UNIVERSITY OF DELHI
M.Tech. Microwaves and Communication

As approved in the meeting of 'Committee of Courses' held on 11th March 2025, in the meeting of 'Faculty of Interdisciplinary and Applied Sciences' held on ___17th March, 2025__________, and meeting of 'Standing Committee' held on _____________

PROGRAMME BROCHURE

XXXXX Revised Syllabus as approved by Academic Council on XXXX, 2025 and Executive Council on YYYY, 2025

M.Tech. in Microwave and Communication

The M.Tech programme in Microwave and Communication is a four semester, i.e., a two-year programme under Faculty of Interdisciplinary & Applied Sciences of University of Delhi. This programme was initially sponsored by the Department of Electronics, Government of India in 1976 with an M.Tech. in Microwave Electronics. This programme is re-structured with an aim to provide the necessary theoretical background and practical experience in the fields of Microwave Devices, Measurements, Microwave Passive and Active Circuits, Advanced Antennas, Monolithic Microwave Integrated Circuit (MMIC), EMI/EMC, Next-generation Communication systems, etc. The current course structure is updated based on the advancements in the field of RF, Microwave, THz to Optical Communication & Circuits. The course caters to all essential needs of the next-generation high-frequency systems while fulfilling the requirements of Research and Industrial applications.

For admission to this postgraduate program of the University of Delhi, all candidates (including those applying for Supernumerary seats) must register for the Common University Entrance Test (Postgraduate) CUET (PG) of the year of applying at pgcuet.samarth.ac.in. For admission and seat allotment, candidates must apply to the Common Seat Allocation System (PG) of the same year of the University of Delhi. So, the candidates must go through the PG Bulletin of Information before applying for M.Tech. (Microwave and Communication) for updated admission procedures.

Minimum Eligibility
For candidates belonging to UR/OBC-NCL/EWS category, the minimum eligibility is 50% marks in aggregate or equivalent grade in the qualifying examination as per the Program-Specific Eligibility.
For candidates belonging to SC/ST/PwBD category, the minimum eligibility is 45% marks in aggregate or equivalent grade in the qualifying examination as per the Program-Specific Eligibility

Admission Criteria:
For admission to M.Tech. (Microwave and Communication), the candidates must fulfill the Program Specific Eligibility and appear in the respective CUET paper. Refer to https://pgcuet.samarth.ac.in/ for the syllabus of the CUET paper.

Category	Program Specific Eligibility	CUET (PG) Paper Code
1A	B.Tech./ B.E./B.Sc. Engg.(4 years course) Electrical/ Electronics/ Electronics and Communication/ Instrumentation/ Radio Physics & Electronics Engineering from a recognized University	MTQP05* (*as decided by the authorities conducting CUET PG)
1B	M.Sc. Electronics or M.Sc. Physics/Applied Physics with specialization in Electronics from a recognized University	

Seats Offered by Department:

Category	UR	SC	ST	OBC	EWS
No. of Seats	13	5	3	9	3
	04 seats are reserved for candidates sponsored from R&D organizations across India				

In addition, Supernumerary seats will be as per University of Delhi rules & regulations.

Age Requirement

No student will be qualified for admission to the M.Tech course unless he/she is 21 years of age on or before 1st October of the year of admission. Relaxation of age limit up to a maximum period of six months based on individual merit may be granted by the Vice-Chancellor.

ORDINANCE

1. There shall be M.Tech. Course in Microwave and Communication in the Department of Electronic Science under the Faculty of Interdisciplinary and Applied Science.
2. The duration of the course will be four semesters which is two academic years.
3. A candidate seeking admission to this course must have passed B.Tech./ B.E./B.Sc. Engg.(4 years course) Electrical/ Electronics/ Electronics and Communication/ Instrumentation/ Radio Physics & Electronics Engineering from a recognized University with at least 50% marks for UR/OBC-NCL/EWS category and 45% marks for SC/ST/PwBD category or an equivalent grade.

   OR

   A candidate seeking admission must have passed M.Sc. Electronics or M.Sc. Physics with specialization in Electronics from a recognized University with at least 50% marks for UR/OBC-NCL/EWS category and 45% marks for SC/ST/PwBD category or an equivalent grade.
4. Candidates for M.Tech. programme will be selected for admission to **33 seats (13 UR, 05 SC, 03 ST, 09 OBC, and 03 EWS)** on the basis of performance in the CUET and **04 seats** are for candidates sponsored from R&D organizations across India. Out of these, the first 10 students will be eligible for a scholarship of Rs.600/- per month except the sponsored candidates.

Fee of the M.Tech programme

A fee will be as per University of Delhi rules & regulations. Candidates must visit the Department website for the updated fee structure.

SCHEME OF EXAMINATION

1. English shall be the medium of instruction and examination.

2. Examinations shall be conducted at the end of each Semester as per the Academic Calendar notified by the University of Delhi.

3. The system of evaluation shall be as follows

3.1 Each theory paper will carry 4 credits i.e. 100 marks out of which 20 marks shall be reserved for internal assessment based on tests, seminars and assignments and 5 marks for attendance as per the table given in ATTENDANCE REQUIREMENT. The duration of written examination for each paper shall be three hours and will be of 75 marks. In the case of a student who has an essential repeat (ER) in one or more theory papers, the internal assessment marks will be carried forward.

3.2 Examinations for practicals for semester I, II and III will comprise of 2 credits i.e. 50 marks. The end semester practical examination for semester I, II and III would be for 6 hours duration and will be of 60% of the total marks i.e. 30 marks. 40% of the total marks i.e. 20 marks will be for the internal assessment based on continuous evaluation throughout the semester.

3.3 Each student has to take up a minor-project **(MTCP302)** based on the hardware and/or software in III semester which will be of 6 credits i.e. 150 marks under the supervision of a department faculty. The project evaluation will be based on the project report submitted by the student and a presentation to a panel of three examiners from the Department faculty as decided by the PG Committee of Courses of the Department every year. The 50% of the marks will be based on continuous internal assessment throughout the semester.

3.4 Students will be required to work on the major project **(MTCP401)** in Semester IV which will be of 16 credits i.e. 400 marks. The project can be carried out in collaboration with an R & D Organization or industry of repute. The collaboration is to be established by the project coordinator.

All students will have to go through a mid-semester project evaluation which will be of 30% of total marks i.e. 120 marks and facilitated by the project coordinator and internal supervisor of the student either through online or offline mode.

On completion of the project work, the student will submit a dissertation and appear for a viva voce examination. The minimum mark required to pass the fourth Semester shall be 50% in project. A student, who fails in the Semester IV Examination, will be required to repeat the Project including the mid-semester evaluation. However, he/she may be allowed to complete it in the span period.

4. Examinations for courses shall be conducted only in the respective odd and even Semesters as per the Scheme of Examination. Regular as well as Ex-Students shall be permitted to appear/reappear in courses of odd semesters only at the end of odd semesters and for even semesters only at the end of odd semesters. There will be no scope for improvement or re-evaluation.

PASS PERCENTAGE AND PROMOTION CRITERIA

(a) The minimum marks required to pass in any paper in a semester shall be 40% in theory and 40% in Practical, wherever applicable. Also, the student must secure atleast 40% marks in the internal assessment (i.e. 10/25) and a minimum of 40% marks in the End semester examination (i.e. 30/75) of each theory paper.

(b) No student will be detained in the I or III Semester based on his/her performance in I or III Semester examination; i.e. the student will be promoted automatically from I to II and III to IV semester.

(c) A student shall be eligible for promotion from Part 1 to Part 2 of the course provided he/she has passed at least 3 core papers and 2 elective papers of I and II semesters taken together. However, the student will have to clear all ER or papers in which he/she is absent while studying in Part 2 of the programme.

(d) A student who has to reappear in a paper prescribed for semester I/III may do so only in the odd semester examinations to be held in November / December. A student who has to reappear in a paper prescribed for Semester II/IV may do so only in the even Semester examinations to be held in May/June.

(e) A student who reappears in a paper shall carry forward the internal assessment marks, originally awarded and the result will be prepared based on the student's current performance in the end semester examination.

(f) Students who do not fulfill the promotion Criteria (c) above shall be declared fail in the Part concerned and can take re-admission as per the University rules.

(g) A student who fails or is absent in any semester's practical examination/mini-project/major project will be declared fail in that semester and will have to take re-admission in the concerned semester in the span period only.

DIVISION CRITERIA

Successful candidates will be classified as per the University rules based upon SGPA and CGPA.

SPAN PERIOD

No student shall be admitted as a candidate for the examination for any of the Parts/Semesters after the lapse of four years from the date of admission to Part 1/Semester I of the M.Tech. Program.

ATTENDANCE REQUIREMENT

No student shall be eligible to take an examination unless he/she has attended at least 60% of the total number of lectures and 60% of practicals seperatly conducted in each semester, during his/her course of study. The 05 marks for the attendance will be as per the table give below:

Attendance percentage (A)	Marks allocated
60% ≤A<65%	1
65% ≤A<70%	2
70% ≤A<75%	3
75% ≤A<80%	4
80% ≤A	5

NOTE:

a) The calendar for the academic year will be as per University notifications.
b) The span period for the M.Tech. degree will be four years from the initial date of admission in a particular academic year.
c) A candidate who fails in Part 1 or Part 2 will be required to repeat that part of the course as a regular student only.
d) There will be no provision of an ex-student.
e) A candidate, who fails in the Semester IV Examination, will be required to repeat the Project. However, he/she may be allowed to complete it in the span period only.
f) The scholarship will be discontinued if the student fails to score at least 60% marks in any examination.
g) If a student fails in any paper, he/she will not be eligible for a merit position and the scholarship will be discontinued.

h) Subject to the statutes and ordinance of the University, M.Tech. Course students shall remain under the control and discipline of the Head, Department of Electronic Science under the Faculty of Interdisciplinary & Applied Sciences (FIAS).

