Department of Electronics Engineering

Proposed Revised Curriculum Structure as per NEP2020

B. Tech. Electronics and Communication Engineering

Sr. No.	Subject	Code	Schemes	Credits	Notional hours
Seventh Semester					
1.	**Elective – V**	EC4XX	3-0-0	03	55
2.	**Elective – VI**	EC4XX	3-0-0	03	55
3.	**Elective – VII**	EC4XX	3-0-0	03	55
4.	**Elective – VIII**	EC4XX	3-0-0	03	55
5.	**Mandatory core** **Project Phase-II**	EC401	0-0-16	08	250
	Minimum Credit Requirement		**Total**	**20**	**470**
7	**Minor / Honor (M/H#4)**	**EC4AA**	**3-0-2**	**4/5**	**70/85**
			Total	**23**	**470**
Eighth Semester					
1	**Mandatory core** Internship training in Industry /Research Organization/ Academic Institute	ECP08	0-0-40	20	800 (20x40)
			Total	**20**	**800**
			Minimum Requirement	**20**	**800**
			Minimum Credit Requirement of full the program (Total)	**162**	**3755**

***NPTEL, SWAYAM and other Massive Open Online Courses (MOOC) approved by DAAC. As per 66th IAAC, Dated 20th March 2024, Resolution No. 66.34 and 61st Senate resolution No. 4, 25th April, 2024**
Subject Pool:

B. Tech. EC Elective -V, VI, VII, VIII (3-0-0)				
Sr. No.	**Subject**	**Code**	**Scheme**	**Credits**
1	5G Wireless Technologies	EC421	3-0-0	3
2	Estimation and Detection Theory	EC423	3-0-0	3
3	Optical Wireless Communication	EC425	3-0-0	3
4	Error Control Coding	EC427	3-0-0	3
5	Digital Satellite Communication	EC429	3-0-0	3
6	EM Interference and Compatibility	EC431	3-0-0	3
7	MIMO Communication systems	EC433	3-0-0	3
8	Deep Learning	EC435	3-0-0	3
9	Radar System	EC437	3-0-0	3
10	Ad-Hoc Networks	EC439	3-0-0	3
11	Optical Networks	EC441	3-0-0	3
12	Cognitive Radio	EC443	3-0-0	3
13	Quantum Communication	EC445	3-0-0	3
14	mmWave Communication	EC447	3-0-0	3
15	Testing and Verification of VLSI Circuits	VL421	3-0-0	3
16	UAV Avionics	VL423	3-0-0	3
17	Processor Architecture	VL425	3-0-0	3
18	Nanoelectronics	VL427	3-0-0	3

B.Tech. IV EC Semester VII 5G WIRELESS TECHNOLOGIES EC421	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**
	At the end of the course the students will be able to:

CO1	Understand and describe the key components, architectures, technical specifications, functions of 5G wireless networks and interactions in enabling 5G services.
CO2	Compare and contrast different 5G radio access technologies (e.g., mMTC, URLLC, eMBB) and their applications and analyze their suitability for various applications, considering factors like latency, reliability, and data rate requirements.
CO3	Apply knowledge of 5G principles, channel models, propagation characteristics to solve basic network design problems, such as coverage planning or capacity estimation.
CO4	Analyze the trade-offs between different 5G deployment strategies and evaluate their suitability for various applications and environments
CO5	Design and simulate a basic 5G network solution for a given scenario, considering factors like coverage, capacity, path loss, fading, antenna configurations, cost, and user requirements.

2. **Syllabus:**

INTRODUCTION	**(04 Hours)**
A vision for 5G, Key disruptive system concept trends; Performance limitations, new design principles, and three paradigm shifts; Critical usage scenarios in 5G: Crowded local access, Bursty IoT, Ultra-reliable and low latency communications; Spectrum: Spectrum for 4G, Spectrum challenges in 5G, 5G spectrum landscape and requirements.	
5G RADIO ACCESS	**(06 Hours)**
Evolution of mobile communication; 5G New Radio Access Technology; 5G NR Global view; NR- Physical Layer: Radio Protocol Architecture; NR PHY-Key Technology components: Modulation, Waveform, Multiple Antennas, Channel Coding; Physical Time Fr Resource; Physical signal; Duplexing scheme; Frame Structure; Physical Layer Challenges.	
MULTICARRIER AND NR WAVEFORMS	**(07 Hours)**
Multicarrier waveforms: OFDM based waveforms, Filterbank based waveforms; Single carrier DFTS-OFDM; NR Waveform: Waveform design requirements for 5G NR, Key performance indicator for NR waveform design, Waveform comparisons for NR; Suitability of OFDM for NR; Scalable OFDM for NR.	
NEW 5G AIR INTERFACE: CHALLENGES FOR EFFICIENT MULTI-SERVICE COEXISTENCE	**(06 Hours)**
Core services and their associated KPIs: Core services, Key performance indicators, KPI relevance to core services; Challenges for 5G design below 6 GHz: Design methodology, Service integration drivers, Link level and System level challenges.	
5G WIRELESS CHANNEL AND PROPAGATIN MODELS	**(06 Hours)**
Introduction; Modeling requirements and scenarios: Channel model requirements, Propagation scenarios; The METIS channel models: Map-based model, Stochastic model; Millimeter-wave channel experimental measurements and results interpretation; Quasi-deterministic approach for millimeter-wave channel modeling; Q-D channel models implementation.	
5G ARCHITECTURE	**(06 Hours)**

	Introduction, NFV and SDN, Basics about RAN architecture; High-level requirements for the 5G architecture; Functional architecture and 5G flexibility; Integration of LTE and new air interface to fulfill 5G requirements, Physical architecture and 5G deployment.	
	MACHINE TYPE COMMUNICATION	**(02 Hours)**
	Use cases and categorization of MTC, MTC requirements; Fundamental techniques for MTC: Data and control for short packets, non-orthogonal access protocols; Massive MTC.	
	DEVICE TO DEVICE COMMUNICATION	**(03 Hours)**
	D2D from 4G to 5G: D2D standardization: 4G LTE D2D, D2D in 5G: research challenges; Radio resource management for mobile broadband D2D, RRM techniques for mobile broadband D2D, RRM and system design for D2D, 5G D2D RRM concept.	
	mmWAVE COMMUNICATION	**(03 Hours)**
	Spectrum and regulations; Channel propagation; Hardware technologies for mmW systems; Deployment scenarios; Architecture and mobility: Dual connectivity, Mobility, Beamforming, Beam finding; Physical layer techniques: Duplex scheme, Transmission schemes.	
	WIRELESS BEYOND 5G	**(02 Hours)**
	A vision for wireless beyond 5G; Expectations and challenges for wireless beyond 5G: Joint Communication and Sensing, Space-Air-Ground Communication, Semantic Communication, Data-Driven Communication System Design.	
		(Total Contact Time: 45 Hours)
3.	**<u>Books Recommended:</u>**	
	1. Angeliki Alexiou, "5G Wireless Technologies", 1st Edition, The Institution of Engineering and Technology, 2017. 2. Afif Osseiran, Jose F. Monserrat, Patrick Marsch, "5G Mobile and Wireless Communication Technologies, Cambridge University Press, 2016. 3. Ali Zaidi, Fredrik Athley, Jonas Medbo, Ulf Gustavsson, Giuseppe Durisi, Xiaoming Chen, "5G Physical Layer, Principles, Models and Technology, Components, Academic Press, 2018. 4. Saad Z. Asif, "5G Mobile Communications: Concepts and Technologies", CRC Press, 2019. 5. Hrishikesh Venkatarman and Ramona Trestian, "5G Radio Access Networks: Centralized RAN, Cloud-RAN and Virtualization of Small Cells", CRC Press, 2017.	

B.Tech. IV EC Semester VII ESTIMATION & DETECTION THEORY EC423	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**
	At the end of the course the students will be able to:

CO1	Describe the basic concepts of signal estimation and linear prediction.
CO2	Apply estimation algorithms for engineering problems
CO3	Analyse performance of different estimation algorithms.
CO4	Evaluate performance of estimation algorithms.
CO5	Design estimator for the problems of interest.

