Master of Technology

(M.Tech.) Degree Program

Microwave and Communication Engineering

Outcome Based Syllabus

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

MASTER OF TECHNOLOGY

in

MICROWAVE AND COMMUNICATION ENGINEERING

Syllabus

(2025 Admission Onwards)

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF ELECTRONICS
COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY
Kochi - 682 022, India

Contents

DEPARTMENT OF ELECTRONICS

VISION

To nourish and tone the legendary status in the field of Electronics by inspiring knowledge seekers to meet the challenges of evolving technology through innovative practices.

MISSION

M1 : *To strengthen technical education in Electronics for graduates by utilising the state of the art facilities and adopting latest trends in technology*

M2 : *To impart knowledge and skills so as to kindle innovation & creativity among students leading to a progressive global career in industry & academy*

M3 : *To facilitate best opportunities for challenging young minds fostered through interaction with leading research organizations as well as industry*

M4 : *To develop and sustain a culture of focused work based on societal needs*

M5 : *To provide with avenues for recognition by participation in challenging platforms, while upholding values, ethics and professionalism*

PROGRAM EDUCATIONAL OBJECTIVES

Graduates will have

PEO1	Graduates apply their technical competence in theory, hardware, software and EDA tools to solve engineering problems in their chosen specialization
PEO2	Graduates apply their communication skill, leadership quality, reasearch aptitute and ethics to build a strong career in thier chosen areas of specialization through continous learning
PEO3	Graduates acquire the capacity for higher professional positions in academics/industry/research and entreprenuership

PEO-Mission Matrix:

Mission	PEO1	PEO2	PEO3
M1	✓	✓	
M2		✓	✓
M3	✓		✓
M4	✓		✓
M5	✓		✓

Programme Outcomes: At the end of the programme, the student will be able to

PO1	Apply engineering knowledge to carry out research, and analysis of technical problems.
PO2	Develop solutions and design system components or processes that meet the specified needs considering all constraints.
PO3	Create, select, and apply appropriate techniques, resources, and modern engineering tools.
PO4	Ability to communicate effectively by preparing and presenting technical reports.
PO5	Apply professional ethics and responsibilities in engineering practice.
PO6	Engage in lifelong learning independently to enhance knowledge and skills that can contribute to the continuous improvement of individuals and society.

Programme Specific Outcomes: At the end of the programme, the student will be able to

PSO1	Acquire competency to design, analyze and evaluate the performance of a wireless communication system, using analytical skills, advanced simulation software and laboratory techniques.
PSO2	Be proficient in the industry standard simulation tools in 3DEM /circuit, wireless system design to develop/innovate in the field of RF / Microwave communication systems.
PSO3	Acquire the necessary skills to evaluate and innovate in building modern wireless communication systems.

PEO-PO Mapping:

	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
PEO1	✓	✓	✓				✓	✓	
PEO2				✓	✓	✓	✓	✓	✓
PEO3	✓	✓	✓	✓	✓	✓	✓	✓	✓

COURSE STRUCTURE

Semester 1

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	25-510-0101	Signal Processing for Communication	3	2	0	3	C	50	50	100
2	25-510-0102	Advanced Communication Systems	3	2	0	3	C	50	50	100
3	25-510-0103	Microwave Devices and Circuits	3	2	0	3	C	50	50	100
4	25-510-0104	Digital Communication Lab	0	0	4	2	C	100	0	100
5	25-510-0105	Microwave Devices and Circuits Lab	0	0	4	2	C	100	0	100
6	25-510-01XX	Program Elective Lab	0	0	4	2	E	100	0	100
7	25-510-01XX	Program Elective	3	1	0	3	E	50	50	100
8	25-510-01XX	Program Elective	3	1	0	3	E	50	50	100
		Interdepartmental Elective*				3	E	50	50	100
		Total				21				

Semester 2

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	25-510-0201	Wireless Communications	3	2	0	3	C	50	50	100
2	25-510-0202	Radar Systems	3	2	0	3	C	50	50	100
3	25-510-0203	Wireless Communication Lab	0	0	4	2	C	100	0	100
4	25-510-02XX	Program Elective	3	1	0	3	E	50	50	100
5	25-510-02XX	Program Elective	3	1	0	3	E	50	50	100
6	25-510-02XX	Program Elective	3	1	0	3	E	50	50	100
		Interdepartmental Elective*				3	E	50	50	100
7	25-510-02XX	Program Elective Lab	0	0	4	2	E	100	0	100
		Total				19				

* At least one interdepartmental elective is mandatory. Need to compulsorily register for the same before third semester. This can be opted instead of a program elective in either first or second semester.

Semester 3

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	25-510-0301	Project Part 1	0	0	28	14	C	100	100	200
2	25-510-0302	Elective-MOOC/NPTEL Course#				2	E	0	100	100
		Total				16				

Need to compulsorily register for one MOOC/NPTEL course and one interdepartmental elective before registering for fourth semester exam.

Semester 4

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	25-510-0401	Project Part 2	0	0	32	16	C	100	100	200
		Total				16				

Electives

No.	Course Code	Course Title	L	T	P	Credits	C/E	CA	ES	Total
1	25-510-0X11	Antennas for Communication Systems	3	1	0	3	E	50	50	100
2	25-510-0X12	Machine Learning	3	1	0	3	E	50	50	100
3	25-510-0X13	Electromagnetic Interference and Compatibility	3	1	0	3	E	50	50	100
4	25-510-0X14	Software Defined Radio for Communication Engineers	3	1	0	3	E	50	50	100
5	25-510-0X15	Information Theory and Coding	3	1	0	3	E	50	50	100
6	25-510-0X16	Optimization Techniques	3	1	0	3	E	50	50	100
7	25-510-0X17	Estimation and Detection Theory	3	1	0	3	E	50	50	100
8	25-510-0X18	Signal Integrity for High-Speed Digital Design	3	1	0	3	E	50	50	100
9	25-510-0X19	Software Defined Radio Lab	0	0	4	2	E	100	0	100
10	25-510-0X20	Antennas Lab	0	0	4	2	E	100	0	100
11	25-510-0X21	5G Technologies and Standards	3	1	0	3	E	50	50	100
12	25-510-0X22	Machine Learning Lab	0	0	4	2	E	100	0	100
13	25-510-0X23	EMI/EMC Lab	0	0	4	2	E	100	0	100
14	25-509-0X15	Analog & RF IC Design **	3	1	0	3	E	50	50	100

** This elective course is mapped to MTech in VLSI and Embedded Systems specialisation.

MASTER OF TECHNOLOGY

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Semester 1

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25-510-0101 **Signal Processing for Communication**

L	T	P	C
3	2	0	3

Prerequisites	:	Signals & Systems, Digital Signal Processing, Mathematics
Course Description	:	This course deals with the basic mathematical foundation needed for communication system design.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Use the concept of vector space in signal analysis	Apply
CO2	Demonstrate the importance of filtering	Apply
CO3	Select a suitable digital filter based on the application	Analyse
CO4	Illustrate the concept of sampling and interpolation	Apply
CO5	Apply multirate signal processing techniques in communication	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2				3	2	
CO2	3	2	2				3	2	3
CO3	3	2	2				3	2	3
CO4	3	2	2					2	3
CO5	3	2	2					2	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Signals & Hilbert Spaces:** Discrete-time basic signals, digital frequency, elementary operations, classes of discrete-time signals, Euclidean Geometry - vectors and notation, inner product, norm, distance, bases, vector space, inner product space, Hilbert space, subspaces, bases and projections
Module 2	**Discrete-time Filters:** Linear Time-Invariant Systems, filtering in time domain, convolution and inner product, Finite Impulse Response (FIR) vs Infinite Impulse Response (IIR), filtering in frequency domain - LTI Eigenfunctions, properties of frequency response, ideal filters, realizable filters, solving Constant Coefficient Difference Equations (CCDEs) using z-transform, pole-zero patterns
Module 3	**Filter Design:** Design fundamentals, filter specifications and trade-offs, FIR filter design - FIR design by windowing, linear phase filters, IIR filter design - impulse invariant technique and bilinear transformation, filter structures

Module 4	**Interpolation and Sampling:** Sampling, inner product and convolution, the sinc function, zero order hold interpolation, first order hold, polynomial interpolations, sinc interpolation, sampling theorem, sampling as a basis expansion, aliasing, oversampling, critical sampling and under sampling, A/D and D/A conversions
Module 5	**Multirate Signal Processing:** Downsampling, properties, frequency domain representation, downsampling of a high pass signal, anti-aliasing filter, upsampling, rational sampling rate changes, multirate identities, multirate filtering

References:

[1] P. Prandoni and M. Vetterli, *Signal Processing for Communications*, 1st ed. EPFL press, 2008.

[2] A. Lapidoth, *A Foundation in Digital Communication*, 2nd ed. Cambridge University Press, 2017.

