Department of Electronics and Communication Engineering
Birla Institute of Technology, Mesra, Ranchi - 835215 (India)

Institute Vision

To become a Globally Recognized Academic Institution in consonance with the social, economic and ecological environment, striving continuously for excellence in education, research and technological service to the National needs.

Institute Mission

- To educate students at Undergraduate, Post Graduate Doctoral and Post-Doctoral levels to perform challenging engineering and managerial jobs in industry.
- To provide excellent research and development facilities to take up Ph.D. programmes and research projects.
- To develop effective teaching and learning skills and state of art research potential of the faculty.
- To build national capabilities in technology, education and research in emerging areas.
- To provide excellent technological services to satisfy the requirements of the industry and overall academic needs of society.

Department Vision

To become a centre of excellence in teaching and research for creating technical manpower to meet the technological needs of the country in the field of Electronics and Communications Engineering.

Department Mission

- To facilitate state of the art Education and Research at Undergraduate, Post Graduate and Doctoral levels to enable to perform challenging engineering and managerial jobs in the field of Electronics and Communication Engineering.
- To build national capabilities in Technology, Education and Research in emerging areas in the field of Electronics and Communication Engineering.
- To create an environment to provide excellent Research and Development facilities to strengthen Ph.D. Programmes and Research Projects.
- To provide excellent Technological Services to bridge the gap between Academics and Industry in order to fulfil the overall academic needs of the society.
- To provide high quality Course Structure in order to turn out qualified professionals to meet the engineering needs of the country.
- To develop effective Teaching Skills and the Research Potentials of the faculty members.
- To ensure All Round Development of the students and to create a platform for turning out engineering professionals who can assume leadership position in society.

M. Tech. in Microwave Engineering

Program Educational Objectives (PEOs)

PEO1	To enable students in Microwave Engineering with expert and professionals in the present generation of Advanced communication techniques.

PEO2	To develop the capability of independent research project in Microwave Engineering applying research principles and methods
PEO3	To train the postgraduate in Microwave Communication with the depth knowledge of various subject of present day interest like Advanced Electromagnetics, EMI/EMC, Microwave material, Microwave Imaging, Smart Antennas, Satellite& mobile Communication
PEO4	To train the postgraduate having the knowledge of different simulation tools used for measure the performance and diagnose the RF and communication signals and systems
PEO5	To prepare students for Compiling and interpreting research data and presenting them in an appropriate format with scientific presentation, taking into consideration scientific principles and methodology, as well as practical applicability.
PEO6	To train students a high level of autonomy, accountability, credibility, ethics, and responsibility for all personal work outputs in the advanced RF field.

Program Outcomes (POs)

After completion of the programme, students will be able to demonstrate

PO1	An ability to independently carry out research /investigation and development work to solve practical problems.
PO2	An ability to write and present a substantial technical report/document.
PO3	A degree of mastery in Microwave Engineering technology at a level higher than the requirements in the appropriate bachelor program.
PO4	Recognise the need for life- long -learning and will prepare oneself to understand, select and apply appropriate techniques and modern engineering and IT tools to solve complex Microwave Engineering for environment and society context.
PO5	Design and implement an independent research project in Microwave Engineering applying research principles and methods.
PO6	Acquire skills in handling instruments, tools, techniques and modelling using advanced software & tools.

<u>**1st Semester**</u>

Programme Core

COURSE INFORMATION SHEET

Course code: EC501
Course title: Microwave Semiconductor devices
Pre-requisite(s): EC201 Electronics Devices
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: I/05
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students to:

1.	Understand the Material Properties of Semiconductors.
2.	Grasp the principle of operation of Microwave BJTs, HBTs, and Tunnel Diodes and apply the same.
3.	Appraise and analyse the characteristics of Microwave Field Effect Transistors.
4.	Evaluate the characteristics of Transferred Electron Devices (TEDs).
5.	Comprehend the characteristics of Avalanche Transit-Time Devices and create their structures.

Course Outcomes:
After the completion of this course, a student will be able to:

CO1	Describe and illustrate the Material Properties of Semiconductors.
CO2	Sketch and explain the characteristics of Microwave BJTs, HBTs and Tunnel Diodes.
CO3	Illustrate with the sketch of the structure of Microwave Field Effect Transistors, diagram their characteristics and analyze them.
CO4	Appraise the principle of operation Transferred Electron Devices (TEDs), schematize their characteristics, assess and summarize their features.
CO5	Schematize the structure and design Avalanche Transit-Time Devices to observe high frequency response. Schematize their characteristics and prepare an inference.

<u>**SYLLABUS**</u>

Module -1:
Material Properties of Semiconductors:
Frequency range for semiconductor materials, Crystalline structure of Si, Strain of SiGe films grown on Si, Crystalline structure of GaAs, wafer orientation for semi-insulating GaAs, Orientation-dependent etching profiles of GaAs, Energy bandgaps of GaAs, Si, and Ge as a function of temperature, Electron velocity for Si, InP and GaAs, Relative dielectric constant of GaAs, Thermal conductivity of various materials, II-V heterostructures used for Microwave and RF Applications, Energy bandgap and associated lattice constants for II-V

heterostructures, Double pulsed doped pseudomorphic HEMT layer structure, InP, SiC, GaN, Comparison of conventional and wide bandgap materials.

(8L)

Module -2:
Microwave Transistors and Tunnel Diodes:
Microwave Bipolar Transistors: Physical Structures, Bipolar Transistor Configurations, Principles of Operation, Amplification Phenomena, Power-Frequency Limitations; Heterojunction Bipolar Transistors (HBTs): Physical Structures, Operational Mechanism, Electronic Applications; Microwave Tunnel Diodes: Principles of Operation, Microwave Characteristics.

(8L)

Module -3:
Microwave Field Effect Transistors:
Junction Field-Effect Transistors (JFETs): Physical Structure, Principles of Operation, Current-Voltage (1-V) Characteristics; Metal-Semiconductor Field-Effect Transistors (MESFETs): Physical Structures, Principles of Operation, Small-Signal Equivalent Circuit, Drain Current Id, Cutoff Frequency f_{co} and Maximum Oscillation Frequency f_{max}; High Electron Mobility Transistors (HEMTs): Physical Structure, Operational Mechanism, Performance Characteristics, Electronic Applications; Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs): Physical Structure, Electronic Mechanism, Modes of Operation, Drain Current and Transconductance, Maximum Operating Frequency, Electronic Applications.

(8L)

Module -4:
Transferred Electron Devices (TEDs):
Gunn-Effect Diodes-GaAs Diode: Background, Gunn Effect; Ridley-Watkins--Hilsum (RWH) Theory: Differential Negative Resistance, Two-Valley Model Theory, High-Field Domain; Modes of Operation: Gunn Oscillation Modes, Limited-Space-Charge Accumulation (LSA) Mode, Stable Amplification Mode; LSA Diodes, InP Diodes, CdTe Diodes; Microwave Generation and Amplification.

(8L)

Module -5:
Avalanche Transit-Time Devices:
Read Diode: Physical Description, Avalanche Multiplication, Carrier Current I_0(t) and External Current I_e(t), Output Power and Quality Factor Q; IMPATT Diodes: Physical Structures, Negative Resistance, Power Output and Efficiency; TRAPATT Diodes: Physical Structures, Principles of Operation, Power Output and Efficiency; BARITT Diodes: Physical Description, Principles of Operation, Microwave Performance; Parametric Devices: Physical Structures, Applications.

(8L)

Books recommended:
Textbooks:

1. Mike Golio, The RF and Microwave Handbook, 2e, CRC Press, 2008.
2. Samuel Y. Liao, Microwave Devices and Circuits, 3e, Prentice-Hall of India, 2003.

Reference books:

1. S. M. Sze, Kwok K. Ng, Physics of Semiconductor Devices, 3e, Wiley-Interscience, 2006.
2. Stephen A. Campbell, The Science and Engineering of Microelectronic Fabrication, 2/e, Oxford University Press, 2001.

3. I. A. Glover, S. R. Pennock and P. R. Shepherd, Microwave Devices, Circuits and Subsystems for Communications Engineering, John Wiley & Sons, 2005.

Gaps in the syllabus (to meet Industry/Profession requirements): Hands-on-practical for Microwave Device fabrication.

POs met through Gaps in the Syllabus: PO6 will be met though Microwave Device design-based assignment, which involves handling of TCAD tools.

Topics beyond syllabus/Advanced topics/Design: Topics beyond syllabus/advanced topics will be covered through the allotment of assignment requiring handling of TCAD tools and simulations.

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	2	1
CO2	3	3	3	3	2	1
CO3	3	3	1	3	2	1
CO4	2	2	2	2	3	1

CO5	2	2	2	2	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3, CD7
CO2	CD1, CD2, CD3, CD7
CO3	CD1, CD2, CD3, CD7
CO4	CD1, CD2, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD6, CD7

COURSE INFORMATION SHEET

Course code: EC503
Course title: Antennas and Diversity
Pre-requisite(s): EC257 Electromagnetic Fields and Waves, EC323 Microwave Theory **&Techniques**
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: I/05
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students to:

1.	Develop and apply the mathematical tools to analyse radiation characteristics of aperture antennas.
2.	Design and analyse various broadband, high gain, planar antennas for wireless applications.
3.	Design and analyse the dielectric resonator antenna
4.	Understand the concept of smart antenna and beam forming techniques by using cellular radio system and its evolution
5.	Explain the need of different diversity schemes used in wireless communication

Course Outcomes:
After the completion of this course, a student will be able to:

CO1	Understand the concept of aperture antennas, dielectric resonator antennas and their applications
CO2	Develop the mathematical tool to analyse radiation characteristics of antennas for wireless applications
CO3	Design the various types of aperture, dielectric resonator antennas to evaluate its performance
CO4	Explain and compare different diversity scheme, smart antennas and algorithms.
CO5	Combine different diversity scheme to enhance system performance

SYLLABUS

Module I:

Aperture Antennas:
Radiation Equations, Rectangular Apertures: Uniform Distribution on an infinite ground plane, Uniform distribution in Space, Circular Apertures: Uniform Distribution on an infinite ground plane, Design Considerations**.**

(8L)

Module II:
Antennas for Wireless Communication: Helical, Normal mode, Axial mode, Design procedure, feed design for helical antenna, Horn Antenna; E-Plane, H-Plane, Pyramidal horn, Whip antenna, Discone antenna.

(8L)

Module III:
Dielectric Resonator Antenna: Introduction to Dielectric Resonator Antennas. Major Characteristics, Simple-Shaped Dielectric Resonator Antennas - The Hemispherical DRA. The Cylindrical DRA. The Rectangular DRA, Coupling to DRAs, Hybrid DRAs Bandwidth Enhancement of DRAs, Low Profile and Compact DRAs, DRAs with High Dielectric Constants, Circular-Polarized and Dual-Polarized DRAs, Ferrite Resonator Antennas.

(8L)

Module IV:
Smart Antenna: Introduction, Cellular Radio Systems Evolution, Signal propagation, Diversity and Combining Techniques, Smart Antenna System, Benefits and drawbacks of Smart Antennas, Antenna beamforming**.**

(8L)

Module V:
Diversity Schemes: Macroscopic diversity scheme, Microscopic diversity scheme – Space diversity, Field diversity, Polarization diversity, Angle diversity, Frequency diversity and time diversity scheme. Combining techniques for Macroscopic diversity, Combining techniques for Microscopic diversity.

(8L)

Books recommended:
Textbooks:
1. Antenna Theory, Analysis and Design, 3/E, A. Balanis, John Wiley.
2. Antennas, J. D. Kraus, TMH
3. Wireless Communications, Principles and Practices, Rappaport, PHI

Reference books:
1. Software Radio A Modern Approach to Radio Engineering, J. H. Reed, Pearson Education.
2. Wireless and Cellular Communications, William C. Y. Lee, McGraw-Hill.
3. Wireless Communications, Principles and Practices, Rappaport, PHI.
4. Smart Antenna, T. K. Sarkar.

Gaps in the syllabus (to meet Industry/Profession requirements): Design and Development of real-time industrial projects.

POs met through Gaps in the Syllabus: PO4 & PO5

Topics beyond syllabus/Advanced topics/Design: Design optimization for industrial and Research projects.

POs met through Topics beyond syllabus/Advanced topics/Design: PO4 & PO5

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure
Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment
1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	3	1	2
CO2	3	2	1	3	2	1
CO3	3	1	2	3	2	1
CO4	3	2	2	3	2	2
CO5	3	3	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD2, CD3, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

COURSE INFORMATION SHEET

Course code: EC505
Course title: Advanced Electromagnetic Engineering
Pre-requisite(s): Electromagnetic Theory and Microwave Engineering

Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: I/05
Branch: ECE

Course Objectives:
This course enables the students to:

1.	To develop an ability to analyse the plane waves functions and various rectangular shaped microwave components and their properties for different modes in rectangular coordinate system.
2.	To develop an ability to analyse the cylinder wave functions and various cylindrical shaped microwave components and their properties for different modes in cylindrical coordinate systems.
3.	To develop an ability to evaluate the spherical wave functions and various spherical shaped microwave components and their properties for different modes in spherical coordinate systems
4.	To develop and ability to evaluate different parameters of microwave components using perturbational and variational techniques.
5.	To develop and ability to analyse the various microwave networks

Course Outcomes:
After the completion of this course, a student will be able to:

CO1	Demonstrate understanding on the plane waves functions and calculation of various performance parameters of different kinds of rectangular microwave components such as; rectangular waveguide, rectangular cavity, partially filled waveguide and dielectric slab waveguide apart from the concepts of surface guided waves and modal expansion of fields
CO2	Have an ability to analyse the cylindrical wave functions and calculation of various performance parameters of different kinds of cylindrical microwave components such as; circular waveguide, circular cavity, parallel plate, partially filled, dielectric slab coated and corrugated radial waveguides apart from the concepts of sources of cylindrical waves, two-dimensional radiation and wave transformations.
CO3	Have an ability to understand the spherical wave functions and evaluation of various performance parameters of spherical cavities, Conical Shaped Spherically Radial Waveguide, Hemispherical Resonator apart from the concepts of orthogonality relationship, space as a waveguide, waveform transformation techniques and scattering by spheres.
CO4	Demonstrate insight to use the perturbational and variational techniques to evaluate the different parameters due to perturbations on cavity walls, cavity materials and waveguide apart from the knowledge of stationary formulas for cavity.
CO5	Have an ability to understand the concepts of various microwave networks

SYLLABUS

Module-I:

The Wave Functions, Plane Waves, Rectangular Waveguide, Alternative Mode Sets, The Rectangular Cavity. Partially Filled Waveguide, Surface Guided Waves, Modal Expansion of Fields. Currents in Waveguides.

(8L)

Module-II:

Cylindrical Wave Functions: The Wave Functions, Circular Waveguide, Radial Waveguides, Partially Filled Radial Waveguide, Sources of Cylindrical Waves, Two-Dimensional Radiation, Wave Transformations, Scattering by Cylinders.

(8L)

Module-III:

Spherical Wave Functions: The Wave Functions, Spherical Cavity, Orthogonality Relationships, Sources of Spherical Waves, Wave Transformations, Scattering by Spheres, Maximum Antenna Gain.

(8L)

Module-IV:

Perturbational and Variational Techniques:

Perturbation of Cavity Walls, Cavity Material Perturbations, Waveguide Perturbations, Stationary Formulas for Cavities, The Reaction Concept, Stationary Formulas for Waveguide, Spectral Domain Analysis

(8L)

Module-V:

Microwave Networks:

Cylindrical Waveguide, Model expansion of waveguides, the network Concept, One-port Network, Two-port Network, Obstacles in waveguide, Posts in waveguide, Waveguide Junctions, Probes in Cavities, Aperture Coupling in Cavities.

(8L)

Books recommended:

Textbooks:

1. Time Harmonic Electromagnetic Fields; By Roger F. Harrington; McGraw Hill Book Company; 1961. (T1)

Reference books:

1. Foundations for Microwave Engineering; Second Edition; By Robert E. Collin; McGraw Hill International Edition; 1992. (R1)
2. Microwave Engineering; Second Edition; by David M. Pozar; John Wiley & Sons; Inc. Copyright 2001, (R2)

<u>Gaps in the syllabus (to meet Industry/Profession requirements):</u> Design of advanced microwave components for industrial projects.

