STUDENT HAND BOOK

ACADEMIC YEAR 2018-19

MASTER OF TECHNOLOGY
RADAR & COMMUNICATION

Koneru Lakshmaiah Education Foundation
(Deemed to be University estd. u/s. 3 of the UGC Act, 1956)
Accredited by **NAAC** as '**A**' Grade University ❖Approved by AICTE ❖ ISO 9001-2015 Certified
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Mission statement of K L E F:

Vision:

To be a globally renowned university.

Mission

To impart quality higher education and to undertake research and extension with emphasis on application and innovation that cater to the emerging societal needs through all-round development of students of all sections enabling them to be globally competitive and socially responsible citizens with intrinsic values.

Vision and Mission statement of ECE department

VISION

To evolve into a globally recognized department in the frontier areas of Electronics & Communication Engineering (ECE).

MISSION

M1- To produce graduates having professional excellence.
M2- To carry out quality research having social & industrial relevance.
M3- To provide technical support to budding entrepreneurs and existing Industries**.**

PROGRAM EDUCATIONAL OBJECTIVES (PEOS):

- **PEO1:** Apply concepts of Statistics, Linear Algebra and Residue Calculus in Communication, Signal processing and Electromagnetic domain.
- **PEO2:** Solve issues in real world communication sectors, and develop feasible and viable communication systems.
- **PEO3:** Inculcate effective communication skills, practice effective team work, professional ethics and pursue research.

Programe Outcomes

PO Number	Description
PO1	An ability to identify, formulate, research literature, analyze complex engineering problems in the area of communications and RADAR to cater national and industrial needs.
PO2	An ability to develop solutions for complex problems in communication system design and RADAR system component or processes that meet the specified needs considering.
PO3	Ability to create and apply appropriate techniques using modern industrial and research tools for modeling and testing of antennas, communications system modules and RADAR systems.
PO4	An ability to design the experiments, analysis and interpretation of data and synthesis of the information using various modern and industrial tools to obtain solutions for complex problems in industries, military and social needs.
PO5	Ability to apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues, ethical principles of engineering practices and the consequent responsibilities relevant to the RADAR engineering.
PO6	Exposure to prerequisite math's and a mathematically rigorous approach to communication theory will provide him with all the necessary background to pursue a career in any field of communications going forward in his career.
PO7	An ability to function effectively as an individual, and as a member or leader in diverse teams and in multi-disciplinary settings for project management by demonstrating the knowledge and understanding of principles of communication systems and radar, and apply those one's own work, as a member and leader in team, to manage projects and in multi-disciplinary environments.

M.TECH - RADAR & COMMUNICATION COURSE STRUCTURE

First Year (First Semester):

S. No.	Course Code	Course Title	Periods			Credits
			L	T	P	
1	18 EC 5101	Modern Digital communication	3	1	2	5
2	18 EC 5102	Microwave Antennas	3	1	2	5
3	18 EC 5103	EMI / EMC Techniques	3	1	0	4
4	18 EC 5104	Radar Engineering	3	1	0	4
5		Elective – 1	3	0	0	3
6		Elective - 2	3	0	0	3
7	18 IE 5149	Seminar	0	0	4	2
		Total	**18**	**4**	**8**	**26**

First Year (Second Semester) :

S. No.	Course Code	Course Title	Periods			Credits
			L	T	P	
1	18 EC 5205	Microwave and Millimetric wave Circuits	3	1	2	5
2	18 EC 5206	Antenna Measurements	3	1	2	5
3	18 EC 5207	Wireless Cellular Communication	3	1	0	4
4	18 EC 5208	Modern Radar Systems	3	1	0	4
5		Elective – 3	3	0	0	3
6		Elective - 4	3	0	0	3
7	18 IE 5250	Term Paper	0	0	4	2
		Total	**18**	**4**	**8**	**26**

Second Year (First & Second Semester) :

S.No	Course code	Course Title	Periods			Credits
			L	T	P	
1	18 IE 6050	Dissertation	0	0	72	36

ELECTIVE COURSES

S.No	Course code	Course Title	Periods			Credits
			L	T	P	
Elective-1						
1	18 EC 51A1	Fundamentals of Electronic Warfare	3	0	0	3
2	18 EC 51A2	Microwave Semi Conductor Devices	3	0	0	3
3	18 EC 51A3	Smart Antennas	3	0	0	3
Elective-2						
1	18 EC 51B1	Phased Array Systems	3	0	0	3
2	18 EC 51B2	GPS & Global Navigation Satellite System	3	0	0	3
3	18 EC 51B3	Optical Communications	3	0	0	3
Elective-3						
1	18 EC 52C1	Estimation & Detection Theory	3	0	0	3
2	18 EC 52C2	Radar Signal Processing	3	0	0	3
3	18 EC 52C3	High Performance Communication Networking	3	0	0	3
Elective-4						
1	18 EC 52D1	RF & Microwave System Design	3	0	0	3
2	18 EC 52D2	VLSI Design	3	0	0	3
3	18 EC 52D3	Remote Sensing & Sensors	3	0	0	3

M. Tech COMMUNICATION & RADAR [A.Y - 2018 - 2019]

S.NO	COURSE CODE	COURSE NAME	CO No	CO	PO								
					1	2	3	4	5	6	7	8	9
1	18EC5101	Modern Digital Communication Techniques	1	Understand different modern digital modulation techniques and probability of error statistics.	1								
			2	Analyze the performance of baseband and pass band data transmission in terms of signaling schemes.	2								
			3	Understand the concepts of block and convolution codes with respect to transfer functions and decoding operations.	1								
			4	Analyze the spread spectrum signals and signal analysis for different digital communication technologies.				2					
			5	Interpret different digital communication modules with respect to signal analysis in application orientation.				2					
2	18EC5102	Microwave Antennas	1	Understand the basic antenna parameters and radiation mechanism for different types.	1								
			2	Identify the significance of aperture of antenna models and their feeding mechanism.		1							
			3	Design microstrip radiators with different shapes, slots and feeding techniques for communication applications.				3					
			4	Analyze the concepts of beam formation with respect to gain, directivity, impedance and polarization.	3								
			5	Estimate the performance characteristics of microwave antennas with the help of electromagnetic tools.					2				
3	18EC5103	EMI/EMC	1	Describe the concept of electromagnetic interference, compatibility and sources of EMI.	1								
			2	Understand the electromagnetic interference in circuits and measurement techniques with open area test sites.			1						
			3	Interpret the conducted and radiated interference and measurements.			2						
			4	Utilize the techniques like grounding, shielding, bonding and EMI filters in the usage of cables , connectors and components.				1					
4	18EC5104	Radar Engineering	1	Understand the concept of radar communication and its ground environment.	1								
			2	Analyze the transmitter characteristics like output power, spectrum	3								

