EC -901 C	Advanced Optical Fiber Communication System

OVERVIEW OF OPTICAL FIBER COMMUNICATION: Introduction to optical commination communication, optical fiber, Types of optical fiber, cut-off wave length, Modes in optical fiber. Fabrication techniques of optical fiber.

DIFFERENT TYPES OF LOSSES IN OPTICAL FIBER: Attenuation, absorption, scattering losses, bending loss,**Dispersion:** Group velocity Dispersion, Polarization mode dispersion. **Nonlinearities in optical fiber:** Self Phase Modulation, Cross Phase Modulation, Four Wave Mixing.

OPTICAL SOURCE AND DETECTOR: LED, LASER, Laser diode, DFB laser, PIN photo detector, APD.

ADVANCED MODULATION FORMATS & Optical Modulators: OOK, BPSK, QPSK, QAM, PAM and other higher modulation formats. MZM, EAM, MRM.

ACTIVE AND PASSIVE OPTICAL COMPONENTS AND SUBSYSTEMS: Coupler, circulator, optical Filters, FBG, CFBG, MZDI, MRR, AWG, MUX/DEMUX, OADM, ROADM, wavelength converter, All-optical regenerator, Optical switches.

MULTIPLEXING TECHNIQUES: WDM, OFDM

OPTICAL AMPLIFIER: Erbium doped fiber amplifier, semiconductor optical amplifier, Raman amplifier.

OPTICAL RECEIVER: Receiver sensitivity, quantum limit, coherent receiver**.**

Optical system performance and monitoring system: eye diagram, eye opening penalty, Q, BER, OSNR, OTDR.

LINK ANALYSIS: Single channel point to point, WDM point to point.

PULSE PROPAGATION IN OPTICAL FIBER: Nonlinear Schrodinger equation, split step Fourier method.

Reference Books:

1. Fiber-Optic Communication Systems, by Govind P. Agrawal
2. Optical Networks-A Practical Perspective, by Rajiv Ramaswami, Kumar Sivarajan and Galen Sasaki
3. Optical fiber communications by Gerd Keiser-McGraw Hill
4. Optical fiber communications: Principles and practice by John M. Senior-Prentice Hall of India

EC 902 C	Advanced Microwave Engineering

Transmission Line Theory: Lumped element circuit model for transmission line, fieldanalysis, Smith chart, quarter wave transformer, generator and load mismatch, impedance matching and tuning.

Microwave Waveguides & Components: Microwave Waveguides, Passive Components,Microwave resonators, power dividers and directional couplers, Ferromagnetic devices and components, Strip Lines, Microwave Tubes.

Microwave Semiconductor Devices & Modelling: PIN diode, Tunnel diodes, Varactor diode, Schottky diode, IMPATT and TRAPATT devices, transferred electron devices, Microwave BJTs, GaAs FETs, low noise and power GaAs FETs, MESFET, MOSFET, HEMT.

Microwave Network Analysis:Impedance and equivalent voltage and current, Impedanceand admittance matrix, The scattering matrix, transmission matrix, Signal flow graph.

Monolithic Microwave Integrated Circuits: Materials, Monolithic Microwave Intregrated-Circuit Growth, MOSFET Fabrication, Hybrid Integrated-Circuit Fabrication.

Reference Books:

1. Matthew M. Radmanesh, "Advanced RF & Microwave Circuit Design: The Ultimate Guide to Superior Design", AuthorHouse, 2009.
2. D.M.Pozar, " Microwave engineering" ,Wiley, 4th edition, 2011.
3. R.Ludwig and P.Bretchko, "R. F. Circuit Design", Pearson Education Inc, 2009.
4. S.Y. Liao, "Microwave circuit Analysis and Amplifier Design", Prentice Hall 1987.

EC- 1001 C	Optical Networks

5. **Introduction:** Different kinds of attenuation in optical fiber, Optical bandwidth, Light Transmission in Optical Fibers, Signal Impairments Along the Lightpath; Optical Transmitters and Modulators, Optical Receivers.
6. **Optical Networking:** Introduction and Challenges: Advantages of optical network, WDM optical networks, WDM network evolution, WDM network construction, broadcast and select optical WDM network, wavelength routed optical WDM network.
7. **Optical Networking Components:**Couplers, Isolators & Circulators, Multiplexers & Filters, OLT, OADM, OXC, CLOS architecture, MEMS, wavelength convertors, Optical Line Amplifiers,Gratings, Bragg grating, Fiber Gratings, Arrayed waveguide gratings,Fabry-perot filters, thin-film filters, Mach-Zehnder interferometers.
8. **SONET/SDH:** SONET/SDH layers, Optical transport network, IP, routing and forwarding, MPLS.
9. **Network Survivability:** Basic concept, Protection in SONET/SDH, Protection in IP Network, Optical Layer Protection scheme.
10. **Optical switching:** Optical packet switching, header and packet format, optical burst switching.
11. **WDM Network Design:** The optical layer, Node Designs, Optical layer cost tradeoff, Lightpath topology design, Routing and wavelength assignment.
12. **Optical Access Network:** Optical time division multiplexing, Synchronization, buffering, Passive optical Network.
13.
14. **Reference Books:**

15. 1. Optical Networks-A Practical Perspective, by Rajiv Ramaswami, Kumar Sivarajan and Galen Sasaki, 3rd Edition
16. 2. WDM optical networks: concepts, design and algorithms- C.Sivarammurthy and Mohan Gurusamy-Prentice Hall of India, 2002
17. 3. Optical Networks, by Black,Miller L Scott,Muhammad Ali Mazidi

EC- 1002 C	Advanced Antennas & Radiating Systems

Linear Wire Antennas: Basics of EM Theory, Infinitesimal dipole, Small dipole, Region separation, Finite lengthdipole, half wave dipole, Ground effects.Loop Antennas: Small Circular loop, Circular Loop of constant current, Circular loop with nonuniform current.

Types of Antennas: Wire antennas, Aperture antennas, Micro strip antennas, Array antennas Reflector antennas, Lens antennas, Radiation Mechanism, Current distribution on thin wire antenna. Fundamental Parameters of Antennas: Radiation Pattern, Radiation Power Density, Radiation Intensity, Directivity, Gain, Antenna efficiency, Beam efficiency, Bandwidth, Polarization, Input Impedance, radiation efficiency, Antenna Vector effective length, Friis Transmission equation, Antenna Temperature.

