INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-501 **Course Title:** Electromagnetic Field Theory and Scattering
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:** Nil
9. **Objective:** To provide insight into electromagnetic field theory and scattering.

10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	**Review of basic electromagnetics:** Maxwell’s equations, electromagnetic boundary conditions, Poynting vector, wave propagation, plane waves, reflection, and transmission at material interface, surface impedance.	7
2.	**Waveguides and transmission lines:** TEM mode in parallel plate waveguides, TE and TM modes in rectangular and circular metal waveguides, wave impedances, dispersion and wave velocity, surface wave propagation in grounded dielectric medium, TE and TM modes of surface waves, hybrid modes in rectangular and circular dielectric waveguides, ridge and rib waveguides, concept of plasmonic waveguides, surface spoof polariton waveguides.	12
3.	**Quasi-optical systems and techniques:** Need for quasi-optical systems at millimeter-wave and terahertz frequency, geometrical optics, Gaussian beams, Bessel beams, X-waves, working principle of Fabry-Perot resonator.	6
4.	**Canonical Scattering Problems:** definition of the scattering problem, Stokes parameters, Mueller matrix, phase functions, scattering and absorption efficiency, extinction, optical shadow theorem, plane wave expansion, spherical harmonics, electromagnetic multipoles, Mie coefficients of a homogenous sphere, electric and magnetic dipoles and directional scattering from isolated sphere, Rayleigh scattering, Rayleigh-Gans approximation, plane wave scattering by conducting and dielectric cylinder.	12
5.	**Advanced wave-matter interaction and their applications:** concept of double negative metamaterials, evolution of metasurface, Fano resonance, toroidal modes and electromagnetic cloaking.	5
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	J. V. Bladel, “Electromagnetic Fields,” IEEE Press Series on Electromagnetic Wave Theory	2007
2.	A. Ishimaru, “Electromagnetic wave propagation, radiation and scattering”, IEEE Press Series on Electromagnetic Wave Theory	2017
3.	S. Khorasani, “Advanced electromagnetics and scattering theory”, Springer	2015
4.	I. Brener, S. Liu, I. Staude, J. Valentine, and C. Holloway, “Dielectric Metamaterials: Fundamentals, Designs, and Applications,” Woodhead Publishing Series in Electronic and Optical Materials	2020
5.	J. D. Jackson, “Classical Electrodynamics,” John Wiley & Sons	1999
6.	D. J. Griffiths, “Introduction to Electrodynamics,” Pearson	2013

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-503 **Course Title:** Terahertz Electronics
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-30 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-60 **PRE:** 0
5. **Credits:** 4 6. **Semester:** Autumn 7. **Subject Area:** PCC
8. **Pre-requisite:** Nil
9. **Objective:** To provide a brief knowledge on terahertz electronics.

10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	**Introduction to Terahertz engineering:** roadmap to Terahertz science and technologies, Terahertz interaction in molecular- and atomic-scale, applications in wireless communication, defense, space, and smart devices.	3
2.	**Terahertz transmission lines and wave propagation:** planar dielectric waveguides, multimodal dielectric guides, flexible polymer waveguides, ribbon waveguides, Silicon-on-Insulator technology, dispersion in periodic structures, diffraction grating, photonic and plasmonic waveguides, bandgap structures and dispersion.	10
3.	**Photonic-inspired Terahertz passive components:** splitter, combiner, polarizer, isolator, diplexer, multiplexer and demultiplexers, directional couplers, grating waveguide couples, open resonator design, Bragg reflector, tunable properties for Terahertz devices using Graphene, liquid crystals, electrostatically actuated cantilevers, and phase-change materials.	12
4.	**Terahertz sources and detectors:** Terahertz pulse generation using photo-mixing and laser interferometry, overview of semiconductor technology, Terahertz power generation in Silicon technology, working principle of HEMT and DHBT, Si-Ge HBT, III–V/Schottky diode-based diode detectors, planar and spatial power combining techniques, direct detection verses heterodyne detection, transistor detector circuits, active and passive mode detection.	8
5.	**Selected applications using Terahertz:** Terahertz time-domain spectroscopy (THz-TDS), Terahertz active and passive imaging, tomographic imaging, Terahertz sensing and non-destructive testing.	9
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	J.S. Rieh, "Introduction to Terahertz Electronics," Springer	2021
2.	R. E. Miles, P. Harrison, and D. Lippens, "Terahertz Sources and Systems," NATO Science Series	2000
3.	P. F. Goldsmith, "Quasi-Optical Systems," IEEE Press Series	1998
4.	D. W. Woolard, W. R. Loerop, and M. S. Shur, "Terahertz Sensing Technology," World Scientific	2003
5.	J. M. Chamberlain and R. E. Miles, "New Directions in Terahertz Technology," NATO ASI Series	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-511 **Course Title:** Linear Algebra and Random Processes
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:** Nil
9. **Objective:** To introduce the students to the theory and applications of linear algebra, random variables and random processes.

