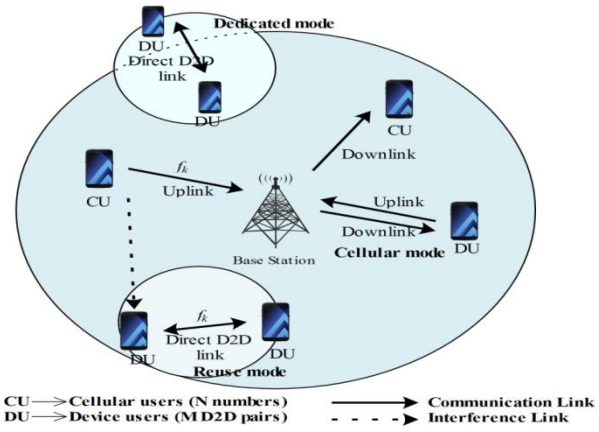
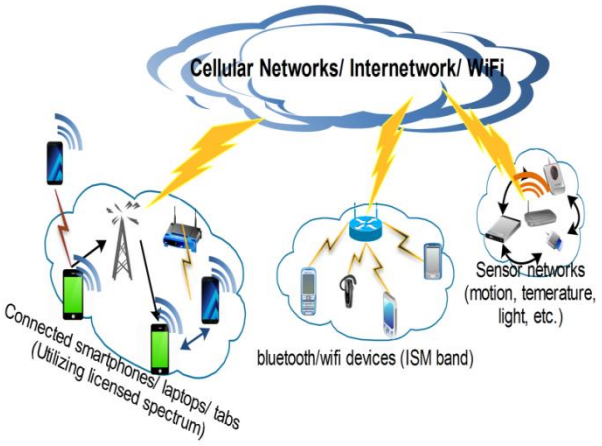
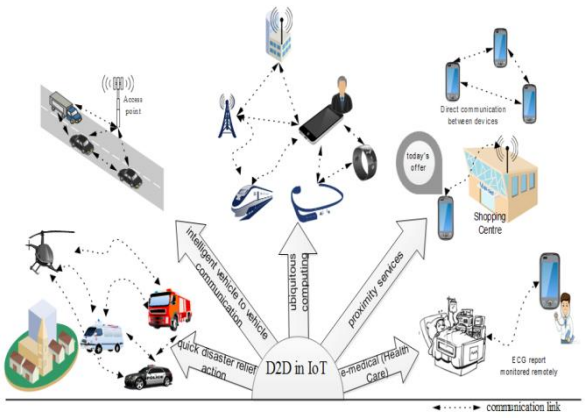
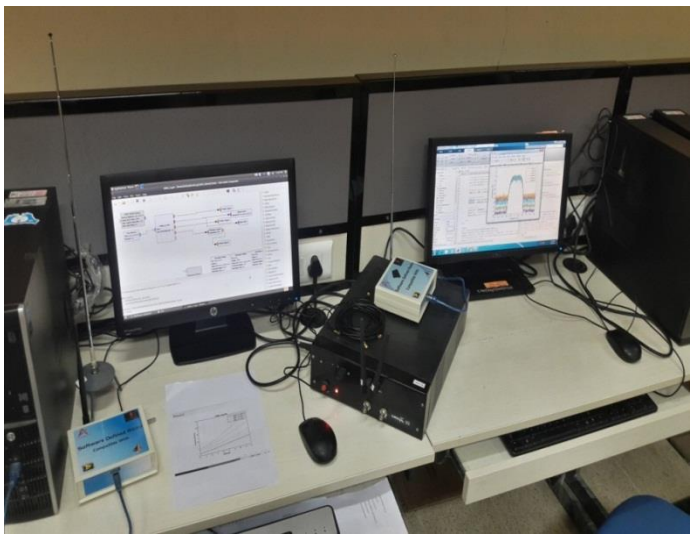
Curriculum & Contents

M Tech (Digital Communication)









ABV-Indian Institute of Information Technology & Management, Gwalior

June 2019

M Tech (Digital Communication)

Semester wise courses

Semester I				
S. No.	**Subject Code**	**Title of the course**	**L-T-P**	**Credits**
1.	MTDC-6101	Applied Mathematics for Communication Engineering	3-1-0	4
2.	MTDC-6102	Digital Communication	3-0-0	3
3.	MTDC-6103	Information Theory and Coding	3-0-0	3
4.	MTAS-6101	Modeling& Simulation	3-0-0	3
5.		Elective-I	3-0-0	3
6.	MTDC-6104	Scientific Computing Laboratory -I (MATLAB, NS2, OPNET etc)	0-0-6	3
7.	MTHS-6101	Professional Ethics		Audit
8.	MTDC-6105	Generic Computing Laboratory		Audit

Semester II				
S. No.	**Subject Code**	**Title of the course**	**L-T-P**	**Credits**
1.	MTHS-6201	Research Methodology	3-0-0	3
2.	MTDC-6201	Detection and Estimation Theory	3-0-0	3
3.	MTDC-6202	Advanced Mobile Communication System	3-0-0	3
4.		Elective-II	3-0-0	3
5.		Elective-III	3-0-0	3
6.	MTDC-6203	Scientific Computing Laboratory-II (Minor Project Based)	0-0-6	3
7.		**Total credits**		**18**

Semester III				
S. No.	**Subject code**	**Title of the course**	**L-T-P**	**Credits**
1.	MTHS-7101	Technical Report Writing	0-0-2	1
2.	MTDC-7102	Seminar	0-0-2	1
3.		Elective-IV	3-0-0	3
4.	MTDC-7199	Major Project Part-I	0-0-12	6
		Total credits		**11**

Semester IV				
S. No.	**Subject code**	**Title of the course**	**L-T-P**	**Credits**
1.	MTDC-7299	Major Project Part-II	0-0-24	12
		Total credits		**12**

Electives *

S. No.	Subject Code	Title of the course	L-T-P	Credits
1.	MTDC-9101	Queuing Theory	3-0-0	3
2.	MTDC-9102	Computer Graph Theory	3-0-0	3
3.	MTDC-9103	Computer Networks	3-0-0	3
4.	MTDC-9104	Internetwork Communication	3-0-0	3
5.	MTDC-9105	Optical Communication	3-0-0	3
6.	MTDC-9106	Adaptive Signal Processing	3-0-0	3
7.	MTDC-9107	Mobile Computing	3-0-0	3
8.	MTDC-9108	Object Oriented Programming (OOPS) + Data Structures	3-0-0	3
9.	MTDC-9109	Digital Signal Processing	3-0-0	3
10.	MTDC-9110	Modern Cryptography	3-0-0	3
11.	MTDC-9111	Game Theory and its Application	3-0-0	3
12.	MTDC-9112	Speech and Audio Signal Processing	3-0-0	3
13.	MTDC-9113	Cognitive Radio	3-0-0	3
14.	MTDC-9114	Advanced Networks	3-0-0	3
15.	MTDC-9115	IoT and its Security	3-0-0	3
16.	MTDC-9116	RF Engineering for wireless networks	3-0-0	3
17.	MTDC-9117	Optimization Techniques	3-0-0	3
18.	MTDC-9118	Microwave & Antennas	3-0-0	3

*** - The list is dynamic and can be expanded based on the requirement of Industry and Academia**

Please note:

a) The course contents are indicative in nature. Actual contents followed may deviate based on students/faculty interests.

b) Typically the evaluation is based on various components such as Minors (In-semester tests), Major examination (End-semester test), assignments, term papers, quizzes, presentations and class participation. The weightages for these components will be decided by the respective course instructors.

Semester I

1	**Code of the subject**	MTDC-6101
2	**Title of the subject**	Applied Mathematics for Communication Engineering
3	**Any prerequisite**	-
4	**L-T-P**	3-1-0
5	**Name of the proposer**	Dr. Jeevaraj S
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ To develop the ability to use the concepts of Linear algebra and Special functions for solving problems related to Networks. ➢ To formulate and construct a mathematical model for a linear programming problem in real life situation. ➢ To expose the students to solve ordinary differential equations by various techniques.
8	**Brief Contents (module wise)**	**MODULE I (LINEAR ALGEBRA):** Vector spaces, Norms, Inner ProductsEigen values using QR transformations, QR factorization Generalized eigenvectors, Canonical forms Singular value decomposition and applications Pseudo inverse, least square approximations Toeplitz matrices and some applications. **MODULE II (LINEAR PROGRAMMING):** Formulation Graphical solution, Simplex method, Two phase method Transportation and Assignment Models **MODULE III (ORDINARY DIFFERENTIAL EQUATIONS):** RungeKutta Methods for system of IVPs, numerical stabilityAdams-Bashforth multistep method, solution of stiff ODEsshooting method, BVP: Finite difference method, orthogonal collocationmethod, orthogonal collocation with finite element method **MODULE IV (TWO DIMENSIONAL RANDOM VARIABLES):** Joint distributions Marginal and Conditional distributions Functions of two dimensional random variables, Regression Curve, Correlation **MODULE V (QUEUEING MODELS):** Poisson Process, Markovian queues, Single and Multi-server Models, Little's formula,Machine Interference Model, Steady State analysis and Self Service queue.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Richard Bronson, Gabriel B.Costa, "Linear Algebra", Second Edition, Academic Press, 2007. ➢ Richard Johnson, Miller & Freund, "Probability and Statistics for Engineers", Seventh Edition, Prentice – Hall of India, Private Ltd., 2007. ➢ Taha, Hamdy A. "Operations research: an introduction", Vol. 790. Pearson/Prentice Hall, 2011. ➢ Donald Gross and Carl M. Harris, "Fundamentals of Queueing Theory", second edition, John Wiley and Sons, New York , 1985. ➢ Moon, Todd K., and Wynn C. Stirling, "Mathematical methods and algorithms for signal processing",Pearson Education, 2000.

