# M. Tech. Degree

IN

***COMMUNICATION SYSTEMS***



**SYLLABUS**

**FOR**

**CREDIT BASED CURRICULUM**

**(For students admitted in 2013)**

## DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

# NATIONAL INSTITUTE OF TECHNOLOGY

**TIRUCHIRAPPALLI – 620 015**

**INDIA**

**CURRICULUM**

***I-SEMESTER***

|  |  |  |
| --- | --- | --- |
| **CODE** | **COURSE OF STUDY** | **L- T- P- C** |
| EC601 | Probability and Stochastic Processes | 3 – 0 – 0 – 3 |
| EC603 | Advanced Digital Signal Processing | 3 – 0 – 0 – 3 |
| EC605 | Microwave Circuits | 3 – 0 - 0 – 3 |
|  | Elective – 1 | 3 – 0 - 0 – 3 |
|  | Elective – 2 | 3 – 0 - 0 – 3 |
|  | Elective – 3 | 3 – 0 - 0 – 3 |
| EC607 | Microwave and MIC Laboratory | 0 – 0 - 3 – 2 |
| **18 - 0 - 3 – 20** |

***II-SEMESTER***

|  |  |  |
| --- | --- | --- |
| EC602 | Advanced Digital Communication | 3 - 0 - 0 – 3 |
| EC604 | Broadband Wireless Technologies | 3 -0 - 0 – 3 |
| EC606 | Optical Communication Systems | 3 - 0 - 0 –3 |
|  | Elective – 4 | 3 - 0 - 0 – 3 |
|  | Elective – 5 | 3 - 0 - 0 – 3 |
|  | Elective – 6 | 3 - 0 - 0 –3 |
| EC608 | Fiber Optics and Communication Laboratory | 0 - 0 - 3 – 2 |
| EC610 | Digital Signal and Image Processing Laboratory | 0 - 0 - 3 – 2 |
| **18 –0 –6 –22** |

***III-SEMESTER***

|  |  |  |
| --- | --- | --- |
| EC647 | Project - Phase I | **0 - 0– 24 – 12** |

***IV-SEMESTER***

|  |  |  |
| --- | --- | --- |
| EC648 | Project - Phase II | **0 - 0 –24 – 12** |

**ELECTIVES**

***I-SEMESTER***

|  |  |  |
| --- | --- | --- |
| EC611 | Detection and Estimation | 3 - 0 - 0 – 3 |
| EC613 | High Speed Communication Networks | 3 -0 – 0 - 3 |
| EC615 | Digital Image Processing | 3 – 0 – 0 – 3 |
| EC659 | Modeling and Synthesis with Verilog HDL | 3 - 0 - 0 – 3 |
| EC661 | Digital Signal Processing structures for VLSI | 3 - 0 - 0 – 3 |

***II- SEMESTER***

|  |  |  |
| --- | --- | --- |
| EC614 | Spectral Analysis of Signals | 3 – 0 – 0 – 3 |
| EC616 | RF MEMS | 3 – 0 – 0 – 3 |
| EC618 | Smart Antennas | 3 – 0 – 0 – 3 |
| EC626 | Advanced Techniques for Wireless Reception | 3 – 0 – 0 – 3 |
| EC656 | Design of ASICs | 3 - 0 - 0 – 3 |
| EC662 | Design of Cognitive Radio | 3 – 0 – 0 – 3 |

**ADDITIONAL ELECTIVES APPROVED BY BoS**

|  |  |  |
| --- | --- | --- |
| EC612 | Architecture of DSPs | 3 – 0 – 0 – 3 |
| EC620 | Ad Hoc Networks | 3 – 0 - 0 – 3 |
| EC622 | Wavelet Signal Processing | 3 - 0 - 0 – 3 |
| EC624 | WDM Optical Networks | 3 – 0 – 0 – 3 |
| EC628 | Error Control Coding | 3 - 0 - 0 – 3 |
| EC630 | Digital Communication Receivers | 3 - 0 - 0 – 3 |
| EC632 | Analysis and Design of Planar Transmission Lines | 3 - 0 - 0 – 3 |
| EC634 | Electromagnetic Metamaterials | 3 – 0 – 0 – 3 |
| EC636 | Bio MEMS | 3 – 0 – 0- 3 |

**SYLLABUS**

**EC601 Probability and Stochastic Processes (3-0-0) 3**

**Pre-Requisite :** MA206 Probability Theory and Random Process

**Course Objectives :**

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

Vector space, Inner product space, norm, Hilbert spaces. Projection theorem. Separable Hilbert spaces and orthonormal bases. Linear functionals. Riesz representation theorem.

Probability spaces. Random variables and random vectors. Distributions and densities. Statistical independence. Expectations, moments and characteristic functions. Infinite sequences of random variables. Convergence concepts. Laws of large numbers.

