INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electronics & Communication Engineering**

1. Subject Code: **ECN-511** Course Title: **Digital Communication Systems**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight**:** **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn** 7. Subject Area**: CORE**

8. Pre-requisite**:** **NIL**

9. Objective: To introduce the students to the principles, techniques and applications of digital communication.

10. Details of Course:

S. No.	**Contents**	**Contact Hours**
1.	Block diagram and sub-system description of a digital communication system. Sampling of low-pass and band-pass signals, analysis of instantaneous, natural and flat-top sampling, signal reconstruction; PAM and bandwidth considerations.	**5**
2.	PCM, signal to quantization noise ratio analysis of linear and non-linear quantizers; Line codes and bandwidth considerations; PCM-TDM hierarchies, frame structures, frame synchronization and bit stuffing. □.	**4**
3.	Quantization noise analysis of DM and ADM; DPCM and ADPCM; Low bit rate coding of speech and video signals. □	**5**
4.	Baseband transmission, matched filter, performance in additive Gaussian noise; Intersymbol interference (ISI), Nyquist criterion for zero ISI, sinusoidal roll-off filtering, correlative coding, equalizers and adaptive equalizers; Digital subscriber lines.	**5**
5.	Geometric representation of signals, maximum likelihood decoding; Correlation receiver, equivalence with matched filter	**3**
6.	Generation, detection and probability of error analysis of OOK, BPSK, coherent and non-coherent FSK, QPSK and DPSK; QAM,	**8**

	MSK and multicarrier modulation; Comparison of bandwidth and bit rate of digital modulation schemes.	
7.	Types of satellite orbits, satellite transponder, multiple access techniques, basic link design.	**4**
8.	Cellular concepts, propagation characteristics, GSM and CDMA standards.	**4**
9.	Optical fiber propagation, loss and dispersion, types of fibers; Optical sources and detectors, connectors and splices; Optical link.	**4**
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors/ Publishers**	**Year of Publication/ Reprint**
1.	Haykin, S., "Communication Systems", 4th Ed., John Wiley & Sons.	**2001**
2.	Lathi, B.P. and Ding, Z., "Modern Digital and Analog Communication Systems", Intl. 4th Ed., Oxford University Press.	**2009**
3.	Proakis, J.G. and Saheli, M., "Digital Communications" , 5th Ed., McGraw-Hill.	**2008**
4.	Sklar, B., and Ray, P.K., "Digital Communication: Fundamentals and Applications", 2nd Ed., Dorling Kindersley (India).	**2009**
5.	Carlson, A.B., Crilly, P.B. and Rutledge, J.C., "Communication Systems: An Introduction to Signals and Noise in Electrical Communication", 4th Ed., McGraw-Hill.	**2002**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electronics & Communication Engineering**

1. Subject Code: **ECN-512** Course Title: **Information and Communication Theory**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Autumn** 7. Subject Area**: CORE**

8. Pre-requisite**:** **NIL**

9. Objective: To provide the essential concepts of information and communication theory and their applications.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Introduction to detection and estimation problem in communication.	**2**
2.	The meaning and axioms of probability; Random variables; Examples of commonly used random variables and their density and distribution functions; Moments and characteristic functions.	**6**
3.	Bivariate distributions and functions of two random variables, joint moments and characteristic functions, conditional distributions and expected values.	**4**
4.	Binary hypothesis testing: Bayes, Neyman-Pearson, maximum likelihood, MAP and minimum probability of error criteria; Bayes, ML and MAP estimation.	**6**
5.	Information, entropy, source coding theorem, Markov sources; Channel capacity theorems for discrete and continuous ensembles; Introduction to rate distortion function.	**8**
6.	Correlation matrix and characteristic functions of sequences of random variables, jointly normal random variables; Mean square estimation, stochastic convergence and limit theorems; Random number generation.	**6**
7.	Random processes, correlation function and power spectrum, random	**10**

	process through linear systems, KLT, ergodicity; Spectral factorization and innovation; Optimum linear filters and mean square estimation.	
	Total	**42**

11. Suggested Books:

S. No.	**Name of Books / Authors/ Publishers**	**Year of Publication/ Reprint**
1.	Papoulis, A. and Pillai, S.U., “Probability, Random Variables and Stochastic Processes”, Tata McGraw-Hill.	**2002**
2.	Cover, T.M. and Thomas, J.A., “Elements of Information Theory”, 2nd Ed., Wiley Interscience.	**2006**
3.	Van Trees, H.L., “Detection, Estimation and Modulation Theory”, Part I, Wiley Interscience.	**2001**
4.	Bose, R., “Information Theory, Coding and Cryptography”, Tata McGraw-Hill.	**2003**
5.	Sayood, K., “Data Compression”, Harcourt India.	**2000**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electronics & Communication Engineering**

1. Subject Code: **ECN-513** Course Title: **Telecommunication Networks**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Spring** 7. Subject Area**: PE**

8. Pre-requisite**:** **NIL**

9. Objective: This course is designed to provide an in - depth study of communication networks with emphasis on development of analytical tools and quantitative performance evaluation.

10. Details of Course:

Sl. No.	**Contents**	**Contact Hours**
1.	Introduction to communication networks**,** network topologies, internetworking, circuit and packet switching; Layered architecture and protocols, OSI reference model and functions of various layers, overview of TCP / IP, ISDN and SS – 7 protocol architectures.	3
2.	Brief characterization of communication channels and fundamental limits in digital transmission; Line codes and modems; Transmission media and transmission impairments; Synchronous and asynchronous time division multiplexing, SONET and SDH.	3
3.	Error detection: Parity check, polynomial representation, cyclic redundancy checks and their capabilities; Error control: Stop and wait, go - back n and selective repeat ARQ strategies, correctness and throughput analysis; Framing and optimum frame size; HDLC and LAPB protocols, throughput analysis of HDLC.	6
4.	Introduction to queuing models, modeling of arrivals, interarrival times and service times, Poisson process; Little's theorem, proof and examples; Continuous–time discrete event process and Markov chain, Birth-Death process; Analysis and applications of M/M/1, M/M/m, M/M/m/m, M/M/m/K and M/M/∞ queues; M/G/1 queue,	15

	vacation, reservation, polling, and priority; G/G/1 queue; Network of queues, Kleinrock's independence assumption, Burke's and Jackson's theorems.	
5.	Classification and performance measures of MAC protocols; Pure-ALOHA and slotted-ALOHA, Markov chain modeling, stability, BEB and other stabilization techniques; Splitting algorithms; Non-persistent, 1-persistent and p-persistent CSMA, performance evaluation; CSMA/CD and CSMA/CA; Polling, reservation and token ring protocols; Overview of IEEE 802 standards and frame structures of 802.3 and 802.5.	8
6.	Main issues in routing, virtual circuit and datagram routing; Classification of routing algorithms; Shortest path algorithms: Bellman-Ford, Dijkstra and Floyd-Warshall; Distributed asynchronous Bellman-Ford algorithm.	4
7.	Objectives and means of flow and congestion control, End-to-end and node by node windows, performance analysis and simplified queuing models; Rate control schemes: Time window, modeling and performance of leaky bucket algorithm.	3
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Bertsekas, D. and Gallager, R., "Data Networks", 2^{nd} Ed., Prentice-Hall of India.	1992
2.	Kumar, A., Manjunath, D. and Kuri, J., "Communication Networking: An Analytical Approach", Morgan Kaufmann.	2004
3.	Schwartz, M., "Telecommunication Networks: Protocols, Modeling and Analysis", Pearson Education.	1987
4.	Stallings, W., "Data and Computer Communication", 8^{th} Ed., Pearson Education.	2007
5.	Walrand, J., "Communication Networks", 2^{nd} Ed., McGraw-Hill.	2009
6.	Kleinrock, L., "Queuing Systems: Theory", 2^{nd} Ed., Wiley Blackwell.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electronics & Communication Engineering**

1. Subject Code: **ECN-515** Course Title: **Coding Theory and Applications**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits**: 3** 6. Semester**: Spring** 7. Subject Area**: CORE**

8. Pre-requisite**: NIL**

9. Objective: To provide an in-depth study of the design of good forward error correction codes and their efficient decoding. .

10. Details of Course:

Sl. No.	**Contents**	**Contact Hours**
1.	Introduction to forward error correction and reliable information transmission; Discrete communication channels and Shannon's theorems revisited.	2
2.	Introduction to groups, rings and fields; Finite fields based on integer and polynomial rings; Binary field arithmetic, construction and properties of GF (2^m); Vector spaces and linear algebra; Logic circuits for finite field arithmetic.	6
3.	Structure of Linear Block Codes, encoding, minimum distance, error detection and correction capabilities, syndrome; Standard array and decoding of block codes; Probability of undetected error over binary symmetric channel; Examples of block codes: Hamming, SEC-DED, Reed-Muller, Golay.	6
4.	Polynomial and matrix description of Cyclic Codes, encoding, decoding; Hamming code and Golay code; Shortened and quasi-cyclic codes; Error trapping decoding.	6
5.	Binary primitive BCH codes, Berlekamp's iterative algorithm for BCH decoding, decoder implementation; Non-binary BCH and Reed-	8

	Solomon (R-S) codes, decoding of R-S codes by Berlekamp's algorithm; Frequency domain representation and decoding of R-S codes.	
6.	Convolutional codes, encoding, trellis description, structural and distance properties; Viterbi algorithm (VA), implementation and performance of VA; SOVA and BCJR algorithms.	8
7.	Introduction to Turbo and LDPC codes; Iterative decoding of Turbo codes; Trellis coded modulation.	4
8.	Burst-error correction, interleaving and concatenation.	2
	Total	**42**

11. Suggested Books:

Sl. No.	**Name of Books/ Authors**	**Year of Publication**
1.	Lin, S. and Costello Jr., D.J., "Error Control Coding", 2nd Ed., Pearson Prentice-Hall.	2004
2.	Blahut, R.E., "Algebraic Codes for Data Transmission", 2nd Ed., Cambridge University Press.	2003
3.	Vucetic, B. and Yuan, J., "Turbo Codes: Principles and Applications", Springer.	2000
4.	McEliece, R., "Theory of Information and Coding", 2nd Ed., Cambridge University Press.	2002
5.	Huffman, W.C. and Pless, V., "Fundamentals of Error Correcting Codes", Cambridge University Press.	2003
6.	Moon, T.K., "Error Correction Coding: Mathematical Methods and Algorithms", Wiley Interscience.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electronics & Communication Engineering**

1. Subject Code: **ECN-516** Course Title: **Advanced Digital Communication Techniques**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight **: CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits**: 3** 6. Semester**: Spring** 7. Subject Area**: PE**

8. Pre-requisite**: NIL**

9. Objective: To expose the students to advanced topics in digital communication with emphasis on source coding, signal design and optimum receiver structures.

10. Details of Course:

Sl. No.	**Contents**	**Contact Hours**
1.	Vector quantization; Sub-band coding of speech, audio and video signals; Linear predictive coding of speech, CELP coders; MPEG standards for audio and video.	6
2.	Characterization of bandpass signals and systems, orthonormal expansion of signals, representation of digitally modulated signals; Non-linear modulation methods with memory.	6
3.	Optimum demodulation of known signals in additive white Gaussian noise; Probability of error for binary and M-ary signaling, and DPSK demodulator.	6
4.	Carrier and symbol synchronization techniques.	4
5.	Characterization of band-limited channels and ISI, signal design for zero ISI and controlled ISI.	4
6.	Optimum demodulator for ISI and AWGN; Linear equalization and decision feedback equalization, adaptive equalizers.	6
7.	Characterisation of fading dispersive channel, tapped delay line model, optimum demodulation for binary signaling, Rake receiver.	5
8.	Direct sequence spread spectrum and CDMA systems, DSSS performance in AWGN and fading channel.	5
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/ Authors	Year of Publication
1.	Proakis, J.G. and Saheli, M., “Digital Communications” , 5th Ed., McGraw-Hill.	2008
2.	Barry, J.R., Lee, E.A. and Messerschmitt, D.G., “Digital Communication”, 3rd Ed., Kluwer.	2004
3.	Benedetto, S. and Biglieri, E., “Principles of Digital Transmission: Wireless Applications”, Springer.	1999
4.	Sayood, K., “Introduction to Data Compression”, 3rd Ed., Morgan Kaufman.	2006

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electronics & Communication Engineering**

1. Subject Code: **ECN-518** Course Title: **Speech and Audio Processing**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Spring** 7. Subject Area**: PE**

8. Pre-requisite**:** **NIL**

9. Objective: To acquaint the students with the concepts in speech and audio processing, and their applications in communication systems.

10. Details of Course:

Sl. No.	**Contents**	**Contact Hours**
1.	Digital speech processing and its applications, production and classification of speech sounds, lossless tube models, digital models for speech signals; Analysis and synthesis of pole-zero speech models, Levinson recursion, lattice synthesis filter.	7
2.	Time dependent processing of speech, pitch period estimation, frequency domain pitch estimation; Discrete-time short-time Fourier transform and its application, phase vocoder, channel vocoder.	6
3.	Homomorphic speech processing, waveform coders, hybrid coders and vector quantization of speech; Model based coding: Linear predictive, RELP, MELP, CELP; Speech synthesis.	9
4.	Principles of speech recognition, spectral distance measures, dynamic time warping, word recognition using phoneme units, hidden Markov models and word recognition, speech recognition systems, speaker recognition.	7
5.	Ear physiology, psychoacoustics, perception model and auditory system as filter bank; Filter bank design and modified discrete cosine transform algorithm for audio compression in MP3 and AAC coders; Standards for high-fidelity audio coding.	7
6.	Tree-structured filter banks, multicomplementary filter banks; Properties	6

	of wavelets and scaling functions, wavelet transform; Filter banks and wavelets, applications of wavelet signal processing in audio and speech coding.	
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Rabiner, L.R. and Schafer, R.W., "Digital Processing of Speech Signals", Pearson Education.	2006
2.	Quatieri, T.F., "Discrete-Time Speech Signal Processing: Principles and Practice", Pearson Education.	2002
3.	Furui, S., "Digital Speech Processing, Synthesis and Recognition", 2^{nd} Ed., CRC Press.	2000
4.	Fliege, N.J., "Multi Rate Digital Signal Processing", John Wiley & Sons.	1999
5.	Spanias, A., Painter, T. and Venkatraman, A., "Audio Signal Processing and Coding", John Wiley & Sons.	2007
6.	Gold, B. and Morgan, N., "Speech and Audio Signal Processing", John Wiley & Sons.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electronics & Communication Engineering**

1. Subject Code: **ECN-522** Course Title: **Digital Signal Processing & Applications**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight : **CWS 25 PRS 0 MTE 25 ETE 50 PRE 0**

