CURRICULUM AND SYLLABUS OF M.TECH. DEGREE PROGRAMME IN TELECOMMUNICATION

(Applicable from 2018 admission)

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

तमसो मा ज्योतिर्गमय

NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

Vision of the Department

The Department of Electronics and Communication Engineering is envisioned to be a leading centre of higher learning with academic excellence in the field of electronics and communication engineering.

Mission of the Department in pursuance of its vision

The mission of the Department of Electronics and Communication Engineering is to impart high quality technical education by offering undergraduate, graduate and research programs in the domain of Electronics and Communication Engineering with thorough foundation in theory along with strong hands-on design and laboratory components, tools and skills necessary for the students to become successful major contributors to society and profession.

Programme Educational Objectives (PEOs)

PEO 1	Graduates apply their knowledge in mathematics, signal processing and communications for fostering skills to, identify, analyze and solve engineering problems pertaining to design, development and deployment of telecommunication systems.
PEO 2	Graduates demonstrate high levels of creativity, critical thinking, research aptitude and technical and communication skills for productive and successful careers in industries, R and D organizations and other allied professions.
PEO 3	Graduates possess commitment to professional ethics and sensitivity to diverse societal needs in their professional careers.
PEO 4	Graduates exhibit a desire for life-long learning through technical training, teaching, research and developmental activities, participation in conferences/workshops and professional societies.

Programme Outcomes (POs) & Programme Specific Outcomes (PSOs)

PO 1	An ability to independently carry out research /investigation and development work to solve practical problems.
PO 2	An ability to write and present a substantial technical report/document.
PO 3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
PSO 1	Ability to learn the latest technologies and products in the area of Communication & Networking.
PSO 2	Competence in using modern tools (software and hardware) for the design and analysis of systems based on communications technology and information networking.

Curriculum for M. Tech. in Telecommunication

Semester I

Sl.No	Code	Title	L	T	P	C
1	EC6301D	Random Processes	3	0	2	4
2	EC6302D	Communication Networks	3	0	2	4
3	EC6303D	Wireless Communication Techniques	3	0	2	4
4		Elective 1	3	0	0	3
5		Elective 2	3	0	0	3
		Total Credits	18			

Semester II

Sl.No	Code	Title	L	T	P	C
1	EC6304D	Estimation and Detection Theory	3	0	2	4
2	EC6305D	Information Theory	3	0	0	3
3	EC6306D	Seminar	0	0	2	1
4		Elective 3	3	0	0	3
5		Elective 4	3	0	0	3
6		Elective 5	3	0	0	3
		Total Credits	17			

Semester III

Sl.No	Code	Title	L	T	P	C
1	EC7301D	Project: Part 1	0	0	24	12
		Total credits	12			

Semester IV

Sl.No	Code	Title	L	T	P	C
1	EC7302D	Project: Part 2	0	0	26	13
		Total Credits	13			

Elective Courses

Sl.No	Code	Title	L	T	P	C
1	EC6311D	Digital Communication Techniques	3	0	0	3
2	EC6312D	Coding Theory	3	0	0	3
3	EC6313D	MIMO Communication Systems	3	0	0	3

4	EC6314D	Multi Carrier Systems and Applications	3	0	0	3
5	EC6315D	Markov Modeling and Theory of Queues	3	0	0	3
6	EC6316D	Secure Communication	3	0	0	3
7	EC6317D	Optical Communication	3	0	0	3
8	EC6318D	Selected Topics in Networks	3	0	0	3
9	EC6319D	Selected Topics in Communication	3	0	0	3
10	EC6320D	Network Security	3	0	0	3
11	EC6321D	Cooperative Communication and Network Coding	3	0	0	3

Notes:

1. A minimum of 60credits have to be earned for the award of M. Tech.Degree in this Programme.
2. A minimum of three elective courses must be credited from the list of electives given for the specialization. A maximum of two electives can be credited from courses offered in any M.Tech. specialization by the Institute,with the consent of the HOD, the Programme Coordinator and the Course Faculty.

Syllabus for M. Tech. in Telecommunication

CORE COURSES

EC6301D RANDOM PROCESSES

Pre-requisites: Nil

L	T	P	C
3	0	2	4

Total Hours: 39L + 26P

Course Outcomes:

CO1: Define random variables and random vectors corresponding to random experiments and to derive their probability distribution functions.

CO2: Demonstrate the use of conditional distributions and moments, Markov and Chebyshev inequalities, and the fundamental laws of large numbers.

CO3: Apply the concept of correlation, covariance and power spectral density of stationary random processes.

CO4: Analyze linear systems involving random processes with special focus on telecommunications and signal processing applications.

Module I: (13 Hours)
Probability axioms, conditional probability, discrete and continuous random variables, cumulative distribution function (CDF), probability mass function (PMF), probability density function (PDF), conditional PMF/PDF, expected value, variance, functions of a random variable,expected value of the derived random variable, multiple random variables, joint CDF/PMF/PDF,functions of multiple random variables, multiple functions of multiple random variables, independent/uncorrelated random variables, sums of random variables, moment generating function, random sums of random variables.

Module 2: (13 Hours)
Sample mean, laws of large numbers, central limit theorem, convergence of sequence of random variables, Introduction to random processes, specification of random processes, nth order joint PDFs, independent increments, stationary increments, Markov property, Markov process, Gaussian process, Poisson process and Brownian motion.

Module 3: (13Hours)
Mean and correlation of random processes, stationary, wide sense stationary and ergodic processes. Random processes as inputs to linear time invariant systems, power spectral density, Gaussian processes as inputs to LTI systems, white Gaussian noise, In-Phase and quadrature representation of random processes.