				analysis and harmonics from transmitter.									
			3	Identify the factors outside the radar and analyze the propagation mechanism with scattering and clutter.			1						
			4	Classify different steps in receiver design and its parameters for determination of position.				2					
5	18EC51A2	Microwave Semiconductor Devices and Applications	1	Understand the behavior of high frequency equivalent circuits and operation of varactor, schottky diodes with applications.				1					
			2	Outline the functionality of tunnel and IMPATT diodes with performance characteristics.	1								
			3	Estimate the applications of Gunn and PIN diodes in microwave integrated circuits.				2					
			4	Categorize different microwave transistors and their applications.			1						
6	18EC51B2	Global Navigation Satellite System	1	Understand GPS and UTC Time, Signal Structure and Get an idea about Receiver Components and Specifications.	1								
			2	Perform Mathematical Analysis to estimate Clock Errors, Total Electron Content and Dual Frequency.		3							
			3	Discussion on GPS Data Processing and Position Fixing.		1							
			4	Understand GNSS Principle of Operation and Architecture. Understand Different Satellite Navigation Systems like Galileo, GLONASS, IRNSS Space, Control and Ground Segments.	1								
7	18EC5205	Microwave and Millimetric wave circuits	1	Classify different microwave circuits based on applications.		1							
			2	Estimate the importance of transformers and resonators in microwave circuit design.			3						
			3	Design of microwave filters and periodic structures.				3					
			4	Understand the feeding principles and excitation techniques in waveguide design.				1					
			5	Construct millimeter wave circuits using electromagnetic tools.				3					
8	18EC5206	Antenna Measurements	1	Understand the concepts of antenna pattern measurements and modeling techniques.		1							
			2	Estimate antenna testing in different environments like elevated, ground, near and radar cross section.			2						
			3	Examine the far field testing of antenna for gain, directivity and patterns.		1							
			4	Analysis of compact ranges and near field testing with cylindrical and spherical scanning.				2					

			5	Determine antenna parameters using measurement instruments like VNA and SR in real time environment.					1				
9	**18EC5207**	**Wireless Cellular Communications**	**1**	Understand the basic elements of cellular mobile radio system design.	1								
			2	Identify different applications of speech coding in wireless systems.		1							
			3	Understand the radio propagation and cellular engineering concepts	1								
			4	Identify digital modulation and demodulation principles and architectures, interference in wireless communication systems.	1								
10	**18EC5208**	**Modern RADAR Systems**	**1**	Summarize the advanced techniques in modern radar system.	3								
			2	Categorize advanced pulse compression waveform modulations and techniques.		1							
			3	Understand the concept of MIMO radar system and applications.				1					
			4	Realize the radar applications related to sparse reconstruction and compressed sensing and digital beam forming.				2					
11	**18EC52C1**	**Estimation and Detection Theory**	**1**	Classify different criteria associated to detection theory at receiver.		1							
			2	Understand the concepts of integration of optimum receiver and matched filter receiver.			1						
			3	Analyze the maximum likelihood estimation methods.		3							
			4	Understand the concepts of estimation in the presence of Gaussian noise and prediction with Kalman filters.			1						
12	**18EC52D1**	**RF and Microwave System Design**	1	Understand the importance of RF & Microwave System design with passive components.	1								
			2	Understand Smith chart concept for analyzing S, Y, Z parameters.		1							
			3	Analyze S-parameters with conversions and modeling.		2							
			4	Design of RF- filters, amplifiers and oscillators.				3					
13	**18 IE 5149**	**Seminar**								3	2	2	2
14	**18 IE 5250**	**Term Paper**								3	2	2	2
15	**18 IE 6050**	**Dissertation**								3	2	2	2

Syllabus

MODERN DIGITAL COMMUNICATION

Course Code :18 EC 5101 **L-T-P : 3-1-2**

Pre-requisite: NIL **Credits: 5**

Syllabus:

Modern Digital Modulation Techniques:

Introduction, Information Capacity, Bits, Bit Rate, Baud rate & M-ary Encoding, ASK, FSK, PSK QAM Bandwidth Efficiency Carrier Recovery, Clock Recovery, DPSK, Trellis Code Modulation, Probability of Error & Bit Error Rate, Error Performance.

Baseband Data Transmission: Introduction – Baseband Binary PAM Systems – Baseband Pulse Shaping, Optimum Transmitting and Receiving Filters – Duobinary Baseband PAM System – Use of Controlled ISI in Duobinary Signaling Schemes, Transmitting and Receiving Filters for Optimum Performance **– M-ary Signaling Schemes** – Analysis and Design of M-ary Signaling Schemes, Binary Versus M-ary Signaling Schemes - Shaping of the Transmitted Signal Spectrum – Effect of Pre coding on the Spectrum, Pulse Shaping by Digital Methods - Equalization - Transversal Equalizer, Automatic Equalizers

Block and Convolutional Channel Codes: Linear Block Codes - The Generator Matrix and Parity Check Matrix, Cyclic Codes, Bounds on Minimum Distance of Linear Block Codes, Non Binary Block Codes – Convolutional Codes – Transfer Function of a Convolutional Code, Optimum Decoding of Convolutional Code –Distance Properties of Binary Convolutional Codes

Spread Spectrum Signals for Digital Communication: Model of Spread Spectrum Digital Communication System – Direct Sequence Spread Spectrum Signals – Error Rate Performance of the Decoder, Some Applications of DS Spread Spectrum Signals, Generation of PN Sequences – Frequency Hopped Spread Spectrum Signals – Performance of FH Spread Spectrum Signals in an AWGN Channel, CDMA System Based on FH Spread Spectrum

