Course Structure for M. Tech Communication Engineering						**Credits**
First Semester	Advanced Communication Systems (EE-205001) 3-0-2-4.	Advanced Topics in Signal Processing (EE-205002) 3-0-2-4	Wireless Communication and Networking (EE-205003) 3-0-2-4	Elective - I 3-0-0-3	Elective - II 3-0-0-3	18
Second Semester	Detection and Estimation Theory (EE-205004) 3-0-0-3	Applied optimization for Communication and Signal Processing (EE 215001) 3-0-2-4	Research Methodology (HS225003) 3-1-0-4	Elective - III 3-0-0-3	Elective - IV 3-0-0-3	17
Third Semester	Seminar (EE 226600) 0-0-0-2	Thesis Part-I (EE 226501) 0-0-0-22				24
Fourth Semester	Thesis Part-II (EE 226502) 0-0-0-24					24

Department of Electrical and Computer Science Engineering

M.Tech, Communication Engineering

Semester – I

Course Scheme

Course Code	**Course Name**	**Lecture hours**	**Tutorial hours**	**Practical hours**	**Credit**
EE-205001	Advanced Communication Systems	3	0	2	4
EE-205002	Advanced Topics in Signal Processing	3	0	2	4
EE-205003	Wireless Communication and Networking	3	0	2	4
	Department Elective- I	3	0	0	3
	Department Elective- II	3	0	0	3
	Total	**15**	**0**	**6**	**18**

Department of Electrical and Computer Science Engineering

M.Tech, Communication Engineering

Semester – II

Course Scheme

Course Code	**Course Name**	**Lecture hours**	**Tutorial hours**	**Practical hours**	**Credit**
EE-205004	Detection and Estimation Theory	3	0	0	3
EE 215001	Applied optimization for Communication and Signal Processing	3	0	2	4
HS225003	Research Methodology	3	1	0	4
	Department Elective- III	3	0	0	3
	Department Elective- IV	3	0	0	3
	Total	**14**	**1**	**2**	**17**

Department of Electrical and Computer Science Engineering

M.Tech, Communication Engineering

Course Scheme

Semester – III

Course Code	Course Name	Lecture hours	Tutorial hours	Practical hours	Credit
EE 226600	Seminar	0	0	0	2
EE 226501	Thesis Part-I	0	0	0	22
	Total				**24**

Semester – IV

Course Code	Course Name	Lecture hours	Tutorial hours	Practical hours	Credit
EE 226502	Thesis Part-II	0	0	0	24
	Total				**24**

List of Department Electives

Course Code	Course Name
EE195011	Digital Image Processing
EE195009	Adaptive and Non Linear Control
EE5008	Satellite Communication
EE195003	Intelligent System and Control
EE-5001	Renewable Energy Infrastructure
CS 214001	Artificial Intelligence and Machine Learning

M.Tech. Communication Engineering

Semester – I

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">EE-205001</td></tr>
<tr><td>II</td><td>Title of the course</td><td colspan="4">Advanced Communication Systems</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>4</td></tr>
<tr><td>IV</td><td>Prerequisite (if any for the student)</td><td colspan="4">No</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">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, AWGN multichannels, Multicarrier communications: OFDM – modulation and demodulation, spectral characteristics, bit and power allocation, channel coding.

Lab: Study of AM/FM transmitter and receiver; Study of optical fiber link; Study of PAM system; Study of numerical aperture in optical fiber; Study of satellite trainer kit at different combination of different uplink and downlink frequency; Calculation of Carrier to Noise ratio for satellite trainer kit wrt different physical distance; Study of 3G mobile trainer kit.</td></tr>
<tr><td>VI</td><td>Text Books</td><td colspan="4">1. J. G. Proakis, “Digital Communication (4/e)”, McGraw- Hill, 2001
2. B.P. Lathi, Zhi Ding, “Modern Digital and Analog Communication Systems (4/e)”,Oxford university Press, 2010.</td></tr>
</table>

M.Tech. Communication Engineering

Semester – I

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">EE-205002</td></tr>
<tr><td>II</td><td>Title of the course</td><td colspan="4">Advanced Topics in Signal Processing</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>4</td></tr>
<tr><td>IV</td><td>Prerequisite</td><td colspan="4">Signals and Systems/Digital signal processing</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">Review of Digital Filters: FIR and FIR Filters Properties of FIR and IIR Filters, Approximation Problem and Realization Problem, Frequency-Domain Description of FIR Filters, Linear-Phase FIR Filters, Four Types of Linear-Phase FIR Filters, Zero Locations for Linear-Phase FIR Filters.