References:

1. Papoulis and S. U. Pillai, *Probability, Random Variables and Stochastic Processes*, 4th Edition, McGraw Hill 2002
2. Geoffrey Grimmett, *Probability and Random Processes*, 3rd edition, Oxford University Press 2001
3. Henry Stark and John W. Woods, *Probability and Random Processes with Applications to Signal Processing*, Prentice Hall, 3rd Edition 2001
4. Sheldon M. Ross, *A First Course in Probability*, Prentice Hall, 2013
5. Anurag Kumar, "*Discrete Event Stochastic Processes, Lecture Notes for an Engineering Curriculum*", Department of Electrical Communication *Engineering*. Indian Institute of Science, Benguluru, 2012

EC6302D COMMUNICATION NETWORKS

Pre-requisites: Nil

L	T	P	C
3	0	2	4

Total Hours: 39L + 26P

Course Outcomes:

CO1: Describe the basic building blocks of a computer network and understand the architecture of the global Internet

CO2: Describe, analyze and compare a number of datalink, network, and transport layer protocols

CO3: Develop a strong theoretical foundation on performance analysis of various queueing models with applications to Internet

CO4: Develop the ability to explore the design and development of more resource efficient and eco-friendly networking technologies

Module 1: (12)

Introduction: General issues in networking - Circuit switching, packet switching and virtual circuit switching - Layered architecture for Internet -Performance metrics for networks - Data link layer – Framing- Error detection- Reliable Transmission – Automatic repeat request (ARQ) schemes and performance analysis- Medium access control (MAC) protocols- Direct Link Networks- -Ethernet and multiple access networks - IEEE 802.11 wireless LANs: Distributed coordination function

Module 2: (12 Hours)

Internetworking :IPV4 and IPV6 - Addressing in internet – Subnetting and supernetting– Routing in Internet –Routing protocols for Internet – Datagram forwarding in Internet - Address resolution protocol (ARQ) – Dynamic host configuration protocol (DHCP) – Mobile IP Transport layer protocol - TCP and UDP - End-to-end reliability in Internet – Time out computation in TCP - TCP flow control and congestion control

Module 3: (15 Hours)

Broadband services and QOS issues: Quality of Service issues in networks- Integrated service architecture- Queuing Disciplines- Weighted Fair Queuing- Random Early Detection- Differentiated Services- Protocols for QOS support- Resource reservation-RSVP- Multi protocol Label switching- Real Time transport protocol.

Performance analysis: Introduction to Queuing theory: Markov chain- Discrete time and continuous time Markov chains- Poisson process- Queuing models for Datagram networks- Little's theorem- M/M/1 queuing systems- M/M/m/m queuing models- M/G/1 queue- Mean value analysis- Time reversibility- Closed queuing networks- Jackson's Networks.

References:

1. Peterson L.L. and Davie B.S., *Computer Networks: A System Approach*, Elsevier, 5th edition, 2012
2. James. F. Kurose and Keith.W. Ross, *Computer Networks, A top-down approach featuring the Internet*, Pearson Education, 5th edition, 2015
3. D. Bertsekas and R. Gallager, *Data Networks*, PHI, 2ndedition, 2000
4. S. Keshav, *An Engineering Approach to Computer Networking*, Pearson Education, 2005

EC6303D WIRELESS COMMUNICATION TECHNIQUES

Pre-requisites: Nil

L	T	P	C
3	0	2	4

Total Hours: 39L + 26P

Course Outcomes:

CO1: Classify the wireless channel of a given wireless communication system into the available analytical or empirical models

CO2: Apply appropriate techniques to mitigate the impact of channel impairments

CO3: Analyze the capacity and reliability of wireless communication systems

CO4: Design and Develop resource efficient and eco-friendly wireless technologies

Module 1: (13 Hours)
Wireless Channel Models, Path loss and Shadowing models, Empirical path loss models, Statistical fading models, Time varying channel impulse response, Narrow band and wideband fading models, Performance of digital modulation schemes over wireless channels

Module 2: (13 Hours)
Time diversity, Frequency and Space diversity, Receive diversity, Concept of diversity branches and signal paths, Performance gains, Selective combining, Maximal ratio combining, Equal gain combining, performance analysis for Rayleigh fading channels, Transmit Diversity, Cellular Networks,Multiple Access- TDMA, FDMA, CDMA, OFDMA, Spatial reuse, Co-channel interference analysis, Spectral efficiency and Grade of Service, Improving capacity -Cell splitting and sectorization.

Module 3: (13 Hours)
AWGN channel capacity, Capacity of flat and frequency selective fading channels, multiuser capacity, opportunistic communication, Uplink (multiple access) channel capacity, Downlink (broadcast) channel capacity, Cellular wireless communication standards – LTE and LTE-Advanced, vision of 5G.

References:

1. Andrea Goldsmith, *Wireless Communications*, Cambridge University press, 2006.
2. David Tse and PramodViswanath, *Fundamentals of Wireless Communication*, Cambridge University Press, South Asian Edition, 2006
3. T.S. Rappaport, *Wireless Communication, Principles and Practice*, PHI, 2002.
4. Simon Haykinand Michael Moher, *Modern Wireless Communications*, Person Education, 2007

EC6304D ESTIMATION AND DETECTION THEORY

Pre-requisites: Nil

L	T	P	C
3	0	2	4

Total Hours: 39L + 26P

Course Outcomes:

CO1: Apply the concepts of probability, random processes and linear algebra understood through various courses for the design and development of estimators that meet specific constraints

CO2: Derive and analyze Classical and Bayesian estimation techniques and to compare the performance of such estimators with standard bounds.

CO3: Develop and analyze detection problems as statistical hypothesis testing problems and apply suitable detection techniques looking at performance demands, simplicity of analysis, ease of implementation, cost of the product etc.

CO4: Investigate the applicability of estimation and detection techniques by implementing scientific research papers in some chosen area, either individually or as a group, using simulation tools and present the result of such studies through oral presentation with audio visual aids and through technical reports.