[3] J. G. Proakis and D. G. Manolakis, *Digital Signal Processing: Principles, Algorithms, and Application*, 4th ed. Pearson Education India, 2007.

[4] A. V. Oppenheim and R. W. Schafer, *Discrete-time Signal Processing*, 2nd ed. Prentice Hall, 1999.

[5] B. Porat, *A Course in Digital Signal Processing*, 1st ed. John Wiley & Sons, 1996.

[6] P. P. Vaidyanathan, *Multirate Systems and Filter Banks*, 1st ed. Pearson Education India, 2006.

[7] D. E. Dudgeon and R. M. Merserau, *Multidimensional Digital Signal Processing*, 1st ed. Prentice Hall, 1984.

[8] S. K. Mitra, *Digital Signal Processing: A Computer-Based Approach.* McGraw-Hill Higher Education, 2001.

[9] C. T. Chen, *Digital Signal Processing: Spectral Computation and Filter Design.* Oxford University Press, Inc., 2001.

[10] E. C. Ifeachor and B. W. Jervis, *Digital Signal Processing: A Practical Approach.* Pearson Education, 2004.

25-510-0102 **Advanced Communication Systems**

L	T	P	C
3	2	0	3

Prerequisites	:	Signals & Systems
Course Description	:	This course deals with the statistical modeling of communication systems.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Use signal analysis for communication	Apply
CO2	Apply the concept of probability in communication system design	Apply
CO3	Illustrate the geometric representation of signals	Apply
CO4	Analyse digital modulation techniques	Analyse
CO5	Examine the issues related with band-limited channels	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2	2			2		2
CO2	3	2	2	2			3	2	
CO3	3	2	2	2			2		2
CO4	3	2	2	2			2	3	
CO5	3	2	2	2			2		2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Fourier Analysis of Signals & Systems :** Fourier series, Fourier transform, inverse relationship between time domain and frequency domain representation, Dirac delta function, Fourier transform of periodic signals, transmission of signals through Linear Time Invariant (LTI) systems, Hilbert transform, pre-envelopes, complex envelopes of band-pass signals, canonical representation of band-pass signals, complex low-pass representations of band-pass systems, linear modulation theory, phase and group delays
Module 2	**Probability and Stochastic Process:** Set theory, probability theory, random variables, distribution functions, the concept of expectation, statistical averages, characteristic functions, Gaussian distribution, Markov and Chebyshev inequalities, central limit theorem, stochastic process - strictly stationary and weakly stationary, mean, correlation, and covariance functions of weakly stationary processes, ergodic processes, Transmission of a Weakly Stationary Process through a LTI filter, cross spectral densities, Poisson process, Gaussian process, noise

Module 3	**Signaling over AWGN Channels:** Geometric representation of signals, the Schwarz inequality, Gram-Schmidt Orthogonalization Procedure, conversion of continuous AWGN channel in to a vector channel, statistical characterization of the correlator outputs, likelihood function for an AWGN channel, Maximum Likelihood (ML) Decoding, correlation receivers, matched filter receiver, probability of error
Module 4	**Optimum Receiver:** Digital modulation using coherent detection – BPSK, BFSK, MSK, Signals with random phase in AWGN Channels, Quadrature receivers, non-coherent orthogonal modulation techniques, BFSK and DPSK using non-coherent detection, BER comparison of signaling schemes over AWGN channels, Carrier phase synchronisation and symbol timing synchronisation
Module 5	**Signaling over Band-Limited Channels:** Error rate due to channel noise in a matched-filter receiver, intersymbol interference, signal design for zero ISI, Ideal Nyquist pulse for distortionless baseband transmission, raised cosine spectrum, square root raised cosine spectrum, Eye pattern, Equalization Techniques- Zero forcing linear Equalization- Decision feedback equalization- Adaptive Equalization

References:

[1] S. Haykin, *Digital Communication Systems*, 1st ed. John Wiley & Sons, 2014.

[2] S. Haykin and M. Moher, *Introduction to Analog and Digital Communications*, 2nd ed. John Wiley & Sons, Inc., 2012.

[3] S. Haykin, *Communication Systems*, 2nd ed. John Wiley & Sons, 2008.

[4] A. B. Carlson and P. B. Crilly, *Communication Systems An Introduction to Signals and Noise in Electrical Communication*, 5th ed. McGraw Hill Higher Education, 2010.

[5] B. Sklar, *Digital Communications: Fundamentals and Applications*, 3rd ed. Pearson, 2021.

[6] J. G. Proakis and M. Salehi, *Digital Communications*, 5th ed. McGraw Hill, 2014.

[7] H. Taub and D. L. Schilling, *Principles of Communication Systems*, 4th ed. McGraw Hill, 2017.

[8] J. G. Proakis, M. Salehi, N. Zhou, and X. Li, *Communication Systems Engineering*, 2nd ed. Prentice Hall of India, 2017.

[9] W. Feller, *An Introduction to Probability Theory and its Applications*, 3rd ed. John Wiley & Sons, 1991.

[10] S. M. Ross, *Introduction to Probability Models*, eleventh ed. Academic press, 2014.

25-510-0103 **Microwave Devices and Circuits**

L	T	P	C
3	2	0	3

Prerequisites : A basic course in Electromagnetic Theory

Course Description : The course introduces the basic microwave design principles and discusses their application in microwave circuits. Through problem- solving and design activities, the course facilitates the students to have an in depth understanding of the transmission line theory and impedance matching techniques, microwave circuit network anal- ysis and gives an overview of active and passive components and discusses the design of practical microwave circuits.

Course Outcome : After the completion of the course, student will be able to

CO1	Understand the behaviour of components and circuits at microwave frequencies using transmission line theory and Smith chart	Understand
CO2	Apply S-parameters in describing RF circuit characteristics and employ various networks for impedance matching	Apply
CO3	Design the various Microwave components	Analyze
CO4	Understand the various microwave passive and active devices and components	Understand
CO5	Design of various Microwave circuits: Amplifiers, Oscillators, Frequency Synthesizers and an understanding of high power sources	Apply

COs to POs & PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3					2	3		
CO2	3	3	2			2	3	3	3
CO3	3	3	2			2	3	3	3
CO4	3		2			2	3		
CO5	3	3	2			2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Transmission Line Theory:** - Revision of Maxwells equations- Behavior of Materials and Components at microwave frequency, Transmission Line Theory, Practical Transmission Lines, Smith Charts- Uses and its Variants. **S Parameters and Matching Networks:** - S Parameters - Signal Flow Graphs. Impedance Matching Networks- Lumped and Distributed Element Matching Networks

Module 2	**Microwave Components:-** Resonators – Transmission line, Cavity and Dielectric resonators; Power dividers and Directional couplers – Basic Properties, T Junction, Wilkinson, Waveguide Directional Couplers, 90^0 & 180^0 Hybrid; **Filters:-** Design, Transformation and Implementation
Module 3	**Passive Devices:** - Schottky Diodes and Detectors, Varactor Diodes, PIN Diode Parameters, Switches, Attenuators, Phase Shifters- diode and Ferrite Phase Shifters, Circulators and Isolators
Module 4	**Active Devices:-** Microwave BJT, HBT, FET & CMOS; MMIC- Technology, Elements & Applications. **Microwave Sources:-** Low power and High power Sources
Module 5	**Microwave Circuits Design:-** Amplifiers- Single stage, Multistage and Broadband; Oscillators, Mixers and Frequency Synthesizers

References:

[1] I. D. Clive Poole, *Microwave Active Circuit Analysis and Design.* Academic Press, Amsterdam, ISBN 9780124078239, 2016.

[2] D. M. Pozar, *Microwave Engineering.* Wiley, 4th ed, Hoboken, NJ, ISBN 9780470631553, 2011.

[3] L. G. Maloratsky, *RF and Microwave Integrated Circuits - Passive Components and Control Devices.* Elsevier, 2004.

[4] K. Chang, *Microwave Solid State Circuits and Applications.* John Wiley, ISBN: 9780471540441, 1994.

[5] M. M. Radmanesh, *Radio Frequency and Microwave Electronics Illustrated.* Prentice Hall, ISBN: 9780130279583, 2001.

[6] Y.-W. Yeom, *Microwave Circuit Design: A Practical Approach Using ADS.* Pearson, ISBN: 9780134085838, 2015.

[7] R. L. . Bretchko, *RF Circuit Design: Theory and Applications.* Pearson Education Inc, ISBN: 9788131762189, 2011.

