राष्ट्रीय प्रौद्योगिकी संस्थान - आंध्र प्रदेश

NATIONAL INSTITUTE OF TECHNOLOGY ANDHRA PRADESH

Department of Electronics and Communication Engineering

M. Tech. (Advanced Communication Systems and Signal Processing (ACSP))

Course Structure

I - Year I – Semester

S. No	Course Code	Course Title	L	T	P	Credit	Cat. Code
1.	25EC611	Probability and Stochastic Processes	3	0	0	3	PCC (T)
2.	25EC612	Advanced Digital Signal Processing	3	0	0	3	PCC (T)
3.	25EC613	Wireless Communications	4	0	0	4	PCC (T)
4.	25EC6xx	Department Elective 1	2	0	0	2	DEC
5.	25EC6xx	Department Elective 2	2	0	0	2	DEC
6.	xxxxxx	Open Elective	2	0	0	2	OEC
7.	25EC610	Digital Signal Processing lab	0	0	2	2	PCC (P)
		Total				18	

I - Year II – Semester

S. No	Course Code	Course Title	L	T	P	Credit	Cat. Code
1.	25EC621	Applied Linear Algebra	2	0	0	2	PCC (T)
2.	25EC622	Machine learning for signal processing	3	0	0	3	PCC (T)
3.	25EC623	Detection and Estimation Theory	3	0	0	3	PCC (T)
4.	25EC6xx	Department Elective 3	2	0	0	2	DEC
5.	25EC6xx	Department Elective 4	2	0	0	2	DEC
6.	25EC620	Communication Lab	0	0	2	2	PCC (P)
7.	25xx6xx	Humanities Elective Course	2	0	0	2	OEC
		Total				16	

II - Year I – Semester

S. No	Course Code	Course Title	L	T	P	Credit	Cat. Code
1.	25EC698	Dissertation				13	PCC

II - Year II – Semester

S. No	Course Code	Course Title	L	T	P	Credit	Cat. Code
1.	25EC699	Dissertation				13	PCC

List of Departmental Electives

1. 25EC631 Information Theory
2. 25EC632 Error Control Codes
3. 25EC633 Wireless Networks
4. 25EC634 Deep Neural Networks for Communications
5. 25EC635 Integrated Sensing and Communication
6. 25EC636 Next Generation Wireless Networks

7. 25EC641 Synthetic Aperture Radar
8. 25EC642 Speech Processing
9. 25EC643 Advanced Digital Image Processing
10. 25EC644 Time Domain Synthetic Radar (TDSR) with P440 UWB Platform
11. 25EC645 VLSI Signal Processing

I - Year I – Semester

25EC611	**Probability Essentials for Communications Engineers**	**PCC**	**3–0–0**	**3 Credits**

Detailed syllabus:

Axiomatic definitions of probability; conditional probability, independence and Bayes theorem, continuity of probability, Borel-Cantelli Lemma; Random variable: probability distribution, density and mass functions, functions of a random variable; expectation, characteristic and moment-generating functions; Chebyshev, Markov and Chernoff bounds; jointly distributed random variables: joint distribution and density functions, joint moments, conditional distributions and expectations, functions of random variables; random vector- mean vector and covariance matrix, Gaussian random vectors;

Sequence of random variables: almost sure and mean-square convergences, convergences in probability and in distribution, laws of large numbers, central limit theorem;

Random process: probabilistic structure of a random process; mean, autocorrelation and autocovariance functions; stationarity - strict- sense stationary and wide-sense stationary (WSS) processes: time averages and ergodicity; spectral representation of a real WSS process-power spectral density, cross-power spectral density, linear time-invariant systems with WSS process as an input- time and frequency domain analyses; examples of random processes: white noise, Gaussian, Poisson and Markov processes.

Discrete-time Markov Chains: The Markov property, hitting times and recurrence, communication classes and class properties, recurrence and invariant probability vector, transience, example: M/M/1 queue, mean drift criteria.

