CURRICULUM & SYLLABI

M.Tech. ADVANCED COMMUNICATION SYSTEMS

Effective from AY: 2024-25



NATIONAL INSTITUTE OF TECHNOLOGY WARANGAL

WARANGAL, TELANGANA

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Vision and Mission of the Institute
National Institute of Technology Warangal

VISION
Towards a Global Knowledge Hub, striving continuously in pursuit of excellence in Education, Research, Entrepreneurship and Technological services to the society

MISSION
- Imparting total quality education to develop innovative, entrepreneurial and ethical future professionals fit for globally competitive environment.
- Allowing stake holders to share our reservoir of experience in education and knowledge for mutual enrichment in the field of technical education.
- Fostering product-oriented research for establishing a self-sustaining and wealth creating centre to serve the societal needs.

Vision and Mission of the Department
ELECTRONICS AND COMMUNICATION Engineering

VISION
Create an Educational environment to prepare the students to meet the challenges of modern electronics and communication Industry through state of art technical knowledge and innovative approaches.

MISSION
- To create learning, Development and testing environment to meet ever challenging needs of the Electronic Industry.
- To create entrepreneurial environment and industry interaction for mutual benefit.
- To be a global partner in training human resources in the field of chip design, instrumentation and networking.
- To associate with international reputed institution for academic excellence and collaborative research.

Program: M.Tech. Advanced Communication Systems

Program Educational Objectives

PEO-1	Conceptualize and prescribe the design flow of a communication system for a given application.
PEO-2	Analyze, model, design and prototype the communication systems and networks with security features to meet the specifications
PEO-3	Choose economical the coding techniques and safety measures to improve the performance by considering the most appropriate models for the available channel.
PEO-4	Select the modern engineering tools to innovatively solve the problems in the design and operation of communication systems and networks.
PEO-5	Pursue life-long learning as a means of enhancing the knowledge base and skills necessary to serve the engineering and scientific community.
PEO-6	Contribute as an individual or a member of a team in product oriented research and demonstrate leadership skills

Program Articulation Matrix

PEO / Mission Statements	**PEO-1**	**PEO-2**	**PEO-3**	**PEO-4**	**PEO-5**	**PEO-6**
To create learning, Development and testing environment to meet ever challenging needs of the Electronic Industry.	**3**	**3**	**3**	**3**		
To create entrepreneurial environment and industry interaction for mutual benefit.	**1**	**2**	**2**	**3**		
To be a global partner in training human resources in the field of chip design, instrumentation and networking.		**1**	**1**	**3**	**2**	**3**
To associate with international reputed institution for academic excellence and collaborative research.				**2**	**3**	**3**

1 - Slightly; 2 - Moderately; 3 - Substantially

Program: M.Tech. Advanced Communication Systems

Program Outcomes

PO1	Engage in critical thinking and pursue investigations/ research and development to solve practical problems.
PO2	Communicate effectively, write and present technical reports on complex engineering activities by interacting with the engineering fraternity and with society at large.
PO3	Demonstrate higher level of professional skills to tackle multidisciplinary and complex problems related to advanced communication systems.
PO4	Identify modulation and demodulation techniques, coding and decoding scheme for the design of a transmitter and receiver.
PO5	Indicate the modern data communication and networking concepts and features to be incorporated for secured data transfer as per societal needs.
PO6	Analyse and evaluate a wireless communication link or network and indicate performance enhancement methods.

CURRICULUM
M.Tech. Advanced Communication Systems

1st Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EC36001	Detection and Estimation Theory	3-0-0	3
2	EC36003	Advanced Digital Communications	3-0-0	3
3	EC36005	RF Engineering	3-0-2	4
4	EC360XX	Professional Elective – I	3-0-0	3
5	EC360XX	Professional Elective – II	3-0-0	3
6	EC36007	Digital Communication Lab	0-1-2	2
7	EC36009	ADSP Techniques Lab	0-1-2	2
		Total Credits		**20**

2nd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EC36002	Advanced Wireless Communication	3-0-0	3
2	EC36004	Wireless Networks	3-0-0	3
3	EC360XX	Professional Elective – III	3-0-0	3
4	EC360XX	Professional Elective – IV	3-0-0	3
5	EC360XX	Professional Elective – V	3-0-0	3
6	EC36006	Wireless Communication Lab	0-1-2	2
7	EC36008	Mobile and Wireless Networks Lab	0-1-2	2
8	EC36096	Minor Project	0-0-0	2
		Total Credits		**21**

3rd Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EC36089	Seminar and Technical Writing	0-0-0	2
2	EC36093	Comprehensive Viva	0-0-0	2
3	EC36097	Dissertation: Part-A	0-0-0	8
4	EC36091	Summer Internship / Research Experience	0-0-0	2
			Total Credits	**14**

4th Semester

S.No.	Code	Course Title	L-T-P	Credits
1	EC36098	Dissertation: Part-B	0-0-0	12
			Total Credits	**12**

Professional Elective Courses:

Professional Elective – I		
S.No.	**Code**	**Course Title**
1	EC16021	Embedded RTOS
2	EC36021	Advanced DSP Techniques
3	EC36023	Mobile Networks

Professional Elective – II		
S.No.	**Code**	**Course Title**
1	EC36025	VLSI System design
2	EC36027	Cyber and Network Securities
3	EC36029	Advanced Optimization Techniques

Professional Elective – III		
S.No.	**Code**	**Course Title**
1	EC16026	Wireless Technologies
2	EC36022	Free Space Optical Communications
3	EC36024	IoT and Sensor Networks

Professional Elective – IV		
S.No.	**Code**	**Course Title**
1	EC26030	CMOS RFIC Design
2	EC36026	5G communications
3	EC36028	RF System Design

Professional Elective – V		
S.No.	**Code**	**Course Title**
1	EC16036	Hardware Security for Embedded Systems
2	EC36030	Machine Learning for Next-Generation Communication Networks
3	EC36032	Information Theory and Coding

The Overall Credit Structure

Course Category	Credits
Program Core	24
Program Electives	15
Minor Project	2
Seminar and Technical Writing	2
Summer Internship / Research Experience	2
Comprehensive Viva-Voce	2
Dissertation	20
Total Graded Credit Requirement	**67**

SYLLABI

M.Tech. Advanced Communication Systems

1st Semester

EC36001 **3-0-0 (3)**

Detection and Estimation Theory

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply discrete-time and continuous-time signal theory to estimate the signal parameters.
CO-2	Extract useful information from random observations in communications.
CO-3	Design and analyze optimum detection schemes.
CO-4	Understand different estimation schemes such as ML, LSE and MMSE estimators.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	-	-	-	-
CO-2	-	2	-	-	-	-
CO-3	-	-	2	-	-	-
CO-4	-	-	2	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Detection theory

Introduction: Detection Theory in Signal Processing; the Detection Problem; Mathematical Detection Problem; Hierarchy of Detection Problems; Role of Asymptotic; Summary of Important PDFs (Fundamental Probability Density Functions); Monte Carlo Performance Evaluation, Number of required Monte Carlo trials.

Statistical Decision Theory: Neyman-Pearson Theorem; Receiver Operating Characteristics; Minimum Probability of Error (ML, MAP, Baye's); Multiple Hypothesis Testing.

Deterministic Signals: Matched Filters – Development of Detector, Performance of Matched Filter; Multiple Signals – Binary case, Performance of Binary Case, M-ary case.

Random Signals: Estimator-Correlator – Energy Detector; Linear Model – Rayleigh Fading Sinusoid, Incoherent FSK for a Multipath Channel; Signal Processing Example – Tapped Delay Line Channel Model.

Estimation Theory

Introduction: Estimation in Signal Processing; Mathematical Estimation Problem; Assessing Estimator Performance.

Minimum Variance Unbiased Estimation: Unbiased Estimators; Minimum Variance Criterion; Existence of the Minimum Variance Unbiased Estimator; Finding the Minimum Variance Unbiased Estimator.

Cramer-Rao Lower Bound: Estimator Accuracy Considerations; Cramer-Rao Lower Bound; General CRLB for Signals in WGN; Extension to a Vector Parameter; Signal Processing Examples – Range Estimation, Sinusoidal Parameter Estimation).

Linear Models: Definition and Properties; Linear Model Examples – Curve Fitting, Fourier Analysis, System Identification.

General Minimum Variance Unbiased Estimation: Sufficient Statistics; Finding Sufficient Statistics; Using Sufficiency to Find the MUV Estimator.

Best Linear Unbiased Estimators: Definition of the BLUE; Finding the BLUE.

Maximum Likelihood Estimation: Example – DC Level in WGN; Finding the MLE; Properties of the MLE; MLE for Transformed Parameters.

Least Squares Estimation: The Least Squares Approach; Linear Least Squares; Order-Recursive Least Squares.

The Bayesian Philosophy: Prior Knowledge and Estimation, Nuisance parameters.

General Bayesian Estimators: Risk Function; Minimum Mean Square Error Estimators; Maximum A Posteriori Estimators.

Kalman Filters and Wiener Filters: Introduction, Summary, Dynamic signal models, Scalar Kalman filter, Kalman versus Wiener filter.

Learning Resources:

Text Books:

1. Steven M. Kay, Fundamentals of Statistical signal processing, volume-1: Estimation theory, Prentice Hall, 2011.
2. Steven M. Kay, Fundamentals of Statistical signal processing, volume-2: Detection theory. Prentice Hall, 2011.