DEPARTMENT OF ELECTRONIC SCIENCE
UNIVERSITY OF DELHI SOUTH CAMPUS

FRAMEWORK FOR M.TECH.(MICROWAVE AND COMMUNICATION)

Part/ Semester	Unique code	Name of Course	L	P	C	Page no.
Part 1	**Semester I**					1
1/I	**MTC101**	Electromagnetic Theory and Transmission Lines	**4**	**-**	**4**	1
	MTCL102	Microwave Planar Lines and Passive Components	**4**	**2**	**6**	3
	Choose any one out of the following					
	MTEL101	Microwave Characterization and Measurement Techniques	**4**	**2**	**6**	6
	MTEL102	Optical Communication Systems	**4**	**2**	**6**	9
	Choose any one out of the following					
	MTE103	Microwave Devices	**4**	**-**	**4**	11
	MTE104	EMI and EMC Technology	**4**	**-**	**4**	13
	Total credit in Semester I				**20**	
Part 1	**Semester II**					15
1/II	**MTC201**	Advanced Communication Theory	**4**	**-**	**4**	15
	MTC202	Microwave Active Circuits	**4**	**-**	**4**	17
	MTCL203	Advanced Antenna Theory and Techniques	**4**	**2**	**6**	19
	Choose any one out of the following					
	MTEL201	Computational Electromagnetics	**4**	**2**	**6**	22
	MTEL202	Radar Technology	**4**	**2**	**6**	23
	Choose any one out of the following					
	MTE203	Metamaterials and Metasurfaces: Concepts and Applications	**4**	**-**	**4**	25
	MTE204	Satellite Communication System	**4**	**-**	**4**	29
	Total credit in Semester II				**24**	
Part 2	**Semester III**					29
2/III	**MTCL301**	Next-Generation Communication Systems	**4**	**2**	**6**	29
	MTCP302	Minor project	**-**	**6**	**6**	31
	Choose any one out of the following					
	MTE301	Terahertz, Nanophotonics and Plasmonics	**4**	**-**	**4**	32
	MTE302	Industrial Microwaves Technology	**4**	**-**	**4**	34
	MTE303	MEMS Design and Technology	**4**	**-**	**4**	36
	Total credit in Semester III				**16**	
Part 2	**Semester IV**					38
2/IV	**MTCP401**	Major project	**-**	**16**	**16**	38
	Total credit in Semester IV				**16**	
Total Credit in all semesters					**76**	

L-credits in lectures, P-credits in practicals, and C- total credits

SEMESTER I

MTC101. Electromagnetic Fields & Guided Wave Theory

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

The Electromagnetic Theory and Transmission Lines course aims to give students a comprehensive understanding of Maxwell's equations to wave equations and to solve various problems related to wave propagation in different mediums and guided structures. Students will learn to solve the wave equation using rectangular, cylindrical, and spherical coordinates and plane waves moving through different materials. Boundary conditions to solve problems at the interface of various materials. Scalar, vector, and Hertz potentials relate to electromagnetic fields and gauges. The course will cover the transmission lines, including their RLCG model, matched, open, short circuit lines and quarter-wave transformers. Students will also learn about different modes (like TE, TM and Hybrid) and their field distribution in rectangular, circular, dielectric slab waveguides and cavities. Finally, they will learn the transverse Resonance Method. Students will build a strong foundation in theoretical skills needed to work with electromagnetic systems and networks.

Course Learning Outcomes

At the end of this course, students will have

CO1. To understand Maxwell's equations and boundary conditions.
CO2. Learn to solve wave equations in rectangular, cylindrical, and spherical coordinates.
CO3. Learn transmission lines and use of Smith to solve the matching problem.
CO4.Develop skills in solving field components for rectangular, circular, dielectric slab waveguides and cavities in different modes (like TE, TM and Hybrid)
CO5. Learn transverse resonance method to solve electromagnetic problems.

Syllabus Contents

Unit-1 **18 lectures**
Review of Maxwell's Equations and boundary conditions, time harmonic electromagnetic fields, generalized current concept, energy and power, complex power; Introduction to wave equation and its solutions: Plane waves in dielectric and conducting media, reflection and refraction of waves. Scalar, vector and Hertz potentials and their relations to fields, and gauges. Theorems and concepts: The source concept, duality, uniqueness, image theory, the equivalence principle, fields in half space, reciprocity, construction of solutions.

Unit-2 **12 lectures**
Basic theory of transmission lines; Computation of RLCG parameters of two-wire and classical

lines; Input Impedance, Short Circuit and Open Circuit lines, Quarter wave transformer, Smith Chart and its applications; Transient domain analysis of transmission lines.

Unit-3 **15 lectures**

Rectangular waveguide: Transverse Electric (TE), Transverse Magnetic (TM), and Dominant TE_{10} mode, Power Density and Power; Rectangular cavity: Transverse Electric (TE), Transverse Magnetic (TM) and Hybrid mode; Partially filled waveguides; Transverse Resonance Method (TRM).

Unit-4 **15 lectures**

Dielectric slab waveguide: Transverse Electric (TE) and Transverse Magnetic (TM); surface guided waves, non-resonant dielectric (NRD) guide. Circular waveguide: Transverse Electric (TE), Transverse Magnetic (TM) modes; Circular cavity.

Suggested Readings:

1. C.A. Balanis, "Advanced Engineering Electromagnetics,"2nd Ed. John Wiley & Sons,2012.
2. R. F. Harrington, "Time-Harmonic Electromagnetic Fields," 2nd Ed. McGraw-Hill, New York, 2001.
3. D. K. Cheng, "Field and Wave Electromagnetics," 2nd Ed., Addison Wesley,1989.
4. Matthew N. O. Sadiku, "Principles of Electromagnetics " 6th Ed. Oxford University Press,2015.
5. Kraus, Daniel A. Fleisch, "Electromagnetics: With Applications "5th Ed. WCB/McGraw-Hill,1999.

MTCL102. Microwave Planar Lines and Passive Components

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

The main objective of this course is to give a comprehensive understanding and simulation exposure to the various transmission lines and their utility for the microwave passive component design that is involved in the microwave system design so that the students can design any passive components using simulation software and understand their behavior through the complete design procedural steps of developing circuit schematic, board files, and S-parameters based characterization.

Course Learning Outcomes

At the end of this course, students will have

CO1. Familiarization with the various types of planar transmission lines used in microwave technology
CO2. Pre-requisite knowledge to design microwave passive components based on the properties of planar transmission lines for microwave applications.
CO3. Knowledge of designing and understanding the microwave passive components with the help of simulating various microwave components
CO4. Understanding of the basic component designs and future scope of these components in the microwave industry

Syllabus Contents

Unit-1 **12 lectures**

S-parameter analysis of the microwave circuits; Conversion of Z, Y, ABCD transmission parameters to S-parameters and vice versa; Shift in reference planes, Generalized S-parameters for one-port and multiport networks, Cascade S-parameters, De-embedding of S-parameters; Applications of S-parameters on matching network design.

Unit-2 **15 lectures**

Review of the development of MIC, MMIC and application of the planar transmission line structures such as stripline, microstrip line, coplanar waveguide line and coupled microstrip line, LTCC Technology. Quasi-static and frequency-dependent closed-form models of planar lines for effective relative permittivity, characteristic impedance, dispersion models, dielectric, conductor, and radiation losses; effect of conductor thickness on parameters of planar transmission lines. Extraction of frequency-dependent RLGC parameters of planar transmission lines,

Unit-3 **15 lectures**

Discontinuities, Circuit models of discontinuities in microstrip lines and the coplanar waveguides: Open-ended, short, gap, step, bent, T-Junction and their compensation techniques. Microwave resonators: Transmission line resonators, Microstrip line resonators -rectangular, circular, and ring; Loaded and unloaded Q, Excitation of resonators.

Unit-4 **18 lectures**

Periodic structures, Filter design methods, Filter transformations; Richards' transformation and Kuroda's identities; Inverters, Coupled Line Filters, coupled-resonator filters; Three-port components: Resistive power divider, Wilkinson power divider. Four-port components: Branch line coupler, Hybrid ring coupler, Coupled line directional coupler, Lange coupler.; Even-odd mode analysis of dividers and couplers; Plane wave propagation in a Ferrite medium, Isolator, Circulator, delay lines and phase shifters; MEMS technology-based microwave components like switches, filters, phase shifters and delay lines.

Suggested Books:

1. David M. Pozar, Microwave Engineering, 4th Edition, John Wiley & Sons, Inc, 2012
2. Michael Steer, Microwave and RF Design: A System Approach, Scitech Publishig Inc., 2010.
3. T. C. Edwards & M. B. Steer, Foundations for Microstrip Circuit Design, John Wiley & Sons, 2016
4. Devendra K. Misra, Radio-Frequency and Microwave Communication Circuits: Analysis and Design, John Wiley & Sons, 2012
5. Subal Kar, Microwave Engineering: Fundamentals, Design And Applications, Orient Blackswan Pvt Ltd 2016.

Microwave Planar Lines and Passive Components Laboratory

Practical Credits: 2 **Total Lectures: 60**

List of Experiments:

A. MATLAB based:

1. To study the synthesis and analysis of the microstrip line and coplanar waveguide by plotting the characteristic impedance and effective relative permittivity.
2. To study the dispersion in the microstrip line by plotting the frequency-dependent permittivity with frequency.
3. To study the conductor and dielectric losses for microstrip and stripline lines as a function of frequency.