10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	Vector spaces, subspaces, bases and dimensions, linear dependence and independence, vector products, orthogonal bases and orthogonal projections, Gram-Schmidt ortho normalization procedure	10
2.	Linear operators and Matrices: Eigen values and Eigen vectors, characteristic polynomial, diagonalization, Hermitian and unitary matrices, singular value decomposition	10
3.	Discrete and continuous random variables: distribution and density functions, conditional distributions and expectations, functions of random variables, moments, sequence of random variables	10
4.	Random process: Probabilistic structure; Mean, auto correlation and auto covariance functions; Strict-sense and wide-sense stationary processes; Power spectral density; LTI systems with WSS process as the input; Examples of random processes - white noise, Gaussian, Poisson and Markov Processes	12
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	S.Axler, "Linear Algebra Done Right", 3rd Edn., Springer International Publishing.	2015
2.	G.Strang, "Linear Algebra and Its Applications", 4th Edn., Cengage Learning.	2007
3.	K.M. Hoffinan and R. Kunze, "Linear Algebra", 2nd Edn., Prentice Hall India.	2015
4.	A. Papoulis and S. Pillai, "Probability, Random Variables and Stochastic Processes", 4th Edn., McGraw Hill.	2017
5.	H. Stark and J.W. Woods, "Probability and Random Processes with Applications to Signal Processing", 3rd Edn., Pearson India.	2001
6.	A. Leon-Garcia, "Probability, Statistics and Random Processes for Electrical Engineers", 3rd Edn., Prentice Hall India.	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:** Nil.
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

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-502 **Course Title:** High Frequency Measurements and Instrumentation
2. **Contact Hours:** **L:** 3 **T:** 1 **P:** 0
3. **Examination Duration (Hrs.):** **Theory:** 3 **Practical:** 0
4. **Relative Weightage:** **CWS:** 20-30 **PRS:** 0 **MTE:** 20-30 **ETE:** 40-60 **PRE:** 0
5. **Credits:** 4 **6. Semester:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To introduce state-of-art and modern industrial measurement techniques with their associated instrumentation for characterization of microwave systems and circuits.