<u>POs met through Gaps in the Syllabus:</u> PO5 & PO6

<u>Topics beyond syllabus/Advanced topics/Design:</u> Analysis, design and optimization of advanced microwave components for industrial projects.

<u>POs met through Topics beyond syllabus/Advanced topics/Design:</u> PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	**% Distribution**
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	2	3	3	2	-
CO2	2	2	3	3	2	-
CO3	2	2	3	3	2	-
CO4	2	2	3	3	2	-
CO5	2	2	3	3	2	-

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	**Course Delivery Method**
CO1	CD1, CD6
CO2	CD1, CD6
CO3	CD1, CD2, CD6
CO4	CD1, CD2, CD6
CO5	CD1, CD2, CD6

Programme Elective – I

COURSE INFORMATION SHEET

Course code: EC506
Course title: Electromagnetic Interference and Electromagnetic Compatibility
Pre-requisite(s): Electromagnetic Theory
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: I/05
Branch: ECE
Name of Teacher:

Course Objectives
This course enables the students to:

1.	Explain requirement of EMI & EMC concept and impart knowledge on different units and standards used for Electromagnetic compatibility in electronic/electric system.
2.	Develop an ability to analyse, measure and evaluate the radiated and conducted emissions to examine the compatibility.
3.	Develop an ability to analyse and evaluate the impact of EMI mitigation techniques such as shielding and grounding.
4.	Develop an ability to explain the impact of EMI on system design.
5.	Review the literature related to EMI & EMC to report it ethically.

Course Outcomes
After the completion of this course, students will be able to:

CO1	Explain the requirement of EMI & EMC concept and impart knowledge on different units and standards used for Electromagnetic compatibility in electronic/electric system.
CO2	Analyse, measure and evaluate radiated and conducted emissions to examine the electromagnetic compatibility.
CO3	Analyse and evaluate the impact of EMI mitigation techniques such as shielding and grounding.
CO4	Explain the impact of EMI on system design.
CO5	Review and write the literature related to EMI & EMC to report it ethically.

SYLLABUS

Module -1:
Introduction: A brief history of EMI/EMC, Analysis of EMI, Type of Noise and Interference, Electromagnetic Compatibility, Radiated Emission and susceptibility, Conducted Emission and Susceptibility, Benefits of good EMC Design, Brief description of EMC regulations, Examples of EMC related problems. EMC requirements for Electronic Systems: Government regulations, Requirement for Commercial products and Military products, Radiated Emission limits for Class A, Class B, FCC and CISPR, measurement of Emissions for verification of compliance: Radiated Emission and Conducted Emissions, Typical product emissions, Additional product requirements, design constraints for products, Advantages of EMC Design.

(8L)

Module -2:
Conducted Emission and Susceptibility: Measurement of Conducted emission: LISN, Common and Differential mode currents, Power supply filters: Basic properties of filters, A

generic power supply filter topology, Effect of filter elements on common and differential mode currents, Separation of conducted emissions into common and differential mode components for diagnostic purpose, Power supplies: Linear and SMPS, Effect of Power Supply Components on Conducted emissions, Power Supply and Filter placement, Conducted Susceptibility.

(8L)

Module -3:

Radiated Emission and Susceptibility: Simple Emission models for wires and PCB lands: Differential mode versus Common mode currents, Differential mode current emission model Common mode current emission model, Current probes, Simple susceptibility models for wires and PCB lands: Shielded cables and surface transfer impedance.

(8L)

Module -4:

Cross talk: Three conductor transmission lines and crosstalk, Transmission line equations for lossless lines, The per unit length parameters: Homogeneous versus Inhomogeneous media, Wide separation approximation for wires, Numerical methods for other structures, The Inductive-Capacitive Coupling Approximation model: Frequency domain Inductive-Capacitive coupling model, Time domain Inductive-Capacitive coupling model, Lumped circuit approximate models. Shielded Wires: Per unit length parameters, Inductive and Capacitive Coupling, Effect of Shield grounding, Effect of pigtails, Effects of Multiple shields, MTL model predictions, Twisted wires: Per unit length parameters, Inductive and Capacitive Coupling, Effects of Twist, Effects of Balancing.

(8L)

Module -5:

Shielding: Shielding Effectiveness, Far field Sources: Exact solution, Approximate solution, Near field sources: Near field versus far field, Electric sources, Magnetic sources, Low frequency, magnetic field shielding, Effect of Apertures. System Design for EMC: Shielding and Grounding, PCB Design, System configuration and design, Electrostatic Discharge, Diagnostic tools.

(8L)

Books recommended:

Textbooks:

1. Paul, C., Introduction to Electromagnetic Compatibility, John Wiley & Sons, 1992.

Reference books:

1. Ott, W. Henry, Electromagnetic Compatibility Engineering, John Wiley & Sons, 2009.

<u>Gaps in the syllabus (to meet Industry/Profession requirements):</u> Design of real-time industrial projects.

<u>POs met through Gaps in the Syllabus:</u> PO5 & PO6

<u>Topics beyond syllabus/Advanced topics/Design:</u> Design optimization for industrial projects.

<u>POs met through Topics beyond syllabus/Advanced topics/Design:</u> PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

<u>Direct Assessment</u>

Assessment Tools	**% Contribution during CO Assessment**
Continuous Internal Assessment	50

Semester End Examination	50

Continuous Internal Assessment	**% Distribution**
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment					
Semester End Examination					

<u>Indirect Assessment</u>

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	1	2	1	3
CO2	2	1	1	1	1	1
CO3	2	1	2	2	3	-
CO4	2	2	2	2	2	2
CO5	1	2	2	3	2	2

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	**Course Delivery Method**
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD7

COURSE INFORMATION SHEET

Course code: EC507
Course title: Electromagnetic and Microwave Applications of Metamaterials
Pre-requisite(s): Electromagnetic Theory and Microwave Engineering
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03

Class: M. Tech.
Semester / Level: I/05
Branch: ECE

Course Objectives:
This course enables the students to:

1.	To develop an ability to understand about left-handed metamaterial and its characteristics and properties
2.	To develop an ability to analyse the physical realization of left-handed metamaterials using the resonant approach.
3.	To develop an ability to analyse the physical realization of left-handed metamaterials using the non-resonant approach
4.	To develop and ability to understand the guided-wave applications of left-handed metamaterials
5.	To develop and ability to understand the radiated-wave applications of left-handed metamaterials

Course Outcomes:
After the completion of this course, a student will be able to:

CO1	Demonstrate understanding of left-handed metamaterial and its characteristics and properties
CO2	Have an ability to design the left-handed metamaterials using the resonant approach.
CO3	Have an ability to design the left-handed metamaterials using the non-resonant approach
CO4	Demonstrate insight the guided-wave applications of left-handed metamaterials.
CO5	Demonstrate insight the radiated-wave applications of left-handed metamaterials.

SYLLABUS

Module 1:
Introduction to Metamaterials:
Definition of Metamaterials and left-handed Metamaterials. Theoretical speculation by Viktor Veselago**.**Wave Propagation in Left-Handed Media, Energy Density and Group Velocity, Negative Refraction, Fermat Principle, Inverse Doppler Effect, Backward Cerenkov Radiation, Negative Goos–Hanchen Shift, Waves at interfaces,Waves through left-handed slabs, Phase Compensation and Amplification of Evanescent Modes , Perfect Tunneling, The Perfect Lens , Losses and Dispersion.

(8L)

Module 2:
Realization of Metamaterials using Resonant Approach:
Scaling Plasmas at Microwave Frequencies, Metallic Waveguides and Plates as One- and Two-Dimensional Plasmas, Wire Media, Spatial Dispersion in Wire Media, Synthesis of Negative Magnetic Permeability, Design and Analysis of the Edge and Broad Coupled SRR, The Double and Multiple Split SRR, Spirals Resonators, Higher-Order Resonances in SRRs, Isotropic SRRs, Scaling Down SRRs to Infrared and Optical Frequencies , 1/2/3 Dimensional SRR-Based Left-Handed Metamaterials, Ferrite Metamaterials, Chiral Metamaterials.

(8L)

Module 3:
Realization of Metamaterials using Non-Resonant Approach:

Ideal homogeneous CRLH TLs, Fundamental TL Characteristics, Equivalent MTM Constitutive Parameters, Balanced and Unbalanced Resonances, lossy CRLH TL model, LC Network Implementation, Difference with Conventional Filters, Transmission Matrix Analysis, Input Impedance, Cutoff Frequencies, Analytical Dispersion Relation, Bloch Impedance, Real Distributed 1D CRLH Structures, General Design Guidelines, Microstrip Implementation, Parameters Extraction.

(8L)

Module 4:

Guided-Waves Applications of Metamaterials:

Dual-Band Components, Dual-Band Property of CRLH TLs, Quarter-Wavelength TL and Stubs, Quadrature Hybrid and Wilkinson Power Divider, Enhanced-Bandwidth Components, Principle of Bandwidth Enhancement, Rat-Race Coupler, Tight Edge-Coupled Coupled-Line Couplers, Generalities on Coupled-Line Couplers, Symmetric Impedance Coupler, Asymmetric Phase Coupler, Negative and Zeroth-Order Resonator. SRRs based Filters and Diplexers Design.

(8L)

Module 5:

Radiated-Wave Applications of Metamaterials:

Fundamental aspects of Leaky-Wave Structures, Principle of Leakage Radiation, Uniform and Periodic LW Structures, Backfire-to-Endfire (BE) leaky-wave (LW) antenna, electronically scanned LW antenna, Passive Retro-Directive Reflector, Two-Dimensional LW Radiation, Conical-Beam Antenna, Full-Space Scanning Antenna, Zeroth Order Resonating Antenna, Dual-Band CRLH-TL Resonating Ring Antenna, Heterodyne Phased Array, Non-uniform Leaky-Wave Radiator, The Future of MTMs.

(8L)

Books recommended:

Textbooks:

1. "Metamaterials with Negative Parameters, Theory, Design and Microwave Applications," by Ricardo Marques, Ferran Martin, and Mario Sorolla "Wiley Series in Microwave and Optical Engineering, Wiley Interscinces 2007" (T1)
2. "Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, The Engineering Approach," Christophe Caloz and Tatsuo Itoh, John Wiley & Sons, Inc., Hoboken, New Jersey 2006. (T2)

Reference books:

1. Foundations for Microwave Engineering; Second Edition; By Robert E. Collin; McGraw Hill International Edition; 1992. (R1)
2. Microwave Engineering; Second Edition; by David M. Pozar; John Wiley & Sons; Inc. Copyright 2001. (R2)

<u>Gaps in the syllabus (to meet Industry/Profession requirements):</u> Design of advanced microwave components using left handed metamaterial.

<u>POs met through Gaps in the Syllabus:</u> PO2

<u>Topics beyond syllabus/Advanced topics/Design:</u> Analysis, design and optimization of advanced microwave components using left handed metamaterial for industrial projects.

<u>POs met through Topics beyond syllabus/Advanced topics/Design:</u> PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3	3	2
CO2	3	2	3	3	3	2
CO3	3	2	3	3	3	2
CO4	3	2	3	3	3	2
CO5	3	2	3	3	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD6, CD7
CO4	CD1, CD2, CD6, CD7
CO5	CD1, CD2, CD6, CD7

COURSE INFORMATION SHEET

Course code: EC508
Course title: Radar Signal Analysis
Pre-requisite(s): Microwave Engineering
Co- requisite(s):

Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: I/05
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students to:

1.	To appraise an overview of Radar Systems.
2.	To perceive the Target Detection, Pulse Integration and Pulse Compression
3.	To grasp Matched Filter and Ambiguity Function-Analog and Discrete Coded Waveforms.
4.	To understand the concept of Radar Clutter.
5.	To grasp the Doppler and Adaptive Array Processing

Course Outcomes:
After the completion of this course, a student will be able to:

CO1	Able to explain the Radar Systems.
CO2	Able to demonstrate Target Detection, Pulse Integration and Pulse Compression
CO3	Able to explain Matched filter and Ambiguity Function-Analog and Discrete Coded Waveforms
CO4	Able to demonstrate the Radar Clutter
CO5	Able to explain Doppler and Adaptive Array Processing

SYLLABUS

Module 1:
Radar Systems (an overview):
Range Measurements, Range Resolution, Doppler Frequency, Coherence, The Radar Equation, Surveillance Radar Equation, Radar Cross Section, Radar Equation with Jamming, Noise Figure Effects of the Earth's Surface on the Radar Equation, Atmospheric Attenuation.
(8L)

Module 2:
Target Detection, Pulse Integration and Pulse Compression:
Target Detection in the Presence of Noise, Probability of False Alarm, Probability of Detection, Pulse Integration, Target Fluctuating, Probability of False Alarm Formulation for a Square Law Detector, Probability of Detection Calculation, Computation of the Fluctuation Loss, Cumulative Probability of Detection, Constant False Alarm Rate (CFAR), Time-Bandwidth Product, Radar Equation with Pulse Compression, Basic Principal of Pulse Compression, Correlation Processor, Stretch Processor.
(8L)

Module 3:
Matched Filter and Ambiguity Function:
The Matched Filter SNR, Mean and Variance of the Matched Filter Output, General Formula for the Output of the Matched Filter, Waveform Resolution and Ambiguity, Range and Doppler Uncertainty, Target Parameter Estimation, Examples of the Ambiguity Function, Stepped Frequency Waveforms, Nonlinear FM Ambiguity Diagram Contours, Interpretation of Range-Doppler Coupling in LFM Signals, Discrete Code Signal Representation, Pulse-Train Codes, Phase Coding, Frequency Codes, Ambiguity Plots for Discrete Coded Waveforms.

(8L)

Module 4:
Radar Clutter:
Clutter Cross Section Density, Surface Clutter, Volume Clutter, Clutter RCS, Clutter Spectrum, Moving Target Indicator (MTI), PRF Staggering, MTI Improvement Factor, Subclutter Visibility, Delay Line Cancelers with Optimal Weights

(8L)

Module 5:
Doppler and Adaptive Array Processing:
CW Radar Functional Block Diagram, Pulsed Radars, Introduction to Adaptive Array Processing, General Arrays, Linear Arrays, Nonadaptive Beamforming, Adaptive Array Processing.

(8L)

Books recommended:
Textbooks:

1. Bassem R. Mahafza, Radar Signal Analysis and Processing Using MATLAB, Chapman and Hall/CRC, 2008.

Reference books:

1. M.I. Skolnik, "Introduction to Radar Systems", 3/e, TMH, New Delhi, 2001
2. Nathanson, F. E., Radar Design Principles, New York, McGraw-Hill, 2nd Edition, 1991
3. Toomay, J. C., Radar Principles for the Non-Specialist, New York, Van Nostrand, Reinhold, 1989
4. Buderi R., The Invention That Changed the World, New York, Simon and Schuster, 1996
5. R.J Sullivan, Radar foundation for imaging & advanced concepts, PHI, 2004.
6. Mark A Richards, Fundamentals of Radar Signal Processing,McGrah -Hill Company, 2005

Gaps in the syllabus (to meet Industry/Profession requirements): Design of real-time industrial projects.

POs met through Gaps in the Syllabus: PO2

Topics beyond syllabus/Advanced topics/Design: Design of real-time industrial projects.

POs met through Topics beyond syllabus/Advanced topics/Design: PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure
Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5

Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3	2	-
CO2	2	2	3	3	2	-
CO3	2	2	3	3	2	-
CO4	2	2	3	3	2	-
CO5	2	2	3	3	2	-

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6, CD7
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD6, CD7
CO4	CD1, CD2, CD6, CD7
CO5	CD1, CD2, CD6, CD7

COURSE INFORMATION SHEET

Course code: EC509
Course title: RF Microelectronics Circuit Design
Pre-requisite(s): EC201 Electronic Devices, EC253 Analog Circuits
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class period per week: 03
Class: M. Tech.
Semester / Level: I/05
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students to:

1.	Understand RF frequency response of MOSFET.
2.	Grasp the RF Technology and basic concepts in RF design and apply the same.

3.	Appraise communication concepts and analyze transceiver architectures.
4.	Appraise and evaluate the basic blocks in RF systems such as LNA, Mixer and VCO and their VLSI implementations.
5.	Comprehend the characteristics of RF synthesizers and Power Amplifiers and create their circuits.