B. Software Based:

4. To design Hi-Low and Stub based Microstrip line low pass filters and high pass filters.
5. To design stub and coupled Microstrip line band pass and band stop filters.
6. To design 3 port Wilkinson equal and unequal power divider in a microstrip line.
7. To design 4-port equal and unequal power branch line coupler in a microstrip line.

C. Measurement-based:

8. To measure frequency and guide wavelength by the microwave test bench.
9. To measure the parameters of the microstrip filters using Vector Network Analyzer (VNA).
10. To measure the parameters of microstrip power dividers using VNA.
11. To measure the parameters of microstrip couplers VNA.

MTEL101. Microwave Characterization and Measurement Techniques

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

The main objective of this course is to give a comprehensive understanding and hands-on exposure to the various characterization and measurement techniques applicable in the Microwave technology, so the students will able to understand the significance of the microwave parameters and their measurement techniques and apply for verification of the industry-oriented microwave component design and development of microwave systems, like mobile communication, microwave sensor analysis, Radar and Satellite etc.

Course Learning Outcomes

At the end of this course, students will have

CO1. Familiarization of the various microwave parameters and their measurements
CO2. Pre-requisite knowledge to perform design and development of any microwave component and their performance verification
CO3. Knowledge of the current broadband characterization techniques and signal analysis in the microwave industry
CO4. Understanding of the basic and advanced measurement techniques for material characterization at the microwave frequencies.

Syllabus Contents

Unit-1 **12 lectures**
Characteristic impedance, Reflection coefficient, Voltage standing wave ratio, VSWR meter, Wavelength and Frequency measurements; Phase velocity, Group velocity; Losses in transmission lines, return loss, insertion loss, reflection loss, mismatch loss; Scattering parameters, Properties of S-parameters, Examples of S-parameter matrices; Noise Figure and equivalent noise temperature.

Unit-2 **16 lectures**
Power sensors, Thermocouples and other thermoelectric sensors, Diode sensors, Thermistors and other bolometers, Calorimeters; Power measurements and calibration, Mismatch uncertainty, Direct power measurement, Ratio measurements; Pulsed power measurements; Attenuation measurements: Power ratio method, Voltage ratio method, Inductive voltage divider, AF substitution method, IF substitution method, RF substitution method, Important considerations for making attenuation measurements.

Unit-3 **18 lectures**
Elements of a microwave network analyzer, Block diagram of Network analyzer, Scalar network analyzer, Vector network analyzer, Calibration of a scalar network analyzer and vector network analyzer, Transmission measurements, Reflection measurements, Measurement errors, One-port error model, Two-port error model, one-port and two-port Calibration techniques, Calibration

and verification standards, Verification of VNA measurements, Dielectric measurement theory, Loss processes, Considerations for practical dielectric measurements, Q-factor and its measurement, Reflection/Transmission based measurement methods, Coaxial probes, Free-field methods, Time domain techniques. Resonator-based methods.

Unit-4 **14 lectures**

Measurement domains, Spectrum analyzer Architecture and its working, Types of spectrum analyzer, spectrum analyzer with harmonic mixer, spectrum analyzer with a tracking preselector, Spectrum analyzer with tracking generator, Typical specifications of Spectrum analyzer, Various controls of Spectrum analyzer, Spectrum analyzer applications, Noise Figure Measurement, Measurement of harmonic distortion, Intermodulation distortion measurement, Amplitude modulation, Frequency modulation, Pulse modulation, Phase noise.

Suggested books:

1. R.J. Collier (Editor), A.D. Skinner (Editor), Microwave Measurements (Materials, Circuits and Devices) 3rd Edition, The Institution of Engineering and Technology, 2007.
2. Joel P. Dunsmore, Handbook of Microwave Component Measurements: with Advanced VNA Techniques, 3rd Edition, John Wiley & Sons Ltd, 2020.
3. Valeria Teppati, Andrea Ferrero and Mohamed Sayed, Modern RF and Microwave Measurement Techniques, Cambridge University Press, 2013.
4. L. F. Chen, C. K. Ong, C. P. Neo, V. V. Varadan, V. K. Varadan, Microwave Electronics: Measurement and Materials Characterization, John Wiley & Sons, Ltd, 2004.
5. David M. Pozar, Microwave Engineering, 4th Edition, John Wiley & Sons, Inc, 2012.
6. Ananjan Basu, An Introduction to Microwave Measurements, CRC Press, 2014.

Microwave Characterization and Measurement Techniques Laboratory

Practical Credits: 2 **Total Lectures: 60**

List of Experiments:

1. To study the low VSWR and high VSWR (using the Double minima method) measurement of waveguide components.
2. To study the calibration of a given attenuator and a wave meter.
3. To determine impedance of various irises (vertical, horizontal, and rectangular cuts)
4. To study the model characteristics of Reflex Klystron (Output power ve Reflector voltage, frequency vs reflector voltage).
5. To study the characteristics of a Directional coupler (Directivity, coupling factor, isolation and insertion loss, S-parameters)
6. To study the characteristics of a Magic tee (Coupling factor, isolation and input VSWR, S-parameters)
7. To study the frequency response of the given filter and determine its characteristics (cutoff frequency or center frequency, bandwidth etc.)
8. To study the characteristics of isolator and circulator (Insertion loss, isolation and input VSWR, S-parameters)

9. To study the characteristics of a phase shifter (Insertion loss, phase and input VSWR).
10. To study the radiation pattern of (a) Horn antenna, (b) Dielectric rod antenna and obtain the antenna parameters (Gain, Directivity, HPBW).

MTEL102. Optical Communication System

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

The main objective of this course is to give a comprehensive understanding and hands-on exposure to the various processes, industrial tools, protocols, and design specifics which are involved in free space optical communication and Optical Fiber Communication (OFC) so that the students can understand the complete details of the Optical Fiber beginning from components of Optical Fibers, different types of Fibers, sources, detectors and the link budget as applicable to the Optical Fiber Communication System.

Course Learning Outcomes

At the end of this course, students will have

CO1 Familiarization of the various types of free space optical communication, Optical Fibers and its components

CO2 Understanding of the Optical Fiber components, their characteristics and their applications.

CO3 Pre-requisite knowledge to perform design of link budget of the Optical Fiber Communication System

CO4 Understanding of the current trends, scope and future trends of the Optical Fiber Communication System.

Syllabus Content

Unit-1 **16 Lectures**

EM Spectrum and Optical Frequencies, Free space optical communication, link budget associated with free space optical communication, Deep space communication, Optical Satellite Communication, Intersatellite and on board optical communication; Introduction to OFC, Optical Spectral bands; Basic Optical Laws and definitions, Mode Theory of Circular Dielectric Waveguides, Optical Fiber modes and configurations; Cut off wavelength and V-number of Fibers; Single mode and multi-mode fibers, Step index and graded index fibers, structure of the graded index fibers, fiber materials, Fiber fabrication, Fiber optic cables; Attenuation, Signal Dispersion in Fibers, Intermodal and Intramodal dispersion, chromatic and waveguide dispersion, group delay, polarization mode dispersion.

Unit-2 **14 Lectures**

Optical Sources, Semiconductor physics for optical sources, direct and indirect band gap semiconductors, Energy momentum diagrams; Light emitting Diodes (LEDs), Physical Structures of LEDs; Lasing actions, Different types of Lasers, Laser Diodes, Structure of Laser Diodes, Fabry Perot Cavity in Laser Diodes; Light Source Linearity. Reliability Considerations; OFC transmitter considerations, source to fiber power launching, lensing schemes for coupling improvement, fiber splicing and optical fiber connectors, Intensity and Sub-intensity modulations.

Unit-3 **14 Lectures**

Optical Detectors, Physical Principles of photodiodes, Photodetector noise, Detector response time; Avalanche and Zener breakdown, Avalanche multiplication noise; Structure of InGaAs Avalanche Photodetectors (APDs), temperature effect on Avalanche Gain, Comparison of Photodetectors; Optical receiver system, Fundamental of receiver operation, Digital Receiver performance, Eye diagrams.

Unit-4 **16 Lectures**

Digital Links, Point to Point links, Power penalties, error control, codes for error control; Coherent detection; Analog links and its overview, Carrier to noise ratio, multi-channel transmission techniques; Microwave Photonics; Wavelength Division Multiplexing (WDM) and Dense Wavelength Division Multiplexing (DWDM); Diffraction gratings, tunable light sources. Basic applications and types of Optical Amplifiers, Semiconductor Optical Amplifiers; Erbium-Doped Fiber Amplifiers, Optical SNR, Raman Amplifiers; General Overview of non-linearities in optical fiber communication, Stimulated Raman and Brillouin Scattering; Optical Networks and Topologies, SONET/SDH; Optical Time domain reflectometry (OTDR).

Books Recommended:-

1. Optical Fiber Communications, Gerd Keiser, Tata Mc Graw Hills, 4th edition, 2008.
2. Introduction to Fiber Optics, Ajoy Ghatak and K. Thayarajan, Cambridge University Press, 1999.
3. Optical Fiber Communications: Principles and Practice, John M. senior, Pearson education Ltd., 2009.
4. Fiber Optic communication systems, G. Agrawal, John Wiley and Sons, 1992.