10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	**Calibration techniques:** definition and need for calibration, power measurements and calibrations in calorimeter, bolometer, thermistor and diode sensors, on-chip and off-chip calibration methodology, open-short-load-thru and through-reflect-line protocols, free-space calibration, time-domain calibrations, reflectometer.	9
2.	**Waveguide instrumentation and packaging:** coaxial cables, coaxial connectors and adaptors, flexible dielectric waveguides, channel capacity in straight and bent waveguides, Beatty-Standard, waveguide rotary joints, radial power combiners, wafer-probes, planar circuit transition to wafer-probes and metal waveguides, chip-to-package wire bonding and flip-chip.	9
3.	**Material spectroscopy:** electromagnetic properties of matter, Lorentz, Drude and Debye model, dipole rotation and polarizability, electromagnetic interaction of water and biosensors, reflection-based material characterization, Nicolson–Ross–Weir algorithm, resonator perturbations, Gaussian wavefront and Fabry-Perot resonators, terahertz time-domain spectroscopy (THz-TDS).	9
4.	**Antenna measurements:** anechoic chamber instrumentation, compact antenna test range, uncertainty and errors in radiation pattern measurements, phase center, estimation of gain and directivity, Wheeler cap-based antenna efficiency, probe-based antenna measurements, phased-array in-situ calibration, electromagnetic scattering measurements.	8
5.	**Active and non-linear measurement systems:** challenges of non-linear characterization, introduction to X-parameters, active load-pull measurement system, multi-tone intermodulation measurements, error-vector-magnitude, excess noise figure measurements, phase noise measurement techniques.	7
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	G. H. Bryant, “Principles of microwave measurements”, IET Electrical Measurement Series, volume 5	1993
2.	L. F. Chen, C. K. Ong and C. P. Neo, V. V. Varadan and V. K. Varadan, “Microwave Electronics: Measurement and Materials Characterization”, John Wiley & Sons	2004
3.	R.J. Collier and A.D. Skinner, “Microwave Measurements”, IET Electrical Measurement Series, volume 4	2007
4	C. Parini, S. Gregson, J. McCormick and D. J. van Rensburg, “Theory and Practice of Modern Antenna Range Measurements”, IET Electromagnetic Wave Series, volume 55	2015
5	P. C. L. Yip “High Frequency Circuit Design and Measurements,” Chapman & Hall	1995

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-514 **Course Title:** Detection and Estimation 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:** Nil
9. **Objective:** To acquaint the students of Communication Engineering with the knowledge of how to use the tools of probability and signal processing to estimate signals and parameters and detect events from data.

10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	Introduction to detection and estimation problem in signal processing and communication	2
2.	Estimation in signal processing; Sufficient statistic, Bias; Minimum variance unbiased estimator; Cramer-Rao lower bound; Best linear unbiased estimator; Maximum likelihood estimation (MLE)	9
3.	Bayesian Estimation – Minimum mean square-error (MMSE) estimators, Maximum a-posteriori (MAP) estimators; Linear MMSE estimation, Linear estimation of signals, Weiner filtering; Kalman filtering – Kalman estimation and tracking	9
4.	Detection theory in signal processing; Hypothesis test – Bayesian, Minimax Neyman-Pearson and composite hypothesis testing; Receiver operating characteristics	8
5.	Detection of deterministic signals with known parameters in Gaussian noise, Matched filters; Detection of random signals with known characteristics, Estimator-correlator; Detection of deterministic signals with unknown parameters, Bayesian approach and generalized likelihood ratio test (GLRT); Detection of random signals with unknown parameters; Expectation maximization; Hidden Markov Model (HMM)	12
6.	Applications of detection and estimation in signal processing and communication – biomedicine, communications, radar, sonar, etc	2
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	S.M. Kay, "Fundamentals of Statistical Signal Processing – Estimation Theory (vol. 1)", Prentice Hall.	2009
2.	S.M. Kay, "Fundamentals of Statistical Signal Processing – Detection Theory (vol. 2)", Prentice Hall.	2009
3.	H.L. Van Trees, "Detection, Estimation and Modulation Theory", Part I, Wiley Interscience.	2013
4.	H. Vincent Poor, "An Introduction to Signal Detection and Estimation", 2nd Edn., Springer.	1998
5.	K.S. Shanmugan and A.M. Breipohl, "Random Signals: Detection, Estimation and Data Analysis", Wiley.	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-554 **Course Title:** Microwave and Millimeter-Wave 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:** Nil
9. **Objective:** To provide an in-depth treatment of the theory of different types of transmission line structures and their applications for the development of integrated circuits at microwave and millimeter wave frequencies.