Radon-Nikodym theorem. Conditional expectations given a σ-field and a random vector. Jensen’s inequality.

Stochastic processes. Separability and measurability. Continuity concepts. Gaussian processes and Wiener processes. Second order processes. Covariance functions and their properties. Linear operations and second order calculus. Orthogonal expansions.

Stationarity in the strict and wide senses. Ergodicity in the q.m.sense. Widesense stationary processes. Herglotz’s and Bochner’s theorems. Spectral representation. L2- stochastic integrals. Spectral decomposition theorem. Low-pass and band-pass processes. White noise and white-noise integrals.

**Course Outcomes :**

Students are able to

* Solve problems that involve probability, random process and the linear algebra in the communication systems.
* Able to understand other related subjects such as wireless communication.

***Text Books:***

*A.Papoulis, S.U.Pillai, “Probability, Random variables and Stochastic processes” 4th edition Tata-Mc Hill (4/e) ,2001*

*R.B.Ash & C.Doleans-Dade, Probability and Measure Theory (2/e), Elsevier, 2005*

***Reference Books:***

*E.Wong & B.Hajek, Stochastic Processes in Engineering systems, Springer, 1985*

*R.B.Ash & W.A.Gardner, Topics in stochastic processes, Academic Press, 1975.*

*Stakgold, I., Green’s Functions and Boundary value Problems (e), Wiley,1998*

**EC603 Advanced Digital Signal Processing (3-0-0) 3**

**Pre-Requisite :** EC202 Digital Signal Processing

**Course Objectives :**

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

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.

**Course Outcomes :**

When a student completes this course, they should be able to:

* Analyze multirate DSP and design efficient digital filters that meet a required frequency response specification and utilize such filters as part of a system to alter the sampling rate of a signal. Develop efficient polyphase implementations of sampling rate converters
* Design multi-channel filter banks to decompose a signal into subbands and then synthesize a full-band signal from the subband components
* Learn to apply linear fitering techniques to engineering problems. Familiar with the design of optimum filter, optimum linear predictor, Levinsion-Durbin algorithm
* Understand the most important adaptive filter generic problems: optimal design, convergence, recursiveness in time, frequency domain implementations.
* Derive the steepest descent, Least Mean Square (LMS), and Recursive Least Squares (RLS) adaptive filter algorithms and understand their performance properties. Analyse the convergence of stochastic gradient algorithms. Familiriase themselves with the concept of adaptive processing of nonstationary signals and Kalman filter.
* Derive and analyse the statistical properties of the conventional spectral estimators, namely the periodogram, averaged periodogram and Blackman-Tukey methods.   
  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.

***Text Books:***

*J.G.Proakis et al, Advanced Digital Signal Processing, McGraw –Hill,1992*

*S.Haykin, Adaptive Filter Theory (3/e), Prentice- Hall,1996*

***Reference Books:***

*D.G.Manolakis et al, Statistical and Adaptive Signal Processing, McGraw-Hill,2005*

*Marple, Spectral Analysis,*

*M.H.Hays, Statistical Digital Signal Processing and Modeling, John-Wiley.*

**EC605 Microwave Circuits (3-0-0) 3**

**Pre-Requisite :** EC204 Transmission Lines and Wave guides

EC205 Engineering Electro magnetics

Network theory

**Course Objectives:**

* 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.

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.

**Course Outcomes:**

* It is certain that the knowledge gained will make them employable in ISRO, DRDO, BEL, Telecom sectors, research divisions etc.

***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. Annapurna Das & S.K.Das, Microwave Engineering (2/e), Tata McGraw Hill, 2010

3. Bhararathi Bhat, Shiben K Koul, Stripline like transmission lines for Microwave Integrated Circuits, New Age International Pvt. Ltd Publishers, 2007.

**EC602 Advanced Digital Communication 3-0-0) 3**

**Pre-Requisite :** EC302 Digital Communication

**Course Objectives:**

* 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.

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.

**Course outcomes:**

Students are able to

* To understand the operation, theoretical analysis and design of baseband, passband data transmission systems.
* To design and implement various digital encoders and decoders.
* To introduces newer technologies such as spread spectrum technology, Advanced -topics in digital communication systems.

***Text Books:***

J.G.Proakis, Digital Communication (4/e), McGraw- Hill, 2001

Simon Haykin, Communication systems (4/e),John Wiley, 2001

B.P. Lathi, Zhi Ding, Modern Digital and Analog Communication Systems (4/e),Oxford university Press, 2010

***Reference Book:***

S.Lin & D.J.Costello, Error Control Coding (2/e) Pearson, 2005

**EC604 Broadband Wireless Technologies (3-0-0) 3**

**Pre-Requisite :** EC302 Digital Communication

**Course Objectives:**

* To get an understanding of mobile radio communication principles, types and to study the recent trends adopted in cellular and wireless systems and standards.