List of Experiments for Optical Communication System Laboratory: -

1. a. Measurement of Fiber Optic Numerical Aperture
   b. Measurement of Fiber Optic using Optical Power Meter
2. a. Setting up Fiber Optical Analog Link
   b. Setting up Fiber Optical Digital Link
3. a. Study of Intensity Modulation Technique using Analog Input Signal
   b. Study of Intensity Modulation Technique using Digital Input Signal
4. a. Study of VI Characteristics of three different LED
   b. Study of Gaussian Illumination profile of three different LED
5. a. Study of Single sided, Double sided, and Triple sided Edge Diffraction
   b. Study of Two different gratings with two different Lasers
6. a. Measurement of Single Knife-Edge Diffraction using Power Meter
   b. Measurement of Polarizer and Analyzer using Power Meter
7. a. Measurement of Half Wave Plate using Power Meter
   b. Measurement of Quatre Wave Plate using Power Meter
8. Study of five different Optical Structures and their refraction and reflection patterns.

MTE103. Microwave Devices

Lecture Credit: 4 **Total Lectures: 60**

Course Learning Objectives:

The objective of this course is to provide knowledge of various microwave devices to the students. It comprises of the detailed knowledge of conventional as well as latest devices of RF and microwave engineering. Students will be able to study microwave semiconductor devices & their related applications. Moreover, they will learn about microwave sources and the integration of microwave devices with microwave-integrated circuits (MIC) and Monolithic Microwave Circuits (MMIC).

Course Learning Outcomes:

At the end of the course, students will be able

CO1. To understand about the microwave devices, MIC & MMIC technologies, and related industrial requirements.

CO2. To have knowledge of unipolar and bipolar microwave devices including various microwave diodes and Transferred Electron devices.

CO3. To attain the knowledge of three terminal microwave devices and their advancement in accordance with the latest technology.

CO4. To gain knowledge of microwave sources and their applications and advancement.

Syllabus Contents

Unit-1 **12 lectures**

Introduction to Microwave Engineering, Concept of guided and unguided medium, Need of High Frequencies for industrial applications, Modern Applications of Microwave Engineering, Microwave components and devices: active and passive, Introduction to Microwave integrated circuits (MIC), Technology of hybrid MICs, and Monolithic Microwave Circuits (MMIC), Surface Mount Devices (SMD) & through-hole components, Integration of microwave devices with MIC and MMIC structures, Electronic packaging, Basics of RF device packaging and thermal management.

Unit-2 **15 lectures**

Introduction and classifications of Microwave solid state devices, Unipolar and Bipolar Devices, Tunnel Diode, Varactor Diode, Schottky diode, Avalanche Transit Time Devices: Read, IMPATT, TRAPATT, BARITT, comparison of microwave diodes with pn junction diode, integration of microwave diodes with microstrip structures and their effects in frequency agility, beam switching and other RF applications.

Transferred electron devices (TED): Gunn Diode; Gunn effect, Ridley–Watkins–Hilsum theory, Modes of operation, Limited Spacecharge Accumulation (LSA) mode of Gunn diode, Applications of TEDs.

Unit-3 **18 lectures**

Microwave Transistors, Concept of Hetero-junction, Hetero-junction Bipolar Transistor (HBT), Field Effect Transistors (FETs); Junction Field Effect Transistor (JFET), metal-oxidesemiconductor field-effect transistor (MOSFET), Metal-Semiconductor Field-Effect Transistor (MESFET); structure, mechanism, modes of operation, transconductance and cut off frequency, High Electron Mobility Transistor (HEMT) and pHEMT; structure, mechanism, & applications.

Unit-4 **15 lectures**

Microwave Sources: Microwave Triodes, Introduction to vacuum tubes, Linear and O-Type Tubes, Klystron; two cavity and multi-cavity, velocity modulation process, bunching process, output power and beam loading, Reflex Klystron; Power Output and efficiency, Traveling wave tubes (TWT), Slow wave structures, Magnetron; Construction & operation, Conventional tube design, Hull or single-anode magnetron, Split-anode magnetron, Cavity magnetron, Applications of magnetron in Radar, Heating and Lighting, Health hazards.

Suggested Books:

1. David M. Pozar, Microwave Engineering, 4/e, Wiley India, 2012
2. Robert E. Collin, Foundation of Microwave Engineering, 2/e, Wiley India, 2012.
3. Samuel Y. Liao, Microwave Devices and Circuits, 3/e, Pearson Education, 2003.
4. George Kennedy & Bernard Davis, Electronic Communication system, 4th ed, Tata McGraw Hill Education Private Limited, 1999.
5. Leo Maloratsky, Passive RF and Microwave Integrated Circuits, Elsevier, 2006.

MTE104. EMI and EMC Technology

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

To provide the students with a comprehensive understanding of electromagnetic compatibility (EMC) and interference (EMI) for their future aspects of modern technologies. It will develop knowledge about the sources of electromagnetic interference and the need for EMC, common EMC/EMI terminology, techniques for identifying EMI sources, their measurements, and control techniques.

Course Learning Outcomes

At the end of this course, students will have

CO1. Information on Sources of EMI

CO2. Exposure of Test Methods for EMC/EMI

CO3.Understanding of EMI control techniques

CO4.Awareness of the regulatory landscape and compliance requirements related to EMI/EMC.

CO5.Knowledge of EMC best practices in product design and development.

Syllabus Contents

Unit-1 **10 lectures**

Basics of Electromagnetic Fields and Waves, Overview of Electromagnetic Compatibility and Interference, Importance of EMC/EMI in Modern Technologies, Key Concepts in Signal and Power Integrity, Conducted and Radiated Emissions.

Unit-2 **16 lectures**

EMI Sources: Antennas, Transmitters, Receivers, and Propagation; Techniques for Identifying EMI Sources; EMI Coupling Modes: Equipment Emissions and Susceptibilities; Common-Mode Coupling and Differential-Mode Coupling Mechanisms: Field to Cable, Ground Impedance, Ground Loop and Coupling Reduction Techniques; Other Coupling Mechanisms: Power Supplies and Victim Amplifiers.

Unit-3 **16 lectures**

Federal Communications Commission (FCC) and International Special Committee on Radio Interference (CISPR) standards and requirements; Conducted emissions test: Voltage method, Current probe method; Radiated Emission test: Open area test site, Semi-anechoic chamber; Conducted immunity test: Substitution method; Radiated immunity test: Reverberation and semi-anechoic chamber test; Electrostatic discharge test.

Unit-4 **18 lectures**

Designing for Electromagnetic Compatibility, Grounding Techniques: Grounding Schemes (Single Point, Multi-Point and Hybrid), Shield Grounding and Bonding; Shielding techniques: Apertures, Gaskets, Printed circuit board level; Filtering and Suppression Methods, Advanced

Strategies for EMC/EMI Mitigation. Shielding effects: Absorption loss, reflection loss, multiple reflection loss; Shielding modelling: metallic enclosure, EMI gasket, cavity resonance; Shielding Effectiveness measurements: Modified radiation method, Dual mode stirred chamber, Transverse electromagnetic (TEM) cell, Coaxial holder, Dual chamber test.

Suggested Books:

1. Dipak L. Sengupta, Valdis V. Liepa, Applied Electromagnetics and Electromagnetic Compatibility, Wiley Inter Science, 2006.
2. Clayton R. Paul, Introduction to Electromagnetic Compatibility, 2nd edition, Wiley, 2006.
3. Bogdan Adamczyk, Foundations of Electromagnetic Compatibility, Wiley, 2017.
4. Xingcun Colin Tong, Advanced Materials and Design for Electromagnetic Interference Shielding, CRC Press, 2008.
5. L. A. Kumar and Y. U. Maheswari, Electromagnetic Interference and Electromagnetic Compatibility, CRC Press, 2023.

SEMESTER II

MTC201. Advanced Communication Theory

Lecture Credits:4 **Total Lectures: 60**

Course Learning Objectives

This course provides an in-depth exploration of advanced communication theory with a focus on wave propagation and its various effects. The course covers the principles of modern communication systems, signal processing, and the effects of various propagation environments. Special attention will be given to the analysis and modeling of wireless channels, including the impact of fading, multipath, and atmospheric conditions on signal propagation. A significant portion of the course is dedicated to understanding the behavior and applications of random processes in communication.

Course Learning Outcomes

At the end of this course, students will have
CO1. Be able to model and analyze communication systems using random processes.
CO2. Understand and apply key concepts in wave propagation in different environments.
CO3. Evaluate the performance of communication systems under various propagation conditions.
CO4. Develop the ability to design and optimize communication systems considering theoretical and practical constraints.

Syllabus Contents

Unit-1 **12 lectures**
Brief history of communication systems, Analog and digital transmission, Review of Fourier analysis, linear systems; Digital Communication techniques, Sampling, quantization, and coding of signals, Modulation and demodulation of ASK, FSK, PSK, QAM, Multiplexing FDM, TDM.

Unit-2 **15 lectures**
Probability and random variables; Baye's theorem; Probability density and probability distribution functions, statistical expectation, and characteristic functions, various continuous and discrete distributions, multiple random variables, transformation of PDFs; Random Processes: description of random and ergodic process, mean, correlation and covariance functions, Stationary and non-stationary process, power and energy; Multiple random process; Random processes in frequency domain; Fourier transform of random processes, power spectrum of stochastic processes; Markov process.

Unit-3 **15 lectures**
Free space propagation model, 2-ray ground reflection model, Basic principle of Diffraction and scattering from obstacles, Atmospheric attenuation; Practical link budget design; Troposphere propagation; Indoor and Outdoor Propagation models, Fading characteristics and multipath; Large-

scale and Small-scale fading, Statistical channel models of fading: Rayleigh, Rician, Diversity techniques.