10. Details of the Course:

S.No.	Contents	Contact Hours
1.	**Fundamental Concepts:** Elements of microwave/millimeter wave integrated circuits; Classification of transmission lines: Planar, quasi-planar and 3-D structures, their basic properties, field distribution and range of applications; Substrate materials and technology used for fabrication.	5
2.	**Analysis of Planar Transmission Lines:** Variational approach for the determination of capacitance of planar structures; Transverse transmission line techniques for multi-dielectric planar structures; Rigorous analysis of dielectric integrated guides; Use of effective dielectric constant in the approximate analysis of dielectric guide.	12
3.	**Metamaterials:** Theory of Composite Right/Left Handed (CRLH) transmission line metamaterials; Representation of CRLH metamaterial by an equivalent homogeneous CRLH TL; L-C network implementation and its physical realization.	6
4.	**Discontinuities:** Analysis of discontinuities in planar and non-planar transmission lines and their equivalent circuit representation.	5
5.	**Passive Circuits:** Design and circuit realization of filters, couplers, phase shifters, and switches using planar and non-planar transmission lines.	8
6.	**Active Circuits:** Design and circuit realization of amplifiers and oscillators using planar and non-planar transmission lines.	6
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Edwards, T.C. and Steer M.B., "Foundations for Interconnects and Microstrip Design", 3rd Ed., John Wiley & Sons.	2001
2.	Wolf, I., "Coplanar Microwave Integrated Circuits", John Wiley & Sons.	2006
3.	Bhat, B. and Koul, S.K., "Stripline Like Transmission Lines", John Wiley & Sons.	1989

4.	Caloz, C. and Itoh, T., “Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications”, Wiley-IEEE Press.	2005
5.	Bhat, B. and Koul, S. K., “Analysis, Design and Applications of Finlines”, Artech House.	1987
6.	Koul, S.K., “Millimeter Wave and Optical Dielectric Integrated Guides and Circuits”, John Wiley & Sons.	1997
7.	Ludwig, R. and Bretchko, P., “RF Circuit Design”, Pearson Education.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-602 **Course Title:** Terahertz 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:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** To expose the students with advanced concepts for analyzing and designing next-generation wireless systems operating at THz frequency bands.

10. Details of the Course:

S.No.	Contents	Contact Hours
1.	**Wireless fundamentals**: Evolution, Mathematical representation of wireless systems, Channel characteristics, Multi-antenna systems, Multi-carrier modulation schemes	6
2.	**Sub-6 GHz and mmWave wireless systems:** Motivation and system model, time and frequency division duplexing, uplink and downlink transmissions, benefits and challenges, relevance in 5G and beyond 5G systems, spectral and energy efficiency	6
3.	**THz communication:** Motivation, Differences between microwave, mmWave and THZ communication, propagation and characteristics, power consumption, multi-antenna signal processing, Applications of THz	6
4.	**Channel models**: MIMO and massive MIMO channel modeling, spatial channel models, 3GPP channel models, mmWave channel models, Terahertz Channel Model	4
5.	**Baseband signal processing:** Channel estimation, pilot assignment, estimating direction of arrivals and departures, Signal detection techniques, hardware impairments	8
6.	**Beamforming:** Beamforming fundamentals, Analog, Digital and Hybrid beamforming architectures, Codebook and non-codebook based beamforming techniques and algorithms	6
7.	THz Modulation schemes and waveform design, Co-existence of THz with 6G technology, Application of THz communication	6
	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.	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
3.	D. Tse and P. Viswanath, "Fundamentals of Wireless Communication", Cambridge University Press.	2005
4.	Saim Ghafoor, Mubashir Husain Rehmani, Alan Davy, ``Next Generation Wireless Terahertz Communication Networks'', CRC Press	2021

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-603 **Course Title:** Millimeter-Wave and Terahertz Antenna Design
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:** Nil
9. **Objective:** This course provides a foundation for millimeter-wave and terahertz antenna design.

