Master of Technology

(2 Years)

DEPARTMENT OF ELECTRONICS ENGINEERING

Indian Institute of Technology (Indian School of Mines), Dhanbad, India

M.Tech.
in
RF & Microwave Engineering (RFME)

Course Structure

M. Tech. in RFME | SEMESTER 1 | Core/Compulsory: 05 | Labs: 02

Course No.	Course Name	L	T	P	C
Semester - 1					
DC 1xx	Advanced Engineering Electromagnetics	3	0	0	9
DC 2xx	Microwave Measurements	3	0	0	9
DC 3xx	Mathematical and Simulation Techniques	3	0	0	9
DC 4xx	Microwave Transmission Lines and Matching Networks	3	0	0	9
DC 5xx	Radio Frequency Integrated Circuits	3	0	0	9
DC xxx	Microwave Measurement Laboratory	0	0	3	3
DC xxx	RF & CAD Project Laboratory	0	0	3	3
	Total	15	0	6	51

M. Tech. in RFME | SEMESTER 2 | Core/Compulsory: 05 | Labs: 02

Course No.	Course Name	L	T	P	C
Semester -2					
DC xxx	D Elective 1	3	0	0	9
DC xxx	D Elective 2	3	0	0	9
DC xxx	D Elective 3	3	0	0	9
DE 5xx	Open Elective 1	3	0	0	9
DE 5xx	Open Elective 2	3	0	0	9
DC xxx	Microwave Design Laboratory	0	0	3	3
DC xxx	Advanced RF & CAD Laboratory	0	0	3	3
	Total	15	0	6	51

List of Electives for Semester 2

Sl. No.	Course No.	Course Name	L	T	P	C
		D Electives:				
1.	DE xxx	Electromagnetic Interference & Compatibility	3	0	0	9
2.	DE xxx	Advanced Antenna Theory	3	0	0	9
3.	DE xxx	Microwave Photonics	3	0	0	9
4.	DE xxx	Numerical Techniques in Electromagnetics	3	0	0	9
5.	DE xxx	Computational Electromagnetics	3	0	0	9
6.	DE xxx	Microwave Communication System	3	0	0	9
		Open Electives:				
1.	OE xxx	Microwave Devices and Networks	3	0	0	9
2.	OE xxx	MIC and MMIC	3	0	0	9

M. Tech. in RFME | SEMESTER 3 |

Course No.	Course Name	L	T	P	C
Semester - 3					
DC xxx	Thesis Unit 1	0	0	0	9
DC xxx	Thesis Unit 2	0	0	0	9
DC xxx	Thesis Unit 3	0	0	0	9
DC xxx	Thesis Unit 4	0	0	0	9
	Total	0	0	0	36

M. Tech. in RFME | SEMESTER 4 |

Course No.	Course Name	L	T	P	C
Semester - 4					
DE xxx/OE xxx	D Elective 4/Open Elective 3	0	0	0	9
DE xxx/OE xxx	D Elective 5/Open Elective 4	0	0	0	9
DC xxx	Thesis Unit 5	0	0	0	9
DC xxx	Thesis Unit 6	0	0	0	9
	Total	0	0	0	36

List of Electives for Semester 4

Sl. No.	Course No.	Course Name	L	T	P	C
		D Electives:				
1.	DE xxx	Smart Antennas	3	0	0	9
2.	DE xxx	RF and Microwave MEMS	3	0	0	9
3.	DE xxx	Radar Engineering	3	0	0	9
		Open Electives:				
1.	OE xxx	Advanced Microwave Measurement & Instrument	3	0	0	9
2.	OE xxx	Microwave Remote Sensing	3	0	0	9

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of

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Semester – I

Course No.	Course Name	L	T	P	C
DC 1xx	Advanced Engineering Electromagnetics	3	0	0	9
DC 2xx	Microwave Measurements	3	0	0	9
DC 3xx	Mathematical and Simulation Techniques	3	0	0	9
DC 4xx	Microwave Transmission Lines and Matching Networks	3	0	0	9
DC 5xx	Radio Frequency Integrated Circuits	3	0	0	9
DC xxx	Microwave Measurement Laboratory	0	0	3	3
DC xxx	RF & CAD Project Laboratory	0	0	3	3
	Total	15	0	6	51

SEMESTER-I | Subject: Advanced Engineering Electromagnetics | D CORE | L-T-P: 3-0-0

Course Philosophy:

To familiarize the students with the basic electromagnetism and formulation of boundary value problem with respect to real time situation. The course prepares the first year PG students where the advance topics like rigours analysis of metallic and dielectric waveguide with Green's function, application of EM theorems, wave solution and reflection and transmission of multiple interfaces will be covered, particularly those including an in-depth description.

Learning Outcomes:

By the end of the course, the students should be able to solve challenging boundary value problems involving waveguide, strip line, cavity and scattering and radiation problems.

Course Structure (39 Lectures)
Module 1 (6 lectures) Maxwell's Equation, Circuit field relations, Boundary conditions, Power & Energy and Time harmonic electromagnetic fields. **Module 2 (12 lectures)** Wave equation and solution, Auxiliary vector potential, Construction of solution, Solution of inhomogeneous vector potential wave equations, Far-field radiation, Radiation and scattering equations with Antenna concept. Rectangular and Circular waveguides and its EM analysis, partially filled waveguide, Transverse resonance method, Dielectric waveguide, Cavity resonators. **Module 3 (10 lectures)** Transverse EM modes, Uniform plane wave in unbounded lossless media- Principal axis & Oblique angle, Transverse EM modes in lossy media, Polarization. Reflection and transmission across an interface, Reflection and transmission of multiple interfaces. **Module 4 (4 lectures)** Duality theorem, Uniqueness theorem, Image theorem, Reciprocity theorem, Reaction theorem, Volume equivalence theorem and Surface equivalence theorem **Module 5 (7 lectures)** Duality Green's function with integral transform techniques, Strum-Liouville problems, Green function in closed and series form, Green's identities and methods, Green's functions of the scalar Helmholtz equation and Dyadic functions.
Text Book: 1. C. A. Balanis, 'Advanced Engineering Electromagnetics', John Wiley & Sons, US, 2nd edition, 2012. **Reference Books:** 1. R. F. Harrington., 'Time Harmonic Electromagnetics Field', John Wiley & Sons and IEEE, USA, 2nd edition, 2001 2. D.K. Cheng, 'Field and Wave Electromagnetics', Addison-Wesley Publishing Company, USA, 2nd edition, 1989. 3. Journal Papers of IEEE Transaction on Antenna and Propagation and IEEE Transaction on Microwave Theory and Techniques

SEMESTER-I | Subject: MICROWAVE MEASUREMENT| D CORE | L-T-P: 3-0-0

Course Philosophy:

The course aims to present the different techniques for measurement and characterization of circuits and antennas for applications in the microwave frequency bands. The student will basically learn how to select the most appropriate instruments and components to organize a measurement setup for a given circuit/microwave property. Moreover, he/she will be able to conduct autonomously some standard measures.