1	**Code of the subject**	MTDC-6102
2	**Title of the subject**	Digital Communication
3	**Any prerequisite**	Students must have some knowledge about Analog modulation.
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Prof. Aditya Trivedi
6	**Will this course require visiting faculty**	NO.
7	**Learning Objectives of the subject (in about 50 words)**	➢ In this course, students should be able to develop signal space representations for digital modulation methods using probability and stochastic process, optimum receivers for AWGN channel and probability of error performance for different modulation techniques in AWGN channel.
8	**Brief Contents (module wise)**	**MODULE I (INTRODUCTION):** Motivation for digital communication systems, Analog vs. digital communication systems, system overview, channel characteristics, signal space concept, etc. **MODULE II (CHARACTERIZATION OF COMMUNICATION SIGNALS AND SYSTEMS):** Representation of band pass signals and systems, representation of band pass noise, vector space concepts for signal representation. **MODULE III (DIGITAL MODULATION):** Introduction, Binary modulation, Vector space concepts for signal representation, M-ary baseband and band pass modulation/demodulation.AWGN performance analysis of detectors for PAM, PSK, QAM, etc. Bit and symbol error probabilities, linear and non- linear modulation. **MODULE IV (OPTIMUM COMMUNICATION FOR ADDITIVE WHITE GAUSSIAN NOISE CHANNEL):** Correlation detection, matched filter detection, ML detector, MAP detector, optimum receivers for signals with random phase in AWGN channel and probability of error performance for different modulation technique in AWGN channel.
9	**Contents for lab (If applicable)**	-
10	**List of text books/references**	➢ John G. Proakis and MasoudSalehi, "Digital Communications", fifth edition, McGraw Hill, 2007/2008. ➢ Bernard Sklar, "Digital Communications: Fundamentals and Applications", second Edition, Prentice Hall, 2001. ➢ Simon Haykin, "Digital Communication" Wiley, 2013. ➢ Sheldon M. Ross, "Introduction to Probability and Statistics", Wiley, 2008.

1	**Code of the subject**	BCCS-9211/ITIT-9211/MTDC-6103
2	**Title of the subject**	Information Theory and Coding
3	**Any prerequisite**	Students should have brief idea about linear algebra.
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Prof. Aditya Trivedi
6	**Will this course require visiting faculty**	NO.
7	**Learning Objectives of the subject (in about 50 words)**	➢ This course gives brief knowledge about the basic algebraic relationships of entropy, relative entropy, and mutual information. ➢ In this course students are going to learn how to compress the data using source coding and how to make data transmission reliable using channel coding. ➢ It introduces the basic principles of encoding, decoding, error detecting and error correcting techniques.
8	**Brief Contents (module wise)**	**MODULE I (INFORMATION THEORY):** Introduction, Discrete memory less source, Binary source. **MODULE II (ENTROPY, RELATIVE ENTROPY, AND MUTUAL INFORMATION):** Entropy, Joint Entropy and Conditional Entropy, Relative Entropy and Mutual Information, Relationship Between Entropy and Mutual Information, Chain Rules for Entropy, Relative Entropy, and Mutual Information, Jensen's Inequality, Log Sum Inequality. **MODULE III (DATA COMPRESSION):** Examples of Codes, Kraft Inequality, Optimal Codes, Bounds on the Optimal Code Length, Kraft Inequality for Uniquely Decodable Codes, Huffman Codes, Shannon–Fano Coding. **MODULE IV (CHANNEL CAPACITY):** Examples of Channel Capacity, Symmetric Channel, Channel Coding Theorem. **MODULE V (ERROR DETECTING AND ERROR CORRECTING CODE):** Simple parity checks , CRC codes, Hamming weight , Hamming distance, Minimum distance decoding, Single/Double parity checks, Hamming codes, Linear block codes, Cyclic codes, Syndrome calculation, Block encoders and Decoders.
9	**Contents for lab (If applicable)**	-
10	**List of text books/references**	➢ Joy A. Thomas and Thomas M. Cover, "Elements of Information Theory" third editionJohn Wiley and Sons, 2006. ➢ John G.Proakias, "Digital Communication", fourth Edition, McGraw Hill,Singapore, 2001. ➢ Bernard Sklar, "Digital Communications: Fundamentals and Applications", second edition, Pearson Prentice Hall, 2001.

1	**Code of the subject**	MTAS-6101
2	**Title of the subject**	Modeling and Simulation
3	**Any prerequisite**	Engineering Mathematics and Probability & Statistics
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Ajay Kumar
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ To teach the application of mathematics and statistics in real life problems.
8	**Brief Contents (module wise)**	**MODULE I (INTRODUCTION):** Concept of a system, System Environment, Modeling and Simulation of Real world problems, Classification of Models and examples, Static and Dynamic models, Principles used in modelling. **MODULE II (SYSTEM STUDIES):** Subsystems, A Corporate models, Block diagram of modeling and simulation, System Analysis, System Design. **MODULE III (MATHEMATICAL MODELS):** Mathematical models in population dynamics, Epidemic Models, some mathematical modeling in Biology and Medicine Innovation diffusion models in marketing. **MODULE IV (SYSTEM SIMULATION):** The technique of simulation, the Monte Carlo Method, Types of system simulation, Continuous and Discrete time Simulation. **MODULE V (PROBABILITY CONCEPTS IN SIMULATION)**: Stochastic variables, Discrete and continuous probability distributions, Measures of probability functions, Random numbers generation. **MODULE VI (STOCHASTIC PROCESSES):** Poisson Process, Markov Process, Queuing Theory, Reliability. **MODULE VII (LINEAR PROGRAMMING IN SIMULATION):** Introduction, Transportation problem, Assignment problem and other simulation techniques in Operation research. **MODULE VIII (SOFTWARE IN SYSTEM SIMULATION):** Numerical computation technique for continuous and discrete models (MATLAB).
9	**Contents for lab (If applicable)**	-
10	**List of text books/references**	➢ Banks, Jerry, I. I. Carson, Barry L. Nelson, and David M. Nicol, "Discrete-event system simulation", Pearson , 2005. ➢ Kishor S Trivedi, "Probability & Statistics With Reliability, Queuing And Computer Science Applications", second edition, Wiley, 2011. ➢ Geoffrey Gordon, System Simulation, Prentice-Hall, 1969.

1	**Code of the subject**	MTDC-6104
2	**Title of the subject**	Scientific Computing Laboratory -I (MATLAB, NS2, OPNET etc)
3	**Any prerequisite**	NO
4	**L-T-P**	0-0-6
5	**Name of the proposer**	Dr. PinkuRanjan
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ Understand basic of MATLAB,NS2,OPNET ➢ Able to perform basic computational techniques ➢ Understand types of computational method
8	**Brief Contents (module wise)**	**MODULE I (MATLAB USAGE AND COMPUTATIONAL ERRORS):** Introduction to MATLAB, Types of Computer Errors, IEEE 64- bit Floating-Point Number Representation, Vectors in MATLAB, Efficient programming techniques System of Linear Equations: Solution for a System of Linear Equations, Solving a System of Linear Equations, Inverse Matrix, Decomposition (Factorization), Iterative Methods to Solve Equations **MODULE II (INTERPOLATION AND CURVE FITTING) :** Interpolation by Lagrange, Newton, and Chebyshev Polynomial, Hermite Interpolating Polynomial, Cubic Spline interpolation, Straight Line, Polynomial Curve, and Exponential Curve Fit, Fourier transform Nonlinear Equations: Bisection Method, Regula Falsi Method, Newton Raphson Method, Secant Method, Newton Method for a System of Nonlinear Equations **MODULE III (NUMERICAL DIFFERENTIATION/INTEGRATION):** Difference Approximation for First Derivative, Approximation Error of First Derivative, Numerical Integration and Quadrature, Trapezoidal Method and Simpson Method, Romberg Integration,Adaptive and Gauss Quadrature. Ordinary Differential Equations: Euler's Method, Runge–Kutta Method, PredMEor–Corrector Method, Vector Differential Equations, Boundary Value Problem (BVP) **MODULE IV (OPTIMIZATION):** Unconstrained Optimization, Constrained Optimization, MATLAB Built-In Routines for Optimization, Matrices and Eigenvalues: Eigenvalues and Eigenvectors, Power Method, Jacobi Method Partial Differential Equations: Elliptic , Hyperbolic, and Parabolic PDE, Finite Element Method (FEM) for solving PDE,
9	**Contents for lab (If applicable)**	-
10	**List of text books/references**	➢ W. Y. Yang, "Applied Numerical methods using MATLAB", Wiley Publications, 2005 ➢ Steven C.Chapra, "Applied Numerical Methods with MATLAB," McGraw-Hill, 2005 ➢ John H. Mathews, "Numerical Methods using MATLAB", volume 3, Prentice Hall, 2004 ➢ Palm, William J., "Introduction to MATLAB® for Engineers", McGraw-Hill, 1998.