25-510-0104 **Digital Communication Lab**

L	T	P	C
0	0	4	2

Prerequisites : Advanced Communication Systems

Lab Description : This lab deals with the basic implementation of a digital communication systems. The lab evaluates a particular modulation scheme and develops techniques to improve its performance. in MATLAB/Octave/Python

Lab Outcome : After the completion of the lab, the student will be able to

CO1	Familiarise the communication toolbox in MATLAB/OCTAVE	Understand
CO2	Implement a digital communication system and evaluate its performance and represent the result in different ways- Constellation diagram, BER plot, eye diagram	Apply
CO3	Innovate and develop new models to cater to modern communication systems	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					2	2	
CO2	3	3	3				3	3	
CO3	3	3	3		3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*: Implementation and performance evaluation of the following experiments in MATLAB/Octave/Python software
1. PCM Modulation & Demodulation
2. Delta Modulation
3. Various digital modulation schemes
4. OFDM
∗ The list is not exhaustive. Additional experiments or projects based on the experiments can be included in the laboratory activity.

References:

[1] [Online:] https://docs.octave.org/latest/

[2] [Online:] https://in.mathworks.com/help/matlab/

25-510-0105	**Microwave Devices and Circuits Lab**				
		L	**T**	**P**	**C**
		0	**0**	**4**	**2**

Prerequisites	:	Microwave Devices and Circuits
Course Description	:	This lab familiarizes the student with the experimental set up for carrying out microwave measurements followed by characterising the various Microwave components. In addition, this lab includes design/characterisation of various planar, passive and active microwave circuits using computer aided design tools.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Setup a X band microwave bench and carry out measurement of various RF parameters	Apply
CO2	Familiarization of measurement with Network Analyzer	Apply
CO3	Computer aided design and characterization of transmission lines, microwave transistors, matching networks and various passive and active components and circuits	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2		3	3	3	3		3
CO2	3			3	3	3	3		3
CO3	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Sample List of Experiments* :
Part A:- Familiarisation of microwave components and measurements
1. Familiarisation of X band Bench set up and do the measurements of various RF parameters
2. The Vector Network Analyzer (one-and two-port network analysis, frequency response)
3. The Gunn Diode and Klystron source (the spectrum analyzer, power meter, V/I curve)
4. Impedance Matching and Tuning (stub tuner,QW transformer, network analyzer)
5. Cavity Resonators (resonant frequency, Q, frequency counter)
6 Directional Couplers, Circulators, Waveguide Tees, Isolators, Attenuators (insertion loss, coupling, directivity)
Part B:- Computer Aided Design and Testing
Computer-Aided Design using industry-standard software and Testing of
1. Planar Transmission Lines
2. Planar Filters
3. Microwave Transistors (Biasing and Layout) and Amplifiers - for maximum power transfer and low noise
4. Matching Network (Design and Layout)
5. Branch Line Couplers & Power Dividers
6. Planar antennas - Rectangular patch with different types of feeds
∗ The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

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Semester 2

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25-510-0201 **Wireless Communications**

L	T	P	C
3	**2**	**0**	**3**

Prerequisites	:	Advanced Communication Systems
Course Description	:	This course reviews the various communication standards in wireless communication. The course will enable the students to understand the challenges in the wireless propagation medium and appreciate the use of advanced communication techniques to meet the rising demands of the telecom industry.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Analyse the type of wireless channel and identify the appropriate model for the same	Analyse
CO2	Apply appropriate techniques to mitigate the impact of channel impairments	Apply
CO3	Analyze the capacity and reliability of wireless communication systems	Analyse
CO4	Understand the latest techniques to appreciate the futuristic wireless systems and to be able to apply them to develop a new prototype	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		2				3	3	
CO2	3	3	2				3	3	
CO3	3	3	2				3	3	
CO4	3	3	2				3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Wireless Channel Modeling:** Wireless Channel Models, Statistical fading models, time-varying channel impulse response, Narrowband and wideband fading models
Module 2	**Capacity of Wireless Channels:** Performance of digital modulation schemes over wireless channels, AWGN channel capacity, Capacity of flat and frequency selective fading channels
Module 3	**Cellular Concept:** Techniques to reduce interference and improve the capacity in cellular systems, **Fading Mitigation Techniques:** Different types of diversity techniques, Various diversity combining techniques, performance analysis for Rayleigh fading channels

Module 4	**Multiple Access Techniques:** Review of Random Multiple Access Protocols, Multiple Access protocols over different generations of cellular systems, Spread Spectrum Techniques, Techniques used in 4G - MIMO/OFDM technique
Module 5	**Modern Technology Standards:** Cellular wireless communication standards - LTE and LTE Advanced, 5G and 6G standards. Introduction to Massive MIMO, mmWave communication, Reconfigurable Intelligent Surfaces for coverage extension in mmWave and THz frequencies, Usage of NOMA among multiple users to improve spectral efficiency

References:

[1] T. S. Rappaport, *Wireless Communications: Principles and Practice*, 2nd ed. Cambridge University Press, 2024.

[2] A. Goldsmith, *Wireless CCommunications*. Cambridge University Press, 2005.

[3] A. F. Molisch, *Wireless Communications*, 2nd ed. John Wiley & Sons, 2011.

[4] G. L. Stüber, *Principles of Mobile Communications*, 2nd ed. Kluwer Academic Publishers, 2001.

[5] D. Tse and P. Viswanath, *Fundamentals of Wireless Communication*. Cambridge University Press, 2005.

[6] A. J. Viterbi, *CDMA: Principles of Spread Spectrum Communication*. Addison Wesley Longman Publishing Co., Inc., 1995.

[7] D. R. Koilpillai, "Introduction to Wireless and Cellular Communications," NPTEL Course, 2023.

[8] A. K. Jagannatham, "Advanced 3G and 4G Wireless Mobile Communications," NPTEL Course, 2014.

[9] A. K. Jagannatham, "Principles of Modern CDMA/ MIMO/ OFDM Wireless Communications (Course sponsored by Aricent)," NPTEL Course, 2021.

25-510-0202	**Radar Systems**

L	T	P	C
3	2	0	3

Prerequisites : A basic course in communication and microwave.

Course Description : In this course, the students are given an overview of different radars and the signal processing associated. Also gives an an insight in to different antennas used in radar applications.

Course Outcome : After the completion of the course, student will be able to

CO1	Understand the different types of radars and analyze different radar functions	Analyze
CO2	Understand the different radar systems, tracking of radar and types of antennas used in radar systems	Understand
CO3	Understand detection of radar signals and analysis of information ex- traction	Analyze
CO4	Understand the radar signal processing and the analysis using software tools	Analyze
CO5	Understand the different radar applications	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2			3	2	2	2
CO2	3					3			
CO3	3	3	2			3	3	2	2
CO4	3	3	2			3	3	2	2
CO5	3					3			2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Radar fundamentals and operation:** Introduction, principles, types of radar, transmitter functions, wave form spectra, receiver functions, Radar equation, Radar cross section
Module 2	**Radar Systems:** Pulse, CW, FM-CW, MTI, Doppler and multimode tech- niques, Tracking Radar: Tracking system parameters, Conical Scan, amplitude comparison DTOA and phase interferometry. Range and velocity tracking, Tracking accuracy, types of antennas using in radar systems
Module 3	**Detection of Radar Signals and information extraction and estimation:** Detection introduction, threshold detection, Signal integration, Binary integrators, CFAR, Theoretical accuracy of radar measurements, ambiguity function and radar waveform design, correlation detection and matched filter receiver

Module 4	**Radar signal processing:** Signal integration, spectrum analysis, windows and resolution, MTI principles and methods, De staggering and processing, Moving Radars and moving clutter, Doppler processing (Software simulation)
Module 5	**Radar Applications:** Instrument landing systems, Electronic Warfare - ECM and ECCM, High resolution radar, range and Doppler resolution, Synthetic aperture radar, Radar in automobile - Movement Detection, Phased array Radar, millimeter wave radars

References:

[1] M. I. Skolnik, *Introduction to Radar Systems.* Tata Mcgraw Hill, 2001.

[2] B. Edde, *Radar: Principles, Technology and Applications.* Pearson Education Inc., 1995.

[3] D. C. Scheleher, *Introduction to Electronic Warfare.* Artech House Inc., 1986.

[4] G. J. Wheeler, *Radar Fundamentals.* Prentice Hall Inc, 1967.

[5] L. Nadav, *Radar Principles.* john Wiley and Sons, 1988.

[6] B. R. Mahafza, *Radar Systems Analysis and Design using MATLAB.* CRC Press, 2013.

[7] M. A. Richards, *Fundamentals of Radar Signal Processing*, 2nd ed. Tata Mcgraw Hill.