Learning Outcomes:
By the end of the course, the students should be able to setup the basic and some advanced microwave measurement setup for the characterization of active and passive devices.

Course Structure (39 Lectures)
Module 1 (12 lectures) Review of measurement and instrumentation basics, Measurement of Q factor (Loaded, unloaded and External Q factor), Dielectric constant measurement (cavity perturbation method, transmission line methods and resonance methods), Permeability measurement. **Module 2 (12 lectures)** Impedance (Double minima method, Smith Chart, Byrne Bridge, directional coupler method, Probe method), frequency and phase measurement, VSWR and power measurement **Module 3 (8 lectures)** Antenna measurement (Far Field measurement, Gain measurement, return loss and VSWR measurement). **Module 4 (7 lectures)** Vector network analyzer (VNA), Calibration techniques, passive and active circuit characterization using network analyzer, Spectrum analyzers, characteristic of spectrum analyzer.
Text Book: 1. Handbook of Microwave Measurements, by Max Sucher, Jerome Fox, volume: I, II, III, IV, 1963. **Reference Books:** 1. Electronics Measurements by Terman & Pettit, 2nd edition, 1952. 2. Dielectric Materials and Applications by A R Von Hippell, 1995. 3. Antenna Theory by C A Balanis, 4th edition, 2016. 4. Application Note of Keysight (Agilent) Technology 5. Practical Radio frequency test and Measurement by Joseph J. Carr, 1st edition, 2002.

SEMESTER-I | Subject: Mathematical and Simulation Techniques | D CORE | L-T-P: 3-0-0

Philosophy: The 5 modules of the course exposes the students to some of the popular tools required for optimization, mathematical analysis, modeling and design through simulations. Monte Carlo simulations find applications in IC design, communication engineering and quantum mechanics. Estimation theory as well signal transforms are being considered as elements of "machine learning", it is highly relevant for researchers in pre-processing of data, feature extraction, and inferring parameters from data gathered from measurements or simulations, and is extremely important within communication and signal processing. Queuing theory Mathematical models for complex systems are rarely solvable analytically, and algorithms for numerical methods based on computational mathematics needs to be understood by researchers in many problem domains. Queuing theory provides a rich and useful set of mathematical models for the analysis and design of service process for which there is contention for shared resources and provides the student with a framework to compute performance metrics in networking and other similar problems. Several commercial software use the various modules forming a part of the course.

Course (40 Lectures)
Module 1 (8 lectures) Introduction to the course, Filtering techniques for signal estimation, Monte Carlo simulation method, Fast computation of Transforms, Tutorials. **Module 2 (8 lectures)** Root finding techniques, Review of Solution of ordinary and partial differential equations, Numerical methods for solution of differential equations, Numerical integration methods, Tutorials. **Module 3 (8 lectures)** Introduction to Finite element method, Boundary point method, Finite difference method, Discretization of differential equations, Tutorials. **Module 4 (8 lectures)** Introduction to Variation technique, Finite Difference Time Domain method, Mode matching method, Tutorials. **Module 5 (8 lectures)** Optimization Techniques, Queuing models. ** Out of 5 modules, any 4 modules may be floated
Books: 1. W. H. Press, S. A. Teukolsky, W. T. Vellerling and B. P.,Flannery.,"Numerical Recipes",Cambridge University Press, 3rd edition, 2007. 2. Monson H Hayes, "Statistical Digital Signal Processing and Modeling",John Wiley & Sons, 1st edition, 1996. 3. B.S Grewal, "Higher Engineering Mathematics", 42nd Edition, Khanna Publishers 2012. 4. Erwin Kreyszig, "Advanced Engineering Mathematics", 10th Edition, John Wiley 2010. 5. David Kincaid and Ward Cheney, "Numerical Analysis: Mathematics of Scientific Computing", 3rd Edition, American Mathematical Society 2010.

SEMESTER-I | Subject: Microwave Transmission Lines and Matching Networks | D CORE | L-T-P: 3-0-0

Philosophy: Microwave networks, irrespective of basic or advanced in nature, consists of different types of transmission lines and active devices. Therefore, understanding of the transmission lines and different active devices is necessary to design a new microwave network or to understand the operation of an existing network. This course fulfils this requirement.

Course Outcome: By the end of the course students are able to solve matching problem with smith chart, also get familiar with different mode and its operation and usefulness.

Course (39 Lectures)
Module 1 (12 lectures) Introduction to two-wire transmission lines, Per unit length parameters of two wire transmission lines, General analysis of TE and TM modes, Introduction to Parallel plate waveguide, rectangular waveguide and circular waveguide, Field theoretic analysis of coaxial line and parallel plate transmission line, Transmission line analogy of waveguide. **Module 2 (9 lectures)** TE and TM mode Surface wave propagation in grounded dielectric slab, Microstrip lines, Strip lines, Coupled microstrip lines, Introduction to other planar transmission lines such as co-planar waveguide. **Module 3 (18 lectures)** Smith chart, Lumped element matching networks (L, Pi and T-network), Single stub and double stub matching network, Application of Smith chart in designing different matching networks, Quarter wave matching network, Theory of small reflections, Multi-section transformers, Tapered line matching network (Exponential, triangular and Chebyshev), Synthesis of tapered line matching networks, Bode-Fano criteria. **Text Book:**

Foundation of Microwave Engineering, R. E. Collin, 2nd edition, 2007.

Reference Books:

1. Microwave Engineering, D. M. Pozar, 4th edition, 2012.
2. Transmission Line Design Handbook (Artech House Antennas and Propagation Library) by Brian C. Wadell, 1991.
3. Transmission Lines and Lumped Circuits: Fundamentals and Applications (Electromagnetism) by G. Miano and A. Maffucci, 1st edition, 2001.