5. Credits**: 3** 6. Semester**: Autumn** 7. Subject Area**: PE**

8. Pre-requisite**: NIL**

9. Objective: To introduce the students to the principles, techniques and applications of digital signal processing.

10. Details of Course:

S. No.	Contents	Contact Hours
1.	Advantages and limitations of digital signal processing; Review of discrete time signal and system analysis using Fourier transform and z-transform; Sampling and discrete time processing of continuous time signals.	**7**
2.	Structures for discrete time systems; Design of digital FIR and IIR filters.	**6**
3.	Multirate DSP and its application in sampling rate conversion, audio coding and high quality A/D conversion .	**6**
4.	Properties and applications of DFT, FFT and decimation algorithms; DCT and its application in multimedia coding.	**5**
5.	Spectral analysis using FFT; Wiener filtering, adaptive filters; LMS and RLS adaptive filtering algorithms; Application of adaptive filtering to echo cancellation and equalization	**8**
6.	General and special purpose hardware for DSP; Real time digital signal processing using TMS 320 family.; Implementation of DSP algorithm on digital signal processors	**6**
	Total	**4**
		42

11. Suggested Books:

S. No.	Name of Books / Authors/ Publishers	Year of Publication/ Reprint
1.	Proakis, J.G, “Digital Signal Processing: Principle, Algorithms and Applications”, 4th Ed., Pearson.	**2007**
2.	Oppenheim, A.V. and Schafer, R.W, “Discrete-Time Signal Processing”, 3rd Ed., Peaerson.	**2009**
3.	Porat, B. “A Course in Digital Signal Processing” , 1st Ed., John Wiley & Sons.	**1996**
4.	Mitra, S.K., “Digital Signal Processing A Computer-Based Approach”, 4th Ed., McGraw-Hill.	**2010**
5.	Weltch , T.B., Wright, C.H.G. and Morrow, G.M., “Real-Time Digital Signal Processing from MATLAB to C with the TMS320C6x DSPs.”, 2nd Ed., CRC Press.	**2012**

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Computer Engineering**

1. Subject Code: **ECN–523** Course Title: **Robotics and Computer Vision**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight: **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5.Credits: **0 3** 6. Semester √

Autumn Spring Both

7. Pre-requisite: **EC- 321 or equivalent**

8. Subject Area: **DEC**

9.Objective: The course introduces the fundamentals of robot dynamics, its features and performance, controller techniques, and image analysis for obstacle avoidance.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	Definition, structure and application areas of Robotics; Introduction to the range of robots currently in use.	4
2.	Direct kinematics of the robot arm, link description and its connection; Frame assignment; Concept of actuator space, joint space and Cartesian space; Inverse kinematics, algebraic solution, geometric solution; Solvabilitly considerations and examples.	6
3.	Manipulator dynamics, basic equations, Newton-Euler dynamic formulation; Lagrange formulation of the manipulator dynamics; Simulation.	8
4.	Controller design, linear and non-linear control approaches, special considerations like coupling, time-variation and model uncertainty; Computed torque, variable structure and adaptive control techniques.	9
5.	Digital image fundamentals, digitization and 2-D parameters, types of operation; Basic tools: Convolution, Fourier transforms and statistical approaches.	6
6.	Image analysis and processing, basic enhancement and restoration techniques, unsharp masking, noise suppression, distortion suppression, segmentation, thresholding, edge finding, binary mathematical morphology, grey-value mathematical morphology.	9
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Fu, K.S., Gonzalez, R.C. and Lee, C.S.G., “Robotics: Control, Sensing, Vision and Intelligence”, McGraw-Hill.	1987
2.	Pratt, W.K., “Digital Image Processing”, 2nd Ed., John Wiley & Sons.	1991
3.	Gonzalez, R.C. and Woods, R.E., “Digital Image Processing”, 3rd Ed., Prentice-Hall.	2008
4.	Klafter, R.D., Chmielewski, T.A. and Negin, M., “Robotic Engineering An Integrated Approach”, Prentice-Hall of India.	2007
5.	Schilling, R. J., “Fundamental of Robotics: Analysis and Control”, Prentice-Hall of India.	2007
6.	Sciavicco, L., “Modeling and Control of Robot Manipulators”, McGraw-Hill.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN– 531** Course Title: **Microwave Engineering**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory 0 3** **Practical 0 0**

4. Relative Weight**:** **CWS 25 PRS 00 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 4** 6. Semester √ **Autumn Spring Both**

7. Pre-requisite**:** NIL

8. Subject Area**: PCC**

9. Objective: To introduce the students to the field theory and circuit theory concepts in the analysis and design of microwave guiding structures and passive components.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Transmission Lines and Waveguides:** Review of TEM, TE, and TM mode solutions of Maxwell's equations; TEM mode transmission lines: lossless line, line with small losses, power flow in a terminated line; Quasi-TEM mode lines: Fields in microstriplines and striplines, losses in microstrips, microstrip discontinuities, coupled lines, slot lines and coplanar waveguides; Surface waveguides: Surface waves along an impedance plane, dielectric-coated conducting plane, slab waveguide, corrugated plane; Wave velocities.	10
2.	**Microwave Circuit Theory Principles:** Equivalent voltages and currents; Z, Y, S, and ABCD parameters; Equivalent circuit representation of microwave junctions; Scattering parameter analysis of microwave junctions; Coupling of waveguides through probes, loops, and apertures.	8
3.	**Impedance Transformers:** Review of single-, double- and triple-stub tuners, waveguide reactive elements, quarter-wave transformers, design of maximally flat and Chebyshev transformers; Introduction to tapered transmission lines.	6
4.	**Power Dividers and Couplers:** Scattering matrix of 3- and 4-port junctions; Design of T-junction and Wilkinson power dividers; Design of 90° and 180° hybrids.	6

5.	**Filters:** Analysis of periodic structures, Floquet's theorem, filter design by insertion loss method, maximally flat and Chebyshev designs.	6
6.	**Resonators:** Principles of microwave resonators, loaded, unloaded and external Q, open and shorted TEM lines as resonators, microstrip resonators, dielectric resonators.	6
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Collin, R.E., "Foundations for Microwave Engineering", 2nd Ed., John Wiley & Sons.	2000
2.	Pozar, D.M., "Microwave Engineering", 3rd Ed., John Wiley & Sons.	2004
3.	Edwards, T.C. and Steer M.B., "Foundations for Interconnects and Microstrip Design", 3rd Ed., John Wiley & Sons.	2001
4.	Ludwig, R. and Bretchko, P., "RF Circuit Design", Pearson Education.	2000
5.	Hunter, I., "Theory and Design of Microwave Filters", IEE Press.	2001
6.	Misra, D.K., "Radio-frequency and Microwave Communication Circuits", John Wiley & Sons.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT/CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN-532** Course Title: **Advanced EMFT**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight: **CWS 25** **PRS 0** **MTE 25** **ETE 50** **PRE 0**

5. Credits: **3** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **Nil**

9. Objective: To introduce the students to analytical techniques used in solving electromagnetic field theory problems.

10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	**Electromagnetic waves:** Coordinate systems; Maxwell's equations for time-varying fields and boundary conditions; Poynting vector; Wave equation; Wave polarization; Wave propagation in perfect and lossy dielectrics; Reflection of waves on a material boundary; Wave functions.	10
2.	**Fundamental Theorems and Concepts:** Electric and magnetic current sources; Duality; Image theory; Equivalence principle; Babinet's principle; Induction theorem; Reciprocity theorem; Auxiliary potentials; Construction of general solutions from wave functions; Radiation fields.	7
3.	**Plane Wave Functions:** Elementary wave functions in rectangular coordinates; TE, TM, and hybrid modes in rectangular waveguides; Partially filled waveguides; Rectangular cavity; Modal expansion of fields in a waveguide; Apertures in conducting screens.	8
4.	**Cylindrical Wave Functions:** Elementary wave functions in cylindrical coordinates; Homogeneously filled and partially filled circular waveguides; Radial waveguides; Cylindrical cavities; Sources of cylindrical waves.	8
5.	**Spherical Wave Functions:** Elementary wave functions in spherical coordinates; Spherical resonator; Sources of spherical waves.	4
6.	**Wave Propagation in Anisotropic Media:** Plane wave propagation in anisotropic and uniaxial crystals; TEM wave propagation in Ferrites; Faraday rotation.	5
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors / Books /Publishers	Year of Publication
1.	Harrington, R.F., “Time-harmonic Electromagnetic Fields”, Wiley-IEEE Press.	2001
2.	Ramo, S., Whinnery, J.R., and Van Duzer, T., “Fields and Waves in Communication Electronics”, 3rd Ed., John Wiley & Sons.	1994
3.	Collin, R.E., “Foundations for Microwave Engineering”, 2nd Ed., John Wiley & Sons.	2000
4.	Balanis, C.E., “Advanced Engineering Electromagnetics”, Wiley India Pvt. Ltd., Reprint	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN– 534** Course Title: **Antenna Theory and Design**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **0 3** **Practical** **0 0**

4. Relative Weight: **CWS 25** **PRS 00 00** **MTE 25** **ETE 50** **PRE 00**

5. Credits: **0 3** 6. Semester √ **Autumn** **Spring** **Both**

7. Pre-requisite: NIL

8. Subject Area: **PCC**

9. Objective: The objective of this course is to provide an in-depth understanding of modern antenna concepts, and practical antenna design for various applications.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Fundamental Concepts:** Radiation pattern, near- and far-field regions, reciprocity, directivity and gain, effective aperture, polarization, input impedance, efficiency, Friis transmission equation, radiation integrals and auxiliary potential functions.	6
2.	**Radiation from Wires and Loops:** Infinitesimal dipole, finite-length dipole, linear elements near conductors, dipoles for mobile communication, small circular loop.	6
3.	**Aperture Antennas:** Huygens' principle, radiation from rectangular and circular apertures, design considerations, Babinet's principle, Fourier transform method in aperture antenna theory.	8
4.	**Horn and Reflector Antennas:** Radiation from sectoral and pyramidal horns, design concepts, prime-focus parabolic reflector and cassegrain antennas.	6
5.	**Microstrip Antennas:** Basic characteristics, feeding methods, methods of analysis, design of rectangular and circular patch antennas.	6
6.	**Antenna Arrays:** Analysis of uniformly spaced arrays with uniform and non-uniform excitation amplitudes, extension to planar arrays, synthesis of antenna arrays using Schelkunoff polynomial method, Fourier transform method, and Woodward-Lawson method.	10
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Balanis, C.A., "Antenna Theory and Design", 3rd Ed., John Wiley & Sons.	2005
2.	Jordan, E.C. and Balmain, K.G., "Electromagnetic Waves and Radiating Systems", 2nd Ed., Prentice-Hall of India.	1993
3.	Stutzman, W.L. and Thiele, H.A., "Antenna Theory and Design", 2nd Ed., John Wiley & Sons.	1998
4.	Elliot, R.S., "Antenna Theory and Design", Revised edition, Wiley-IEEE Press.	2003
5.	Garg, R., Bhartia, P., Bahl, I. and Ittipiboon, A., "Microstrip Antenna Design Handbook", Artech House.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN–539** Course Title: **Fiber Optic Systems**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight: **CWS 25 PRS 00 00 MTE 25 ETE 50 PRE 00**

5. Credits: **0 3** 6. Semester √ **Autumn Spring Both**

7. Pre-requisite: NIL

8. Subject Area: **PEC**

9. Objective: To provide the concepts of optical fibres, sources and detectors used in optical communication systems.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Planar Optical Waveguides:** Wave propagation in planar optical waveguides, ray theory, electromagnetic mode theory, phase and group velocity, dispersion.	5
2.	**Optical Fibre Waveguides:** Wave propagation in cylindrical fibres, modes and mode coupling, step and graded index fibres, single-mode fibres.	5
3.	**Transmission Characteristics of Fibres:** Attenuation, material absorption and scattering loss, bend loss, intra-modal and inter-modal dispersion in step and graded fibres, overall dispersion in single and multi-mode fibres.	7
4.	**Optical Fibre Connection:** Optical fiber cables, stability of characteristics, fibre alignment; Fibre splices, connectors, couplers.	4
5.	**Optical Sources:** Absorption and emission of radiation, population inversion and laser oscillation, p-n junction, recombination and diffusion, stimulated emission and lasing, hetero-junctions, single-frequency injection lasers and their characteristics, light emitting diode structures and their characteristics.	6
6.	**Optical Detectors:** Optical detection principles, p-n, p-i-n, and avalanche photodiodes.	3

7.	**Optical Communication System:** System description and design considerations of an optical fibre communication system, noise in detection process, power budgeting, rise time budgeting, maximum transmission distance.	5
8.	**Optical networks:** WDM concepts and principles, basic networks, SONET/SDH, broadcast-and-select WDM networks, wavelength-routed networks, nonlinear effects on network performance, performance of WDM & EDFA systems; Solitons; Optical CDMA.	7
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Senior, J.M., "Optical Fiber Communications", 2nd Ed., Prentice-Hall of India.	1999
2.	Keiser, G., "Optical Fiber Communications," 3rd Ed., McGraw-Hill.	2000
3.	Ghatak, A. and Thyagarajan, K., "Introduction to Fiber Optics", Cambridge University Press.	1999
4.	Cheo, P.K., "Fiber Optics and Optoelectronics", 2nd Ed., Prentice-Hall.	1990
5.	Govar, J., "Optical Communication Systems", 2nd Ed., Prentice-Hall of India.	1996
6.	Snyder, A.W. and Love, J.D., "Optical Waveguide Theory", Chapman & Hall.	1983

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN – 541** Course Title: **Computational Techniques for Microwaves**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **0 3** **Practical** **0 0**

4. Relative Weight: **CWS 25** **PRS 00** **MTE 25** **ETE 50** **PRE 00**
00

5. Credits: **0 4** 6. Semester √
Autumn **Spring** **Both**

7. Pre-requisite: NIL

8. Subject Area: **PEC**

9. Objective: The objective of this course is to introduce the students to advanced computational techniques for the solution of partial differential equations and integral equations encountered in electromagnetic boundary value problems.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Fundamental Concepts:** Review of Maxwell's equations and boundary conditions, integral equations versus differential equations, radiation and edge conditions, modal representation of fields in bounded and unbounded media.	6
2.	**Green's Functions:** Green's function technique for the solution of partial differential equations, classification of Green's functions, various methods for the determination of Green's functions including Fourier transform technique and Ohm-Rayleigh technique, dyadic Green's functions, determination of Green's functions for free space, transmission lines, waveguides, and microstrips.	12
3.	**Integral Equations:** Formulation of typical problems in terms of integral equations: wire antennas, scattering, apertures in conducting screens and waveguides, discontinuities in waveguides and microstriplines; Solution of Integral equations: General Method of Moments (MoM) for the solution of integro-differential equations, choice of expansion and weighting functions, application of MoM to typical electromagnetic problems.	12
4.	**Finite Element Method:** Typical finite elements, Solution of two-dimensional Laplace and Poisson's equations, solution of scalar Helmholtz equation.	6
5.	**Finite-difference Time-domain Method:** Finite differences, finite difference	6

	representation of Maxwell's equations and wave equation, numerical dispersion, Yee's finite difference algorithm, stability conditions, programming aspects, absorbing boundary conditions.	
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Collin, R.E., "Field Theory of Guided Waves", 2^{nd} Ed., Wiley-IEEE Press.	1991
2.	Peterson, A.F, Ray, S.L. and Mittra, R., "Computational Methods for Electromagnetics", Wiley-IEEE Press.	1998
3.	Harrington, R.F., "Field Computation by Moment Methods", Wiley-IEEE Press.	1993
4.	Sadiku, M.N.O., "Numerical Techniques in Electromagnetics", 2^{nd} Ed., CRC Press.	2001
5.	Stutzman, W.L. and Thiele, H.A., "Antenna Theory and Design", 2^{nd} Ed., John Wiley & Sons.	1998
6.	Volakis, J.L., Chatterjee, A. and Kempel, L.C., "Finite Method for Electromagnetics", Wiley-IEEE Press.	1998
7.	Taflov, A. and Hagness, S.C., "Computational Electrodynamics", 3^{rd} Ed., Artech House.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN-542** Course Title: **Microwave Integrated Circuits**

