

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECC-505

Course Title: Linear Algebra and Random Processes

L-T-P: 3-1-0

Credits: 4

Subject Area: PCC

Course Outline:

Vector spaces & subspaces, bases and dimensions, linear dependence and independence, vector products, orthogonal bases, and orthogonal projections, Gram-Schmidt orthonormalization procedure, linear operators and matrices, eigen values and eigen vectors, characteristic polynomial, diagonalization, Hermitian and unitary matrices, singular value decomposition. Discrete and continuous random variables, distribution and density functions, conditional distributions and expectations, functions of random variables, moments, random process, probabilistic structure: mean, autocorrelation and auto-covariance functions, strict-sense and wide-sense stationary processes, power spectral density; LTI systems with WSS process as the input; Examples of random processes

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECC-511

Course Title: Digital Signal Processing and Communication Techniques

L-T-P: 3-0-2

Credits: 4

Subject Area: PCC

Course Outline:

Discrete time Fourier transform, Discrete Fourier transform, Fast Fourier transform, Design of finite impulse response filters, Design of infinite impulse response filters, Multirate signal processing, Lowpass equivalent of bandpass signals, Linear and nonlinear modulation techniques, Signal design for band-limited channels, Channel equalization techniques

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECC-513

Course Title: Principles of Wireless Communications

L-T-P: 3-1-0

Credits: 4

Subject Area: PCC

Course Outline:

Wired (AWGN) Channel and its BER analysis; Wireless channels: physical modeling, input/output model, Rayleigh channel and its BER analysis, channel characteristics: time and frequency, point-to-point communication, diversity techniques, channel uncertainty and estimation, multiple access and interference management, narrow-band and wide-band systems, capacity of wireless channels, MIMO capacity, diversity-multiplexing tradeoff, MIMO receiver design, transmit power allocation, MIMO precoding, Space-time block codes, multi-carrier communication, OFDM and its application to wireless communication, MIMO-OFDM system, peak-to-average power ratio (PAPR), non-orthogonal multiple access, introduction and motivation, system model, successive interference cancellation.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECC-515

Course Title: Information and Coding Theory

L-T-P: 3-1-0

Credits: 4

Subject Area: PCC

Course Outline:

Introduction to probability, uncertainty and information, entropy; Joint and conditional entropies, Mutual information, Source coding theorems, Kraft-McMillan inequality, prefix code, variable and fixed length codes; Discrete memoryless channels, Binary symmetric channels (BSC), Capacity of a discrete channel; Channel coding theorem; Entropy for sources with memory, Markov sources, Information measures for continuous random variables - Extensions of the discrete measures to the continuous case; Differential entropy, Entropy power, Mutual information, Distortion; Rate distortion function; Capacity for waveform channel, channel capacity theorem, Bandwidth efficiency, Shannon's Limit, Source coding - Introduction to data compression, lossless and lossy compression, entropy coding; Huffman code, Shannon-Fano code, Arithmetic code, Run-length code, Lempel-Ziv code, Channel coding - Error correcting codes, minimum distance principles, error detection and correction capabilities; Linear block code, Single parity check code, repetition code, Hamming code; Binary cyclic code; Convolutional code

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECT-501
Algorithms

Course Title: Inference and Learning

L-T-P: 3-0-0

Credits: 3

Subject Area: STAR

Course Outline:

Review of Probability Theory: Bayes theorem, Random variables, Probability Distributions, Moments, Conditional Expectation, Entropy, Kullback-Leibler Divergence, Data Processing Inequality, Review of Optimization Theory: Convex sets and functions, Duality, Karush-Kuhn-Tucker (KKT) Optimality Conditions, Fixed point method for solving KKT conditions, Maximum Likelihood Inference: Maximum Likelihood (ML) criterion, Sufficient Statistics, Neyman Factorization theorem, Asymptotic consistency of ML estimation, Bayesian Inference: Maximum A posteriori Probability (MAP) estimation, Sequential Bayesian Inference, Inference in presence of latent variables: Expectation Maximization (EM), EM algorithm as Majorization Minimization, Gaussian Mixture Model, Variational Inference: Majorization Minimization, Mean Field Approximation, Evidence Lower Bound (ELBO), Sparse Inference: Sparse Signal Model, Sparse solutions of linear systems, Sparse Linear Regression, Inference in Graphical models: Graphical models, Factor Graphs, Sum-Product Algorithm, Message-Passing over Factor Graphs, Inference using Maximum Entropy Principle: Exponential Family Distributions, Maximum Entropy Method.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECL-514 **Course Title:** Detection and Estimation Theory

