# SYLLABUS OF COURSE WORK

**OF**

## DOCTOR OF PHILOSOPHY

**Department of Electronics and Communication Engineering**

(Faculty of Science & Technology)

Aliah University

IIA/27, Newtown, Kolkata 700160, West Bengal, India

# Contents

| Course Code | Course Title | Credit |
|---|---|---|
| PHD/RM-01 | Research Methodology | 04 |
| PHD/RPE-02 | Research and Publication Ethics | 02 |
| PHD/LR-03 | Literature Review, Report and Seminar Presentation | 04 |
| PHD/SP-04 | Subject Paper (.....) | 04 |

# Detailed Syllabi

**Course name: Research Methodology**
**Course code: PHD/RM-01; Credit: 4**
**Lecture: 40**

**Identification of the Problem:** Identifying and design/formulating the problem.

**Solving the problem:**
a) Analytical methods
b) Numerically solving
c) Simulation by computer programming
d) Experimental observations
e) Theoretical modeling

**Developing a research plan:** Objective; Steps for solving the problem; Description of approach, Stating any assumptions; Details of techniques

**Data collection:** Experimental data, field data, theoretically obtained data

**Analyzing data:** Error analysis, statistical analysis

**Computational approach:**
1. Literature survey: Using web, handling search engines
2. Computer usage: For collecting/analyzing data; simulations; graphical and pictorial representation.
3. Preparing presentations:
i) Research papers: Using word processing software – MS Word/Latex/others, Drawing graphs and diagrams – Origin/Excel/ChemDraw/Photoshop/Others.
ii) Seminar presentations – Power point for oral and poster presentations

**Text/Reference Books:**


1. Dawson, Catherine, 2002, Practical Research Methods, New Delhi, UBS Publishers'Distributors

2. Kothari, C.R.,1985, Research Methodology- Methods and Techniques, New Delhi, Wiley Eastern Limited.

3.Kumar, Ranjit, 2005, Research Methodology-A Step-by-Step Guide for Beginners,(2nd.ed.),Singapore, Pearson Education.

**Course name: Research and Publication Ethics**
**Course code: PHD/RPE-02; Credit: 2**
**Lecture: 20**

**PHILOSOPHY AND ETHICS**

1. Introduction to philosophy: definition, nature and scope, concept, branches
2. Ethics: definition, moral philosophy, nature of moral judgements and reactions

**SCIENTIFICCONDUCT**

1. Ethics with respect to science and research
2. Intellectual honesty and research integrity
3. Scientific misconducts: Falsification, Fabrication, and Plagiarism(FFP)
4. Redundant publications: duplicate and overlapping publications, salami slicing
5. Selective reporting and misrepresentation of data

**PUBLICATION ETHICS**

1. Publication ethics: definition, introduction and importance
2. Best practices / standards setting initiatives and guidelines: COPE, WAME, etc.
3. Conflicts of interest
4. Publication misconduct: definition, concept, problems that lead to unethical behavior and vice versa, types
5. Violation of publication ethics, authorship and contributorship
6. Identification of publication misconduct, complaints and appeals
7. Predatory publishers and journals

**OPEN ACCESS PUBLISHING**

1. Open access publications and initiatives
2. SHERPA/RoMEO online resource to check publisher copyright & self-archiving policies
3. Software tool to identify predatory publications developed by SPPU
4. Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

**PUBLICATION MISCONDUCT**

**A.** Group Discussions (2 hrs.)

1. Subject specific ethical issues, FFP, authorship
2. Conflicts of interest
3. Complaints and appeals: examples and fraud from India and abroad

**B.** Software tools (2 hrs.)

Use of plagiarism software like Tumitin, Urkund and other open source software tools

**DATABASES AND RESEARCH METRICS**

**A.** Databases (4 hrs.)

1. Indexing databases
2. Citation databases: Web of Science, Scopus, etc.

**B.** Research Metrics (3 hrs.)

1. Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score
2. Metrics: h-index, g index, i10 index, altmetrics

**Book: ACADEMIC INTEGRITY AND RESEARCH QUALITY by UGC**

**Course name: Literature Review, Report and Seminar Presentation**
**Course code: PHD/LR-03; Credit: 4**
**Lecture: 40**

The relevance of the research project from perspective of the subject.
Detailed review of state of the art.
Scope of the work.
Significance of the project.
Expected outcome.

**Course name: Subject Paper (Microwave Devices, Circuits and Antenna)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

Overview of Gunn devices, oscillator using Gunn diode, PIN diode, IMPATT devices, Klystron, and microwave and mm wave performance of IMPATT and TRAPAT

Review of scattering matrix concept in the light of vector network analyzer, impedance matching network, couplers, power dividers, resonators and filters, Detectors, mixers, attenuators

Different Types of feed Technology: Probe feed, Slot coupled microstrip feed, coplanar feed. Different Types of CPW feed: Inductive, capacitive, square and circular feed. Advance antennas for communication system: Dielectric resonator antenna (DRA), Metamaterial in antenna, Microstrip antenna, Smart antenna, Conformal antenna.

Overview of basic radio wave propagation mechanisms, Friis transmission formula, microwave radio link and calculation of link budget. Effect on radio wave propagation due to rain, fog, snow, ice, atmospheric gases, Earth's magnetic field.

Measurement of Wavelength, Frequency and Impedance-Introduction, Equivalent circuit of Cavity wave meters, Typical wave meters, resonant cavities, Methods of frequency measurements-direct method - Interpolation method, Standard wave reflectors, Measurement of reflection coefficient, Low, Medium, High VSWR measurements, Standing wave pattern, Slotted Line section and its limitation, Impedance measurement techniques, Reflectometer.

**Books**

1. David M Pozar, Microwave Engineering, John Wiley & Sons

2. R E Collin, Antenna & Radio wave Propagation, McGraw Hill Book Co.
3. Jordan & Balman, Electromagnetic waves & Radiating System
4. R E Collin, Microwave Engineering, McGraw Hill CO.

**Course name: Subject Paper (Phased Array Antenna System)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

Introduction, System Requirements for Radar and Communication Antennas, Array Characterization for Radar and Communication Systems, Array Architecture and Control Technology

Linear and Planar arrays, various grid configurations, Concept of cell and grid, Calculation of minimum number of elements, Radiation pattern, Grating lobe formation, Rectangular and triangular grid design of arrays

Corporate Feed, Lens and Reflect feed Techniques, Optimum f/d ratio, basic building block for corporate feed network, Series, Parallel feed networks, Comparison of various feeding techniques, Antenna Array Architecture, Brick/ Tile Type construction.

Snake feed, Frequency-phase scanning, Phase scanning, Digital phase shifter PIN diode and Ferrite phase shifters for phased arrays, Beam pointing errors due to digitization, Beam pointing accuracy.

