M Tech
in
Electronics and Communication Engineering
(Microwaves)
with Minors in
Quantum Technology/ Artificial Intelligence & Machine Learning/ Environmental Engineering & Sustainability

Under Curriculum and Credit Framework for Postgraduate Programme (CCFPP), as per N.E.P. 2020
w.e.f. 2026 – 2027



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Introductory Note

The Master of Technology (M.Tech.) program in Electronics and Communication Engineering with specialization in Microwaves, offered with the option of earning a Minor in Quantum Technology / Artificial Intelligence & Machine Learning / Environmental Engineering & Sustainability, has been meticulously designed under the Curriculum and Credit Framework for Postgraduate Programme (CCFPP), as per the National Education Policy (NEP) 2020, effective from the academic session 2026–2027. This program represents a significant milestone in the postgraduate education offered by the Department of Physics, The University of Burdwan, catering to the ever-growing demands of the wireless communication, defense, space, radar, and emerging technology industries.

The microwave frequency spectrum serves as the backbone of modern technological infrastructure, enabling high-speed 5G/ 6G communication, satellite broadcasting, radar surveillance, navigation systems, and the emerging Internet of Things (IoT). With the rapid proliferation of millimeter-wave (mm-Wave) technologies for next-generation wireless systems, the relevance of specialized microwave engineering education has never been more critical. This program is thoughtfully structured to address these contemporary challenges while building a strong foundation in classical microwave theory and practice.

A distinctive feature of this program is the integration of interdisciplinary minor specializations in one of the cutting-edge domains of Quantum Technology, Artificial Intelligence & Machine Learning, and Environmental Engineering & Sustainability. These minors, offered through SWAYAM/ NPTEL platforms, enable students to develop complementary expertise that enhances their core microwave engineering competencies, making them versatile professionals capable of addressing complex challenges at the intersection of multiple technological domains.

The program spans four semesters with a total credit load of 90 credits. The curriculum is designed to progressively build competence—from foundational theoretical knowledge in the first semester to advanced system-level design, hands-on measurement skills, and culminating in a year-long research-intensive project in the third and fourth semesters.

Program Structure and Pedagogical Philosophy

Semester-wise Breakdown

Semester I establishes the core pillars of microwave engineering through four foundational courses:

- **PG2MTMW1011 (Analytical and Computational Methods in Electromagnetics):** Equipping students with analytical techniques (Green's functions, separation of variables) and numerical methods (FDM, FDTD, MoM, FEM) essential for modeling complex electromagnetic phenomena.
- **PG2MTMW1012 (Microwave and mm-Wave Circuits):** Building expertise in passive circuit design, network analysis (S-parameters, ABCD matrices), Smith chart applications, impedance matching, resonators, filters, and planar microwave components.
- **PG2MTMW1013 (Microwave and mm-Wave Vacuum and Solid-State Devices):** Covering the physics and applications of active devices ranging from klystrons and TWTs to Gunn diodes, IMPATTs, and HEMTs, along with MMIC technology and device selection strategies.

- **PG2MTMW1014 (Microwave and mm-Wave Communication Systems):** Providing a systems-level understanding of terrestrial microwave links, propagation modeling using ITU-R standards, link budgeting, digital modulation, and modern transport technologies.

Semester II transitions to specialized and applied domains:

- **PG2MTMW2011 (Microwave and mm-Wave Test & Measurement):** A full practical course (0-0-6) offering hands-on proficiency with VNAs, spectrum analyzers, power meters, and advanced measurement techniques including injection-locking, gain compression, and radiation pattern measurements.
- **PG2MTMW2012 (Satellite and Mobile Communication):** Covering orbital mechanics, space/ground segment engineering, satellite link budgets, DVB-S2X standards, and terrestrial cellular RF planning with emerging NTN integration.
- **PG2MTMW2013 (Antenna, Radar and Navigation):** Integrating antenna theory (microstrip, horn, reflector, phased arrays), radar signal processing (MTI, FMCW, SAR), and navigation systems (VOR, DME, GPS/GNSS) into a unified framework.
- **PG2MTMW2014 (Microwave and mm-Wave Active Circuits and Transceiver Systems):** Delving into amplifier design (LNA, PA, broadband), oscillators, mixers, frequency synthesis, and complete receiver architectures with cascade analysis.

Semesters III and IV are dedicated to the capstone project work (40 credits total), where students undertake independent research and development at reputed institutions and laboratories across the country, including The University of Burdwan. This project component enables students to demonstrate mastery over the specialization and contribute original work to the field.

