List of Semester Wise Courses for M.Tech in RF and Microwave Engineering

			Min. Credits
Semester V/VI (Optional courses)	1	Electromagnetic Field Theory	4
	2	Microwave Devices and Circuits	3
	3	Antenna and Propagation	3
Semester VII	1	Basics of RF and Microwave	3
	2	Computational Electromagnetics	4
	3	Master Specialization I	3
Semester VIII	4	Master Specialization II	3
	5	Master Specialization III	3
	6	Master Specialization IV	3
	7	Master Specialization V	3
	8	Master Specialization VI	3
Semester IX	9	Master Specialization VII	3
	10	Master Specialization VIII	3
		Dissertation	9
Semester X		Dissertation	15

Total credits: 55 (Minimum)

List of courses for M.Tech in RF and Microwave Engineering

Optional/ Core Courses		Credits
1	Electromagnetic Field Theory	4
2.	Microwave Devices and Circuits	3
3.	Antenna and Propagation	3
Master Core		
1*	Basics of RF and Microwave	3
2*	Computational Electromagnetics	4
Master Specialization		
3*	RF and Microwave Passive Components	4
4*	RF and Microwave Active Circuits	3
5*	Advanced Microwave Measurements	3
6*	Advanced Antenna Systems	3
7*	RADAR systems	3
8*	Introduction to RF MEMS	3
9*	EMI/EMC	3
10*	Terahertz: Technology and Applications	3

Note:

1. The optional courses already exist in B.Tech course structure.
2. *The Master Core/ Specialized courses (star marked) are new courses for M.Tech specialization in RF and Microwave Engineering.

Optional/ Core Courses

1. Electromagnetic Field Theory

Maxwell's Equation: Faraday's law, Transformer and motional EMFs, Displacement current, Maxwell equations in final forms, Time varying potentials, Time-Harmonic Fields. Electromagnetic Wave Propagation: Waves in general, Wave propagation in lossy dielectrics, Plane waves in lossless dielectrics, Plane waves in free space, Plane waves in good conductors, Power and Poynting vector, Reflection of a plane wave at normal and oblique incidence. Transmission Lines: Transmission line parameters and equations; Input impedance, SWR, and Power; Smith Chart, Some applications of Transmission lines, Transients on transmission lines, Microstrip transmission lines. Waveguides: Rectangular waveguides, Transverse Magnetic modes, Transverse Electric modes, Wave propagation in the guide, Power transmission and attenuation, Waveguide current and mode excitation, Waveguide resonators.

Text/ Reference Books:

1. M. N. O. Sadiku, Elements of Electromagnetics Oxford University Press (India).
2. Hayt and Buck, Engineering Electromagnetics TMH.
3. Ramo, Whinnery and Van Duzer, John Fields and Waves in Communications Electronics Wiley & Sons.
4. David K Cheng, Field and Wave Electromagnetics Pearson Education (India)

2. Microwave Devices and Circuits

Applications of Microwaves: Civil and Military, Medical, EMI/ EMC. Mathematical Model of Microwave Transmission-Concept of Mode, Features of TEM, TE and TM Modes, Losses associated with microwave transmission, Concept of Impedance in Microwave transmission. Analysis of RF and Microwave Transmission Lines- Coaxial line, Rectangular waveguide, Circular waveguide, Strip line, Micro strip line. Microwave Network Analysis- Equivalent voltages and currents for non-TEM lines, Network parameters for microwave circuits, Scattering Parameters. Passive and Active Microwave Devices- Microwave passive components: Directional Coupler, Power Divider, Magic Tee, Attenuator, Resonator. Microwave active components: Diodes, Transistors, Oscillators, Mixers. Microwave Semiconductor Devices: Gunn Diodes, IMPATT diodes, Schottky Barrier diodes, PIN diodes. Microwave Tubes: Klystron, TWT, Magnetron. Microwave Design Principles- Impedance transformation, Impedance Matching, Microwave Filter Design, RF and Microwave Amplifier Design, Microwave Power Amplifier Design, Low Noise Amplifier Design, Microwave Mixer Design, Microwave Oscillator Design. Microwave Antennas- Antenna parameters, Antenna for ground based systems, Antennas for airborne and satellite borne systems, Planar Antennas. Microwave Measurements- Power, Frequency and impedance measurement at microwave frequency, Network Analyzer and measurement of scattering parameters, Spectrum Analyzer and measurement of spectrum of a microwave signal, Noise at microwave frequency and measurement of noise figure. Measurement of Microwave antenna parameters. Microwave Systems- Radar, Terrestrial and Satellite Communication, Radio Aids to Navigation, RFID, GPS. Modern Trends in Microwaves Engineering- Effect of Microwaves on human body, Medical and Civil applications of microwaves, Electromagnetic interference and Electromagnetic Compatibility (EMI & EMC), Monolithic Microwave ICs, RFMEMS for microwave components, Microwave Imaging.