1	**Code of the subject**	MTHS-6101
2	**Title of the subject**	Professional Ethics
3	**Any prerequisite**	Nil
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Prof. V.S.R. Krishnaiah
6	**Will this course require visiting faculty**	Yes
7	**Learning Objectives of the subject (in about 50 words)**	➢ The primary objective of this course is to sensitize students on the concept of Ethics and Human Values and make them understand the relevance of these ideas in their day to day personal and professional lives. ➢ The Course aims to instill moral and social values as well as professional code of conduct in the students to make them good quality professionals so as to perform their professional responsibilities better in their future career.
8	**Brief Contents (module wise)**	**MODULE-I:** Definitions of Ethics, Engineering Ethics, and Morality. Categorization of Ethics, Differentiation of Morality and Ethics, Ten personal ethical behaviors which are globally acceptable, Definition of virtues, Elaboration of cardinal virtues, Definition of human values, Shalome H Shwartz value classification with examples **MODULE-II:** Definition of Profession and Professional, Responsibilities of professionals, the objectives of any one professional association, ACM Code of Ethics and Professional Conduct, IEEE Code of Ethics. **MODULE-III:** Significance of ethics in ICT sector, Global Ethical Issues in ICT Sector with examples, Definitions of CSR, The stakeholders and their expectations from an organization, The Company Act 2013, Benefits of CSR in organization, Examples of CSR in ICT sector. **MODULE-IV:** Definition of Emotional intelligence, Importance of Emotional intelligence for Professionals, Five elements of Emotional intelligence, Significance of EI for professional success with examples, Ethical Dilemmas, Main features of Whistle Blowing, Preparation for Professionals and CEOs for avoiding unethical issues in their organizations
9	**Contents for lab**	NA
10	**List of text books/references**	➢ R.Subramanian, "Professional Ethics", Oxford University Press, 2013 ➢ Daniel Goleman, "Working with Emotional Intelligence", Bloomsbury, 2004.

1	**Code of the subject**	MTDC-6105
2	**Title of the subject**	Generic Computing Laboratory
3	**Any prerequisite**	-
4	**L-T-P**	Audit
5	**Name of the proposer**	Dr. Binod Prasad
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ This course is intended for post graduate student to learn how to simulate and realize different blocks of a communication system. ➢ To generate different modulated symbols and analyzing their bit error rate performance.
8	**Brief Contents (module wise)**	**MODULE I:** Generation of random variables: discrete, Poisson, binomial, geometric, continuous, Gaussian, exponential, lognormal. Rayleigh. Generation of PN sequence and their autocorrelation. **MODULE II:** Simulation of arrival process in a Poisson based arrival process, throughput simulation for ALOHA and S-ALOHA protocols, BER performance of BPSK modulated signal under AWGN channel. **MODULE III:** implementation of basics blocks of a communication system in octave-generation of different modulated symbol: BPSK, QPSK, Mapping and demapping of Symbols onto a Constellation,Adding Noise, BER analysis for different modulation scheme, AM modulation and demodulation.
9	**Contents for lab (If applicable)**	-
10	**List of text books/references**	➢ T.S. Rappaport, “Wireless Communications: Principles and Practice”, volume 2, Prentice Hall publication, 1996 ➢ Viswanathan, Mathuranathan. "Simulation of digital communication systems using Matlab." Mathuranathan Viswanathan at Smashwords (2013).

Semester II

1	**Code of the subject**	MTHS-6201
2	**Title of the subject**	Research Methodology
3	**Any prerequisite**	No
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Prof. Pankaj Srivastava
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ To enable researchers (Ph.D., MTech students), irrespective of their discipline, in developing the most appropriate methodology for their research studies. ➢ To make them familiar with the art of using different research methods and techniques
8	**Brief Contents (module wise)**	**MODULE I (RESEARCH FUNDAMENTALS)**: Research, types of research, Research vs research methods, Research process, Relevant and quality research. Problem-solving in engineering, Identification of research topic, Problem definition, Literature survey, literature survey, Literature review, Research Design. **MODULE II (MATHEMATICAL MODELLING & SIMULATION)**: Models in general, Mathematical models, Model classifications, Modeling of engineering systems Theoretical models, Empirical models, Model evaluation, Limitations of mathematical models. Simulation models, Steps in a simulation study, Simulation software, Validation and data collection, Applications. **MODULE III (HYPOTHESES TESTING , ANALYSIS & SCALING TECHNIQUES):** Formulation of Hypothesis, Testing of hypothesis, Analysis of variance, Design of experiments, Multivariate analysis, Simple regression and correlation, measurement & scaling techniques. **MODULE IV (ANALYSIS AND INTERPRETATION OF DATA)**: Data checking, Data analysis, Statistical, Graphical and Numerical data analysis, Interpretation of results in research , need for Interpretation, Accuracy, Precision, Uncertainty and variability, Repeatability and reproducibility, Error definition and classification, Analysis of errors, Statistical analysis of errors. **MODULE V (SKILLS AND ETHICS IN RESEARCH):** Basic communication model, Preparing papers for journals, synopsis of research work, Reference citation, Listing of References. Thesis writing, Steps in writing the report, presentation of graphs, figures, tables, Structure of thesis report, main body of thesis, summary, references, Evaluation of a thesis, Ethics in research, Intellectual property rights, copyright laws, Patent rights.
9	**Contents for lab (If applicable)**	Introduction to LaTex software, Practical applications of SPSS, ANOVA, Applications and case studies of parametric and non-parametric tests
10	**List of text books/references**	➢ Kothari, Chakravanti Rajagopalachari, “Research methodology: Methods and techniques”, New Age International, 2004. ➢ Kumar, Ranjit. “Research methodology: A step-by-step guide for beginners”,Sage Publications Limited, 2019. ➢ Kirk G. Rasmussen, “Guide to Research & Documentation” fifth edition, Prentice Hall, 2002. ➢ R. Panneerselvam, “Research Methodology,” Prentice- Hall, 2004 ➢ R Ganeshan, “Research Methodology for Engineers”, MJP Publishers, 2011.

1	**Code of the subject**	BCCS-9212/ITIT-9212/MTDC-6201
2	**Title of the subject**	Detection and Estimation Theory
3	**Any prerequisite**	Student must have basic knowledge about linear algebra, probability and random process.
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Prof. Aditya Trivedi
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ Detection theory involves detecting one hypothesis from two or more than two hypotheses. This may be done based on Bayes detection, Minmax detection, NP test. ➢ Estimation theory is a branch of statistics that deals with estimating the values of parameters based on measured empirical data that has a random component using various estimators. ➢ In general, the information that one wishes to extract from such observation is unknown to the observer, it is useful to cast detection and estimation problems in a probabilistic framework in which unknown behavior is assumed to be random. ➢ Applications of the theory of signal detection and estimation are in many areas, such as communications, automatic control, telecommunication, radar etc.
8	**Brief Contents (module wise)**	**MODULE I (BACKGROUND):** Review of Gaussian variables and processes. **MODULE II (STATISTICAL DECISION THEORY):** Bayesian, minimax, and Neyman-Pearson decision rules, likelihood ratio, composite hypothesis testing. **MODULE III (DETECTION OF DETERMINISTIC SIGNALS):** Matched filter detector and its performance. **MODULE IV (DETECTION OF RANDOM SIGNALS):** Estimator-correlator, linear model, general Gaussian detection. **MODULE V (NONPARAMETRIC DETECTION):** Detection in the absence of complete statistical description of observations. **MODULE VI (ESTIMATION OF SIGNAL PARAMETERS)**: Minimum variance unbiased estimation, Fisher information matrix, Cramer-Rao bound, sufficient statistics. **MODULE VII (SIGNAL ESTIMATION IN DISCRETE-TIME):** Linear Bayesian estimation, Weiner filtering, dynamical signal model, discrete Kalman filtering.
9	**Contents for lab (If applicable)**	-
10	**List of text books/references**	➢ H. L. Van Trees, "Detection, Estimation and Modulation Theory", John Wiley and sons, 2004. ➢ MouradBarkat,"Signal detection and estimation", Artech House 1991. ➢ Poor, H. Vincent, "An Introduction to Signal Detection and Estimation", Springer 1998.

1	**Code of the subject**	MTDC-6202
2	**Title of the subject**	Advanced Mobile Communication System
3	**Any prerequisite**	Basics of digital communication, probability and random process
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Binod Prasad
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ This course is intended for post graduate students to provide system view of mobile communication network through the description of upcoming wireless communication technology. ➢ To gain knowledge of different advanced topics on access schemes, diversity and modulation. To learn about the recent developments in cellular system standard.
8	**Brief Contents (module wise)**	**MODULE I:** Overview of cellular communication, cellular system concept, principle and design fundamental, Cell structure, frequency reuse, cell splitting, channel assignment, handoff, interference, capacity, power control; Overview of 2G and 3G cellular standards. **MODULE II:** DifferentPropagation mechanism of a signal, Wirelesschannel models: Path Loss and Shadowing Models, multipath and small scale fading-Doppler shift, statistical multipath channel models, narrowband and wideband fading models, power delay profile, average and RMS delay spread, coherence bandwidth and coherence time, flat and frequency selective fading, slow and fast fading, average fade duration and level crossing rate. **MODULE III**: Fading mitigation and equalization scheme, Modulation scheme: BPSK, QPSK, QAM, MSK and GMSK, multicarrier modulation, OFDM. **MODULE IV**: Capacity of fading channels, multiple access techniques-FDMA, TDMA, CDMA and SDMA, Diversity-receiver diversity: selection combining, threshold combining, maximal ratio combining, equal gain combining, transmit diversity: Alamouti scheme. **MODULE V**: MIMO system, narrowband system model, decomposition of MIMO channel, MIMO channel capacity, spatial multiplexing, BLAST architecture, diversity-multiplexing tradeoff. **MODULE VI**: Wireless system and standards: AMPS, GSM, EDGE, GPRS, IS-95, CDMA, 2000 , WCDMA, LTE and WiMAX.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Andrea Goldsmith, “Wireless Communications”, Cambridge University Press, 2005 ➢ David Tse and PramodViswanath, “Fundamentals of Wireless Communications”, Cambridge University Press, 2005. ➢ Theodore Rappaport,“Wireless Communications: Principles and Practice”, Prentice Hall, 1996.