Textbooks:

1. H. Stark and J. W. Woods, "*Probability and Random Processes with Applications to Signal Processing*," Prentice Hall, 2002.
2. A. Papoulis and S. U. Pillai, "*Probability, Random Variables and Stochastic Processes*," 4th Edn., McGraw-Hill, 2002.
3. Anurag Kumar, "Discrete Event Stochastic Processes", Lecture notes available on Author's webpage.
4. Sheldon M Ross, "Stochastic Processes", Wiley Series

25EC612	Advanced Digital Signal Processing	PCC	3–0–0	3 Credits

Detailed syllabus:

Wiener filtering, Optimum linear prediction, Levinson- Durbin algorithm, Prediction error filters.

FIR adaptive LMS algorithm, convergence of adaptive algorithms, Fast algorithms.

Applications: Noise canceller, echo canceller and equalizer.

Recursive least squares algorithms, matrix inversion lemma, convergence analysis of the RLS algorithm, adaptive beam forming, Kalman filtering.

Spectrum estimation, estimation of autocorrelation, periodogram method, nonparametric methods, parametric methods.

Textbooks:

1. J.G.Proakis, M. Salehi, *"Advanced Digital Signal Processing"*, McGraw –Hill,1992.

2. S.Haykin, *"Adaptive Filter Theory (3/e)"*, Prentice- Hall,1996.

3. D.G. Manolakis V.K. Ingle and S.M. Kogon, *"Statistical and Adaptive Signal Processing",* McGraw-Hill,2005.

25EC613	**Wireless Communications**	**PCC**	**4–0–0**	**4 Credits**

Detailed syllabus:

Wireless channel: pathloss and shadowing, free space pathloss, ray tracing, empirical pathloss models, combined pathloss and shadowing, outage probability under pathloss and shadowing. Small scale fading: time varying channel impulse response, narrowband fading models, autocorrelation, PSD, wideband fading models, power delay profile, coherence bandwidth, Doppler spread, coherence time, discrete-time model.

Performance of digital modulation over wireless channels: Error probability for M-PSK, M-PAM, and M-QAM. Error probability for FSK, and CPFSK. Fading: Outage probability, average probability of error, Doppler spread and Inter symbol interference.

Diversity: Receive diversity, Selection combining, threshold combining, maximal ration combining. Transmit diversity: time diversity, antenna diversity – Alamouti scheme, frequency diversity.

Capacity of wireless channels, Capacity with channel state information (CSI) at transmitter, CSI at receiver, CSI at both transmitter and receiver. Capacity of frequency selective channels.

Multichannel and Multicarrier systems: Multicarrier modulation with overlapping subcarriers, Mitigation of subcarrier fading, FFT based multicarrier systems, minimizing peak to average ratio in multicarrier systems.

Narrowband MIMO model, Parallel decomposition of MIMO channels, MIMO channel capacity, MIMO diversity gain: beamforming, multiplexing gain with multiple antennas, Diversity-multiplexing trade-off, V-Blast and D-Blast Space time block codes

Multiuser channels, multiple access techniques: FDMA, TDMA, space-division multiple access, power control, downlink channel capacity, uplink channel capacity, uplink-downlink duality, multiuser diversity.

Cellular Concepts: Frequency reuse, channel assignment strategies, Handoff strategies, Trunking and grade of service, Improving cell coverage and capacity in cellular systems. Evolution of wireless communications from 1G to 6G.

Textbooks:

1. Andrea Goldsmith, "*Wireless Communications*", Cambridge university press
2. David Tse, and Pramod Viswanath, "*Fundamentals of Wireless Communication*", Cambridge university press
3. Theodore S Rappaport, *"Wireless Communications: Principles and Practice"*, PHI.
4. Andreas F. Molisch, *"Wireless Communications"*, John Wiley.

25EC610	Advanced Digital Signal Processing Lab	PCC		2 Credits

List of experiments:

1. Introduction to Code Composer Studio (CCS) & DSP Development
2. Addressing Modes in DSP and Introduction to Interrupts.
3. FFT and Bit Reversal Operations.
4. FFT and Its Applications in Signal Analysis
5. FIR Filtering using MATLAB and Code Composer Studio Interface.
6. Spectral Estimation Techniques.
7. Optimum Filtering Using Wiener Filters.
8. Adaptive Filtering – LMS Algorithm
9. Recursive Least Squares (RLS) Algorithm
10. Applications – Audio Codec, Real-Time Data Exchange & Digital Communication using BPSK

