Indian Institute of Space Science and Technology

Thiruvananthapuram

Curriculum and Syllabus for

M.TECH RF AND MICROWAVE ENGINEERING

Department of Avionics

[From Academic Period 2022- 23]
(Approved By Academic Council on 27-4-2022)
Version1/17-05-2022

Program Educational Objectives (PEO)

1. Strengthen basic and advanced concepts in design of active & passive RF circuits and antennas through numerical/ analytical and computational skills in the area of RF and Microwave Engineering.
2. Empower the graduates with required knowledge and skills to pursue research/higher studies by developing appropriate academic curriculum with proper balance between theoretical and experimental exposure.
3. Encourage and inculcate innovative learning and research practices through appropriate components in the curriculum to enhance curiosity & creativity and thus enabling the graduates to take up state of the art research challenges in Industry/Academia/R&D organizations.
4. Instill a deep sense of ethics, social values, professionalism, interpersonal/leadership skills and ability to work in a team.

Program Outcomes (PO)

Program Outcomes	Statements
PO1	An ability to independently carry out research /investigation and development work to solve practical problems
PO2	An ability to write and present a substantial technical report/document
PO3	Students should be able to demonstrate a degree of mastery over the area as per the specialization of the program. The mastery should be at a level higher than the requirements in the appropriate bachelor program.
PO4	To ensure in-depth understanding of the fundamental and advanced concepts in the broad area of RF and Microwave Engineering.
PO5	To develop the ability to analyze/compute advanced mathematical aspects of applied RF and Electromagnetic systems, design and testing of advanced microwave circuits and radiating systems.
PO6	To encourage independent research/investigation skills to understand, solve and deal with practical problems in the area of Microwave and mm- wave technology.

COURSE STRUCTURE

Semester I

Code	Course Title	L	T	P	C
MA615	Advanced Engineering Mathematics	3	0	0	3
AVR611	Advanced Electromagnetic Engineering	3	0	0	3
AVR612	Microwave Circuits and Systems	3	0	0	3
AVR613	Microwave Semiconductor Devices	3	0	0	3
E01	Elective I	3	0	0	3
AVR631	Microwave Circuit Lab	0	0	1	1
AVR851	Seminar-I (Course Based)	0	0	0	1
	Total	15	0	1	17

Semester II

Code	Course Title	L	T	P	C
AVR621	Antenna Theory and Design	3	0	0	3
AVR622	Computational Methods for Electromagnetics	3	0	0	3
E02	Elective II	3	0	0	3
E03	Elective III	3	0	0	3
AVR852	RF Engineering Design	0	0	0	2
AVR641	Antenna Design Lab	0	0	1	1
AVR853	Seminar-II	0	0	0	2
	Total	12	0	2	17

Semester III

Code	Course Title	L	T	P	C
AVR854	Project Work Phase I	0	0	0	18
	Total	0	0	0	18

Semester IV

Code	Course Title	L	T	P	C
AVR855	Project Work Phase II	0	0	0	18
	Total	0	0	0	18

Summary

Semester	Credit
I	17
II	17
III	18
IV	18
Total	**70**

List of Electives

AVR861	RF IC and Microwave MEMS
AVR862	Millimeter Wave Integrated Circuits
AVR863	RF Packaging and Electromagnetic Compatibility
AVR864	Adaptive And Smart Antennas
AVR865	Phased Array Antennas
AVR866	Satellite Communication
AVR867	Optoelectronics And Fiber Optic Communication
AVR868	Wireless Channels And UWB Radios
AVR869	Remote Sensing
AVR870	Mobile Communication
AVR871	Electromagnetic and Microwave Application of Metamaterials
AVM863	RF Integrated Circuits
AVR874	RF Photonics
AVR873	Radar Systems
AVD622	Signal Processing for Communication (from M. Tech DSP)
AVD882	Wireless Communication (from M. Tech DSP)
AVD611	Modern Signal Processing (from M. Tech DSP)
	Any other relevant approved M. Tech course offered by other branches of the Department of Avionics

SEMESTER I

MA615	Advanced Engineering Mathematics	(3-0-0) 3 Credits

Complex integration: Cauchy-Goursat Theorem (for convex region), Cauchy's integral formula, Higher order derivatives, Morera's Theorem, Cauchy's inequality and Liouville's theorem, Fundamental theorem of algebra, Maximum modulus principle, Taylor's theorem, Schwarz lemma.
Laurent's series, Isolated singularities, Meromorphic functions, Rouche's theorem, Residues, Cauchy's residue theorem, Evaluation of integrals, Riemann surfaces. Direct and iterative methods for linear systems, eigenvalue decomposition and QR/SVD factorization, stability and accuracy of numerical algorithms, sparse and structured matrices, Gradient method for optimization. Finite element method: Finite element formulation of boundary value problems, one- and two dimensional finite element analysis. Functional and their differentiation, Euler-Lagrange equation, Boundary value problems, Variational principles, Rayleigh-Ritz Methods.

Textbooks/References:

1. Advanced Engineering Mathematics, Kreyszig, E., 9th edition, John Wiley, 2005.
2. Complex analysis for Mathematics and Engineering, Mathews, J. H. and Howell, R., Narosa, 2005.
3. Numerical Linear Algebra, V. Sundarapandian, Prentice-Hall, 2008.
4. Numerical Analysis, R. L. Burden and J. D. Faires, Brooks/Cole, 2001.
5. Calculus of Variations, I. M. Gelfand and S. V. Fomin, Prentice Hall, 1963.
6. Calculus of Variations with Applications, A. S. Gupta, Prentice Hall, 1997.
7. Advanced Engineering Mathematics, Jain, R. K. and Iyengar, S. R. K., Narosa, 2005.
8. Advanced Engineering Mathematics, Greenberg, M. D., Pearson Education, 2007.
9. Complex Variables and Applications, Churchill, R. V. and Brown, J. W., 6th ed., McGraw-Hill, 2004.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand fundamental concepts and theorems related to complex numbers, analytic functions, elementary functions, complex integration, and power series.
CO2	Know how to utilize residue theory to evaluate contour integrals, improper integrals, and integrals over the real line, and also know about the concept of conformal mapping and its applications.
CO3	Demonstrate how fundamental concepts of interpolation, numerical differentiation, and integration can be used for achieving better approximation and its analysis.
CO4	Acquire comprehensive understanding of linear algebraic systems, eigenvalues, eigenvectors, and various methods for solving linear systems
CO5	Utilize MATLAB programming to evaluate linear algebraic systems.

