ACADEMIC AFFAIRS OFFICE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

No. Acd./1052 Dated: August 04, 2021

Head, Department of Electronics & Communication Engg.

On the recommendation of IAPC members, the Chairman, IAPC considered and approved the following PECs of Department of Electronics & Communication Engg. and PCCs for M.Tech. (Communication Systems) along with its revised course structure:

1. **PECs for B.Tech. III Yr (Appendix-A)**

   a) ECN-357: Electronic Sub-Systems
   b) ECN-358: Machine Learning in Semiconductor Manufacturing
   c) ECN-359: Compound Semiconductor Devices and Circuits
   d) ECN-360: Introduction to Information and Communication Theory

2. **PECs for M.Tech. (RF & Microwave) (Appendix-B)**

   a) ECN-621: Introduction to Microwave Measurements
   b) ECN-622: Nonionizing Radiations and Health Risks

3. **PECs for M.Tech. (Communication Systems) (Appendix-C)**

   a) ECN-618: Wireless technologies: 5G and Beyond
   b) ECN-619: Introduction to Compressed Sensing
   c) ECN-620: Advanced Wireless Communication

4. **PEC for M.Tech. (Microelectronics & VLSI) (Appendix-D)**

   a) ECN-561: Compact Modeling of Semiconductor Devices

5. **PCCs for M.Tech. (Communication Systems) along with its revised course structure (Appendix-E)**

   a) ECN-517: Digital communication and signal processing techniques
   b) ECN-519: Wireless Communication Systems

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Assistant Registrar (Curriculum)

Copy to (through e mail):-

1. All faculty
2. Head of all Departments/ Centres
3. Dean, Academic Affairs
4. Associate Dean of Academic Affairs (Curriculum)
5. Channel i/ acad portal/ Academic webpage of iitr.ac.in

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-357 **Course Title:** Electronic Sub-Systems
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Both 7. **Subject Area:** PEC
8. **Pre-requisite:** Knowledge of Network theory, signals and systems and digital logic.
9. **Objective:** To understand the operation, design and analysis of important electronic sub-systems.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Synthesis of Passive Networks**: RC, RL, RLC networks. Preliminaries of Passive Network Synthesis: Foster Form, Cauer Form, Brune, Bot-Duffin, Darlington. Biquadratic Synthesis of One-Port RLC Networks, Synthesis of n-Port Resistive Networks: Basic notations and Realizations.	7
2.	**Active filters**: Review of Operational Amplifier (Op-Amp), transfer functions, first/second order active filters, types of active filters: low-pass active filter, high-pass active filter, band-pass active filter, band-reject (Notch) active filter, all-pass active filter, biquad filter, sensitivity, filter approximation introduction to switched capacitor filters.	10
3.	**Digital Sub-Systems**: Review of adders, subtraction, overflow, ripple carry adders, high-speed adders**;** Sequential Multiplication: Add-and-shift approach, booth's algorithm; parallel multiplication: Wallace trees; sequential division, shift registers, decoder/multiplexers, Memories: Organization, types of memories, operation of memory.	8
4.	**Noise in Electronic Sub-Systems**: Power spectral density, Circuit noise: Input referred noise, noise equivalent bandwidth, thermal noise, noise figure, noise temperature, shot noise, flicker noise, other noise sources, correlation, noise and feedback, jitter and transients.	9
5.	**Mixed-Signal Systems** ADC/DAC**:** Nyquist-rate converters, oversampling converters, ideal A/D converter, Quantization noise, Resolution, offset and gain error, Integral non-linearity (INL) error, Differential non-linearity (DNL) error, ideal D/A converter, Nyquist-rate D/A converters, Nyquist-rate A/D converters, oversampling converter. PLL**:** Block-diagram of PLL, order of PLL system, PLL Frequency Synthesizers, higher-order PLLs, Computer-Aided-Design of PLLs.	8
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Network Analysis and Synthesis, by Franklin F. Kuo, Wiley.	2006
2.	Principles of Active Network Synthesis and Design, by Gobin Daryanani, Wiely.	2003
3.	CMOS: Circuit Design, Layout and Simulation, R. Jacob Baker, Wiley.	2017
4.	Arithmetic and Logic in Computer Systems, by Mi Lu, Wiley.	2004
5.	Digital Electronics: Sequential and Arithmetic Logic Circuits, by Tertulien Ndjountche, Wiley.	2016

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-358 **Course Title:** Machine Learning in Semiconductor Manufacturing
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Both 7. **Subject Area:** PEC
8. **Pre-requisite:** None
9. **Objective:** To understand machine learning and its application in semiconductor manufacturing by enhancing statistical process control (SPC).