25-510-0203	**Wireless Communication Lab**	**L**	**T**	**P**	**C**
		0	**0**	**4**	**2**

Prerequisites : Fundamentals of Wireless Communication

Lab Description : Modelling of a wireless channel and analysis of the performance of a modern wireless communication system using MATLAB/Octave/ Python

Lab Outcome : After the completion of the lab, the student will be able to

CO1	Understand the communication toolbox in MATLAB/OCTAVE	Understand
CO2	Implement a basic channel model in a wireless communication system	Apply
CO3	Compare the performance of BER and outage probability under various traditional and modern modulation schemes	Apply
CO4	Develop a wireless communication system and evaluate the performance of various diversity combining schemes	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3	3	
CO2	3	3					3	3	3
CO3	3	3				3	3	3	3
CO4	3	3				3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
Implementation of the following in MATLAB/Octave/Python	
1	Model a wireless channel using the Jakes Rayleigh fading channel model
2	Implement a BPSK communication system under additive white Gaussian noise (AWGN). Obtain the BER performance (Eb/N_o Vs Error rate) through Monte-Carlo simulations and compare the error performance with theoretical plots obtained using analysis
3	Simulate a wireless commutation system under flat Rayleigh fading using a digital modulation scheme for various diversity combining schemes. (i) Obtain the BER performance (BER Vs Average bit SNR) for the above schemes using 1×2 ($N_t \times N_r$) system and 1×4 ($N_t \times N_r$) system. (ii) Compare the BER curves in (i) with a SISO system. Measure the diversity gain in each case from the BER curves for a target probability of error of 10^{-3}

4	Plot the Outage Probability vs. average SNR normalized to the Threshold SNR for the system in Q3. and evaluate its performance for various Receiver diversity branches using Maximal ratio combining and Equal gain combining schemes
5	Develop a Rayleigh fading simulator for a mobile communications channel and plot the received signal amplitude for different Doppler frequencies

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

References:

[1] T. S. Rappaport, *Wireless Communications: Principles and Practice*, 2nd ed. Cambridge University Press, 2024.

[2] S. Haykin, *Communication systems.* John Wiley & Sons, 2008.

[3] A. Goldsmith, *Wireless Communications.* Cambridge university press, 2005.

[4] [Online]. Available: https://www.3gpp.org/specifications-technologies/releases/release-15

MASTER OF TECHNOLOGY

in

MICROWAVE AND COMMUNICATION ENGINEERING

Semester 3

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

25-510-0301	**Project Part 1**

L	T	P	C
0	**0**	**28**	**14**

Prerequisites : None
Lab Description : This is the first part of the final project.
Course Outcome : After the completion of the course, the student will be able to

CO1	Identify unresolved problems and challenges in the selected domain through literature survey	Analyze
CO2	Determine appropriate tools and procedures for design, development & verification	Evaluate
CO3	Develop practical solutions for the chosen problem for a given specification	Create
CO4	Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals	Create

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2	3	3	3			3	3		3
CO3	3	3	3	3		3	3	3	3
CO4	3			3	3	3	3		

3-High; 2-Medium; 1-Low

Course Content:

The major project in fourth semester offer the opportunity to apply and extend knowledge acquired in the three semesters of the M.Tech. program. The major project can be analytical work, simulation, hardware design or a combination of these in the emerging areas of electronics under the supervision of a faculty from the Dept. of Electronics or in R and D institutes/ Industry. The specific project topic undertaken will reflect the common interests and expertise of the student(s) and supervisor. Students doing their projects outside the department will be assigned an internal supervisor.

Students will be required to

- perform a literature search to review current knowledge and developments in the chosen technical area
- undertake detailed technical work in the chosen area using one or more of the following:
  - Analytical models
  - Computer simulations
  - Hardware implementation

The emphasis of major project shall be on facilitating student learning in technical, project management and presentation spheres. Project work will be carried out individually. The project supervisor/internal supervisor shall do monthly evaluation of the progress. M.Tech. project evaluation committee for the course shall evaluate the project work during the fourth semester in two stages. The first evaluation shall be conducted in the middle of the semester. This should be followed by the end semester evaluation. By the time of the first evaluation, students are expected to complete the literature review, have a clear idea of the work to be done, and have learnt the analytical / software / hardware tools. By the time of the second evaluation, they are expected to present the results of their progress in the chosen topic, write technical report of the study and results. They are expected to communicate their innovative ideas and results in reputed conferences and/or journals.

25-510-0302	MOOC/NPTEL Course	L	T	P	C
					2

Prerequisites : None

Course Description : This course has to be completed through MOOC mode using NPTEL/SWAYAM or other university approved MOOC platforms.

Course Outcome : After the completion of the course, the student will be able to

CO1	Demonstrate the ability for independent learning	Apply
CO2	Follow ethical practices for timely submissions	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2				3	3	3			

3-High; 2-Medium; 1-Low

Course Content:

Massive Open Online Courses (MOOCs) are free online courses available for anyone to enroll.MOOCs provide an affordable and flexible way to learn new skills, advance your career and deliver quality educational experiences at scale. The students have to complete a minimum 8 week duration course which will yield them a credit of 2. The selection of the course will be dependent on their specialisation and should be approved by the committee constituted for the same. The modality of the course will be as per the university guidelines on MOOC courses.

MASTER OF TECHNOLOGY

in

MICROWAVE AND COMMUNICATION ENGINEERING

Semester 4

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

25-510-0401	Project Part 2

L	T	P	C
0	0	32	16

Prerequisites	:	Successful completion of 25-510-0301 Project: Part 1
Lab Description	:	This is the second and final part of the final project.
Course Outcome	:	After the completion of the course, the student will be able to

CO1	Identify unresolved problems and challenges in the selected domain through literature survey	Analyze
CO2	Determine appropriate tools and procedures for design, development & verification	Evaluate
CO3	Develop practical solutions for the chosen problem for a given specification	Create
CO4	Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals	Create

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3			3	3	3	3		
CO2	3	3	3			3	3		3
CO3	3	3	3	3		3	3	3	3
CO4	3			3	3	3	3		

3-High; 2-Medium; 1-Low

Course Content:

Project: Part 2 is a continuation of Project: Part 1 in the third semester. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their innovative ideas and results in reputed conferences and/or journals. The project supervisor/internal supervisor shall do monthly evaluation of the progress. The M. Tech. project evaluation committee of the department shall evaluate the project work during the fourth semester in two phases. The first evaluation shall be conducted towards the middle of the semester. This shall be followed by the end semester evaluation by the committee.

MASTER OF TECHNOLOGY

in

MICROWAVE AND COMMUNICATION ENGINEERING

Electives

DEPARTMENT OF ELECTRONICS

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Kochi - 682 022, India

25-510-0X11 **Antennas for Communication Systems**

L	T	P	C
3	1	0	3

Prerequisites	:	Electromagnetic fields, General familiarity with transmission lines
Course Description	:	The objective of this course is to provide an understanding of antenna concepts, and modern antenna designs. Starting from the basic antenna parameters, the course will discuss various types of antennas including the planar antennas along with an in-depth study on the analysis and design of arrays. A brief glimpse to the design on antennas for the future wireless technologies is given at the end with a view that the student can further explore the topic, if interested.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Apply mathematical fundamentals of the antenna theory to understand the basic principle of radiation, along with a physical understanding of how different types of antennas radiate and to measure their various figures of merit	Apply
CO2	Acquire an understanding of antenna arrays enabling them to analyse its different types and configuration	Analyse
CO3	Familiarise with the working of several conventional antennas as well as antennas for modern wireless systems	Understand
CO4	Evaluate an appropriate antenna/array type depending on the application and develop a preliminary design for a given frequency of operation	Evaluate

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3			2	3	2	2
CO2	3	3	3			2	3	3	2
CO3	3	3	2			2	3	2	2
CO4	3	3	3			3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Preliminary Topics and Basic Definitions:** Review of Maxwell's Equations and Boundary conditions, Wave equations, Hertzian dipoles, Half-wave dipoles, Antenna radiation mechanism, Fundamental parameters and Figures of merit; Antenna measurements- Principle, Ranges, and Parameters

Module 2	**Wire Antennas:** Finite Length Dipoles, Monopoles, Inverted-F Antennas, Loop Antennas, Yagi-Uda and Log-periodic antennas
Module 3	**Types of Antennas:** Broadband Antennas- Helical, Bi-conical, Frequency Independent Antennas; Aperture Antennas- Radiation from apertures, Horn and Parabolic dish antennas, Microstrip patch antennas
Module 4	**Arrays:** Array Factor, Pattern Multiplication, Uniform and Non-uniform Excitation, Mutual Coupling, Phased Arrays and Array Feeding Techniques, Array synthesis approaches
Module 5	**Modern Antennas:** Antenna Design Requirements for Smartphones, Wireless Dongles, Wearable Devices, Base stations and Access points; MIMO Antenna configurations, Pattern and polarization diversity; mm-Wave Antennas and their feeding techniques; Terahertz Antenna Technologies for 6G Communication Systems

References:

[1] W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design*, 3rd ed. John Wiley & Sons, 2012.

[2] C. A. Balanis, *Antenna Theory: Analysis and Design*, 4th ed. John wiley & sons, 2016.

[3] J. D. Kraus, R. J. Marhefka, and A. S. Khan, *Antennas and Wave Propagation*, 4th ed. Tata McGraw-Hill Education, 2017.