Credit Distribution and L-T-P Structure

The program employs a well-balanced L-T-P (Lecture-Tutorial-Practical) structure:

- Semester I: 16-4-8 (Total 28 Credits)
- Semester II: 13-3-6 (Total 22 Credits)
- Semester III: 0-0-20 (Total 20 Credits - Project)
- Semester IV: 0-0-20 (Total 20 Credits - Project)

Grand Total: 29 Credits of Theory, 7 Credits of Tutorial, and 54 Credits of Practical/Project work (Total 90 Credits)

This structure ensures that students develop both analytical rigor (through theory and tutorial hours) and hands-on proficiency (through extensive practical and project components).

Minor Courses

The program includes two Minor Courses (PG2MTMW1021 in Semester I and PG2MTMW2021 in Semester II), each carrying 04 credits, offered through SWAYAM/NPTEL platforms. Students must choose courses from the same field in both semesters from one of the following areas:

- Quantum Technology

- Artificial Intelligence & Machine Learning
- Environmental Engineering & Sustainability

This structured minor pathway ensures depth of learning in the chosen interdisciplinary domain, complementing the core microwave engineering curriculum.

Distinctive Features of the Program

1. **Vertical Integration:** The curriculum ensures seamless progression from fundamental concepts (Semester I) to advanced design and research (Semesters III & IV), with each course building upon the knowledge acquired in previous courses, as evidenced by the clearly defined prerequisites for each course.
2. **Balanced Theory and Practice:** With dedicated laboratory components (L-T-P structure), a full practical course on test and measurement (PG2MTMW2011), and extensive practical sessions in all Semester I courses, students develop both analytical rigor and hands-on proficiency.
3. **Industry-Relevant Competencies:** The inclusion of ITU-R propagation models, DVB-S2X standards, load-pull characterization, modern CAD tools, and professional planning software ensures graduates are industry-ready.
4. **Research Orientation:** The year-long project work (40 credits), extensive computational modeling components, and emphasis on technical writing and seminar presentations cultivate a strong research mindset, directly addressing PO1 (independent research capability).
5. **Regulatory and Compliance Awareness:** Courses incorporate spectrum management, ITU-R recommendations, EMI/EMC compliance, and intellectual property rights, preparing students for professional engineering practice.
6. **mm-Wave Integration:** All core courses have been updated to include millimeter-wave perspectives, reflecting the growing importance of frequencies above 30 GHz in 5G/6G, automotive radar, satellite communications, and emerging terahertz technologies.
7. **Interdisciplinary Minor Specializations:** The unique inclusion of minors in Quantum Technology, AI/ML, and Environmental Engineering & Sustainability, offered through SWAYAM/ NPTEL, enables students to develop complementary expertise that enhances their core microwave engineering competencies and aligns with NEP 2020's vision of holistic and multidisciplinary education.
8. **Program Articulation and Accountability:** The inclusion of Course Articulation Matrices (CAMs) for each course and a comprehensive Program Articulation Matrix (PAM) demonstrates strong alignment between individual course outcomes and program-level outcomes, ensuring transparency, continuous improvement, and accreditation readiness.
9. **Comprehensive Skill Development:** The curriculum addresses all three Program Outcomes—research capability (PO1), technical reporting (PO2), and mastery over specialization (PO3)—with strong correlations (average mapping of 2.96, 2.27, and 2.86 respectively), ensuring holistic graduate development.

10. **Project-Based Learning:** The 40-credit project work (Semesters III and IV) represents the capstone experience, enabling students to demonstrate the highest level of mastery across all PSOs, with Project-II achieving a perfect 3.00 mapping to PSO1, PSO2, PSO3, and PSO4.

Program Outcome (PO)

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

Program Specific Outcome (PSO)

PSO1:	Ability to design and develop advanced passive and active microwave subsystems—including planar couplers/ filters, low-noise/ power amplifiers, and oscillators using rigorous S-parameter network theory, impedance matching techniques, and non-linear device physics to meet the specified performance criteria.
PSO2:	Ability to characterize and validate microwave components, terrestrial/ satellite communication links, and radar systems using precision RF instrumentation (VNA, Spectrum Analyzer, Power Meter) and standard ITU-R propagation/ interference models, ensuring measurement accuracy, regulatory compliance, and link reliability.
PSO3:	Model complex electromagnetic phenomena using suitable computational techniques and execute system-level simulations of transceivers, phased arrays, and radar processors using CAD platforms, enabling accurate performance prediction and optimization of real-world microwave systems.
PSO4: (Minors)	Ability to apply interdisciplinary knowledge from emerging fields, including Quantum Technology, Artificial Intelligence & Machine Learning, or Environmental Engineering & Sustainability to augment microwave engineering practice, enabling advanced sensing, communication, computational modeling, and sustainable design solutions for complex real-world problems.