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Semiconductor Manufacturing:** Manufacturing and quality control, semiconductor manufacturing unit processes and process organization.	4
2.	**Process Monitoring:** Process flow, wafer state measurements, equipment state measurements	2
3.	**Statistical Process Control (SPC):** Probability distributions, sampling, estimation, hypothesis testing, Control charts: single and multivariate.	6
4.	**Machine Learning:** Introduction to the machine learning paradigm, difference from SPC.	4
5.	**Regression:** Linear regression, regularization, K-nearest neighbors (KNN), resampling techniques, subset selection. Non-linear regression: Polynomial, generalized additive models (GAMs)	8
6.	**Classification:** Logistic regression, application in defect detection in semiconductors.	4
7.	**Unsupervised Learning:** Clustering, PCA, anomaly detection in semiconductor manufacturing using unsupervised learning	4
8.	**Support Vector Machines:** Maximal margin classifier, support vector classifier. Application to improving yield in semiconductor manufacturing.	4
9.	**Early Detection and Remediation:** Fault detection using SPC vs machine learning. Beyond detection: Early remediation with machine learning.	4
10.	**Extension to other industries:** Electronics Component manufacturing, etc.	2
Total		**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Gary S. May, Costas J. Spanos, **Fundamentals of Semiconductor Manufacturing and Process Control,** Wiley	2006
2.	Douglas Montgomery, George Runger, **Applied Statistics and Probability for Engineers**, 7th edition, Wiley	2018
3.	Gareth James, Daniela Witten, Trevor Hastie, Robert Tibshirani, **An Introduction to Statistical Learning**, Springer	2013
4.	Ian Goodfellow, Yoshua Bengio, Aaron Courville, **Deep learning**, MIT Press	2016

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-359 **Course Title:** Compound Semiconductor Devices and Circuits
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Both 7. **Subject Area:** PEC
8. **Pre-requisite:** None
9. **Objective:** This course will provide a thorough understanding of compound semiconductor based power electronic devices; RF electronic devices; light emitters; solar cells and photo-detectors.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction**: Brief history of compound semiconductor devices; direct and indirect bandgap semiconductors; compound semiconductor crystal structures and their importance in device-design.	3
2.	**Power Electronic Devices**: Requirements for a power electronic device; Baliga Figure of Merit; Power Schottky diodes; power Bipolar Junction Transistors (BJTs); High Electron Mobility Transistors (HEMTs); power MOSFETs; Insulated Gate Bipolar Transistors (IGBTs); concepts of avalanche breakdown and edge-termination techniques.	7
3.	**Basic Power Electronic Circuits**: Requirements of power electronic circuits; theory of inductors and capacitors in power electronics; Buck, Boost and Buck-Boost DC-DC converters; DC-AC Inverter design; concepts of freewheeling and flyback diodes; smart-grid integration.	6
4.	**RF electronic Devices:** Requirements of an RF electronic Device; Johnson and Keys figures of Merit; RF Schottky diodes, HEMTs, Hetero-junction Bipolar Transistors (HBTs); emerging RF energy harvester devices. Introduction to RF electronic circuits; design considerations for RF power amplifiers.	8
5.	**Light Emitting Devices**: concepts of radiative and non-radiative recombination processes; theory of quantum wells; Light Emitting Diodes (LEDs)- IR, visible and UV range; principles of laser diode- population inversion, mirror design, Bragg reflectors, gain medium; optical and electrical injection; surface and edge emitting lasers; VCSELs. Concepts of LED and laser driver circuits; optical switches.	8
6.	**Solar cells and photo-detectors**: principles of Si and non-Si solar cells; Solar power grid and integration circuits; concepts of photo-detectors in IR, visble and UV region; photodiodes- P-N junction photodiode, P-i-N photodiode, Avalanche Photodiode, Schottky Photodiode, MSM photodiode; concepts of emerging self-powered photodiodes; optical sensors; concepts of image detection using photo-detector array.	7
7.	**Emerging electronic systems and applications:** concepts and requirements of LIDAR, surveillance drones, self-driving cars, satellite communication, vertical in-house horticulture, light-fidelity (Li-Fi) routers, UV water filtration systems, medical imaging and surgical systems. Other emerging applications.	3
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Ben G. Streetman and Sanjay K. Banerjee, “Solid State Electronic Devices,” Pearson Education India Pvt. Ltd.	2015
2.	S. M. Sze and Kwok K. Ng, “Physics of Semiconductor Devices,” Wiley	2008
3.	B. Jayant Baliga, “Fundamentals of Power Semiconductor Devices (second edition),” Springer.	2019
4.	Issa Batarseh and Ahmad Harb, “Power Electronics Circuit Analysis and Design,” Springer	2018
5.	Pallab Bhattacharya, “Semiconductor Optoelectronic Devices (Second Edition),” Pearson	2017
6.	Ajoy Ghatak and K.Thyagarajan, “Lasers- Fundamentals and Applications,” Laxmi Publications	2019
7.	Chetan S. Solanki, “Solar Photovoltaics - Fundamentals, Technologies and Applications,” Prentice Hall India Learning Private Limited	2015

