Proposed Course Structure and Syllabus of UG 3rd Semester to 8th Semester, Electronics and Telecommunication Engineering

Department of Electronics and Telecommunication Engineering
Indian Institute of Engineering Science and Technology, Shibpur
Howrah, 711103

ELECTRONICS AND TELECOMMUNICATION ENGINEERING

Course Structure for the 3rd Semester B. Tech.

Sl no	Course Name	Course Code	Class Load/ Week			Credit	Total Class Load/ Week	Full Marks
			L	T	P			
1	Mathematics III	MA2101	3	0	0	3	3	100
2	Network Theory	ET2101	3	1	0	4	4	100
3	Basic Electronics	ET2102	3	0	0	3	3	100
4	Electronic Devices	ET2103	4	0	0	4	4	100
5	Signals and Systems	ET2104	4	0	0	4	4	100
	Theory Sub Total					**18**	**18**	**500**
6	Network Theory Lab	ET2171	0	0	3	2	3	50
7	Basic Electronics Lab	ET2172	0	0	3	2	3	50
8	Electronic Devices Lab	ET2173	0	0	3	2	3	50
9	Modelling and Simulation Lab	ET2174	0	0	3	2	3	50
	Sessional Sub Total					**8**	**12**	**200**
	3rd Semester Total					**26**	**30**	**700**

Course Structure for the 4th Semester B. Tech.

Sl no	Course Name	Course Code	Class Load/ Week			Credit	Total Class Load/ Week	Full Marks
			L	T	P			
1	Analog Electronics	ET2201	4	0	0	4	4	100
2	Digital Electronics	ET2202	4	0	0	4	4	100
3	Microelectronics Technology	ET2203	3	0	0	3	3	100
4	Electronic Instrumentation and Control	ET2204	4	0	0	4	4	100
5	Electromagnetic Theory and Radio Wave Propagation	ET2205	3	0	0	3	3	100
	Theory Sub Total					**18**	**18**	**500**
6	Analog Electronics Lab	ET2271	0	0	3	2	3	50
7	Digital Electronics Lab	ET2272	0	0	3	2	3	50
8	Microelectronics Technology Lab	ET2273	0	0	3	2	3	50
9	Electronic Instrumentation and Control Lab	ET2274	0	0	3	2	3	50
	Sessional Sub Total					**8**	**12**	**200**
	4th Semester Total					**26**	**30**	**700**

Course Structure for the 5th Semester B. Tech.

Sl no	Course Name	Course Code	Class Load/ Week			Credit	Total Class Load/ Week	Full Marks
			L	T	P			
1	Integrated Circuits and Systems	ET3101	4	0	0	4	4	100
2	Analog and Digital Communications	ET3102	4	0	0	4	4	100
3	Transmission Lines and Antennas	ET3103	4	0	0	4	4	100
4	Microprocessors and Microcontrollers	ET3104	3	0	0	3	3	100
5	Data Structure and Algorithms	ET3105	3	0	0	3	3	100
	Theory Sub Total					**18**	**18**	**500**
6	Integrated Circuits and Systems Lab	ET3171	0	0	3	2	3	50
7	Analog and Digital Communications Lab	ET3172	0	0	3	2	3	50
8	Transmission Lines and Antennas Lab	ET3173	0	0	3	2	3	50
9	Microprocessors and Microcontrollers Lab	ET3174	0	0	3	2	3	50
	Sessional Sub Total					**8**	**12**	**200**
	5th Semester Total					**26**	**30**	**700**

Course Structure for the 6th Semester B. Tech.

Sl no	Course Name	Course Code	Class Load/ Week			Credit	Total Class Load/ Week	Full Marks
			L	T	P			
1	Digital Signal Processing	ET3201	3	0	0	3	3	100
2	VLSI and CAD	ET3202	4	0	0	4	4	100
3	Wireless and Mobile Communications	ET3203	3	0	0	3	3	100
4	Computer and Communication Networks	ET3204	4	0	0	4	4	100
5	Computer Organization and Architecture	ET3205	3	0	0	3	3	100
	Theory Sub Total					**17**	**17**	**500**
6	Digital Signal Processing Lab	ET3271	0	0	3	2	3	50
7	VLSI and CAD Lab	ET3272	0	0	3	2	3	50
8	Wireless Communication and Networking Lab	ET3273	0	0	3	2	3	50
	Sessional Sub Total					**6**	**9**	**150**
	6th Semester Total					**23**	**26**	**650**

Course Structure for the 7th Semester B. Tech

Sl no	Course Name	Course Code	Class Load/ Week			Credit	Class Load/ Week	Full Marks
			L	T	P			
1	Digital Image Processing and Computer Vision	ET4101	3	0	0	3	3	100
2	Microwave and Radar Engineering	ET4102	3	0	0	3	3	100
3	Dep. Elective-I	ET412*	3	0	0	3	3	100
4	Open Elective (HSS)		3	0	0	3	3	100
	Theory Sub Total					**12**	**12**	**400**
5	Digital Image Processing and Computer Vision Lab	ET4171	0	0	3	2	3	50
6	Microwave and Radar Engineering Lab	ET4172	0	0	3	2	3	50
7	B. Tech. Project Part I	ET4191	0	0	3	4	3	100
8	Internship (Evaluation)	ET4192	0	0	0	2	0	50
	Sessional Sub Total					**10**	**09**	**250**
	7th Semester Total					**22**	**21**	**650**

Course Structure for the 8th Semester B. Tech

Sl no	Course Name	Course Code	Class Load/ Week			Credit	Class Load/ Week	Full Marks
			L	T	P			
1	Optoelectronics and Optical Communication	ET4201	3	0	0	3	3	100
2	Dep. Elective-II	ET422*	3	0	0	3	3	100
3	Open Elective-I	ET4261	3	0	0	3	3	100
	Theory Sub Total					**09**	**09**	**300**
4	Optoelectronics and Optical Communication lab	ET4271	0	0	3	2	3	50
5	B. Tech. Project Part II	ET4291	0	0	6	8	6	200
6	Seminar	ET4292	0	0	0	2	0	50
7	Comprehensive Viva Voce	ET4293	0	0	0	2	0	100
	Sessional Sub Total					**14**	**09**	**400**
	8th Semester Total					**23**	**18**	**700**

LIST OF ELECTIVE PAPERS UG

DEP ELECTIVE-I

1. Adaptive Signal Processing (ET4121)
2. Principles of Electromagnetic Compatibility (ET4122)
3. IoT and Embedded Systems (ET4123)

DEP ELECTIVE-II

1. Green Communications (ET4221)
2. Sensors and Actuators for Electronic Systems (ET4222)
3. Smart Antennas (ET4223)

OPEN ELECTIVE-I

1. Satellite Communication (ET4261)

3rd Sem Electronics and Telecommunication Engineering

Network Theory (ET2101)

L-T-P: 3-1-0 Credit: 4 Full Marks-100

Sl. No.	Module Name and Topics	Class hours
1.	**Introduction:** Networks/Circuits, Importance **Energy source:** Source Characteristics, Transformation of Sources.	3
2.	**General Analysis Methods:** Mesh Analysis, Node Analysis, Super Mesh and Node Analyses, Source Shifting Techniques.	6
3.	**Transient and Steady State Responses:** RL, RC and RLC Series and Parallel Circuits with various kinds of Excitations using Differential Equation approach and Laplace Transform.	9
4.	**Synthesis of Complex Waveforms:** Pulse, Square, Triangular, Saw Tooth, Impulse; Solution of Circuit Problems with these Waveforms. Initial and Final Value Theorems.	6
5.	**Network Theorems:** Transform Impedance and Admittance, Series and Parallel combination; Thevenin, Norton, Superposition, Millmann, Reciprocity, Compensation, Maximum Power Transfer, Telegene's Theorems.	6
6.	**Network Functions:** Driving Point and Transfer Functions, One-Port Network, Two-Port Network Parameters, Parameters Conversion, Input and Output Impedances, Image Impedance, Characteristic Impedance.	8
7.	**Resonance:** Series and Parallel, Q-Factor, BW.	4
8.	**Concept of Poles and Zeros:** Restriction on Poles and Zeros in s-plane, Time-Domain Behaviour from Pole-Zero Plot.	2
9.	**Elements of Network Synthesis:** Hurwitz Polynomial, Real and Reactive Functions, Synthesis of RL, RC, LC Networks.	6
	Total	**50**

Text Books/References:

1. Circuits and Networks Analysis and Synthesis – Sudhakar & Shyammohon
2. Network Analysis - Van Valkenburg
3. Networks and Systems - D. Roy Choudhury
4. Network Analysis and Synthesis - Wadhwa
5. Circuit Theory - Iyer
6. Network Analysis and Synthesis - F. Kuo
7. Network Synthesis - Van Valkenburg

