ANNEXURE 2

M.Tech in Electronics and Communication Engineering (ECE)

Course Structure and Syllabus

Semester I

S.No.	Course Name		Credits
1	Mathematical Foundations for ECE	Core	4
2	Machine Learning	Core	4
3	Advanced Control Systems	Core	4
4	Analog Integrated Circuits	Core	4
5	RF and Microwave Components	Core	4

Semester II

S.No.	Course Name		Credits
1	Advanced Digital Signal Processing	Core	4
2	Elective-I	Elective	4
3	Elective-II	Elective	4
4	Elective III	Elective	4
5	Elective IV	Elective	4

Semester III

S.No.	Course Name		Credits
1	Academic Ethics and Technical Writing	Core	4
2	Research Methodology	Core	4
3	Research Reading and Laboratory	Core	4
4	Seminar	Core	4
5	Minor Dissertation	Core	8

Semester IV

S.No.	Course Name		Credits
1	Major Dissertation	Core	16

List of Electives Courses for M. Tech (ECE)

S.No.	Course Name	Credits
1.	Introduction to Quantum Computing	4
2.	Image Processing	4
3.	Nonlinear Dynamics	4
4.	Mobile Application Development	4
5.	Natural language Processing	4
6.	Deep Learning	4
7.	CAD for VLSI Design	4
8.	Embedded Systems	4
9.	Applied Antenna Technology	4
10.	CAD for RF and Microwave Passive Circuits	4
11.	Microstrip Components and Circuits	4
12.	Selected Topics on RF and Microwave Active Circuits for Communication System	4
13.	Detection and Estimation Theory	4
14.	Introduction to Trapped ion Dynamics	4
15.	Quantum Communication and Cryptography	4
16.	Basics of RF and Microwave	3
17.	Computational Electromagnetics	3
18.	RF and Microwave Passive Components	
19.	RF and microwave Active Circuits	3
20.	Advanced Microwave Measurement	4
21.	Advanced Antenna System	3
22.	RADAR System	3
23.	Introduction to RF MEMS	3
24.	Electromagnetic Interference/ Electromagnetic Compatibility	3
25.	Terahertz: Technology and Application	3
26.	Router and Switch Design and Analysis	4

Syllabus

Core Courses

1. Mathematical Foundations for ECE

Introduction to Probability, Random variables; Expectation, Variance, Moment generating function, Characteristic function; Bivariate and multivariate distributions - Joint, marginal and conditional distributions, Covariance, correlation, order statistics; Central limit theorem, Sampling distributions, Theory of Estimation, Maximum likelihood estimation, Testing of Hypotheses.

Fourier Analysis, including orthogonality of sinusoids, trigonometric and exponential forms of Fourier series, Fourier integrals and Fourier transforms; Laplace transform, z transform, Linear, Constant-Coefficient Differential Equations, Difference equations.

Matrices and their properties (determinants, traces, rank, nullity) Subspaces, hyperplanes, Linear Dependence and Span, Basis, Eigenvalues and eigenvectors; Matrix factorizations; Inner products; Distance measures; Projections.

Linear programming, Simplex method, Duality in linear programming, Convex optimization and Quadratic programming; Least squares optimization, Unconstrained optimization; Newton method, Gradient descent, Stochastic gradient descent and Conjugate gradient descent methods; Constrained optimization, KKT conditions.

Suggested Readings

- S. M. Ross, Probability Models, 11th Edition, Academic Press, 2014
- K. S. Trivedi, Probability and Statistics with Reliability, Queuing and Computer Science Applications, 2nd Edition, Wiley, 2004
- E. Kreyszig (with H. Kreyszig and E. Normington), Advanced Engineering mathematics, 10th Edition, Wiley, 2011.
- W Forst, D Hoffmann, Optimization—Theory and Practice, Springer-Verlag New York, 2010.

2. Machine Learning

Introduction to various machinelearning paradigms, Bayesian decision theory, Neural Networks: Linear and nonlinear discriminants using Perceptron and multilayer Perceptron, Introduction to Deep Learning-CNNs, Reinforcement Learning, Support vector machines. Unsupervised learning (clustering)& Decision Trees. Dimension reduction techniques & Genetic algos.

Suggested Readings

- Pattern Classification" by R. O. Duda, P. E. Hart and D. G.Stork.
- Pattern Recognition and Machine Learning by Christopher M. Bishop.
- An Introduction to Statistical Learning" by Gareth James, Daniela Witten, Trevor Hastie
- and Robert Tibshirani.

- Introduction to Machine Learning by Ethem Alpaydin, MIT Press, 2010.
- T.M. Mitchell, Machine Learning McGraw-Hill, 1997.
- S. Marsland, Machine learning: an algorithmic perspective, CRC Press, Taylor and Francis Group, 2015.
- Reinforcement Learning: An Introduction", Sutton and Barto, 2nd Edition.

3. Advanced Control Systems

Transient response-steady state response-Measures of performance of the standard first order and second order system-effect on an additional zero and an additional pole-steady error constant and system- type number-PID control-Analytical design for PD, PI,PID control systems. State variable representation-Conversion of state variable models to transfer functions-Conversion of transfer functions to state variable models-Solution of state equations-Concepts of Controllability and Observability-Stability of linear systems-Equivalence between transfer function and state variable representations-State variable analysis of digital control system-Digital control design using state feedback. Nonlinear Systems: common physical nonlinearities, phase plane methods, singular points, stability of nonlinear systems, phase trajectories, describing function, stability analysis of describing function, jump resonance.

Suggested Readings

- I. J. Nagrath and M. Gopal, Control Systems Engineering, New Age International Publishers
- Benjamin C. Kuo, Automatic Control Systems, Prentice Hall of India Publisher

4. Analog Integrated Circuits

Introduction to Analog Design, Basic MOS Device Physics: Structure, VI characteristics, Small-signal model, Biasing schemes; Single Stage Amplifiers: Common Source, Source Follower, Common Gate, Cascode; Differential Amplifiers: Basic Differential Pair, Common Mode Response, Differential Pair with MOS loads; Passive and Active Current Mirrors: Basic Current Mirror, Cascode Current Mirrors, Active Current Mirrors; Frequency Response of Amplifiers: CS stage, Miller Effect , Noise: Statistical Characteristic of noise, type of noise, representation of noise in circuits, Noise in single stage amplifiers/Differential pairs; Feedback Amplifiers: Properties of feedback circuits, and type of feedback topology, Nonlinearity, Oscillators: Ring, LC, and voltage controlled oscillators, Short channel effects and MOS Device modelling.