Calculation of search frame time, airborne phased array design, electronic scanning radar, parameter calculation, Application of phased arrays, Phased Array Radar Systems, Active Phased Array, TR/ATR Modules.

**BOOKS:**

1. Robert J. Mailloux, "Phased Array Antenna Hand Book", Artech House, Boston, London, 1994
2. Olliner, A.A, and G.H. Knittel, "Phased Array Antennas", Artech House, 1972.
3. Kahrilas. PJ, "Electronic Scanning Radar Systems Design Handbook", Artech House, 1976.
4. Skolnik. MI, "Radar Handbook", Mc Graw Hill, NY, Mc Graw Hills-2007
5. Galati,G-(editor), "Advanced Radar Technique and Systems", Peter Peregrinus Ltd, London, 1993

**Course name: Subject Paper (Microwave Integrated Circuits)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

Introduction to Monolithic Microwave Integrated Circuits (MMICs), their advantages over discrete circuits, MMIC fabrication techniques, thick and thin film technologies and materials, encapsulation and mounting of active devices. Microstrips on semiconductor substrates

Analysis of stripline and microstripline, Method of conformal Transformation, Characteristic parameters of strip, Microstrip lines, Microstrip Circuit Design, Impedance transformers, Filters,
Lumped constant Microstrip circuits

Coupled Microstrips and Directional couplers, Even and odd mode analysis, Theory of coupled microstrip, Calculations for a coupled pair of Microstrips, Branch line couplers. Lumped Elements for MICs, Design and fabrication of lumped elements, circuits using lumped
elements.

Nonreciprocal components for MICs, Microstrip on Ferrimagnetic substrates, Microstrip circulators. Isolators and phase shifters, Design of microstrip circuits – high power and low power circuits.

**BOOKS:**

1. Gupta KC and Amarjit Singh, "Microwave Integrated circuits", Wiley Eastern, 1974.
2. Leo Young, "Advances in Microwaves", Academic Press.
3. Bharathi Bhat,and S.K. Koul, "Strip line-like Transmission Lines for Microwave Integrated Circuits", New Age International, 2007
4. Microwave Integrated circuit, K. C. Gupta.

**Course name: Subject Paper (Smart Antennas)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

Introduction, Need for Smart Antennas, Overview, Smart Antenna Configurations, Switched-Beam Antennas, Adaptive Antenna Approach, Space Division Multiple Access (SDMA), Architecture of a Smart Antenna System, Receiver, Transmitter, Benefits and Drawbacks, Basic Principles, Mutual Coupling Effects

Introduction, Array Response Vector, Received Signal Model, Subspace-Based Data Model, Signal Autocovariance, Conventional DOA Estimation Methods, Conventional Beamforming Method, Capon's Minimum Variance Method, Subspace Approach to DOA Estimation, MUSIC Algorithm, ESPRIT Algorithm, Uniqueness of DOA Estimates.

Classical Beam former, Statistically Optimum Beamforming Weight Vectors, Maximum SNR Beam former, Multiple Sidelobe Canceller and Maximum, SINR Beam former, Minimum Mean Square Error (MMSE), Direct Matrix Inversion (DMI), Linearly Constrained Minimum Variance (LCMV), Adaptive Algorithms for Beamforming

The Vector Channel Impulse Response and the Spatial Signature, Spatial Processing Receivers, Fixed Beam forming Networks, Switched Beam Systems, Adaptive Antenna Systems, Wideband Smart Antennas, Spatial Diversity, Diversity Combining, and Sectoring, Digital Radio Receiver Techniques and Software Radios for Smart Antennas, Transmission Beam forming.

Non-Coherent CDMA Spatial Processors, Coherent CDMA Spatial Processors and the Spatial Processing Rake Receiver, Multi-User Spatial Processing, Dynamic Re-sectoring Using Smart Antennas, Downlink Beam forming for CDMA.

Range Extension in CDMA, Single Cell Systems with Spatial Filtering at the IS-95 Base Station, Reverse Channel Performance of Multi-cell Systems with Spatial Filtering at the Base Station, Reverse Channel Spatial Filtering at the WLL Subscriber Unit, Range and Capacity Analysis Using Smart Antennas –A Vector Based Approach

**Books:**

1. T.S Rappaport, "Smart Antennas Adaptive Arrays Algorithms and Wireless Position Location", IEEE press 1998, PTR – PH publishers 1999.

2. Lal Chand Godara, “Smart Antennas”, CRC Press, LLC-2
3. T.S. Rappaport and J.C. Liberti, “Smart Antennas for Wireless Communications”, Prentice Hall, 1999
4. Tapan K Sarkar ,” Smart Antennas “,IEEE Press, John Wiley & Sons Publications,2003
5. L.C.Godara, “Applications of antenna arrays to mobile communications, Part I: Performance improvement, feasibility, and system considerations”, Proc. IEEE, vol. 85, no.7, pp.1031-1060, 1997.

**Course name: Subject Paper (Computational Electromagnetics)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

Basic Principles of Electromagnetic Theory, Analytical Methods and Orthogonal Functions, Green’s Function, Fourier Transform Method. Elements of Computational Methods, Basis Functions, Convergence and Discretization Error, Stability of Numerical Solutions, Formulations for the Computational method.
Finite Difference Approximations, Treatment of Interface and Boundary Conditions, Finite Difference Analysis of Guiding Structures, Analysis of Enclosed Microstrip Line, Analysis of Geometries with Open Boundaries ,Wave Propagation and Numerical Dispersion, Analysis of Ridge Waveguide

Pulse Propagation in a Transmission Line, FDTD Analysis in One Dimension, Source or Excitation of the Grid .Absorbing Boundary Conditions for One-Dimensional Propagation, Applications of One Dimensional FDTD Analysis, Reflection at an Interface, Determination of Propagation Constant, Design of Material Absorber, Exponential Time-Stepping Algorithm in the Lossy Region, Extraction of Frequency Domain Information from the Time Domain Data, Dispersive Materials ,FDTD Analysis in Two Dimensions ,Unit Cell in Two Dimensions ,Numerical Dispersion in Two Dimensions, Absorbing Boundary Conditions for Propagation in Two Dimensions, Perfectly Matched Layer ABC, FDTD Analysis in Three Dimensions ,Yee Cell ,Numerical Dispersion in Three Dimensions, Absorbing Boundary Conditions and PML for Three Dimensions , Implementation of Boundary Conditions in FDTD, Perfect Electric and Magnetic Wall Boundary Conditions
Basic Steps in Finite Element Analysis ,Segmentation or Meshing of the Geometry, Derivation of the Element Matrix ,Assembly of Element Matrices, Solution of System Matrix, Post processing, FEM Analysis in One Dimension, Treatment of Boundary and Interface Conditions ,Accuracy and Numerical Dispersion, FEM Analysis in Two Dimensions , Solution of Two-Dimensional Wave Equation ,Element Matrix for Rectangular Elements, Element Matrix for Triangular Elements ,Capacitance of a Parallel Plate Capacitor Cutoff Frequency Waveguide Modes
Introduction, Point Matching and Galerkin’s Methods , Eigen value Analysis Using MoM Static Charge Distribution on a Wire, Analysis of Strip Line