2. Contact Hours: **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight**:** **CWS 25 PRS 00 00 MTE 25 ETE 50 PRE 00**

5. Credits**:** **0 4** 6. Semester **Autumn** **Spring** √ **Both**

7. Pre-requisite**:** NIL

8. Subject Area**: PEC**

9. Objective: To introduce the students to the advanced topics of Microwave Integrated Circuits in Microstrip Technology.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Planar Transmission Lines and Lumped Elements for MICs:** Fundamentals of the theory of transmission lines, Foundations of Microstrip lines, Striplines, Higher modes in microstrips and striplines, Slotlines, Coplanar waveguides, Coplanar strips; Launching Techniques: Coaxial line to microstrip transition, Rectangular waveguide to microstrip transition, microstrip to slot-line transition, microstrip to coplanar waveguide (CPW) transition; Lumped Components: Capacitors, Inductors and Resistors.	10
2.	**Discontinuities and Bends:** Introduction, open-circuit end correction, corners, symmetrical step, T-junction, series gaps, Bends	5
3.	**Microwave Planar Filters:** Periodic structures, Filter design by the Image Parameter method, Filter design by the Insertion Loss method, Filter transformations, Filter implementation, Stepped-Impedance Low-Pass filters, Coupled line filters, Filters using coupled resonators.	10
4.	**4-Port Network Design:** Introduction; Even-and odd-mode analysis; Branch-line couple, Branch-line coupler with improved coupling performance, Branch-line coupler with multiple sections; Introduction to Hybrid-ring couplers, qualitative description and complete analysis of hybrid-ring couplers, Hybrid-ring couplers with modified ring impedances; Introduction to parallel-coupled lines and directional couplers; Even- and odd-analysis of parallel-coupled lines; Coupled-line parameters; Multiple-	7

	section directional couplers; The Lange Coupler	
5.	**Nonlinear RF Circuits:** Introduction; Power Gain Relations; Simultaneous conjugate Matching; Stability Considerations; Power gain for matched, unmatched, unilateral conditions; Noise characterization and design options; Switches: Pin Diode switches, FET switches, MEMS switches; Variable attenuators, Phase shifters, Detectors and Mixers; Amplifiers: Small signal amplifiers, Low noise amplifiers, Power amplifiers; Oscillators.	10
	Total	**42**

11. Suggested Books:

Sl. No.	**Name of Books / Authors**	**Year of Publication**
1.	Fooks, E.H. and Zakarevicius, R.A., “Microwave Engineering Using Microstrip Circuits,” Prentice-Hall.	1990
2.	Franco di Paolo, “Networks and Devices using Planar Transmission Lines,” CRC Press.	2000
3.	Pozar, D.M., “Microwave Engineering”, 3rd Ed., John Wiley & Sons.	2004
4.	Roberto Sorrentino and Giovanni Bianchi, “Mirowave and RF Engineering” John Wiley & Sons.	2010
5.	Ludwig, R. and Bretchko, P., “RF Circuit Design”, Pearson Education.	2000
6.	Misra, D.K., “Radio-frequency and Microwave Communication Circuits”, John Wiley & Sons.	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: ECN-543 Course Title: **High Power mm/THz Wave Engineering**

2. Contact Hours: **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight: **CWS 25 PRS 00 00 MTE 25 ETE 50 PRE 00**

5. Credits: **0 4** 6. Semester **Autumn** √ **Spring** **Both**

7. Pre-requisite: NIL

8. Subject Area: **PEC**

9. Objective: To introduce the students to the basic principles and design aspects of gyrotrons

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Review of Gyro-Devices and Principle of Gyrotron:** Introduction, Classification of Fast Wave Microwave Sources, Gyrotron Oscillator and Gyroklystron Amplifier, Cyclotron Autoresonance Maser (CARM), Gyro-TWT (Travelling Wave Tube) and Gyrotwystron Amplifier, Gyro-BWO (Backward Wave Oscillator), Overview of Gyro-Devices, Magnicons and Gyroharmonic Converters, Free Electron Lasers, Basic Principle of Gyrotrons, Eigenmodes of Tapered, Open Resonator Cavities, Physical Model for the High Frequency Fields in a Resonator, Coaxial Cavity Structures, Complex Cavities	8
2.	**Calculation of RF Behaviour and Practical Considerations:** Equation of Motion, Self-Consistent Calculations, Dimensionless Variables, Mode Competition in Gyrotron Oscillators, Energy Transfer to a Single Mode, Mode Suppression, Startup, Time Dependent Formulation, Current Neutralization, Mode Competition with Different Harmonics, Wall Losses , Voltage Depression and Limiting Current, Choice of Beam Radius, Fresnel Parameter, Starting Current, Rieke Diagrams for Gyrotrons	10
3.	**Electron Optical and Guiding System:** Introduction, Magnetron Injection Gun-General Remarks Preliminary Design, Codes for the Design of MIGs, Design Procedure of MIGs, Beam Guidance, Beam Dump-Collecting System-General Remarks, Theory of Depressed Collectors, Magnetic Decompression, Design of Depressed Collectors for Gyrotrons, Some	8

	General Remarks	
4.	**Output Taper, Quasi-optical Launcher and RF Window:** Output Taper, Methods of Taper Analysis and Synthesis, Quasi-optical Mode Converter, Basic Principle of Quasi-optical Mode Converters, Improved Quasi-optical Mode Converters, Remarks about RF Window, Practical Aspects of High Power Windows, Theory of Disc Type Windows, Broadband Output Windows, Diamond Windows for Gyrotrons, Concluding Remarks.	8
5.	**Applications and Examples:** Introduction, ECRH Applications, ECR Discharges for Generation of Multiply Charged Ions and Soft X-Rays, High Frequency Broadband ESR Spectroscopy, Processing of Advanced Ceramics, Experimental Setup, Experimental Results, Millimeter-Wavelength Radar, Active Millimeter Wave Meteorology-Cloud Radar, Space Debris Monitoring Radar, High Power Nanosecond Radar, RF-Drivers for TeV Linear Colliders, A Very High-Power 140 GHz Conventional Gyrotron, A 165 GHz Coaxial Gyrotron, Multifrequency Gyrotron, Second Harmonic Gyrotrons, Concluding Remarks	8
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Kartikeyan, Borie & Thumm. "Gyrotrons: High Power Micorwave and Millimeter Wave Technology", Springer.	2004
2.	Gregory S. Nusinovich "Introduction to the Physics of Gyrotrons", John Hopkins University Press.	2004
3.	A. S. Gilmour, Jr. "Klystrons, Traveling Wave Tubes, Magnetrons, Crossed-Field Amplifiers, and Gyrotrons", Artech House.	2011

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE **:** **Dept. of Electronics and Communication Engg.**

1. Subject Code: **ECN - 544** **Course Title**: **Advanced Radar Engineering**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** | 0 | 3 | **Practical** | 0 | 0 |

4. Relative Weightage**:** **CWS** 25 **PRS** 00 **MTE** 25 **ETE** 50 **PRE** 00

5. Credits**:** | 0 | 4 | 6. Semester ✓ **Autumn** **Spring** - **Both**

7. Pre-requisite**: NIL** 8. Subject Area**: PEC**

9. Objective: The objective of this course is to introduce different type of radar systems for military and civilian applications to the students.

10. Details of Course:

Sl. No.	Particulars	Contact Hours
1.	Basic radar definitions; radar equation; receiver noise; probability of detection and signal-to-noise ratio; receiver bandwidth; target cross-section and cross-section fluctuations with statistical description of RCS; antenna coverage and gain; system losses,	6
2	**Signal Models for Radar**: Amplitude models, range equation and its distributed target forms, Clutter: signal to clutter ratio, temporal and spatial correlation of clutter, compound models for RCS; Noise model and signal to noise ratio; spatial model: variation with angle, variation with range, projections, multipath, spectral models.	7
3.	**Types of Radar:** CW, FMCW and multiple-frequency CW radars; **MTI:** delay line cancelers; transversal filters; low, medium, and high-prf radars; staggered prf; multiple prf ranging; digital MTI; doppler filter bank and its generation; Reflection of radar waves; **Tracking radars**: conical scan radar; error signal of conical-scan radar; monopulse radars; error signal of amplitude comparison monopulse	12
4.	**FUNDAMENTALS for DETECTION**: Radar detection as hypothesis Testing: Neyman-Pearson detection rule, likelihood ratio test; threshold detection of radar signals: non-coherent integration of nonfluctuating targets, Albersheim and Shnidaman equations; Binary integration.	6
5.	**Phased array and Imaging radar-** Phase array working and feed systems; Introduction to Beamforming: conventional beamforming, adaptive beamforming; Synthetic aperture radars(SAR) and pulse compression techniques; SAR	11

	Fundamentals: cross range resolution in Radar, synthetic aperture viewpoint, Stripmap SAR Data Characteristics: Stripmap SAR Geometry, Stripmap SAR data set; Strippmap SAR Image formation Algorithm, Introduction of Plolarimetric and Interferometric SAR and its principle, Remote sensing applications of radars	
	Total	42

11. Suggested Books:

S.No.	Name of Books / Authors	Year of Publication
1.	Skolnik, M.I., "Introduction to radar systems", 2nd edition, McGraw Hill	1997
2.	Hovanessian, S.A., "Radar system design and analysis", Artech House	1984
3.	Levanon, N., "Radar principles", John Wiley & Sons	1988
4.	Richards, M. A., “Fundamental of Radar Signal Processing” Tata McGrawhill	2005
5.	Sullivan, R. J., “ Radar Foundations for Imaging and Advanced Concepts” PHI	2004
6.	Harold Mott, “Remote Sensing with Polarimetric Radar” IEEE Press	2007
7.	Nathanson, F E, “ Radar Design Principles” Scitech Publishing,	2002
8.	Meikle Hamish “Modern Radar System” Artech House	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Computer Engineering**

1. Subject Code: **ECN–548** Course Title: **RF and Microwave MEMS**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight: **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**
00

5. Credits: **0 3** 6. Semester **Autumn** **Spring** √ **Both**

7. Pre-requisite: NIL

8. Subject Area: **PEC**

9. Objective: To introduce the students to the new area of Microelectromechanical Systems (MEMS) and their applications in RF and wireless engineering.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction:** RF MEMS for microwave applications, MEMS technology and fabrication, mechanical modeling of MEMS devices, MEMS materials and fabrication techniques.	6
2.	**MEMS Switches:** Introduction to MEMS switches; Capacitive shunt and series switches: Physical description, circuit model and electromagnetic modeling; Techniques of MEMS switch fabrication and packaging; Design of MEMS switches.	12
3.	**Inductors and Capacitors:** Micromachined passive elements; Micromachined inductors: Effect of inductor layout, reduction of stray capacitance of planar inductors, folded inductors, variable inductors and polymer-based inductors; MEMS Capacitors: Gap-tuning and area-tuning capacitors, dielectric tunable capacitors.	9
4.	**RF Filters and Phase Shifters:** Modeling of mechanical filters, micromachined filters, surface acoustic wave filters, micromachined filters for millimeter wave frequencies; Various types of MEMS phase shifters; Ferroelectric phase shifters.	6
5.	**Transmission Lines and Antennas:** Micromachined transmission lines, losses in transmission lines, coplanar transmission lines, micromachined waveguide components; Micromachined antennas: Micromachining techniques to improve antenna performance, reconfigurable antennas.	6

6.	**Integration and Packaging:** Role of MEMS packages, types of MEMS packages, module packaging, packaging materials and reliability issues.	3
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Varadan, V.K., Vinoy, K.J. and Jose, K.J., "RF MEMS and their Applications", John Wiley & Sons.	2002
2.	Rebeiz, G.M., "MEMS: Theory Design and Technology", John Wiley & Sons.	1999
3.	De Los Santos, H.J, "RF MEMS Circuit Design for Wireless Communications", Artech House.	1999
4.	Trimmer, W., "Micromechanics & MEMS", IEEE Press.	1996
5.	Madou, M., "Fundamentals of Microfabrication", CRC Press.	1997
6.	Sze, S.M., "Semiconductor Sensors", John Wiley & Sons.	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN–549** Course Title: **RF CMOS Transceiver Design**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight**:** **CWS 25 PRS 00 00 MTE 25 ETE 50 PRE 00**

5. Credits**:** **0 3** 6. Semester √ **Autumn** **Spring** **Both**

7. Pre-requisite**:** NIL

8. Subject Area**: PEC**

9. Objective: To introduce the students about the various concepts and components of RF CMOS transceiver structure.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**A review of MOS device physics:** Introduction, FETs-short history, MOSFET physics-long channel approximations	2
2.	**Characteristics of passive components:** Introduction, Inter connects at RF frequencies-skin effects, Resistors, Capacitors, Inductors, Transformers, Interconnects at High Frequencies	4
3.	**Oscillators and Synthesizers:** Introduction, The problem with purely linear Oscillators, Resonators, A catalogue of tuned oscillators, Negative resistance oscillators, Frequency synthesizers	6
4.	**Noise**: Introduction, Thermal noise, Shot noise, Flicker noise, Popcorn noise, Classical two-port noise theory, examples of noise calculation **Phase noise**: Introduction, General considerations, Role of linearity and time variation in phase noise, Circuit examples, Amplitude response	6
5.	**Phase-locked Loops:** Introduction, History of PLLs, Linearized PLL models, Noise properties of PLLs, Phase detectors, sequential phase detectors, Loop filters and charge pumps, PLL design examples	6
6.	**RF power amplifiers:** Introduction, class A, AB, B, and C power amplifiers, class D amplifiers, class E amplifiers, Class F amplifiers, summery of PA characteristics, RF PA design examples	8
7.	**LNA design**: Introduction, LNA topologies- power match vs. noise match, Power constrained noise optimization, Design examples, Linearity and	6

	large-signal performance, Spurious free dynamic range	
8.	**Mixers**: Introductions, Mixer fundamentals, Nonlinear systems as linear mixers, Multiplier-based mixers, Sub sampling mixers	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Robert Caverly, “CMOS RFIC Design Principles”, ARTECH HOUSE, INC.	2007
2.	Xiaopeng Li, Ismail, Mohammed, “Multi-standard CMOS wireless receivers Analysis and design” The Springer International Series in Engineering and Computer Science, Vol. 675.	2002
3.	Thomas H. Lee, “The Design of CMOS Radio-Frequency Integrated Circuits” Cambridge Univ. Press	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN – 550** Course Title: **Radar Signal Processing**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** | 0 | 3 | **Practical** | 0 | 0 |