LinearArrays: Two element array, N Element array: Uniform Amplitude and spacing,Broadside and End fire array, Super directivity, Planar array, Design consideration.
Aperture Antennas: Huygen's Field Equivalence principle, radiation equations,Rectangular Aperture, Circular Aperture.
Horn Antennas: E-Plane, H-plane Sectoral horns, Pyramidal and Conical horns.
Micro strip Antennas: Basic Characteristics, Feeding mechanisms, Method of analysis,Rectangular Patch, Circular Patch.
Reflector Antennas: Plane reflector, parabolic reflector, Cassegrain reflectors, Introductionto MIMO.

Reference Books:

1. Electromagnetic Waves & Radiating Systems, Jordon &Balmin
2. Antenna Theory: Analysis & Design, by Balanis
3. I.J.Bhal and P.Bhartia, "Micro-strip antennas", Artech house, 1980.

A	Advanced Communication Techniques

Overview of Internet-Concepts, challenges and history: Overview of -ATM. TCP/IPCongestion and Flow Control in Internet-Throughput analysis of TCP congestion control. TCP forhigh bandwidth delay networks. Fairness issues in TCP.

Real Time Communications over Internet: Adaptive applications. Latency and throughputissues. Integrated Services Model (intServ). Resource reservation in Internet. RSVP.Characterization of Traffic by Linearly Bounded Arrival Processes (LBAP). Leaky bucketalgorithm and its properties.

Packet Scheduling Algorithms-requirements and choices: Scheduling guaranteed serviceconnections. GPS, WFQ and Rate proportional algorithms. High speed scheduler design. Theoryof Latency Rate servers and delay bounds in packet switched networks for LBAP traffic;Active Queue Management - RED, WRED and Virtual clock. Control theoretic analysis of activequeue management.

IP address lookup-challenges: Packet classification algorithms and Flow Identification-Grid of Tries, Cross producting and controlled prefix expansion algorithms.

Admission control in Internet:Concept of Effective bandwidth. Measurement basedadmission control. Differentiated Services in Internet (DiffServ). DiffServ architecture andframework.

IPV4, IPV6, IP tunnelling: IPswitching and MPLS, Overview of IP over ATM and itsevolution to IP switching. MPLS architecture and framework. MPLS Protocols. Trafficengineering issues in MPLS.

Reference Books:

1. Zhang Wang, "Internet QoS", Morgan Kaufman, 2001.
2. George Kesidis, "ATM Network Performance", Kluwer Academic, Research Papers, 2005.

B	Remote Sensing

Techniques for measuring the structure, content, properties nd motions of the atmosphere by remote means. Interactions between propagated wave and the atmospheric medium. Scattering absorption and radiation of electromagnetic waves in microwave, between and optical spectrum. Application to measurement of temperature, humilities, rain, invertion layers, wave winds, turbulence etc.

Real-time processing of large volumes of data including high data rate signal and image processing, optical, accousto optical and optical and optical and optical-electronic hybrid processing, realtime pattern recognition processors for such airborne applications as target recognition, tracking, and terminal guidance.
Physical description of continuous image prosperities of the human visual system, sampling and quantization of imager, matrix representation of image forming and image processing systems, unitary transforms and image compression and image enhancement and restoration.
Volume scattering and emission theory. Radiation transfer method. Behaviour of various surfaces, vegetable connopies.
Principle of spectro radio metry, Meterological satellite system, radio meters, Infrared spectrometer and multispectral scanner, System on the LAND SAT satellites airborn scanner etc.

Reference Books:

1. Remote Sensing and GIS, Book by BasudebBhatta
2. Remote Sensing, Principles & Applications by by B. C. Panda

C	Statistical Information Processing

Review of random variables: Probability Concepts, distribution and density functions,moments, independent, uncorrelated and orthogonal random variables; Vector-spacerepresentation of Random variables, Vector quantization, Tchebaychef inequality theorem, CentralLimit theorem, Discrete &Continuous Random Variables.Random process: Expectations, Moments,Ergodicity, Discrete-Time Random Processes Stationaryprocess, autocorrelation and auto covariance functions, Spectral representation of random signals,Properties of power spectral density, Gaussian Process and White noise process.

Random signal modelling:MA(q), AR(p), ARMA(p,q) models, Hidden Markov Model &its applications ,Linear System with random input , Forward and Backward Predictions, LevinsonDurbin Algorithm.

Statistical Decision Theory: Bayes' Criterion, Binary Hypothesis Testing, M-ary Hypothesis Testing, Minimax Criterion, Neyman-Pearson Criterion, Composite HypothesisTesting.Parameter Estimation Theory: Maximum Likelihood Estimation, Generalized Likelihood RatioTest ,Some Criteria for Good Estimators, Bayes' Estimation Minimum Mean-Square ErrorEstimate, Minimum, Mean Absolute Value of Error Estimate Maximum A Posteriori Estimate , Multiple Parameter Estimation Best Linear Unbiased Estimator ,Least-Square EstimationRecursive Least-Square Estimator.

Spectral analysis: Estimated autocorrelation function, Periodogram, Averaging theperiodogram (Bartlett Method), Welch modification, Parametric method, AR(p) spectralestimation and detection of Harmonic signals.

Information Theory and Source Coding: Introduction, Uncertainty, Information andEntropy, Source coding theorem, Huffman, ShanonFano, Arithmetic , Adaptive coding , RLE ,LZW Data compaction, , LZ-77, LZ-78. Discrete Memory less channels, Mutual information,channel capacity, Channel coding theorem, Differential entropy and mutual information forcontinuous ensembles.

Application of Information Theory: Group, Ring & Field, Vector, GF addition,multiplication rules. Introduction to BCH codes, Primitive elements ,Minimal polynomials,Generator polynomials in terms of Minimal polynomials, Some examples of BCH codes,&Decoder, Reed- Solomon codes & Decoder, Implementation of Reed Solomon encoders anddecoders.

Reference books:

1. Rosen K.H, "Elementary Number Theory", Addison-Wesley, 6th edition, 2010.
2. R G. Gallager, "Information theory and reliable communication", Wiley, 1st edition, 1968.
3. MouradBarkat , "Signal Detection and Estimation", Artech House, 2nd Edition, 2005.