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, Diversity Schemes and Combining Techniques. Design parameters at the base station, Practical link budget design using path loss models.

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, 4G and beyond 4G.

Smart antenna systems, Beamforming. MIMO Systems. RAKE receiver, Channel modeling, Ultra Wideband communications.

**Course Outcomes :**

* Mathematical descriptions with intuitive explanations of the physical facts will assist the students in acquiring a deeper understanding of the area.
* Students will be able to understand from very basic concepts to quite advanced topics in mobile communication and will be able to do research in this area.

***Text Books:***

*A.F.Molisch, Wireless Communications, Wiley, 2005.*

*A.Goldsmith, Wireless Communications, Cambridge University Press, 2005.*

***Reference Books:***

*P.Muthu Chidambara Nathan, Wireless Communications, PHI, 2008.*

*Ke-Lin Du, M.N.S.Swamy, Wireless Communication Systems, Cambridge University Press, 2010.*

*K.Fazel & S. Kaiser, Multi-carrier and Spread Spectrum Systems, Wiley, 2003*

*S.G. Glisic, Advanced Wireless Communications, 4G Technologies, Wiley, 2004.*

*W.C.Y.Lee, Mobile Communication Engineering. (2/e), McGraw- Hill, 1998.*

*S.G. Glisic, Adaptive CDMA, Wiley, 2003*

**EC606 Optical Communication Systems (3-0-0) 3**

**Pre- Requisite :** EC403 Fiber Optic Communication

**Course Objectives :**

* To treat design and operating characteristics of optical fiber communication systems.

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.

**Course Outcomes:**

* At the end of the course, the students are expected to gain an appreciation of the role of optical components in determining the performance of practical optical communications systems.

***Text Books:***

*G.P.Agrawal, Fiber Optic Communication Systems (4/e), Wiley, 2010*

*B.P.Pai , Guided Wave Optical Components and Devices, Elsevier , 2006*

***Reference Books:***

*C.S.Murthy & M.Gurusamy, WDM Optical Networks, PHI, 2002*

*R.Ramaswami, K.N. Sivarajan* *Galen Sasaki, Optical Networks, (3/e), Elsevier, 2009.*

*G.P.Agrawal, Non linear Fiber Optics, (4/e), Elsevier, 2006.*

**EC611 Detection and Estimation (3-0-0) 3**

**Pre-Requisite :** MA206 Probability Theory and Random Process

**Course Objectives :**

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

Binary hypothesis testing; Bayes, minimax 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 noncausal filters.

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

**Course Outcomes:**

When a student completes this course, the student is :

* Familiar with fundamental concept Statistical Decision Theory and Hypothesis Testing: Baysian, Minimax, and Neyman-Pearson optimum criteria
* Familiar with detection of known signals in the presence of Gaussain noise, Laplacian noise: models and structure. Signal selection for optimum detection.
* Familiar with Bayesian parameter estimation (minimum mean square error (MMSE), minimum mean absolute error (MMAE), maximum a-posterior probability (MAP) estimation methods).
* Familiar with Non-random parameter estimation (sufficient statistics, Fisher's factorization theorem, minimum variance unbiased estimators (MVUE), Cramer-Rao lower bound (CRLB), etc). Maximum likelihood (ML) parameter estimation.
* Able to understand to which type of estimation problems linear estimation can be applied. Understand the relationship between optimal filtering, linear estimation, and Wiener/Kalman filtering. Implement Wiener and Kalman filters (time discrete) and state space models.

***Text Books:***

*H.V.Poor, An Introduction to Signal Detection and Estimation (2/e) Springer, 1994.*

B.C.Levy, *Priciples of Signal Detection and Parameter Estimation, Springer, 2008.*

***Reference Books:***

H.L.Vantrees, Detection, Estimation and Modulation theory, Part I, Wiley.

*M.D.Srinath & P.K.Rajasekaran, Statistical Signal Processing with Applications, Wiley.*

*J.C.Hancock & P.A. Wintz, Signal Detection Theory, Mc-Graw Hill.*

**EC613 High Speed Communication Networks (3-0-0) 3**

**Pre-Requisite :** EC352 Networks and Protocols

**Course Objectives:**

* To introduce the high speed communication networks that have spurred the development of new applications.
* To identify the design issues related to the Internet protocol (IP), entire TCP/IP protocol suite and network technologies dominating the high-speed scene.
* The emergence of high-speed communication networks is inevitable and so does the need to understand them.
* This course also explains various performance and analysis issues involved in understanding the need of high-speed data transmission.

Broadband ISDN. Protocol reference model. SDH-basic features. ATM standard. Multistage networks.

Protocol layers and their service models. Internet protocol stack. Link layer and Local area networks. Network layer and routing.

Transport layer. Congestion control. Application layer protocols. Web and HTTP. FTP and e-mail.

Mobile ad hoc networking. Protocol performance and open issues. Routing approaches. Power save protocols. Ad hoc network security.