Signals Emerging Digital Communication Technologies.: The North American Hierarchy, Digital Services, Broad band Digital Communication: SONET, Digital Switching Technologies, Broadband Services for Entertainment and Home office Applications, Video Compression, High Definition Television(HDTV)

TEXT BOOKS

1. Advanced Electronic Communications Systems, by Wayne Tomasi, 6 Edition Pearson Education.

2. K Sam Shanmugam, Digital and Analog Communication Systems, John Wiley and sons (Asia) Pvt Ltd.

REFERENCES

1. Simon Haykin, Digital communications, John Wiley and sons, 1998

2. Wayne Tomasi, Advanced electronic communication systems, 4th Edition Pearson Education Asia, 1998

3. B.P.Lathi Modern digital and analog communication systems, 3rd Edition, Oxford University press

MICROWAVE ANTENNAS

Course Code :18 EC 5102 **L-T-P : 3-1-2**

Pre-requisite: NIL **Credits: 5**

Syllabus:

Introduction to Antenna Theory: Antenna Radiation concept, Types of Antennas, Antenna parameters, Friis Transmission equation.

Aperture Antenna: Introduction, Pyramidal Horns- Design Procedure, Conical and Corrugated Horns, Aperture Corrugated Horns, Reflected Antennas- Parameters, Analysis of front-fed parabolic reflector, Feed methods and feed types, Cassegrain Reflector Horns.

Microstrip Radiators: Introduction, Rectangular Microstrip Antenna analysis and Design, Circular Microstrip Antenna Analysis and Design.

Pencil-Beam and Fanned-Beam Antennas: Pencil-beam Requirements and Techniques, Geometrical Parameters, The Surface-current and Aperture-field distributions, The Radiation Field of the Reflector, The Antenna Gain, Primary Pattern Designs for maximizing gain, Impedance Characteristics, The Vertex-plate matching Technique, Rotation of Polarization Technique, Structural Design Problems. Simple Fanned-Beam Antennas: Applications of Fanned Beams and methods of Production, Symmetrically Cut Paraboloids, Feed Offset and Contour Cutting of Reflectors, The Parabolic Cylinder and Line Source, Parallel-plate Systems, Pillbox Design Problems.

Shaped-Beam Antennas:

Shaped-beam Applications and Requirements, Effect of a Directional Target Response Survey of Beam-shaping Techniques, Design of Extended Feeds, Cylindrical Reflector Antennas, Reflector Design on the Basis of Ray Theory, Radiation Pattern Analysis, Double Curvature Reflector Antennas, Variable Beam Shape.

Text Books:

1. Constantine A. Balanis – "Antenna Theory-Analysis and Design", 3rd Edition, John Wiley, 2005.
2. Samuel Silver, "Microwave Antenna - Theory and design", IEE Press, 1984.

Reference Books:

1. Ramesh Garg, Prakash Bhatia, "Microstrip Antenna Design - Hand Book" Architect House Inc. 2001.
2. Bahl IJ, and Bhartia N, "Microstrip Antennas", Artech House, 1982.
3. James.J R. Hall, P S. Wood.C., "Micro strip Antenna-Theory and Design", PeterPeregrinu, 1981.

EMI / EMC TECHNIQUES

Course Code :18 EC 5103 **L-T-P : 3-1-0**

Pre-requisite: NIL **Credits: 4**

Syllabus:

Introduction, Natural and Nuclear sources of EMI / EMC: 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 inter-modulation, cross talk in transmission lines, transients in power supply lines, electromagnetic interference (EMI). Open area test sites and measurements.

Radiated and conducted interference measurements and ESD: 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. ESD, Electrical fast transients / bursts, electrical surges.

Grounding, shielding, bonding and EMI filters: Principles and types of grounding, shielding and bonding, characterization of filters, power lines filter design.

Cables, connectors, components and EMC standards: EMI suppression cables, EMC connectors, EMC gaskets, Isolation Transformers, optoisolators, National / International EMC standards.

Text Books:

1. Dr. V.P. Kodali, "Engineering Electromagnetic Compatibility", IEEE Publication, Printed in India by S. Chand & Co. Ltd., New Delhi, 2000.
2. Electromagnetic Interference and Compatibility IMPACT series, IIT – Delhi, Modules1 – 9.

Reference Books :

1. C.R. Pal, "Introduction to Electromagnetic Compatibility", A John Wiley & Sons, Inc. Publication, 1992.
2. Terence Rybak, Mark Steffka, "Automotive Electromagnetic Compatibility (EMC)", Kluwer Academic Publisher, London.

RADAR ENGINEERING

Course Code :18 EC 5104 **L-T-P : 3-1-0**

Pre-requisite: NIL **Credits: 4**

Syllabus:

The Radar and its Ground Environment: Primary and Secondary Radar, Coordinate systems and range, Main monostatic radar components, Basic quantities, maximum range, Secondary radar, Bistatic radar, Performance.

Transmitters: Transmitter power, Power output stage, Spectrum and side bands, Pulse compression, Harmonics from the Transmitter.

Factors outside the Radar, propagation, scattering and clutter: Amplitude and phase of the echo, Effects of the atmosphere, Scattering without fading, overview of scattering models, second-time-around effect, scenario to simulate a typical radar environment.

Receiver: Dynamic range, the control of gain, and sensitivity time control, radio frequency section, Intermediate frequency amplifier and filter, limiters, receiver characteristics.

Determination of position: Fire control radars, sector scan radars, fast scanning radars, surveillance radars, accuracy.

Text Books

1. Hamish Meikle, “Modern Radar Systems”, Second Edition, Artech House Radar Library.

FUNDAMENTALS OF ELECTRONIC WARFARE

Course Code :18 EC 51A1 **L-T-P : 3-0-0**

Pre-requisite: NIL **Credits: 3**

Syllabus:

Targets of Electronic Warfare Operations: A General Description of Targets of Electronic Warfare Operations, Mathematical Models of Electronic Systems as Targets of Electronic Warfare, Mathematical Models of Automated Systems for the Control of AAD Forces as Targets of EW, Mathematical Models of Automated Systems for the Control of AAD Weapons as Targets of Electronic Warfare

Mathematical Models of Signals, Systems and Techniques for Electronic Jamming: A General Description of the Basic Elements of Electronic Jamming, Mathematical Models of Jamming Signals, Mathematical Models of Systems and Techniques for Jamming.