Suggested Readings

- Behzad Razavi, Design of Analog CMOS Integrated Circuits, Mc Graw Hill
- A.S. Sedra and K.C. Smith, Microelectronic Circuits, Saunder's College Publishing
- Paul R. Gray, and Robert G. Meyer, Analysis and Design of Analog Integrated Circuits, John Wiley.

5. RF and Microwave Components

Review of basic microwave theory: Transmission lines theory. Network analysis: Z, ABCD, Y, T and S-parameters. Impedance matching using Smith Chart: Lumped, Single stub, Double stub, Single section, Double section, quarter-wave transformer. Power Divider and Couplers:

Wilkinson Power Divider, Equal and unequal Power division, Branch line couplers, Rat-race couplers, directional coupler. Filters: lumped as well as distributed elements.
Microwave switches: series and shunt switches, Insertion loss and Isolation, Bandwidth Analysis of SPST (series and shunt switches), and SPDT (series and shunt configuration).
Implementation of RF and Microwave planar components such as transmission line, dividers, couplers and filters using simulators.
Familiarization of photolithography technique and fabrication of planar passive RF and microwave components. Measurement with Vector Network Analyzer.
Generalized S-parameters and Smith Chart basics. Review of RF switches, Microwave Phase shifters: Phase shifters types- Switched line, loaded line, hybrid coupled, low pass type, series and shunt type switched line phase shifters

Suggested Readings

- D. M. Pozar, Microwave Engineering, John Wiley, USA.
- T. C. Edwards et al, Microstrip Circuit Design, John Wiley, USA

6. Advanced Digital Signal Processing

Overview of Signal and Systems: Analog Signal Analysis, Overview of Digital Signal Processing, Basic Elements of a Digital Signal Processing System, Advantages of Digital Signal Processing, Classification of Signals, The Concept of Frequency in Continuous-Time and Discrete-Time Domain, Discrete-Time Signals and Systems, Analysis Of Discrete-Time Linear Shift-Invariant Systems, Linearity, Causality and Stability Criterion, Discrete-Time Systems Described by Difference Equations, Sampling and Reconstruction of Analog Signals. Discrete-time Fourier transform: The Fourier Transform of Discrete-Time Signals (DTFT), Properties of the DTFT, Frequency Response ff an LTI Discrete-Time System, Fourier Series of Discrete-Time Signals (DTFS). Discrete Fourier Transform: Frequency Domain Sampling and the DFT, Properties of the DFT, Linear Filtering Methods Based on the DFT, Efficient Computation of the DFT: Decimation-in-Time and Decimation-in Frequency Fast Fourier Transform Algorithms. Z Transform: Introduction to the Z-Transform, Inverse Z-Transform, Properties of the Z-Transform, Relationship Between the Fourier Transform and the Z-Transform, Rational Z-Transforms, the System Function, Analysis of Linear Time-Invariant Systems in the Z-Domain. Digital filter structures: Responses of Digital Filters, Realization of Digital Filters, Finite Impulse Response Filter Design, Infinite Impulse Response Filter Design, Digital Filter Categories, Realization, Structures for FIR and IIR Digital Filters, Representation of Numbers: Fixed-Point, Floating Point, Error Resulting from Rounding and Truncation. Digital filter design: Design of IIR filter from Analog filters: IIR filter design using approximation of derivative, Impulse Invariant method, Bilinear transformation; Design of linear phase FIR digital filters, Symmetry and Anti-symmetry FIR filters, FIR digital filter design using the windowing method and the frequency-sampling method.

List of Experiments:

- Explore multirate signal processing techniques.
- Study adaptive filtering techniques.
- Introduce wavelet transform and its applications.
- Explore statistical techniques in signal processing.
- Introduce compressed sensing principles.
- Study non-linear signal processing techniques.
- Integrate machine learning with DSP techniques.

- Explore advanced image processing techniques using DSP.
- Design and implement a real-time DSP system.

Suggested Readings

- Signals & Systems, A. V. Oppenheim, and A. S. Willsky, 2nd Edition, Prentice Hall, 1997
- Digital Signal Processing: Principles, Algorithms and Applications, John G. Proakis & Dimitris G. Manolakis, Pearson Education.
- Digital Signal Processing, Sanjit K. Mitra, Tata McGraw Hill Publication
- Discrete-Time Signal Processing, Alan Oppenheim, Ronald Schafer, 2009

7. Academic Ethics and Technical Writing

Significance and ways to carry out literature review; Structure and components of a research report, project proposal and research paper; Ethics: definition, moral philosophy, nature of moral judgements and reactions; Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP); Redundant publications: duplicate and overlapping publications, salami slicing; Selective reporting and misrepresentations of data; Publication ethics; Conflicts of interest; Publication misconduct and its identification; Violation of publication ethics, authorship and contributorship; Predatory publishers and journals; Open access and subscription based publications; Online resource to check publisher copyright and self-archiving policies; Journal finder tools; Conflict of interest; Plagiarism and its detection tools; Indexing and citation databases; Impact factor; h-index; g-index; i10 index etc.

Suggested Reading

- Ethics in Science Education, Research and Governance, Edited by K. Muralidhar, A. Ghosh, & A.K. Singhvi. New Delhi: Indian National Science Academy. ISBN: 9788193948217, 2019.
- Research Evaluation Metrics. UNESCO Curriculum for Researchers by U. Kanjilal and A.K. Das, ISBN: 978-92-3-100082-9, 2015.
- Concepts of openness and open access by D.P. Madalli, ISBN: 978-92-3-100079-9, 2015.