2. **Syllabus:**

LINEAR PREDICTION	**(19 Hours)**
Linear Prediction and Optimum Linear Filters, Forward and Backward Linear Prediction, Solution of The Normal Equations-Levinson-Durbin and Schur Algo, Pede's Approximation, AR Lattice and ARMA Process and Lattice Ladder Filter, Wiener Filter, Kalman Filter, Adaptive Filter, Linear Mean Square Estimation, Estimation Error, Least Square Errors, Minimum Mean Square Error.	
ESTIMATION	**(09 Hours)**
Estimation Based on Statistical Analysis, Bayesian Estimation, MAP and ML Detection Rules, Cramer-Rao Inequality.	
SPECTRUM ESTIMATION	**(05 Hours)**
APPLICATIONS OF ESTIMATION THEORY	**(13 Hours)**
Wireless Channel Estimation, Pilot Based and Training Sequence Based Estimation And Blind Estimation, Estimation Theory Applied For Speech, Image And Video Compression Coding, Time Delay Estimation, Velocity Estimation, Detection of Signal In Gaussian Noise.	
	(Total Contact Time: 45 Hours)

3. **Books Recommended:**

1. Steven M. Key, "Fundamentals of Statistical Signal Processing (Volume II): Detection Theory", 3rd Ed., Prentice Hall PTR, Reprint 2022
2. Steven M. Key, "Fundamentals of Statistical Signal Processing (Volume I): Estimation Theory", 3rd Ed., Prentice Hall PTR, reprint 2012
3. Anderson B. D. O and Moore J. B.,"Optimal Filtering",Prentice-Hall,1981
4. Ljung L.,"System Identification Theory For The User",Prentice-Hall,2006
5. Maybeck P. S.,"Stochastic Models, Estimation And Control, Vol. 1, 2, 3",Academic Press,1999
6. Saeed V. Vaseghi,"Advanced Digital Signal Processing And Noise Reduction", Wiley, 2nd Edition,2008.
7. Monson Hayes,"Statistical Digital Signal Processing And Modeling", John Wiley & Sons Inc., 1st Edition,2002
8. Proakis John and Manolakis,"Digital Signal Processing",Prentice-Hall, 3rd Edition, 2007

B.Tech. IV EC Semester VII OPTICAL WIRELESS COMMUNICATION EC425	Scheme	L	T	P	Credit
		3	0	0	03

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Describe atmospheric channels for the intended terrestrial free space optical link
CO2	Apply the concepts of OWC to calculate the system performance under background noise effects.
CO3	Analyse various modulation/demodulation techniques in designing of transmitter/receiver for OWC system.
CO4	Compare various detection techniques under different atmospheric conditions
CO5	Evaluate the OWC system under different weather conditions.

2. Syllabus:

INTRODUCTION **(06 Hours)**

General introduction, optical channel - Beam divergence, atmospheric losses, weather condition influence, atmospheric turbulence effects viz., scintillation, beam wander, beam spreading, etc.

CHANNEL MODELLING **(08 Hours)**

Linear time invariant model, channel transfer function, optical transfer function, models of turbulence induced fading viz., lognormal, exponential, K distribution, I- distribution, gamma-gamma distribution, Optical wave models - Plane, spherical and Gaussian, range equation, transmitting and receiving antenna gains.

BACKGROUND NOISE EFFECTS **(07 Hours)**

Background noise source, detector FOV, diffraction limited FOV, spatial modes, background noise power calculation.

MODULATION TECHNIQUES **(08 Hours)**

Power efficiency, BW efficiency, bit versus symbol error rates, error rate evaluation for isochronous modulation schemes viz., M-PPM, OOK, mxn PAPM schemes, subcarrier modulation, an isochronous modulation schemes - DPPM, DHPIM, DAPPM, psd and bandwidth requirement.

DETECTION TECHNIQUES **(09 Hours)**

Photon counter, PIN/APD, PMT, coherent techniques viz., homodyne and heterodyne, bit error rate evaluation in presence of atmospheric turbulence, concept of adaptive threshold.

WEATHER IMPAIRMENTS **(07 Hours)**

Effect of turbulence and weather conditions viz., drizzle, haze fog on error performance and channel capacity, link availability.

(Total Contact Time: 45 Hours)

3. Books Recommended:

1. Z. Ghassemlooy, W. Popoola, S. Rajbhandari, “Optical Wireless Communications”,2nd Ed., CRC Press, 2019.
2. L. C. Andrews, R.L.Phillips, “Laser Beam Propagation through Random Media”, 2nd Ed., SPIE Press, USA, 2005.
3. J. H. Franz, V. K. Jain, “Optical Communications: Components and Systems”, 1st Ed., Narosa Publishing House, 2000.
4. D. Chadha, “Terrestrial Wireless Optical Communication”, 1st Ed., Tata McGraw-Hill, 2012.

	5. Ivan B. Djordjevic , “Advanced Optical and Wireless Communications Systems”, 2nd Edition, Springer, 2022. 6. Ramaswami Rajiv and Sivarajan K. N., "Optical Networks: A Practical Perspective", Elsevier, Morgan Kaufmann Publishers, 3rd Ed., 2012

B.Tech. IV EC Semester VII ERROR CONTROL CODING EC427	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**
	At the end of the course the students will be able to:

CO1	Understand channel coding theorem , importance of error correction in data communication
CO2	Discuss various mathematical tools: groups and finite fields, Linear algebra in the development of codes and sequences.
CO3	Analyze various Block code encoder and decoder
CO4	Design and Develop different error correcting codes for appraise of reaching data rate to Shannon limit.
CO5	Compare and contrast the strengths and weaknesses of various errors correcting code

2. Syllabus:

CHANNEL CAPACITY AND CODING	**(05 Hours)**

Introduction, Communication system block Diagram, Channel Models, Channel Capacity, Channel Coding, The Shannon Limit, Hamming Distance, Channel code rate, Few Points of Information Theory. Decoding Probability

BLOCK CODES	**(05 Hours)**

Introduction to Block Codes, Single Parity Check Codes, Product Codes, Repetition Codes, Hamming Codes, Minimum Distance Of Block Codes, Soft - Decision Decoding, Automatic Repeat Request Schemes.

LINEAR CODES	**(06 Hours)**

Definition of Linear Codes, Generator Matrices, The Standard Array, Parity - Check Matrices, Error Syndromes, Error Detection And Correction, Shortened And Extended Linear Codes.

CYCLIC CODES	**(06 Hours)**

Definition Of Cyclic Codes, Polynomials, Generator Polynomials, Encoding Cyclic Codes, Decoding Cyclic Codes, Factors Of xn+1, Parity-Check Polynomials, Dual Cyclic Codes, Generator And Parity-Check Matrices Of Cyclic Codes, Design of cyclic Encoder using LFSR, Cyclic Decoder using LFSR, The Meggitt Decoder

BCH CODES	**(10 Hours)**

Linear Algebra, Galois Field, Primitive Field elements, Irreducible and primitive polynomials, minimal polynomials, Definition and Construction of Binary BCH Codes, Error Syndromes In Finite Fields, Decoding SEC and DEC Binary BCH codes, The Error location Polynomial, the Peterson Gorenstein Zierler decoder, Reed-Solomon Codes

CONVOLUTION CODES	**(08 Hours)**

Convolution, Encoding Convolutional Codes, Generator Matrices for Convolutional Codes, Generator Polynomials For Convolutional Codes, Graphical Representation Of Convolutional Codes, The Viterbi Decoder

ADVANCE ERROR CONTROL CODING	**(05 Hours)**

Concept Of Puncturing, Interlever, Turbocode, Introduction to LDPC Codes, Applications of Error Control Coding

	(Total Contact Time: 45 Hours)
3.	**<u>Books Recommended:</u>**
	1. Gravano Salvatore, "Introduction to Error Control Codes", 1^{st} Ed., Oxford University Press, 2007. 2. Shu Lin/ Daniel J. Costello Jr., “Error Control Coding, Fundamental and Applications, Prentice Hall series in computer applications in electrical engineering” 2^{nd} Ed., Series, 2005. 3. Ranjan Bose, “Information theory, coding and cryptography”, Tata McGraw-Hill,2^{nd} Edition, April 2008 4. Moon Tood K., "Error Correction Coding - Mathematical Methods and Algorithms", 1^{st} Ed., Wiley- Interscience, 2006. 5. Sklar Bernard, "Digital Communications - Fundamentals and Applications", 2^{nd} Ed., Pearson Education-LPE, 2009

B.Tech. IV EC Semester VII **DIGITAL SATELLITE COMMUNICATION** EC429	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**
	At the end of the course the students will be able to:

CO1	Describe terminology relating to Satellite system communication, orbital mechanism, orbital effects on communication etc.
CO2	Apply satellite communication techniques incorporating advanced satellite multiple accesses schemes, modulation and coding schemes.
CO3	Analyse satellite link budget, C/I calculations
CO4	Classify the state-of-the-art access schemes, coding schemes, functionality of satellite systems,
CO5	Design problem based on, satellite networking, Navigation and satellite personal communications.