Electronic Warfare Effectiveness Criteria: General Characteristics of the Criteria, Information Indicators of the Effectiveness of Jamming Signals, Systems and Techniques of Electronic Attack, Energy Effectiveness Criteria of Jamming Signals and Techniques of Electronic Jamming, Operational and Tactical Indicators of EW Effectiveness

Active Jamming of Radar -The Jamming Equation: Fundamental Concepts, The Jamming Equation for Monostatic Radar Using Active Jamming, Reduction of the Jamming Equation to Canonical Form -Methods of Determining Information Damage, Specifics of the Jamming Equation Using Active Jamming against Various Types of Radar, Particulars of Jamming Radar Using Screening Jamming with Limited Information Quality Indicators -Use of the Jamming Equation for Analysis of the Electronic Environment

Targets and Decoys: Types of False Radar
Targets, Decoys and Disposable EW Devices, Parameters Simulated by False Radar Targets and Radar Decoys, Thermal Decoys, The Use of Towed and Launched Decoys, Selecting Decoy Launch Time

TEXT BOOK

Sergei A. Vakin,Lev N. Shustov, Robert H. Dunwell, "Fundamentals of Electronic Warfare, Artech House

MICROWAVE SEMICONDUCTOR DEVICES

Course Code :18 EC 51A2 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**
Syllabus:

Introduction: Transient and ac behavior of p-n junctions, effect of doping profile on the capacitance of p-n junctions, noise in p-n junctions, high-frequency equivalent circuit, varactor diode; Schottky effect, Schottky barrier diode; Heterojunctions.

Tunnel and Avalanche Transit Time diodes: Tunneling process in p-n junction and MIS tunnel diodes, V-I characteristics and device performance, backward diode. Impact ionization, IMPATT diode, small-signal analysis of IMPATT diodes.

Gunn diode: Two-valley model of compound semiconductors, vd-E characteristics, Gunn effect, modes of operation, power frequency limit.

PIN Diodes: Construction and operation of microwave PIN diodes, equivalent circuit, PIN diode switches and modulators.

Microwave Transistor: High frequency limitations of BJT, microwave bipolar transistors, Operating characteristics of MISFETs and MESFETs, short-channel effects, high electron mobility transistor.

Text books:

1. Liao, S.Y., "Microwave Devices and Circuits", 4th Ed., Pearson Education 2002.
2. Rebeiz, M.G., "R.F. MEMS: Theory, Design and Technology", 2nd Ed.,Wiley-Interscience 2003.

Reference Books:

1. Sze, S.M., and Ng, K.K., "Physics of Semiconductor Devices", 3rd Ed.,Wiley-Interscience 2006.
2. Glover, I.A., Pennoek, S.R. and Shepherd P.R., "Microwave Devices, Circuits and Sub-Systems", 4th Ed., John Wiley & Sons 2005.
3. Golio, M., "RF and Microwave Semiconductor Devices Handbook", CRC Press 2002.

SMART ANTENNAS

Course Code :18 EC 51A3 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**
Syllabus:

Smart Antennas: Introduction, Need for Smart Antennas, Overview, Smart Antenna Configurations, Switched-Beam Antennas, Adaptive Antenna Approach, Space Division Multiple Access (SDMA), Architecture of a Smart Antenna System, Receiver, Transmitter, Benefits and Drawbacks, Basic Principles, Mutual Coupling Effects.

DOA Estimation Fundamentals: Introduction, Array Response Vector, Received Signal Model, Subspace-Based Data Model, Signal Auto-covariance, Conventional DOA Estimation Methods, Conventional Beam forming Method, Capon's Minimum Variance Method, Subspace Approach to DOA Estimation, MUSIC Algorithm, ESPRIT Algorithm, Uniqueness of DOA Estimates .

Beam Forming Fundamentals: Classical Beam former, Statistically Optimum Beam forming Weight Vectors, Maximum SNR Beam former, Multiple Side-lobe Canceller and Maximum, SINR Beam former, Minimum Mean Square Error (MMSE), Direct Matrix Inversion (DMI), Linearly Constrained Minimum Variance (LCMV), Adaptive Algorithms for Beam forming

Integration and Simulation of Smart Antennas: Overview, Antenna Design, Mutual Coupling, Adaptive Signal Processing Algorithms, DOA, Adaptive Beam forming, Beam forming and Diversity Combining for Rayleigh-Fading, Channel, Trellis-Coded Modulation (TCM) for Adaptive Arrays, Smart Antenna Systems for Mobile Ad Hoc Networks (MANETs), Protocol, Simulations, Discussion.

Space–Time Processing: Introduction, Discrete Space–Time Channel and Signal Models, Space–Time Beam forming, Inter-symbol and Co-Channel Suppression, Space–Time Processing for DS-CDMA, Capacity and Data Rates in MIMO Systems, Discussion.

Text Books:

1. Constantine A. Balanis & Panayiotis I. Ioannides, "Introduction to Smart Antennas", Morgan & Claypool Publishers' series-2007
2. Joseph C. Liberti Jr., Theodore S Rappaport - "Smart Antennas for Wireless Communications IS-95 and Third Generation CDMA Applications", PTR – PH publishers, 1st Edition, 1989.

Reference Books:

1. T.S Rappaport - "Smart Antennas Adaptive Arrays Algorithms and Wireless Position Location", IEEE press 1998, PTR – PH publishers 1999.
2. Lal Chand Godara, "Smart Antennas", CRC Press, LLC-2004.

PHASED ARRAY SYSTEMS

Course Code :18 EC 51B1 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**
Syllabus:

Conventional Scanning Techniques: Mechanical versus electronic scanning, Techniques of Electronic scanning, Frequency, Phase and time delay scanning principle, Hybrid scanning techniques.

Array Theory: Linear and Planner arrays, various grid configuration, Concept of cell and grid, Calculation of minimum number of elements, Radiation pattern, Grating lobe formation, Rectangular and triangular grid design of arrays.

Feed Networks for phased Arrays: Corporate Feed, Lens and Reflect feed Techniques, Optimum f/d ratio basic building block for corporate feed network, Series, Parallel feed networks, Comparison of various feeding techniques, Antenna Array Architecture, Brick/ Tile Type construction.