[4] S. K. Koul and G. Karthikeya, *Antenna Architectures for Future Wireless Devices.* Signals and Communication Technology, Springer, 2022.

[5] U. Nissanov and G. Singh, *Antenna Technology for Terahertz Wireless Communication.* Springer Nature, 2023.

[6] W. Hong and C.-Y. D. Sim, *Microwave and Millimeter-wave Antenna Design for 5G Smartphone Applications.* John Wiley & Sons, 2023.

25-510-0X12 **Machine Learning**

L	T	P	C
3	**1**	**0**	**3**

Prerequisites : None

Course Description : This course provides a broad introduction to machine learning and how to apply learning algorithms.

Course Outcome : After the completion of the course, student will be able to

CO1	Design linear, nonlinear regression and logistic regression models	Apply
CO2	Design Artificial Neural Network for solving ML problems	Apply
CO3	Design Support Vector Machine for solving ML problems	Apply
CO4	Design unsupervised learning methods like clustering algorithms and dimensionality reduction algorithms	Apply
CO5	Design ML system suitable to the problem and analyse the model performance	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2	2			3	2	2
CO2	3	3	2	2			3	2	2
CO3	3	3	2	2			3	2	2
CO4	3	3	2	2			3	2	2
CO5	3	3	2	2			3	2	2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Concept of learning models, Supervised Learning, Unsupervised Learning, Reinforcement Learning. Linear Regression with One Variable - idea of cost function, and gradient descent method for learning, Linear Regression with Multiple Variables- Multiple Features, Gradient Descent for Multiple Variables, Feature Scaling, Learning Rate, Normal Equation, Non-invertibility, Polynomial Regression, Logistic Regression-classification, hypothesis representation, decision boundary, cost function, optimization, multiclass classification
Module 2	**Artificial Neural Network:** Artificial Neural Network: Introduction, mathematical model of neuron, activation functions, network architectures, Learning-cost function, gradient descent, optimisation, XOR problem, multilayer perceptron, back propagation algorithm, differentiability, feature scaling, initialization, stopping criteria. Deep Learning, Universal function approximation, feature extraction, Pattern recognition and classification, Stochastic Gradient Descent and Batch Gradient Descent

Module 3	**Support Vector Machine:** Introduction, optimization objective, large margin classification, support vectors, Separating hyperplane approaches, support vector machine formulation, SVMs for Linearly Non Separable Data, SVM Kernels, Hinge Loss formulation
Module 4	**Unsupervised Learning:** Clustering: Introduction, k-means algorithm, optimization, random initialization, clustering. Dimensionality Reduction: Data compression, visualization, principal component analysis algorithm, reconstruction from compressed representation
Module 5	**ML System Design and Evaluation Measures:** Learning with large datasets, stochastic gradient descent, batch and mini-batch gradient descent. Evaluating a Hypothesis, Model Selection, Regularisation, Training Validation Testing, Diagnosing Bias vs. Variance. Two Class Evaluation Measures, Confusion Matrix, Precision Recall curve, ROC Curve, Area Under Curve(AUC). Applications of machine learning and deep learning architectures in system design, Deep Learning in Communication Systems, Signal Classification and Pattern Recognition

References:

[1] T. Mitchell, *Machine Learning.* McGraw-Hill, 1997.

[2] S. Haykin, *Neural Networks and Learning Machines*, 3rd ed. Pearson Education India, 2016.

[3] T. Hastie, R. Tibshirani, and J. H. Friedman, *The Elements of Statistical Learning: Data Mining, Inference, and Prediction*, 2nd ed. Springer Series in Statistics, 2016.

[4] C. M. Bishop, *Pattern Recognition and Machine Learning.* Springer - Information Science and Statistics, 2011.

[5] S. S. Shwartz and S. B. David, *Understanding Machine Learning: From Theory to Algorithms.* Cambridge University Press, 2014.

[6] E. Alpaydin, *Introduction to Machine Learning*, 2nd ed. MIT Press, 2010.

[7] M. Mohri, A. Rostamizadeh, and A. Talwalkar, *Foundations of Machine Learning.* MIT Press, 2012.

25-510-0X13 Electromagnetic Interference and Compatibility

L	T	P	C
3	**1**	**0**	**3**

Prerequisites : General familiarity with EM fields, transmission lines and circuit theory

Course Description : The objective of this course is to provide an understanding of important concepts of Electromagnetic Compatibility which are fundamental for the design of electronics systems and devices in order to minimize electromagnetic interference. These concepts will be applied to a frequency range covering conduction and radiation, according the applicable standards.

Course Outcome : After the completion of the course, student will be able to

CO1	Implement the various measurement techniques for electromagnetic interference and for electromagnetic compatibility	Apply
CO2	Recognize the various agencies and standards associated with EMI/EMC	Understand
CO3	Analyse various EM compatibility issues with regard to the design of PCBs and ways to improve the overall system performance	Analyse
CO4	Apply real-world EMC design constraints and make appropriate trade-offs to achieve the most cost effective design that meets all requirements	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2				3		3
CO2	3	3	2				3		2
CO3	3	3	3				3	3	3
CO4	3	3	3			3	3	3	2

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Aspects of EMC:** EMI Sources, EMC units, Signal source specification, Advantages of EMC Design, EMC Requirements for Electronic Systems, Measurement of Radiated and Conducted Emissions. **Signal Spectra:** Spectra of Digital Waveforms, Spectral Bounds for Trapezoidal Waveforms, Spectrum Analyzer principle

Module 2	**Signal Integrity:** Transmission-Line Equations, High-Speed Digital Interconnects, Effect of Terminations, Matching Schemes, Effects of Line Discontinuities. **Non-ideal Behavior of Components:** Wires, resistors, capacitors, inductors, Printed Circuit Board (PCB), Effect of Component Leads, Mechanical Switches
Module 3	**Conducted Emissions and Conducted Susceptibility:** Measurement, Power Supplies, Filters, Placement. **Radiated Emissions and Conducted Susceptibility:** Simple Emission Models for Wires and PCB Lands, Simple Susceptibility Models for Wires and PCB Lands
Module 4	**Crosstalk:** Three-Conductor Transmission Lines and Crosstalk, Shielded Wires, Twisted Wires. **Shielding:** Shielding Effectiveness- Far-Field Sources, Near-Field Sources; Low Frequency, Magnetic Field Shielding
Module 5	**System Design for EMC:** Shielding, Ground, PCB Design, System Configuration and Design, Common EMC Issues in Practice and Design Guidelines

References:

[1] C. R. Paul, *Introduction to Electromagnetic Compatibility*, three ed. John Wiley & Sons, 2022.

[2] H. W. Ott, *Electromagnetic Compatibility Engineering*, 2nd ed. John Wiley & Sons, 2009.

[3] W. D. Kimmel and D. Gerke, *Electromagnetic Compatibility in Medical Equipment*. IEEE & Interpharm Press, 1995.

[4] V. P. Kodali, *Engineering EMC Principles, Measurements and Technologies*, 2nd ed. Wiley-Blackwell, 2001.

25-510-0X14 Software Defined Radio for Communication Engineers

L	T	P	C
3	1	0	3

Prerequisites	:	Basic knowledge of Communication Systems, Digital Signal Processing
Course Description	:	This course provides an overview of software-defined radio systems and the technologies necessary for their successful implementation. The student will also appreciate the current and future trends in the SDR space.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Demonstrate understanding of the need, characteristics and benefits of SDR	Understand
CO2	Analyze the RF Chain of SDR and components for overall performance	Apply
CO3	Compare direct digital synthesis with analog signal synthesis in SDR	Apply
CO4	Apply the insight to appreciate the usage of SDR for modern communication applications	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3					2	2		
CO2	3						2		
CO3	3					3	2	2	
CO4	3					3	3	2	

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Software radio concepts:** Introduction, need, characteristics, benefits and design principles of Software Radios. Traditional radio implemented in hardware (first generations of 2G cell phones), Software controlled radio (SCR), Software defined radio (SDR), Ideal software radio (ISR), Ultimate software radio (USR)
Module 2	**Radio frequency implementation issues :** The purpose of RF Front-End, Dynamic range, RF Receiver Front-End Topologies, Enhanced Flexibility of the RF Chain with Software Radios, Importance of Components to Overall performance, Transmitter Architecture and their issues, Noise and Distortion in RF Chain

Module 3	**Digital generation of signals:** Introduction, Comparison of Direct Digital Synthesis with Analog Signal Synthesis, Approaches to Direct Digital Synthesis, Analysis of Spurious Signals, Spurious components due to Periodic Jitter.**Multirate Signal Processing:** Introduction, Sample Rate Conversion Principles, Polyphase Filters, Digital Filter Banks
Module 4	**Case studies:** Software Defined Radio for Wi-Fi Jamming, Experimental study of OFDM implementation utilizing GNU Radio and USRP-SDR, Developing a generic software-defined radar transmitter using GNU Radio
Module 5	**Case studies :** 5G New Radio Prototype Implementation Based on SDR, Challenges of 5G testing using SDR, Characterisation of 5G using SDR platform

References:

[1] J. H. Reed, *Software Radio: A Modern Approach to Radio Engineering.* Prentice Hall Professional, 2002.