Design of Liner Phase and minimum phase FIR Filters: Frequency-Sampling Design, Least Squared Error Frequency-Domain Design, Windowing FIR Filter Design, Chebyshev Approximation, Remz Exchange Algorithm, Parks-McGlellan Algorithm, Design of Maximally Flat (Butterworth) Filters. Minimum Phase and Complex Approximation. Least-Squares and Eigen Filter Design of Linear Phase Filters. Peak Constrained Quadratic Programs for Design of Linear Phase FIR Filters, Semi Definite Programming (SDP) for FIR Filter Designing.

Fundamentals of Multirate Digital Signal Processing: Sample Rate Alteration Devices, Multirate, Structures for Sampling Rate Conversion, Polyphase Decomposition, Nyquist Filters. Connection of Multirate Systems with Filter Banks. Two-Channel Perfect Reconstruction Filter Banks. Introduction to Wavelet Filter banks.

Lab: To generate basic signals like Unit impulse, Unit step, Unit ramp, and Exponential signals using MATLAB; Find frequency response of a given system, given in (Transfer Function /Differential equation form); To write a MATLAB program to evaluate the impulse response of the given system; To write the MATLAB code to find the DFT / IDFT of given signal; To implementation of Fast Fourier Transform (FFT) of the given sequence using MATLAB; Write a MATLAB program to verify Power Spectral Density of the given signal; Design of FIR filters of Low pass and high pass filter using MATLAB commands; To implementation of IIR low pass and high pass filter and verify Frequency response of analog IIR filter using MATLAB (LP/HP); To generate the sinusoidal signal using filter; To implementation of decimation by factor of M; To verify FIR filters using Code Composer Studio; Design FIR Filter Low pass/High pass (LP/HP) Using Windowing technique</td></tr>
</table>

VI	Textbook Reference Books	Text: Digital Filter Design by T.W. Parks and C. S. Burrus ,1987, John Wiley and Sons Inc., Canada. References: Digital Signal Processing by Andreas Antoniou, 2006, Tata McGraw-Hill Publishing Co. Ltd., New Delhi.

M.Tech. Communication Engineering

Semester – I

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">EE 205003</td></tr>
<tr><td>II</td><td>Title of the course</td><td colspan="4">Wireless Communication and Networking</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>4</td></tr>
<tr><td>IV</td><td>Prerequisite</td><td colspan="4">Digital Communication and Computer Networks</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">Wireless Communication: Error functions used in wireless communication theory; Approximated error functions and their utility in wireless communication systems; Multipath fading; Fading channels; Efficient digital modulation schemes and their error performance in AWGN as well as in fading channels; point-to-point communication (detection, diversity), maximal ratio combining (MRC), capacity of wireless channels.

Wireless Networking: Single hop and Multi hop communication in Wireless environment; application scenarios and issues; Medium Access Control protocols in resource constrained networks: Contention based, Schedule based; Standards: 802.11 WiFi, 802.15.4, Bluetooth Low Energy; Routing Protocols: Gossip based routing, Geographic Routing, Clustering / aggregation based routing; broadcast and multicast routing; Case studies of Application Design
Lab: Platform: MATLAB

Wireless Communication: SEP plots of efficient modulation schemes (SQAM, RQAM, cross-QAM, TQAM) in AWGN channel; SEP plots of efficient modulation schemes (SQAM, RQAM, cross-QAM, TQAM) in Rayleigh, Nakagami-m, Nakagami-q and Nakagami-n fading channels; Calculation of relative error between Gaussian Q function and their approximations; MRC diversity plots

