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(13A02402) CONTROL SYSTEMS ENGINEERING

Course Objective:
In this course it is aimed to introduce to the students the principles and applications of control systems in everyday life. The basic concepts of block diagram reduction, time domain analysis solutions to time invariant systems and also deals with the different aspects of stability analysis of systems in frequency domain and time domain.

UNIT I   CONTROL SYSTEMS CONCEPTS
Open Loop and closed loop control systems and their differences- Examples of control systems- Classification of control systems, Feedback Characteristics, Effects of positive and negative feedback. Mathematical models – Differential equations of Translational and Rotational mechanical systems, and Electrical Systems, Block diagram reduction methods – Signal flow graph - Reduction using Mason's gain formula. Transfer Function of DC Servo motor - AC Servo motor - Synchro transmitter and Receiver

UNIT II   TIME RESPONSE ANALYSIS
Step Response - Impulse Response - Time response of first order systems – Characteristic Equation of Feedback control systems, Transient response of second order systems - Time domain specifications – Steady state response - Steady state errors and error constants – Effects of proportional, integral, derivative Controllers, Design of P, PD, PI, PID Controllers.

UNIT III   STABILITY ANALYSIS IN FREQUENCY DOMAIN
The concept of stability – Routh's stability criterion – Stability and conditional stability – limitations of Routh's stability. The root locus concept - construction of root loci-effects of adding poles and zeros to G(s)H(s) on the root loci.

UNIT IV   FREQUENCY RESPONSE ANALYSIS
Introduction, Frequency domain specifications-Bode diagrams-Determination of Frequency domain specifications and transfer function from the Bode Diagram-Stability Analysis from Bode Plots. Polar Plots-Nyquist Plots- Phase margin and Gain margin-Stability Analysis.
Compensation techniques – Lag, Lead, Lead-Lag Compensators design in frequency Domain.

UNIT V   STATE SPACE ANALYSIS OF CONTINUOUS SYSTEMS
Concepts of state, state variables and state model, derivation of state models from Schematic models, differential equations, Transfer function, block diagrams, Diagonalization- Solving the Time invariant state Equations- State Transition Matrix and it's Properties. System response through State Space models.

Text Books:
1. Modern Control Engineering – by Katsuhiko Ogata – Prentice Hall of India Pvt. Ltd., 5th edition, 2010.
2. Control Systems Engineering – by I. J. Nagrath and M. Gopal, New Age International (P) Limited, Publishers, 5th edition, 2007.

Reference Books:
1. Control Systems Engineering - by NISE 5th Edition – John wiley & sons, 2010.
2. Control Systems – by – A. Nagoor Kani- First Edition RBA Publications, 2006.
3. Automatic Control Systems– by B. C. Kuo and Farid Golnaraghi – John wiley and sons, 8th edition, 2003.

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(13A05401) COMPUTER ORGANIZATION AND ARCHITECTURE

Course Objective:

- *To learn the fundamentals of computer organization and its relevance to classical and modern problems of computer design*
- *To make the students understand the structure and behavior of various functional modules of a computer.*
- *To understand the techniques that computers use to communicate with I/O devices*
- *To study the concepts of pipelining and the way it can speed up processing.*
- *To understand the basic characteristics of multiprocessors*

Learning Outcome:

- *Ability to use memory and I/O devices effectively*
- *Able to explore the hardware requirements for cache memory and virtual memory*
- *Ability to design algorithms to exploit pipelining and multiprocessors*

UNIT I
Introduction to Computer Organization and Architecture
Basic Computer Organization – CPU Organization – Memory Subsystem Organization and Interfacing – I/O Subsystem Organization and Interfacing – A Simple Computer Levels of Programming Languages, Assembly Language Instructions, Instruction Set Architecture Design, A simple Instruction Set Architecture

UNIT II
CPU Design and Computer Arithmetic
CPU Design: Instruction Cycle – Memory – Reference Instructions – Input/output and Interrupt – Addressing Modes – Data Transfer and Manipulation – Program Control.
Computer Arithmetic: Addition and Subtraction – Multiplication Algorithms – Division Algorithms – Floating-Point Arithmetic Operations – Decimal Arithmetic unit.