Simulation software. Introduction to Simulation software. The Network simulator (ns-2), GloMoSim, Qualnet simulator. Features and Comparison. Routing, Power saving and Secure routing protocol implementation using GloMoSim.

**Course Outcomes:**

* Define the various high-speed networking technologies and their design issues.
* Compare and contrast the congestion control mechanism and traffic management used in high-speed network environment.
* Conclude the Quality of Service (QoS) in IP Networks, Broadband technologies, Mobile Adhoc Networking and Simulation Software evaluate their performances.

***Reference Books:***

A.Pattavina, Switching Theory, Wiley, 1998.

J.F.Kurose & K.W. Ross, Computer networking, (3/e), Pearson education, 2005.

S.Basagni & M.Conti, Mobile Ad Hoc Networking, Wiley, 2004.

<http://www.isi.edu/nsnam/ns/index.html>.

<http://pcl.cs.ucla.edu/projects/glomosim/>.

<http://www.qualnet.com/>.

**EC615 Digital Image Processing (3-0-0) 3**

**Pre-Requisite :** EC201Signals and Systems

**Course Objectives :**

* To treat the 2D systems as an extension of 1D system design and discuss techniques specific to 2D systems.

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, 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.

**Course Outcomes :**

* The ability to develop any image processing application.
* Students will understand the rapid advances in Machine vision.

***Text Books:***

Rafael C.Gonzalez, Richard E.Woods, Digital Image processing, Pearson edition, Inc3/e,2008.

*Anil K.Jain, Fundamentals of Digital Image Processing, PHI,1995*

***Reference Books:***

*J.C. Russ, The Image Processing Handbook, (5/e), CRC, 2006*

*R.C.Gonzalez & R.E. Woods; Digital Image Processing with MATLAB, Prentice Hall, 2003*

**EC659 Modeling and Synthesis with Verilog HDL** **(3 – 0 - 0) 3**

**Pre-Requisite :** EC209 Digital Circuits and Systems

**Course Objectives:**

* To verify and design the digital circuit by means of Computer Aided Engineering tools which involves in programming with the help of Verilog HDL.

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.

**Course Outcomes:**

* Thus the design is done successfully using Verilog HDL and the system functionality is verified by simulation.

***Text Books:***

*M.D.Ciletti, Modeling, Synthesis and Rapid Prototyping with the Verilog HDL, PHI, 1999.*

*S. Palnitkar, Verilog HDL – A Guide to Digital Design and Synthesis, Pearson, 2003.*

***Reference Books:***

*J Bhaskar, A Verilog HDL Primer (3/e),* *Kluwer, 2005.*

*M.G.Arnold, Verilog Digital – Computer Design, Prentice Hall (PTR), 1999.*

**EC661 Digital Signal Processing Structures for VLSI (3 – 0 - 0) 3**

**Pre-Requisite :** EC202 Digital Signal Processing

**Course Objectives:**

* To make an in depth study of DSP structures amenable to VLSI implementation.

An overview of DSP concepts, Representations of DSP algorithms. Loop bound and iteration bound.

Transformation Techniques: Retiming, Folding and Unfolding

Pipelining of FIR filters. Parallel processing of FIR filters. Pipelining and parallel processing for low power, Combining Pipelining and Parallel Processing. Systolic Architecture Design

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.

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.

**Course Outcomes:**

* Students will get an idea about the implementation of signal processing algorithms in VLSI hardware.
* Students will get exposure to synchronous, asynchronous and pipelined VLSI architectures.

***Text Book:***

*K.K.Parhi, VLSI Digital Signal Processing Systems, John-Wiley, 2007****Reference Books:***

*U. Meyer - Baese, Digital Signal Processing with FPGAs, Springer, 2004*

**EC614 Spectral Analysis of Signals (3-0-0) 3**

**Pre-Requisite :** EC202 Digital Signal Processing

**Course Objectives:**

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

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.

**Course Outcomes:**

When a student completes this course, they should be able to:

* Derive and analyse the statistical properties of the conventional spectral estimators, namely the periodogram, averaged & modified periodogram and Blackman-Tukey methods.
* 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.
* Define techniques for calculating moments in spectral and temporal domains; Analyze filter bank method, capon methods for spectrum estimation.
* Demonstrate knowledge and understanding of the principles of parametric and non-parametric array processing algorithms.
* Select an appropriate array processing algorithms for frequency estimation and sonar, radar applications.

***Text Books:***

*P.Stoica & R.Moses, Spectral Analysis of signals, Pearson,2005*

*Marple, Introduction to Spectral Analysis, Prentice Hall.*

***Reference Book:***

*S.M.Key, Fundamentals of Statistical Signal Processing, Prentice Hall PTR, 1998*

**EC616 RF MEMS (3-0-0) 3**

**Pre-Requisite :** EC307 Antennas and Propagation

EC405 Microwave Electronics

**Course Objectives:**

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

Introduction – 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. Micromachined 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.