2.	**Syllabus:**	
	COMMUNICATION SATELLITE : ORBIT AND DESCRIPTION	**(05 Hours)**
	Orbit Period & Velocity, Effects Of Orbital Inclination, Azimuth & Elevation, Coverage Angle & Slant Range, Eclipse, Placement Of A Satellite In A Geostationary Orbit, Satellite Description.	
	EARTH STATION	**(06 Hours)**
	Earth Station Antenna, High Power Amplifier, Low Noise Amplifier, Upconvertrer, Down Converter, Monitoring & Control, Reliability.	
	SATELLITE LINK	**(06 Hours)**
	Basic Link Analysis, Interference Analysis, Rain-Induced Attenuation, Rain-Induced Cross Polarization Interference, System Availability, Satellite Links Design, Satellite-Satellite Link Using Lasers.	
	FREQUENCY DIVISION MULTIPLE ACCESS	**(04 Hours)**
	FDM-FM-FDMA, SCPC, FM-FDMA TV, Companded FDM-FM-FDMA And SSB-AM-FDMA, Intermodulation Products, Resulting From Amplitude Nonlinearity And from both Amplitude & Phase Nonlinearities, Optimized C / I Plus Noise Ratio.	
	TIME DIVISION MULTIPLE ACCESS	**(08 Hours)**
	TDMA Frame Structure, TDMA Burst Structure, TDMA Frame Efficiency, TDMA Super frame Structure, Frame Acquisition & Synchronization, Satellite Position Determination, Burst Time Plan, Control & Coordination By The Reference Station, TDMA Timing, TDMA Equipment, Advanced TDMA Satellite Systems.	
	EFFICIENT TECHNIQUES: DEMAND ASSIGNMENT MULTIPLE ACCESS & DIGITAL SPEECH INTERPOLATION	**(05 Hours)**
	The Erlang B Formula, Types Of Demand Assignments, DAMA Characteristics, Real –Time Frame Reconfiguration, DAMA Interfaces, SCPC–DAMA, SPADE, Digital Speech Interpolation.	
	SATELLITE SPREAD SPECTRUM COMMUNICATIONS	**(05 Hours)**
	Direct Sequence Spread Spectrum System, Direct Sequence Code Division Multiple Access, Frequency Hop Spread Spectrum Systems, Frequency Hop Code Division Multiple Access, DS Acquisition & Synchronization, FH Acquisition & Synchronization, Satellite On-Board Processing.	
	MOBILE SATELLITE NETWORKS	**(03 Hours)**

	Operating Environment, MSAT Network Concept, CDMA MSAT Network, Statistics of Mobile Propagation.
	SATELLITE APPLICATION AND CHALLENGES **(03 Hours)** VSAT, Radarsat, GPS, Navigation, Interferences
	(Total Contact Time: 45 Hours)
3.	**Books Recommended:**
	1. Pratt T. and Bostian C. W., "Satellite Communications" John Wiley & Sons, 2nd Ed., 2003. 2. HaTri. T., "Digital Satellite Communications", McGraw-Hill, 2nd Ed., Reprint 2017 3. Roddy Dennis, "Satellite Communications", McGraw-Hill, 4th Ed., 2006, 4. Tomasi Wayne, "Advanced Electronic Communication Systems", PHI, 6th Ed., 2014 5. Nagaraja N.S., "Elements Of Electronic Navigation", TMH, 2nd Ed., 2000.

B.Tech. IV EC Semester VII EM INTERFERENCE AND COMPATIBILITY EC431	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**
	At the end of the course students will be able to:

CO1	Classify the different sources of electromagnetic interference and the standards for EMC.
CO2	Implement the fundamentals those are essential for product design with EMC compliance and various EMC standards under the environments of radiation and conduction interference.
CO3	Analyze the hazards of cross talk interference and model the methods to avoid it.
CO4	Evaluate the utility of different EMC methods in different environments.
CO5	Design a system for EMC.

2.	**Syllabus:**	
	INTRODUCTION	**(05 Hours)**
	History of EMI/EMC, Analysis of EMI, Types of noise and interference, Electromagnetic Compatibility, Benefits of good EMC design, EMC regulations (Government, Commercial And Military), Examples of EMC related problems.	
	EMC REQUIREMENTS FOR ELECTRONIC SYSTEMS	**(06 Hours)**
	Radiated emission limits for Class A, Class B, FCC And CISPR, Measurement of Emissions for Verification of Compliance, Radiated Emission and Susceptibility, Conducted Emissions and Susceptibility, Typical Product Emissions, Additional Product Requirements, Design Constraints for Products, Advantages of EMC Design.	
	CONDUCTED EMISSION AND SUSCEPTIBILITY	**(07 Hours)**
	Measurement Of Conducted Emission: LISN, Common and Differential Mode Currents, Power Supply Filters, Basic Properties of Filters, a Generic Topology, Effect of Filter Elements on Common and Differential Mode Currents, Separation of Conducted Emissions In to Common And Differential Mode Components For Diagnostic Purpose, Power Supplies: Linear and SMPS, Effect of Power Supply Components on Conducted Emissions, Power Supply and Filter Placement, Conducted Susceptibility.	
	RADIATED EMISSION AND SUSCEPTIBILITY	**(07 Hours)**
	Simple Emission Models for Wires And PCB Lands: Differential Mode Versus Common Mode Currents, Differential Mode Current Emission Model, Common Mode Current Emission Model, Current Probes, Simple Susceptibility Models for Wires And PCB Lands: Shielded Cables and Surface Transfer Impedance.	
	CROSS TALK	**(10 Hours)**
	Three Conductor Transmission Lines and Crosstalk, Transmission Line Equations for Lossless Lines, The Per Unit Length Parameters: Homogeneous versus Inhomogeneous Media, Wide Separation Approximation for Wires, Numerical Methods for Other Structures, The Inductive-Capacitive Coupling Approximation Model: Frequency Domain Inductive-Capacitive Coupling Model, Time Domain Inductive-Capacitive Coupling Model, Lumped Circuit Approximate Models, Shielded Wires, Inductive and Capacitive Coupling, Effect of Shield Grounding, Effect of Pigtails, Effects of Multiple Shields, MTL Model Predictions, Twisted Wires, Inductive and Capacitive Coupling, Effects of Twist, Effects of Balancing.	
	SHIELDING	**(05 Hours)**
	Shielding Effectiveness, Far Field Sources, Exact Solution, Approximate Solution, Near Field Sources: Near Field versus Far Field, Electric Sources, Magnetic Sources, Low Frequency, Magnetic Fielding Shielding, Effect of Apertures.	
	SYSTEM DESIGN FOR EMC	**(05 Hours)**

	Shielding and Grounding, PCB Design, System Configuration and Design, Electrostatic Discharge, Diagnostic Tools.
	(Total Contact Time: 45 Hours)
3.	**<u>Books Recommended:</u>**
	1. Paul Clayton, "Introduction to Electromagnetic Compatibility", 2^{nd} Ed., 2006, Wiley Interscience, Reprint 2017. 2. Kaiser K. L., "Electromagnetic Shielding", 1st Ed., CRC Press, 2006. 3. Ott H. W., "Noise Reduction Techniques in Electronic Systems", 2^{nd} Ed., Wiley Interscience, 1988. 4. Goedbloed, "Electromagnetic Compatibility", 1^{st} English Language Ed., Prentice Hall, 1993. 5. V. Prasad Kodali, "Engineering Electromagnetic Compatibility, Principles, Measurement and Technologies", IEEE Press, 1996.