AVR611	Advanced Electromagnetic Engineering	(3-0-0) 3 Credits

Introduction to waves: The wave equation, waves in perfect dielectrics, lossy matter, reflection of waves, transmission line concepts, waveguide and resonator concepts, radiation and antenna concepts. Theorems and concepts: Duality, uniqueness, image theory, the equivalence principle, induction theorem, reciprocity theorem, Green's function and integral equation. Plane wave functions: The wave function, plane waves, rectangular waveguide and cavity, partially filled waveguide, dielectric slab waveguide, surface guided waves, currents in waveguides. Cylindrical wave function: The wave function, circular waveguide and cavity, radial waveguides, source of cylindrical waves, wave transformations, scattering by cylinders and wedges, apertures in cylinders and wedges. Spherical wave function: The wave function, spherical cavity, space as waveguide, source of spherical waves, scattering by sphere, apertures in sphere. Green's Functions: Green's function technique for the solution of partial differential equations, classification of Green's functions, various methods for the determination of Green's functions including Fourier transform technique and Ohm-Rayleigh technique, dyadic Green's functions, determination of Green's functions for free space, transmission lines, waveguides, and micro strips.

Textbooks/References:

1. Time Harmonic Electromagnetic Fields, R. F. Harrington, Wiley Interscience, IEEE Press, 2001.
2. C. A. Balanis, Advanced Electromagnetic Engineering, John Wiley & Sons, 1989.
3. Field Theory of Guided Waves, R. E. Collin, 2nd Ed, Wiley Interscience, IEEE Press, 1991.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Familiarize fundamental concepts of electromagnetic theory using Maxwell's equation in different format, wave equations, different coordinate system and their applications in different medium and boundary conditions.
CO2	Understand wave equation, boundary conditions and familiarize solutions wave equation in interfaces like dielectric-metal, dielectric-dielectric and various cases of polarization'
CO3	Familiarize with wave impedance, medium impedance, skin-effect, skin-depth, pointing vector and applying them in various guiding and propagating cases.
CO4	Apply plane waves for various guiding medium such as rectangular, dielectric, dielectric slab, partially filled waveguides, rectangular cavity resonator and associated modes and currents and understanding their uses for real world applications.
CO5	Learn the wave function and applying it in circular waveguide and cavity, radial waveguides and practical applications of cylindrical /spherical waves and wave transformations in scattering by cylinders and wedges, apertures in cylinders and wedges and scattering in spherical objects
CO6	Apply microwave network concepts in obstacles and posts in waveguides, diaphragms in waveguides, waveguide junctions, waveguide feeds, excitation of apertures, modal expansion in cavities and probes in cavities

AVR612	Microwave Circuits and Systems	(3-0-0) 3 Credits

Introduction to Wireless Systems: Classification of wireless systems; Design and performance issues include the choice of operating frequency, multiple access and duplexing, circuit switching versus packet switching, propagation, radiated power and safety; Cellular telephone systems and standards.
Noise and Distortion in Microwave Systems cover basic threshold detection, noise temperature and noise figure, noise figure of a lossy transmission line, and noise figure of cascade systems which include noise figure of passive networks, two-port networks, mismatched transmission lines, and Wilkinson power dividers. It also discusses dynamic range and inter-modulation distortion.
Resonators focus on the principles of microwave resonators, loaded, unloaded and external Q, open and shorted TEM lines as resonators, microstrip resonators, and dielectric resonators.
Power Dividers and Couplers examine the scattering matrix of - and -port junctions, design of T-junction and Wilkinson power dividers, and the design of 90° and 180° hybrids.
Filters are analyzed through periodic structures, Floquet's theorem, and filter design by the insertion loss method, including maximally flat and Chebyshev designs.
Microwave Amplifier Design compares active devices such as BJT, MOSFET, MESFET, HEMT, and HBT, circuit models for FETs and BJTs, two-port power gains, and the stability of transistor amplifier circuits. Amplifier design using S-parameters includes design for maximum gain, maximum stable gain, design for specified gain, low-noise amplifier design, and design of class-A power amplifiers.
Mixers cover mixer characteristics like image frequency, conversion loss, and noise figure, and devices for mixers such as PN junctions, Schottky barrier diode, and FETs. Diode mixers include small-signal characteristics of diode, single-ended mixer, large-signal model, and switching model. FET Mixers cover single-ended mixers and other FET mixers, balanced mixers, and image reject mixers.
Switches discuss devices for microwave switches such as PIN diode, BJT, and FET, including device models, types of switches, switch configurations, basic theory of switches, and multi-port, broad-band, and isolation switches.
Oscillators and Frequency Synthesizers include general analysis of RF oscillators, transistor oscillators, voltage-controlled oscillators, dielectric resonator oscillators, frequency synthesis methods, analysis of first and second order phase-locked loop, and oscillator noise and its effect on receiver performance.

Textbooks/References:

1. Microwave and RF Design of Wireless Systems, Pozar, D. M John Wiley & Sons, 2001.
2. Microwave Transistor Amplifiers: Analysis and Design, Gonzalez, G., 2nd Ed., Prentice-Hall, 1997.
3. Microwave Solid State Circuit Design Bahl, I. and Bhartia, P., 2nd Ed., John Wiley & Sons, 2003.
4. RF and Microwave Circuit and Component Design for Wireless Systems, Chang, K., Bahl, I. and Nair, V., Wiley Interscience, 2002.

5. RF/Microwave Circuit Design for Wireless Applications Rohde, U. L. and Newkirk, D. P., , John Wiley & Sons, 2000.
6. RF and Microwave Circuit Design for Wireless Applications, Larson, L. E., Artech House, 1996.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Learn and familiarize the wireless communication system and circuits, passive and active devices in terms of its gain and noise performance, link budget equations and its importance in wireless circuit.
CO2	Learn the basics of transmission line for interconnect design, characteristic impedance, scattering parameters for different microwave network, and passive microwave circuit design.
CO3	Evaluate the importance of matching circuit design considering lumped and transmission line and analyse RF transistors and FETs and their high frequency behaviour.
CO4	Compare active devices such as BJT, MOSFET, MESFET, HEMT, and HBT
CO5	Design microwave amplifiers for specified gain, power and noise performance. Understand use of packaged transistor model to design different driver, LNA and Power Amplifier.
CO6	Analyze non-linear microwave active circuits and design different mixing components
CO7	Design RF and microwave circuit using CAD.

AVR613	Microwave Semiconductor Devices	(3-0-0) 3 Credits

Transient and AC behavior of p-n junctions, effect of doping profile on the capacitance of p-n junctions, noise in p-n junctions, high-frequency equivalent circuit, varactor diode and its applications; Schottky effect, Schottky barrier diode and its applications; Heterojunctions. Tunneling process in p-n junction and MIS tunnel diodes, V-I characteristics and device performance, backward diode. Impact ionization, IMPATT and other related diodes, small-signal analysis of IMPATT diodes. Two-valley model of compound semiconductors, V_d-E characteristics, Gunn effect, modes of operation, small-signal analysis of Gunn diode, power frequency limit. Construction and operation of microwave PIN diodes, equivalent circuit, PIN diode switches, limiters and modulators. High frequency limitations of BJT, microwave bipolar transistors, heterojunction bipolar transistors; Operating characteristics of MISFETs and MESFETs, short-channel effects, high electron mobility transistor.