Basic Electronics (ET2102)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	**Semiconductors and P-N junctions:** Intrinsic and doped semiconductors, drift and diffusion currents. depletion region, built-in potential, P-N junction with applied voltage: forward and reverse modes of operation, junction current-voltage relationship, reverse breakdown. P-N junction as a varactor, Schottky-barrier diode.	4
2	**Diode circuits:** Static and dynamic characteristic, large-signal and small-signal operation, large-signal and small-signal diode model. Half-wave, full-wave, bridge and peak rectifiers. Clipping, clamping (DC restorer) and voltage doubler circuits.	6
3	**Basics of amplifier:** Concept of signal amplification, concept of gain (voltage, current, power), expressing gain in decibels, circuit models for amplifiers (voltage, current, transconductance, transimpedance), relationship among amplifier models, frequency spectrum of signal, non-linearity and total harmonic distortion (THD), need for small-signal equivalent circuit, need for frequency response analysis.	4
4	**RC and CR circuits:** Time-domain response: voltage and current responses for step input, periodic pulse input with different time periods. Frequency-domain responses. Concept of filtering, integrator and differentiator.	4
5	**Bipolar junction transistors:** Structures, regions of operation, current-voltage relationship, capacitive effects in BJT junctions. BJT as an amplifier and as a switch, large-signal and small-signal operation, large-signal and small-signal BJT models. Operating modes: CB, CE and CC configurations and characteristics; dependence of β on various parameters. BJT biasing: CB, CE, CC amplifiers; stability factor, thermal runway and bias compensation.	10
6	**Metal oxide semiconductor (MOS) field effect transistor (FET):** Structures, regions of operation, current-voltage relationship. MOSFET as an amplifier and as a switch, large-signal and small-signal operation, large-signal and small-signal MOSFET models. Operating modes: CG, CS, CD configurations and characteristics; MOSFET biasing: CG, CS, CD amplifiers.	10
7	**Biasing circuits (using BJT and MOSFET):** Basic current source and current steering (or mirroring) circuits.	2
	Total	**40**

Text Books/References:

1. Solid State Electronics Devices- Streetman, Banerjee, PHI, New Delhi.
2. Microelectronic Circuits: Sedra, Smith, Oxford University Press
3. Fundamental of Microelectronics: Behzad Razavi, Wiley
4. Electronic Principles: Malvino, TMH
5. Integrated Electronics: Millman and Halkias, Mcgraw Hill
6. Electronic Circuits: Schilling, Belove, TMH

Electronic Devices (ET 2103)

L-T-P: 4-0-0 Credit: 4 Full Marks: 100

Sl. No.	Module Name & Topics	Class hours
1.	**Physics of Semiconductor Devices**: Equilibrium carrier concentrations; Thermal Equilibrium and wave particle duality; Intrinsic semiconductor : Bond and band models; Extrinsic semiconductor: Bond and band models, calculation of carrier concentrations from allowed energy states, density of states and Fermi Dirac statistics, Carrier transport; Random motion; Drift and diffusion; mobility, velocity saturation, Excess carriers; Injection level; Lifetime; Direct and indirect semiconductors Procedure for analyzing semiconductor devices; Basic equations and approximations	14
2.	**P-N Junction diode**: Unbiased & biased p-n junction, Diode current equation, Voltage-current characteristics, Junction capacitances, Effect of high field on charge carriers in semiconductors, Impact ionization, Carrier multiplication, avalanche breakdown of junction, Zener diode and Zener breakdown, Photodiode, Solar cell, Metal-semiconductor schottky barrier diode..	6
3.	**Bipolar Junction Transistor (BJT**): Basic principle of operation, Base width modulation, Eber-Moll model, hybrid-pi model, Equivalent circuit of BJT, Switching Characteristics, Photo transistor, High frequency transistor.	8
4.	**Ohmic and Rectifying junctions**; Schottky diodes, Schottky transistors.	2
5.	**Field Effect Transistor:** Device structure and operation, common source DC characteristics. Metal Oxide Semiconductor (MOS) capacitance: C-V characteristics, threshold voltage, body effect. MOSFET: Device structure and operation, common source DC characteristics. FET small-signal equivalent circuit; SPICE level-1 model; Differences between a FET and a BJT	10
6.	Special purpose Devices: Solar cell, Tunnel diode; Gunn diode; IMPATT diode; Varactor Diode; MESFET	6
7.	Recent Developments: Heterojunction FET; Heterojunction Bipolar Transistor	2
	Total	**48**

Text Books/References:

1) Solid State Electronics Devices- Streetman, Banerjee, PHI, New Delhi
2) Semiconductor Physics and Devices – D.A. Neaman, Tata McGraw Hill
3) Physics of semiconductor devices, S. M. Sze, John Willey & Sons, N.Y.
4) Integrated Electronics – Millman & Halkias, TMH
5) Semiconductor Devices-J.Singh

Signals and Systems (ET2104)

L-T-P: 4-0-0 Credit: 4 Full Marks: 100

Sl. No	Module Name and Topics	Class hours
1.	Signals and systems, definitions, classification and representation of signals.	4
2.	Concepts of linear vector space and orthogonal signal representation	4
3	Discrete signals and systems, sampling, digitization and reconstruction of analog signals. State representation.	6
4	**LTI systems**: linearity, causality, stability, impulse response, convolution, transfer function. Signal distortion in transmission, conditions for distortionless transmission.	8
5	Fourier series, Fourier transform and its properties.	6
6	Random variables, random vectors, and random processes, classification, characterization.	6
7	Random signals and their properties, auto and cross-correlation, power spectral density. Thermal and shot noise.	6
8	System response to random signals, functions of random signals.	4
9	An introduction to analog filter design.	4
	Total	**48**

Text Books/References:

1) Signals & Systems- Oppenheim, Willisky &Nawab
2) Principles of Linear Systems and Signals-B.P.Lathi
3) Signals & Systems- S. Haykin
4) Modern digital and analog communication systems- B. P. Lathi

Network Theory Lab (ET2171)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Network Theory (ET2101)

Basic Electronics Lab (ET2172)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Basic Electronics (ET2102)

Electronic Devices Lab (ET2173)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Electronic Devices (ET2103)

Modelling and Simulation Lab (ET2174)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory consists of modeling and simulation based on the concept of Basic Electronics (ET2102), Electronic Devices (ET2103) and Signals and Systems (ET2104)

4th Sem Electronics and Telecommunication Engineering

Analog Electronics (ET2201)

L-T-P: 4-0-0 Credit: 4 Full Marks:100

Sl. No.	Module Name and Topics	Class hours
1	**BJT amplifiers:** Low-frequency small-signal operation of BJT amplifiers (CE, CB, CC); small-signal gain, input resistance, output resistance; high-frequency BJT models; frequency response of single-stage BJT amplifiers. Miller's theorem.	6
2	**MOSFET amplifiers:** Low-frequency small-signal operation of MOSFET amplifiers (CS, CG, CD); small-signal gain, input resistance, output resistance. Cascode amplifiers. High-frequency MOSFET models; frequency response of single-stage MOSFET amplifiers.	8
3	**MOSFET current mirrors:** Voltage-current characteristics, output resistance and minimum sustainable voltage.	2
4	**MOSFET differential amplifiers:** Basic structure and principle of operation, calculation of differential gain, common mode gain, DC offsets, common mode rejection ratio (CMRR) and input common mode range (ICMR).	6
5	**Multistage amplifiers:** Cascaded stage, cascode stage, Darlington pair, Low frequency response and high frequency response of multistage amplifier	4
6	**Tuned amplifiers:** Principle of operation, tuned amplifier circuits, selectivity, instability in tuned amplifiers, stability techniques, use of transformer in tuned amplifier.	3
7	**Feedback:** Basic theory, properties of negative feedback, effect of negative feedback on gain and bandwidth, basic feedback topologies (series-shunt, series-series, shunt-series, shunt-shunt), concept of stability; gain margin and phase margin.	4
8	**Noise:** Device thermal, flicker and shot noise, and their power spectral density. Noise in resistor, BJT and MOSFET. Concept of input referred and output referred noise.	2
9	**Oscillators:** Working principle, Barkhausen criteria, RC oscillators, ring oscillators, LC oscillators, and other oscillator topologies.	5
10	**PLL (phase locked loop) /DLL (delay locked loop):** Need for PLL/DLL, their applications, working principle, overview of different building blocks, loop transfer function, loop stability. Output noise in terms of block noise.	5
11	**Basics of power amplifiers:** Classification of output stages: class A, B, AB, C, D.	3
	Total	**48**

Textbook/References:

1. Sedra and Smith, "Microelectronic Circuits," Oxford University Press
2. Behzad Razavi, "Fundamental of Microelectronics," Wiley
3. Malvino, "Electronic Principles," Tata Mcgraw Hill
4. Millman and Halkias, "Integrated Electronics", Mcgraw Hill
5. R L Boylestad and L Nashelsky, "Electronic Devices and Circuit Theory," Pearson
6. Schilling and Belove, "Electronic Circuits," Mcgraw Hill

Digital Electronics (ET2202)