B.Tech. IV EC Semester VII MIMO COMMUNICATION SYSTEMS EC433	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**
	At the end of the course students will be able to:

CO1	Describe basic terminologies associated with MIMO technology and understand the advancements in the technology.
CO2	Apply the developed fading concepts in MIMO system analysis.
CO3	Analyse various performance metrices for MIMO System.
CO4	Evaluate performance trade-offs in MIMO technology.
CO5	Design space time codes and optimum MIMO Communication systems under given conditions.

2.	**Syllabus:**	
	INTRODUCTION TO MULTI ANTENNA SYSTEM	**(03 Hours)**
	Need for MIMO Systems, MIMO wireless communication, Benefits of MIMO technology, Basic Building Block, MIMO channel & signal model, Error/Outage Probabilities over fading channels, Multiple antennas in wireless Communication, A fundamental Trade-off, MIMO transceiver design, Applications of MIMO systems.	
	CLASSICAL AND GENERALIZED FADING DISTRIBUTIONS	**(07 Hours)**
	Introduction to fading distributions, Classical fading distributions, Generalized fading distributions	
	MIMO CHANNEL MODELLING	**(08 Hours)**
	Physical channel modelling: Electromagnetic Models, Geometry Based Models, Empirical Models,. Analytical MIMO channel modelling: Fully correlated MIMO channels, separately correlated MIMO channel model, and Uncorrelated MIMO channel model.	
	MIMO CHANNEL CAPACITY	**(10 Hours)**
	Power allocation in MIMO System: Uniform, Adaptive and Near optimal power allocation, Capacity of simplified MIMO channels: Capacity for deterministic and random channels, Capacity of i.i.d., separately correlated and keyhole Raleyigh fading MIMO channel.	
	SPACE TIME CODES	**(08 Hours)**
	Design criteria for space time codes, Transmit Diversity for two antennas: The Alamouti Scheme-Transmission scheme, Optimal receiver for Alamouti Scheme, Performance analysis of Alamouti Scheme, Orthogonal Space Time Block codes (OSTBC), Space time trellis codes: Design principle, Representation of Space-Time trellis code for PSK constellations, Performance Analysis for Space-Time Trellis codes, Comparison of Space -Time Block & Trellis Codes.	
	MIMO DETECTION TECHNIQUES	**(07 Hours)**
	ML detection, Linear suboptimal detection: zero forcing and MMSE detection technique, Sphere decoding Advanced MIMO detection techniques: Successive Interference Cancellation, Lattice reduction-based detector	
	ADVANCE TOPICS IN MIMO WIRELESS COMMUNICATION	**(02 Hours)**
	Space time block coded spatial modulation, MIMO based cooperative communication, Large scale MIMO systems, MIMO cognitive radios	
	(Total Contact Time: 45 Hours)	
3.	**Books Recommended:**	

	1. Rakesh Singh Kshetrimayum, “Fundamentals of MIMO Wireless Communications,” Cambridge University Press, 2017 2. Ezio Biglieri, R.Calderbank, Anthony C., Andrea Goldsmith, Arogyaswami Paulraj, H. Vincent Poor, “MIMO Wireless Communications”, Cambridge University Press, 2007. 3. H. Khaleghi Bizaki, “MIMO Systems, Theory and Applications”, Intech, 2011. 4. Mohinder Jankiraman, “Space-Time Codes and MIMO Systems”, Artech House, Boston, London, 2004. 5. Tolga m. Duman, Ali Ghrayeb, “Coding for MIMO Communication Systems”, 1st Ed., John Wiley & Sons Ltd., 2007. 6. Savo G. Glisic, “Advanced Wireless Communications”, John Wiley & Sons, 2007.

B.Tech. IV EC Semester VII **DEEP LEARNING** **EC435**	**Scheme**	**L**	**T**	**P**	**Credit**
		3	**0**	**0**	**03**

1.	**Course Outcomes (COs):**
	At the end of the course the students will be able to:

CO1	Describe Basic Concepts of Machine Learning, Pattern Classification, and Neural Network (NN), and Explain How NN Learn and Function.
CO2	Demonstrate and Implement Single-Layer and Multi-Layer Perceptron Learning Algorithms, Analyzing Their Effectiveness for Various Classification Tasks.
CO3	Examine The Principles of Deep Learning Algorithms, Including CNNs And RNNs, and Apply Them to Various Applications Like Image and Sequence Data Processing.
CO4	Evaluate the Performance of Deep Learning Models Using Different Optimization Techniques and Network Training Strategies.
CO5	Design and Develop Advanced Deep Learning Models, Utilizing Principles of Regularization and Optimization, for Real-World Applications in Different Domains.

2. Syllabus:

INTRODUCTION	**(07 Hours)**
Brief History and Evaluation of Deep Learning, Brief Overview of Supervised and Unsupervised Machine Learning Algorithms, Difference Between Machine Learning and Deep Learning, Applications of Deep Learning, Review of Linear Algebra, Vector Calculus and Probability Theory, Discriminant Function and Decision Surface, Perceptron Algorithm.	
INTRODUCTION NEURAL NETWORKS	**(12 Hours)**
Biological Inspirations for Artificial Neurons, Single Layer Perceptron, Multilayer Perceptron (MLP), Activation Functions, Loss Functions, Computational Graph, Back Propagation Algorithm, Example of Back Propagation, Vanishing and Exploding Gradient Problem, Overfitting and Underfitting, Bias-Variance Trade-off, Autoencoder, Autoencoder vs PCA.	
CONVOLUTIONAL NEURAL NETWORK (CNN)	**(08 Hours)**
Convolution, Cross Correlation, Padding, Stride, Pooling, and Their Impact on the Output Dimension, Receptive Filed and Feature Maps, Building Blocks of CNN, MLP vs CNN, Popular CNN architectures: LeNet, AlexNet, VGG, ResNet, GoogleNet, Transfer Learning, Modern CNN Architectures.	
OPTIMIZATION TECHNIQUES AND REGULARIZATION	**(06 Hours)**
Gradient Descent (GD), Batch GD, Mini-Batch GD, Stochastic GD, Momentum Optimizer, Momentum and Nesterov Accelerated Gradient (NAG) Optimizer, RMSProp, Adam. Regularization Techniques: L1, L2 Regularization, Dropout, Early Stopping. Batch Normalization, Instance Normalization, Group Normalization.	
SEQUENTIAL AND GENERATIVE MODELS	**(12 Hours)**
Basics of Sequence Data and Recurrent Neural Network (RNN) Architecture, Long Short-Term Memory (LSTM), Challenges in Training RNNs (Exploding/Vanishing Gradients), Word Embedding, Attention Mechanism, Transformer Architecture, Comparison Between RNNs, CNNs, and Transformers, Overview of Generative Models, Difference Between Generative and Discriminative Models, Variational Autoencoders, Generative Adversarial Networks, Recent Trends in Deep Learning.	
	(Total Contact Time: 45 Hours)

3. Books Recommended:

1. Ian Goodfellow, Yoshua Benjio, Aaron Courville, “Deep Learning,” 1st Ed, The MIT Press, 2017.

	2. Eugene Charniak, "Introduction to Deep Learning," 1st Ed, The MIT Press, 2019. 3. Charu C. Aggarwal, "Neural Networks and Deep Learning: A Textbook," 1st Ed, Springer, 2018. 4. Francois Chollet, "Deep Learning with Python," 1st Ed, Manning, 2017. 5. David Foster, "Generative Deep Learning: Teaching Machines to Paint, Write, Compose, and Play," 1st Ed, O'Reilly Media, 2022.
4.	**Reference Book and Materials:**
	1. Christopher M. Bishop, "Pattern Recognition and Machine Learning", Springer; 2nd Ed., 2011. 2. Aurélien Géron, "Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems," 3rd Ed, O'Reilly Media, 2022.