Reference Books:

1. Harry L. Van Trees and John Wiley & Sons, Detection Estimation and Modulation Theory, Part I, Inc. 2011, 2nd Edition.
2. A. Papolis and S. Unnikrishna Pillai, Probability Random Variables and stochastic processes, The McGraw-Hill 2010, 4th Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/117103018
2. https://onlinecourses.nptel.ac.in/noc22_ee60

EC36003 **3-0-0 (3)**

Advanced Digital Communications

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design optimum receivers for digital modulation techniques
CO-2	Compare the various modulation schemes from the point of view of bandwidth, circuit complexity and noise performance.
CO-3	Determine the probability of error for a given scheme
CO-4	Design an equalizer in the context of band-limited linear filter channels

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	-	2	-	-
CO-2	-	-	-	-	2	-
CO-3	-	-	-	-	2	-
CO-4	-	-	-	-	-	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Elements of a Digital Communication System, mathematical models for communication channels, Communication channels and their characteristics. Representation of bandpass signals and system, Signal space representations.

Modulation Schemes: Representation of digitally modulated signals, Memoryless modulation methods-Pulse Amplitude Modulation, Phase Modulation schemes, Quadrature Amplitude Modulation, Multi dimensional signaling - Spectral characteristics of Digitally modulated signals .

Receiver and Channel Estimation: Optimum receiver for signals corrupted by AWGN, Performance of the optimum receiver for memoryless modulation, Optimum receiver for CPM signals and signals with random phase in AWGN channel. Signal parameter estimation, Carrier phase estimation, Symbol timing estimation, Joint estimation of carrier phase and symbol timing, Performance characteristics of ML estimators.

Detection System: Characterization of band-limited channels, Signal design for band-limited channels, Probability of error in detection of PAM, Modulation codes for spectrum shaping. Optimum Receiver for channels with ISI and AWGN, Linear equalization, Decision feedback equalization, Reduced complexity ML detectors, Iterative equalization and decoding-Turbo equalization.

Multicarrier Systems: Multi Carrier Communications, Orthogonal Frequency Division Multiplexing(OFDM), Modulation and Demodulation of OFDM system, Algorithm implementation IFFT/FFT of OFDM, Peak to average Power Ratio in multi carrier Modulation

Learning Resources:

Text Books:

1. J.G. PROAKIS, Digital communications, MGH, 2001, 4th edition.
2. Upamanyu Madhow, Fundamentals of Digital Communication, Cambridge University Press, 2008.

Reference Books:

1. Michael Rice, Digital Communications: A Discrete-Time Approach, Prentice Hall, 2008.

Other Suggested Readings:

1. https://nptel.ac.in/courses/117105144
2. https://onlinecourses.nptel.ac.in/noc21_ee11

EC36005 **3-0-2 (4)**

RF Engineering

Pre-Requisites: **None**

Course Outcomes:

CO-1	Simulate passive circuits in microstrip line technology
CO-2	Design microstrip lowpass, high pass, bandpass and bandstop filters.
CO-3	Design microstrip based couplers and power dividers
CO-4	Use and measure S-parameters using microwave instruments

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	-	2	-	-
CO-2	-	-	-	-	2	-
CO-3	-	-	-	-	2	-
CO-4	-	-	-	-	-	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Scattering Parameters: Scattering and chain scattering matrices, Generalized scattering matrix, Analysis of two port Networks, scattering matrix, representation of microwave components (directional coupler, circulators, hybrids, and isolators).

Planar Transmission Line: Microstrip lines: Geometry of microstrip, quasi-TEM mode of propagation, Static-TEM parameters, Characteristic impedance, effective permittivity, synthesis formulae, analysis formulae, dispersion in microstrip.

High Frequency Filter Design: Filter design using Insertion loss method, characterization by power loss ratio, Maximally flat low pass filter, Equal-ripple low pass filter, Filter transformations: impedance and frequency scaling, bandpass and bandstop transformations, Filter implementation: Richard's transformation, Kuroda's identities.

Power Dividers And Directional Couplers: Basic properties of dividers and Couplers. Even mode and odd mode analysis, Wilkinson power divider, quadrature hybrid, and coupled line directional coupler.

Microwave Measurement Systems: Instrumentation concepts and measurement techniques in Spectrum analyzer, Signal generator, Vector network analyzer, and Noise figure analyzers.

LAB Experiments

1. Design and simulation of microstrip low pass filter using 2.5D and 3D simulator (using stubs and stepped impedance filter).
2. Design and simulation of microstip bandpass filter using 2.5D and 3D simulator
3. Design and simulation of microstrip branch line coupler using using 2.5D and 3D simulator.
4. Design and simulation of microstrip coupled line coupler using using 2.5D and 3D simulator
5. Design and simulation of Wilkinson power divider using using 2.5D and 3D simulator.
6. Measurement of passive components using Vector Network Analyzer, Spectrum Analyzer and Signal Generator.

7. Fabrication and testing of microstrip low pass and bandpass filter.
8. Fabrication and testing of a microstip branch line coupler and Wilkinson power divider

Learning Resources:

Text Books:

1. D. M. Pozar, Microwave Engineering, John Wiley & Sons, 2007, 3rd Edition.
2. R. Sorrentino and G. Bianchi, Microwave and RF Engineering, John Wiley & Sons, 2010.
3. Reinhold Ludwig and Gene Bogdanvov, —RF Circuit Design – Theory and Application, Pearson, 2012, 2nd Edition.

Reference Books:

1. E.da Silva, —High Frequency and Microwave Engineering, Butterworth Heinmann publications, Oxford, 2001.
2. T. C. Edwards, Foundations of Interconnects and Microstrip lines, John Wiley & Sons, 2000.

Other Suggested Readings:

1. https://nptel.ac.in/courses/117102012
2. https://onlinecourses.nptel.ac.in/noc23_ee36/

EC36007 **0-1-2 (2)**

Digital Communication Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the different line codes and infer the quality of the received signal using eye diagram
CO-2	Appreciate the principle of generation and detection of BPSK, DPSK, DEPSK, MSK, GFSK, GMSK signals.
CO-3	Appreciate the principle of generation and detection of QPSK, DQPSK signals.
CO-4	Generate and detect rate ½ convolutional code
CO-5	Use a software tool to generate time domain and frequency domain descriptions of various binary digital modulation schemes.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	-	2	-	-	-
CO-2	-	-	-	2	-	-
CO-3	-	-	-	-	2	-
CO-4	-	-	-	-	-	2
CO-5	-	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Hardware related experiments:

1. Sampling and reconstruction of low pass signals
2. Time Division Multiplexing
3. BPSK/DPSK generation & detection
4. QPSK/OQPSK generation &detection
5. 8-QAM generation & detection
6. FSK generation and detection

Simulation based experiments: (Matlab/Labview simulation)

1. Sampling & reconstruction of low pass signals
2. BPSK Modulation & detection
3. BER of BPSK in AWGN channel
4. QPSK generation & detection
5. BER of QPSK in AWGN channel
6. QAM generation & detection
7. 16 QAM constellation diagram
8. Generation of Nyquist-I pulse
9. Designing an equalizer in the context of baseband binary data transmission
10. OFDM generation and detection

(Any of the 5 `Hardware related experiments' and 5 more `Simulation based experiments' are performed by all the students of M.Tech. batch).

Learning Resources:

Text Books:

1. J.G. PROAKIS, Digital communications, MGH, 2001, 4th edition.
2. Upamanyu Madhow, Fundamentals of Digital Communication, Cambridge University Press, 2012.

Reference Books:

1. Michael Rice, Digital Communications: A Discrete-Time Approach, Prentice Hall, 2008.

Other Suggested Readings:

1. https://nptel.ac.in/courses/117105144
2. https://onlinecourses.nptel.ac.in/noc21_ee11

EC36009 **0-1-2 (2)**

ADSP Techniques Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Estimate the Power Spectra for data sequences in MATLAB using various Non-parametric methods and understand the quality of the spectral estimate.
CO-2	Able to Implement Parametric methods (AR, MA and ARMA) in MATLAB and understand their spectral estimation.
CO-3	Understand and implement various digital filter structures in MATLAB.
CO-4	Understand the concepts and implement LMS, RLS, Kalman filter in MATLAB.
CO-5	Comprehend the concepts and methods for the estimation of higher-order spectra.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	2	-	1	3	2
CO-2	-	2	-	1	3	2
CO-3	-	2	-	1	3	2
CO-4	-	2	-	1	3	2
CO-5	-	2	-	1	3	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

To supplement the courses i) Detection and estimation and ii) Advanced DSP.

Experiments based on topics in:

i) DSP, linear algebra, and Discrete-time random processes (as needed).
ii) Spectral estimation (temporal): Non-parametric spectrum estimation, parametric methods for rational spectra (ARMA, MA, AR processes) and line spectra.
iii) Array signal processing (spatial): Subspace algorithms – MUSIC, ESPRIT, Root-MUSIC, Applications – direction-of-arrival (DOA) estimation, signal separation
iv) Optimum filtering (Wiener-Hopf equations, Wiener filters).
v) Adaptive filtering
vi) Gradient-based adaptive filters (LMS)
vii) Recursive least squares
viii) Other potential topics: Neural networks, Kalman filter, Signal analysis: PCA, LDA, ICA, NMF, Least-squares signal processing.

Learning Resources:

Text Books:

1. J. G. Proakis and D.G Manolakis, —DSP Principles, Algorithms and Applications‖, PHI, 2000, 3rd Edition
2. Steven M. Kay, — Modern Spectral Estimation, Theory and Applications ‖, Pearson, 2010.
3. M. Schwartz and L. Shaw, — Signal Processing – Discrete Spectral Analysis, Detection and Estimation‖ , McGraw Hill, 1975

Reference Books:

1. Chrysostomos L.Nikias, Athina P.Petropulu, —Higher-order Spectra Analysis‖, prentice hall signal processing series, 1993.