Unit-4 **18 lectures**

Multiple Access Techniques: Time Division Multiple Access (TDMA), Frequency Division Multiple Access (FDMA), Code Division Multiple Access (CDMA), Spread Spectrum Techniques, Direct sequence spread spectrum; Orthogonal Frequency Division Multiplexing (OFDM); MIMO Systems: Basic principles, spatial multiplexing, diversity gain; Channel capacity and Shannon's Theorem, Error control coding, Channel Estimation and Equalization; Methods to combat multipath fading; Introduction to Data communication, Wireless protocols: IEEE 802.xx, Network layers; Routing, mobility management, Transport layer protocols for wireless networks; Introduction to software defined radio.

Suggested Books:

1. D. C., Montgomery, & G. C. Runger, Applied statistics and probability for engineers. John Wiley & Sons, 2020.
2. T. S. Rappaport, Wireless communications: principles and practice. Cambridge University Press, 2024.
3. B. Sklar, Digital communications: fundamentals and applications. Pearson Publications, 2021.
4. B. A. Forouzan, Data communications and networking. Huga Media, 2007.
5. Hwei P. Hsu, Schaum's Outlines: Probability, Random Variables, and Random Processes, McGraw-Hill Education, 2019.
6. Simon Haykin, Digital Communication Systems, Wiley, 2013.

MTC202. Microwave Active Circuits

Lecture Credits:4 **Total Lectures: 60**

Course Learning Objectives

The main objective of this course is to give a comprehensive understanding and hands-on exposure to the various processes, industrial tools, protocols, and design specifics which are involved in Microwave Active Circuits Designing so that the students can design any Active circuit component like Amplifiers, Oscillators, Mixers, etc. for a specific application using industry-standard software after going through the complete procedural steps.

Course Learning Outcomes

At the end of this course, students will have

CO1 Familiarization of the various types of Microwave devices/components

CO2 Understanding of the Microwave Active components, their characteristics and their applications.

CO3 Pre-requisite knowledge to perform design of these microwave active components

CO4 Understanding of the current trends and scope of the microwave active circuits industry

Syllabus Content

Unit-1 **16 Lectures**

Introduction to RF and Microwave active circuits and its application to MMIC; Description of a complete system; Review of the Transmission Lines, Reflection coefficient & VSWR; Analytic solutions for Impedance matching using Quarter wave, Single stub and Double Stub Matching; Impedance matching using Z and ZY Smith Chart; Signal flow diagram; Derivation of Reflection and Transmission coefficients using Signal Flow Graphs; Derivation of Gain (Unilateral and Bilateral) using Signal Flow Graphs; Equivalent circuit and models of microwave diode and transistor.

Unit-2 **14 Lectures**

S-parameter description of active devices; Classification of RF amplifiers for low noise, medium power and high-power application; Biasing, stability and Noise consideration; Matching considerations for maximum power and minimum reflection; Different types of Power Amplifiers and their characteristics.

Unit-3 **14 Lectures**

Design of microwave amplifier circuits: Narrow band amplifiers; Unilateral and Bi-lateral amplifier designs, Input and Output Stability Circles, broad band amplifiers, broadband matching; Potentially Stable and Unconditionally Stable Conditions; Constant Gain Circles; Unilateral Figure of Merit; Maximum Available Gain and Maximum Stable Gain; Low Noise Amplifiers: Input and Output Stability Circles for LNA; Considerations on the improvement of S/N ratio; 3-dB compression Points; Intermodulation Products; Dynamic Range; Spurious Free Dynamic Range (SFDR) considerations; Gain bandwidth product; Multistage Amplifiers; Cascaded Amplifier Designs.

Unit-4 **16 Lectures**

Classification and Design of microwave oscillators: characteristics and performance evaluation; Bark-Hausen Criterion for Oscillation; Types of Oscillators: Negative Resistance and Positive Feedback Oscillators; Signal Flow Graphs for Single Port and Dual Port Oscillators; Conversion of Dual port to Single port Oscillators; Phase locked loop circuit, Voltage Controlled Oscillators (VCOs), Phase Noise; Dielectric Resonator based Oscillators. Basic mixer concept: Frequency domain characteristics, Losses in Microwave Mixers; Single ended mixer design, Single and double balanced mixer; Image Rejection Mixer and Harmonic Mixer; Microwave Detectors; Microwave Switches: Single Pole Single Throw (SPST) and Single Pole Double Throw (SPDT) Switches.

Suggested Books:

1. Microwave Transistor Amplifier: Analysis and Design, Gonzalez Guillermo, Prentice Hall,1984.
2. Microwave Circuit Analysis and Amplifier Design, Samuel, Y. Liao, Prentice Hall, 1987.
3. High-Frequency Amplifier, Ralph S. Carson, Wiley-Interscience 1982.
4. Microwave Engineering 4^{th} edition, D. M. Pozar, John Wiley & Sons, 2011.

MTCL203. Advanced Antenna Theory and Techniques

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

The course Antenna Theory and Technique aims to provide a comprehensive understanding of the theory of various antennas. Students will learn electromagnetic radiation theory and antenna analyzing parameters such as directive gain, polarization characteristics, beam width, and efficiency. They will explore various types of antennas and their applications in communication systems. Students will learn to derive the field components of various antennas like wire antennas, aperture antennas, parabolic reflector antennas and microstrip patch antennas. Students will study various feed techniques such as probe feed, microstrip line feed, and insert feed. The course also covers circularly polarized microstrip antennas. Students will also learn antenna arrays, including linear and planar arrays with Binomial and Chebyshev distribution patterns. Finally, students will learn modern antennas, including mobile handset and base station antennas, and they will also gain insights into feed networks for microstrip antenna arrays. This course will provide the necessary theoretical foundations to design, analyze, and optimize antennas.

Course Learning Outcomes

At the end of this course, students will have

CO1. To understand the radiation mechanism in antenna and various antenna parameters.

CO2. Learn to derive the field components of a wire antenna like a dipole, loop, helix and Yagi-Uda.

CO3. Learn to compute the field components of various aperture antennas.

CO4. Develop skills in solving field components for square, rectangular and circular microstrip patch antenna

CO5. Learn the linear and planar antenna arrays and provide the knowledge of beam scanning using Binomial and Chebyshev distribution.

Syllabus Contents

Unit-1 **15 lectures**

Theory & mechanism of electromagnetic radiation, Coordinate system and transformation of field quantities in different coordinate systems, Basic concept and definition: Input impedance, Bandwidth, Gain, Directivity, Radiation Pattern, Beam width, Polarization, Co-polarization, Cross-polarization, Axial ratio, Efficiency; Concept of Far-field and Near Field, Introduction to RADAR and its equation. Radiation Integrals and Auxiliary Potential Functions and their application to the analysis of wire antenna, dipole, loop antenna, helix antenna and Yagi-Uda Antenna.

Unit-2 **15 lectures**

Introduction to two-element Array; Aperture antenna: Introduction, theory of aperture antenna including the Fourier transform method and application to slot, waveguide and horn antenna; Design consideration of parabolic reflector antenna.

Unit-3 **15 lectures**

Microstrip antenna: Rectangular and Circular patch; Feed to microstrip antenna: probe feed, microstrip line feed, aperture feed, electromagnetically fed microstrip patch; Circularly polarized microstrip antenna. Effect of Perfect Electric Conductors (PEC) and Perfect Magnetic Conductors (PMC) on the performance of Antenna.

Unit-4 **15 lectures**

Theory of linear array: Two-element and multi-element array, isotropic and non-isotropic array, Binomial and Chebyshev distribution; Planar array, phased array and adaptive antenna; Feed network of microstrip antenna array; MIMO Antenna, Antenna for mobile communication: handset antenna and base station antenna.

Suggested Books:

1. C. A. Balanis, “Antenna Theory Analysis and Design,” 3rd Ed. Wiley Interscience,2009.
2. J. D. Kraus, Ronald Marhefka, and Ahmad S. Khan "Antennas and Wave Propagation” 5th Ed. McGraw Hill Education, 2017.
3. Warren L. Stutzman and Gary A Thiele, “Antenna theory and design” 2nd Ed. Wiley India Pvt Ltd., 2009.
4. I J Bahl and P Bhartia, “Microstrip Antennas” Artech House,1980.
5. R E Collin, “Antennas and Radio Wave Propagation”, 4th Ed. McGraw-Hill Inc., US,1985.
6. Robert S Elliot, “Antenna Theory and Design” Revised Ed. Wiley-IEEE Press, 2003.

Advanced Antenna Theory and Techniques Laboratory

Practical Credits: 2 **Total Lectures: 60**

List of Experiments:

1. To design a Dipole antenna and analysis of its various parameters.
2. Study the Effect of Perfect Electric Conductor (PEC) and Perfect Magnetic Conductor on dipole antenna’s performance.
3. To study and design of rectangular and circular microstrip patch antennas.
4. To study the effect of various feeds in the microstrip patch antenna.
5. To study and design of Aperture antenna (rectangular slot)
6. To study and design of circularly polarized microstrip patch antenna.
7. To study and design of planar microstrip array antenna.
8. Measurement of antenna parameters using a Vector Network Analyzer.
9. Measurement of the radiation pattern of microstrip patch antennas, and analysis of co-polarization and cross-polarization.

MTEL201. Computational Electromagnetics

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

The course on Computational Electromagnetics aims to provide students with a comprehensive understanding of numerical methods and computational techniques used to solve electromagnetic problems. Students will gain a knowledge of Maxwell's equations and boundary conditions, along with various numerical methods and their classifications. The course will delve into the finite difference time domain (FDTD) method, including its principles, formulations, stability, accuracy, and applications in microwave circuit simulation. Additionally, students will explore contour integration, conformal mapping, and integral equation methods, including the method of moments. The course will conclude with an introduction to advanced topics like the finite element method, Monte Carlo methods, mode matching methods, coupled cavity methods, and the lattice Boltzmann method.