Micromachined transmission lines. Coplanar lines. Micromachined directional coupler and mixer.

Micromachined antennas. Microstrip antennas – design parameters. Micromachining to improve performance. Reconfigurable antennas.

**Course Outcomes:**

* At the end of the course students should be able to analyze different MEMS technologies
* They are also expected to be familiar with the micro machined designs for the design of reconfigurable antennas.

***Text Book:***

*Vijay.K.Varadan etal, RF MEMS and their Applications, Wiley-India, 2011.*

***Reference Books:***

*H.J.D.Santos, RF MEMS Circuit Design for Wireless Communications, Artech House, 2002.*

*G.M.Rebeiz, RF MEMS Theory, Design, and Technology, Wiley, 2003.*

**EC618 Smart Antennas (3-0-0) 3**

**Pre-Requisite :** EC 307- Antennas and Propagation

(Any B.E/ B.Tech course on Antennas and Radio Wave Propagation).

**Course Objectives:**

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

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.

**Course Outcomes:**

* At the end of the course, the students are expected to evaluate a system requirement for the implementation and design of an appropriate Smart Antenna.

***Text Books:***

*T.S.Rappaport & J.C.Liberti, Smart Antennas for Wireless Communication, Prentice Hall (PTR) , 1999.*

*R.Janaswamy, Radio Wave Propagation and Smart Antennas for Wireless Communication, Kluwer, 2001.*

***Reference Book:***

*M.J. Bronzel, Smart Antennas, John Wiley, 2004.*

**EC626 Advanced Techniques for Wireless Reception (3-0-0) 3**

**Pre-Requisite :** EC 604 Broadband Wireless Technologies

**Course Objectives:**

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

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.

**Course Outcomes:**

* Mathematical descriptions with intuitive explanations of the physical facts will assist the students in acquiring a deeper understanding of the area.
* Provides a complete framework for developing, analyzing and understanding the explicit algorithms needed for advanced processing in emerging wireless systems.

***Text Books:***

*X.Wang & H.V.Poor, Wireless Communication Systems, Pearson, 2004.*

*R.Janaswamy, Radio Wave Propagation and Smart Antennas for Wireless Communication, Kluwer, 2001.*

***Reference Books:***

*Mohamed Ibnkahla, Signal Processing for Mobile Communications, CRC Press, 2005.*

*A.V.H. Sheikh, Wireless Communications Theory & Techniques, Kluwer Academic Publications, 2004.*

*A.Paulraj et al, Introduction to Space-time Wireless Communications, Cambridge University Press, 2003.*

**EC656 Design of ASICs** **(3 – 0 - 0) 3**

**Pre-Requisite :** EC308 VLSI Systems

**Course Objectives:**

* To prepare the student to be an entry-level industrial standard cell ASIC or FPGA designer.
* To give the student an understanding of issues and tools related to ASIC/FPGA design and Implementation, including timing, performance and power optimization, routing, partitioning, floor planning.
* To give the student an understanding of basics of System on Chip, Platform based design

Types of ASICs, VLSI Design flow, Programmable ASICs - Antifuse, SRAM, EPROM, EEPROM based ASICs. Programmable ASIC logic cells and I/O cells. Programmable interconnects. Latest Version - FPGAs and CPLDs and Soft-core processors.

Trade off issues at System Level: Optimization with regard to speed, area and power, asynchronous and low power system design. ASIC physical design issues, System Partitioning, Power Dissipation, Partitioning Methods.

ASIC floor planning, Placement and Routing.

System-On-Chip Design - SoC Design Flow, Platform-based and IP based SoC Designs, Basic Concepts of Bus-Based Communication Architectures, On-Chip Communication Architecture Standards, Low-Power SoC Design

High performance algorithms for ASICS/ SoCs as case studies –Canonic Signed Digit Arithmetic, KCM, Distributed Arithmetic, High performance digital filters for sigma-delta ADC, USB controllers, OMAP.

**Course Outcomes :**

* Students will demonstrate an understanding of issues involved in ASIC design, including technology choice, design management, tool-flow, verification, debug and test, as well as the impact of technology scaling on ASIC design.
* Students will demonstrate an understanding of how to optimize the performance, area, and power of a complex digital functional block, and the tradeoffs between these.
* Student will understand the basics of System on Chip and On chip communication architectures such as AMBA,AXI utilizing Platform based design.