Other Suggested Readings:

1. https://nptel.ac.in/courses/117/101/117101001
2. https://onlinecourses.nptel.ac.in/noc19_ee50

2nd Semester

EC36002 **3-0-0 (3)**

Advanced Wireless Communication

Pre-Requisites: **None**

Course Outcomes:

CO-1	Model the wireless channel to estimate the path loss
CO-2	Evaluate the performance of digital modulation techniques over wireless channels using software and hardware techniques
CO-3	Suggest the possible techniques to improve the performance of wireless systems using modern tools
CO-4	Identify the advantages of multicarrier modulation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	-	2	-	-
CO-2	-	-	-	-	2	-
CO-3	-	-	-	-	2	-
CO-4	-	-	-	-	-	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Wireless Channels: Radio wave propagation, Physical modeling for wireless channels, Path loss and Shadowing, outage probability under path loss and shadowing, time and frequency coherence, Statistical multipath channel models, narrowband fading models, wideband fading models, Discrete-time model, Space-time channel models.

Capacity Of Wireless Channels: AWGN channel capacity, capacity of flat fading channels, channel distribution Information known at transmitter or receiver and both capacity comparisons, Capacity of frequency selective fading channels-time invariant- time variant.

Performance Of Digital Modulation Over Wireless Channels: SNR and bit/symbol energy, error probability for BPSK, QPSK, MPSK, MPAM, MQAM, Index Modulation over fading channels. Error probability for FSK and CPFSK, error probability approximation for coherent modulations and differential modulation, Q-function representation, outage probability, average probability of error, inter symbol interference.

Diversity: Receiver diversity: selection combining (SC), maximal ratio combining (MRC), equal gain combining (EGC), transmitter diversity: channel known at the transmitter, channel unknown at the transmitter, Alamouti scheme, diversity analysis for non-coherent and differentially coherent modulation.

Equalization: equalizer noise enhancement, equalizer types, zero forcing equalizer, MMSE equalizer, maximum likelihood sequence estimation, decision feedback equalization, adaptive equalizers

Learning Resources:

Text Books:

1. Andrea goldsmith, Wireless Communication, Cambridge University Press, 2015, South Asia Edition.
2. Theodore S. Rappaport, Wireless Communications Principles and Practice, Pearson Education. (Indian Edition is available), Third Edition.

Reference Books:

1. David Tse, Pramod Viswanath, Fundamentals of Wireless Communication, Cambridge University Press
2. Todd K Moon, Wynn C. Stirling, Mathematical Methods and Algorithms for Signal Processing, Prentice Hall

Other Suggested Readings:

1. https://nptel.ac.in/courses/117104099
2. https://onlinecourses.nptel.ac.in/noc24_ee10

EC36004 **3-0-0 (3)**

Wireless Networks

Pre-Requisites: **None**

Course Outcomes:

CO1	Identify and explain the fundamental concepts of wireless network architecture, layer technologies and Wireless LAN, PAN and MAN devices.
CO2	Represent the RF and IR communication spectrum details and propagation principles.
CO3	Understand the concepts of wireless LAN standards, both infrastructure and Ad-Hoc and their implementation details
CO4	Identify and explain the Wireless LAN security methodologies
CO5	Understand wireless PAN and MAN standards and their implementation details
CO6	Identify the important aspects of future wireless networking technologies.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	-	3	2	-
CO-2	3	3	3	2	2	2
CO-3	3	3	3	3	3	-
CO-4	2	3	2	2	3	2
CO-5	2	-	-	-	-	-
CO-6	2	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introducing Wireless Networking, Wireless Network Logical Architecture, the OSI & TCP Network Models, Network Layer Technologies, Data Link Layer Technologies, Physical Layer Technologies, Wired Network Topologies, Wireless LAN Devices, Wireless PAN Devices, Wireless MAN Devices.

Wireless Communication: Radio Communication Basics, RF Spectrum, Spread Spectrum Transmission, Wireless Multiplexing and Multiple Access Techniques, Ultra-Wideband, Near Field Communications, Infrared Communication Basics.

Wireless LAN: The 802.11 WLAN Standards, 802.11 MAC Layer, 802.11 PHY Layer, Implementing Wireless LANs, A Case Study: Voice over WLAN.

Ad-Hoc Wireless Networks, MAC Protocols for Ad-hoc Wireless Networks, Classification of MAC protocols, Contention-Based Protocols, Contention-Based Protocols with Reservation Mechanisms, Contention-Based Protocols with Scheduling Mechanisms, Routing Protocols for Ad-hoc Wireless Networks, Classification of Routing Protocols; Table Driven Routing Protocols; On-Demand Routing Protocols, Hybrid Routing Protocols, Hierarchical Routing Protocols and Power-Aware Routing Protocols. Transport Layer and Security Protocols.

Security, Hacking Threat WLAN Security, WEP – Wired Equivalent Privacy Encryption, Wi-Fi Protected Access, WPA IEEE 802.11i and WPA2, WLAN Security Measures, Wireless Hotspot Security.

Wireless PAN: Wireless PAN Standards, Bluetooth (IEEE 802.15.1), Wireless USB, ZigBee (IEEE 802.15.4), IrDA, Near Field Communications, Implementing Wireless PANs, Wireless PAN Technology Choices, Pilot Testing, Wireless PAN Security, 6LoWPAN.

Wireless MAN: Wireless MAN Standards, 802.16 Wireless MAN Standards, Metropolitan Area Mesh Networks, Implementing Wireless MANs, Wireless Mesh Network Routing, Network Independent Roaming, Gigabit Wireless LANs, Cognitive Radio, Sigfox / LoRa.

Learning Resources:

Text Books:

1. Steve Rackley, Wireless Networking Technology, Elsevier, 2007.
2. Ivan Marsic Wireless Networks- Local and Ad Hoc Networks, Rutgers University, 2008.
3. Wireless Communications and Networks, William Stallings, Pearson, 2005, Second Edition.
4. A. S. Tanenbaum, Computer Networks, PHI, 2003, Third Edition.

Reference Books:

1. Koushik Sinha, Sasthi C. Ghosh, Bhabani Wireless Networks and Mobile Computing, Chapman and Hall/CRC, 2015.
2. C. Siva Ram Murthy & B. S. Manoj Ad-hoc Wireless Networks, Pearson Education, 2011, 2nd Edition.

Other Suggested Readings:

1. http://doktora.kirbas.com/Kitaplar/Wireless%20Networking%20Complete.pdf
2. www.tutorialspoint.com/wimax/
3. http://www.infotech.monash.edu.au/units/archive/2012/s2/fit5083.html
4. http://www.utdallas.edu/~venky/
5. https://nptel.ac.in/courses/106105160

EC36006 **0-1-2 (2)**

Wireless Communication Lab

Pre-Requisites: None

Course Outcomes:

CO-1	Calculate the SNR versus BER using different modulation techniques under fading and non-fading environment.
CO-2	Calculate the SNR versus BER under fading and non-fading environment using Matlab
CO-3	Performance of Multitap indirect and direct channel equalization.
CO-4	Design, implement, and distribute stand-alone applications using Labview.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	-	-	-	-
CO-2	1	1	-	-	-	-
CO-3	-	2	-	-	-	-
CO-4	-	-	2	-	-	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Virtual Lab:

1. Introduction to the Labview
2. Performance of BPSK and QPSK.
3. Performance of 8PSK and QAM.
4. Performance of SNR versus BER for BPSK, QPSK, 8PSK, 16-QAM under AWGN channel
5. Performance of SNR versus BER for BPSK, QPSK, 8PSK, 16-QAM under fading channel coefficient.
6. Design a cellular mobile system and radio resource allocation based on SNR using MATLAB.
7. Estimation of channel in non-fading environment
8. Estimation of channel in fading environment
9. Performance of SNR versus BER of BPSK, QPSK and QAM over AWGN and Rayleigh channel using Matlab.
10. Performance of Multitap indirect channel equalization.
11. Performance of Multitap direct channel equalization.

Learning Resources:

Text Books:

1. Andrea goldsmith, Wireless Communication, Cambridge University Press, 2015, South Asia Edition.
2. Todd K Moon, Wynn C. Stirling," Mathematical Methods and Algorithms for Signal Processing", Prentice Hall

Other Suggested Readings:

1. https://nptel.ac.in/courses/117104099

EC36008 **0-1-2 (2)**

Mobile and Wireless Networks Lab

Pre-Requisites: **None**

Course Outcomes:

CO-1	Implement discrete event simulations.
CO-2	Design different traffic sources corresponding to end-user services.
CO-3	Evaluate the effect of queueing and different line-rates, and observe their effects on end-to-end delay.
CO-4	Implement wired and wireless access control protocols.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	-	-	2	-
CO-2	2	-	3	-	2	-
CO-3	-	-	-	2	2	-
CO-4	-	2	-	2	1	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

1. Overview of discrete event simulator, creating modules, generating and handling messages.
2. Creating a tree type wired access network, with an optical line terminal and optical network unit modules, with round robin scheduling for media access control.
3. Creating Pareto based ON OFF traffic sources.
4. Implementation of the multi-point control protocol in an optical access network.
5. Implementation of a long-reach passive optical network.
6. Implementation of a token ring, SONET, and RPR.
7. Implementation of a wireless mesh network with multiple hosts and interference with INET module.
8. Implementation of CSMA with acknowledgements.
9. Implementation of ad-hoc routing.
10. Implementation of obstacles and realistic radio models with INET module.