UNIT III
Register Transfer Language and Design of Control Unit
Register Transfer: Register Transfer Language – Register Transfer – Bus and Memory Transfers – Arithmetic Micro operations – Logic Micro operations – Shift Micro operations.
Control Unit: Control Memory – Address Sequencing – Micro program Example – Design of Control Unit.

UNIT IV
Memory and Input/output Organization
Memory Organization: Memory Hierarchy – Main Memory – Auxiliary Memory – Associative Memory – Cache Memory – Virtual Memory.
Input/output Organization: Input-Output Interface – Asynchronous Data Transfer – Modes of Transfer – Priority Interrupt – Direct Memory Access (DMA).

UNIT V
Pipeline and Multiprocessors
Pipeline: Parallel Processing – Pipelining – Arithmetic Pipeline – Instruction Pipeline.
Multiprocessors: Characteristics of Multiprocessors – Interconnection Structures – Inter Processor Arbitration – Inter Processor Communication and Synchronization.

Text Books:
1. *"Computer Systems Organization and Architecture", John D. Carpinelli, PEA, 2009.*
2. *"Computer Systems Architecture", 3/e, M. Moris Mano, PEA, 2007.*

Reference Books:
1. *"Computer Organization", Carl Hamacher, Zvonks Vranesic, SafeaZaky, 5/e, MCG, 2002.*
2. *"Computer Organization and Architecture", 8/e, William Stallings, PEA, 2010.*
3. *"Computer Systems Architecture a Networking Approach", 2/e, Rob Williams.*
4. *"Computer Organization and Architecture" Ghoshal, Pearson Education, 2011.*
5. *"Computer Organization and Architecture", V. Rajaraman, T. Radakrishnan.*
6. *"Computer Organization and Design", P. Pal Chaudhuri, PHI*
7. *"Structured Computer Organization", Andrew S. Janenbaum, Todd Austin*
8. *"Computer Architecture" Parahmi, Oxford University Press*

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(13A04501) ANTENNAS & WAVE PROPAGATION

Course Objective:
1. *To introduce the fundamental principles of antenna theory and various types of antennas.*
2. *Applying the principles of antennas to the analysis, design, and measurements of antennas.*
3. *To know the applications of some basic and practical configurations such as dipoles, loops, and broadband, aperture type and horn antennas.*

Learning Outcome:
Through lecture, and out-of-class assignments, students are provided learning experiences that enable them to:
a. *Understand the basic principles of all types of antennas and*
b. *Analyze different types of antennas designed for various frequency ranges.*
c. *Become proficient with analytical skills for understanding practical antennas.*
d. *Design some practical antennas such as dipole, Yagi - uda, and horn antennas.*
e. *Determine the radiation patterns (in principal planes) of antennas through measurement setups.*
f. *Develop technical & writing skills important for effective communication.*
g. *Acquire team-work skills for working effectively in groups.*

UNIT I
Antenna Basics & Dipole antennas: Introduction, Basic antenna parameters- patterns, Beam Area, Radiation Intensity, Beam Efficiency, Directivity-Gain-Resolution, Antenna Apertures, Effective height, Fields from oscillating dipole, Field Zones, Shape-Impedance considerations, Polarization – Linear, Elliptical, & Circular polarizations, Antenna temperature, Antenna impedance, Front–to-back ratio, Antenna theorems, Radiation – Basic Maxwell's equations, Retarded potential-Helmholtz Theorem, Radiation from Small Electric Dipole, Quarter wave Monopole and Half wave Dipole – Current Distributions, Field Components, Radiated power, Radiation Resistance, Beam width, Natural current distributions, far fields and patterns of Thin Linear Center-fed Antennas of different lengths, Illustrative problems.

UNIT II
VHF, UHF and Microwave Antennas - I: Loop Antennas - Introduction, Small Loop, Comparison of far fields of small loop and short dipole, Radiation Resistances and Directives of small and large loops (Qualitative Treatment), Arrays with Parasitic Elements - Yagi - Uda Arrays, Folded Dipoles & their characteristics. Helical Antennas-Helical Geometry, Helix modes, Practical Design considerations for Monofilar Helical Antenna in Axial and Normal Modes. Horn Antennas- Types, Fermat's Principle, Optimum Horns, Design considerations of Pyramidal Horns, Illustrative Problems.