[2] T. J. Rouphael, *RF and Digital Signal Processing for Software-defined Radio.* Elsevier, 2008.

[3] C. R. Johnson Jr and W. A. Sethares, "Telecommunication breakdown," *Concepts of Communication Transmitted via Software-Defined Radio*, 2004.

[4] [Online]. Available: https://www.gnuradio.org/doc/doxygen-3.7.4.1/index.html

[5] [Online]. Available: https://pysdr.org/content/intro.html

[6] A. M. Wyglinski, R. Getz, T. Collins, and D. Pu, *Software-defined Radio for Engineers.* Artech House, 2018.

[7] L. Y. Hosni, A. Y. Farid, A. A. Elsaadany, M. A. Safwat *et al.*, "5G New Radio Prototype Implementation based on SDR," *Communications and Network*, vol. 12, no. 01, pp. 1–27, 2019.

25-510-0X15 **Information Theory and Coding**

L	T	P	C
3	1	0	3

Prerequisites : Advanced Communication Systems

Course Description : This course provides an introduction about the lossy and lossless compression techniques in coding theory. It also delves into the modern coding theory concepts that can be adopted for the relevant application based on the rate requirements.

Course Outcome : After the completion of the course, the student will be able to

CO1	Understand the basic theory behind compression algorithms for Lossless and Lossy Data Compression.	Understand
CO2	Apply channel capacity and coding techniques to achieve efficient and reliable communication.	Apply
CO3	Design encoders and decoders for a given error correcting capability	Apply
CO4	Analyse the problem and apply suitable signal compression methods that satisfy the rate constraints for various applications.	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3								
CO2	3	3					3		
CO3	3	3	3	3	3	3	3	3	3
CO4	3	3	3	3	3	3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Information Theory:** Entropy, Memoryless sources, Markov sources, Entropy of a discrete Random variable, Joint, conditional and relative entropy, Mutual Information and conditional mutual information, Differential Entropy, Joint, relative and conditional differential entropy, Mutual information
Module 2	**Source Coding:** Shannon's Source Coding Theory and algorithms – Kraft inequality, Huffman algorithm, Arithmetic coding, Lempel Ziv coding, Coding for sources with memory

Module 3	**Error Correction Coding:** Channel coding theorem, Error Correction Codes – Introduction to Galois fields, polynomial arithmetic, linear block codes for error correction, Cyclic Codes, BCH codes, Reed Solomon Codes, Convolutional codes, Trellis coded Modulation, Codes for 4G and 5G - LDPC and Turbo Codes, Capacity achieving Polar Codes (proposed for the uplink control channels in 5G)
Module 4	**Lossy Compression:** Rate Distortion Theory: Calculation of rate-distortion function (Binary Source, Gaussian Source); Converse to the rate-distortion function; Computation of channel capacity and the rate distortion function, The Rate-Distortion-Accuracy Tradeoff: JPEG Case Study
Module 5	**Compression standards** Review of Transforms - Transform coding - Subband coding - Wavelet Based Compression, Data Compression standards: Speech Compression Standards, Audio Compression standards, Image Compression standards, Video Compression Standards, The role of compression standards in image processing

References:

[1] T. M. Cover and J. A. Thomas, *Elements of information theory.* John Wiley & Sons, 2006, vol. 1.

[2] R. Bose, *Information theory, coding and cryptography.* McGraw-Hill, 2003.

[3] S. Lin and D. J. Costello, *Error control coding.* Pearson Education, 2004.

[4] P. S. Satyanarayan, *Concepts of information theory and coding.* Dynaram Publication, 2005.

[5] R. B. Wells, *Applied coding and information theory for engineers.* Pearson Education, 2004.

[6] T. Richardson and R. Urbanke, *Modern coding theory.* Cambridge university press, 2008.

[7] X. Luo, H. Talebi, F. Yang, M. Elad, and P. Milanfar, "The rate-distortion-accuracy tradeoff: Jpeg case study," *arXiv preprint arXiv:2008.00605*, 2020.

25-510-0X16	**Optimization Techniques**			

L	T	P	C
3	**1**	**0**	**3**

Prerequisites : A basic course in Advanced mathematics

Course Description : Through problem solving and design and developement activities, the course facilitates the students to have an in depth understanding of the Optimization techniques, in various fields.

Course Outcome : After the completion of the course, student will be able to

CO1	Achieve Knowledge of design and development of problem solving skills.	Apply
CO2	Understand the principles of optimization.	Understand
CO3	Design and develop analytical skills.	Analyze
CO4	Summarize the Linear, Non-linear and Geometric Programming	Apply
CO5	Understands the concept of Dynamic programming.	Understand

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	1			2		2	1
CO2	3					2			1
CO3	3	3	1			2		2	1
CO4	3	3	1			2		2	1
CO5	3					2			1

Course Content:

Module 1	**Introduction:** -Introduction to optimization, engineering applications of optimization, Formulation of structural optimization problems as programming problems. Optimization Techniques: Classical optimization techniques, single variable optimization, multivariable optimization with no constraints, unconstrained minimization techniques and algorithms constrained optimization solutions by penalty function techniques, Lagrange multipliers techniques and feasibility techniques
Module 2	**Linear Programming:** - Linear programming, standard form of linear programming, geometry of linear programming problems, solution of a system of linear simultaneous equations, pivotal production of general systems of equations, simplex algorithms, revised simpler methods, duality in linear programming
Module 3	**Non-linear programming:**- Non-linear programming, one dimensional minimization methods, elimination methods, Fibonacci method, golden section method, interpolation methods, quadratic and cubic methods, Unconstrained optimization methods, direct search methods, random search methods, descent methods

Module 4	**Constrained optimization techniques:** - Constrained optimization techniques such as direct methods, the complex methods, cutting plane method, exterior penalty function methods for structural engineering problems. Formulation and solution of structural optimization problems by different technique. **Convex optimisation:**- Convex Sets, Convex Functions and Generalizations, Convex Optimization Problems, Semidefinite Programming
Module 5	**Geometric programming:**- Geometric programming, conversion of NLP as a sequence of LP/ geometric programming. Dynamic programming: Dynamic programming conversion of NLP as a sequence of LP/ Dynamic programming

References:

[1] S. Rao, *Optimization – Theory and Practice*, 5th ed. Wiley Eastern Ltd, 2019.

[2] K. Uri, *Optimum structural design : concepts, methods, and applications.* McGraw-Hill, 1981.

[3] B. Richard, *Schaum's outline of theory and problems of operations research.* McGraw-Hill, 1997.

[4] B. S.S., *Structural optimization using sequential linear programming.* Vikas Publishing House Pvt. Ltd., 2003.

[5] S. H. Z. Edwin K. P. Chong, *An Introduction to Optimisation.* John Wiley & Sons, 2013.

[6] C. M. S. Mokhtar S. Bazaraa, Hanif D. Sherali, *Nonlinear Programming: Theory and Algorithms.* John Wiley & Sons, 2005.

[7] L. V. Stephen Boyd, *Convex Optimization.* Cambridge University Press, 2004.

25-510-0X17	Estimation and Detection Theory

L	T	P	C
3	1	0	3

Prerequisites : Basic probability theory, Basics of Linear Algebra, Basic Communication Theory

Course Description : The course outlines the basics of estimation and detection theory. It introduces the students to classical and Bayesian estimators, estimation bounds, hypothesis testing, and various detection methods to detect signals under noise.

Course Outcome : After the completion of the course, the student will be able to

CO1	Understand the classical estimation and detection techniques	Understand
CO2	Apply the various estimation techniques for modern wireless applications	Apply
CO3	Mathematically identify and solve practical detection and estimation problems and analyze their performance	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3						2		
CO2	3	3				3	2		
CO3	3	3				3	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Estimation Theory:** Minimum variance unbiased estimation, best linear unbiased estimation Cramer-Rao lower bound (CRLB) Maximum Likelihood estimation (MLE), Bayseaen estimation-Minimum Mean-square error (MMSE) , Maximum a Posteriori (MAP) estimation, Least Squares (LS) Estimation
Module 2	**Estimation and Filtering:** Recursive LS method Kalman filtering, Application: MIMO Wireless Channel Estimation, Error Covariance of Estimation, Equalization for Frequency Selective Channels, Kalman Filtering, Wiener filtering
Module 3	**Introduction to Signal Detection:** Formulation of the binary hypothesis testing problem, Maximum Likelihood-based Optimal Detection, Likelihood Ratio Test and Performance, Neyman Pearson Criterion for optimal detection, Minimum probability of error detector, Bayesian minimum risk detector

Module 4	**Detection of Deterministic/Random Signals:** Matched Filter Detector, Detection of signal under White noise and colored noise, Performance of Matched filter detection, Random signal detection- performance of Random signal detection, Detectors for MIMO
Module 5	**Signals with unknown parameters**. Deterministic Signals with unknown parameters, Generalized Log likelihood Ratio Test (GLRT), Bayesian Approach, GLRT for the Linear Model

References:

[1] H. V. Poor, *An introduction to signal detection and estimation.* Springer Science & Business Media, 2013.