4. Relative Weight: **CWS** | 15 | **PRS** | 00 | **MTE** | 35 | **ETE** | 50 | **PRE** | 00 |

5. Credits: | 0 | 3 | 6. Semester | | **Autumn** | √ **Spring** | | **Both**

7. Pre-requisite**: NIL**

8. Subject Area**: PEC**

9. Objective: To introduce the students to the concepts of radar signal processing.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	Introduction to radar systems, History and applications of radar, Basic radar function, Radar classifications, elements of pulsed radar, The radar equation, A preview of basic radar signal processing.	6
2.	Signal models, Components of a radar signal, Amplitude models, Clutter, Noise model and signal-to-noise ratio, Jamming, Frequency models: the Doppler shift, spatial models.	6
3.	Sampling and quantization of pulsed radar signals, Domains and criteria for sampling radar signals, Sampling in the fast time dimension, Sampling in slow time: selecting the pulse repetition interval, Sampling the Doppler spectrum,	7
4.	Radar waveforms, Introduction, The waveform matched filter, Matched filtering of moving targets, The radar ambiguity function, The pulse burst waveform, frequency-modulated pulse compression waveforms, The stepped frequency waveform, Phase-modulated pulse compression waveforms, Costas frequency codes.	8
5.	Doppler processing, Alternate forms of the Doppler spectrum, Moving target indication (MTI), Pulse Doppler processing, Dwell-to-dwell stagger, Additional Doppler processing issues, Clutter mapping and the moving target detector,	7

6	Detection of radar signals in noise: detection fundamentals, detection criteria, Threshold detection in coherent systems, Threshold detection of radar signals, binary integration, CFAR detection, CA CFAR, Additional CFAR topics	8
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Fundamentals of Radar Signal Processing, Mark A. Richards	2005
2.	Adaptive Radar Signal Processing, Simon Haykin	2006
3.	Skolnik, M.I., "Introduction to Radar Systems", 2nd Ed., McGraw-Hill.	1997

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN – 551** Course Title: **Adaptive Beam Forming and Smart Antennas**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** 0 3 **Practical** 0 0

4. Relative Weight: **CWS** 15 **PRS** 00 **MTE** 35 **ETE** 50 **PRE** 00

5. Credits: 0 3 6. Semester **Autumn** [ ] **Spring** [√] **Both** [ ]

7. Pre-requisite**: NIL**

8. Subject Area**: PEC**

9. Objective: To introduce the students to the theory of smart antennas and adaptive beam forming techniques.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	Introduction, What is a Smart Antenna, Fundamentals of Electromagnetic Fields, Maxwell's Equations, Helmholtz Wave Equation, Propagation in Spherical Coordinates, Boundary Conditions, Plane wave Reflection and Transmission Coefficients, Propagation Over Flat Earth, Knife-Edge Diffraction.	10
2.	**Antenna Fundamentals**, Antenna Field Regions, Power Density, Radiation Intensity, Basic Antenna Nomenclature, Antenna pattern, Antenna bore sight, Principal plane patterns, Beam width, Directivity, Beam solid angle, Gain, Effective aperture, Friis Transmission Formula, Magnetic Vector Potential and the Far Field, Linear Antennas, Infinitesimal dipole, Finite length dipole, Loop Antennas, Loop of constant phasor current, **Array Fundamentals,** Linear Arrays, Two element array, Uniform N-element linear array, Uniform N-element linear array directivity, Array Weighting, Beam steered and weighted arrays, Circular Arrays, Beam steered circular arrays, Rectangular Planar Arrays, Fixed Beam Arrays, Butler matrices, Fixed Side lobe Canceling, Retro-directive Arrays, Passive retro-directive array, Active retro-directive array.	10
3.	**Principles of Random Variables and Processes,** Definition of Random Variables, Probability Density Functions, Expectation and Moments, Common Probability Density Functions, Gaussian density, Rayleigh	

	density, Uniform density, Exponential density, Rician density, Laplace density, Stationarity and Ergodicity, Autocorrelation and Power Spectral Density, Correlation Matrix, **Propagation Channel Characteristics,** Flat Earth Model, Multipath Propagation Mechanisms, Propagation Channel Basics, Fading, Fast fading modeling, Channel impulse response, Power delay profile, Prediction of power delay profiles, Power angular profile, Prediction of angular spread, Power delay-angular profile, Channel dispersion, Slow fading modeling, Improving Signal Quality, Equalization, Diversity, Channel coding, MIMO.	10
4.	Angle-of-Arrival Estimation, Vector basics, Matrix basics, Array Correlation Matrix, AOA Estimation Methods, Bartlett AOA estimate, Capon AOA estimate, Linear prediction AOA estimate, Maximum entropy AOA estimate, Pisarenko harmonic decomposition AOA estimate, Min-norm AOA estimate, MUSIC AOA estimate, Root-MUSIC AOA estimate, ESPRIT AOA estimate, Smart Antennas, Introduction, The Historical Development of Smart Antennas, Fixed Weight Beam forming Basics, Maximum signal-to-interference ratio, Maximum likelihood, Minimum variance, Adaptive Beam forming, Least mean squares, Recursive least squares, Constant modulus, Least squares constant modulus, Conjugate gradient method,	12
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Smart Antennas, T. K. Sarkar, Michael C. Wicks, M. Salazar-Palma, Robert J. Bonneau, John Wiley & Sons, 2005	
2.	Introduction to Smart Antennas, Constantine A. Balanis, Panayiotis I. Ioannides, Morgan & Claypool Publishers, 2007	2005
3.	Smart antennas for Wireless communications by Frank Gross & Various Research Papers	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN- 552** Course Title: **Soft Computing Techniques for RF Engineering**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **0 3** **Practical** **0 0**

4. Relative Weight: **CWS 25** **PRS 00 00** **MTE 25** **ETE 50** **PRE 00**

5. Credits: **0 3** 6. Semester √ **Autumn** **Spring** **Both**

7. Pre-requisite: NIL

8. Subject Area: **PEC**

9. Objective: To introduce the students to the basic techniques for soft computing.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Fuzzy Logic:** Crisp set and Fuzzy set, Basic concepts of fuzzy sets, membership functions. Basic operations on fuzzy sets, Properties of fuzzy sets, Fuzzy relations; Propositional logic and Predicate logic, fuzzy If – Then rules, fuzzy mapping rules and fuzzy implication functions, Applications.	12
2.	**Neural Networks:** Basic concepts of neural networks, Neural network architectures, Learning methods, Architecture of a back propagation network, Applications	10
3.	**Genetic Algorithms:** Basic concepts of genetic algorithms, encoding, genetic modeling	10
4.	**Hybrid Systems:** Integration of neural networks, fuzzy logic and genetic algorithms.	10
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	S. Rajasekaran and G.A.Vijaylakshmi Pai.. Neural Networks Fuzzy Logic, and Genetic Algorithms, Prentice Hall of India.	2003
2.	K.H.Lee.. First Course on Fuzzy Theory and Applications, Springer-Verlag.	2005
3.	J. Yen and R. Langari.. Fuzzy Logic, Intelligence, Control and Information, Pearson Education	2007

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN–554** Course Title: **Microwave and Millimeter Wave Circuits**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weightage: **CWS 25 PRS 00 00 MTE 25 ETE 50 PRE 00**

5. Credits: **0 3** 6. Semester **Autumn** **Spring** √ **Both**

7. Pre-requisite: NIL

8. Subject Area: **PEC**

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:

Sl. 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:

Sl. No.	Name of Books / Authors	Year of Publication
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 DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN–555** Course Title: **Microwave Imaging**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight: **CWS 25 PRS 00 00 MTE 25 ETE 50 PRE 00**

5. Credits: **0 3** 6. Semester **Autumn Spring √ Both**

7. Pre-requisite: NIL

8. Subject Area: **PEC**

9. Objective: To built up a concept for understanding the principle of microwave imaging and its applications

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Electromagnetic Scattering:** Maxwell's equation, interface conditions, constitutive equations, Wave Equations and Their Solutions, Volume Scattering by Dielectric Targets, Volume Equivalence Principle, Integral Equations, Surface Scattering by Perfectly Electric Conducting Targets.	8
2.	**Electromagnetic Inverse Scattering Problem:** Two-Dimensional Inverse Scattering, Discretization of the Continuous Model, Scattering by Canonical Objects: The Case of Multilayer Elliptic Cylinders	6
3.	**Imaging Configurations and Model Approximations:** Objectives of the Reconstruction, Multiillumination Approaches, Tomographic Configurations, Scanning Configurations, Configurations for Buried-Object Detection, Born-Type Approximations, Extended Born Approximation, Rytov Approximation, Kirchhoff Approximation.	8
4.	**Qualitative Reconstruction Methods:** Generalized Solution of Linear Ill-Posed Problems, Regularization Methods, Singular Value Decomposition,	8

	Regularized Solution of a Linear System Using Singular Value Decomposition, Qualitative Methods for Object Localization and Shaping, Synthetic Focusing Techniques, Qualitative Methods for Imaging Based on Approximations.	
5.	**Imaging Techniques:** Back projection, w-k, beamforming, synthetic aperture imaging, Kirchoff"s method	6
6.	**Microwave Imaging Apparatuses, Systems and Applications:** Scanning Systems for Microwave Tomography, Antennas for Microwave Imaging, Civil and Industrial Applications, Medical Applications of Microwave Imaging, Shallow Subsurface Imaging.	6
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Matteo Pastorino, “Microwave Imaging”, Wiley & Sons	2010
2.	V. C. Chen and H. Ling, “Time-Frequency Transforms for Radar Imaging and Signal Analysis”, Artech House	2002
3.	Bernard D. Steinberg, “Microwave Imaging Techniques”, Wiley & Sons	1991
4.	Taylor, D.J., “Introduction to Ultra-wideband Radar Systems”, CRC Press.	1995
5.	D. R. Wehner, “High-Resolution Radar”, 2nd Ed.,, Artech House	1994

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1.Subject Code**: ECN–571** Course Title**: SEMICONDUCTOR DEVICE MODELING**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 00**

4. Relative Weight**: CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 3** 6. Semester √ **Autumn Spring Both**

7. Pre-requisite**: EC –142 and UG – Engineering Mathematics**

8. Subject Area: **PCC and DEC**

9. Objective: The course will provide adequate understanding ofsemiconductor device modeling aspects, useful for designing devices in electronic, and optoelectronic applications

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction to Numerical Modeling:**Fundamental semiconductor equations, Finite difference scheme, Error analysis, Solution of a system of Linear Equations, Direct Method:LU-decomposition, Tri-diagonal system, Relaxation Method,Numerical solution of Non-Linear Equations: Newton-Raphson method, Finite difference discretization example: Current continuity and energy relations, Introduction to circuit simulations	12
2.	**Modeling of LASER diode:** Rate equations, Numerical schemes: Small signal modeling, and Large signal modeling, Equivalent circuits	7
3.	**MESFET Modeling:** Bridging betweentime and frequency domains:Harmonic Balance Method, MESFET small signal and large signal equivalent circuit, numerical device simulation and parameter extraction	9
4.	**Quantum Physics Aspects of Device Modeling:** Effective mass Schrödinger equation, Matrix representation, Dirac notation, WKB Approximation, Time dependent and independent perturbation theories, Fermi’s golden rule, semi-classical transport in semiconductors: Boltzmann transport equation, numerical scheme, Introduction to Monte Carlo simulations	8

5.	**Introduction to Quantum Effect Device Modeling:** Double barrier resonant tunneling diode, Device modeling through transfer matrix approach, Numerical estimation of diode current density, coupled Poisson-Schrödinger scheme for electron transmission simulations	6
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/ Authors	Year of Publication
1.	Selberherr, S., Analysis and Simulation of Semiconductor Devices, Springer-Verlag	1984
2.	Arora, N., MOSFET Models for VLSI Circuit Simulation, Springer-Verlag	1993
3.	C.M. Snowden, and, E. Snowden, Introduction to Semiconductor Device Modeling, World-Scientific	1998
4.	W.J. McCalla,Fundamentals of Computer-Aided Circuit Simulation, Kluwer Academic	1987
5.	Leonard I. Schiff, Quantum Mechanics, Third Edn.,Tata Mc-Graw-Hill	2010
5.	Research papers in specific area	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1.Subject Code**: ECN–572** Course Title**: MOS DEVICE PHYSICS**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 00**

4. Relative Weight**: CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 3** 6. Semester √ **Autumn Spring Both**

7. Pre-requisite**: EC - 142**

8. Subject Area**: PCC and DEC**

9. Objective: The course will provide detail understanding of Metal-Oxide-Semiconductor (MOS) Capacitor and allied field effect devices, required for designing VLSI&ULSI CMOS circuits

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**MOS Capacitor:** Energy band diagram of Metal-Oxide-Semiconductor contacts, Mode of Operations: Accumulation, Depletion, Midgap, and Inversion, 1D Electrostatics of MOS, Depletion Approximation, Accurate Solution of Poisson's Equation, CV characteristics of MOS, LFCV and HFCV, Non-idealities in MOS, oxide fixed charges, interfacial charges, Midgap gate Electrode, Poly-Silicon contact, Electrostatics ofnon-uniform substrate doping, ultrathin gate-oxide and inversion layer quantization, quantum capacitance, MOS parameter extraction	10
2.	**Physics of MOSFET:**Drift-Diffusion Approach for IV, Gradual Channel Approximation, Sub-threshold current and slope, Body effect, Pao&Sah Model, Detail 2D effects in MOSFET, High field and doping dependent mobility models, High field effects and MOSFET reliability issues (SILC, TDDB, & NBTI), Leakage mechanisms in thin gate oxide, High-K-Metal Gate MOSFET devices and technology issues, Intrinsic MOSFET capacitances and resistances, Meyer model	15