I - Year II – Semester

25EC621	**Applied Linear Algebra**	**PCC**	**2–0–0**	**2 Credits**

Detailed syllabus:

Vector spaces, linear independence, basis and dimension, linear maps and matrices, fundamental subspaces, rank and its properties, rank-nullity theorem, eigenvalues and eigenvectors, invariant subspaces, inner products; Norms- vector norms, matrix norms, dual norms, Gram-Schmidt process, orthonormal basis; determinant and their properties, spectral theorem, unitary and orthogonal transformations, operators on real and complex vector spaces; singular value decompositions (SVD), properties of SVD, system of linear equations, QR decomposition, LU decomposition, Cholesky decomposition, whitening methods, least squares, constrained least squares, positive definite and semidefinite matrices, positive and nonnegative matrices.

Textbooks / References:

1. S. Boyd, and L. Vandenberghe, "*Introduction to Applied Linear Algebra- Vectors, Matrices, and Least Squares*," 1st Ed., Cambridge University Press, 2018.
2. G. H. Golub and C. F. Van Loan, "*Matrix Computations*," 4th Ed., John Hopkins University press, 2013.
3. R. A. Horn and C. R. Johnson, "*Matrix Analysis*," 2nd Ed., Cambridge University Press, 2012.
4. G. Strang, "*Linear Algebra and Its Applications*," 4th Ed., Cengage India Pvt. Ltd., 2005.
5. S. Axler, "*Linear Algebra Done Right*," 3rd Ed., Springer, 2015.
6. L. N. Trefethen and D. Bau, III, "*Numerical Linear Algebra, Society for Industrial and Applied Mathematics (SIAM)*," 1997.
7. S. R. Ghorpade and B. V. Limaye, "*A Course in Calculus and Real Analysis*," 2nd Ed., Springer, 2018.
8. K. Hoffman, and R. Kunze, "*Linear Algebra*," 2nd Ed., Prentice-Hall Pvt. Ltd., 1971.

25EC622	**Machine Learning for Signal processing**	**DEC**	**3-0-0**	**3 Credits**

Detailed syllabus:

Supervised Learning: Linear models for regression and classification, Bias-variance decomposition, Bayesian regression, regression with regularization, Discriminant functions, probabilistic generative models, probabilistic discriminative models, Multiclass classification, Support Vector Machines: The Nonlinear Case, Decision Trees: Splitting Criterion, Stop-Splitting Rule, Class Assignment Rule. Multilayer perceptron.

Graphical Models: Bayesian networks, conditional independence, Markov random fields, inference in graphical models.

Unsupervised learning:
K-means clustering, Mixtures of Gaussian, Principal component analysis (PCA), Probabilistic PCA, Kernel PCA.

Perceptron, the perceptron algorithm, the XOR problem, the multi-layer perceptron, backpropagation algorithm, variants of gradient descent scheme, The loss function choice and RELU activation function, Regularization and dropout, Batch normalization,

Applications to Communications and Signal processing: Examples of feature extraction and classification in images and speech. Applications in modulation and channel estimation.

Textbooks:

1. Christopher M. Bishop, *"Pattern recognition and Machine Learning,"* Springer
2. Trevor Hastie, Robert Tibshirani, Jerome Friedman, *"The Elements of Statistical Learning,"* Springer
3. D. Yu and L. Deng, *"Automatic Speech Recognition: A Deep Learning Approach,"* Springer.

25EC623	Detection and Estimation Theory	PCC	3-0-0	3 Credits

Pre-requisites:

Detailed syllabus:

Hypothesis testing: Binary hypothesis testing, MAP criteria, bayes risk, Neyman-Pearson theorem, multiple hypothesis tests, Performance of Binary Receivers in AWGN, Sequential Detection and Performance.

Signal detection with random parameters: Detection of known signals in noise, Matched filter, Performance evaluations, Composite Hypothesis Testing, Unknown Phase, Unknown Amplitude, Unknown Frequency, White and Colored Gaussian Noise for Continuous Signals, Estimator Correlator.