L-T-P: 4-0-0 Credit: 4 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	Review of Binary Number systems, Logic Gates, Boolean Algebra. Gray Reflected Binary Code. Logic expressions: Standard Sum of products and Standard Product of sums, Logic minimization by Karnaugh map, Quine-McClusky method	4
2	**Combinatorial Logic circuits**: Half adder, Full adder, Half subtractor, Full subtractor, Parallel addition and subtraction for n-bit binary numbers. Realization of Multiplexers, Decoders, De-multiplexers using logic gates. Encoder: Binary to BCD encoder circuit. Cascadable magnitude comparator.	6
3	**Sequential logic circuits**: Flip-flops: NOR based and NAND based S-R flip-flops, Master-Slave flip-flop, Capacitive storage flip-flop. J-K flip-flop, D flip-flop. Race-around Condition. Shift Registers.	6
4	Integrated Injection Logic (IIL). Diode Transistor Logic (DTL): NAND gate realization, Integrated circuit DTL gate, Fan-out of DTL gate. Transistor Transistor Logic (TTL) and its advantage over DTL. Emitter Coupled Logic (ECL).	4
5	**Implementation of digital circuits using CMOS**: Complementary CMOS logic. Pseudo NMOS logic, Dynamic CMOS logic, Domino CMOS, Pass transistor logic, NP Domino logic. CVSL.	4
6	**Counters**: Asynchronous ripple counter, synchronous counter, up, down and controlled up-down counter, loadable up-down counter. Non-binary counters: modulo and arbitrary type. Ring Counter and Johnson counter. Sequence Generator	6
7	Signed binary number system. Controlled adder/subtractor in 1's com and 2's com systems, overflow detection. Carry look-ahead adder.	4
8	Serial processing, parallel processing and pipelining in digital circuits. Serial addition. Binary multiplication: unsigned and signed array multiplier, serial multiplier. Combinatorial shifter. Constant multiplier.	6
9	**Binary division**: serial divider, parallel divider. Concepts of state machines: Mealy and Moore machine, state transition table & diagram	4
10	**Hazards in combinational circuits**: Static and dynamic hazards. Hazards in sequential circuits. Elimination of hazards.	4
	Total	**48**

Text Books/References:

1. Digital Integrated Electronics-Taub, Schilling
2. Computer Arithmetic-Kai Hwang
3. Digital Design, Principles and Practices-John F.Wakerly
4. Switching and Finite Automata Theory-Zvi Kohavi
5. Digital Design-M. Morris Mano
6. CMOS VLSI Design-Weste, Harris, Banerjee

Microelectronics Technology (ET2203)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1.	**IC technology**: introduction, common semiconductor materials, semiconductor measurements.	3
2.	**Preparation of single crystal silicon**: Czochralsky and float zone technique, wafer cleaning	4
3.	**Diffusion**: predeposition, drive in diffusion	4
4.	**Oxidation**: dry and wet oxidation, properties and characterization	4
5.	**Photolithography**: clean room concepts, mask fabrication, proximity and contact printing, repeat and step method, photoresists, yield	4
6.	**Etching**: wet and dry, isotropic and anisotropic	3
7.	**Metallization**: evaporation, sputtering, multilevel metallization, electro migration	3
8.	**Epitaxy**: liquid phase, vapor phase, chemical vapor deposition, plasma deposition.	3
9.	**Ion implantation**: equipment description, principle of operation, electronics and nuclear collision, implant damage and annealing	4
10.	**Bipolar and CMOS processes**: fabrication process flow, isolation techniques, resistor, capacitor and inductor fabrication	4
11.	**MEMS technology**: Bulk and surface micromachining, applications in sensors and RF circuits packaging	4
	Total	**40**

Text Books/References:

1. Fundamentals of Semiconductor Fabrication, G.S.May and S.M.Sze, John Wiley
2. Microchip Manufacturing, Peter Van Zant, Mc Graw Hill
3. Semiconductor Manufacturing Technology, M.Quirk, J.Serda

Electronic Instrumentation and Control (ET2204)

L-T-P: 4-0-0 Credit: 4 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1.	**Basics of measurements**: Static & Dynamic characteristics of an instrument, Errors in measurement-its type, source and minimization techniques, Calibration and standards.	3
2.	**Transducer & Sensor**: Definition, characteristics of transducer & sensor, types of transducers, Starin gauge- resistive & semiconductor, LVDT. Temperature and pressure sensors.	5
3.	**Multimeter**: Analog & Digital type- Galvanometer, ammeter, voltmeter, series and shunt type ohmmeter	2
4.	**Cathode Ray Oscilloscope**: Basic principle, types, CRT, other subsystems, Triggering & Synchronization, Single channel, Dual channel-dual trace & dual beam, Digital Storage Oscilloscope (DSO), Sampling oscilloscope.	4
5.	**Other Measuring Equipments & Instruments**: AC & DC bridges, Digital Tachometer, Universal counter, Q-meter, Spectrum analyzer, Network analyzer. Signal Generator, Function Generator.	5
6.	**Display & Recorders**: Different types of display – LED, LCD, Gas discharge type 7 segment & others, Recorders- objectives & selection for particular application.	3
7.	**Data Acquisition System (DAS)**: Objective, signal conditioning of input, Single channel and Multichannel DAS.	2
8	**Basic concepts of Control**: Notion of feedback, open- and closed-loop systems. Modeling and representations of different control systems: Ordinary differential equations, Transfer functions, Block diagrams, Signal flow graphs,	4
9	**Performance Analysis**: First order, second order and higher order systems, extraction of system parameters, error analysis for various types of inputs, transient analysis.	2
10	**Stability analysis**: Routh-Hurwitz criteria, Root-locus methods, Frequency responses, Polar Plots, Bode-plots, Gain-margin and phase-margin, Nyquist plots	8
11	**Compensator design**: Proportional, PI and PID controllers, Lead-lag compensators.	8
12	**State Space Concepts:** State space representation, solution of state equation of LTI systems, controllability and observability	2
	Total	**48**

Textbook/References:

1. H. Kalsi, Electronic Instrumentation, 2nd Edition, Tata McGraw Hill Publishing, New Delhi.
2. A.D. Helfrick & W. D. Cooper, Modern Electronic Instrumentation & Measurement Techniques, PHI Learning Pvt. Ltd., New Delhi.
3. D. A. Bell, Electronic Instrumentation & Measurement, 3rd Edition, Oxford University Press, New Delhi.,
4. G. Franklin, J.D. Powell and A. Emami-Naeini, Feedback Control of Dynamic Systems,Addison Wesley, 1986.
5. I.J. Nagrath and M. Gopal, Control System Engineering, 2nd Edn.Wiley Eastern, New Delhi, 1982.

6. J.C. Doyle, B.A. Francis and A.R. Tannenbaum, Feedback Control Theory, Maxwell Macmilan International Edn. 1992.
7. C.L. Phillips and R.D. Harbour, Feedback Control Systems, Prentice Hall, 1985
8. B.C. Kuo, Automatic Control Systems, 4th Edn. Prentice Hall of India, New Delhi, 1985.

Electromagnetic Theory and Radio Wave Propagation (ET2205)

L-T-P: 3-0-0 Credit:3 Full Marks-100

Sl. No.	Module Name and Topics	Class hours
1.	**Introduction:** Importance of EM theory, Classifications.	1
2.	**Coordinate systems & Vector calculus:** Rectangular, Cylindrical, Spherical coordinate systems; Gradient, Divergence, Curl and their physical significance in EM theory; Stokes and Divergence theorems.	4
3.	**Electrostatics:** Coulomb's & Gauss's Laws and their Applications, Potential, Continuity Equation, Poisson's & Laplace Equations, Uniqueness Theorem, Boundary Value Problems.	5
4.	**Magnetostatics:** Magnetic Forces, Biot-Savart Law & Ampere's Law and their Applications, Hall Effect.	3
5.	**Electromagnetic Induction:** Faraday's law and its applications.	2
6.	**Maxwell's Equations:** Time Varying Electric and Magnetic Fields, Displacement Current, Maxwell's Equations, Time-harmonic Fields.	3
7.	**Boundary Conditions:** Electric & Magnetic.	3
8.	**Electromagnetic Wave Propagation:** Wave Equations, Plane Wave propagation, Skin Depth, Pointing theorem, Reflection and Refraction of plane waves.	12
9.	**Radio Wave Propagation Modes:** Surface wave, Space wave, Tropospheric Wave, Ionospheric Wave.	7
	Total	**40**

Text Books/References:

1. Elements of electromagnetics - Sadiku
2. Electromagnetic waves and radiating systems - Jordan & Balmain
3. Electromagnetics - Kraus
4. Engineering electromagnetics - Hayt
5. Field and wave electromagnetics - Cheng

Analog Electronics Lab (ET2271)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Analog Electronics (ET2201)

Digital Electronics Lab (ET2272)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Digital Electronics (ET2202)

Microelectronics Technology Lab (ET2273)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Microelectronics (ET2203)

Electronic Instrumentation and Control Lab (ET2274)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Electronic Instrumentation and Control (ET2204)

5th Sem Electronics and Telecommunication Engineering

Integrated Circuits and Systems (ET3101)