L-T-P: 3-1-0 **Credits:** 4 **Subject Area:** PEC

Course Outline:

Introduction to estimation and detection problem in signal processing and communications, Estimation in signal processing; Sufficient statistics; Bias; Minimum variance unbiased estimator; Cramer-Rao lower bound; Best linear unbiased estimator; Maximum likelihood estimation (MLE), Bayesian estimation – Minimum mean square error (MMSE) estimation; Maximum a-posteriori (MAP) estimators; Linear MMSE estimation; Linear estimation of signals – Weiner filtering; Kalman filtering, Detection theory in signal processing; Hypothesis test – Bayesian and Neyman-Pearson theorem; Receiver operator characteristics, Detection of deterministic signals with known parameters in Gaussian noise – Matched filters; Detection of random signals with known characteristics – Estimator-correlator; Detection of deterministic signals with unknown parameters; Bayesian approach – generalized likelihood ratio test (GLRT), Detection of random signals with unknown parameters – Expectation maximization; Hidden Markov model (HMM), Application of detection and estimation in signal processing in communication – biomedicine, communications, radar, sonar, etc.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECL-614

Course Title: Adaptive Signal Processing Techniques

L-T-P: 3-0-2

Credits: 4

Subject Area: PEC

Course Outline:

Assumptions, requirements, and applications of adaptive signal processing, Optimum linear combiner and Wiener-Hopf equations, Steepest-descent algorithm and its stability; Principles of stochastic gradient descent, LMS algorithm and its variants, Least squares method, RLS adaptive filtering algorithms, Kalman filter and its variants

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECL-556 Course Title: 5G Standards and 6G Wireless Technologies

L-T-P: 3-1-0

Credits: 4

Subject Area: PEC

Course Outline:

5G NR overview: introduction, motivation, and architecture, core and access network functionalities, time- and frequency- domain frame structure, 5G-NR numerology, bandwidth parts, slot configurations, 5G data and control channels: physical downlink shared channel (PDSCH), physical uplink shared channel (PUSCH), physical downlink control channel (PDCCH), physical uplink control channel (PUCCH), synchronization signals and procedures. Candidate 6G technologies: Cell-free/distributed wireless systems, reconfigurable intelligent surfaces, full-duplex communication, and among others, the constituent system model, channel model, beamforming techniques, centralized/ decentralized uplink and downlink operations, capacity bounds and spectral efficiency

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECL-557 **Course Title:** Principles of Sparse Recovery and Compressed Sensing

L-T-P: 3-1-0

Credits: 4

Subject Area: PEC

Course Outline:

Review of mathematical preliminaries: Vector/matrix norms, Orthobasis expansion, Gaussian and subgaussian random variables, basic concentration inequalities, Principles of sparse recovery: Unique and stable sparse solutions of underdetermined linear systems, Unique sparse representation and uncertainty principle, Sensing matrix design, Null-space property (NSP), Mutual Coherence based uniqueness and stable recovery guarantees, Restricted Isometry Property (RIP), Johnson-Lindenstrauss lemma, Sparse recovery with random matrices, Compressed sensing & its connections to sparse recovery: Sparse representation of signals, compressible signals, encoding and decoding in compressed sensing, Sparse recovery methods: Convex optimization algorithms – Basis Pursuit and LASSO, Greedy algorithms - Orthogonal Matching Pursuit (OMP), Compressive Sampling (CoSAMP), Thresholding-based sparse recovery methods, MAP estimation-based sparse recovery, Applications: Sub-Nyquist sampling, signal compression, signal-denoising, sparse linear regression, sparse inference in wireless communications