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-360 **Course Title:** Introduction to Information and Communication Theory
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Both 7. **Subject Area:** PEC
8. **Pre-requisite:** Knowledge of digital communication
9. **Objective:** To familiarize students with the concept of information and communication theory to understand the ultimate limits of data transmission and data compression.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Preliminaries:** Introduction to probability and random variables; elements of a digital communication system, source encoder and decoder, channel encoder and decoder.	3
2.	**Introduction to Information Theory**: Uncertainty and information; measure of information, entropy, joint, conditional, and relative entropies, mutual information; chain rule for entropy, relative entropy, and mutual information; discrete memoryless channels (DMC), capacity of DMCs.	6
3.	**Gaussian Channel:** Capacity for AWGN channel, bandwidth efficiency, Shannon's limit; channel capacity theorem; parallel Gaussian channels; capacity region of a broadcast Gaussian channel, capacity of orthogonal and non-orthogonal multiple access schemes (TDMA, FDMA, CDMA, and NOMA).	10
4.	**Wireless Channel:** Channel modeling, fading, coherence time, coherence bandwidth; capacity of SISO and MIMO wireless channels, spatial multiplexing gain, diversity techniques, diversity-multiplexing tradeoff; outage probability.	10
5.	**Source Coding:** Source coding theorem, classes of source codes based on decoding complexity and length, Huffman code, Shannon-Fano code; **Channel Coding:** Channel coding theorem, error detection and correction capabilities, repetition code, linear block codes.	9
6.	Applications of information theory in communication and signal processing applications-physical layer security, wiretap channel, secrecy capacity, secrecy outage probability, etc.	4
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Ranjan Bose, "Information Theory, Coding and Cryptography", Third Edition, McGraw Hill Education	2016
2.	Upamanyu Madhow, "Fundamentals of Digital Communication", Cambridge University Press	2008

3.	John G. Proakis and Masoud Salehi, “Digital Communications”, Fifth Edition, McGraw-Hill Education	2008
4.	Simon Haykin, “Digital Communication Systems”, John Wiley & Sons, Inc	2014
5.	Tse and Viswanath, “Fundamentals of Wireless Communication”, Cambridge University Press	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-621 **Course Title**: Introduction to Microwave Measurements
2. **Contact Hours:** **L:** 3 **T:** 0 **P:** 2
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 10-25 **PRS:** 25 **MTE:** 15-25 **ETE:** 30-40 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Knowledge of electromagnetic theory.
9. **Objective:** The objective of this course is the in-depth understanding of various microwave instruments such as network analyzer, spectrum analyzer, synthesized source, noise figure meter etc.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Preliminaries:** Concept of Transmission Lines and S-parameters	8
2.	**Traditional Measurement Techniques:** The Power Meter, Transmission Measurement, Reflection Measurement	6
3.	**Vector Network Analyzer:** Basic Vector Measurements, Architecture of the Vector Network Analyzer, Network Analyzer Calibration, Frequency Offset and Mixer Measurement, Time Gating, Material Property Measurement Using the VNA	6
4.	**Spectrum Analyzer:** Common Measurements Using the Spectrum Analyzer, Types of Signal Analyzers, Basic Idea behind Spectrum Analyzers, Building Blocks of a Spectrum Analyzer, Features of the Spectrum Analyzer, Dynamic Range and Sensitivity, Component Characterization	7
5.	**Noise Measurements:** Noise Measurement Basics, Special Consideration for Mixers, Phase Noise, Phase Noise Measurement Techniques	7
6.	**Microwave Signal Generation:** Oscillator Circuits: The Crystal Oscillator, Tunable Oscillator, Direct Digital Synthesis, PLL-Based Synthesizers, Fractional-N Synthesis.	8
Total		**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Thomas H. Lee, Planar Microwave Engineering: A Practical Guide to Theory, Measurement, and Circuits [1 ed.], Cambridge University Press	2004
2.	R. Collier and D. Skinner, Microwave Measurements [3 ed.], IET Press, [IET Electrical Measurement 12]	2007
3.	G. H. Bryant, Principles of microwave measurements P. Peregrinus Ltd. [IEE electrical measurement series 5]	1993
4.	A. Basu, An Introduction to Microwave Measurements, CRC Press.	2015