Course Outcomes:

After the completion of this course, a student will be able to:

CO1	Illustrate and Interpret RF frequency response of MOSFET.
CO2	Sketch and explain the RF technology and basic concepts in RF design.
CO3	Diagram and explain communication concepts in transceiver architectures.
CO4	Appraise the basic blocks in RF systems such as LNA, Mixer and VCO, schematize, assess and summarize their features.
CO5	Design and schematize basic blocks in RF systems such as RF Synthesizer and Power Amplifiers. Schematize their characteristics and prepare an inference.

SYLLABUS

Module -1:

RF frequency response of MOSFET:

Derivation and estimation of MOS capacitor, MOS capacitor in cutoff, linear and saturation region, derivation and estimation of MOSFET's long-channel model including threshold voltage, body effect, transconductance (g_m), output conductance (g_{ds}), small-signal output resistance (r_o), A Medium-Frequency Small-Signal Model for the Intrinsic Part, Intrinsic Transition Frequency, Noise in MOSFET: white noise, flicker noise, High frequency Small-Signal Model, Transition Frequency (f_T) and Maximum oscillation (f_{max}) of MOSFET.

(8L)

Module -2:

RF technology and basic concepts in RF design:

Introduction to RF and Wireless Technology: Challenges in RF Design, Complexity Comparison, Design Bottleneck, Applications, Choice of Technology; Basic concepts in RF Design: Units in RF Design, Time Variance, Nonlinearity, Effects of nonlinearity; Noise as Random Process, effect of transfer function on noise, device Noise, Representation of Noise in Circuits. Sensitivity and Dynamic Range.

(8L)

Module -3:

Communication concepts and transceiver architectures:

Analog modulation, Digital modulation, Spectral Regrowth, Mobile RF Communications, Multiple Access techniques Wireless standards; Receiver Architectures: Basic Heterodyne Receivers, Modern Heterodyne Receivers, Direct-Conversion Receivers, Image Reject Receivers, Low-IF Receivers; Transmitter Architectures: Direct-Conversion Transmitters, Modern Direct-Conversion Transmitters, Heterodyne Transmitters.

(8L)

Module -4:

Basic blocks in RF systems and their VLSI implementation:

Low Noise Amplifier: General considerations, Problem of input matching, Basic LNA Topologies (Common-Source Stage with Inductive Load, Common-Source Stage with Resistive Feedback). Mixers: General Considerations, Active Down-conversion Mixers, Improved Mixer Topologies. Oscillators: Performance Parameters, Voltage-Controlled Oscillators (VCOs), LC VCOs with Wide Tuning Range, Basic concepts and effect of phase noise, Design procedure, LO Interface, Mathematical Model of VCOs, Basic concepts quadrature oscillators.

(8L)

Module -5:

Radio Frequency Synthesizer and Power Amplifiers:

Phase-locked loops: Basic concepts, Type-I PLLs, Type-II PLLs (Phase/Frequency detectors, Charge-pump PLLs). Radio Frequency Synthesizes: General considerations, Basic integer-N synthesizer, Basic concepts of fractional-N synthesizers. Power Amplifiers: General Considerations, Classification of Power Amplifiers, High-Efficiency Power Amplifiers.

(8L)

Books recommended:

Textbooks:

1. John W. M. Rogers, Calvin Plett, Radio Frequency Integrated Circuit Design, Artech House, 2010.
2. Yannis Tsividis, Colin McAndrew, Operation and Modeling of MOS Transistor, Oxford University Press, 3rd edition, 2011.
3. Behzad Razavi, RF Microelectronics, 2e, Prentice Hall, 2011.

Reference books:

1. Samuel Y. Liao, Microwave Devices and Circuits, 3e, Prentice-Hall of India, 2003.
2. Paul R. Gray, Paul J. Hurst, Stephen H. Lewis and Roberst G. Meyer, Analysis and Design of Analog Integrated Circuits, 5/e, Wiley, 2009.
3. The Design of CMOS Radio-Frequency Integrated Circuits by Thomas H. Lee. Cambridge University Press, 2004.

Gaps in the syllabus (to meet Industry/Profession requirements): Hands-on-practical for RF IC (Radio Frequency Integrated Circuit) fabrication.

POs met through Gaps in the Syllabus: PO6 will be met though RF circuit design-based assignment, which involves handling of RF equipments and CAD tools.

Topics beyond syllabus/Advanced topics/Design: Microelectronic Circuit Designs related to Digital, Analog and Mixed-Signal (such as ADC and DAC).

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					

Semester End Examination					

Indirect Assessment
1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	2	1
CO2	3	3	3	3	2	1
CO3	3	3	1	3	2	1
CO4	2	2	2	2	3	2
CO5	2	2	2	2	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3, CD6
CO2	CD1, CD2, CD3, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD2, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD6, CD7

Open Elective-I

COURSE INFORMATION SHEET

Course code: EC547
Course title: Fundamentals of MEMS
Pre-requisite(s): Any Branch in UG Engg/Applied Science
Co-requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: I/05
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students:

1.	Introduction to MEMS and micro fabrication to develop an ability, enthusiasm

	critical thinking in microengineering process, materials and design issues
2.	To study the essential material properties and understanding of microscale physics for use in designing MEMS devices
3.	To study various sensing and transduction technique to develop an ability and understanding of microscale physics for use in designing MEMS devices
4.	To develop an inclination towards electronics system design and manufacturing
5.	To develop the fundamental concepts of MEMS technology& their applications in different areas

Course Outcomes:
After the completion of this course, students will be:

CO1	Demonstrate knowledge on fundamental principles and concepts of MEMS Technology
CO2	Have an ability to analyse various techniques for building micro-devices in silicon, polymer, metal and other materials
CO3	Correlate micro-systems technology for technical feasibility as well as practicality using modern tools and relevant simulation software to perform design and analysis.
CO4	Have an ability to compare physical, chemical, biological, and engineering principles involved in the design and operation of current and future micro-devices
CO5	Be fluent with the design, simulation and development MEMS Devices.

SYLLABUS

Module-1:
Introduction: The History of MEMS Development, Intrinsic characteristics of MEMS, MEMS sensors and actuators, Sensor noise and Design complexity. Introduction to Microfabrication Essential overview of frequently used micro fabrication processes. Thin film deposition techniques, wafer bonding Silicon Based MEMS processes, MEMS Materials.

(8L)

Module-2:
Essential Electrical and Mechanical Concepts: Crystal planes & orientations, General Scalar relation between Tensile stress and strain, Mechanical properties of silicon and related thin films, Flexural Beam bending Analysis, Dynamic System, Resonant Frequency and quality factor, Electromechanical and Direct Analogy in Electrical and Mechanical domain.

(8L)

Module -3:
Sensing and Actuation schemes: Electrostatic Sensors and Actuators, Thermal sensors and actuators, Piezoresistive Sensors, Piezoelectric Sensors and Actuators, Magnetic Actuators. Comparison of Major Sensing and Actuation Methods and their Applications.

(8L)

Module 4:
MEMS Packaging and Integration. Role of MEMS packages. Mechanical support Electrical interface Protection from the environment Thermal considerations Types of MEMS packages Metal packages Ceramic packages Plastic packages 368, Multilayer packages Embedded overlay Wafer-level packaging, Microshielding and self-packaging, Flip-chip assembly Multichip module packaging, Wafer bonding.

(8L)

Module 5:

Case studies for selected MEMS Products: Blood Pressure Sensor, Microphone, Accelerometer, Performance and Accuracy.

(8L)

Books recommended:

Textbooks:

1. Foundations of MEMS by Chang Liu, Second Edition, Pearson, ISBN 978-81-317-6475-6.
2. RF MEMS and Their Applications**,** Vijay K.Varadan, K.J.Vinoy and K.A.Jose, Wiley India Pvt Ltd.,Wiley India Edition, ISBN 978-81-265-2991-9.

Reference books:

1. MarcMadou, Fundamentals of Microfabrication by, CRC Press, 1997.Gregory Kovacs, Micromachined Transducers Sourcebook WCB McGraw-Hill, Boston, 1998.
2. M.-H. Bao, Micromechanical Transducers: Pressure sensors, accelerometers,and gyroscopes by Elsevier, New York, 2000.
3. RF MEMS and Their Applications,Vijay K. Varadan K.J. Vinoy K.A. Jose Pennsylvania State University, USA, John Wiley & Sons Ltd -2003.

Gaps in the syllabus (to meet Industry/Profession requirements): Design of real-time industrial /Research projects.

POs met through Gaps in the Syllabus: PO3 & PO6

Topics beyond syllabus/Advanced topics/Design: Design optimization for industrial projects, Micro-fabrication techniques and MEMS devices.

POs met through Topics beyond syllabus/Advanced topics/Design: PO3 & PO4

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments

CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	2	3	2	1
CO2	3	3	3	3	2	1
CO3	3	3	1	3	2	1
CO4	2	2	2	2	3	2
CO5	2	2	2	2	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3, CD6
CO2	CD1, CD2, CD3, CD6
CO3	CD1, CD2, CD3, CD4, CD6,
CO4	CD1, CD2, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD6, CD7

Programme Core

COURSE INFORMATION SHEET

Course code: EC502
Course title: Microwave Measurement Lab
Pre-requisite(s): EC257 Electromagnetic Fields and Waves
Co- requisite(s):
Credits: L: 0 T: 0 P: 4 C: 2
Class schedule per week: 04
Class: M. Tech.
Semester / Level: I/05
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students to:

1.	Develop the ability to analyze the propagation modes in free space and waveguide
2.	Develop the ability to analyze the performance parameters of microwave active devices
3.	Develop the ability to analyze the performance parameters of RF Mixer and Switch
4.	Develop an ability to analyze, measure and evaluate crosstalk, radiated and conducted emissions to examine the shielding effectiveness of conducting materials.
5.	Develop the ability to analyze the performance parameters of different types of

	Radars

Course Outcomes:
After the completion of this course, a student will be able to

CO1	Understand the various propagation modes in free space and waveguide
CO2	Measure and analyze the performance parameters of microwave active devices
CO3	Measure and analyze the performance parameters of RF Mixer and Switch
CO4	To analyze, measure and evaluate crosstalk, radiated and conducted emissions to examine the shielding effectiveness of conducting materials
CO5	Measure and analyze the performance parameters of different types of Radars

SYLLABUS

LIST OF EXPERIMENTS:

1. Analysis of various propagation modes in free space.
2. Analysis of various propagation modes in waveguide.
3. Measurement of performance parameters of microwave amplifier
4. Measurement of performance parameters of microwave voltage-controlled oscillator
5. Measurement of performance parameters of RF mixer
6. Measurement of performance parameters of RF Switch
7. To study electrostatic discharge, different crosstalk in the cable and its reduction technique and to measure crosstalk in a three-conductor transmission line using VNA
8. To measure the conducted emission using LISN and radiated emission from mobile tower and mobile phone.
9. To measure the performance parameter of an EMI sensor and Shielding Effectiveness of conducting material.
10. To evaluate the performance of Doppler Radar
11. To evaluate the performance of MTI radar
12. To evaluate the performance of FM CW Radar

Books recommended:
Textbooks:

1. David M. Pozar, "Microwave Engineering", Third Edition, Wiley India.
2. R. Ludwig and G. Bogdanov, “RF Circuit Design, Theory and Applications”, Pearson, 2nd Edition.

Reference books:

3. Paul, C., Introduction to Electromagnetic Compatibility, John Wiley & Sons, 1992.
4. M.I. Skolnik, “Introduction to Radar System”,McGraw Hill 2nd Edition

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure
Direct Assessment

Assessment Tools	% Contribution during CO Assessment

Progressive Evaluation	60
End Semester Evaluation	40

Progressive Evaluation	**% Distribution**
Day to day performance & Lab files	30
Quiz (zes)	10
Viva	20

End Semester Evaluation	**% Distribution**
Examination Experiment Performance	30
Quiz	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Progressive Evaluation					
End Semester Evaluation					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	2	3
CO2	2	3	3	3	2	3
CO3	2	3	3	3	2	3
CO4	2	3	3	3	2	3
CO5	2	3	3	3	2	3

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD3, CD7
CO2	CD3, CD7
CO3	CD3, CD7
CO4	CD3, CD7
CO5	CD3, CD7

COURSE INFORMATION SHEET

Course code: EC504
Course title: Antenna Lab
Pre-requisite(s): EC257 Electromagnetic Fields and Waves, EC323 Microwave Theory & Techniques
Co- requisite(s):
Credits: L: 0 T: 0 P: 4 C: 2
Class schedule per week: 04
Class: M. Tech.
Semester / Level: I/05
Branch: ECE
Name of Teacher:

Course Objectives
This course enables the students:

1.	To understand important and fundamental antenna engineering parameters.
2.	To develop the basic skills to learn software and apply in the design of various antennas.
3.	To develop the basic skills necessary to measure antenna performance parameters.
4.	To apply the concepts learnt through theory
5.	Develop the ability to analyze the performance parameters of different types of antenna

Course Outcomes
After the completion of this course, students will be able to:

CO1	Have the ability to implement the theoretical knowledge and prepare the reports and present the results.
CO2	Apply numerical modelling tools (software) to design antennas, with particular reference to low profile printed antennas.
CO3	Have the ability to perform antenna measurements.
CO4	Understand and visualize the radiation characteristics and its limitations and provide the environment friendly solutions in terms of antenna design.
CO5	Have the ability to Practically verify different microwave antenna theories.

SYLLABUS

List of Experiments

1. Design of a rectangular microstrip patch antenna for operating frequency 1.88GHz with ε_r =4.4, h=31 mils with inset feed.
   (IE3D)

2. Design of a rectangular microstrip patch antenna for operating frequency 1.88GHz with ε_r =4.4, h=31 mils with coaxial feed.
   (IE3D)

3. Design of a rectangular microstrip patch antenna for operating frequency 5 GHz with ε_r =3.2, h=0.762mm & transformer coupled microstrip feed.
   (IE3D)

4. Design of a circular microstrip patch antenna for circular polarization with dual feed. Assume resonant frequency =2.78GHz, ε_r =2.33, h=2.184mm, tanδ=0.0012. (IE3D)

5. Design of a rectangular microstrip patch antenna for operating frequency 1.88GHz with ε_r =4.4, h=31 mils & inset feed. (HFSS)

6. Design of a rectangular microstrip patch antenna for operating frequency 1.88GHz with ε_r =4.4, h=31 mils & transformer coupled microstrip feed. (HFSS)

7. To plot the radiation pattern of a directional antenna.

8. To plot the radiation pattern of an omnidirectional antenna.

9. To calculate the resonant frequency and estimate the VSWR of an antenna.

10. To prove inverse square law for any antenna.

11. Characterization of a linearly polarized and circularly polarized antenna.

12. The gain measurement of an antenna under test.

Books recommended:

Textbooks:

1. Antenna Theory, Analysis and Design, 3/E, A. Balanis, John Wiley.
2. Antennas, J. D. Kraus, TMH
3. Wireless Communications, Principles and Practices, Rappaport, PHI

Reference books:

1. Software Radio A Modern Approach to Radio Engineering, J. H. Reed, Pearson Education.
2. Wireless and Cellular Communications, William C. Y. Lee, McGraw-Hill.
3. Wireless Communications, Principles and Practices, Rappaport, PHI.

Gaps in the syllabus (to meet Industry/Profession requirements):

POs met through Gaps in the Syllabus:

Topics beyond syllabus/Advanced topics/Design:

POs met through Topics beyond syllabus/Advanced topics/Design:

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Progressive Evaluation	60
End Semester Evaluation	40

Progressive Evaluation	% Distribution
Day to day performance & Lab files	30
Quiz (zes)	10
Viva	20

End Semester Evaluation	% Distribution
Examination Experiment Performance	30
Quiz	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Progressive Evaluation					
End Semester Evaluation					

<u>Indirect Assessment</u>

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	3	3	3	2	3
CO2	2	3	3	3	2	3
CO3	2	3	3	3	2	3
CO4	2	3	3	3	2	3
CO5	2	3	3	3	2	3

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD3
CO2	CD3
CO3	CD5, CD3
CO4	CD5, CD3, CD7
CO5	CD3, CD7

2nd Semester

Programme Core

COURSE INFORMATION SHEET

Course code: EC550
Course title: Microwave & MM-wave Integrated Circuits and Applications
Pre-requisite(s): EC323Microwave Theory & Technique
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: II/05
Branch: ECE
Name of Teacher:

Course Objectives
This course enables the students:

1.	State the concept of MMIC and MM-wave technology along with their fabrication techniques
2.	Comprehensive knowledge of the passive circuit elements for microwave and MM-wave technology.
3.	Illustrate basic of active elements for microwave and MM-wave technology.
4.	Enhance skills of different measurement techniques for microwave and MM-wave technology.
5.	Design systems and its application for microwave and MM-wave technology.