**Books:**

1. Analytical and computational methods in Electromagnetics by Ramesh Garg, Artech House
2. Computational Electromagnetics by Raj Mittra, Springer
3. Computational Electromagnetics by Anders Bondeson, Springer

**Course Name: Subject Paper (Fiber Optic Communication and Network)**
**Course Code: PHD/SP-04**
**Credit: 4**
**Lecture: 40 Hrs.**

1. Evolution of optical fiber communication system, Wave guiding fundamentals: NAs,

Acceptance angle, Wave equation for step index fiber, modal equation, concept of Modes, V number, Number of modes, cut off wavelength, LP modes. Attenuation and Dispersion mechanisms and their effects. Special type Fibers-PMF, PCF & DCF. Fiber Nonlinearities-SPS, XPS, FWM

2. Optical sources and Acousto-optic and Electro-optic modulators, Photodetectors, noises, optical receiver configuration, receiver sensitivity.
3. Couplers, Isolators, Polarizers, Circulators, Filters, Add/Drop Mux/Demux, Optical Amplifiers, Optical MEMS.
4. System design issues, Link analysis, Intensity modulation/ direct detection system, Coherent communication, Soliton communication, Multiplexing mechanism: OTDM and WDM. RoF and Microwave Photonics concepts and techniques.
5. Optical network evolution and concepts: Optical networking terminology, Optical network node and switching elements, Wavelength division multiplexed networks. Optical network transmission modes, layers and protocols: Synchronous networks, Asynchronous transfer mode (ATM), OSI reference model, Optical transport network, Access networks, Internet protocol, Wavelength routing networks: Routing and wavelength assignment, Optical circuit switched and packet switched networks, Multiprotocol Label Switching, Optical burst switching networks.

**Reference Books:**


1. John M Senior, *'Optical Fiber Communications: Principles and Practice'*, PHI.
2. G Keiser, *'Optical Fiber Communications'*, McGraw Hill Education, India.
3. D K Mynbaev and L L Scheiner, *'Fiber Optic Communication Technology'*, Pearson.
4. Rajiv Ramaswami and Kumar N. Sivarajan, *'Optical networks-A practical perspective'*, Academic Press.
5. Jasprit Singh *'Optoelectronics- An Introduction to Materials and Devices'*, McGraw Hill Education, India.
6. A. Yariv and P. Yeh, *'Photonics: Optical Electronics in Modern Communications'*, Oxford University Press.


**Course Name: Subject Paper (Laser Principles and Applications)**
**Course Code: PHD/SP-04**
**Credit: 4**
**Lecture: 40 Hrs.**

1. **Basic Laser Principles:** Absorption, Spontaneous and Stimulated Emission process and Einstein's coefficients. Population inversion, Pumping and pumping schemes, laser gain, Optical resonator cavities and its types, stability.
2. **Characteristics of Laser:** Concept of coherence, Temporal and Spatial coherence, Coherence length and time, Brightness and Intensity, Directionality and Monochromaticity, Laser modes, CW and Pulsed Lasers. Laser hazards for different laser classes and laser safety measures.
3. **Types of Lasers and operation:** Solid, liquid & gas lasers, operational principle of Ruby, He-Ne, Nd: YAG, $CO_2$, Dye and Semiconductor Lasers, fiber laser, Tunable diode lasers-tuning methods--high power semiconductor diode lasers- frequency control of laser output-mode locking of semiconductor lasers, Ultrafast lasers: Ti: Sapphire Laser-energy levels-pumping mechanism, Ultrafast fiber lasers- energy level diagram-pumping Characteristics of Ultrafast lasers.
4. **Laser Applications:** Material Processing: Drilling, Cutting and Welding process with laser. Laser hardening. Medical Science: Medical lasers, Laser diagnostic, Laser in ophthalmology, laser in glaucoma, Laser for general surgery, Laser in dermatology, Laser in dentistry.

Hologram and their characteristics. LIDAR.

**Reference Books:**


1. K. R. Nambiar – *'Laser Principles, Types and Application'*, New Age International.
2. S. A. Ahmad – '*Laser concepts and Applications'* New Age International.
3. A. K. Katiyar, CK Pandey and Manisha Bajpai- 'Fundamentals of Laser Systems and Applications', Wiley, India.
4. William T. Silfvast – *'Laser Fundamentals'*, Cambridge University Press.


**Course Name: Subject Paper (Nanophotonics)**
**Course Code: PHD/SP-04**
**Credit: 4**
**Lecture: 40 Hrs.**

1. Foundations for Nanophotonics; Confinement of photons and electrons, Propagation through a classically forbidden zone: Tunneling, Localization under a periodic potential: Bandgap, Cooperative effects for photons and electrons, Nanoscale optical interactions, Nanoscale confinement of electronic interactions, Quantum confinement effects, Nanoscale electronic energy transfer. Near-field interaction, Near field microscopy, Nanoscale enhancement of optical interactions.
2. Quantum confined materials: Quantum wells, Quantum wires, Quantum dots, Quantum rings, Manifestations of quantum confinement, Optical properties, Quantum confined stark effect. Nanoplasmonics: optical response of metals, plasmons, Optical properties of metal nanoparticles, size dependent absorption and scattering, coupled nanoparticles, Metal-dielectric core-shell nanoparticles. Local electromagnetic fields in metal nanoparticles.
3. Growth Methods for Nanomaterials, MBE, MOCVD, LPE, Laser-Assisted Vapor Deposition (LAVD). Characterization of Nanomaterials, X-Ray diffraction, X-Ray photoelectron spectroscopy (XPS), Transmission electron microscopy (TEM), Scanning electron microscopy (SEM), Scanning probe microscopy (SPM), Scanning tunneling microscopy (STM).
4. Photonic Crystals: Basics concepts, Bandgap and band structures in two- and three-dimensional lattices. Periodic structures in nature, Experimental methods of fabrication, Photonic crystal fibers (PCF). Plasmonic enhancement of secondary radiation; Enhancement of emission and scattering of light, Local density of states in plasmonic nanostructures, Hot-spots in plasmonic nanostructures, Raman scattering enhancement in metal–dielectric nanostructures, Luminescence enhancement in metal–dielectric nanostructures.