Course Learning Outcomes

At the end of this course, students will have
CO1. To understand the fundamental principles of electromagnetics.
CO2. Explore FDTD methods used in computational electromagnetics.
CO3. Learn conformal computational techniques to solve electromagnetic problems.
CO4. To explore advanced topics in microwave engineering through computational approaches.

Syllabus Contents

Unit-1 **12 lectures**
Review of Maxwell's computational equations, Boundary conditions Dirichlet and Neumann. Basics of Computational Methods, Overview of numerical methods, Classification of EM problems and respective methods, 2D and 3D modelling.

Unit-2 **18 lectures**
Cell structures, grid pattern, and fundamentals of Finite difference technique. Basic principles and formulation of Parabolic, Hyperbolic, and Elliptic model; Implicit and Explicit method, Stability and Accuracy, 3D Yee's Model. Source Excitation in FDTD, Perfectly Matched Layer and Absorbing Layer, Modelling and simulation of microwave circuits, and Application of FDTD method.

Unit-3 **16 lectures**
Direct Construction Approach for Green's Function, Eigenfunction Expansion of Green's Function. Conformal mapping, Cauchy's integral theorem, and Calculus of Residues. Fundamental of Method of Moments (MoM), Integral Equations for electromagnetic problems, Green's functions and Basis functions, and Solution techniques for MoM.

Unit-4 **14 lectures**

Fundamentals of Finite Element Method (FEM), Variational principles and weak formulations, Mesh generation and refinement, Finite Element Discretization and Governing Equation. Introduction to Monte Carlo Methods, and Mode Matching Methods.

Suggested Books:

1. M. N. O. Sadiku, Computational Electromagnetics with MATLAB, CRC Press, Fourth Edition, 2018.
2. D. B. Davidson, Computational Electromagnetics for RF and Microwave Engineering. Cambridge University Press, Second Edition, 2010.
3. R. Garg, Analytical and Computational Methods in Electromagnetics. Artech House, 2008.
4. J.-M. Jin, Theory and Computation of Electromagnetic Fields. John Wiley & Sons, 2015.
5. K. Chang, Encyclopedia of RF and Microwave Engineering (6 Volume Set), Second Edition. Wiley, 2023.

Computational Electromagnetics Laboratory

Practical Credits: 2 **Total Lectures: 60**

List of Experiments:

Computational Electromagnetics Laboratory using MATLAB or Python Programming

1. To implement finite difference approximations for first and second derivatives.
2. To compare the derivative of the following function with its Finite Difference Technique processed form and plot it.
   i) sin (x) and sin (cos (tan (x^2))) by forward difference technique
   ii) sec (x) by backward difference technique
   iii) 1/x by central difference technique
3. To simulate the propagation of a plane wave using the 1D FDTD method.
4. To solve the heat diffusion problem by Finite Difference Time Domain (FDTD) Technique.
5. To solve the wave problem in a single dimension by FDTD Technique.
6. To solve the Elliptic PDE for Laplace equation by using the FDTD Technique.
7. To analyze the dispersion error and Courant stability criterion.
8. To calculates the 2D Green's function for the Helmholtz equation in free space.
9. To find the charge distribution on the rod using MOM/FDTD/FEM, where metal rod length of 1m is maintained at 2.0V potential.
10. To form global matrices of the Finite Element Method, consider the global stiffness matrix assembly for a simple 1D problem with 3 elements and 4 nodes.

MTEL202. RADAR Technology

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

The main objective of this course is to give a comprehensive understanding and hands-on exposure to the various processes, industrial tools, protocols, and applications which are involved in RADAR systems so that the students can understand the principles behind RADAR Communication and its system perspectives.

Course Learning Outcomes

At the end of this course, students will have

CO1 Familiarization of the various types of RADARs

CO2 Understanding of the RADAR components, their characteristics and their applications.

CO3 Pre-requisite knowledge to understand detection theory and signatures used in RCS and its allied components

CO4 Understanding of the current trends and scope of the RADAR systems industry

Syllabus Content

Unit-1 **16 Lectures**

Introduction to RADAR - definition and basic concepts, Block Diagram; Friss free space equation and RADAR equation; RADAR equation under different cases – range performance, Signal to Noise Ratio Considerations, Power requirements at transmitter and receiver ends; Radar Cross Section (RCS) – Different types, detectability of different geometries and their RCS signatures; Introduction to Stealth Technology.

Unit-2 **14 Lectures**

Theory of detection, Detectability of the different RADAR signatures; Clutter Theory, Representation of Clutter under different conditions, sea clutter, urban clutter, desserts; Introduction to the concept of Ducting, Conditions at which ducting takes place; Minimum detectible signal, Effect of weather, Land and Sea Clutter effects on the EM signals, Detection of various Targets.

Unit-3 **14 Lectures**

Types of RADAR – Continuous wave (CW) and Frequency modulated Radar, Moving Target Indicator (MTI) and Pulsed Doppler Radar, Tracking Radar, Synthetic Aperture RADAR (SAR) and Inverse Synthetic Aperture RADAR (ISAR); Light Detection and Ranging (LIDAR), its components, transmitters and receivers in LIDAR.

Unit-4 **16 Lectures**

Elements of RADAR – Transmission details, Klystron amplifier, Travelling wave tubes (TWT) Amplifier, Magnetron Amplifier, Solid State Transmitters, Phase shifters and its application in Transmitters; Receiver Details, Noise Figure, Mixers, Displays, Pulse Position Indicator (PPI) and Digital Displays; Circulator and Antenna elements, Signal Processing design, Matched filter

Receiver, Constant False Alarm rate (CFAR) Receivers. Examples of different types of RADAR in operation (application specific), Radio Frequency Identification (RFID), propagation of RADAR Waves, Round of Earth approximation, Refraction, Diffraction, Attenuation, Over the Horizon (OTH) RADAR, Air Surveillance RADAR, Bistatic RADAR, millimeter waves and future of RADAR Technology.

Suggested Books:

1. Introduction to RADAR Systems, Merill L Skolnik, Tata Mc Graw Hills, 2003.
2. Introduction to RADAR analysis, Bassem R. Mazhafa, CRC Press, 2000.
3. RADAR Signal analysis and processing using MATLAB, Bassem R. Mazhafa, CRC Press, 2008.

RADAR Technology Laboratory

Practical Credits: 2 **Total Lectures: 60**

List of Experiments:

RADAR Technology Laboratory using MATLAB

1. To study the different components of RADAR Communication System. Measurement of Range and Velocity using RADAR kit.
2. To establish the Friss equation and RADAR Range equation for different power levels and RCS
3. To plot the Pulse Position Indicator (PPI) using MATLAB GUIDE
4. To write a MATLAB code to understand Constant False Alarm Rate (CFAR)
5. To plot the RCS responses for different objects
6. To plot the Clutter response along with RCS of different objects
7. To simulate the concept of SAR using Simulink on MATLAB
8. To simulate the concept of ISAR using Simulink on MATLAB

MTE203. Metamaterials and Metasurfaces: Concepts and Applications

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

Electromagnetic metamaterials and Metasurfaces find potential applications in advanced communication, defence and energy sectors by leading to innovative designs of filters, sensors, radomes/shields, antennas, intelligent reflectors, energy harvesting structures, as well as superlenses. The subject of electromagnetic metamaterials is an interdisciplinary one, involving fields as circuit design, electromagnetics, classical optics, solid state physics, microwave / antenna engineering and material sciences. Besides the conventional spatial metamaterials, recently, there has been an emphasis on using time-modulation to realize extensive EM properties. In this course, students learn the basic concepts of Metamaterials and Metasurfaces and their application in the design of filters, sensors, radomes/shields, antennas, intelligent reflectors, energy harvesting structures, as well as superlenses.

Course Learning Outcomes

At the end of this course, students will have

CO1. To understand the basic concepts of Metamaterials and Metasurfaces
CO2. To learn the theory and properties of negative permittivity and permeability media.
CO3. To learn the Composite Right-Left Handed (CRLH) Transmission Lines
CO4. To learn the concept of Negative and Zeroth-Order Resonators
CO5. To learn the Artificial High-Impedance Surface, Artificial Magnetic Conductor (AMC), Electromagnetic Bandgap Structures (EBG)

Syllabus Contents

Unit-1 **14 lectures**
General Historical perspective and idea of Metamaterials (MTMs), Maxwell's Equations and EM Boundary Conditions, Formulation and Solution of Wave-equation, Phasor Concepts, Plane-wave propagation in simple medium, Dispersive model for the dielectric permittivity, Phase velocity and group velocity.

Unit-2 **16 lectures**
Metamaterials and homogenization procedure, Ionospheric Plasma, Metals and plasmons at optical frequencies, Wire mesh structures such as low-frequency plasmas, Diamagnetism in a stack of metallic cylinders, Split-ring resonator media; Media with negative permittivity and permeability: theory and properties, Origins of negative refraction and other properties, Design of Superlenses for optics.

Unit-3 **14 lectures**
Ideal Homogeneous CRLH TLs (Composite Right-Left Handed Transmission Lines), LC Network Implementation and distributed 1D CRLH Structures, Conversion from Transmission Line to

constitutive Parameters, Dual-band and enhanced band guided wave components. Negative and Zeroth-Order Resonators, Zeroth-Order Resonators based antenna, Backfire-to-Endfire (BE), Leaky-Wave (LW) Antennas and their Electronic Scanning.

