M. Tech. Degree

IN

COMMUNICATION SYSTEMS

SYLLABUS
FOR
CREDIT BASED CURRICULUM
(For students admitted in 2024)

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
TIRUCHIRAPPALLI – 620 015
TAMIL NADU, INDIA

Institute Vision and Mission

Vision

- To be a university globally trusted for technical excellence where learning and research integrate to sustain society and industry.

Mission

- To offer undergraduate, postgraduate, doctoral and modular programmes in multi-disciplinary / inter-disciplinary and emerging areas.
- To create a converging learning environment to serve a dynamically evolving society.
- To promote innovation for sustainable solutions by forging global collaborations with academia and industry in cutting-edge research.
- To be an intellectual ecosystem where human capabilities can develop holistically.

Department Vision and Mission

Vision

- To excel in education and research in Electronics and Communication Engineering

Mission

- To educate with the state of art technologies to meet the growing challenges of the industry.
- To carry out research through constant interaction with research organizations and industry.
- To equip the students with strong foundations to enable them for continuing Education.

Program Educational Objectives (PEOs)

- **PEO1:** Graduates of the programme will be professional Telecommunication Engineers, Researchers, and Academicians with ethical and societal responsibility.

- **PEO2:** Graduates of the programme, as part of an organization, will continue to learn and handle cutting-edge technology.

Program Outcomes (POs)

- **PO1:** An ability to independently carry out research /investigation and development work to solve practical problems in communication systems.
- **PO2:** An ability to write and present a substantial technical report/document in communication systems.
- **PO3:** Students should be able to demonstrate mastery over communication systems. The mastery should be at a level higher than the requirements in the appropriate bachelor program.

CURRICULUM

The total minimum credits required for completing the M.Tech. Communication Systems Programme in Electronics and Communication Engineering is 80

SEMESTER I

Sl. No.	CODE	COURSE OF STUDY	C
1.	EC601	Linear Algebra and Stochastic Processes	4
2.	EC603	Advanced Digital Signal Processing	4
3.	EC605	Microwave Circuits	4
4.		Elective – 1	3
5.		Elective – 2	3
6.		Elective – 3	3
7.	EC607	Microwave and MIC Laboratory	2
		TOTAL	23

SEMESTER II

Sl. No.	CODE	COURSE OF STUDY	C
1.	EC602	Advanced Digital Communication	4
2.	EC604	Broadband Wireless Technologies	4
3.	EC606	Optical Communication Systems	4
4.		Elective – 4	3
5.		Elective – 5	3
6.		Elective – 6	3
7.	EC608	Fiber Optics and Communication Laboratory	2
8.	EC610	Digital Signal and Image Processing Laboratory	2
		TOTAL	25

SUMMER TERM (Evaluation in Semester III)

Sl. No.	CODE	COURSE OF STUDY	C
1.	EC649	Internship/Industrial Training/Academic Attachment(I/A) (6 Weeks to 8 Weeks)	2

SEMESTER III

Sl. No	CODE	COURSE OF STUDY	C
1	EC647	Project – Phase I	12
		TOTAL	12

SEMESTER IV

SL. No	CODE	COURSE OF STUDY	C
1	EC648	Project - Phase II	12
		TOTAL	12

In addition to the Programme electives, students have to do 2 Open Electives offered by the institute or PG-level Online Courses from NPTEL (Can be completed from Semester I-IV) as given in the list in the next page. If students opt to do open electives from institute, they can choose open electives offered by VLSI or other departments.

Sl. No.	CODE	COURSE OF STUDY	C
1.		Open Elective I/Online Course I	3
2.		Open Elective II/Online Course II	3
		TOTAL OPEN ELCTIVE CREDITS	6
		GRAND TOTAL(23+25+2+12+12+6)	80

LIST OF PROGRAMME ELECTIVES

Sl. No	CODE	COURSE OF STUDY	C
1.	EC611	Detection and Estimation	3
2.	EC612	DSP Architecture	3
3.	EC613	High Speed Communication Networks	3
4.	EC614	Spectral Analysis of Signal	3
5.	EC615	Digital Image Processing	3

6.	EC616	RF MEMS	3
7.	EC617	Smart Antennas	3
8.	EC618	Ad Hoc Networks	3
9.	EC619	Wavelet Signal Processing	3
10.	EC620	WDM Optical Networks	3
11.	EC621	Advanced Techniques for Wireless Reception	3
12.	EC622	Error Control Coding	3
13.	EC623	Digital Communication Receivers	3
14.	EC624	Analysis Methods for Passive MIC	3
15.	EC625	Electromagnetic Metamaterials	3
16.	EC626	Bio MEMS	3
17.	EC627	Substrate Integrated Waveguide Technology: Design and Analysis	3
18.	EC628	Pattern Recognition and Computational Intelligence	3
19.	EC629	Photonic Integrated Circuits and Systems	3
20.	EC630	Fiber-Optic Sensors	3
21.	EC631	Optical Wireless Communications	3
22.	EC632	Foundations of Artificial Intelligence	3
23.	EC633	Introduction to Soft Computing and Machine Learning	3
24.	EC634	Next Generation WLAN	3
25.	EC635	Electromagnetic Interference and Compatibility	3
26.	EC636	Computer Vision	3
27.	EC637	Natural Language Processing	3
28.	EC638	Optimization Methods in Machine Learning	3
29.	EC639	Hardware for Deep Learning	3
30.	EC640	Image and Video Processing	3

31.	EC641	Automated Test Engineering for Electronics	3
32.	EC654	Electronic Design Automation Tools	3
33.	EC656	Design of ASICs	3
34.	EC646	Verilog HDL: Digital Design and Modeling	3
35.	EC663	Optimization of Digital Signal Processing structures for VLSI	3
36.	EC664	Cognitive Radio	3
37.	EC642	Radiating Systems	3
38.	EC643	Advanced Topics in 5G/B5G Wireless Communication	3

LIST OF OPEN ELECTIVES (Offered to VLSI and other departments)

Sl. No	CODE	COURSE OF STUDY	C
1.	EC703	Pattern Recognition and Computational Intelligence Techniques	3
2.	EC704	High Speed Networks and Internet	3
3.	EC705	Design for Electromagnetic Compatibility	3

LIST OF NPTEL ONLINE COURSES

Sl. No	CODE	COURSE OF STUDY	C
1.	EC801	Fundamentals of MIMO Wireless Communications	3
2.	EC802	Evolution of Air Interface Towards 5G	3
3.	EC803	Introduction to Industry 4.0 and Industrial Internet of Things	3
4.	EC804	VLSI Data Conversion Circuits	3
5.	EC805	Introduction to Time-Varying Electrical Networks	3
6.	EC806	Power Management Integrated Circuits	3
7.	EC807	Optical Wireless Communications beyond 5G Networks and IOT	3
8.	EC808	5G Wireless Standard Design	3

COURSE OUTCOME AND PO MAPPING

PROGRAMME CORE (PC):

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

Course Code	Course Title	CO	Course outcomes At the end of the course student will be able to	PO1	PO2	PO3
EC601	Linear Algebra and Stochastic Process	CO1	solve the problems associated with Linear algebra	3		2
		CO2	solve the problem associated with transformation of random variables	3		2
		CO3	summarize the concepts associated with multiple random variables and to solve the problems associated with Multivariate Gaussian random vector	3		3
		CO4	summarize the concepts associated with random process and to compute the power spectral density of the output of the system.	3		3
		CO5	recognize the usage of random process in telecommunication engineering and to solve the corresponding problems.	3		3
EC603	Advanced Digital Signal Processing	CO1	apply multirate DSP for applications and design efficient digital filters & construct multi-channel filter banks	3		2
		CO2	select linear filtering techniques to engineering problems	3		3
		CO3	describe the most important adaptive filter generic problems and algorithms	3		3
		CO4	describe the statistical properties of the conventional spectral estimators	3		3
		CO5	implement and present a recent research paper in ADSP	3	3	3
EC605	Microwave Circuits	CO1	Understand the basics of Scattering matrix and two port characterization and importance of matching circuits.	3	1	2
		CO2	Analyze the working principles of couplers, power dividers etc. and their design.	3	1	2
		CO3	Design the different types of MIC filters and their implementation.	3	1	2
		CO4	Understand the complexities of microwave amplifier design and its stability features.	3	1	2
		CO5	Analyze and appreciate the design principles of microwave oscillators.	3	1	2
EC602	Advanced	CO1	Understand the operation, theoretical analysis and design of baseband, passband data	3	2	1

	Digital Communication		transmission systems.			
		CO2	Design and implement various error control codes.	3	2	2
		CO3	Summarize spread spectrum technology and its application.	3	1	1
		CO4	Compare single carrier and multicarrier communication systems.	3	2	1
		CO5	Do research in the digital communication systems.	3	3	2
EC604	Broadband Wireless Technologies	CO1	discuss the cellular system design and technical challenges	1	1	3
		CO2	analyze the Mobile radio propagation and practical link budget design	3	2	1
		CO3	analyze fading, diversity concepts, channel models, and design parameters at Base Station (BS).	3	2	3
		CO4	analyze Multiuser Systems, CDMA, WCDMA network planning and OFDM Concepts	3	3	3
		CO5	summarize the principles and applications of wireless systems and standards, smart antenna, beamforming and MIMO systems	3	3	3
EC606	Optical Communication Systems	CO1	Understand the modulation and demodulation schemes in the coherent optical systems.	3	3	3
		CO2	understand the various types of the optical amplifiers	3	3	3
		CO3	analyse various multiplexing techniques used and evaluate the recent advances in this field	3	3	3
		CO4	compare the merits and demerits, potential applications of microwave semiconductor devices.	3	3	3
		CO5	analyse the operating principle of WDM solutions systems	3	3	3

ESSENTIAL LABORATORY REQUIREMENTS (ELR):

Course Code	Course Title	CO	Course outcomes At the end of the course student will be able to	PO1	PO2	PO3
EC607	Microwave and MIC Laboratory	CO1	Design and measure the parameters of MIC components	2	2	3
		CO2	Design and measure the parameters of MIC filters	2	2	3

		CO3	Design and simulate the planar antennas using CAD tools	2	2	3
		CO4	Measure the characteristics of Microwave sources	2	2	3
		CO5	Design and measure the parameters of planar antennas	2	2	3
EC608	Fiber Optics and Communication Laboratory	CO1	Understand the basic concepts and advancements in fiber optic technology and wireless communication systems.	3	2	1
		CO2	Understand the channel characteristics of fiber optics and wireless communication systems and the concept of the optical amplifier.	3	2	1
		CO3	Demonstrate the digital modulation schemes and error control coding techniques.	3	2	1
		CO4	Interpret the fiber optic and wireless communication system models by using the simulation software.	3	2	1
		CO5	Analyze the operating principle of WDM solutions systems and the effect of nonlinearity in optical fiber.	3	2	1
EC610	Digital Signal and Image Processing Laboratory	CO1	design simple adaptive filters	3	2	2
		CO2	study the performance of periodogram power spectrum estimator	3	2	2
		CO3	learn basic image processing transforms	3	2	3
		CO4	learn basic image processing techniques to improve the quality of image	3	2	3

PROGRAMME ELECTIVES (PE):

Course Code	Course Title	CO	Course outcomes At the end of the course student will be able to	PO1	PO2	PO3
EC613	High Speed Communication Networks	CO1	compare and analyse the fundamental principles of various high speed communication networks and their protocol architectures	3	2	2
		CO2	examine the performance modeling, congestion control issues and traffic management in IP networks	3	2	2
		CO3	compare and analyse the various routing protocols in IP networks	3	2	2
		CO4	study of various wireless LAN standards, Blue tooth and high data rate personal area	3	2	2

			networks			
		CO5	examine quality of service in IP networks.	3	2	2
EC615	Digital Image Processing	CO1	Reproduce the need for image transforms, different types of image transformation and their properties.	2		2
		CO2	Compare different techniques employed for the enhancement of images.	2		2
		CO3	Compare various spatial and frequency domain techniques of image processing.	3		2
		CO4	Summarize various morphological operations and segmentation techniques.	3		2
		CO5	Summarize various pattern recognition concepts and demonstrate the image pattern classifier.	3		3
EC625	Electromagnetic Metamaterials	CO1	learn and understand the properties of metamaterials and the effect of properties on fundamental phenomena	1	1	2
		CO2	understand the theory of Transmission line theory of Metamaterials.	1	1	2
		CO3	discuss different types of SRR and to derive equivalent circuit	1	1	2
		CO4	discuss the metamaterial properties for performance enhancement of antenna.	1	1	2
		CO5	learn the design of microwave components using metamaterials.	1	1	2
EC628	Pattern Recognition and Computational Intelligence	CO1	summarize various techniques involved in linear regression techniques	2		2
		CO2	summarize various techniques involved in dimensionality reduction techniques	2		3
		CO3	summarize various techniques involved in linear classifier techniques	3		3
		CO4	summarize various techniques involved in probabilistic generative and discriminative model	3		3
		CO5	summarize various techniques involved in computational intelligence techniques.	3		3
EC629	Photonic Integrated Circuits	CO1	Recognize the fundamental concept of optical waveguides.	2	2	1
		CO2	Classify the different types of optical waveguides.	1	2	1
		CO3	Classify the couplers, modulators and devices for communication applications	3	2	1
		CO4	Summarize the fabrication technologies for design of optical waveguides	1	2	1

		CO5	Discuss the various nonlinear effects in integrated optical waveguides and integrated optical systems.	2	2	1
EC634	Next Generation WLAN	CO1	To understand basics of WLAN systems including standardizing bodies, unlicensed spectrum ranges, network types.	1	2	1
		CO2	Appreciate physical layer challenges and solutions in 802.11 standards and be able to simulate channel conditions	2	2	1
		CO3	Be able to explain MAC layer steps in WLAN along with the motivation and impacts on throughput and coexistence	2	2	1
		CO4	Trace the steps followed in a typical WLAN network with a clear understanding of security, power save, and network entry procedures	2	2	2
		CO5	Analyze real-life protocol traces under various conditions and correlate with the concepts learnt in the earlier sections.	2	2	2
EC635	Electromagnetic Interference and Compatibility	CO1	Understand the various sources of Electromagnetic interference	3	1	2
		CO2	Familiarize the fundamentals those are essential for product design with EMC compliance and various EMC standards	3	1	2
		CO3	would gain knowledge to understand the concept of Shielding and grounding related to product design.	3	1	2
		CO4	Design PCBs which are electromagnetically compatible	3	1	2
		CO5	understand and differentiate the various EMC pre compliance measurement	3	1	2

Course Code	**:**	**EC601**
Course Title	**:**	**Linear Algebra and Stochastic Processes**
Number of Credits	**:**	**4**
Course Type	**:**	**Core**

COURSE OBJECTIVE

- The subject introduces the probability, random process and the linear algebra that are required for the theoretical analysis of the communication systems.

COURSE CONTENT

Vector spaces. Four fundamental vector spaces of the matrix. Rank-Nullity theorem. Projection theorem.- Linear transformation matrix with different basis- Gram-Schmidt orthogonalization procedure. QR factorization. Eigen values and Eigen vectors. Diagonalization of the matrix. Schur's lemma. Hermitian Matrices- Unitary Matrices - Normal Matrices. Singular Value Decomposition.

Probability spaces. Random variables and random vectors. Distributions and densities-Conditional distributions and densities. Independent random variables. Transformation of random variables

Expectations. Indicator. Moment generating function. Characteristic function. Multiple random variable. Gaussian random vector. Co-variance matrix. Complex random variables. Sequence of random variable-Central limit theorem.

Strictly stationary random process. Wide sense stationary random process. Complex random process. Jointly strictly and wide sense stationary of two random processes. Correlation matrix obtained from random process. Ergodic process. Independent random process. Uncorrelated random process. Random process as the input and output of the system. Power spectral density.

White random process. Gaussian random process. Cyclo-stationary random process. Wide sense cyclo stationary random process. Sampling and reconstruction of random process. Band pass random process. Applications of Linear algebra and Stochastic process for telecommunication.

Mini Project

Text Books

1. *R.B.Ash & C.Doleans-Dade, "Probability and Measure Theory (2/e)", Elsevier, 2005*
2. *A.Papoulis, S.U.Pillai, "Probability, Random variables and Stochastic processes" 4th edition Tata-Mc Hill (4/e) ,2001*
3. *G.Strang, "Linear Algebra", Thomson Brooks/Cole Cengage Hill (4/e), 2006*

Reference Books

1. *Stakgold, I., Green's "Functions and Boundary value Problems (e)", Wiley,1998*
2. *E.S.Gopi, "Mathematical summary for digital signal processing applications with Matlab", Springer,2011.*
3. *E.Wong & B.Hajek, "Stochastic Processes in Engineering systems", Springer, 1985.*
4. *R.B.Ash & W.A.Gardner, "Topics in stochastic processes", Academic Press, 1975.*
5. *Recent literature in Linear Algebra and Stochastic Processes.*

COURSE OUTCOMES

Students are able to

CO1: solve the problems associated with Linear algebra

CO2: solve the problem associated with transformation of random variables

CO3: summarize the concepts associated with multiple random variables and to solve the problems associated with Multivariate Gaussian random vector

CO4: summarize the concepts associated with random process and to compute the power spectral density of the output of the system.

CO5: recognize the usage of random process in telecommunication engineering and to solve the corresponding problems.

Course Code	**:**	**EC603**
Course Title	**:**	**Advanced Digital Signal Processing**
Number of Credits	**:**	**4**
Course Type	**:**	**Core**

COURSE OBJECTIVE

- To provide rigorous foundations in multirate signal processing, power spectrum estimation and adaptive filters.

COURSE CONTENT

Review of sampling theory. Sampling rate conversion by integer and rational factors. Efficient realization and applications of sampling rate conversion.

Wiener filtering. Optimum linear prediction. Levinson- Durbin algorithm. Prediction error filters.

Adaptive filters. FIR adaptive LMS algorithm. Convergence of adaptive algorithms. Fast algorithms. Applications: Noise canceller, echo canceller and equalizer.

Recursive least squares algorithms. Matrix inversion lemma. Convergence analysis of the RLS algorithm. Adaptive beam forming. Kalman filtering.

Spectrum estimation. Estimation of autocorrelation. Periodogram method. Nonparametric methods. Parametric methods.