[2] S. M. Kay, *Fundamentals of statistical signal processing: estimation theory.* Prentice-Hall, Inc., 1993.

[3] S. M. Kay, *Fundamentals of statistical signal processing: detection theory.* Prentice-Hall, Inc., 1993.

[4] P. Moulin and V. V. Veeravalli, *Statistical inference for engineers and data scientists.* Cambridge University Press, 2019.

25-510-0X18 Signal Integrity for High-Speed Digital Design

L	T	P	C
3	1	0	3

Prerequisites : This course will discuss the principles of signal integrity and its applications in the proper design of high-speed digital circuits. This course is designed to give the students the theoretical and simulation tools needed to determine where signal integrity issues may arise, how to prevent such problems and how to resolve problems when they arise in practice.

Course Outcome : After the completion of the course, student will be able to

CO1	Understand how high-frequency signals propagate on cables and circuit board traces	Understand
CO2	Understand design parameters that affect signal integrity including reflections, attenuation, and crosstalk	Understand
CO3	Develop the skills for analysing high-speed circuits with signal behaviour modelling	Apply
CO4	Design PCB's with consideration of signal integrity and impedance matching	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	2				3	2	2
CO2	3	3	2				3	2	2
CO3	3	3	3				3	2	2
CO4	3	3	3			2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction to Signal Integrity:** Definitions, Signal quality on a single net; Cross talk. Creating circuit models; the role of measurements. **The Physical Basis of Resistance, Capacitance and Inductance**: Bulk resistivity, resistance per length, sheet resistance, current flows in capacitors, power and ground planes and decoupling capacitance, capacitance per length. 2D solvers; Partial inductance, effective inductance, total or net inductance, and ground bounce, loop inductances, current distribution and skin depth, Eddy currents, 2D model examples of inductance circuits

Module 2	**Transmission Lines and Reflections:** Driving a transmission line, return paths. Characteristic and controlled impedance. Frequency variation of the characteristic impedance. Reflection at impedance changes. Source impedance. Bounce diagrams. Simulating reflected waveforms. Measuring reflections with TDR. Effects of corners and vias. Loaded lines
Module 3	**Lossy lines, Rise Time Degradation and Material Properties:** Losses in transmission lines, modeling lossy transmission line. Signal velocity. The bandwidth of an inter connect. Time domain behavior of lossy lines. Eye diagram of transmission line. Pre-emphasis and equalization. Modeling, simulation, verification, and testing of lossy line examples
Module 4	**Cross Talk in Transmission Lines:** Origin of coupling, cross talk in transmission lines: NEXT and FEXT, describing cross talk. The Maxwell capacitance matrix and 2D field solvers, the inductance matrix. Near-end cross talk. Far-end cross talk. Decreasing Far-End cross talk. De-embedding: Basic Concepts of De-embedding. Different de-embedding methods. Phase uncertainty and error analysis
Module 5	**Differential Signaling:** Removal of common-mode noise, Differential crosstalk, Differential crosstalk, Differential crosstalk; I/O design considerations: Push–pull transmitters, CMOS receivers, ESD Protection circuits, On-chip termination

References:

[1] E. Bogatin, *Signal and Power Integrity -Simplified, (3rd Edition),*. Prentice Hall, 2018.

[2] H. L. H. Stephen H. Hall, *Advanced signal integrity for high-speed digital designs.* John Wiley, 2009.

[3] H. Johnson and M. Graham, *High-Speed Digital Design: A Handbook of Black Magic.* Prentice Hall, 1993.

[4] D. Brooks, *Signal Integrity Issues and Printed Circuit Board Design.* Prentice Hall, 2003.

[5] G. H. S. Hall and J. McCall, *High Speed Digital Design: A Handbook for Interconnect Theory and Design Practices.* Wiley IEEE Press, 2000.

25-510-0X19	**Software Defined Radio Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Advanced Communication Systems
Lab Description	:	Implementation of basic analog and digital communication systems in SDR using GNURadio/ Labview
Lab Outcome	:	After the completion of the lab, the student will be able to

CO1	Familiarize with the GNU Radio and Labview software	Understand
CO2	Generate the block schematic in GNU Radio/ Labview and test using software defined radio (SDR) transceivers	Apply
CO3	Implement and analyse basic analog and digital communication systems in SDR	Analyse
CO4	Implement and analyse an end-to-end communication system prototype using SDR	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3		3					2	
CO2	3	3	3					3	
CO3	3	3	3	2	3	3		3	3
CO4	3	3	3	2	3	3		3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
Implementation of the following in MATLAB/Octave/Python	
1	To setup an FM Receiver
2	To setup an FM Transmitter and Receiver Station
3	To demonstrate BPSK/QPSK Modulation & Demodulation
4	To demonstrate DPSK Modulation & Demodulation
5	To setup a 2×2 MIMO system

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

References:

[1] [Online]. Available: https://www.gnuradio.org/doc/doxygen-3.7.4.1/index.html

[2] [Online]. Available: https://pysdr.org/content/intro.html

[3] A. M. Wyglinski, R. Getz, T. Collins, and D. Pu, *Software-defined Radio for Engineers.* Artech House, 2018.

25-510-0X20 **Antennas Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Taken with Antennas for Communication Systems
Course Description	:	The objective of this lab is to introduce the design, simulation and verification of performance of various antennas and arrays
Course Outcome	:	After the completion of the course, student will be able to

CO1	Characterise the performance of the various standard antenna/array designs using open source/licensed CAD tools	Apply
CO2	Measure the radiation performance different antennas using a Network Analyser and an anachoic chamber	Analyse
CO3	Develop an antenna design for a given set of design parameters and verify its performance	Apply

COs to POs Mapping

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3	3				3	3	3
CO2	3	2	3				3	2	2
CO3	3	3	3			2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarization with antenna simulation tools and measurement equipments
2	Design, simulation and analysis of basic antenna types: Dipole, Horn (different types), Patch (various types of feed and different polarizations)
3	Measurement of antenna characteristics and the radiation patterns of standard antennas: Horn, Dipole, Vivaldi, Spiral etc
4	Design and simulation of different types of antenna arrays

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

References:

[1] W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design.* John Wiley & sons, 3rd edition, 2012.

[2] C. A. Balanis, *Antenna Theory Analysis and Design.* John Wiley & sons, 4th edition, 2016.

[3] J. D. Kraus, R. J. Marhefka, and A. S. Khan, *Antennas and Wave Propagation*. Tata Macgraw Hill, 4th edition, 2017.

[4] S. K. Kaul and K. S. Karthikeya, *Antenna Architectures for Future Wireless Devices*. Signals and Communication Technology, Springer, 2021.

[5] U. Nissanov and G. Singh, *Antenna Technology for Terahertz Wireless Communication*. Springer, 2023.

[6] W. Hong and C. Y. D. Sim, *Microwave and Millimeter-Wave Antenna Design for 5G Smartphone Applications*. IEEE Press, 2023.

25-510-0X21 **5G Technologies and Standards**

L	T	P	C
3	1	0	3

Prerequisites	:	Digital Communications, Advanced Communication Systems, Wireless Networks
Course Description	:	The aim of this course is to let the students understand that air Interface is one of the most important elements that differentiate between 2G, 3G, 4G and 5G. While 3G was CDMA based, 4G was OFDMA based; this course reveals the contents of air interface for 5G. This course gives an overview of 5G vision that aims to provide extremely low delay services, great service in crowd, enhanced mobile broadband, ultra-reliable and secure connectivity, ubiquitous QoS, and highly energy efficient networks.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Understand the evolution of mobile communication standards developed over the years	Understand
CO2	Analyse the 5G potential and applications, case studies	Analyse
CO3	Interpretation of how virtualisation of network functions helps in scalability and ease of operations	Apply
CO4	Analyse the use of advanced techniques in cellular communications	Analyse
CO5	Appraise the current Status and future challenges for 5G and beyond	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	2	2							
CO2	3	2					3		3
CO3	3					2	2		
CO4	3	2				2	3		3
CO5	3	2		2	2	2	3		3

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Evolution from 1G to 5G:** Analog voice systems in 1G; digital radio systems in 2G, voice and messaging services, TDMA based GSM,CDMA, 2.5G (GPRS), 2.75G (EDGE); IMT2000: 3G UMTS, W-CDMA, HSPA, HSPA+, 3G services and data rates; IMT Advanced: 4G, LTE, VoLTE, OFDM, MIMO, LTE Advanced Pro (3GPP Release 13+); IMT2020: 5G, enhancements in comparison to IMT Advanced