Unit-4 **16 lectures**

Artificial High-Impedance Surface design, Artificial Magnetic Conductor (AMC), EBG (Electromagnetic Bandgap Structures), Gain-enhancement in antennas using MTM superstrates, Design of FSS Radomes for EMI Shielding and Absorbers, Beam-steering using Intelligent Reflecting Surfaces (IRS).

Suggested Books:

1. D. K. Cheng, Field and Wave Electromagnetics, Pearson Education Asia Ltd, Second Ed. 2006.
2. S. A. Ramakrishna and T. M. Grzegorczyk, Physics and Applications of Negative Refractive Index Materials, CRC Press, Taylor & Francis Group and SPIE Press, 2009.
3. G. V. Eleftheriades and K. G. Balmain, Negative Refraction Metamaterials: Fundamental Principles and Applications, Copyright: IEEE, John Wiley & Sons, Inc., Hoboken, New Jersey, 2005.
4. C. Caloz and T. Itoh, Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, The Engineering Approach, John Wiley & Sons, Inc., Hoboken, New Jersey, 2006.

MTE204. Satellite Communication System

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

The course on Satellite Communication System aims to provide students with a comprehensive understanding of satellite systems, knowledge of orbits and satellite launching. Students will gain a knowledge of satellite sub-systems, link analysis, G/T and C/N ratio analysis. The course will delve into atmospheric effects on propagation and knowledge of different multiple access techniques. Additionally, students will explore the earth station technologies. The course will conclude with an introduction of satellite packet communication methods and protocols.

Course Learning Outcomes

At the end of this course, students will have
CO1. To understand the fundamental principles of satellite systems.
CO2. Explore satellite sub-systems, link analysis, and analysis of G/T and C/N ratio.
CO3. Learn about the effects of atmosphere on propagation and multiple access techniques.
CO4. Develop the knowledge of earth station technologies.
CO5. The knowledge of satellite packet communication methods and protocols.

Syllabus Content

Unit-1 **14 lectures**
Introduction to Satellite Systems, Orbit and Description: A brief History of Satellite Communication, Satellite Frequency bands, Satellite Systems, Applications, Orbital Period and Velocity, Effects of Orbital inclination, Azimuth and Elevation, Coverage and Slant range, Eclipse, Orbital perturbations, Placement of a Satellite in a Geo-Stationary Orbit, Satellite systems in India, Propagation effects: Introduction, Atmospheric Absorption, Cloud Attenuation, Tropospheric and Ionospheric Scintillation and Low angle fading, Rain Induced attenuation, rain-induced cross polarization interference, applications of satellite.

Unit-2 **14 lectures**
Satellite Sub-Systems: Altitude and orbit control system, TT & C Sub-System, Altitude control Sub-System, Power Systems, Communication Subsystems, Satellite antenna Equipment. Satellite Link: Satellite uplink and downlink analysis; Spot beam, multiple beam, frequency reuse, Basic transmission theory, Satellite receiving systems, system noise temperature and Gain to noise temperature (G/T) ratio, Basic Link Analysis, Interference Analysis, Design of satellite links for specified carrier-to-noise ratio (C/N), (with and without frequency Re-use), Link Budget.

Unit-3 **14 lectures**
Multiple Access: Frequency Division Multiple Access (FDMA), Intermodulation, Calculation of C/N. Time Division Multiple Access (TDMA), Frame structure, Burst structure, Satellite Switched TDMA Onboard processing, Demand Assignment Multiple Access (DAMA) – Types of Demand Assignment, Characteristics, CDMA Spread Spectrum Transmission and Reception.

Unit-4 **18 lectures**

Earth Station Technology: Transmitters, Receivers, Antennas, Tracking systems, Terrestrial Interface, Power Test methods, Lower Orbit Considerations. Satellite Navigation & Global Positioning Systems: Radio and Satellite Navigation, GPS Position Location principles, GPS Receivers, GPS C/A code accuracy, Differential GPS, Global Navigation Satellite System (GNSS), Indian Regional Navigation Satellite System (IRNS).

Satellite Packet Communications: Message Transmission by FDMA: M/G/1 Queue, Message Transmission by TDMA, TDMA Frame, PURE ALOHA-Satellite Packet Switching, Slotted Aloha, Non-terrestrial satellites, Low Earth Orbit (LEO) satellites, small satellite, CubeSat.

Suggested Books:

1. Timothy Pratt, Charles Bostian and Jeremy Allnutt, Satellite Communications, 2nd Edition, John Wiley & Sons, 2003.
2. Wilbur L. Pritchand, Robert A Nelson and Henri G. Suyderhoud, Satellite Communication Engineering, 2nd Edition, Prentice Hall, 1993.
3. Tri. T.Ha, Digital Satellite Communications, 2nd Edition, McGraw Hill.1990,
4. Dennis Roddy, Satellite Communications, 2nd Edition, McGraw Hill, 1996.
5. M. Richharia, Satellite Communications: Design Principles, 2nd Edition, BS Publications, 2003.
6. K. N Raja Rao, Fundamental of Satellite Communications, Prentice Hall India Pvt., Limited, 2004.

SEMESTER III

MTCL301. Next-Generation Communication Systems

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

This course delves into the design, analysis, and implementation of next-generation communication systems. It covers cutting-edge technologies such as 5G/6G, massive MIMO, millimeter-wave communications, software-defined networks, and quantum communication. The course emphasizes both theoretical foundations and practical applications, preparing students to contribute to the future of wireless communications.

Course Learning Outcomes

At the end of this course, students will have

CO1. Understand the architecture and key technologies driving next-generation communication systems.

CO2. Analyze the performance and limitations of current and future wireless communication systems.

CO3. Develop skills to design and evaluate next-generation communication protocols and systems.

CO4. Gain hands-on experience with modern communication tools and simulation environments.

Syllabus Contents

Unit-1 **12 lectures**

Introduction to mobile communication system, evolution from 1G to 5G (GSM, GPRS, LTE, LTA etc), Key requirements and use cases for next-generation systems; Overview of 5G New Radio (NR) and 6G vision.

Unit-2 **16 lectures**

5G Radio Access Network (RAN) architecture and components; 5G NR (New Radio) and core network architecture; deployment scenarios; Functional split options in 5G RAN; Network slicing and software-defined networking (SDN); Security challenges in 5G; Introduction to Open-RAN alliance.

Unit-3 **16 lectures**

Fundamentals of URLLC, Techniques for achieving low latency and high reliability; Applications: Autonomous vehicles, industrial automation, Massive Machine-Type Communication (mMTC) and Internet of Things (IoT); Characteristics of mMTC, IoT protocols and standards, Challenges and solutions for massive connectivity.

Unit-4 **16 lectures**

Fundamentals of millimeter-wave communication; Challenges: Propagation, beamforming, hardware design, Concept of Massive Multiple-Input Multiple-Output (MIMO) and spatial multiplexing; Introduction to Li-Fi; AI and Machine Learning in Communication Systems; Role of AI in network management and optimization; Machine learning techniques for communication networks; AI-driven wireless resource allocation.

Suggested Books:

1. Dahlman, E., Parkvall, S., & Skold, J. 5G NR: The Next Generation Wireless Access Technology. Academic Press, 2018
2. Huang, K. C., & Wang, Z., Millimeter wave communication systems. John Wiley & Sons, 2011.
3. Milovanovic, D. A., Bojkovic, Z. S., & Fowdur, T. P. (Eds.). Driving 5G Mobile Communications with Artificial Intelligence Towards 6G. CRC Press, 2023
4. Chen, W., Gaal, P., Montojo, J., & Zisimopoulos, H. Fundamentals of 5G communications: Connectivity for enhanced mobile broadband and beyond. McGraw-Hill Education, 2021.
5. Milovanovic, D. A., Bojkovic, Z. S., & Fowdur, T. P. (Eds.). (2023). Driving 5G Mobile Communications with Artificial Intelligence Towards 6G. CRC Press.

Next-Generation Communication Systems Laboratory

Practical Credits: 2 **Total Lectures: 60**

List of Experiments:

1. To study and analyze the 5G NR waveforms using 5G toolbox in MATLAB.
2. To study and simulate 5G NR end-to-end wireless communication links in MATLAB.
3. To study the multiple-input multiple-output (MIMO) system in MATLAB
4. To study the Orthogonal Frequency Division Multiplexing (OFDM) in MATLAB.
5. To study the role of AI in network management and optimization using MATLAB.
6. To capture and study the Live RF Signals using Software defined radio (SDR) kit.
7. To design a communication system by implementing 8,16 QAM using SDR kit.
8. To design a MIMO system with multiple antennas in SDR and evaluate its performance.
9. To study 5G NR Waveform Generation and Testing using 5G testbed.
10. To study the End-to-End 5G Network and Performance Analysis using 5G testbed.
11. To study the generation and capture of live 5G Signals using antenna and RF instruments.

MTCP302. Minor-Project

Practical Credits: 6

Each student has to take up a mini-project based on the hardware and/or software in III semester which will be of 6 credits i.e. 150 marks. The project evaluation will be based on the project report submitted by the student and a presentation to a panel of three examiners from the Department faculty as decided by the PG Committee of Courses of the Department every year. The 50% of the marks will be based on continuous internal assessment evaluation throughout the semester.

MTE301. Terahertz, Nanophotonics and Plasmonics

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

The main objective of this course is to give a comprehensive understanding and hands-on exposure to the various processes, industrial tools, protocols, and design specifics which are involved in Nano Photonics and Plasmonics so that the students can understand the interaction of Light frequencies and THz frequencies with metal and dielectrics. This is most needed for future communication systems largely envisaged for extreme high frequencies.