Mini Project

Text Books

1. *J.G.Proakis, M. Salehi, "Advanced Digital Signal Processing", McGraw –Hill, 1992.*
2. *S.Haykin, "Adaptive Filter Theory (3/e)", Prentice- Hall, 1996.*

Reference Books

1. *D.G.Manolakis, V. K. Ingle, and S. M. Kogon ,"Statistical and Adaptive Signal Processing", McGraw-Hill,2005*
2. *S.L.Marple,"Digital Spectral Analysis", 1987.*
3. *M.H.Hays," Statistical Digital Signal Processing and Modeling", John-Wiley, 2001.*
4. *Recent literature in Advanced Digital Signal Processing.*

COURSE OUTCOMES

Students are able to

CO1: apply multirate DSP for applications and design efficient digital filters & construct multi-channel filter banks.
CO2 select linear filtering techniques to engineering problems.
CO3: describe the most important adaptive filter generic problems and algorithms.
CO4: describe the statistical properties of the conventional spectral estimators.
CO5: implement and present a recent research paper in ADSP

Course Code	**:**	**EC605**
Course Title	**:**	**Microwave Circuits**
Number of Credits	**:**	**4**
Course Type	**:**	**Core**

COURSE OBJECTIVE

CLO1	**To design Impedance matching circuits**
CLO2	**To design power divider circuits using microstrip technology**
CLO3	**To design MIC filters for various application**
CLO4	**To analyze and design the amplifier for RF applications**
CLO5	**To understand the operation of RF oscillators**

COURSE CONTENT

Introduction and application of microwave circuits - Two-port network characterization. ABCD parameters, Conversion of S matrix in terms of ABCD matrix. Scattering matrix representation of microwave components. Review of Smith chart and its application- Impedance matching using Lumped and Distributed approach.

Microwave Passive circuit design: Characteristics, properties, design parameters and applications- Design and realization of MIC Power dividers. 3 dB hybrid design. Directional Coupler design- Hybrid ring design.

Microwave filter design- Filter design by insertion loss method –Richards and Kuroda transformation. K inverter, J inverter. Resonator filters. Realization using microstrip lines and strip lines.

Microwave amplifier design- Power gain equations -Stability considerations. Maximum gain design, Design for specific gain -Low Noise Amplifier Design. High power design.

Microwave oscillator design. One – port and two – port negative resistance oscillators and oscillator design

Mini Project

Text Books:

1. *Reinhold Ludwig, RF circuit design, 2nd edition, Prentice Hall 2014, ISBN: 978-0131471375*
2. *David. M. Pozar, Microwave engineering, 4th edition, John Wiley, 2011, ISBN: 978-0470631553.*
3. *Devendra K. Misra, "Radio-Frequency and microwave communication circuits analysis and design", 2nd edition, University of Wisconsin-Mulwaukee, A John Wiley & Sons Publication*

Reference Books:

1. *B. Bhat, S. K Koul, "Stripline like transmission lines for Microwave Integrated Circuits", New Age International Pvt. Ltd Publishers, 2007.*
2. *I.J.Bahl & P.Bhartia, "Microwave Solid state Circuit Design (2/e)", Wiley, 2003.*
3. *Matthew M. Radmanesh, Radio Frequency and Microwave Electronics Illustrated, Prentice Hall, 2012*
4. *S.Y.Liao, "Microwave Circuit Analysis and Amplifier Design", Prentice-Hall, 1986.*
5. *G. Mathaei, L young, E.M.T. Jones, "Microwave filters, Impedance-Matching networks and Coupling structures", Artech House Books.*

COURSE OUTCOMES

Students are able to

CO1: Understand the basics of Scattering matrix and two port characterization and importance of matching circuits.

CO2: Analyze the working principles of couplers, power dividers etc. and their design.
CO3: Design the different types of MIC filters and their implementation.
CO4: Understand the complexities of microwave amplifier design and its stability features.
CO5: Analyze and appreciate the design principles of microwave oscillators.

Course Code	**:**	**EC607**
Course Title	**:**	**Microwave and MIC Laboratory**
Number of Credits	**:**	**2**
Course Type	**:**	**Laboratory**

COURSE OBJECTIVE

CLO1	**To Design of various MIC components and parameters measurement**
CLO2	**MIC filter design and measurement of parameters**
CLO3	**Design of Microstrip antenna and simulation**
CLO4	**Coupler design and performance measurement**
CLO5	**Microstrip line design and parameters measurement**

List of Experiments:

1. Characteristics of Reflex Klystron
2. Characteristics of Gunn diode
3. Impedance Measurement
4. Frequency and Wavelength Measurement
5. Characteristics of Branch line directional coupler
6. Study of 3dB power divider
7. Study of Rat-race Hybrid ring
8. Study of Filters
9. Antenna Measurements
10. Study of 50Ω Microstrip Line
11. Study of Parallel line directional coupler

COURSE OUTCOMES

At the end of the course students are able to do

CO1: Design and measure the parameters of MIC components
CO2: Design and measure the parameters of MIC filters
CO3: Design and simulate the planar antennas using CAD tools
CO4: Measure the characteristics of Microwave sources
CO5: Design and measure the parameters of planar antennas

Course Code	**:**	**EC602**
Course Title	**:**	**Advanced Digital Communication**
Number of Credits	**:**	**4**
Course Type	**:**	**Core**

COURSE OBJECTIVE

- This subject gives an in depth knowledge and advancement in digital communication systems. It introduces some of the upcoming technologies like Multiuser - communication, Multi channel and Multicarrier communication technologies.

COURSE CONTENT

Baseband data transmission- Nyquist criterion for zero ISI, Correlative level coding, Optimum design of transmit and receive filters, Equalization.

Passband Digital transmission- Digital modulation schemes, Carrier synchronization methods, Symbol timing estimation methods.

Error control coding - Linear block codes, cyclic codes-encoding and decoding, Non-binary codes, Convolutional codes, Decoding of convolutional codes, Trellis coded modulation, Interleaver, Turbo coding, Performance measures.

Spread spectrum communication- D S and F H spread spectrum, CDMA system based on FH and DS spread spectrum signals, Applications, Synchronization of spread spectrum signals.

Multichannel and Multicarrier communication Systems, Multi user communication systems.

Mini Project

Text Books

1. *J.G.Proakis," Digital Communication (4/e)", McGraw- Hill, 2001*
2. *S. Haykin, "Communication systems (4/e)",John Wiley, 2001*
3. *B.P. Lathi, Zhi Ding, "Modern Digital and Analog Communication Systems (4/e)",Oxford university Press, 2010*

Reference Book

1. *S.Lin & D.J.Costello, Error Control Coding (2/e) Pearson, 2005*
2. *Recent literature in Advanced Digital Communication.*

COURSE OUTCOMES

At the end of course student will be able to

CO1: Understand the operation, theoretical analysis and design of baseband, passband data transmission systems.
CO2: Design and implement various error control codes.
CO3: Summarize spread spectrum technology and its application.
CO4: Compare single carrier and multicarrier communication systems.
CO5: Do research in the digital communication systems.

Course Code	**:**	**EC604**
Course Title	**:**	**Broadband Wireless Technologies**
Number of Credits	**:**	**4**
Course Type	**:**	**Core**

COURSE OBJECTIVE

CLO1	To understand the fundamentals of wireless communication system and capacity improvement methods in cellular system.
CLO2	To learn the mobile radio propagation and practical link budget design.
CLO3	To identify and describe the different types of fading, diversity concepts and design parameters at the base station (BS).
CLO4	To understand the various access technologies such as CDMA and OFDMA.
CLO5	To learn the latest advancements in wireless broadband technologies including 4G and beyond 4G.

COURSE CONTENT

Introduction to Wireless Communication. The Cellular concept, System design, Capacity improvement in cellular systems, Co channel interference reduction. Intelligent cell concept and applications. Technical Challenges.

Mobile radio propagation: Reflection, Diffraction. Outage probability under path loss and Shadowing. Calculation of boundary coverage and area coverage. Practical link budget design using path loss models.

Fading. Multipath Propagation. Parameters of mobile multipath channels. Statistical Channel models, Diversity Schemes and Combining Techniques. Design parameters at the base station. RAKE receiver.

Multiuser Systems: CDMA- Principle, Network design, Link capacity, Power control. WCDMA-Network planning, MC-CDMA, OFDM, Cellular mobile communication beyond 3G.

Wireless Systems and Standards. Ultra-wideband communications. Smart antenna systems, Beam forming. MIMO Systems. Massive MIMO. 4G and beyond 4G. NOMA and 5G.

Mini Project

Text Books

1. *A.F.Molisch, Wireless Communications, Wiley, 2005.*
2. *A.Goldsmith, Wireless Communications, Cambridge University Press, 2005.*

Reference Books

1. *P. Muthu Chidambara Nathan, "Wireless Communications", PHI, 2013.*
2. *D.Tse, P.Viswanath, "Fundamentals of Wireless Communication", Cambridge University Press, 2005.*
3. *S.G. Glisic, "Advanced Wireless Communications", 4G Technologies, Wiley, 2004.*
4. *W. C. Y.Lee, "Mobile Communication Engineering", (2/e), McGraw- Hill, 1998.*
5. *Gordon L.Stubder, "Principles of Mobile Communication", 3rd edition, Springer, 2013.*
6. *Recent literature in Broadband Wireless Technologies.*

COURSE OUTCOMES

Students are able to

CO1: discuss the cellular system design and technical challenges.

CO2: analyze the Mobile radio propagation, and practical link budget design.

CO3: analyze fading, diversity concepts, channel models, and design parameters.

CO4: analyze Multiuser Systems, CDMA, WCDMA network planning and OFDM Concepts.

CO5: summarize the principles and applications of wireless systems and standards, smart antenna, beam forming and MIMO systems.

Course Code	**:**	**EC606**
Course Title	**:**	**Optical Communication Systems**
Number of Credits	**:**	**4**
Course Type	**:**	**Core**

COURSE OBJECTIVE

- To prepare the students understand the various process and subsystems involved in the optical communication.
- To enable the students appreciate the different multiplexing technologies in the fiber optic communication.
- To design optical communication systems to serve a defined purpose

COURSE CONTENT

Fundamentals of coherent systems: Basic concepts. Modulation and demodulation schemes. System performance.

Semiconductor optical amplifiers. EDFA and Raman amplifiers – modeling and analysis. Analysis and digital transmission with high power fiber amplifiers.

Multichannel systems: WDM light wave systems. TDM and code division multiplexing.

Advances in wavelength division multiplexing / demultiplexing technologies.

SONET/SDH, ATM, IP, storage area networks. Wavelength routed networks. Next generation optical Internets.

Soliton systems: Nonlinear effects. Soliton – based communication. High speed and WDM soliton systems

Mini Project

Text Books

1. *G.P.Agrawal, "Fiber Optic Communication Systems (4/e)", Wiley, 2010*
2. *B.P.Pal , "Guided Wave Optical Components and Devices", Elsevier , 2006*

Reference Books

1. *C.S.Murthy & M.Gurusamy, "WDM Optical Networks", PHI, 2002*
2. *R.Ramaswami, K.N. Sivarajan, "Optical Networks", (2/e), Elsevier, 2002.*
3. *G.P.Agrawal, "Non linear Fiber Optics", (4/e), Elsevier, 2010*
4. *A Selvarajan, S. Kar, T. Srinivas, "Opticl fiber communication principles and systems", Tata McGraw Hill, 2005.*
5. *Recent literature in Optical Communication Systems.*

COURSE OUTCOMES

Students are able to

CO1: understand the modulation and demodulation schemes in the coherent optical systems.
CO2: understand the various types of the optical amplifiers
CO3: analyse various multiplexing techniques used and evaluate the recent advances in this field
CO4: compare the merits and demerits, potential applications of microwave semiconductor devices.
CO5: analyse the operating principle of WDM solutions systems.

Course Code	**:**	**EC608**
Course Title	**:**	**Fiber Optics and Communication Laboratory**
Number of Credits	**:**	**2**
Course Type	**:**	**Laboratory**

COURSE OBJECTIVE

CLO1	To prepare the students understand the various process and subsystems involved in the optics and communication systems.
CLO2	To enable the students, gain the knowledge of different encoding and multiplexing technologies in the fiber optics and wireless communication systems.
CLO3	To design optics and communication systems to serve a defined purpose.

List of Experiments

1. Measurement of Numerical Aperture in Optical Fiber
2. Measurement of Attenuation and Bending Loss in Optical Fiber
3. BER Measurement and Eye Pattern observation for the optical link
4. Characterization of Erbium Doped Fiber Amplifier
5. Wavelength Division Multiplexing Link
6. Four Wave Mixing Nonlinear Effect in Optical Fiber
7. Characteristics of AWGN and BSC Channels
8. Digital Modulation Schemes
   a. BPSK Modulator and Demodulator
   b. 16-Quadrature Amplitude Modulator and Demodulator
9. Error Control Codes
   a. Convolutional Encoder and Decoder
   b. Cyclic Encoder and Decoder
10. Path Loss in Wireless Propagation Models
11. Rayleigh and Rician Fading Channels
12. OFDM-802.11a
13. Intensity Modulation Systems using analog and digital input signal

COURSE OUTCOMES

At the end of course student will be able to

CO1: Understand the basic concepts and advancements in fiber optic technology and wireless communication systems.

CO2: Understand the channel characteristics of fiber optics and wireless communication systems and the concept of the optical amplifier.

CO3: Demonstrate the digital modulation schemes and error control coding techniques.

CO4: Interpret the fiber optic and wireless communication system models by using the

simulation software.
CO5: Analyze the operating principle of WDM solutions systems and the effect of nonlinearity in optical fiber.

Course Code	**:**	**EC610**
Course Title	**:**	**Digital Signal and Image Processing Laboratory**
Number of Credits	**:**	**2**
Course Type	**:**	**Laboratory**

COURSE OBJECTIVE

Students will implement various algorithms learnt in advanced digital signal processing and image processing

List of Experiments:

1. Generation of spatially correlated multivariate Gaussian process with desired mean vector and the required co-variance matrix.
2. Forward linear predictor and backward linear predictor
3. Design and realization of the adaptive filter using LMS algorithm and RLS algorithm
4. Noise cancellation using Winner filter and adaptive filter
5. Performance study of periodogram power spectrum estimator and modified periodogram estimator
6. Nonparametric and methods of power spectrum estimator (Bartlett;s and Welch's methods)
7. AR method of power spectrum estimation
8. (A) Transmultiplexer

   (B) Quadrature –mirror filter
9. Representation of the 2D image signal as the linear combinations of PCA (Eigen faces)
10. Image compression using discrete cosine transformation (DCT).
11. Discrete Multitone Transmission (DMT)
12. Orthogonal Frequency-division multiplexing (OFDM)
13. Implementation of Multiple-input Multiple output (MIMO)
14. Speech recognition using Support Vector Machine (SVM)
15. Study of wireless-telecommunication using Wicomm-T, Wireless digital communication system SDR platform.

COURSE OUTCOMES

Students are able to

CO1: design simple adaptive filters

CO2: study the performance of periodogram power spectrum estimator

CO3: learn basic image processing transforms

CO4: learn basic image processing techniques to improve the quality of image

Course Code	**:**	**EC611**
Course Title	**:**	**Detection and Estimation**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- The objective of this course is to make the students conversant with those aspects of statistical decision and estimation which is indispensable tools required for the optimal design of digital communication systems.

COURSE CONTENT

Binary hypothesis testing; Bayes, mini- max and Neyman-Pearson tests. Composite hypothesis testing.

Signal detection in discrete time: Models and detector structures. Coherent detection in independent noise. Detection in Gaussian noise. Detection of signals with random parameters. Detection of stochastic signals. Performance evaluation of signal detection procedures.

Bayesian parameter estimation; MMSE, MMAE and MAP estimates. Nonrandom parameter estimation. Exponential families. Completeness theorem. ML estimation. Information inequality. Asymptotic properties of MLEs.

Discrete time Kalman- Bucy filter. Linear estimation. Orthogonality principle. Wiener- Kolmogorov filtering – causal and non -causal filters.

Signal detection in continuous time: Detection of deterministic signals in Gaussian noise. Coherent detection in white Gaussian noise.

Text Books

1. *H.V.Poor, "An Introduction to Signal Detection and Estimation (2/e) Springer", 1994.*
2. *B.C.Levy, "Priciples of Signal Detection and Parameter Estimation, Springer", 2008.*

Reference Books

1. *H.L.Vantrees, "Detection, Estimation and Modulation theory", Part I, Wiley, 1987.*
2. *M.D.Srinath & P.K.Rajasekaran, "Statistical Signal Processing with Applications", Wiley, 1979.*
3. *J.C.Hancock & P.A. Wintz, "Signal Detection Theory", Mc-Graw Hill, 1966.*
4. *Recent literature in Detection and Estimation.*

COURSE OUTCOMES

Students are able to

CO1: summarize the fundamental concept on Statistical Decision Theory and Hypothesis Testing
CO2: summarize the various signal estimation techniques with additive noise
CO3: summarizer with Bayesian parameter estimation (minimum mean square error (MMSE), minimum mean absolute error (MMAE), maximum a-posterior probability (MAP) estimation methods).
CO4: compare optimal filtering, linear estimation, and Wiener/Kalman filtering.
CO5: construct Wiener and Kalman filters (time discrete) and state space models.

Course Code	**:**	**EC612**
Course Title	**:**	**DSP Architecture**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVES

- To give an exposure to the various fixed point and floating point DSP architectures and to implement real time applications using these processors.

COURSE CONTENT

Fixed-point DSP architectures. TMS320C54X, ADSP21XX, DSP56XX architecture details. Addressing modes. Control and repeat operations. Interrupts. Pipeline operation. Memory Map and Buses. TMS320C55X architecture and its comparison.

Floating-point DSP architectures. TMS320C67X, DSP96XX architectures. Cache architecture. Floating-point Data formats. On-chip peripherals. Memory Map and Buses.

On-chip peripherals and interfacing. Clock generator with PLL. Serial port. McBSP. Parallel port. DMA. EMIF. Serial interface- Audio codec. Sensors. A/D and D/A interfaces. Parallel interface- RAM and FPGA. RF transceiver interface.

DSP tools and applications. Implementation of Filters, DFT, QPSK Modem, Speech processing. Video processing, Video Encoding / Decoding. Biometrics. Machine Vision. High performance computing (HPC).

Digital Media Processors. Video processing sub systems. Multi-core DSPs. OMAP. CORTEX, SHARC, SIMD, MIMD Architectures.

Text Books

1. *B.Venkataramani&M.Bhaskar,” Digital Signal Processor, Architecture, Programming and Applications”,(2/e), McGraw- Hill,2010*
2. *S.Srinivasan&Avtar Singh, “Digital Signal Processing, Implementations using DSP Microprocessors with Examples from TMS320C54X”, Brooks/Cole, 2004*

Reference Books

1. *S.M.Kuo&Woon-Seng S.Gan, “Digital Signal Processors: Architectures, Implementations, and Applications”, Printice Hall, 2004.*
2. *N. Kehtarnavaz& M. Kerama, “DSP System Design using the TMS320C6000”, Printice Hall, 2001.*
3. *S.M. Kuo&B.H.Lee,”Real-Time Digital Signal Processing, Implementations, Applications and Experiments with the TMS320C55X”, John Wiley, 2001.*
4. *Recent literature in DSP Architecture.*

COURSE OUTCOMES

Students are able to

CO1: learn the architecture details fixed and floating point DSPs

CO2: infer about the control instructions, interrupts, and pipeline operations, memory and buses.