**Reference Books:**


1. Sergey V Gaponenko- *'Introduction to Nanophotonics'*, Cambridge University Press.
2. M Ohtsu, K Kobayashi, T Kawazoe, T Yatsui and M Nuruse- *'Principles of Nanophotonics'*, CRC Press, 2008.
3. P N Prasad- *'Nanophotonics'*, Wiley Interscience
4. P P Yupapin, K Srinuanjan, S Kamoldilok,- '*Devices, Circuits and Systems: Nanophotonics'*, Pan Stanford Publishing.


**Course Name: Subject Paper (Satellite in Navigation and Remote Sensing)**
**Course Code: PHD/SP-04**
**Credit: 4**
**Lecture: 40 Hrs.**

1. **Overview of Satellite System:** A brief history of satellite communication, future scope satellite communication. Orbital Mechanism: Orbits, look angle, orbital period and velocity, azimuth and orbital inclination, coverage angle slant range, orbital perturbation, placement of satellite in geostationary orbit. Attitude and Orbit Control system, TT&C subsystem, Attitude Control subsystem, Power systems, Communication subsystems, Satellite Antenna Equipment.
2. **Satellite Link Design:** Basic link analysis, interference analysis, attenuation due to rain, Design of satellite link with specified C/N (with and without frequency reuse). Link budget. Propagation effects and their impact on satellite earth link.
3. **Multiple Access Techniques:** Frequency Division Multiple Access (FDMA) - Intermodulation, Calculation of C/N, Time Division Multiple Access (TDMA) - Frame Structure, Burst Structure, Satellite Switched TDMA, On-board Processing, Demand Assignment Multiple Access (DAMA), CDMA, Spread Spectrum Transmission and Reception. Introduction to VSAT systems: low earth orbit and non-geostationary satellite systems. Direct broadcast Television and Radio.
4. **Satellite Navigation and the Global Positioning System**: Radio and Satellite Navigation, GPS Position, Location Principles, GPS Receivers, GPS C/A Code, Accuracy, Differential GPS.
5. **Remote Sensing:** Basic of remote sensing, Electromagnetic Radiation principles, Atmospheric window, Indian satellite sensing satellite system, Active, Passive, ground based and space based remote sensing. Spatial, spectral, radiometric and temporal resolution, satellite sensors, detectors and scanning technique, FOV and error sources, Image analysis and Interpretation weather RADAR, LIDAR, acoustic sounding systems, TRMM, AURA-MLS, Megha Tropiques Altimeter, Scatterometer, Radiometer. Ground based and radio occultation techniques, spectral response of water, Sea surface temperature, wind speed, color monitor, clouds and aerosol, water vapors, convective system, Trace gases.

**Text/Reference Books:**


1. Timothy Pratt, Charles Bostian, Jeremy Allnutt- *"Satellite Communications",* 2nd Edition, 2003, John Wiley & Sons.
2. Dennis Roddy- *"Satellite Communications",* 4th Edition, 2017, Tata McGraw-Hill.
3. R. N. Mutagi- *"Satellite Communication: Principles and Applications",* 1st Edition, 2016, Oxford Univ Press.
4. G. S. Rao- *"Global Navigation Satellite Systems"*, Tata McGraw-Hill, 2010.
5. Basudeb Bhatta- *"Remote Sensing and GIS"*, 2nd Edition, 2011, Oxford University Press.


**Course name: Subject Paper (Advanced Digital Signal Processing)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

**Introduction to Multi-rate Digital Signal Processing** – Sample rate reduction – decimation by integer factors- sampling rate increase – interpolation by integer facto – Design of practical sampling rate

converters Filter Specification- filter requirement for individual stages – Determining the number of stages and decimation factors – Sampling rate conversion using poly-phase filter structure – poly-phase implementation of interpolators.

**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

**Development of Adaptive Filter Theory & Searching the Performance surface:** Introduction to Filtering - Smoothing and Prediction – Linear Optimum Filtering, Problem statement, Principle of Orthogonality - Minimum Mean Square Error, Wiener- Hopf equations, Error Performance - Minimum Mean Square Error.

**Searching the performance surface** – Methods & Ideas of Gradient Search methods -Gradient Searching Algorithm & its Solution - Stability & Rate of convergence - Learning Curves.

**Steepest Descent Algorithms:** Gradient Search by Newton's Method, Method of Steepest Descent, Comparison of Learning Curves.

**LMS Algorithm & Applications:** Overview - LMS Adaptation algorithms, Stability &Performance analysis of LMS Algorithms - LMS Gradient & Stochastic algorithms - Convergence of LMS algorithm-Normalized LMS algorithm-Advantages of NLMS over LMS.

**Applications:** Noise cancellation – Cancellation of Echoes in long distance telephone circuits, Adaptive Beam forming.

Frequency domain algorithms, Least Squares Estimation, Recursive Least Squares algorithm

**Text/Reference Books:**


1. Digital Sinal Processing: A Computer Based approach, Sanjit K. Mitra, McGraw Hill Education
2. Adaptive Filter Theory Fourth Edition by Simon Haykin
3. Digital Signal Processing Emmanuel C Ifeachor, Barrie W Jrevis, Pearson Education
4. Adaptive Signal Processing, Bernie Widrow and Stearns, Prentice Hall,
5. Fundamentals of Adaptive Filtering, Ali Sayed, Wiley, 2003
6. Theory and Applications of DSP L.R Rabiner and B gold
7. Electronic filter Design Hand Book A .B Williams and FT Taylor, McGraw Hill
8. Wavelets and Subband Coding Valterli &Kovaceric, PHI.
9. Analog Devices & Texas Instruments Users Manuel of TMS320C4X and ADSP 2106x.
10. Fundamentals of Statistical Signal Processing: Estimation Theory by Steven Kay, Prentice Hall, 1993
11. Kernel Adaptive Filtering, Liu, Principe and Haykin, Wiley 2010


**Course name: Subject Paper (Digital Signal and Image Processing)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

I. Discrete Time Signal and Systems: Basics of signals – period, frequency, phase - a mathematical representation of signals - discrete-time signals - data acquisition – sequences – linear shift-invariant systems – stability and causality – linear constant coefficient difference equations – frequency domain – representation of discrete-time systems and signals – representation of discretetime signals by Fourier transform.

II. Transform Analysis: Linear time Invariant systems - Discrete Fourier Transform – computation of DFT – decimation in time FFT and Frequency -Signal Analysis methods: Time and frequency

domain analysis – STFT– wavelet - Z-transform – the region of convergence – relation between Z-transform and Fourier transform.