Course Outcomes
After the completion of this course, students will be:

CO1	Able to explain the requirement of MMIC and MM-wave technologies and their fabrication techniques.
CO2	Able to analyse passive circuit elements for microwave and MM-wave technology.
CO3	Able to analyze the active elements for microwave and MM-wave technology.
CO4	Examine different measurement techniques for microwave and MM-wave technology.
CO5	Aspire for pursuing a carrier in system application for microwave and MM-wave technology.

SYLLABUS

Module -1:
Introduction to Monolithic Microwave Integrated Circuits (MMICs) technology, different types of MMIC, Advantages, disadvantages and application of MMICs, MMIC fabrication techniques, Thick and Thin film technologies and materials, Encapsulation and mounting of active devices, Introduction to MM-Wave Integrated Circuits, GaAs Fabrication Technology and various processes, Materials used for MM-wave Integrated Guides.

(11L)

Module -2:
Passive Circuit elements: Transmission lines for Microwave Integrated Circuits, Discontinuities, Lumped elements

Passive Components: Introduction, Power transfer in parallel-coupled guides, Parallel Guide Directional Couplers, Other Directional Couplers, Ring Resonator Filters.

(6L)

Module -3:

Active Semiconductor circuit elements: Schottky-barrier diodes, Varactor diodes, p-i-n diodes, Bipolar Transistors, MESFETs, HEMTs Active Components: Introduction, Image Guide Detector Circuits, Oscillators, Electronic Phase Shifters, Balanced Mixers, Amplifiers, High Frequency Devices, Low Noise MM-wave Amplifiers, Monolithic Mixers.

(11L)

Module -4:

Measurement Techniques:

Introduction, Test fixture measurements, Probe station measurements, Thermal and cryogenic measurements, Experimental field probing techniques,

MM-wave measurement techniques: Electric field probe, Measurement of Attenuation constant and guide wavelength. Measurement at Radiation Loss at bents.

(6L)

Module -5:

System Application:

MICs in Phased Array Radars, MICs in Satellite Television Systems, Microwave Radio Systems,

Monolithic MM-wave Transceiver.

(6L)

Books recommended:

Textbooks:

1. MMIC Design by I. D. Robertson, The Institution of Electrical Engineers, U.K., 1995
2. Microwave Integrated circuit by K. C. Gupta, A. Singh, John Wiley & Sons, 1974
3. Millimeter wave Integrated Circuit by E. Carey and S. Lidholm, Springer, 2005
4. Millimeter Wave and Optical Dielectric Integrated Guides and Circuits by S. K. Koul, John Wiley & Sons, 1997.
5. Microwave Integrated Circuits by I. Kneppo, J. Fabian, P. Bezousek, P. Hrnicko and M. Pavel, Springer.

Reference books:

1. Stripline-like Transmission lines for Microwave Integrated circuits, B. Bhat, S. K. Koul, Wiley Eastern Ltd., New Delhi.

Gaps in the syllabus (to meet Industry/Profession requirements): Hands on experience on solution of Real time Industrial Project and management.

POs met through Gaps in the Syllabus: **PO5, PO6**

Topics beyond syllabus/Advanced topics/Design: Microwave and mm-Wave Microelectronics, High-power broadband solid-state isolators, Broadband, outphasing, multi-way power amplifiers on-chip.

POs met through Topics beyond syllabus/Advanced topics/Design: PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Continuous Internal Assessment	50

Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

<u>Indirect Assessment</u>

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Course Delivery Method

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	2	3	3	1	2
CO2	2	2	3	3	2	1
CO3	2	2	3	3	2	1
CO4	2	2	3	3	2	3
CO5	2	2	3	3	2	2

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD6
CO2	CD1, CD2, CD3, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD2, CD3
CO5	CD1, CD2

COURSE INFORMATION SHEET

Course code: EC551
Course title: RF Circuit Design
Pre-requisite(s): EC257 Electromagnetic Fields and Waves, EC323Microwave Theory & Technique
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3

Class schedule per week: 03
Class: M. Tech.
Semester / Level: II/05
Branch: ECE
Name of Teacher:

Course Objectives
This course enables the students:

1.	To explain radio frequency design concept and impart knowledge on design and implementation of high frequency transceiver system.
2.	To develop an ability to analyze various components of radio frequency communication system architecture.
3.	To develop an ability to analyze the impact of different design parameters in transceiver circuit design, besides developing an insight to make use of several high frequency design techniques.
4.	To develop the prototype models of the various RF circuit components.
5.	To review and refer the literature related to RF Circuit design and report it ethically.

Course Outcomes
After the completion of this course, students will be:

CO1	Able to explain radio frequency design concept and impart knowledge on design and implementation of high frequency transceiver system.
CO2	Able to develop an ability to analyze various components of radio frequency communication system architecture.
CO3	Able to develop an ability to analyze the impact of different design parameters in transceiver circuit design, besides developing an insight to make use of several high frequency design techniques.
CO4	Able to develop the prototype models of the various RF circuit components.
CO5	Able to review and refer the literature related to RF Circuit design and report it ethically.

SYLLABUS

Module -1:
Introduction: Importance of RF Design, RF Behavior of Passive Components: High Frequency Resistors, High-Frequency Capacitors, High-Frequency Inductors. Chip Components and Circuit Board Considerations: Chip Resistors, Chip Capacitors, Surface-Mounted Inductors.

(6L)

Module -2:
RF Filter Design: Basic Resonator and Filter Configurations: Filter Type and Parameters, Low-Pass Filter, High Pass Filter, Bandpass and Bandstop Filters, Insertion Loss, Special Filter Realizations: Butterworth –Type, Chebyshev and Denormalization of Standard Low-Pass Design. Filter Implementations: Unit Elements, Kuroda's Identities and Examples of Microstrip Filter Design. Coupled Filter: Odd and Even Mode Excitation, Bandpass Filter Section, Cascading Bandpass Filter Elements, Design Examples.

(10L)

Module -3:

Matching and Biasing Network: Impedance Matching using Discrete Components: Two Component Matching Networks, Forbidden regions, Frequency Response and Quality Factor, Microstrip Line Matching Networks: From Discrete Components to Microstrip Lines, Single-Stub Matching Networks, Double-Stub Matching Networks, Amplifier Classes of Operation and Biasing Network: Classes of Operation and Efficiency of Amplifiers, Bipolar Transistor Biasing Networks, Field Effect Transistor Biasing Networks.

(8L)

Module -4:

RF Transistor Amplifier Design: Characteristics of Amplifiers, Amplifier Power Relations: RF source, Transducer Power Gain, Additional Power Relations, Stability Considerations: Stability Circles, Unconditional Stability, Stabilization Methods, Constant Gain: Unilateral Design, Unilateral Figure of Merit, Bilateral Design, Operating and Available Power Gain Circles. Noise Figure Circles, Constant VSWR Circles. Broadband, High Power and Multistage Amplifiers.

(8L)

Module -5:

RF Oscillators and Mixers: Basic Oscillator Model: Negative Resistance Oscillator, Feedback Oscillator Design, Design Steps, Quartz Oscillators. High Frequency Oscillator Configuration: Fixed Frequency Oscillators, Dielectric Resonator Oscillators, YIG-Tuned Oscillators, Voltage Controlled Oscillators, Gunn Element Oscillator. Basic Characteristics of Mixers: Basic Concepts, Frequency Domain Considerations, Single-Balanced Mixer Double-Balanced Mixer.

(8L)

Textbooks:

1. RF Circuit Design Theory and Application, Reinhold Ludwig and Pavel Bretchko, Ed. 2004, Pearson Education.

Reference books:

1. Microstrip Filters for RF/Microwave Applications, Jia-Sheng Hong, M. J. Lancaster, John Wiley & Sons, 2001.

Gaps in the syllabus (to meet Industry/Profession requirements) : Hands on experience on real-time industrial projects and management.

POs met through Gaps in the Syllabus: PO5 & PO6

Topics beyond syllabus/Advanced topics/Design: Design of Millimeter wave circuits and components.

POs met through Topics beyond syllabus/Advanced topics/Design: PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10

Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	1	2	2	1
CO2	2	1	2	2	2	1
CO3	2	1	2	2	2	1
CO4	3	1	3	3	3	1
CO5	1	3	1	1	1	1

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD7

COURSE INFORMATION SHEET

Course code: EC553
Course title: Numerical Techniques in Electromagnetics
Pre-requisite(s): EC257 Electromagnetic Fields and Waves
Co- requisite(s): Computational Electromagnetics Lab.
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: II/05
Branch ECE
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Understand the need of numerical techniques and classification of EM problems
2.	Study the various numerical techniques used in analysing EM problems
3.	Solve simple EM problems using numerical techniques
4.	Apprehend Finite Element Method
5.	Appraise Monte Carlo (MC) methods

Course Outcomes

After the completion of this course, students will be able:

CO1	To classify the EM problems.
CO2	To acquire theoretical knowledge and explain various numerical methods of electromagnetics.
CO3	To formulate real life problem to mathematical model.
CO4	To apply various deterministic numerical methods to different static, scattering and radiation problems
CO5	To apply non-deterministic numerical methods to different static, scattering and radiation problems

SYLLABUS

Module -1:

Introduction: Need for Numerical Solution of Electromagnetic problems, Selection of a numerical method, Classification of Electromagnetic problems, Classification of Solution Region, Classification of Boundary Conditions.

(7L)

Module -2:

Finite Difference (FD) and Finite Difference Time Domain (FDTD Methods: Introduction, FD schemes for parabolic, hyperbolic & Elliptical partial differential equations, solving the Laplace, diffusion and wave equations by FD method. Application to Guided structures: microstrip line and rectangular waveguide. Yee's FD algorithms, Accuracy & stability, Lattice truncation condition, Initial fields, Absorbing Boundary conditions for FDTD, Scattering problems.

(9L)

Module -3:

Integral Equations and Method of Moments (MoM): Classification of Integral Equations, Relation between Differential and Integral Equations, Green's function: definition, Green's function for free space, Solution of integral equations using MoM, Quasi-static problems (thin conducting wire, parallel plate capacitor), Dipole antenna current distribution & input impedance, mutual impedance of two short dipoles, Scattering from a dipole antenna.

(8L)

Module -4:

Finite Element Method: Finite Element Discretization, Element Governing Equations, Assembling of all Elements, Solving the resulting equations, Typical Applications.

(9L)

Module -5:

Monte Carlo (MC) methods: Introduction, Fixed and Floating Random Walks, Markov Chains, Solving typical electromagnetic Problems with random walk and Markov chain methods.

(7L)

Books recommended:

Textbooks:

1. Numerical Techniques in Electromagnetics Mathew N. O. Sadiku (CRC Press)

Reference books:

1. Analytical and Computational Methods in Electromagnetics, Ramesh Garg, Artech House, 2008.

Gaps in the syllabus (to meet Industry/Profession requirements): Hands on experience on real-time industrial projects and management.

POs met through Gaps in the Syllabus: NIL

Topics beyond syllabus/Advanced topics/Design: Advanced Numerical and Theoretical Methods for Photonic Crystals and Metamaterials.

POs met through Topics beyond syllabus/Advanced topics/Design: PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	**% Distribution**
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	2	3	2	1

CO2	2	1	3	3	2	2
CO3	2	2	3	3	3	3
CO4	3	2	3	3	3	3
CO5	3	2	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcome	Course Delivery Method
CO1	CD1, CD2, CD6
CO2	CD1, CD2, CD6
CO3	CD1, CD2, CD3, CD4, CD6
CO4	CD1, CD2, CD3, CD4, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD6, CD7

Programme Elective – II

COURSE INFORMATION SHEET

Course code: EC555
Course title: Advanced Array Synthesis
Pre-requisite(s): EC325 Antenna and Wave Propagation
Co-requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: II/05
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students:

1.	To appraise an overview of antennas and antenna Array
2.	To perceive the arrays such as linear, planar, 3D and conformal
3	To analyze pattern synthesis techniques for arrays
4.	To grasp the various orthogonal synthesis methods for linear, non-linear and 3D arrays
5.	To understand the orama program computer tool

Course Outcomes:
After the completion of this course, students will be:

CO1	Able to explain the concept of Antennas and Antenna Array.
CO2	Able to explain the Arrays such as linear, planar, 3D. Conformal and Pattern Synthesis for Arrays
CO3	Able to use pattern synthesis techniques for different types of arrays
CO4	Able to analyse the orthogonal Synthesis Methods for linear, non-linear and 3D arrays
CO5	Able to demonstrate the orama program computer tool

SYLLABUS

Module 1:
Antennas and Antenna Array:
Introduction, Antenna Array Factor, Elements and Array Types, Antenna Parameters and Indices, Antenna Input Impedance, Antenna Arrays Classification, Array Factor Classification.

(6L)

Module 2:
Arrays: Linear, Planar, 3D and Conformal:
Introduction, Linear Arrays, Uniform Linear Arrays, Chebyshev Linear Arrays, Linear Arrays from Sampling or Root Matching of Line Sources, Planar Arrays, 3-D Arrays, Conformal Arrays.

(8L)

Module 3:
Pattern Synthesis for Arrays:
Introduction, Uniform Linear Array Synthesis, Chebyshev Array Synthesis, Synthesis by Sampling or by Root Matching, Synthesis by Fourier Transform, The Woodward - Lawson (WL) Method, Array Synthesis as an Optimization Problem, Synthesis by Convolution of Linear, Planar and 3-D Arrays.

(10L)

Module 4:
The Orthogonal Methods:
Introduction, Synthesis of Non-uniformly Spaced Linear Arrays: The Matrix Inversion Method, Synthesis of Non-uniformly Spaced Linear Arrays: The Orthogonal Method, Quantized Excitation and Geometry Synthesis of a Linear Array: The Orthogonal Perturbation Method, Synthesis of Non-uniformly Spaced Planar Arrays: The Orthogonal Method, Synthesis of Non-uniformly Spaced 3-D Arrays: The Orthogonal Method, Synthesis of Non-uniformly Spaced 3-D Arrays with Arbitrarily Oriented Dipoles: The Non-parallel Orthogonal Method, Synthesis of Arrays of Wire Antennas: The MoM Orthogonal Method, Synthesis of General Antenna Arrays: The Orthogonal Compensation Method, Synthesis of Conformal Arrays: The Conformal Orthogonal Method.

(10L)

Module 5:
The Orama Computer Tool:
Introduction, Description of the ORAMA Program, Element Types, Design Examples.

(6L)

Textbooks:

1. John Sahalos "Orthogonal Methods for Array Synthesis: Theory and the ORAMA Computer Tool" Wiley 2006.

Reference books:

1. Arun K. Bhattacharyya "Phased Array Antennas: Floquet Analysis, Synthesis, BFNs and Active Array Systems" Wiley 2006.
2. Robert Mailloux "Electronically Scanned Arrays", Morgan and Claypool Publication.
3. Jeffrey D Connor "Antenna Array Synthesis Using the Cross Entropy Method" Proquest 2011.

Gaps in the syllabus (to meet Industry/Profession requirements): Hands on experience on real-time industrial projects and management.

