Indian Institute of Space Science and Technology
Department of Space, Govt. of India
Thiruvananthapuram, India.

Curriculum and Syllabus for
M.TECH
RF AND MICROWAVE ENGINEERING – R2014

FIRST SEMESTER

Code	Course Title	Lecture Hours	Tutorial	Practical Credits	Total Credits
MA615	Advanced Engineering Mathematics	3	1	0	4
AVR611	Advanced Electromagnetic Engineering	3	1	0	4
AVR612	Microwave Circuits and Systems	3	1	0	4
AVR613	Microwave Semiconductor Devices	3	1	0	4
AVR631	Microwave Circuit Lab	0	0	1	1
Total		12	4	1	17

SECOND SEMESTER

Code	Course Title	Lecture Hours	Tutorial	Practical Credits	Total Credits
AVR621	Antenna Theory and Design	3	1	0	4
AVR622	Computational Methods for Electromagnetics	3	1	0	4
E01	Elective I	3	0	0	3
E02	Elective II	3	0	0	3
AVR641	Antenna Design Lab	0	0	1	1
AVR851	Seminar	0	0	0	3
Total		12	2	1	18

THIRD SEMESTER

Code	Course Title	Lecture Hours	Tutorial	Practical Credits	Total Credits
E03	Elective III	3	0	0	3
AVR852	Project Work Phase I	0	0	0	12
Total		3	0	0	15

FOURTH SEMESTER

Code	Course title	Lecture Hours	Tutorial	Practical Credits	Total Credits
AVR853	Project Work Phase II	0	0	0	20
Total		0	0	0	20

ELECTIVE COURSES

Course Code	Course Name
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 Metamaetrials

SEMESTER I

MA615	ADVANCED ENGINEERING MATHEMATICS	(3- 1 - 0) 4 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, eigen value 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.

Functionals and their differentiation, Euler-Lagrange equation, Boundary value problems, Variational principles, Rayleigh-Ritz Methods

Textbooks/References:

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

AVR611	ADVANCED ELECTROMAGNETIC ENGINEERING	(3- 1 - 0) 4 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.

Perturbation and variational techniques: Introduction, perturbation of cavity walls, cavity material perturbation, stationary formula for cavity, Ritz procedure, reaction concept, stationary formulas for waveguide, impedance and scattering.

Microwave Networks: Modal expansion in waveguides, Network concepts, One- and two- port network representation, obstacles and posts in waveguides, diaphragms in waveguides, waveguide junctions, waveguide feeds, excitation of apertures, modal expansion in cavities, probes in cavities, aperture coupling to cavities.

Textbooks/References:

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

AVR612	**MICROWAVE CIRCUITS AND SYSTEMS**	**(3- 1 - 0) 4 credits**

Introduction to Wireless Systems: Classification of wireless systems; Design and performance issues: 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: Basic threshold detection, noise temperature and noise figure, noise figure of a lossy transmission line; Noise figure of cascade systems: Noise figure of passive networks, two-port networks, mismatched transmission lines and Wilkinson power dividers; Dynamic range and inter-modulation distortion.

Resonators: Principles of microwave resonators, loaded, unloaded and external Q, open and shorted TEM lines as resonators, microstrip resonators, dielectric resonators.

Power Dividers and Couplers: Scattering matrix of 3- and 4-port junctions; Design of T junction and Wilkinson power dividers; Design of 90° and 180° hybrids.

Filters: Analysis of periodic structures, Floquet's theorem, filter design by insertion loss method, maximally flat and Chebyshev designs.

Microwave Amplifier Design: Comparison of active devices such as BJT, MOSFET, MESFET, HEMT, and HBT; Circuit models for FETs and BJTs; Two-port power gains; Stability of transistor amplifier circuits; Amplifier design using S-parameters: Design for maximum gain, maximum stable gain, design for specified gain, low-noise amplifier design, design of class-A power amplifiers.

Mixers: Mixer characteristics: Image frequency, conversion loss, noise figure; Devices for mixers: p-n junctions, Schottky barrier diode, FETs; Diode mixers: Small-signal characteristics of diode, single-ended mixer, large-signal model, switching model; FET Mixers: Single-ended mixer, other FET mixers; Balanced mixers; Image reject mixers.

Switches: Devices for microwave switches: PIN diode, BJT, FET; Device models; Types of switches; Switch configurations; Basic theory of switches; Multi-port, broad-band and isolation switches.

Oscillators and Frequency Synthesizers: 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, oscillator noise and its effect on receiver performance.