III. Filter Design Techniques: Signal noise – inherent noise, EMI noise, random noise, speckle noise, process induced noises, etc. — basic digital filter structures – FIR and IIR filters design of FIR filters by window method – rectangle – Hanning, Hamming – Kaiser – IIR filters design – bilinear transformation.

IV. Digital Image Characterization: Light perception – eye physiology – visual phenomena – monochrome vision model – 2D-image sampling & reconstruction – image sampling systems – aliasing effects - Image representation – 2D-systems – 2D-Fourier Transform — image reconstruction systems – vector-space image representation – image quantization

V. Image Processing: Image Enhancement - Introduction to image representation – spatial and frequency domain – generalized 2D linear operator – superposition – filtering - convolution and de-convolution – unitary transformations – Fourier transform – cosine transformation – image reconstruction and enhancement – contrast manipulation – histogram modification – noise-cleaning – image analysis – edge detection – contour quantification – texture analysis – statistical analysis

**Books:**


1. Digital Signal Processing – Principles, Algorithms and Applications - J.G.Proakis & D.G. Manolakis, Pearson Education/ PHI.
2. Digital Signal Processing- Alan V. Oppenheim, Ronald W. Schafer
3. Digital Signal Processing by Sanjit Mitra, 4th edition, 2011, McGraw-Hill, New York, NY.
4. Digital Sinal Processing: A Computer Based approach, Sanjit K. Mitra, McGraw Hill Education
5. Adaptive Filter Theory Fourth Edition by Simon Haykin
6. Digital Image Processing by Rafael C Gonzalez & Richard E Woods, 3rd Edition
7. Fundamentals of Digital Image Processing by Anil K Jain
8. Digital Image Processing by William K Pratt
9. Fundamentals of electronic image processing by Arthur R. Weeks Jr., Wiley


**Course name: Subject Paper (Selected Topics in Machine Learning)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

Unit 1: Introduction to Machine Learning, Probability Theory, Model Selection, The Curse of Dimensionality, Decision Theory, Information Theory
Unit 2: Probability Distributions: Binary Variables, Multinomial Variables, The Gaussian distribution, The Exponential Family, Nonparametric Methods
Unit 3: Linear Models for Regression: Linear Basis Function Models, The Bias-Variance Decomposition , Bayesian Linear Regression ,Bayesian Model Comparison, The Evidence Approximation, Limitations of Fixed Basis Functions
Unit 4: Linear Models for Classification L: Discriminant Functions, Probabilistic Generative Models, Probabilistic Discriminative Models , The Laplace Approximation, Bayesian Logistic Regression Unit 5: Neural Networks and Kernel Methods

**TEXTBOOK:** Christopher M. Bishop. 2006. Pattern Recognition and Machine Learning (Information Science and Statistics). Springer-Verlag New York, Inc., Secaucus, NJ, USA. 4.2
**REFERENCE BOOKS**: As prescribed by the instructor

**Course name: Subject Paper (Pattern Recognition)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

UNIT-I
Pattern & Pattern classes, Pattern recognition Design Cycle, Feature Extraction: Feature processing & normalization, Learning (Supervised, Unsupervised, Reinforced). Preliminary concepts and pre-processing phases, coding, normalization, filtering, linear prediction, Feature extraction and representation thresholding, contours, regions, textures, template matching, Hidden Markov Models, Taxonomy of pattern classifiers Performance measurement metrics: Confusion matrix, Accuracy, Precision, Recall, ROC curve, Area Under Curve (AUC), Confidence intervals. Data partitioning ( K-fold cross validation, Leave one out , Leave m-out)
UNIT-II
Data structure for pattern recognition, statistical pattern recognition, clustering Technique and application. Study of pattern classifiers: Supervised and unsupervised.
UNIT-III
Pattern Classifiers: Statistical: Bayesian theorem, Bayesian classifier: Minimum distance, Maximum likelihood), Naïve Bayes, Linear Discriminant Analysis, k- Nearest Neighbour (KNN), Artificial Neural Network etc. and Case studies.
UNIT-IV
Clustering techniques and algorithms, Deep learning, Selected topics from research papers
UNIT-V
Selected topics from research papers and reference books

**TEXTBOOK**

1. R. O. Duda, P. E. Hart and D. G. Stork, Pattern Classification, John Wiley, 2001.
2. K. Fukunaga, Statistical pattern Recognition; Academic Press, 2000.
3. Devi V.S.; Murty, M.N., Pattern Recognition: An Introduction, Universities Press, Hyderabad, 2011

**REFERENCE BOOKS**

1. S. Theodoridis and K. Koutroumbas, Pattern Recognition, 4th Ed., Academic Press, 2009.

**Course name: Subject Paper (Selected Topics on Artificial Intelligence)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

**Unit 1**
Introduction [What is AI, Areas, Current uses].
Review of Mathematical Logic- Propositional Logic: Logical implication. Finite models and truth values., Predicate Calculus: Infinite models and truth values., Representing Knowledge about the World [Domain: General, blocks world]
Logical Reasoning- Logical consequence, Relation with deduction: Soundness and completeness, Resolution refutation procedure
**Unit 2**
Machine Learning- Symbolic learning-Transformation based learning, Probabilistic learning-Markov Models, Hidden MM, Viterbi ; Rule based systems
**Unit 3**
Search-Hill climbing, Best first, A*, Game tree search, min-max

Other topics (depending on time available: 5 lectures)- Constraint Satisfaction/Planning, Applications [Expert systems, vision], Philosophical issues, History of AI.

**Unit 4**

Different application of AI-based on research topic

NOTE: A crucial aspect of the course is a serial assignment, which connects knowledge representation (and reasoning), with machine vision, analyzed, interpreted and are carried out by machine. Students get to build a system. In additional to the above, students will have to: (a) Study some additional topics as told by the teacher on their own. (b) Present a term paper and/or project at the end of the course.

**Text/Reference Books:**


1. Artificial Intelligence – a modern approach. By Stuart Russell and Peter Norvig (Pearson)
2. Artificial Intelligence. By Kevin Knight, Elaine Rich, and Shivashankar B. Nair (3rd Edition, McGraw Hill Education)
3. Christopher Bishop. Pattern Recognition and Machine Learning. First Edition. Springer, 2006.
4. Mitchell Tom M. "Machine Learning", Tata McGraw-Hill
5. S. J. Russell, P. Norvig. Artificial Intelligence: A Modern Approach. Third Edition, Prentice-Hall, 2010.
6. Müller Andreas C. and Sarah Guido. "Introduction to Machine Learning with Python: A Guide for Data Scientists" 2016


**Course name: Subject Paper (Advanced Sensor Design)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

Basic concept of MEMS sensors, quartz crystal microbalance sensor, metal oxide semiconductor sensor, and molecular imprinted polymer-based sensor. Characteristics, micro-sensing, and application of the sensors. Actuation methods of electrostatic actuation, thermal actuation, piezoelectric and piezoresistive actuation, spin coating actuation, sensing materials and fabrication materials for substrate, polymers, metals, and dielectrics, study the chemical and electrical properties of the fabrication sensing material. Sensor case studies of bio-sensors, chemical sensors, pressure sensors, gas sensors, food processing, environmental measurement, drug delivery and food & agriculture systems.