3.	**SOI MOSFET:**FDSOI and PDSOI, 1D Electrostatics of FDSOI MOS, V_T definitions, Back gate coupling and body effect parameter, IV characteristics of FDSOI-FET, FDSOI-sub-threshold slope,Floating body effect, single transistor latch, ZRAM device, Bulk and SOI FET: discussions referring to the ITRS	7
4.	**Nanoscale Transistors:**Diffusive, Quasi Ballistic & Ballistic Transports, Ballistic planer and nanowire-FET modeling: semi-classical and quantum treatments	6
5.	**Advanced MOSFETs:**Strain Engineered Channel materials, Mobility in strained materials, Electrostatics of double gate, and Fin-FET devices	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/ Authors	Year of Publication
1.	S.M. Sze & Kwok K. Ng, Physics of Semiconductor Devices, Wiley	2007
2.	Yuan Taur&Tak H. Ning, Fundamentals of Modern VLSI Devices, Cambridge	1998
3.	Mark Lundstrom& Jing Guo, Nanoscale Transistors: Device Physics, Modeling & Simulation, Springer	2005
4.	YannisTsividis, Operation and Modeling of the MOS Transistor, Oxford University Press	2^{nd}Edn.
5.	J.P. Colinge, Silicon-on-Insulator Technology: Materials to VLSI, Springer	1997
6.	Research papers in specific area	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1. Subject Code**: ECN–573** Course Title**: Digital VLSI Circuit Design**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight**: CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 3** 6. Semester **√ Autumn Spring Both**

7. Pre-requisite**: EC – 142, EC -104, EC - 201**

8. Subject Area**: PCC and DEC**

9. Objective: To acquaint the students with the fundamental concepts of digital VLSI circuit design

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Review of MOSFET operation and CMOS process flow**: MOS Threshold voltage, MOSFET I-V characteristics: Long and short channel, MOSFET capacitances, lumped and distributed RC model for interconnects, transmission lines, CMOS process flow, Layout and design rules.	6
2.	**CMOS inverter**: Static characteristics, power consumption, dynamic behavior, buffer design using the method of logical effort.	6
3.	**Combinational logic**: Transistor sizing in static CMOS logic gates, static CMOS logic gate sizing considering method of logical effort, dynamic logic, pass-transistor logic, common mode and other cross-coupled logic families.	6
4.	**Sequential logic**: Static latches and flip-flops (FFs), dynamic latches and FFs, sense-amplifier based FFs, NORA-CMOS, Schmitt trigger, monostable and astable circuits.	8
5.	**Memories and array structures**: MOS-ROM, SRAM cell, memory peripheral circuits, signal to noise ratio, power dissipation,	6
6.	**Course Project**: SPICE based project on a digital VLSI sub-system design	2
6.	**Timing issues**: Timing fundamentals, clock distribution, jitter, self-timed circuit design, synchronizers and arbiters, basic building blocks of PLLs, clock	8

	synthesis and synchronization using PLLs.	
	Total	**42**

11. Suggested Books:

Sl. No.	**Name of Books/ Authors**	**Year of Publication**
1.	Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, “Digital Integrated Circuits: A Design Perspective,” Prentics Hall	2003
2.	Sung-Mo Kang, Yusuf Liblebici, “CMOS Digital Integrated Circuits,” Tata Mc Graw Hill	2003
3.	R. Jacob Baker, “CMOS Mixed-Signal Circuit Design,” Wiley India Pvt. Ltd.	2009
4.	Ivan Sutherland, R. Sproull and D. Harris, “Logical Effort: Designing Fast CMOS Circuits”, Morgan Kaufmann	1999

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT/CENTRE: **Dept. of Electronics and Communication Engineering**

1. Subject Code: **ECN-574** Course Title: **Semiconductor Materials, Devices & Characterization**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 3 Practical 0**

4. Relative Weight: **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **3** 6. Semester: **Autumn** 7. Subject Area: **PCC and DEC**

8. Pre-requisite: **Nil**

9. Objective: To provide a thorough knowledge of semiconductor materials, devices and their characterization.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Semiconductor properties:** Crystal structure, intrinsic and doped crystals, excess carriers and current transport.	4
2.	**Band structure of semiconductors:** Band structure, carrier energy and Fermi distributions for free carriers, donor and acceptor impurities, determination of band gap, impurity ionization, and critical temperatures for intrinsic ionization and onset of impurity deionization.	6
3.	**Inhomogeneous impurity distribution:** Impurity diffusion processes and profile derivations, built-in electric field and carrier profiles.	4
4.	**Junction diode:** p-n junction, tunnel diode, quasi Fermi levels, depletion width capacitance and its application in doping profile determination, I-V characteristics of narrow and wide base diodes and their equivalent circuits, breakdown mechanisms, small signal ac impedance.	6
5.	**Bipolar transistor fundamentals:** Formation of transistor, current gains, dc and low frequency characteristics, base resistance and power gain, drift and graded base transistors.	6
6	**Surface field effect transistors:** Surface states, measurement of surface charge, Q-V/I-V characteristics and equivalent circuit models of MOS capacitor and MOSFET.	6
7	**Metal-semiconductor junctions:** Rectifying and ohmic contacts, role of surface states, application in energy level characterization; Comparison of p-n junction and Schottky diodes.	6

8	**Pressure effects:** Dependence of energy bandgap on pressure, evaluation of energy pressure coefficients, direct-indirect conversion and identification of defect levels.	4
	Total	42

11. Suggested Books:

Sl. No.	**Name of Authors / Books / Publishers**	**Year of Publication /Reprint**
1.	Rabaey, J.M., Chandrakasan, A. and Nikolic B., “Digital Integrated Circuits: A Design Perspective”, 2nd Ed., Prentice-Hall of India.	2006
2.	Kang, S. and Leblebici, Y., “CMOS Digital Integrated Circuits: Analysis and Design”, Tata McGraw-Hill.	2003
3.	Pucknell, D.A. and Eshraghian, K., “Basic VLSI Design”, 3rd Ed., Prentice-Hall of India.	1994
4.	Eshraghian, K., Pucknell, D.A. and Eshraghian, S., “Essentials of VLSI Circuit and System”, 2nd Ed., Prentice-Hall of India.	2005
5	Hodges, D.A., Jackson, H.G. and Saleh, R.A., “Analysis and Design of Digital Integrated Circuits in Deep Submicron Technology”, 3rd Ed., Tata McGraw-Hill.	2005
6	Uyemera, P.J., “Introduction to VLSI Circuits and Systems”, 4th Ed., John Wiley & Sons.	2003

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT/CENTRE: **Dept. of Electronics and Communication Engineering**

1. Subject Code: **ECN–575** Course Title: **Microelectronics Lab -1**

2. Contact Hours: **L: 0** **T: 0** **P: 3**

3. Examination Duration (Hrs.): **Theory 0** **Practical 03**

4. Relative Weight: **CWS 0** **PRS 100** **MTE 0** **ETE 0** **PRE 0**

5. Credits: **2** 6. Semester: **Autumn** 7. Subject Area: **PCC**

8. Pre-requisite: **EC - 142**

9. Objective: To provide knowledge of characterization of devices and fabrication techniques.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
	Study of Hall effect in semiconductors. (1) Four probe method for resistivity and bandgap measurement of semiconductors. (1) Study of Magneto resistance in semiconductors. (1) I-V characteristics of devices with variation in temperature.(1) C-V characteristics of p-n junction and MOS capacitor.(1) Device characteristics of LED, lasers and solar cells. (3) Study of working of diffusion furnace. (1) Fabrication and characterization of Schottky diodes. (1) Deposition of thin films using physical vapor deposition (vacuum evaporator) and spin coating techniques. (1) MOSFET process/device simulation and parameter extraction. (1)	14x3
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors / Books / Publishers	Year of Publication/Reprint
1.	Lindmayer, J. and Wrigley, C. Y., “Fundamentals of Semiconductor Devices”, D.Van Nostrand Co.	2004
2.	Streetman, B.G. and Banerjee, S., “Solid State Electronic Devices”, 6^{th} Ed., Prentice Hall of India.	2008
3.	Tyagi, M.S., “Introduction to Semiconductor Materials and Devices”, John Wiley & Sons.	1991

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN–576** Course Title: **Simulation Laboratory 1**

2. Contact Hours: **L: 0 T: 0 P: 3**

3. Examination Duration (Hrs.): **Theory 0 0 Practical 0 3**

4. Relative Weight: **CWS 00 PRS 100 MTE 00 ETE 00 PRE 00**

5. Credits: **0 2** 6. Semester √ **Autumn Spring Both**

7. Pre-requisite: **EC – 142, EC -104, EC - 201**

8. Subject Area: **PCC**

9. Objective: To provide hands-on experience on the behavioral and structural modeling in a Hardware Description Language (HDL), SPICE circuit simulation and layout

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1	**HDL based** (1) Behaviour and structural modeling of a VLSI sub-system in a HDL. (2) Implementation and analysis of the sub-system of (1) in IC Compiler.	
2	**SPICE and Layout** (1) Layout of an optimally sized CMOS combinational circuit driving a large load. (2) Extraction and SPICE simulation of the layout in (1)	14 x 4
	Total	**56**

11. Suggested Books:

Sl. No	Name of Books/ Authors	Year of Publication
1.	Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, “Digital Integrated Circuits: A Design Perspective,” Prentics Hall	2003
2.	R. Jacob Baker, H. W. Li, D. E. Boyce, “CMOS, Circuit Design, Layout, and Simulation,” Wiley India Pvt. Ltd.	1997
3.	Bhasker, J., “A VHDL Primer,” Pearson India.	2005
4.	Volnei A. Pedroni , “Circuit Design and Simulation with VHDL,” 2nd Ed. PHI India	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT/CENTRE: **Dept. of Electronics and Communication Engineering**

1. Subject Code: **ECN-577** Course Title: **VLSI Technology**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight: **CWS 25** **PRS 00** **MTE 25** **ETE 50** **PRE 00**

5. Credits: **3** 6. Semester: **Spring** 7. Subject Area: **PCC and DEC**

8. Pre-requisite: **EC - 142**

9. Objective: To provide knowledge of various processes and techniques for VLSI fabrication technologies.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction to VLSI technology:** Device scaling and Moore's law, basic device fabrication methods, alloy junction and planar process.	4
2.	**Crystal growth:** Czochralski and Bridgman techniques, Characterization methods and wafer specifications, defects in Si and GaAs.	4
3.	**Oxidation:** Surface passivation using oxidation. Deal-Grove model, oxide characterization, types of oxidation and their kinematics, thin oxide growth models, stacking faults, oxidation systems.	4
4.	**Diffusion and ion-implantation:** Solutions of diffusion equation, diffusion systems, ion implantation technology, ion implant distributions, implantation damage and annealing, transient enhanced diffusion and rapid thermal processing.	6
5.	**Epitaxy and thin film deposition:** Thermodynamics of vapor phase growth, MOCVD, MBE, CVD, reaction rate and mass transport limited depositions, APCVD/LPVD, equipments and applications of CVD, PECVD, and PVD.	5
6	**Etching:** Wet etching, selectivity, isotropy and etch bias, common wet etchants, orientation dependent etching effects; Introduction to plasma technology, plasma etch mechanisms, selectivity and profile control plasma etch chemistries for various films, plasma etch systems.	4
7	**Lithography:** Optical lithography contact/proximity and projection printing, resolution and depth of focus, resist processing methods and resolution enhancement, advanced lithography techniques for nanoscale pattering, immersion, EUV,	5

	electron, X-ray lithography.	

11. Suggested Books:

Sl. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Plummer, J.D., Deal, M.D. and Griffin, P.B., “Silicon VLSI Technology: Fundamentals, Practice and Modeling”, 3rd Ed., Prentice-Hall.	2000
2.	Sze, S.M., “VLSI Technology”, 4th Ed., Tata McGraw-Hill.	1999
3.	Chang, C.Y. and Sze, S.M., “ULSI Technology”, McGraw-Hill.	1996
4.	Gandhi, S. K., “VLSI Fabrication Principles: Silicon and Gallium Arsenide”, John Wiley and Sons.	2003
5	Campbell, S.A., “The Science and Engineering of Microelectronic Fabrication”, 4th Ed., Oxford University Press.	1996

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN–581** Course Title: **Analog VLSI Circuit Design**

2. Contact Hours: **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight: **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **0 4** 6. Semester √ **Autumn Spring Both**

7. Pre-requisite: **EC142 and EC-201**
8. Subject Area: **PEC and DEC**

9. Objective: To acquaint the students with basic CMOS analog building blocks and sub-system design.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction**: Motivation for analog VLSI and mixed signal circuits in CMOS technologies and issues thereof.	1
2.	**CMOS device fundamentals**: Basic MOS models, device capacitances, parasitic resistances, substrate models, transconductance, output resistance, f_T, frequency dependence of device parameters.	3
3.	**Single stage amplifiers**: Common source amplifier, source degeneration, source follower, common gate amplifier, cascade stage.	5
4.	**Differential Amplifiers**: Basic differential pair, common mode response, differential pair with MOS loads, Gilbert Cell, device mismatch effects, input offset voltage.	4
5.	**Current Mirrors, Current and Voltage Reference**: Basic current mirrors, cascode current mirrors, active current mirrors, low current biasing, supply insensitive biasing, temperature insensitive biasing, impact of device mismatch.	4
6.	**Frequency Response of Amplifiers**: Miller effect, CS amplifier, source follower, CG amplifier, cascade stage, differential amplifier, Multistage amplifier.	4
7.	**Feedback**: Feedback topologies, effect of load, modeling input and output ports in feedback circuits	3

8.	Noise: Statistical characteristics, types of noise, single stage amplifiers, differential pair, noise bandwidth, impact of feedback on noise.	3
9.	**Operational Amplifiers**: Performance parameters, One-stage and two-stage Op Amps, gain boosting, comparison, common mode feedback, input range, slew rate, power supply rejection, noise in Op Amps	6
10.	**Stability and Frequency Compensation**: Multi pole systems, phase margin, frequency compensation	3
11.	**High Performance CMOS Op-Amp**: Buffered Op-amps, High speed/Frequency Op-amps, Differential output op-amps, low noise and low voltage op-amps	6
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/Authors	Year of Publication
1.	Razavi, B., "Design of Analog CMOS Integrated Circuits", 1st Ed., Mc Graw Hill.	2001
2.	Gray, P.R., Hurst, P. J., Lewis, S.H., Meyer, R.G., "Analysis and Design of Analog Integrated Circuits", 4th Ed., John Wiley and Sons.	2001
3.	Baker, R. J., Li, H. W. and Boyce, D. E., "CMOS Circuit Design ,Layout and Simulation", Prentice-Hall of India.	1998

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT/CENTRE: **Dept. of Electronics and Communication Engineering**

1. Subject Code: **ECN-582** Course Title: **Semiconductor Microwave Devices and Applications**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight: **CWS 25** **PRS 00** **MTE 25** **ETE 50** **PRE 00**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC and DEC**