Wireless Networking: Set up single-hop and multi-hop ad-hoc network and enable communication among nodes; implementation and analysis of the address distribution scheme; implementation of distributed content sharing scheme in infrastructure-less network.</td></tr>
<tr><td>=VI</td><td>Textbook Reference Books</td><td colspan="4">1. M. K. Simon and M.-S. Alouini, “Digital Communication over Fading Channels’, 2nd ed. Wiley, 2005.
2. David Tse and Pramod Viswanath, ``Fundamentals of Wireless Communication," Cambridge University Press, 2005.
3. Holger Karl & Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks," John Wiley.</td></tr>
</table>

M.Tech. Communication Engineering

Semester – II

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">EE-205004</td></tr>
<tr><td>II</td><td>Title of the course</td><td colspan="4">Detection and Estimation Theory</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>IV</td><td>Prerequisite (if any for the student)</td><td colspan="4">No</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">Background material: recap of probability, calculus, linear algebra
Estimation Theory Minimum variance unbiased estimation, best linear unbiased estimation Cramer-Rao lower bound (CRLB)

Maximum Likelihood estimation (MLE): exact and approximate methods (EM, alternating max, etc.) Bayesian inference & Least Squares Estimation (from Kailath et al's Linear Estimation book)
Basic ideas, adaptive techniques, Recursive LS, etc.

Kalman filtering (sequential Bayes) Finite state Hidden Markov Models: forward-backward algorithm, Viterbi (ML state estimation), parameter estimation (f-b + EM) Graphical Models
Applications: image processing, speech, communications (to be discussed with each topic)

Sparse Recovery and Compressive Sensing introduction
Monte Carlo methods: importance sampling, MCMC, particle filtering, applications in numerical integration (MMSE estimation or error probability computation) and in numerical optimization (e.g. annealing)

Detection Theory, Likelihood Ratio testing, Bayes detectors, Minimax detectors, Multiple hypothesis tests, Neyman-Pearson detectors (matched filter, estimator-correlator etc.), Wald sequential test, generalized likelihood ratio tests (GLRTs), Wald and Rao scoring tests, Applications</td></tr>
<tr><td>VI</td><td>Text/Reference Books</td><td colspan="4">1. V. Poor, An Introduction to Signal Detection and Estimation
2. H. Van Trees, Detection, Estimation, and Modulation Theory</td></tr>
</table>

M.Tech. Communication Engineering

Semester – II

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">HS 225003</td></tr>
<tr><td>II</td><td>Title of the course</td><td colspan="4">Research Methodology</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>1</td><td>0</td><td>4</td></tr>
<tr><td>IV</td><td>Prerequisite (if any for the student)</td><td colspan="4">No</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">Introduction to engineering research: Definition, characteristics and types, basic research terminology, qualities of a researcher, research methods vs methodology, overview of engineering research methods, role of Information and Communication Technology (ICT) in research, research ethics, intellectual property rights and scholarly publishing.

Research formulation: Defining and formulating the research problem, selecting the problem, necessity of defining the problem, literature survey – significance in defining a problem, various sources, critical review, identifying gap areas from literature review and research databases, development of working hypothesis.

Research design and data analysis: Research design – basic principles, need of research design, features of good design, important concepts relating to research design, observation and facts, laws and theories, method validation, observation and collection of data, methods of data collection, sampling methods, data processing and analysis, hypothesis testing, generalization and interpretation.

Technical writing: Types (thesis, report, journal papers etc.), qualities, structure and components of good technical document, use of software tools (Word processing, latex, etc.), illustrations and tables, bibliography, referencing and footnotes. Oral presentation – planning, software tools, creating and making effective presentation, use of visual aids, importance of effective communication.</td></tr>
<tr><td>VI</td><td>Text/reference Books</td><td colspan="4">1. Blessing, L.T.M., Chakrabarti, A., DRM, a Design Research Methodology, Springer, 2009, ISBN: 978-1-84882-586-4.
2. Chandra, S., Sharma, M.K., Research Methodology, Narosa Publishing House, 2013, ISBN: 978-81-8487-246-0.
3. Cohen, L., Manion, L., Morrison, K., Research Methods in Education, Routledge (Taylor and Francis Group), 2011, ISBN: 978-0-415-58336-7.
4. Goddard, W., Melville, S., Research Methodology – an Introduction, Juta and Company Ltd., 2004, ISBN: 978-0-702-15660-1.
5. Kothari, C.R., Garg, G., Research Methodology – Methods and Techniques, New Age International, 2014, ISBN: 978-81-224-3623-5.</td></tr>
</table>