Detection of multiple hypotheses: Bayes Criterion, MAP Criterion, M-ary Detection Using Other Criteria, Signal Space Representations, Performance of M-ary Detection Systems, Sequential Detection of Multiple Hypotheses, Linear models, Rayleigh fading sinusoid.

Fundamentals of estimation theory: Formulation of the General Parameter Estimation Problem, Relationship between Detection and Estimation Theory, Types of Estimation Problems. Properties of estimators: Unbiasedness, efficiency, Criteria for good estimators, Minimum variance unbiased estimation, Cramer-Rao lower bound, asymptotic properties. Parameter estimation: Random parameter, Bayes estimation, Mean square error (MSE), linear minimum mean-square estimates, linear square estimation, Maximum Likelihood Estimation, Least Square Estimation, Generalized Likelihood Ratio Test, Linear minimum variance estimator, BLUE.

Textbooks:

1. Harry L. Van Trees, *"Detection, Estimation, and Modulation Theory, Part I,"* John Wiley & Sons, Inc. 2001.
2. Steven M.kay, *"Fundamentals of Statistical signal processing, volume-1:Estimation theory"*. Prentice Hall 1993.
3. Steven M.kay, *"Fundamentals of Statistical signal processing, volume-2: Detection theory"*. Prentice Hall 1993
4. A.Papoulis and S.Unnikrishna Pillai, *"Probability, Random Variables, and stochastic processes"*, 4ed. The McGraw-Hill 2002.

References:

1. H. V. Poor, "*An Introduction to Signal Detection and Estimation"*, 2nd edition, Springer, 1994.
2. S. M. Kay, "*Fundamentals of Statistical Signal Processing: Detection* Theory", Prentice Hall PTR, 1998.
3. S. M. Kay, "*Fundamentals of Statistical Signal Processing: Estimation Theory"*, Prentice Hall PTR, 1993.
4. H. L. Van Trees, "*Detection, Estimation and Modulation Theory, Part I"*, John Wiley, 1968.

5. https://www.iitg.ac.in/eee/syllabusdetails.php?slno=QVhTTDhXc1cxaVRVSGVkeC9kSUk1QT09
6. Detection and Estimation Theory : Department of EEE
7. Estimation and Detection Theory (EE 527)

25EC620	Communication Lab	PCC		2 Credits

List of Experiments:

1. Generation of standard signals (sine, satooth, rect etc ..) using GNU Radio and analyzing them in time and frequency using QT GUI Scope and Spectrum of GNU Radio.

2. Transmitting the standard signals over the Pluto SDR or BladeRF and observing them in oscilloscope and spectrum analyzer.

3. Generating standard signals from Rohde & Schwaz Signal Generator, feeding the signal into Pluto SDR or BladeRF and observing them in QT GUI Scope or Spectrum of GNU Radio

4. Multirate signal processing exercises

a. Decimation

b. Interpolation

c. Rational resampling

5. Generating file in MATLAB loading into GNU Radio to transmit using Pluto SDR / Blade RF from one unit and receiving the signal in another unit with Pluto SDR / Blade RF interface with GNU Radio. Sending the received file for MATLAB analysis.

a. SISO

b. SIMO

c. MIMO

Components Required:

1. Pluto SDR

2. Blade RF 2X2

3. Textronix Spectrum Analyzer

4. Rohde & Schwarz Signal Generator

5. Radio synchronizer

6. Attenuators of 5 dB

7. SMA Cables

8. BNC to SMA connector

9. SMA male to SMA male

10. SMA male to SMA female (I connector)

Texts/References:

1. Jean-Michel Friedt and Hervé BoeglenM. Salehi, and G. Bauch, Communication Systems Engineering with GNU Radio: A Hands-on Approach, **DOI:10.1002/9781394218912**

Departmental Electives:

25EC631	Information Theory	DEC	2-0-0	2 Credits

Detailed syllabus:

Basic information theoretic quantities: entropy, relative entropy, mutual information, Relation among these quantities, chain rules. Jensen's inequality, log-sum inequality, Data-processing inequality, Fano's inequality.

Asymptotic equipartition property: theorem and proof, Consequences of AEP – Data compression. High – probability sets and the typical sets.

Data Compression: Kraft inequality, optimal codes, bounds on optimal code length, Huffman code, Optimality of Huffman code.