XX	Cognitive Radio

Introduction to Cognitive Radios: Digital dividend, cognitive radio (CR) architecture,functions of cognitive radio, dynamic spectrum access (DSA), components of cognitive radio,spectrum sensing, spectrum analysis and decision, potential applications of cognitive radio.
Spectrum Sensing: Spectrum sensing, detection of spectrum holes (TVWS), collaborativesensing, geo-location database and spectrum sharing business models (spectrum of commons, realtime secondary spectrum market).
Optimization Techniques of Dynamic Spectrum Allocation: Linear programming, convexprogramming, non-linear programming, integer programming, dynamic programming, stochasticprogramming.
Dynamic Spectrum Access and Management: Spectrum broker, cognitive radioarchitectures, centralized dynamic spectrum access, distributed dynamic spectrum access, learningalgorithms and protocols.
Spectrum Trading: Introduction to spectrum trading, classification to spectrum trading,radio resource pricing, brief discussion on economics theories in DSA (utility, auction theory),classification of auctions (single auctions, double auctions, concurrent, sequential).
Research Challenges in Cognitive Radio: Network layer and transport layer issues, crosslayerdesign for cognitive radio networks.

Reference books:

1. Bruce Fette, "Cognitive radio technology", Elsevier, 2nd edition, 2009.
2. Linda Doyle, "Essentials of Cognitive Radio", Cambridge University Press, 2009.

D	Laser and Optoelectronics

Quantum Theory of Atomic Energy Levels – Radiative and Nonradiative decay of excited state atoms – Emission Broadening and linewidth – Radiation and Thermal equilibrium – Conditions for laser action – Laser Oscillation above threshold - Laser Amplifiers – Requirements for obtaining population inversion – Rate Equations for three and four level systems – Laser pumping requirements – Laser Cavity modes – Stable resonators – Gaussian beams- Special Laser Cavities – Q-switching and Mode locking – Generation of ultra fast Optical pulses- Pulse compression
Atomic Gas Lasers – He-Ne, Argon ion, He-Cd — Molecular Gas Lasers – CO2, Excimer, Nitrogen—X-Ray Plasma Laser — Free-Electron Laser — Organic Dye lasers — Solid-state lasers – Ruby, Nd:YAG, Alexandrite, Ti:Sapphire
Electronic and Optical properties of semiconductors- electron-hole pair formation, PN Junction, diffusion, injection efficiency, quantum efficiency, homo-junction and hetero-junction, Excitation absorption, donor-acceptor and impurity band absorption, LED, Semiconductor lasers, Hetero-junction Lasers, quantum well lasers, VCSEL, DFB and DBR Lasers
Detection of Optical radiations – Basic Principle, Thermal detectors, Photomultipliers, photoconductive detectors, Photodiodes, Avalanche photodiodes, CCDs, Image Intensifiers, Arrays, Solar Cells, noise considerations
Optoelectronic Modulators – Basic principle, Birefringence, Optical Activity, EO, AO and MO Effects and modulators

Reference books:

1. Laser Fundamentals – W.T. Silfvast, Second Edition, Cambridge University Press, 2004
2. Principles of Lasers – O. Svelto, Fourth edition, Springer, 1998
3. Photonics: Optical Electronics in Modern Communications – A. Yariv and P. Yeh, Sixth Edition, Oxford University Press, 2007
4. Semiconductor Optoelectronic devices – Pallab Bhattacharya, Prentice Hall of India, 1995 5. Semiconductor Optoelectronics – Jasprit Singh, Tata McGraw Hill, 1995
6. Optoelectronics - an Introduction – Wilson and Hawkes, Prentice Hall, 1998

E	Computer Vision and Image Processing - Fundamentals and Applications

Introduction to Computer Vision and Basic Concepts of Image Formation: Introduction and Goals of Computer Vision and Image Processing, Image Formation Concepts.

Fundamental Concepts of Image Formation: Radiometry, Geometric Transformations, Geometric Camera Models. Camera Calibration, Image Formation in a Stereo Vision Setup, Image Reconstruction from a Series of Projections**.**

Image Processing Concepts: Image Transforms. Image Processing Concepts: Image Transforms, Image Enhancement. Image Processing Concepts: Image Filtering, Colour Image Processing, Image Segmentation.

Image Descriptors and Features: Texture Descriptors, Colour Features, Edges/Boundaries**.** Object Boundary and Shape Representations**.**

Interest or Corner Point Detectors, Histogram of Oriented Gradients, Scale Invariant Feature Transform, Speeded up Robust Features, Saliency.

Fundamentals of Machine Learning: Linear Regression, Basic Concepts of Decision Functions, Elementary Statistical Decision Theory, Parameter Estimation, Clustering for Knowledge Representation, Dimension Reduction, Linear Discriminant Analysis. Applications of **Computer Vision:** Artificial Neural Network for Pattern Classification, Convolutional Neural Networks, Auto encoder, Machine Learning Algorithms and their Applications in Image Segmentation**.**

Applications of Computer Vision: Motion Estimation and Object Tracking, Gesture Recognition, Face and Facial Expression Recognition, Image Fusion.

Reference Books:

1. Forsyth & Ponce, "Computer Vision-A Modern Approach", Pearson Education.
2. M.K. Bhuyan , " Computer Vision and Image Processing: Fundamentals and Applications", CRC Press.
3. Richard Szeliski, "Computer Vision- Algorithms & Applications", Springer.

F	Wireless & Mobile Communication

Cellular Communication Fundamentals: Cellular system design, Frequency reuse, cellsplitting, handover concepts, Co channel and adjacent channel interference, interference reduction techniques and methods to improve cell coverage, Frequency management and channelassignment.GSM architecture and interfaces, GSM architecture details, GSM subsystems, GSMLogical Channels, Data Encryption in GSM, Mobility Management, Call Flows in GSM.2.5 GStandards: High speed Circuit Switched Data (HSCSD), General Packet Radio Service (GPRS),2.75 G Standards: EDGE,

Spectral efficiency analysis based on calculations for Multiple access technologies:TDMA,FDMA and CDMA,Comparison of these technologies based on their signal separation techniques,advantages, disadvantages and application areas.Wireless network planning (Link budget andpower spectrum calculations)

Mobile Radio Propagation: Large Scale Path Loss, Free Space Propagation Model,Reflection, Ground Reflection (Two-Ray) Model, Diffraction, Scattering, Practical Link BudgetDesign using Path Loss Models, Outdoor Propagation Models, Indoor Propagation Models, SignalPenetration into Buildings. Small Scale Fading and Multipath Propagation, Impulse ResponseModel, Multipath Measurements, Parameters of Multipath channels, Types of Small Scale Fading:Time Delay Spread; Flat, Frequency selective, Doppler Spread; Fast and Slow fading.