***Text Books:***

M.J.S. Smith : Application Specific Integrated Circuits, Pearson, 2003

***Reference Books:***

H.Gerez, Algorithms for VLSI Design Automation, John Wiley, 1999

*Jan.M.Rabaey et al, Digital Integrated Circuit Design Perspective (2/e), PHI 2003*

*David A.Hodges, Analysis and Design of Digital Integrated Circuits (3/e), MGH 2004*

Hoi-Jun Yoo,  Kangmin Leeand Jun Kyong Kim, Low-Power NoC for High-Performance SoC Design, CRC Press, 2008

SudeepPasricha and NikilDutt, On-Chip Communication Architectures System on Chip Interconnect, Elsveir, 2008

**EC662 Design of Cognitive Radio**  **(3 – 0 - 0) 3**

**Pre-Requisite :** EC201 Signals and Systems

EC202 Digital Signal Processing

**Course Objectives:**

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

Overview of Multirate systems, 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.

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.

Block diagram of a Software Defined Radio. Concept of Cognitive Radio, Beneﬁts of Using SDR for Cognitive Radio, Cognitive Radio Architecture, Cognitive Engine, Cognitive Networks.

A Basic OFDM System Model, OFDM based cognitive radio, MIMO-OFDM, Channel estimation, synchronization and frequency offset estimation. Spectrum sensing techniques for Cognitive Radio.

**Course Outcomes:**

* The ability to analyse, design, and implement any application using FPGA.
* Students will understand how signal processing concepts can be used for efficient FPGA based system design. And will understand the rapid advances in Cognitive radio technologies.

***Text Books:***

*J. H. Reed, Software Radio, Pearson, 2002.*

*U. Meyer, Baese, Digital Signal Processing with FPGAs, Springer, 2004.*

*HüseyinArslan Cognitive Radio, Software Defined Radio and Adaptive Wireless Systems, Springer.*

***Reference Books:***

*Tsui, Digital Techniques for Wideband receivers, Artech House, 2001.*

*S. K. Mitra, Digital Signal processing, McGrawHill, 1998.*

*Tzi-Dar Chiueh, Pei-Yun Tsai,OFDM baseband receiver design for wireless communications,Wiley, 2007.*

*Thomas W. Rondeau, Charles W.Bostian, Artificial Intelligence in Wireless Communication, 2009.*

**EC612 Architecture of DSPs (3-0-0) 3**

**Pre-Requisite :** EC202 Digital Signal Processing

EC208 Microprocessor and Microcontrollers

**Course Objectives:**

* To give an exposure to the various fixed point & a floating point DSP architectures and to develop applications using these processors.

Architecture of TMS 320C54X processors. Addressing modes. Assembly instructions. Pipelining. Interrupts.

Clock generator. Timer. Serial ports. Parallel ports. Host-port interface (HPI). Comparison with TMS320C55X processor architecture and instruction set.

Architecture of TMS 320C67X processor. CPU data paths and control. Addressing modes. Instruction set. Pipeline operation.

Interfacing with serial I/O. A/D, D/A converters. Parallel interfacing. Interfacing with RAM, EEPROMs, FPGAs. Wait state generation. DSP tools: Assembler. Debugger. C compiler. Linker and loader.

VLIW Architecture. Multiprocessor DSPs, SHARC, SIMD, MIMD Architectures and Analog Devices DSPs. Applications: Digital Filter, Adaptive filter, Spectrum analyzer, Echo cancellation, Modem, Voice synthesis and recognition.

**Course Outcomes:**

* Students are able to understand the basics and fundamentals of fixed and floating point architectures of various DSPs.
* Students will be able to implement the signal processing algorithms in DSPs and interfacing projects.

***Text Books:***

*B.Venkataramani & M.Bhaskar, Digital Signal Processor, Architecture, Programming and Applications,(2/e), McGraw- Hill,2010*

*S.Srinivasan & Avtar Singh, Digital Signal Processing, Implementations using DSP Microprocessors with Examples from TMS320C54X, Brooks/Cole, 2004.*

***Reference Books:***

*Sen M.Kuo & Woon-Seng S.Gan, Digital Signal Processors: Architectures, Implementations, and Applications, Printice Hall, 2004*

*N. Kehtarnavaz & M. Kerama, DSP System Design using the TMS320C6000, Printice Hall, 2001.*

*S.M. Kuo & B.H.Lee: Real-Time Digital Signal Processing, Implementations, Applications and Experiments with the TMS320C55X, John Wiley, 2001.*

**EC620 Ad Hoc Networks (3-0-0)3**

**Pre-Requisite :** Computer Communication

EC352 Networks and Protocols

**Course Objectives:**

* To understand the established and emerging areas of wireless networking.
* To understand the ad hoc network protocols and its significance.

Mobile ad hoc networking with a view of 4G wireless: Imperatives and Challenges.

MAC Protocols for ad hoc wireless networks. Design goals of a MAC Protocol for ad hoc wireless networks. Contention-based Protocols. Contention-based Protocols with Reservation Mechanisms. Contention-based Protocols with Scheduling Mechanisms. Multichannel MAC Protocol.

Routing approaches. Proactive and Reactive Protocols. Clustering and Hierarchical Routing. Multipath Routing. Security aware Routing.

