M. Tech.

IN

COMMUNICATION SYSTEMS ENGINEERING

CURRICULUM

(For students admitted in 2016-17)

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

TIRUCHIRAPPALLI – 620 015

TAMIL NADU, INDIA

CURRICULUM

The total minimum credits for completing the M.Tech. programme in Communication Systems is 66 .

SEMESTER I

Sl. No.	Course Code	Course of	Credits
1.	EC601	Linear Algebra and Stochastic Processes	3
2.	EC603	Advanced Digital Signal Processing	3
3.	EC605	Microwave Circuits	3
4.		Elective – 1	3
5.		Elective – 2	3
6.		Elective – 3	3
7.	EC607	Microwave and MIC Laboratory	2
Total			**20**

SEMESTER II

Sl. No.	Course Code	Course Title	Credits
1.	EC602	Advanced Digital Communication	3
2.	EC604	Broadband Wireless Technologies	3
3.	EC606	Optical Communication Systems	3
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			**22**

SEMESTER III

Course Code	Course Title	Credits
EC647	PROJECT WORK - PHASE I	12
Total		**12**

SEMESTER IV

Course Code	Course Title	Credits
EC648	PROJECT WORK - PHASE II	12
Total		**12**

LIST OF ELECTIVES

Sl. No.	Course Code	Course Title	Credits
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	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	3
20.	EC630	Fiber-Optic Sensors	3
21.	EC631	Optical Wireless Communications	3
22.	EC656	Design of ASICs	3
23.	EC662	Modeling and Synthesis with Verilog HDL	3
24.	EC663	Optimization of Digital Signal Processing structures for VLSI	3
25.	EC664	Cognitive Radio	3

LIST OF OPEN ELECTIVES

Sl. No.	Course Code	Course Title	Credits
1.	EC603	Advanced Digital Signal Processing	3
2.	EC613	High speed Communication Networks	3

Course Code	**:**	**EC601**
Course Title	**:**	**Linear Algebra and Stochastic Processes**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

Course Learning 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.

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

At the end of the course student will be able

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	**:**	**3**
Course Type	**:**	**Core**

Course Learning 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.

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

At the end of the course student will be able

CO1: summarize multirate DSP and design efficient digital filters.
CO2: construct multi-channel filter banks.
CO3: select linear filtering techniques to engineering problems.
CO4: describe the most important adaptive filter generic problems.
CO5: describe the various adaptive filter algorithms.
CO6: describe the statistical properties of the conventional spectral estimators.

Course Code	**:**	**EC605**
Course Title	**:**	**Microwave Circuits**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

Course Learning Objective

- To make the students familiarize with ABCD parameters, S parameters, Applications of planar transmission lines in the practical microwave circuits, Design and layout of all Microwave Integrated Circuit Design components and then systems.

Course Content

Two-port network characterization. Scattering matrix representation of microwave components.
Planar transmission lines: Characteristics, properties, design parameters and applications. Design and realization of MIC Components. 3 dB hybrid design. Backward Directional Coupler, Hybrid ring and Power dividers.
MIC filters. Kuroda transformation. K inverter, J inverter. Resonator filters. Realization using microstrip lines and strip lines.
Microwave amplifier design. Power gain equations. Maximum gain design. Low noise Design. High power design. Stability considerations.
Microwave oscillator design. One – port and two – port negative resistance oscillators. Oscillator design using large – signal measurements.

Text Books

1. *I.J.Bahl & P.Bhartia, "Microwave Solid state Circuit Design (2/e)", Wiley, 2003.*
2. *S.Y.Liao, "Microwave Circuit Analysis and Amplifier Design", Prentice-Hall, 1986.*

Reference Books

1. *G.Gonzalez, "Microwave Transistors and Amplifiers (2/e)", Prentice-Hall, 1997.*
2. *A. Das & S.K.Das, "Microwave Engineering (2/e)", Tata McGraw Hill, 2010.*
3. *B. Bhat, S. K Koul, "Stripline like transmission lines for Microwave Integrated Circuits", New Age International Pvt. Ltd Publishers, 2007.*
4. *Recent literature in Microwave Circuits.*

Course outcomes

At the end of the course student will be able

CO1: understand the basics of Scattering matrix and two port characterization.