Module 1: (10 Hours)
Fundamentals of Estimation Theory: Role of Estimation in Communication Systems, Desirable Properties of Estimators, Minimum Variance Unbiased (MVU) Estimators, Finding MVU Estimators, Cramer-Rao Lower Bound, Scalar and Vector parameter Estimation Scenarios, Transformation of Parameters, Linear Modeling- Generic Formulation and Examples

Module 2: (14 Hours)
Deterministic Parameter Estimation: Best Linear Unbiased Estimator (BLUE), Maximum Likelihood Estimation (MLE), Closed form and Numerical Determination Cases, Non-linear MLE, Least Squares Estimation (LSE)-Batch Processing, Geometric Representation of LSE, Order Recursive LSE and Sequential LSE
Random Parameter Estimation: Philosophy of Bayesian Estimators, Minimum Mean Square Error (MMSE) Estimator, Multivariate Gaussian Random Variables, Jointly Gaussian Case, Bayesian Linear Model, MAP Estimator, Linear MMSE Estimator and Sequential Linear MMSE Estimator, Wiener and Kalman Filters

Module 3: (15 Hours)
Fundamentals of Detection Theory: Hypothesis Testing - General Modeling of Binary Hypothesis Testing Problem, Bayes' Detection, MAP Detection, ML Detection, Minimum Probability of Error Criterion, Min-Max Criterion, Neyman-Pearson Criterion, Receiver Operating Characteristic Curves, Multiple Hypothesis Testing,Composite Hypothesis Testing,Detection of Signals in White Gaussian Noise (WGN): Binary Detection of Known Signals in WGN, M-ary Detection of Known Signals in WGN, Matched Filter Approach.

References:

1. Steven M. Kay, *Statistical Signal Processing: Vol. 1: Estimation Theory,* Pearson Education, 2009.
2. Steven M. Kay, *Statistical Signal Processing: Vol. 2: Detection Theory,* Pearson Education, 2009.
3. Jerry M. Mendel, *Lessons in Estimation Theory for Signal Processing, Communication and Control*, Prentice Hall Inc., 1995
4. Ralph D. Hippenstiel, *Detection Theory- Applications and Digital Signal Processing*, CRC Press, 2002.

EC6305D INFORMATION THEORY

Pre-requisites: Nil

Total Hours: 39L

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Analyze the fundamental limits on the error free representation of information signals and the transmission of such signals over a noisy communication.

CO2: Design and analyze practical lossless data compression techniques with varying efficiencies as per problem requirements.

CO3: Analyze the capacity of discrete and continues channels and find the ways to achieve the capacity.

CO4: Analyze the capacity of networks and multiuser channels.

Module I: (13 Hours)

Entropy - Memory less sources- Markov sources- Entropy of a discrete random variable- Joint, conditional and relative entropy- Mutual Information and conditional mutual information- Chain relation for entropy, relative entropy and mutual Information- Source coding problem - Kraft's inequality - Optimal codes- Huffman code - Shannon's Source Coding Theorem – Introduction to Rate distortion Theory- Rate distortion function of binary and Gaussian sources.

Module 2: (13 Hours)

Capacity of discrete memoryless channels - Arimoto - Blahut algorithm - Asymptotic Equipartition Property (AEP) - Proof of Shannon's Channel Coding Theorem and its converse - Channels with feedback - Joint source channel coding Theorem – Differential entropy - Capacity of Continuous Channels - Waveform channels- Gaussian channels- Mutual information and Capacity calculation for band limited Gaussian channels- Shannon limit- Parallel Gaussian Channels - Capacity of channels with colored Gaussian noise - Water filling algorithm.

Module 3: (13 Hours)

Network Information theory - Network information flow problem- Max flow- Min cut theorem - Multiple sources and destinations - Joint typicality - Slepian- Wolf theorem – Wiener-Ziv Coding- Gaussian multiple user channels - Multiple access channels - Broadcast channels - Interference channels - Relay Channels - Capacity bounds and achievability - Coding for achievability.

References:

1. Thomas M. Cover and Joy A. Thomas, *Elements of Information Theory*, Wiley India Pvt. Ltd., 2nd Edition 2013
2. Abbas El Gamal, Young-Han Kim, *Network Information Theory*, Cambridge University Press 2011
3. R. J. McEliece, *The theory of information and coding*, Addison Wesley Publishing Co., 1977
4. David J. C. MacKay, *Information Theory, Inference and Learning Algorithms*, Cambridge University Press, 2005
5. T. Bergu, *Rate Distortion Theory a Mathematical Basis for Data Compression* PH Inc. 1971.

EC6306D SEMINAR

Pre-requisites: Nil

L	T	P	C
0	0	2	1

Total Hours: 26P

Course Outcomes:

CO1: Survey the literature on new research areas and compile findings on a particular topic

CO2: Organize and illustrate technical documentation with scientific rigor and adequate literal standards on the chosen topic strictly abiding by professional ethics while reporting results and stating claims.

CO3: Demonstrate communication skills in conveying the technical documentation via oral presentations using modern presentation tools.

The objective of the seminar is to impart training to the students in collecting materials on a specific topic in the broad domain of Engineering/Science from books, journals and other sources, compressing and organizing them in a logical sequence, and presenting the matter effectively both orally and as a technical report. The topic should not be a replica of what is contained in the syllabi of various courses of the M.Tech program. The topic chosen by the student shall be approved by the Faculty-in-Charge of the seminar. The seminar evaluation committee shall evaluate the presentation of students. A seminar report duly certified by the Faculty-in-Charge of the seminar in the prescribed form shall be submitted to the department after the approval from the committee.

EC7301D PROJECT: PART 1

Pre-requisites: Nil

L	T	P	C
0	0	24	12

Total Hours: 312P

Course Outcomes:

CO1: Developaptitude for research and independent learning.