CO3: illustrate the features of on-chip peripheral devices and its interfacing with real time application devices.

CO4: learn to implement the signal processing algorithms and applications in DSPs.

CO5: learn the architecture of advanced DSPs.

Course Code	**:**	**EC613**
Course Title	**:**	**High Speed Communication Networks**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

CLO1	To familiarize students with the importance of protocol stacks and to learn various High speed network technologies
CLO2	To Understand the analytical models based on Queuing theory and to assess reliability in data transfer
CLO3	To know the implementation of host to host communication
CLO4	To study various LAN and PAN standards, its architecture and technologies
CLO5	To analyse key concerns in IP networks and ensure QoS

COURSE CONTENT

The need for a protocol architecture, The TCP/IP protocol architecture, Internetworking, Packet switching networks, Frame relay networks, Asynchronous Transfer mode (ATM) protocol architecture, High speed LANs.

Application of queuing theory to the analysis of performance of communication networks, Transport layer services-Principles of Reliable data transfer, Congestion control and flow control mechanism.

Virtual circuits and datagrams, Router architecture, Forwarding and addressing in the internet, Interior routing protocols, Exterior routing protocols and multicast.

IEEE 802.11 architecture and services, medium access control and physical layer, Wi-Fi protected access, IEEE 802.15 protocol architecture, Blue tooth and Personal Area Networks.

Quality of service in IP networks, Integrated and differentiated services, Protocols for QOS support-Resource reservation protocol, Multiprotocol label switching, Real time transport protocol. Simulation study on QoS provisioning in IP network.

Text Books

1. *W.Stallings,"High speed networks and internets" 2nd edition, Pearson education, 2002.*
2. *W. Stallings,"Wireless communication and networks"2nd edition, Pearson publication, 2013.*
3. *J.F.Kurose and K.W.Ross", Computer networking" 3rd edition, Pearson education,2005.*

Reference Books

1. *M. Schwartz, "Telecommunication networks, protocols, modelling and analysis", Pearson education,2004*
2. *Jean walrand and Praveen Varaiya," High performance communication networks",2nd edition, Morgan Kaufmann publishers, 2005.*
3. *Saadawi, Ammar and El Hakeem,"Fundamentals of telecommunication Networks", Wiley series in Telecommunications and signal processing, 1994.*

COURSE OUTCOMES

Students are able to

CO1: compare and analyse the fundamental principles of various high speed communication networks and their protocol architectures

CO2: examine the performance modeling, congestion control issues and traffic management in IP networks

CO3: compare and analyse the various routing protocols in IP networks

CO4: study of various wireless LAN standards, Blue tooth and high data rate personal area networks

CO5: examine quality of service in IP networks.

Course Code	:	**EC614**
Course Title	:	**Spectral Analysis of Signals**
Number of Credits	:	**3**
Course Type	:	**Elective**

COURSE OBJECTIVE

- To give an exhaustive survey of methods available for power spectrum estimation.

COURSE CONTENT

Periodogram and correlogram. Blackman – Tukey, Bartlett, Welch and Daniel methods. Window design considerations.

Parametric methods for rational spectra. Covariance structure of ARMA processes. AR, MA and ARMA signals. Multivariate ARMA signals.

Parametric methods for line spectra. Models of sinusoidal signals in noise. Nonlinear least squares, high order Yule-Walker, min-norm, Pisarenko, MUSIC and ESPRIT methods.

Filter bank methods. Filter-bank interpretation of the periodogram. Refined filter-bank and Capon methods.

Spatial methods. Array model. Nonparametric methods; beam forming and Capon method. Parametric methods; nonlinear least squares, Yule-Walker, min-norm, Pisarenko, MUSIC and ESPRIT methods.

Text Books

1. *P.Stoica & R.Moses, "Spectral Analysis of signals", Pearson, 2005.*
2. *Marple, "Introduction to Spectral Analysis", Prentice Hall.*

Reference Book

1. *S.M.Key, "Fundamentals of Statistical Signal Processing", Prentice Hall PTR, 1998.*
2. *Recent literature in Spectral Analysis of signals.*

COURSE OUTCOMES

Students are able to

CO1: derive and analyse the statistical properties of the conventional spectral estimators, namely the periodogram, averaged & modified periodogram and Blackman-Tukey methods.

CO2: formulate modern, parametric, spectral estimators based upon autoregressive (AR), moving average (MA), and autoregresive moving average (ARMA) models, and detail their statistical properties. Describe the consequence of the term resolution as applied to a spectral estimator.

CO3: define techniques for calculating moments in spectral and temporal domains; Analyze filter bank method, capon methods for spectrum estimation.

CO4: demonstrate knowledge and understanding of the principles of parametric and non-parametric array processing algorithms.

CO5: select an appropriate array processing algorithms for frequency estimation and sonar, radar applications.

Course Code	**:**	**EC615**
Course Title	:	**Digital Image Processing**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVES

- To explore various techniques involved in Digital Image Processing.

COURSE CONTENT

Elements of Visual perception. Image sensing and Acquisition. Imaging in different bands. Digital Image Representation. Relationship between pixels. Image transformations: 2D-DFT, DCT, DST, Hadamard, Walsh, Hotelling transformation, 2D-Wavelet transformation, Wavelet packets.

Image Enhancements in spatial domain and Frequency domain. Image Restoration techniques. Color Image processing.

Error free compression: Variable length coding, LZW, Bit-plane coding, Lossless predictive coding Lossy compression: Lossy predictive coding, transform coding, wavelet coding. Image compression standards (CCITT, JPEG, JPEG 2000) and Video compression standards.

Summary of morphological operations in Binary and Gray Images. Image segmentation: Point, Line and Edge segmentation. Edge linking and Boundary detection. Segmentation using thresholding, Region based segmentation. Segmentation by morphological watersheds. Use of motion in segmentation.

Feature Extraction from the Image: Boundary descriptors, Regional descriptors, Relational descriptors. Dimensionality reduction techniques, Discriminative approach and the Probabilistic approach for image pattern recognition.

Text Books

1. *R. C.Gonzalez, R.E.Woods," Digital Image processing", Pearson edition, Inc3/e, 2008.*
2. *A.K.Jain," Fundamentals of Digital Image Processing", PHI,1995*

Reference Books

1. *J.C. Russ," The Image Processing Handbook", (5/e), CRC, 2006*
2. *R.C.Gonzalez & R.E. Woods; "Digital Image Processing with MATLAB", Prentice Hall, 2003*
3. *E.S.Gopi, "Digital Image processing using Matlab", Scitech publications, 2005*

COURSE OUTCOMES

Students are able to

CO1: Reproduce the need for image transforms, different types of image transformation and their properties.
CO2: Compare different techniques employed for the enhancement of images.
CO3: Compare various spatial and frequency domain techniques of image processing.
CO4: Summarize various morphological operations and segmentation techniques.
CO5: Summarize various pattern recognition concepts and demonstrate the image pattern classifier.

Course Code	**:**	**EC616**
Course Title	:	**RF MEMS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To impart knowledge on basics of MEMS and their applications in RF circuit design.

COURSE CONTENT

Micromachining Processes - methods, RF MEMS relays and switches. Switch parameters. Actuation mechanisms. Bistable relays and micro actuators. Dynamics of switching operation.

MEMS inductors and capacitors. Micro-machined inductor. Effect of inductor layout. Modeling and design issues of planar inductor. Gap-tuning and area-tuning capacitors. Dielectric tunable capacitors.

MEMS phase shifters. Types. Limitations. Switched delay lines. Fundamentals of RF MEMS Filters.

Micro-machined transmission lines. Coplanar lines. Micro-machined directional coupler and mixer.

Micro-machined antennas. Microstrip antennas – design parameters. Micromachining to improve performance. Reconfigurable antennas.

Text Books

1. *Vijay. K. Varadan, K.J. Vinoy, and K.A. Jose, "RF MEMS and their Applications", Wiley-India, 2011.*

Reference Books

1. *H. J. D. Santos, "RF MEMS Circuit Design for Wireless Communications", Artech House, 2002.*
2. *G. M. Rebeiz, "RF MEMS Theory, Design, and Technology", Wiley, 2003.*
3. *Recent literature in RF MEMS.*

COURSE OUTCOMES

Students are able to

CO1: learn the Micromachining Processes
CO2: learn the design and applications of RF MEMS inductors and capacitors.
CO3: learn about RF MEMS Filters and RF MEMS Phase Shifters.
CO4: learn about the suitability of micro-machined transmission lines for RF MEMS
CO5: learn about the Micro-machined Antennas and Reconfigurable Antennas

Course Code	**:**	**EC617**
Course Title	:	**Smart Antennas**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To gain an understanding and experience with smart antenna environments, algorithms and implementation.

COURSE CONTENT

Spatial processing for wireless systems. Adaptive antennas. Beam forming networks. Digital radio receiver techniques and software radios.

Coherent and non-coherent CDMA spatial processors. Dynamic re-sectoring. Range and capacity extension – multi-cell systems.

Spatio – temporal channel models. Environment and signal parameters. Geometrically based single bounce elliptical model.

Optimal spatial filtering – adaptive algorithms for CDMA. Multitarget decision – directed algorithm.

DOA estimation – conventional and subspace methods. ML estimation techniques. Estimation of the number of sources using eigen decomposition. Direction finding and true ranging PL systems. Elliptic and hyperbolic PL systems. TDOA estimation techniques.

Text Books

1. *T.S.Rappaport & J.C.Liberti, Smart Antennas for Wireless Communication, Prentice Hall (PTR) , 1999.*
2. *R.Janaswamy, Radio Wave Propagation and Smart Antennas for Wireless Communication, Kluwer, 2001.*

Reference Book

1. *M.J. Bronzel, Smart Antennas, John Wiley, 2004.*
2. *Recent literature in Smart Antennas.*

COURSE OUTCOMES

Students are able to

CO1: compare the performances of digital radio receivers and software radios.
CO2: study the CDMA spatial processors to analyze the multi-cell systems.
CO3: analyze the channel models for smart antenna systems.
CO4: study the environmental parameters for signal processing of smart antenna systems.
CO5: evaluate the requirements for the design and implementation of smart antenna systems.

Course Code	**:**	**EC618**
Course Title	:	**Ad Hoc Networks**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To analyse the various design issues and challenges in the layered architecture of Ad hoc wireless networks

COURSE CONTENT

Cellular and ad hoc wireless networks, Applications of ad hoc wireless networks. Issues in ad hoc wireless networks-medium access scheme, routing, transport layer protocols, security and energy management. Ad hoc wireless internet.

Design goals of a MAC protocol, Contention based protocols; Contention based protocols with reservation mechanisms and scheduling mechanisms, MAC protocols using directional antennas.

Table driven routing protocols, On demand routing protocols, hybrid routing protocols, Hierarchical routing protocols, Power aware routing protocols, Tree based and mesh based multicast routing protocols

Network security requirements-Issues and challenges, network security attacks, key management, secure routing protocols

Energy management schemes-Battery management, transmission power management, system power management schemes. Quality of service solutions in ad hoc wireless networks.

Text books

1. *C.Siva ram murthy,B.S. Manoj, "Ad hoc wireless networks-Architectures and protocols" Pearson Education, 2005*
2. *Stefano Basagni, Marco Conti, "Mobile ad hoc networking", Wielyinterscience 2004*
3. *Charles E.Perkins ,"Ad hoc networking", Addison Wesley,2001*

References books

1. *Xiuzhen Cheng, Xiao Huang ,Ding Zhu DU ,"Ad hoc wireless networking", Kluwer Academic Publishers,2004*
2. *George Aggelou,"Mobile ad hoc networks-From wireless LANs to 4G networks, McGraw Hill publishers, 2005*
3. *Recent literature in Ad Hoc Networks.*

COURSE OUTCOMES

Students are able to

CO1: compare the differences between cellular and ad hoc networks and the analyse the challenges at various layers and applications
CO2: summarize the protocols used at the MAC layer and scheduling mechanisms
CO3: compare and analyse types of routing protocols used for unicast and multicast routing
CO4: examine the network security solution and routing mechanism
CO5: evaluate the energy management schemes and Quality of service solution in ad hoc networks

Course Code	**:**	**EC619**
Course Title	:	**Wavelet Signal Processing**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To expose the students to the basics of wavelet theory and to illustrate the use of wavelet processing for data compression and noise suppression.

COURSE CONTENT

Limitations of standard Fourier analysis. Windowed Fourier transform. Continuous wavelet transform. Time-frequency resolution.

Multiresolution analysis and properties. The Haar wavelet, Structure of subspaces in MRA

Haar decomposition-1, Haar decomposition-2, Wavelet reconstruction, Haar wavelet and link to filter bank, demo on wavelet decomposition, Wavelet packets

Wavelet methods for signal processing. Noise suppression. Representation of noise-corrupted signals using frames. Algorithm for reconstruction from corrupted frame representation.

Wavelet methods for image processing. Burt- Adelson and Mallat's pyramidal decomposition schemes. 2D-dyadic wavelet transform.

Text Books

1. *E.Hernandez & G.Weiss, A First Course on Wavelets, CRC Press, 1996.*
2. *L.Prasad & S.S.Iyengar, Wavelet Analysis with Applications to Image Processing, CRC Press, 1997.*

Reference Books

1. *A.Teolis, Computational Signal Processing with Wavelets, Birkhauser, 1998*
2. *R.M. Rao & A.S. Bopardikar, Wavelet Transforms, Addition Wesley, 1998.*
3. *J.C. Goswami & A.K. Chan, Fundamentals of Wavelets, John Wiley,1999.*
4. *Recent literature in Wavelet Signal Processing.*

COURSE OUTCOMES

Students are able to

CO1: understand about windowed Fourier transform and difference between windowed Fourier transform and wavelet transform.

CO2: understand wavelet basis and characterize continuous and discrete wavelet transforms

CO3: understand multi resolution analysis and identify various wavelets and evaluate their time-frequency resolution properties

CO4: implement discrete wavelet transforms in signal processing applications

CO5: understand about wavelet methods in image processing

Course Code	**:**	**EC620**
Course Title	:	**WDM Optical Networks**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVES

- To prepare the students understand the building blocks of optical network architecture.
- To enable the students appreciate the different routing networks in the WDM technology.
- To design optical network topology and routing to serve a defined application.

COURSE CONTENT

First generation optical networks. SONET/SDH. Computer interconnects. Metropolitan area networks. Layered architecture.

WDM optical network evolution. Enabling technologies. WDM optical network architecture. Wavelength routed networks.

Wavelength routing networks. Optical layer. Node designs. Network design and operations. Routing and wavelength assignment.

Wavelength convertible networks, performance evaluation. Networks with sparse wavelength conversion. Converter placement and allocation problems.

Virtual topology design problem, light path routes, implementation in broadcast and select networks.

Text Books

1. *R.Ramaswami & K.N.Sivarajan, Optical Networks, A Practical Perspective (3/e), Elsevier,2010*
2. *C.Sivaramamurthy & M.Gurusamy, WDM optical Networks, PHI, 2002.*
3. *S. B. Morris, "Network Management, MIBs and MPLS: Principles, Design and Implementation", 2003.*

Reference Books

1. *K.M.Sivalingam & S.Subramanium, Optical WDM Networks- Principles & Practice, Kluwer Academic Publications, 2000.*
2. *T.E.Stern & K.Bala, Multiwavelength Optical Networks- A Layered Approach, (1/e), Printice Hall 1999.*
3. *Biswanath Mukherjee, Optical WDM Networks, Springer 2006.*
4. *Recent literature in WDM Optical Networks.*

COURSE OUTCOMES

Students are able to

CO1: understand the structure of the first generation networks and SONET.
CO2: understand the salient features of WDM network architecture of the optical amplifiers
CO3: analyse various methods of optical nodal design and routing.
CO4: compare the merits and demerits of various wavelength networks.
CO5: design the virtual topology and routing for the select optical networks.

Course Code	**:**	**EC621**
Course Title	**:**	**Advanced Techniques for Wireless Reception**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To get an understanding of signal processing techniques for emerging wireless systems.

COURSE CONTENT

Wireless signaling environment. Basic signal processing for wireless reception. Linear receivers for synchronous CDMA. Blind and group-blind multiuser detection methods. Performance issues.

Robust multiuser detection for non-Gaussian channels; asymptotic performance , implementation aspects.

Adaptive array processing in TDMA systems. Optimum space-time multiuser detection. Turbo multiuser detection for synchronous and turbo coded CDMA.

Narrowband interface suppression. Linear and nonlinear predictive techniques. Code- aided techniques. Performance comparison.

Signal Processing for wireless reception: Bayesian and sequential Montecarlo signal processing. Blind adaptive equalization of MIMO channels .Signal processing for fading channels. Coherent detection based on the EM algorithm. Decision-feedback differential detection. Signal processing for coded OFDM systems.

Text Books

1. *X.Wang & H.V.Poor, "Wireless Communication Systems", Pearson, 2004.*
2. *R.Janaswamy, "Radio Wave Propagation and Smart Antennas for Wireless Communication", Kluwer, 2001.*

Reference Books

1. *M.Ibnkahla, "Signal Processing for Mobile Communications", CRC Press, 2005.*
2. *A.V.H. Sheikh, "Wireless Communications Theory & Techniques", Kluwer Academic Publications, 2004.*
3. *A.Paulraj* ,Arogyaswami, *R. Nabar, and D.Gore, "Introduction to Space-time Wireless Communications", Cambridge University Press, 2003.*
4. *Recent literature in Advanced Techniques for Wireless Reception.*

COURSE OUTCOMES

Students are able to

CO1: discuss the Wireless signaling environment and Performance issues.
CO2: analyze the channel modeling and multiuser detection.
CO3: analyze the Adaptive array processing and turbo coded CDMA.
CO4: analyze Linear and nonlinear predictive techniques.
CO5: analyze the Signal Processing Techniques for wireless reception.

Course Code	**:**	**EC622**
Course Title	**:**	**Error Control Coding**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To explain the importance of modern coding techniques in the design of digital communication systems.

COURSE CONTENT

Review of modern algebra. Galois fields. Linear block codes; encoding and decoding. Cyclic codes. Non-binary codes.

Convolutional codes. Generator sequences. Structural properties. ML decoding. Viterbi decoding. Sequential decoding.

Modulation codes. Trellis coded modulation. Lattice type Trellis codes. Geometrically uniform trellis codes. Decoding of modulation codes.

Turbo codes. Turbo decoder. Interleaver. Turbo decoder. MAP and log MAP decoders. Iterative turbo decoding. Optimum decoding of turbo codes.