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-622 **Course Title**: Nonionizing Radiations and Health Risks
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage: CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Engineering Electromagnetics
9. **Objective:** To introduce mechanism and effect of interaction of electromagnetic energy with biological systems

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction:** Fundamentals of electromagnetics- Electromagnetics, RF/Microwave energy, Penetration in Biological tissues and skin effect, Dielectric measurements and exposure; Environmental electromagnetic field and Bio-systems	8
2.	**Electromagnetic Interaction Mechanism in Biological Materials:** Bioelectricity, Tissue characterization, Thermodynamics and energy	6
3.	**Biological Effects:** Absorption – Fundamentals, Dosimetry and SAR, Thermal considerations; Nervous Systems- Effect on brain and spinal cord, blood brain barrier, nervous system modelling and simulations; Cells and membranes; Molecular level; Low level exposure and ELF components; Ear, Eye and heart; Influence on drugs; Nonthermal, Microthermal and Isothermal effects; Epidemiology studies; Interferences; radiation hazards and exposure standards	8
4.	**Thermal Therapy:** Heating principle, hyperthermia, method of thermometry- invasive and non-invasive	6
5.	**Protection of Biological and medical Environments:** Concept of e. m. wave absorbers- classification, fundamental principles and theory, applications, e.m. wave absorbers using equivalent transformation method of material constant, method to improve e. m. field distribution in small room	6
6.	**Electromagnetic Delivery Systems for Therapeutic applications:** transmission lines and waveguides for medical applications; antennas; RF/Microwave ablation, Perfusion chamber, Endometrial ablation, E. M. based method for measuring blood perfusion in hear muscle, Lumen measurements of arteries using RF equipments, RF tissue Welding	8
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	C. Furse, C. and C. Durney, "Basic introduction to Bioelectromagnetics", 2nd Edition, CRC Press	2019
2.	K. Karipidis and A. W. Wood, "Non-ionizing Radiation Protection", John Wiley & Sons	2017
3.	M. Gandolfo, "Biological Effects and Dosimetry of Nonionizing Radiation: Radio Frequency and Microwave Energies", Springer	2013
4.	A. V. Vorst, A Rosen and Y Kotsuka, "RF/Microwave Interaction with Biological Tissues", John Wiley & Sons	2006
5.	M Kato, "Electromagnetics in Biology", Springer	2006
6.	J Malmivuo and R Plonsey, "Bioelectromagnetism - Principles and Applications of Bioelectric and Biomagnetic Fields", New York, Oxford University Press	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-618 **Course Title**: Wireless technologies: 5G and Beyond
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Basic knowledge of wireless communication systems.
9. **Objective:** The main objective of this course is to provide exposure to advanced research topics in the field of Beyond 5G/6G wireless systems.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**5G NR Overview:** Introduction and Motivation, Adaptive modulation and coding, Time-domain and frequency-domain frame structure, 5G NR Numerology, Hybrid Automatic repeat request protocol	6
2.	**5G transmit and receive chain for data and control information:** CRC, Transport block segmentation/concatenation, Rate matching/rate recovery, Interleaving/deinterleaving	8
3.	**Cell-free/distributed wireless system:** Introduction and Motivation, System model for uplink/downlink, Channel modelling, Channel estimation, Beamforming techniques, Centralized/Decentralized uplink and downlink operation, Capacity bounds and spectral efficiency	12
4.	**mmWave MIMO Wireless Systems:** Introduction and motivation, millimeter wave propagation and channel models, Analog, Digital and Hybrid Processing, Sparse channel estimation	6
5.	**Full-duplex future wireless system:** Introduction and motivation, Self-interference cancellation, active/passive cancellation, FD massive MIMO system	5
6.	**Multi-hop massive MIMO communication:** Introduction and motivation, Transmission model for amplify-and-forward and decode-and-forward protocols, Multi-pair multi-hop communication, Capacity and asymptotic analysis	5
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Erik Dahlman, Stefan Parkvall, Johan Skold, ``5G NR: The Next Generation Wireless Access Technology'', Academic Press	2018
2.	Sassan Ahmadi, ``5G NR: Architecture, Technology, Implementation, and Operation of 3GPP New Radio Standards'', Academic Press	2019
3.	Özlem Tugfe Demir, Emil Björnson and Luca Sanguinetti, "Foundations of User-Centric Cell-Free Massive MIMO", Foundations and Trends® in Signal Processing, Now publishers	2021