Frequency Scanned Array Design: Snake feed, Frequency-phase scanning, Phase scanning, Digital phase shifter PIN diode and Ferrite phase shifters for phased arrays, Beam pointing errors due to digitalization, Beam pointing accuracy.

Search Patterns: Calculation of search frame time, airborne phased array design, Electronic scanning radar parameter calculation, Application of phased arrays, Phased Array Radar Systems, Active Phased Array, TR/ATR Modules.

Text Books:

1. Olliner, A.A, and G.H. Knittel, "Phased Array Antennas", Artech House, 1972.
2. Kahrilas. PJ, "Electronic Scanning Radar Systems Design Handbook", Artech House, 1976.

Reference Books:

1. Skolnik. MI, "Radar Handbook", Mcgraw Hillso, NY,McGrow Hills-2007.
2. Galati,G-(editor), "Advanced Radar Technique and Systems", Peter Peregrims Ltd, London,1993.

GPS & GLOBAL NAVIGATION SATELLITE SYSTEM

Course Code :18 EC 51B2 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**
Syllabus:

GPS Signals: GPS and UTC Time, Signal structure, C/A and P-code, ECEF and ECI coordinate systems and WGS 84 datum, Important components of receiver and specifications.

GPS error Models: Ionospheric error, Tropospheric error, Ephemeris error, Clock errors, Satellite and receiver instrumental biases, Antenna phase center variation, multipath, estimation of Total Electron Content(TEC) using Dual Frequency measurement, Various DOP's, UERE.

GPS data processing and position fixing: RINEX navigation and observation formats, Code and Carrier phase observables, Linear combinations and derived observables, Ambiguity resolutions, Cycle slips, Position estimation.

GNSS fundamentals: Trilateration, Hyperbolic navigation, Transit, GNSS principle of operation, Architecture, Operating frequencies, orbits, Keplerian elements.

Other satellite Navigation Systems: Galileo, GLONASS, IRNSS, Space, control and ground segments and Signal characteristics.

Text Books:

1. Global Navigation Satellite Systems – G. S. Rao, McGraw-Hill publications, New Delhi, 2010.
2. GPS Theory and Practice - B.Hofmann Wollenhof, H.Lichtenegger, and J.Collins, Springer Wien, New York, 2000.

Reference Books:

1. Introduction to GPS - Ahmed El -Rabbany, Artech House, Boston, 2002.
2. Global Positioning System Signals, Measurements, and Performance - Pratap Misra and Per Enge, Ganga-Jamuna Press, Massachusetts, 2001.

OPTICAL COMMUNICATIONS

Course Code :18 EC 51B3 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**
Syllabus:

Signal propagation in Optical Fibers: Geometrical Optics approach and Wave Theory approach, Loss and Bandwidth, Chromatic Dispersion, Non Linear effects- Stimulated Brillouin and Stimulated Raman Scattering, Propagation in a Non-Linear Medium, Self Phase Modulation and Cross Phase Modulation, Four Wave Mixing, Principle of Solutions.

Fiber Optic Components for Communication & Networking: Couplers, Isolators and Circulators, Multiplexers, Bragg Gratings, Fabry-Perot Filters, Mach Zender Interferometers, Arrayed Waveguide Grating, Tunable Filters, High Channel Count Multiplexer Architectures, Optical Amplifiers, Direct and External Modulation Transmitters, Pump Sources for Amplifiers, Optical Switches and Wavelength Converters.

Modulation and Demodulation: Signal formats for Modulation, Subcarrier Modulation and Multiplexing, Optical Modulations – Duobinary, Single Side Band and Multilevel Schemes, Ideal and Practical receivers for Demodulation, Bit Error Rates, Timing Recovery and Equalization, Reed-Solomon Codes for Error Detection and Correction.

Transmission System Engineering: System Model, Power Penalty in Transmitter and Receiver, Optical Amplifiers, Crosstalk and Reduction of Crosstalk, Cascaded Filters, Dispersion Limitations and Compensation Techniques.

Fiber Non-Linearities and System Design Considerations: Limitation in High Speed and WDM Systems due to Non-linearities in Fibers, Wavelength Stabilization against Temperature

Variations, Overall System Design considerations – Fiber Dispersion, Modulation, Non-Linear Effects, Wavelengths, All Optical Networks.

Text Books:

1. Rajiv Ramaswami and Kumar N. Sivarajan, "Optical Networks: A Practical Perspective", 2nd Ed., 2004, Elsevier Morgan Kaufmann Publishers, Elsevier.
2. Gerd Keiser, "Optical Fiber Communications", 3rd Ed., 2000, McGraw Hill.

Reference Books:

1. John.M.Senior, "Optical Fiber Communications: Principles and Practice" 2nd Ed., PE, 2000.
2. Harold Kolimbris, "Fiber Optics Communication", 2nd Ed., PEI, 2004.
3. Uyless Black, "Optical Networks: Third Generation Transport Systems", 2nd Ed., PEI, 2009.
4. Govind Agarwal, "Optical Fiber Communications", 2nd Ed., TMH, 2004.
5. S.C.Gupta, "Optical Fiber Communications and Its Applications", PHI, 2004.

MICROWAVE AND MILLIMETRIC WAVE CIRCUITS

Course Code :18 EC 5205 **L-T-P : 3-1-2**
Pre-requisite: NIL **Credits: 5**
Syllabus:

Analysis of Microwave Circuits: Introduction, Microwave Components – E-plane Tee, H-plane Tee, Magic Tee, Directional Coupler, Isolator, Circulator & their Scattering.

Transformers & Resonators: Parameters, Impedance Transformers – Quarter wave Transformers, Microwave Resonators – Rectangular and Cylindrical Resonators.

Filters And Periodic Structures: Design of Narrow Band Low Pass, Band Pass and High Pass Filters, Maximally flat and Chebyshev Designs, Introduction to Periodic Structures, Floquet's Theorem, Circuit Theory Analysis of Infinite and Terminated Structures.

Obstacles In Wave Guides: Introduction, Posts in Waveguides, Diaphragms in Waveguides, Waveguide Junctions, Waveguide Feeds, Excitation of Apertures.