Space-time codes. MIMO systems. Space-time codes. MIMO systems. Space-time block codes (STBC) – decoding of STBC.

Text Books

1. *S.Lin & D.J.Costello, "Error Control Coding (2/e)", Pearson, 2005.*
2. *B.Vucetic & J.Yuan, "Turbo codes", Kluwer, 2000*

Reference Books

1. *C.B.Schlegel & L.C.Perez, "Trellis and Turbo Coding", Wiley,2004.*
2. *B.Vucetic & J.yuan, "Space-Time Coding", Wiley, 2003.*
3. *R.Johannaesson & K.S.Zigangirov, "Fundamentals of Convolutional Coding", Universities Press, 2001.*
4. *Recent literature in Error Control Coding.*

COURSE OUTCOMES

Students are able to

CO1: understand the need for error correcting codes in data communication and storage systems.

CO2: identify the major classes of error detecting and error correcting codes and how they are used in practice. Construct codes capable of correcting a specified number of errors.

CO3: use the mathematical tools for designing error correcting codes, including finite fields.

CO4: explain the operating principles of block codes, cyclic codes, convolution codes, modulation codes, Turbo codes etc.

CO5: design an error correcting code for a given application.

Course Code	**:**	**EC623**
Course Title	**:**	**Digital Communication Receivers**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To expose the students to the latest trends in the design of digital communication receivers with particular emphasis on synchronization, channel estimation and signal processing aspects.

COURSE CONTENT

Baseband PAM. Clock recovery circuits. Error tracking and spectral – line generating synchronizers. Squaring and Mueller and Muller synchronizers.

Channel models. Receivers for PAM. Optimum ML receivers. Synchronized detection. Digital matched filter.

ML synchronization algorithms – DD and NDA. Timing parameter and carrier phase estimation – DD and NDA.

Performance analysis of carrier and symbol synchronizers. Feedback and feed forward synchronizers. Cycle slipping Acquisition of carrier phase and symbol timing.

Fading channels. Statistical characterization. Flat and frequency selective fading channels. Optimal receivers for data detection and synchronization parameter estimation. Realizable receiver structures for synchronized detection.

Text Books

1. *H.Meyer , M. Moeneclaey, and S. A. Fechtel, "Digital Communication Receivers", Wiley, 1998.*
2. *U.Mengali & A.N.D.Andrea, "Synchronization Techniques for Digital Receivers", Kluwer , 1997.*

Reference Books

1. *N.Benuveruto & G.Cherubini, "Algorithms for Communication Systems and their Applications", Wiley, 2002.*
2. *H.Meyer & G.Ascheid, "Synchronization in Digital Communications", John Wiley, 1990.*
3. *Recent literature in Digital Communication Receivers.*

COURSE OUTCOMES

Students are able to

CO1: summarize baseband PAM and Synchronizers.
CO2: model and distinguish the channels.
CO3: interpret optimum receivers and matched filter receivers.
CO4: summarize phase and carrier estimation methods.
CO5: compare carrier and symbol synchronizers.

Course Code	**:**	**EC624**
Course Title	**:**	**Analysis Methods for Passive MIC**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To make the students confident in designing M, I, C, components in any planar transmission line and also to familiarize multi-layer structure.

COURSE CONTENT

Parameters of planar transmission line variants. Static and dynamic analysis methods for microstripline, coplanar waveguide, coplanar strips, striplines and slot line.

Spectral domain methods. Formulation of quasi static and dynamic spectral domain analyses. Galekin's method.

Hybrid mode analysis. Formulation. Application in planar transmission lines. Characteristic equation. Evaluation of parameters.

Coplanar lines , quasi-static and full wave analysis. Design equations. Comparison with microstrip and slot lines.

General analysis of coupled lines. Design considerations for microstrip lines and coplanar waveguides.

Text Books

1. *T.Itoh, "Numerical Techniques for Microwave and Millimeter Wave Passive Structures", John Wiley& Sons,1989.*
2. *C.Nguyen, "Analysis Methods for RF, Microwave and Planar Transmission Line Structures", Wiley, 2000*

Reference Book

1. *C. Nquyen, "Analysis Methods for RF, Microwave, and Millimeter-Wave Planar Transmission Line Structures", Wiley Inter science, 2000.*
2. *Bharathi Bhat and Shiben K Koul, "Stripline like transmission lines for Microwave Integrated Circuits" John Wiley & Sons Inc (March 1, 1990)*
3. *Recent literature in Passive MIC.*

COURSE OUTCOMES

Students are able to

CO1: analyze any planar transmission lines, usage of different planar transmissions lines for various frequencies and for various antennas.
CO2: appreciate the features of different spectral domain methods.
CO3: understand the hybrid mode analysis and its application in planar transmission lines
CO4: understand the analysis and design equations of coplanar lines and
CO5: appreciate the design considerations of microstrip and coplanar waveguides.

Course Code	**:**	**EC625**
Course Title	**:**	**Electromagnetic Metamaterials**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

CLO1	**Introduce metamaterial properties and effect of properties on electromagnetic concept**
CLO2	**To explore Transmission line model metamaterials and CRLH parameters**
CLO3	**To learn SRR, CSRR structures and its equivalent circuit**
CLO4	**To discuss Metamaterial Inspired Antennas**
CLO5	**MIC component design using metamaterials**

COURSE CONTENT

Introduction - Definition of Metamaterials (MTMs) and Left-Handed (LH) MTMs, Theoretical Speculation by Viktor Veselago, Experimental Demonstration of Left-Handedness, Conventional Backward Waves and Novelty of LH MTMs, Terminology, Transmission Line (TL) Approach, Composite Right/Left- Handed (CRLH) MTMs, Left-Handedness from Maxwell's Equations, Boundary Conditions, Reversal of Doppler Effect, Reversal of Snell's Law: Negative Refraction.

TL Theory of MTMs, Ideal Homogeneous CRLH TLs: Fundamental TL Characteristics, Equivalent MTM Constitutive Parameters, Balanced and Unbalanced Resonances, Lossy Case, LC Network Implementation, Difference with Conventional Filters, Transmission Matrix Analysis, Input Impedance, General Design Guidelines, Microstrip Implementation, Parameters Extraction, Conversion from Transmission Line to Constitutive Parameters.

An overview of different types of SRR and CSRR, Equivalent circuit model for MSRR, Labyrinth and spiral resonator, Parameters extraction using NRW approach.

LH-TL loaded antenna, Electrically small antenna, Thin wavelength resonator design, Partial metamaterial loading, Sub-wavelength antenna, Metamaterial substrate, Metamaterial superstrate, CSRR loaded antenna, OCSRR loaded monopole antenna, Bandwidth enhancement, Notch function using SRR in UWB antenna, MTM inspired antenna.

Guided-Wave Applications - Dual-Band Components: Dual-Band Property of CRLH TLs - Quarter-Wavelength TL and Stubs - Passive Component Examples: Quadrature Hybrid and Wilkinson Power Divider - Enhanced-Bandwidth Components: Principle of Bandwidth Enhancement - Rat-Race Coupler Example.

Text Book

1. *Christophe Caloz, Tatsuo Itoh, "Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications "by John Wiley & Sons, Inc., Hoboken, New Jersey, 2006.*
2. *Ricardo Marqués, Ferran Martín, Mario Sorolla, Metamaterials with Negative Parameters: Theory, Design, and Microwave Applications, Wiley, Inc.,2008*
3. *Filippo Capolin, Theory and Phenomena of Metamaterials, CRC Press, 2009*

COURSE OUTCOMES

Students are able to

CO1: learn and understand the properties of metamaterials and the effect of properties on fundamental phenomena

CO2: understand the theory of Transmission line theory of Metamaterials.

CO3: discuss different types of SRR and to derive equivalent circuit

CO4: discuss the metamaterial properties for performance enhancement of antenna.

CO5: learn the design of microwave components using metamaterials.

Course Code	**:**	**EC626**
Course Title	**:**	**Bio MEMS**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To train the students in the design aspects of Bio MEMS devices and Systems. To make the students aware of applications in various medical specialists especially the Comparison of conventions methods and Bio MEMS usage.

COURSE CONTENT

Introduction-The driving force behind Biomedical Applications – Biocompatibility - Reliability Considerations-Regularity Considerations – Organizations - Education of Bio MEMS-Silicon Micro fabrication-Soft Fabrication techniques

Micro fluidic Principles- Introduction-Transport Processes- Electro kinetic Phenomena-Micro valves –Micro mixers- Micro pumps.

SENSOR PRINCIPLES and MICRO SENSORS: Introduction-Fabrication-Basic Sensors-Optical fibers-Piezo electricity and SAW devices-Electrochemical detection-Applications in Medicine

MICRO ACTUATORS and DRUG DELIVERY: Introduction-Activation Methods-Micro actuators for Micro fluidics-equivalent circuit representation-Drug Delivery

MICRO TOTAL ANALYSIS: Lab on Chip-Capillary Electrophoresis Arrays-cell, molecule and Particle Handling-Surface Modification-Microsphere-Cell based Bioassay Systems
Detection and Measurement Methods-Emerging Bio MEMS Technology-Packaging, Power, Data and RF Safety-Biocompatibility, Standards

Text Book

1. *Steven S. Saliterman, Fundamentals of Bio MEMS and Medical Micro devices, Wiley Interscience, 2006.*

Reference Books

1. *Albert Folch , Introduction to Bio MEMS, CRC Press, 2012*
2. *Gerald A. Urban, Bio MEMS, Springer, 2006*
3. *Wanjun wang, steven A. Soper, Bio MEMS, 2006.*
4. *M. J. Madou, "Fundametal of Micro fabrication",* 2002.
5. *G.T. A. Kovacs, "Micro machined Transducers Sourcebook", 1998*.
6. *Recent literature in Bio MEMS.*

COURSE OUTCOMES

Students are able to

CO1: learn and realize the MEMS applications in Bio Medical Engineering
CO2: understand the Micro fluidic Principles and study its applications.
CO3: learn the applications of Sensors in Health Engineering.
CO4: learn the principles of Micro Actuators and Drug Delivery system
CO5: learn the principles and applications of Micro Total Analysis

Course Code	**:**	**EC627**
Course Title	**:**	**Substrate Integrated Waveguide Technology: Design and Analysis**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To make the students familiar with Substrate Integrated Waveguide (SIW) Technology with emphasis on Circuits Analysis, Design and Layout of SIW components.

COURSE CONTENT

Introduction: Substrate Integrated Waveguide Technology, SIW Circuits Composed of Metallic Posts, SIW Circuits with Dielectric Posts.

A typical SIW circuit and its equivalent problem, Field expressions, Boundary conditions, Z-matrix, S-matrix Sub-ports combination Modeling of losses.

Even-Odd Mode Analysis of a Symmetrical Circuit, Half circuit with PMC symmetry wall, half circuit with PEC symmetry wall, Microstrip or planar transmission line to SIW Transition and Half Mode SIW.

Substrate Integrated Circuits (SICs) and components, Filters, couplers Mixers, Amplifiers and SIW antennas.

Numerical Technique for SIW analysis: Methods of line.

Reference Books

1. *Xuan Hui Wu, Ahmed Kishk, Analysis and Design of Substrate Integrated Waveguide Using Efficient 2D Hybrid Method.*
2. *P. Arcioni, Roselli, Rogier, A. Georgiadis Microwave and Millimeter Wave Circuits and Systems: Emerging Design, Technologies and Applications, 2nd Edition, Published by John Wiley & Sons.*
3. *Recent literature in Substrate Integrated Waveguide Technology.*

COURSE OUTCOMES

Students are able to

CO1: Gain knowledge & will be employable in all the corporate and R&D sections deals with Microwave Integrated Circuits.

Course Code	**:**	**EC628**
Course Title	**:**	**Pattern Recognition and Computational Intelligence**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- The subject aims to make the students to understand the mathematical approach for pattern recognition. and computational intelligence

COURSE CONTENT

Linear regression techniques: Least square technique, Maximum Likelihood technique, Regularization technique, Error components of regression model, predictive distribution, Bayes technique, Kernel smoothing technique, Gaussian process technique

Dimensionality reduction techniques: Principal Component Analysis, Linear Discriminant Analysis, Kernel Linear Discriminant Analysis, Independent Component Analysis

Linear classifier techniques: Nearest mean, Nearest neighbour, Support Vector Machine, Kernel Trick, Relevance Vector Machine

Probabilistic generative model: K-means algorithm, Fuzzy k-means algorithm, Gaussian Mixture Mode, Hidden Markov model. Probabilistic discriminative model: Logistic regression model.

Computational intelligence techniques: Particle Swarm Optimization, Ant Colony Optimization, Social Emotional Optimization algorithms, Genetic algorithm, Simulated annealing, Artificial Neural Network. Case study on the applications of PRCI in telecommunication

Text Books

1. *C.M.Bishop,"Pattern recognition and machine learning",Springer,2006*
2. *E.S.Gopi, "Pattern recognition and Computational intelligence using matlab, Transactions on computational science and computational intelligence, Springer, 2019*

Reference Books

1. *Sergious Thedorodis ,Konstantinos Koutroumbas, Pattern recognition, Elsevier, Fourth edition,2009*
2. *Richard O.Duda, Peter.E.Hart, David G.Stork, "Pattern classification", Wiley, Second edition,2016*
3. *E.S.Gopi, ''Algorithm collections for Digital signal Processing application using Matlab-Springer ,2007*
4. *Recent literature in the related topics*

COURSE OUTCOMES

Students are able to

CO1: summarize various techniques involved in linear regression techniques
CO2: summarize various techniques involved in dimensionality reduction techniques
CO3: summarize various techniques involved in linear classifier techniques
CO4: summarize various techniques involved in probabilistic generative and discriminative model
CO5: summarize various techniques involved in computational intelligence techniques.

Course Code	**:**	**EC629**
Course Title	**:**	**Photonic Integrated Circuits and Systems**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- The photonic integrated circuits course will introduce the basics of various integrated optical waveguides and devices used in optical communication applications.
- This course also covers materials and fabrication technology for optical integrated circuits.

COURSE CONTENT

Brief history of optical communication, Advantages of integrated optics configuration, Guided TE and TM Modes of Symmetric and anti-symmetric planar waveguides: Step-index and graded-index waveguides. Strip and channel waveguides, anisotropic waveguides. Marcatili's Method, Effective-Index method and perturbation method of analysis, Beam propagation method.

Directional couplers, Coupled mode analysis of uniform and reverse delta-beta couplers. Applications as power splitters, Y-junction, optical switch; Phase and amplitude modulators, filters, A/D converters, Y-splitters, Mode splitters, polarization splitters; Mach-Zehnder interferometer based devices.

Integrated light sources and photodetectors, Acousto-optic waveguide devices. Arrayed waveguide devices, Nano-photonic-devices: Metal/dielectric plasmonic waveguides, long and short range surface Plasmon modes supported by thin metal films, applications in waveguide polarizers.

Materials. Glass, lithium niobate, silicon, compound semiconductors, polymers. Fabrication of integrated optical waveguides and devices. Lithography, ion-exchange, deposition, diffusion process. Waveguide characterisation, end-fire and prism coupling, grating and tapered couplers.

Nonlinear effects in integrated optical waveguides, Self-phase modulation, Cross-phase modulation, Four-wave mixing, Stimulated Brillouin Scattering, Stimulated Raman Scattering, Photonic crystal-based devices, Integrated optical communication systems, IO-RF spectrum analyzer, Optical sensing, Reconfigurable Photonic Systems

Reference Books

1. *H Nishihara, M Haruna and T Suhara, Optical Integrated Circuits; McGraw-Hill Book Company, New York, 1989.*
2. *A Ghatak and K Thyagarajan, Optical Electronics, Cambridge University Press, 1989.*
3. *T. Tamir, Guided wave opto-electronics, Springer Verilag, 1990*
4. *K. Okamota, Fundamentals of Optical waveguides, Academic Press, 2006.*
5. *T. Tamir, Integrated Optics, Springer Verlag, New York, 1982.*
6. *C. R. Pollock and M Lipson, Integrated photonics, Kluwer Pub, 2003.*
7. *Recent journals and conference proceedings.*

COURSE OUTCOMES

Students will be able to

CO1: Recognize the fundamental concept of optical waveguides.
CO2: Classify the different types of optical waveguides.
CO3: Classify the couplers, modulators and devices for communication applications
CO4: Summarize the fabrication technologies for design of optical waveguides
CO5: Discuss the various nonlinear effects in integrated optical waveguides.

Course Code	**:**	**EC630**
Course Title	**:**	**Fiber-Optic Sensors**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- The objective of this course is to understand the basic concepts and working principles of various optical fibers based photonic sensors.
- This course will be useful to design and develop sensors for sensing various physical parameters in practical applications.

COURSE CONTENT

Review of propagation characteristics of single, multimode optical fibers and Photonic crystal fibers. Surface Plasmon modes supported by metal-dielectric interface.

Optical modulators for fiber optic sensors. Intensity, phase, polarization and wavelength modulation schemes. Intensity based sensors using microbends and tapers in multi-mode fibers. Position sensors, Polarization sensors.

Fiber optic SAGNAG interferometer sensors, SAGNAG effect, Fiber Optic gyros, Mach-Zehnder interferometer sensors. Fiber optic magnetic, current sensors.

Fiber grating sensors. Single parameter, Multiparameter grating sensors. Sensors based on modal interference. Fiber optic biosensors. Industrial applications.

Distributed optical fiber sensors, Optical scattering in fiber, Sensors based on Rayleigh, Raman and Brillouin scattering. Fiber sensors based on Surface Plasmon Resonance (SPR) and Surface Plasmon wave (SPW). Photonic crystal fiber sensors. Noise effects in sensors.

Reference Books

1. *Ajoy Ghatak and K Thyagarajan, Introduction to Fiber Optics, Cambridge University Press, 1998.*
2. B.P.Pal, Guided Wave Optical Components and Devices, Elsevier, 2005
3. *Z. Fang, K.K.Chin, R. Qu, H. Cai, Fundamentals of Optical Fiber Sensors, Wiley, 2012.*
4. *Eric Udd and W. B. Spillman, Fiber Optic Sensors, An introduction for Engineers and Scientists, 2nd Ed, Wiley, 2012.*
5. *Shizhuo Yin, Paul B Ruffin, Francis T. S. Yu, Fiber Optic Sensors, 2nd Ed. CRC Press, 2008*
6. *Recent journals publications and conference proceedings.*

COURSE OUTCOMES

Students are able to

CO1: Summarize the basic propagation principle in optical fibers.
CO2: Construct the different types of modulators for optical fiber sensors.
CO3: Construct the grating sensors and distributed sensors in fibers.
CO4: Describe the theoretical principle of fiber sensors based on surface Plasmon effect.
CO5: Describe the design of application specific fiber optic sensors.