POs met through Gaps in the Syllabus: PO5 & PO6

Topics beyond syllabus/Advanced topics/Design: Evaluation and mixed optimization Algorithm, Internal Synthesis problem beam-forming networks

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	3	2	1
CO2	1	1	2	3	3	2
CO3	2	2	2	3	3	2
CO4	2	3	3	3	3	3
CO5	3	3	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcome	Course Delivery Method
CO1	CD1, CD2, CD6
CO2	CD1, CD2, CD3, CD6
CO3	CD1, CD2, CD3, CD4, CD6
CO4	CD1, CD2, CD3, CD4, CD6

CO5	CD1, CD2, CD3, CD4, CD6

COURSE INFORMATION SHEET

Course code: EC556
Course title: RF Micro-Electro-Mechanical-Systems
Pre-requisite(s): EE101 Basic Electrical, ME101 Basic Mechanical, EC323 Microwave Theory &Techniques
Co-requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: II/05
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students:

1	Understand the basics of MEMS and RF MEMS
2.	Identify MEMS devices for a given application & Classification the different microfabrication process, microsensors, micro actuators and compare them
3.	Design micro machined passive components
4.	Analyze reliability issues in MEMS structures
5.	Introduce various opportunities in the emerging field of MEMS

Course Outcomes:
After the completion of this course, students will be:

CO1	Identify various RF for MEMS devices, materials, their parameters and packaging standards
CO2	Formulate fabrication steps and deposition techniques for MEMS devices
CO3	Develop the concept of Mechanical and electrical analogy, simulation of MEMS devices and modelling, Transmission lines
CO4	Analyze the reliability and design issues in MEMS structures and learn about RF MEMS Filters and RF MEMS Phase Shifters
CO5	Simulate micro machined passive components such as Inductors, Capacitors, Switches, and Antennas and evaluate the performance

SYLLABUS

Module –1
Introduction to MEMS, general concepts on miniaturization and Radio frequency MEMS, Need for RF MEMS components in communications, space and defence applications Micro fabrications for MEMS Electromechanical transducers, Micro sensing for MEMS, Materials for MEMS and fabrication techniques, Thin films for MEMS and their deposition Techniques, Polymer MEMS, Silicon based MEMS, MEMS packaging.

(8L)

Module-2
RF transmission lines: theory, high frequency effects Sections of transmission lines Transmission line examples: microstrip, CPW. S-parameter theory Micro machined

Transmission lines, Losses in transmission lines, Micro shield and membrane supported Transmission lines.

(8L)

Module-3

Micro machined RF filter, Micro Mechanical filters, Surface Acoustic wave filter, Bulk Acoustic Wave, Micro machined filter for mm wave frequencies, Micro machined Phase shifter, Types of phase shifter and limitations, MEMS phase shifter, Ferroelectric phase shifters and applications.

(8L)

Module-4

RF MEMS Switches and Micro Relays: Basic design guidelines Switch parameters, Switches for RF and microwave Applications, Actuation Mechanism for MEMS Switches, Dynamics of the switch operation, MEMS switch design and modelling Micro machined MEMS Inductors, modelling and design issues of planar inductors, MEMS Capacitors.

(8L)

Module-5

Micro machined Antenna, Basic characteristics and Design parameter of antenna, Micromachining techniques to improve antenna performance, Fabrication process of small antenna, Reconfigurable antenna.

(8L)

Books recommended:

Textbooks:

1. RF MEMS and Their Applications by Vijay K.Varadan ,K.J.Vinoy,K.A.Jose Wiley India Ltd, 2011 ISBN -978-81-265-2991-9.
2. RF MEMS Theory, Design and Technology by Gaberiel M.Rebiz, John Wiley & Sons, 2003. ISBN-13: 978-0471201694, ISBN-10: 0471201693
3. Fundamentals of Microfabrication by Marc Madou, CRC Press, 1997.Gregory Kovacs

Reference books:

1. Introduction to Microelectromechanical (MEM) Microwave Systems, H.J. De Los Santos, Artech house, 1999.
2. RF MEMS Circuit Design for Wireless Communications, H.J. De Los Santos, Artech House, 2003.
3. Microwave Engineering 2nd ed D.M. Pozar, John Wiley 2003
4. RF and Microwave Coupled-Line Circuits, R. Mongia, I.J. Bahl, and P. Bhartia Artech House, 1999.

Gaps in the syllabus (to meet Industry/Profession requirements): Design and Development of real-time industrial projects.

POs met through Gaps in the Syllabus: PO4 & PO5

Topics beyond syllabus/Advanced topics/Design: Micromechanical Signal Processors, Optical MEMS. Micro/Nano Fabrication, Micro-robotics. Wireless Sensor Networks, sensor interfaces, computation.

POs met through Topics beyond syllabus/Advanced topics/Design: PO4, PO5, PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	**% Distribution**
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	-	1	2	1	1
CO2	3	1	1	3	2	1
CO3	3	1	2	3	2	1
CO4	3	2	2	3	2	2
CO5	3	2	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD3, CD6
CO2	CD1, CD2, CD3, CD6, CD7
CO3	CD1, CD2, CD3, CD4, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

COURSE INFORMATION SHEET

Course code: EC 557
Course title: Microwave Photonics
Pre-requisite(s): EC323 Microwave Theory & Techniques, EC425 Optoelectronics Devices

Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: II/05
Branch: ECE
Name of Teacher:
Course Objectives:
This course enables the students to:

1.	Understand the basic concepts of microwave photonics
2.	Understand the characteristics of the components of microwave photonic system
3.	Understand the concepts of photonic processing of RF signal
4.	Understand the design aspects of microwave fibre optic link, and application of microwave photonics in sensing and imaging
5.	Appraise Terahertz sensing imaging techniques

Course Outcomes:
After the completion of this course, students will be to:

CO1	Explain the key properties of microwave photonics
CO2	Explain the key characteristics of microwave photonic components
CO3	Explain the photonic processing of RF signal
CO4	Design the microwave fiber optic link for RF over fiber
CO5	Design the microwave photonics system for terahertz sensing and imaging applications

SYLLABUS

Module -1:
Basic concepts of microwave photonics, Microwave link architecture, E/O conversion, External modulation, O/E conversion, Photodetection, O/O components, Signal transport and signal generation, Signal processing, Radio over fibre.

(6L)

Module -2:
Microwave photonics components, Fast lasers sources, Tunable sources, Mode locked microchip lasers, Fast modulators, Electro-absorption modulators and photo-oscillators, High speed photodetectors, Travelling wave (TW) photodetector, GaAs MESFET Optical Detector, HBT phototransistor for optic/millimeter-wave converter.

(10L)

Module -3:
Microwave photonics signal processing (MWPSP), Fundamental concepts and limitations, Optical sources of performance limitation, Electrical sources of performance limitation, Incoherent MWPSP, Fibre delay line filters, Bragg grating delay line filter, Incoherent RF optical filter.

(8L)

Module -4:
Microwave Fibre-Optic link design, Requirements, Modulation techniques, Interfacing, Intrinsic link gain performance, Signal to noise performance, Link dynamic range, Fibre Radio systems, RF over fibre, IF over fibre, Baseband over fibre, WDM in fibre radio system, Optical Control of Phased Array antenna, Multi-Beam Photonic Array Feed antenna.

(8L)

Module -5:

Terahertz sensing techniques, Pulsed and Continuous wave system, Time domain spectroscopic system, Explosive identification, Terahertz imaging techniques, Passive and active imaging, CCD-based two-dimensional imaging, Space shuttle foam inspection, Tomography.

(8L)

Books recommended:

Textbooks:

1. Stavros Iezekiel, "Microwave photonics: Devices and applications", IEEE Press, Willey,2009.
2. Anne Vilcot, Béatrice Cabon & Jean Chazelas, MICROWAVE PHOTONICS: From Components to Applications and Systems, Kluwer academic publishers.

Reference book:

1. Vincent J. Urick Jr, Jason D.McKinney, Keith J.Williams, Fundamentals of Microwave photonics, Willey Press.
2. Chi H. Lee, Microwave photonics, CRC Press
3. Anne Vilcot, MICROWAVE PHOTONICS: From Components to Applications and Systems, Kluwer academic publishers.

Gaps in the syllabus (to meet Industry/Profession requirements): By learning software and hardware used by the companies

POs met through Gaps in the Syllabus: PO4 & PO6

Topics beyond syllabus/Advanced topics/Design: Millimeter wave photonics

POs met through Topics beyond syllabus/Advanced topics/Design: PO4 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors

CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	3	2	1
CO2	3	2	1	3	2	1
CO3	3	2	2	3	2	1
CO4	3	2	2	3	2	2
CO5	3	3	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD7

COURSE INFORMATION SHEET

Course Code: EC558
Course Title: Modern Optimization Techniques
Pre-requisite(s): EC251 probability and Random Processes
Co-requisite(s):
Credits: L:3 T:0 P: 0 C: 3
Class schedule per week: 03
class: M. Tech.
Semester / Level: II/05
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students to:

1.	Gain understanding on optimization theory and its elements
2	Demonstrate single variable optimization, linear programming, dynamic programming concepts and techniques.
3	Demonstrate multivariable and constraint optimization concepts and techniques.
4	Understand on advance single and multi-objective optimization techniques such as GA, PSO, Pareto font, NSGA
5	Demonstrate an ability to apply the optimization techniques to various areas of Engineering and Science.

Course Outcomes
On the completion of this course, the students will be able to:

CO1	Develop an understanding to formulate an optimization problem and its characteristics.
CO2	Have an ability to analyse and formulate algorithms for design optimization.
CO3	Apply optimum solutions employing the single objective evolutionary techniques for engineering applications.
CO4	Apply optimum solutions employing the multi objective evolutionary techniques for engineering applications.
CO5	Develop an ability to use the optimization techniques to communication, medical applications, control, power, mechanical problems, chemical, biology, finance and economics.

SYLLABUS

Module 1:

Basics of Optimization:

Optimal problem formulation, Design variables constraints, Objective function, Variable bounds, Search methods: optimality Criteria, Bracketing methods: Exhaustive search methods, Region – Elimination methods; Interval halving method, Fibonacci search method, Golden section search method, Point-estimation method; Successive quadratic estimation method.

(8L)

Module 2:

Classical Optimization Methods-I:

Gradient-based methods: Newton-Raphson method, Bisection method, Secant method, Cauchy's steepest descent and Newton's method. Linear Programming: Graphical method, Simplex Method, Revised simplex method, Duality in Linear Programming (LP), integer linear programming, Dynamic programming, Sensitivity analysis.

(8L)

Module 3:

Classical Optimization Methods-II:

Optimality criteria, Unidirectional search, Direct search methods: Simplex search method, Hooke-Jeeves pattern search method. Gradient based method, conjugate gradient method, concept of Lagrangian multiplier, complex search method, characteristics of a constrained problem. Direct methods: The complex method, Cutting plane method, Indirect method: Transformation Technique, Basic approach in the penalty function method, Interior penalty function method, convex method.

(8L)

Module 4:

Single Objective Evolutionary Optimization Techniques:

Genetic algorithm and its working principle, GA variants, Particle swarm optimization and its working principle, Differential evolution, Ant Colony Optimization, Applications in Engineering problems.

(8L)

Module 5:

Single Objective Evolutionary Optimization Techniques:

Multi objective Optimization problem, Dominance and Pareto-Optimality, Pareto font, Multi-objective Evolutionary Algorithms, Multi Objective genetic Algorithm, NSGA, Constrained Multi-objective Evolutionary Algorithms, Application to communication, medical, clustering, bioinformatics, control, finance.

(8L)

Books recommended:

Textbooks

1. Optimization for Engineering Design - Kalyanmoy Deb, 2006, PHI
2. Kalyanmoy Deb, Multi-Objective Optimization using Evolutionary Algorithms, Wiley India publisher, 2010
3. S.S. Rao, Engineering Optimization, Theory and practice, New age International Publisher, 2012.
4. D.E. Goldberg, genetic Algorithm in search, optimization and machine learning, Addison-Wesley Longman Publisher, 1989.

Reference book:

1. Analytical Decision Making in Engineering Design - Siddal.
2. G. Hadley, "Linear programming", Narosa Publishing House, New Delhi, 1990.

Gaps in the Syllabus (to meet Industry/Profession requirements): Hands on experience on real time industrial projects and management.

POs met through gaps in the Syllabus: PO6

Topics beyond Syllabus /Advanced topics/Design: Hardware architecture design of optimization techniques

POs met through Topics beyond SYLLABUS/Advanced topics/Design: PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	**% Distribution**
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	1	2	2	-	2
CO2	3	2	2	3	-	1
CO3	3	2	2	3	1	1
CO4	3	3	2	3	1	2
CO5	-	1	1	1	-	2

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3, CD6
CO2	CD1, CD2, CD3, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD2, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4

COURSE INFORMATION SHEET

Course code: EC559
Course title: Mixed Signal VLSI Design
Pre-requisite(s): EC253 Analog Circuits, EC203 Digital System Design
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: II/05
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students to:

1.	Understand the basics of sampling theory
2.	Apply the mixed-signal design trends and challenges
3.	Analyze the analog and discrete time filters
4.	Appraise and evaluate different types of data converters and their VLSI implementations.
5.	Apprehend the characteristics of frequency synthesizers and phased lock loop and create their circuits.

Course Outcomes:
After the completion of this course, students will be able to:

CO1	Describe and illustrate Basics of Sampling and Aliasing
CO2	Sketch and explain the mixed-signal design trends and challenges.
CO3	Diagram and explain the analog and digital filters.
CO4	Appraise the data converters and schematize, assess and summarize their features.
CO5	Design and schematize the frequency synthesizers and phased lock loop. Schematize their characteristics and prepare an inference.

SYLLABUS

Module -1:

Basics of Sampling and Aliasing:

Sampling: Impulse Sampling, Decimation, The Sample-and-Hold (S/H), The Track-and-Hold (T/H), Interpolation, K-Path Sampling, Switched-Capacitor Circuits, Non-Overlapping Clock Generation, Circuits: Implementing the S/H, Finite Op-Amp Gain-Bandwidth Product, Autozeroing, Correlated Double Sampling (CDS), Selecting Capacitor Sizes, The S/H with Gain, Implementing Subtraction in the S/H, A Single-Ended to Differential Output S/H.

(8L)

Module - 2:

Mixed-Signal Design Trends and Challenges:

Design flow: Top-down design, Bottom-up Design, Constraint Management, Mixed-Signal Verification, Behavioral Modeling, Mixed-Signal Hardware Description Languages, Low Power Verification, Design for Test, Mixed-Signal layout & Chip Planning, Interconnects and data transmission, Substrate Noise, AMS IP Reuse, Full-chip Signoff, IC/Package Co-Design.

(8L)

Module - 3:

Analog and Digital Filters:

Analog Filters: Integrator Building Blocks: Lowpass Filters, Active-RC Integrators, Effects of Finite Op-Amp Gain Bandwidth Product, Active-RC SNR, MOSFET-C Integrators, gm-C (Transconductor-C) Integrators, Discrete-Time Integrators, The Bilinear Transfer Function, *Digital Filters:* Sinc-Shaped Digital Filters: The Counter, Lowpass Sinc Filters, Bandpass and Highpass Sinc Filters, Interpolation using Sinc Filters, Decimation using Sinc Filters, FIR Filters, The Bilinear Transfer Function.

(8L)

Module - 4:

Data converters:

Basics of Analog to digital converters (ADC), Basics of Digital to analog converters (DAC), Parameters of data converters, Quantization Noise, Quantization Noise Voltage Spectral Density, Signal-to-Noise Ratio (SNR), Clock Jitter, Improving SNR using Averaging, ADCs: Successive approximation ADCs, Dual slope ADCs, High-speed ADCs (e.g. flash ADC, pipeline ADC and related architectures), Hybrid ADC structures, High-resolution ADC (e.g. delta-sigma converters). DACs: Resistor string, R-2R Ladder networks, Current steering, Charge scaling DACs, Cyclic DAC, Pipelined DACs

(8L)

Module - 5:

Phased lock loop:

Frequency Synthesizers and Phased lock loop: Simple PLL: Phase Detector, Basic PLL Topology, Dynamics of Simple PLL, Charge-Pump PLLs, Non-ideal Effect in PLLs: PFD/CP Nonidealities, Jitter in PLLs, Analog PLL, Digital PLL. Delay locked loops (DLL).

(8L)

Books recommended:

Textbooks:

1. CMOS mixed-signal circuit design by R. Jacob Baker, Wiley India, IEEE press, reprint 2008.
2. CMOS circuit design, layout and simulation by R. Jacob Baker, Revised second edition, IEEE press, 2008.
3. Design of analog CMOS integrated circuits by Behzad Razavi, McGraw-Hill, 2003.