L-T-P: 4-0-0 Credit: 4 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	**Introduction to Operational Amplifier (Op Amp)**: Block diagram representation and analysis of equivalent circuits of typical Op Amp. Characteristics of Ideal Op Amp, Inverting and Non inverting configurations for Ideal Op amp.	2
2	**Practical Op Amp in Inverting and Non inverting configurations**: Determination of input resistance, output resistance, open loop gain, bandwidth. Parameters of practical Op Amp: Offset voltage and current, CMRR, PSRR, slew rate.	4
3	**Linear applications of Op Amp**: Sign changer, phase shifter, summing amplifier, voltage to current converter, current to voltage converter, instrumentation amplifier. Analog integrator and differentiator. Electronic Analog Computation, Realization of active RC filters using Op Amp: Butterworth and Chebyshev filter transfer functions and circuits for low pass and high pass filters. Active RC band-pass filter. Band reject filter: Twin-T notch. Delay equalizer. Switched capacitor filters. Schmitt trigger, relaxation oscillator, triangular wave generator, Wien bridge oscillator.	10
4	**Non-linear applications of Op Amp**: Comparators, Sample and hold circuit, precision diode, precision half wave and full wave rectifier, peak detector and average detector. Logarithmic amplifier, antilog amplifier, Analog multiplier and divider.	6
5	Voltage regulator basics, voltage follower regulator, adjustable output regulator, LM317 & LM337 Integrated circuits regulators, Regulated power supply: Basics of Monolithic regulator and Switching regulator	6
6	Integrated circuit timer type 555 as astable and monostable multivibrators	2
7	**Data converters**: Sampling, Quantization. Digital to Analog converters: Weighted resistor, R-2R ladder. Specifications of D/A Converter. Analog to Digital converters: Successive approximation type, counting type, dual slope type, Voltage to frequency converter type, Voltage to time converter type. Flash ADC, Pipelined ADC, Sigma delta ADC, A/D Converter Specifications.	8
8	**Semiconductor memories**: SRAM and DRAM: MOS cell, array architecture, decoding and column circuit, BJT cell. Programmable ROM, Serial Access Memory, Content Addressable Memory, Charged Coupled Device, Memory Hybrids and Multi-Chip Modules (MCMs), Introduction to Memristors (Brief Overview).	6
9	Application Specific Integrated Circuit: An Introduction. Programmable Logic Arrays: Pseudo-nMOS, Dynamic PLA. Field Programmable Gate Array: Configurable Logic Block, Input Output Block, Routing Channel of FPGA.	4
	Total	**48**

Text Books/References:

1. Digital Integrated Electronics-Taub, Schilling, McGraw Hill India
2. Op-Amps and Liner Integrated Circuits – Ramakant A Gayakwad, Pearson

3. Integrated Electronics- Millman, Halkias, Tata McGraw-Hill Education
4. CMOS VLSI Design-Weste, Harris, Banerjee, Pearson
5. Application Specific Integrated Circuits by J. Smith, Pearson

Analog and Digital Communications (ET3102)

L-T-P: 4-0-0 Credit: 4 Full Marks: 100

Sl. No	Module Name and topics	Class hours
1.	**Introduction**: Elements of an electronic communication system, Modulation: necessity and types	2
2.	**Amplitude modulation and demodulation schemes**: DSB/ SSB/ VSB spectral analysis	4
3	**Angle modulation and demodulation systems**: narrowband, wideband, spectral analysis	6
4	**Channel noise**: types, modelling, SNR analysis of amplitude modulation and angle modulation in presence of channel noise	5
5	Elements of digital communication systems, advantages; Sampling theorem	2
6	PCM, DPCM, DM	4
7	**Base band transmission and reception**: line codes, ISI and its control, matched filter, MAP and ML	10
8	**Digital modulation demodulation techniques**: ASK, FSK, PSK, DPSK, QAM	4
9	Spectral analysis and probability of error calculation of digital modulation schemes : ASK, PSK, FSK	4
10	**Elements of information theory**: Measure of information, entropy, mutual information	3
11	Source-coding and channel-coding theorems	2
12	**Introduction to Error Correcting Codes**: importance, classification; linear block codes	2
	Total	**48**

Text Books/References:

1. Modern digital and analog communication systems- Lathi
2. Principles of communication system-Taub, Schilling
3. Electronic communication system- Kennedy
4. Communication Systems- Simon Haykin,

Transmission Lines and Antennas (ET3103)

L-T-P: 4-0-0 Credit: 4 Full Marks-100

Sl. No.	Module Name and Topics	Class hours
1	**Transmission Lines:** Brief Layout and Applications, Parameters, Equivalent Circuit, Equations, Characteristic Impedance, Input Impedance, Distortion-less Line, Reflection, Standing Wave, RF Lines as Circuit Elements, Impedance Matching.	13
2	**Smith chart:** Smith Chart Theory and Applications.	4
3	**Guided Waves and Wave Guide:** Parallel Plane Wave-Guide, Rectangular / Circular Waveguide, TE and TM Modes, Wave Impedance.	7
4.	**Antenna Concepts and Parameters:** Source of Radiation, Retarded Potential, Radiation Pattern, Beam-width, Directivity, Gain, Radiation Resistance, Effective Aperture, Effective Height, Friis Transmission Formula.	4
5.	**Fields and Properties:** Hertzian Dipole, Half-wave Dipole, Loop Antenna, Horn Antenna.	10
6.	**Analysis of Arrays:** Broad-side and End-fire Array, Pattern Multiplication, Yagi-Uda Array.	4
7.	**Microstrip Antennas:** Basic characteristics, Feeding methods, Methods of analysis, Design of rectangular and circular patch antennas	4
8	**Antenna Measurement:** Gain, Radiation pattern, Basics of Anechoic chamber	2
	TOTAL	**48**

Text Books/References:

1. Electromagnetic waves and radiating systems- Jordan & Balmain
2. Elements of Electromagnetics- Sadiku
3. Electromagnetics- Kraus
4. Antennas – J.D. Kraus
5. Antenna Theory – C.A. Balanis

Microprocessors and Microcontrollers (ET3104)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	**Introduction with 8085 and 8086 architecture**: Functional diagram, Register organization, Memory segmentation, Programming model, Memory addressing, Physical memory organization, Signal descriptions of 8086-common function signals, timing diagrams.	6
2	**Instruction set and assembly language programming of 8085 and 8086**: Instruction formats. Addressing modes, instruction set assembler directives. Macros, Simple programs involving logical, branch and call instructions. Sorting, evaluating arithmetic expressions, string manipulations.	6
3	**Interrupts of 8085 and 8086**	4
4	**I/O Interface**: 8255 PPI, various modes of operation and interfacing to 8086, interfacing of key board, display. Stepper motor interfacing, D/A &A/D converter.	4
5	**Interfacing with advanced devices**: PPI, KEYBOARD, USART, DMA controller, interrupt controller, programmable timer, CRT controller Standard interfaces like RS-232C, USB.	2
6	**Communication Interface**: Serial communication standards, Serial data transfer schemes. 8251 USART architecture and interfacing. RS- 232. IEEE-4-88, Prototyping and trouble shooting.	2
7	**Intel 80386 and Pentium:** Key features of Intel 80386 - internal architecture of 80386 - operating modes - paging mechanism -address translation in PVAM (non-paged and paged modes) - features of Pentium processor – internal architecture of Pentium processor - list of operating modes - features of Pentium Pro processor.	6
8	**Introduction to microcontrollers**: overview of 8051 microcontroller, Architecture, I/O ports, Memory organization, addressing modes and instruction set of 8051, Simple programs. Programming Timer interrupts, programming external hardware interrupts, and Programming the serial communication interrupts, Programming 8051 timers and counters.	6
9	**8051 Interfacing:** LCD interfacing, Keyboard interfacing. ADC 0808 interfacing to 8051, Serial ADC Max1112 ADC interfaces to 8051, DAC interfacing, Sensor interfacing and signal conditioning. Relay, PWM, DC and stepper motor: Relays and opt isolators, stepper motor interfacing, DC motor interfacing and PWM. 8051 interfacing with 8255: Programming the 8255, 8255 interfacing, C programming for 8255.	4
	Total	**40**

Text Books/References:

1. Microprocessor architecture, programming and application with the 8085- Gaonkar, Pearson
2. 8086/8088 family (Design, programming & inteface)- Uffenbeck, Pearson
3. 8088 & 8086 microprocessors (Programming, interfacing, software, hardware and application)- Triebel & Singh, Pearson
4. D. V. Hall, "Microprocessor and Interfacing Programming & Hardware" TMH