Course Code	**:**	**EC631**
Course Title	**:**	**Optical Wireless Communications**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- This subject provides the in-depth knowledge in Optical Wireless Communication systems. It covers the emerging Optical wireless communication trends and their applications.

COURSE CONTENT

Introduction to Optical Wireless Communication: Optical communication systems- wireless access- Need of Optical Wireless Communication (OWC)-block diagram-challenges- Application -Optical sources-optical detectors-Optical Detection Statistics

Optical wireless communication theory - channel modeling - Indoor optical wireless communication channel-LOS propagation model-Spherical and Guassian wave model-outdoor channel- Attenuation-Beam Wander-Turbulence (Scintillation/Fading)-Turbidity (rain, fog, snow)-Cloud-free line of sight-log normal negative exponential- gamma-gamma turbulence model-modulation schemes for optical wireless-Analogue intensity modulation-Digital base band-pulse modulation-subcarrier intensity modulation –optical polarization shift keying- BER performance analysis

Free space optical communications: Introduction-operating principles-characteristics-Qos and availability--FSO OFDM communication-FSO underwater- Free space optical networks-laser satellite communication.

Coded modulation techniques for OWC- Coded MIMO for OWC- Indoor OWC MIMO channel-Point to point OW MIMO communications- MIMO FSO-Wireless optical CDMA Communication system-System description-indoor wireless optical CDMA-FSO CDMA

Visible light communications- VLC principle- VLC system model- system implementation-VLC applications
Infrared optical wireless communications - Optical wireless in sensor networks- FSO Sensor networks.

Reference Books

1. *Z. Ghassemlooy, W.Popoola, S. Rajbhandari "Optical Wireless Communications- Systems and channel modelling with MATLAB" CRC press, Taylor & Francis, 2013.*
2. *Shlomi Armon, John R. Barry, Geroge K. Karagiannidis, Robert Schober, Murat Uysal "Advanced Optical Wireless Communication Systems" Cambridge university press, 2012.*
3. *Heinz, Phd. Willebrand, "Free Space Optics," Sams, 1st Ed., 2001.*
4. *Stamatioas V. Kartalopouls "Free space optical Networks for Ultra Broadband services" John Wiley & Sons, 2011.*
5. *Morris Katzman, "Laser Satellite Communication," Prentice Hall Inc., New York, 1991.*
6. *Roberto Ramirez-Iniguez, Sevia M.Idrus, Ziran sun "Optical wireless communications: IR for wireless connectivity" CRC Press, Taylor and Francis Group, 2007.*
7. *Recent literature in Optical Wireless Communication.*

COURSE OUTCOMES

Students are able to
CO1: interpret the principles of Optical wireless communication devices and systems.
CO2: model the channel for indoor and outdoor OWC systems and analyze the impact of modulation techniques on bandwidth and power efficiency.
CO3: summarizes the free space optical communication and Laser satellite communication.
CO4: summarizes the coded modulation techniques for OWC, coded MIMO and CDMA techniques in FSO.
CO5: summarizes the principle of Visible Light, Infrared Communications and utilization of OWC in sensor networks.

Course Code	**:**	**EC632**
Course Title	**:**	**Foundations of Artificial Intelligence**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- Approaches to produce "intelligent" systems, Knowledge representation (both symbolic and neural network), search and machine learning.
- To learn the principles and fundamentals of designing AI programs.

COURSE CONTENT

Introduction to artificial Intelligence, problem solving as state space search, Uninformed search, heuristic search, informed search, constrained satisfaction problem

Knowledge representation and Reasoning-Introduction to knowledge representation, propositional logic, first order logic, inference in first order logic, answer extraction, procedural control of reasoning, reasoning under uncertainty, Bayesian network, decision network.

Planning and decision making- Introduction to planning, plan space planning, planning graph and graph plan, practical planning and acting, sequential decision problems, making complex decisions.

Machine learning- Introduction to ML, learning decision trees, linear regression, SVM, supervised learning, unsupervised learning, reinforcement learning,

Introduction to deep learning and neural network learning

Text Books

1. *Patrick Henry Winston, Artificial Intelligence, Third Edition, Addison-Wesley Publishing Company, 2004.*
2. *Stuart Russell and Peter Norvig, Artificial Intelligence: A Modern Approach, 3rd Edition, PHI 2009.*

Reference Books

1. *Nils J Nilsson, Principles of Artificial Intelligence, Illustrated Reprint Edition, Springer Heidelberg, 2014.*
2. *Nils J. Nilsson, Quest for Artificial Intelligence, First Edition, Cambridge University Press, 2010.*

COURSE OUTCOMES

Students are able

CO1: To learn the concepts of artificial intelligence
CO2: To study problem solving techniques
CO3: To understand the representation of knowledge and reasoning mechanism
CO4: To learn to panning and decision making
CO5: To study network models used for learning

Course Code	**:**	**EC633**
Course Title	**:**	**Introduction to Soft Computing and Machine Learning**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- Focus on fundamental concepts and techniques for approaching artificial intelligence.

COURSE CONTENT

Learning and generalisation-structure of neural networks Neuron, Nerve structure and synapse, Artificial Neuron and its model, activation functions, McCulloch Pitts - neuron model – simple perceptron – Adaline and Madaline, Neural network architecture: Linear seperability, single layer and multilayer feed forward networks, recurrent networks.

Various learning techniques; Supervised Learning Neural Networks –Reinforcement Learning – Unsupervised Learning Neural Networks, Auto-associative and hetero-associative memory, Content addressable memory, Back propagation algorithm, factors affecting back propagation training, gradient descent, the Steepest Descent algorithm, The Back-propagation algorithm applications. Stability-plasticity dilemma, Adaptive Resonance Architectures I , II – Advances in Neural Networks, – Examples. BIONET **-** Case study of connectionist expert systems for medical diagnosis.

Basic concepts of fuzzy logic, Fuzzy sets and Crisp sets, Fuzzy set theory and operations, Properties of fuzzy sets, Fuzzy and Crisp relations, Fuzzy to Crisp conversion Fuzzy Inference Systems – Fuzzy Expert Systems – Fuzzy Decision Making, Adaptive Neuro-Fuzzy Inference Systems – Coactive Neuro-Fuzzy Modeling – Classification and Regression Trees – Data Clustering Algorithms.

Fuzzy logic control – Case studies: Inverted pendulum – Home heating system – Mountain car problem. Introduction, Building block hypothesis, working principle, Basic operators and Terminologies like individual, gene, encoding, fitness function and reproduction, Genetic modeling: Significance of Genetic operators, Inheritance operator, cross over, inversion & deletion, mutation operator, Bitwise operator, GA optimization problems, JSP (Job Shop Scheduling Problem), TSP (Travelling Salesman Problem), Differences & similarities between GA & other traditional methods, Applications of GA.

From Conventional AI to Computational Intelligence **-** Machine Learning Basics, Passive reinforcement learning – direct utility estimation – adaptive dynamic programming – temporal-difference learning – active reinforcement learning – exploration – learning an action-utility function – Generalization in reinforcement learning – policy search – applications in game playing – applications in robot control.

Text Books

1. *S. Rajasekaran & G.A. Vijayalakshmi Pai, "Neural Networks, Fuzzy Logic and Genetic Algorithm: Synthesis and Applications" Prentice Hall of India.*
2. *N.P.Padhy,"Artificial Intelligence and Intelligent Systems" Oxford University Press.*

Reference Books

1. *Y. S. Abu-Mostafa, M. Magdon-Ismail, and H.-T. Lin, "Learning from Data", AML Book Publishers, 2012.*
2. *P. Flach, "Machine Learning: The art and science of algorithms that make sense of data", Cambridge University Press, 2012.*
3. *K. P. Murphy, "Machine Learning: A probabilistic perspective", MIT Press, 2012.*
4. *C. M. Bishop, "Pattern Recognition and Machine Learning", Springer, 2007.*
5. *D. Barber, "Bayesian Reasoning and Machine Learning", Cambridge University Press, 2012.*
6. *M. Mohri, A. Rostamizadeh, and A. Talwalkar, "Foundations of Machine Learning", MIT Press, 2012.*
7. *T. M. Mitchell, "Machine Learning", McGraw Hill, 1997.*

COURSE OUTCOMES

Students are able to

CO1: To explain theory underlying Soft computing
CO2: To construct algorithms to learn neural network models
CO3: To implement fuzzy logic algorithms
CO4: To construct algorithms to learn Genetic Algorithm models
CO5: To apply reinforcement learning techniques

Course Code	:	**EC634**
Course Title	:	**Next Generation WLAN**
Number of Credits		**3**
Course Type	:	**Elective**

COURSE OBJECTIVE

- To expose students to wireless local area network standards, technologies, and operations with real-life traces to correlate with the concepts

COURSE CONTENT

WLAN Introduction and Basics - 802.11 protocol stack basics, RF spectrum of operations, unlicensed band usage, Types of networks and their usage, Role of Wi-Fi alliance. Exercises: Survey of WLAN products in consumer appliances like laptops, phones, tablets, and other devices, their type; Visit WFA webpage to get a list of WLAN certified products and the various certification programs listed.

WLAN Physical Layer - Indoor multipath channel conditions and models, Delay spread and ISI impacts on high data rate transmission, Evolution of the WLAN PHY. Layer, OFDM design and parameters for WLAN, MIMO usage in WLAN, **Exercises**: Matlab Simulation of channel models and studying their characteristics, 802.11 waveform generation using Matlab and checking spectrum and evm effects due to frequency offset

WLAN MAC Layer - CSMA/CA principles used for WLAN MAC, Details of MAC protocol, Medium reservation and hidden nodes, MAC Frame Aggregation and QoS in WLAN, Roaming. **Exercises:** Calculate duration of a frame transmission based on size, rate, and the MAC protocol IFS'**.** Calculate NAV values in RTS/CTS frames MAC throughput calculation with and without aggregation.

WLAN Network Operations - Network Entry Process in WLAN, Security Evolution, Power save concepts, Throughput and performance of WLAN. **Exercises:** Traces with experimental setup explained can be given to students with opensource tool like wireshark**.** All the network operations can be converted to suitable exercises in the hands on analysis section.

WLAN Protocol Analysis - Sniffing WLAN Frames and analysis using open source tools, Inferring capabilities of APs and clients, Analysing network entry steps and debugging connection problems, Analysing Data transmission and debugging performance issues, Analysis of Roaming performance.

Text Books

1. *Eldad Perahia and Robert Stacey, Next Generation wireless LANS 802.11n and 802.11ac, 2nd edition, Cambridge University Press, 2013*
2. *Mathew Gast, 802.11 Wireless Networks: The Definitive Guide, 2nd Edition, OReily, 2009*

Reference Books

1. *Mathew Gast, 802.11n: A Survival Guide: Wi-Fi Above 100 Mbps, OReilly, 2012*
2. *Mathew Gast, 802.11ac: A Survival Guide: Wi-Fi at Gigabit and Beyond, OReilly, 2012*

Course Outcomes:

Students are able to

CO1: To understand basics of WLAN systems including standardizing bodies, unlicensed spectrum ranges, network types.

CO2: Appreciate physical layer challenges and solutions in 802.11 standards and be able to simulate channel conditions

CO3: Be able to explain MAC layer steps in WLAN along with the motivation and impacts on throughput and coexistence

CO4: Trace the steps followed in a typical WLAN network with a clear understanding of security, power save, and network entry procedures

CO5: Analyze real-life protocol traces under various conditions and correlate with the concepts learnt in the earlier sections.

Course Code	**:**	**EC635**
Course Title	**:**	**Electromagnetic Interference and Compatibility**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

CLO1	**To provide insight into various sources of electromagnetic interferences**
CLO2	**To study the various compliance requirement for Electronic product design**
CLO3	**To understand the various grounding and shielding techniques**
CLO4	**To apply the various PCB design rules for better EMC**
CLO5	**To understand the various measurement concepts and devices for EMC compliance**

COURSE CONTENT

Introduction to EMI and EMC- Various EMC requirements and standards-Need for EMC and its importance in electronic product design - sources of EMI - few case studies on EMC.

Conducted and radiated emission -power supply line filters-common mode and differential mode current-common mode choke- switched mode power supplies. Shielding techniques- shielding effectiveness-shield behavior for electric and magnetic field -aperture-seams-conductive gaskets- conductive coatings

Grounding techniques- signal ground-single point and multi point grounding-system ground-common impedance coupling -common mode choke-Digital circuit power distribution and grounding.

Contact protection - arc and glow discharge-contact protection network for inductive loads-C, RC, RCD protection circuit- inductive kick back. RF and transient immunity-transient protection network- RFI mitigation filter-power line disturbance- ESD- human body model- ESD protection in system design.

PCB design for EMC compliance-PCB layout and stack up- multi layer PCB objectives- Return path discontinuities-mixed signal PCB layout. EMC pre compliance measurement-conducted and radiated emission test-LISN-Anechoic chamber.

Text Books:

1. *H. W. Ott, Electromagnetic Compatibility Engineering, 2nd edition, John Wiley & Sons, 2011, ISBN: 9781118210659.*
2. *C. R. Paul, Introduction to Electromagnetic Compatibility, 2nd edition, Wiley India, 2010, ISBN: 9788126528752*

Reference Book:

1. *K. L. Kaiser, Electromagnetic Compatibility Handbook, 1st edition, CRC Press, 2005. ISBN: 9780849320873*

COURSE OUTCOMES

Students are able to

CO1: Understand the various sources of Electromagnetic interference

CO2: Familiarize the fundamentals those are essential for product design with EMC compliance and various EMC standards

CO3:. would gain knowledge to understand the concept of Shielding and grounding related to product design.

CO4:. Design PCBs which are electromagnetically compatible

CO5: understand and differentiate the various EMC pre compliance measurement

Course Code	**:**	**EC636**
Course Title	**:**	**Computer Vision**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- The focus of this course is the understanding of algorithms and techniques used in computer vision.
- Provide pointers into the literature and exercise a project based on a literature search and one or more research papers.
- Practice software implementation of different concepts and techniques covered in the course.
- Utilize programming and scientific tools for relevant software implementation.

COURSE CONTENT

Introduction: overview of computer vision, related areas, and applications; overview of software tools; overview of course objectives.; introduction to OpenCV. Image formation and representation: imaging geometry, radiometry, digitization, cameras and projections, rigid and affine transformations, Filtering: convolution, smoothing, differencing, and scale space

Feature detection: edge detection, corner detection, line and curve detection, active contours, SIFT and HOG descriptors, shape context descriptors, Model fitting: Hough transform, line fitting, ellipse and conic sections fitting, algebraic and Euclidean distance measures.

Camera calibration: camera models; intrinsic and extrinsic parameters; radial lens distortion; direct parameter calibration; camera parameters from projection matrices; orthographic, weak perspective, affine, and perspective camera models.

Motion analysis: the motion field of rigid objects; motion parallax; optical flow, the image brightness constancy equation, affine flow; differential techniques; feature-based techniques; regularization and robust estimation; motion segmentation through EM, Motion tracking: statistical filtering; iterated estimation; observability and linear systems; the Kalman filter; the extended Kalman filter

Object recognition and shape representation: alignment, appearance-based methods, invariants, image Eigen spaces, data-based techniques.

Text Books

1. *Computer Vision: Algorithms and Applications, R. Szeliski, Springer, 2011.*
2. *Computer Vision: A Modern Approach, D. Forsyth and J. Ponce, Prentice Hall, 2nd ed., 2011.*
3. *Introductory techniques for 3D computer vision, E. Trucco and A. Verri, Prentice Hall, 1998.*

COURSE OUTCOMES

Students are able

CO1: To understand the fundamental problems of computer vision.
CO2: To learn techniques, mathematical concepts and algorithms used in computer vision to facilitate further study in this area.
CO3: To get an idea regarding the camera calibration and its importance.
CO4: To study different kinds of motion estimation methodologies and its applications.
CO5: To understand the basic concepts of object and shape recognition techniques

Course Code	**:**	**EC637**
Course Title	**:**	**Natural Language Processing**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE LEARNING OBJECTIVE

- Understand NLP tasks in syntax, semantics and pragmatics
- Implement machine learning techniques used in NLP

Introduction – Why NLP? NLP versus speech recognition- Applications-problem of ambiguity- role of machine learning in NLP- Basic neural networks for NLP

Words – Morphology and Finite State transducers-Tokenization – Computational Phonology and Pronunciation Modelling

Probabilistic models in NLP — Role of language models- Simple N-gram model – Evaluation: Perplexity and Word Error Rate. Parts of Speech Tagging- Hidden markov models–Viterbi algorithm, Maximum Entropy Markov model

Semantic analysis - Lexical semantics and word-sense disambiguation. Compositional semantics. Semantic Role Labeling and Semantic Parsing

Machine Translation - Statistical translation, word alignment, phrase-based translation, and synchronous grammars, evaluation.

Reference Books

1. Natural Language Processing, by Jacob Eisenstein, MIT Press.
2. Speech and Language Processing by Daniel Jurafsky and James H. Martin
3. Foundations of Statistical Natural Language processing by Manning C. D. and Schutze H., First Edition, MIT Press, 1999
4. Neural Network Methods for Natural Language Processing by Yoav Goldberg, Morgan & Claypool Publishers.

COURSE OUTCOMES

Students are able to
CO1: Understand NLP and the role of machine learning in NLP
CO2: Describe finite state transducer operations and pronunciation modelling in NLP
CO3: Illustrate various probabilistic models in NLP.
CO4: Study semantic analysis in NLP
CO5: Learn various machine translation approaches and the different evaluation metrics.