Course Learning Outcomes

At the end of this course, students will have

CO1 Familiarization of the various types of Nano photonic devices/components

CO2 Understanding of the Nano photonics and plasmonic components, their characteristics and their applications.

CO3 Pre-requisite knowledge to perform design of these nano photonic and plasmonic components

CO4 Understanding of the current trends and scope of the THz communication industry

Syllabus Content

Unit-1 **14 Lectures**

Motivation, brief introduction to nanophotonics, plasmonics and metamaterials; Overview of current status of research in academia and industry in the fields of nanophotonics, plasmonics, and metamaterials; Electromagnetic theory of light; Electromagnetic properties of material; Constitutive relationships and material parameters; Electromagnetic waves in dielectric media; Polarization of light; Reflection and refraction; Fresnel equations; Absorption, dispersion, and scattering of electromagnetic waves.

Unit-2 **14 Lectures**

Electromagnetic waves in periodic structures-Matrix theory of dielectric layered media; Fabry–Perot Etalon; Bragg Grating; 1D Photonic crystals — Bloch modes, Dispersion relation and photonic band structure; Real and reciprocal lattices; 2D and 3D Photonic crystals; Bandgap engineering; Devices based on photonic crystals; Emerging Applications of Photonic Crystals.

Unit-3 **16 Lectures**

Optical properties of metals; Surface Plasmon Polaritons (SPP) on planar interfaces; SPP modes for shape resonances, gratings, and light scattering from rough surfaces; Applications of SPPs: Surface Enhanced Raman Spectroscopy (SERS), Sensing, Subwavelength properties in light-guiding and plasmonic circuitry, plasmonic subwavelength enhanced transmission of light; Plasmonic nanoparticles; Localized plasmon resonances; Chain of plasmonic nanoparticles; Applications of localized plasmon resonances.

Unit-4 **16 Lectures**

Metamaterials concept; Effective medium theories; Negative-permittivity and negative-permeability metamaterials; Double-Negative Materials; Perfect absorbers; Super lens, Hyperbolic metamaterials and application in high-resolution imaging; Introduction to Metasurfaces; Perfect control over transmission and reflection using metasurfaces; Introduction to Transformation Optics; Transformation optics and metamaterials, Introduction to alternative materials; Nanofabrication: Thin films —Physical methods; Chemical methods; Epitaxy; Photolithography, Non-optical lithography; Pattern transfer; Nanophotonic characterization.

Suggested Books:

1. Plasmonics: Fundamentals and Applications, S. Maier, Springer (2007)
2. Fundamentals of Photonics, 3rd Edition. by Bahaa E. A. Saleh, Malvin Carl Teich.(2019)
3. Fundamentals and Applications of Nanophotonics. by Joseph W. Haus (2016)
4. Optical Metamaterials: Fundamentals and Applications, W. Cai and V. Shalaev Springer (2010)

MTE302. Industrial Microwaves Technology

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

This subject provides a comprehensive understanding of microwave heating principles, technology, and applications. It will explore the physics behind microwave heating, including dielectric properties, permeability, and frequency effects. The course will cover the technical aspects of microwave heating systems, such as components, generators, waveguides, applicators, and materials processing. Furthermore, students will gain insights into the principles and applications of microwave medical applications and plasma systems.

Course Learning Outcomes

At the end of this course, students will have
CO1. Understand the fundamentals of microwave heating.
CO2. Explain the dielectric properties and permeability of materials and microwave heating.
CO3. Understand the components and systems used in microwave heating and its regulations.
CO4. Analyse the applications of microwave medical application.

Syllabus Contents

Unit-1 **12 lectures**
Microwave as a Heat Source, Microwave Heating of Substrates in Solutions, Microwave Heating of a Solid Substance, Difference between Microwave Heating and Conventional Heating. Heating Methods: Direct Heating, Selective Heating, and Hotspots or Local Heating. Stages of Superheating, and its applications.

Unit-2 **18 lectures**
Parameters in Microwave Heating: Dielectric constant, electric and magnetic permeability. Mechanism of microwave heating, including dipole rotation, conduction loss, and dielectric and magnetic loss heating. Penetration depth, Skin depth, and Frequency effects. Overview of electromagnetic and thermodynamics simulations. Basics of Microwave oven concepts. Microwave Chemistry in Liquid Media. Microwave Materials Processing in Solid Media. Hybrid cooking system.

Unit-3 **14 lectures**
Components in Microwave Heating Equipment: Microwave Generators, Waveguides, Isolators, Power Monitors, Tuners, Iris, and Short Plungers. Single-mode versus Multimode Applicators and Temperature Measurements. Interaction between electromagnetic waves and biological materials. Microwave cancer diagnosis and thermal ablation. Mathematical Models for the Complex Permittivity of Biological Tissue.

Unit-4 **16 lectures**
Common Techniques for Microwave Cancer Diagnosis. Antennas and wearable sensors for biomedical diagnostics and therapeutic applications. Microwave Plasma Systems for Plasma

Processing at Reduced Pressures, Microwave-assisted Plasma generation. Hybrid Microwave Plasma System with Magnetized Hollow Cathode. RF High-Power Sources. LINAC Basic Concepts and Constituents. Role of Linear Accelerators in Health Care. Accelerator-Based Radiation Therapy.

Suggested Books:

1. S. Horikoshi, R. F. Schiffmann, J. Fukushima, and N. Serpone, Microwave Chemical and Materials Processing. Springer, First Edition, 2017.
2. G. B. Awuah, H. S. Ramaswamy, and J. Tang, Radio-Frequency Heating in Food Processing. CRC Press, First Edition, 2014.
3. C. Li, M.-R. Tofighi, D. Schreurs, and T.-S. J. Horng, Principles and Applications of RF/Microwave in Healthcare and Biosensing, Academic Press, First Edition, 2016.
4. L. Wang, Electromagnetic Waves and Antennas for Biomedical Applications, IET, 2021.
5. L. Bardos and H. Barankova, Microwave Plasma Sources and Methods in Processing Technology. John Wiley & Sons, First Edition, 2022.

MTE303. MEMS Design and Technology

Lecture Credits: 4 **Total Lectures: 60**

Course Learning Objectives

In this course, students explore Radio-Frequency Microelectromechanical System (RF MEMS) technology and its use in microwave systems. They learn about MEMS fabrication techniques and key materials used in RF MEMS devices. The course focuses on developing mechanical modelling skills for MEMS devices like switches, filters, and antennas to improve performance through analysis. Students gain knowledge of various MEMS switches, such as capacitive shunt and series switches, including their physical properties and electromagnetic behaviour. The course covers modelling principles for mechanical filters, micromachined filters, surface acoustic wave filters and phase shifters. Designing and fabricating MEMS switches with packaging considerations and ensuring device reliability. Students also study micromachined transmission lines, coplanar transmission lines, and micromachined waveguide components, learning techniques to optimize antenna performance and integrate MEMS devices effectively in practical applications.

Course Learning Outcomes

At the end of this course, students will have
CO1. Understanding of RF MEMS Fundamentals and Fabrication
CO2. Knowledge about mechanical modeling of MEMS Devices
CO3. Exposure to design and fabrication of MEMS Switches
CO4. Concepts of MEMS Transmission line, Filters, Phase Shifters, antennas and their integration

Syllabus Contents

Unit-1 **12 lectures**
RF MEMS for microwave applications, MEMS technology and fabrication, mechanical modelling of MEMS devices, MEMS materials; BioMEMS; VLSI and Micro-electromechanical Technologies for MEMS.

Unit-2 **16 lectures**
Introduction to MEMS switches; Capacitive shunt and series switches: Physical description, circuit model and electromagnetic modelling; Design of MEMS switches; Techniques of MEMS switch fabrication and packaging. Micromachined filters, surface acoustic wave filters,Various types of MEMS phase shifters; Ferroelectric phase shifters.

Unit-3 **18 lectures**
Introduction to Electrostatic Sensors and Actuators, Interdigitated Finger Capacitors, Applications of Comb Drive Devices. Thermal Sensing and Actuation: Introduction, Sensors and Actuators Based on Thermal Expansion, Thermal Couples, Thermal Resistors, Applications. Magnetic Actuation: Essential Concepts and Principles, Fabrication of Micromagnetic Components, Case Studies of MEMS Magnetic Actuators.

Unit-4 **14 lectures**

Role of MEMS packages, types of MEMS packages, module packaging, packaging materials and reliability issues.

Suggested Books:

1. V. K.Varadan, K. J. Vinoy, and K.J. Jose, RF MEMS and their Applications, John Wiley & Sons. 2002.
2. G.M. Rebeiz, MEMS: Theory Design and Technology, John Wiley & Sons. 1999.
3. H. J. De Los Santos, RF MEMS Circuit Design for Wireless Communications, Artech House. 1999.
4. W. Trimmer, Micromechanics & MEMS, IEEE Press. 1996.
5. M. Madou, Fundamentals of Microfabrication, CRC Press. 1997
6. S. M. Sze, Semiconductor Sensors, John Wiley & Sons. 1994

SEMESTER IV

MTCP401. Major Project

Practical Credits: 16

Students will be required to work on the major project in Semester IV which will be of 16 credits i.e. 400 marks and can be carried out in collaboration with an R& D Organization or industry of repute in the related areas of microwave and communication. The collaboration is to be established by the project coordinator.

All students will have to go through a mid-semester project evaluation which will be of 30% of total marks i.e. 120 marks and will be facilitated by the project coordinator and internal supervisor of the student either through online or offline mode.