		6. Kumar, R., Research Methodology – a Step-by-Step Guide for Beginners, SAGE, 2011, ISBN: 978-1-84920-300-5. 7. Pandey, P., Pandey, M.M., Research Methodology – Tools and Techniques, Bridge Centre, 2015, ISBN: 978-606-93502-7-0. 8. Panneerselvam, R., Research Methodology, PHI Learning Pvt. Ltd., 2014, ISBN: 978-81-203-4946-9. 9. Rugg, G., Petre, M., A Gentle Guide to Research Methods, Open University Press, 2007, ISBN: 978-0-335-21927-8. 10. Singh, Y.K., Fundamentals of Research Methodology and Statistics, New Age International, 2006, ISBN: 978-81-224-2418-8. 11. Walliman, N., Research Methods – the Basics, Routledge (Taylor and Francis Group), 2011, ISBN: 978-0-415-48994-2.

M.Tech. Communication Engineering

Semester – II

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">EE 215001</td></tr>
<tr><td>II</td><td>Title of the course</td><td colspan="4">Applied Optimization for Communication and Signal Processing</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>4</td></tr>
<tr><td>IV</td><td>Exposure</td><td colspan="4">Basic knowledge of -Calculus, Probability, Matrices</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">Introduction to properties of Vectors, Norms, Subspaces, Orthogonal Projections, Least Square Approximations Positive Semi-Definite matrices, Gaussian Random Vectors, Derivatives and Gradients, Hessians

Some important Matrix Factorization, LU factorization, Eigenvalues and Eigenvectors, Singular Value Decomposition.

Introduction to Convex Optimization – Convex sets, Convex Functions, Hyperplanes/ Half-spaces, Application: Power constraints in Wireless Systems

Convex/ Concave Functions, Examples, Conditions for Convexity. Application: Beamforming in Wireless Systems,

Convex Optimization problems, Linear Program. Application: Optimal Filter Designing

Convex optimization Problems: LS, WLS, QCQP, SOCP Problems. Application: Beamforming in Wireless Systems, Design of Linear Phase FIR filters

Duality Principle and KKT Framework for Optimization. Application: Optimization OFDM Systems and Filter Band Designing

Convex optimization for Machine Learning, Principal Component Analysis (PCA), Support Vector Machines

Lab: Convex optimization using Matlab and CVX
I. FIR Filter Design via Convex Optimization
Chebychev design of an FIR filter given a desired H(w) n
Maximize stopband attenuation of a bandpass IIR filter
Maximize stopband attenuation of a linear phase lowpass FIR filter
Maximize stopband attenuation of a lowpass FIR filter (magnitude design)
Maximize stopband attenuation of a lowpass IIR filter
Minimize order of a linear phase lowpass FIR filter
Minimize order of a lowpass FIR filter (magnitude design)
Minimize stopband ripple of a linear phase lowpass FIR filter</td></tr>
</table>

		Minimize transition bandwidth of a linear phase lowpass FIR filter Design of Eigen filter Design of optimal frequency localized orthogonal wavelet filter bank Design of optimal biorthogonal Filter bank II. Antenna Array Pattern Synthesis via Convex Optimization Minimize side lobe level of a uniform linear array via spectral factorization Minimize side lobe level of an FIR broadband far-field antenna array Minimize side lobe level of an array with arbitrary 2-D geometry
VI	Textbook/ Reference Books	1. Convex Optimization by Stephen Boyd, 2004, Cambridge Press. 2. Convex Optimization for Signal Processing and Communications, 2017 **by** *Chong-Yung Chi Wei-Chiang and Li Chia-Hsiang Lin, CRC Press*

M.Tech. Communication Engineering

Department Electives

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">EE 195011</td></tr>
<tr><td>II</td><td>Title of the course</td><td colspan="4">Department Electives: Digital Image processing</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>IV</td><td>Prerequisite</td><td colspan="4">Nil</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">Introduction
Light, Brightness adaption and discrimination, Pixels, coordinate conventions, Imaging Geometry, Perspective Projection, Spatial Domain Filtering, sampling and quantization.