Course Code	**:**	**EC638**
Course Title	**:**	**Optimization Methods In Machine Learning**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE LEARNING OBJECTIVE

- The course aims to equip students with advanced techniques and methods in optimization that are tailored to large-scale statistics and machine learning problems

COURSE CONTENT

Basics of convex optimization- convex sets, convexity-preserving operations, examples of convex programs (linear programming (LP), second-order cone programming (SOCP), semidefinite programming (SDP)), convex relaxation, KKT conditions, duality

Gradient-based methods- gradient descent, subgradient, mirror descent, Frank–Wolfe method, Nesterov's accelerated gradient method, ODE interpretations, dual methods, Nesterov's smoothing, proximal gradient methods, Moreau–Yosida regularization

Operator splitting methods- augmented Lagrangian methods, alternating direction method of multipliers (ADMM), monotone operators, Douglas–Rachford splitting, primal and dual decomposition

Stochastic and nonconvex optimization-dual averaging, Polyak–Juditsky averaging, stochastic variance reduced gradient (SVRG), Langevin dynamics, escaping saddle points, landscape of nonconvex problems, deep learning

Applications of optimization methods in Image/Video/Multimedia Processing

Textbooks:

1. *Stephen Boyd and Lieven Vandenberghe's book: Convex Optimization*
2. *Nesterov's old book: Introductory Lectures on Convex Optimization: A Basic Course*
3. *Nesterov's new book: Lectures on Convex Optimization*
4. *Neal Parikh and Stephen Boyd's monograph: Proximal Algorithms*
5. *Sebastien Bubeck's monograph: Convex Optimization: Algorithms and Complexity*

References

1. *Moritz Hardt's Berkeley EE 227C course note*
2. *Prateek Jain and Purushottam Kar's survey on nonconvex optimization*
3. *Kristin Bennett, Emilio Parrado-Hernandez. Interplay of Optimization and Machine Learning Research, Journal of Machine Learning Research, 2006.*
4. *Nati Srebro, Ambuj Tewari. Stochastic Optimization for Machine Learning, Tutorial at International Conference on Machine Learning, 2010.*

COURSE OUTCOMES

Students are able

CO1: To learn the basic concepts of convex optimization

CO2: To study gradient based optimization techniques

CO3: To understand the problem solving using operator splitting methods

CO4: To learn stochastic and non-convex optimization Techniques,

CO5: To execute applications of optimization techniques in different domains

Course Code	**:**	**EC639**
Course Title	**:**	**Hardware for Deep Learning**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE LEARNING OBJECTIVE

To get an idea about deep learning and how to implement deep learning algorithms on FPGA

COURSE CONTENT

Introduction to Deep Learning: From AI to DL, Neural Network: Perceptrons, Back Propagation, Over-fitting, Regularization. Deep Networks: Definition, Motivation, Applications, Convolution Neural Network (CNN): Basic architecture, Activation functions, Pooling, Handling vanishing gradient problem, Dropout, Weight initialization methods, Batch Normalization. Training Neural networks, Additional CNN Components, Famous CNNs, Applications, Software libraries.

Computing Convolutions: Mapping Matrix multiplication, Computational Transforms, Accelerator Architectures, Dataflow Taxonomy

Reducing the Complexity: Light weight models, reducing precision, Aggressive Quantization, pruning & Deep compression.

The Deep Learning Acceleration Landscape: parallelism in deep learning, Traditional programmable hardware, specialized deep learning hardware platforms, deep learning software stack, Specialized research ASICs.

FPGAs for Deep Learning: Overview of hardware architectures for deep learning, Effective management of FPGA memory resources, optimizing algorithms and data representation for FPGA arithmetic resources, Integrating hardware and software.

Text Books

1. *Ian Goodfellow, Yishuv Bengio and Aaron Courville, "Deep Learning." MIT Press. 2016. ISBN: 978-0262035613. Available online for free at: http://www.deeplearningbook.org*
2. *Vivienne Sze; Yu-Hsin Chen; Tien-Ju Yang; Joel S. Emer, "Efficient Processing of Deep Neural Networks" Morgan & Claypool Publishers, 1st Edition, 2020.*
3. *Tushar Krishna, Hyoukjun Kwon, Angshuman Parashar, Michael Pellauer, and Ananda Samajdar, "Data Orchestration in Deep Learning Accelerators", Morgan & Claypool Publishers, 1st Edition, 2020.*

References

1. *Piotr Antonik, "Application of FPGA to Real-Time Machine Learning", Springer, 2018.*
2. *Stanford C231n, 2017*
3. *Sze, et al. https://eyeriss.mit.edu/ ISCA Tutorial 2019*
4. *Sze, et al. "Efficient Processing of Deep Neural Networks: A Tutorial and Survey", Proceedings of the IEEE, 2017*
5. *Prof. Adam Teman https://www.eng.biu.ac.il/temanad/hardware-for-deep-learning/*
6. *https://jameswhanlon.com/*

Course outcomes

Students are able to

CO1: Understand the context of convolutional neural networks and deep learning algorithms.

CO2: Know how to use convolution in deep learning techniques.

CO3: Understand the necessity and importance of light weight models with low complexity through specialized hardware architecture

CO4: Know how to optimize hardware performance in deep neural network applications.

CO5: Discuss, suggest and evaluate specialised hardware architectures to implement deep learning algorithms in FPGA and utilise deep learning concepts in resource constrained reliable systems.

Course Code	**:**	**EC640**
Course Title	**:**	**Image and Video Processing**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE LEARNING OBJECTIVE

- The course aims to equip students with basic image and video processing techniques.

COURSE CONTENTS

Image Formation and Representation: 3D to 2D projection, photometric image formation, trichromatic colour representation, video format (SD, HD, UHD, HDR), contrast enhancement (concept of histogram, nonlinear mapping, histogram equalization)

Review of 1D Fourier transform and convolution: Concept of spatial frequency. Continuous and Discrete Space 2D Fourier transform. 2D convolution and its interpretation in frequency domain. Implementation of 2D convolution. Separable filters. Frequency response. Linear filtering (2D convolution) for noise removal, image sharpening, and edge detection. Gaussian filters, DOG and LOG filters as image.

Geometric mapping and Feature detection: Geometric mapping (affine, homography), Feature based camera motion estimation (RANSAC). Image warping. Image registration. Panoramic view stitching, Feature detection (Harris corner, scale space, SIFT), feature descriptors (SIFT). Bag of Visual Word representation for image classification.

Motion estimation: optical flow equation, optical flow estimation (Lucas-Kanade method, KLT tracker); block matching, multi-resolution estimation. Deformable registration (medical applications), Moving object detection (background/foreground separation): Robust PCA (low rank + sparse decomposition). Global camera motion estimation from optical flows. Video stabilization. Video scene change detection.

Video Coding: block-based motion compensated prediction and interpolation, adaptive spatial prediction, block-based hybrid video coding, rate-distortion optimized mode selection, rate control, Group of pictures (GoP) structure, tradeoff between coding efficiency, delay, and complexity, depth from disparity, disparity estimation, view synthesis. Multiview video compression. Depth camera (Kinect). 360 video camera and view stitching.

Text Book/References:

1. *Richard Szeliski, Computer Vision: Algorithms and Applications. (Available online:"Link") (Cover most of the material, except sparsity-based image processing and image and video coding)*
2. *(Optional) Y. Wang, J. Ostermann, and Y.Q.Zhang, Video Processing and Communications. Prentice Hall, 2002. "Link" (Reference for image and video coding, motion estimation, and stereo)*
3. *(Optional) R. C. Gonzalez and R. E. Woods, Digital Image Processing, Prentice Hall, (3rd Edition) 2008. ISBN number 9780131687288. "Link" (Good reference for basic image processing, wavelet transforms and image coding).*

COURSE OUTCOMES

Students are able to

CO1: Understand the concept of image formation and representation

CO2: Know the need of transformation and convolution

CO3: Understand the necessity and importance of feature detection and geometric mapping

CO4: Know how to do motion estimation in video

CO5: To understand the basic ideas of video coding

Course Code	**:**	**EC641**
Course Title	**:**	**Automated Test Engineering for Electronics**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE CONTENT

Printed Circuit Boards (PCBs) – types of PCB – multilayer PCBs – Plated though Hole Technology (PTH) - Surface Mount Technology (SMT) – Ball Grid Array (BGA) Technology. Bare PCB electrical test concepts, Loaded PCB Visual inspection, Automated Optical inspection systems, X-Ray inspection systems-Measuring Passive components – 2 wire, 3 wire, 4 wire and 6 wire measurement concepts, Guarding techniques, Shorts location, Most common manufacturing defects, Automated Manufacturing defect analyzers, Nodal Impedance / analog signature analysis. Flying probe testers.

Concepts of PCB Trouble-shooting, Symptom recognition, Bracketing technique, Failure types and fault causes, Manual Trouble shooting, Use of DMM, Oscilloscope, Signal Generators, Logic Probes, Logic Pulsers, Logic Analyzers, Automated Test Techniques – CPU Emulation technique, ROM Emulation, In-Circuit Comparators, In- Circuit Emulators, Functional Testing of Digital ICs, Library models, Concepts of In-circuit Testing, - Back Driving technique – international defence standards - Auto Compensation, In-Circuit Test of Open collector / Emitter Devices, Tri-State, Bi-Directional Devices, Concepts of Digital Guarding, Analog and Mixed Signal ICs Test, advantages and limitations of in-circuit testing, AC – DC Parametric testing, –Advanced test techniques- Boundary Scan Test , Learn and compare technique – digital signatures, Bus Cycle Signature Test , Analog signatures.

ATE system components, Main Test Vector processor, Digital Subsystem, Pin Electronics, Programmable drive and threshold levels, RAM behind each pin, Controlling slew rate, Skew between channels, Data formats, Digital and analog simulation, Test Vector Generation, Fault simulation, Fault coverage, Test Languages, Verilog, VHDL, Automatic compare, Analog Sub system, Digital and analog matrix switch circuits, digital and analog highways, Integration of JTAG, Boundary Scan Test, BSDL, External Instrumentation, Functional and Timing tests. Concepts of Test Program (T.P) Generation. Commercially available off the shelf Test Equipment's (COTS)

Board Functional Test (BFT) techniques – Go-No-go Test – Diagnostic Test, Reliability Test, Thermal Shock Test, Full functional Edge to edge test, Cluster Test – Guided Probe Backtracking Technique – Simulators – Online and Offline Simulation - Fault Simulation– Comprehensiveness of Board program – Fault Dictionary– Analysis – BS and Non-BS device testing–- Sample board programming and testing – BS interconnect and simulating faults - External Instrumentation used for board testing – PXI Instrumentation – Integration of PXI instruments for testing

Design for testability (DFT) and Design for manufacturability (DFM) - Basics of ATPG, – Fault Models — Design considerations for edge functional test, Design considerations for Bus Cycle Signature Test, Design considerations for Boundary Scan Test, Built-in Self-Test, Modular Design– ATE for test - DFM - Manufacturing phases in industry oriented Production process – strategies – new strategy - benefits of new strategies

Reference Books:

1. *Test Engineering for Electronic Hardware – S R Sabapathi, Qmax Test Equipments P Ltd., 2011*
2. *Practical Electronic Fault Finding and Troubleshooting - Robin Pain Newnes, Reed Educational and professional publishing Ltd., 1996*
3. *The Fundamentals of Digital Semiconductor Testing, Floyd, Pearson Education India, Sep-2005*
4. *Building a Successful Board Test Strategy-Stephen F Scheiber-Butterworth Heinemann*

COURSE OUTCOMES

Students are able to

CO1: Understand PCB and various manufacturing techniques.

CO2: Understand common PCB failure detection techniques.

CO3: Understand the various ATE system components.

CO4: Know different board functional test techniques.

CO5: Understand the basic considerations for design manufacturability and testability.

Course Code	**:**	**EC654**
Course Title	**:**	**Electronic Design Automation Tools**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objective

- To make the students exposed to Front end and Back end VLSI CAD tools.

Course Content

OS Architecture: System settings and configuration. Introduction to UNIX commands, Handling directories, Filters and Piping, Wildcards and Regular expression, Power Filters and Files Redirection. Working on Vi editor, Basic Shell Programming, TCL Scripting language.

Circuit simulation using Spice - circuit description. AC, DC and transient analysis. Advanced spice commands and analysis. Models for diodes, transistors and Opamp. Digital building blocks. A/D, D/A and sample and hold circuits. Design and analysis of mixed signal circuits.

Synthesis and simulation using HDLs-Logic synthesis using Verilog. Memory and FSM synthesis. Performance driven synthesis, Simulation- Types of simulation. Static timing analysis. Formal verification. Switch level and transistor level simulation.

System Verilog- Introduction, Design hierarchy, Data types, Operators and language constructs. Functional coverage, Assertions, Interfaces and test bench structures.

Analog/Mixed Signal Modelling and Verification: Analog/Mixed signal modelling using Verilog-A and Verilog-AMS. Event Driven Modelling: Real number modelling of Analog/Mixed blocks modelling using Verilog-RNM/System Verilog. Analog/Digital Boundary Issues: boundary issues coverage. Introduction to Universal Verification Methodology (UVM).

Text Books

1. *M.J.S.Smith, "Application Specific Integrated Circuits", Pearson, 2008.*
2. *M.H.Rashid, "Spice for Circuits and Electronics using Pspice", 2nd Edition, PHI.*
3. *S.Sutherland, S. Davidmann and P. Flake, "System Verilog for Design", 2nd Edition, Springer, 2006.*

Reference Books

1. *H.Gerez, "Algorithms for VLSI Design Automation", John Wiley, 1999.*
2. *Z. Dr Mark, "Digital System Design with System Verilog", Pearson, 2010.*
3. *Sharon Rosenberg and Kathleen Meade, "A Practical Guide to Adopting the Universal Verification Methodology (UVM)", 2nd edition, 2010.*

Course outcomes

After successful completion of the course the students are able to

CO1: execute the special features of VLSI back end and front end CAD tools and UNIX shell script

CO2: write Pspice code for any electronics circuit and to perform monte-carlo analysis and sensitivity/worst case analysis.

CO3: design synthesizable Verilog and VHDL code.

CO4: explain the difference between Verilog and system Verilog and are able to write system Verilog code.

CO5: Model Analog and Mixed signal blocks using Verilog A and Verilog AMS.

Course Code	**:**	**EC656**
Course Title	**:**	**Design of ASICs**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVES

- To prepare the student to be an entry-level industrial standard ASIC or FPGA designer.
- To give the student an understanding of issues and tools related to ASIC/FPGA design and implementation.
- To give the student an understanding of basics of System on Chip and Platform based design.
- To give the student an understanding of High performance algorithms

COURSE CONTENT

Introduction to Technology, Types of ASICs, VLSI Design flow, Design and Layout Rules, Programmable ASICs - Antifuse, SRAM, EPROM, EEPROM based ASICs. Programmable ASIC logic cells and I/O cells. Programmable interconnects. Advanced FPGAs and CPLDs and Soft-core processors.

ASIC physical design issues, System Partitioning, Floorplanning and Placement. Algorithms: K-L, FM, Simulated annealing algorithms. Full Custom Design: Basics, Needs & Applications. Schematic and layout basics, Full Custom Design Flow.

Semicustom Approach: Synthesis (RTL to GATE netlist) - Introduction to Constraints (SDC), Introduction to Static Timing Analysis (STA). Place and Route (Logical to Physical Implementation): Floorplan and Power-Plan, Placement, Clock Tree Synthesis (clock planning), Routing, Timing Optimization, GDS generation.

Extraction, Logical equivalence and STA: Parasitic Extraction Flow, STA: Timing Flow, LEC: Introduction, flow and Tools used. Physical Verification: Introduction, DRC, LVS and basics of DFM.

System-On-Chip Design - SoC Design Flow, Platform-based and IP based SoC Designs, Basic Concepts of Bus-Based Communication Architectures. High performance algorithms for ASICs/ SoCs as case studies – Canonic Signed Digit Arithmetic, KCM, Distributed Arithmetic, High performance digital filters for sigma-delta ADC.

Text Book

1. *M.J.S. Smith : Application Specific Integrated Circuits, Pearson, 2003*
2. *Sudeep Pasricha and NikilDutt, On-Chip Communication Architectures System on Chip Interconnect, Elsevier, 2008*

Reference Books

1. *H.Gerez, Algorithms for VLSI Design Automation, John Wiley, 1999*
2. *Jan.M.Rabaey et al, Digital Integrated Circuit Design Perspective (2/e), PHI 2003*
3. *David A.Hodges, Analysis and Design of Digital Integrated Circuits (3/e), MGH 2004*
4. *Hoi-Jun Yoo, Kangmin Leeand Jun Kyong Kim, Low-Power NoC for High-Performance SoC Design, CRC Press, 2008*
5. *An Integrated Formal Verification solution DSM sign-off market trends, www.cadence.com.*
6. *Recent literature in Design of ASICs.*

COURSE OUTCOMES

Students able to

CO1: demonstrate VLSI tool-flow and appreciate FPGA and CPLD architectures.

CO2: understand the issues involved in ASIC design, including technology choice, design management and tool-flow.

CO3: understand the algorithms used for ASIC construction.

CO4: understand Full Custom Design Flow and Tool used.

CO5: understand Semicustom Design Flow and Tool used - from RTL to GDS and Logical to Physical Implementation

Course Code	**:**	**EC646**
Course Title	**:**	**Verilog HDL: Digital Design and Modeling**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVES

- To design combinational, sequential circuits using Verilog HDL.
- To understand behavioral and RTL modeling of digital circuits
- To verify that a design meets its timing constraints, both manually and through the use of computer aided design tools
- To simulate, synthesize, and program their designs on a development board
- To verify and design the digital circuit by means of Computer Aided Engineering tools which involves in programming with the help of Verilog HDL.

COURSE CONTENT

Hardware modeling with the verilog HDL. Encapsulation, modeling primitives, different types of description.

Logic system, data types and operators for modeling in verilog HDL. Verilog Models of propagation delay and net delay path delays and simulation, inertial delay effects and pulse rejection.

Behavioral descriptions in verilog HDL. Synthesis of combinational logic.

HDL-based synthesis - technology-independent design, styles for synthesis of combinational and sequential logic, synthesis of finite state machines, synthesis of gated clocks, design partitions and hierarchical structures.

Synthesis of language constructs, nets, register variables, expressions and operators, assignments and compiler directives. Switch-level models in verilog. Design examples in verilog.

Text Books

1. *M.D.Ciletti, "Modeling, Synthesis and Rapid Prototyping with the Verilog HDL", PHI, 1999.*
2. *S. Palnitkar, "Verilog HDL – A Guide to Digital Design and Synthesis", Pearson, 2003.*

Reference Books

1. *J Bhaskar, "A Verilog HDL Primer (3/e)", Kluwer, 2005.*
2. *M.G.Arnold, "Verilog Digital – Computer Design", Prentice Hall (PTR), 1999.*
3. *Recent literature in Modeling and Synthesis with Verilog HDL.*

COURSE OUTCOMES

Students are able to

CO1: understand the basic concepts of verilog HDL
CO2: model digital systems in verilog HDL at different levels of abstraction
CO3: know the simulation techniques and test bench creation.
CO4: understand the design flow from simulation to synthesizable version
CO5: get an idea of the process of synthesis and post-synthesis

Course Code	**:**	**EC663**
Course Title	**:**	**Optimizations of Digital Signal Processing Structures for VLSI**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- To understand the various VLSI architectures for digital signal processing.
- To know the techniques of critical path and algorithmic strength reduction in the filter structures.
- To enable students to design VLSI system with high speed and low power.
- To encourage students to develop a working knowledge of the central ideas of implementation of DSP algorithm with optimized hardware.

COURSE CONTENT

An overview of DSP concepts, Pipelining of FIR filters. Parallel processing of FIR filters. Pipelining and parallel processing for low power, Combining Pipelining and Parallel Processing.

Transformation Techniques: Iteration bound, Retiming, Folding and Unfolding

Pipeline interleaving in digital filters. Pipelining and parallel processing for IIR filters. Low power IIR filter design using pipelining and parallel processing, Pipelined adaptive digital filters.