Learning Resources:

Text Books:

1. Queuing systems, Leonard Kleinrock, Vol 1, Wiley-Interscience; 1st edition.
2. Wireless communications,- Andrea Goldsmith, Cambridge University Press, India, 2nd edition.

EC36096 **0-0-0 (2)**

Minor Project

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world projects
CO-2	Plan and monitor project tasks individually or as a team
CO-3	Demonstrate practical experience in project execution
CO-4	Communicate project findings clearly through reports and presentations

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	3	
CO-2	2	2	2	2	2	
CO-3	2	2	2	2	2	
CO-4	1	1	1	1	1	

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Students are expected to choose real world or relevant problems and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel can decide the suitability and worthiness of the project

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Identification of Problem Domain	
II	Study of Existing Systems and establishing clear objectives	
III	Planning of project and work distribution within the team	
IV	Proper Documentation and Technical Writing	
V	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II	X			
III		X	X	
IV				X
V				X

3rd Semester

EC36089 **0-0-0 (2)**

Seminar and Technical Writing

Pre-Requisites: **None**

Course Outcomes:

CO-1	Consolidate ideas based on expert talks attended
CO-2	Prepare a well-organized report employing elements of critical thinking and technical writing
CO-3	Demonstrate the ability to describe, interpret and analyze the subject matter and develop competence in presenting

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2		2			3
CO-2	2		2			3
CO-3	2		2			3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

In Seminar and Technical Writing, every student is expected to prepare a well-organized report based on one / all of the following:

- by attending at least 5 expert lectures/ invited talks/ Seminar/ Popular lectures etc. organized by the institute/any of the departments, ideally in a specific domain or with the same theme.
- prepare a business or marketing plan based on patent search

The student is expected to consolidate the ideas from these lectures/patent searches and may even include material from other sources to strengthen the content of the report. The student should prepare a well-organized report based on the above and present it to the panel constituted by the department, for evaluation.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria.

Criteria	Description	Weightages
I	Clarity on the topic	
II	List of lectures attended	
III	Report	
IV	Presentation	
V	Response to questions	

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3
I	X		
II	X		
III		X	
IV			X
V			X

EC36093 **0-0-0 (2)**

Comprehensive Viva-Voce

Pre-Requisites: **None**

Course Outcomes:

CO-1	Comprehend the knowledge gained in the course work
CO-2	Demonstrate the ability in problem solving
CO-3	Communicate effectively using engineering terminology

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3		
CO-2	3	3	3	3		
CO-3	2	2	2	2		

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

In Comprehensive viva-voce each student will be evaluated for their overall comprehension of the course work and laboratory training that they have undergone. The students will be expected to answer questions orally, write down simple equations, draw plots, schematics, write simple code etc. as questioned by the panel. Assessment will be done by the panel based on the student response.

EC36097 **0-0-0 (8)**

Dissertation: Part-A

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify a topic in advanced areas of Communication Engineering.
CO-2	Review literature to identify gaps and define objectives and scope of the work.
CO-3	Employ the ideas from literature and develop research methodology.
CO-4	Develop a model, experimental set-up and / or computational techniques necessary to meet the objectives.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	2	3	1	-	3
CO-2	3	2	3	1	-	3
CO-3	3	3	3	3	3	3
CO-4	3	3	3	3	3	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – A will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Selection of Topic	
II	Literature Survey	
III	Defining the Objectives and Solution Methodology	
IV	Performance of the Task	

Evaluation Criteria - CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X

Refer to the M.Tech. – Regulations for any further information regarding mid-term review and end semester evaluation, etc.

EC36091 **0-0-0 (2)**

Summer Internship/Research Experience

Pre-Requisites: **None**

Course Outcomes:

CO-1	Apply engineering principles to real-world problems, gaining practical experience
CO-2	Plan, manage and execute the work with ethical consideration
CO-3	Review the social and environmental impact of the work
CO-4	Communicate the learnings through report and presentation

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	3	3	3	3	
CO-2	2	2	2	2	2	
CO-3						3
CO-4						

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Description:

Every student has to undergo either a Summer Internship / Research project. The summer internship may be undergone in an Industry/Research organization or any premier academic Institution, including NIT Warangal for 6-8 weeks. The research project shall be registered under the guidance of any faculty member in the institute. The student is required to submit a report and present the work before an evaluation committee, nominated by the Head of the Department.

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria. Weightage for each criterion will be determined by the panel and will be informed to the students.

Criteria	Description	Weightages
I	Relevance of the area of work	
II	Performance of the Task	
III	Crucial learnings from the work	
IV	Report Preparation	
V	Presentation and Response to questions	

Evaluation Criteria-CO Mapping

CO / Criteria	CO1	CO2	CO3	CO4
I	X			
II		X		
III			X	
IV				X
V				X

4th Semester

EC36098 **0-0-0 (12)**

Dissertation: Part-B

Pre-Requisites: **EC36097**

Course Outcomes:

CO-1	Identify the materials and methods for carrying out experiments/develop a code.
CO-2	Execute the research methodology with a concern for society, environment and ethics
CO-3	Analyse, discuss and justify the results/trends and draw valid conclusions.
CO-4	Prepare the report as per recommended format and present the work orally adhering to stipulated time.
CO-5	Explore the possibility to publish/present a paper in peer reviewed journals/conference proceedings without plagiarism.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	3	3	2	3
CO-2	2	-	3	3	2	3
CO-3	3	-	3	3	2	3
CO-4	3	3	3	3	3	3
CO-5	3	3	3	-	-	3

1 - Slightly; 2 - Moderately; 3 - Substantially

Description:

Students are expected to choose real-world contemporary problem and apply the engineering principles learned, to solve the problem through building prototypes or simulations or writing codes or establishing processes/synthesis/correlations etc. The department constituted panel will decide the suitability and worthiness of the project.

Dissertation Evaluation:

i. The dissertation shall be submitted as per the schedule given in the academic calendar.
ii. The dissertation supervisor will periodically review the progress of the student and finally give his/her assessment of the work done by the student.
iii. The Dissertation Part – B will be evaluated for 100 marks, with the following weightages:

Sub-component	**Weightage**
a) Periodic evaluation by Guide	40 marks
b) Mid-term review	20 marks
c) End Semester viva-voce examination	40 marks

Evaluation Criteria:

The student will be evaluated by the panel based on the below criteria as a continuation of Dissertation Part A. Weightage for each criterion will be determined by the panel and will be informed to the students.

Task	Description	Weightages
IV	Performance of the Task	
V	Dissertation Preparation	
VI	Review (Presentation & Understanding)	
VII	Viva-Voce	
VIII	Publications /Possibility of publication	

Evaluation Criteria-CO Mapping:

CO / Criteria	CO1	CO2	CO3	CO4	CO5
IV	X	X			
V				X	
VI			X		
VII				X	
VIII					X

Refer to the M.Tech. – Regulations for any further information regarding mid-term review and end semester evaluation, etc.

Professional Electives

Professional Elective - I

EC16021 **3-0-0 (3)**

Embedded RTOS

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the basic concepts of embedded C/C++
CO-2	Understand real-world software development challenges
CO-3	Develop the programs for real time application using C++
CO-4	Apply the concepts of OOPS programming
CO-5	Develop graphical user interface using python

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	1	2	2	1	1
CO-2	1	1	2	2	1	1
CO-3	2	2	2	2	2	1
CO-4	1	1	2	2	1	1
CO-5	1	1	-	-	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Embedded Systems: Embedded systems Overview, Embedded Systems Vs General Computing Systems, History of Embedded Systems, Classification, Major Application Areas, Purpose of Embedded Systems, Characteristics of embedded computing applications, Design Challenges, Common Design Metrics

Real-Time Operating Systems: Architecture of the kernel, Tasks and Task Scheduler, Scheduling algorithms, Interrupt Service Routines, Semaphores, Mutex, Mailboxes, Message queues, Event Registers, Pipes, Signals, Timers, Memory management, Priority Inversion problem. Overview of COTS/FOSS operating systems Applications and examples of user level/ Kernel programming and debugging

Learning Resources:

Text Books:

1. David E-Simon: An Embedded software Primer, Pearson Education, 2007.
2. K.V.K.K. Prasad,Real-Time Systems: Concepts Design and Programming, Dreamtech Press, 2005.

Reference Books:

1. Kernighan, Brian W, Ritchie, Dennis M,C Programming language, Prentice Hall,1988 (2nd Edition)
2. Michael J. Pont,Embedded C, Addison-Wesley, Kenneth Lambert, Fundamentals of Python: Course Technology Publishing, Cengage Learning, 2012 ISBN-13: 978-1-111-82270-5

EC36021 **3-0-0 (3)**

Advanced DSP Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the properties, functioning of DCT, KLT and wavelet transforms for 1-D and 2-D signals.
CO-2	Implement adaptive filter algorithms for applications in noise cancellation, deconvolution, enhancement and channel equalization.
CO-3	Apply higher order spectra for solving Non-Gaussian, non-linear stochastic problems.
CO-4	Design a decimator or interpolator for the given specifications
CO-5	Understand the operation of TMD 320 C5x/6x DSP processors for application problems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	-	-	-	-	-
CO-2	-	2	1	-	-	-
CO-3	-	-	2	-	-	-
CO-4	-	-	-	2	-	-
CO-5	-	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Review of Discrete time Signals and Systems, Discrete Time Fourier Transform, Z-Transform

Transform techniques: Discrete cosine transforms(DCTs), Discrete sine transforms(DSTs), KL transforms, Hadamard transforms, Walsh transforms and Wavelet transforms, Applications of DCTs and Wavelets.