CO2: Demonstrate the ability to carry out literature survey and select unresolved problems in the domain of the selected project topic.

CO3: Gain the expertise to use new tools and techniques for the design and development.

CO4: Acquire the knowledge and awareness to carry out cost-effective and environment friendly designs.

CO5: Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals.

The major project in the third and fourth semesters offer the opportunity to apply and extend knowledge acquired in the first year of the M. Tech. program. The major project can be analytical work, simulation, hardware design or a combination of these in the emerging areas of Communication Engineering under the supervision of a faculty from the ECE Department. The specific project topic undertaken will reflect the common interests and expertise of the student(s) and supervisor. Students will be required to1) perform a literature search to review current knowledge and developments in the chosen technical area; 2) undertake detailed technical work in the chosen area using one or more of the following:

- Analytical models
- Computer simulations
- Hardware implementation

The emphasis of major project shall be on facilitating student learning intechnical, project management and presentation spheres. Project work will be carried out individually. The M. Tech. project evaluation committee of the department shall evaluate the project work during the third semester in two phases. The first evaluation shall be conducted in the middle of the semester. This should be followed by the end semester evaluation. By the time of the first evaluation, students are expected to complete the literature review, have a clear idea of the work to be done, and have learnt the analytical / software / hardware tools. By the time of the second evaluation, they are expected to present the results of their advancements in the chosen topic, write an interim technical report of the study and results and clearly state the work plan for the next semester.

EC7302D PROJECT: PART 2

Pre-requisites: Successful completion of EC7301D Project: Part 1

L	T	P	C
0	0	26	13

Total Hours: 338P

Course Outcomes:

CO1: Developaptitude for research and independent learning.

CO2: Demonstrate the ability to carry out literature survey and select unresolved problems in the domain of the selected project topic.

CO3: Gain the expertise to use new tools and techniques for the design and development.

CO4: Acquire the knowledge and awareness to carry out cost-effective and environment friendly designs.

CO5: Develop the ability to write good technical report, to make oral presentation of the work, and to publish the work in reputed conferences/journals.

EC7302D Project: Part 2 is a continuation of EC7301D Project: Part 1in the third semester. Students should complete the work planned in the third semester, attaining all the objectives, and should prepare the project report of the complete work done in the two semesters. They are expected to communicate their innovative ideas and results in reputed conferences and/or journals. The M. Tech. project evaluation committee of the department shall evaluate the project work during the fourth semester in two phases. The first evaluation shall be conducted towards the end of the semester. This should be followed by a second evaluationby the committee including an external examiner.

ELECTIVE COURSES

EC 6311D DIGITAL COMMUNICATION TECHNIQUES

Pre-requisites: Nil

Total Hours: 39L

L	T	P	C
3	0	0	3

Course outcomes

CO1: Demonstrate the limitations of communication systems for effectively utilizing the fundamental resources for communication namely bandwidth and power.

CO2: Analyze systematically the flow and processing of information from the source to various blocks at the transmitter side and understand the inverse operations at the receiver.

CO3: Design and analyze various processing units of a digital communication system such as line coding and pulse shaping, various modulation techniques, equalization, synchronization and detection

CO4: Develop a framework for the performance evaluation of various modulation schemes in AWGN channels using the concepts of signal space and derive expressions for the probability of error.

Module 1: (17 hours)

Memoryless digital modulations: PAM, phase modulations, QAM and orthogonal multidimensional signals. Signal space representation-connecting Linear Vector Space to Physical Waveforms- Scalar and Vector Communication over Memory less Channels. Optimum waveform receiver in additive white Gaussian noise (AWGN) channels - Cross correlation receiver, Matched filter receiver and error probabilities. Optimum waveform receiver for colored Gaussian noise channels. Optimum Receiver for Signals with random phase in AWGN Channels- Optimum receiver for Binary Signals- Optimum receiver for M-ary orthogonal signals- Probability of error for envelope detection of Mary Orthogonal signals.

Module 2: (12 hours)

Carrier Recovery and Symbol Synchronization in Signal Demodulation- Carrier Phase Estimation-Effect of additive noise on the phase estimate- Maximum Likelihood phase estimation- Symbol Timing Estimation-Maximum Likelihood timing estimation- Receiver structure with phase and timing recovery-Joint Estimation of Carrier phase and Symbol Timing- Frequency offset estimation and tracking.

Module 3: (10 hours)

Communication over band limited Channels- Optimum pulse shaping- Nyquist criterion for zero ISI, partial response signaling- Equalization Techniques- Zero forcing linear Equalization-Decision feedback equalization- Adaptive Equalization.

References:

1. Edward. A. Lee and David. G. Messerschmitt, *Digital Communication*, Allied Publishers (Third edition),2003.
2. J Marvin.K.Simon, Sami. M. Hinedi and William. C. Lindsey, *Digital Communication Techniques*, PHI,1999.
3. Sheldon.M.Ross*, Introduction to Probability Models*, Academic Press, 7th edition,2001.
4. J.G. Proakis, *Digital Communication*, MGH 4th edition, 2001.