UNIT III
VHF, UHF and Microwave Antennas - II: Micro strip Antennas- Introduction, features, advantages and limitations, Rectangular patch antennas- Geometry and parameters, characteristics of Micro strip antennas, Impact of different parameters on characteristics, reflector antennas - Introduction, Flat sheet and corner reflectors, parabola reflectors- geometry, pattern characteristics, Feed Methods, Reflector Types - Related Features, Lens Antennas - Geometry of Non-metallic Dielectric Lenses, Zoning, Tolerances, Applications, Illustrative Problems.

UNIT IV

Antenna Arrays & Measurements: Point sources - Definition, Patterns, arrays of 2 Isotropic sources- Different cases, Principle of Pattern Multiplication, Uniform Linear Arrays – Broadside Arrays, Endfire Arrays, EFA with Increased Directivity, Derivation of their characteristics and comparison, BSAa with Non-uniform Amplitude Distributions - General considerations and Bionomial Arrays, Illustrative problems.

Antenna Measurements: Introduction, Concepts- Reciprocity, Near and Far Fields, Coordination system, sources of errors, Patterns to be Measured, Pattern Measurement Arrangement, Directivity Measurement , Gain Measurements (by comparison, Absolute and 3-Antenna Methods).

UNIT V

Wave Propagation: Introduction, Definitions, Characterizations and general classifications, different modes of wave propagation, Ray/Mode concepts, Ground wave propagation (Qualitative treatment) - Introduction, Plane earth reflections, Space and surface waves, wave tilt, curved earth reflections, Space wave propagation - Introduction, field strength variation with distance and height, effect of earth's curvature, absorption, Super refraction, M-curves and duct propagation, scattering phenomena, tropospheric propagation, fading and path loss calculations, Sky wave propagation - Introduction, structure of Ionosphere, refraction and reflection of sky waves by Ionosphere, Ray path, Critical frequency, MUF, LUF, OF, Virtual height and Skip distance, Relation between MUF and Skip distance, Multi-HOP propagation, Energy loss in Ionosphere, Summary of Wave Characteristics in different frequency ranges, Illustrative problems.

Text Books:

1. John D. Kraus and Ronald J. Marhefka and Ahmad S.Khan, "Antennas and wave propagation," TMH, New Delhi, 4th Ed., (special Indian Edition), 2010.
2. E.C. Jordan and K.G. Balmain, "Electromagnetic Waves and Radiating Systems," PHI, 2nd Edn, 2000.

Reference Books:

1. C.A. Balanis, "Antenna Theory- Analysis and Design," John Wiley & Sons, 2nd Edn., 2001.
2. K.D. Prasad, Satya Prakashan, "Antennas and Wave Propagation," Tech. India Publications, New Delhi, 2001.
3. E.V.D. Glazier and H.R.L. Lamont, "Transmission and Propagation - The Services Text Book of Radio," vol. 5, Standard Publishers Distributors, Delhi.
4. F.E. Terman, "Electronic and Radio Engineering," McGraw-Hill, 4th edition, 1955.
5. John D. Kraus, "Antennas," McGraw-Hill (International Edition), 2nd Edn., 1988.

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY ANANTAPUR

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(13A04502) DIGITAL COMMUNICATION SYSTEMS

Course Objective:

- *The students to be able to understand, analyze, and design fundamental digital communication systems.*
- *To know various coding techniques such as source coding, line coding, and channel coding.*
- *To understand various digital modulation techniques and their applications.*
- *The course focuses on developing a thorough understanding of digital communication systems by using a series of specific examples and problems.*

Learning Outcome:

At the end of the course, the students should be able to:

- *Know the difference between source coding, channel coding, and line coding techniques and apply their concepts in the analysis and design of digital communication systems.*
- *Understand the basic principles of baseband and passband digital modulation schemes.*
- *Analyze probability of error performance of digital systems and are able to design digital communication systems.*
- *Understand the basics of information theory and error correcting codes.*

UNIT I
Source Coding Systems: Introduction, sampling process, quantization, quantization noise, conditions for optimality of quantizers, encoding, Pulse-Code Modulation (PCM), Line codes, Differential encoding, Regeneration, Decoding & Filtering, Noise considerations in PCM systems, Time-Division Multiplexing (TDM), Synchronization, Delta modulation (DM), Differential PCM (DPCM), Processing gain, Adaptive DPCM (ADPCM), Comparison of the above systems.