4. Mixed-Signal Methodology Guide, by Jess Chen et al., First Edition, September 11, 2014
5. Tony Chan Carusone, David A. Johns and Kenneth W. Martin, Analogue Integrated Circuit Design, 2/e, John Wiley & Sons, 2012.

Reference books:

1. CMOS Integrated ADCs and DACs by Rudy V. dePlassche, Springer, Indian edition, 2005.
2. Electronic Filter Design Handbook by Arthur B. Williams, McGraw-Hill, 1981.
3. Design of analog filters by R. Schauman, Prentice-Hall 1990 (or newer additions).
4. An introduction to mixed-signal IC test and measurement by M. Burns et al., Oxford university press, first Indian edition, 2008.

Gaps in the syllabus (to meet Industry/Profession requirements): Hands-on-practical for fabrication of mixed-signal VLSI circuit.

POs met through Gaps in the Syllabus: PO6

Topics beyond syllabus/Advanced topics/Design: Fabrication of mixed-signal circuit.

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	2	1
CO2	3	3	3	3	2	1
CO3	3	3	1	3	2	1
CO4	2	2	2	2	3	1
CO5	2	2	2	2	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3, CD6, CD7
CO2	CD1, CD2, CD3, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD2, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD6, CD7

Open Elective-II

COURSE INFORMATION SHEET

Course code: EC597
Course title: Fundamentals of Microwaves
Pre-requisites: Any Branch in UG Engg/Applied Science
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Level: II/ 05
Branch: ECE
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Understand important and unique engineering issues at microwave wave frequencies basic concepts of microwave systems.
2.	Understand the concept of microwave network theory and the use of scattering matrix.
3.	Design, analyse and solve problems related to microwave waveguide. transmission lines.
4.	Analyse, test and use various passive microwave components for different applications.
5.	Design and implement the microwave layouts

Course Outcomes

After the completion of this course, students will be able to:

CO1	To understand about the microwave frequencies and the waveguides that are used in communication.

CO2.	Understand and Analyse various parameters and characteristics of the various waveguide components.
CO3.	Apply Smith chart use for solution of transmission line problems and impedance matching
CO4	Analyse the difference between the conventional tubes and the microwave tubes for the transmission of the EM waves.
CO5	Acquire knowledge about the measurements to be done at microwaves.

SYLLABUS:

Module: 1

Introduction to microwaves: Microwave frequencies, advantages of microwaves, Special features and general applications of microwaves.

(6L)

Module:2

Microwave transmission lines and wave guides: Mathematical model of Microwave Transmission Concept of Mode, Characteristics of TEM, TE and TM Modes, Losses associated with microwave transmission, Concept of Impedance in Microwave Transmission line equations & solutions, reflection and transmission coefficient, standing wave and standing wave ratio, line impedance and admittance, impedance matching, Rectangular and circular waveguides-theory and analysis.

(10L)

Module:3

Microwave Network Analysis: Network parameters for microwave Circuits, Scattering Parameters. Microwave Passive components: Directional Coupler, Power Divider, Magic Tee, Wave-guide Corners, Bends, Twists, Attenuator, Circulator, Isolator and Resonator.

(9L)

Module:4

Microwave sources: Tubes and circuits: Limitations of conventional tubes at UHF & Microwave, Klystrons, multicavity klystron, Reflex klystron, travelling wave tube, Magnetron. Solid state devices: Tunnel diode, Varactor diodes, PIN diodes, Gunn diodes, IMPATT and TRAPATT diodes.

(9L)

Module: 5

Microwave Measurements Power, Frequency and impedance measurement at microwave frequency, Network Analyzer and measurement of scattering parameters, spectrum Analyzer and measurement of spectrum of a microwave signal.

(6L)

Books recommended:

Textbooks:

1. Samuel Y.Liao, “ Microwave Devices and Circuits”, 3 rd edition, Pearson education
2. R.E.Collin, “Foundations for microwave Engineering”, 2 nd edition,Tata Mc Graw Hill,1992.
3. David Pozar, Microwave Engineering, 3rd edition, (Wiley, 2005).

Reference books

1. Microwave Technology, Dennis Roddy, PHI

Gaps in the syllabus (to meet Industry/Profession requirements): Hands on experience on real time industrial project and management

<u>POs met through Gaps in the Syllabus:</u> PO4 & PO5

<u>Topics beyond syllabus/Advanced topics/Design:</u>
Microwave amplifier Mixer, mm wave trans receiver High power broadband solid state isolators

<u>POs met through Topics beyond syllabus/Advanced topics/Design:</u> PO4, PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure
<u>Direct Assessment</u>

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

<u>Indirect Assessment</u>
1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	2	1	3	1	2
CO2	3	2	1	3	2	1
CO3	3	1	2	3	2	1
CO4	3	2	2	3	2	2
CO5	3	3	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD6
CO2	CD1, CD2, CD3, CD7

CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD5, CD7

Programme Core

COURSE INFORMATION SHEET

Course code: EC552
Course title: Microwave Integrated Circuit Lab.
Pre-requisite(s): EC323 Microwave Theory &Techniques
Co- requisite(s):
Credits: L: 0 T: 0 P: 4 C: 2
Class schedule per week: 04
Class: M. Tech.
Semester / Level: II/05
Branch: ECE
Name of Teacher:

Course Objectives
This course enables the students:

1.	To develop an understanding for design & analysis of LPF/ BPF and phase shifter
2.	To develop an understanding for design and analysis of coupled line coupler and branch line coupler.
3.	To develop an understanding for design and analysis of microstrip diplexer and power divider.
4.	To develop an understanding of active components based microstrip circuits such as LNA, oscillators and mixer
5.	**To develop an understanding of combination of active and passive microwave circuits and their fabrications and measurement.**

Course Outcomes
After the completion of this course, students will be able to:

CO1	Demonstrate understanding of the design & analysis of LPF/ BPF and phase shifter.
CO2	Demonstrate understanding of the design and analysis of coupled line coupler and branch line coupler.
CO3	Demonstrate understanding of the design and analysis of microstrip diplexer and power divider.
CO4	Understand and analyse the active components based microstrip circuits such as LNA, oscillators and mixer
CO5	Demonstrate understanding of combination of active and passive microwave circuits and their fabrications and measurement.

SYLLABUS

List of Experiments:
(Experiments will be in 1-30 GHz)

1) Design of microstrip low pass filter/ band pass filter.

2) Design of microwave band 45^0 and 90^0 Phase Shifters.
3) Design of coupled line coupler with arbitrary coupling coefficient
4) Design of 3-dB branch line coupler by using open stubs
5) Design of planar microstrip diplexer and triplexer using resonators.
6) Design of microstrip 3dB Wilkinson power divider
7) Design of high gain Low Noise Amplifier
8) Design of microstrip transistor Oscillator
9) Design of matched microwave mixer
10) Design of microstrip tuneable filter with PIN/ Varactor diode
11) Fabrication and Measurement of passive LPF/ BPF
12) Fabrication and Measurement of microstrip tuneable filter with PIN/ Varactor diode.

Books recommended:
Textbooks:

1. Microwave Integrated circuit, K. C. Gupta, John Wiley, Newyork, 1974
2. Microstrip lines and Slot lines, K.C. Gupta, R. Garg., I. Bahl, P. Bhartia, Artech House, Boston, 1996.

Reference books:

1. RF Circuit Design, Reinhold Ludwig and Pavel Bretchko, Pearson, 2006.
2. Stripline-like Transmission lines for Microwave Integrated circuits, B. Bhat, S. K. Koul, Wiley Eastern Ltd., New Delhi.
3. Microwave Integrated Circuits, By Ivan Kneppo, J. Fabian, P. Bezousek

Gaps in the syllabus (to meet Industry/Profession requirements): Hands on experience on solution of Real time Industrial Project and management

POs met through Gaps in the Syllabus: PO5, PO6

Topics beyond syllabus/Advanced topics/Design: through experiments involving design of circuits on advanced topics

POs met through Topics beyond syllabus/Advanced topics/Design: PO4, PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure
Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Progressive Evaluation	60
End Semester Evaluation	40

Progressive Evaluation	**% Distribution**
Day to day performance & Lab files	30
Quiz (zes)	10
Viva	20

End Semester Evaluation	**% Distribution**
Examination Experiment Performance	30
Quiz	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**

Progressive Evaluation					
End Semester Evaluation					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	2	1
CO2	3	3	3	2	1	1
CO3	2	3	3	2	2	1
CO4	3	3	3	3	1	2
CO5	3	3	3	3	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD3, CD7
CO2	CD1, CD3, CD7
CO3	CD1CD3, CD7
CO4	CD1, CD3, CD6, CD7
CO5	CD1, CD3, CD6, CD7

COURSE INFORMATION SHEET

Course code: EC554
Course title: Computational Electromagnetics Lab.
Pre-requisite(s): MATLAB
Co- requisite(s): EC 553 Numerical technique in Electromagnetics
Credits: L: 0 T: 0 P: 4 C: 2
Class schedule per week: 04
Class: M. Tech.
Semester / Level: II/05
Branch: ECE
Name of Teacher:

Course Objectives

This course enables the students:

1.	Conceptualize the basics of numerical techniques to be used in EM.
2.	Recognize the nature of the problem under consideration.

3.	Develop codes for various numerical techniques.
4.	Apply developed code to EM problems.
5.	Prepare reports, explain and present the results ethically.

Course Outcomes

After the completion of this course, students will be:

CO1	Able to conceptualize the basics of numerical techniques to be used in EM.
CO2	Able to recognize the nature of the problem under consideration.
CO3	Able to develop codes for various numerical techniques.
CO4	Able to apply developed code to EM problems.
CO5	Able to prepare reports, explain and present the results ethically.

SYLLABUS

List of Experiments:

EXP 1

Solve the differential equation

$d^2y/dx^2+4x = 3$, for $0 \leq x \leq 1$

Given $y(0) = y(1) = 1$, by finite difference method

EXP 2

Solve the one-dimensional Diffusion Equation. (Heat equation.)

$\partial^2\Phi/\partial x^2 = \partial\Phi/\partial t$, $0 \leq x \leq 1$

having the boundary conditions

$\Phi(0, t) = 0 = \Phi(1,t) = 0, \quad t > 0$

and the initial condition

$\Phi(x,0) = 100$

by finite difference method in time domain

EXP 3

Solve the one-dimensional wave eqn.

$\Phi_{tt}=\Phi_{xx}$, $0 < x < 1$, $t \geq 0$

having the boundry conditions

$\Phi(0, t) = 0 = \Phi(1,t)$, $t \geq 0$

and the initial conditions

$\Phi(x,0) = \sin\pi x$, $0 < x < 1$,

$\Phi_t(x,0) = 0$, $0 < x < 1$

by finite difference method in time domain

EXP 4

Solve the two dimensional La Place equation

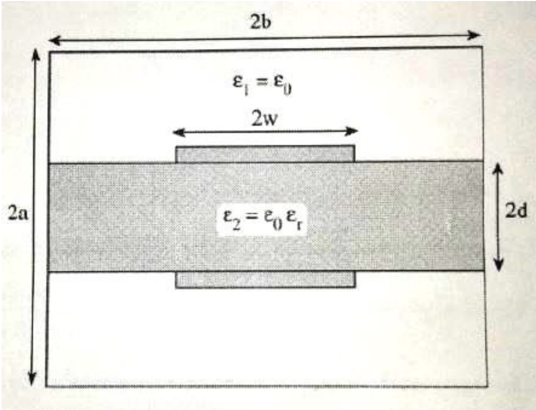
$\nabla^2V = 0, \qquad 0 \leq x, y \leq 1$

With $V(x,1) = 45x(1-x)$, $V(x,0) = 0 = V(0,y) = V(1,y)$

by finite difference method

EXP 5

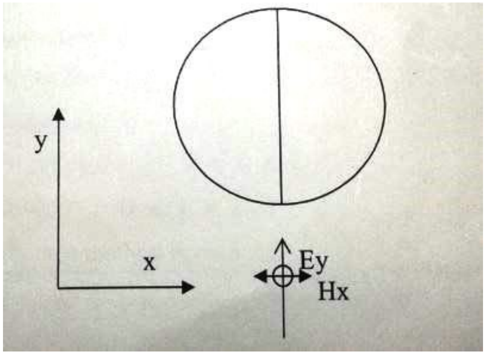
Find the characteristics impedance of a shielded double strip transmission line as shown in the figure.



Where a = b = 2.5cm, d = 0.5, ω = 1cm, $\varepsilon_1 = \varepsilon_0$, $\varepsilon_2 = 2.35\varepsilon_0$
and the thickness of the strip is neglected. The potential difference applied between the outer metal shield and the inner strips is V_d = 100mV.

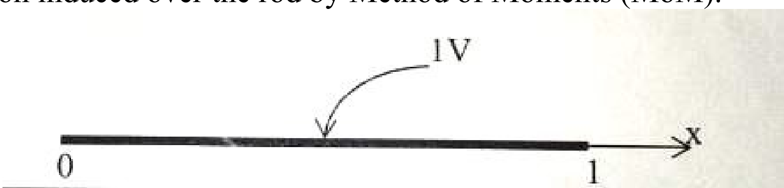
EXP 6

Consider the scattering of **a + y** directed plane wave by a dielectric cylinder which is infinite along the Z-axis. The incident plane wave is Z – polarised and has amplitude 1 mV. The cross section of the cylinder is circular of radius 6cm. The geometry is shown in the figure. Find the variation of $\mathbf{E_z}$ along the diameter shown by the solid line in time domain by Yee's FDTD method.



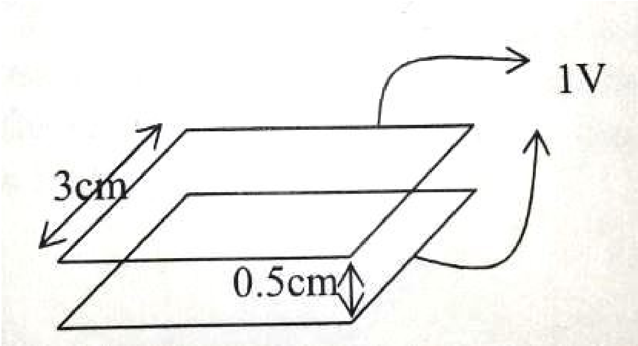
EXP 7

A metal rod of length 1m is placed along the X -axis.it is maintained at 1V potential. Find the charge distribution induced over the rod by Method of Moments (MoM).



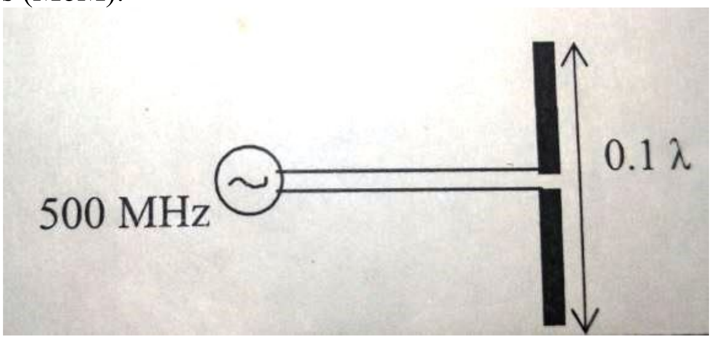
EXP 8

A parallel plate capacitor with air as dielectric is given a potential difference 1V across its plates. The area of each square plate is $A = 9cm^2$ and they are $d = 0.5cm$ apart. Find its capacitance by method of moments (MoM). Compare your result with the formula $C = \varepsilon_0 A/d$.



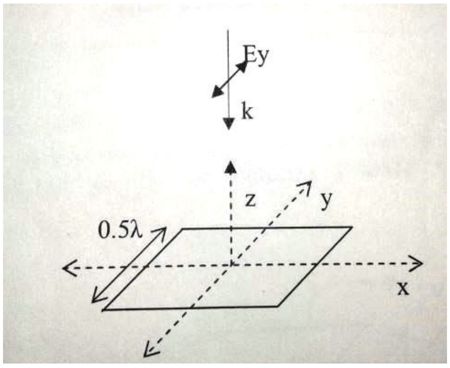
EXP 9

A cylindrical dipole antenna of length 0.01λ and radius 0.001λis fed at the centre by a signal generator of frequency 500MHz and amplitude 1mV as shown. Find the current distribution and the input impedance of the dipole by solving Electric Field Integral Equation (EFIE) by Method of Moments (MoM).