Adaptive Filter theory: Stochastic gradient based algorithms LMS algorithm, stability analysis, Mean-squared error behavior. Convergence analysis, Normalized LMS algorithm, Gradient adaptive lattice algorithm. Prediction, filtering and smoothing, adaptive equalization, noise cancellation, blind deconvolution, adaptive IIR filters, RLS algorithms-GRLS, Gauss- Newton and RML.

Multirate signal processing: Decimation, Interpolation, polyphase filters and their structures, Subband coding of speech signals, filter banks, Quadrature mirror filters.

Optimum linear filters: Wiener filters for filtering and prediction, FIR wiener filter, orthogonality principle in LMS estimation, IIR wiener filter, state-space (Kalman) filters, Method of least squares, data windowing, principle of orthogonality, Innovation process, statement of the kalman filtering problem, Estimation of the state using innovations process, Riccati equation, filtering, kalman filter as the unifying basis for RLS filters.

Learning Resources:

Text Books:

1. JG Proakis, DG Manolakis, DSP Principles, Algorithms and Applications, PHI Private Ltd., 2001, 3rd Edition.
2. S. Haykin, Adaptive Filter Theory, PRENTICE HALL., 2001, 2nd Edition.
3. V.Udayashankara, Modern Digital Signal Processing, PHI, 2012, 2nd Edition.

Reference Books:

1. SM Kay, Modern spectral estimation, PH Int, 1997
2. Proakis, C. M. Rader, Fuyun, Ling CL., Mcmillan, Advanced digital signal processing, Publishing Company, NY, 1992.
3. Prabhakar S. Naidu, Modern Digital signal processing An Introduction, Narosa Publishing House,2003.
4. B. Widrow & D. Stearns, Adaptive Signal processing, PH Int 1987 S.J.Orfanidis, Optimum Signal Processing; An Introduction, McGraw Hill Book Company, 1992, Second Edition.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc21_ee20
2. https://onlinecourses.nptel.ac.in/noc20_ee21

EC36023 **3-0-0 (3)**

Mobile Networks

Pre-Requisites: **None**

Course Outcomes:

CO1	Assess the wireless network performance and trade-offs
CO2	To understand the various technologies in wireless networks.
CO3	Suggest the architectures for wireless wide area networks
CO4	Handle the planning and design issues for Adhoc wireless networks

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3		3	3	3	3
CO2	3		3	3	3	3
CO3	3		3	3	3	3
CO4	3		3	3	3	3

1 - Slightly; **2 - Moderately;** **3 – Substantially**

Syllabus:

Wireless Area Networks: WPAN: System model - protocol stack of IEEE 802.15; Bluetooth: Network architecture - operation- specification and application models; Radio Frequency Identification (RFID): Types and specifications; ZIGBEE and WBAN: Standard and architecture; WLAN: Network architecture - protocol stack of IEEE 802.11 - physical layer and MAC layer mechanism (CSMA/CA and WiFi MAC overview; Wide bandwidth channel access techniques (802.11n/ac) ; Energy efficiency and rate control).

Wireless Wide Area Networks: GSM, 3G wireless systems : Concept of Spread Spectrum - System Processing Gain - Direct-Sequence Spread Spectrum - Frequency-Hopping Spread Spectrum Systems - Requirements of Spreading Codes- evolution of IS 95 to CDMA 2000- Downlink (Forward) (BS to MS) - Uplink (Reverse) (MS to BS) - Power Control in CDMA –WCDMA.

Wireless Internet: IP for wireless domain - mobile IP - IPv6 advancements –IPV6 network layer in the internet; mobility management functions - location management - registration and handoffs; TCP in wireless domain: TCP over wireless - types - mobile transaction - impact of mobility; Wireless security and standards.

Wideband Wireless Technologies: UWB Radio Communication: Fundamentals of UWB - major issues - operation of UWB systems - comparisons with other technologies - advantages and disadvantages

Adhoc wireless networks: Characteristics of Adhoc Networks, Classifications of MAC Protocols - Table driven and Source initiated On Demand routing protocols, DSDV, AODV, DSR and Hybrid Protocols.

Fourth Generation Systems and New Wireless Technologies- 4G Vision - 4G Features and Challenges - Applications of 4G; 4G Technologies - LTE FDD vs TDD comparison; frame structure and its characteristics; Smart Antenna Techniques - OFDM-MIMO Systems - Adaptive Modulation and Coding with Time-Slot Scheduler - Bell Labs Layered Space Time (BLAST) System - Software-Defined Radio - Cognitive Radio.

Learning Resources:

Text Books:

1. Theodore Rappaport —Wireless Communication, Prentice Hall, 2nd Edition.
2. William Stallings —Wireless Communications and Networks, Prentice Hall.
3. Schwartz —Mobile Wireless Communications, Cambridge University Press.
4. Mark and Zhuang —Wireless Communications and Networking, Prentice Hall.
5. Vijay Garg K, Wireless Communications and Networks, Morgan Kaufmann Publishers (Elsevier), 2007, 2nd Edition

Reference Books:

1. Clint Smith and Daniel Collins, 3G Wireless Networks, Tata McGraw Hill, 2007, 2nd Edition.
2. Amitabha Ghosh and Rapeepat Ratasuk, Essentials of LTE and LTE-A, Cambridge University Press, 2011.
3. Dharma Prakash Agrawal and Qing-An Zeng, Introduction to wireless mobile systems Thomson India, 2007.
4. Siva Ram Murthy C and Manoj B S, Ad Hoc Wireless Networks: Architectures and Protocols, Prentice Hall, 2004.

Other Suggested Readings:

1. http://doktora.kirbas.com/Kitaplar/Wireless%20Networking%20Complete.pdf
2. www.tutorialspoint.com/wimax/
3. http://www.infotech.monash.edu.au/units/archive/2012/s2/fit5083.html
4. http://www.utdallas.edu/~venky/
5. https://nptel.ac.in/courses/106106167

Professional Elective - II

EC36025 **3-0-0 (3)**

VLSI System Design

Pre-Requisites: **None**

Course Outcomes: At the end of the course, the student will be able to

CO1	Model the behaviour of a MOS Transistor
CO2	Understanding CMOS Inverter
CO3	Design combinational and sequential circuits using CMOS gates
CO4	Identify the sources of power dissipation in a CMOS circuit.
CO5	Analyze SRAM cell and memory arrays

Course Articulation Matrix:

	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	-	2	2	-	-
CO2	-	-	2		-	-
CO3	-	-	2	2	-	-
CO4	-	-	2	-	-	-
CO5	-	-	-	-	-	2

1 - Slightly; 2 - Moderately; 3 – Substantially

Syllabus:

MOS Transistors, CMOS Logic, CMOS Fabrication and Layout, Design Partitioning, Fabrication, Packaging, and Testing, MOS transistor Theory, Long Channel I-V Characteristics, C-V Characteristics, Non-Ideal I-V Effects, DC Transfer Characteristics. The CMOS Inverter:

The Static CMOS Inverter -An Intuitive Perspective, Evaluating the Robustness of the CMOS Inverter: The Static Behavior, Performance of CMOS Inverter: The Dynamic Behavior.

CMOS Processing Technology, CMOS Technologies, Layout Design Rules, CMOS Process Enhancements, Technology-Related CAD Issues, Manufacturing Issues, Circuit Simulation- A SPICE Tutorial, Device Models, Device Characterization, Circuit Characterization, Interconnect Simulation. Combinational Circuit Design, Circuit Families, Silicon-On-Insulator Circuit Design, Sub Threshold Circuit Design, Sequential Circuit Design, Circuit Design of Latches and Flip-Flops, Static Sequencing Element Methodology, Sequencing Dynamic Circuits, Synchronizers, Wave Pipelining.

Power, Sources of Power Dissipation, Dynamic Power, Static Power, Energy-Delay Optimization, Low Power Architectures, Robustness, Variability, Reliability, Scaling, Statistical Analysis of Variability, Variation-Tolerant Design. Delay, Transient Response, RC Delay Model, Linear Delay Model, Logical Effort of Paths, Timing Analysis Delay Models, Datapath Subsystems,Addition/Subtraction, One/Zero Detectors, Comparators, Counters, Boolean Logical Operations, Coding, Shifters, Multiplication.

Array Subsystems, SRAM, DRAM, Read-Only Memory, Serial Access Memories, Content-Addressable Memory, Programmable Logic Arrays, Robust Memory Design, Special-Purpose Subsystems.

CMOS Testing-The need for testing, Manufacturing test principles, Design strategies for test, Chip level test techniques, System level test techniques, Layout design for improved testability.

Learning Resources:

Text Books:

1. Neil H.E. Weste, David Harris, Ayan Banerjee, CMOS VLSI Design – A Circuits and Systems Perspective, Pearson Education, 2006, 3rd Edition.
2. Neil H. E. Weste, Kamran Eshraghian, Principles of CMOS VLSI DESIGN:A Systems Perspective, Pearson Education, 2006, 2nd Edition.

Reference Books:

1. Jan M RABAEY, Digital Integrated Circuits, Pearson Education, 2003, 2nd Edition.
2. Douglas A. Pucknell, Kamran Eshraghian, Basic VLSI Design, PHI, 1994, 3rd Edition.