Energy efficient communication in ad hoc networks. Measuring energy consumption. Power save Protocols. Maximum life time Routing.

Secure routing Protocols. Intrusion detection. Security considerations in ad hoc sensor networks. Key management. Performance modeling and estimation. Overview of Probability and Stochastic Process. Queuing analysis. Self-similar traffic.

**Course Outcomes:**

* Ability to analyze the existing network.
* Propose solutions for the challenges prevailing in ad hoc networks.

***Reference Books:***

*S.Basagni & M.Conti, Mobile Ad Hoc Networking, Wiley, 2004.*

*C.S.Murthy & B.S. Manoj, Ad Hoc Wireless Networks, Pearson, 2004.*

*C.Perkins, Ad Hoc Networking, Addison Wesley, 2000.*

*Willliam Stallings, High-Speed Networks and Internets (2/e), Pearson, 2002.*

*Imrich Chlamtac, Marco Conti, Jennifer J.-N.Liu, ”Mobile ad hoc networking: imperatives and challenges” Ad Hoc Networks(2003), pages 13-64, Elsevier.*

**EC622 Wavelet Signal Processing (3-0-0) 3**

**Pre-Requisite :** Linear Operators and Integral Equations

**Course Objectives:**

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

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.

**Course Outcomes:**

By the end of this course, students will be able to:

* Understand about windowed Fourier transform and difference between windowed Fourier transform and wavelet transform.
* Understand wavelet basis and characterize continuous and discrete wavelet transforms
* Understand multiresolution analysis and identify various wavelets and evaluate their time-frequency resolution properties
* implement discrete wavelet transforms with multirate digital filters
* understand about wavelet packets
* design certain classes of wavelets to specification and justify the basis of the application of wavelet transforms to different fields.

***Text Books:***

*E.Hernandez & G.Weiss, A First Course on Wavelets, CRC Press, 1996.*

*L.Prasad & S.S.Iyengar, Wavelet Analysis with Applications to Image Processing, CRC Press, 1997.*

***Reference Books:***

*A.Teolis, Computational Signal Processing with Wavelets, Birkhauser, 1998*

*R.M. Rao & A.S. Bopardikar, Wavelet Transforms, Addition Wesley, 1998.*

*J.C. Goswami & A.K. Chan, Fundamentals of Wavelets, John Wiley,1999.*

**EC624 WDM Optical Networks (3-0-0) 3**

**Pre-Requisite :** EC403 Fiber Optic Communication

EC352 Networks and Protocols

**Course Objectives:**

* To gain an understanding with the principles of optical networking and future optical networks.

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.

**Course Outcomes:**

* At the end of the course, the students are expected to be familiar with the elements of WDM networks, SONET/SDH based access networks, wavelength routing networks, today’s and future access networks.

***Text Books:***

*C.Sivaramamurthy & M.Gurusamy, WDM optical Networks, PHI, 2002.*

*R.Ramaswami& K.N.Sivarajan, Optical Networks (2/e), Elsevier,2002*

***Reference Books:***

*K.M.Sivalingam & S.Subramaniam, Optical WDM Networks- Principles & Practice,*

*Kluwer Academic Publications, 2000.*

*T.E.Stern & K.Bala, Multiwavelength Optical Networks- A Layered Approach, (1/e), Prentice Hall PTR, 1999.*

*B.Mukherjee, Optical Communication Networks, (1/e), McGraw Hill, 1997.*

**EC628 Error Control Coding (3-0-0) 3**

**Pre-Requisite :** EC302 Digital Communication

**Course Objectives:**

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

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.

**Course Outcomes:**

By the end of this course, students will be able to:

* Understand the need for error correcting codes in data communication and storage systems.
* 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.
* Use the mathematical tools for designing error correcting codes, including finite fields.
* Explain the operating principles of block codes, cyclic codes, convolutional codes, modulation codes, Turbo codes etc.
* Design an error correcting code for a given application.
* 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.

***Text Books:***

*S.Lin & D.J.Costello, Error Control Coding (2/e), Pearson, 2005.*

*B.Vucetic & J.Yuan, Turbo codes, Kluwer, 2000*

***Reference Books:***

*C.B.Schlegel & L.C.Perez, Trellis and Turbo Coding Wiley,2004.*

*B.Vucetic & J.yuan, Space-Time Coding, Wiley, 2003.*

*R.Johannaesson & K.S.Zigangirov, Fundamentals of Convolutional Coding, Universities Press, 2001.*

**EC630 Digital Communication Receivers (3-0-0) 3**

**Pre-Requisite :** EC611 Detection and Estimation

EC302 Digital Communication

**Course Objectives:**

* 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.

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 feedforward 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.

**Course Outcomes:**

When a student completes this course, they should be able to:

* Understand about baseband PAM and Synchronizers
* Model and analyze the channels.
* Design optimum receivers and matched filter revivers
* Understand about phase and carrier estimation
* Understand carrier and symbol synchronizers
* Analyze fading channels.