UNIT II
Baseband Pulse Transmission: Introduction, Matched filter, Properties of Matched filter, Matched filter for rectangular pulse, Error rate due to noise, Inter-symbol Interference (ISI), Nyquist's criterion for distortion less baseband binary transmission, ideal Nyquist channel, Raised cosine filter & its spectrum, Correlative coding – Duo binary & Modified duo binary signaling schemes, Partial response signaling, Baseband M-array PAM transmission, Eye diagrams.

UNIT III
Signal Space Analysis: Introduction, Geometric representation of signals, Gram-Schmidt orthogonalization procedure, Conversion of the Continuous AWGN channel into a vector channel, Coherent detection of signals in noise, Correlation receiver, Equivalence of correlation and Matched filter receivers, Probability of error, Signal constellation diagram.

UNIT IV
Passband Data Transmission: Introduction, Passband transmission model, Coherent phase-shift keying – binary phase shift keying (BPSK), Quadrature shift keying (QPSK), Binary Frequency shift keying (BFSK), Error probabilities of BPSK, QPSK, BFSK, Generation and detection of Coherent BPSK, QPSK, & BFSK, Power spectra of above mentioned modulated signals,M-array PSK, M-array quadrature amplitude modulation (M-array QAM), Non-coherent orthogonal modulation schemes -Differential PSK, Binary FSK, Generation and detection of non-coherent BFSK, DPSK, Comparison of power bandwidth requirements for all the above schemes.

UNIT V

Channel Coding: Error Detection & Correction - Repetition & Parity Check Codes, Interleaving, Code Vectors and Hamming Distance, Forward Error Correction (FEC) Systems, Automatic Retransmission Query (ARQ) Systems, Linear Block Codes – Matrix Representation of Block Codes, Convolutional Codes – Convolutional Encoding, Decoding Methods.

Text Books:
1. Simon Hakin, "Communication Systems," Wiley India Edition, 4th Edition, 2011.
2. A. Bruce Carlson, & Paul B. Crilly, "Communication Systems – An Introduction to Signals & Noise in Electrical Communication", McGraw-Hill International Edition, 5th Edition, 2010.

Reference Books:
1. Sam Shanmugam, "Digital and Analog Communication Systems", John Wiley, 2005.
2. B.P. Lathi, & Zhi Ding, "Modern Digital & Analog Communication Systems", Oxford University Press, International 4th edition, 2010.
3. Bernard Sklar, "Digital Communications", Prentice-Hall PTR, 2nd edition, 2001.
4. Herbert Taub & Donald L Schilling, "Principles of Communication Systems", Tata McGraw-Hill, 3rd Edition, 2009.
5. J. G. Proakis, M Salehi, Gerhard Bauch, "Modern Communication Systems Using MATLAB," CENGAGE, 3rd Edition, 2013.

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(13A04503) LINEAR IC APPLICATIONS

Course Objective:
- *To make the student understand the basic concepts in the design of electronic circuits using linear integrated circuits and their applications. To introduce some special function ICs.*

Learning Outcome:
Upon completion of the course, students will be able to:
- *Understand the basic building blocks of linear integrated circuits and its characteristics.*
- *Analyze the linear, non-linear and specialized applications of operational amplifiers.*
- *Understand the theory of ADC and DAC.*

UNIT I
DIFFERENTIAL AMPLIFIERS AND OPAMPS
Differential Amplifiers: Differential amplifier configurations, Balanced and unbalanced output differential amplifiers, current mirror, level Translator.
Operational amplifiers: Introduction, Block diagram, Ideal op-amp, Equivalent Circuit, Voltage Transfer curve, open loop op-amp configurations.

UNIT II
OP-AMP WITH NEGATIVE FEEDBACK AND FREQUENCY RESPONSE
Introduction, feedback configurations, voltage series feedback, voltage shunt feedback and differential amplifiers, properties of Practical op-amp.
Frequency response: Introduction, compensating networks, frequency response of internally compensated op-amps and non compensated op-amps, High frequency op-amp equivalent circuit, open loop gain Vs frequency, closed loop frequency response, circuit stability, slew rate.

UNIT III
OP-AMP APPLICATIONS -1
DC and AC amplifiers, peaking amplifier, summing, scaling and averaging amplifiers, instrumentation amplifier, voltage to current converter, current to voltage converter, integrator, differentiator, active filters.

