Averaging and Linear Filtering, Single-Trail Analysis and adaptive analysis using basis functions.

The Electrical Activity of Neuromuscular System: Human muscular system, Electrical signals of motor unit and gross muscle, Electromyogram signal recording, analysis, EMG applications.

Frequency-Time Analysis of Bioelectric Signal and Wavelet Transform: Frequency domain representations for biomedical Signals, Higher-order spectral analysis, correlation analysis, wavelet analysis: continuous wavelet transform, discrete wavelet transform, reconstruction, recursive multi resolution decomposition, causality analysis, nonlinear dynamics and chaos: fractal dimension, correlation dimension, Lyapunov exponent.

Machine Learning Tools for Medical Signal Classification: Support Vector Machine, Hidden Markov Model, Neural Networks.

Medical Applications: Application of Event Related Potential in understanding human psychology, Cognitive neuroscience and higher order brain function: Attention, language, memory and executive functions and damage to the nervous system, Application of EEG and ECG signal processing over different cognitive and physical task.

Texts:

1. Willis J. Tompkins, Biomedical Digital Signal Processing: C Language Examples and Laboratory Experiments for the IBM PC, Prentice Hall India
2. Eugene N. Bruce, Biomedical Signal Processing and Signal Modeling, John Wiley & Sons, 2006.
3. Rangaraj M. Rangayyan, Biomedical Signal Analysis: A Case-Study Approach, John Wiley & Sons, 2002
4. Steven J. Luck, An Introduction to the Event-Related Potential Technique, Second Edition, THE MIT PRESS
5. Leif Sornmo and Pablo Laguna, Bioelectrical Signal Processing in Cardiac and Neurological Applications, Academic Press, 2005

References:

1. Hojjat Adeli & Samanway Ghosh-Dastidar, Automated EEG based Diagnosis of Neurological Disorders, CRC Press.
2. Thomas P. Trappenberg, Fundamentals of Computational Neuroscience, Oxford University Press. 2002.
3. Mike X Cohen, Analyzing Neural Time Series Data Theory and Practice, THE MIT PRESS
4. Nait-Ali, Amine, Advanced Biosignal Processing, Spingers(Ed.). 2009
5. C. Koch, Biophysics of Computation. Information Processing in Single Neurons, Oxford University Press: New York, Oxford
6. Peter Dayan and LF Abbott, Theoretical Neuroscience Computational and Mathematical Modeling of Neural Systems, MIT 2001.
7. F. Rieke and D. Warland and R. de Ruyter van Steveninck and W. Bialek, Spikes: Exploring the Neuronal Code, A Bradford Book. MIT Press. Cambridge, Massachusetts, London, England, 1997.