8. Research Methodology

Research: meaning, objective and types; Research process; Criteria of good research; Research problem: meaning, necessity to define and techniques involved in defining a research problem; Research design: meaning, need, characteristics and types; Sampling design: implications, steps, selection criteria, characteristics, types and concept of random sample; Measurement techniques: scales, source of errors, sound measurement and techniques of developing

measuring tools; Scaling techniques: meaning, classification, various scaling and scale construction techniques; Data collection techniques; Processing and analysis of data: processing operations, elements of analysis, statistics in research and regression analysis; Sampling: need, fundamental terminologies, sampling distributions sampling theories, estimation and sample size; Hypotheses testing: significance, procedure, various parametric tests; Chi-square test, ANOVA and Multivariate analysis techniques.

Suggested Reading

- Research Methodology: Methods and Techniques by C.R. Kothari, ISBN (13): 978-81-224-2488-1, 2nd Edition, 2004.
- Research design: Qualitative, Quantitative, and Mixed Methods Approaches by J.W. Creswell and J.D. Creswell, 5th Edition, 2019.
- Management Research Methodology: Integration of Principles, Methods and Techniques by K. N. Krishnaswamy, M. Mathirajan and Appa Iyer Sivakumar, 1st Edition, 2006.

9. Research Reading and Laboratory

The student will read research papers, and related thesis reports which are relevant to his/her area of work and any other technical or scientific literature which the supervisor may assign for a better understanding of the domain in which the student is pursuing his/her doctoral research work. The evaluation and assessment for this course will be conducted by the supervisor.

10. Seminar

The Seminar course would include seminars related to the dissertation work. This course would be evaluated by a seminar evaluation committee comprising atleast three faculty members.

11. Minor Dissertation

Student would pursue the minor dissertation in the school and submit it to the school for evaluation. The dissertation of each student is to be evaluated, through viva-voce/ presentation, by the minor-dissertation evaluation committee of the School.

12. Major Dissertation

Student would pursue the major dissertation in the school and submit it to the school for evaluation. The dissertation of each student is to be evaluated through viva-voce/ presentation in the school conducted by the committee comprising the supervisor and one external expert, from outside the university, in the related area, as recommended by the special committee of the School and approved by the Competent Authority of the University.

Elective Courses

1. Introduction to Quantum Computing

Introduction, Linear algebrs and the dirac notation: Overview, Computers and the Strong Church–Turing Thesis, The Circuit Model of Computation, A Linear Algebra Formulation of the Circuit Model, Reversible Computation, A Preview of Quantum Physics, Quantum Physics and Computation, The Dirac Notation and Hilbert Spaces, Dual Vectors, Operators, The Spectral Theorem, Functions of Operators, Tensor Products, The Schmidt Decomposition Theorem, Some Comments on the Dirac Notation. Qubits and the framework and the framework of quantum mechanics: The State of a Quantum System, Time-Evolution of a Closed System, Composite Systems, Measurement, Mixed States and General Quantum Operations, Mixed States, Partial Trace, General Quantum Operations, Quantum model of computation: The Quantum Circuit Model, Quantum Gates, 1-Qubit Gates, Controlled-U Gates, Universal Sets of Quantum Gates, Efficiency of Approximating Unitary Transformations, Implementing Measurements with Quantum Circuits. Superdense coding and quantum teleportation: Superdense Coding, Quantum Teleportation, An Application of Quantum Teleportation. Introductory quantum algorithms: Probabilistic Versus Quantum Algorithms, Phase Kick-Back, The Deutsch Algorithm, The Deutsch–Jozsa Algorithm, Simon's Algorithm. Algorithms with superpolynomial speed-up: Quantum Phase Estimation and the Quantum Fourier Transform, Error Analysis for Estimating Arbitrary Phases, Periodic States, GCD, LCM, the Extended Euclidean Algorithm, Eigenvalue Estimation, Finding-Orders, The Order-Finding Problem, Some Mathematical Preliminaries, The Eigenvalue Estimation Approach to Order Finding, Shor's Approach to Order Finding, Finding Discrete Logarithms, Hidden Subgroups, More on Quantum Fourier Transforms, Algorithm for the Finite Abelian Hidden Subgroup Problem, Related Algorithms and Techniques. Algorithms based on Amplitude amplification: Grover's Quantum Search Algorithm, Amplitude Amplification, Quantum Amplitude Estimation and Quantum Counting, Searching Without Knowing the Success Probability, Related Algorithms and Techniques

Suggested Readings

- Paul Kaye, Raymond Laflamme, and Michele Mosca, An Introduction to Quantum Computing, Oxford University Press (2007).
- Eleanor Rieffel and Wolfgang Polak, A Gentle Introduction to QUANTUM COMPUTING, MIT USA

2. Image Processing

Digital image fundamentals: basics of visual perception, image acquisition, image sampling and quantization, pixel relationships, Intro. to mathematical tools used in DIP, etc. Intensity transformation and spatial, gamma correction, histogram equalization and matching, spatial convolution, filter masks, image sharpening, Gabor filters, Intro. to bilateral filtering (supplement) etc. Color image processing: Color models, color transformations, color corrections, processing of color images, etc. Filtering in the frequency domain: Fourier transform of 2-D signals and sampling, the DFT in 1-D and 2-D and properties, image smoothing and sharpening in the frequency domain, frequency domain features, etc. Basics of Fourier Imaging, 2-D DSP topics based on additional textbooks: wavelets and filter-banks, 2-D filter design, etc. Image restoration and reconstruction: mean and order statistics filters, image degradation estimation, Wiener filtering, Intro. to regularization-based restoration (supplement), morphological image processing: Basic operations on binary images such as: dilation, erosion, opening and closing, various applications of morphological filters, etc., image segmentation: Edge detection and linking, thresholding, region-based segmentation, clustering

and super pixels, morphological watershed segmentation, etc. Feature extraction: binary image feature, region features, texture features, corner detection, etc.