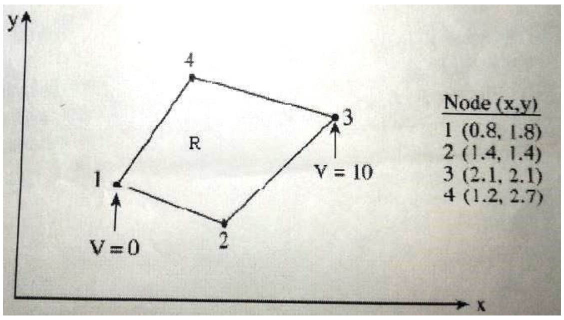
EXP 10

A plane wave of frequency 1 GHz and amplitude 1mV with electric field polarized along y-axis is incident upon a conducting square plate of dimension 0.5 λ along the –z direction. The plate is situated over the X-Y plane with origin at the centre. Find the current distribution induced over the plate by solving Electric Field Integral Equation (EFIE) by method of moments (MoM).

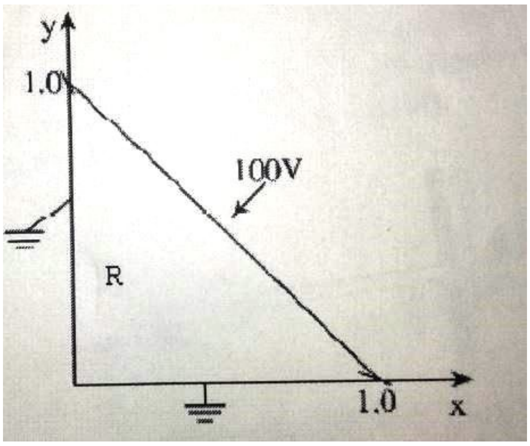


EXP 11

Find the potential in the region R Shown in the figure by Finite Element Method (FEM). The coordinates of the four nodes and the potential at nodes 1 and 3 are specified.



EXP 12
Solve La Place equation inside the region R as shown in the figure by Finite Element Method (FEM).



Books recommended:
Textbooks:

1. Numerical Techniques in Electromagnetics by Mathew N. O. Sadiku (CRC Press)

Reference books:

1. Principles of Electromagnetics Mathew N. O. Sadiku, 3rd Ed.

Gaps in the syllabus (to meet Industry/Profession requirements): Hands on experience on solution of real time industrial projects and management.

POs met through Gaps in the Syllabus: PO4, PO5 and PO6

Topics beyond syllabus/Advanced topics/Design: Through simulations based on advanced topics after completion of compulsory twelve experiments.

POs met through Topics beyond syllabus/Advanced topics/Design: PO4, PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure
Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Progressive Evaluation	60
End Semester Evaluation	40

Progressive Evaluation	% Distribution
Day to day performance & Lab files	30

Quiz (zes)	10
Viva	20

End Semester Evaluation	**% Distribution**
Examination Experiment Performance	30
Quiz	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Progressive Evaluation					
End Semester Evaluation					

<u>Indirect Assessment</u>

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	3	3	3	2	1
CO2	3	2	3	3	2	1
CO3	3	2	3	3	2	1
CO4	3	3	3	3	2	1
CO5	3	3	3	3	2	2

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcome CO	**Course Delivery Method**
CO1	CD5, CD9
CO2	CD5, CD9
CO3	CD5, CD9
CO4	CD, CD9
CO5	CD5, CD9

<u>3rd Semester</u>

Programme Core

EC600 Thesis (Part I) Credit: 8

COURSE INFORMATION SHEET

Course code: EC602

Course title: Microwave Imaging
Pre-requisite(s): EC325 Antenna and Wave Propagation, EC257 Electromagnetic Fields and Waves
Co-requisite (s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: III/06
Branch: ECE
Name of Teacher:

Course Objectives
This course enables the students:

1.	To a brief theoretical foundation of RF, microwave and THz imaging techniques and associated physics by introducing the concept of electromagnetic inverse scattering and reconstruction algorithms for the microwave/THz imaging.
2.	To acquire electromagnetic wave propagation in multi-layered media, linear and nonlinear inversions and optimization schemes for microwave imaging
3.	To analyse microwave imaging using frequency domain approach.
4.	To analyze microwave imaging using time domain approach.
5.	To develop the ability to appraise the concepts of microwave imaging for various real-life applications

Course Outcomes
On the completion of this course, the students will be able:

CO1	To explain the fundamental concepts of microwave inverse scattering.
CO2	To explain electromagnetic wave propagation in multi-layered media, linear and nonlinear inversions and to analyze analytical and numerical models for microwave imaging.
CO3	To understand microwave imaging using frequency domain approach.
CO4	To understand microwave imaging using time domain approach
CO5	To appraise the apply the concepts of microwave imaging for various real-life applications

SYLLABUS

Module-1:
Electromagnetic Scattering Theory, Scattering Parameters, Basics of Transmission-Line Theory, Transmission Matrix, Electromagnetic Inverse Scattering: Theory and Formulation, Microwave Imaging Methodologies and Various Parameters**.**

(6L)

Module-2:
Electromagnetic Wave Propagation in Multi-Layered Media, Linear and Nonlinear Inversions and Born approximations, Inverse Problem from Mathematical Point of View, Focusing Using Antenna Arrays, Optimization Schemes for Microwave Imaging**.**

(8L)

Module-3:
Frequency Domain Approaches: Generalization of the Microwave Imaging Problem for the Stratified Media; Direct Problem Formulation and Its Inverse Solution for the Planar Inhomogeneous Structures.

(9L)

Module-4:
Time Domain Approaches: Microwave Imaging of Stratified Media using Time Domain Refection Approach, Simplified Microwave Imaging Scheme using Time Domain Refection Transmission Approach, Microwave and THz Imaging of Inhomogeneous Media**.**

(9L)

Module-5:
Microwave Imaging Techniques for Security Applications, Detection of Concealed Objects using Microwaves and Millimetre waves, Ground Penetrating Radar, Microwave Tomography for Medical and Industrial Applications**.**

(8L)

Books recommended:

Textbooks

1. Matteo Pastorino, Microwave Imaging, John Wiley & Sons, Apr 2010.
2. Natalia K. Nikolova, Introduction to Microwave Imaging, Cambridge University Press, 2017.

References books:

3. Jaleel Akhtar, Microwave Imaging: Reconstruction of One-Dimensional Permittivity Profiles. VDM Publishing, 2008.

Gaps in the syllabus (to meet Industry/Profession requirements): Hands on experience on real-time industrial projects and management.

POs met through Gaps in the Syllabus: PO5 & PO6

Topics beyond syllabus/Advanced topics/Design: Electron Cyclotron Emission Imaging and Microwave Imaging Reflectometry.

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	**% Distribution**
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors

CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	1	2	1
CO2	2	1	2	3	3	3
CO3	2	2	2	2	3	2
CO4	2	3	3	2	3	2
CO5	3	3	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcome	Course Delivery Method
CO1	CD1, CD2, CD6
CO2	CD1, CD2, CD3, CD6,
CO3	CD1, CD2, CD3, CD4, CD6
CO4	CD1, CD2, CD3, CD4, CD6,
CO5	CD1, CD2, CD3, CD4, CD6

Programme Elective – III

COURSE INFORMATION SHEET

Course code: EC517
Course title: Satellite Based Wireless Communication
Pre-requisite(s): EC357 Wireless Network, EC413 Satellite Communication
Co-requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: III/06
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students:

1.	To acquire the concepts, fundamentals and importance of satellite communication, and impart knowledge on all the elements and aspects of satellite communication along with acquiring knowledge on various types of satellites used for several applications.
2.	To analyze, design and evaluate the satellite link for a specific frequency band.
3.	To explain the propagation on satellite earth paths and its influence on link design.
4.	To develop the ability to acquire the knowledge various multiple access

	techniques in satellite communication.
5.	To develop the ability to appraise satellite networking and types of satellite networks.

Course Outcomes:

After the completion of this course, students will:

CO1	Demonstrate the concepts, fundamentals and importance of satellite communication, and impart knowledge on all the elements and aspects of satellite communication along with acquiring knowledge on various types of satellites used for several applications.
CO2	Have an ability to analyze, design and evaluate the satellite link for a specific frequency band.
CO3	Have an ability to explain the propagation on satellite earth paths and its influence on link design.
CO4	Acquire the knowledge of the various multiple access techniques in satellite communication.
CO5	Have an ability to demonstrate the concept of satellite networking and types of satellite networks.

SYLLABUS

Module 1:

Introduction to Satellite Communications and Orbital Aspects of Earth Satellites:
Origin, History, Current Technology State and Overview of Satellite System Engineering, Orbital Mechanics and Orbital Elements, Azimuth and Elevation, Coverage Angle and Slant Range, Placement of a Satellite in a Geostationary Orbit.

(6L)

Module 2:

Satellite Link Design: Basic Radio Transmission Theory, System Noise Temperature and G/T Ratio, Uplink and Downlink Design, Interference Analysis, Carrier-to-Noise plus Interference Ratio, Interference to and from Adjacent Satellite Systems, Terrestrial Interference, Cross-polarization Interference, Intermodulation Interference, Design of Satellite Links for Specified Carrier-to-Noise plus Interference Ratio, Digital Satellite Link.

(9L)

Module 3:

Propagation on Satellite-Earth Paths and Its Influence on Link Design: Absorbitive Attenuation Noise by Atmospheric Gases, Rain Attenuation, Noise due to Rain, Rain Depolarization, Tropospheric Multipath and Scintillation Effects.

(9L)

Module 4:

Multiple Access Techniques in Satellite Communications: Frequency Division Multiple Access, FDMA, SCPC, MCPC. Time Division Multiple Access, TDMA: random (ALOHA, S-ALOHA) and time synchronized access. Code Division Multiple Access, CDMA, Fixed and On-demand Assignment.

(8L)

Module 5:

Satellite Networking and Types of Satellite Networks: Advantages and Disadvantages of Multibeam Satellites, Interconnection by Transponder Hopping, Interconnection by On-board Switching, Interconnection by Beam Scanning, On-Board Processing, Intersatellite Links, Fixed Point Satellite Network, INTELSAT, Mobile Satellite Network, INMARSAT, Low Earth Orbit and Medium Earth Orbit Satellite Systems, Very Small Aperture Terminal (VSAT) Network, Direct Broadcast Satellite Systems, Global Positioning System.

(9L)

Books recommended:

Textbooks:

1. Digital Satellite Communications, 2/e, McGraw-Hill, 1990.Tri T. Ha
2. Satellite Communications, John Willey and Sons, 2000T. Pratt, C.W. Bostian

Reference books:

1. Satellite Communications Systems Engineering, Pearson Education, 2/e; 2003 W.L. Prichard, H.G. Suyderhoud and R.A. Nelson

Gaps in the syllabus (to meet Industry/Profession requirements): Hands on experience on real-time industrial projects and management.

POs met through Gaps in the Syllabus: PO5 & PO6

Topics beyond syllabus/Advanced topics/Design:
OFDM based CSMA/CA, Multiple access schemes for Ad-hoc Network

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	1	1	2	3	2	1
CO2	1	1	2	3	2	2
CO3	2	2	2	3	3	2
CO4	2	3	3	3	3	2
CO5	3	3	3	3	3	2

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcome	Course Delivery Method
CO1	CD1, CD2, CD6
CO2	CD1, CD2, CD3, CD6
CO3	CD1, CD2, CD3, CD4, CD6
CO4	CD1, CD2, CD3, CD4, CD6,
CO5	CD1, CD2, CD3, CD4, CD6,

COURSE INFORMATION SHEET

Course code: EC603
Course title: Millimetre Wave for Wireless Communication
Pre-requisite(s): EC323 Microwave Theory & Techniques
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 03
Class: M. Tech.
Semester / Level: III/6
Branch: ECE
Name of Teacher:

Course Objectives

This course enables the students:

1.	To develop a brief theoretical foundation of Mm Wave technology, its potential use in Wireless Communications and its standards.
2.	To learn various channel effects in Mm Wave scenario and exposing the students to baseband techniques, antenna requirements, and Physical layer design and algorithms.
3.	To get exposed to the goals and challenges of new emerging applications of Mm Wave in Wireless Communications.
4.	To apply the acquired knowledge in the field of Mm Wave Wireless Communication in the future communication technologies.
5.	To review the literature related to Mm wave for Wireless Communication and to report it ethically.

Course Outcomes

After the completion of this course, students will be:

CO1	Be able to explain the fundamental concepts of Mm Wave Wireless Communication.
CO2	Be able to analyze various channel effects in Mm Wave communication scenario and understand various design considerations.

CO3	To get exposed to the goals and challenges of new emerging applications of Mm Wave in Wireless Communications.
CO4	Be able to analyze challenges and various emerging applications of Mm Waves in Wireless Communications research field.
CO5	Be able to review the literature related to Mm wave for Wireless Communication and to report it ethically.

SYLLABUS

Module-I:
Introduction: A Preview of MmWave Implementation Challenges, Emerging Applications of MmWave Communications, MmWave Standardization.
(6L)

Module-II:
Radio Wave Propagation for MmWave: Large-Scale Propagation Channel Effects, Small-Scale Channel Effects, Spatial Characterization of Multipath and Beam Combining, Angle Spread and Multipath Angle of Arrival, Antenna Polarization, Outdoor and Indoor Channel Models.
(8L)

Module-III:
Antennas and Array for MmWave Applications: Fundamentals of On-Chip and In-Package MmWave Antennas, Fundamentals of On-Chip and In-Package MmWave Antennas, In-Package Antennas, Antenna Topologies for MmWave Communications, Techniques to Improve Gain of On-Chip Antennas, Adaptive Antenna Arrays — Implementations for MmWave Communications, Characterization of On-Chip Antenna Performance.
(9L)

Module-IV:
Multi-Gbps Digital Baseband Circuits: Review of Sampling and Conversion for ADCs and DACs, Device Mismatches: An Inhibitor to ADCs and DACs, Goals and Challenges in ADC Design, Encoders, Trends and Architectures for MmWave Wireless ADCs, Digital to Analog Converters.
(9L)

Module-V:
MmWave Physical Layer Design and Algorithms: Practical Transceivers, High-Throughput PHYs, PHYs for Low Complexity, High Efficiency, Future PHY Considerations, Challenges when Networking mmWave Devices.
(8L)

Books recommended:
Textbooks:

1. Theodore S. Rappaport, Robert W. Heath Jr., Robert C. Daniels, James N. Murdock, Millimeter Wave Wireless Communications, Prentice Hall, 2014.

Reference books:

1. Prakash Bhartia, and Inder Bahl, MmWave Engineering and Applications, Wiley-Interscience

Gaps in the syllabus (to meet Industry/Profession requirements): Hands on experience on real time industrial projects and management.

POs met through Gaps in the Syllabus: PO5 & PO6

<u>Topics beyond syllabus/Advanced topics/Design:</u> Applications of Millimeter wave in 5G wireless communication.

<u>POs met through Topics beyond syllabus/Advanced topics/Design:</u> PO5 & PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

<u>Direct Assessment</u>

Assessment Tools	**% Contribution during CO Assessment**
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	**% Distribution**
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment					
Semester End Examination					

<u>Indirect Assessment</u>

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	2	1	2	2	2	1
CO2	2	2	2	1	2	1
CO3	2	2	2	2	2	1
CO4	2	2	2	1	2	1
CO5	1	3	2	2	2	1

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	**Course Delivery Method**
CO1	CD1, CD6
CO2	CD1, CD6, CD7
CO3	CD1, CD2, CD3, CD6, CD7
CO4	CD1, CD3, CD6, CD7

CO5	CD1, CD2, CD3, CD4, CD7

COURSE INFORMATION SHEET

Course code: EC604
Course title: Microwave measurement and Material Characterization
Pre-requisite(s): E323 Microwave Theory &Techniques, EC257 Electromagnetic Fields and Waves
Co- requisite(s):
Credits: L: 3 T: 0 P: 0 C: 3
Class schedule per week: 3
Class: M. Tech.
Semester / Level: III/06
Branch: ECE
Name of Teacher:

Course Objectives

This course enables the students to:

1	Understand the Electromagnetic Properties of Materials
2.	Comprehend Reflection and Transmission/Reflection Methods
3.	Understand various Resonator Methods
4.	Grasp Resonant Perturbation Methods
5.	Appraise various Planar-Circuit Methods

Course Outcomes

After the completion of this course, students will be able to:

CO1	Discuss the parameters describing the electromagnetic properties of materials at microscopic and macroscopic scales.
CO2	Categorize electromagnetic materials.
CO3	Identify suitable method for material characterization.
CO4	Apply various methods to characterize materials at microwave frequencies.
CO5	Acquire the capability to modify basic material characterization techniques.