1	**Code of the subject**	MTDC-6203
2	**Title of the subject**	Scientific Computing Lab-II
3	**Any prerequisite**	Basics of wireless communication
4	**L-T-P**	0-0-6
5	**Name of the proposer**	Dr. Binod Prasad
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ To develop the ability of implementing and analyzing the performance of a communication system under different communication techniques and algorithm.
8	**Brief Contents (module wise)**	**MODULE I:** Numerical methods techniques for communication related problem, nonlinear equations, numerical solution of systems of algebraic equations, least squares, unconstrained optimization, polynomial interpolation, numerical differentiation and integration, numerical solution of ordinary differential equations, truncation error, numerical stability for time dependent problems and stiffness.. **MODULE II:** Concepts and techniques of realizing different fading channel, modulation schemes, and diversity techniques, Performance measures: outage, average snr, average symbol/bit error rate **MODULE III:** In this module research papers in the field of the wireless communication is assigned to the students. Students will learn to implement the techniques from the previous modules on the specific assigned research problems. **MODULE IV:** Presentation, documentation of methods and results from scientific computations in the form of technical reports, with suitable use of figures, tables, equations, cross-references, and bibliography.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ T.S. Rappaport ,"Wireless Communications: Principles and Practice", second edition, Prentice Hall publication, 2002. ➢ EuroScipy tutorial team: Python Scientific lecture notes. http: //scipy-lectures.github.com.

Semester III

1	**Code of the subject**	MTHS-7101/MTIS-7101
2	**Title of the subject**	Technical Report Writing
3	**Any prerequisite**	-
4	**L-T-P**	0-0-2
5	**Name of the proposer**	Dr. Arun Kumar
6	**Will this course require visiting faculty**	Yes
7	**Learning Objectives of the subject (in about 50 words)**	➢ To learn written communication skills in the wake of present day professional world ➢ To enhance the understanding of written communication with practice oriented approach ➢ To collect, analyze and report data ➢ To familiarize with grammar and usage ➢ To acquire higher order writing skills through project assignments
8	**Brief Contents (module wise)**	**MODULE I:** Fundamentals of communication **MODULE II:** Elements of Report writing **MODULE III:** Types of reports such as memo, corrigendum **MODULE** IV: Technical reports **MODULE V:** Sources of data **MODULE VI:** Data analysis **MODULE VII:** Illustrating data **MODULE VIII:** Mechanics of writing **MODULE IX:** Report structure **MODULE X:** Oral presentation **MODULE XI:** Issues related to plagiarism and ways to counter the same
9	**Contents for lab (If applicable)**	Data Analysis , Report writing , Report presentation
10	**List of text books/references**	➢ Sharma, R.C. and K. Mohan, Business Correspondence and Report Writing, fifth edition, Tata McGraw Hill, 2016. ➢ Gerson, Sharon J and Stern M. Gerson, Technical Writing: Process and Product, third edition, Pearson, 2000.

1	**Code of the subject**	MTDC-7102
2	**Title of the subject**	Seminar
3	**Any prerequisite**	-
4	**L-T-P**	0-0-2
5	**Name of the proposer**	Dr. Binod Prasad
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ This course is intended for students pursuing post-graduation in specialized area. Students will have to choose a recent topic in communication related areas or industry practices and prepare a write up along with suitable presentation and demonstration.
8	**Brief Contents (module wise)**	NA
9	**Contents for lab (If applicable)**	-
10	**List of text books/references**	-

1	**Code of the subject**	MTDC-7199
2	**Title of the subject**	Major Project Part-I
3	**Any prerequisite**	Academic honesty, ethics and a deeper understanding of the topic under research
4	**L-T-P**	0-0-12
5	**Name of the proposer**	Dr. K. K. Pattanaik
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ The course will help understand the system level details of the Internetworking technology, issues, and approaches.
8	**Brief Contents (module wise)**	The purpose of this course is to enable the student to develop deeper knowledge, understanding, capabilities and attitudes in the context of the programme of study. Specific learning outcomes for a Master's thesis are for the student to demonstrate: • Considerably more in-depth knowledge of the major subject/field of study, including deeper insight into current research and development work. • Deeper knowledge of methods in the major subject/field of study. • A capability to contribute to research and development work. • The capability to to create, analyse and critically evaluate different technical/architectural solutions. • The capability to clearly present and discuss theconclusions as well as the knowledge and arguments that form the basis for these findings in written and spoken English. • A consciousness of the ethical aspects of research and development work. Overall a Master's thesis for a 12 credit course must be considerably more ambitious with respect to the scientific level or technical/architectural realisation.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	

Semester IV

1	**Code of the subject**	MTDC-7299
2	**Title of the subject**	Major Project Part-II
3	**Any prerequisite**	Academic honesty, ethics and a deeper understanding of the topic under research
4	**L-T-P**	0-0-24
5	**Name of the proposer**	Dr. K. K. Pattanaik
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ The course will help understand the system level details of the Internetworking technology, issues, and approaches.
8	**Brief Contents (module wise)**	This shall be in continuation to the Major Project Part-I. A thesis should be written at the end of the programme and must delve more deeply into and synthesise knowledge acquired in previous studies. A thesis for M.Tech. should place emphasis on the technical/scientific/artistic aspects of the subject matter.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	

Electives

1	**Code of the subject**	MTDC-9101
2	**Title of the subject**	Queuing Theory
3	**Any prerequisite**	Basic knowledge of Engineering Mathematics and Statistics
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Ajay Kumar
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ To teach the applications of queuing theory related to computer networks.
8	**Brief Contents (module wise)**	**MODULE I:** Basics of Probability and Statistics, Random processes- Introduction, classification, Stationary process – Wide Sense StationaryStrict Sense Stationary, Markov Process , Markov Chain, Problems based on Markov Process. **MODULE II:** Transition probabilities, Limiting distributions, Poisson Process - Properties, Poisson Process – Problems **MODULE III:** Queuing system – introduction, Markovian Models, Birth and Death Process, Little's Formula, M/M/1, Infinite Capacity, M/M/1, Finite Capacity, M/M/c, Infinite Capacity, M//M/c, Finite Capacity and finite population, M/M/∞ queue. **MODULE IV:** Non Markovian queues- M/G/1 queue, GI/M/1 queue, GI/M/m queue, GI/G/1 queue, M/G/m queue, GI/G/m queue, Pollaczek- Khinchine formula. **MODULE V:** Priority queues-Queues with preemption, queues with time dependent priorities. Series queues, Open Networks, Closed Networks, batch service, batch arrival.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ K. S. Trivedi, "Probability and Statistics with Reliability, Queuing and Computer Science Applications" , seondedition, John Wiley and Sons, 2002. ➢ A.O. Allen, "Probability, Statistics and Queuing Theory with Computer Applications",2nd edition, Elsevier, 2005. ➢ Srivastava, H. M., &Kashyap, B. R. K., "Special functions in queuing theory and related stochastic processes", ACADEMIC PRESS, 1982.

1	**Code of the subject**	MTDC-9102
2	**Title of the subject**	Computer Graph Theory
3	**Any prerequisite**	NIL
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Anuraj Singh
6	**Will this course require visiting faculty**	No
7	**Objectives of the subject (in about 50 words)**	➢ To develop ability to solve real life problems, translating them one form to another, using appropriate mathematical and computational techniques ➢ To prepare abstract and critical mathematical thinking,most directly related to computer science ➢ To foster rigorous thinking skills that can enhance the quality of work of computing professionals ➢ To relate and apply the concepts to practical applications of computer science
8	**Brief Contents (module wise)**	**MODULE I:** Introduction to graphs, Paths and Circuits, Trees and Fundamental Circuits, Spanning Tree, Matrix Tree Theorem, Euler Graph, Hamiltonian Graph, Isomorphism **MODULE II:** Cut-sets and Cut vertices, Planar and Dual graphs, Kurtowski Theorem, Euler Identity **MODULE III**: Matrix representation of Graphs, Coloring, Chromatic Number, Brooks Theorem, Five-color theorem, Matching **MODULE IV:** Directed graph, Underlying graph, Outdegree, in-degree, Connectivity, Orientation, Eulerian directed graphs, Hamilton directed graphs, Arborescence, Tournament **MODULE V:** Applications of Graph Theory: In Switching and Coding Theory, Electrical Network Analysis **MODULE VI**: Operations Research, Markov Processes, Computer Algorithm
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ DeoNarsingh, "Graph Theory With Applications To Engineering And Computer Science", Prentice Hall of India, 1992. ➢ West, Douglas B., "Introduction to Graph Theory", Pearson Education, 2002. ➢ Mott J.L., Kandel, A. and Baker T.P., "Discrete Mathematics for Computer Scientists and Mathematicians", Prentice Hall of India, 2001. ➢ Reinhard Diestel, "Graph Theory", Springer International Edition, 2004.