B.Tech. IV EC Semester VII RADAR SYSTEM EC437	Scheme	L	T	P	Credit
		3	0	0	03

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Define the basic concepts related with radar technology
CO2	Understand various components and various antenna mechanism used for radar technology
CO3	Apply specific use of technology for various requirement.
CO4	Implement and analyze the working of different schemes of RADAR.
CO5	Design radar transmitter and receiver system.

2. Syllabus:

INTRODUCTION	**(05 Hours)**
Radar Block Diagram, Radar Equation, Detection of Signal in Noise, Receiver Noise and S/N Ratio, Transmitter Power, Pulse Repetition Frequency and Range Ambiguities, Beam Shapes, Introduction to Doppler Effect, CW and FMCW RADAR	
MTI AND PULSE DOPPLER RADAR	**(05 Hours)**
Introduction To MTI And Doppler Radar, Delay Line Cancellers, Staggered PRFs, Digital MTI Processing, Moving Target Indicator, Limitation to MTI Performance, Pulse Doppler Radar.	
TRACKING RADAR	**(05 Hours)**
Tracking With Radar, Monopulse Tracking, Conical Scan and Sequential Lobing, Limitation To Tracking Accuracy, Tracking In Range and Acquisition.	
INFORMATION FROM RADAR SIGNALS	**(06 Hours)**
Basic Radar Measurements, Theoretical Accuracy of Radar Measurements, Ambiguity Diagram, Pulse Compression, Target Recognition.	
RADAR CLUTTER	**(10 Hours)**
Introduction, Surface Clutter Radar Equation, Land Clutter, Sea Clutter, Weather Effects, Detection of Targets In Clutter.	
RADAR ANTENNA	**(08 Hours)**
Functions of Radar Antenna, Reflector Antennas, Electronically Steered Phased Array Antennas, Frequency Scan Arrays, Cosecant Squared Antenna Pattern, Effects of Errors on Radiation Pattern, Radomes.	
OTHER RADARS TOPICS	**(06 Hours)**
Synthetic Aperture RADAR, Air-Surveillance RADAR, Optical RADAR.	
	(Total Contact Time: 45 Hours)

3. Books Recommended:

	1. Sklonik Merrill, “Introduction to Radar Systems”, 3rd Ed., Tata McGraw-Hill, 2017. 2. Mark A. Richards, “Fundamentals of Radar Signal Processing”, 2nd Ed., McGraw-Hill Education, 2014. 3. Hannen-Toomay, “Principles of Radar”, 3rd Ed., PHI-NEW DELHI, 2010. 4. Mark A. Richards, William A. Holm, James A. Scheer, “Principles of Modern Radar: Basic Principles (Radar, Sonar and Navigation)”, Sci Tech Publishing Inc; 2010. 5. Nicolaos S. Tzannes, “Communication and Radar Systems”,1^{st} Ed., iUniverse, 2000.

B.Tech. IV EC Semester VII AD-HOC NETWORKS EC439	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**
	At the end of the course the students will be able to:

CO1	Show the basic knowledge of architecture, issues, protocols of Mobile Adhoc Networks and the standard Adhoc networks-Bluetooth, WiFI, WiMax, WSN etc.
CO2	Explain differences between fixed and Adhoc network protocols, mobility constraints and dynamic approaches in Adhoc Networks.
CO3	Apply protocols and techniques in MANETs, developing algorithms for recent standard Adhoc networks overcoming the constraints
CO4	Evaluate various techniques and protocols/algorithms, case study and problem solving as per given data.

2.	**Syllabus:**	
	INTRODUCTION	**(04 Hours)**
	Introduction To Generations In Wireless Systems, Introduction To Mobile Ad-Hoc Networks (MANETS), Classification Of Mobile Data Networks, MANET issues, Wireless Channel Related Issues	
	MAC LAYER ISSUES OF ADHOC NETWORKS	**(04 Hours)**
	CSMA with Hidden and Exposed Terminal Issues, MACA and MACAW protocols	
	NETWORK LAYER ISSUES IN ADHOC NETWORKS	**(06 Hours)**
	Challenges, Proactive and Reactive Algorithms, Limitations of Bellman Ford Algorithm, DSDV, WRP, CGSR protocols, DSR, AODV, Location aided, hybrid protocols, multicast protocols	
	TRANSPORT LAYER ISSUES	**(06 Hours)**
	Challenges, data flow control mechanisms, congestion control protocols, security aspects	
	BLUETOOTH	**(06 Hours)**
	Bluetooth Network Structure: Piconet & Scatternet, Bluetooth Specifications, Bluetooth Protocol Stack, Bluetooth Media Access Control Consideration, Asynchronous Connectionless And Synchronous Connection Oriented Communication Link, Modified Bluetooth	
	WIFI - IEEE802.11 STANDARDS	**(04 Hours)**
	Various 802.11 Protocols (a to s), WiFi Architecture, Security Enhancement, QoS Enhancement, Physical & MAC Layer Aspects Of 802.11 a,b,g,n; WiFi MAC: Point Coordinate Function, Distributed Coordinate Function, Hybrid Coordinate Function	
	WiMAX - IEEE802.16 STANDARDS	**(05 Hours)**
	Various 802.16 (a to e) Protocols, WiMAX Air Interface / Physical Layer, WiMAX Architecture, WiMAX Protocol Architecture, WiMAX And WiFi Interworking, WiMAX Mode: TDD And FDD, QoS In WiMAX	
	WIRELESS SENSOR NETWORK	**(06 Hours)**
	Sensor node architecture, Sensor Network architecture, Zigbee IEEE 802.15.4, Mobile Computing Aspects, Introduction to IoT	
	UWB	**(02 Hours)**
	UWB Air Interface	

	IEEE802.20 AND BEYOND	**(02 Hours)**
	(Total Contact Time: 45 Hours)	
3.	**<u>Books Recommended:</u>**	
	1. C.Siva RamaMurthy, B.S.manoj, "Adhoc Wireless Networks-Architectures and Protocols", Pearson, 1st Ed 2007 2. Toh C. K."Ad-hoc Mobile Wireless Networks-Protocol and Systems", LPE, Pearson Education, 2nd Edition, 2009 3. Upena Dalal,"Wireless Communication", Oxford University, 1st Edition, 2009 4. Taieb Znati, Kazem Sohraby, Daniel Minoli, "Wireless Sensor Networks: Technology, Protocols and Applications, Wiley publications, 1st Edition, January 2010 5. Sudip Misra, Isaac Woungang, Subhas Chandra Misra (Editors) "Guide to Wireless Adhoc Networks" Springerlink, 2009 (Open Access) 6. Jonathan Loo, Jesus Hamilton Ortiz, Jaime Lloret Mauri (Editors), "Mobile Adhoc Networks", CRC Press, 1st Edition, 2012 (Open Access)	

B.Tech. IV EC Semester VII OPTICAL NETWORKS EC441	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**
	At the end of the course the students will be able to:

CO1	Classify the Architectures of the Client Layers in Optical Layer, Frame Structures and Protocols for Optical Networks
CO2	Relate different Optical Network Technologies and their Components to Compute Range Budget.
CO3	Analyse the Network Control and Management Strategies for the Optical Networks.
CO4	Reorganize Protection in SONET/SDH, Point-To-Point Links, Ring Interconnection Protection with Client Layers.
CO5	Compare OTDM, Optical AND Gates, OPS, Optical PLL, Tuneable Delays for Future Optical Networks.