EC6312D CODING THEORY

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39L

Course Outcomes:

CO1: Analyze various types of linear block and non-block codes such as BCH codes, RS codes, LDPC codes, Convolutional codes, Turbo Codes and Polar codes and investigate the relationship between code rate, block length and error correction/detection capabilities using knowledge of Galois field arithmetic

CO2: Derive channel encoder and decoder specifications to meet the error correction, bandwidth and power consumption requirements of real life applications

CO3: Design efficient encoder and decoder algorithms for the required specifications

CO4: Analyze the performance of the developed codes considering constraints onresources and provide innovative solutions

Module 1: (16 Hours)
Groups- Rings- Fields- Field extension - Galois Field arithmetic - Minimal polynomial andconjugates- Vector space- Linear Block codes- Properties- Minimum Distance- Bounds -Error detection and correction- Cyclic codes- Encoder and decoder circuits- Error trapping decoding – BCHcodes- Decoding of BCH codes- Circuit configurations -. Reed Solomoncodes- Generation and detection algorithms

Module 2: (13 Hours)
Convolutional Codes - Generator matrix - State, tree and trellis diagram- Transfer function – MaximumLikelihood decoding - Hard versus Soft decision decoding- The Viterbi Algorithm- Soft output Viterbi algorithm – Sequential decoding

Module 3: (10 Hours)
Recursive Systematic Convolutional Coders – Turbo codes - Two way APP decoding- Low density parity check codes- Encoding - Belief propagation decoding – Polar codes – Encoding and decoding – Concatenated codes

References:

1. Shu Lin and Daniel. J. Costello Jr., *Error Control Coding: Fundamentals and applications*,Second Edition, Pearson Education, 2010
2. R.E. Blahut*, Theory and Practice of Error Control Coding*, Addison-Wesley; Reprint. 1983.
3. W.C. Huffman and Vera Pless, *Fundamentals of Error correcting codes*, Cambridge University Press, 2010.
4. Ron M. Roth Introduction *to Coding Theory* Cambridge University Press, 2006
5. Elwyn R. Berlekamp, *Algebraic Coding Theory* Revised edition,World Scientific, 2015
6. Robert McEliece*The Theory of Information and Coding*, Cambridge University Press, 2002

EC6313D MIMO COMMUNICATION SYSTEMS

Pre-requisites: EC6303D Wireless Communication Techniques

Total Hours: 39L

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Design precoders for MIMO communication systems.

CO2: Design MIMO communication transceivers with and without channel state information.

CO3: Design space time codes for MIMO systems.

CO4: Analyze and design optimum MIMO Communication systems for given channel conditions.

Module 1: (13 Hours)

Review of performance of SISO fading channels and channel models - - MIMO channel models, Classical i.i.d. and extended channels, Frequency selective and correlated channel models, Capacity of MIMO Channels with and without channel state information - Ergodic and outage capacity - Capacity bounds and Influence of channel properties on the capacity – Capacity of correlated channels with KPF channel model.

Module 2: (13 Hours)

Sources and types of diversity - Analysis under Rayleigh fading - Diversity and channel knowledge - Alamouti space time code - MIMO spatial multiplexing - Space time receivers –Matched filter bound - ML, ZF, MMSE and BLAST receivers- Sphere decoding, - Diversity multiplexing trade-off (DMT).

Module 3: (13 Hours)

Space time block codes- real and complex orthogonal designs - Code design criteria for quasi-static channels (Rank, determinant and Euclidean distance) - Orthogonal designs, Generalized orthogonal designs, Quasi-orthogonal designs and Performance analysis - Space Time Trellis Codes - Representation of STTC - shift register -generator matrix, state-transition diagram- trellis diagram - Code construction - Delay diversity as a special case of STTC and Performance analysis.

References:

1. Paulraj, R. Nabar and D. Gore, *Introduction to Space-Time Wireless Communications*, Cambridge University Press 2003
2. Hamid Jafarkhani, Space-Time Coding: Theory and Practice, Cambridge University Press 2005
3. E.G. Larsson and P. Stoica, Space-Time Block Coding for Wireless Communications, Cambridge University Press 2008
4. EzioBiglieri , Robert Calderbank et al MIMO Wireless Communications Cambridge University Press 2007
5. David Tse and PramodViswanath, Fundamentals of Wireless Communication, Cambridge University Press, South Asian Edition, 2006

EC6314D MULTICARRIER SYSTEMS AND APPLICATIONS

Pre-requisites: EC6303D Wireless Communication Techniques

Total Hours: 39L

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Analyze the issues with single carrier ad SISO communication systems and identify methods to overcome those using multicarrier and MIMO communication systems.

CO2: Design various OFDM systems, analyze their impairments and quantify performance.

CO3: Design and analysis of channel estimation and offset estimation of OFDM systems

CO4: Design of modern multiple access techniques.

Module 1: (13 Hours)

Review of fading channels and modeling- Communication using multiple carries: Single carrier vs multicarrier transmission – Multicarrier and OFDM systems - OFDM modulation and Demodulation – OFDM guard interval and guard band - Cyclic Prefix - Modulation with overlapping sub channels - Matrix representation of OFDM- BER analysis of OFDM communication systems- Vector coding - Coded OFDM - Synchronization in OFDM - Inter carrier interference- Timing and carrier frequency offset estimation – Effect of Integer carrier offset and fractional carrier offset.

Module 2: (13 Hours)

Channel estimation in OFDM - Pilot arrangements for channel estimation – Block, Comb and Lattice structures – Training symbol based channel estimation – DFT based channel estimation – Decision directed channel estimation – Channel estimation for fast time-varying channels - Clipping in OFDM systems - Nonlinearity of power amplifier - PAPR properties and PAPR reduction techniques.

Module 3: (13 Hours)

Multiple access techniques - OFDM-TDMA, OFDMA - Carrier assignment strategies, Synchronization and Channel estimation in OFDMA - Modified forms of multicarrier transmission techniques: Single carrier FDMA - Generalized frequency division multiplexing (GFDM) - Universal filtered multicarrier systems (UFMC) –Spectrum Efficiency in OFDMA – MIMO OFDM And multiuser ODFM – Standards and Applications.

References:

1. Ahmad R.S. Bahai, B.R. Saltzberg, M. Ergen*, Multi carrier Digital Communications- Theory and Applications of OFDM*, Second Edition, Springer, 2004.
2. R. Prasad, *OFDM for Wireless Communication,*Artech House, 2006.
3. Yong Soo Cho, Jaekwon Kim et. al. *MIMO-OFDM wireless Communication with Matlab*, Wiley IEEE Press, 2010.