1	**Code of the subject**	MTDC-9103
2	**Title of the subject**	Computer Networks
3	**Any prerequisite**	Fundamentals of Internet and web technology, Mobile computing
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. K. K. Pattanaik
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ The course will help understand the purpose and overview of the Internetworking technology, issues, and approaches using top-down philosophy.
8	**Brief Contents (module wise)**	**MODULE I(COMPUTER NETWORKS AND THE INTERNET):** A Nuts-and-Bolts Description of Internet, A Services Description, The Network Edge, Client and Server Programs, The Network Core, ISPs and Internet Backbones, Performance in Packet-Switched Networks, Protocol Layers and Their Service Models, The Development of Packet Switching, Proprietary Networks and Internetworking, The Internet Explosion, Recent Developments. **MODULE II (APPLICATION LAYER):** Network Application Architectures, Processes Communication, Transport Services, Transport Services, Application-Layer Protocols, The Web and HTTP, User-Server Interaction: Cookies, Web Caching, Peer-to-Peer Applications, P2P File Distribution, Searching for Information in a P2P Community, Case Study: P2P Internet Telephony with Skype, Socket Programming with TCP and UDP **MODULE III (TRANSPORT LAYER):** Relationship Between Transport and Network Layers Overview of the Transport Layer in the Internet, Principles of Reliable Data TransferBuilding a Reliable Data Transfer Protocol, Pipelined Reliable Data Transfer Protocols, Round-Trip Time Estimation and Timeout, Principles of Congestion Control, The Causes and the Costs of Congestion, Approaches to Congestion Control, TCP Congestion Control, Fairness. **MODULE IV (THE NETWORK LAYER):** Network Service Models, Datagram Networks, Router architecture: Input Ports, Switching, Output Ports, Queuing. The Internet Protocol (IP),IP Security VPNs, Routing, Broadcast and Multicast Routing. **MODULE V(THE LINK LAYER AND LOCAL AREA NETWORKS):** Link Layer Services, Multiple Access protocols, Link-Layer Addressing, Ethernet, Link-Layer, PPP: The Point-to-Point Protocol, Link Virtualization. **MODULE VI(WIRELESS AND MOBILE NETWORKS):** Wireless Links and Network Characteristics, WiFi: 802.11 Wireless LANs, Beyond 802.11: Bluetooth and WiMax, Cellular Internet Access, Mobility Management: Principles Routing to a Mobile Node, Mobile IP, Managing Mobility in Cellular Networks, Handoffs in GSM, Wireless and Mobility: Impact on Higher-layer Protocols. **MODULE VII(MULTIMEDIA NETWORKING):** Multimedia Networking Applications, Streaming Stored Audio and Video, Making the Best of the Best-Effort Service, Protocols for Real-Time Interactive Applications, Providing Multiple Classes of Service,Providing Quality of Service Guarantees.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ James F. Kurose , Keith W. Ross., "Computer Networking: A top-down approach featuring the Internet" ,seventh edition, Pearson 2005.

1	**Code of the subject**	MTDC-9104
2	**Title of the subject**	Internetwork Communication
3	**Any prerequisite**	NO
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. PinkuRanjan
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ Explain how an internet works, which different components are included and why they are included. ➢ Give an account of how Internet works on protocol level, what protocols are used, and what functionality these protocols contribute with. ➢ Understand optical fiber communication, both from a components view and its application in the core and access networks of Internet. ➢ Choose/design an appropriate protocol for a new application considering the requirements and usage of the application. ➢ Describe basic principles of source and channel coding for packet networks, Internet service provider pricing, special networks for clouds and Internet-of things.
8	**Brief Contents (module wise)**	Introduction, Packet switching vs Circuit Switching, the TCP/IP model, the network layer (IPv4 IPv6, routers, switches, DHCP, mobility in LTE, virtualcircuits, routing), the transport layer (UDP, TCP), optical fiber communication, sensor networks, Internet service provider pricing, clouds (Clos networks), DNS, multicasting, peer-2-peer, Skype NAT traversal, source and channelcoding for packet networks (error concealment, interleaving, multiple description coding, layered coding, Shannon bounds).
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Behrouz A. Forouzan, “TCP/IP Protocol Suite” McGraw-Hill, 2002 ➢ B.A. Forouzan, “Data communication & Networking”, fourth Edition TMH, 2007. ➢ Mahbub Hasan & Raj Jain, ” High performance TCP/IP Networking”, PHI , 2005 ➢ Douglas. E.Comer, “Internetworking with TCP/IP “, Volume I PHI, 1995. ➢ Larry L. Perterson and Bruce S. Davie , “Computer Networks- A Systems Approach”, Morgan Kaufmann, 2011, ➢ JochenSchiiler, “Mobile Communications”, Pearson, second Edition 2003.

1	**Code of the subject**	MTDC-9105
2	**Title of the subject**	Optical Communication
3	**Any prerequisite**	Knowledge of digital communication fundamentals
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Binod Prasad
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ This course is intended to impart the knowledge of optical communication with different transmission, modulation and multiplexing technique. Further, to learn about different network algorithm like SONET, and optical CDMA .
8	**Brief Contents (module wise)**	**MODULE I:** Introduction to optical communications systems, Brief overview of optical fibres, sources and photo detectors; Design optimization of single mode fibres. Optical transmitters: LED driver circuits: saturated transistor and emitter-coupled configurations, Laser driver circuits, mean and peak power control circuits, temperature control circuits, Source and line coding in optical systems. **MODULE II:** Optical receivers: PIN-based receivers, APD-based receivers, Receiver noise processes, Receiver circuits: preamplifiers – Trans-impedance and high-input-impedance amplifiers; Digital optical communication links: BER in quantum limit, BER analysis for PIN-based and APD-based receivers in presence of shot and thermal noise components. **MODULE III:** Modulation schemes, multiple access networks, WDM Components, TDM, Subcarrier and Code division multiplexing, Elements of coherent optical communication systems: Fundamental concepts and requirements for lasers, Frequency alignment and polarization control schemes, PSK, FSK, DPSK generation and demodulation techniques. Optical Link design, Power budget and rise-time budget, Design of digital and analog communication systems. **MODULE IV:** Nonlinear effects in fiber optic links. Concept of self-phase modulation, group velocity dispersion and solution based communication. Optical amplifiers: Semiconductor optical Amplifier, EDFA, Raman Amplifier, Wideband Optical Amplifiers, pumping phenomenon, LAN and cascaded in-line amplifiers. Limitations, Post-and Pre-compensation techniques, Equalizing filters, fiber based gratings **MODULE V:** WDM system design, SONET/SDH: Limitations of PDH multiplexing, SONET/SDH layers, SONET/SDH frame structure, SONET/SDH physical layer, Elements of SONET/SDH infrastructure.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Gerd Keiser, “Optical Fiber Communications”, fourth Edition,McGraw Hill, 2008 ➢ John M. Senior , “Optical Fiber Communication”, third edition, Pearson,2009. ➢ G. Agrawal , “Fiber optic Communication Systems” John Wiley and sons, 2002.

1	**Code of the subject**	MTDC-9106
2	**Title of the subject**	Adaptive Signal Processing
3	**Any prerequisite**	Digital Signal Processing
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Vinal Patel
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ Development of various adaptation algorithms and assessing them in terms of convergence rate, computational complexity, robustness against noisy data, hardware complexity, numerical stability. ➢ The course will present several examples of adaptive filter applications like channel equalization, echo cancellation, noise cancellation, interference suppression.
8	**Brief Contents (module wise)**	**MODULE I:** Introduction to Adaptive Systems Adaptive Systems: Definitions, Characteristics, Applications, Example of an Adaptive System. The Adaptive Linear Combiner – Description, Weight Vectors, Desired Response Performance function – Gradient & Mean Square Error. **MODULE II:** Development of Adaptive Filter Theory & Searching the Performance surface: Introduction to Filtering – Smoothing and Prediction – Linear Optimum Filtering, Problem statement, Principle of Orthogonally – Minimum Mean Square Error, Wiener- Hopf equations, Error Performance – Minimum Mean Square Error, Estimation of phase shift between two narrow band signals using Orthogonal Decomposer. **MODULE III:** Steepest Descent Algorithms: Searching the performance surface – Methods & Ideas of Gradient Search methods – Gradient Searching Algorithm & its Solution – Stability & Rate of convergence – Learning Curves Gradient Search by Newton's Method, Method of Steepest Descent, Comparison of Learning Curves. **MODULE IV:** LMS Algorithm & Applications: LMS Adaptation algorithms, Stability & Performance analysis of LMS Algorithms – LMS Gradient & Stochastic algorithms – Convergence of LMS algorithm. Applications: Adaptive BFSK, BPSK, ASK demodulators and delay estimation. Introduction to RLS Algorithm, Statement of Kalman filtering problem, Innovation Process, Estimation of State using the Innovation Process- Expression of Kalman Gain, Filtering Example estimation of state from observations of noisy observed narrow band signals. Target tracking using only DOA.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ H. Sayed, "Adaptive Filters", John Wiley & Sons, 2008. ➢ S. Haykin, "Adaptive Filter Theory", Fourth Edition, Pearson Education LPE, 2007. ➢ Alexander D. Poularikas, Zayed M. Ramadan, "Adaptive filtering primer with MATLAB", CRC Press, 2006.