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECL-558

Course Title: Wireless Communication: Advanced Concepts and Applications

L-T-P: 3-1-0

Credits: 4

Subject Area: PEC

Course Outline:

Multi-user MIMO systems and its capacity analysis, massive MIMO system model, time division duplexing (TDD) and frequency division duplexing (FDD), uplink and downlink transmissions, channel hardening, favorable propagations, spectral and energy efficiency analysis, sub-6GHz channel model, 3GPP/5G-NR channel model, receiver design, channel estimation, pilot contamination, signal detection, linear and non-linear detectors (ML, MAP, sphere decoding, SIC, etc.), mmWave MIMO wireless systems: introduction and motivation, millimeter wave propagation and channel models, analog, digital and hybrid beamforming architectures, TeraHertz (THz) communications, potential advancements in massive MIMO technologies, applications of artificial intelligence in wireless communication

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECL-562

Course Title: Optical Wireless Communication

L-T-P: 3-1-0

Credits: 4

Subject Area: PEC

Course Outline:

Introduction to optical wireless communication and its applications; optical source, optical detector; optical wireless channel; coherent modulation and detection, subcarrier-intensity modulation and direct detection; effect of turbulence and weather conditions; error performance and channel capacity; free-space optical communication link availability, laser safety; visible light communication, system description, channel models, channel delay spread, SNR Analysis, system implementations.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECL-563

Course Title: Machine Learning and Signal Processing
for Neuroinformatics

L-T-P: 3-1-0

Credits: 4

Subject Area: PEC

Course Outline:

Introduction to Neuroinformatics, Neuroimaging and Fundamentals of Neuroscience, Physiological Time-Series, Data protocols, ML with imaging, and physiological data, Human Factors and interpretability, Signal Processing schemes for Neuroinformatics, Advanced Topics in Neuroinformatics, Ethical and Practical issues, Emerging trends and Future of Neuroinformatics

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Electronics and Communication Engineering

Subject Code: ECT-502

Course Title: Semiconductor Technology and its Applications

L-T-P: 3-0-0

Credits: 3

Subject Area: STAR

Course Outlines:

A broad overview of semiconductor technologies, CMOS technology and its scaling, CMOS enabled digital and analog circuits; memory devices for non-volatile data storage, SRAM and DRAM circuit operation, processor architecture, concepts of radio frequency (RF) circuits, non-silicon technologies for power and RF electronics, amplifiers and mixers, concepts of power electronic circuits, optoelectronic devices, solar modules and photo-detector circuits, micro-electromechanical systems.

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE/SCHOOL: Department of Electronics & Communication Engg.

Subject Code: ECT-504

Course Title: Applications of RF Technology in
Defence and Space Applications

L-T-P: 3-0-0

Credits: 3

Subject Area: STAR

Syllabus: Unit 1: Foundation – Transmission Line Theory, Smith Chart, Network Analysis using Sparameters, Impedance Matching. 12 Hours

Unit 2: Power Combiners for Defence and Space Applications – Rectangular Waveguide, Corporate, Radial Combiner, E-plane Sectoral, and Magic T combiners. 10 Hours

Unit 3: Antennas for Defence and Space Applications – Microstrip Patch Antenna, Waveguide Horn Antenna, Antenna Arrays 8 Hours

Unit 4 : Filters for Defence and Space Applications – Stepped Impedance Low Pass Filters. Band Pass Filters, Tunable Band Pass Filters, Multi-Functional Filters 6 Hours

Unit 5: Optimization Techniques – Linear and Aggressive Space Mapping Technique 6 Hours

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: Electronics and Communication Engineering

Subject Code: ECL-554

Course Title: Communication Systems Lab

L-T-P: 0-0-3

Credits: 02

Subject Area: PEC

Course Outline:

Design and implement a circuit using ICs/USRPs to modulate and demodulate the standard analog and digital modulations schemes, such as: AM-DSB, FM, PPM, PWM, ASK, BPSK, QAM, etc. Also, design and implement the constituent circuits such as VCO, PLL, sample and hold circuit, etc. Implement