Channel Capacity: Examples of channel capacity – binary symmetric channel, and binary erasure channel, Properties of channel capacity, Channel coding theorem with proof, Source – Channel separation theorem.
Differential entropy, AEP for continuous random variables, Gaussian channels, Capacity of Gaussian channels.
Gaussian multiuser channels: multiple access channel, broadcast channel, relay channel, interference channel. Capacity of Gaussian MAC and Gaussian broadcast channels.

Textbooks:

1. Thomas M. Cover, Joy A. Thomas, *"Elements of Information Theory"*, Wiley – Interscience.
2. Imre Csiszar, Janos Korner, Akademiai Kiado, *"Information Theory*", Budapest.

25EC632	Error Control Codes	DEC	2-0-0	2 Credits

Detailed syllabus:

Review of modern algebra, Galois fields.

Linear block codes; encoding and decoding, Cyclic codes. Non- binary codes.

Convolutional codes, Generator sequences, Structural properties, ML decoding, Viterbi decoding. Sequential decoding.

Modulation codes, Trellis coded modulation, Lattice type Trellis codes, geometrically uniform trellis codes, Decoding of modulation codes.

Turbo codes, Turbo decoder, Interleaver, Turbo decoder, MAP and log MAP decoders, Iterative turbo decoding, optimum decoding of turbo codes, LDPC codes.

Textbooks:

1. S.Lin & D.J.Costello, *"Error Control Coding (2/e)"*, Pearson, 2005.
2. B.Vucetic & J.Yuan, *"Turbo codes"*, Kluwer, 2000.

25EC633	Wireless Networks	DEC	2-0-0	2 Credits

Detailed syllabus:

Network architecture: review of layered architecture, Link layer protocols: Error detection, CRC checks, Automatic repeat requests, Network layer protocols: Packet numbering, window flow control, error recovery. Routing: Bellman – Ford and Dijkstra's algorithms, Transport layer protocols: Transmission control protocol (TCP), error recovery in TCP, flow control in TCP.

Delay models: Queueing models, Little's theorem, M/M/1 queueing system, M/M/m, and M/M/∞, M/M/m/m systems. M/G/1 system: queues with vacations, reservations and polling, priority queueing.

Types of traffic and QoS requirements, real-time stream sessions, elastic transfers, TCP performance over wireless links.

Multiple access: Cellular OFDMA-TDMA, resource allocation over a single carrier, multicarrier resource allocation, random access protocols: ALOHA, CSMA, CSMA/CA, and CSMA/CD, IEEE 802.11 WLAN protocols,

Optimal routing and Scheduling: Network topology and link activation constraints, Link scheduling and schedulable region, routing and scheduling a given flow vector, maximum weight scheduling, routing and scheduling for elastic traffic.

Textbooks:

1. Anurag Kumar, D. Manjunath, and Joy Kuri, *"Wireless Networking,"* Morgan Kaufmann Publishers.
2. Dimitri Bertsekas, Robert Gallager, *"Data Networks,"* Second Edition, PHI.
3. Kurose, Ross, *"Computer Networking: A Top-Down Approach,"* Pearson.

25EC634	**Deep Neural Networks for Communications**	**DEC**	**2-0-0**	**2 Credits**

Detailed syllabus:

Convolutional Neural Networks: Convolution operation, pooling, AlexNet, ResNet, VGG Net, GoogleNet, DenseNet

Recurrent Neural Networks (RNN), bidirectional RNN, LSTM, GRU, Attention mechanism, Generative Adversarial Networks, Capsule Networks.

Autoencoders, regularized autoencoders, stochastic encoders and decoders, Transfer learning and domain adaptation.

Applications of DNN to 5G and 6G communications: Automatic Modulation Classification, Channel Estimation and Equalization, in MIMO systems, Beamforming and Receiver design in Massive MIMO Systems.

Textbooks:

1. Ian Goodfellow and Yoshua Bengio and Aaron Courville, *"Deep Learning,"* MIT Press
2. Yonina C. Eldar, et al, *"Machine Learning and Wireless Communications,"* Cambridge University Press

25EC641	Synthetic Aperture Radar	DEC	2-0-0	2 Credits

Detailed syllabus:

Radar Fundamentals: Electromagnetic scattering, Scattering from PECs, Radar Cross section, Radar Range Equation, Range of Radar Detection, Radar waveforms, Pulsed radar.