Textbooks/References:

1. Microwave Devices and Circuits, Liao, S. Y., 3rd Ed., Pearson Education 2002.
2. R.F. MEMS: Theory, Design and Technology, Rebeiz, M. G., 2nd Ed., Wiley Interscience, 2003.
3. Physics of Semiconductor Devices, Sze, S. M., and Ng, K. K., 3rd Ed., Wiley-Interscience 2006.
4. Microwave Devices, Circuits and Sub-Systems, Glover, I. A., Pennock, S. R. and Shepherd, P. R., 4th Ed., John Wiley & Sons, 2005.
5. RF and Microwave Semiconductor Device Handbook, Golio, M., CRC Press 2002.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand fundamentals of semiconductor devices and high frequency modelling of compound semiconductors.
CO2	Understand the modelling of Schottky and MESFET
CO3	Design devices at frequency zone using MESFET and HEMT
CO4	Design microwave and RF devices using IMPATT Diode, PIN diode and other high-frequency devices

AVR631	Microwave Circuits Lab	(0-0-1) Credits

1. Radio-Frequency Characteristics of Components
2. Introduction to Microwave Measurements: Detection of RF Power and Development of a Scalar Reflectometer
3. Introduction to Network Analysis
4. Introduction to Microstrip Transmission Lines and Computer-Aided Design
   lab5.mdl - IC-CAP file for measurement control
5. Introduction to Microwave Transistors
6. Matching Network Design and Circuit Layout
7. Amplifier Design for Maximum Power Transfer
8. Amplifier Nonlinear Performance and Inter modulation
9. Low Noise Amplifier Design
10. Resistive Mixer Design using Diode

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Familiarize basic RF related equipments and components, network analyzer and spectrum Analyzer.
CO2	Learn CAD software and understand the scattering parameter, concept of linear and non linear simulation. Understand Smith chart in the context of scattering response.
CO3	Design matching circuit using g lumped and distribute elements (S- Parameter Simulation).
CO4	Learn different circles for design of BJT or FET amplifiers. EM simulation verification of the schematic design and study linear and non linear characterization.
CO5	Design amplifier using noise consideration, noise circles drawing and learning different mixer design approaches and switches using PIN diode and FET transistors.

AVR 851	Seminar –I (Course Based)	(0-0-1) 1 Credits

1. Presentation (Topic to be chosen by students based on the options offered by the faculty members)
2. Contact Hours (12 HRS) [This depends with the interaction with the concerned faculty member]
3. Preparation of Report.
4. Evaluation is based on presentation and report submission.

EO1	Elective1	(3-0-0) 3 Credits

To be selected from the offered Elective List

SEMESTER II

AVR621	Antenna Theory and Design	(3- 0- 0) 3 credits

Fundamental: Concepts of antenna parameters, Radiation from Wires and Loops: Infinitesimal dipole, finite-length dipole, linear elements near conductors, dipoles for mobile communication, small circular loop, Aperture Antennas: Huygens' principle, radiation from rectangular and circular apertures, design considerations, Babinet's principle, Fourier transform method in aperture antenna theory, Horn and Reflector Antennas: Radiation from sectoral and pyramidal horns, design concepts, prime focus parabolic reflector and casse grain antennas Microstrip Antennas: Basic characteristics, feeding methods, methods of analysis, design of rectangular and circular patch antennas, Antenna Arrays: Analysis of uniformly spaced arrays with uniform and non-uniform excitation amplitudes, extension to planar arrays, synthesis of antenna arrays using Schelkunoff polynomial method, Fourier transform method, and Woodward-Lawson method.

Textbooks/References:

1. Antenna Theory and Design, Balanis, C. A., 3rd Ed., John Wiley & Sons 2005.
2. Electromagnetic Waves and Radiating Systems, Jordan, E. C. and Balmain, K. G 2nd Ed., Prentice-Hall of India 1993.
3. Antenna Theory and Design, Stutzman, W. L. and Thiele, H. A., 2nd Ed., John Wiley & Sons 1998.
4. Microstrip Antenna Design Handbook, Garg, R., Bhartia, P., Bahl, I. and Ittipiboon, A., Artech House 2001.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Familiarize basics of antenna parameters and its operating mechanism.
CO2	Analyze linear antennas in presence of the conductor, multiple identical wire antennas in the overall radiation,.
CO3	Familiarize uniform and non-uniform linear arrays in different Cartesian axis and its array characterization and extend to planar array design.
CO4	Design different antenna array and synthesis as per specification.
CO5	Design rectangular and circular geometry with different aperture's field with basics of aperture antenna radiation concepts from the Heisenberg's principle.
CO6	Design microstrip patch antenna using aperture antenna theory. Also design parameters and equations of patch antenna and patch antenna arrays.

AVR622	Computational Methods for Electromagnetics	(3- 0- 0) 3 credits

Fundamental Concepts: Integral equations versus differential equations, radiation and edge conditions, modal representation of fields in bounded and unbounded media. Finite Difference Methods: Introduction, Finite Difference Schemes, Finite differencing of parabolic PDE, Finite Differencing of Hyperbolic PDE, Finite differencing of elliptic PDE, Accuracy and stability of FD Solutions, Practical Applications in Guided structure. Integral Equations: Formulation of typical problems in terms of integral equations: wire antennas, scattering, apertures in conducting screens and waveguides, discontinuities in waveguides and microstrip lines; Solution of Integral equations: General Method of Moments (MoM) for the solution of integro-differential equations, choice of expansion and weighting functions, application of MoM to typical electromagnetic problems. Finite Element Method: Typical finite elements, Solution of two-dimensional Laplace and Poisson's equations, solution of scalar Helmholtz equation. Finite-difference Time-domain Method: Finite differences, finite difference representation of Maxwell's equations and wave equation, numerical dispersion, Yee's finite difference algorithm, stability conditions, programming aspects, absorbing boundary conditions.

Textbooks/References:

1. Field Theory of Guided Waves, Collin, R. E., 2nd Ed., Wiley-IEEE Press, 1991.
2. Computational Methods for Electromagnetics, Peterson, A. F., Ray, S. L., and Mittra, R., Wiley-IEEE Press, 1998.
3. Field Computation by Moment Methods, Harrington, R. F., Wiley-IEEE Press, 1993.
4. Numerical Techniques in Electromagnetics, Sadiku, M. N. O., 2nd Ed., CRC Press, 2001.
5. Finite Element Method for Electromagnetics, Volakis, J. L., Chatterjee, A., and Kempel, L. C., Wiley-IEEE Press, 1998.
6. Computational Electrodynamics, Taflove, A., and Hagness, S. C., 3rd Ed., Artech House.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Learn the fundamentals of different numerical methods, electromagnetic theorems, integral equations versus differential equations, radiation and edge conditions, and modal representation of fields in bounded and unbounded media.
CO2	Understand finite difference schemes, finite differencing of parabolic PDE, hyperbolic PDE, elliptic PDE, accuracy and stability of FD solutions and practical applications in guided structure.

CO3	Evaluate integral equations: wire antennas, scattering, apertures in conducting screens and waveguides, discontinuities in waveguides and microstrip lines and solution of integral equations.
CO4	Analyze finite differences, finite difference representation of Maxwell's equations and wave equation, numerical dispersion, Yee's finite difference algorithm, stability conditions, programming aspects, absorbing boundary conditions.
CO5	Apply typical finite elements, Solution of two-dimensional Laplace and Poisson's equations, solution of scalar Helmholtz equation.