SEMESTER-I | Subject: Radio Frequency Integrated Circuits | D CORE | L-T-P: 3-0-0

Philosophy: The course aims to give flavor of design techniques of integrated Radio Frequency circuits. So, students will learn design aspects of integrated circuits in Radio Frequency which will help them to get job in industries related to RF circuit design.

Course Outcome: By the end of the course student will able to do following: 1. Calculate noise (amplitude and phase), linearity, and dynamic range performance metrics for RF devices and circuits; 2. Discuss transceiver architectures relevant to current wireless communications standards and their relative advantages and disadvantages; 3. Discuss active and passive device technologies relevant to RFICs and their relative performance advantages and disadvantages. 4. Utilize RF/microwave CAD software in the design

Course (39 Lectures)

Module 1 (7 lectures)

Fundamentals of RF circuits and systems: Duplexing, FDMA, dB, dBm, Voltage gain, Channel, ACR, AACR, Noise factor, NF of a cascaded system, Sensitivity, HD, Gain compression, P1dB, Cross modulation, Inter modulation, IM3, IIP3, SFDR, Transmit mask.

Module 2 (7 lectures)

Transmitter and Receiver architectures: Review of modulation schemes, Receiver architectures, Transmitter architectures Passive and active components for CMOS RFIC: Review of MOSFET, RF transistor layout, CMOS process, Capacitors, Varactors, Resistors, Inductors, Transformers, Transmission lines Resonance, Matching, S-parameters, etc. Noise in electrical circuits and NF calculations, Two port noise theory.

Module 3 (6 lectures)

Low Noise Amplifiers: Resistive terminated CS and CG LNA, Inductive degenerated LNA, Shunt feedback LNA, Noise canceling LNAs, Linearity improvement techniques.

Module 4 (6 lectures) Power Amplifiers: Basics and Class A, B, C, D, E, F and other configurations, Power combining, Linearity improvement techniques.

Module 5 (6 lectures) Mixers: Specifications, NL system as a mixer, Active mixers, Passive mixers.

Module 6 (8 lectures)

Oscillators: Introduction, LC Oscillators, Phase noise, Introduction to PLLs; Type-I PLLs, Charge pump PLLs: Mathematical model, Design issues and Phase noise, Frequency synthesizers: Integer N synthesizers, Dividers.

Text Book:

RF Microelectronics by Behzad Razavi, Pearson, Second Edition, 2012.

Reference Books:

1. Microwave Transistor Amplifier, Analysis and Design by Gullermo Gonzalez, Prentica Hall, Second Edition, 1996.
2. Radio Frequency Integrated Circuit Design (Artech House Microwave Library) by J. Rogers and C. Plett, 2003.
3. Radio Frequency Integrated Circuits and Technologies, by Frank Ellinger, 2nd edition, 2008.
4. The Design of CMOS Radio-Frequency Integrated Circuits, by Thomas H. Lee, 2nd edition, 2004.

SEMESTER-I | Lab: Microwave Measurement Lab | D CORE | L-T-P: 0-0-3

Philosophy: The lab aims to help familiarize the students with the basic microwave instruments and components along with state-of-the-art instrument like vector network analyzer, spectrum analyzer, LCR meter, power meter etc.

Lab Outcome: by the end of the lab, the students should be able to perform and setup the various experiments to characterize the different microwave components involving waveguide, power divider, filters, antenna, etc.

1. Impedance and VSWR measurement of Waveguide Discontinuities-Inductive and Capacitive diaphragms/ antennas.
2. Dielectric constant measurement using two-point method, infinite sample method and cavity perturbation method
3. To study the dispersion diagram of waveguide.
4. Radiation Pattern Measurement of Horn antennas.
5. Gain Measurement of Horn antennas.
6. Study of coupling (Q-factor) properties of microwave resonator.
7. Characterization of microwave amplifier using spectrum analyzer and power meter.
8. Familiarization of basic operation of VNA.
9. Studies of Complex network parameter of microwave passive circuit using VNA.
10. Studies of Non-ideal behavior of passive components at high frequencies using LCR meter.
11. Characterization of non-reciprocal devices using VNA.
12. Study of modulation schemes on spectrum analyzer.

SEMESTER-I | RF & CAD Laboratory| D CORE | L-T-P: 0-0-3

Philosophy: The lab aims to help familiarize the students with the electromagnetic simulation software like HFSS/IE3D/CST/ADS or Equivalent. Furthermore, student will simulate the problems involving waveguide, power divider, filters, antenna, etc.

Lab Outcome: by the end of the lab, the students should be able to simulate and get the results different kind of boundary value problem.

1. Rectangular Microstrip Antenna & Circular Microstrip antenna.
2. Microstrip and wire Monopole Antenna
3. Microstrip Wideband Antennas
4. Horn antennas
5. Multi-band Antennas
6. Couplers
7. Microstrip and Waveguide Filters
8. Microstrip and Waveguide Tee Component
9. Design of Circulators
10. RCS Simulations of standard objects
11. Slot Antenna for high gain applications
12. Amplifier Design

Detailed Syllabi

of

M. Tech. in RFME

Semester – II

Course No.	Course Name	L	T	P	C
Semester -II					
DC xxx	D Elective 1	3	0	0	9
DC xxx	D Elective 2	3	0	0	9
DC xxx	D Elective 3	3	0	0	9
DE 5xx	Open Elective 1	3	0	0	9
DE 5xx	Open Elective 2	3	0	0	9
DC xxx	Microwave Design Laboratory	0	0	3	3
DC xxx	Advanced RF & CAD Laboratory	0	0	3	3
	Total	15	0	6	51

List of Electives for Semester II

Sl. No.	Course No.	Course Name	L	T	P	C
		D Electives:				
1.	DE xxx	Electromagnetic Interference & Compatibility	3	0	0	9
2.	DE xxx	Advanced Antenna Theory	3	0	0	9
3.	DE xxx	Microwave Photonics	3	0	0	9
4.	DE xxx	Numerical Techniques in Electromagnetics	3	0	0	9
5.	DE xxx	Computational Electromagnetics	3	0	0	9
6.	DE xxx	Microwave Communication System	3	0	0	9
		Open Electives:				
1.	OE xxx	Microwave Devices and Networks	3	0	0	9
2.	OE xxx	MIC and MMIC	3	0	0	9

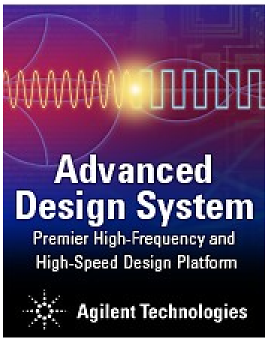
SEMESTER-II | Lab: Microwave Design Lab | D CORE | L-T-P: 0-0-3

Using MATLAB and Simulation software (HFSS/IE3D/CST/ADS or Equivalent) followed by development of prototype:

Philosophy: The lab aims to provide the idea to the student about the analytical way to solve the problem followed by the verification of the same through simulation software and experimental demonstration.