Spatial Domain Filtering
Intensity transformations, contrast stretching, histogram equalization, Correlation and convolution, smoothing filters, sharpening filters gradient and Laplacian.

Filtering in the Frequency domain
Fourier Transforms and properties, FFT (Decimation in Frequency and Decimation in Time Techniques), Convolution, Correlation, 2-D sampling, Discrete Cosine Transform, Frequency domain filtering.

Image Restoration
Basic Framework, Interactive Restoration, Image deformation and geometric transformations, image morphing, Restoration techniques, Noise characterization, Noise restoration filters, Adaptive filters, Linear, Position invariant degradations, Estimation of Degradation functions, Restoration from projections.

Image Compression
Encoder-Decoder model, Types of redundancies, Lossy and Lossless compression, Entropy of an information source, Shannon's 1st Theorem, Huffman Coding, Arithmetic Coding, LZW coding, Transform Coding, Sub-image size selection, blocking artifacts, DCT implementation using FFT, Run length coding, JPEG, Lossless predictive coding, Lossy predictive coding, Wavelet based Image Compression

Morphological Image Processing:
Basics, SE, Erosion, Dilation, Opening, Closing, Hit-or-Miss Transform, Boundary Detection, Hole filling, Connected components, convex hull, thinning, thickening, skeletons, pruning, Geodesic Dilation, Erosion, Reconstruction by dilation and erosion.</td></tr>
</table>

		Image Segmentation Boundary detection based techniques, Point, line detection, Edge detection, Edge linking, local processing, regional processing, Hough transform, Thresholding, Iterative thresholding, Otsu's method, Moving averages, Multivariable thresholding, Region based segmentation, Watershed algorithm
VI	Textbook Reference Books	1. Digital Image Processing, 3rd Edition, by Rafael C Gonzalez and Richard E Woods. Publisher: Pearson Education 2. A. K. Jain, Fundamentals of digital image processing, Prentice Hall, 1989. 3. W. K. Pratt, Digital image processing, Prentice Hall, 1989.

M.Tech. Communication Engineering

Department Electives

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">EE 205005</td></tr>
<tr><td>II</td><td>Title of the course</td><td colspan="4">Department Electives: Adaptive and Nonlinear Control</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>IV</td><td>Prerequisite</td><td colspan="4">An Undergraduate Control Systems Course is mandatory for this Course.</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">Adaptive Control: Introduction, Recursive parameter estimation, Model reference adaptive control, Adaptive pole placement control, Robust adaptive control schemes, Averaging-based analysis, Adaptive control of nonlinear systems; Nonlinear Control: Introduction, Second-order systems and Phase Plane Analysis, Fundamentals of Lyapunov Stability Theory, Advanced Stability Theory, Stabilization and Global Feedback Linearization: differential geometric method, Nonlinear Control Design Tools: Lyapunov redesign, Backstepping, Nonlinear Observers, Nonlinear Output Regulation, Passivity and Dissipativity</td></tr>
<tr><td>VI</td><td>Textbook Reference Books</td><td colspan="4">1. Petros Ioannou and Baris Fidan, Adaptive Control Tutorial, SIAM, 2006.

2. K. J. Astrom and B. Wittenmark, Adaptive Control, 2nd Edition, Addison-Wesley, 1995

3. P. A. Ioannou and J. Sun, Robust Adaptive Control, Prentice- Hall, 1995 (available now at http://wwwrcf.usc.edu/~ioannou/ RobustAdaptiveBook95pdf/Robust_Adaptive_Control.pdf)

4. K. S. Narendra and A. M. Annaswamy, Stable Adaptive Systems, Prentice-Hall, 1989

5. S. Sastry and M. Bodson, Adaptive Control, Prentice-Hall, 1989 (available now at http://www.ece.utah.edu/%7Ebodson/acscr/index.html)