Equalization, Diversity: Equalizers in a communications receiver, Algorithms for adaptiveequalization, diversity techniques, space, polarization, frequency diversity, Interleaving.

Code Division Multiple Access: Introduction to CDMA technology, IS 95 systemArchitecture, Air Interface, Physical and logical channels of IS 95, Forward Link and Reverse linkoperation, Physical and Logical channels of IS 95 CDMA, IS 95 CDMA Call Processing, softHandoff, Evolution of IS 95 (CDMA One) to CDMA 2000, CDMA 2000 layering structure andchannels.

Higher Generation Cellular Standards:3G Standards: evolved EDGE, enhancements in 4Gstandard, Architecture and representative protocols, call flow for LTE, VoLTE, UMTS,introduction to 5G.

Reference Books:

1. V.K.Garg, "IS-95 CDMA & CDMA 2000", Pearson Education, 4th edition, 2009.
2. T.S.Rappaport, "Wireless Communications Principles and Practice", 2nd edition, PHI,2002.

G	RFID

Module 1: Automatic Identification Systems, Comparison of Different ID Systems, Components of an RFID System, Fundamental Differentiation Features, Transponder Construction Formats, Frequency, Range and Coupling, Active and Passive Transponders, Information Processing in the Transponder, Selection Criteria for RFID Systems, 1-Bit Transponder, Full- and Half-Duplex Procedure, Sequential Procedures, Near-Field Communication (NFC).
Module 2: Frequency Ranges and Radio Licensing Regulations, European Licensing Regulations, National Licensing Regulations in Europe – Germany, National Licensing Regulations – USA, Comparison of National Regulations, Full active transponders, Spectrum use and performance limitations, Data formats, encoding methods and standards, Data integrity and security for RFID,
Module 3: Data Flow in an Application, Components of a Reader, Integrated Reader ICs, Connection of Antennas for Inductive Systems, Reader Designs, Near-Field Communication, Glass and Plastic Transponders.
Module 4: ISO/IEC 69873 – Data Carriers for Tools and Clamping Devices, ISO/IEC 10374 – Container Identification, VDI 4470 – Anti-theft Systems for Goods, Item Management, Contactless Smart Cards, Public Transport, Contactless Payment Systems, NFC Applications, Electronic Passport, Ski Tickets, Access Control, Transport Systems, Animal Identification, FCC Rules for ISM Band, Identity, Standards, and Guidelines for Securing RFID Systems.

Reference Books:

1. Klaus Finkenzeller, 'RFID Handbook', Wiley, 2nd edition, 2003.
2. RFID Systems: Research Trends and Challenges, by Bolic M., Simplot-Ryl D., Stojmenovic I., 1st edition, 2011.

H	DSP and Communication networking

Short introduction- Discrete time systems & signals, z-transform, difference equation, filter design by transformation-impulse and step invariant, bi-linear z-transform, matched z-transform, discrete Fourier transform, state variable model. FIR filter design, frequency windowing technique, Chebyshev and Butterworth criterion. Filter performance and design in presence of noise, FIR filters banks-sub band decomposition. Inverse filtering, Deconvolution, signal reconstruction, time frequency analysis- STFT, WT, DSP hardware-design methodologies, popular architectures and overview of programming application notes. Filter implementation: topology, scalling, co-efficient quantization error, signal quantization, sensitivity analysis.

Reference Books:

1. Li Tan, "Digital Signal Processing", Elsevier, 2011.
2. A.V. Oppenheim and Schafer, "Discrete Time Signal Processing", Prentice Hall, 1989.

I	Digital Communication Networks and Protocol

Short introduction- Discrete time systems & signals,z-transform,difference equation,filter design by transformation-impulse and step invariant, bi-linear z-transform,matched z transform, signal model-AR,MA,ARMA,state variable model,lattice structure.

FIR filter design:frequency windowing technique,equi ripple chebyshev&butterworth criterion. Filter performance and design in presence of noise,FIR filters banks-subband decomposition.Inverse filtering deconvolution and equalization techniques- Weiner,linear prediction etc.,

Signal reconstruction: time frequency analysis STFT, WT,DSP hardware-design methodologies,popular architectures and overview of programming application notes.filter implementation: topology,scaling, co-efficient quantization,signal quantization,sensitivity analysis.Overview of communication & networking

Reference Books:

1. J.G. Proakis, Manolakis "Digital Signal Processing", Pearson, 4th Edition
2. A. K. Jain, "Fundamentals of Digital Image Processing", Prentice Hall

J	Artificial Intelligence & Soft Computing

Reasoning, Machine Learning, Intelligent Search, Intelligent Planning, Perception, Applications in Expert Systems, Machine Vision and Robotics, Control, Signal Processing and Pattern Recognition. Applications in System Design, Prediction, Optimization and Identification problems, Use of Fuzzy Logic, Neurocomputing and Evolutionary Algorithms in the above problems.

Reference Books:

1. Artificial Intelligence & Soft Computing by Amit Konar
2. Artificial Intelligence & Soft Computing for beginners by Anindita Das

K	Digital image processing

Introduction and signal digitization, Pixel relationship, Camera models & imaging geometry, Image interpolation, Image transformation, Image enhancement, Image restoration, Image registration, Colour image processing, Image segmentation, Morphological image processing, Object representation ,description and recognition.

Books and References:

1. Digital Image Processing by Rafael C Gonzalez & Richard E Woods, 3rd Edition
2. Fundamentals of Digital Image Processing by Anil K Jain
3. Digital Image Processing by William K Pratt

L	Satellite Communication

Architecture of Satellite Communication System: Principles and architecture of satelliteCommunication, Brief history of Satellite systems, advantages, disadvantages, applications, andfrequency bands used for satellite communication and their advantages/drawbacks.