Lab Outcome: by the end of the lab, the students get the confidence into all three aspect of the designing of any boundary value problem through theoretical study, simulation and an experimental validation of the basic electromagnetic problems.

1. Design and analysis of low-pass microstrip filter.
2. Design and analysis of single-band microstrip patch antenna.
3. Design and analysis of Dielectric Resonator Antenna.
4. Design and analysis of microstrip coupler
5. Design and analysis of microstrip circulator
6. Design and analysis of band-pass microstrip filter
7. Design and analysis of log-periodic antenna
8. Design and analysis of fractal antenna
9. Design and analysis of microstrip power divider
10. Design and analysis of microstrip attenuator
11. Design and analysis of frequency reconfigurable antenna
12. Design and analysis of frequency reconfigurable high-pass filter



SEMESTER-II | Lab: Advanced RF & CAD Laboratory | D CORE | L-T-P: 0-0-3

Philosophy: The lab aims to help train the students with the electromagnetic simulation software like HFSS/IE3D/CST/ADS or Equivalent. Also, student will simulate the cutting-edge problems involving waveguide, power divider, filters, antenna, etc

Lab Outcome: by the end of the lab, the students should be able to simulate and get the results for different kind challenging problems.

1. Ultra-wideband microstrip antenna
2. Multi-band microstrip antenna
3. High gain microstrip antenna
4. Circularly polarized microstrip antenna
5. Reconfigurable microstrip antenna
6. Wideband Dielectric Resonator Antenna
7. Circularly polarized Dielectric Resonator Antenna
8. MIMO antenna design and analysis
9. Multi-band band-pass filter
10. High-Q Cavity filter
11. SAR analysis of handheld devices
12. EMI/EMC analysis of different practical appliances

CST

ANSYS

IE3D

Zeland Software, Inc.

SEMESTER-II | Subject: Electromagnetic Interference & Compatibility | D ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

This course is designed to familiarize the students with different concepts related to EMI and EMC. At the end of the course the students will have the knowledge required to design an electromagnetically compatible system.

Learning Outcomes:

At the end of the course the student able to learn the concepts of

- ✤ Real-world EMC design
- ✤ Designing electronic systems that function without errors or problems related to electromagnetic compatibility

Course Structure (39 Lectures)
Module 1 (12 lectures) Introduction of EMI & EMC, Aspects of EMC, Common EMC units, CISPR & FCC limits, Measurement of conducted and radiated emission, Antenna factor, Additional product requirements, Design Constraints for products, Advantages of EMC design, Spectra of digital waveforms, Time domain analysis of transmission lines, High speed digital interconnects and signal integrity, Lumped circuit approximate models, Non-ideal behavior of components (wires, PCB boards, leads, resistors, capacitors, inductors) , ferromagnetic materials and ferrite beads, common-mode chokes, Electromechanical devices, Digital circuit devices, Effect of component variability, Mechanical switches. **Module 2 (17 lectures)** Power supply filters, conducted susceptibility, Simple emission models for wires and PCB lands, Simple susceptibility model for wires and PCB lands, Three conductor transmission lines and crosstalk, Electrostatic discharge, The transmission-line equations for lossless lines, The per-unit-length parameters, The inductive-capacitive coupling approximate model, Lumped-circuit approximate model, Shielded wires, Twisted wires. **Module 3 (10 lectures)** Shielding effectiveness for far field and near field sources, Low frequency magnetic field shielding, Effect of apertures, Different ground systems, System configuration and design.
Text Books: 1. Clayton R. Paul, 'Introduction to Electromagnetic Compatibility', Wiley – India, 2nd edition, 2010. **Reference books:** 1. Engineering Electromagnetic Compatibility: Principles, Measurements, and Technologies, by V. Prasad Kodali , Wiley-IEEE Press Home , 2nd edition, 2001 2. Electromagnetic Compatibility Engineering by Henry W. Ott , 1st edition, 2009. 1. Electromagnetic Compatibility of Integrated Circuits: Techniques for low emission and susceptibility, by Sonia Ben Dhia, Mohamed Ramdani, Etienne Sicard, 1st Edition, 2006.

SEMESTER-II | Subject: Advanced Antenna Theory | D ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

This course will enable the students to study Antennas/Antenna array & their characteristics and propagation patterns. It will expose students to application of particular antenna in particular communication system, and to make them aware of design guidelines and analysis of different antennas.

Learning Outcomes:

At the end of this module, students are expected to be able to

1) Recognize the different types of antennas & their utilization as required in different communication systems
2) Classify and analysis antennas with applications
3) Comprehend EM wave propagation effects & pattern in different media

Course Structure (39 Lectures)
Module 1 (10 lectures) Introduction to Antenna: Antenna Types, Radiation mechanism, Fundamental parameters of Antennas. Radiation Integrals and Auxiliary Potential Functions: Vector Potential for Electric and magnetic Current Sources, Electric and Magnetic fields for Electric and Magnetic Current Sources, Solution of Inhomogeneous vector Potential Wave Equation, Far Field radiation, Duality Theorem, Reciprocity and Reaction Theorem. **Module 2 (10 lectures)** Wire and Loop Antenna: Infinitesimal dipole its radiation field, small dipole, finite length dipole, half wave length dipole, and their applications. Comparison of small loop with short dipole, Loop antenna radiation pattern its parameters and their application. **Module 3 (10 lectures)** Antenna Array analysis and Synthesis: Linear arrays, Array of two and N- isotropic point sources, principle of pattern Multiplication, linear arrays of n elements, broadside, End-fire radiation pattern, directivity, Beamwidth and null directions, array factor. Mutual impedance between Linear Elements, Mutual Coupling in Arrays. **Module 4 (9 lectures)** Analysis of microstrip patch, slot antenna, analysis of aperture antenna and antenna array, Antenna RCS, and RCS reduction.
Text Book: 1. C. A. Ballanis , "Antenna Theory, Analysis and Design " , John Wiley & Sons, Third edition , 2005. **Reference Books:** 2. John D. Kraus and Ronalatory Marhefka, "Antennas and wave propagation", Tata McGraw-Hill Book Company, 2002. 3. E.C.Jordan and Balmain, "Electro Magnetic Waves and Radiating Systems", PHI, 1968, Reprint 2003. 4. L.V. Blake and M.W. long, “Antennas, Fundamentals, Design, Measurement” Third Edition, SciTech publishing, 2009.