AVR 852 RF Engineering Design (0- 0- 2) credits

1. Broad topic to be chosen by the students based on the topics suggested by the faculties.
2. Contact hours: 24 hours
3. Students are supposed to design and or develop a prototype in the area of passive/Active circuits/Antennas.

EO2 Elective II (3-0-0) 3 Credits

To be selected from the offered Elective List

EO3 Elective III (3-0-0) 3 Credits

To be selected from the offered Elective List

AVR641 Antenna Design Lab (0- 0 - 1) 1 Credit

Experiment 1: Introduction to Antenna Parameters
Experiment 2: Wire Antennas (Dipole Antenna, Loop Antennas)
Experiment 3: Complementary of Wire Antennas (Different types of Slot Antennas)
Experiment 4: Linear Arrays Introduction, Broadside Array, End-Fire Array
Experiment 5: Scanning Performances of Phased Array Antenna and their Design

Experiment 6: Yagi-Uda Antenna Design
Experiment 7: Horn Antennas Design (Pyramidal and Circular)
Experiment 8: Microstrip Patch Antenna and their Array Configuration
Experiment 9: Reflector Antennas (Parabolic Reflector and Flat Reflector)
Experiment 10: Antenna Measurement

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Understand of wire antennas simulation like dipole, loop, folded dipole and monopole antenna.
CO2	Simulate antenna array properties, linear and planar wire antenna array behavior, pattern synthesis study using antenna array.
CO3	Design aperture antenna radiation pattern and its behavior for patch antenna, horn antenna, and reflector antenna.
CO4	Design antennas for given specification.

AVR853 **Seminar II** **(0- 0 - 0) 3 Credit**

1. Presentation (Topic to be chosen by students based on the options offered by the faculty members).
2. Contact Hours (24 hours) [Faculty Interaction].
3. Seminar-II should be aimed for a detailed literature survey for 3rd and 4th Sem projects.
4. Students should concentrate on literatures, some designs analysis, calculations etc. and present a consolidated report to the panel.
5. Preparation of report.
6. Evaluation is based on the presentation and report submission.

SEMESTER III

AVR854	Project Work Phase I	(0- 0 - 0) 18 credits

- In Phase-I, students are supposed to show a progress report at the semester end.
- Multiple intermediate review meetings can be called by the supervisor and the course-coordinator.
- A report in the prescribed format on the literature survey, theoretical analysis, design guidelines, simulation, and experimental results, etc., is to be submitted to the committee.
- Final evaluation is done based on the supervisor’s mark, work done, presentation, and interaction.

SEMESTER IV

AVR855	Project Work Phase II	(0- 0 - 0) 18 credits

- In Phase-II, students are supposed to show the full work including the work done in Phase-I.
- Multiple intermediate review meeting during the semester can be called by the supervisor and the course-coordinator.
- A report in the prescribed format on the literature survey, theoretical analysis, design guidelines, simulation, development of the prototype and experimental characterization etc. to be submitted to the committee.
- Final evaluation is done based on the supervisor's mark, work done, quality of the work, novelty of the work, presentation before the committee and interaction in the panel.
- Students are encouraged to report their work in peer reviewed International conferences and journals.

ELECTIVE COURSES

AVR861	**RF IC & Microwave MEMS**	**(3- 0 - 0) 3 Credits**

Intro to MMIC, Processing & Layers, Passive MMIC Elements & Models, Active MMIC Elements & Models Biasing, Amplifiers.
Introduction to MMICs. Technologies: GaAs/Si/InP: MESFET HEMT BJT HBT. Applications, Circuit basics. Fabrication Technology. MMIC components, Active devices, Passive lumped elements, Micro strip elements.
Introduction: RF MEMS for microwave applications, MEMS technology and fabrication, mechanical modelling of MEMS devices, MEMS materials and fabrication techniques.
MEMS Switches: Introduction to MEMS switches; Capacitive shunt and series switches: Physical description, circuit model and electromagnetic modelling; Techniques of MEMS switch fabrication and packaging; Design of MEMS switches.
RF Filters and Phase Shifters: Modeling of mechanical filters, micro machined filters, surface acoustic wave filters, micro machined filters for millimeter wave frequencies; Various types of MEMS phase shifters; Ferroelectric phase shifters.
Transmission Lines and Antennas: Micro machined transmission lines, losses in transmission lines, coplanar transmission lines, micro machined waveguide components; Micro machined antennas: Micromachining techniques to improve antenna performance, reconfigurable antennas.
Integration and Packaging: Role of MEMS packages, types of MEMS packages, module packaging, packaging materials and reliability issues.

Textbooks/References:

1. RF MEMS and their Applications, Varadan, V.K., Vinoy, K.J. and Jose, K.J., John iley & Sons. 2002.
2. MEMS: Theory design and Technology, Rebeiz, G.M., John iley & Sons. 1999.
3. RF MEMS Circuit design for wireless Communications, e Los Santos, H.J, Artech House. 1999
4. Micromechanics & MEMS, Trimmer, IEEE Press.
5. Fundamentals of Microfabrication, Madou, M., CRC Press.
6. Semiconductor Sensors, Sze, S.M., John Wiley & Sons, 1994.

AVM863	**RF Integrated Circuits**	**(3- 0 - 0) 3 Credits**

On-chip RF passive components, resonant circuits, matching circuits. Noise – source, modelling, noise figure, noise temperature, noise figure of cascaded systems. Linearity – HD, IMD, IP2, IP3.

ACLR, AACLR. Basics of wireless communication. LNA design, input matching for power, input matching for noise. Advanced LNA circuits. Mixer topologies – active and passive. Receiver architectures. Voltage controlled oscillator topologies – theory and design. Phase locked loops (PLL) – theory, design of individual elements and the complete system. Power amplifier classes and topologies – theory and design. Transmitter architectures.

Textbooks/References

1. RF Microelectronics by Behzad Razavi, Pearson publication.
2. The Design of CMOS Radio-Frequency Integrated Circuits by Thomas H. Lee, Cambridge.

AVR862	**Millimeter Wave Integrated Circuits**	**(3- 0 - 0) 3 Credits**

Fundamental Concepts: Elements of microwave/millimeter wave integrated circuits; Classification of transmission lines: Planar, quasi planar and 3-D structures, their basic properties, field distribution and range of applications; Substrate materials and technology used for fabrication. Analysis of Planar Transmission Lines: Variational approach for the determination of capacitance of planar structures; Transverse transmission line techniques for multi-dielectric planar structures; Rigorous analysis of dielectric integrated guides; Use of effective dielectric constant in the approximate analysis of dielectric guide. Metamaterials: Theory of Composite Right/Left Handed (CRLH) transmission line metamaterials; Representation of CRLH metamaterial by an equivalent homogeneous CRLH TL; L-C network implementation and its physical realization. Discontinuities: Analysis of discontinuities in planar and non-planar transmission lines and their equivalent circuit representation. Passive Circuits: Design and circuit realization of filters, couplers, phase shifters, and switches using planar and non-planar transmission lines. Active Circuits: Design and circuit realization of amplifiers and oscillators using planar and nonplanar transmission lines.