UNIT IV
OP-AMP APPLICATIONS -2
Oscillators, Phase shift and wein bridge oscillators, Square, triangular and sawtooth wave generators, Comparators, zero crossing detector, Schmitt trigger, characteristics and limitations.
Specialized applications: 555 timer IC (monostable & astable operation) & its applications, PLL, operating principles, Monolithic PLL, applications.

UNIT V
ANALOG TO DIGITAL AND DIGITAL TO ANALOG CONVERTERS
Analog and Digital Data Conversions, D/A converter – specifications – weighted resistor type, R-2R Ladder type, Voltage Mode and Current-Mode R - $2R$ Ladder types -switches for D/A converters, high speed sample-and-hold circuits, A/D Converters –specifications – Flash type – Successive Approximation type – Single Slope type – Dual Slope type – A/D Converter using Voltage-to-Time Conversion – Over-sampling A/D Converters.

Text Books:
1. D. Roy Chowdhury, "Linear Integrated Circuits", New Age International (p) Ltd, 2nd Edition, 2003.
2. K.Lal Kishore, "Operational Amplifiers and Linear Integrated Circuits", Pearson Education,2007.

Reference Books:
1. Ramakanth A. Gayakwad, "Op-Amps & Linear ICs", PHI, 4th edition,1987.
2. R.F.Coughlin & Fredrick Driscoll, "Operational Amplifiers & Linear Integrated Circuits", 6th Edition, PHI.
3. David A. Bell, "Operational Amplifiers & Linear ICs", Oxford University Press, 2nd edition, 2010.
4. Sergio Franco, "Design with Operational Amplifiers & Analog Integrated Circuits" McGraw Hill, 1988.
5. C.G. Clayton, "Operational Amplifiers", Butterworth & Company Publ. Ltd./ Elsevier, 1971.

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(13A04504) DIGITAL IC APPLICATIONS

Course Objective:
- *To be able to use computer-aided design tools for development of complex digital logic circuits*
- *To be able to model, simulate, verify, analyze, and synthesize with hardware description languages*
- *To be able to design and prototype with standard cell technology and programmable logic*
- *To be able to design tests for digital logic circuits, and design for testability*

Learning Outcome:
- *Able to use computer-aided design tools for development of complex digital logic circuits.*
- *Able to model, simulate, verify, analyze, and synthesize with hardware description languages.*
- *Able to design and prototype with standard cell technology and programmable logic.*
- *Able to design tests for digital logic circuits, and design for testability.*

UNIT I
CMOS LOGIC: Introduction to logic families, CMOS logic, CMOS steady state electrical behavior, CMOS dynamic electrical behavior, CMOS logic families.
BIPOLAR LOGIC AND INTERFACING: Bipolar logic, Transistor logic, TTL families, CMOS/TTL interfacing, low voltage CMOS logic and interfacing, Emitter coupled logic, Comparison of logic families, Familiarity with standard 74XX and CMOS 40XX series-ICs – Specifications.

UNIT II
The VHDL Hardware Description Language: Design flow, program structure, types and constants, functions and procedures, libraries and packages.
The VHDL design elements: Structural design elements, behavioral design elements, time dimension and simulation synthesis.

UNIT III
Combinational Logic Design: Decoders, encoders, three state devices, multiplexers and demultiplexers, Code Converters, EX-OR gates and parity circuits, comparators, adders & subtractors, ALUs, Combinational multipliers, VHDL models for the above ICs.

UNIT IV
Design Examples (using VHDL): Barrel shifter, comparators, floating-point encoder, and dual parity encoder.
Sequential logic Design: Latches & flip flops, PLDs, counters, shift register and their VHDL models, Synchronous design methodology.

UNIT V
ROMs: Internal Structure, 2D – decoding commercial types, timing and applications.
Static RAMs: Internal Structure, timing and standard SRAMs, Synchronous SRAMs.
Dynamic RAMs: Internal Structure, timing and standard DRAMs, Synchronous DRAMs.