Synthetic Aperture Radar: SAR Modes, SAR System Design, Resolution in SAR, SAR Image formation, Range compression, Azimuth Compression, SAR imaging, SAR Focusing algorithms, Example of a Real SAR Imagery, Problems in SAR imaging, Advanced topics in SAR

Inverse Synthetic Aperture Radar imaging and its basic concepts: SAR versus ISAR, The Relation of Scattered Field to the image function in ISAR, One dimensional(1D) Range profile,1D Cross Range Profile, Two-Dimensional(2D) ISAR Image formation,2D ISAR image formation,3D ISAR image formation.

Imaging Issues in Inverse Synthetic Aperture Radar: Fourier related Issues, Image Aliasing, polar reformatting revisited, Zero Padding, point spread function, Windowing.

Textbooks:

1. Inverse Synthetic Aperture Radar imaging with MATLAB algorithms second edition wiely , by caner ozdemir
2. Synthetic Aperture Radar Processing by Giorgio Franceschetti, Riccardo Lanari

25EC642	Speech Processing	DEC	2-0-0	2 Credits

Detailed syllabus:

Introduction to Speech Processing: Overview of the human speech production system, acoustic and physiological mechanisms of speech production, glottal signal characteristics and source features, significance of glottal activity regions, speech signal characteristics, acoustic/articulatory characteristics of different speech sounds -vowels and consonants.

Time Domain Models for Speech Processing: Introduction- Window considerations, short time energy and average magnitude short time average zero crossing rate, Speech Vs Silence discrimination using energy and zero crossing, Pitch period estimation using a parallel processing approach, the short time autocorrelation function, the short time average magnitude difference function, Pitch period estimation using the autocorrelation function.

Speech Analysis: Basic principles of Linear Predictive Analysis: The Autocorrelation Method, The Covariance Method, Solution of LPC Equations: Cholesky Decomposition Solution for Covariance Method, Durbin's Recursive Solution for the Autocorrelation Equations, Comparison between the Methods of Solution of the LPC Analysis Equations, Applications of LPC Parameters: Pitch Detection using LPC Parameters, Formant Analysis using LPC Parameters.

Speech Modeling: Speech data preparation and feature engineering, Machine learning versus deep learning models in speech classification tasks (age, gender, dialect/accent), Automatic speech recognition (ASR) – statistical models- Hidden Markov Models (HMMs) for ASR, Deep learning speech recognition pipeline (end-to-end models).

Textbooks:

1. L. Rabiner, Biing-Hwang Juang and B. Yegnanarayana, *"Fundamentals of Speech Recognition,"* Pearson Education Inc.2009
2. L.R. Rabiner and S. W. Schafer, "*Digital Processing of Speech Signals*," Pearson Education, 2008.
3. Thomas F. Quateri, *"Discrete Time Speech Signal Processing: Principles and Practice*," 1st Edition, PE, 2001.

References:

1. Douglas O'Shaughnessy, *"Speech Communication,"* University Press, 2001

25EC643	**Advanced Digital Image Processing**	**DEC**	**2-0-0**	**2 Credits**

Detailed syllabus:

Introduction: Fundamentals of Image Processing, Applications, Image processing system components, Image sensing and acquisition, Sampling and quantization, Neighbors of pixel adjacency connectivity, Regions and boundaries, Distance measures.

Image Transforms: Basic concept of spatial domain and frequency domain, Unitary transform, Discrete Fourier Transform- 2D DFT, 4 order DFT Transform coefficients, Forward and inverse transform, Discrete Cosine Transform- 2D DCT, 4 order DCT Transform Coefficients, Forward and Inverse DCT, Hadamard Transform.

Enhancement and Restoration: Frequency and Spatial Domain, Contrast Stretching, Histogram Equalization, Low pass and High pass filtering**,** Restoration: Noise models, mean, order—statistics, adaptive filters, Band reject, Band pass and notch filters.