Data Structures and Algorithms (ET 3105)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1.	**Introduction:** ADT - concepts, data structure and ADT, properties applicable for ADT. Notion of algorithm, pseudo code conventions, Performance analysis, Time and space complexities, Asymptotic notation, Big oh notation, omega notation, theta notation, Average and worst case analysis, Probabilistic analysis, Amortized analysis.	4
2.	**Linked Lists:** Linear linked list, circular linked list, doubly linked list, Multi-list, applications	2
3.	**Stacks, Queues and Trees:** Stacks and queues - Concepts and applications, Single Ended and Double Ended queues. Trees - Binary trees. Properties, Binary tree traversals, Expression trees, Conversion from general tree to binary tree. Binary Search Trees and operations on BST, Height balanced tree – AVL tree, Bit tree, Hashing	10
4.	**Graph:** Representations of Graph, Graph traversal and its applications	4
6	**Recurrence and Recursion:** Recurrence relations, Divide and conquer relations, Solving of recurrences by iteration method and substitution method, Master theorem, Design of recursive algorithms	6
7	**Sorting and Searching:** Insertion sorts, Exchange sorts, Selection sort, Quick sort, Merge sort, Distribution sort. Comparisons of different sorting algorithms. Sequential search, Binary search, Interpolation search and comparisons	8
8	**Algorithm Design Techniques:** Divide and conquer strategy with examples, Greedy strategy, Huffman coding algorithm & Data structures of disjoint sets, Knapsack Problem & Single source shortest path. Dynamic programming: Principle of optimality, General Dynamic Programming Algorithm, Optimal binary search trees	6
	Total	**40**

Text Books/References:

1. Fundamentals of Data Structures in C, by E. Horowitz, S. Sahani and S. Anderson-Freed, Universities Press
2. Introduction to Algorithms, by T. H. Corman , C.E. Leiserson, R. L. Rivest, MIT Press
3. The Art of Computer Programming, by Donald E. Knuth, Addison-Wesley Professional

Integrated Circuits and Systems Lab (ET3171)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Integrated Circuits and Systems (ET3101)

Analog and Digital Communications Lab (ET3172)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Analog and Digital Communications (ET3102)

Transmission Lines and Antennas Lab (ET3173)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Transmission Lines and Antennas (ET3103)

Microprocessors and Microcontrollers Lab (ET3174)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Microprocessors and Microcontrollers (ET3104)

6th Sem Electronics and Telecommunication Engineering

Digital Signal Processing (ET3201)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No	Module Name and Topics	Class hours
1	**Introduction:** Introduction to DSP with its advantages and disadvantages, Elementary discrete time signals and systems, Memory-less systems, Linear systems, Time-invariant systems, casualty, stability.	2
2	**Discrete-Time LTI Systems:** Input output relation, Linear convolution, Properties of LTI system, Difference equations, and Eigen functions of LTI systems.	2
3	**Transform Domain LTI System:** Frequency response of LTI system, Frequency response for rational system function, All pass system, Minimum Phase system, and Linear systems with generalized linear phase, Discrete Time Fourier Transform (DTFT) and its properties, Parseval's relation.	6
4	**Z-transform:** Importance of Z-transform in DSP, Relationship between Z-transform and DTFT, Properties of Z-transform, Inverse Z-transform.	4
6	**Digital filter:** Basics of digital filter, Classification of digital filter based on architecture and frequency response	4
7	**Finite Impulse Response (FIR) filter:** Linear-phase design of FIR filter, Window method, Frequency sampling method, Parks-McClellan algorithm	4
8	**Infinite Impulse Response (IIR) filter:** Design strategy of IIR filter-Butterworth and Chebyshev approximation of IIR filter using Approximation of derivatives, Impulse invariance and Bilinear transformation method	6
9	**Filter structure:** Direct form I, Direct form II, Cascade form, Parallel form.	4
10	**DFT and FFT:** DTFT and its Properties of DFT, Circular Convolution, Linear convolution using DFT, Algorithm for fast DFT computation, FFT, Decimation in Time, Decimation in frequency.	8
	Total	**40**

Text Books/References:

1. Digital Signal Processing: A Computer-based Approach, S.K. Mitra, McGraw-Hill, 2001.
2. Digital Filters: Analysis, Design and Applications, A. Antoniou, McGraw-Hill, 2001.
3. Digital Signal Processing: Theory, Analysis and Digital-filter Design, B. Somanathan Nair, Prentice-Hall, 2004.
4. Discrete Time Signal Processing, Oppenheim, Schafer, Buck Pearson

VLSI and CAD (ET3202)

L-T-P: 4-0-0 Credit: 4 Full Marks: 100

SL. No.	Module Name and Topics	Class hours
1	**Introduction to VLSI**: Role of CAD in VLSI. Classification of VLSI: digital, analog, mixed signal. Basics of digital VLSI design, synchronous and asynchronous system design.	2
2	**VLSI Design Flow**: The various steps of design flow, system specification, hierarchical design.	2
3	**VHDL**: Syntax, Hierarchical modeling, simulator directives, instantiating modules, gate level modeling.	4
4	**Verilog**: Syntax, Hierarchical modeling, simulator directives, instantiating modules, gate level modeling.	4
5	CMOS layout design rule, Gate layout, Stick diagram	2
6	**Delay modeling**: RC delay model, linear delay model, logical efforts, timing analysis.	4
7	**Circuit Simulation**: Device Model, Device Characterization, Circuit Characterization.	4
8	**Case Study**: CORDIC Algorithm, VLSI architecture design of (i) Serial CORDIC processor (i) Parallel CORDIC processor	6
9	**Case Study**: VLSI architecture design of a (i) Serial FFT processor (ii) Parallel FFT processor (ii) Running DFT Processor	6
10	**Introduction to VLSI Physical design**: Steps of VLSI Physical design processes, Partitioning: Kernighan-Lin (K-L) method, F-M Partitioning Method, ratio-cut method, Floorplanning: Slicing and Non-slicing floor planning, Simulated annealing method, Routing: Maze routing, Line-search method, Global routing and Channel routing.	8
11	Array compilers, hardware software co-design, overview of high-level synthesis tools (HLS), Overview of System on Chip	2
12	**VLSI Testing**: Fundamentals of VLSI testing. Automatic test pattern generation. Design for testability. Scan design. Test interface and boundary scan. BIST for testing of logic and memories. Test automation.	4
	Total	**48**

Text Books/References:

1.CMOS Digital Integrated Circuits, S.M.Kang and Y.Leblebici.
2.VLSI Design Techniques for Analog and Digital Circuits, Geiger, Allen and Strader.
3.Digital Integrated Circuits, Rebaey.
4.Introduction to Digital Systems, Ercegovac, Land and Moreno.
5.CMOS VLSI Design, Weste, Harris and Banerjee
6. The VLSI Handbook, Wai Kai Chen, IEEE and CRC press
7. An introduction to VLSI Physical Design by Majid Sarrafzadeh

Wireless and Mobile Communications (ET3203)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	**Evolution of mobile radio communication**: Brief history; overview of wireless generations-1G, 2G, 3G, 4G and 5G (services, key technologies and regulatory issues); 6G vision and requirements	4
2	**Introduction and Basic Cellular System Design:** , Cellular concept, Cellular systems, Frequency -reuse, Co-channel interference and its reduction, GOS, Frequency spectrum utilization, Traffic and channel assignments, Various handoff strategies, Dropped call rate, Leaky feeders, Brief introduction to cellular switching and traffic,	4
3	**Path Loss Models for Mobile Radio Propagation:** Point to Point Propagation Model, Foliage loss, Base Station Antenna Design issues, Free space propagation model, Reflection, Diffraction analysis using Fresnel Zone geometry and Knife Edge diffraction model, Outdoor propagation models, Indoor propagation models, Signal penetration into buildings.	4
4	**Small Scale Fading and Multipath:** Causes of fading, Reciprocity theorem, Amplitude and Selective fading, Doppler shift, Impulse response model of multipath channel, Doppler spread and coherence time, Types of small scale fading, Rayleigh and Rician distributions, Statistical analysis of Multipath fading channels, Fading behavior analysis using channel models, Bit error rate and word error rate in fading environment.	4
5	**Modulation Techniques :** Review of BPSK, QPSK, BFSK; GMSK and QAM; Spread Spectrum Modulation-DSSS, FHSS; Multicarrier modulation-OFDM	6
6	**Wireless Link Improvement Techniques:** Equalization, Diversity, Error Correcting Codes- Block Error Correction Codes, Convolution Codes, overview of Turbo and LDPC codes	8
7	**Multiple Access in Wireless System:** Frequency division multiple access, Time division multiple access, Code division multiple access, Space division multiple access, Random access, ALOHA, S-ALOHA, CSMA-CA	6
8	**LTE and LTE**-A for Mobile Broadband: Basic Transmission-reception scheme, overview of multiantenna transmission, spectrum flexibility, power control and interference management,	2
9	**Energy-Efficient (Green) Wireless Communications:** Importance of Energy-efficiency in Wireless Communications (economic and environmental perspectives); Technical issues in green communications	2
	Total	**40**

Text Books/References:

1.Wireless Communication : Theodore S. Rappaport, Second Edition, Pearson.
2.Wireless Communications : Andrea Goldmsith, Cambridge University Press
3. Modern Wireless Communications : Simon Haykin, Michael Moher, Indian Edition,2011

Computer and Communication Networks (ET3204)