EC36027 **3-0-0 (3)**

Cyber and Network Securities

Pre-Requisites: **None**

Course Outcomes:

CO-1	Have a fundamental understanding of the objectives of cryptography and network security.
CO-2	Apply mathematical foundations to solve security problems in system and communication networks
CO-3	Become familiar with the cryptographic techniques that provide information and network security
CO-4	Be able to evaluate the security of communication systems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	3	-	-	-	-
CO-2	3	-	-	-	-	-
CO-3	-	1	-	-	-	-
CO-4	-	2	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Cyber Security: Security requirements and attacks, CIA model, Symmetric ciphers, AES, Block cipher operation, PRBS generation and stream ciphers, Asymmetric ciphers, PKC and RSA, ECC, Data Integrity Algorithms, Hash functions, Digital signatures, User authentication, digital envelope.

Network Security and Internet Applications: Security Requirements and Attacks, Confidentiality with Conventional Encryption, Secure Socket Layer and Transport Layer Security, IPv4 and IPv6 Security, Wi-Fi Protected Access. transport level security, WLAN security, E-mail security, Malicious software, firewalls.

P2P network security: Introduction and Applications of P2P Networks, Centralized Directory, Query Flooding, Distributed Hash Table, Attacks on P2P Networks, Distributed Denial-of-Service, Poisoning the Network, Privacy and Identity, Blocking of P2P Traffic, Securing P2P Networks, Encrypting P2P Traffic, Anonymous P2P.

Learning Resources:

Text Books:

1. William Stallings, Cryptography and Network Security, Pearson, 2011.
2. Bruce Schneier, Applied Cryptography, Wiley India Pvt. Ltd. 2009, 2nd Edition.

Reference Books:

1. Jie Wang, Zachary A. Kissel, Introduction to Network Security, Wiley India Pvt. Ltd. 2015.

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc23_cs127
2. https://nptel.ac.in/courses/106106129

EC36029 **3-0-0 (3)**

Advanced Optimization Techniques

Pre-Requisites: **None**

Course Outcomes:

CO-1	Ability to formulate mathematical models of real world problems
CO-2	Understand the major limitations and capabilities of deterministic operations
CO-3	Handle, solve and analyze problems using linear programming and other mathematical programming algorithms.
CO-4	Solve various multivariable optimization problems.
CO-5	Use search techniques methods to find optimal solutions of Non-Linear Problems

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	-	-	-
CO-2	-	-	3	-	-	-
CO-3	-	-	-	-	-	3
CO-4	3	-	-	-	-	-
CO-5	3	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Statement of an optimization problem, Classification of optimization problems, Overview of various optimization Techniques, Classical optimization techniques: Single variable optimization, Multivariable optimization, Unconstrained optimization and Constrained optimization**.**

Genetic algorithm (GA): Fundamentals of Genetic algorithm, History, Basic concepts, working principle, Encoding, Design of Fitness function, Reproduction, Crossover, Mutation operator in GA, Applications of GA for standard Bench mark test functions Fundamentals.

Swarm intelligence: Main inspiration source, Basic particle swarm optimization, Initialization techniques, Theoretical investigations and parameter selection, Design of PSO algorithm using computational statistics,

Differential Evolution: Classical differential evolution- An outline, Mutation, cross over, new modifications of DE.

Teaching Learning Based Optimization (TLBO), Applications of TLBO for standard Bench mark test functions, Case studies Basic Steps in Differential Evolution algorithm

Wavelet Mutation: Basic Wavelet Theory, wavelet theory in mutation operation, Wavelet Mutation (WM) to improve further the optimization performance of Evolutionary Optimization Techniques through mutation.

Hybridization: Hybridization of GA, PSO, DE etc.

Learning Resources:

Text Books:

1. S Rajasekharan, G.A Vijaya Lakshmi Pai, Neural Networks, Fuzzy logic, and Genetic algorithms, Synthesis and Applications, Prentice hall of India, 2007
2. K. Deb, Optimization for Engineering Design Algorithms and Examples, Prentice-Hall of India Pvt. Ltd., New Delhi, 1995.
3. D.K. Pratihar, Soft Computing, Narosa Publishing House, New Delhi, 2008

Reference Books:

1. Milani Mitchel, An introduction to Genetic algorithms, MIT Press, 1998.
2. Richard W Daniels, An Introduction to Numerical Methods and Optimization Techniques, Elsevier North Holland Inc
3. AE Eiben and J.E Smith, Introduction to Evolutionary Computing, Springer, 2010

Other Suggested Readings:

1. https://nptel.ac.in/courses/111105039
2. https://nptel.ac.in/courses/105108127

Professional Elective - III

EC16026 **3-0-0 (3)**

Wireless Technologies

Pre-Requisites: **None**

Course Outcomes: After the completion of the course the student will be able to:

CO1	Understand the fundamentals of wireless technologies for embedded systems and their application in real-time scenarios.
CO2	Understand wireless technologies and wireless transmission technology.
CO3	Understand the fundamentals of MAC, routing, transport control protocols, and their design considerations.
CO4	Understand various wireless networking standards and their connectivity for wireless embedded systems.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	-	-	-	-	1
CO-2	-	-	-	-	-	1
CO-3	2	1	2	2	2	1
CO-4	1	1	1	-	2	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to wireless communication: Electromagnetic spectrum, Radio waves, Associated bands, Network and Service Architecture, Cellular and Non-cellular Wireless Networks, and their application in embedded systems.

Wireless Communications understanding, Criteria, Range, Frequency Bands, Power Consumption, Topology, Constrained Devices, Constrained-Node Networks, Data Rate and Throughput, Latency and Determinism, Overhead and Payload. Wireless systems and standards.

Wireless Networking: Multiple access schemes – TDMA, FDMA, CDMA. Random Multiple Access Schemes – ALOHA, slotted ALOHA, CSMA/CA, OFDMA. Performance analysis issues. MAC layer scheduling and connection admission in wireless networks. Resource allocation and mobility management.

Wireless Networking:

i) Wi-Fi standard (IEEE 802.11), IEEE 802.11n (Wi-Fi 4), IEEE 802.11ac (Wi-Fi 5), IEEE 802.11ax (Wi-Fi 6), Channels, Service sets, Media Access Control, Wireless Security, Wired Equivalent Privacy (WEP), WPA2 & 3.

ii) Bluetooth standard (IEEE 802.15.1), Bluetooth 5, Channels, Service sets, Media Access Control, Wireless Security.

iii) RFID & NFC, Physical Layer, MAC Layer, Topology, Security.

iv) Broadband over power lines (BPL) (IEEE 1901.2a), Physical Layer, MAC Layer, Topology, Security.

v) Licensed LTE-M, EC-GSM & NB-IoT standards, data rate, and connectivity.

vi) Unlicensed MIOTY, LoRa & Sigfox standards, data rate, and connectivity.

vii) Cellular 5G, Visible Light, Infra Red, and Satellite Connectivity.

vii). Network Layer: IPv6, 6LoWPAN, RPL, IPSec, Transport Layer: TLS1.3, DTLS, TCP, TCP/UDP, and Application Layer: HTTP, XXMPP, DPWS, SOAP, CoAP, MQTT.

Learning Resources:

References:

1. Dr. Raul Aquino santos, MSc. Arthur Edwards Block,Embedded systems and wireless Technology : Theory and Practical Applications (University of Colima, Mexico) publication ,2012,1 st Edition Boca Raton

2. Frank Adelstein, sandeep K.S. Gupta, Gold Richard III, and Loren Schwiebert,Fundamentals of Mobile and pervasive computing Publisher: McGraw-Hill Education, 2005, ISBN-10:0071412379, ISBN- 13: 978-0071412377 to be verified

EC36022 **3-0-0 (3)**

Free Space Optical Communications

Pre-Requisites: **None**

Course Outcomes:

CO1	Learn the principles of free space optical (FSO) communication and the light transmission through the air.
CO2	Understand about the modulation and demodulation techniques used in FSO systems.
CO3	Expose atmospheric/free-space channel characterization with different atmospheric conditions.
CO4	Design transmitter and receiver for FSO link and analyze the link feasibility in terms of error performance and channel capacity.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	2	-	-	-	-
CO-2	-	-	-	3	-	-
CO-3	1	-	2	-	2	-
CO-4	-	-	-	-	1	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to free space optical (FSO) communication system: FSO channels: atmospheric channel, underwater optical channel, atmospheric losses, weather condition influence, atmospheric turbulence effects i.e. scintillation, beam spreading, etc. FSO communication application areas, FSO challenges.

Optical sources and detectors: LED structure, LED efficiencies, LASER diode, modes and threshold conditions, structure of common Laser Types: Fabry–Perot Laser, distributed feedback laser. PIN Photo detector, avalanche photo diode, photo detection noises, comparison of photo detectors.

Channel modeling: linear time invariant model, channel transfer function, models of turbulence induced fading such as log-normal turbulence model, exponential, K distribution, gamma-gamma distribution, indoor optical wireless communication channel, LOS propagation model, Non-LOS propagation model, outdoor optical channel modelling,

Modulation techniques: analogue intensity modulation, digital baseband modulation techniques: baseband modulations, on–off keying, error performance on Gaussian channels, power efficiency, BW efficiency, bit versus symbol error rates, different modulation schemes such as M-PPM, DPPM, DAPPM schemes, subcarrier modulation, optical polarization shift keying: binary PolSK.

Detection techniques and link performance analysis: direct detection optical receivers, coherent techniques i.e. homodyne and heterodyne, bit error rate evaluation in presence of atmospheric turbulence, visible light communication system, range equation of FSO link, atmospheric turbulence, effect of turbulence and weather conditions i.e. drizzle, haze fog on error performance and channel capacity.