Image Compression & Color Image Processing: Fundamentals, Models, Error free and lossy compression, Standards. Color Image Processing: Color models, Pseudo color Image processing, Color transformation and segmentation.

Textbooks:

1. Rafel C. Gonzalez and Richard E. Woods, "*Digital Image Processing,*" Second Edition, Pearson Education
2. Bhabatosh Chanda and Dwijesh Majumder, *"Digital Image Processing"* PHI
3. Anil K Jain, *"Fundamentals of Digital Image Processing,"* PHI
4. Rafel C. Gonzalez and Richard E. Woods, *"Digital Image Processing Using MATLAB,"* Pearson Education.

25EC635	Integrated Sensing and Communication	DEC	2-0-0	2 Credits

Detailed syllabus:

Introduction: About ISAC, Evolution of ISAC, Comparison between radar, communication & ISAC, Sensing Applications in Perceptive Mobile Networks, Types of Sensing, Bands & Spectrum for ISAC, System Design Approaches

Waveforms and Signal Modeling: Radar-centric and comm-centric waveforms (FMCW, OFDM, OTFS); Delay-Doppler signal models for radar sensing; Pulse compression and matched filtering; Interleaved and overlaid waveform design; Ambiguity function shaping for joint delay-Doppler estimation.

Joint Processing and Resource Optimization: Delay, Doppler, and angle estimation from communication signals, Channel estimation aided by sensing (radar-assisted beam alignment) Joint beam forming, power allocation, and bandwidth sharing, Cramer-Rao Bounds and fundamental trade-offs, ISAC with MIMO/OFDM/OTFS systems.

Practical Applications and Research Trends: UAV swarms and collision avoidance, mmWave/THz sensing in indoor and vehicular environments, Passive ISAC and covert communication, AI/ML for task splitting: sensing vs. comms resource scheduling, Research challenges: spectrum coexistence, security, hardware limitations.

Textbooks:

1. Fan Liu et al., "*Integrated Sensing and Communication: Towards Dual-Functional Wireless Networks for 6G*", IEEE JSAC, 2020
2. IEEE-ComSoc ISAC Online Course Materials
3. M. Skolnik, "*Radar Handbook*," McGraw Hill
4. Chia-Kai Wen et al., "*Overview of Joint Radar and Communication*," IEEE Signal Processing Magazine, 2022
5. IEEE RadarConf, Globecom, and ICASSP proceedings.

25EC644	**Time Domain Synthetic Radar (TDSR) with P440 UWB Platform**	**DEC**	**2-0-0**	**2 Credits**

Detailed syllabus:

Introduction to UWB Radar and TDSR P440 Module: Overview of Ultra-Wideband (UWB) radar: principles, resolution, and penetration; Features and architecture of the Time Domain Synthetic Radar (TDSR) P440 module; Regulatory compliance: FCC and ETSI standards; Hardware setup: antennas, host interfacing (USB, UART), and deployment scenarios; P440 system block diagram and signal chain overview.

Precision Ranging and Signal Integration with P440: Time-of-flight (ToF) ranging using P440's coherent pulse transmission; Achieving sub-2 cm ranging accuracy in multipath environments using P440 signal integration; Pulse accumulation and coherent averaging with P440 SDK; Peer-to-peer distance measurements and angle-independent localization; Live demonstration: using P440 for robot/drone-based indoor navigation and ranging.

Target Detection and Radar Sensing Applications using P440: Operating P440 in monostatic and multistatic radar modes; Target detection using reflection amplitude and signal delay data from P440; Real-time object presence and motion/gesture recognition using P440 radar returns; Implementation of through-wall detection and short-range obstacle detection; Signal pre-processing techniques (clutter removal, background subtraction) using P440 API and scripts.

Software Control and Application Prototyping: Introduction to the TDSR P440 SDK, sample code, and API-based radar control; Interfacing P440 with Raspberry Pi/PC and real-time data collection; Data visualization using Python or MATLAB (range profiles, amplitude plots); Application design: human presence detection, security alerts, short-range tracking; Project development using P440 radar for commercial/industrial scenarios (e.g., inventory monitoring, smart entry).