2.	**Syllabus:**	
	INTRODUCTION	**(08 Hours)**
	Network terminologies, OSI model, Telecommunications Network Architecture, Services: Circuit Switching, and Packet Switching, Multiplexing Techniques, Second-Generation Optical Networks, The Optical Layer, Transparency and Network Evolution, WDM Networking Evolution, Point-to-Point WDM Systems, Wavelength Add/Drop Multiplexer (WADM), Fibre and Wavelength Cross connects, Broadcast-and-Select Networks, Wavelength-Routed (Wide-Area) Optical Network, WDM Economics.	
	OPTICAL METRO AND TRANSPORT NETWORKS	**(09 Hours)**
	Client Layers of the Optical Layer, SONET/SDH, Multiplexing, SONET/SDH Layers, Optical Transport Network, ATM, FDDI, Ethernet, IP, OTN. Fibber to the Curb (FTTC), PON Evolution, PON Technologies, OLT, Splitters, ONU, PON Range Budget, TPON, GPON, WDM PON and other Networks, Free Space optics (FSO), Free Space Optical Networks.	
	WAVELENGTH ROUTED OPTICAL NETWORKS	**(07 Hours)**
	Optical Routers and Optical Switches, Wavelength continuity constraint, Basics of Wavelength Conversion, Wavelength Conversion Techniques, Optoelectronic Approach, Optical Gating, Interferometric Technique, Wave Mixing, Converter Switches.	
	NETWORK CONTROL AND MANAGEMENT	**(07 Hours)**
	Basic Functions of Network Control and Management, Dynamic Routing and Wavelength Assignment, Fixed Routing and Fixed-Alternate-Path Routing, Adaptive Routing Based on Global Information, Adaptive Routing Based on Neighbourhood Information, Adaptive Routing Based on Local Information, various resource reservation techniques and fault management.	
	NETWORK SURVIVABILITY	**(08 Hours)**
	Basic Concepts, Protection and Restoration, Protection in SONET/SDH, Point-to-Point Links, Ring Interconnection Protection in the Client Layers: Resilient Packet Rings, Ethernet, MPLS, IP etc., Optical Layer Protection Schemes, GMPLS Protection.	
	FUTURE OPTICAL NETWORKS	**(06 Hours)**

	Photonic Packet Switching (OPS) Optical Time Division Multiplexing (OTDM), Bit Interleaving, Packet Interleaving, Optical AND Gates, Synchronization, Tunable Delays, Optical Phase Lock Loop, Optical Packet Switching (OPS) and Optical Burst Switching.
	(Total Contact Time: 45 Hours)
3.	**<u>Books Recommended:</u>**
	1. Volkmar Bruckner, "Elements of Optical Networking, Basics and Practice of Glass Fiber Optical Data Communication", Springer Vieweg 2nd Edition 2024. 2. Hemani Kaushal, V.K. Jain, SubratKar, "Free Space Optical Communication", 1st Ed., Springer, 2017. 3. Ramaswami Rajiv and Sivarajan K. N., "Optical Networks: A Practical Perspective", Elsevier, Morgan Kaufmann Publishers, 3rd Ed., 2012. 4. Biswanath Mukherjee, "Optical WDM Networks", 1st Ed., Springer; 2006. 5. C. S. Murthy & M. Gurusamy, "WDM Optical Networks", 1st Ed., PHI, 2002.

B.Tech. IV EC Semester VII COGNITIVE RADIO EC443	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**
	At the end of the course the students will be able to:

CO1	Explain the fundamentals of SDR and CR with basic differences.
CO2	Compare the optimum spectrum sensing techniques
CO3	Analyse the sensing accuracy versus sensing overhead for given conditions.
CO4	Evaluate the performance of spectrum sensing and spectrum management techniques over cognitive radio
CO5	Design and analysis of performance parameters over CR architecture for the given techniques and parameters

2.	**Syllabus:**	
	SOFTWARE DEFINED RADIO (SDR)	**(09 Hours)**
	Essential functions of the SDR, SDR architecture, design principles of SDR, traditional radio implemented in hardware and SDR, transmitter architecture and its issues, A/D & D/A conversion, parameters of practical data converters, techniques to improve data converter performance, complex ADC and DAC architectures, digital radio processing, reconfigurable wireless communication systems.	
	COGNITIVE RADIO (CR) FEATURES AND CAPABILITIES	**(10 Hours)**
	CR functions, CR architecture, components of CR, CR cycle, CR and dynamic spectrum access, interference temperature, CR architecture for next generation networks, CR standardization, Concept of primary and secondary users, Licensed and unlicensed spectrums in CR.	
	SPECTRUM SENSING AND IDENTIFICATION	**(09 Hours)**
	Primary signal detection, energy detector, cyclostationary feature detector, matched filter, cooperative sensing, spectrum opportunity, spectrum opportunity detection, fundamental trade-offs: performance versus constraint, sensing accuracy versus sensing overhead.	
	SPECTRUM MANAGEMENT OF COGNITIVE RADIO NETWORKS	**(08 Hours)**
	Spectrum decision, spectrum sharing and spectrum mobility, mobility management of heterogeneous wireless networks, research challenges in CR Spectrum switching	
	COGNITIVE RADIO NETWORKS (CRN) ARCHITECTURE	**(09 Hours)**
	Terminal architecture of CRN, diversity radio access networks, routing in CRN, Control of CRN, Self-organization in mobile communication networks, security in CRN, cooperative communications, cooperative wireless networks, user cooperation and cognitive systems	
		(Total Contact Time: 45 Hours)
3.	**Books Recommended:**	

	1. Kwang-Cheng Chen and Ramjee Prasad, “Cognitive Radio Networks”, John Wiley & Sons, Ltd, 2009. 2. Alexander M. Wyglinski, Maziar Nekovee, and Y. Thomas Hou, “Cognitive Radio Communications and Networks - Principles and Practice”, Elsevier Inc., 2010. 3. Bruce Fette, “Cognitive radio technology”, Elsevier, 2nd edition, 2009. 4. Jeffrey H. Reed “Software Radio: A Modern Approach to radio Engineering”, Pearson Education Asia, 2006. 5. Linda Doyle, “Essentials of Cognitive Radio”, Cambridge University Press, 2009.

B.Tech. IV EC Semester VII QUANTUM COMMUNICATION EC445	Scheme	L	T	P	Credit
		3	0	0	03

1.	**<u>Course Outcomes (COs):</u>**
	At the end of the course, students will be able to:

CO1	Explain the fundamentals concepts of quantum mechanics
CO2	Apply the concept of Quantum key distribution and cryptography protocols for quantum communication
CO3	Analyze the effect of quantum entanglement and its role in optical communication.
CO4	Explore and evaluate the quantum communication protocols for long-distance/satellite-based communication and quantum optical network integration.
CO5	Design simple quantum optical communication systems.

2.	**<u>Syllabus:</u>**	
	FUNDAMENTALS OF QUANTUM MECHANICS	**(08 Hours)**
	Introduction to quantum states and operators, Quantum superposition and entanglement, Quantum measurement and uncertainty principle, Basics of quantum information theory	
	QUANTUM KEY DISTRIBUTION (QKD) AND CRYPTOGRAPHY PROTOCOLS	**(07 Hours)**
	Principles of quantum key distribution, Types of QKD protocols, QKD applications in secure communication, Practical considerations in QKD implementation, Overview of quantum cryptographic protocols, Quantum key exchange and authentication, post-quantum cryptography considerations, Quantum-resistant cryptographic algorithms	
	QUANTUM ENTANGLEMENT IN OPTICAL COMMUNICATION	**(06 Hours)**
	Understanding quantum entanglement, Quantum teleportation, Applications of entanglement in optical communication, Bell inequalities and their significance, Experimental demonstrations of entanglement	
	DESIGN AND IMPLEMENTATION OF QUANTUM OPTICAL COMMUNICATION SYSTEMS	**(10 Hours)**
	System architecture and components, Quantum transmitters and receivers, Quantum repeaters and amplifiers, Signal processing in quantum optical systems	
	LONG-DISTANCE AND SATELLITE-BASED QUANTUM COMMUNICATION	**(06 Hours)**
	Challenges in long-distance quantum communication, Quantum communication via satellites, Quantum key distribution in satellite networks, Global quantum communication initiatives	
	QUANTUM OPTICAL NETWORK INTEGRATION	**(08 Hours)**
	Integration challenges and opportunities, Quantum routers and switches, Quantum network security considerations, Scalability and interoperability in quantum optical networks	
		(Total Contact Time: 45 Hours)
3.	**<u>Books Recommended:</u>**	
	1. Quantum Communication, Quantum Networks, and Quantum Sensing, Ivan B. Djordjevic, Academic Press, Elsevier, 2022 2. Protecting Information: From Classical Error Correction to Quantum Cryptography, S. Loepp & W. K. Wooters, Cambridge Press, 2006	