Textbooks/References:

1. Advances in Microwaves, Leo Young and H. Sobol, Ed. Vol.2, Academic Press Inc., 1974.
2. Stripline-like transmission lines for MICs, B.Bhat and S. Koul, John Wiley, 1989.
3. Handbook of Microwave Technology, T.K. Ishii, vol. I, Academic Press, 1995.

AVR863 RF Packaging and Electromagnetic Compatibility (3- 0 - 0) 3 credits

EMC Requirements for Electronic Systems: Sources of EMI; Aspects of EMC; Radiated susceptibility; Conducted susceptibility; Electrostatic discharge; Design constraints for products; Advantages of EMC design; Transmission line per-unit-length parameters: Wire type structures, PCB structures; High-speed digital interconnects and signal integrity. Non-ideal Behavior of Components: Spurious effects of wires, PCB, component leads, resistors, capacitors, inductors, ferromagnetic materials, electromagnetic devices, MMIC components, digital circuit devices, and mechanical switches. Conducted and Radiated Emissions: Measurement of conducted emissions; Power supply filters; Power supply and its placement; Conducted susceptibility; Simple emission models for wires and PCB leads; Simple radiated susceptibility models for wires and PCB leads. Crosstalk: Three-conductor transmission lines, shielded wires, twisted wires, shielding. System Design for EMC: Safety ground; PCB design; System configuration and design.

Textbooks/References:

1. Introduction to Electromagnetic Compatibility, Paul, C.R., Wiley Interscience, 2006.
2. Electromagnetic Compatibility Handbook, Kaiser, K.L., CRC Press.
3. Engineering Electromagnetic Compatibility: Principles, Measurement and Technologies, Kodali, V.P., IEEE Press.

AVR864 Adaptive and Smart Antennas (3- 0 - 0) 3 credits

Adaptive Array Concept: Motivation of using Adaptive Arrays, Adaptive Array problem statement, Signal Environment, Array Element Spacing considerations, Array Performance, Nulling Limitations due to miscellaneous array effects, Narrow band and broad band signal processing considerations Optimum Array Processing: Steady state performance limits and the Wiener solution, Mathematical Preliminaries, Signal Description for conventional and signal aligned arrays, Optimum Array Processing for narrowband applications, Optimum Array Processing for broadband applications, Optimum Array Processing for perturbed propagation conditions Adaptive Algorithms: The least mean square error (LMS) algorithm, the Differential Steepest descent algorithm, the accelerated gradient approach, Gradient algorithm with constraints, Simulation studies. Recursive Methods for Adaptive Error Processing: The weighted Least Square Error Processor, Updated Covariance Matrix Inverse, Kalman Filter methods for Adaptive Array Processing, the minimum variance processor, Simulation studies. Effect of Mutual Coupling on Adaptive Antennas: Accounting for mutual effects for dipole array compensation using open-circuit voltages, compensation using the minimum norm formulation, Effect of mutual coupling-Constant Jammers, Constant Signal, Compensation of mutual coupling Constant Jammers, Constant Signal, Result of different elevation angle.

Textbooks/References:

1. Smart antennas: Adaptive arrays, algorithms and wireless position location, T. S. Rappaport, IEEE Press, 1998.
2. Smart antennas for wireless communications, Frank Gross, McGraw-Hill, 2006.
3. Adaptive antenna arrays, S. Chandran, trends and applications, Springer, 2009.

AVR865	**Phased Array Antennas**	**(3- 0 - 0) 3 credits**

Phased Arrays in Radar and Communication Systems: System requirements for radar and communication antennas, Array characterization for radar and communication systems, Fundamental results from array theory, Array size determination, Time-delay compression. Pattern characteristics of Linear and Planar Arrays: Array analysis, characteristics of linear and planer arrays, scanning to end fire, Thinned arrays. Pattern Synthesis for Linear and Planar Arrays: Linear arrays and planar arrays with separable distributions, circular planar arrays and adaptive arrays. Electronic Scanning Radar Systems: Frequency and phase scanning, Phase design techniques.

Textbooks/References:

1. Phased array antenna handbook, R. J. Mailloux, Artech house, 2005.
2. Phased array antennas, R. C. Hansen, John Wiley and Sons, 1998.
3. Array and phased array antennas basics, H. J. Visser, John Wiley and Sons, 2005.
4. Adaptive antennas and phased array for radar and communications, Alan J. Fenn, Artech house, 2007.

AVR866	**Satellite Communication**	**(3- 0 - 0) 3 credits**

Basic Principles: General features, frequency allocation for satellite services, properties of satellite communication systems.
Satellite Orbits: Introduction, Kepler's laws, orbital dynamics, orbital characteristics, satellite spacing and orbital capacity, angle of elevation, eclipses, launching and positioning, satellite drift and station keeping.
Satellite Construction (Space Segment): Introduction; attitude and orbit control system; telemetry, tracking and command; power systems, communication subsystems, antenna subsystem, equipment reliability and space qualification.
Satellite Links: Introduction, general link design equation, system noise temperature, uplink design, downlink design, complete link design, effects of rain.
Earth Station: Introduction, earth station subsystem, different types of earth stations.

The Space Segment Access and Utilization: Introduction, space segment access methods, TDMA, FDMA, CDMA, SDMA, assignment methods. The Role and Application of Satellite Communication.

Textbooks/References:

1. Satellite Communications, Timothy Pratt, Charles W. Bostian, John Wiley & Sons.
2. Satellite Communications, Dennis Roddy, 3rd Ed., Mc. Graw-Hill International Ed. 2001.
3. Satellite Communication Systems Engineering, W. L. Pritchard, J. A. Sciulli, Prentice-Hall, Inc., NJ.
4. Satellite Communication Engineering, M. O. Kolawole, Marcel Dekker, Inc. NY.

AVR867 Optoelectronics and Fiber Optic Communication (3- 0 - 0) 3 credits

Planar Optical Waveguides: Wave propagation in planar optical waveguides, ray theory, electromagnetic mode theory, phase and group velocity, dispersion. Optical Fibre Waveguides: Wave propagation in cylindrical fibres, modes and mode coupling, step and graded index fibres, single-mode fibres. Transmission Characteristics of Fibres: Attenuation, material absorption and scattering loss, bend loss, intra-modal and inter-modal dispersion in step and graded fibres, overall dispersion in single and multi-mode fibres. Optical Fibre Connection: Optical fiber cables, stability of characteristics, fibre alignment; Fibre splices, connectors, couplers. Optical Sources: Absorption and emission of radiation, population inversion and laser oscillation, pn junction, recombination and diffusion, stimulated emission and lasing, hetero-junctions, single frequency injection lasers and their characteristics, light emitting diode structures and their characteristics. Optical Detectors: Optical detection principles, p-n, p-i-n, and avalanche photodiodes. Optical Communication System: System description and design considerations of an optical fibre communication system, noise in detection process, power budgeting, rise time budgeting, maximum transmission distance. Optical networks: WDM concepts and principles, basic networks, SONET/SDH, broadcast-and select WDM networks, wavelength-routed networks, nonlinear effects on network performance, performance of WDM & EDFA systems; Solitons; Optical CDMA.