EC6315D MARKOV MODELING AND THEORY OF QUEUES

Pre-requisites: EC6301D Random Processes

Total Hours: 39L

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Demonstrate knowledge in the domain of discrete event stochastic processes such asrenewal and regenerative processes, Markov processes and Semi-Markov processes.

CO2: Understand the theory of discrete and continuous time Markov chains and their characterization

CO3: Develop an understanding of the various queuing models and their applications in telecommunications and networking

CO4: Demonstrate the ability to build simulation model for a queuing system, conduct performance evaluation and present the results in the form of technical reports and oral presentations

Module 1: (13 Hours)
Stochastic Processes: Renewal Processes - Reward and Cost Models, The renewal equation - Renewal Theorems- Poisson Process; Point Processes; Regenerative Processes.

Module 2: (13 Hours)
Discrete Time Markov Chain - Transition Probabilities, Communication Classes, Irreducible Chains; positive recurrence and invariant probability vector, Continuous Time Markov Chain - Pure-Jump Continuous-Time Chains, Regular Chains, Birth and Death Process, Markov renewal sequences -Semi-Markov Processes.

Module 3: (13 Hours)
Single Class and Multi-class Queuing Networks: Simple Markovian queues; M/G/1 queue; G/G/1 queue; Open queuing networks; Closed queuing networks; Mean value analysis; Multi-class traffic model; Service time distributions; BCMP networks; Priority systems.

References:

1. Anurag Kumar, "*Discrete Event Stochastic Processes, Lecture Notes for an Engineering Curriculum",*Department of Electrical Communication *Engineering*. Indian Institute of Science, Benguluru, 2012
2. D. Bertsekas and R, Gallager, *Data Networks*, PHI, 2nd Edition, 2000
3. Sheldon M. Ross*, Introduction toProbability Models*, Academic Press, 9^{th} edition, 2007

EC6316D SECURE COMMUNICATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39L

Course Outcomes:

CO1: Develop strong mathematical foundations from abstract algebra and number theory for the design and analysis of various cryptographic primitives such as cipheralgorithms, hash function, key exchange algorithms and digital signature algorithms

CO2: Analyze thoroughly various properties of basic cryptographic primitives whenapplied to secure communication services and develop innovative algorithms

CO3: Design and implement cryptographic systems to meet the specifications in termsof security, circuit complexity and power consumption by effectively making use ofvarious primitives

CO4: Explore the security challenges in modern communication systems and devise newmethodologies to overcome these challenges

Module 1 (12 Hours)
Mathematical Fundamentals:Rings and fields - Homomorphism- Euclidean domains - Principal Ideal Domains – UniqueFactorization Domains -- Field extensions- Splitting fields - Divisibility- Euler theorem – ChineseRemainder Theorem - Primality.

Module 2: (16 Hours)
Algorithms and Analysis:Cryptographic services and primitives –Private and public key cryptosystems- Key exchange - Basic encryption techniques - Concept of cryptanalysis- Perfect secrecy –- Block ciphers - Cryptographic algorithms - Features of DES, AES – Linear and differentialcryptanalysis –Stream ciphers - LFSR based schemes- Linear complexity – Correlation attacks- Algebraic attacks – Hashing algorithms- SHA- Collision properties- Birthday paradox.

Module 3: (11 Hours)
Applications:Security in communication systems- interactive session security and end to end security- Key distribution and management- Authentication for access control – threshold cryptography and secret sharing- Security issues and solutions for distributed storage.

References:

1. Alfred J. Menezes, Jonathan Katz, Paul C. van Oorschot, Scott A. Vanstone, *Handbook of Applied Cryptography*, 5th Edition, CRC Press, 2001
2. Bruce Schneier, *Applied Cryptography: Protocols, Algorithms and Source Code in C*, 2nd Edition, Wiley, 2007
3. Wade Trappe, Lawrence C. Washington, *Introduction to Cryptography With Coding Theory*, 2nd Edition, Pearson, 2007
4. Maria WelledaBaldoni,Giulia Maria PiacentiniCattaneo,CiroCiliberto,DanieleGewurz, *Elementary Number Theory, Cryptography and Codes*, Springer-verlagGmbh, 2009
5. William Stallings, *Cryptography and Network Security: Principles and Practice*, 7th Edition, Pearson Education Limited, 2016

EC6317D OPTICAL COMMUNICATION

Pre-requisites: Nil

L	T	P	C
3	0	0	3

Total Hours: 39L

Course Outcomes:

CO1: Adapt to venture deeper into the advances made in the field of optical communication

CO2: Relate to the inventory of optical systems

CO3: Demonstrate an understanding of the language, basic operation and design of basic optical modules

CO4: Apply the understanding to the design of optical systems and other allied fields appreciating the trade-offs between various system parameters and specifications

Module 1: (10 Hours)
Optical Fibers: Geometrical optics description - wave propagation –solution to Maxwell's equations in a circular waveguide - chromatic dispersion - polarization mode dispersion – dispersion induced limitations - fiber losses - nonlinear optical effects – Kerr effect, self and cross phase modulation, steepening - solitons in optical fibers

Module 2: (15 Hours)
Optical Transmitters: Light emitting diodes and Laser diodes –principles of operation, concepts of line width, phase noise, switching and modulation characteristics – typical LED and LD structures - transmitter design. Optical Receivers: PN detector, pin detector, avalanche photodiode – Principles of operation, concepts of responsivity, sensitivity and quantum efficiency, noise in detection, typical receiver configurations (high impedance and transimpedancereceivers) - Optical Amplifiers: Semiconductor amplifiers - Raman amplifiers - Doped fiber amplifiers - parametric amplifiers – principles of operation, amplifier noise, signal to noise ratio, gain, gain bandwidth, gain and noise dependencies, intermodulation effects, saturation induced crosstalk, wavelength range of operation