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-619 **Course Title**: Introduction to Compressed Sensing
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Knowledge of linear algebra and probability theory.
9. **Objective:** To introduce the basic concepts and mathematics behind sparse signal recovery and compressed sensing.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Mathematical Preliminaries:** Vector/matrix norms, Orthobasis expansion, Gaussian/Sub-Gaussian random variables and properties, basic concentration inequalities, basics of convex optimization and constrained optimization	8
2.	**Principles of sparse recovery:** Unique and stable sparse solutions of underdetermined linear systems, Unique sparse representation and uncertainty principle, Sensing matrix design, Null-space property (NSP), Mutual coherence based uniqueness and stable recovery guarantees, Restricted Isometry Property (RIP), Relationship between RIP and NSP, Johnson-Lindenstrauss lemma, Sparse recovery with random matrices	16
3.	**The compressed sensing problem & connections to sparse recovery:** Sparse representation of signals, compressible signals, union of subspaces	3
4.	**Sparse recovery methods:** Convex optimization algorithms – Basis Pursuit and LASSO, Greedy algorithms- Orthogonal Matching Pursuit (OMP), Thresholding-based sparse recovery methods, MAP estimation-based sparse recovery methods	10
5.	**Applications:** Sub-Nyquist sampling, signal compression, signal-denoising, sparse linear regression, sparsity in wireless communication.	5
Total		**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Michael Elad, ``Sparse and Redundant Representations - From Theory To Applications in Signal & Image Processing”, 2010, Springer Publications.	2010
2.	Simon Foucart and Holger Rauhut, ``A Mathematical Introduction to Compressive Sensing”, 2013, Birkhäuser.	2013
3.	Yonina Eldar and Gitta Kutyniok, ``Compressed Sensing: Theory and Applications”, Cambridge University Press.	2012

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-620 **Course Title**: Advanced Wireless Communication
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Basic knowledge of wireless communication.
9. **Objective:** To acquaint the students with the advanced but essential concepts, techniques and algorithms needed for understanding and designing modern wireless communication systems.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction**: Introduction to multiple-input multiple-output (MIMO) systems and its relevance, diversity-multiplexing trade-offs, single-user and multi-user MIMO systems	4
2.	**Massive MIMO systems:** Motivation and system model, time and frequency division duplexing, uplink and downlink transmissions, benefits and challenges, relevance for the existing wireless standards, spectral and energy efficiency	6
3.	**Channel Models**: MIMO and massive MIMO channel modeling, spatial channel models, 3GPP channel models, mmWave channel models	6
4.	**Receiver designing:** • Channel estimation: sounding signals and estimation techniques, the issues of pilot contamination, pilot assignment techniques, estimating direction of arrivals and departures • Signal detection: linear detectors like MF, ZF, and MMSE, non-linear detectors such as ML, Sphere decoding, SIC, Neighborhood Search, and matching Pursuit algorithms, Soft decoding	10
5.	**Beamforming:** Beamforming fundamentals, Analog, Digital and Hybrid beamforming architectures, Beamforming techniques and algorithms such as phase minimization etc, quantization effects.	4
6.	**Beam management:** Beam sweeping, reference signals for beam management, Synchronization signals, beam measurement, determination and reporting	4
7.	**Potential advancements:** Index modulation for massive MIMO systems**,** Extremely large aperture arrays, Heterogenous massive MIMO, Holographic/RIS massive MIMO,	4
8.	**Deep/Machine Learning for Wireless Communication:** Overview of DL/ML Modelling, Data set generation and acquisition, training the model. Example problems like modulation design, channel estimation, signal detection etc., intelligent massive MIMO.	4
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	T. Marzetta, E. Larsson, H. Yang, and H Ngo, "Fundamentals of Massive MIMO. Cambridge", Cambridge University Press, 2016.	2016
2.	A. Chockalingam and B. Rajan, "Large MIMO Systems", Cambridge University Press, 2014.	2014
3.	E. Björnson, J. Hoydis and L. Sanguinetti, "Massive MIMO Networks: Spectral, Energy, and Hardware Efficiency", Foundations and Trends in Signal Processing: Vol. 11, No. 3-4, pp 154–655, (2017).	2017
4.	D. Tse and P. Viswanath, "Fundamentals of Wireless Communication", Cambridge University Press, 2nd edition, 2005.	2005
5.	A. Goldsmith, "Wireless Communications", Cambridge University Press, 2005.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-561 **Course Title:** Compact Modeling of Semiconductor Devices
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Spring **7. Subject Area:** PEC
8. **Pre-requisite:** Fundamentals of semiconductor device physics
9. **Objective:** To introduce students to the field of compact modeling and familiarize them with the tools and methods used in industry-standard compact model development