**Text/Reference Books:**


1. Tai Ran Hsu, MEMS & Micro systems Design and Manufacture Tata McGraw Hill, New Delhi, 2002.
2.Ramon Pallas-Arenyand Johan G. Webster "Sensor and Signal Conditioning" John Wiley, New York 1991.
3. Elliot Williams, "AVR Programming: Learning to Write Software for Hardware", Maker Media, Incorporated,
2014.
4. Dan Sheingold-Editior "Transducer Interfacing Handbook", Analog Devices Inc 1980.
5. A.K. Sawhney, "A course in Electrical and Electronic Measurements and Instrumentation", Dhanpat Ray & Co.
6. Henry Ott, "Noise Reduction Technique In Electronic Systems", N.Y.John Wiley And Sons 1988

**Course name: Subject Paper ( IoT and Wireless sensor Network)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

IoT Conceptual Framework, Sources of IoT, M2M communication. Modified OSI Model for the IoT/M2M Systems, data enrichment, data consolidation and device management at IoT/M2M Gateway, web communication protocols used by connected IoT/M2M devices, Message communication protocols (CoAP-SMS, CoAP-MQ, MQTT, XMPP) for IoT/M2M devices. Internet connectivity, Internet-based communication, IPv4, IPv6,6LoWPAN protocol, IP Addressing in the IoT, Application layer protocols: HTTP, HTTPS, FTP, TELNET and ports. Cloud computing paradigm for data collection, storage and computing, Cloud service models. Sensor and signal conditioning circuit design for IoT application. Characteristics of the sensor and transducer. Prototyping Embedded device software, Programming Embedded Device Arduino Platform using IDE, Reading data from sensors and devices, Devices, Gateways, Internet and Web/Cloud services software development.

**Text/Reference Books:**

1. Kazem Sohraby, Daniel manoli , "Wireless Sensor networks- Technology, Protocols and Applications", Wiley InterScience Publications 2010.
2. Holger Karl, Andreas Willig, "Protocols and Architectures for Wireless Sensor Networks" 2011, 1 st ed., John Wiley & Sons, New Jersey.
3. Jun Zheng, Abbas Jamalipour, "Wireless Sensor Networks: A Networking Perspective", 2014, 1 st ed., Wiley-IEEE Press, USA.
4. Alessandro Bassi, Martin Bauer, Martin Fiedler, Thorsten Kramp, Rob van Kranenburg, Sebastian Lange, Stefan Meissner, "Enabling things to talk – Designing IoT solutions with the IoT Architecture Reference Model", Springer Open, 2016
5. Jan Holler, Vlasios Tsiatsis, Catherine Mulligan, Stamatis Karnouskos, Stefan Avesand, David Boyle, "From Machine to Machine to Internet of Things", Elsevier Publications, 2014.

**Course name: Subject Paper ( Cyber Physical System(Industrial IoT))**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

Industry 4.0: Cyber Physical Systems and Next Generation Sensors, Collaborative Platform and Product Lifecycle Management, Augmented Reality and Virtual Reality, Artifical Intelligence, Big Data and Advanced Analysis . Industrial IoT: Security and Fog Computing - Fog Computing in IIoT, Security in IIoT, Industrial IoT- Application Domains: Factories and Assembly Line, Food Industry. Industrial IoT- Application Domains: Healthcare, Power Plants, Inventory Management & Quality Control, Plant Safety and Security (Including AR and VR safety applications), Facility Management

**REFERENCE BOOKS**: As instructed by the teacher.

**Course name: Subject Paper ( Artificial Intelligence(AI) in Communication))**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

Introduction to AI and its applications in communication Machine learning and deep learning techniques for communication AI-driven communication network management and optimization AI-enabled communication services (speech recognition, natural language processing, etc.) AI for network security, resource allocation, and quality of service (QoS) Ethical, legal, and social implications of AI in communication Introduction to AI and its applications in communication Machine learning and deep learning techniques for communication AI-driven communication network management and optimization AI-enabled communication services (speech recognition, natural language processing, etc.) AI for network security, resource allocation, and quality of service (QoS) Ethical, legal, and social implications of AI in communication,

**REFERENCE BOOKS**: As instructed by the teacher.

**Course name: Subject Paper ( Security in Mobile Networks)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

Pre-authentication and authentication models in Ad Hoc Networks, Promoting Identity-based key management, attacks and countermeasures, Secure and resilient data aggregation, Secure routing in MANET, Intrusion Detection System in MANET . Security in Mobile Cellular Networks: Security issues in GSM, 3G and 4G networks, Authentication and encryption, Security concerns in 5G networks Security in Sensor Networks and IoT: Security Issues, Key Management Schemes, Secure Routing in Sensor Networks, Energy-aware security mechanisms, Security and privacy issues in IoT, Identity and access management, Data Integrity, Best practices for IoT security

**REFERENCE BOOKS**: As instructed by the teacher

**Course Name**: Subject Paper (VLSI Architecture for Signal Processing)
**Course Code** : **Credits** : 4
**Lectures** : 40
**Digital Design Approaches**:
Types of IC Design flows. ASIC, custom Design, Structured ASIC, Gate Array, FPGA.

**Data Representations** :
Fixed point and floating point representations, Qm.n format, IEEE754 formats, Floating points for GPU, Fixed point multiplier and adder. Tree adder, Carry Save Adder, Compressor tree, precision-scalable MACs for ANNs on edge devices.

**Sequential Circuits & Static Timing Analysis** :
Flip flop circuit, Timing parameters. Static Timing Analysis (STA), different PVT conditions, timing data and PVT conditions. Liberty file format, interpolation, setup and hold time analysis, negative slack and fixing, clock jitter, skew, phase, insertion delay etc. State machine -Moore vs Mealy, their impact on timing paths.

**High Level Synthesis and Accelerators** :
Scope of accelerator design. Graphical representation of DSP algorithms, Iteration Bound and related algorithms. Pipelining and parallel processing, retiming, unfolding, folding. Systolic Array design, FIR Systolic Arrays, Matrix-multiplier. Scheduling techniques. C-based HLS, loop optimization techniques, memory packing.