Millimeter Wave Circuits: Wave Propagation in microstriplines, Discontinues in Microstrips, Parallel Coupled lines, Power Dividers and Directional Couplers, Microwave and Millimeter Wave Integrated Circuits

TEXT BOOKS

1. Roger F. Harrington, "Time-Harmonic Electromagnetic Fields", Mc graw-hill
2. Robert E Collin, "Foundation for Microwave Engineering", Mc Graw-Hill.

REFERENCE BOOKS

1. Cam Nguyun, “Analysis Methods for RF, Microwave, and Millimeter-Wave Planar Transmission Line Structures”, John Wiley & Sons, Inc. 2000.
2. Hoffman R. K., “Handbook of Microwave Integrated Circuits”, Artech House Publishers, 1987.

ANTENNA MEASUREMENTS

Course Code :18 EC 5206 **L-T-P : 3-1-2**
Pre-requisite: NIL **Credits: 5**
Syllabus:

Antenna Pattern Measurements: Basic Considerations, Pattern Formats, Fresnel Region Measurements, Modeling Techniques,**Antenna Range Design and Evaluation**: Introduction, Electromagnetic Design Consideration, Antenna Range Evaluation.

Antenna Testing: Introduction, Types of of Ranges: Elevated Ranges, Ground Ranges, Near Field Ranges, Radar Cross Section Ranges.

Far Field Range Design: Introduction, Designing the Range, Source Design, Receiving Site Design, Ground Ranges.

Far Field Antenna Tests: Introduction, Pattern Testing, Gain and Directivity, Polarization. **Far Field Pattern Errors**: Introduction, Error Estimates, Error Correction, Antenna Errors.

Compact Ranges: Introduction, Room Design, Feed Design, Reflector Design. **Near Filed Testing**: Introduction, Planar Near Field Ranges, Errors, Cylindrical and Spherical Scanning

TEXT BOOKS

1.Evans, Gray E," Antenna measurements techniques", Artech House, Inc
2.J S Hollis, T J Lyon, L Clayton," Microwave Antenna Measurements” , Scientific Atlants, Inc

WIRELESS CELLULAR COMMUNICATION

Course Code :18 EC 5207 **L-T-P : 3-1-0**
Pre-requisite: NIL **Credits: 4**
Syllabus:

Introduction to Cellular Mobile Systems: Cellular Mobile Telephone Systems, A Basic Cellular System, Operation of Cellular Systems. **Elements of Cellular Mobile Radio System Design:** General Description of the problem, Concept of Frequency reuse channels, Co-Channel Interference Reduction Factor, Handoff Mechanism, Cell Splitting.

Speech Coding for Wireless Systems Applications: Introduction to Digital Signal Processing (DSP) Techniques in Wireless Telephone and Broadcast Systems, Speech Coding Techniques for

Audio and Voice – Pulse Code Modulation, DPCM, Delta Modulation, Vocoder and Linear Predictive Coding, Performance Comparison of Speech Processing Techniques.

Radio Propagation and Cellular Engineering Concepts: Fundamental Radio Propagation and System Concepts, Propagation Characteristics, Models of Multipath-faded radio signals – Un modulated Carrier, Envelope and Phase faded, Level Crossing rate and fade Duration, Delay Spread Measurements.

Digital Modulation-Demodulation (Modem) Principles and Architectures: Coherent Modem – Baseband Modem Equivalence, Coherent and Differentially Coherent Binary Phase Shift Keying Systems, Synchronization – Carrier Recovery and Symbol Timing Recovery, Differential Encoding and Decoding Requirement, Quadrature Phase shift Keying – Coincident and offset Types, Pi/4 DQPSK Modems – Architecture.

Interference In Wireless Digital Communication: Carrier-to-Interference and Carrier-to-Noise Limited Systems, Cochannel Interference, Adjacent Channel Interference. Externally caused Cochannel Interference, Definitions and performance of Spectral and Power Efficiency, Relationship of the Bit-Energy to Noise-Density Ratio and the Carrier-to-Noise Ratio, Power Efficiency and Bit-Error-Rate performance in an Additive White Gaussian Noise Environment, Concepts of Diversity Branch and Signal paths; Combining and Switching Methods.

TEXT BOOKS

1. Dr Kamilo Feher Wireless Digital Communications, Prentice Hall of India, New Delhi – 1999
2. William Cy Lee, Mobile Cellular Telecommunications, 2nd Edition, MC Graw Hill.

MODERN RADAR SYSTEMS

Course Code :18 EC 5208 **L-T-P : 3-1-0**
Pre-requisite: NIL **Credits: 4**
Syllabus:

Overview: Advanced Techniques in Modern Radar: Introduction, Radar Modes, Radar and System Topologies.

Advanced Pulse Compression Waveform Modulations and Techniques: Introduction, Stretch Processing, Stepped Chirp Waveforms, Nonlinear Frequency Modulated Waveforms, Stepped Frequency Waveforms, Quadriphase Signals, Mismatched Filters.

MIMO Radar: Introduction, An Overview of MIMO Radar, The MIMO Virtual Array, MIMO Radar Signal Processing, Waveforms for MIMO Radar, Applications of MIMO Radar.

Radar Applications of Sparse Reconstruction and Compressed Sensing: Introduction, CSTheory, SR Algorithms, Sample Radar Applications.

Adaptive Digital Beamforming: Introduction, Digital Beamforming Fundamentals, Adaptive Jammer Cancellation, Adaptive Beamformer Architectures, Wideband Cancellation.

TEXT BOOKS

1. William L.Melvin, James A. Scheer, "Principles of Modern Radar", volume II: Advanced Techniques, SciTech Publishing.

ESTIMATION AND DETECTION THEORY

Course Code :18 EC 52C1 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**
Syllabus:

Detection Theory: Maximum likelihood decision criterion; Neymann-Pearson criterion; Probability of error criterion; Bayes risk criterion; Minimax criterion; Robust detection; Receiver operating characteristics.

Detection Theory: Vector observations; The general Gaussian problem; Waveform observation in additive Gaussian noise; The integrating optimum receiver; Matched filter receiver.