	3. Quantum Computation and Quantum Information, M. Nielsen and I. L. Chuang, Cambridge Press, 2006
4.	**Additional Resources:**
	1. Relevant Journals and Conference publications

B.Tech. IV EC Semester VII mmWAVE COMMUNICATION EC447	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**
	At the end of the course the students will be able to:

CO1	Understand the basics of millimetre wave communication challenges and solutions
CO2	Explain the mmWave propagation wirelessly with supporting hardware and antenna technology
CO3	Apply above fundamentals for the 5G and beyond systems and evaluate their performances for various channel conditions
CO4	Design of mmWave circuits, antennas for various applications

2. Syllabus:

BASICS OF MMWAVES	**(05 Hours)**

Millimetre wave characteristics, atmospheric attenuation, propagation losses, and usable bands, New Radio communication specifications, mmWave antennas, applications, backhaul, fronthaul, Indian Government Initiatives

RADIO WAVE PROPAGATION FOR MMWAVE	**(09 Hours)**

mmWave Propagation: Large- and small-scale channel effects, spatial characterisation of multipath and beam combining, angle spread and multipath angle of arrival, antenna polarisation, spatio-temporal characteristics, **mmWave Channel Models**: Narrow band models, Wideband models, Indoor models, Outdoor models,

MMWAVE ANTENNA TECHNOLOGY	**(10 Hours)**

Massive MIMO Communications, Potential benefits for mm wave systems, Spatial, Temporal and Frequency diversity, Dynamic spatial, frequency and modulation allocation, Antenna beam width, polarization, advanced beam steering and beam forming, On-chip and In package mm wave antennas, Techniques to improve gain of on-chip antennas, Implementation for mm wave in adaptive antenna arrays.

MMWAVE RF AND ANALOG DEVICES AND MULTI-GBPS BASEBAND CIRCUITS	**(12 Hours)**

Basic concepts: mmWave transistors and Devices, Millimetre wave generation and amplification, HEMT, transistor configurations, Analog mm wave components, Consumption factor theory, Trends and architectures for mm wave wireless, ADC's and DAC's, Modulation for millimetre wave communications, Millimetre wave link budget, Transceiver architecture, Practical transceivers.

DESIGN AND APPLICATION OF MMWAVE COMMUNICATION SYSTEM	**(09 Hours)**

Emerging applications of mmWave communication, Device to Device communications over 5G systems, Use of Graphene surfaces, Intelligent reflecting surfaces,

Design Guidelines: Channel Model Considerations, System Design Considerations, Antenna Design Considerations, Link Budget Analysis

(Total Contact Time: 45 Hours)

3. Books Recommended:

	1. K.C. Huang, Z. Wang, "Millimeter Wave Communication Systems", Wiley-IEEE Press, March 2011. 2. Robert W. Heath, Robert C. Daniel, James N. T.S. Rappaport, Murdock, “Millimeter Wave Wireless Communications”, PH, 2014. 3. Xiang, W.Zheng, K. Shen, X.S, “5G Mobile Communications”, Springer, 2016.

B.Tech. IV EC Semester VII TESTING AND VERIFICATION OF VLSI CIRCUITS VL421	Scheme	L	T	P	Credit
		3	0	0	03

1. Course Outcomes (COs):

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

CO1	Understand test patterns required to detect faults in a circuit
CO2	Demonstrate the testability of a circuit
CO3	Implement methods/techniques to improve the testability of digital circuits
CO4	Analyse Logic BIST circuits
CO5	Design the formal verification techniques

2. Syllabus:

INTRODUCTION	**(08 Hours)**
Scope Of Testing And Verification In VLSI Design Process, Issues In Test And Verification Of Complex Chips, Embedded Cores And SOCs	
VLSI TESTING OF FAULT MODELS	**(20 Hours)**
Fundamentals Of Automatic Test Pattern Generation, Design For Testability, Scan Design, Test Interface And Boundary Scan, System Testing and Test For SOC, Delay Fault Testing	
Mu TESTING OF LOGIC AND MEMORIES	**(10 Hours)**
Test Automation, Design Verification Techniques Based On Simulation, Analytical And Formal Approaches	
VERIFICATION	**(07 Hours)**
Functional Verification, Timing Verification, Formal Verification, Basics of Equivalence Checking And Model Checking, Hardware Emulation	
	(Total Contact Time: 45 Hours)

3. Books Recommended:

1. Bushnell M. and Agrawal V. D.,“Essentials Of Electronic Testing For Digital, Memory And Mixed-Signal VLSI Circuits”,Kluwer Academic Publishers,2013.
2. Abramovici M., Breuer M. A. and Friedman A. D.,“Digital Systems Testing And Testable Design”,IEEE Press,1990.
3. Erik Seligman, Tom Schubert and M V Achutha Kiran Kumar, “ Formal Verification An Essential Toolkit for Modern VLSI Design ”, Morgan Kaufmann Publisher, 2023
4. Rashinkar P., Paterson and Singh L.,“System-On-A-Chip Verification-Methodology And Techniques”,Kluwer Academic Publishers,2001.
5. Neil H. E. Weste and David Harris,“Principles Of CMOS VLSI Design”,Addison Wesley, 3rd Edition,2004

B.Tech. IV EC Semester VII UAV Avionics System VL423	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**	
	At the end of the course, students will be able to:	

CO1	Describe avionics components' working and interfacing
CO2	Relate for different avionics components and their interfacing
CO3	Illustrate the data communication between different avionics components
CO4	Explain GNSS signal processing flow in SoCs
CO5	Design and develop basic IPs and codes in SoC for GNSS receiver and communication transceiver
CO6	Implement system design for positioning of drones using SoCs

2.	**Syllabus**	
	Working of UAV Avionics systems	**(14 Hours)**
	Electronic Speed Controllers, Drone Motors, Ranging Sensors: Light detection and ranging (LiDAR), Laser detection and ranging (LADAR), Synthetic Aperture radar (SAR), Homing Radar, Positioning and Motion Sensors: Gyroscope, accelerometer, magnetometer; Pressure sensor, velocity sensor, Current and Voltage sensors, DC-DC Converters, Telemetry Communication Modules, Remote Servo Control Modules, Flight controller and mission controller onboard computer.	
	UAV Embedded Controller and Software	**(14 Hours)**
	Peripheral protocols like I2C, UART, and SPI; Sensor Interfacing: Accelero/Gyro/Magneto-meter module, Ultrasonic distance sensors, Infrared distance sensors, Lidar, pressure sensor, velocity sensor; Actuator Interfacing: BLDC motor, Servo motor, Solenoid Valve, Encoder DC motor, Gimble; Battery management System interfacing, Flight control software, Mission Control software, GNSS module interfacing, Robotic Motion peripheral interfacing: Motors, Motor Drivers, Motor Shields, ADC, DAC and PWM, Camera Interfacing, remote data logging, Introduction to ROS, Gazebo, and Mission Planner.	
	SoC-based GNSS receiver	**(11 Hours)**
	Introduction to SoC with RF front ends, Example of SoC designs, architecture of Processor subsystem and Programmable logic sections, data interchange between PS and PL, Implementation of control IPs for PL section including controlling RF front-end and digital control and data channels, FPGA based GNSS receiver Acquisition and Tracking algorithms, PL section system design and integration, Interface design between PL and PS, Implementation of control routines in PS section, AXI-based programming to control PS from PL section, testing of PL and PS section design, PS-PL integrated based band signal processing for GNSS receiver.	
	SoC-based Telemetry module	**(6 Hours)**
	Basics of telemetry transceiver design, radio communication aspect of the transceiver, Implementation of RF signal transmitter and receiver in PL section, Implementation of modulator and demodulator in PL section, DMA controller implementation for data exchange between PS and PL, Implementation of PL routines to get send/receive data between PS/PL and UART interface of PS section, testing of telemetry module.	
		(Total Contact Time: 45 Hours)
3.	**Books Recommended:**	