1	**Code of the subject**	MTDC-9107
2	**Title of the subject**	Mobile Computing
3	**Any prerequisite**	Computer Networks
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Prasenjit Chanak
6	**Will this course require visiting faculty**	NA
7	**Learning Objectives of the subject (in about 50 words)**	➢ This is a PG elective course open to PG and UG students who have taken a previous introductory networking course. We will cover interesting topics across a variety of mobile systems (wireless LANs, cellular systems, and sensor networks), and revisit the design of the various layers of the networking stack in the context of wireless communication. ➢ The course will comprise of lectures, four problem sets, exams (midsem and endsem), and a course project.
8	**Brief Contents (module wise)**	**MODULE I:** Overview of wireless and mobile systems (wireless LANs, cellular systems, sensor networks, etc.) and the challenges therein **MODULE II:** The radio channel and wireless physical layer design. **MODULE III:** Medium access, multiplexing, link adaptation. **MODULE IV:** Multihop routing protocols, routing metrics. **MODULE V:** Multicast, multihop data forwarding, opportunistic routing. **MODULE VI:** Solutions to handle mobility at various layers of the networking stack. **MODULE VII:** TCP behavior over wireless, other transport layer issues. **MODULE VIII:** Energy efficiency, localization, security. **MODULE IX:** Smartphone-based platform architectures and applications. **MODULE X:** Future directions: dynamic spectrum access, heterogenuous networks, internet of things.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	**Textbook** ➢ Jochen Schiller, "Mobile Communications", second edition, Pearson education, 2008. **Papers and articles** ➢ Physical layer design and MIMO: 802.11 with Multiple Antennas for Dummies ➢ Wireless link characteristics: Link-level Measurements from an 802.11b Mesh Network ➢ Bit rate adaptation (SampleRate algorithm): Bit-rate Selection in Wireless Networks ➢ 802.11 link-layer throughput calculations: When Is 54 Not Equal to 54? A Look at 802.11a, b, and g Throughput ➢ A WiFi multicast proposal: DirCast: A Practical and Efficient Wi-Fi Multicast System ➢ Proposals to minimize energy spent in idle state in wireless networks. One deals with WiFi-like networks, and the other with cellular networks. Both papers have some interesting insights into energy consumption in practice. E-MiLi: Energy-Minimizing Idle Listening in Wireless Networks, RadioJockey: Mining Program Execution to Optimize Cellular Radio Usage. ➢ Mobile IP: Mobile Networking through Mobile IP. ➢ Multihop routing protocols: DSDV, DSR, AODV. ➢ Data transfer over multihop networks: Flush: A Reliable Bulk Transport Protocol for Multihop Wireless Networks, PIP: A Connection-Oriented, Multi-Hop, Multi-Channel TDMA-based MAC for High Throughput Bulk

		Transfer. ➢ Opportunistic routing: ExOR: Opportunistic MultiHop Routing for Wireless Networks, Trading Structure for Randomness in Wireless Opportunistic Routing. ➢ TCP performance over wireless links: A Comparison of Mechanisms for Improving TCP Performance over Wireless Links. ➢ Buffer bloat problem: Bufferbloat: Dark Buffers in the Internet. ➢ TCP buffer sizing: see section 2 of Sizing Router Buffers. ➢ Transport layer mobility schemes. MSOCKS: An Architecture for Transport Layer Mobility, Migrate: An End-to-End Approach to Host Mobility. ➢ Android architecture. Understanding Android Security and slides based on this tutorial. ➢ Energy saving techniques at the application layer. Energy profiling tool and case studies of popular apps: Fine Grained Energy Accounting on Smartphones with Eprof. Power consumption in browsers: Who Killed My Battery: Analyzing Mobile Browser Energy Consumption. Code offloading and remote execution: MAUI: Making Smartphones Last Longer with Code Offload.

1	**Code of the subject**	MTDC-9108
2	**Title of the subject**	Object Oriented Programming (OOPS) + Data Structures
3	**Any prerequisite**	None
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Santosh Singh Rathore
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ To investigate object-oriented methods including object-oriented programming, analysis and design. To reinforced the use of object-oriented features such as encapsulation, information hiding, inheritance and polymorphism.
8	**Brief Contents (module wise)**	**MODULE I:** Object oriented thinking: Need for OOP Paradigm, Procedural programming vs object oriented programming, object oriented concepts. Class and object concepts: specifying a class, Defining members inside and outside class, etc. **MODULE II:** Constructor and destructor concepts, Operator overloading and Type Conversion, Inheritance and polymorphism concepts. **MODULE III:** Templates: Class template, class template with parameter, function template, function template with parameter. Exception handling and STL. **MODULE IV:** Introduction to elementary data organization, arrays.Basic data structure concepts: Stack, queue, linked list, recursion, Searching, sorting, binary tree and file structure. **MODULE V:** Hashing, Huffman codes, heaps
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ HM Deitel and PJ Deitel "C++ How to Program", Seventh Edition, PrenticeHall 2010. ➢ Brian W. Kernighan and Dennis M. Ritchie, "The C programming Language", Prentice-Hall2006. ➢ Bjarne Stroustrup, "The C++ Programming language", Third edition, PearsonEducation, 2000. ➢ A. M. Tenenbaum, "Data Structures using C & C++", second edition, Prentice-Hall. ➢ Bruno R Preiss, "Data Structures and Algorithms with Object Oriented Design Pattern in C++", Jhon Wiley & Sons, Inc, 2008. ➢ GilbergForozan , "Data Structure – A pseudo code approach with C++", Cengage Learning, New Delhi.

1	**Code of the subject**	MTDC-9109
2	**Title of the subject**	Digital Signal Processing
3	**Any prerequisite**	Signals & Systems
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Vinal Patel
6	**Will this course require visiting faculty**	NA
7	**Learning Objectives of the subject (in about 50 words)**	➢ This course is designed to provide students with a comprehensive treatment of the important issues in design, implementation and applications of digital signal processing concepts and algorithms.
8	**Brief Contents (module wise)**	**MODULE I:** Sampling and Reconstruction of continuous time signals: Sampling theorem, Prefiltering to avoid aliasing, Frequency domain representation of sampling, Reconstruction of a band limited signal from its samples, Changing the sampling rate using discrete-time processing, Multirate signal processing. **MODULE II:** Characterization and properties of discrete time signals and systems: Discrete-Time sequences and systems, Properties of linear time-invariant systems, Linear convolution, Introduction of z-transform, Properties of the region of convergence of the z-transform, The inverse z-transform, Properties of the z-transform. **MODULE III:** Discrete Fourier transform (DFT) and its properties, Circular and linear convolution using the discrete Fourier transform, Efficient computation of the discrete Fourier transform, FFT algorithm, Decimation-in-Time and Decimation-in-Frequency FFT algorithm. **MODULE IV:** Digital filter design techniques: Design of Discrete-time IIR Filters from Continuous-time Filters: Impulse invariance method, Bilinear transformation, Design of FIR filters, constant group delay and its consequences, generalized linear phase filters, four types of linear phase FIR filters Type I - Type IV, frequency response expressions for Type I through Type IV filters.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Alan V. Oppenheim and Ronald W. Schafer, , "Discrete-Time Signal Processing", third edition, Prentice Hall, 2010, ➢ John G. Proakis and Dimitris K. Manolakis, "Digital Signal Processing" fourth edition, Prentice Hall, 2007, . ➢ SanjitMitra, "Digital Signal Processing"fourth edition, McGraw-Hill, New York, NY, 2011.

1	**Code of the subject**	MTDC-9110
2	**Title of the subject**	Modern Cryptography
3	**Any prerequisite**	NIL
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr Anuraj Singh
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ To develop a framework to understand and implement cryptographic aspects. ➢ To enhance an ability to analyze a problem, and identify and define the computing requirements for data security ➢ To prepare abstract and critical thinking background for computer science students
8	**Brief Contents (module wise)**	**MODULE I (INTRODUCTION):** Classical Encryption Techniques: Symmetric Cipher Model, Substitution Techniques, Transposition Techniques, Steganography, Security Attacks, Stream Cipher and Block Cipher **MODULE II (FINITE FIELDS AND NUMBER THEORY):** Groups, Rings, Fields, Modular Arithmetic, Euclid's Algorithm, Finite Fields Of Form GF (p) And GF (2^n).Polynomial Arithmetic, Prime Numbers, Fermat's And Euler's Theorem, Testing For Primality, The Chinese Remainder Theorem, Discrete Logarithms. **MODULE III (SYMMETRIC CIPHER):** Block Cipher Principles, Data Encryption Standard, Multiple Encryption, Triple Des, Advanced Encryption Standard (AES), Block Cipher Modes of Operation, Blowfish, RC5 Algorithm. **MODULE IV (PUBLIC KEY ENCRYPTION):** Principles Of Public Key Cryptosystems, The RSA Algorithm, Key Management, Diffie Hellman Key Exchange, Elgamal Encryption. Elliptic Curve Arithmetic, Elliptic Curve Cryptography. **MODULE V (CRYPTOGRAPHIC PROTOCOLS):** Authentication Requirement, Authentication Function, MAC, Hash Functions, Security of Hash Function , Digital Signatures, Authentication Protocols, SHA, MD5, SHA-1.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ William Stallings, "Cryptography and Network security", fourth edition, Prentice Hall of India, New Jersey, 2008. ➢ Christof Paar, Jan Pelzl, "Understanding Cryptography", Springer-Verlang, Berlin, 2010 ➢ Behrouz A Forouzan, "Cryptography and Network security", Tata Mc-Graw Hill, New York, 2007.