Maximum Likelihood Estimation; Bayes cost method Bayes estimation criterion – Mean square error criterion; Uniform cost function; absolute value cost function; Linear minimum variance - Least squares method;

Estimation in the presence of gaussian noise -Linear observation; Non-linear estimation. Properties of estimators**:** Bias, Efficiency, Cramer Rao bound Assymptotic properties; Sensitivity and error analysis

Prediction: Kalman filter. Sufficient statistics and statistical estimation of parameters: Concept of sufficient statistics; Exponential families of distributions; Exponential families and Maximum likelihood estimation; Uniformly minimum variance unbiased estimation.

TEXT BOOKS

1.Steven M. Kay, Statistical Signal Processing: Vol. 1: Estimation Theory, Vol. 2: Detection Theory, Prentice Hall Inc., 1998.
2.Harry L. Van Trees, Detection, Estimation and Modulation Theory, Part 1, John Wiley & Sons

REFERENCES

1.James L. Melsa and David L. Cohn, Decision and Estimation Theory, McGraw Hill, 1978.
2.Dimitri Kazakos, P. Papantoni Kazakos, Detection and Estimation, Computer Science Press,
3.Jerry M. Mendel, Lessons in Estimation Theory for Signal Processing,
Communication and Control, Prentice Hall Inc.
4. Sophocles J. Orfanidis, Optimum Signal Processing 2nd edn., McGraw Hill.
5.Monson H. Hayes, Statistical Digital Signal Processing and Modelling, John Wiley & Sons
6. Scott C. Statistical Signal Processing , June 14, 2004.

RADAR SIGNAL PROCESSING

Course Code :18 EC 52C2 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**
Syllabus:

Angle-of-Arrival Estimation in the Presence of Multipath: The Low-Angle Tracking Radar Problem, Spectrum Estimation Background, Thomson's Multi-Taper Method, Comparison of Some Popular Spectrum Estimation Procedures, Multi-taper Spectrum Estimation, *F*-Test for the Line Components

Time–Frequency Analysis of Sea Clutter: An Overview of Non-stationary Behavior and Time–Frequency Analysis, Theoretical Background on Non-stationary, High-Resolution Multi-taper Spectrograms

Dynamics of Sea Clutter: Statistical Nature of Sea Clutter: Classical Approach, Is There a Radar Clutter Attractor, Hybrid AM/FM Model of Sea Clutter, Modeling Sea Clutter as a Non-stationary Complex Autoregressive Process

Sea-Clutter Non-stationary: The Influence of Long Waves: Radar and Data Description, Statistical Data Analyses, Modulation of Long Waves: Hybrid AM/FM Model, Non-stationary AR Model

Two New Strategies for Target Detection in Sea Clutter: Bayesian Direct Filtering Procedure, Operational Details, Experimental Results on the Bayesian Direct Filter, Correlation Anomally Detection Strategy - Overview

TEXT BOOKS

1. I. Haykin, Simon S, "Rader Adaptive signal processing", John Wiley & Sons
2. Mark A Richards, "Fundamentals of Radar signal processing", M C Graw Hill

HIGH PERFORMANCE COMMUNICATION NETWORKS

Course Code :18 EC 52C3 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**
Syllabus:

Principles of Networks networking principles: Network services, High performance networks, Network elements, network mechanisms, layered architecture

Packet Switched Networks Principles: OSI & TCP/IP models, transmission media, routing algorithms, Congestion control algorithms, Internetworking, Ethernet(IEEE 802.3), Tokenring (IEEE 802.5),Tokenbus (IEEE802.4), FDDI.

Network security: (cryptography, symmetric key algorithms, private key algorithms, digital signatures, authtication protocols)

The Internet And TCP/IP Networks & Circuit Switched Networks: Overview of Internet protocols, Internet control protocols, Elements of transport Protocols, TCP & UDP , Performance of TCP/IP networks, SONET, DWDM, Solitons

Optical Networks: Fiber principles (elements of optical fiber communication, acceptanceangle, Numerical aperture, modes, fiber types), optical links(point to point links,attenuation,optical budgeting, dispersion),splices ,connectors optical Lans,non Semiconductors, opticalamplifiers,Erbium doped Fiber mplifiers, couplers/splitters, optical switches ATM networks Main features of ATM, Addressing , signaling, routing, ATM header structure

TEXT BOOKS

1. Jean Walrand and Pravin variya , " High performance Communication networks", 2nd edition, Harcourt and Morgan Kauffman, London 2000
2. Andrew S. Tanenbaum, "Computer networks", PHI Private limited, new Delhi

REFERENCES

1. Gerd Keiser, MC Graw Hill International edition, optical fiber communication , third edition
2. John M Senior, PHI limited, optical fiber communication , third edition
3. Leon Gracia, Widjaja, " Communication Networks", Tata Mc Graw –Hill, New Delhi, 2000.
4. Behroz a. Forouzan, "Data communication and networking ", Tata MC Graw –Hill, New Delhi
5. Sumit Kasera, Pankaj Sethi, " ATM Networks", Tata Mc Graw- Hill, New Delhi , 2000

RF & MICROWAVE SYSTEM DESIGN

Course Code :18 EC 52D1 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**
Syllabus:

Introduction: Importance of RF and Microwave Concepts and Applications- and Units-Frequency Spectrum, RF and Microwave Circuit Design, Dimensions - RF Behavior of Passive Components: High Frequency Resistors, High Frequency Capacitors, High Frequency Inductors, General Introduction, Types of Transmission Lines-Equivalent Circuit representation.

The Smith Chart: Introduction, Derivation of Smith Chart, Description of two types of smith chart, Z-Y Smith chart, Distributed Circuit Applications, Lumped Element Circuit Applications. SINGLE AND MULTIPORT NETWORKS: Basic Definitions, Interconnecting Networks.

Scattering Parameters: Scattering Parameters: Definition, Meaning, Chain Scattering Matrix, Conversion Between S- and Z-parameters, Signal Flow Chart Modelling.

Stability and Gain Considerations – RF Design RF Source, Transducer Power Gain, Additional Power Relations-Stability Considerations: Stability Circles, Unconditional Stability, and Stabilization Methods-Unilateral and Bilateral Design for Constant Gain- Noise Figure Circles- Constant VSWR Circles.