10. **Details of the Course:**

S.No.	Contents	Contact hours
1.	**Introduction to antenna engineering:** Antenna Parameters, Basic antenna types, their working principle and radiation mechanism	6
2.	**Antenna Arrays:** N-element Linear array, Broadside array, End fire Array, Planar Array and its design considerations	8
3.	**Phased array and beamforming:** Power Dividers, Couplers and Hybrids, Butler Matrix, Rotmen Lens and different beamforming techniques	8
4.	**Reconfigurable antenna technologies:** working principle of active and non-linear semiconductor devices, varactor diode, pin-diode, Schottky diode, MEMS technology, liquid crystal technology, example of pattern, frequency and polarization reconfigurablity	6
5.	**Massive MIMO Antenna Systems:** Concept of Massive MIMO, Design and its applications	4
6.	**Integrated antenna design and packaging:** Packaging Technologies, Additive Manufacturing AiP Designs and Applications, 3D AiP for Power Transfer, Sensor Nodes, and IoT Applications	5
7.	**Application-oriented antennas for mm-wave and terahertz frequency:** leaky-wave antennas, waveguide slotted array, radio telescope system, case-study of Event Horizon Telescope, antenna system for cellular base stations, MIMO antenna topology, antennas for automotive radar.	5
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Constantine A. Balanis, "Antenna Theory: Analysis and Design," 4th Edition, Wiley	2016
2.	D. Liu, B. Gaucher, U. Pfeiffer, and J. Grzyb, "Advanced Millimeter-Wave Technologies," Wiley	2009
3.	Z. N. Chen, "Handbook of Antenna Technologies," Springer	2015
4.	Duixian Liu; Yueping Zhang, "Antenna-in-Package Technology and Applications," Wiley IEEE Press	2020
5.	A. Boriskin and R. Sauleau, "Aperture Antennas for Millimeter and Sub-Millimeter Wave Applications," Springer	2018

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-604 **Course Title:** High Speed 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:** Both **7. Subject Area:** PEC
8. **Pre-requisite:** Nil
9. **Objective:** This course will provide a thorough understanding high speed electronic devices used in advanced communication systems, smart electronic gadgets, defense and space applications.

10. **Details of the Course:**

S.No.	Contents	Contact Hours
1.	**Introduction**: History and overview of high speed electronics; RF, mm-wave and THz frequency bands; requirements of high-speed semiconductor devices.	2
2.	**Parameters governing the high speed performance of a devices**: carrier mobility, doping concentration; temperature; charge carrier transit time; junction capacitances; ON-state resistances and their dependence on the device geometry; contact resistance; interconnect capacitances in ICs and MMICs.	5
3.	**Materials for high speed devices**: brief revision of the crystal structure; carrier mobility and saturation velocity of different semiconductor materials; Comparison of III–V binary and ternary semiconductors such as GaN, (Al/In) GaAs, InP and SiGe with Si; Baliga High Frequency Figure of Merit (BHFM) and Johnson figure of merit (JFOM).	4
4.	**High-speed diodes:** Metal semiconductor contacts and Schottky barrier diodes; Thermionic Emission model; carrier transport in forward and reverse bias and their dependence on different physical parameters; Effect of interface states on the Schottky barrier height and the I-V characteristics; metal insulator semiconductor (MIS) diodes; Gunn diodes and Tunnel diodes; RTD.	8
5.	**Field Effect Transistors (FETs)**: MOSFET and MESFET; Pinch-off voltage and threshold voltage of a MESFET; MESFET I-V characteristics; velocity overshoot effects; GaAs, InP and GaN based high speed FETs; short channel effects.	8
6.	**High Electron Mobility Transistors (HEMTs)**: concept of Hetero-structures; Modulation Doped FETs (MODFETs) for high electron mobility; working principle of polar and non-polar HEMTs; InGaAs/InP HEMT; AlGaN/GaN HEMTs and emerging HEMT devices.	5
7	**Bipolar Junction transistors (BJTs):** Merits of BJTs over FETs; hetero-junction bipolar transistors (HBTs) and their working principle; GaAs and InP based HBTs; SiGe HBTs and the concept of strained layer devices.	4
8	**Selected high speed circuits:** basics of RF power amplifiers, local oscillators and mixers; monolithic microwave integrated circuits; concepts of RF energy harvesting circuits.	6
	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.	Peter Ashburn, “SiGe Heterojuntion Bipolar Transistor,” Wiley	2003
4.	Behrat Razavi, “RF Microelectronics,” Pearson	2011
5.	Marian K. Kazimierczuk, “RF Power Amplifiers,” Wiley.	2014

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-605 **Course Title:** Surface Electromagnetics
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:** Nil
9. **Objective:** To gain insight into the electromagnetics of wave-surface interaction.