***Text Books:***

*H.Meyer et al, Digital Communication Receivers, Wiley, 1998.*

*U.Mengali & A.N.D’Andrea, Synchronization Techniques for Digital Receivers, Kluwer , 1997.*

***Reference Books:***

*N.Benuveruto & G.Cherubini, Algorithms for Communication Systems and their Applications, Wiley, 2002.*

*H.Meyer & G.Ascheid, Synchronization in Digital Communications, John Wiley, 1990.*

**EC632 Analysis and Design of Planar Transmission Lines (3-0-0) 3**

**Pre-Requisite :** EC205Engineering Electromagnetics

EC204Transmission lines and waveguides

Numerical analysis-Matlab-fundamentals and Basics.

**Course Objectives:**

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

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 quasistatic 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.

**Course Outcomes:**

* Will be able to analyze any planar transmission lines, usage of different planar transmissions lines for various frequencies and for various antennas.

***Text Books:***

*T.Itoh, Numerical Techniques for Microwave and Millimeter Wave Passive Structures, John Wiley & Sons,1989.*

*C.Nguyen, Analysis Methods for RF, Microwave and Planar Transmission Line Structures, Wiley, 2000*

***Reference Book:***

*C. Nquyen, Analysis Methods for RF, Microwave, and Millimeter-Wave Planar Transmission Line Structures, Wiley Interscience, 2000*

**EC 634 Electromagnetic Metamaterials (3- 0- 0) 3**

**Pre-Requisite :** EC204Transmission lines and waveguides

M.I.C.components

Antennas

**Course Objectives:**

* To find the alternative design of M.I.C, ANTENNA, RESONATORS, Filters and Miniaturization techniques.

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 -MTMs and Photonic Band-Gap (PBG) Structures. - Left-Handedness from Maxwell’s Equations - Boundary Conditions - Reversal of Doppler Effect - Reversal of Vavilov-Cerenkov Radiation - 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: Principle - Difference with Conventional Filters - Transmission Matrix Analysis - Input Impedance - Cut-off Frequencies - Real Distributed 1D CRLH Structures: General Design Guidelines - Microstrip Implementation - Parameters Extraction - Experimental Transmission Characteristics - Conversion from Transmission Line to Constitutive Parameters.

Two-Dimensional MTMs - Principle of the TMM - Scattering Parameters - Voltage and Current Distributions - Interest and Limitations of the TMM; Transmission Line Matrix (TLM) Modeling Method: TLM Modeling of the Unloaded TL Host Network - TLM Modeling of the Loaded TL Host Network (CRLH) - Relationship between Material Properties and the TLM Model Parameters -Suitability of the TLM Approach for MTMs; Negative Refractive Index (NRI) Effects: Negative Phase Velocity - Negative Refraction - Negative Focusing.

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.

Tight Edge-Coupled Coupled-Line Couplers (CLCs): Generalities on Coupled-Line Couplers - TEM and Quasi-TEM Symmetric Coupled-Line Structures with Small Interspacing: Impedance Coupling (IC) - Non-TEM Symmetric Coupled-Line Structures with Relatively Large Spacing: Phase Coupling (PC) - Summary on Symmetric Coupled-Line Structures - Asymmetric Coupled-Line Structures -Advantages of MTM Couplers - Symmetric Impedance Coupler - Radiated-Wave Applications and examples - Uniform and Periodic Leaky-Wave Structures - “Real-Artificial” Materials: the Challenge of Homogenization – Special Topics of Interest.

**Course Outcomes:**

* Students will be exposed to the new concept of dielectric constant and permittivity. The application of negative permittivity and negative dielectric constant and various design methods of the MIC components including Antennas, Filters and Resonators.

***Text Book:***

*Christophe Caloz, Tatsuo Itoh,”Electromagnetic Metamaterilas: Transmission Line Theory and Microwave Applications” by John Wiley & Sons, Inc., Hoboken, New Jersey, 2006.*

**EC636 Bio MEMS (3-0-0) 3**

**Pre-Requisite :** Planar transmission lines basics and RF MEMS fundamentals

**Course Objectives:**

* To train the students 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.

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

MICRIACTUATORS 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

**Course Outcomes:**

* The successful Bio MEMS students will have a opportunity to work in the state of the art hospitals.
* The students will be having high potential to carry out research in Bio MEMS area both National universities and in International universities.

***Text Book:***

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

***Reference Books:***

*Albert Folch , Introduction to Bio MEMS, CRC Press, 2012*

*Gerald A. Urban, Bio MEMS, Springer, 2006*

*Wanjun Wang, Steven A. Soper, BioMEMS   
Marc J. Madou, Fundamental of Micro fabrication,*

*Gregory T. A. Kovacs, Micro machined Transducers Sourcebook*