Textbooks/References:

1. Optical Fiber Communications, Senior, J.M., 2nd Edition, Prentice-Hall of India, 1999.
2. Optical Fiber Communications, Keiser, G.,3rd Edition, McGraw-Hill, 2000.
3. Introduction to Fiber Optics, Ghata, A. and Thyagarajan, K., Cambridge University Press. 1999
4. Fiber Optics and Optoelectronics, Cheo, P.K., 2nd Ed., Prentice-Hall. 1990
5. Optical Communication Systems, Govar, J., 2nd Ed., Prentice-Hall of India. 1996
6. Optical Waveguide Theory, Snyder, A.W. and Love, J.D., Chapman & Hall. 1983.

AVR868 Wireless Channels and UWB Radios (3- 0 - 0) 3 credits

Fundamental Concepts: Terrestrial links, satellite links, macrocells, microcells, picocells, body centric systems, UWB systems; Cellular concept; Multiple-access schemes and duplexing; Review of antenna parameters; Friss transmission formula.

Propagation Mechanisms: Review of reflection, refraction, and transmission of electromagnetic waves on a plane boundary; Rough surface scattering; Computation of field strength using ray optics; Wedge diffraction theory; Ray-fixed coordinate system; Uniform theory of diffraction. Basic Propagation Models: Path loss, noise modeling, free space loss, plane earth loss, link budget. Terrestrial Fixed Links: Path profiles, tropospheric refraction, obstruction loss, multiple knife-edge diffraction, multiple edge diffraction integral, diffraction over objects of finite size, influence of clutter.

Satellite Fixed Links: Effect of troposphere and ionosphere on path loss and noise.

Mobile Communication Links: Empirical and physical models for path loss; Statistical shadowing and its impact on coverage; Correlated shadowing; Narrowband fast fading: AWGN channel and narrowband fast fading channels, Rayleigh and Rician distributions, Doppler effect; Wideband fast fading: Cause and effect, wideband channel model and its parameters, frequency domain effects; Diversity techniques to overcome the effects of multipath channel. Ultra-wideband (UWB) Radio: Definition, benefits and applications of properties of UWB signals and systems; Waveform generation: Gaussian waveforms, waveform design for specific spectral masks, practical constraints; UWB channel models: Multipath channel model, path loss model, two-ray propagation model, measurement of channel characteristics; UWB antennas: Challenges in UWB antenna design, radiation of UWB signals, types of UWB antennas, beam forming for UWB signals.

Introduction to Body-Centric Wireless Systems.

Textbooks/References:

1. Antennas and Propagation for wireless Communication Systems, Saunders, S.R., John Wiley & Sons. 1999.
2. Antenna Theory and Design, Stutzman, W.L. and Thiele, H.A. 2nd Ed. John iley & Sons. 1998.
3. Wireless Communications: Principles and Practice, Rappaport, T.S., Pearson Education. 2002.
4. Ultra Wideband Signals and Systems in Communication Engineering, Ghavami, M., Michael, L.B., and Kohno, R., 2nd Ed., John Wiley & Sons.
5. Ultra-wideband Radio Technology, Siwia, K. and McKeown, John Wiley & Sons.
6. Antennas and Propagation for Body-Centric Wireless Communication, Hall, P.S. and Hao, Y. (Eds.), Artech House.
7. Wireless Information Networks, Pahlavan, K. and Levesque, A.H., John Wiley & Sons. 1995.
8. Land-mobile Radio System Engineering, Hess, G.C., Artech House, 1993.

AVR869	REMOTE SENSING	(3- 0 - 0) 3 credits

Remote sensing: definition, Components of Remote Sensing - Energy, Sensor, Interacting Body - Active and Passive Remote Sensing – Platforms – Aerial and Space Platforms – Balloons, Helicopters, Aircraft and Satellites – Synoptivity and Repetivity – Electro Magnetic Radiation (EMR) – EMR spectrum – Visible, Infra-red (IR), Near IR, Middle IR, Thermal IR and Microwave – Black Body Radiation - Planc 's law – Stefan Boltzman law. EMR interaction with atmosphere and earth materials: Atmospheric characteristics – Scattering of EMR – Raleigh, Mie, Non-selective and Raman Scattering – EMR Interaction with Water vapor and ozone – Atmospheric Windows – Significance of Atmospheric windows – EMR interaction with Earth surface Materials – Radiance, Irradiance, Incident, Reflected, Absorbed and Transmitted Energy – Reflectance – Specular and Diffuse Reflection Surfaces- Spectral Signature – Spectral Signature curves – EMR interaction with water, soil and earth surface: Imaging spectrometry and spectral characteristics. Optical and Microwave remote sensing: Satellites - Classification – Based on Orbits and Purpose – Satellite Sensors - Resolution – Description of Multi Spectral Scanning – Along and Across Track Scanners – Description of Sensors in Landsat, SPOT, IRS series – Current Satellites - Radar – Speckle - Back Scattering – Side Looking Airborne Radar – Synthetic Aperture Radar – Radiometer – Geometrical characteristics; Sonar remote sensing systems. Geographic information systems: GIS – Components of GIS – Hardware, Software and Organizational Context – Data – Spatial and Non-Spatial – Maps – Types of Maps – Projection – Types of Projection - Data Input – Digitizer, Scanner – Editing – Raster and Vector data structures – Comparison of Raster and Vector data structure – Analysis using Raster and Vector data – Retrieval, Reclassification, Overlaying, Buffering – Data Output–Printers and Plotters Visual Interpretation of Satellite Images – Elements of Interpretation - Interpretation Keys Characteristics of Digital Satellite Image – Image enhancement – Filtering – Classification - Integration of GIS and Remote Sensing – Application of Remote Sensing and GIS – Urban Applications- Integration of GIS and Remote Sensing – Application of Remote Sensing and GIS – Water resources – Urban Analysis – Watershed Management – Resources Information Systems. Global positioning system – an introduction.