Text Books:
1. *Digital Design Principles & Practices – John F. Wakerly, PHI/ Pearson Education Asia, 3rd Ed., 2005.*
2. *A VHDL Primer – J. Bhasker, Pearson Education/ PHI, 3rd Edition.*

Reference Books:
1. *Digital System Design Using VHDL – Charles H. Roth Jr., PWS Publications, 2nd edition, 2008.*
2. *Fundamentals of Digital Logic with VHDL Design – Stephen Borwn and Zvonko Vramesic, McGraw Hill, 2nd Edition., 2005.*

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(13A04505) IC APPLICATIONS LAB

Course Objective:
- *To verify the applications of Op-amp*
- *To verify applications IC555 and IC566*
- *To use computer-aided design tools for development of complex digital logic circuits*
- *To model, simulate, verify, analyze, and synthesize with hardware description languages*
- *To design and prototype with standard cell technology and programmable logic*
- *To design tests for digital logic circuits, and design for testability*

Learning Outcome:
- *Able to verify applications of Op-amp*
- *Able to verify applications of IC555 and IC566*
- *Able to use computer-aided design tools for development of complex digital logic circuits.*
- *Able to model, simulate, verify, analyze, and synthesize with hardware description languages.*
- *Able to design and prototype with standard cell technology and programmable logic.*
- *Able to design tests for digital logic circuits, and design for testability.*

Minimum Twelve Experiments to be conducted:
Part A (IC Application Lab):
1. OP AMP Applications – Adder, Subtractor, Comparator Circuits.
2. Active Filter Applications – LPF, HPF (first order).
3. Function Generator using OP AMPs.
4. IC 555 Timer – Monostable and Astable Operation Circuit.
5. IC 566 – VCO Applications.
6. Voltage Regulator using IC 723.
7. 4 bit DAC using OP AMP.

Part B (ECAD Lab):
Simulate the internal structure of the following Digital IC's using VHDL / VERILOG and verify the operations of the Digital IC's (Hardware) in the Laboratory
1. Logic Gates- 74XX.
2. Half Adder, Half Subtractor, Full Adder, Full Subtractor & Ripple Carry Adder.
3. 3-8 Decoder -74138 & 8-3 Encoder- 74X148.
4. 8 x 1 Multiplexer -74X151 and 2x4 Demultiplexer-74X155.
5. 4 bit Comparator-74X85.
6. D Flip-Flop 74X74.
7. JK Flip-Flop 74X109.
8. Decade counter-74X90.
9. Universal shift register -74X194.

Equipment required for Laboratories:
1. RPS
2. CRO
3. Function Generator
4. Multi Meters
5. IC Trainer Kits (Optional)
6. Bread Boards
7. Components: -   IC741, IC555, IC566, 7805, 7809, 7912 and other essential components.
8. Analog IC Tester

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(13A04506) ANALOG COMMUNICATION SYSTEMS LAB

Course Objective:
- *To provide a real time experience for different analog modulation systems and demodulation schemes*
- *To provide exposure to the real time behavior of different elements available in analog communication system such as filters, amplifiers etc*
- *To perform radio receiver measurements and antenna measurements*

Learning Outcome:
After completion of the course the students will be able
- *To experience real time behavior of different analog modulation schemes*
- *Technically visualize spectra of different analog modulation schemes*
- *Analyze practical behavior of different elements available in analog communication system such as filters, amplifiers etc.*
- *Measure characteristics of radio receiver and antenna measurements.*

List of Experiments: (All Experiments are to be conducted)

1. Amplitude modulation and demodulation.
2. Frequency modulation and demodulation.
3. Characteristics of Mixer.
4. Pre-emphasis & de-emphasis.
5. Pulse amplitude modulation & demodulation.
6. Pulse width modulation & demodulation
7. Pulse position modulation & demodulation.
8. Radio receiver measurements – sensitivity selectivity and fidelity.
9. Measurement of half power beam width (HPBW) and gain of a half wave dipole antenna.
10. Measurement of radiation pattern of a loop antenna in principal planes.

Equipment required for the Laboratory:
1. Regulated Power Supply equipments   0 – 30 V
2. CROs   0 – 20 M Hz.
3. Function Generators   0 – 3 M Hz
4. RF Signal Generators   0 – 1000 M Hz
5. Multimeters
6. Required electronic components (active and passive) for the design of experiments from 1 - 7
7. Radio Receiver Demo kits or Trainers.
8. RF power meter   frequency range 0 – 1000 MHz
9. Spectrum Analyzer
10. Dipole antennas (2 Nos.)   850 MHz – 1GHz
11. Loop antenna (1 no.)   850 MHz – 1GHz
12. Bread Boards