Textbooks:

1. Mark A. Richards, "*Fundamentals of Radar Signal Processing,*" 2nd Edition, McGraw Hill, 2014.
2. Bassem R. Mahafza, "*Radar Systems Analysis and Design Using MATLAB*," 4th Edition, CRC Press, 2013.
3. Time Domain P440 Radar Documentation and Developer Resources → Available via https://www.hebi.us or archived Time Domain support sites. Includes SDK/API guides, integration manuals, application notes, and hardware datasheets.
4. IEEE Papers on UWB Radar Applications.

25EC645	VLSI Signal Processing	DEC	2-0-0	2 Credits

Detailed syllabus:

UNIT-I Introduction to DSP Systems: Introduction; representation of DSP algorithms: Block Diagram, signal flow graph, data flow graph, dependence graph, Pipelining and Parallel processing of FIR filters, Pipelining and Parallel processing for low power systems

UNIT-II RETIMING, ALGORITHMIC STRENGTH REDUCTION: Loop bound, iteration bound, longest path matrix algorithm, Retiming – definitions and properties, Unfolding – an algorithm for unfolding, properties of unfolding, sample period reduction and parallel processing application

UNIT-III FAST CONVOLUTION, PIPELINING AND PARALLEL PROCESSING OF IIR FILTERS: Fast convolution – Cook-Toom algorithm, modified Cook-Toom algorithm, Pipelined and parallel Recursive filters – Look-Ahead pipelining in first-order IIR filters.

UNIT-IV BIT-LEVEL ARITHMETIC ARCHITECTURES: Bit-level arithmetic architectures – parallel multipliers with sign extension, parallel carry-ripple and Carry-save multipliers, Design of Lyon's bit-serial multipliers using Horner's rule.

Textbooks:

1. R. Keshab K. Parhi, *"VLSI Digital Signal Processing Systems, Design and implementation,"* Wiley, Interscience, 2007
2. U. Meyer – Baese, *"Digital Signal Processing with Field Programmable Gate Arrays,"* Springer, Second Edition, 2004

REFERENCES:

1. Mohammad Isamail and Terri Fiez, "*Analog VLSI signal and information processing,*" McGraw Hill, 1994
2. S.Y. Kung, H.J. White House, T. Kailath, "*VLSI and Modern Signal Processing*," Prentice.

Web References:

1.https://drive.google.com/file/d/0BzoKWH8M1BoTb1d4SVNFSlZMdHM/view?usp=sharing
2.http://annaunivhub.blogspot.com/2015/05/vl7101-vlsi-signal-processing-notes.html E-

Text Books:

1.https://www.stuvia.com/doc/323898/vlsi-signal-processing-important-notes

2.https://drive.google.com/file/d/0BzoKWH8M1BoTdUpldzR3QkY3QlU/view?usp=sharing

MOOC Course

1.https://onlinecourses.nptel.ac.in/noc16_ec13/preview

2.http://viplab.cs.nctu.edu.tw/course/VLSIDSP2015_Fall.php

25EC636	**Next Generation Wireless Networks**	**DEC**	**2-0-0**	**2 Credits**

Detailed syllabus:
Introduction to 5G and beyond communications: Evolution of cellular systems, requirements, goals, and vision of the next generation wireless communication systems.

Introduction to multiple access technologies: TDMA, FDMA, CDMA, OFDMA, Non-Orthogonal Multiple Access (NOMA), Rate Splitting Multiple Access (RSMA), Index Modulation Multiple Access (IMMA) etc. and their applications.

MIMO: Point-to-point MIMO, virtual MIMO (relaying), capacity of MIMO systems. Massive MIMO: Multiuser MIMO, uplink/downlink data transmission, capacity bounds, achievable rate, mmWave massive MIMO: Challenges and channel modeling analog, digital, and hybrid beamforming block diagonalization and OMP algorithm.

NOMA, Intelligent reflecting surfaces (IRS), wireless energy harvesting, SWIPT, integrated sensing and communication.

Text Books:

1. T. S. Rappaport, R. W. Heath Jr., R. C. Daniels, and J. M. Murdock, "*Millimeter Wave Wireless Communication*," Pearson Education, 2015.
2. E. Bjorson, J. Hoydis, and L. Sanguinetti, "*Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency*," now Publishers, 2018.