Module 2	**Basics of 5G :** 5G potential and applications; Usage scenarios: enhanced mobile broadband (eMBB), ultra reliable low latency communications (URLLC), massive machine type communications (MMTC), D2D communications, V2X communications, Massive MIMO
Module 3	**5G architecture:** Spectrum for 5G, spectrum access/sharing; millimetre Wave communication, channels and signals/waveforms in 5G, carrier aggregation, small cells, dual connectivity, NFV and SDN, Basics about RAN architecture, centralized RAN, open RAN, High-level requirements for the 5G architecture, Functional architecture and 5G flexibility, Physical architecture and 5G deployment
Module 4	**5G radio-access technologies:** Orthogonal multiple-access systems, Spread spectrum multiple-access systems, Capacity limits of multiple-access methods, Non-orthogonal multiple access (NOMA), Massive MIMO, beam formation, FAPI: PHY API Specification, user plane protocol- Service Data Adaptation Protocol (SDAP); multi-access edge computing (MEC); software defined networking (SDN), network function virtualization (NFV); network slicing; restful API for service-based interface; private networks
Module 5	**Current state and Challenges ahead :** 5G penetration in developed countries; deployment challenges in low-middle income countries, stronger backhaul requirements, dynamic spectrum access and usage of unlicensed spectrum, contrasting radio resource requirements; large cell usage: LMLC; possible solutions for connectivity in rural areas (Bharat-Net, TVWS, Long-range WiFi, FSO); non-terrestrial fronthaul/backhaul solutions: LEOs, HAP/UAV, Vision for 6G

References:

[1] [Online]. Available: https://www.3gpp.org/specifications-technologies/releases/release-15

[2] E. Dahlman, S. Parkvall, and J. Skold, *5G NR: The Next Generation Wireless Access Technology.* Academic Press, 2020.

[3] A. Osseiran, J. F. Monserrat, and P. Marsch, *5G Mobile and Wireless Communications Technology.* Cambridge University Press, 2016.

[4] S. Ahmadi, *5G NR: Architecture, Technology, Implementation, and Operation of 3GPP New Radio Standards.* Academic Press, 2019.

[5] E. Dahlman, S. Parkvall, and J. Skold, *4G, LTE-advanced Pro and the Road to 5G.* Academic Press, 2016.

25-510-0X22 **Machine Learning Lab**

L	T	P	C
0	0	4	2

Prerequisites : None

Lab Description : This lab provides experiments to implement machine learning algorithms using Python with the help of open source libraries such as sklearn, keras, pytorch, etc.

Course Outcome : After the completion of the lab, the student will be able to

CO1	Design and implement linear, nonlinear regression and logistic regression models	Apply
CO2	Design and implement ANN for solving ML problems	Apply
CO3	Design and implement SVM for solving ML problems	Apply
CO4	Design and implement unsupervised learning methods like clustering algorithms and dimensionality reduction algorithms	Apply
CO5	Design ML system suitable to the problem, analyse and evaluate the model performance	Analyse

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1			3	3	2	2	3	2	3
CO2			3	3	2	2	3	2	3
CO3			3	3	2	2	3	2	3
CO4			3	3	2	2	3	2	3
CO5			3	3	2	2	3	3	3

3-High; 2-Medium; 1-Low

Course Content:

Sample List of Experiments*	
1	Familiarisation Python, Jupyter notebook, and libraries such as sklearn, keras and pytorch
2	Implement the Linear and Logistic Regression model with gradient descent optimisation
3	Implement Artificial Neural Network models and optimise using back propagation algorithm
4	Implement Support Vector Machines for classification tasks for linear and non-linear data
5	Implement k-means clustering algorithm and Principle Component Analysis algorithm

6	Solution proposal for a real world problem, model a neural network, pre-process the data, train the model and evaluate the performance and improve the learning through parameter tuning

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

References:

[1] A. Géron, *Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow*, 3rd ed. " O'Reilly Media, Inc.", 2022.

[2] J. Krohn, *Deep Learning with TensorFlow, Keras, and PyTorch.* Pearson, 2020.

[3] Documentations of python libraries.

25-510-0X23 **EMI/EMC Lab**

L	T	P	C
0	0	4	2

Prerequisites	:	Taken with Electromagnetic Interference and Compatibility
Course Description	:	The objective of this lab is to familiarise the student with the significance of EMI/EMC and their impact in circuit design using appropriate experiments and simulation studies.
Course Outcome	:	After the completion of the course, student will be able to

CO1	Measure the conducted emission, radiated emission and crosstalk.	Apply
CO2	Determine the EM compatibility of a device	Analyse
CO3	Apply EMI mitigation techniques such as shielding.	Apply

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	2	2				3	2	2
CO2	3	2	2			2	3	2	3
CO3	3	3	3			2	3	2	2

Sample List of Experiments*

1	Familiarise with conducted and radiated emission measurement and simulation setup
2	Study and simulate different crosstalk in the cable and its reduction technique
3	Measure crosstalk in a three conductor transmission line using VNA
4	tudy the characteristics and measure the conducted emission of a Current Probe
5	Measure board level emission using Magnetic Field loop Probes
6	Measure radiated emission from mobile tower and mobile phone
7	Design and simulate an EMI Sensor and EMI Filter

* The list is not exhaustive. Additional experiments or project based on the experiments can be included in the laboratory activity.

References:

[1] C. R. Paul, *Introduction to Electromagnetic Compatibility*, three ed. John Wiley & Sons, 2022.

[2] H. W. Ott, *Electromagnetic Compatibility Engineering*, 2nd ed. John Wiley & Sons, 2009.

[3] W. D. Kimmel and D. Gerke, *Electromagnetic Compatibility in Medical Equipment*. IEEE & Interpharm Press, 1995.

[4] V. P. Kodali, *Engineering EMC Principles, Measurements and Technologies*, 2nd ed. Wiley-Blackwell, 2001.

25-509-0X15	**Analog & RF IC Design**

L	T	P	C
3	**1**	**0**	**3**

Prerequisites : Circuit analysis

Course Description : This course introduces students to the analysis and design of basic analog integrated circuit components like amplifiers, current mirrors and biasing circuits. Specifications and trade-offs involved in analog design are covered. The course also covers various factors involved in the design of RF integrated circuit components.

Course Outcome : After the completion of the course, student will be able to

CO1	Perform small signal analysis using MOSFET models	Apply
CO2	Design single stage and differential amplifiers for given specification	Apply
CO3	Discuss about appropriate current sources and voltage references for biasing	Undersatnd
CO4	Understand the basic building blocks of RF ICs and the trade-offs involved in RF designs	Understand
CO5	Explain the methodologies for designing RF IC components with given specifications	Undersatnd

COs to POs and PSOs Mapping:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PSO1	PSO2	PSO3
CO1	3	3					3		
CO2	3	3					3		
CO3	3						3		
CO4	3						3		
CO5	3						3		

3-High; 2-Medium; 1-Low

Course Content:

Module 1	**Introduction:** Review of 4 terminal MOSFET, small signal model and analysis, high frequency model **RF Basic Concepts:** Non linearity and its effects, noise, sensitivity & dynamic range, passive impedance transformation, scattering parameters, bandwidth estimation techniques
Module 2	**Single Stage Amplifiers:** Single stage amplifiers - common source, source follower, common gate, cascode amplifiers, frequency response, noise

Module 3	**Differential Amplifiers:** Basic differential pair, common mode response, frequency response, noise, MOS transistor mismatch, effect of transistor mismatch **Current Mirrors & Biasing:** Basic and cascode current mirrors, effect of transistor mismatch, biasing techniques, self biasing circuits, supply independent bias circuits, bandgap reference
Module 4	**Low Noise Amplifiers:** Input matching, LNA topologies, gain and band switching, non linearity calculations, power constrained design optimizations, design examples **Mixers:** Mixer fundamentals, mixing using non linear systems, multiplier based mixers
Module 5	**Oscillators:** Ring oscillators, LC oscillators, inductors and capacitors, voltage controlled oscillators **Phase Locked Loops**: Simple PLL, Type II PLL, Non-idealities, phase noise

References:

[1] B. Razavi, *Design of Analog CMOS Integrated Circuit*, 2nd ed. McGraw Hill India, 2017.

[2] T. H. Lee, *The Design of CMOS Radio-Frequency Integrated Circuits*, 2nd ed. Cambridge University Press, 2014.

[3] B. Razavi, *RF Microelectronics*, 2nd ed. Prentice Hall, 2012.

[4] P. E. Allen and D. R. Holberg, *CMOS Analog Circuit Design*, 3rd ed. Oxford University Press, 2013.

[5] R. Jacob Baker, *CMOS Circuit Design, Layout and Simulation*, 3rd ed. Wiley-Blackwell, 2010.