L-T-P: 4-0-0 Credit: 4 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	**Introduction** to Communication Networks and Services**:** Data communication components, Data representation; network architectures; protocol layers, and their service models (OSI and TCP/IP models)	5
2	**Principles of network applications**: Remote logging, electronic mail, file sharing; HTTP and WWW, ISP and Domain name systems (DNS), Simple network management protocol(SNMP)	8
3	**Reliable and unreliable transport-layer protocols**: TCP and UDP, port numbers; multiplexing and demultiplexing; flow control and congestion control, fairness; delay, jitter, and loss in packet-switched networks, bandwidth, throughput, and quality-of-service	8
4	**Network layer services and protocols**: Switching fabric; routing and forwarding; queues and buffering; virtual circuit and datagram networks; internet protocol (IP):IPv4, IPv6; link state and distance vector algorithms; routing in the internet: RIP, OSPF, BGP; broadcast and multicast routing schemes	8
5	**Link layers services and protocols:** services at link layer; Ethernet, hubs, bridges, and switches, link layer addressing; error detection and correction; multiple access protocols: channelized access-TDMA, FDMA, CDMA, random access-ALOHA, S-ALOHA, CSMA, CSMA/CD, CSMA/CA	9
6	**Physical-layer services and systems**: types of physical media-Coax, fiber, twisted pair, DSL, HFC; overview of transmission and reception techniques in WiFi, low power wireless networks (LoWPAN); bit transmission and reception-modulation, multiplexing, equalization and synchronization	10
	Total	**48**

Textbooks/ Reference Books:

1. Computer Networking: A Top-Down Approach, by J. F. Kurose and K. W. Ross, Pearson India 6th Edition
2. Computer Networks: A Systems Approach, fifth edition, by Larry Peterson and Bruce Davie, Morgan Kaufmann Publishers, 5th Edition, 2011
3. Data Communication and Networking, by B. A. Forouzan, McGraw Hill Education; Fifth edition, 2017

Computer Organization and Architecture (ET3205)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	**Organization of Computers:** 1) Different Subsystems of Computing System: CPU, memory, input-output subsystems, ALU and control unit, hardwired control unit, micro-programmed control unit. 2) Instruction Set Representation: Machine instructions, addressing modes, operands, instruction formats, instruction execution cycle, Case study - instruction sets of some common CPUs. 3) Instruction Set Architectures:, RTL interpretation of instructions, CISC and RISC architectures. ARM Instruction sets.	10
2	**Memory System Design**: 1) Internal Organization of a memory chip, organization of a memory unit, error correction memories, interleaved memories. 2) Concepts of cache memory, mapping methods, fetch and write mechanisms. 3) Memory management unit - Concept of virtual memory, address translation, hardware support for memory management 4) Secondary Storage (Magnetic HDD, Optical Disk and Magnetic Tape)	10
3	**Input/ Output Subsystem:** Input-output subsystems, I/O transfers - program controlled, interrupt driven and DMA, privileged and non-privileged instructions, software interrupts and exceptions. Programs and processes - role of interrupts in process state transitions.	8
5.	**Introduction to multicore processors:** Hyper threading technology - define core -limitations of single core processor - concept of multi core processing advantages - homogeneous and heterogeneous multicore processors - single core and multicore processors comparison - major issues in multicore processing- important technological features of IA processors .	4
4	**Some Performance Enhancement Concepts**: 1) Basic concepts of pipelining, throughput and speedup, pipeline hazards. floating point arithmetic processor, linear and nonlinear pipeline processor, superscalar pipeline 2) Parallel Processing and related performance enhancements. 3) Warehouse-scale Computers 4) Multithreaded Processors	8
	Total	**40**

Text Books/References:

1. Computer Architecture by Hennessy and Patterson, Morgan Kaufman Publishers.
2. Advanced Computer Architecture – Hwang, McGraw-Hill Education.
3. Computer Architecture and Organization- Hays, McGraw Hill Education.
4. Computer Organization – Hamacher, Vranesik and Zaky, McGraw Hill Education

Digital Signal Processing Lab (ET3271)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Digital Signal Processing (ET3201)

VLSI and CAD Lab (ET4172)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of VLSI and CAD (ET3202)

Wireless Communication and Networking Lab (ET3273)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory courses of Wireless and Mobile Communications (ET3203), Computer and Communication Networks (ET3204).

7th Sem Electronics and Telecommunication Engineering

Digital Image Processing and Computer Vision (ET4101)

L-T-S: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	**Introduction:** Light, Brightness adaption and discrimination, Co-ordinate conventions, Sampling and quantization, Pixels	2
2	**Point Processing Techniques:** Point processing and structural processing, Different point processing operations, Histograms, Histogram equalization	4
3	**Image Segmentation:** Boundary detection, Point line detection, Edge detection, Hough transform, Thresholding, Iterative thresholding, Otsu's method, Region-based segmentation, Watershed algorithm	6
4	**Spatial Domain Filtering:** 2-dimensional filtering, Mean filtering, Median filtering, Outlier method, Gaussian filter	2
5	**Filtering in the Frequency domain:** Fourier transform and its properties in 2 dimension, FFT (decimation in time and decimation in frequency), Convolution, Correlation, Frequency domain filtering	2
6	**Image Restoration:** Basic framework, Restoration techniques, Noise characterization, Noise restoration filters, Adaptive filters, Estimation of degradation functions, Restoration from projections	6
7	**Image Compression:** Encoder-decoder model, Types of redundancies, Lossless and lossy compression, Huffman, Arithmetic, Golomb, LZ and Run length coding, FAX compression (CCITT Group-3 and Group-4), Symbol-based coding, JBIG-2, Bit-plane encoding, Bit-allocation, Zonal coding, Threshold coding, JPEG, Lossless predictive coding, Lossy predictive coding	8
8	**Wavelet-based Image Compression:** Expansion of functions, Multi-resolution analysis, Scaling functions, MRA refinement equation, Wavelet series expansion, Discrete Wavelet Transform (DWT), Fast Wavelet Transform, 2-D Wavelet Transform, Digital image watermarking	4
9	**Morphological Image Processing:** Fundamentals of morphological operations, Erosion, Dilation, Opening, Closing, Thinning, Thickening, Hit-or-miss transform, Boundary detection, Connected components, Skeletons	4
10	**Color Models:** RGB, HSV, YIQ	2
	Total	**40**

Text Books/References:

1. R. C. Gonzalez and R. E. Woods, Digital Image Processing, Pearson Education, 2002.
2. A. K. Jain, Fundamentals of Digital Image Processing, Prentice Hall, 1989.

Microwave and Radar Engineering (ET4102)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	**Microwave System**: Introduction, Features, Different frequency bands of microwave and their applications	2
2	**Generation of Microwave by Vacuum tubes**: High frequency limitations of conventional tubes, Two cavity klystron amplifier, Reflex klystron, Magnetron, slow wave structures, Traveling Wave Tubes – forward & backward.	6
3	**Reciprocal type Passive components**: Waveguide attenuators, Matched load, Phase changer, Waveguide tees – H-plane & E-plane, Magic Tee, Directional couplers, Waveguide irises, bends, twists, taper, Waveguide filters.	6
4	**Nonreciprocal ferrite devices**: Faraday rotation in ferrites, Isolator, Circulator, Gyrator and their applications.	4
5	**Microwave Measurements**: Detection of microwave signal, Measurement of power, frequency, attenuation, cavity Q, noise factor, dielectric constant. VSWR measurement – slotted waveguide & reflectometer technique.	6
6	**Microwave Integrated Circuits**: Materials for MICs, Planar transmission line – strip line, micro-strip line, slot line, coplanar line. Fabrication of different passive components on MIC. Power combiner, design of amplifiers using solid state devices.	5
7	**EMI and EMC**: Occurrence of EMI, Various EMI standards, Methods of eliminating EMI, Testing and test facility of EMI.	5
8	**Radar technology**: Radar range equation, Pulsed radar system, CW radar, MTI radar, radar display, different scanning and tracking techniques, System losses, Monopulse radar, Phased array radar, Radome and Rotadome.	6
	Total	**40**

Text Books/References:

1. Microwave Devices & Circuits , S.Y. Liao, Prentice Hall of India, New Delhi.
2. Introduction to Radar System, M. I. Skolnik, Tata McGraw Hill Book Co., New Delhi
3. Microwave Engineering , D. M. Pozar, John Willey & Sons Inc., New York.
4. Microwave Engineering: Passive, Active and Nonreciprocal Circuits, J. Hellszoin, McGraw Hill International Edition.

Digital Image Processing and Computer Vision Lab (ET4171)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Digital Image Processing and Computer Vision (ET4101)

Microwave and Radar Engineering Lab (ET3272)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Microwave and Radar Engineering (ET4102)

B. Tech. Project Part I (ET4191)

L-T-P: 0-0-3 Credit: 4 Full Marks: 100

In the 7th semester students normally in groups of three or four will be assigned a project work on an appropriate topic related to this branch of engineering. All the groups will carry out a review work on the project topic, prepare a report and give an oral presentation of these introductory studies.

Internship (Evaluation) (ET4192)

L-T-P: 0-0-0 Credit: 2 Full Marks: 50

The students will submit a report and give a seminar on 6th semester summer training.