8. Pre-requisite: **Nil**

9. Objective: To introduce to the students the principles of operation of various microwave and millimeter wave semiconductor devices and their circuit applications.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	Transient and ac behaviour of p-n junctions, effect of doping profile on the capacitance of p-n junctions, noise in p-n junctions, high-frequency equivalent circuit, varactor diode and its applications; Schottky effect, Schottky barrier diode and its applications; Heterojunctions.	8
2.	Tunneling process in p-n junction and MIS tunnel diodes, V-I characteristics and device performance, backward diode.	3
3.	Impact ionization, IMPATT and other related diodes, small-signal analysis of IMPATT diodes.	4
4.	Two-valley model of compound semiconductors, Vd-E characteristics, Gunn effect, modes of operation, small-signal analysis of Gunn diode, power frequency limit.	4
5.	Construction and operation of microwave PIN diodes, equivalent circuit, PIN diode switches, limiters and modulators.	3
6.	High frequency limitations of BJT, microwave bipolar transistors, heterojunction bipolar transistors; Operating characteristics of MISFETs and MESFETs, short-channel effects, high electron mobility transistor.	7

7.	Characteristics and design of microstrips, slotlines and coplanar waveguides.	3
8.	Design considerations for microwave and millimeter wave amplifiers and oscillators, circuit realization, noise performance.	7
9.	Introduction to MEMS for RF applications: micromachining techniques for fabrication of micro switches, capacitors and inductors.	3
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Sarrafzadeh, M. and Wong, C.K., “An Introduction to VLSI Physical Design”, 4th Ed., McGraw-Hill.	1996
2.	Wolf, W., “Modern VLSI Design System on Silicon”, 2nd Ed., pearson Education.	2000
3.	Sait, S.M. and Youssef, H “VLSI Physical Design Automation: Theory and practice”, World scientific.	1999
4.	Dreschler, R., “Evolutionary Algorithm for VLSI CAD”, 3rd Ed., springer	2002
5.	Sherwani, N.A., “Algorithm for VLSI Physical Design Automation”, 2nd ED., Kluwer.	1999
6	Lim, S.K., “Practical problems in VLSI physical Design Automation”, Springer.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT/CENTRE: **Dept. of Electronics and Communication Engineering**

1. Subject Code: **ECN-583** Course Title: **Optoelectronic Materials and Devices**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight: **CWS** **25** **PRS** **00** **MTE** **25** **ETE** **50** **PRE** **00**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC and DEC**

8. Pre-requisite: **Nil**

9. Objective: To develop understanding of optical materials, working of optoelectronic devices and their applications.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	Optical processes in semiconductors, EHP formation and recombination, absorption and radiation in semiconductor, deep level transitions, Auger recombination, luminescence and time resolved photoluminescence, optical properties of photonic band-gap materials.	7
2.	Junction photodiode: PIN, heterojunction and avalanche photodiode; Comparisons of various photodetectors, measurement techniques for output pulse.	5
3.	Photovoltaic effect, V-I characteristics and spectral response of solar cells, heterojunction and cascaded solar cells, Schottky barrier and thin film solar cells, design of solar cell.	6
4.	Modulated barrier, MS and MSM photodiodes; Wavelength selective detection, coherent detection; Microcavity photodiode.	7
5.	Dynamic effects of MOS capacitor, basic structure and frequency response of charge coupled devices, buried channel charge coupled devices.	5
6.	Electroluminescent process, choice of light emitting diode (LED) material, device configuration and efficiency; LED: Principle of operation, LED structure, frequency response, defects, and reliability.	5

7.	Semiconductor laser diode, Einstein relations and population inversion, lasing condition and gain, junction lasers, hetrojunction laser, multi quantum well lasers, beam quantization and modulation.	7
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Liao, S.Y., “Microwave Devices and Circuits”, 4thEd., Pearson Education.	2002
2.	Rebeiz, M.G., “R.F. MEMS: Theory, Design and Technology”, 2ndEd., Wiley-Interscience.	2003
3.	Sze, S.M., and Ng, K.K., “Physics of Semiconductor Devices”, 3rdEd. Wiley-Interscience.	2006
4.	Glover, I.A., Pennoek, S.R. and Shepherd P.R., “Microwave Devices, Circuits and Sub-Systems”, 4th Ed., John Wiley & Sons.	2005
5.	Golio, M., “RF and Microwave Semiconductor Devices Handbook”, CRC Press.	2002
6	Zumbahlen, H.(ed.), “Linear Circuit Design Handbook”, Elsevier.	2008

NAME OF DEPT./CENTRE: **Electronics and Computer Engineering**

1. Subject Code: **ECN–584** Course Title: **Mixed Signal Circuit Design**

2. Contact Hours: 3 **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight: **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **0 4** 6. Semester **Autumn Spring Both**
x (Spring)

7. Pre-requisite: **Analog VLSI Circuit Design, Digital VLSI Circuit Design, MOS Device Physics**

8. Subject Area: **PEC and DEC**

9. Objective: To acquaint students with CMOS mixed signal circuit design.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Signals, Filters and Tools**: Sinusoidal signal, Comb filters and representation of signals	2
2.	**Sampling and Aliasing**: Impulse Sampling, Decimation, K-Path Sampling Sample-and-Hold, Track-and-Hold, Implementation of S/H, Discrete Analog Integrator	3
3.	**Analog Filters**: Integrator building blocks, MOSFET-C Integrator g_m-C Integrators, Discrete time Integrators, Filtering topologies, Bilinear and Biquadratic Transfer function	5
4.	**Digital Filters**: SPICE Models for DACs and ADCs, Sinc Shaped digital filters, Bandpass and Highpass sinc Filters, Filtering topologies, FIR Filter, Concept of stability and Overflow	6
5.	**Data Convertor SNR**: Quantization noise, Signal-to-Noise Ration (SNR), Concept of Spectral Density, Clock Jitter reduction techniques, Improving SNR using Averaging and Feedback	6
6.	**Data Convertor Design**: One bit ADC and DAC, Passive Noise shaping, Improving SNR and Linearity, Improving Linearity using Active circuits,	6
7.	**Noise Shaping Data Converters**: First Order Noise Shaping, Second order noise shaping, noise shaping topologies, Cascaded Modulators	4
8.	**Bandpass Data Converters**: Continuos Time bandpass noise shaping, Active and Passive component bandpass modulators, switched capacitor bandpass modulator, Digital I/Q Extraction to bandpass	4

9.	**High Speed Data Converters**: Topologies, path settling time, implementation, generation of clock signals and comparators, Clocked comparators, ADC	6
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/Authors	Year of Publication
1.	Baker Jacob R, "CMOS Mixed signal Circuit Design," Wiley IEEE Press	2009
2.	Baker Jacob R., "CMOS circuit design layout and simulation" Wiley IEEE	2010
3.	Razavi, B., "Design of Analog CMOS Integrated Circuits", 1st Ed., Mc Graw Hill.	2001

NAME OF DEPT./CENTRE: **Electronics and Computer Engineering**

1. Subject Code: **ECN–585** Course Title: **VLSI System Design**

2. Contact Hours: 3 **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight: **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **0 4** 6. Semester **Autumn** **Spring** √ **Both**

7. Pre-requisite: **Digital Electronics, Non-Linear Circuits**

8. Subject Area: **PEC and DEC**

9. Objective:

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction to Placement and Routing:** PNR and Routing, Placement Optimisation, Routing Algorithms and its application to simple design issues	4
2.	Introduction to Static Timing Analysis: STA with ideal clocks, flip-flop behavior analysis using state diagrams, STA using clock jitters, Example Study for a real chip, Multiple Clock, data transition with respect to power analysis,	6
3.	**Introduction to Clock Tree:** Clock Tree synthesis- H-tree, Buffering, Synthesis timing, set-up analysis with multiple clock,	6
4.	Stack subsystem design, control timing, generation of control signals. Register to Register Transfer. Combinational Logic. The Programmable Logic Array. Basic concept, Circuit design, and stick diagram of example. Finite State Machines,	6
5.	Datapath Operators, Adder, Parity Generator, Comparator ALU, Multiplexer Multiplier, Shifter	6
6.	Design Abstraction, Design Description Language VHDL/VERILOG, Register Transfer Design, Data and Control Flow Representations, Scheduling and Allocation Algorithms, Data and Control Synthesis and Optimization	6

7.	**Layout Generation:** Partitioning, Floor Planning, Placement, Routing – Global, Channel and Switch box Routing, Power and Clock distribution, Pad Design	4
8.	Memory Units: Read-Only Memories – ROM Cells Read/Write Memory - SRAM and DRAM Cells, Address Decoder, Sense Amplifier, Programmable Logic Arrays, Application Specific IC Design issues	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/Authors	Year of Publication
1.	Jan M. Rabaey, Anantha Chandrakasan, and Borivoje Nikolic 'Digital Integrated Circuits: A Design Prespective. Second Edition, A Prentice-Hall Publication Hall, 2003	2003
2.	N.Weste and D.Harris, "CMOS VLSI Design: Circuits and Systems Perspective," Fourth edition, Addison Wesley, 2010	2010

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1. Subject Code**: ECN–586** Course Title**: Device-Circuit Interaction**

2. Contact Hours: **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight**: CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 4** 6. Semester **Autumn** √ **Spring** **Both**

7. Pre-requisite**: EC – 142, EC -104, EC - 201**

8. Subject Area**: PEC and DEC**

9. Objective: To acquaint the students with microelectronics device and circuit interaction issues.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Performance of Circuits using Short-Channel MOSFETs**: Circuit performance considering short channel and narrow width effects, mechanical stress.	8
2.	**Performance of Circuits using Nanoscale MOSFETs**: Quantum confinement of carriers, quasi-ballistic transport and band-to-band tunneling, impact of carrier confinement and quasi-ballistic transport on circuit performance.	8
3.	**FinFETs and GAA Transistors**: I-V characteristics, device capacitances, parasitic effects of extension regions, performance of simple combinational gates and amplifiers, novel circuits using FinFETs and GAA devices.	12
4.	**Steep Slope Devices**: Tunnel FETs, I-MOS, resonant TFETs, ferroelectric negative capacitance devices, circuits using steep slope devices.	8
5.	**Germanium and III-V Integration in MOSFETs**: Mobility and injection velocity enhancement, hetero-junction issues at source/drain-channel interface, performance of circuits using compound semiconductor devices.	6
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/ Authors	Year of Publication
1.	Yuan Taur and T. Ning, “Fundamentals of Modern VLSI Devices,” Cambridge University Press.	1998
2.	Mark Lundstrom and J. Guo, “Nanoscale Transistors: Device Physics, Modeling and Simulation,” Springer.	2007
3.	J. –P. Colinge, “FinFETs and Other Multi-Gate Transistors,” Springer.	2009
4.	Selected papers from IEEE, Elsevier and IOP journals.	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT/CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN-587** Course Title: **Nanoscale Devices**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight: **CWS** **25** **PRS** **00** **MTE** **25** **ETE** **50** **PRE** **00**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC and DEC**

8. Pre-requisite: **MOS device physics, VLSI technology**

9. Objective: To provide knowledge of device physics/operation, technologies and issues in nanoscale CMOS and other emerging devices.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**CMOS scaling challenges in nanoscale regimes:** Moor and Koomey's law, Leakage current mechanisms in nanoscale CMOS, leakage control and reduction techniques, process variations in devices and interconnects.	6
2.	**Device and technologies for sub 100nm CMOS:** Silicidation and Cu-low k interconnects, strain silicon – biaxial stain and process induced strain; Metal-high k gate; Emerging CMOS technologies at 32nm scale and beyond – FINFETs, surround gate nanowire MOSFETs, heterostructure (III-V) and Si-Ge MOSFETs.	10
3.	**Device scaling and ballistic MOSFET:** Two dimensional scaling theory of single and multigate MOSFETs, generalized scale length, quantum confinement and tunneling in MOSFTEs, velocity saturation, carrier back scattering and injection velocity effects, scattering theory of MOSFETs.	10
4.	**Emerging nanoscale devices:** Si and hetero-structure nanowire MOSFETs, carbon nanotube MOSFETs, Tunnel FET, quantum wells, quantum wires and quantum dots; Single electron transistors, resonant tunneling devices.	10
5.	**Non-classical CMOS**: CMOS circuit design using non-classical devices – FINFETs, nanowire, carbon nanotubes and tunnel devices.	6
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Lundstrom, M., “Nanoscale Transport: Device Physics, Modeling, and Simulation”, Springer.	2005
2.	Maiti, C.K., Chattopadhyay, S. and Bera, L.K., “Strained-Si and Hetrostructure Field Effect Devices”, Taylor and Francis.	2007
3.	Hanson, G.W., “Fundamentals of Nanoelectronics”, Pearson India.	2008
4.	Wong, B.P., Mittal, A., Cao Y. and Starr, G., “Nano-CMOS Circuit and Physical Design”, Wiley.	2004
5	Sandip Kundu, Aswin Sreedhar, “Nanoscale CMOS VLSI Circuits: Design for Manufacturability” McGraw Hill	2010
6	Research and Review papers in specific area	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1. Subject Code**: ECN–588** Course Title**: Performance and Reliability of VLSI Circuits**

2. Contact Hours: **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight**: CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 4** 6. Semester **Autumn Spring √ Both**

7. Pre-requisite**: MOS Device Physics, Digital VLSI Circuit Design, Analog VLSI Circuit Design**

8. Subject Area**: PEC and DEC**

9. Objective: To acquaint the students with state-of-the-art circuit performance and reliability models of VLSI circuits.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Nanoscale MOSFET Characteristics**: Quasi-ballistic I-V characteristics, terminal capacitances of transistors considering quantum effects, parasitic resistances in nanoscale MOSFETs.	5
2.	**Delay and Timing Models**: Classical delay models of logic gates, logic gate delay models for nano-regime CMOS technologies, timing parameters of sequential circuit elements, access-time of CMOS memories, impact of process/temperature/supply-voltage variations on timing parameters.	12
3.	**Power Consumption**: Models for dynamic power, short circuit power and leakage power of CMOS circuits, full-chip power estimation techniques, impact of process/temperature variations on power consumption.	6
4.	**Reliability of CMOS Circuits**: Circuit performance considering NBTI/PBTI, oxide breakdown, random telegraph noise, radiation damage.	11
5.	**Analog Circuit Performance Parameters**: Impact of parasitic effects, process/temperature variation, device reliability effects.	8

	Total	42

11. Suggested Books:

Sl. No.	Name of Books/ Authors	Year of Publication
1.	Yuan Taur and T. Ning, “Fundamentals of Modern VLSI Devices,” Cambridge University Press.	1998
2.	Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, “Digital Integrated Circuits: A Design Perspective,” Prentics Hall	2003
3.	Behzad Razavi, “Design of Analog CMOS Integrated Circuits”, Tata McGraw-Hill.	2002
4.	Selected papers from IEEE, Elsevier and IOP journals.	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1.Subject Code**: ECN–589** Course Title**: Advanced VLSI Interconnects**

2. Contact Hours: **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 00**

4. Relative Weight**: CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 4** 6. Semester **Autumn** √ **Spring** **Both**