Systolic Architecture Design: Systolic Array Design Methodology, FIR Systolic Arrays, Selection of Scheduling Vector. Redundant arithmetic: Redundant Number Representations, Carry-Free Radix-2 addition and subtraction, Hybrid radix-4 addition, Radix-2 hybrid redundant multiplication architectures.

Synchronous pipelining and clocking styles, clock skew and clock distribution in bit level pipelined VLSI designs. Wave pipelining, constraint space diagram and degree of wave pipelining, Implementation of wave-pipelined systems, Asynchronous pipelining.

Text Book

1. *K.K.Parhi, VLSI Digital Signal Processing Systems, John-Wiley, 2007*

Reference Books

1. *U. Meyer -Baese, Digital Signal Processing with FPGAs, Springer, 2004*
2. *Wayne Burleson, Konstantinos Konstantinides, Teresa H. Meng, VLSI Signal Processing, 1996.*
3. *Richard J. Higgins, Digital signal processing in VLSI, 1990.*
4. *Sun Yuan Kung, Harper J. Whitehous e, VLSI and modern signal processing, 1985*
5. *Magdy A. Bayoumi, VLSI Design Methodologies for Digital Signal Processing, 2012*
6. *Earl E. Swartzlander, VLSI signal processing systems, 1986.*
7. *Recent literature in Optimizations of Digital Signal Processing Structures for VLSI.*

COURSE OUTCOMES

Students are able to

CO1: understand the overview of DSP concepts and design architectures for DSP algorithms.

CO2: improve the overall performance of DSP system through various transformation and optimization techniques.

CO3: perform pipelining and parallel processing on FIR and IIR systems to achieve high speed and low power.

CO4: optimize design in terms of computation complexity and speed.

CO5: understand clock based issues and design asynchronous and wave pipelined systems

Course Code	**:**	**EC664**
Course Title	**:**	**Cognitive Radio**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

COURSE OBJECTIVE

- This subject introduces the fundamentals of multi rate signal processing and cognitive radio.

COURSE CONTENT

Filter banks-uniform filter bank. Direct and DFT approaches. Introduction to ADSL Modem. Discrete multitone modulation and its realization using DFT. QMF. STFT. Computation of DWT using filter banks.

DDFS- ROM LUT approach. Spurious signals, jitter. Computation of special functions using CORDIC. Vector and rotation mode of CORDIC.CORDIC architectures.

Block diagram of a software radio. Digital down converters and demodulators Universal modulator and demodulator using CORDIC. Incoherent demodulation - digital approach for I and Q generation, special sampling schemes. CIC filters. Residue number system and high speed filters using RNS. Down conversion using discrete Hilbert transform. Under sampling receivers, Coherent demodulation schemes.

Concept of Cognitive Radio, Benefits of Using SDR, Problems Faced by SDR, Cognitive Networks, Cognitive Radio Architecture. Cognitive Radio Design, Cognitive Engine Design,

A Basic OFDM System Model, OFDM based cognitive radio, Cognitive OFDM Systems, MIMO channel estimation, Multi-band OFDM, MIMO-OFDM synchronization and frequency offset estimation. Spectrum sensing to detect Specific Primary System, Spectrum Sensing for Cognitive OFDMA Systems.

Text Books

1. *J. H. Reed, "Software Radio", Pearson, 2002.*
2. *U. Meyer – Baese, "Digital Signal Processing with FPGAs", Springer, 2004.*
3. *H. Arslan "Cognitive Radio, Software Defined Radio and Adaptive Wireless Systems", University of South Florida, USA, Springer, 2007.*

Reference Books

1. *S. K. Mitra, "Digital Signal processing", McGrawHill, 1998*
2. *K.C.Chen, R.Prasad, "Cognitive Radio Networks", Wiley, 2009-06-15.*
3. *T. W. Rondeau, C.W.Bostian, "Artificial Intelligence in Wireless Communications", 2009.*
4. *Tusi, "Digital Techniques for Wideband receivers", Artech House, 2001.*
5. *T. DarcChiueh, P. Yun Tsai," OFDM baseband receiver design for wireless communications", Wiley, 2007*
6. *Recent literature in Cognitive Radio.*

COURSE OUTCOMES

Students are able to

CO1: gain knowledge on multirate systems.
CO2: develop the ability to analyze, design, and implement any application using FPGA.
CO3: be aware of how signal processing concepts can be used for efficient FPGA based system design.
CO4: understand the rapid advances in Cognitive radio technologies.
CO5: explore DDFS, CORDIC and its applications.

Course Code	**:**	**EC642**
Course Title	**:**	**Radiating Systems**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning Objective:

To prepare the students to understand the operating principles of various RF radiating systems
To design suitable antenna systems for various defined applications.

Course Content:

Review of antenna theory, dipoles, monopole and loop antennas

Linear and planar arrays, array synthesis, phased arrays

Helical antennas, radiation from apertures, aperture distribution

Horn, parabolic dish antennas, Yagi – Uda and log-periodic antennas

Microstrip antennas and arrays.

Text books:

- J.D. Karus, Antennas, McGraw Hill, 1988.
- Balanis, Antenna Theory - Analysis and design, John wiley, 1982.

Reference books:

- R.E. Collin, Antennas and radiowave propagation, McGraw Hill, 1985.
- R.C. Johnson and H. Jasik, Antenna Engineering Handbook, McGraw Hill, 1984.
- I.J. Bahl and P. Bhartia, Microstrip antennas, Artech house,1980
- G. Kumar and K. P. Ray, Broadband Microstrip Antennas, Artech House, 2003.

COURSE OUTCOMES

At the end of the course, students will be able to

CO1: Understand the various antenna parameters and fundamentals of radiating structures.
CO2: Understand the theory behind antenna array and its various configurations.
CO3: Learn broadband, End-fire, and aperture antennas
CO4: Learn various microstrip antenna and array structures.
CO5. Simulate, design, and optimize antennas for diverse applications using advanced tools and principles, factors like radiation patterns, gain, and efficiency.

Course Code	**:**	**EC643**
Course Title	**:**	**Advanced Topics in 5G/B5G Wireless Communication**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Objectives:
The objective of this course is to help students get familiarized with the latest advancements in 5G and B5G Wireless Communications.

Course Content:

5G New radio frame structure, Numerology, Standardization, Review of orthogonal frequency division multiplexing, Review of multiple input multiple output systems.

Orthogonal time frequency space, non-orthogonal multiple access, Index modulation, Spatial modulation, intelligent reflecting surface, full duplex, physical layer security.

mmWAVE and massive MIMO: Spectrum, Beamforming, Angle of arrival, Angle of departure , Channel model, Precoding, Massive MIMO with imperfect CSI, Multi cell massive MIMO, Imperfect CSI, Pilot Contamination, Channel Estimation

Ultra Dense Networks: Poisson point Process, Device-to-Device Networks, Femtocells, Macrocells, Heterogeneous networks, Coverage, Rate of cellular networks.

Coding: Low density parity check code, Log likelihood ratio, soft input soft output decoder, Rate matching, Puncturing, Polar code, successive cancellation decoding of polar codes

Textbooks:

1. “5G NR: The Next Generation Wireless Access Technology”, Erik Dahlman, Stefan parkvall, Johan Skold, Elsevier, 2E, 2020
2. “5G Physical Layer :Principals, Models and Technology Components”, Ali Zaidi , et al., Academic Press, 2018.

Reference Books:

1. “Delay Doppler Communications -Principles and Applications”, Yi Hong et al., Elsevier, 2022.
2. “OTFS - Orthogonal Time Frequency Space Modulation-A waveform for 6G”, Surva Sekhar Das, Ramjee Prasad , River Publishers Series in Communication, 2021.
3. “LDPC Coded Modulations”, M. Franceschini et al., Springer, 2009
4. “Massive MIMO Networks-Spectral, Energy and Hardware Efficiency”, E.Bjornson et al., NOW Publishers, 2017
5. “Millimetre Wave Communications”, M.G. Sache, MDPI Publishers, 2020
6. “Stochastic Geometry Analysis of Cellular Networks”, B Blaszczyszyn et al., Cambridge University Press, 2018

COURSE OUTCOMES
CO1: Students will learn about the different 5G Modulation Waveforms
CO2: Students will learn about 5G Numerology, Frame structure.
CO3: Students will learn about mmwave , beamforming and massive MIMO systems
CO4: Students will learn to analyze ultra dense networks, derive coverage, rate of heterogeneous networks.
CO5: Students will learn about LDPC and polar codes

Course Code	**:**	**EC703**
Course Title	**:**	**Pattern Recognition and Computational Intelligence Techniques**
Number of Credits	**:**	**3**
Course Type	**:**	**Open Elective (for other specialization/department)**

COURSE OBJECTIVE

- The subject aims to make the students to understand the mathematical approach for pattern recognition. and computational intelligence

COURSE CONTENT

Linear regression techniques: Least square technique, Maximum Likelihood technique, Regularization technique, Error components of regression model, predictive distribution, Bayes technique, Kernel smoothing technique, Gaussian process technique

Dimensionality reduction techniques: Principal Component Analysis, Linear Discriminant Analysis, Kernel Linear Discriminant Analysis, Independent Component Analysis

Linear classifier techniques: Nearest mean, Nearest neighbour, Support Vector Machine, Kernel Trick, Relevance Vector Machine

Probabilistic generative model: K-means algorithm, Fuzzy k-means algorithm, Gaussian Mixture Mode, Hidden Markov model. Probabilistic discriminative model: Logistic regression model.

Computational intelligence techniques: Particle Swarm Optimization, Ant Colony Optimization, Social Emotional Optimization algorithms, Genetic algorithm, Simulated annealing, Artificial Neural Network.

Text Books

1. C.M.Bishop,"Pattern recognition and machine learning",Springer,2006
2. E.S.Gopi, "Pattern recognition and Computational intelligence using matlab, Transactions on computational science and computational intelligence, Springer, 2019

Reference Books

1. Sergious Thedorodis ,Konstantinos Koutroumbas, Pattern recognition, Elsevier, Fourth edition,2009
2. Richard O.Duda, Peter.E.Hart, David G.Stork, "Pattern classification", Wiley, Second edition,2016
3. E.S.Gopi, ''Algorithm collections for Digital signal Processing application using Matlab-Springer ,2007
4. Recent literature in the related topics

COURSE OUTCOMES

Students are able to

CO1: summarize various techniques involved in linear regression techniques
CO2: summarize various techniques involved in dimensionality reduction techniques
CO3: summarize various techniques involved in linear classifier techniques
CO4: summarize various techniques involved in probabilistic generative and discriminative model
CO5: summarize various techniques involved in computational intelligence techniques.

Course Code	**:**	**EC704**
Course Title	**:**	**High Speed Networks and Internet**
Number of Credits	**:**	**3**
Course Type	**:**	**Open Elective (for other specialization/department)**

COURSE OBJECTIVE

To impart the students a thorough exposure to the layered architecture of communication network and to analyse the protocols adopted for traffic management, routing and QOS provisioning.

COURSE CONTENT

The need for a protocol architecture, The TCP/IP protocol architecture, Internetworking, Packet switching networks, Frame relay networks, Asynchronous Transfer mode (ATM) protocol architecture, High speed LANs.

Application of queuing theory to the analysis of performance of communication networks, Transport layer services-Principles of Reliable data transfer, Congestion control and flow control mechanism.

Virtual circuits and datagrams, Router architecture, Forwarding and addressing in the internet, Interior routing protocols, Exterior routing protocols and multicast.

Wireless LAN technology, IEEE 802.11 WLAN protocol architecture, services, medium access control and physical layer,, Blue tooth and Personal Area Networks.

Quality of service in IP networks, Integrated and differentiated services, Protocols for QOS support-Resource reservation protocol, Multiprotocol label switching, Real time transport protocol. Simulation study on QoS provisioning in IP network.

Text Books

1.W.Stallings,"High speed networks and internets" 2nd edition, Pearson education, 2002.
2.W. Stallings,"Wireless communication and networks"2nd edition, Pearson publication, 2013.
3.J.F.Kurose and K.W.Ross", Computer networking" 3rd edition, Pearson education,2005.

Reference Books

1.M. Schwartz, "Telecommunication networks, protocols, modelling and analysis", Pearson education,2004
2.Jean Walrand and Praveen Varaiya," High performance communication networks",2nd edition, Morgan Kaufmann publishers, 2005.
3.Saadawi, Ammar and El Hakeem,"Fundamentals of telecommunication Networks", Wiley series in Telecommunications and signal processing, 1994.

COURSE OUTCOMES

Students are able to

CO1: compare and analyse the fundamental principles of various high speed communication networks and their protocol architectures
CO2: examine the performance modeling, congestion control issues and traffic management in IP networks
CO3: compare and analyse the various routing protocols in IP networks
CO4: study of various wireless LAN standards, Blue tooth and high data rate personal area networks
CO5: examine quality of service in IP networks.

Course Code	**:**	**EC705**
Course Title	**:**	**Design for Electromagnetic Compatibility**
Number of Credits	**:**	**3**
Course Type	**:**	**Open Elective (for other specialization/department)**

COURSE OBJECTIVE

- Electromagnetic interference (EMI) is a potential threat to the present day electronic systems. The main objective of the course is to provide insight into various sources of electromagnetic interferences and how to design an electronic product which is electromagnetically compatible with each other.

COURSE CONTENT

Overview of Electromagnetic Interference and Compatibility- Importance of Addressing EMC Issues Early- Examples of EMC Disasters- Various EMC requirements and standards- sources of EMI

Coupling Mechanisms- Common Impedance Coupling- Electric Field Coupling- Magnetic Field Coupling- Electromagnetic Radiation-Conducted and radiated emission -power supply line filters-common mode and differential mode current- common mode choke- switched mode power supplies.

Grounding techniques- signal ground-single point and multi point grounding--Digital circuit power distribution and grounding -Shielding techniques- shielding effectiveness-shield behavior for electric and magnetic field -aperture-seams-conductive gaskets- conductive coatings.

Circuit Components and Parasitics-Resistance, Capacitance and Inductance- Absolute Capacitance, Self Capacitance and Mutual Capacitance, Self Inductance, Mutual Inductance, Partial Inductance, Internal and External Inductance- Component Parasitics-Rules and Tools for Estimating Parasitic Values. Contact protection network.

RF and transient immunity-transient protection network- RFI -mitigation filter-power line disturbance- ESD- human body model- ESD protection in system design. PCB design for EMC compliance-PCB layout and stack up- Strategies for Mixed-Signal PCB Layout EMC pre compliance measurement-conducted and radiated emission test-LISN-Anechoic chamber.

Text Books:

1. H. W. Ott, Electromagnetic Compatibility Engineering, 2nd edition, John Wiley & Sons, 2011, ISBN: 9781118210659.
2. C. R. Paul, Introduction to Electromagnetic Compatibility, 2nd edition, Wiley India, 2010, ISBN: 9788126528752

Reference Book:

K. L. Kaiser, Electromagnetic Compatibility Handbook, 1st edition, CRC Press, 2005. ISBN: 9780849320873

COURSE OUTCOMES

Students are able to

CO1: Understand the various sources of Electromagnetic interference

CO2: Familiarize the fundamentals those are essential for product design with EMC compliance and various EMC standards

CO3:. would gain knowledge to understand the concept of Shielding and grounding related to product design.

CO4:. Design PCBs which are electromagnetically compatible

CO5: understand and differentiate the various EMC pre compliance measurement

Course Code	**:**	**EC801**
Course Title	**:**	**Fundamentals of MIMO Wireless Communications**
Number of Credits	**:**	**3**
Course Type	**:**	**Online Course**

COURSE OBJECTIVE

To introduce students to the fundamentals of multiple antenna communication

COURSE CONTENT

Evolution of wireless system, Layered view of Transmitter and Receiver, Large scale propagation models, Path loss, Shadowing, Small scale model.

Coherence time, Doppler spectrum, Flat fading, Frequency selective fading, Coherence bandwidth, Delay Doppler characteristics

MIMO Channel, Statistical Properties, Maximal Ratio Combining, Selective Combining, Spatial Diversity, Probability of error in multiple antenna systems, Diversity gain, Transmit diversity.

Fundamentals of Information Theory, Entropy, Capacity, Source Coding, Huffman theorem

Capacity of deterministic MIMO channels, Capacity of channel unknown at transmitter, Capacity of channel known at transmitter, Capacity of random channel

Text books

1. Principles of Mobile Communications by G. Stuber, Springer, 2nd ed..
2. Wireless Communications by A. Goldsmith, Cambridge

Reference Books

1. Introduction to Space Time Wireless Communications by A. Paulraj, Nabar and Gore
2. Space Time Wireless Communication Systems,by Bolskei, Gesbert, et al.
3. MIMO wireless communications, by Biligeri, et al.
4. Space Time Coding, by Jafarkhani
5. LTE, UMTS and The Long Term Evolution by Sesia, Toufik and Baker
6. OFDM for Wireless Communications by R. Prasad
7. UMTS for LTE by Holma and Toshala
8. Adaptive PHY-MAC Design for Broadband Wireless Systems by R. Prasad, S. S. Das and Rahman
9. Single and Multi Carrier MIMO Transmission for Broadband Wireless Systems by R. Prasad, Rahman and S. S. Das.

COURSE OUTCOMES

CO1: Students will learn about the evolution of wireless systems.
CO2: Students will learn about the basics of wireless channels.
CO3: Students will learn about receive and transmit diversity schemes in MIMO.
CO4: Students will learn to apply information theoretic concepts in a wireless system.
CO5: Students will learn to derive the capacity of wireless systems under different scenarios.

Course Code	**:**	**EC802**
Course Title	**:**	**Evolution of Air Interface Towards 5G**
Number of Credits	**:**	**3**
Course Type	**:**	**Online Course**

COURSE OBJECTIVE

This course will prepare students for research and make them industry ready to work in 5G technology.

COURSE CONTENT

Overview of 5G communication technology, Introduction to mm wave, Propagation models,

Introduction to MIMO, W-OFDM, F-OFDM, UFMC, FBMC, GFDM, adaptive OFDM, Modulation and coding in 5G

Propagation characteristics of 5G channel models, Basics of MIMO, Massive MIMO, Pilot contamination, Beamforming

Heterogeneous ultra dense networks, Femtocells, Small cells, Device-to-device

Non-orthogonal-multiple access, MIMO-NOMA, QoS provisioning for real time traffic.

Textbooks

1.Evolution of Air Interface for 5G, River Publishers 2018, Journal and conference papers, white papers.
2. "5G NR: The Next Generation Wireless Access Technology", Erik Dahlman, Stefan parkvall, Johan Skold, Elsevier, 2E, 2020

COURSE OUTCOMES

CO1: Students will learn about the development of 5G technology.
CO2: Students will learn about various waveforms used in 5G.
CO3: Students will learn about MASSIVE MIMO and the technologies associated with it.
CO4: Students will learn about heterogeneous networks.
CO5: Students will learn about non orthogonal multiple access.