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	**Introduction:** Introduction to modeling, key differences between different types of models, specific requirements for compact models, use and importance of compact models, familiarization with existing industry-standard compact models and their history	2
2.	**Modeling fundamentals:** Mathematics required for compact modeling, maximum and minimum functions, various types of smoothing functions, continuity and differentiability, convergence criteria, numerical blow-ups, clamping functions, stitching functions, function choice, electrical equivalent circuits, handling differential equations, transient simulations, modeling methodology: semi-empirical, empirical, physical and look-up-table models	5
3.	**Simulation and Coding:** SPICE simulation basics, simulators, coding syntax and practices, Verilog-Adetails, Verilog-A syntax, Verilog-A coding practices	3
4.	**Two and three terminal devices**: MOSCAP and resistor compact models, relaxation time, terminal ccurrent and charges, frequency dependence	4
5.	**MOSFETs:** Compact modeling of MOSFET electrostatics and transport, concept of core model, buildinga core model, add-on effects, short-channel effects, MOSFET charges, terminal currents and charges, parasitics, frequency dependence, MOSFET model types: surface potential based models, charge based models	6
6.	**Advanced modeling concepts:** binning, binning equations, instance parameters vs model parameters, macro definitions, backward-compatibility and incompatibility, speed/performance, accuracy, noise modeling, self-heating model, non-quasi-static model, quantum effects, band-structure effects, parasitics, ballistic transport, quasi-ballistic transport	8
7.	**Case study and advanced device effects:** Study of industry-standard compact models: BSIMBULK, BSIM-CMG, BSIM-IMG, ASM-HEMT. Introduction to current devices (FinFETs, GAAFETs, FD-SOI, HEMTs) through case study. Discussion on problems encountered in modeling these devices along with solutions adopted at present, scope for improvement	8
8.	**Magnetic devices:** Compact modeling of STT-MRAM, concepts, key criteria for MTJ compact model, tunnel resistance model, switching model, performance criteria, key problems, scope for improvement	3

9.	**Ferroelectric devices:** Compact modeling of ferroelectric materials and devices, NCFETs, L-K equation, domain picture, multi-domain modeling, switching model, MFMIS models vs MFIS models, current scenario, scope for improvement	3
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	Y. Tsividis and C. Mc Andrew, "Operation and Modeling of the MOS Transistor", Oxford Univ. Press	2010
2.	C. Hu, "Modern Semiconductor Devices for Integrated Circuits", Pearson	2009
3.	Y. S. Chauhan et.al., "FinFET Modeling for IC Simulation and Design: Using the BSIM-CMG standard", Academic Press	2015
4.	C. Hu, "Industry Standard FDSOI Compact Model BSIM-IMG for IC Design", Wood head publishing	2019
5.	G. Gildenblat, "Compact Modeling: Principles, Techniques and Applications", Springer	2010
6.	W. Liu and C. Hu, "Bsim4 and Mosfet Modeling For Ic Simulation", World Scientific Publishing Co.	2011
7.	W. Liu," MOSFET Models for SPICE Simulation: Including BSIM3v3 and BSIM4", Wiley-IEEE Press	2001