Textbooks/References:

1. Remote sensing of the environment, Jensen, J.R., Prentice Hall, 2000.
2. Remote Sensing and Image Interpretation, Lillesand T.M. and Kiefer R, John Wiley and Sons, Inc, New York, 1987.
3. Singal Remote Sensing, Tata McGraw-Hill, New Delhi, 1990.
4. Fundamentals of remote sensing, George Joseph, Universities Press.
5. Remote Sensing Methods and Applications, Michael Hord, John Wiley & Sons, New York, 1986

AVR870	Mobile Communication	(3- 0 - 0) 3 credits

Cellular Concept: Frequency reuse, channel assignment, hand off, interference and system capacity, tracking and grade of service, improving coverage and capacity in cellular systems. Mobile radio propagation: Free space propagation model, outdoor propagation models, indoor propagation models, small scale multipath propagation, impulse model, small scale multipath measurements, parameters of mobile multipath channels, types of small scale fading, statistical models for multipath fading channels. Modulation techniques: minimum shift keying, Gaussian MSK, M-ARY QAM, M-ARY FSK, Orthogonal Frequency Division Multiplexing, Performance of digital modulation in slow-flat fading channels and frequency selective mobile channels. Equalization: survey of equalization techniques, linear equalization, non-linear equalization, algorithms for adaptive equalization. diversity techniques, rake receiver. Coding: vocoders, linear predictive coders, selection of speech coders for mobile communication, GSM Codec and RS Codes for CDPD. Multiple Access Techniques: FDMA, TDMA, CDMA, SDMA, Capacity of cellular CDMA and SDMA. Wireless systems and standards: second generation and third generation wireless networks and standards, LL, Blue Tooth. AMPS, GSM, IS-95 and ECT.

Text Books/References:

1. Wireless Communication: Principles and Practice, T. Rappaport, Prentice Hall PTR
2. Wireless and Mobile Communication, Palanivelu, T. G., Nakkeeran, R, PHI.
3. Principles of Mobile Communication Stüber, Gordon L., 2nd ed., Springer publications.

AVR871	Electromagnetic and Microwave Application of Metamaterials	(3- 0 - 0) 3 credits

Introduction to Metamaterials: Electrodynamics of Left-Handed Media, Wave Propagation in Left-Handed Media, Energy Density and Group Velocity, Negative Refraction, Fermat Principle, Other Effects in Left-Handed Media, Inverse Doppler Effect Backward Cerenkov Radiation, Negative Goos–Hanchen Shift Backward Leaky and Complex Waves, Phase Compensation and Amplification of Evanescent Modes, Perfect Tunneling, The Perfect Lens, Losses and Dispersion.
Synthesis of Bulk Metamaterials: Scaling Plasmas at Microwave Frequencies, Metallic Waveguides and Plates as One- and Two-Dimensional Plasmas, Wire Media, Spatial Dispersion in Wire Media, Synthesis of Negative Magnetic Permeability, Design and Analysis of the Edge and Broad Coupled SRR, The Double and Multiple Split SRR, Spirals Resonators, Higher-Order Resonances in SRRs, Isotropic SRRs, Scaling Down SRRs to Infrared and Optical Frequencies, 1/2/3 Dimensional SRR-Based Left-Handed Metamaterials, Ferrite Metamaterials, Chiral Metamaterials.
Transmission Line Analysis of Metamaterials: Ideal Homogeneous CRLH TLs, LC Network Implementation: Principle, Difference with Conventional Filters, Transmission Matrix Analysis,

Input Impedance, Cutoff Frequencies, Analytical Dispersion Relation, Bloch Impedance, Effect of Finite Size in the Presence of Imperfect Matching, Real Distributed 1D CRLH Structures, Two dimensional metamaterials.

Microwave Applications of Metamaterial Concepts: Filters- Stopband Filters, Bandpass Filters Based on Alternate Right-/Left-Handed (ARLH) Sections Implemented by Means of SRRs, Bandpass Filters Based on Alternate Right-/Left-Handed (ARLH) Sections Implemented by Means of CSRRs, CSRR-Based Bandpass Filters with Controllable, Highpass Filters and Ultrawide Bandpass Filters. Tunable Notch Filters and Stopband Filters, Synthesis of Metamaterial Transmission Lines with Controllable Characteristics and Applications, Miniaturization of Microwave Components.

Antenna Applications: Definition of small antennas, Limits of small antennas, Chu limit, Metamaterial based electrically small antennas, Efficiency, Q factor. Meta-structure for frequency notched antennas, Application of meta materials in leaky wave antennas, Time domain analysis and studies of various UWB antennas with and without Metamaterial loading.

Metamaterial Cloaking: Definition and general concepts, Comparison between electromagnetic invisibility and other low observability techniques, brief summary of the main techniques used to achieve electromagnetic invisibility, Figures of merit to describe the effectiveness of a cloaking device, critical comparison among the different approaches to cloaking, Scattering cancellation: principles and design techniques, Scattering cancellation based on volumetric metamaterials (plasmonic cloaking),Scattering cancellation based on meta surfaces (mantle cloaking).

Text Books/References:

1. Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications, Christophe Caloz, Tatsuo Itoh, Wiley-IEEE Press, 2005.
2. Metamaterials: Physics and Engineering Explorations, Nader Engheta and Richard W Ziolkowski, Wiley-IEEE Press, 2006.
3. Metamaterials with Negative Parameters: Theory, Design and Microwave Applications, Ricardo Marqués, Ferran Martín, Mario Sorolla, Wiley Publication

AVR874	**RF Photonics**	**(3- 0 - 0) 3 credits**

Optical properties of semiconductor materials -Optical absorption and emission-Diode lasers-edge emitting, vertical cavity surface emitting lasers, direct modulation-frequency chirping-steady state characteristics-noise. Dielectric waveguides, perturbation and coupled mode theory, Photonic crystals, metamaterials, plasmonic, Integrated optics and photonic integrated circuits. Optical modulators-Electrooptic, Electro absorption, Photodetectors. Optical delay lines, Optical based true time delays. Optoelectronic integrated circuits, Silicon photonics.

Texts/References:

1. Fundamentals of Photonics, B. Saleh and M. Teich, Wiley-Interscience, 2nd Edition, 2007.
2. Diode Lasers and Photonic Integrated Circuits, L. A. Coldren, S. W. Corzine and M. L. Mashanovitch, 2nd Edn., Wiley, 2012.
3. Photonics, A. Yariv and P. Yeh, 6th Edition, Oxford, 2007.
4. Semiconductor Optoelectronics Devices, P. Bhattacharya, 2nd Edition., PHI, 2009.
5. Integrated Optics, R. G. Hunsperger, Springer, 1995.
6. Laser Fundamentals, W. T. Silfvast, 2nd Edition, Cambridge, 1993.
7. Optical Integrated Circuits, Nishihara, McGraw Hill.

AVR873	**Radar Systems**	**(3- 0 - 0) 3 credits**

Nature of Radar and Applications, Simple form of Radar Equation, Radar Block Diagram and Operation, Prediction of Range Performance, Minimum Detectable Signal, Radar Receivers, Transmitter Power, CW and Frequency Modulated Radar, MTI and Pulse Doppler Radar, Tracking Radar, Detection of Radar Signals in Noise, Airborne Radar, Space borne Radar, Synthesis aperture radar, SHAR and MST radar.

Text Books/References.

1. Introduction to Radar Systems, M.I. Skolnik, McGraw hill, 2000.
2. Radar Handbook, M.I. Skolnik, McGraw hill, 2nd edition, 1990.
3. Battacharya, Radar Systems and Radar Aids to Navigation, A.K. Sen and A.B. Khanna Publications, 1988.