Course Code	:	**EC803**
Course Title	:	**Introduction to Industry 4.0 and Industrial Internet of Things**
Number of Credits	:	**3**
Course Type	:	**Online Course**

COURSE OBJECTIVE

•To get the understanding on the foundational concepts of Industry 4.0 and the Industrial Internet of Things (IIoT) for practical applications across industries.

•To get an understanding on the IIoT enabling technologies such as Big Data Analytics, Fog computing and Software Defined Networks (SDN), and strategic considerations for potential application domains.

COURSE CONTENT

Introduction: Sensing & actuation, Communication and Networking
Industry 4.0: Globalization and Emerging Issues, The Fourth Revolution, LEAN Production Systems, Smart and Connected Business Perspective, Smart Factories. Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artificial Intelligence, Big Data and Advanced Analysis.
Cybersecurity in Industry 4.0, Basics of Industrial IoT: Industrial Processes,Industrial Sensing & Actuation, Industrial Internet Systems.

IIoT-Introduction, Industrial IoT: Business Model and Reference Architecture: IIoT-Business Models, IIoT Reference Architecture,. Industrial IoT- Layers: IIoT Sensing, IIoT Processing, IIoT Communication, Industrial IoT- Layers: IIoT Communication, IIoT Networking

Industrial IoT: Big Data Analytics and Software Defined Networks: IIoT Analytics - Introduction, Machine Learning and Data Science , R and Julia Programming, Data Management with Hadoop. Industrial IoT: Big Data Analytics and Software Defined Networks: SDN in IIoT, Data Center Networks, Industrial IoT: Security and Fog Computing: Cloud Computing in IIoT,, ParIndustrial IoT: Security and Fog Computing - Fog Computing in IIoT, Security in IIoT

Industrial IoT- Application Domains: Factories and Assembly Line, Food Industry. Industrial IoT- Application Domains: Healthcare, Power Plants, Inventory Management & Quality Control, Plant Safety and Security (Including AR and VR safety applications), Facility Management.

Industrial IoT- Application Domains: Oil, chemical and pharmaceutical industry, Applications of UAVs in Industries, Real case studies:
Case study - I: Milk Processing and Packaging Industries
Case study - II: Manufacturing Industries - Part I
Case study - III: Manufacturing Industries - Part II
Case study - IV: Student Projects - Part I
Case study - V: Student Projects - Part II
Case study - VI: Virtual Reality Lab
Case study - VII: Steel Technology Lab

Textbooks

1.S. Misra, A. Mukherjee, and A. Roy, 2020. Introduction to IoT. Cambridge University Press.
2. S. Misra, C. Roy, and A. Mukherjee, 2020. Introduction to Industrial Internet of Things and Industry 4.0. CRC Press.
3. Research Papers

COURSE OUTCOMES

At the end of the course student will be able

CO1: Understand the development towards emergence of Industry 4.0

CO2: Learn the basic concepts of Industry 4.0

CO3: Learn the networking and communication concepts behind Industrial Internet of Things

CO4: Examine the technologies driving the Industrial Internet of Things (IIoT)

CO5: Investigate case studies and practical examples where Industry 4.0 and IIoT technologies have been successfully deployed

Course Code	**:**	**EC804**
Course Title	**:**	**VLSI Data Conversion Circuits**
Number of Credits	**:**	**3**
Course Type	**:**	**Online Course**

COURSE OBJECTIVE

- To understand sampling and quantization in time and frequency domains, reduction of quantization noise by oversampling and noise shaping concepts.
- To design discrete-time and continuous-time Delta Sigma modulators, Flash A/D converter-Sample and hold circuits, preamplifiers and latches, D/A converter-Current Steering.

COURSE CONTENT

Course overview and introduction. Sampling, Spectral properties of sampled signals, Oversampling and its implications on anti-alias filter design. Time Interleaved Sampling, Analysis of a Ping-Pong Sampling system. Ping-pong Sample and Holds continued, Analysis of Offset and Gain Errors in Time-Interleaved Sample and Holds. Sampling Circuits (NMOS, PMOS and CMOS Switches), Distortion due to the Sampling Switch. Thermal Noise in Sample and Holds, Charge Injection in a Sampling Switch.

Bottom Plate Sampling, The Gate Bootstrapped Switch. The Gate Bootstrapped Switch, the Nakagome Charge-Pump. Characterizing a Sample-and-Hold, Correct choice of input frequency, Discrete Fourier Series Refresher. FFT Leakage and the Rectangular Window. FFT Leakage, Spectral Windows, the Hann Window. Spectral Windows, the Blackman Window, Introduction to Switch Capacitor Amplifiers. Switch Capacitor Circuits, Parasitic Insensitive SC Amplifiers. Nonidealities in SC Amplifiers - Finite Opamp Gain and DC Offset, Finite Opamp Gain-Bandwidth Product.

Introduction to Fully Differential Operation. Fully-differential operation, motivation for common-mode feedback. Fully Differential SC-circuits, the "Flip-Around" Sample and Hold, DC Negative Feedback in SC Circuits. ADC Terminology, Offset and Gain Error, Differential Nonlinearity (DNL). Integral Nonlinearity (INL), Dynamic Characterization of ADCs, SQNR, Quantization Noise Spectrum. Quantization Noise Spectrum (contd), SFDR, Flash A/D Converter Basics.

Flash A/D Converter Basics, the Regenerative Latch. The Regenerative Latch. Motivation to use a Preamp, Preamp Offset Correction (Autozeroing). Autozeroing a Differential Preamp, Subtracting References from the Input. Coupling Capacitor Considerations in an Autozeroed Preamp. Transistor Level Preamp Design. Necessity of an up-front sample and hold for good dynamic performance. Timing issues in a flash ADC. Bubble Correction Logic in a Flash ADC, Comparator Metastability, Case Study. Flash ADC Case Study.

D/A Converter Basics, INL/DNL, DAC Spectra and Pulse Shapes. NRZ vs RZ DACs, DAC Architectures. Binary Weighted versus Thermometer DACs. Binary vs Thermometer DACs, Current Steering DACs. Current Steering DACs. Current Cell Design in a Current Steering DAC. Current Cell Design, Layout Considerations in Current Steering DACs.

Oversampled Approaches to Data Convresion, Benefits of Oversampling. Oversampling with Noise Shaping, Signal and Noise Transfer Functions, First and Second Order Delta-Sigma Converters.

Signal Dependent Stability of DSMs, the Describing Function Method. Stability in DSMs. Maximum Stable Amplitude of DSMs and Relation to Out of Band Gain, Systematic NTF Design. Systematic NTF Design, the Bode Sensitivity Integral and its Implications on NTF Design.

Textbooks

1. CMOS Data Converters for Communication - M. Gustavsson, J. Wikner, and N. Tan. Kluwer Academic Publishers, 2000.
2. Principles of Data Conversion System Design - Behzad Razavi.

Reference Books

1. Delta-Sigma Data Converters: Theory, Design, and Simulation - by Steven R. Norsworthy, Richard Schreier, Gabor C. Temes (the Yellow Bible of Delta-Sigma Converters)
2. Understanding Delta-Sigma Data Converters - by Richard Schreier, Gabor C. Temes (the Green Bible of Delta-Sigma Converters)

COURSE OUTCOMES

At the end of the course student will be able to

CO1: understand sampling concepts and design sample and hold circuits.

CO2: understand and design high performance A/D and D/A circuits.

CO3: understand non-idealities in a data conversion system.

CO4: understand advanced concepts and design methods in data conversion circuits.

CO5: understand oversample data conversion circuits.

Course Code	**:**	**EC805**
Course Title	**:**	**Introduction to time varying electrical networks**
Number of Credits	**:**	**3**
Course Type	**:**	**Online Course**

COURSE OBJECTIVE

- To introduce analog, mixed-signal and RF circuit designers to the area of time-varying circuits and systems.
- To introduces linear time-varying (LTV) and linear periodically time-varying (LPTV) circuits. The applications of the theory are illustrated with practical examples.

COURSE CONTENT

Motivation for the topics covered in the course, review of linearity and time-variance; Review of electrical network basics, incidence matrix, Tellegen's theorem; Tellegen's theorem (cntd), its use to prove reciprocity in bilateral networks, reciprocity in networks with controlled sources.

Reciprocity in networks with controlled sources (contd), inter-reciprocal networks; Modified Nodal Analysis (MNA) formulation to write network equations; MNA formulation (contd), MNA stamps of circuit elements, Reciprocity and inter-reciprocity revisited, Reciprocity and inter-reciprocity (contd), the adjoint network.; Introduction to noise in electronic circuits; Noise in RLC circuits, Nyquist's theorem, Bode's Noise Theorem.

Bode's noise theorem (contd), input referred noise sources in networks; Input-referred noise sources (contd) - equivalent noise voltage and current sources; Equivalent noise sources, noise factor, Need to study time-varying circuits and systems; Linear time-varying (LTV) system basics; Linear Periodically Time-Varying (LPTV) systems basics. Harmonic transfer functions, the Zadeh expansion; MNA equations in LPTV networks with Harmonic transfer matrices; LPTV circuit example : the sampling mixer.

Impedance and admittance in LPTV networks, Norton and Thevenin equivalents; The N-path principle; N-path circuits (contd) - the time-interleaved. N-path circuits (contd) - the multiphase dc-dc converter, introduction to the N-path filter; N-path filters (contd) - input impedance and gain; N-path filters (contd). Reciprocity and inter-reciprocity in LPTV networks - time-reversal to generate the adjoint; Inter reciprocity (contd), transfer-function theorem; Inter-reciprocity (contd), the frequency-reversal theorem.

Inter-reciprocal signal-flow graphs. Example : chopped amplifiers; Chopped-amplifiers with sinusoidal and square-wave modulation; Adjoint networks - the switched-RC kernel example; time domain implications of adjoint networks. Time-domain implications of the adjoint - example of a switched-RC network. Sampled LPTV networks; Equivalent LTI filter of a sampled LPTV system; derivation of the equivalent impulse response, switched-RC network example; Cont. time delta-sigma as a sampled LPTV system. Response of LPTV systems to modulated inputs; equivalent LTI filter; Introduction to noise in LPTV networks, noise in switched-RLC networks, the Bode noise theorem applied to LPTV networks

Text Books

- "Engineering Circuit Analysis", William H. Hayt, Jr., Jack E. Kemmerly, Jamie D. Phillips, Steven M. Durbin, (9th edition, McGraw Hill).
- Alan Oppenheim, Alan Willsky, S. Nawab,"Signals and Systems", Pearson, 2006.

Reference Books

- Erwin Kreyszig, "Advanced Engineering Mathematics", John Willey & Sons, Inc.
- Dr. B.S.Grewal, "Higher Engineering Mathematics", Khanna Publishers.

COURSE OUTCOMES

At the end of the course student will be able to

CO1: understand linearity and time-variance in electrical networks.
CO2: understand reciprocity and inter-reciprocity in networks.
CO3: understand Bode's noise theorem and Linear time-varying (LTV) system.
CO4: understand impedance and admittance in LPTV networks, N-path filters.
CO5: understand inter-reciprocal signal-flow graphs and response of LPTV systems.

Course Code	**:**	**EC806**
Course Title	**:**	**Power management integrated circuits**
Number of Credits	**:**	**3**
Course Type	**:**	**Online Course**

COURSE OBJECTIVE

- To understand and design power management integrated circuits such as voltage & current references, low-dropout regulators, and DC-DC converters.
- To understand the design challenges of state-of-the-art power management unit (PMU) designed for IoT and RF applications.

COURSE CONTENT

Introduction to Power Management and Voltage Regulators: Need of power management, power management applications, classification of power management, power delivery of a VLSI system, power conversion, discrete vs. integrated power management, types of voltage regulators (switching Vs linear regulators) and applications, converter's performance parameters (voltage accuracy, power conversion efficiency, load regulation, line regulation, line and load transient response, settling time, voltage tracking), local Vs remote feedback, kelvin sensing, Point-of-Load (POL) regulators.

Linear Regulators: Bandgap Voltage Reference, Low Drop-Out Regulator (LDO), Source and sink regulators, shunt regulator, pass transistor, error amplifier, small signal model and stability analysis, compensation techniques, current limiting, power supply rejection ratio (PSRR), NMOS vs. PMOS regulator, current regulator.

Switching DC-DC Converters: Types (Buck, boost, buck-boost), power FETs, choosing L and C, PWM modulation, leading, trailing and dual edge modulation, Losses in switching converters, output ripple, voltage Vs current mode control, CCM and DCM modes, hysteretic control, switched capacitor dc-dc converters, Small signal model of dc-dc converter, loop gain analysis of un-compensated dc-dc converter, type-I, type-II and type-III compensation, compensation of a voltage mode dc-dc converter, compensation of a current mode dc-dc converter, Selecting topology, selecting switching frequency and external components, sizing power FETs, segmented power FET, designing building blocks (gate driver, PWM modulator, error amplifier, oscillator, ramp generator, feedback resistors), current sensing, PFM/PSM mode for light load, effect of parasitic on reliability and performance, current limit and short circuit protection, soft start control, chip level layout and placement guidelines, board level layout guidelines, EMI considerations.

Introduction to Advanced Topics in Power Management: Digitally controlled dc-dc converters, digitally controlled LDOs, time-based control for voltage regulators, adaptive compensation, dynamic voltage scaling (DVS), Single-Inductor Multiple-Outputs (SIMO) Converters, dc-dc converters for LED lighting, Li-ion battery charger.

Text Books

- Fundamentals of Power Electronics, 2nd edition by Robert W. Erickson, Dragan Maksimovic, Springer (India) Pvt. Ltd, 2005.
- Ke-Horng Chen, "Power Management Techniques for Integrated Circuit Design", Wiley-IEEE Press, 2016.

Reference Books

- Mona M. Hella, Patrick Mercier, "Power Management Integrated Circuits", CRC Press, 2016.

- Selected papers from IEEExplore (https://ieeexplore.ieee.org/Xplore/home.jsp).

COURSE OUTCOMES

At the end of the course student will be able to

CO1: understand the power management unit specifications for given target applications.
CO2: understand and analyse the performance of power management integrated circuits.
CO3: appreciate the challenges involved in the design of a high performance PMU design.
CO4: design various types of voltage & current references, LDO's, and DC-DC converters.
CO5: design high efficiency on-chip power management circuits

Course Code	**:**	**EC807**
Course Title	**:**	**Optical Wireless Communications beyond 5G Networks and IOT**
Number of Credits	**:**	**3**
Course Type	**:**	**Online Course**

COURSE OBJECTIVE
In this course students will be exposed to optical wireless communications for modern 5G networks and Internet of things applications

COURSE CONTENT
Existing wireless Access Schemes, OWC/Radio Comparison, Potential OWC Application Areas, LEDs and Lasers (Internal and External Quantum Efficiency, Power and Luminous Efficiency, and Modulation Bandwidth)

PIN and APD Photodetector, Photodetection Techniques, Photodetection Noise, LOS Propagation Model, Non-LOS Propagation Model, Interference from other other Light sources, Atmospheric Channel Loss, Beam Divergence, Pointing Loss, Different Atmospheric Turbulence Models

Absorption, scattering, Turbulence, Multipath interference, Physical obstruction, and Background noise, Digital Baseband Modulation Techniques like PAM, PPM, PIM etc., Multi-carrier Modulation (OFDM) for OWC, Color Shift Keying, NOMA etc.

Effect of Ambient Light Sources on Indoor OWC Link Performance, Link Performance for Multipath Propagation, FSO Link Performance under the Effect of Atmospheric turbulence, Atmospheric Turbulence-Induced Penalty and mitigation strategies

Indoor OWC link, O-OFDM and CSK Modulation Schemes, WiFi/LiFi Co-existence, V2V Communications

Text Books
1."Advanced Optical Wireless Communication Systems", Shlomi Arnon, John Barry, George Karagiannidis, Robert Schober, and Murat Uysal, CAMBRIDGE UNIVERSITY PRESS
2. “Optical Wireless Communications System and Channel Modelling”, Z. Ghassemlooy W. Popoola S. Rajbhandari, CRC Press

COURSE OUTCOMES
CO1: Review of basics of optical wireless communication
CO2: Expose students to photodetector performance and atmospheric effects
CO3: Expose students to different modulation techniques used in optical wireless communication
CO4: Analysis of free space optical communication
CO5: Expose students to Indoor optical wireless communication link , and advanced LiFi concepts

Course Code	**:**	**EC808**
Course Title	**:**	**5G Wireless Standard Design**
Number of Credits	**:**	**3**
Course Type	**:**	**Online Course**

COURSE OBJECTIVE

The objective of this course is to bridge the gap between the theory and practise of 5G wireless communication systems, and consequently also the gap between academia and industry.

COURSE CONTENT

Introduction, Key 5G Technologies, Adaptive Modulation and Coding, Hybrid automatic repeat request, Orthogonal frequency division multiplexing, 5G Numerology, 5G frame structure

5G physical downlink shared channel (PDSCH) transmit chain– CRC generation, 5G PDSCH transmit chain – code block segmentation, 5G PDSCH transmit chain – LDPC coding, 5G PDSCH transmit chain – rate matching, 5G PDSCH transmit chain – interleaving and concatenation

5G PDSCH transmit chain – scrambling and modulation,5G PDSCH receive chain, 5G PDSCH – map receiver design,5G baseband-RF conversion, Indigenous 5G network architecture

5G physical downlink control channel (PDCCH) transmit chain- Introduction, 5G PDCCH transmit chain – CRC and segmentation, 5G PDCCH transmit chain – Polar encoding, 5G PDCCH transmit chain – CRC Interleaver, 5G PDCCH transmit chain – sub-block interleaver, 5G PDCCH transmit chain – rate matching, 5G PDCCH transmit chain – control resource set design

5G physical uplink control channel (PUCCH), Multiple input multiple output (MIMO) transceiver chain, 5G demodulation reference signal (DM-RS) design, 5G sounding reference signal (SRS) design, 5G channel state estimation reference signal (CSI-RS), 5G MIMO codebook design, 5G FR1/FR2 design, 5G Initial Access

Reference books

1. 3 GPPP Standards Documents
2. "5G NR: The Next Generation Wireless Access Technology", Erik Dahlman, Stefan parkvall, Johan Skold, Elsevier, 2E, 2020
3. IEEE Papers

COURSE OUTCOMES

CO1: Review of basics of 5G technology, numerology and frame structure
CO2: Expose students to different stages of PDSCH transmit chain
CO3: Expose students to different stages of PDCCH transmit chain
CO4: Students will learn basics of SRS, DRS, CSI-RS design
CO5: Students will get exposed to MIMO transceiver design