Module 3: (14 Hours)
Coherent Lightwave Systems: Homodyne and heterodyne detection - optical hybrids and balanced receivers - Modulation formats: ASK, FSK, PSK, QAM - Demodulation schemes – BER and receiver sensitivityMultichannel Systems: WDM systems – TDM systems – OFDM systems – CDM systems

References:

1. G. P. Agrawal,*Fiber-Optic Communication Systems,* 4th Edition., John Wiley and Sons, 2010
2. R. L. Freeman*, Fiber-Optic Systems for Telecommunications*, John Wiley and Sons, 2002
3. Leonid Kazovsky, Sergio Benedetto and Alan Willner, *Optical Fiber Communication Systems*, ArtechHouse, 1996

EC6318D SELECTED TOPICS IN NETWORKS

Pre-requisites: EC6302D Communication Networks
EC6303D Wireless Communication Techniques

Total Hours: 39L

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Design security algorithm and protocols for networks
CO2: Analyze the 802.11 MAC protocol to find throughput and latency
CO3: Analyze various enhancements done to TCP and IP to improve performance of wireless networks
CO4: Analyze and design data gathering and MAC protocols used in wireless sensor networks
CO5: Design localization algorithms used in wireless sensor networks

Module 1: (13Hours)
Network Security - Security Attacks - Cryptographic Tools - Principles of Ciphers - Symmetric-Key Ciphers - Public-Key Ciphers – Authenticators - Predistribution of Public Keys and Symmetric Keys - Authentication Protocols - Originality and Timeliness Techniques - Public-Key and Symmetric-Key Authentication Protocols - Diffie-Hellman Key Agreement- Secure Systems –Example Systems - Pretty Good Privacy (PGP) - Secure Shell (SSH) - Transport Layer Security (TLS, SSL, HTTPS) - IP Security (IPsec) - Wireless Security (802.11i) – Firewalls - Strengths and Weaknesses. Spatial Point Processes and their Applications - Point Processes in 1D and 2D - Formulation of Point Processes - One-dimensional Poisson Process - Spatial Poisson Process - Transforming a Point Process

Module 2: (13Hours)
Wireless Local Area Networks – IEEE 802.11 Standards – Multiple Access in IEEE 802.11 – Performance Modeling and Throughput - Stochastic Model for a Wide Area TCP Connection. Mobile Network Layer – Mobile IP – Goals, assumptions and requirements – Entities and Terminology – IP packet delivery – Agent discovery –Registration – Tunneling and encapsulation – Optimizations – Reverse Tunneling – IPv6 – IP micro-mobility support. Mobile Transport Layer - Traditional TCP - Congestion control - Slow start - Fast retransmit/fast recovery - Implications of mobility - Classical TCP improvements - Indirect TCP - Snooping TCP - Mobile TCP - Fast retransmit/fast recovery - Transmission/time-out freezing - Selective retransmission - Transaction-oriented TCP - TCP over 2.5/3G wireless networks - Performance enhancing proxies

Module 3: (13Hours)
Introduction to the time synchronization problem - Protocols based on sender/receiver synchronization - Protocols based on receiver/receiver synchronization. Localization and positioning - Properties - Possible approaches - Mathematical basics for the trilateration problem - Single-hop localization - Positioning in multihop environments - Impact of anchor placement - Topology control - Motivation and basic ideas - Controlling topology in flat networks – Power control - Hierarchical networks by dominating sets - Hierarchical networks by clustering - Combining hierarchical topologies and power control - Adaptive node activity

References:

1. Peterson, Larry L., and Bruce S. Davie, *Computer networks: a systems approach*. Elsevier, 2007
2. Kumar, Anurag, D. Manjunath, and Joy Kuri, *Communication Networking: An Analytical Approach* Elsevier, 2004
3. Schiller and Jochen H., *Mobile communication,* .2ndEd, Pearson education, 2004
4. Karl, Holger, and Andreas Willig, *Protocols and architectures for wireless sensor networks,* John Wiley and Sons, 2007
5. Baddeley, Adrian, ImreBárány, and Rolf Schneider, *Spatial point processes and their applications. Stochastic Geometry: Lectures given at the CIME Summer School held in Martina Franca, Italy, September 13–18, 2004* (2007): 1-75

EC6319D SELECTED TOPICS IN COMMUNICATION

Pre-requisites:EC6303D Wireless Communication Techniques

Total Hours: 39L

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Demonstrate the need for advanced digital modulation techniques that save bandwidth and power andevaluate the performance of such modulation techniques.

CO2: Design sophisticated equalization techniques to correct the amplitude and phase distortion effects that may be present in signals received through a wireless communication channel

CO3: Appraise the need for multicarrier communication techniques for providing next generation wireless communication services.

CO4: Model multiuser communication systems from an information theoretic point of view under various types of channel conditions

Module 1:(15 Hrs)
Constant Envelope Modulation Schemes: QPSK- Staggered QPSK- Differentially encoded QPSK-Power Spectral Density considerations. Continuous Phase Modulation (CPM) schemes-CPFSK, MSK, SFSK, Gaussian MSK. Coding for bandwidth constrained channels- Trellis Coded Modulation (TCM) – Unger Boeck Trellis Coding -TCM Encoding & Decoding.Communication over band limited channels: Optimum pulse shape design for digital signaling through band limited AWGN channels- Optimum demodulation of digital signals in the presence of ISI and AWGN- Equalization- Zero forcing equalizer, fractionally spaced equalizer, transversal filter equalizer.

Module 2: (12 hours)
Multicarrier Digital Communication: Introduction to OFDM- Modeling of OFDM for Time varying random channels- Clipping in Multicarrier Systems- Out of band emission-Bit loading and Peak-to average Power ratio- Synchronization in OFDM Systems- Time & frequency offset-Timing and frame synchronization-Phase Noise effects- Channel estimation and Equalization- Channel Coding in OFDM Systems - OFDM based multiple access techniques.