SYLLABUS

Module -1:

Electromagnetic Properties of Materials:
Materials Research and Engineering at Microwave Frequencies, Physics for Electromagnetic Materials, General Properties of Electromagnetic Materials.

(6L)

Module -2:

Reflection and Transmission/Reflection Methods: Introduction, Coaxial-Line Reflection Method, Free-Space Reflection Method, Measurement of Both Permittivity and Permeability Using Reflection Methods. Transmission/Reflection: Working Principle of Transmission/Reflection Methods, NRW algorithm Coaxial Air-Line Method, Hollow Metallic Waveguide Method, Free-Space Method.

(9L)

Module -3:

Resonator Methods: Introduction, Dielectric Resonator Methods, Coaxial Surface-Wave Resonator Methods, Split-Resonator Method, Dielectric Resonator Methods.

(9L)

Module -4:

Resonant Perturbation Methods: Basic Theory, Cavity-Perturbation Method, Dielectric Resonator Perturbation Method, Measurement of Surface Impedance.

(8L)

Module -5:

Planar-Circuit Methods:

Introduction, Stripline Methods, Microstrip Methods, Coplanar-Line Methods.

(8L)

Books recommended:

Textbooks:

1. Microwave Electronics: Measurement and Materials Characterization, L. F. Chen, C. K. Ong, C. P. Neo, V. V. Varadan, Vijay K. Varadan, John Wiley, ISBN: 978-0-470-84492-2

Gaps in the syllabus (to meet Industry/Profession requirements): Hands on experience on real-time industrial projects and management

POs met through Gaps in the Syllabus: Nil

Topics beyond syllabus/Advanced topics/Design: Measurement of permittivity and permeability tensor.

POs met through Topics beyond syllabus/Advanced topics/Design: NA

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets

CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	2	1	3	3	3	2
CO2	2	1	3	3	2	2
CO3	1	1	3	3	3	2
CO4	3	2	3	3	3	3
CO5	3	2	3	3	3	3

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcome	Course Delivery Method
CO1	CD1, CD2, CD6
CO2	CD1, CD2, CD6
CO3	CD1, CD2, CD6
CO4	CD1, CD2, CD3, CD4, CD6, CD7
CO5	CD1, CD2, CD3, CD4, CD6, CD7

Massive Open Online Course (MOOC)

COURSE INFORMATION SHEET

Course code: EC615
Course title: Basics of Software defined Radio and Applications
Pre-requisite(s): basic knowledge of signal processing, concepts in wireless Communication and networks
Co- requisite(s):
Credits: L: 0 T: 0 P: 0 C: 2
Class schedule per week: N/A
Class: M. Tech.
Semester / Level: III/06
Branch: ECE
Name of Teacher:

Course Objectives

This course enables the students to:

1.	Understand the basic components of software defined radio.
2.	Understand the distortion parameters and nonlinear Distortion in Transmitted Signals.
3.	Calculate power requirement in power amplifier for SDR.
4.	Understand Digital Pre-distortion Techniques for Linear/Nonlinear Distortion.
5.	Appraise Digital Predistortion Techniques.

Course Outcomes

After the completion of this course, students will be to:

CO1	Able to analyse the basic components of software defined radio.
CO2	Demonstrate understanding about distortion parameters and nonlinear Distortion in Transmitted Signals
CO3	Able to calculate power requirement in power amplifier for SDR

CO4	Demonstrate understanding about Digital Pre-distortion Techniques for Linear/Nonlinear Distortion
CO5	Design and analyse the various algorithms used for software defined radio.

SYLLABUS

Module 1: Basic components of software defined radios, Software defined radio architectures-Part A, Software defined radio architectures- Part B.

Module 2: Distortion parameters, Sources and metrics of distortion in a transceiver, Nonlinear distortion and nonlinearity specifications, Power amplifiers: Nonlinear Distortion in Transmitted Signals.

Module 3: Power amplifier Line-up for linearity & power requirement calculations, Linearization Techniques for nonlinear distortion in SDR.

Module 4: Predistortion Techniques for nonlinear distortion in SDR.

Module 5: Digital Predistortion Techniques for Linear/Nonlinear Distortion.

References

https://onlinecourses.nptel.ac.in/noc18_ec01/preview

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	**% Distribution**
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets

CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	-	2	3	1	-	1
CO2	1	2	3	2	2	2
CO3	1	1	3	1	1	2
CO4	3	1	3	3	2	1
CO5	1	3	3	1	2	2

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD1, CD2, CD3, CD6
CO2	CD1, CD2, CD3, CD6
CO3	CD1, CD2, CD3, CD6
CO4	CD1, CD2, CD3, CD6, CD7
CO5	CD1, CD2, CD3, CD6, CD7

COURSE INFORMATION SHEET

Course code: EC616
Course title: High Speed Semiconductor Devices
Pre-requisite(s): EC201 Electronics Devices
Co- requisite(s):
Credits: L: 0 T: 0 P: 0 C: 2
Class schedule per week: N/A
Class: M. Tech.
Semester / Level: III/06
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students to:

6.	Understand the Si-CMOS, SOI-CMOS devices and their limitations for high speed operation.
7.	Apply the Materials for high speed devices and circuits.
8.	Appraise and analyze the characteristics of the Metal Semiconductor Field Effect Transistor (MESFET) and other high-speed devices.
9.	Evaluate the characteristics of the High Electron Mobility Transistors (HEMT).
10.	Comprehend the characteristics of the Hetero junction Bipolar transistors (HBTs) and create their structures.

Course Outcomes:
After the completion of this course, a student will be able to:

CO1	Describe and illustrate the the Si-CMOS, SOI-CMOS devices and their limitations for high speed operation.
CO2	Sketch and explain the characteristics of the Materials for high speed devices and circuits.

CO3	Illustrate with the sketch of the structure of Metal Semiconductor Field Effect Transistor (MESFET) and other high-speed devices, diagram their characteristics and analyze them.
CO4	Appraise the principle of operation High Electron Mobility Transistors (HEMT), schematize their characteristics, assess and summarize their features.
CO5	Schematize the structure and design Hetero junction Bipolar transistors (HBTs) to observe high frequency response. Schematize their characteristics and prepare an inference.

SYLLABUS

Module -1:

Si-CMOS, SOI-CMOS devices and their limitations for high speed operation: CMOS Logic circuits with scaled down devices. Silicon on Insulator (SOI) wafer preparation methods and SOI based devices and SOI-CMOS circuits for high speed low power applications.

Module -2:

Materials for high speed devices and circuits:

Merits of III –V binary and ternary compound semiconductors (GaAs, InP, InGaAs, AlGaAs etc.), silicon-germanium alloys and silicon carbide for high speed devices, as compared to silicon-based devices. Brief outline of the crystal structure, dopants and electrical properties such as carrier mobility, velocity versus electric field characteristics of these materials. Material and device process technique with these III-V and IV – IV semiconductors.

Module -3:

Metal semiconductor Field Effect Transistor (MESFET):

Pinch off voltage and threshold voltage of MESFET. D.C. characteristics and analysis of drain current. Velocity overshoot effects and the related advantages of GaAs, InP and GaN based devices for high speed operation. Sub threshold characteristics, short channel effects and the performance of scaled down devices.

Module -4:

High Electron Mobility Transistors (HEMT):

Hetero-junction devices. The generic Modulation Doped FET(MODFET) structure for high electron mobility realization. Principle of operation and the unique features of HEMT. InGaAs/InP HEMT structures.

Module -5:

Hetero junction Bipolar transistors (HBTs):

Principle of operation and the benefits of hetero junction BJT for high speed applications. GaAs and InP based HBT device structure and the surface passivation for stable high gain high frequency performance. SiGe HBTs and the concept of strained layer devices.

Books recommended:

Textbooks:

1. Mike Golio, The RF and Microwave Handbook, 2e, CRC Press, 2008.
2. Samuel Y. Liao, Microwave Devices and Circuits, 3e, Prentice-Hall of India, 2003.
3. High Speed Devices and Circuits, NPTEL video lecture by Prof. K. N. Bhat, IIT, Madras.

Reference books:

1. S. M. Sze, Kwok K. Ng, Physics of Semiconductor Devices, 3e, Wiley-Interscience, 2006.
2. Stephen A. Campbell, The Science and Engineering of Microelectronic Fabrication, 2/e, Oxford University Press, 2001.
3. I. A. Glover, S. R. Pennock and P. R. Shepherd, Microwave Devices, Circuits and Subsystems for Communications Engineering, John Wiley & Sons, 2005.

Gaps in the syllabus (to meet Industry/Profession requirements): Hands-on-practical for fabrication of High-Speed Semiconductor Devices.

POs met through Gaps in the Syllabus: PO6.

Topics beyond syllabus/Advanced topics/Design: High Speed Diodes.

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	% Contribution during CO Assessment
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	% Distribution
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	CO1	CO2	CO3	CO4	CO5
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
CD2	Assignments
CD3	Laboratory experiments/Teaching aids/Seminars
CD4	Mini Projects
CD5	Industrial visits/in-plant training
CD6	Self- learning such as use of NPTEL materials and internets
CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	PO1	PO2	PO3	PO4	PO5	PO6
CO1	3	3	3	3	2	1
CO2	3	3	3	3	2	1
CO3	3	3	1	3	2	1

CO4	2	2	2	2	3	1
CO5	2	2	2	2	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
CO1	CD2, CD3, CD6, CD7
CO2	CD2, CD3, CD6, CD7
CO3	CD2, CD3, CD6, CD7
CO4	CD2, CD3, CD6, CD7
CO5	CD2, CD3, CD6, CD7

COURSE INFORMATION SHEET

Course code: EC617
Course title: Nanoelectronic Devices and Materials
Pre-requisite(s): EC201 Electronic Devices
Co- requisite(s):
Credits: L: 0 T: 0 P: 0 C: 2
Class schedule per week: N/A
Class: M. Tech.
Semester / Level: III/06
Branch: ECE
Name of Teacher:

Course Objectives:
This course enables the students to:

1.	Understand the issue in scaling MOSFET in the sub-100 nm regime and the state of the art in the areas of semiconductor device physics.
2.	Appraise and apply Fundamental Properties of Carbon Nanotube and its Synthesis techniques.
3.	Analyze how to assemble Carbon Nanotubes toward Practical Applications and Separation of Metallic and Semiconducting Single-Wall Carbon Nanotubes.
4.	Evaluate Electronic Applications of Single-Walled Carbon Nanotubes.
5.	Comprehend the characteristics of the Spintronics and Molecular electronics and create their structures.

Course Outcomes:
After the completion of this course, students will be able to:

CO1	Describe and illustrate the Basic CMOS Process flow and MOS Scaling theory
CO2	Sketch and explain Gate oxide scaling trend and integration Issues
CO3	Illustrate with the sketch the heterostructure growth techniques, diagram their characteristics and analyze them.
CO4	Appraise the Nonclassical CMOS structures and integration issues and schematize, assess and summarize their features.
CO5	Schematize the structure and design Heterostructure device and write down its synthesis techniques

SYLLABUS

Module -1:

MOS process flow and scaling theory

Overview: Nano devices, Nano materials, Nano characterization, Definition of Technology node, Basic CMOS Process flow, MOS Scaling theory, Issues in scaling MOS transistors: Short channel effects, Description of a typical 65 nm CMOS technology, Requirements for Nonclassical MOS transistor.

Module -2:

Gate oxide scaling trend and integration Issues:

MOS capacitor, Role of interface quality and related process techniques, Gate oxide thickness scaling trend, SiO_2, versus High-k gate dielectrics; Integration issues of high-k, Interface states, bulk charge, band offset, stability, reliability, Metal gate transistor: Motivation, requirements, Integration Issues, Transport in Nano MOSFET, velocity saturation, ballistic transport, injection velocity, velocity overshoot.

Module -3:

Heterostructure growth techniques:

Compound semiconductor heterostructure growth and characterization: Quantum wells and, thickness measurement techniques: Contact - step height, Optical - reflectance and ellipsometry. AFM. Characterization techniques for nanomaterials: FTIR, XRD, AFM, SEM, TEM, EDAX etc.; Applications and interpretation of results; emerging nanomaterials: Nanotubes, nanorods and other nanostructures, LB technique, Soft lithography etc. Microwave assisted synthesis, Self-assembly etc.

Module -4:

Nonclassical CMOS structures and integration issues:

SOI - PDSOI and FDSOI, Ultrathin body SOI - double gate transistors, integration issues, Vertical transistors - FinFET and Surround gate FET, Metal source/drain junctions - Properties of Schottky junctions on Silicon, Germanium and compound semiconductors -work function pinning.

Module -5:

Heterostructure devices and synthesis:

Germanium Nano MOSFETs: strain, Advantages of Germanium over Silicon, PMOS versus NMOS; MOSFETs in the context of channel strain; Compound semiconductors - material properties, MESFETs; Hetero structure FETs exploiting novel materials, strain; Synthesis of Nanomaterials: CVD, Nucleation growth, ALD, Epitaxy, MBE.

Books recommended:

Textbooks:

1. Yuan Taur and T H Ning, Fundamentals of Modern VLSI Devices, 2nd Edition, Cambridge, reprint 2016.
2. Qing Zhang, Carbon Nanotubes and Their Applications - Pan Stanford Series on Carbon-Based Nanomaterials, CRC Press, 2012.
3. George W. Hanson, Fundamentals of Nanoelectronics, Pearson, 2009.
4. Nanoelectronics: Devices and Materials, NPTEL video lecture by Prof. Navakanta Bhat, Indian Institute of Science, Bangalore.

Reference book:

1. The Physics of Low-Dimensional Semiconductors, John H. Davies, Cambridge University Press, 1998.
2. Introduction to Nanotechnology, C. P. Poole Jr., F. J. Owens, Wiley (2003).
3. Silicon VLSI Technology, Plummer, Deal, Griffin, Pearson Education India.
4. Encyclopedia of Materials Characterization, Edited by: Brundle, C. Richard; Evans, Charles A. Jr.; Wilson, Shaun; Elsevier.

Gaps in the syllabus (to meet Industry/Profession requirements): Hands-on-practical for fabrication of nanoelectronic devices.

POs met through Gaps in the Syllabus: PO6.

Topics beyond syllabus/Advanced topics/Design: CNFET**,** SET, Memristor, MTJ**.**

POs met through Topics beyond syllabus/Advanced topics/Design: PO6

Course Outcome (CO) Attainment Assessment Tools and Evaluation Procedure

Direct Assessment

Assessment Tools	**% Contribution during CO Assessment**
Continuous Internal Assessment	50
Semester End Examination	50

Continuous Internal Assessment	**% Distribution**
3 quizzes	30 (3×10)
Assignment(s)	10
Seminar before a committee	10

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**	**CO5**
Continuous Internal Assessment					
Semester End Examination					

Indirect Assessment

1. Student Feedback on Faculty
2. Student Feedback on Course

Course Delivery Methods

CD1	Lecture by use of boards/LCD projectors/OHP projectors
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CD7	Simulation

Mapping between Course Outcomes and Program Outcomes

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**
CO1	3	3	3	3	2	1
CO2	3	3	3	3	2	1

CO3	3	3	1	3	2	1
CO4	2	2	2	2	3	1
CO5	2	2	2	2	3	1

< 34% = 1, 34-66% = 2, > 66% = 3

Mapping between Course Outcomes and Course Delivery Method

Course Outcomes	Course Delivery Method
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CO3	CD2, CD3, CD6, CD7
CO4	CD2, CD3, CD6, CD7
CO5	CD2, CD3, CD6, CD7

4th Semester

Programme Core

EC650 Thesis (Part II) Credit: 16