Suggested Readings

- Fundamentals of Digital Image processing by A. K. Jain, Pearson Education
- Digital Image Processing by R. C. Gonzalez and R. E. Woods, Pearson Education

3. Nonlinear Dynamics

History of dynamics, importance of being nonlinear, formulation of dynamics using differential equations, state space representation, brief introduction of chaos and fractals.Flow along a line, fixed points and stability, impossibility of oscillations in one dimensional motion, concept of bifurcation: saddle node bifurcation, trans-critical bifurcation, pitchfork bifurcation, examples of bifurcations: laser threshold, insect outbreak. Introduction to two dimensional linear systems, definition and examples, classifications of linear systems, phase portraits, fixed point and linearization, conservative and reversible systems. Concept of limit cycles, ruling out closed orbits, Poincare-Bendixson theorem, applications: weakly nonlinear oscillators, relaxation oscillators, bifurcations revisited. Introduction to chaos, example of a chaotic waterwheel, simple properties of the Lorentz system, concept of strange attractor and chaos.

Suggested Readings

- S. Strogatz, Nonlinear Dynamics and Chaos. Reading, MA: Addison-Wesley, 1994. ISBN: 9780201543445.
- M. Lakshmanan, and S. Rajasekar, Nonlinear Dynamics: Integrability, Chaos and Patterns, Springer Verlag, 2003.

4. Mobile Application Development

History of Mobile-Mobile ecosystem, Mobile Information Architecture, Mobile Design, Types of mobile application, Brief discussion on Java Programming, API levels, Introduction to Android and IOS-Architecture, components and features. Tools for App development, creating your first project- Layouts, Views and Resources, Text and Scrolling Views, Activity Lifecycle and Saving State. Views-Text View, Edit Text Button, Radio Button, Check Box, Toggle, Switch, Chip, Time Picker, Date Picker, API-Components Basics: Activities, Services, Broadcast Receivers, Content Providers. Activities and Implicit Intents, User Input Controls Menus, Selection components (Grid View, List View, Spinner), Adapters, Custom Adapters, Complex UI components, Creating custom and compound Views. Notifications- Toast, Dialogs, Status bar Notifications. Android-Shared Preferences, Android File System- Internal storage, External storage, SQLite, IOS: local Storage and session Storage, Client-Side Database.

Suggested Readings

- App Programming Guide for iOS-Apple developer - 2014 Apple Inc
- Paul Deitel, Harvey Deitel, Android for programmers an app-driven approach Deitel developer series, Abbey Deitel, Michael Morgano-2012 Pearson Education, Inc.

5. Natural language Processing

Characteristics of Natural language – ambiguity, incompleteness, imprecision; Linguistic Essentials – Part of speech, Lexicography, morphology, Phrase structure grammar, theory, Semantics and pragmatics; Grammatical frameworks – Chomsky hierarchy, X-bar theory, LFG, Unification grammar, Knowledge Representations – Frames, Scripts, Conceptual graphs; Applications of Statistical Techniques - Word Sense Disambiguation, Lexical Acquisition, Markov Model for Part-of-speech tagging, Probabilistic CFG, Named Entities; Theories of Parsing, Parsing Algorithms - probabilistic and shallow parsing; Scope Ambiguity and Attachment Ambiguity resolution. Lexical Knowledge Networks, Wordnet Theory; Semantic Roles; Word Sense Disambiguation; Metaphors; Coreferences.Sentiment Analysis; Text Entailment; Robust and Scalable Machine Translation;Word vector embeddings, RNNs in language models, Vanishing gradient problem, Sequence to Sequence learning, Attention, Augmented RNNs, Transformers, Pretraining, Question Answering systems, Natural Language generation

Suggested Readings

- Manning D. Statistical Foundation of Natural language Processing, MIT Press, 1999.
- James A. Introduction to Natural Language Understanding, Addison Wesley, 1991.
- Harris M.D. Natural Language Processing, Benjamin/Cumming, 1991.

6. Deep Learning

Machine Learning: features, weights, Artificial Neural Network, loss function, cost function, ANN: forward propagation; Backpropagation, Stochastic Gradient Descent, Batch gradient descent, mini batch gradient descent, Optimisers: Momentum, RMSProp, Adam, Deep Learning Experiments: Datasets, training-validation testing set, Evaluation measures: accuracy, precision, recall, f-measure, Model Improvement: Overfitting vs underfitting, Bias vs Variance, Regularization: L1, L2 regularization, Dropout, Early stopping, Data normalization, Batch normalization, Hyper parameter Tuning: random, coarse to fine, Network architecture search. Imbalance data problem, Data Augmentation in image: Cropping, Flipping, Rotation, Brightness, Contrast, Color Augmentation, Saturation, Convolutional Neural Networks: convolution, striding, padding, pooling, Alexnet Architecture, Image classification (ImageNet Challenge), Well known CNN architectures VGG16&19, Residual Block, Resnet50, 1x1 convolution, XceptionNet, EfficientNet, Transfer learning, Object Detection: setup problem and cost function, well known datasets, Evaluation measure: Average precision, Mean average precision, Two stage detector, single stage detector, RCNN, Fast RCNN, Faster RCNN, SSD, YOLO1-4, RetinaNet, EfficientDet, Image Segmentation: setup problem and cost function, various dataset, Semantic segmentation, Instance segmentation, Evaluation measure: IoU/Jacard Index, Dice score, Mean pixel accuracy, Segnet, Unet, Mask R-CNN.Generative Learning, Variational Auto-encoders, Generative Adversarial Neural Networks, GL Applications: Image generation, font generation, video generation, anime face/celebrity face generation, Deep Reinforcement Learning, Markov decision Processing, Exploration vs Exploitation, Value Iteration vs Policy Iteration, RL Applications: Robotics, gaming, Ad Targeting, recommendation system, decision making, Model optimization for Deployment, Pruning, Quantization and binarization, Transferred or Compact Convolutional Filters, Knowledge distillation

Suggested Readings

- Ian Goodfellow, Yoshua Bengio, Aaron Courville and Yoshua Bengio, Deep learning. Vol. 1. C (1st ed.), Cambridge: MIT press, 2016. ISBN 978-0262035613.

- Aston Zhang, Zack C. Lipton, Mu Li and Alex J. Smola, Dive into Deep Learning (1st ed.), Corwin, 2019. ISBN 978-1544361376.