Rf Filters, Amplifiers And Oscillators Design Generalization-Basic Resonator and Filter Configurations: Low Pass, High Pass, Band Pass and Band Stop type Filters-Filter Implementation using Unit Element and Kuroda's Identities Transformations. Introduction, Types and Characteristics of Amplifiers, Small Signal Amplifiers, Design of different types of amplifiers (NBA, HGA, MGA, LNA, MNA, BBA), Design of Large Signal Amplifiers Oscillator vs Amplifier Design, Design procedure of Transistor Oscillators.

1.Mathew M. Radmanesh, "Radio Frequency & Microwave Electronics", Pearson Education Asia, Second Edition,
2.Reinhold Ludwig and Powel Bretchko," RF Circuit Design – Theory and Applications", Pearson Education Asia, First Edition.

REFERENCES

1.Joseph . J. Carr, "Secrets of RF Circuit Design", McGraw Hill Publishers, Third Edition.
2.Ulrich L. Rohde and David P. New Kirk, "RF / Microwave Circuit Design", John Wiley & Sons USA, 2000.
3.Roland E. Best, "Phase - Locked Loops: Design, simulation and applications", McGraw Hill Publishers 5TH
4.Devendra K.Misra ,"Radio Frequency and Microwave Communication Circuits – Analysis and Design "John Wiley & Sons, Inc.
7. Ian Hickman, " RF HandBook ", Butter Worth Heinemann Ltd., Oxford, 1993.
8. Ulrich L.Rohde, T.T.N.Bucher, " Communication Recievers ", McGraw-Hill, New York, 1998.

VLSI DESIGN

Course Code :18 EC 52D2 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**
Syllabus:

Design Methodology: Structured design techniques; Programmable logic; Gate array and sea of gates design; cell based design; full custom design; Design flow; Design Economics.

Data path Subsystems: Adders; One/zero Detectors; Comparators; Counters; Shifters; Multipliers; Power and Speed Trade-off.

Memory and Array Subsystems: SRAM, DRAM, ROM, Serial access memories; CAM, PLAs; Array yield, reliability; Power dissipation in Memories.

Special-purpose Subsystems: Packaging; power distribution; I/O pads; **Interconnect:** Interconnect parameters; Electrical wire models, capacitive parasitics; Resistive parasitics; Inductive parasitic; Crosstalk; Advanced Interconnect Techniques.

Timing Issues: Timing classification; Synchronous design; Self-timed circuit design; **Clock Synthesis and Synchronization:** Synchronizers; Arbiters; Clock Synthesis; PLLs; Clock generation; Clock distribution; Synchronous Vs Asynchronous Design.

TEXT BOOKS

1.Neil H. E. Weste, David. Harris and Ayan Banerjee,, "CMOS VLSI Design" - Pearson Education, Third
Edition, 2004.
2.Jan M. Rabaey, Anantha Chandrakasan, Borivoje Nikolic, "Digital Integrated Circuits" Pearson Education,
Second Edition.

REFERENCES:

1.Sung-Mo Kang, Yusuf Leblebici, "CMOS Digital Integrated Circuits" TMH, Third Edition, 2003
2. Wayne Wolf, "Modern VLSI Design ", 2nd Edition, Prentice Hall,1998.

SIMULATION BOOKS

1. Etienne Sicard, Sonia Delmas Bendhia, "Basics of CMOS Cell Design", TMH, EEE, 2005.

REMOTE SENSING AND SENSORS

Course Code :18 EC 52D3 **L-T-P : 3-0-0**
Pre-requisite: NIL **Credits: 3**

Syllabus:

Basics of Remote Sensing : Principles of Remote sensing, History of Remote sensing, Remote sensing in India, Electromagnetic Radiation and Electromagnetic Spectrum, EMR quantities: Nomenclature and Units Thermal Emission of Radiation, Radiation Principles (Plank's Law, Stephen Boltezman law), Interaction of EMR with the Earth Surface (Wien's displacement law, Kirchoffs Law) Spectral signature, Reflectance characteristics of Earths cover types, Remote sensing systems.

Platforms and sensors : Platforms, Remote sensing sensors, resolutions Across track and along the track scanning, Optical sensors, Thermal scanners, Microwave sensing radar satellite missions, Landsat series, SPOT series, IRS satellite series, IKNOS

Microwave Remote Sensing: Airborne and Space borne radar systems basic instrumentation. System parameters - Wave length, Polarization, Resolutions, Radar geometry. Target parameters - Back scattering, Point target, Volume scattering, Penetration, Reflection, Bragg resonance, Cross swath variation. Speckie radiometric calibration. Radar - Grametry - Introduction, Mosaicing Stereoscope. Application : Geology, Forestry, Land use, Soils etc. Future trends and Research

Thermal Imaging system : Thermal Imaging System: Introduction - IR region of theElectromagnetic spectrum, Atmospheric transmission, Kinetic and radiant temperature, Thermal properties of materials, Emissivity, Radiant temperature. Thermal conductivity. Thermal capacity, thermal inertia, Apparent thermal inertia, Thermal diffusivity. IR - radiometers, Airborne and Satellite TTR scanner system, Characteristics of IR images ,i) Scanner distortion, ii) image irregularities, iii) Film density and recorded iv)Temperature ranges. Effects of weather on images i) Clouds, ii) Surface winds, iii) Penetration of smoke plumes. Interpretation of thermal imagery. Advantages of Thermal imagery

Meteorological satellites: Meteorological satellite characteristics and their orbits, TIROS, NIMBUS, NOAA, TIROS N, SEASAT, GOES, METEOSAT, INSAT. Measurement of Earth and Atmospheric energy and Radiation budget parameters from satellites

Text books:

1. P.H. Swain and S.M. Davis, "Remote Sensing: The quantitative approach", McGraw Hill.
2. W Travelt, "Imaging Radar for Resource Survey: Remote Sensing Applications", Chapman & Hall.

Reference Books:

1. Floyd, F. Sabins, Jr: "Remote Sensing Principles and Interpretation", Freeman and Co. San Franscisco, 1978
2. C.P.L.O., Longman, "Applied Remote Sensing", Scientific and Technical Publishers.
3. E.C. Barrett & L.F Curtis, "Introduction to Environmental Remote Sensing", Chapman and Hall, London
4. George Joseph, "Fundamentals of remote sensing", Universities Press.