Text/ Reference Books

1. R.E. Collins, Microwave Circuits, McGraw Hill
2. K.C. Gupta and I.J. Bahl, Microwave Circuits, Artech house

3. Antenna and Propagation

Fundamental Concepts- Physical concept of radiation, Radiation pattern, near-and far-field regions, reciprocity, directivity and gain, effective aperture, polarization, input impedance, efficiency, Friis transmission equation, radiation integrals and auxiliary potential functions. Radiation from Wires and Loops- Infinitesimal dipole, finite-length dipole, linear elements near conductors, dipoles for mobile communication, small circular loop. Aperture and Reflector Antennas- Huygens' principle, radiation from rectangular and circular apertures, design considerations, Babinet's principle, Radiation from sectoral and pyramidal horns, design concepts, prime-focus parabolic reflector and cassegrain antennas. Broadband Antennas- Log-periodic and Yagi-Uda antennas, frequency independent antennas, broadcast antennas. Micro strip Antennas- Basic characteristics of micro strip antennas, 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, Woodward-Lawson method. Basic Concepts of Smart Antennas- Concept and benefits of smart antennas, Fixed weight beam forming basics, Adaptive beam forming. Different modes of Radio Wave propagation used in current practice.

Text/ Reference Books

1. J.D. Kraus, Antennas, McGraw Hill, 1988.
2. C.A. Balanis, Antenna Theory - Analysis and Design, John Wiley, 1982.
3. R.E. Collin, Antennas and Radio Wave Propagation, McGraw Hill, 1985.
4. .R.C. Johnson and H. Jasik, Antenna Engineering Handbook, McGraw Hill, 1984.
5. .I.J. Bahl and P. Bhartia, Micro Strip Antennas, Artech House,1980.
6. R.K. Shevgaonkar, Electromagnetic Waves, Tata McGraw Hill, 2005
7. R.E. Crompton, Adaptive Antennas, John Wiley

Master Core Courses

1. Basics of RF and Microwave

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

Text/ Reference Books

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

2. Computational Electromagnetics

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

Text/ Reference Books

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

Master Specialized Courses

3. RF and Microwave Passive Components

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

Text/ Reference Books

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

4. RF and Microwave Active Circuits

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

Text/ Reference Books

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

5. Advanced Microwave Measurement

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

Text/ Reference Books

1. A. Basu ‘Introduction to Microwave Measurements,’ CRC Press 2014.

2. Keysight Technologies Application Notes.
3. C.A. Balanis, 'Antenna Theory - Analysis and Design', John Wiley-India Edition, 2005.

6. Advanced Antenna Systems

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

Text/ Reference Books

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

7. RADAR Systems

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

Text/ Reference Books

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

8. Introduction to RF MEMS

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

Text/ Reference Books

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

9. Electromagnetic Interference/Electro-magnetic Compatibility

BASIC THEORY: Intra and inter system EMI, Elements of Interference: Conducted and Radiated EMI emission and susceptibility, EMC Engineering Application. COUPLING MECHANISM: Coupling paths, Coupling via the supply network, Common mode coupling, Differential mode coupling, Impedance coupling, Radiative coupling, Ground loop coupling, Cable related emissions and coupling, Transient sources, Automotive transients. Categorization of the electromagnetic interference: emission, susceptibility, transients, crosstalk, shielding and compatibility, signal integrity. EMI MITIGATION TECHNIQUES: Working principle of Shielding, LF Magnetic shielding, Apertures and shielding effectiveness, Choice of Materials for H, E, and free space fields, Gasketting and sealing, PCB Level shielding, Principle of Grounding. STANDARDS AND REGULATION: Need for Standards, EMI Standardizing for different application. IEC, ANSI, FCC, AS/NZS, CISPR, BSI, CENELEC, ACEC. MIL461E. EMI TEST METHODS AND INSTRUMENTATION: Fundamental considerations, EMI Shielding effectiveness tests, Open field test, TEM cell for immunity test, Shielded chamber, Shielded anechoic chamber, EMI test receivers, Spectrum analyser, EMI test wave simulators, EMI coupling networks, Line impedance stabilization networks, Feed through capacitors, Antennas, Current probes. BASICS OF BIOLOGICAL EFFECTS OF EM WAVES: Ionizing and non-ionizing radiation. Theoretic and diagnostic use of EM waves. Measurement techniques of EM radiation. Protective design techniques.

Text/ Reference Books

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

10. Terahertz: Technology and Applications

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

Rectification concept and technological challenges. Design and development of nano-rectennas. Fabrication and measurement techniques.

Text/ Reference Books

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