7. CAD for VLSI Design

Introduction to VLSI Design: Overview of VLSI technology, VLSI design flow, challenges. Verilog/VHDL: introduction and use in synthesis, modeling combinational and sequential logic, writing test benches.Logic synthesis: two-level and multilevel gate-level optimization tools, state assignment of finite state machines. Basic concepts of high-level synthesis: partitioning, scheduling, allocation and binding. Technology mapping.Synthesis of reversible logic circuits: Basic concepts of reversible circuits and synthesis. Exact, Transformation-based synthesis, and ESOP-based synthesis methods.Physical design and Verification. Review of MOS/CMOS fabrication technology. VLSI design styles: full-custom, standard-cell, gate-array and FPGA. Physical design automation algorithms: floor-planning, placement, routing, compaction, design rule check, power and delay estimation, clock and power routing, etc. Special considerations for analog and mixed-signal designs.

Suggested Readings

- Principles of CMOS VLSI Design, Systems Perspective, 1993. Neil H. E. Weste and Kamran Eshraghian.
- Basic VLSI Design, Prentice Hall of India, 1995. Douglas A Pucknell and Kamran Eshraghian.
- CMOS VLSI Design: A Circuits and Systems Perspective, Pearson Education, 2015. Neil H. E. Weste and David Money Harris.
- Contemporary logic design, Addison-Wesley Pub, 2005. R.H. Katz and Gaetano Borriello.
- Verilog VHDL synthesis: a practical primer, 1998. J. Bhasker.
- Algorithms for VLSI physical design automation, Kluwer Academic Publishers, 1995. N.A. Sherwani.Digital VLSI systems design, Springer, 2007. S. Ramachandran.

8. Embedded Systems

Basics of computer architecture and the binary number system: Basics of computer architecture, Computer languages, RISC and CISC architectures, Number systems, Number format conversions, Computer arithmetic, Units of memory capacity.Introduction to Embedded systems: Application domain of embedded systems, Desirable features and general characteristics of embedded systems, Model of an Embedded System, Microprocessor vs Microcontroller, Example of a Simple embedded system, Classification of Scum : 4/8/16/32 Bits, History of embedded systems, Current trends.Embedded Systems – The hardware point of view: Micro-controller Unit(MCU), Memory for embedded systems, Low power design, Pull-up and pull-down resistors. Sensors and Actuators: Sensors, Analog to Digital Converters, Actuators. Examples of Embedded Systems: Mobile Phone, Radio frequency identification(RFID), Biomedical Applications, Wireless sensor networks(WISENET), Robotics. Automated design of Digital IC's : History of integrated circuit(IC) design, Types of Digital IC's, ASIC design, ASIC design: the complete sequence.Real – time Operating Systems: Real-time tasks, Real-time systems, Types of Real-time tasks, Real-time operating systems, Real- time scheduling algorithms, Rate Monotonic Algorithm, The Earliest deadline first algorithm, Qualities of a Good RTOS. Hardware Software Co-design and Embedded

Product development lifestyle management: Hardware Software Co-design, Modeling of Systems, Embedded Product Development Lifecycle Management, Lifestyle Models.
Embedded Design: A Systems Perspective: A typical Example, Product Design, The Design Process, Testing, Bulk Manufacturing. Internet of Things: Sensing and Actuation From Devices, Communication Technologies, Multimedia Technologies, Circuit Switched Networks, Packet Switched Networks.

Suggested Readings

- Lyla B. Das, Embedded Systems: An Integrated Approach, Pearson
- Raj Kamal, Embedded Systems Architecture, Programming and Design, Tata Mcgraw Hill

9. Applied Antenna Technology

Antenna and Antenna performance parameters, Wire Antennas, discone & conical monopole, equiangular spiral antenna, fractal antenna concept & Technology, corrugated horn antenna, multimode horn antenna, smart antennas - benefit, drawbacks and design, adaptive beam forming, array theory, electrically small and large antennas. Lens antenna, electrically and physically small antennas, ground plane antenna, sleeve antenna, turnstile antenna, submerged antenna, surface wave and leaky wave antenna, Bluetooth antenna, rooftop antenna, rail antenna, embedded antenna, Radome design. Micro strip and planar antennas, various types of feeding methods for micro strip antennas, Analysis of rectangular patch antenna, cavity/model Expansion technique, Micro strip patch antenna array. Planar Antenna Array, scanning techniques, Feeding Networks for antenna arrays, Frequency scanned array design, Multi beam radiation patterns.

Suggested Readings

- Antenna theory- Analysis and Design, by C.A. Balanis, Wiley India Edition.
- Antenna, By J.D.Kraus & others, McGraw Hill-special India Edition.
- Phased Array Antennas, By R.C. Hansen, Wiley.

10. CAD for RF and Microwave Passive Circuits

Review of Basic RF and Microwave Theory, Study of Planar Micro strip Transmission lines. Smith chart analysis, Impedance matching technique. Network analysis: Z, ABCD, Y, T, S-parameters, Study of RF and Microwave Power Dividers: Branch line couplers, Wilkinson Power Divider, Directional coupler. Design of RF Filters (LPF, HPF, BPF)- lumped as well as distributed Study of RF Switches using PIN diodes- Single Pole Single Throw, Single Pole Double Throw Bandwidth Analysis of different switches.

Design Lab

- Familiarization with Impedance Matching Technique using SImulator
- Design and Study of Wilkinson Power Divider using Simulator
- Design and Study of Branch Line Coupler using Simulator
- Design and study of lumped element filters using Simulator
- Design and Study of distributed element filters using simulator
- Design and Study of RF switches using PIN diode using Simulator

Suggested Readings

- D. M. Pozar, Microwave Engineering, Wiley, 2011.
- B. Bhat and S. K. Koul, Strip line Like Transmission Lines for Microwave Integrated Circuits, New Age Intl. Pvt. Ltd., 2007.
- Key sight Technologies Application Notes.

11. Micro strip Components and Circuits

Methods of Micro strip Analysis, Losses, Transmission, and reflection characteristics. Slot line and coplanar waveguide coupled micro strip line and direction coupler Branch line couplers, Impedance transformers, power dividers, circulators, isolators Micro strip filtered and antennas, lumped and distributed components, Micro strip design technology.