SEMESTER-II | Subject: Numerical Techniques in Electromagnetics | D ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

To familiarize the students with the basic as well as advanced numerical and analytical techniques in electromagnetics for different boundary value problem with respect to real time situation. The course prepares PG students where the advance topics like spectral domain, finite difference time domain, mode matching, method of separation variable, etc. will be covered, particularly those including an in-depth description.

Learning Outcomes:

By the end of the course, the students should be able to solve challenging boundary value problems involving planer and 3D antennas, filter and other waveguide problems.

Course (39 Lectures)
Module 1 (7 lectures) Maxwell’s Equation, Circuit field relations, Boundary conditions, Power & Energy and Time harmonic electromagnetic fields, Classification of EM Problems and Some Important Theorem, etc. **Module 2 (12 lectures)** Wave equation and solution, Auxiliary vector potential, Construction of solution, Solution of inhomogeneous vector potential wave equations, Mode Matching Techniques for waveguide structure and solution construction, method of separation variable methods. **Module 3 (6 lectures)** Spectral Domain Methods, Mesh generation in Rectangular and Arbitrary Domain, Transmission Line Matrix method, Method of Line: Solution to Laplace Equation, Wave Equation and Time Domain Solution.

Module 4 (4 lectures)
Variational Method: Construction of Functional from PDEs, Rayleigh Ritz Method, Weighted Residual Method, Eigen Value Problems and Practical Applications. Application to Study Open Ended Waveguide Problem. Moment Method, Finite Element Method: Solution to Poisson, Laplace and Wave Equation.

Module 5 (8 lectures)
Finite Difference Method: Finite Difference Schemes, Differencing of Parabolic, Hyperbolic and Elliptic PDEs, Accuracy and Stability in PD, Application in Guided Structure, Wave Scattering (FDTD), Absorbing Boundary Conditions, Finite Differencing for Non-Rectangular System.

Books:

1. C. A. Balanis, 'Advanced Engineering Electromagnetics', Jhon Wiley & Sons, USA, 2nd edition, 2012.
2. R. F. Harrington., 'Time Harmonic Electromagnetics Field', Jhon Wiley & Sons and IEEE, USA, 2nd edition, 2001.
3. Matthew N.O. Sadiku, 'Numerical Techniques in Electromagnetics, 3rd edition, 2009, A&M University, Texas, USA
4. Journal Papers of IEEE Trans. on Antenna and Propagation & IEEE Transaction on Microwave Theory and Techniques.

SEMESTER-II | Subject: Microwave Photonics | D ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

- Microwave Photonics is a field that fuses microwave and optical technologies to bring out the best of both worlds. This subject will explore this interdisciplinary field, starting by looking at the basics to investigating interesting applications that may not be possible using just one of these disciplines.

- This course will cover topics from: Introduction to microwave photonics, basic optical and RF components (optical sources, modulators, receivers, passive devices, RF mixers, wireless receivers); microwave photonics signal processing; optoelectronic oscillators, photonic integrated circuits for microwave photonics (different platforms of integration, filter designs – micro resonators, nonlinear effects).

Learning Outcomes:

This subject will explore the close interactions of lightwave and microwave and understand the physical principles of the hybrid field. Students will learn and investigate the microwave photonics principles through a number of cutting-edge system applications ranging from high-speed fibre-wireless links to microwave photonic signal processing. The focus will be on link and subsystem design and performance analysis that are usually not covered in other subjects. Through these studies, students will understand the different functionalities that can only be created by combining the two different disciplines.

Course Structure (39 Lectures)

Module 1(L-12): Introduction to Microwave Photonics: An introductory overview, Advantages of Microwave photonics over conventional Microwave techniques. Photonic devices and its application at high frequency, Limitation of direct modulation at high frequency, Microwave photonic detectors.

Module 2(L-12): Microwave photonic components: High speed Modulator. Electro-optic modulators: Biasing and transfer characteristic of Mach-Zehnder Modulator (MZM), Electro-absorption modulators, Fiber Bragg Grating filter, Semiconductor optical amplifier.

Module 3(L-10): Microwave photonic systems: Introduction to Radio over fiber, Photonic microwave signal generation and processing, Optoelectronic microwave oscillator, Microwave photonic mixer, Microwave photonic filter, Terahertz signal generation and detection

Module 4L-5): Microwave photonics in instrumentation and measurement: Photonic approach of microwave frequency measurement.

Text Books:

1. Microwave Photonics by Chi H. Lee, 2nd edition, 2013.

Reference books:

2. Microwave Photonics: Devices and Applications by Stavros Iezekiel, 1st edition, 2009.
3. Microwave Photonics: From Components to Applications and Systems, by Anne Vilcot, Béatrice Cabon, Jean Chazelas, 1st edition, 2003.
4. Microwave Photonics: Devices and Applications, by Stavros Iezekiel, Wiley publication, 2009.

SEMESTER-II | Subject: Subject: Computational Electromagnetics | D ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

The course prepares PG students to familiarize the students with the advanced computational technique based on finite difference method and finite difference time domain method with respect to real time situation.

Learning Outcomes:

By the end of the course, the students should be able to apply FDTD concept to any boundary value problem and code the same on the MATLAB. Furthermore, demonstrate an awareness of available methods to model and solve electromagnetics related real-life engineering problems.

Course Structure (39 Lectures)

Module 1 (10 lectures)

Introduction to FDTD, The Finite-Difference Time-Domain Method Basic Equations, FDTD Updating Equations for One/Two/Three-Dimensional Problems. Numerical Stability and Dispersion, CFL Condition for the FDTD Method.