Programme: M Tech(DC)

1	**Code of the subject**	MTDC-9111
2	**Title of the subject**	Game Theory and its Application
3	**Any prerequisite**	Basic knowledge of Engineering Mathematics and Statistics
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr Ajay Kumar
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ To teach the applications of game theory, auction and equilibrium.
8	**Brief Contents (module wise)**	**MODULE I:** Introduction to Game Theory, Dominant Strategies and Nash Equilibrium, Alternate Strategies: Maximin, Maximax, and Minimax Regret Solvability, N-Player Games, Mixed Strategy Nash Equilibria, Subgame Perfection in Discrete Choice Games. **MODULE II:** Continuous Games and Imperfect Competition, Infinitely Repeated Games, Tacit Collusion: An application of Infinites Repeated Games, imperfect Information: Simultaneous-play, bayesian Games, Applications of Bayesian Games: Auctions and Voting, Cournot's Duopoly with Imperfect Information. **MODULE III:** Radio Spectrum, With Arbitrary Distribution of Valuations,Extensive Form Game with Perfect Information, Stackelberg Model of Duopoly, Buying Votes, Committee Decision-Making, Repeated games, The Prisoner's Dilemma, General Result, Supermodular Game and Potential Game, Supermodular Game and Potential Game. **MODULE IV:** Wireless Networks: Resource Allocations, Admission Control, Routing in Sensor and Ad-Hoc Networks, Modeling Network Traffic and Strategic Network Formation, Rubinstein Bargaining Model with Alternating Offers, Nash Bargaining Solution, Relation of Axiomatic and Strategic Model, Auction and Mechanism Design with Applications, Revenue Equivalence, Risk Averse Bidders, Asymmetries among Bidders, Mechanism, Optimal Mechanism.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Martin Osborne, "An Introduction to Game Theory", Oxford University Press, 2003 ➢ Prajit Dutta, "Strategies and Games", MIT Press 1999. ➢ K H Ericson, "Game Theory", Createspace Independent Publishing Platform.

1	**Code of the subject**	MTDC-9112
2	**Title of the subject**	Speech and Audio Signal Processing
3	**Any prerequisite**	Digital Signal Processing
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Vinal Patel
6	**Will this course require visiting faculty**	NA
7	**Learning Objectives of the subject (in about 50 words)**	➢ To learn the basic techniques for speech signal processing. After learning, students will understand Speech analysis, Speech coding, and Speech recognition. ➢ To understand a relevant set of concepts and techniques in the field of digital audio processing, and their application to problems arising from real applications.
8	**Brief Contents (module wise)**	**MODULE I:** Speech Fundamentals: Articulatory Phonetics – Production and Classification of Speech Sounds; Acoustic Phonetics – acoustics of speech production; Review of Digital Signal Processing concepts; Short-Time Fourier Transform, Filter-Bank and LPC Methods. **MODULE II:** Speech Analysis: Features, Feature Extraction and Pattern Comparison Techniques: Speech distortion measures – mathematical and perceptual – Log Spectral Distance, Cepstral Distances, Weighted Cepstral Distances and Filtering, Likelihood Distortions, Spectral Distortion using a Warped Frequency Scale, LPC, PLP and MFCC Coefficients, Time Alignment and Normalization – Dynamic Time Warping, Multiple Time – Alignment Paths, Time-scale and pitch modification Quadrature mirror filter (QMF), MP3 coding. **MODULE III:** Statistical models for speech recognition. Vector quantization models and applications in speaker recognition. Gaussian mixture modelling for speaker and speech recognition. Discrete and Continuous Hidden Markov modelling for isolated word and continuous speech recognition. Using the HTK toolkit for building a simple speech recognition system.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Lawrence Rabiner and Biing-Hwang Juang, “Fundamentals of Speech Recognition”, Pearson Education, 2003. ➢ Gold, B.; Morgan, N.; Ellis, D. “Speech and audio signal processing: processing and perception of speech and music”, second edition, Wiley-Blackwell, 2011.

1	**Code of the subject**	MTDC-9113
2	**Title of the subject**	Cognitive Radio
3	**Any prerequisite**	NO
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. PinkuRanjan
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ Know the basics of the software defined radios. ➢ Learn the design of the wireless networks based on the cognitive radios ➢ Understand the concepts of wireless networks and next generation networks
8	**Brief Contents (module wise)**	**MODULE I (INTRODUCTION TO SOFTWARE DEFINED RADIO):** Definitions and potential benefits, software radio architecture evolution, technology trade offs and architecture implications. **MODULE II (SDR ARCHITECTURE):** Essential functions of the software radio, basic SDR, hardware architecture, Computational processing resources, software architecture, top level component interfaces, interface topologies among plug and play modules, **MODULE III(INTRODUCTION TO COGNITIVE RADIOS):** Marking radio self-aware, cognitive techniques – position awareness, environment awareness in cognitive radios, optimization of radio resources, Artificial Intelligence Techniques. **MODULE IV (COGNITIVE RADIO ARCHITECTURE):** Cognitive Radio – functions, components and design rules, Cognition cycle – orient, plan, decide and act phases, Inference Hierarchy, Architecture maps, Building the Cognitive Radio Architecture on Software defined Radio Architecture **MODULE V (NEXT GENERATION WIRELESS NETWORKS):** The XG Network architecture, spectrum sensing, spectrum management, spectrum mobility, spectrum sharing, upper layer issues, cross – layer design.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Joseph MitolaIII,"Software Radio Architecture: Object-Oriented Approaches to Wireless System Engineering", John Wiley & Sons Ltd, 2000. ➢ Thomas W.Rondeau, Charles W. Bostain, "Artificial Intelligence in Wireless communication", ARTECH HOUSE ,2009. ➢ Bruce A. Fette, "Cognitive Radio Technology", Elsevier, 2009. ➢ Ian F. Akyildiz, Won – Yeol Lee, Mehmet C. Vuran, ShantidevMohanty, "Next generation / dynamic spectrum access / cognitive radio wireless networks: A Survey" Elsevier Computer Networks, 2006. ➢ Simon Haykin, "Cognitive Radio: Brain –Empowered Wireless Communications", IEEE Journal on selected areas in communications, 2005. ➢ HasariCelebi, HuseyinArslan, "Enabling Location and Environment Awareness in Cognitive Radios", Elsevier Computer Communications, 2008. ➢ Markus Dillinger, KambizMadani, Nancy Alonistioti, "Software Defined Radio", John Wiley, 2003. ➢ HuseyinArslan, "Cognitive Radio, SDR and Adaptive System", Springer, 2007. ➢ Alexander M. Wyglinski, Maziarnekovee, Y. Thomas Hu, "Cognitive Radio Communication and Networks", Elsevier, 2010.

1	**Code of the subject**	MTDC-9114
2	**Title of the subject**	Advanced Networks
3	**Any prerequisite**	Fundamentals of Computer Networks
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. K. K. Pattanaik
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ The course will help understand the system level details of the Internetworking technology, issues, and approaches.
8	**Brief Contents (module wise)**	**MODULE I:** Congestion Control and Resource Allocation Issues in resource allocation: Network model, Taxonomy and Evaluation of resource allocation mechanisms, Queuing concepts for allocating bandwidth and buffer at routers; In depth analysis of the behaviour of TCP congestion control; Congestion avoidance mechanisms: Tahoe, Reno, Vegas, and variants of these; Quality of service: Application requirements, Real-time audio case study; Taxonomy of real-time applications; Flowspecs; Reservation protocol, Differentiated services; Equation based congestion control. **MODULE II (APPLICATIONS):** Do applications need their own protocols?; Discussion on traditional protocols: SMTP, MIME, IMAP, HTTP, DNS, SNMP; Web Services: Custom application protocols (WSDL, SOAP), Defining application protocols, Transport protocols; REST architecture; Multimedia applications; Resource allocation for multimedia applications; Overlay networks; Case study: Gnutella, BitTorrent; Content distribution networks. **MODULE III(SOFTWARE DEFINED NETWORKS):** History and Evolution of Software Defined Networking (SDN): Separation of Control Plane and Data Plane, IETF Forces, Active Networking. Control and Data Plane Separation: Concepts, Advantages and Disadvantages, the OpenFlow protocol; **MODULE IV (CONTROL PLANE AND DATA PLANE):** Overview, Existing SDN Controllers including Floodlight and OpenDaylight projects; Customization of Control Plane: Switching and Firewall using SDN Concepts; Data Plane: Software-based and Hadrware-based Data plane; Programmable Network Hardware. **MODULE V (NETWORK VIRTUALIZATION)**Concepts, Applications, Existing Network Virtualization Framework (VMWare and others), Mininet based examples. **MODULE VI(Use Cases of SDNs):** Data Centers, Internet Exchange Points, Backbone Networks, Home Networks, Traffic Engineering.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Larry L. Petterson and Bruce S. Davie. , “Computer Networks ASytems Approach” Morgan Kaufmann publishers, 2007. ➢ Thomas D. Nadeau, Ken Gray, “SDN: Software Defined Networks, An Authoritative Review of NetworkProgrammability Technologies, O'Reilly Media, 2013. ➢ PaulGoransson and Chuck Black, “Software Defined Networks: A Comprehensive Approach”, Morgan Kaufmann publishers, 2016. ➢ Tiwari, Vivek. "SDN and OpenFlow for beginners with hands on labs." MMDD Multimedia LLC., , 2013.