Suggested Readings

- Foundation of Micro strip Circuit Design, by T.C. Edwards, Wiley & Sons.
- Micro strip filters for RF/Microwave applications, by Hong & Lancaster, Wiley & Sons.
- Micro strip Circuits, By Feed Gardiol, Wiley & Sons.

12. Selected Topics on RF and Microwave Active Circuits for Communication System

Microwave Amplifier Theory and Design, Stability Analysis, Gain Analysis, Linearity Analysis, Noise Figure Analysis. Study and Design of Low Noise Amplifier, Power Amplifier using simulator. Analysis of Mixer Circuits. Discussion on latest research undergoing in the above mentioned areas.

Suggested Readings

- G. Gonzales, Microwave Transistor Amplifiers, Prentice Hall, 1996
- S. A. Maas, Nonlinear Microwave and RF Circuits, Artech, 2003
- B.Bhat and S.K.Koul, Stripline Like Transmission Lines For Microwave Integrated Circuits –New Age Intl. Pvt Ltd., 2007.
- Research papers from IEEE and other good quality journals.

13. Detection and Estimation Theory

Introduction: Review of Gaussian Variables and Processes; Problem Formulation and Objective of Signal Detection and Signal Parameter Estimation in Discrete-Time Domain. Statistical Decision Theory: Bayesian, Min-Max, and Neyman-Pearson Decision Rules, Likelihood Ratio, Receiver Operating Characteristics, Composite Hypothesis Testing, Locally Optimum Tests, Detector Comparison Techniques, Asymptotic Relative Efficiency. Detection of Deterministic Signals: Matched Filter Detector and its Performance; Generalized Matched Filter; Detection of Sinusoid with Unknown Amplitude, Phase, Frequency and Arrival Time, Linear Model. Detection of Random Signals: Estimator-Correlator, Linear Model, General Gaussian Detection, Detection of Gaussian Random Signal with Unknown Parameters, Weak Signal Detection. Estimation of Signal Parameters :Minimum Variance Unbiased Estimation, Fisher Information Matrix, Cramer-Rao Bound, Sufficient Statistics, Minimum Statistics, Complete Statistics; Linear Models; Best Linear Unbiased Estimation; Maximum Likelihood Estimation, Invariance Principle; Estimation Efficiency; Bayesian Estimation: Philosophy, Nuisance Parameters, Risk Functions, Minimum Mean Square Error Estimation, Maximum Aposteriori Estimation.

Suggested Readings

- Detection, Estimation and Modulation Theory: Part I, II, and III by H. L. Van Trees, John Wiley, NY, 1968.
- An Introduction to Signal Detection and Estimation by H. V. Poor, Springer, 2/e, 1998. Fundamentals of Statistical Signal Processing: Estimation Theory by S. M. Kay, Prentice Hall PTR, 1993.
- Fundamentals of Statistical Signal Processing: Detection Theory by S. M. Kay, Prentice Hall PTR, 1998.

14. Introduction to Trapped ion Dynamics

History of trapped ion dynamics, concept behind ion trapping, construction and working of Paul and Penning traps, trap analysis in some contemporary traps. Introduction to methods of harmonic balance, perturbation techniques such as LP and MLP methods, formulation of equation of motion: Mathieu equation, solution of the Mathieu equation for charged particle dynamics. The concept of micromotion and excess micromotion inside Paul trap, dynamics in presence of excess micromotion, concept of multipoles inside Paul trap, dynamics, and related phenomena on account of hexapole, octopole fields. State space decomposition of ordinary differential equations, simulation of trajectories and phase portraits for linear and nonlinear Paul traps.

Suggested Readings

- M. Knoop, N. Madsen and R. C. Thompson, Physics with trapped charged particles
- l. Nayfeh, Perturbation Methods, Wiley.

15. **Quantum Communication and Cryptography**

Introduction to quantum communication: quantum. Networks, difference between classical and quantum networks, overview of the current quantum networks deployed, Photon polarization: Maxwell's equations, applications of polarization in quantum networks, Composite quantum networks, Nonlinear and Quantum Optical Sources, CASCADE Algorithm, Quantum entanglement and teleportation, experimental quantum teleportation, no cloning theorem, Information Theory, Components from Broadband QKD (Quantum Key Distribution) and Implementation, Review of classical cryptography, quantum public key encryption, digital hash functions, key exchange protocols, MACs, quantum error correcting codes.

Suggested Readings:

- Daniel J. Rogers, Broadband Quantum Cryptography, Springer International Publishing, 2020
- Thomas Vidick, Stephanie Wehner, Introduction to Quantum Cryptography, Cambridge University Press, 2023
- Federico Grasselli, Quantum Cryptography: From Key Distribution to Conference Key Agreement, Springer International Publishing, 2021
- Ramona Wolf, Quantum Key Distribution: An Introduction with Exercises, Springer International Publishing, 2021
- Daniel J. Bernstein, J. Buchman, E. Dahmen, Post-Quantum Cryptograph

16. Basics of RF and Microwave

Basics of Electromagnetic Waves: Electromagnetic spectrum, RF and Microwave region and band designations, applications of RF and Microwaves. Maxwell equations, plane waves and scattering, TEM mode, waveguide TE and TM Modes modes, Cavity resonator, Dielectric resonator, Fourier series and transform, autocorrelation and power spectral density, holes and electrons in semiconductors, p-n junction. Basic Transmission line parameters: Lumped and distributed circuits, Transmission lines - propagation characteristics, reflection coefficient, VSWR, power, return loss, insertion loss, scattering parameters and Smith chart applications to RF and Microwave. Introduction of various transmission lines like two conductor line, coaxial line, Microstrip line, coplanar waveguide (CPW), slotline, Rectangular and Circular waveguides.