Orbital Analysis: Orbital equations, Kepler's laws of planetary motion, Apogee andPerigee for an elliptical orbit, evaluation of velocity, orbital period, angular velocity etc of asatellite, concepts of Solar day and Sidereal day.
Satellite sub-systems: Architecture and Roles of various sub-systems of a satellite systemsuch as Telemetry, tracking, command and monitoring (TTC & M), Attitude and orbit controlsystem (AOCS), Communication sub-system, power sub-systems, antenna sub-system.
Typical Phenomena in Satellite Communication: Solar Eclipse on satellite, its effects,remedies for Eclipse, Sun Transit Outage phenomena, its effects and remedies, Doppler frequencyshift phenomena and expression for Doppler shift.
Satellite link budget: Flux density and received signal power equations, Calculation ofSystem noise temperature for satellite receiver, noise power calculation, Drafting of satellite linkbudget and C/N ratio calculations in clear air and rainy conditions, Case study of PersonalCommunication system (satellite telephony) using LEO.

Modulation and Multiple Access Schemes used in satellite communication: Typical casestudies of VSAT, DBS-TV satellites and few recent communication satellites launched by NASA/ISRO. GPS.

Reference Books:

1. Dennis Roddy, "Satellite Communication", McGraw Hill, 4th Edition, 2008.
2. Tri T. Ha, "Digital Satellite Communications", Tata McGraw Hill, 2009.
3. Timothy Pratt and Others, "Satellite Communications", Wiley India, 2nd edition,2010.

M	Internet of Things (IoT)

Smart cities and IoT revolution: Fractal cities, From IT to IoT, M2M and peer networkingconcepts, Ipv4 and IPV6.
Software Defined Networks SDN: From Cloud to Fog and MIST networking for IoTcommunications, Principles of Edge/P2P networking, Protocols to support IoT communications,modular design and abstraction, security and privacy in fog.
Wireless sensor networks: introduction: IOT networks (PAN, LAN and WAN), Edgeresource pooling and caching, client side control and configuration.
Smart objects as building blocks for IoT: Open source hardware and Embedded systemsplatforms for IoT, Edge/gateway, IO drivers, C Programming, multithreading concepts.
Operating systems requirement of IoT environment: study of mbed, RIoT, andContikioperating systems, introductory concepts of big data for IoT applications.
Applications of IoT: Connected cars IoT Transportation, Smart Grid and Healthcare sectorsusing IoT, Security and legal considerations, IT Act 2000 and scope for IoT legislation.

Reference Books:

1. A Bahaga, V. Madisetti, "Internet of Things- Hands on approach", VPT publisher, 2014.
2. A. McEwen, H. Cassimally, "Designing the Internet of Things", Willey, 2013.
3. Samuel Greenguard, "Internet of things", MIT Press, 2015.

N	Modern Data Transmission Technology

Network Design Issues: Network Performance Issues, Network Terminology, centralizedand distributed approaches for networks design, Issues in design of voice and data networks.
Layered and Layer less Communication: Cross layer design of Networks, Voice Networks(wired and wireless) and Switching, Circuit Switching and Packet Switching, StatisticalMultiplexing.
Data Networks and their Design: Link layer design- Link adaptation, Link LayerProtocols, Retransmission. Mechanisms (ARQ), Hybrid ARQ (HARQ), Go Back N, SelectiveRepeat protocols and their analysis.
Queuing Models of Networks : Traffic Models , Little's Theorem, Markov chains, M/M/1and other Markov systems, Multiple Access Protocols , Aloha System , Carrier Sensing ,Examples of Local area networks,

Inter-networking: Bridging, Global Internet , IP protocol and addressing , Sub netting ,Classless Inter domain Routing (CIDR) , IP address lookup , Routing in Internet. End to EndProtocols, TCP and UDP. Congestion Control, Additive Increase/Multiplicative Decrease , SlowStart, Fast Retransmit/ Fast Recovery,
Congestion avoidance: RED TCP Throughput Analysis, Quality of Service in Packet
Networks. Network Calculus, Packet Scheduling Algorithms.

Reference Books:

1. D. Bertsekas and R. Gallager, "Data Networks", 2nd Edition, Prentice Hall, 1992.
2. Walrand, "Communications Network: A First Course", 2nd Edition, McGraw Hill, 2002.

XX	Software Defined Networking

Introduction to Programmable Networks, History and Evolution of Software Defined Networking (SDN), Fundamental Characteristics of SDN, Separation of Control Plane and Data Plane, Active Networking.
Control and Data Plane Separation: Concepts, Advantages and Disadvantages, the basics of OpenFlow protocol.
Network Virtualization: Concepts, Applications, Existing Network Virtualization Framework, Mininet A simulation environment for SDN.
Overview, Existing SDN Controllers including Floodlight and OpenDaylight projects. Customization of Control Plane: Switching and Firewall Implementation using SDN Concepts. Data Plane: Software-based and Hadrware-based; Programmable Network Hardware.
Programming SDNs: Northbound Application Programming Interface, Current Languages and Tools, Composition of SDNs. Network Functions Virtualization (NFV) and Software Defined Networks: Concepts, Implementation and Applications.
Data Center Networks: Packet, Optical and Wireless Architectures, Network Topologies. Use Cases of SDNs: Data Centers, Internet Exchange Points, Backbone Networks, Home Networks, Traffic Engineering

Reference Books:

1. Thomas D. Nadeau, Ken Gray, "SDN: Software Defined Networks, An Authoritative Review of Network Programmability Technologies", O'Reilly Media, August 2013.
2. Paul Goransson, Chuck Black, Timothy Culver. "Software Defined Networks: A Comprehensive Approach", Morgan Kaufmann Publishers, 2016.
3. Fei Hu, "Network Innovation through OpenFlow and SDN: Principles and Design", CRC Press, 2014.
4. Vivek Tiwari, "SDN and OpenFlow for Beginners", Amazon Digital Services, Inc., ASIN: , 2013.
5. Nick Feamster, Jennifer Rexford and Ellen Zegura, "The Road to SDN: An Intellectual History of Programmable Networks" ACM CCR April 2014.
6. Open Networking Foundation (ONF) Documents, https://www.opennetworking.org, 2015.
7. OpenFlow standards, http://www.openflow.org, 2015.

O	Modern Digital Communication Techniques

Introduction to digital communication systems, Source Coding Characterization of Communication Signals & Systems Signal space Representation, Representation of Memory less Modulation Methods Nonlinear modulation methods, Optimal receivers of AWGN Receiver for non-ideal channel, Probability of error of different modulation schemes, Fundamentals of estimation and detection theory used in digital communication, Carrier phase and symbol timing synchronization techniques, Channel estimation and equalization techniques, Power Adaptation methods for colored noise channel.