DEP ELECTIVE-I

Adaptive Signal Processing (ET4121)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	**Adaptive systems:** Definitions and characteristics - applications – properties-examples - adaptive linear combiner input signal and weight vectors - performance function-gradient and minimum mean square error - introduction to filtering-smoothing and prediction - linear optimum filtering-orthogonality - Wiener – Hopf equation.	4
2	**Searching performance surface-stability and rate of convergence:** Learning curve-gradient search - Newton's method - method of steepest descent - comparison - Gradient estimation - performance penalty - variance - excess MSE and time constants – mis-adjustments.	4
3	**Least mean squares adaptive filter**: LMS adaptive algorithm, Properties of LMS adaptive filter, Normalized forms, Finite precision effects, Adaptive beam forming.	4
4	**Transform domain adaptive filters**: Block Adaptive Filters, Fast LMS Algorithm, Un-constrained Frequency Domain Adaptive Filtering, Self-Orthogonalising Adaptive Filters, Adaptive lattice filters.	6
5	**Adaptive Multirate signal processing:** Decimation and interpolation, Filters in sampling rate alteration systems, Polyphase decomposition and efficient structures, Digital filter banks.	6
6	**Least squares adaptive filters:** Godard algorithm, Lattice, Recursive Least Squares (RLS) adaptive filtering.	4
7	**Overview of Non-Linear Adaptive Filtering:** Blind Deconvolution, Back Propagation Learning.	4
9	**Realization of Adaptive Filters**: Pipelining of adaptive digital filters, pipelined adaptive lattice architectures, VLSI architectures for adaptive FIR filter systems. A case study: Realization of a transform domain adaptive equalizer.	8
	Total	**40**

Text Books/References:

1. Haykin, Simon S. Adaptive filter theory. Pearson Education India, 2005.
2. Widrow, Bernard, and Samuel D. Stearns. "Adaptive Signal Processing Prentice-Hall." Englewood Cliffs, NJ (1985).
3. Alexander, Thomas S. Adaptive signal processing: theory and applications. Springer Science & Business Media, 2012.
4. Vaidyanathan, Parishwad P. Multirate systems and filter banks. Pearson Education India, 2006.
5. Naresh Shanbhag, K.K. Parhi, "Pipelined Adaptive Digital Filters": Kluwer Academic Publishers.

Principles of Electromagnetic Compatibility (ET4122)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Name and Topics	Class hours
1	**Introduction, Standards:** Electromagnetic environment - natural noise, man-made noise, CW and transient sources, home environment, practical examples, Aspects of EMC, Decibels and Common EMC Units, Current Standards	10
2	**Requirements for Electronic Systems**: EMC Requirements for Commercial Products, Requirements for Military Products, Design Constraints for Products, Advantage of EMC design	4
3	**Behavior of Circuit Components:** Wires, resistors, capacitors, inductors, Effect of Component Leads, Mechanical Switches, Transmission lines, Printed Circuit Board (PCB) lines.	10
4	**Signal Wave form & Spectral Analysis:** Energy signal, Power signal, Basic Principles of spectrum analyzer	4
5	**Conducted & Radiated Emissions:** Concepts, Simple emission model, Measurement of Conducted & Radiated Emissions	6
6	**Crosstalk & Shielding:** Transmission lines & Crosstalk, Electric and magnetic field shielding.	6
	Total	**40**

Text Books/References:

1. Introduction to Electromagnetic Compatibility- Clayton R. Paul
2. Applied Electromagnetics and Electromagnetic Compatibility- D.L. Sengupta and Valdis V. Liepa
3. Engineering Electromagnetic Compatibility – V.P. Kodali

IoT and Embedded Systems (ET4123)

L-T-P: 3-0-0 Credit: 3 Full Marks-100

Sl. No.	Module Name and Topics	Class hours
1	Introduction and Examples of Embedded Systems, Concept of Embedded System Design: Design challenge, Processor technology, IC technology, Design technology, Trade-offs,	2
2	Terminology - Gates - Timing diagram – Memory Microprocessor buses - Direct memory access Interrupts – Built interrupts - Interrupts basis - Shared data problems Interrupt latency – Embedded system evolution trends - Round robin- Round robin with interrupt function Rescheduling architecture - algorithm.	4
3	**Concept of Real Time Operating System:** Task and Task states - Task and data - Semaphore and shared data operating system services - Message queues timing functions - Events - Memory management - Interrupt routines in an RTOS Environment - Basic design using RTOS.	6
4	**Embedded Hardware, Software and Peripherals:** Peripheral-Processor Interfacing Concepts - Review of Peripheral Interface protocols - SPI, I2C, UART, AXI and One-wire with case studies of interface with Sensors, Radio and ADCs. Hardware Timers and Interrupt handling, Interrupt service routines. Software Development environment.	6
5	**Advanced Processors/Controllers:** Introduction to ARM CPU Architecture, Programmers Model for ARM CPU, Operating Modes , Instruction set, ARM Exception Handling , Pipelining, Comparative Study of ARM cores – ARMv4 to ARM Cortex	4
6	**Memory and Interfacing:** Memory: Memory write ability and storage performance - Memory types - composing memory Advance RAM interfacing communication basic - Microprocessor interfacing I/O addressing Interrupts - Direct memory access – Arbitration multilevel bus architecture - Serial protocol -Parallel protocols - Wireless protocols - Digital camera example.	4
7	**Embedded Systems in the context of IoT:** Overview of Internet of Things (IoT) and Industrial IoT (IIoT), Role of embedded systems in IoT, challenges of designing embedded IoT hardware, optimization of the performance of embedded IoT, role of analytics in optimizing embedded IIoT, introduction to embedded cyber security and data security.	6
8	**Software and Hardware Components of IoT Components:** Hardware Components- computing (Node MCU, Raspberry Pi, etc.), communication, sensing, actuation, I/O interfaces; Software Components - programming APIs (using Python/Node.js/Arduino), communication and application protocols (e.g., MQTT, ZigBee, BLE);	4
9	**Case Studies:** IoT case studies: Industrial automation /Transportation/Agriculture/Healthcare/Home Automation	4
	Total	**40**

Text Books/ References:

1. David E Simon, “An embedded software primer ", Pearson education Asia, 2001.
2. Raj Kamal, “Embedded Systems- Architecture, Programming and Design” Tata McGraw Hill, 2006.
3. J.W. Valvano, "Embedded Micro-computor System: Real Time Interfacing"
4. Jack Ganssle, "The Art of Designing Embedded Systems", Newnes, 1999.
5. “The Internet of Things” by Samuel Greengard
6. “Internet of Things: Architectures and Design Principles” by Raj Kamal
7. Vijay Madisetti, Arshdeep Bahga, "Internet of Things - A Hands on Approach", University Press.

8th Sem Electronics and Telecommunication Engineering

Optoelectronics and Optical Communication (ET4201)

L-T-P: 3-0-0 Credit: 3 Full Marks:100

Sl. No.	Module Name and Topics	Class hours
1	**Black body radiation**: Planck's Law, Einstein's A & B coefficients, line-shape, optical gain, three and four level system, gain saturation; Optical Amplifier: optical pumping, noises in optical amplifier, Fabrey-Perot cavity, Lasers, output power from laser, EDFA.	6
2	**Semiconductor laser**: recombination process, material property of III-V semiconductor, E-K diagram, density of states, optical emission, gain, quasi Fermi level and inversion, Homojunction, heterojunction and QW Laser, modulation rate in semiconductor laser.	6
3	**Detection process**: noises, SNR, background radiation, Johnson noise, Dark current noise, 1/f noise, combined effect of all noise, Digital signal and BER, coherent detection. Optical detector: Negative electron affinity detector, characteristics parameters of external photoeffect detector, photo conductive detector, pn junction detector, quantum efficiency, PIN, noise in p-n and PIN, spectral characteristics, APD, commercial optical detection, Figures of merit of photodetectors (Responsivity, Q.E., Long wavelength cut-off, Noise equivalent power (NEP), Speed of Response, Bandwidth).	8
4	**Dispersion**: total dispersion, single mode waveguide dispersion, dispersion management, fiber fabrication process and measurement technique like OTDR, Attenuation, Scattering; Wavelength Division Multiplexing (WDM): principles of operations, various WDM components, Figures of Merit, specialty of DWDM, All optical MUX & DEMUX.	4
5	**Planar slab waveguide**: infinite slab waveguide, EM analysis, wave vector, modes, mode confinement, symmetric and asymmetric waveguide, properties of mode, number of guided modes, numerical aperture. Modes in rectangular waveguide. Circular waveguide: wave equation in cylindrical coordinate, solution, field distribution in step index fiber, V number, modes, Single mode and multimode fiber, LP and HE mode, power confinement	8
6	**Couple mode theory**: derivation of coupling equation using ideal mode, non-degenerate mode coupling, intermode coupling, degenerate mode coupling, Crosstalk.	8
	Total	**40**

Textbook/References:

1. Fundamentals of optoelectronics- Clifford R. Pollock
2. Introduction to Fiber optics- Ajoy K. Ghatak
3. Optical fiber communication- Gerd Keiser

Optoelectronics and Optical Communication lab (ET4271)

L-T-P: 0-0-3 Credit: 2 Full Marks-50

This laboratory is based on the theory course of Optoelectronics and Optical Communication (ET4201)

B. Tech. Project Part II (ET4291)

L-T-P: 0-0-6 Credit: 8 Full Marks: 200

This sessional work entails carrying out a project work and presentation of a thesis based on project work done. The project work will involve a review work which is already completed by the project group in B.Tech Project I (ET4191), planning/design/construction and testing/software development/experimentation on the problems already assigned to the students in the 7^{th} Semester. Every student will be required to submit the thesis before the evaluation of his/her performance in the sessional work.