10. **Details of the Course:**

S.No.	Contents	Contact Hours
1.	**Introduction to Surface Electromagnetics:** Maxwell equations, Classical Uniform EM Surfaces, Surface Equivalence Theorem, Features of Periodic EM Surfaces, Frequency Selective Surface, Soft/Hard Surface, Electromagnetic Bandgap Surface.	8
2.	**Analytical Modeling of Electromagnetic Surfaces:** concept of unit cell, Main Functionalities of Metasurfaces, Metasurfaces versus Thin Slabs of Homogeneous Materials and Other Artificial Periodic Surfaces, Quasi-periodic Structures, Homogenization Models of Metasurfaces: Polarizability-Based Model, Susceptibility-Based Model, Model Based on Equivalent Impedance Matrix, Bi-anisotropy and Nonreciprocity.	8
3.	**Electromagnetic Metasurface:** Metasurface Boundary Conditions, Impedance-Type Boundary Conditions, Conditions of Reciprocity, Passivity, and Loss, Synthesis Procedure, Relation with Scattering Parameters, Negative Refraction Metasurface, Metafilms, Metascreens, Metagratings, Guided Waves on a Single Metasurface, Controllable Reflections and Transmissions, Coding and Programmable Metasurfaces, Non-uniqueness of the Scattering Problem: Non-radiating Sources and Cloaking Devices, Cloaking Design with Mie Solutions, Cloaking Design with Non-radiating Sources, Control of Wave Propagation Direction in Transmission and Reflection, Control of Polarization in Reflection and Reflection.	10
4.	**Modulated Metasurface Antennas and Transmitarray:** Adiabatic Floquet Waves, Pixel Modeling, Full-Wave Homogenized Impedance Analysis, Efficiency of Metasurface Antennas, FSS-Type Reconfigurable Design, Concept and Design Procedure of Transmit array Antennas, Example of Multibeam Modulated Metasurface Antennas.	4
5.	**Orbital Angular Momentum Beam Generation Using Textured Surfaces:** Bessel–Gaussian Beams, Laguerre–Gaussian (Helical) Beams, OAM Beams, Near-Field Applications of OAM Beams, Potential Far-Field Applications of OAM Beams, OAM Beam Generation Using Reflectarray Antennas.	4
6.	**Applications of Metasurfaces in the Microwave to Terahertz Regime:** Ultrathin Electromagnetic Absorbers, Artificial Grounds for Low-Profile Antennas, Antenna Superstrates and Coatings, Modulated Metasurfaces for Leaky Wave Radiation, Scattering Signature Control, Recent Developments in Terahertz Metasurface and Metamaterial Technology, Holography.	8
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	D.-K.-Cheng, “Field and Wave Electromagnetics,” Pearson Education	2006
2.	F. Yang and Y. R.-Samii, “Surface Electromagnetics,” Cambridge University Press	2019
3.	S. I. Bozhevolnyi, P. Genevet, and F. Ding, “Metasurface: Physics and Application,” MDPI	2018
4.	N. Engheta and R. W. Ziolkowski, “Metamaterials: Physics and Engineering Explorations,” IEEE Press	2006
5.	C. Caloz and K. Achouri, “Electromagnetic Metasurface: Theory and Applications,” Wiley	2021

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-606 **Course Title:** High-Frequency Dielectric Guides
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:** Nil
9. **Objective:** To provide in-depth knowledge on the topic of dielectric guides.