AVD882	**Wireless Communication**	**(3- 0 - 0) 3 credits**

Wireless Communications and Diversity: Introduction to Wireless Channel and Fading - Rayleigh/Rician Fading, Broadband Wireless Channel Modeling: Introduction to LTV Systems, Channel Delay Spread, Coherence Bandwidth, BER Comparison of Wired and Wireless Communication Systems. Introduction to Diversity, Multi-antenna Maximal Ratio Combiner, BER with Diversity, Spatial Diversity and Diversity Order. ISI and Doppler in Wireless Communications, Doppler Spectrum and Jakes Model. Spread spectrum: PN Sequences, DSSS with BPSK, Signal space dimensionality and processing gain, Frequency-Hop SS. CDMA- Introduction to CDMA, Multipath diversity, RAKE Receiver. OFDM: Introduction to OFDM, Multicarrier Modulation and Cyclic Prefix, Channel model and SNR performance, OFDM Issues – PAPR, Frequency and Timing Offset Issues, channel estimation. MIMO: Introduction to MIMO, MIMO Channel Capacity, SVD and Eigen modes of the MIMO Channel, MIMO Spatial Multiplexing – BLAST, MIMO Diversity – Alamouti, OSTBC, MRT, MIMO - OF M. U B

(Ultrawide Band): UWB Definition and Features, UWB Wireless Channels, U B ata Modulation, Uniform Pulse Train, Bit-Error Rate Performance of U B.

Textbook and References:

1. Fundamentals of Wireless Communications – David Tse and Pramod Viswanath, Publisher - Cambridge University Press.
2. Wireless Communications: Principles and Practice –Theodore Rappaport - Prentice Hall. Wireless Communications: Andrea Goldsmith, Cambridge University Press.
3. MIMO Wireless Communications – Ezio Biglieri – Cambridge University Press.
4. Modern Wireless Communications- Simon Haykin and Michael Moher, Person Education, 2007
5. Wireless Digital Communications: Modulation and Spread Spectrum Techniques, Kamilo Feher- Prentice-Hall, Inc., 1995.
6. Spread Spectrum and CDMA. Principles and Applications. Ipatov Valery, P- - John Wiley & Sons Ltd.
7. MIMO-OFDM wireless communications with MATLAB. Cho, Y. S., Kim, J., Yang, W. Y., Kang, C. G. John Wiley & Sons. 2010.

AVD622	**Signal Processing for Communication**	**(3-0-0) 3 Credits**

Motivating examples of digital communications. Spectrum availability and channels. Channel modeling base band and pass band channels. Digital modulation schemes for base band and pass band channels. Line coding, Pulse amplitude modulation, Phase modulation, CPFSK, Frequency shift keying, QAM.

Band limited channels and inter symbol interference (ISI). Signal design for band limited channels -Nyquist criterion and Pulse Shaping, Partial response signaling. Nonideal bandlimited channels - receivers for channels with ISI and AWGN-ML receiver, its performance. Signal processing algorithms for linear Equalization. Carrier and Symbol synchronization, Carrier Phase estimation: ML estimation, PLL, Symbol timing estimation: ML timing estimation, Joint estimation of carrier phase and symbol timing. Case studies of digital communication receivers.

Noise modeling in communication systems-additive white Gaussian noise (AWGN)channels. Signal space concepts: Geometric structure of the signal space, vector representation, signal norms, and inner product, orthogonality, Gram-Schmidt orthogonalization. Optimum receiver for AWGN channels: Optimal detection and error probability for digital signaling schemes. Matched filter and Correlation receiver.

Case study of design of digital communication system receiver with emphasis on signal processing algorithms.

Textbooks and References:

1. Communication systems, Simon Haykin,4th edition Wiley,2001.
2. Introduction to Communication Systems, Upamanyu Madhow, Cambridge University Press, 2014.
3. Fundamentals of Digital Communication, Upamanyu Madhow, Cambridge University Press, 2008.
4. Digital communication, BernardSklar,2nd edition, Pearson Education, 2000.
5. Digital Communication, John Proakis & MasoudSalehi,5th edition, McGraw-Hill,2008.
6. Signal processing for communications, Prandoni, Paolo, and Martin Vetterli. EPFL press, 2008.

Course Outcomes (COs):

Course Outcomes	Statements
CO1:	Design different digital modulation system and analyze the performance in terms of error rate and spectral efficiency
CO2:	Develop skills to design and implement multi-carrier modulation system including techniques for channel estimation, synchronization, and equalization.
CO3:	Analyze the performance of the multi-carrier modulation system in terms of PAPR, error rate and spectral efficiency
CO4:	Understand the concepts of MIMO system to configure the antenna for beam forming, spatial multiplexing and spatial diversity to achieve the desired performance in terms of data rate, reliability, and coverage
CO5:	Design and develop MIMO OFDM, hybrid beam forming, OTFS systems for 5G/6G.

AVD611 Modern Signal Processing (3-0-0) 3 Credits

Analysis of LTI system: Phase and magnitude response of the system, minimum phase, maximum phase, all pass. Multirate signal processing: Interpolation, decimation, sampling rate conversion, filter bank design, poly phase structures. Time-frequency representation; frequency scale and resolution; uncertainty principle, short-time fourier transform. Multi-resolution concept and analysis, Wavelet transform (CWT, DWT). Optimum Linear Filters: Innovations Representation of a Stationary Random Process, Forward and Backward linear prediction, Solution of the Normal Equations. Power Spectral Estimation: Estimation of Spectra from Finite Duration Observations of a signal, the Periodogram, Bartlett, Welch and Blackman, Tukey methods, Comparison of performance of Non-Parametric Power Spectrum Estimation Methods. Parametric Methods: Auto-

Correlation and Model Parameters, AR (Auto-Regressive), Moving Average (MA), and ARMA Spectrum Estimation. Frequency Estimation-Eigen Decomposition of autocorrelation matrix, Piscaranko's Harmonic Decomposition Methods, MUSIC Method. Adaptive Filter Theory: LMS, NLMS and RLS, Linear Prediction. DSP Processor architecture- DSP Number representation for signals, Study of fixed point and floating-point DSP processor and its architectures.

Reference Books:

1. Digital Signal Processing, Mitra, S.K., 3rd Edition, McGraw Hill 2008.
2. Discrete-time signal processing, Oppenheim, Alan V - Pearson Education India.
3. Multirate Systems and Filter Banks, P.P. Vaidyanathan, Prentice-Hall,1993.
4. Statistical digital signal processing and modeling, Monson H. Hayes, John Wiley & Sons.
5. Wavelet Basics, Y.T. Chan, Kluwer Publishers, Boston. 1993.
6. A Friendly Guide to Wavelets, Gerald Kaiser, Birkhauser, NewYork, 1992.
7. Digital signal processing: principles algorithms and applications, Proakis, John G. - PHI.
8. Adaptive filter theory, Haykin, Simon S. - Pearson Education India.

Course Outcomes (COs):

Course Outcomes	Statements
CO1	Ability to design and analyze LTI systems.
CO2	Understand and apply multi rate signal processing in DSP.
CO3	Designing optimum filters and spectral estimators for different signal processing applications.
CO4	Apply adaptive signal processing algorithms for real time applications.