Module 2 (9 lectures)

Building Objects in the Yee Grid, Defining the Problem Space Parameters, Defining the Objects in the Problem Space, Material Approximations, Sub cell Averaging Schemes for Tangential and Normal Components, Defining Objects Snapped to the Yee Grid, Creation of the Material Grid, Improved Eight-Sub cell Averaging.

Module 3 (8 lectures)

Perfectly Matched Layer Absorbing Boundary, Theory of PML, Theory of PML at the Vacuum–PML Interface, Theory of PML at the PML–PML Interface, PML Equations for Three-Dimensional Problem Space, PML Loss Functions, FDTD Updating Equations for PML and MATLAB Implementation for Two-Dimensional TEz and TMz Case, Convolutional Perfectly Matched Layer.

Module 4 (12 lectures)

Scattering Parameters, S-Parameters and Return Loss calculations, Near-Field to Far-Field Transformation, Implementation of the Surface Equivalence Theorem, Frequency Domain Near-Field to Far-Field Transformation, Implementation of the Thin-Wire Formulation, Thin-Wire Dipole Antenna, Filter design etc.

Text Books:

1. Atef Z. Elsherbeni and Veysel Demir, 'The Finite-Difference Time-Domain Method for Electromagnetics with MATLAB Simulations' SciTech Publishing, Inc Raleigh, NC, 2nd edition, 2015.

Reference Books:

1. Matthew N.O. Sadiku, 'Numerical Techniques in Electromagnetics, 3rd Edition, 2009, Prairie View A&M University, Texas, USA
2. Journal Papers of IEEE Transaction on Antenna and Propagation and IEEE Transaction on Microwave Theory and Techniques.

SEMESTER-II | Subject: Microwave Communication System | D ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

The course aims to make a bridge between the different practical requirements of communication in microwave frequency and design of microwave components & systems. So, students can understand the application domain of different microwave components which they study extensively.

Learning Outcomes:

1. Use of different modulation and demodulation techniques used in microwave communication
2. Identify and solve basic microwave communication problems
3. Analyze transmitter and receiver circuits and Compare and contrast design issues, advantages, disadvantages and limitations of microwave communication systems.

Course Structure (39 Lectures)
Module 1 (10 lectures) LOS and tropospheric scattered communication system; the satellite link analysis and design; communication transponder system **Module 2 (14 lectures)** The transmission of analog and digital signals through satellite and various modulation techniques employed. **Module 3 (6 lectures)** The multiple access techniques like FDMA, TDMA, SSMA, DAMA, etc; future trends in microwave communications. **Module 4 (10 lectures)** Satellite Navigation and Global Positioning System and Wireless networking.
Text Books: 1. Satellite Communication, by Timothy Pratt, Charles Bostian, Jeremy Allunutt, Wiley International, Second Edition, 2002. **Reference Book:** 1. Microwave Engineering, by David M. Pozar, Wiley International, Fourth Edition, 2012. 2. RF and microwave wireless systems, by Kai Chang, 1st edition, 2000. 3. Microwave devices, circuits and subsystems for communications engineering, by Ian A. Glover, Steve Pennock, Peter Shepherd, 1st edition, 2007.

SEMESTER-II | Subject: Microwave Devices and Networks | Open ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

The course aims to make a bridge between the different practical requirements of communication in microwave frequency and design of microwave components & systems. So, students can understand the application domain of different microwave components which they study extensively.

Learning Outcomes:

1. Understanding the design concept of various RF/Microwave devices.
2. Knowledge of Microwave Circuit Analysis and Impedance matching.
3. Understanding the behavior of non-linear RF/Microwave Devises.
4. Ability to design discrete RF/ Microwave Devices.

Course Structure (39 Lectures)
Module 1 (12 lectures) Wilkinson power divider, Coupled line directional coupler, Lange coupler, Coupled line filter, Coupled resonator filter, Capacitive coupled filter. **Module 2 (12 lectures)** Tunnel diode, TRAPATT diode, pin diode, Varactor diode, Introduction to parametric amplifier, Manley-Rowe power relation, HEMT, HBT. **Module 3 (10 lectures)** Microwave detectors and mixers, Microwave amplifiers, Microwave oscillators. **Module 4 (5 lectures)** Reflex klystron, two cavity klystron, Helix TWT, Coaxial Magnetron, Inverted coaxial magnetron and linear magnetron.
Text Book: 1. Microwave Engineering, by David M. Pozar, Wiley International, Fourth Edition, 2012. **Reference Book:** 1. Foundation of Microwave Engineering, by R. R. Collin, Wiley International, Second Edition, 2001. 2. Microwave Devices and Circuits, by Samuel Liao, 3rd edition, 1990. 3. Microwave devices, circuits and subsystems for communications engineering, by Ian A. Glover, Steve Pennock, Peter Shepherd, 1st edition, 2007.

SEMESTER-II | Subject: MIC and MMIC | Open ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

MIC and MMIC technology provides the core component for wide range of microwave and millimeter wave communication, radar and sensing systems. The course aims to present different features of microwave circuits in integrated form. So, students will learn different aspects of integrated circuits in microwave frequency,

Learning Outcomes:

1. Acquire knowledge about Microwave Integrated Circuits.
2. Gain knowledge and understanding of lumped elements for MIC.
3. Develop understanding of the fundamentals required to design & implement Integrated Circuits operating at microwave frequencies.
4. Acquire a knowledge about Microwave Semiconductor Devices.

Course Structure (39 Lectures)
Module 1 (10 lectures) Conductor and dielectric losses in planar transmission lines, coupled lines, multi-conductor lines, discontinuities, Basic Passive Components - Lumped elements in MIC & MMIC. Realization in microstrip and suspended stripline Basics of MIC, MMIC. **Module 2 (14 lectures)** MEMS technologies. Realization of planar transmission lines and filters in MEMS. **Module 3 (6 lectures)** Active device technologies and design approaches, Fabrication and modeling: Bipolar junction transistor, Hetero-junction bipolar transistor, High electron mobility transistor, MESFET, CMOS, BiCMOS. **Module 4 (10 lectures)**

Packaging, Interconnects, Monolithic Integrated Antenna, Phase Shifters-PIN diode- Equivalent circuit and Characteristics, Basic series and shunt switches in microstrip. Overview of Transceiver Design
Text Book: 1. RFIC and MMIC design and technology by I. D. Robertson and S. Lucyszyn, The Institute of Electrical Engineers, Second Edition 2001. **Reference Book:** 1. Advanced Millimeter-wave Technologies: Antennas, Packaging and Circuits by Duixian Liu, Ulrich Pfeiffer, Janusz Grzyb, Brian Gaucher. Wiley, First Edition 2009. 2. RFIC and MMIC Design and Technology, by I. D. Robertson, S. Lucyszyn, 2nd edition, 2001.