Reference books:

1. Digital Communications by John G. Proakis.
2. Digital Communications by Bernard Sklar.
3. Digital Communications by Robert Gallager.

4. Digital Communications by Simon Haykin.
5. Modern Digital and Analog communications by B.P. Lathi

P	Introduction to Coding Theory

Introduction to error control coding, Introduction to linear block codes, generator matrix and parity check matrix, Properties of linear block codes: Syndrome, error detection
Decoding of linear block codes, Distance properties of linear block codes
Some simple linear block codes: Repetition codes, Single parity check codes, Hamming codes, Reed Muller codes, Bounds on size of codes: Hamming bound, Singleton bound, Plotkin bound, Gilbert-Varshamov bound
Low density parity check codes, Decoding of low density parity check codes-I: Belief propagation algorithm on BEC, Decoding of low density parity check codes-I: Belief propagation algorithm on BSC and AWGN channels
Introduction to convolutional codes-I: Encoding, state diagram, trellis diagram, Introduction to convolutional codes-II: Classification, realization, distance properties, Decoding of convolutional codes-I: Viterbi algorithm
Decoding of convolutional codes-II: BCJR algorithm, Performance bounds for convolutional codes
Turbo codes, Turbo decoding
Distance properties of turbo codes, Convergence of turbo codes, Applications of linear codes

Reference Books:

1. "Error Control Coding", by Shu Lin and Daniel J. Costello, Jr., second edition, Prentice Hall, 2004.
2. Todd K. Moon, "Error Correction Coding", 1st Edition, Wiley-Interscience, 2006.
3. F. J. MacWilliams, N. J. A. Sloane, "The Theory of Error-Correcting Codes", North-Holland, Amsterdam, 1977
4. R. E. Blahut, "Algebraic Codes for Data Transmission", 1st Edition, Cambridge University Press 2003.
5. Cary W. Huffman, Vera Pless, "Fundamentals of Error-Correcting Codes", 1st Edition, Cambridge University Press, 2003.
6. Rolf Johannesson and Kamil Sh. Zigangirov, ``Fundamentals of Convolutional Coding'', IEEE Press, 1999.

Q	Mathematical Methods And Techniques In Signal Processing

Review of vector spaces, inner product spaces, orthogonal projections, state variable representation, Review of probability and random processes, Signal geometry and applications
Sampling theorems multirate signal processing decimation and expansion
Sampling rate conversion and efficient architectures, design of high decimation and interpolation filters, Multistage designs.
Introduction to 2 channel QMF filter bank, M-channel filter banks, overcoming aliasing, amplitude and phase distortions.
Subband coding and Filter Designs: Applications to Signal Compression
Introduction to multiresolution analysis and wavelets, wavelet properties
Wavelet decomposition and reconstruction, applications to denoising
Derivation of the KL Transform, properties and applications.
Topics on matrix calculus and constrained optimization relevant to KL Transform derivations.
Fourier expansion, properties, various notions of convergence and applications.

Reference Books:

1. Moon & Stirling, Mathematical Methods and Algorithms for Signal Processing, Prentice Hall, 2000.
2. P. P. Vaidyanathan, Multirate systems and filter banks, Prentice Hall, 2000.
3. A. Boggess& F. J. Narcowich, A First Course in Wavelets with Fourier Analysis, Prentice Hall, 2001.
4. G. Strang, Introduction to Linear Algebra, 2016.
5. H. Stark & J. W. Woods, Probability and Random Processes with Applications to Signal Processing, 2014.

R	Photonic integrated circuit

Review of Electromagnetic Waves, Photonic integrated circuits: an introduction, Material technology for integrated optics, Introduction to guided wave optics,Integrated optical waveguide design,Coupling light in a waveguide

system, Integrated photonic Passive devices, Integrated photonic Active devices, Semiconductor Light sources and Photodetectors, Material engineering and fabrication, A Photonic integrated circuit technology: Silicon, III-V and beyond, Application of Photonic circuit in Communication and Sensing

Reference Books:

1. Fundamentals of Photonics, B.E.A Saleh and M.C. Teich, Wiley, New York, 1991
2. Photonic Devices. Cambridge, J. Liu, Cambridge University Press, 2005.
3. Fundamentals of Optoelectronics, Clifford R. Pollock, Irwin, 1995.
4. Diode Lasers and Photonic Integrated Circuits, Larry A. Coldren Scott W. Corzine Milan L. Mašanović, Wiley-Interscience.

T	EMI/EMC

Natural and Nuclear sources of EMI / EMC : Introduction, Electromagnetic environment, History, Concepts, Practical experiences and concerns, frequency spectrum conservations. An overview of EMI / EMC, Natural and Nuclear sources of EMI.

EMI from apparatus, circuits and open area test sites : Electromagnetic emissions, noise from relays and switches, non-linearities in circuits, passive intermodulation, crosstalk in transmission lines, transients in power supply lines, electromagnetic interference (EMI). Open area test sites and measurements.

Radiated and conducted interference measurements: Anechoic chamber, TEM cell, GH TEM Cell, characterization of conduction currents / voltages, conducted EM noise on power lines, conducted EMI from equipment, Immunity to conducted EMI detectors and measurements. UNIT-IV:ESD, Grounding, shielding, bonding and EMI filters : Principles and types of grounding, shielding and bonding, characterization of filters, power lines filter design. ESD, Electrical fast transients / bursts, electrical surges.

Cables, connectors, components: Introduction, EMI suppression cables, EMC connectors, EMC gaskets, Isolation transformers, opto-isolators, Transient and Surge Suppression Devices.

EMC standards- National / International .: Introduction, Standards for EMI and EMC, MIL Standards, IEEE/ANSI standards, CISPR/IEC standards, FCC regulations, Euro norms, British Standards, EMI/EMC standards in JAPAN, Conclusions.

Reference Books:

1. Engineering Electromagnetic Compatibility by Dr. V.P. Kodali, IEEE Publication, Printed in India by S. Chand & Co. Ltd., New Delhi,2000.
2. Electromagnetic Interference and Compatibility IMPACT series, IIT – Delhi, Modules 1 – 9.
References:
3.Introduction to Electromagnetic Compatibility, NY, John Wiley, 1992, by C.R. Pal.

U	MIMO Communication Systems

Introduction to Multi-antenna Systems: Motivation, Types of multi-antenna systems, MIMO vs. multi-antenna systems.