**Books:**


1. J. M. Rabaey, A. Chandrakasan, B. Nikolic , “Digital Integrated Circuits”, 2 ed., Pearson (India).
2. Neil H. Weste and David Harris, “CMOS VLSI Design- A Circuit and System Perspective”, 3ed, Pearson (India).
3. Keshab K. Parhi, “VLSI Digital Signal Processing Systems- Design and Implementation” Wiley (India).
4. Geroge A. Constantinides, Peter Y. K. Cheung, and Wayne Luck, “Synthesis and Optimization of DSP Algorithms,” Kluwer Academic Publisher.
5. “High-Level VLSI Synthesis,” Raul Camposano and Wayne Wolf (eds.), Kluwer International Series in Engineering and Computer Science, Springer-Science+Business Media, LLC.

6. Pong P. Chu, "FPGA Prototyping by VHDL Examples (Xilinx Spartan 3 Version)", Wiley (India).
7. Xilinx ISE/Vivado and Synopsys Primetime User guides, available online, also along with s/w installation.

**Course name: Subject Paper (Optical Communication and Network)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

**Overview of Optical Fiber Communication**
Introduction, Evolution of Light wave Systems, Basic concepts of analog & digital signal, modulation types & formats, multiplexing, data hierarchies

**Optical Fiber**
Review of fiber types and transmission characteristics, Wave equation for step index fiber, Bessel equation and its solution, Eigen value equation and concept of Modes, LP modes, fiber birefringence, spot size, confinement factor, Dispersion characteristics and management, Nonlinear optical effects-SBS, SRS and Nonlinear Phase Modulation-SPM, XPM, FWM

**Optical Sources and Optical Modulators**
Tunable laser sources, Optical Phase/Intensity Modulators

**Optical Receiver Noise and Receiver Sensitivity**
Noises for P-I-N and APD type receiver, Receiver Sensitivity, BER, Q-parameter, Sensitivity degradation

**Lightwave Systems**
System Architectures-point to point links, distribution networks and local area networks, Design Guidelines-loss limited & dispersion limited lightwave systems, link budgeting & rise time budgeting calculation

**WDM Concepts and Components**
High capacity WDM lightwave systems, Optical Amplifiers, WDM Components-Star Couplers, Circulators, Fiber Bragg grating, Tunable Optical Filters, Add/Drop Mux/DeMux, Optical Cross Connects, Optical MEMS, Wavelength Router, Wavelength Converters

**Integrated Optics and Photonic Circuits**
Integrated Optics Technology-material and process, Wave guiding-couple mode theory, IO Devices, Applications, Photonic Switching

**Optical Networks**
Network Concepts, Topologies, SONET/SDH, Multiple Access WDM Networks, Passive Optical Networks, IP over DWDM, Optical Ethernet

**Text/Reference Books:**

G Keiser, *'Optical Fiber Communications'*, McGraw Hill Education, India
D K Mynbaev and L L Scheiner, *'Fiber Optic Communication Technology'*, Pearson
John Gowar, *'Optical Communication Systems'*, PHI
John M Senior, *'Optical Fiber Communications: Principles and Practice'*, PHI
R Ramaswamy and K N Sivarajan, 'Optical Networks: A Practical Perspective', Elsevier Morgan Kaufmann Publishers

**Course name: Subject Paper (Theory of Statistical)**
**Course code: PHD/SP-04; Credit: 4**

**Lecture: 40**

**LINEAR ALGEBRA AND NUMERICAL ANALYSIS**:
Vectors, Linear independence, vector spaces and basis vectors, Matrices, Linear equations, solutions of simultaneous linear and non-linear equations, Special matrix forms – diagonal matrix, exchange matrix,triangular matrix, Toeplitz matrix, Hankel matrix, symmetric matrix, parametric matrix, centro symmetric matrix, Quadratic and Hermitian forms, solution of matrix eigen value and eigen vectors and optimization theory.

**DISCRETE-TIME RANDOM PROCESSES:**
Definition and description of random processes with practical examples. Time average, ensemble average, covariance, autocorrelation, cross correlation. Stationary process, ergodic process, WSS process, power spectrum of random processes. Filtering of random processes – filtering of white noise, spectral shaping filter, spectral factorization. Special random processes – Autoregressive moving average process (ARMA model), autoregressive process (AR model), moving average process, harmonic process (MA model).

**SIGNAL MODELING**:
Least squares method, Padé approximation method, filter design using Padé approximation, Prony's method of signal modeling, filter design using Prony's method, FIR least square inverse filter, iterative prefilters, Stochastic models – ARMA model, AR model, MA model.

**OPTIMUM FILTERS:**
The FIR Wiener filter, linear prediction, noise cancellation, Lattice representation for the FIR Wiener filter, The IIR Wiener filter, The noncausal and causal IIR Wiener filter, causal Wiener filtering, causal Wiener prediction Wiener deconvolution and discrete Kalman filter.

**THEORIES AND HYPOTHESIS OF PROBABILITY AND STATISTICS**:
Definition and postulates of probability, Field of probability, mutually exclusive events, Decision theory, Bay's likelihood ratio, ideal observer strategy, Neyman-Pearson strategy, Bay's strategy for single and multiple sample values, optimum linear estimation composite hypothesis testing, optimum detection with incomplete knowledge of the signal, adaptive detection and estimation. Bernoulli trial, Discrete Distributions, Continuous distributions, Probable errors, Linear regression, Introduction to non-linear regression, Correlation, Analysis of variance.

**Text/Reference Books:**


1. An Introduction to Statistical Communication Theory- John B. Thomas, Wiley.
2. Statistical digital signal processing and modelling, - Monson N. Hays – Wiley
3. Detection, Estimation and Modulation theory– Part I/ Edition 2,- Harry L. Van Trees, John Wiley & Sons,
   NY, USA, 2013.
4. Numerical Mathematical Analysis- J. B. Scarborough, Oxford University Press
5. Elementary Numerical Analysis- S. D. Cone, Mc. Graw Hill.
6. Introduction to Mathematical Probability- J. V. Uspensky, Tata Mc. Graw Hill
7. Digital communication, 4th ed. - J. G. Proakis, MGH International edition


**Course name: Subject Paper (Radar Signal Processing)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

A Preview of Basic Radar Signal Processing, Radar range equation, Signal Models, components of a Radar Signal, Amplitude Models, clutter, Noise Model and Signal -to -Noise Ratio, Jamming, Frequency Models-The Doppler Shift, Spatial Models, Spectral Model

Sampling and Quantization of Pulsed Radar Signals, Domains and Criteria for Sampling Radar Signals, Sampling in the Fast Time Dimension, Sampling in Slow Time – Selecting the Pulse Repetition Interval, Sampling the Doppler Spectrum, Sampling in the Spatial and Angle Dimensions, Quantization, I/Q Imbalance and Digital I/Q

Doppler Processing, Alternate Forms of the Doppler Spectrum, Moving Target Indication (MTI), Pulse Doppler Processing, Pulse Pair Processing, Additional Doppler Processing Issues, Clutter Mapping and the Moving Target Detector, MTI for moving platforms

Introduction to Synthetic Aperture Imaging, Introduction to SAR Fundamentals, Stripmap SAR Data Characteristics, Stripmap SAR Image Formation Algorithms, Spotlight SAR Data Characteristics, the Polar Format Image Formation Algorithm for Spotlight SAR, Interferometric SAR

Introduction to Beamforming and Space-Time Adaptive Processing- Spatial Filtering, Space-Time Signal Environment, Space Time Signal Modeling, Processing the Space Time Signal, Computational issues in STAP, Reduce – Dimension STAP, Advanced STAP Algorithms and Analysis, Limitations to STAP.