10. **Details of the Course:**

S.No.	Contents	Contact Hours
1.	**Fundamentals of electromagnetic fields:** Maxwell equations, wave equation, boundary conditions, radiation condition, phase and group velocity, constitutive relations, concept of anisotropy.	8
2.	**Planar dielectric waveguides:** slow wave propagation in dielectric waveguides, TE and TM modes, geometrical loss factor, dispersion relations, Marcatili's approximate method, approximate solution for a rectangular dielectric waveguide, leaky modes along an asymmetric dielectric waveguide, multi-layered dielectric slab waveguides, Sommerfeld–Zenneck surface impedance waveguide.	8
3.	**Circular and elliptical waveguides:** hybrid modes in rod waveguide, dispersion relations, cut-off conditions, hollow dielectric rod waveguides, even-dominant modes, odd-dominant modes, Sommerfeld–Goubau Wire.	6
4.	**Photonic crystal waveguides:** guided waves in periodic structures, stop-band and pass-band structures, concept of Bragg reflector and band-gap design, dielectric waveguide array	4
5.	**Circuit development using dielectric guides:** coupled mode theory, directional couplers and power dividers using dielectric guides, signal distortion in dielectric guides, inter-modal dispersion, channel capacity, excitation of dielectric guides on a planar platform, low-loss terahertz ribbon waveguide, bending of dielectric guides, leaky-wave antenna design on dielectric guides, on-chip fabrication techniques for dielectric guides.	8
6.	**Dielectric resonators:** natural modes of dielectric bodies, hybrid modes in rectangular and cylindrical dielectric resonators, whispering gallery modes, concept of dielectric resonator antenna, dielectric ring resonator.	8
	Total	**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	C. Yeh and F. I. Shimabukuro, “The Essence of Dielectric Waveguides,” Springer	2008
2.	S. K. Koul, “Millimeter Wave Optical Dielectric Integrated Guides and Circuits,” Wiley Series in Microwave and Optical Engineering	1997
3.	D. Marcuse, “Theory of Dielectric Optical Waveguides,” Academic Press	1991
4.	D. Lioubtchenko, S. Tretyakov, S. Dudorov, “Millimeter-Wave Waveguides,” Springer	2003
5.	Y. Shestopalov, Y. Smirnov, E. Smolkin, “Optical Waveguide Theory: Mathematical Models, Spectral Theory and Numerical Analysis,” Springer Series in Optical Sciences	2022

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

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

1. **Subject Code:** ECN-607 **Course Title:** Terahertz Sensing and Imaging
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:** Nil
9. **Objective:** To provide knowledge on Terahertz Sensing and Imaging Technology.

10. **Details of the Course:**

S.No.	Contents	Contact Hours
1.	**Transmission and propagation of terahertz waves in waveguides:** Introduction, Main challenges of the plastic-based terahertz fiber optics, Devices based on subwavelength fibers, Hollow-core fibers, Composite terahertz materials	8
2.	**Fundamental aspects of surface plasmon polaritons at terahertz frequencies**: Introduction, The Drude model, Surface plasmon polaritons on planar surfaces, Multilayered structures, New trends in terahertz plasmonics	6
3.	**Fundamental aspects of terahertz near-field imaging and sensing:** Introduction, Terahertz near-field measurements, Near-fields of various subwavelength holes, Kirchhoff formalism for near-field estimate	6
4.	**Terahertz bio-sensing techniques:** Introduction, Sensing of water dynamics by terahertz waves, Sensing of proteins, Binding-state dependent sensing, Characteristic resonances of biomolecules in the terahertz range, Water-mediated terahertz molecular imaging	6
5.	**Terahertz integrated devices and systems:** Introduction, Integrated terahertz biosensor chip, Terahertz oscillators integrated with patch antennas, discussion on resonant tunneling diodes	8
6.	**Applications of terahertz technology:** Terahertz applications in the aerospace industry, Terahertz applications in the wood products industry, Terahertz applications in art conservation Applications of terahertz technology in the semiconductor industry	8
	Total	**42**

11. **Suggested Books:**

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	Dwight L. Woolard, William R. Loerop, Michael Shur, “Terahertz Sensing Technology: Electronic Devices and Advanced Systems Technology,” World Scientific Publishing Company	2004
2.	Daryoosh Saeedkia, “Handbook of terahertz technology for imaging, sensing and communications,” Woodhead Publishing	2013
3.	Daniel R. Grischkowsky, “Daniel Mittleman, Sensing with Terahertz Radiation,” Springer	2003
4.	Joo-Hiuk Son, “Terahertz Biomedical Science and Technology,” CRC Press	2014

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:** Spring **7. Subject Area:** PEC
8. **Pre-requisite:** Nil.
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”, 2^{nd} 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-637 **Course Title:** Microwave Photonic ICs
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:** Nil
9. **Objective:** To provide advanced EM concepts for designing microwave photonics ICs.