6. M. Krstic, I. Kanellakopoulos, and P. Kokotovic, Nonlinear and Adaptive Control Design, Wiley-Interscience, 1995

7. H. K. Khalil, Nonlinear Systems, Prentice Hall, 3rd edition, 2002</td></tr>
</table>

M.Tech. Communication Engineering

Department Electives

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">EE 5001</td></tr>
<tr><td>II</td><td>Title of the course</td><td colspan="4">Department Electives: Renewable Energy Infrastructure</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>IV</td><td>Prerequisite</td><td colspan="4">Basics of Electrical and Electronics Engineering, Power Systems</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">Sustainability: Why Energy Matters (and Money); Global Warming (Physics),
History and Impact; Renewable Sources that are replenished: Wind, Solar, Ocean Waves, Geothermal; Wind Energy: Forecasting Challenges, Wind Turbines: Dynamics and Control, Wind Wakes; Solar Energy: Harnessing the
Power of Sun: Science and Technology of Solar Photovoltaics (PV), Solar PV
Connection to virtual Grid, Optimization issues; Renewable Energy storage
Issues, Challenges; Hybrid Solar-Wind System; Wind Farm; Solar Farm; Pol-
icy and Ethical Issues; Energy Conservation related issues; Hydrogen and Fuel Cells; Bio-energy.</td></tr>
<tr><td>VI</td><td>Text/reference Books</td><td colspan="4">1. Wind Energy Handbook, 2nd Edition, Tony Burton, Nick Jenkins, DavidSharpe, Ervin Bossanyi

2. Solar Electricity Handbook - 2015 Edition: A simple, practical guide to solar energy - designing and installing solar PV systems, Michael Boxwell, Greenstream Publishing; 2015 Edition

3. Hydrogen and Fuel Cells: A volume in Sustainable World, Bent Sorensen

4. Non-conventional Energy Resources, B H Khan, Third Edition, McGrawHill Education</td></tr>
</table>

M.Tech. Communication Engineering

Department Electives

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">EE-5008</td></tr>
<tr><td>II</td><td>Title of the course</td><td colspan="4">Department Electives: Satellite Communication</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>IV</td><td>Prerequisite (if any for the student)</td><td colspan="4">No</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">Kepler’s Laws, Newton’s law, orbital parameters, orbital perturbations, station keeping, geo stationary and non-Geo-stationary orbits – Look Angle Determination- Limits of visibility -eclipse-Sub satellite point –Sun transit outage-Launching Procedures - launch vehicles and propulsion. Spacecraft Technology- Structure, Primary power, Attitude and Orbit control, Thermal control and Propulsion, communication Payload and supporting subsystems, Telemetry, Tracking and command. Satellite uplink and downlink Analysis and Design, link budget, E/N calculation- performance impairments-system noise, inter modulation and interference, Propagation Characteristics and Frequency consideration System reliability and design lifetime, Modulation and Multiplexing: Voice, Data, Video, Analog – digital transmission system, Digital video Broadcast, multiple access: FDMA, TDMA, CDMA, Assignment Methods, Spread Spectrum communication, compression – encryption, Transponder and their Access, Transmitter and Receiver, Antenna Systems TVRO, MATV, CATV, Test Equipment Measurements on G/T, C/No, EIRP, Antenna Gain, INTELSAT Series, INSAT, VSAT, Mobile satellite services: GSM, GPS, INMARSAT, LEO, MEO, Direct Broadcast satellites (DBS)- Direct to home Broadcast (DTH), HTS, Digital audio broadcast (DAB), Satellite Navigational System, GPS, IRNSS.</td></tr>
<tr><td>VI</td><td>Text Books</td><td colspan="4">1. Timothy Pratt, Charles Bostian, Jeremy Allnutt, “Satellite Communication”, John Wiley International 2006.

2. Dennis Roddy, “Satellite Communications”, McGraw Hill 2014.</td></tr>
<tr><td>VII</td><td>Reference Books</td><td colspan="4">1. Louis J. Ippolito “Introduction to Satellite Communications “John Wiley International 2018.