Detailed Syllabi

M. Tech. in RFME

Semester – III

Course No.	Course Name	L	T	P	C
	Semester - 3				
DC xxx	Thesis Unit 1	0	0	0	9
DC xxx	Thesis Unit 2	0	0	0	9
DC xxx	Thesis Unit 3	0	0	0	9
DC xxx	Thesis Unit 4	0	0	0	9
	Total	0	0	0	36

M. Tech. in RFME

Semester – IV

Course No.	Course Name	L	T	P	C
	Semester - 4				
DC xxx	D Elective 4/Open Elective 3	0	0	0	9
DC xxx	D Elective 5/Open Elective 4	0	0	0	9
DC xxx	Thesis Unit 5	0	0	0	9
DC xxx	Thesis Unit 6	0	0	0	9
	Total	**0**	**0**	**0**	**36**

List of Electives for Semester IV:

Sl. No.	Course No.	Course Name	L	T	P	C
		D Electives:				
1.	DE xxx	Smart Antennas	3	0	0	9
2.	DE xxx	RF and Microwave MEMS	3	0	0	9
3.	DE xxx	Radar Engineering	3	0	0	9
		Open Electives:				
1.	OE xxx	Advanced Microwave Measurement & Instrument	3	0	0	9
2.	OE xxx	Microwave Remote Sensing	3	0	0	9

SEMESTER-IV | Subject: Smart Antennas | D ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

This course will enable the students to study the Types of Smart Antenna Systems, what are the benefits of smart antenna technology and gain an understanding and experience with smart antenna environments and implementation.

Learning Outcomes:

At the end of this module, students are expected to be able to

1. Compare the performances of digital radio receivers and software radios.
2. Study the CDMA spatial processors to analyze the multi-cell systems.
3. Analyze the channel models for smart antenna systems.
4. Evaluate the requirements for the design and implementation of smart antenna systems.

Course Structure (39 Lectures)
Module 1 (10 lectures) Introduction to Smart Antennas, Need for Smart Antennas, 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, Mutual Coupling Effects.. **Module 2 (10 lectures)** DOA Estimation Fundamentals, Introduction to Array Response Vector, Received Signal Model, The Subspace Based Data Model, Signal Auto-covariance Matrices, Conventional DOA Estimation Methods: Conventional Beam forming Method, Capon's Minimum Variance Method, and Subspace Approach to DOA Estimation, The MUSIC Algorithm, The ESPRIT, Algorithm, and Uniqueness of DOA Estimates. **Module 3 (10 lectures)** Beam forming Fundamentals, The Classical Beam former-Statistically Optimum Beam forming Weight Vectors, The Maximum SNR Beam former, The Multiple Side lobe Canceller and the Maximum, SINR Beam former-Minimum Mean Square Error (MMSE), Direct Matrix Inversion, (DMI), Linearly Constrained Minimum Variance (LCMV), Adaptive Algorithms for Beam forming. **Module 4 (9 lectures)** Space–Time Processing: Introduction, Discrete Space–Time Channel and Signal Models, Space–Time, Beam forming, Inter symbol and Co-Channel Suppression, ISI Suppression, CCI, Suppression, Data Rates in MIMO Systems, MIMO in Wireless Local Area Networks, Mobile Stations' Smart Antennas, Combining Techniques, RAKE Receiver Size, Mutual Coupling Effects, Dual-Antenna Performance Improvements, Downlink Capacity Gains.
Text Book: 1. Introduction to Smart Antennas, By C. A. Balanis & P. I. Ioannides, Morgan & Claypool Publication, 2007. **Reference Books:** 1. Smart Antennas for Wireless Communications IS-95 and Third Generation CDMA Applications, By J. C. Liberti Jr., T. S Rappaport , PTR – PH publishers, 1999. 2. Smart Antennas, By Lal Chand Godara, CRC Press, 1st edition, 2004. 3. Smart Antennas Adaptive Arrays Algorithms and Wireless Position Location, By T.S. Rappaport, IEEE Press, PTR – PH publishers, 1998.

SEMESTER-IV | Subject: RFID | D ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

This course is designed to familiarize the students with radio frequency identification technique. At the end of the course the students will be able to design their own RFID systems for different applications.

Learning Outcomes:

At the end of this module, students are expected to be able to

1. Familiarized with RFID systems

2. Applications of RFID
3. International standard and applications.

Course Structure (39 Lectures)
Module 1 (08 lectures) 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 (10 lectures)** 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 (6 lectures)** 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 (9 lectures)** 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.
Text Book: 1. Klaus Finkenzeller, 'RFID Handbook', Wiley, 2nd edition, 2003. **Reference Books:** 1. RFID Systems: Research Trends and Challenges, by Bolic M., Simplot-Ryl D., Stojmenovic I., 1st edition, 2011. RFID Design Principles (Artech House Microwave Library), by Harvey Lehpamer, 1st edition, 2008.

SEMESTER-IV | Subject: Radar Engineering | D ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

This course is designed to familiarize the students with the different kinds of radar systems and their operations. It will also provide different concepts related to radar detection and radar signal processing to the students. At the end of the course the students will be able to understand the operation of radar systems and they will be able to work on more complex modern radar systems.

Learning Outcomes:

At the end of this module, students are expected to be able to
1) Acquired knowledge about Radar and Radar Equations.
2) Understanding the working principal of MTI and Pulse Doppler Radar.
3) Foster ability to work using Detection of Signals in Noise and Radio Direction Finding.
4) Foster ability to work using Instrument Landing System

Course Structure (39 Lectures)
Module 1 (10 lectures) Radar fundamentals, Derivation of range equation, the search radar equation, Jamming and radar range with jamming, Radar clutter and radar range with clutter, Radar range with combined interferences sources. Noise and false alarms, Detection of one sample of signal with noise, Integration of pulse trains, Detection of fluctuating targets, CFAR, Optimum and matched filter Theory, Loss factors in detection. Definition of radar cross section, Radar cross section of simple and complex objects, spatial distribution of cross section, Bistatic cross section. **Module 2 (10 lectures)**

CW and FM Radar: Doppler Effect, CW and FMCW Radar, Airborne Doppler Navigation, Multi frequency CW Radar. Delay lines and line cancellors, Subclutter Visibility. MTI using range gates and filters, Pulse Doppler radar, Non-coherent MTI radar.