7. Pre-requisite**: EC – 201, Digital VLSI Circuit Design**

8. Subject Area**: PEC and DEC**

9. Objective: To provide in depth knowledge of interconnect modeling and performance analysis; introduction and analysis of futuristic material based interconnects such GNRs, CNTs and fiber optics.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Preliminary concepts** Interconnects for VLSI applications, metallic interconnects, optical interconnects, superconducting interconnects, advantages of copper interconnects, challenges posed by copper interconnects, fabrication process, even and odd mode capacitances, miller theorem, transmission line equations, resistive interconnection as ladder network, propagation modes in microstrip interconnection, slow wave mode propagation, propagation delays.	8
2.	**Parasitic extraction** Parasitic resistance, effect of surface/interface scattering and diffusion barrier on resistance, Capacitance: parallel-plate capacitance, fringing capacitance, coupling capacitance, methods of capacitance extraction, Inductance: self inductance, mutual inductance, methods of inductance extraction, high frequency losses, frequency dependent parasitics, skin effect, dispersion effect.	8

3.	**Modeling of interconnects and Crosstalk analysis** Elmore model, Transfer function model, even and odd mode model, Time domain analysis of multiconductor lines, Finite Difference Time Domain (FDTD) method, performance analysis using linear driver (Resistive) and nonlinear driver (CMOS), advanced interconnect techniques to avoid crosstalk.	8
4.	**Future VLSI Interconnects** Optical interconnects, Superconducting interconnects, Nanotechnology interconnects, Silicon nanowires, Carbon nanotubes, Graphene nanoribbons: system issues and challenges, material processing issues and challenges, design issues and challenges.	9
5.	**Carbon nanotube and Graphene nanoribbon VLSI interconnects** Quantum electrical properties: quantum conductance, quantum capacitance, kinetic inductance, Carbon nanotube (CNT) and Graphene nanoribbon (GNR) interconnects, electron scattering and lattice vibrations, electron mean free path, single-wall CNT and single layer GNR resistance model, multi-wall CNT and multi-layer GNR resistance model, transmission line interconnect models, performance comparison of CNTs, GNRs and copper interconnects.	9
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/ Authors	Year of Publication
1.	High-Speed VLSI Interconnects, Ashok K. Goel	2007
2.	Advanced Nanoscale ULSI Interconnects: Fundamentals and Applications, Y.S. Diamand	2009
3.	Carbon nanotube and Graphene Device Physics, H.S Philip Wong and Deji Akinwande	2011

INDIAN INSTITUTE OF TECHNOLOGY

Name of Department: **Electronics and Communication Engineering**

1. Subject Code: **ECN–590** Course Title: **Organic Electronics**

2. Contact Hours: **L:** 3 **T** 1 0

3. Examination Duration (Hrs): **Theory** 3 **Practical** 0

4. Relative Weight: **CWS** 25 **PRS** 0 **MTE** 25 **ETE** 50 **PRE** 0

5. Credits: 4

6. Semester: **Spring**

7. Subject Area: **PEC and DEC**

8. Pre-requisite: Semiconductors; electronic materials properties, Microelectronics, VLSI circuit

9. Objective: Study, modeling and simulation of organic material based devices and circuits. Acquaint the students with the conducting polymers, small-molecules, organic materials, different structures of OFETs, OLEDs and various applications of organic thin film transistors.

10. Details of the Course:-

Sl. No.	Contents	Contact Hours
1.	**Organic and Inorganic Materials & Charge Transport:** Introduction; Organic Materials: Conducting Polymers and Small Molecules, Organic Semiconductors: *p*-type, *n*-type, Ambipolar Semiconductors, Charge Transport in Organic Semiconductors, Charge Transport Models, Energy Band Diagram, *Organic and inorganic materials for*: Source, Drain and Gate electrodes , Insulators, Substrates ; Comparison between Organic and Inorganic Semiconductors.	8
2.	**Device Physics and Structures: Organic Thin Film Transistors:** Overview of Organic Field Effect Transistor (OFET); Operating Principle; Classification of Various Structures of OFETs; Output and Transfer Characteristics; OFETs Performance Parameters: Impact of Structural Parameters on OFET; Extraction of Various Performance Parameters, Advantages, Disadvantages and Limitations.	8
3.	**Organic Device Modeling and Fabrication Techniques:** Modeling of OTFT Different Structures, Origin of Contact Resistance, Contact Resistance Extraction, Analysis of OFET Electrical Characteristics, Validation and Comparison of OFETs. Organic Devices and Circuits Fabrication Techniques.	8

4.	**OLEDs and Organic Solar Cells** *Organic Light Emitting Diodes (OLEDs):* Introduction; Different Organic Materials for OLEDs; Classification of OLEDs, Output and Transfer Characteristics; Various Optical, Electrical and Thermal properties, Advantages, Disadvantages and Limitations. *Organic Solar Cells*: Introduction, Materials, various properties, Characteristics, Advantages, Disadvantages and Limitations and Applications;	10
5.	**OTFT Applications** Organic Inverters: Inverter Circuits based on Different Materials Combination and Configurations; All-*p*-type, Organic Complementary Inverter Circuits, Hybrid Complementary Inverters, Comparison between All P-Type, Fully Organic and Hybrid Complementary Inverter Circuits; Logic Circuit Implementation; Organic Memory: Organic Static Random Access Memory (OSRAM) Organic DRAM, Shift registers and other Important Organic Memory Designs. OTFT as Driver for organic Light Emitting Diodes (OLEDs). Addition of More Applications based on Recent Technology Development.	8
	Total	**42**

11. Suggested Books:

SL. No.	Name of Authors/Books/Publishers	Year of Publication/Reprint
	Text Books	
1.	Hagen Klauk, *Organic Electronics: Materials, Manufacturing and Applications,* Wiley-VCH Verlag Gmbh & Co. KGaA, Germany.	2006
2.	Klaus Mullen, Ullrich Scherf, *Organic Light Emitting Devices*: *Synthesis, Properties and Applications*, Wiley-VCH Verlag Gmbh & Co. KGaA, Germany.	2005
	Reference Books	
1.	Hagen Klauk, *Organic Electronics II: More Materials and Applications*, Wiley-VCH Verlag Gmbh & Co. KGaA, Weinheim, Germany, 2012	2012
2.	Flora Li, Arokia Nathan, Yiliang Wu, Beng S. Ong, Organic Thin Film Transistor Integration: A Hybrid Approach, Wiley-VCH, Germany; 1st Ed.	2011
3.	Wolfgang Brutting, *Physics of Organic Semiconductors*, Wiley-VCH Verlag Gmbh & Co. KGaA, Germany.	2005
4.	Dresselhaus, M.S., Dresselhaus, G. and Avouris, P., Carbon Nanotubes: Synthesis, Structure, Properties and Applications. New York: Springer- Verlag,	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1. Subject Code**: ECN–591** Course Title**: VLSI Physical Design**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 0 3** **Practical 0 0**

4. Relative Weight**: CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 4** 6. Semester **Autumn** **Spring √** **Both**

7. Pre-requisite**: Digital VLSI Circuit Design**

8. Subject Area**: PEC and DEC**

9. Objective: To develop understanding of state-of-the-art tools and algorithms, which address design tasks such as floor planning, module placement and signal routing for VLSI logic and physical level design

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction:** Layout and design rules, materials for VLSI fabrication, basic algorithmic concepts for physical design, physical design processes and complexities.	2
2.	**Partition:** Kernigham-Lin's algorithm, Fiduccia Mattheyes algorithm, Krishnamurty extension, hMETIS algorithm, multilevel partition techniques.	6
3.	**Floor-Planning:** Hierarchical design, wirelength estimation, slicing and non-slicing floorplan, polar graph representation, operator concept, Stockmeyer algorithm for floorplanning, mixed integer linear program.	10
4.	**Placement:** Design types: ASICs, SoC, microprocessor RLM; Placement techniques: Simulated annealing, partition-based, analytical, and Hall's quadratic; Timing and congestion considerations.	8
5.	**Routing:** Detailed, global and specialized routing, channel ordering, channel routing problems and constraint graphs, routing algorithms, Yoshimura and Kuh's method, zone scanning and net merging, boundary terminal problem, minimum density spanning forest problem, topological routing, cluster graph representation.	12

6.	**Sequential Logic Optimization and Cell Binding:** State based optimization, state minimization, algorithms; Library binding and its algorithms, concurrent binding	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/ Authors	Year of Publication
1.	Sarrafzadeh, M. and Wong, C.K., "An Introduction to VLSI Physical Design", 4th Ed., McGraw-Hill.	1996
2.	Wolf, W., "Modern VLSI Design System on Silicon", 2nd Ed., Pearson Education.	2000
3.	Sait, S.M. and Youssef, H., "VLSI Physical Design Automation: Theory and Practice", World Scientific.	1999
4.	Dreschler, R., "Evolutionary Algorithms for VLSI CAD", 3rd Ed., Springer	2002
5.	Sherwani, N.A., "Algorithm for VLSI Physical Design Automation", 2nd Ed., Kluwer.	1999
6.	Lim, S.K., "Practical Problems in VLSI Physical Design Automation", Springer.	2008

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT/CENTRE: **Dept. of Electronics and Communication Engineering**

1. Subject Code: **ECN-592** Course Title: **Compound Semiconductors and RF Devices**

2. Contact Hours: **L: 3** **T: 1** **P: 0**

3. Examination Duration (Hrs.): **Theory 3** **Practical 0**

4. Relative Weight: **CWS 25** **PRS 00** **MTE 25** **ETE 50** **PRE 00**

5. Credits: **4** 6. Semester: **Spring** 7. Subject Area: **PEC and DEC**

8. Pre-requisite: **Nil**

9. Objective: To provide knowledge of various compound semiconductor alloys, and their growth, properties, devices and applications.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**III-V opto- and high frequency materials:** Bonds, crytstal lattices, crystallographic planes and directions, direct and indirect semiconductors and their comparison for optical applications, optical processes of absorption and emission , radiative and non-radiative deep level transitions, phase and energy band diagrams of binary, ternary and quaternary alloys, determination of cross-over compositions and band structures.	10
2.	**High frequency devices:** Gunn diode, RWH mechanism, v-E characteristic, formation of domains, modes of operation in resonant circuits, fabrication, control of v-E characteristics by ternary and quaternary alloys.	8
3.	**Heterostructures:** Introduction, abrupt isotype/anisotype junctions, band diagrams and band off-sets, electrical and optoelectronic properties, symmetrical and asymmetrical p-n diodes and their characteristics, 2-Dimensional Electron Gas (2-DEG).	8
4.	**Heterostructure devices:** HBT, MOSFET, HEMT, quantum well and tunneling structures, lasers, LED and photodetectors, optoelectronic IC's and strained layer structures.	8
5.	**Miscellaneous devices:** Compound semiconductor MESFETs, infrared and window effect in photovoltaic converters, strain sensors and their sensitivities, QWITT and DOVETT devices.	8
	Total	42

11. Suggested Books:

Sl. No.	Name of Authors / Books / Publishers	Year of Publication /Reprint
1.	Arora, N., “MOSFET Models for VLSI Circuit Simulation: Theory and Practice”, 4th Ed., Springer-Verlag.	1993
2.	Tsividis, Y., “Operation and Modeling of the MOS Transistor”, 2nd Ed., Oxford University Press.	2003
3.	Sze, S. M., and Ng, K. K., “Physics of Semiconductor Devices”, 3rd Ed., Wiley-Interscience.	2006
4.	Liu, W., “MOSFET Models for Spice Simulation (including BSIM3V3 and BSIM4)”, Wiley-IEEE Press	2001

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1. Subject Code**: ECN–593** Course Title**: CAD for VLSI**

2. Contact Hours: **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight**: CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 4** 6. Semester **Autumn** **Spring** √ **Both**

7. Pre-requisite**: Digital VLSI Circuit Design, EC - 201**

8. Subject Area**: PEC and DEC**

9. Objective: To provide knowledge on the front end design aspects of VLSI chip manufacturing cycle.

10. Details of the Course:

Sl. No.	**Contents**	**Contact Hours**
1.	**Introduction:** Evolution of design automation; CMOS realizations of basic gates.	3
2.	**Circuit and system representation:** Behavioral, structural and physical models, design flow.	4
3.	**Modeling techniques:** Types of CAD tools, introduction to logic simulation and synthesis.	4
4.	**HDL:** Syntax, hierarchical modeling, Verilog/VHDL construct, simulator directives, instantiating modules, gate level modeling.	6
5.	**Delay modeling:** Event based and level sensitive timing control, memory initialization, conditional compilation, time scales for simulation.	5
6.	**Advanced modeling techniques:** Static timing analysis, delay, switch level modeling, user defined primitive (UDP), memory modeling.	5
7.	**Logic synthesis:** Logic synthesis of HDL construct, technology cell library, design constraints, synthesis of Verilog/VHDL construct.	6
8.	**Model optimization:** Various optimization techniques, design size.	4
9.	**FPGAs based system design:** Commercial FPGA architecture, LUT and routing architecture, FPGA CAD flow; Typical case studies.	5
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/ Authors	Year of Publication
1.	Weste, N. and Eshraghian, K., “Principles of CMOS VLSI Design –A Systems Perspective”, 2nd Ed., Addison Wesley.	2006
2.	Palnitkar, S., “Verilog HDL”, 2nd Ed., Pearson Education.	2004
3.	Wolf, W., “Modern VLSI Design: System on Chip”, 2nd Ed., Prentice Hall of India.	2002

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN– 594** Course Title: **VLSI Digital Signal Processing**

2. Contact Hours: **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight: **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits: **0 4** 6. Semester **Autumn** **Spring** √ **Both**

7. Pre-requisite: **Digital VLSI Circuit Design**

8. Subject Area: **PEC and DEC**

9. Objective: To provide knowledge on transformations for high speed VLSI digital signal processing using pipelining, retiming, and parallel processing techniques.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction to DSP Systems:** Typical DSP programs, Area-speed-power tradeoffs, Representation methods of DSP systems	2
2.	**Iteration Bound:** Iteration, Iteration period, Iteration bound, Algorithms to compute iteration bound – Longest path matrix, Minimum cycle matrix	4
3.	**Pipelining and Parallel Processing:** Introduction to pipelining and parallel processing, Pipelining of FIR digital filters, Parallel processing, Pipelining and parallel processing for low power	5
4.	**Retiming:** Retiming formulation, Retiming for clock period minimization, K-slow transformation, Retiming 2-slow graph	4
5.	**Unfolding:** Algorithm for unfolding, Properties of unfolding, Application of unfolding, Sample period reduction, Word and bit-level parallel processing	6
6.	**Folding:** Folding technique, Folding transformation, Retiming for folding	4
7.	**Fast Convolution:** Introduction, Cook-Toom algorithm and modified Cook-Toom algorithm, Winograd algorithm and modified Winograd algorithm, Iterated convolution, Cyclic convolution, Design of Fast convolution algorithm by inspection.	6
8.	**Algorithmic Strength Reduction in Filters and Transforms:** Introduction, Parallel FIR filters, Two-parallel and three-parallel low-complexity FIR filters,	6