Module 3: (12 hours)
Multiuser and multi-antenna systems: Review of Information Theory- Basics Entropy, mutual information, AEP, Source & Channel Coding Theorems- Single User Gaussian Channels AWGN Channel, Parallel Channels, Fading Channels, MIMO channels- Multiple-Access Channels: Discrete Memory less Gaussian and MIMO. Broadcast Channel: Discrete Memory less, Degraded, Gaussian, and MIMO. Interference Channel: Discrete Memory less, Strong & Very Strong Interference, Gaussian. Relay Channel: Discrete Memory less, Degraded, and Gaussian.

References:

1. Edward A. Lee & David G. Messerschmitt: *Digital Communication*, Kluwer Academic Publishers, 3/e, 2003.
2. Ahmad R. S. Bahai, Burton R. Saltzberg, Mustafa Ergen, *Multi-carrier Digital Communications: Theory and Applications of OFDM*, Springer, 2/e, 2004.
3. T. Cover and Thomas, *Elements of Information Theory*, John Wiley & Sons, 2/e, 2006
4. John G.Proakis, *Digital Communication*, McGraw Hill, 4th edition, 2001.
5. Andrea Goldsmith, *Wireless Communications*, Cambridge University Press, 2005.

EC6320D NETWORK SECURITY

Pre-requisites: EC6302D Communication Networks

Total Hours: 39L

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Analyze the objectives for various cryptographic services such as confidentiality, data integrity verification and data authentication in communication networks

CO2: Design of various cryptographic primitives such as cipher algorithms, hash function, key exchange algorithm, digital signature algorithms, and key management.

CO3: Analyze thoroughly various properties of basic cryptographic primitives when applied to different types of wireless networks and develop innovative algorithms to address the security challenges in evolving wireless networks

CO4: Investigate latest developments in cryptography and cryptanalysis through discussions and presentations on recent literature

CO5: Explain the ethical aspects of privacy, in communication and social issues associated with lack of efficient systems for protection of privacy.

Module 1: (10 Hours)
Introduction to basic objectives of cryptography - secret-key and public-key cryptography - Block ciphers - Modes of operation - DES and its variants – AES - linear and differential cryptanalysis - stream ciphers - message digest algorithms - properties of hash functions - MD5 and SHA-1 - keyed hash functions - attacks on hash functions.

Module 2: (12 Hours)
Modular arithmetic -gcd, primality testing - Chinese remainder theorem - finite fields - Intractable problems - Integer factorization problem - RSA problem - discrete logarithm problem - Diffie-Hellman problem - Public key encryption – RSA - Elliptic curve cryptography - Key exchange -Diffie- Hellman algorithms - Digital signatures – RSA – DSS – DSA – ECDSA - blind signatures -threshold cryptography - key management.

Module 3: (17 Hours)
Network Security – Electronic Mail Security- Pretty Good Privacy – S/MIME – IP security – overview and architecture – authentication header – encapsulating security payload – combing security associations – web security requirements Secure Socket Layer and Transport Layer Security – secure electronic transactions, Authentication applications: X-509, Kerberos, RADIUS.Wireless network security - WEP, WPA2 (802.11i), security in Bluetooth.

References:

1. Perlman, Radia, Charlie Kaufman, and Mike Speciner.*Network security: private communication in a public world*. Pearson Education India, 2016.
2. Stallings, W. *Cryptography and network security: principles and practice*. 7th ed. Upper Saddle River: Prentice Hall, 2017
3. Stallings, *Network security essentials applications and standards*, Pearson education, 2017
4. Menezes, A. J.; Van Oorschot, P. C.; Vanstone, S. A. *Handbook of applied cryptography* CRC Press, 1997
5. Stajano, F. *Security for ubiquitous computing,* .Chichester: John Wiley and Sons, 2002

EC6321D COOPERATIVE COMMUNICATION AND NETWORK CODING

Pre-requisites: EC6303D Wireless Communication Techniques

Total Hours: 39L

L	T	P	C
3	0	0	3

Course Outcomes:

CO1: Apply the fundamental knowledge in wireless communications to the design of relay communications with constraints on power, bandwidth and complexity

CO2: Analyze the different possible configurations of relay networks and protocols for cultivate abilities to choose such network architectures that suit to high data rate wireless communication systems

CO3: Design cooperative communication systems with networking coding concepts and analyze the achievable performance of some of the popular techniques and configurations.

Module 1: (14 Hours)
Cooperative communication: Overview of cooperative communication and relaying- Cooperation protocols- Amplify and forward(AF) relaying – Decode and forward(DF) relaying- Quantize and forward relaying- Compress and forward relaying- Adaptive cooperation strategies- Hierarchical cooperation.

Module 2: (15 Hours)
Cooperative communication with single relay- Analysis for AF relaying and DF relaying-Comparison-Cooperative communication with multiple relays- Multi-node DF protocol- Multi-node AF protocol-Distributed Space Time Coding- Relay selection

Module 3: (10 Hours)
Network coding: Introduction to network Coding-Merits-Challenges-Multicast in lossless wireless network: Scalar linear network coding- Random linear network coding-Delay and throughput analysis- Multicast network code construction- Physical layer network coding- Index coding- Equivalence between Network coding and Index coding

References:

1. K.J. Ray Liu, Ahamed K. Sadek, Weifeng Su and Andres Kwasinski, *Cooperative communications and Networking*, Cambridge University Press 2009.
2. Y.-W. Peter Hong, Wan-Jen Huang, C.-C. Jay Kuo, *Cooperative Communications and Networking: Technologies and System Design*, Springer 2010.
3. Tracey Ho, Desmond S. Lun, *Network Coding: An introduction,* Cambridge University Press, 2008
4. Christina Fragouli and EminaSoljanin, *Network Coding Fundamentals*, Now Publishers Inc, 2007