Textbooks/References:

1. Pozar, D.M. "Microwave and RF Design of Wireless Systems", John Wiley & Sons. 2001
2. Gonzalez, G., "Microwave Transistor Amplifiers: Analysis and Design", 2nd Ed., Prentice-Hall. 1997

3. Bahl, I. and Bhartia, P., "Microwave Solid State Circuit Design", 2nd Ed., John Wiley & Sons. 2003
4. Chang, K., Bahl, I. and Nair, V., "RF and Microwave Circuit and Component Design for Wireless Systems", Wiley Interscience. 2002
5. Rohde, U.L. and Newkirk, D.P., "RF/Microwave Circuit Design for Wireless Applications", John Wiley & Sons. 2000
6. Larson, L.E., "RF and Microwave Circuit Design for Wireless Applications", Artech House. 1996

AVR613	**MICROWAVE SEMICONDUCTOR DEVICES**	**(3- 1 - 0) 4 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, vd-E characteristics, Gunn effect, modes of operation, small-signal analysis of Gunn diode, powerfrequency 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. Liao, S.Y., "Microwave Devices and Circuits", 4th Ed., Pearson Education (2002).
2. Rebeiz, M.G., "R.F. MEMS: Theory, Design and Technology", 2nd Ed.,Wiley-Interscience (2003).
3. Sze, S.M., and Ng, K.K., "Physics of Semiconductor Devices", 3rd Ed.,Wiley-Interscience (2006).
4. Glover, I.A., Pennoek, S.R. and Shepherd P.R., "Microwave Devices, Circuits and Sub-Systems", 4th Ed., John Wiley & Sons (2005).
5. Golio, M., "RF and Microwave Semiconductor Devices Handbook", CRC Press (2002).

AVR631	**MICROWAVE CIRCUIT LAB**	**(0- 0 - 1) 1 credit**

SEMESTER II

AVR621	ANTENNA THEORY AND DESIGN	(3- 1 - 0) 4 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 cassegrain 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. Balanis, C.A., "Antenna Theory and Design", 3rd Ed., John Wiley & Sons (2005).
2. Jordan, E.C. and Balmain, K.G., "Electromagnetic Waves and Radiating Systems", 2nd Ed., Prentice-Hall of India (1993).
3. Stutzman, W.L. and Thiele, H.A., "Antenna Theory and Design", 2nd Ed., John Wiley & Sons (1998).
4. Garg, R., Bhartia, P., Bahl, I. and Ittipiboon, A., "Microstrip Antenna Design Handbook", Artech House (2001).

AVR622	COMPUTATIONAL METHODS FOR ELECTROMAGNETICS	(3- 1 - 0) 4 credits

Fundamental Concepts: Integral equations versus differential equations, radiation and edge conditions, modal representation of fields in bounded and unbounded media.

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 microstrips.

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. Collin, R.E., "Field Theory of Guided Waves", 2nd Ed., Wiley-IEEE Press. 1991

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

E01	ELECTIVE I	(3- 0 - 0) 3 credits

E02	ELECTIVE II	(3- 0 - 0) 3 credits

AVR641	ANTENNA DESIGN LAB	(0- 0 - 1) 1 credit

AVR851	SEMINAR I	(0- 0 - 0) 3 credits

SEMESTER III

E03	**ELECTIVE III**	**(3- 0 - 0) 3 credits**

AVR852	**PROJECT WORK PHASE I**	**(0- 0 - 0) 12 credits**

SEMESTER IV

AVR854	**PROJECT WORK PHASE II**	**(0- 0 - 0) 20 credits**

ELECTIVE COURSES

AVR861	RF IC AND 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, Microstrip 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.
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, micromachined filters, surface acoustic wave filters, micromachined filters for millimeter wave frequencies; Various types of MEMS phase shifters; Ferroelectric phase shifters.
Transmission Lines and Antennas: Micromachined transmission lines, losses in transmission lines, coplanar transmission lines, micromachined waveguide components; Micromachined 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. Varadan, V.K., Vinoy, K.J. and Jose, K.J., "RF MEMS and their Applications", John Wiley & Sons. 2002.
2. Rebeiz, G.M., "MEMS: Theory Design and Technology", John Wiley & Sons. 1999.
3. De Los Santos, H.J, "RF MEMS Circuit Design for Wireless Communications", Artech House. 1999
4. Trimmer, W., "Micromechanics & MEMS", IEEE Press. 1996
5. Madou, M., "Fundamentals of Microfabrication", CRC Press. 1997
6. Sze, S.M., "Semiconductor Sensors", John Wiley & Sons. 1994.

AVR862	MILLIMETER WAVE INTEGRATED CIRCUITS	(3- 0 - 0) 3 credits

Fundamental Concepts: Elements of microwave/millimeter wave integrated circuits; Classification of transmission lines: Planar, quasiplanar 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 non-planar transmission lines.