Suggested Readings

- Electromagnetics with Applications by John Kraus, Daniel Fleisch
- Microwave Engineering by D. M. Pozar
- Microwave Devices and Circuits by Samuel Y. Liao
- Foundations of Interconnect and Microstrip Design by T. C. Edwards and M. B. Steer

17. Computational Electromagnetics

Introduction to Computational Electromagnetics and Mathematical Preliminaries: Review of vector calculus: chain rule, gradient, divergence, curl operations; common theorems in vector calculus; Maxwell equations: regimes, methods of solving, boundary conditions; uniqueness and equivalence theorem. Interpolation, numerical integration, integral equation: line charge, basic methods; basis functions; Helmholtz equation. Huygen's principle & extinction theorem; surface integral equations: formulation; Green's function: motivation, 1D, 2D, 3D formulations with example.
Method of moments: Motivation; linear vector spaces; formulation of MoM; surface integral equations; volume integral equations, PEC: formulation, setting up of surface integral equations; radar cross section: definition, computational considerations.
Finite element method: Motivation; Basic framework; basis function in 1D, 2D; weak form; generating system of equation; 1D wave equation; 2D shape functions; radiation boundary condition; total fieldscatter field formulation; matrix assembly; far field calculations; numerical considerations.
Finite difference time domain: Motivation; 1D, 2D, 3D formulations; stability criteria(s); dispersive media; absorbing boundary condition; perfectly matched layer; boundary conditions; sources in FDTD, brief introduction to MEEP.
Applications of computational techniques: Inverse problems; Hertz dipole & antenna; radiation pattern; Pocklington's integral equation; source & circuit modelling of antenna; mutual coupling in antenna; hybrid methods.

Suggested Readings

- Computational methods for electromagnetics – Peterson, Ray, Mitra, IEEE Press.
- Advanced Engineering Electromagnetics – C A Balanis, Wiley India.
- Waves and fields in inhomogeneous media- W. C. Chew, IEEE Press.
- Finite Element Method for Electromagnetics: Antennas, Microwave Circuits and Scattering
- Applications – Volakis, Chaterjee and Kempel, Wiley.

18. RF and Microwave Passive Components

Review of basic microwave theory: Transmission lines theory. Network analysis: Z, ABCD, Y, T and S parameters. Impedance matching using Smith Chart: Lumped, Single stub, Double stub, Single section, Double section, quarter-wave transformer. Power Divider and Couplers: Wilkinson Power Divider, Equal and unequal Power division, Branch line couplers, Rat-race couplers, directional coupler. Filters: lumped as well as distributed elements. Implementation of RF and Microwave planar components such as transmission line, dividers, couplers and filters using simulators. Familiarization of photolithography technique and fabrication of planar passive RF and microwave components. Measurement with Vector Network Analyzer.

Suggested Readings

- D. M. Pozar, Microwave Engineering, John Wiley, USA.
- T. C. Edwards et al, Microstrip Circuit Design, John Wiley, USA

19. RF and Microwave Active Circuits

Generalized S-parameters and Smith Chart basics. Microwave switches: series and shunt switches, Insertion loss and Isolation. Microwave Phase shifters: Phase shifters types-Switched line, loaded line, hybrid coupled, low pass type, series and shunt type switched line phase shifters. Small signal amplifiers: Derivation of expression for gain, input/output reflection coefficients, Impedance matching, Low Noise Maximum Gain, Stability, Narrow band Design, Broadband Design, Noise Analysis, Power amplifiers. Microwave Mixers: Single ended, Balanced mixers. Microwave Oscillators.

Suggested Readings

- Shiban K Koul and B. Bhat, Microwave Phase shifters, Volume-I and II, Artech House, USA
- T. T. Ha, Microwave Amplifier Design, John Wiley, USA
- G. Gonzales, Microwave. Transistor Amplifiers, Prentice Hall, USA
- S. A. Maas, Nonlinear Microwave and RF Circuits, Artech, 2003.
- S. Cripps, RF Power Amplifiers for Wireless Communication.
- D. M. Pozar, Microwave Engineering, John Wiley, USA.

20. Advanced Microwave Measurement

Theory of operation of network analyzer, VNA calibration, TRL calibration, SOLT calibration, spectrum analyzer measurement, synthesized signal generation, noise measurements, dielectric measurement. Antenna Measurement Techniques: Antenna Range, Radiation Pattern, Gain Measurement, Directivity Measurement, Radiation Efficiency, Impedance Measurement, and Polarization Measurement. Nonlinear Functions, large-signal parameters, Large-signal-response measurements, nonlinear circuits measurements (power amplifier and mixer), X-parameters.

Suggested Readings

- Basu ‘Introduction to Microwave Measurements,’ CRC Press 2014.
- Keysight Technologies Application Notes.
- C.A. Balanis, ‘Antenna Theory - Analysis and Design’, John Wiley-India Edition, 2005.

21. Advanced Antenna Systems

Fundamentals of Antenna, Antenna Radiation Hazards, Dipole Antennas, Monopole Antennas, Loop Antennas, Slot Antennas, Linear and Planar Arrays, Microstrip Antennas (MSA), Rectangular MSA, MSA Parametric Analysis, Circular MSA, :Broadband MSA, Compact MSA, Tuneable MSA, :Circularly Polarized MSA, MSA Arrays, MIMO Antenna, Helical Antennas, Horn Antennas, Yagi-Uda & LogPeriodic Antennas, Reflector Antennas, Smart Antennas, Adaptive Beam.

Suggested Readings

- J.D. Kraus, Antennas, McGraw Hill, 1988.
- C.A. Balanis, Antenna Theory - Analysis and Design, John Wiley, 1982.
- R.E. Collin, Antennas and Radio Wave Propagation, McGraw Hill, 1985.
- I.J. Bahl and P. Bhartia, Micro Strip Antennas, Artech House,1980.
- R.E. Crompton, Adaptive Antennas, John Wiley

22. RADAR Systems

Radar theory, different types of radars, Radar signal analysis for range accuracy and resolution. Radar signal detection and estimation techniques, clutter and noise suppression, propagational characteristics over land and sea. Electronic counter measure.

Suggested Readings

- M. I. Skolnik, Introduction to Radar Systems, McGraw Hill, 1980.
- D. K. Barton, Modern radar systems analysis, Artech House, 1988.
- B. Edde, Radar: Principles, Technology, Applications, Prentice Hall, 1993.