Seminar (ET4292)

L-T-P: 0-0-0 Credit: 2 Full Marks: 50

A seminar is organized where the students have to present his work to evaluate their performance in B.Tech Project (ET4291) after taking an oral representation on project work done.

Comprehensive Viva Voce (ET4293)

L-T-P: 0-0-0 Credit: 2 Full Marks: 100

A viva voce test for the students will be taken at the end of 8^{th} Semester to evaluate their depth of knowledge and level of understanding of different subjects studied by them in this field of engineering.

DEP ELECTIVE-II

Green Communications (ET4221)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Names and Topics	Class hours
1.	**Introduction:** Key concept, environmental and economic motivations; categorization of green communication concepts; energy efficiency metrics and performance tradeoffs of green wireless networks	4
2.	**Modeling Embodied Energy for Communication Devices**: Approaches to reduce ict energy consumption, embodied energy and its meaning in ICT technology, embodied energy assessment of an ICT equipment, total energy consumption model; Case Study :embodied/operating energy of a BS in cellular network	6
3.	**Energy Efficiency in Wireline Networks** : routing, switching and transport Ethernet, brief overview of energy efficient Ethernet, green optical networks	6
4.	Energy efficient networking in data centers	4
5.	Energy efficient standards for wireline communication	2
6.	**Energy Efficient Wireless Communication-Part-1**: Energy efficiency metrics for green wireless communications; techniques for improving base station energy efficiency: sleep mode, femtocell and relaying techniques, multiple antennas	6
7.	**Energy Efficient Wireless Communication-Part-II**: Network Planning and management for green operation	6
8.	**Energy Efficient Wireless Communication-Part-III**: Standardization activities in for energy efficient wireless communication in 3GPP and IoT communications	6
	Total	**40**

Text Books/References:

1. Green Communications: Principles, Concepts, and Practice, Konstantinos Samdanis by (Editor), Peter Rost (Editor), Andreas Maeder (Editor), Michela Meo (Editor), Christos Verikoukis (Editor), Wiley publications, 2015.
2. Green Radio Communication Networks, by Ekram Hossain (Editor), Vijay K. Bhargava (Editor), Gerhard P. Fettweis (Editor), Cambridge University press, 2012
3. Green Communications: Theoretical Fundamentals, Algorithms, and Applications, by Jinsong Wu (Editor), Sundeep Rangan (Editor), Honggang Zhang (Editor), CRC press, 2012.

Sensors and Actuators for Electronic Applications (ET4222)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Names and Topics	Class hours
1	**Basics of Sensors and Actuators:** Introduction, Classification of Sensors and Actuators, Static and Dynamic Characterization, Calibration of Sensors and Actuators	4
2	**Fabrication Technologies:** Micromechanical Process Design, Bulk Micromachining, Surface Micromachining, Non-lithographic patterning	5
3	**Mechanical Sensors:** Principle of operation, ,Piezoresistivity, Piezoresistive Sensors, Capacitive Sensors	4
4	**Magnetic Sensors:** Principle of operation, Magnetic Effects and Magnetic Materials, Integrated Hall Sensors, Magnetotransistors, Other Magnetic Sensors	4
5	**Thermal Sensors:** Principle of operation, Heat Transfer, Thermal Structures, Thermal-Sensing Elements, Thermal and Temperature Sensors	4
6	**Chemical and Biological Sensors:** Principle of operation of gas sensors, Interaction of Gaseous Species at Semiconductor Surface, The Electrical Properties of Compressed Powders, FET Devices for Gas and Ion Sensing Principle of operation of biosensors, Mass Transport in Biosensors, FET and Impedance Based Sensing	8
7	**Actuators:** Working principles of actuators, piezoelectric and piezoresistive actuators, micrcopumps, micrcovalves	4
8	**Interfacing Electronics:** Sensor interfacing with microcontroller, design of front end analog blocks, algorithms for reliability enhancement, low power design	7
	Total	**40**

Text Books/References:

1. Semiconductor Sensors-S. M. Sze
2. Micro-sensors: Principles and Applications- Julian W. Gardner, Florin Udrea
3. Sensor Technology and Devices- Ljubiša Ristić
4. Piezoelectric Sensors and Actuators: Fundamentals and Applications, Springer, 2018 Senturia S. D.

Smart Antennas (ET4223)

L-T-P: 3-0-0 Credit: 3 Full Marks:100

Sl. No.	Module Name and Topics	Class hours
1	**Introduction**: Antenna Basics, Phased array antenna, power pattern, beam steering, degree of freedom, adaptive antennas, smart antennas – key benefits of smart antenna technology, wide band smart antennas, Propagation Channels.	6
2	**Smart Antennas For Wireless Communications**: Spatial Processing for Wireless Systems, Key Benefits of Smart Antenna Technology, The Vector Channel Impulse Response and the Spatial Signature, Spatial Processing Receivers, Fixed Beam forming Networks, Switched Beam Systems, Adaptive Antenna Systems, Wideband Smart Antennas, Diversity Techniques	8
3	**Multiple Input - Multiple Output (MIMO) Communications Systems:** MIMO for frequency selective scenarios.	4
4	**Adaptive Processing**: Sample matrix inversion algorithm, unconstrained LMS algorithm, normalized LMS algorithm, Constrained LMS algorithm, Perturbation algorithms, neural network approach, Adaptive beam space processing, and Implementation issues.	6
5	**Direction of Arrival Estimation (DOA) Methods**: Spectral estimation methods, linear prediction method, Maximum entropy method, Maximum likelihood method, Eigen structure methods, MUSIC algorithm – root music and cyclic music algorithm, the ESPRIT algorithm.	8
6	**Implementation of Smart Antenna System:** DOA based beam former design using simulation and hardware. Adaptive beam forming implementation using Altera Stratix series FPGA, QRD RLS Algorithm. CORDIC algorithm.	6
7	**Applications of Smart antennas**	2
	. **Total**	**40**

Text Books/References:

1. T.S. Rappaport and J.C. Liberti, “Smart Antennas for Wireless Communications”, Prentice Hall, 1999
2. Tapan K Sarkar ,” Smart Antennas “,IEEE Press, John Wiley & Sons Publications,2003

OPEN ELECTIVE-I

Satellite Communications (ET4261)

L-T-P: 3-0-0 Credit: 3 Full Marks: 100

Sl. No.	Module Names and Topics	Class hours
1	**Overview of Satellite Communication**: Historical background of satellite communication, Classification of satellites, General structure of satellite communication, Satellite frequency allocation and bands, Different applications of satellites.	3
2	**Satellites orbits and inclination**: Selection of orbits, Look angles, Orbital perturbation, Sun transit outage.	2
3	**Spacecraft and its subsystem**: Altitude and orbit control system, Telemetry Tracking and command, Power system, Communication Subsystems, Antenna Subsystems, Reliability & space qualification, Different launch vehicles and launch mechanisms.	5
4	**Satellite Link Design**: General link design equation, System noise temperature, C/N and G/T ratio, Uplink design, Down link design, Complete link design, Satellite link design with specified (C/N), Dependence of (C/N) ratio on earth station parameters.	5
5	**Analog Satellite communication**: FDM, Generation of FM signal, FM with multiplexed telephone signal. Companded Single Side Band (CSSB) system, Single channel per carrier (SCPC), Analog television transmission.	4
6	**Digital Satellite Communication**: Digital base band signal transmission, Digital modulation techniques, Digital transmission of voice and TV signal, Digital demodulation techniques,	4
7	**Multiple Access technique**: TDMA, FDMA, CDMA, SDMA, , Mixed access system, DAMA, PAMA and RMA techniques.	4
8	**Encoding & forward error correction**: Error detection coding- linear block code, cyclic code, Golay code, convolution code, Automatic repeat request, implementation of error detection and correction methods in satellite link.	3
9	**Inter-satellite link**: LEO-LEO, LEO-MEO, LEO-GEO, GEO-GEO.	2
10	**Earth station Technology**: Subsystem of an earth station, Small earth station, different types of earth stations, Frequency co-ordination, Earth station of future.	2
11	**Special purpose communication satellites**: DBS, INMARSAT, VSAT, MSAT, GPS, RADARSAT, INTELSAT, INSAT, Regional satellites.	6
	Total	**40**

Text Books/References:

1. T. Pratt, C. Bostian, J. Allnutt, Satellite Communication (2nd Ed.), John Willey.
2. A.K. Maini & V. Agarwal, Satellite Communications, John Willey.
3. K.N. Rajarao, Fundamentals of Satellite Communication, Prentice Hall of India. Roddy, Satellite Communication (2nd Ed.), McGraw Hill Book Co.