CO2: analyze the design principles of passive microwave components such as couplers and power dividers.

CO3: distinguish between the different types of MIC filters and their implementation.

CO4: understand the complexities of microwave amplifier design and its stability features.

CO5: identify the suitable microwave power sources of given specification for the selected application.

CO6: appreciate the design principles of microwave oscillators.

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

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 Code	**:**	**EC602**
Course Title	**:**	**Advanced Digital Communication**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

Course Learning 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.

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 the course student will be able

CO1: understand the operation, theoretical analysis and design of baseband, pass band data transmission systems.

CO2: design and implement various digital encoders and decoders.

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	**:**	**3**
Course Type	**:**	**Core**

Course Learning Objective

- To expose the students to understand mobile radio communication principles and to study the recent trends adopted in cellular systems and wireless standards.

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. Fading. Multipath Propagation. Channel modeling, Diversity Schemes and Combining Techniques.

Design parameters at the base station, Practical link budget design using path loss models. Smart antenna systems, Beam forming. MIMO Systems. RAKE receiver.

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

GSM, IS-95, GPRS, UMTS, WLAN, WPAN, WMAN, Ultra Wideband communications, 4G and beyond 4G.

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 Communication"s, PHI, 2008.*
2. *Ke-Lin Du, M.N.S.Swamy, "Wireless Communication Systems", Cambridge University Press, 2010.*
3. *K. Fazel & S. Kaiser," Multi-carrier and Spread Spectrum Systems", Wiley, 2003*
4. *S.G. Glisic, "Advanced Wireless Communications", 4G Technologies, Wiley, 2004.*
5. *W. C. Y.Lee, "Mobile Communication Engineering", (2/e), McGraw- Hill, 1998.*
6. *S.G. Glisic, "Adaptive CDMA", Wiley, 2003*
7. *Recent literature in Broadband Wireless Technologies.*

Course outcomes

At the end of the course student will be able

CO1: discuss the cellular system design and technical challenges.

CO2: analyze the Mobile radio propagation, fading, diversity concepts and the channel modeling.

CO3: analyze the design parameters, link design, smart antenna, beam forming and MIMO systems.

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

CO5: summarize the principles and applications of wireless systems and standards.

Course Code	**:**	**EC606**
Course Title	**:**	**Optical Communication Systems**
Number of Credits	**:**	**3**
Course Type	**:**	**Core**

Course Learning Objectives

- 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

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

At the end of the course student will be able

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**

List of Experiments

1. Measurement of Numerical Aperture
2. Measurement of Attenuation and Bending Loss
3. Study of Analog Link
4. Proximity Sensor
5. Study of BER and Q-factor estimation in the optical system simulation
6. EDFA design for DWDM link
7. Study the Characteristics of a Communication channels
   AWGN
   BSC
8. Analog and Digital Modulation
   Frequency Modulation and Demodulation
   QPSK Modulation and Demodulation
9. Conventional Encoder and Decoder
10. OFDM-802.11a
11. Installation of GLOMMOSIM

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

List of Experiments:

1. Generation of Multivariate Gaussian generated data with desired mean vector and the required co-variance matrix.
2. (A) Sub-band Discrete Fourier Transformation
   (B) Non-Uniform Discrete Fourier Transformation
   (C) Warped Discrete Fourier Transformation
3. (A) Transmultiplexer
   (B) Quadrature –mirror filter
4. Design and Realization of the adaptive filter using LMS algorithm (solved using steepest-descent algorithm)
5. Representation of the 2D image signal as the linear combinations of PCA (Eigen faces)
6. Image compression using discrete cosine transformation (DCT).
7. Discrete Multitone Transmission (DMT)
8. Orthogonal Frequency-division multiplexing (OFDM)
9. Multiple-input Multiple output (MIMO)
10. Speech recognition using Support Vector Machine (SVM)
11. Study of wireless-telecommunication using Wicomm-T, Wireless digital communication system SDR platform.