23. Introduction to RF MEMS

Introduction, origin and driving force for MEMS and BioMEMS basics; extension of IC technologies for MEMS fabrication, major technologies for MEMSL: bulk and surface micromachining, LIGA process anisotropic etching of silicon, piezoresistive -piezoelectric effect, peizo-resistive silicon based pressure sensor, capacitive pressure sensor, RF switch design, fabrication and characterization, actuation in MEMS, MEMS accelerometer design, fabrication, vibration sensor, energy harvesting devices, piezoelectric materials for MEMS, MEMS based RF and microwave circuits.

Suggested Readings

- Stephen D Santuria, Microsystem Design, Kluwer Academic, 2001
- Marc J. Madou, Fundamentals of Microfabrication, CRC Press, 1997
- Hector J. De Los Santos, "RF MEMS Circuit Design for Wireless Applications", Artech House, 2002
- Tai-Ran Hsu MEMS & Microsystem, Design and manufacture, McGraw Hill

24. Electromagnetic Interference/Electro-magnetic Compatibility

Basic Theory: Intra and inter system EMI, Elements of Interference: Conducted and Radiated EMI emission and susceptibility, EMC Engineering Application. Coupling Mechanism: Coupling paths, Coupling via the supply network, Common mode coupling, Differential mode coupling, Impedance coupling, Radiative coupling, Ground loop coupling, Cable related emissions and coupling, Transient sources, Automotive transients. Categorization of the electromagnetic interference: emission, susceptibility, transients, crosstalk, shielding and

compatibility, signal integrity. EMI mitigation techniques: Working principle of Shielding, LF Magnetic shielding, Apertures and shielding effectiveness, Choice of Materials for H, E, and free space fields, Gasketting and sealing, PCB Level shielding, Principle of Grounding. Standards and Regulations: Need for Standards, EMI Standardizing for different application. EMI Test Methods and Instrumentation: Fundamental considerations, EMI Shielding effectiveness tests, Open field test, TEM cell for immunity test, Shielded chamber, Shielded anechoic chamber, EMI test receivers, Spectrum analyser, EMI test wave simulators, EMI coupling networks, Line impedance stabilization networks, Feed through capacitors, Antennas, Current probes. Basics of biological effects of EM waves: Ionizing and non-ionizing radiation. Theoretic and diagnostic use of EM waves. Measurement techniques of EM radiation. Protective design techniques.

Suggested Readings

- Henry W. Ott, "Electromagnetic Compatibility Engineering", John Wiley & Sons Inc Newyork, 2009.
- Daryl Gerke and William Kimmel, "EDN Designers Guide to Electromagnetic Compatibility", Elsevier Science & Technology Books, 2002.
- W Scott Bennett, "Control and Measurement of Unintentional Electromagnetic Radiation", John Wiley & Sons Inc., (Wiley Interscience Series) 1997.
- Dr Kenneth L Kaiser, "The Electromagnetic Compatibility Handbook", CRC Press 2005.
- Paul, C.R., "Introduction to Electromagnetic Compatibility", 2nd ed., Wiley (2010).
- David K. Cheng, "Field and Wave Electromagnetics" 2nd ed. Pearson Education, (2009).

25. Terahertz: Technology and Applications

Basic THz Terminologies. Physical Principles of THz Interaction with Matter. Electromagnetic Waves in Matter. THz Radiation and Elementary Excitations. Laser Basics. THz Detectors and Sources. Ultrafast Optics. THz Emitters and Detectors based on Photoconductive Antennas. Optical Rectification. Freespace Electro-optic Sampling. Ultrabroadband Terahertz Pulses. Terahertz Radiation from Electron Accelerators. Novel Techniques for Generating Terahertz Pulses. Continuous-Wave Terahertz Sources and Detectors. Photomixing. Difference Frequency Generation and Parametric Amplification. FarInfrared Gas Lasers. P-Type Germanium Lasers. Frequency Multiplication of Microwaves. Quantum Cascade Lasers. Backward Wave Oscillators. Free-Electron Lasers. Thermal Detectors: Bolometers, Pyroelectric Detectors, Golay Cells. Heterodyne Receivers. Terahertz Optics.Dielectric Properties of Solids in the Terahertz Region. Materials for Terahertz Optics. Optical Components. Terahertz Waveguides. Artificial Materials at Terahertz Frequencies. Terahertz Phonon-Polaritons Imaging with Broadband THz Pulses. Imaging with Continuous-Wave THz Radiation. Millimeter-Wave Imaging for Security. Medical Applications of T-Ray Imaging. Concealed Objects Real-Time Imaging for Security. Compact wireless technologies. Terahertz ultrafast wireless communications. Short distance ultrabroadband communication. THz communication for space applications. THz Energy Harvesting - Rectification concept and technological challenges. Design and development of nano-rectennas. Fabrication and measurement techniques.

Suggested Readings

- Yun-Shik Lee, Principles of Terahertz Science and Technology, Springer 2009.
- Erik Bründermann, et al., Terahertz Techniques, Springer 2012.
- R. A. Lewis, Terahertz Physics, Cambridge University Press 2012.
- Ali Rostami, Hassan Rasooli, and Hamed Baghban, Terahertz Technology: Fundamentals and Applications, Springer 2010.

26. Router and Switch Design and Analysis

Basics of computer networks, TCP/IP protocol stack, switching, switching and bridging, interconnecting LANs, learning switches, spanning trees, switches vs routers, buffer sizing, routing, interdomain and intradomain routing, routing algorithms and protocols, RIP, OSPF, BGP, IP addressing, classless interdomain, longest prefix match, NAT, IPv6, IPv4 to IPv6, IPv6 routing table entries, router design, basic router architecture, crossbar switching, scheduling and fairness, max-min fairness, router as DHCP server, SNMP, traffic engineering, measuring, modelling and controlling traffic, Queuing Models, SDN, Programming of SDN, router attacks and security, Firewall, DNS security.

Suggested Readings:

- Computer Networks by A.S. Tanenbaum, Prentice Hall of India.
- Computer Networking: A Top-Down Approach Featuring the Internet by J. Kurose and K.W.
  Ross, Addison-Wesley.
- Anurag Kumar, D. Manjunath and Joy Kuri, Communication Networking: Analytical approach, Elsevier, 2004.
- I. Kaj, Stochastic Modeling in Broadband Communications Systems, SIAM, 2002