Module 3 (10 lectures)

Application of Digital signal processing to radar system. Different types of tracking techniques, tracking in range, tracking in Doppler, Search Acquisition radar, Comparison of Trackers. Height finding radars, Air traffic control Radars and data handling, Atmospheric effects of radar, Electromagnetic compatibility aspects, Airborne Radars, Synthetic Aperture Radar, Secondary surveillance Radars, LTIR.

Module 4 (9 lectures)

Matched filter receiver, detection criteria, detectors, integrators, constant-false-alarm rate receiver, basic radar measurement, ambiguity diagram, pulse compression, target recognition, surface-clutter, land clutter, sea clutter, weather clutter, detection of targets in clutter, ECM and ECCM.

Text Books:

1. Modern Radar System Analysis, By David Barton .K - Artech House, 1st edition, 1988.

Reference Books:

2. Radar Design Principles Signal Processing and The Environment, By Fred NathansonMcgraw Hill, 1969.
3. Introduction to Radar systems, By Skolnik - Mcgraw Hill, 3rd edition, 2002.
4. Radar Fundamentals, By Ian Faulconbridge, Argos Press Hill, 1st edition, 2002.
5. Sushrut Das, 'Microwave Engineering', Oxford University Press., 3rd edition, 2015.

SEMESTER-IV | Subject: Advanced Microwave Measurement & Instrument | Open ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

Provide the student with experience in measurements of RF and microwave hardware and signals using modern equipment.

Learning Outcomes:

At the end of this module, students are expected to be able to

1) Handle high end instruments like VNA, Spectrum analyzer, power meter, etc.
2) Characterize different passive and active microwave devices.
3) Able to setup experiments for real time situations.

Course Structure (39 Lectures)

Module 1 (5 lectures)

Fundamentals of electromagnetics and microwave engineering, basic instruments for microwave measurements, and Introduction to RF and Microwave Measurements, Overview of State-of-the-Art Microwave Measurements, S-Parameters and Related Black-Box Representation.

Module 2 (20 lectures)

Time Domain Reflectometry (TDR): measure characteristics of various connector families, transmission lines, complex loads, Spectrum Analyzer: for measurement of simple signals on a spectrum analyzer to understand resolution bandwidth, video bandwidth, dynamic range, noise, etc, Spectrum analyzer architecture, network analyzer architecture, error correction model, Material Property Measurement Using the VNA, scalar network analyzer.

Module 3 (14 lectures)

Power meter, LCR meter, Noise figure measurement, Noise Measurements Definition, Noise Measurement Basics, special Consideration for Mixers, Phase Noise, Phase-Noise Measurement Techniques signal generator architecture and measurements, amplifier characterization, mixer characterization, design and build a simple single stub transmission line matching circuit etc.

Text Book:

Principles of Microwave Measurements, Geoff H. Bryant, The Institution of Engineering and Technology, 1993.

Reference Books:

1. Microwave Measurements, By Arlie E. Bailey, Institution of Engineering & Technology, 2nd edition, 1988.
2. Application notes of Vector Network Analyzer, Keysight, USA
3. Application notes of Spectrum Analyzer, Keysight, USA
4. Application notes of Power meter, LCR meter, Noise Figure Measurement, Keysight, USA

SEMESTER-IV | Subject: Microwave Remote Sensing | Open ELECTIVE | L-T-P: 3-0-0

Course Philosophy:

This course will enable the students to learn about fundamentals and application of radar remote sensing and radiometry also learn about airborne and space borne radar systems.

Learning Outcomes:

At the end of this module, students are expected to be able to
1) Understand the fundamentals of radar remote sensing and radiometry.
2) Apply the concept of radar remote sensing.
3) Study about different airborne and space borne radar systems.
4) Study about special topics in radar remote sensing.

Course Structure (39 Lectures)

Module 1 (10 lectures)

Passive Survey System: Introduction, History, plane waves, antenna systems, Resolution Concepts, Radiometry, Passive microwave sensing components, Emission laws, Roughness and Dielectric Constant, Radiometers, Components, Brightness temperature, Antenna temperature, Power, temperature correspondence, passive microwave interaction with atmospheric constituents, Emission characteristics of various earth features, Passive missions.

Module 2 (10 lectures)

Data products and Applications Active Survey System: Basics, RADAR operation and measurements, RADAR equation, RAR, frequency bands, SLAR Imaging Geometry, Geometric Distortions, SAR, Concepts, Doppler principle & Processing System Parameters and fading concepts, Target Parameters. Interaction with Earth surface and vegetation, Physical Scattering Models, Surface and Volume Backscattering. Platforms..

Module 3 (10 lectures)

Sensors and Data Processing: Airborne, Space borne and Indian missions, Data products and selection procedure, SAR Image Processing software, Measurement and discrimination, Backscatter Extraction, Pre-processing and speckle filtering, Image Interpretation, SAR Image Fusion.

Module 4 (9 lectures)

Applications in Agriculture, Forestry, Geology, Hydrology, cryospace studies, landuse mapping and ocean related studies, military and surveillance applications, search and rescue operations, ground and air target detection and tracking - case studies. Imaging and Non Imaging Metrics: SAR interferometry, Basics, differential SAR interferometry, SAR polarimetry, Polarisation Types, Information Extraction, Altimetry, Principle, Location systems, Calibration- applications.

Text Books: Microwave remote sensing, By Ulaby, F.T., Moore, K.R. and Fung, vol-1,vol-2 Addison-Wesley Publishing, 1986.

Reference Books: 1. Principles and applications of Imaging RADAR, Manual of Remote sensing, vol.2, By Floyd. M.Handerson and Anthony, J. Lewis ASPRS, Jhumurley and sons, Inc, 3rd edition, 1998.

2. Air and space born radar systems-An introduction, By Philippe Lacomme, Jean clande Marchais, Jean Philippe Hardarge and Eric Normant, Elsevier publications, 1st edition, 2007.

3. Introduction to microwave remote sensing, By Iain H.woodhouse, 1st edition, 2005.

4. Radar foundations for Imaging and Advanced Concepts, By Roger J Sullivan, Knovel, SciTech Pub., 2004.