Diversity: Exploiting multipath diversity, Transmit diversity, Space-time codes, The Alamouti scheme, Delay diversity, Cyclic delay diversity, Space-frequency codes, Receive diversity, The rake receiver, Combining techniques, Spatial Multiplexing, Spectral efficiency and capacity, Transmitting independent streams in parallel, Mathematical notation

The generic MIMO problem: Singular Value Decomposition, Eigenvalues and eigenvectors, Equalising MIMO systems, Disadvantages of equalising MIMO systems, Predistortion in MIMO systems, Disadvantages of pre distortion in MIMO systems, Pre-coding and combining in MIMO systems, Advantages of pre-coding and combining, Disadvantages of precoding and combining, Channel state information.

Codebooks for MIMO: Beamforming, Beamforming principles, Increased spectrum efficiency, Interference cancellation, Switched beamformer, Adaptive beamformer, Narrowband beamformer, Wideband beamformer

Case study: MIMO in LTE, Codewords to layers mapping, Pre-coding for spatial multiplexing, Pre-coding for transmit diversity, Beamforming in LTE, Cyclic delay diversity based pre-coding, Pre-coding codebooks, Propagation Channels, Time & frequency channel dispersion, AWGN and multipath propagation channels, Delay spread values and time variations, Fast and slow fading environments, Complex baseband multipath channels, Narrowband and wideband channels, MIMO channel models

Channel Estimation: Channel estimation techniques, Estimation and tracking, Trainingbased channel estimation, Blind channel estimation, Channel estimation architectures, Iterativechannel estimation, MMSE channel estimation, Correlative channel sounding, Channel estimationin single carrier systems, Channel estimation for CDMA, Channel estimation for OFDM.

Reference Books:

1. I.J.Bhal and P.Bhartia, "Micro-strip antennas", Artech house, 1980.
2. R.C.Johnson and H.Jasik, "Antenna Engineering hand book", Mc-Graw Hill, 1984.
3. John D Kraus, Ronald J Marhefka, Ahmad S Khan, "Antennas for All Applications",TataMcgraw-hill.

XX	Network Security and Cryptography

Network Security: Introduction, Basic Security Concepts, Threats, Vulnerabilities, and Attacks, Encryption, Digital Signatures, and Certification Authorities, Kerberos Key Exchange, Encryption on the World Wide Web, E-Mail Security, Operating System Security, LAN Security, Media and Protocols, Routers and SNMP, Virtual Private Networks, Firewalls, Biometrics, Policies and Procedures, Auditing, Monitoring, and Intrusion Detection, Crisis Management, Cookies and Cache, Security of Web-based Systems.

Reference Books:

1. William Stallings, "Cryptography and Network Security, Principles and Practices", Pearson Education, 3rd Edition.
2. Christopher M. King, ErtemOsmanoglu, Curtis Dalton, "Security Architecture,Design Deployment and Operations", RSA Press.

V	VLSI design

MOS TRANSISTOR THEORY: NMOS and PMOS transistors, CMOS logic, MOS transistor theory – Introduction, Enhancement mode transistor action, Ideal I-V characteristics, DC transfer characteristics, Threshold voltage Body effect- Design equations- Second order effects. MOS models and small signal AC characteristics, Simple MOS capacitance Models, Detailed MOS gate capacitance model, Detailed MOS Diffusion capacitance model.

CMOS TECHNOLOGY AND DESIGN RULE: CMOS fabrication and Layout, CMOS technologies, P -Well process, N -Well process, twin -tub process, MOS layers stick diagrams and Layout diagram, Layout design rules, Latch up in CMOS circuits, CMOS process enhancements, Technology – related CAD issues, Fabrication and packaging.

INVERTERS AND LOGIC GATES : NMOS and CMOS Inverters, Inverter ratio, DC and transient characteristics , switching times, Super buffers, Driving large capacitance loads, CMOS logic structures , Transmission gates, Static CMOS design, dynamic CMOS design.

CIRCUIT CHARACTERISATION AND PERFORMANCE ESTIMATION: Resistance estimation, Capacitance estimation, Inductance, switching characteristics, transistor sizing, power dissipation and design margining. Charge sharing .Scaling.

VLSI SYSTEM COMPONENTS CIRCUITS AND SYSTEM LEVEL PHYSICAL DESIGN: Multiplexers, Decoders, comparators, priority encoders, Shift registers. Arithmetic circuits – Ripple carry adders, Carry look

ahead adders, High-speed adders, Multipliers. Physical design – Delay modelling ,crosstalk, floor planning, power distribution. Clock distribution. Basics of CMOS testing.

Reference Books:

1. Neil H.E. Weste and Kamran Eshraghian, Principles of CMOS VLSI Design, Pearson Education ASIA, 2nd edition, 2000.
2. John P.Uyemura "Introduction to VLSI Circuits and Systems", John Wiley & Sons, Inc., 2002.
3. Eugene D.Fabricius, Introduction to VLSI Design McGraw Hill International Editions, 1990.
4. Pucknell, "Basic VLSI Design", Prentice Hall of India Publication, 1995. 5. Wayne Wolf "Modern VLSI Design System on chip. Pearson Education, 2002.

W	Broadband Network and Network Management

Synchronous and Asynchronous Networks, Optical Fiber based Backbone and Information Superhighways, SONET & SDH standards. IP over SONET and WDM, STS & STM Framing, ATM and STM systems, ATM Layers. User Network & Network-Network Interfaces. Virtual paths and Virtual circuits, Cell Loss Effects, Intelligent Networks. Network Management and Control, TMN Architecture and Functional Requirements. Interface and Protocol Requirements, Information Modeling and Model representations. System Management Functions, OSI System Management, Internet SNMP, ODP/OMG. COBRA as technologies for TMN.

Reference Books:

1. Network Management: Principles and Practice 2nd Edition, Kindle Edition

X	Advanced Microprocessors and Microcontrollers

Intel 8086 (16-bit): Architecture, addressing modes, instruction set, assembler and crossassembler, input-output, system design using 8086. Intel 80386 and upgrades (32-bit): Basic programming model, addressing modes, instruction set, memory and I/O management, math coprocessor, upgrades of the 80386. A typical 16-bit microcontroller with RISC architecture and integrated A-D converter e.g. PIC18Cxxx family: advantages of Harvard architecture, instruction pipeline, analog input, PWM output, serial I/O, timers, in-circuit and self programmability. Instruction set. Typical application. Development tools.