1	**Code of the subject**	MTIS-9115
2	**Title of the subject**	IoT and its Security
3	**Any prerequisite**	Introduction to IoT
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. DebanjanSadhya
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ Deep dive into common IoT components and technologies to protect systems and devices. ➢ Learn current security issues related to the IoT and common security architectures. ➢ Identify Threats, Vulnerabilities and Risks. ➢ Discuss privacy regulations and standards that apply to securing IoT systems and keeping stakeholder information private.
8	**Brief Contents (module wise)**	**MODULE I:** IntroductiontoIoT Systems and Technologies: IoT Hardware and Software, IoT Communication and Messaging Protocols, IoT Interfaces and Services. **MODULE II:** An Introduction to IoT Security: Threats, Vulnerabilities and Risks, Case Study: The Mirai Botnet Opens up Pandora's Box, Today's Attack Vectors, Current IoT Security Regulations, Current IoT Privacy Regulations, Introduction to IoT Security Architectures. **MODULE III**: Conducting an IoT Threat Model: What is Threat Modeling, Identifying Assets, Creating a System Architecture, Documenting Threats, and Rating Threats. **MODULE IV**: Deep Dive on Privacy: IoT Privacy Concerns, Privacy by Design (PbD), Conducting a Privacy Impact Assessment (PIA), Case Study: The Connected Barbie **MODULE V**: Research trends.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Li Da Xu, Shancang Li, "Securing the Internet of Things", *Syngress*. 2017 ➢ Drew Van Duren, Brian Russell, "Practical Internet of Things Security", *Packt Publishing*, 2016. ➢ Edgar Weippl, "Internet of Things Security: Fundamentals, Techniques and Applications", *River Publishers 2018*.

1	**Code of the subject**	MTDC-9116
2	**Title of the subject**	RF Engineering for Wireless Networks
3	**Any prerequisite**	Wireless Networks
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. W. Wilfred Godfrey
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ To understand the basics of RF Engineering and to introduce the design of RF and microwave systems
8	**Brief Contents (module wise)**	**MODULE I (NETWORKS AND MATRICES):** Scattering and chain scattering matrices, Generalized scattering matrix, Analysis of two port networks,Interconnection of networks. Positive real concepts, scattering matrix, representationof microwavecomponents (directional coupler, circulators, hybrids and isolators). **MODULE II (HIGH FREQUENCY CIRCUIT DESIGN):** Tuned Circuits, Filter design-Butterworth filter, Chebyshev filter, impedance matching. High frequencyamplifier, BJT and FET amplifier, Broadband Amplifiers RF Oscillators, Colpitts, Hartley Oscillators, PLL. High Frequency Integrated Circuits. **MODULE III (MICROWAVE AMPLIFIER DESIGN):** Types of amplifiers, Power gain equations. Introduction to narrow band amplifiers basic concepts,Maximum gain design, Low noise design. High power design, Negative resistance, reflectionamplifiers –various kinds –stability considerations, Microwave transistor amplifier design –input and output matching networks – constant noise figure circuits. **MODULE IV (MICROWAVE TRANSISTOR OSCILLATOR DESIGN):** One port and two port negative resistance oscillators. Oscillator configurations, Oscillator design usinglarge signal measurements, Introduction to Microwave CAD packages, Microwave integrated circuits,MIC design for lumped elements. **MODULE V (RF AND MICROWAVE ANTENNAS):** Radiation from surface current and line current distribution, Basic Antenna parameters, Feedingstructure-Patch Antenna, Ring Antenna, Micro strip dipole, Micro strip arrays, Traveling wave Antenna, Antenna System for Mobile Radio-Antenna Measurements and Instrumentation.Propagation characteristics of RF and Microwave signals, Introduction to EBG structures.
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ Matthew M.Radmanesh, "RF and Microwave Design Essentials", Author House, Bloomington,2007. ➢ Daniel Dobkin, "RF Engineering for Wireless Networks", Elsevier, London, 2005. ➢ Reinhold Ludwig and Gene Bogdanov, "RF Circuit Design – Theory and Applications", second Edition,Pearson, 2012. ➢ E.da Silva, "High Frequency and Microwave Engineering", Butterworth Heinmann Publications,Oxford, 2001. ➢ David.M.Pozar, "Microwave Engineering", John Wiley and Sons,Third Edition, 2005. ➢ Kraus.J.D, Marhefka.R.J. Khan.A.S. "Antennas for All Applications", 3 rdEdition, Tata McGraw Hill,2006. ➢ Balanis. A, "Antenna Theory Analysis and Design", John Wiley and Sons, New York, Third Edition,2005.

1	**Code of the subject**	MTDC-9117
2	**Title of the subject**	Optimization Techniques
3	**Any prerequisite**	-
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Prof. Joydip Dhar
6	**Will this course require visiting faculty**	No
7	**Learning Objectives of the subject (in about 50 words)**	➢ This course covers elementary to research level for computer science and engineering. It emphasizes mathematical definitions, properties and proofs as well as applicable methods.
8	**Brief Contents (module wise)**	**MODULE I:** Introduction to Optimization Techniques, Nature &Characteristic, features of O.R., Models &Modeling in Operation Research. Methodology of O.R. Linear Programming - Mathematical Model, Assumptions of Linear Programming, Graphical Method, Principles of Simplex method and its Applications, Two Phase & Big M- method, Revised simplex method , Duality, Dual simplex method- Primal, Dual Relationship and sensitivity analysis. **MODULE II:** Linear Programming: Mathematical formation of linear programming problem, Special types of linear programming problems - Transportation and assignment problems, Unbalanced Assignment problems, Crew based assignment problems, Test for Optimality, Degeneracy in Transportation Problems, Unbalanced Transportation Problems. **MODULE III:** Definition of Probability, Sample Space, Algebra of Events, Addition and multiplication law of probability, Conditional Probability. Dynamic Programming-Features and applications of dynamic programming. **MODULE IV:** Decision Theory, Integer Programming, Gomory Method and Branch & Bound Method, Non-linear optimization, Recent development in non-linear optimization techniques
9	**Contents for lab (If applicable)**	-
10	**List of text books/references**	➢ Pronsen, Richard, "Theory and Problems of Operation Research," McGraw Hill, 1983. ➢ Hiller, F.S. &Liberman, G.J., "Introduction to Operations Research", second Edition. Holden 1974. ➢ Kapoor, V.K.: Operation Research, Sultan Chand & Co., New Delhi.

1	**Code of the subject**	MTDC-9118
2	**Title of the subject**	Microwave & Antennas
3	**Any prerequisite**	EM Theory and Transmission lines
4	**L-T-P**	3-0-0
5	**Name of the proposer**	Dr. Binod Prasad
6	**Will this course require visiting faculty**	NO
7	**Learning Objectives of the subject (in about 50 words)**	➢ To understand the applications of microwave engineering ➢ To learn about the performance of microwave tubes and devices ➢ To give insight of the radiation phenomena and a basic understanding of the radiation characteristics of different types of antennas
8	**Brief Contents (module wise)**	**MODULE I**: Introduction to microwaves, Microwave Frequency bands, Applications of microwaves.TE, TM and TEM Waves, Coaxial cable, Rectangular and circular waveguides, Rectangular waveguide cavity resonators, Circular waveguide cavity resonators. **MODULE II**: Introduction and applications of Impedance and Equivalent voltages and currents, Impedance, admittance, transmission and scattering matrix representations, Network matrices transformations, directional couplers and power dividers; Ferrite devices and circulators. **MODULE III**: Strip Lines,Scattering Matrix-Significance, formulation and properties. S-Matrix calculations for-2 port network junction, E plane, H-plane and E-H (Magic Tee) Tees, Directional coupler, Isolator and Circulator. **MODULE IV**: Microwave tubes: Limitations of conventional tubes, O and M type classification of microwave tubes, reentrant cavity, velocity modulation, Klystron amplifier, Reflex klystron oscillator, Magnetrons, Traveling wave tubes. **MODULE V**: Microwave solid-state devices: Microwave bipolar transistor, FET, MESFET, Varactor Diode, PIN Diode, Shottky Barrier Diode, Tunnel Diode, TEDs, Gunn Diodes, IMPATT diode and TRAPATT diode. **MODULE VI**: Introduction to antennas and its significance, review of electromagnetic fields Scalar electric potential, vector magnetic potential, radiation from an alternating current element, Induction field, radiation field power radiated by a current element, Definition of electric dipole and directional property, radiation resistance, basic antenna parameters. **MODULE VII**: Antennas array, Two Element Array, Linear Arrays, Multiplication of Patterns, Binomial Array, Antenna Gain, Effective Area, Reflector Antennas, Lens Antenna, Helical Antennas, Loop Antennas, Horn Antennas, Log periodic, Microstrip Antennas
9	**Contents for lab (If applicable)**	NA
10	**List of text books/references**	➢ S.Y.LIAO, “Microwave devices and circuits”, Third Edition, Prentice Hall of India, 1991. ➢ R.E.Collin, “Foundations for Microwave Engineering,”, Mc Graw Hill, second Edition, 2011. ➢ E.C. Jordan & K.G. Balmain, “Electromagnetic waves & Radiating Systems”, PHI, 2007.

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