2. TERESA M. BRAUN, “Satellite Communications Payload and System” John Wiley International 2018.</td></tr>
</table>

M.Tech. Communication Engineering

Department Electives

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">EE 195003</td></tr>
<tr><td>II</td><td>Course Title</td><td colspan="4">Department Electives: Intelligent Systems and Control</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>0</td><td>3</td></tr>
<tr><td>IV</td><td>Prerequisite(If any for the student)</td><td>Nil</td><td></td><td></td><td></td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4">Introduction of Artificial Intelligence and background and related fields.

Biological foundations to intelligent systems II: Fuzzy logic, knowledge representation and inference mechanism, genetic algorithm, and fuzzy neural networks.

Biological foundations to intelligent systems I: Artificial neural networks, Back-propagation networks, Radial basis function networks, and recurrent networks.

Fuzzy and expert control (standard, Takagi-Sugeno, mathematical characterizations, design example), Parametric optimization of fuzzy logic controller.

Application of neuro-fuzzy inference systems to robotics
System identification using neural and fuzzy neural networks.
Genetic Algorithm and applications.

Stability analysis: Lyapunov stability theory and Passivity Theory.
Applications to ball and beam system, helicopter system, flight system, robot manipulator, inverted pendulum and inertia wheel pendulum control and visual motor coordination.</td></tr>
<tr><td>VI</td><td>Reference books:</td><td colspan="4">1. Intelligent Control Systems Using Soft Computing Methodologies, Edited by Ali Zilouchian Mo Jamshidi, CRC press, 2001.

2. Intelligent systems and control: Principles and applications, L. Behera and I Kar, Oxford, 2009

3. Intelligent Control A Hybrid - Approach Based on Fuzzy Logic, Neural Networks and Genetic Algorithms by Nazmul Siddique, Springer 2013</td></tr>
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M.Tech. Communication Engineering

Department Electives

<table>
<tr><td>I</td><td>Course Code</td><td colspan="4">CS 214001</td></tr>
<tr><td>II</td><td>Course Title</td><td colspan="4">Artificial Intelligence and Machine Learning</td></tr>
<tr><td rowspan="2">III</td><td rowspan="2">Credit Structure</td><td>L</td><td>T</td><td>P</td><td>C</td></tr>
<tr><td>3</td><td>0</td><td>2</td><td>4</td></tr>
<tr><td>IV</td><td>Prerequisite</td><td colspan="4">Computer Programming, Data Structures and Algorithms</td></tr>
<tr><td>V</td><td>Course Content</td><td colspan="4"><u>Module 1:</u> Introduction to Artificial Intelligence and Machine Learning; Applications; Search Algorithms: introduction, breadth first search, depth first search, bidirectional search, A*; (3 Hrs)

Basics of Machine learning: Supervised learning, Unsupervised learning, Semi Supervised learning, Reinforcement learning, etc. (3 Hrs)

<u>Module 2:</u> Regression: Single variable and multivariate Linear Regression, model representation, cost function; Non-linear regression – polynomial regression; Classic algorithms: support vector regression, decision tree regression, random forest regression etc.; Error metrics and measures (9 Hrs)

<u>Module 3:</u> Classification: Hypothesis representation, decision boundary, cost function, gradient descent algorithm, overfitting and regularization etc.; (3 Hrs)

Classic algorithms: Logistic regression, Naïve bayes, Decision Tree, Ensemble learning, K Nearest Neighbour, Support Vector Machine; Multiclass classification; Error metrics and measures: precision, recall, scores etc., skewed classes scenario (9 Hrs)

<u>Module 4:</u> Artificial Neural Networks: Neurons and brain, Non-linear hypothesis, Model representation, Back Propagation algorithm, Regression and Classification (9 Hrs)

Unsupervised Learning: Clustering algorithms: K-means clustering, Dendrograms and Hierarchical clustering, DBSCAN; Error metrics and measures (3 Hrs)

Dimensionality reduction: Motivation, Principal Component Analysis (3 Hrs)</td></tr>
<tr><td>VI</td><td>Text/References</td><td colspan="4">1. Artificial Intelligence - A Modern Approach, Stuart Russell, Peter Norvig, Pearson publisher
2. Understanding Machine Learning - From Theory to Algorithms, Shai Shalev-Shwartz and Shai Ben-David, Cambridge University Press
3. Machine Learning, Tom Mitchell, MacGrow Hill publisher</td></tr>
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