Learning Resources:

Text Books:

1. Hemani Kaushal, V.K. Jain, Subrat Kar, Free Space Optical Communication Springer (India), 2017, 1st Edition.
2. Z.Ghassemlooy, W.Popoola, S.Rajbhandari, Optical Wireless Communications, CRC Press, 2013, 1st Edition.

Reference Books:

1. Arun K. Majumdar, Zabih Ghassemlooy, A. Arockia Bazil Raj, Principles and Applications of Free Space Optical Communications, IET publisher, 2019,1st Edition.
2. L.C.Andrews, R.L.Phillips, Laser Beam Propagation through Random Media, SPIE Press, USA, 2005, 2nd Edition.
3. Gerd Keiser, Optical Fiber Communication, Tata McGraw-Hill Ltd., 2008, 4th Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108106167
2. https://onlinecourses.nptel.ac.in/noc21_ee42

EC36024 **3-0-0 (3)**

IOT and Sensor Networks

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand IOT design requirements
CO-2	Compare various technologies and protocols
CO-3	Study Cloud storage and intelligent analytics
CO-4	Analyze security requirements along with threat model

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	-	-	-
CO-2	-	2	-	-	-	3
CO-3	-	-	-	3	-	-
CO-4	-	-	-	-	3	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Architectures: IoT and the connected world, Architecture of IoT, Security issues, Opportunities for IoT Relevance of Internet to network of Things, network management, security, mobility and longevity, desirable features of a distributed architecture for a system of things

Technologies: Wireless protocols, Connectivity options, Low-power design, range extension techniques, data-intensive IoT, MAC and routing aspects.

Data storage and analysis: Managing high rate sensor data, Processing data streams, Data consistency in an intermittently connected or disconnected environment,
Identifying outliers and anomalies

Security in IOT: Threat models, Defensive strategies and examples

Cloud Computing: Introduction, Types of Cloud Computing, Cloud Computing: A Paradigm Shift, Price and Value Models, Security and Governance, IAAS AND PAAS, SAAS, AWS, Azure, IBM Watson

Learning Resources:

Text Books:

1. Adrian McEwen, Hakim Cassimally, Designing the Internet of Things, Wiley 2013
2. Naveen Balani, Enterprise IoT, CreateSpace Independent Publishing Platform ,2016

Reference Books:

1. Nayan B. Ruparelia, Cloud Computing, MIT Press 2016

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc22_cs53
2. https://nptel.ac.in/courses/106105166

Professional Elective - IV

EC26030 **3-0-0 (3)**

CMOS RFIC Design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Understand the design bottlenecks specific to RF IC design
CO-2	Identify noise sources and develop noise models for the devices and systems.
CO-3	Identify various Transmitter and receiver architectures
CO-4	Design various RF amplifiers

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	2	1	3	1	1	-
CO-2	2	1	2	3	1	2
CO-3	3	2	3	3	2	2
CO-4	3	3	2	3	3	3

Syllabus:

Basic concepts of RF IC design: Design Bottle necks of RF IC design Non linearity and Time invariance Sensitivity and dynamic range, Passive impedance transformation, RF radio receiver front end non idealities and design parameters: Effects of nonlinearity, 1 dB compression point, Derivation of required noise figure at receiver front end, Required IIP_3 at receiver front end, Partitioning of required NF at receiver front end and IIP_3 into individual NF and IIP_3.

Noise: Noise sources in MOSFETs, Modeling of thermal noise and flicker noise, noise analog integrated circuits.

Transceiver architectures: General considerations, receiver architecture, Transmitter Architecture, transceiver performance tests.

Low Noise Amplifier: Introduction, General Philosophy, Matching Networks, Comparison of Narrowband and wideband LNA. Wideband LNA Design: DC Bias, Gain ad Frequency Response, Noise Figure.
Narrowband LNA: Principles, core amplifier design, noise figure, power dissipation, trade-offs between noise figure and power dissipation, noise contribution from other sources.

Mixers: Active mixer, modeling mixers, unbalanced mixer circuits, single balanced mixer circuit, double balanced mixer circuits, Quantitative description of Gilbert mixer, conversion gain, Distortion, analysis of Gilbert mixer. Passive mixers: switching mixer, distortion in unbalanced switching mixer, conversion gain and noise.

Frequency synthesizer: PLL based frequency synthesizer: Concepts of PLL, phase detector, charge pump, RF Synthesizer architectures, Frequency Dividers, VCO, LC oscillators, Ring oscillator, Phase noise, Loop filter and system design.

Learning Resources:

Text Books:

1. Bosco Leung, VLSI for wireless communication, Springer, 2011, 2nd Edition.
2. Behad Razavi, RF Microelectronics, Prentice Hall, 2011, 2nd Edition

Reference Books:

1. Rovert Caverly, CMOS RFIC Design Principles, Artech House, 1st Edition, 2007
2. Hooman Darabi, Radio Frequency Integrated Circuits and Systems, Cambridge University Press, 2020, 2nd Edition.

Other Suggested Readings:

1. NPTEL Courses (https://nptel.ac.in/courses/106103182/)

EC36026 **3-0-0 (3)**

5G Communications

Pre-Requisites: **EC36002, EC36003**

Course Outcomes:

CO1	Learn 5G Technology advances and their benefits
CO2	Learn the key RF, PHY, MAC and air interface changes required to support 5G
CO3	Learn Device to device communication and millimeter wave communication
CO4	Understand the Implementation options for 5G

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	1	-	-	-	3
CO-2	1	1	3	-	-	-
CO-3	1	-	2	1	-	-
CO-4	1	-	-	-	-	-

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Introduction to Cell technologies, handoff, cellular capacity, 2G,3G, 4G standards. Basic Architectural difference in 2G, 3G & 4G systems with introduction to 5G technology. Regulations for 5G,Spectrum Analysis and Sharing for 5G.

The 5G wireless Propagation Channels: Multipath Propagation, Doppler spread, large and small-scale propagation models. Flat & frequency selective fading, Fast and slow fading, Various fading distributions, Link budgeting. Channel modeling requirements, propagation scenarios and challenges in the 5G channel modeling.

5G NR(new radio) and 5G core network (5GCN): Basics about RAN architecture, 5G RAN, ORAN, Network slicing, 5G frame structure, NFV and SDN, High-level requirements for the 5G architecture, Integration of LTE and new air interface to fulfill 5G Requirements, Enhanced Multi-RAT coordination features, Physical architecture and 5G deployment.

Transmission and Design Techniques for 5G: Basic requirements of transmission over 5G, Modulation Techniques – Orthogonal frequency division multiplexing (OFDM), generalized frequency division multiplexing (GFDM), filter bank multi-carriers (FBMC) and universal filtered multi-carrier (UFMC), Multiple Accesses Techniques – orthogonal frequency division multiple accesses (OFDMA), generalized frequency division multiple accesses (GFDMA), non-orthogonal multiple accesses (NOMA).

Interference management, mobility management, and security for 5G: Network deployment types, Ultra-dense network or densification, Moving networks, Heterogeneous networks, Interference management in 5G, Interference management in UDN, Interference management for moving relay nodes, Interference cancelation, mobility management in 5G, User equipment controlled versus network-controlled handover, Mobility management in heterogeneous 5G networks.

Device-to-device (D2D) and machine-to-machine (M2M) type communications: Extension of 4G D2D standardization to 5G, radio resource management for mobile broadband D2D, multi-hop and multi-operator D2D communications.

Millimeter-wave Communications: Millimeter wave transmission and reception, Spectrum regulations, deployment scenarios, physical layer techniques, interference and mobility management, Spatial Modulation (SM).

Learning Resources:

Text Books:

1. Martin Sauter ,Wiley-Blackwell, From GSM to LTE–Advanced Pro and 5G: An Introduction to Mobile Networks and Mobile Broadband, 2017, 2nd Edition.
2. Athanasios G.Kanatos, Konstantina S.Nikita, Panagiotis Mathiopoulos, New Directions in Wireless Communication Systems from Mobile to 5G,CRC Press, 2018, , 1st Edition.
3. Wei Xiang, Kan Zheng, Xuemin(Sherman) Shen, 5G Mobile Communications, Springer, 2017, , 1st Edition.
4. Theodore S.Rappaport, Robert W.Heath, Robert C.Danials, James N.Murdock Millimeter Wave Wireless Communications, Prentice Hall Communications, 2015, 1st Edition.

Reference Books:

1. Jonathan Rodriguez, John Wiley & Sons, Fundamentals of 5G Mobile Networks, 2015, 1st Edition.
2. Amitabha Ghosh and Rapeepat Ratasuk Essentials of LTE and LTE-A, Cambridge University Press, 2011 1st Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/108105134
2. https://onlinecourses.nptel.ac.in/noc24_ee152

EC36028 **3-0-0 (3)**

RF system design

Pre-Requisites: **None**

Course Outcomes:

CO-1	Design RF amplifier, oscillators and other related circuits.
CO-2	Simulate RF Systems using modern microwave/RF design packages.
CO-3	Design and evaluate RF and Microwave amplifiers and oscillators using packages.
CO-4	Design a RF mixer circuit

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	-	-	-	-	-	3
CO-2	2	-	-	3	-	3
CO-3	2	-	-	-	-	3
CO-4	-	-	-	-	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Basic Concepts In RF Design: Non linearity, effects of non linearity, harmonic distortion, gain compression, cross modulation, intermodulation, cascaded non-linear stages, sensitivity and dynamic range, noise.

Transmitter And Receiver Architectures: General considerations, basic heterodyne receivers, direction conversion receivers, Image reject receivers: Hartley receiver and Weaver receivers. Transmitter general considerations, Direct conversion transmitter and heterodyne transmitter.