	3-parallel fast FIR filter, Parallel filter algorithms from linear convolutions, Discrete Cosine Transform and Inverse DCT.	
9.	**Pipelined and Parallel Recursive and Adaptive Filters:** Introduction, Pipeling in 1st order IIR digital filters, Pipelining in higher order IIR digital filters, Parallel processing for IIR filters, Combined pipeling and parallel processing for IIR filters.	5
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/ Authors	Year of Publication
1.	Parhi, Keshab K., "VLSI Digital Signal Processing Systems: Design and Implementation", John Willey & Sons.	1999
2.	John G. Proakis, Dimitris Manolakis: Digital Signal Processing: Principles, Algorithms and Applications, 4th ed, Pearson.	2006
3.	Sen M. Kuo, Woon-Seng Gan: Digital Signal Processors: Architectures, Implementations, and Applications, Prentice Hall.	2005

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1.Subject Code**: ECN– 595** Course Title**: VLSI Testing & Testability**

2. Contact Hours: 42 **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 00**

4. Relative Weight**: CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 4** 6. Semester **Autumn Spring √ Both**

7. Pre-requisite**:** Introduction to analog and digital circuits and design, Physical VLSI Design

8. Subject Area**: PEC and DEC**

9. Objective: Upon completion of this course, students will be able to understand the VLSI chip testing mechanism, systems using existing test methodologies, equipments, and tools.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	Motivation for testing, Design for testability, the problems of digital and analog testing, Design for test, Software testing. **Faults in Digital Circuits:** Controllability, and Observability, Fault models - stuck-at faults, Bridging faults, intermittent faults.	05
2.	**Digital Test Pattern Generation:** Test pattern generation for combinational logic circuits, Manual test pattern generation, Automatic test pattern generation - Roth's D-algorithm, Developments following Roth's D algorithm, Pseudorandom test pattern generation, Test pattern generation for sequential circuits, Exhaustive, non-exhaustive and pseudorandom 70 test pattern Generation, Delay fault testing.	07
3.	**Signatures and Self Test:** Input compression output compression arithmetic, Reed-Muller and spectral coefficients, Arithmetic and Reed-Muller coefficients, Spectral coefficients, Coefficient test signatures, Signature analysis and online self test. **Testability Techniques:** Partitioning and ad-hoc methods and scan-path testing, Boundary scan and IEEE standard 1149.1, Offline built in Self Test (BIST), Hardware description languages and test.	10
4.	**Testing of Analog and Digital circuits:** Testing techniques for Filters, A/D Converters, Programmable logic devices and DSP, Test generation algorithms for combinational logic circuits – fault table, Boolean difference, Path sensitilization, D-algorithm, Podem, Fault simulation techniques – serial single fault propagation,	12

	Deductive, Parallel and concurrent simulation, Test generation for a sequential logic, Design for testability – adhoc and structured methods, Scan design, Partial scan, Boundary scan, Pseudo-random techniques for test vector generation and response compression, Built–in-Self test, PLA test and DFT.	
5.	**Memory Design and Testing:** Memory Fault Modeling, testing, And Memory Design For Testability And Fault Tolerance RAM Fault Modeling, Electrical Testing, Peusdo Random Testing-Megabit DRAM Testing-Nonvolatile Memory Modeling and Testing-IDDQ Fault Modeling and Testing-Application Specific Memory Testing.	08
	Total	**42**

11. Suggested Books:

Sl. No.	**Name of Books/ Authors**	**Year of Publication**
1.	M. L. Bushnell and V. D. Agrawal, *Essentials of Electronic Testing for Digital, Memory,and Mixed-Signal VLSI Circuits,* Kluwer Academic Publishers.	2000
2.	A.K Sharma, *Semiconductor Memories Technology, Testing and Reliability*, IEEE Press.	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT. /CENTRE: **Electronics and Communication Engineering**

1.Subject Code**: ECN–596** Course Title**: MEMS & NEMS**

2. Contact Hours: **L: 3 T: 1 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 00**

4. Relative Weight**: CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**

5. Credits**: 0 4** 6. Semester **Autumn Spring √ Both**

7. Pre-requisite**: VLSI Technology**

8. Subject Area**: PEC and DEC**

9. Objective: The course will provide understanding of underlying principles of MEMS and NEMS devices, and will provide insight to design related technologies.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction to Micro-fabrication:**Cleaning, Oxidation, Diffusion, Mask making, Lithography, Etching, Ion Implantation, CVD, PVD, Metallization; Surface micromachining and Bulk Micromachining, DRIE, LIGA, Fabrication of high aspect ratio deformable structures	8
2.	**Elasticity in Materials:**Stress, strain calculations, Normal and Shear strains and constitutive relations, Plane stress, biaxial stress, residual stress, energy relations, Load-deflection calculations in beams, cantilevers (rectangular cross section), Elastic deformation in square plate, Resonant frequency calculations: Rayleigh-Ritz method	14
3.	**MEMS Capacitive Switch:**Lumped model, pull-in voltage, Electromechanical deflection modeling, pull-in instability, switching time and pull-in voltage scaling, Physical effects in nanoscale gap-size, squeeze-film damping , perforated MEMS Capacitive switch, Comb actuators, Accelerometer, Pressure sensor, Energy approach: Lagrangian Mechanics applicable to MEMS capacitive switches, Reliability in RF-capacitive switch	12
4.	**MEMS Sensors:** Thermal sensor, Interaction of Thermal-Electrical Fields, Numerical design of thermal sensors, Bio-MEMS design problems	4

5.	**Optical MEMS:**2-D, 3-D switches, design examples	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/ Authors	Year of Publication
1.	Rebeiz, G.M., RF MEMS: Theory Design and Technology,Wiley	1999
2.	Stephen D. Senturia, Microsystem Design, Kluwer Academic	2001
3.	Madou, M., Fundamentals of Microfabrication, CRC Press	1997
4.	Sandana A., Engineering biosensors: kinetics and design applications, Academic Press	2002
5.	Related research papers	

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electronics & Communication Engineering**

1. Subject Code: **ECN-612** Course Title: **Wireless Networks**

2. Contact Hours: **L: 3** **T: 0** **P: 0**

3. Examination Duration (Hrs.): **Theory** **3** **Practical** **0**

4. Relative Weight : **CWS** **25** **PRS** **0** **MTE** **25** **ETE** **50** **PRE** **0**

5. Credits**:** **3** 6. Semester**: Spring** 7. Subject Area**: CORE**

8. Pre-requisite**:** **NIL**

9. Objective: To acquaint the students with the concepts and the issues involved in the design of wireless networks.

10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	Wireless network topologies, infrastructure and ad-hoc networks, different generations of wireless networks; The cellular concept and design fundamentals, coverage and capacity expansion techniques.	5
2.	Large scale path loss modeling and shadow fading, indoor and outdoor propagation models; Multipath and Doppler, impulse response model of multipath channel, types of small scale fading, Rayleigh and Ricean fading, simulation model.	5
3.	Constant envelope modulation techniques, GMSK; OQPSK and $\pi/4$ QPSK; Spread spectrum modulation and RAKE receiver; OFDM; Performance in fading and multipath channels.	5
4.	Fixed assignment and andom access; Capacity and performance of FDMA, TDMA, DS/CDMA and FH/CDMA; WCDMA and OFDMA; Access techniques for WLAN, Bluetooth and mobile data networks; Quality of service enabled wireless access, access methods for integrated services.	6
5.	Location and handoff management, classification of handoffs and handoff algorithms, mobile IP; Power control, and techniques of	6

	power control, power saving mechanisms, energy efficient designs; Security in wireless networks.	
6.	GSM: Reference architecture, registration, call establishment, handoff mechanisms, communication in the infrastructure, GPRS; IS-95: reference architecture, physical layer, radio resource and mobility management; IMT 2000: Physical layer, handoff, power control; Introduction to cordless systems and wireless local loop technologies.	5
7.	Reference and layered architecture of IEEE 802.11 WLANs, physical layer alternatives, MAC scheme and frame format, handoff and power management; Protocol architecture, physical and MAC layer of Hiperlan-1 and Hiperlan-2; IP telephony using WLANs.	5
8.	Wireless home networking; HomeRF; Bluetooth: Protocol stack, physical and MAC layer.	3
9.	Broadband wireless access and IEEE 802.16; Next generation broadband wireless networks and navigational services.	2
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Pahalvan, K. and Krishnamurthy, P., "Principles of Wireless Networks: A Unified Approach", Pearson Education.	2002
2.	Stallings, W., "Wireless Communications and Networking", Pearson Education.	2002
3.	Rappaport, T.S., "Wireless Communications: Principles and Practice", 2nd Ed., Pearson Education.	2002
4.	Prasad, R. and Munoz, L., "WLANs and WPANs: Towards 4G Wireless", Artech House.	2003
5.	Haykin, S. and Moher, M., "Modern Wireless Communication", Pearson Education.	2005
6.	Pandya, R., "Mobile and Personal Communication Systems and Services", Prentice-Hall of India.	2000

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPTT./CENTRE: **Department of Electronics & Communication Engineering**

1. Subject Code: **ECN-614** Course Title: **Adaptive Signal Processing Techniques**

2. Contact Hours: **L: 3** **T: 0** **P: 3**

3. Examination Duration (Hrs.): **Theory** **0** **Practical** **0**

4. Relative Weight **: CWS 15 PRS 25 MTE 20 ETE 40 PRE 0**

5. Credits**: 3** 6. Semester**: Spring** 7. Subject Area**: PE**

8. Pre-requisite**: NIL**

9. Objective: To acquaint the students with the concepts, algorithms and applications of adaptive signal processing in wireless communication systems.

10. Details of Course:

Sl. No.	Contents	Contact Hours
1.	Linear optimum filtering and adaptive filtering, linear filter structures, adaptive equalization, noise cancellation and beam forming.	3
2.	Optimum linear combiner and Wiener-Hopf equations, orthogonality principle, minimum mean square error and error performance surface; Steepest – descent algorithm and its stability.	5
3.	LMS algorithm and its applications, learning characteristics and convergence behaviour, misadjustment; Normalized LMS and affine projection adaptive filters; Frequency domain block LMS algorithm.	10
4.	Least squares estimation problem and normal equations, projection operator, exponentially weighted RLS algorithm, convergence properties of RLS algorithm; Kalman filter as the basis for RLS filter; Square-root adaptive filtering and QR- RLS algorithm; Systolic-array implementation of QR – RLS algorithm.	10
5.	Forward and backward linear prediction; Levinson-Durbin algorithm; Lattice predictors, gradient-adaptive lattice filtering, least-squares lattice predictor, QR-decomposition based least-squares lattice filters.	10
6.	Adaptive coding of speech; Adaptive equalization of wireless channels; Antenna array processing.	4
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books/Authors	Year of Publication
1.	Haykin, S., “Adaptive Filter Theory”, Pearson Education.	2002
2.	Widrow, B. and Stearns, S.D., “Adaptive Signal Processing”, Pearson Education.	1985
3.	Manolakis, D.G., Ingle, V.K. and Kogon, M.S., “Statistical and Adaptive Signal Processing”, Artech House.	2005
4.	Sayed Ali, H., “Fundamentals of Adaptive Filtering”, John Wiley & Sons.	2003
5.	Diniz, P.S.R., “Adaptive Filtering: Algorithms and Practical Implementation”, Kluwer.	1997
6.	Sayeed, Ali, H., “Adaptive Filters”, Wiley-IEEE Press.	2008
7.	Scharf, L.L., “Statistical Signal Processing: Detection, Estimation, and Time Series Analysis”, Addison-Wesley.	1991

INDIAN INSTITUTE OF TECHNOLOGY ROORKEE

NAME OF DEPT./CENTRE: **Electronics and Communication Engineering**

1. Subject Code: **ECN – 631** Course Title: **RF Receiver Design**

2. Contact Hours: **L: 3 T: 0 P: 0**

3. Examination Duration (Hrs.): **Theory 0 3 Practical 0 0**

4. Relative Weight: **CWS 25 PRS 00 MTE 25 ETE 50 PRE 00**
00

5. Credits: **0 3** 6. Semester √
Autumn Spring Both

7. Pre-requisite: NIL

8. Subject Area: **PCC**

9. Objective: To present to the students a cohesive overview of the fundamental concepts required for the design and analysis of RF stages of a modern wireless system.

10. Details of the Course:

Sl. No.	Contents	Contact Hours
1.	**Introduction to Wireless Systems**: Classification of wireless systems; Design and performance issues: Choice of operating frequency, multiple access and duplexing, circuit switching versus packet switching, propagation, radiated power and safety; Cellular telephone systems and standards.	4
2.	**Noise and Distortion in Microwave Systems:** Basic threshold detection, noise temperature and noise figure, noise figure of a lossy transmission line; Noise figure of cascade systems: Noise figure of passive networks, two-port networks, mismatched transmission lines and Wilkinson power dividers; Dynamic range and inter-modulation distortion.	6
3.	**Microwave Amplifier Design**: Comparison of active devices such as BJT, MOSFET, MESFET, HEMT, and HBT; Circuit models for FETs and BJTs; Two-port power gains; Stability of transistor amplifier circuits; Amplifier design using S-parameters: Design for maximum gain, maximum stable gain, design for specified gain, low-noise amplifier design, design of class-A power amplifiers.	12
4.	**Mixers:** Mixer characteristics: Image frequency, conversion loss,	8

	noise figure; Devices for mixers: p-n junctions, Schottky barrier diode, FETs; Diode mixers: Small-signal characteristics of diode, single-ended mixer, large-signal model, switching model; FET Mixers: Single-ended mixer, other FET mixers; Balanced mixers; Image reject mixers.	
5.	**Switches:** Devices for microwave switches: PIN diode, BJT, FET; Device models; Types of switches; Switch configurations; Basic theory of switches; Multi-port, broad-band and isolation switches.	4
6.	**Oscillators and Frequency Synthesizers:** General analysis of RF oscillators, transistor oscillators, voltage-controlled oscillators, dielectric resonator oscillators, frequency synthesis methods, analysis of first and second order phase-locked loop, oscillator noise and its effect on receiver performance.	8
	Total	**42**

11. Suggested Books:

Sl. No.	Name of Books / Authors	Year of Publication
1.	Pozar, D.M. "Microwave and RF Design of Wireless Systems", John Wiley & Sons.	2001
2.	Gonzalez, G., "Microwave Transistor Amplifiers: Analysis and Design", 2nd Ed., Prentice-Hall.	1997
3.	Bahl, I. and Bhartia, P., "Microwave Solid State Circuit Design", 2nd Ed., John Wiley & Sons.	2003
4.	Chang, K., Bahl, I. and Nair, V., "RF and Microwave Circuit and Component Design for Wireless Systems", Wiley Interscience.	2002
5.	Rohde, U.L. and Newkirk, D.P., "RF/Microwave Circuit Design for Wireless Applications", John Wiley & Sons.	2000
6.	Larson, L.E., "RF and Microwave Circuit Design for Wireless Applications", Artech House.	1996
7.	Egan, W. F., "Practical RF Circuit Design", John Wiley & Sons.	1998