	1. Reg Austin, “Unmanned Aircraft Systems”, 1st Edition, Willy Publication 2. R.P.G. Collinson, “Introduction to Avionics Systems”, 3rd Edition Springer Dordrecht Heidelberg London New York 3. Andey Lennon, “Basics of R/C Model Aircraft Design”, 1st Edition, 1996, Model Airplane News Publication 4. John Baichtal, Building your own Drone: A begginers’ Guide to Drones,UAVs, and ROVs, 2015, 1st Edition. 5. Clive Max Maxfield, “The Design Warrior’s Guide to FPGAs”, 1st Edition, Newnes, Elsevier, Oxford OX2 8DP, UK
4.	**<u>Reference Material:</u>**
	1. https://docs.xilinx.com/v/u/en-US/dh0050-zynq-7000-design-overview-hub 2. https://xilinx.github.io/video-sdk/v1.5/c_apis.html 3. https://digilent.com/reference/vivado/getting-started-with-ipi/2018.2 4. https://www.dgca.gov.in/digigov-portal/?dynamicPage=dynamicPdf/130650715&maincivilAviationRequirements/6/0/viewDynamicRulesReq

B.Tech. IV EC Semester VII PROCESSOR ARCHITECTURE VL425	Scheme	L	T	P	Credit
		3	0	0	03

1. Course Outcomes (COs):

At the end of the course the students will be able to:

CO1	Discuss different processor architectures and system-level design processes.
CO2	Demonstrate the components and operation of a memory hierarchy and the range of performance issues influencing its design.
CO3	Analyze the organization and operation of current generation parallel computer systems, including multiprocessor and multicore systems.
CO4	Evaluate the principles of I/O in computer systems, including viable mechanisms for I/O and secondary storage organization.
CO5	Develop systems programming skills in the content of computer system design and organization.

2. Syllabus:

COMPUTER ABSTRACTIONS AND TECHNOLOGY	**(04 Hours)**
Technologies for building processors and memory, Performance, Power wall, the switch from uniprocessors to Multiprocessors.	
INSTRUCTION SET ARCHITECTURE OF 64-BIT RISC-V	**(08 Hours)**
RISC-V addressing modes, instruction types, logical operations, instructions for making decisions, supporting procedures, RISC-V addressing for Wide Immediate and addresses, parallelism and instructions, comparison with MIPS and x86 Architectures.	
PIPELINING	**(11 Hours)**
An overview of pipelining, pipelined data-path and control, Data hazards: Forwarding versus Control, Control hazards, Exceptions, Parallelism via instructions, Real stuff: ARM CortexA53 and Intel Core i7 Pipelines, Case study: ILP and matrix multiply.	
PARALLEL PROCESSORS	**(13 Hours)**
Parallel programs, Flynn's taxonomy, Hardware multithreading, multicore and shared memory multiprocessors, Graphics processing units, Clusters and message passing multiprocessors, Multiprocessor networks, Benchmarking of Intel Core i7 960 and NVIDA Tesla GPU, Case study: Multiprocessors and matrix multiply, Cache coherence, Advanced Cache optimizations, Real stuff: The ARM Cortex-A53 and Intel Core i7 memory hierarchy, Case study: Cache blocking and matrix multiply.	
STORAGE AND INTERCONNECTION	**(09 Hours)**
The basic principles of interconnection network design, On-Chip Interconnection Network, Router Architecture, Network interface design, Case Study: NoC	

(Total Contact Time: 45 Hours)

3. Books Recommended:

	1. David A. Patterson, John L. Hennessy, "Computer Organization and Design: The Hardware Software Interface [RISC-V Edition]", The Morgan Kaufmann Series in Computer Architecture and Design, 2017 2. John L Hennessy, "Computer architecture: a quantitative approach", 6th Ed., Morgan Kaufmann Publishers, 2019 3. Leander Seidlitz, "RISC-V ISA Extension for Control Flow Integrity", Technische Universität München, 2019 4. Andrew Waterman, KrsteAsanović, The RISC-V Instruction Set Manual: Volume I: User-Level ISA, riscv.org, 2017 5. Andrew Waterman, KrsteAsanović, The RISC-V Instruction Set Manual: Volume II: Privileged Architecture, riscv.org, 2017
4.	**Reference Book:**
	1. William James Dally, Brian Patrick Towles, "Principles and Practices of Interconnection Networks", Morgan Kaufmann, Year: 2004 2. Bernard Goossens, "Guide to Computer Processor Architecture: A RISC-V Approach, with High-Level Synthesis", Springer Nature, 2023

B.Tech. IV EC Semester VII NANOELECTRONICS VL427	Scheme	L	T	P	Credit
		3	0	0	03

1.	**Course Outcomes (COs):**	
	At the end of the course the students will be able to:	

CO1	Define various carrier transport mechanisms, properties of semiconductor materials, and novel devices using mathematical equations.
CO2	Describe the physics needed for special classes of nanoelectronic devices and their applications.
CO3	Illustrate the working of various nanoelectronic devices.
CO4	Analyse various nanoelectronic devices.
CO5	Design novel devices, processes and applications based on them.

2.	**Syllabus**	
	FUNDAMENTALS OF NANOSCALE PHYSICS	**(12 Hours)**
	Top-Down and Bottom-Up Approach, Potential of Nanotechnology and Nanoelectronics, Classical Particles, Quantum Mechanics of Electrons, Free and Confined Electrons, Quantum Structures.	
	BAND THEORY OF SOLIDS	**(09 Hours)**
	Electrons in Periodic Potential, Kronig-Penney Model of Band Structure, Band Theory of Solids, Graphene and Carbon Nanotubes.	
	TUNNEL JUNCTION AND APPLICATIONS OF TUNNELING	**(06 Hours)**
	Tunnelling Through a Potential Barrier, Potential Energy Profiles for Material interfaces, Applications of Tunnelling: Field Emission, Gate-Oxide Tunnelling and Hot Electron Effects in MOSFETS, STM and Double Barrier Tunnelling, and The Resonant Tunnelling Diode.	
	COULOMB BLOCKADE AND THE SINGLE-ELECTRON TRANSISTOR	**(06 Hours)**
	Coulomb Blockade: Coulomb Blockade in a Nanoscale capacitor, Tunnel Junctions, Tunnel Junction Excited by a Current Source, and Coulomb Blockade in Quantum dot circuit, Single-Electron Transistor.	
	QUANTUM STRUCTURES	**(12 Hours)**
	Quantum Wells, Quantum Wires and Quantum Dots, Ballistic Transport and Spin Transport.	
		(Total Contact Hours: 45 Hours)
3.	**Books Recommended:**	

1. Hanson, G. W., “Fundamentals of Nanoelectronics”, 1st Ed., Pearson Education, 2009.
2. Rogers, Pennathur and Adams, “Nanotechnology: Understanding Small Systems”, CRC Press, Tayler and Francis Group, 2008.
3. Mahalik N. P., “Micromanufacturing and Nanotechnology”, Springer, 2006
4. Kohler and Fritzsche, “Nanotechnology: An Introduction ToNanostructuring Techniques”, 1st Edition, 1st Reprint, Wiley-VCH, 2004.
5. Fahrner W. R. (Ed),“Nanotechnology And Nanoelectronics: Materials, Devices, Measurement Techniques”, Springer Publications, 2005.