Books and References:

1. Barry B. Brey, The Intel Microprocessors: 8086/8088, 80186/80188, 80286, 80386, 80486, Pentium, Pentium pro Processor, Pentium II, Pentium III, Pentium 4, and Core2 ... - Architecture, Programming, and Interfacing.
2. Nilesh B. Bahadure, Microprocessors: The 8086/8088, 80186/ 80286, 80386/80486 and the Pentium Family.
3. Muhammad Ali Mazidi, PIC Microcontroller and Embedded Systems: Using assembly and C for PIC 18, 1e Paperback – 1 January 2008 by (Author)

Y	Advanced Mathematical Techniques

Linear Mathematics: Matrices (types and operations including elementary row and column operations), inverse; Determinants (rules of computation); Linear Equations and Cramer's rule; Vector space (concepts of

span/basis/dimension); Eigen values and Eigen vectors; Linear Programming (Graphical and Simplex solution); First order Difference equation (First order equations and solution).

Vector Calculus: Laws of vector algebra, operations- dot, cross, triple products; Vector function – limits, continuity and derivatives, geometric interpretation; Gradient, divergence and curl – formulae; Orthogonal curvilinear coordinates; Jacobians, gradient, divergence, curl and Laplacian in curvilinear coordinates; Special curvilinear coordinates. Gauss,s divergent theorem, Green's theorem, Stoke's theorem.

Complex Numbers: Functions Analysis including limits and continuity, derivatives; Cauchy Riemann Equations; Integrals, Cauchy theorem and Cauchy integral formulae; Analytic Functions; Taylor's series, Singular points and poles; Laurent's Series, Residues, Residue Theorem; Conformal mapping, Riemann's mapping theorem; Some general transformations, mapping a half plane into a circle; The Schwarz-Christoffel transformation; The solution of Laplace equation by conformal mapping.

Differential equations: of higher order, existence and uniqueness of solutions; Some engineering applications (mechanics and electric circuits); Numerical methods for solutions; General Linear Differential Equation of order n; Linear Operators; Fundamental theorem on linear differential equations; Solutions for constant coefficients; The nonoperator techniques; The complementary solution of homogeneous equation, the particular solution; Method of reduction of order and inverse operators; Linear equations with variable coefficients; Simultaneous differential equations; Applications.

Laplace Transforms: Transforms of elementary functions, transforms of derivatives and derivatives of transforms, inverse transforms, transforms of periodic functions, unit step function, shifting theorems, solutions of ODE's using Laplace transforms.

Numerical Analysis: Determination of roots of polynomials and transcendental equations by Newton-Raphson, Secant method and the method of Falsi position. Solutions of linear simultaneous linear algebraic equations by Gauss Elimination and Gauss- Siedal iteration methods. Curve fitting – linear and nonlinear regression analysis. Backward, Forward and Central difference relations and their uses in Numerical differentiation and integration(Trapezoidal, Simpson's 1/3-rd & 3/8-th and Weddles rule), Applications of difference relations in the solution of partial differential equations. Numerical solution of ordinary differential equations by Euler, Modified Euler, Runge-Kutta and Predictor-Corrector method.

Books & References:

1. Advanced Engineering Mathematics- H. K. Dass, S. Chand & Comp.
2. Engineering Mathematics-B,S, Grewal, Khanna Publisher.
3. Engineering Mathematics- K.C. Das & B. K. Pal, U. N. Dhur& sons-Vol. I, II, III
4. Thomas G.B and Finney, R. L. " Calculas and Analytic Geometry", 6th AditionWesley/Narosa, 1985 Piskunov, " Differential and Integral Calculus", Vol-I & II, Mir Publishers, Moscow, 1979.

XX	Antenna Analysis & Synthesis

Theories of radiation, Kirchoff's principles, Schelkunoff's equivalent principles. Integral transform methods, Green's function, Linear antennas as boundary value probe current distribution and impedance.

Radiation from apertures, general formulas for scattering and diffraction in and effective area of apertures. Different kind of aperture antennas. Reflector antennas. Appropriate methods for solving reflector antenna problems. Primary feed system design, Shaped beam antennas.

Cassegrain antenna system. Antenna array analysis and synthesis. Synthesis optimizations, Phased arrays. Integrated antennas.

Books and References:
Constantine A. Balanis, Antenna Theory: Analysis and Design, 4th Edition.
Sanjay Kumar, SaurabhShukla, Wave Propagation and Antenna Engineering

Z	Electronic System Design

Signal Conditioning, Instrumentation and isolation amplifiers, analog filtersand analog switches. Signal measurement in the presence of noise: synchronous detection, signal averaging. Noise in electronic systems: design of low noise circuits.
Interfacing of analog and digital circuits. Programmable circuits, architecture of a typical FPGA and its application. Case studies. A/D and D/A conversion: sampling and quantization, antialiasing and smoothening filters. Switched capacitor circuits and applications.
Books and References:
Jens Lienig , Hans Bruemmer, Fundamentals of Electronic Systems Design 1st ed. 2017 Edition.

XX	Discrete mathematics

Logic: Proposition and Predicate Logic, introduction to proof techniques, Advanced proof techniques, resolution, induction, Set theory and relations, Various types of relations and functions, Combinatorics Part I: permutations, combinations, sum rule, product rule, pigeon-hole principle, Ramsey numbers, Combinatorics Part II: Combinatorial proofs, Catalan numbers, counting using recursion, principal of inclusion-exclusion, advanced counting techniques, Recurrence equations and various methods of solving recurrence equations, Cardinality theory, countable and uncountable sets, Cantors diagonalization, uncomputable functions, Graph theory Part I: basic definitions, Eulers theorem, bipartite graphs and matching, Halls marriage theorem, various operations on graphs, Graph theory part II: isomorphism, vertex-connectivity, edge-connectivity, Euler graphs and Hamiltonian graphs, various characterizations, vertex and edge coloring, Abstract algebra: groups, rings, fields, Basic number theory: modular arithmetic, prime numbers and properties, GCD, Chinese remainder theorem, Fermats little theorem, RSA cryptosystem.

Books and References:

1. Kenneth Rosen, Discrete Mathematics and Its Applications Seventh Edition.
2. Kenneth H. Rose, Discrete Mathematics and Its Applications: With Combinatorics and Graph Theory.