Microwave Transistor Amplifier Design: Types of amplifiers, power gain equations. Stability considerations, Constant gain circles, unilateral case and bilateral case, constant noise circles, Low noise amplifier design and high power amplifier design.

Microwave Oscillator Design: One port and two port negative resistance oscillators. Oscillator's configurations, Oscillator design using large signal measurements, Introduction to Microwave CAD Packages, Microwave integrated circuits, MIC design for lumped elements.

Microwave Mixer Design: Basic operation of a mixer, mixer spectral products, conversion gain/loss, types of mixer circuits, Single ended mixer, single balanced mixer, Image reject mixer, and sub harmonic mixer.

Learning Resources:

Text Books:

1. B. Razavi, RF Microelectronics, Prentice hall, 2012, 2nd Edition.
2. González, G. Microwave transistor amplifiers: analysis and design ,Englewood Cliffs, N.J.: Prentice-Hall, 1997, , 2nd Edition.
3. Reinhold Ludwig and Gene Bogdanvov, —RF Circuit Design – Theory and Applications, Pearson, 2012, 2nd Edition

Reference Books:

1. I. Bahl and P. Bhartia, Microwave solid state circuit design, John Wiley.
2. David. M. Pozar, Microwave Engineering‖, John Wiley and Sons, Third Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/117102012
2. https://onlinecourses.nptel.ac.in/noc24_ee75

Professional Elective - V

EC16036 **3-0-0 (3)**

Hardware Security for Embedded Systems

Pre-Requisites: **None**

Course Outcomes: At the end of the course, students will be able to

CO1	Comprehend the basics of embedded firmware, hardware and software vulnerabilities their causes
CO2	Identify the vulnerabilities related to embedded systems using state of the art tools technologies
CO3	Realize the principle aspects of a comprehensive security strategy in Embedded systems
CO4	Understand and apply countermeasures against the introduced attacks

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	1	1	1	1
CO-2	2	1	1	1	1	1
CO-3	2	-	1	-	1	1
CO-4	-	-	-	-	-	1

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction to Embedded Systems: Embedded hardware units, Embedded system software, Device drivers and interrupt services, Inter-process communication and synchronization of processes

Embedded System Security and Trust: Physical attacks, Side channel analysis, Trusted integrated circuit, Trusted platform module (TPM), Hardware Trojans, Cryptographic hashing, Stack-based attacks against embedded systems (Code injection and return-oriented programming), Physically unclonable functions, Fault injection attacks, Reverse engineering, Supply chain security and trust

Embedded Hardware Security and Hacking: Securing external memory, JTAG/Debug port considerations, Physical attack vectors, Temper detection and logging, Soldering techniques, Board analysis methodology, Component Identification, Device instrumentation, Bus monitoring and decoding, Access via JTAG

Embedded Software Security and Exploitation: Fundamentals of embedded software security, Common firmware vulnerabilities, Software vulnerabilities in ARM/MIPS/etc, Embedded code vulnerabilities, Assembly code analysis, Exploitation techniques on ARM/MIPS/x86,Defenses against ARM exploits, Security practices for embedded software, Defensive software architectures, Defensive hardware interfaces

Learning Resources:

Text Books:

1. Tehranipoor, Mohammad, Wang, Cliff (Eds.), Springer Introduction to Hardware Security and Trust
2. David Kleidermacher and Mike Kleidermacher, Embedded Systems Security: Practical Methods for Safe and Secure Software and Systems Development, Elsevier Science, Newnes Publication

Reference Books:

1. Louis Goubin and Mitsuru Matsui, Cryptographic Hardware and Embedded Systems, Springer-Verlag Berlin and Heidelberg GmbH & Co. KG

Other Suggested Readings:

1. https://onlinecourses.nptel.ac.in/noc22_cs48
2. https://onlinecourses.nptel.ac.in/noc22_cs93

EC36030 **3-0-0 (3)**

Machine Learning for Next Generation Communication Networks

Pre-Requisites: **EC36002**

Course Outcomes:

CO-1	Design machine learning algorithms for spectrum access and sharing
CO-2	Design reinforcement algorithms for resource allocation
CO-3	Design deep learning algorithms for optimizing coverage and channel capacity
CO-4	Apply machine learning algorithms for optimizing energy efficiency, modulation, coding, channel equalization and signal detection.

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	3	-	-	2	2	2
CO-2	3	-	-	3	2	-
CO-3	3	-	-	-	2	-
CO-4	1	-	2	3	-	3

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Machine Learning for Spectrum Access and Sharing: Online Learning Algorithms for Opportunistic Spectrum Access, Performance Measures of the Online Learning Algorithms, Random and Deterministic Approaches, The Adaptive Sequencing Rules Approach, Structure of Transmission Epochs, Learning Algorithms for Channel Allocation, Distributed Learning

Machine and Reinforcement Learning for Resource Allocation in Cognitive Radio Networks: Use of Q-Learning for Cross-layer Resource Allocation, Deep Q-Learning and Resource Allocation, Cooperative Learning and Resource Allocation, Decentralized Resource Minimization, Resource Minimization Approaches, Optimized Allocation

Deep Learning–Based Coverage and Capacity Optimization: Related Machine Learning Techniques for Autonomous Network Management, Data-Driven Base-Station Sleeping Operations by Deep Reinforcement Learning, Deep Q-Learning Preliminary and its Applications to BS Sleeping Control, Dynamic Frequency Reuse through a Multi-Agent Neural Network Approach

Machine Learning in Energy Efficiency Optimization: Self-Organizing Wireless Networks, Traffic Prediction and Machine Learning, Cognitive Radio and Machine Learning, Deep Learning, Positioning of Unmanned Aerial Vehicles, Traffic Prediction, Mobility Prediction

Machine Learning–Based Adaptive Modulation and Coding (AMC) Design: Overview of ML-Assisted AMC, k-NN-Assisted AMC, Algorithm for k-NN-Assisted AMC, Performance Analysis of k-NN-Assisted AMC System, RL-Assisted AMC

Machine Learning for Joint Channel Equalization and Signal Detection: Overview of Neural Network-Based Channel Equalization, Multilayer Perceptron-Based Equalizers, Functional Link Artificial Neutral Network-Based Equalizers, Radial Basis Function-Based Equalizers, Deep-Learning-Based Equalizers

Learning Resources:

Text Books:

1. Fa-Long Luo, Machine Learning for Future Wireless Communications, John Wiley and Sons, 2020
2. Ruisi He, Z Ding, Applications of Machine Learning in Wireless Communications, IET Telecommunication series 81.
3. K. K. Singh, A. Singh, K. Cengiz, Dac-Nhuong Le, Machine Learning and Cognitive Computing for Mobile Communications and Wireless Networks, Wiley 2020.

EC36032 **3-0-0 (3)**

Information Theory and Coding

Pre-Requisites: **None**

Course Outcomes:

CO-1	Identify the major classes of error detecting and error correcting codes and how they are used in practice.
CO-2	Specify specific error detecting and error correcting codes in a precise mathematical manner.
CO-3	Develop and execute encoding and decoding algorithms associated with the major classes of error detecting and error correcting codes.
CO-4	Construct codes capable of correcting a specified number of errors

Course Articulation Matrix:

	PO-1	PO-2	PO-3	PO-4	PO-5	PO-6
CO-1	1	-	-	2	-	-
CO-2	-	-	-	-	2	-
CO-3	-	-	-	-	2	-
CO-4	-	-	-	-	-	2

1 - Slightly; **2 - Moderately;** **3 - Substantially**

Syllabus:

Introduction: Entropy, Relative Entropy, Mutual Information Inequalities, Entropy rate. Asymptotic Equipartition Property (AEP): Consequences of the AEP.

Channel capacity: Discrete Memory less Channel, Channel Coding Theorem and its converse, Feedback capacity, Source Channel Separation Theorem. Differential Entropy: Definition, Properties. Gaussian Channel: Definition, Parallel Gaussian Channels, Channels with Colored Gaussian Noise, Gaussian Channels with Feedback.

Linear Block Codes: Groups, Fields and Vector Spaces, Construction of Galois Fields of Prime Order Syndrome Error Detection, Standard Array and Syndrome Decoding, Hamming Codes, LDPC Codes.

Cyclic Codes: Polynomial Representation of Code words, Generator Polynomial, Systematic Codes, Generator Matrix, Syndrome Calculation and Error Detection, Decoding of Cyclic Codes, Meggit decoder, BCH codes, generator polynomials with minimal polynomials, BCH decoding, non BCH codes(RS codes), RS encoding and decoding.

Convolutional Codes: Convolutional Encoder Representation, Tree, Trellis, and State Diagrams, Distance Properties of Convolutional Codes, Punctured Convolutional Codes and Rate Compatible Schemes, Decoding of Convolutional Codes: Maximum Likelihood Detection, The Viterbi Algorithm.

Learning Resources:

Text Books:

1. Todd K. Moon, Error Correction coding, John Wiley, 2005
2. Shu lin/ Daniel J.Costello Jr., Error Control Coding, Prentice Hall series in computer applications in electrical engineering series, 2005, 2nd Edition.
3. Robert Gallager, Information Theory and Reliable Communication, Springer, 1972

Reference Books:

1. T.M. Cover and J.A. Thomas, Elements of Information Theory, John Wiley & Sons,1991.
2. Ranjan Bose, Information Theory, coding and cryptography, McGraw Hill, 2008, 2nd Edition.

Other Suggested Readings:

1. https://nptel.ac.in/courses/117101053
2. https://nptel.ac.in/courses/108102117