**Text/Reference Books:**


1. M.I. Skolnik, *Introduction to Radar Systems*, 3rd Edition, 2001, TMH.
2. Mark A. Richards, *Fundamentals of Radar Signal Processing*, McGraw Hill
3. A Hein, *Processing of SAR Data: Fundamentals, Signal Processing, Interferometry*, 2010,Springer
4. Fred E. Nathanson, *Radar Design Principles: Signal Processing and The Environment*, 2nd Edition, 1999, PHI.
5. Peyton Z. Peebles, Jr., *Radar Principles*, 2004, John Wiley.
6. R. Nitzberg, *Radar Signal Processing and Adaptive Systems*, 1999, Artech House.
7. F.E. Nathanson, *Radar Design Principles*, 1st Edition, 1969, McGraw Hill.
8. Bassem Mahafza, *Radar Signal Processing and Analysis using Matlab*, 2010,CRC Press


**Course name: Subject Paper (Software Define Radio and Cognitive Radio)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

**INTRODUCTION TO SOFTWARE RADIO CONCEPTS :**

The need for software radios, what is a software radio, characteristics and benefits of a software radio, Design principles of a software radio.

**RADIO FREQUENCY IMPLEMENTATION ISSUES :**

The purpose of the RF front-end, Dynamic range: The principal Challenge of receiver design, RF receiver front-end topologies, Enhanced flexibility of the RF chain with software radios, Importance of the components of overall performance, transmitter architectures and their issues, noise and distortion in the RF chain, ADC and DAC distortion.

**DIGITAL HARDWARE CHOICES :**

Introduction, Key Hardware Elements, DSP Processors, FPGA, Tradeoffs in using DSPs FPGAs and ASICs, Power Management Issues , Combinations of DSPs , FPGAs and ASICs.

**INTRODUCTION TO COGNITIVE RADIOS:**
Digital dividend, cognitive radio (CR) architecture, functions of cognitive radio, dynamic spectrum access (DSA), components of cognitive radio, spectrum sensing, spectrum analysis and decision, potential applications of cognitive radio.

**SIGNAL PROCESING :** Spectrum sensing, detection of spectrum holes (TVWS), collaborative sensing, geo-location database and spectrum sharing business models (spectrum of commons, real time.

**DYNAMIC SPECTRUM ACCESS AND MANAGEMENT:**
Spectrum broker, cognitive radio architectures, centralized dynamic spectrum access, distributed dynamic spectrum access, learning algorithms and protocols.

**Text/Reference Books:**

1. Software Radio: A Modern Approach to Radio Engineering By Jeffrey H. Reed Pearson Education Low Price Edition
2. Dynamic Spectrum Access and Management in Cognitive Radio Networks, Ekram Hossain, Dusit Niyato, Zhu Han, Cambridge University Press.
3. Cognitive radio networks, Kwang-Cheng Chen, Ramjee Prasad, John Wiley & Sons Ltd.
4. Cognitive Radio, Software Defined Radio, and Adaptive Wireless Systems, Huseyin Arslan, Springer.

**Course name: Subject Paper (Advanced Communication and Networks)**
**Course code: PHD/SP-04; Credit: 4**
**Lecture: 40**

**Module 1**: SOFTWARE DEFINED RADIO Operating principles- Ideal concept, Receiver architecture, Joint Tactical Radio System, Amateur Radio or Home Use, spectrum management, Resource management

**Module 2**: COGNITIVE RADIO Digital dividend, cognitive radio (CR) architecture, functions of cognitive radio, dynamic spectrum access (DSA), components of cognitive radio, spectrum sensing, spectrum analysis and decision, potential applications of cognitive radio. Case studies on cross-layer design for cognitive radio networks.

**Module 3**: OFDM PRINCIPLES Motivation for Multi Carrier Vs. Single Carrier, OFDM Introduction and System Model and Block Diagram, Design of the OFDM Signal, OFDM System Model, Synchronization Errors, Performance of an Uncoded OFDM System, Mathematical Modeling, Analytical Evaluation of the BER, PAPR.

**Module 4**: MIMO BASICS Motivation, Types of multi-antenna systems, MIMO vs. multi-antenna systems, Spectral efficiency and capacity, transmitting independent streams in parallel, the generic MIMO problem, Singular Value Decomposition, Predistortion in MIMO systems, Precoding and combining in MIMO systems.

**Module 5**: LTE vs. WI-MAX Review of ceullar generations, 3GPP evolution towards LTE/LTE-Advanced standardization, LTE/LTE-Advanced Radio Resource Management, Radio network deployment and frequency planning, Spectrum management, 4G Mobile WiMAX (IEEE 802.16m-2011), Femto cells in advanced WiMAX systems, WiMAX Interworking with LTE/LTE-Advanced networks, Mobile IP, IEEE 802.21 for seamless, Mobility, Introduction to 5G.

**Module 6**: Introduction to Cooperative Communications Brief History of Cooperative and Relay Channels- Characteristics of Wireless Channels - Techniques to Exploit Spatial Diversity-Capacity of Wireless -Diversity-and-Multiplexing Tradeoff- Decode-and-Forward Relaying Schemes

**Text/Reference Books:**

1. Mitola III, J., "Cognitive Radio Architecture: The Engineering Foundation of Radio XML", WileyInterscience. 2006

2. Pietrzyk, S., "OFDMA for Broadband Wireless Access", Artech House. 2006

3. Gilsic, S.G., "Advanced Wireless Networks: 4G Technology", John Wiley & Sons. 2006

REFERENCE BOOKS:

1. Y.W. Peter Hong, Wan-Jen Huang C.-C. Jay Kuo, "Cooperative Communications and Networking", Springer edition,2013

2. Yan Zhang, Hsiao-Hwa Chen, Mohsen Guizani, "Cooperative Wireless Communications", CRC Press, 2014

3. John G.. Proakis, and Masoud Salehi. *Digital communications*. McGraw-Hill., 5th Edition,2008.