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **531** **M.Tech. (Communication Systems)**
Department: **EC** **Department of Electronics and Communication Engineering**
Year: **I**

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	**Subject Code**	**Course Title**	**Subject Area**	**Credits**	**L**	**T**	**P**	**Theory**	**Practical**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
		Semester- I (Autumn)												
1.	ECN-510	Digital Communication Laboratory	PCC	2	0	0	3	0	3	-	50	-	-	50
2.	ECN-511	Linear Algebra and Random Processes	PCC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
3.	ECN-517	Digital communication and signal processing techniques	PCC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
4.	ECN-519	Wireless Communication Systems	PCC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
5.	ECN-515	Information and Coding Theory	PCC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
		Total		**18**										
		Semester-II (Spring)												
1.	ECN-600	Project	PCC	2	0	0	3	0	0	-	100	-	-	-
2.	ECN-700	Seminar	SEM	2	-	-	-	-	-	-	-	-	100	-
3.		ELECTIVE-I	PEC	3/4										
4.		ELECTIVE-II	PEC	3/4										
5.		ELECTIVE-III	PEC	4										
6.		ELECTIVE-IV	PEC	4										
		Total		**18/20**										

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

Program Code: **531** **M.Tech. (Communication Systems)**
Department: **EC** **Department of Electronics and Communication Engineering**
Year: **II**

Teaching Scheme					**Contact Hours/Week**			**Exam Duration**		**Relative Weight (%)**				
S. No.	**Subject Code**	**Course Title**	**Subject Area**	**Credits**	**L**	**T**	**P**	**Theory**	**Practical**	**CWS**	**PRS**	**MTE**	**ETE**	**PRE**
Semester- I (Autumn)														
1.	ECN-701A	Dissertation Stage-I (to be continued next semester)	DIS	12	-	-	-	-	-	-	-	-	100	-
		Total		**12**										
Note: Students can take 1 or 2 audit courses as advised by the supervisor, if required.														
Semester-II (Spring)														
1.	ECN-701B	Dissertation Stage-II (continued from III semester)	DIS	18	-	-	-	-	-	-	-	-	100	-
		Total		**18**										

Summary				
Semester	1	2	3	4
Semester-wise Total Credits	**18**	**18-20**	**12**	**18**
Total Credits	**66-68**			

Program Elective Courses M.Tech. (Communication Systems)

Teaching Scheme					Contact Hours/Week			Exam Duration		Relative Weight (%)				
S. No.	Subject Code	Course Title	Subject Area	Credits	L	T	P	Theory	Practical	CWS	PRS	MTE	ETE	PRE
1.	ECN-514	Detection and Estimation Theory	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
2.	ECN-612	Wireless Networks	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
3.	ECN-613	Telecommunication Networks	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
4.	ECN-614	Adaptive Signal Processing Techniques	PEC	4	3	0	2	3	0	10-15	10-20	20-30	40-50	
5.	ECN-615	Advanced Coding Theory	PEC	4	3	0	2	3	0	10-15	10-20	20-30	40-50	
6.	ECN-616	Speech and Audio Processing	PEC	4	3	0	2	3	0	10-15	10-20	20-30	40-50	
7.	ECN-617	Image Processing and Computer Vision	PEC	4	3	0	2	3	0	10-15	10-20	20-30	40-50	
8.	ECN-618	Wireless Technologies: 5G and Beyond	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
9.	ECN-619	Introduction to Compressed Sensing	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
10.	ECN-620	Advanced Wireless Communication	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
11.	ECN-531	Microwave Engineering *	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
12.	ECN-539	Fiber Optic Systems*	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
13.	ECN-550	Radar Signal Processing *	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
14.	ECN-555	Microwave Imaging *	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
15.	ECN-573	Digital VLSI Circuit Design*	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
16.	ECN-594	VLSI Digital Signal Processing*	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-
17.	ECN-631	RF Receiver Design *	PEC	4	3	1	0	3	0	20-35	-	20-30	40-50	-

*Courses offered from other specialization groups of the ECE department

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-517 **Course Title**: Digital communication and signal processing techniques
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Signal and systems or equivalent.
9. **Objective:** To establish the theoretical groundwork for advanced applications of digital communication and digital signal processing techniques.