10. **Details of the Course:**

S.No.	Contents	Contact Hours
1.	**Introduction and review:** Optical communications: short-reach, long-haul, and data centers communications, Economic drivers towards photonic integration, Interaction of optical waves with dielectric and metal interfaces, Boundary conditions, total internal reflection, Review of silicon PN-and PIN-junctions, Junction diode static and transient characteristics	4
2.	**Fundamentals of Si photonics**: Symmetric dielectric waveguides, Asymmetric dielectric waveguides, Rectangular waveguides, Computational methods for integrated photonics, Marcatilli's and effective index methods, Propagation matrix, finite difference time domain, eigenmode expansion, Design and fabrication of silicon waveguide structures, Waveguide loss, scattering, absorption, radiation, Adiabatic mode converters, Dispersion in optical waveguides, group delay, dispersion engineering	8
3.	**Passive devices**: Coupling to waveguide: edge, grating, evanescent coupling, spot-size converters, packaging solutions and economic/functional/power constraints, coupled mode theory, coupled optical waveguides, Power splitters, Mach-Zehnder interferometer, Cascaded MZI optical filters, Star couplers, Wavelength division multiplexing, Optical ring resonators, Add-drop multiplexers, Waveguide Bragg gratings, Polarization dependence and management, Waveguide polarization splitters and rotators, Optical isolation, Wavelength multiplexers figures of merit	8
4.	**Transmitter active devices**: Electro-optical effects in silicon, Thermal phase shifter, thermo-optic switch, Carrier-induced electro-optical effects, Carrier-Injection phase shifter, PN-junction carrier distribution, optical phase response, small signal response, Forward biased PIN junction variable optical attenuator, Micro-ring modulators and switches, small-signal response, ring modulator design, Carrier depletion phase shifter, PN-junction carrier distribution, optical phase response, small signal response, Traveling wave design of reverse-biased electro-optic modulator, Modulators for advanced modulation formats, Transmitter figures of merit	10
5.	**Receiver active devices**: Germanium photodetectors, Fabrication approaches, III-V integration with silicon photonics, Integrated photodetectors, lasers and amplifiers, Receiver figures of merit	4
6.	**Photonic systems:** Introduction to photonic systems for short-reach and long-haul optical communications, Modulation formats, receiver and transmitter characteristics, optical link budget, BER and penalties, Introduction to data center optical networks, Optical switching, Optical switches	3

7.	**Emerging applications** of Si photonics in quantum computing, neuromorphic computing, and biological sensing, Comparison of technological advantages and businessmodels, State of silicon photonics industry, Skills and competencies	5
Total		**42**

11. Suggested Books:

S.No.	Name of Authors/Book/Publisher	Year of Publication/ Reprint
1.	A. Balanis, “Advanced Engineering Electromagnetics,” Wiley	2012
2.	S. L. Chuang, “Physics of Photonic Devices, 2nd edition,” Wiley	2009
3.	B. E. A. Saleh & M. C. Teich, “Fundamentals of Photonics,” Wiley, 2nd edition (2007)	2007
4.	L. Coldren, S. Corzine, M.L. Mashanovitch , “Diode Lasers and Photonic Integrated Circuits,” Wiley 2nd Edition (2012)	2012
5.	V. J. Urick, Keith J. Williams, Jason D. McKinney, “Fundamentalsof Microwave Photonics,” Wiley	2015
6.	Chi H. Lee, “Microwave Photonics,” Second Edition, CRC Press	2013
7.	Stavros Iezekiel, “Microwave photonics: devices and applications,” Wiley	2009

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:** Spring **7. Subject Area:** PEC
8. **Pre-requisite:** Nil.
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-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:** Spring **7. Subject Area:** PEC
8. **Pre-requisite:** Nil.
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