Textbooks/References:

1. Leo Young and H. Sobol, Ed. Advances in Microwaves, Vol.2, Academic Press Inc., 1974.
2. B.Bhat and S. Koul, Stripline-like transmission lines for MICs, John Wiley, 1989.
3. T.K. Ishii, Handbook of Microwave Technology, 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: Wiretype 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. Paul, C.R., “Introduction to Electromagnetic Compatibility”, Wiley Interscience. 2006
2. Kaiser, K.L., “Electromagnetic Compatibility Handbook”, CRC Press. 2004
3. Kodali, V.P., “Engineering Electromagnetic Compatibility: Principles, Measurement and Technologies”, IEEE Press. 2001.

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. T. S. Rappaport, Smart antennas: Adaptive arrays, algorithms and wireless position location, IEEE Press, 1998.
2. Frank Gross, Smart antennas for wireless communications, McGra-Hill, 2006.
3. S. Chandran, Adaptive antenna arrays, 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 endfire, 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. R. J. Mailloux, Phased array antenna handbook, Artech house, 2005.
2. R. C. Hansen, Phased array antennas, John Wiley and Sons, 1998
3. H. J. Visser, Array and phased array antennas basics, John Wiley and Sons, 2005.
4. Alan J. Fenn, Adaptive antennas and phased array for radar and communications, 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. Timothy Pratt, Charles W. Bostian, Satellite Communications, John Wiley & Sons.
2. Dennis Roddy, Satellite Communications, 3rd Ed., Mc. Graw-Hill International Ed. 2001.
3. W. L. Pritchard, J. A. Sciulli, Satellite Communication Systems Engineering, Prentice-Hall, Inc., NJ.
4. M. O. Kolawole, Satellite Communication Engineering, 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, p-n 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. Senior, J.M., “Optical Fiber Communications”, 2nd Ed., Prentice-Hall of India. 1999
2. Keiser, G., “Optical Fiber Communications,” 3rd Ed., McGraw-Hill. 2000
3. Ghatak, A. and Thyagarajan, K., “Introduction to Fiber Optics”, Cambridge University Press. 1999
4. Cheo, P.K., "Fiber Optics and Optoelectronics", 2nd Ed., Prentice-Hall. 1990
5. Govar, J., "Optical Communication Systems", 2nd Ed., Prentice-Hall of India. 1996
6. Snyder, A.W. and Love, J.D., "Optical Waveguide Theory", 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. Saunders, S.R., “Antennas and Propagation for Wireless Communication Systems”, John Wiley & Sons. 1999.
2. Stutzman, W.L. and Thiele, H.A. “Antenna Theory and Design”, 2nd Ed. John Wiley & Sons. 1998
3. Rappaport, T.S., “Wireless Communications: Principles and Practice”, Pearson Education. 2002
4. Ghavami, M., Michael, L.B., and Kohno, R., “Ultra Wideband Signals and Systems in Communication Engineering”, 2nd Ed., John Wiley & Sons. 2007
5. Siwiak, K. and McKeown, D., “Ultra-wideband Radio Technology”, John Wiley & Sons. 2004
6. Hall, P.S. and Hao, Y. (Eds.), “Antennas and Propagation for Body-Centric Wireless Communication”, Artech House. 2006
7. Pahlavan, K. and Levesque, A.H., "Wireless Information Networks", John Wiley & Sons. 1995
8. Hess, G.C., "Land-mobile Radio System Engineering", 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 - Planck'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 vapour 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 Organisational 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. Jensen, J.R., Remote sensing of the environment, Prentice Hall, 2000.
2. Lillesand T.M. and Kiefer R.W., "Remote Sensing and Image Interpretation", John Wiley and Sons, Inc, New York, 1987.
3. Singal, "Remote Sening", Tata McGraw-Hill, New Delhi, 1990.
4. George Joseph, Fundamentals of remote sensing, Universities Press.
5. Mischael Hord, "Remote Sensing Methods and Applications", John Wiley & Sons, New York, 1986

AVR642 MILLIMETER WAVE INTEGRATED CIRCUITS LAB (0- 0 -1) 1 credits

AVR643 EMI AND EMC TESTING LAB (0- 0 -1) 1 credits

(Need to be removed)

AVR 871 Electromagnetic and Microwave Application of Metamaetrials (3-0-0-3)

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

Defination of small antennas, Limits of small antennas, Chu limit, Metamatetial based electrically small antennas, Efficiency, Q factor. Meta-structure for frequency notched antennas, Application of maetamaterials 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 appr oaches to cloaking, Scattering cancellation: principles and design techniques, Scattering cancellation based on volumetric metamaterials (plasmonic cloaking),Scattering cancellation based on metasurfaces (mantle cloaking)