10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Discrete time fourier transform, Discrete Fourier Transform, Discrete Cosine Transform, Fast Fourier Transform, Application of different transforms for a linear time-invariant system, system stability, conversion between different transforms	9
2.	Digital filter structures: Finite Impulse Response filters (structure, design and implementation), Infinite impulse response filters (structure, design and implementation), Frequency limit conversion in digital and analog filters	7
3.	Sampling and resampling in time and frequency domains, interpolation (up-sampling), down-sampling, arbitrary sample-rate conversion, Multistage implementation of sampling rate conversion; Sampling rate conversion of band-pass signals, Application of multirate signal processing.	5
4.	Sampling, Characterization of Band-Pass signals, lowpass equivalent of bandpass signals, Signal-space concepts, orthogonal expansion of signals	4
5.	Linear modulation, orthogonal and biorthogonal modulation, differential modulation, nonlinear modulation; phase modulation, quadrature amplitude modulation, continuous-phase modulation.	7
6.	Band-limited channels; Inter-Symbol Interference (lSI); characterization of band-limited channels, signal design for band-limited channels. Channel equalization: optimum maximum-likelihood estimation, maximum-likelihood sequence estimation; linear equalization, MSE equalizer; decision feedback equalization, coefficient optimization, predictive decision feedback equalization.	10
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	R.G. Gallager, "Principles of Digital Communication", Cambridge 2008 University Press.	2008
2.	S. Haykin, " Communication Systems, Wiley.	2001
3.	V.M. Gadre and A.S. Abhvankar, "Multiresolution and Multirate Signal Processing - Introduction, Principles and Applications", Mc-Graw Hill.	2017
4.	lG. Proakis, "Digital Signal Processing: Principles, Algorithms and 2007 Applications", 4th Edn., Pearson.	2007
5.	P.P. Vaidyanathan, "Multirate Systems and Filter Banks", Prentice Hall.	1992
6.	J.G. Proakis and M. Salehi, "Digital Communications", 5thEdn., McGraw Hill.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPARTMENT/CENTRE: Department of Electronics and Communication Engineering

1. **Subject Code:** ECN-519 **Course Title**: Wireless Communication Systems
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-35 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-50 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Autumn **7. Subject Area:** PCC
8. **Pre-requisite:** Basic knowledge of signal and system and information theory.
9. **Objective:** To acquaint the students with the concepts and the issues involved in the design of wireless communication systems.
10. **Details of the Course**

S.No.	Contents	Contact hours
1.	Wired (AWGN) Channel and its BER analysis; Wireless channels: Physical modeling, input/output model, Rayleigh channel and its BER analysis, time and frequency coherence, statistical channel models	6
2.	Point-to-point communication: Detection in a Rayleigh fading channel, diversity techniques, channel uncertainty and estimation	6
3.	Cellular systems: Multiple access and interference management, narrow-band and wide-band systems	4
4.	Capacity of wireless channels, MIMO capacity, Diversity-multiplexing tradeoff, MIMO receiver design, Transmit power allocation, MIMO precoding, Space-time block codes	12
5.	Multi-carrier communication, OFDM and its application to wireless communication: Subcarrier mapping, synchronization, PAPR reduction techniques	8
6.	Non-orthogonal Multiple-Access: Introduction and motivation, System model, successive interference cancellation, outage probability analysis, Uplink and downlink NOMA system, Capacity analysis	6
Total		**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication / Reprint
1.	D. Tse and P. Viswanath, "Fundamentals of Wireless Communication", 2005 Cambridge University Press.	2005
2.	Y. Li and G.L. Stuber, "Orthogonal Frequency Division Multiplexing for 2006 Wireless Communications", Springer.	2006
3.	Y.S. Cho, J. Kim, W.Y. Yang and C.G. Kang, "MIMO-OFDM Wireless 2010 Communications with MATLAB", John Wiley & Sons.	2010

4.	"5G Mobile and Wireless Communications Technology", A. Osseiran, IF. 2016 Monserrat and P. Marsch (eds.), Cambridge University Press.	2016
5.	A. Goldsmith, "Wireless Communications", Cambridge University Press.	2012
6.	Yuanwei Liu, Zhijin Qin, Zhiguo Ding, ``Non-Orthogonal Multiple Access for Massive Connectivity'', Springer.	2020