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

Course Learning 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

At the end of the course student will be able

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 Learning Objective

- 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

At the end of the course student will be able

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 Learning Objective

- To impart the students a thorough exposure to the various high speed networking technologies and to analyse the methods adopted for performance modeling , traffic management and routing

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. Multistage networks
Overview of probability and stochastic process, Queuing analysis, single server and multi-server queues, queues with priorities, networks of queues, Self similar Data traffic
Congestion control in data networks and internets, Link level flow and error control, TCP traffic control, Traffic and congestion control in ATM networks
Overview of Graph theory and least cost paths, Interior routing protocols, Exterior routing protocols and multicast.
Quality of service in IP networks, Integrated and differentiated services, Protocols for QOS support-Resource reservation protocol, Multiprotocol label switching, Real time transport protocol.

Text Books

1. *W. Stallings," High Speed networks and Internets", second edition, Pearson Education,2002*
2. *A. Pattavina,"Switching Theory", Wiley, 1998.*
3. *J. F. Kurose and K. W. Ross", Computer networking" 3rd edition, Pearson education,2005*

Reference Books

1. *Mischa Schwartz," Telecommunication networks, protocols, modeling and analysis", Pearson education,2004*
2. *Giroux, N. and Ganti, S." Quality of service in ATM networks", Prentice Hall ,1999*
3. *Recent literature in High Speed Communication Networks.*

Course outcomes

At the end of the course student will be able

Students are able to

CO1: compare and analyse the fundamental principles of various high speed communication networks and their protocol architectures
CO 2: analyse the methods adopted for performance modeling of traffic flow and estimation
CO 3: examine the congestion control issues and traffic management in TCP/IP and ATM networks
CO 4: compare, analyse and implement the various routing protocols in simulation software tools
CO 5: examine the various services.

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

Course Learning 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

At the end of the course student will be able

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 Learning Objective

- 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

At the end of the course student will be able

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 Learning 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

At the end of the course student will be able

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 Learning 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

At the end of the course student will be able

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 Learning 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

At the end of the course student will be able

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 Learning 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.

Wavelet bases. Balian-Low theorem. Multiresolution analysis. (MRA). Construction of wavelets from MRA. Fast wavelet algorithm.

Compactly supported wavelets. Cascade algorithm. Franklin and spline wavelets. Wavelet packets.
Hilbert space frames. Frame representation. Representation of signals by frames. Iterative reconstruction. Frame algorithm.

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

At the end of the course student will be able

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 with multirate digital filters
CO5: understand about wavelet packets
CO6: design certain classes of wavelets to specification and justify the basis of the application of wavelet transforms to different fields.

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

Course Learning 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

At the end of the course student will be able

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 Learning 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

At the end of the course student will be able

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 Learning 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

At the end of the course student will be able

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.

CO6: understand the fundamental limits of error correction. Develop and execute encoding and decoding algorithms associated with the major classes of error detecting and error correcting codes.

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

Course Learning 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

At the end of the course student will be able

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.
CO6: distinguish various fading channels.

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

Course Learning 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. *Recent literature in Passive MIC.*

Course outcomes

At the end of the course student will be able

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 Learning Objective

- To understand the properties of metamaterials and MTM inspired structures for antenna performance improvement, microwave components.

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

At the end of the course student will be able

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 Learning 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

At the end of the course student will be able

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 Learning 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

At the end of the course student will be able

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 Learning Objective

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

Course Content

Polynomial curve fitting – The curse of dimensionality - Decision theory - Information theory - The beta distribution - Dirichlet distribution-Gaussian distribution-The exponent family: Maximum likelihood and sufficient statistics -Non-parametric method: kernel-density estimators - Nearest neighbour methods.

Linear models for regression and classification: Linear basis function models for regression - Bias variance decomposition-Bayesian linear regression-Discriminant functions - Fisher's linear discriminant analysis (LDA) - Principal Component Analysis (PCA) - Probabilistic generative model - Probabilistic discriminative model- Independent Component Analysis (ICA)

Kernel methods: Dual representations-Constructing kernels-Radial basis function networks-Gaussian process-Maximum margin classifier (Support Vector Machine) –Relevance Vector Machines-Kernel-PCA, Kernel-LDA.

Mixture models: K-means clustering - Mixtures of Gaussian - Expectation-Maximization algorithm-Sequential models: Markov model, Hidden-Markov Model (HMM) - Linear Dynamical Systems (LDS).

Neural networks: Feed- forward Network functions-Network training - Error Back propagation - The Hessian Matrix - Regularization in Neural Network - Mixture density networks – Bayesian Neural Networks - Particle swarm optimization-Genetic algorithm-Ant colony optimization-Bacterial foroging-Simulated annealing – Fuzzy logic systems

Text Books

1. *C.M.Bishop,"Pattern recognition and machine learning",Springer,2006*
2. *E.S.Gopi, ''Algorithm collections for Digital signal Processing application using Matlab-Springer ,2007*

Reference Books

1. *Sergious Thedorodis ,Konstantinos Koutroumbas, Pattern recognition, Elsevier, Fourth edition,2009*
2. *Recent literature in Pattern recognition and computational intelligence.*

Course outcomes

At the end of the course student will be able

CO1: summarize the various techniques involved in pattern recognition

CO2: identify the suitable pattern recognition techniques for the particular applications.

CO3: categorize the various pattern recognition techniques into supervised and unsupervised.

CO4: summarize the mixture models based pattern recognition techniques

CO5: summarize the various computational intelligence techniques for pattern recognition

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

Course Learning Objectives

- 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.

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, Fiber pigtailing.

Nonlinear effects in integrated optical waveguides, Self-phase modulation, Cross-phase modulation, Four-wave mixing, Stimulated Brillouin Scattering, Stimulated Raman Scattering.

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

At the end of the course student will be able

CO1: Summarize the fundamental concept of optical waveguides.

CO2: Construct the different types of optical waveguides.

CO3: Construct the couplers, modulators and devices for communication applications

CO4: Summarize fabrication technologies for design of optical waveguides

CO5: Describe the various nonlinear effects in integrated optical waveguides.

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

Course Learning Objectives

- 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

At the end of the course student will be able

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 Communication**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning 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

At the end of the course student will be able

CO 1: interpret the principles of Optical wireless communication devices and systems.

CO 2: model the channel for indoor and outdoor OWC systems and analyze the impact of modulation techniques on bandwidth and power efficiency.

CO 3: summarizes the free space optical communication and Laser satellite communication.

CO 4: summarizes the coded modulation techniques for OWC, coded MIMO and CDMA techniques in FSO.

CO 5: summarizes the principle of Visible Light, Infrared Communications and utilization of OWC in sensor networks.

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

Course Learning 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
At the end of the course student will be able

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

CO6: understand about STA, LEC, DRC, LVS, DFM

CO7: understand the basics of System on Chip and on chip communication architectures appreciate high performance algorithms for ASICs

Course Code	**:**	**EC662**
Course Title	**:**	**Modeling and Synthesis with Verilog HDL**
Number of Credits	**:**	**3**
Course Type	**:**	**Elective**

Course Learning 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

At the end of the course student will be able

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 Learning Objectives

- 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.
Algorithms for fast convolution: Cook-Toom Algorithm, Cyclic Convolution. Algorithmic strength reduction in filters and transforms: Parallel FIR Filters, DCT and inverse DCT, Parallel Architectures for Rank-Order Filters.
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. Whitehouse, 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

At the end of the course student will be able

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 Learning 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

At the end of the course student will be able

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 application.