Semester wise and Course wise Distribution of Credit & Marks under CCFPP as per NEP, 2020

Semester-I

Course Type	Course Code	Name of the Course	Credit	L - T - P	Marks	Marks Distribution Th. - Pr. - IA
Core Course (Th & Pr)	PG2MTMW1011	Analytical and Computational Methods in Electromagnetics	6	3 - 1 - 2	75	40 - 20 - 15
Core Course (Th & Pr)	PG2MTMW1012	Microwave and mm-Wave Circuits	6	3 - 1 - 2	75	40 - 20 - 15
Core Course (Th & Pr)	PG2MTMW1013	Microwave and mm-WaveVacuum and Solid-State Devices	6	3 - 1 - 2	75	40 - 20 - 15
Core Course (Th & Pr)	PG2MTMW1014	Microwave and mm-Wave Communication Systems	6	3 - 1 - 2	75	40 - 20 - 15
Minor Course (Th)	PG2MTMW1021	Minor-I (To be opted from SWAYAM/ NPTEL)	4	4 - 0 - 0	75	75 - 00 - 00
Total			**28**	**16 - 4 - 8**	**375**	**235 - 80 - 60**

Semester-II

Course Type	Course Code	Name of the Course	Credit	L - T - P	Marks	Marks Distribution Th. - Pr. - IA
Core Course (Pr)	PG2MTMW2011	Microwave and mm-Wave Test & Measurement	6	0 - 0 - 6	75	00 - 60 - 15
Core Course (Th)	PG2MTMW2012	Satellite and Mobile Communication	4	3 - 1 - 0	75	60 - 00 - 15
Core Course Th)	PG2MTMW2013	Antenna, Radar and Navigation	4	3 - 1 - 0	75	60 - 00 - 15

Course Type	Course Code	Name of the Course	Credit	L - T - P	Marks	Marks Distribution Th. - Pr. - IA
Core Course (Th)	PG2MTMW2014	Microwave and mm-Wave Active Circuits and Transceiver Systems	4	3 - 1 - 0	75	60 - 00 - 15
Minor Course (Th)	PG2MTMW2021	Minor-II (To be opted from SWAYAM/ NPTEL)	4	4 - 0 - 0	75	75 - 00 - 00
Total			**22**	**13 - 3 - 6**	**375**	**255 - 60 - 60**

Semester-III

Course Type	Course Code	Name of the Course	Credit	L - T - P	Marks	Marks Distribution Th. - Pr. - IA
Project	PG2MTMW3031	Project-I	20	0 - 0 - 20	250	0-250-0 Preparation & Submission of Project Report (12 Credits)-150 Marks, Seminar Presentation (4 credits, 50 Marks) & Viva-voce (4 Credits, 50 Marks)
Total			**20**		**250**	**0 - 250 - 0**

Semester-IV

Course Type	Course Code	Name of the Course	Credit	L - T - P	Marks	Marks Distribution Th. - Pr. - IA
Project	PG2MTMW4031	Project-II	20	0 - 0 - 20	250	0-250-0 Preparation & Submission of Project Report (12 Credits)-150 Marks, Seminar

Course Type	Course Code	Name of the Course	Credit	L - T - P	Marks	Marks Distribution Th. - Pr. - IA
						Presentation (4 credits, 50 Marks) & Viva-voce (4 Credits, 50 Marks)
Two-credit Compulsory Course	PG2MTMW4041	Community Engagement	This shall not be taken into consideration in the calculation of SGPA and CGPA			
Total			**20**		**250**	**0 - 250 - 0**

Summary of Credit and Marks Distribution for Calculation of CGPA & SGPA

Semester	Total Credit	L - T - P	Total Marks	Marks Distribution
I	28	16 - 04 - 08	375	235 - 80 - 60
II	22	13 - 03 - 06	375	255 - 60 - 60
III	20	00 - 00 - 20	250	00 - 250 - 00
IV	20	00 - 00 - 20	250	00 - 250 - 00
Grand Total	**90**	**29 - 07 - 54**	**1250**	**490 - 640 - 120**

DETAILED SYLLABUS

Semester-I

PG2MTMW1011 (Analytical and Computational Methods in Electromagnetics)

Course Type: Core Course (Th & Pr)

Credit: 06

L-T-P: 3-1-2

Marks Distribution: 40 (Th) -20 (Pr) -15 (IA)

Pre-requisites: Electromagnetic Field Theory, Engineering Mathematics, Transmission Lines and

Waveguides, Programming Fundamentals

Course Outcomes (COs):

CO1:	Formulate and solve canonical electromagnetic boundary value problems using advanced analytical techniques, including orthogonal function expansions, Green's functions, separation of variables, and conformal mapping.
CO2:	Implement Finite Difference Method (FDM) and Finite Difference Time Domain (FDTD) schemes to solve static and time-domain electromagnetic problems, incorporating numerical stability criteria, dispersion analysis, and absorbing boundary conditions for microwave waveguide and scattering applications.
CO3:	Apply the Method of Moments (MoM) to transform integral equations (Hallen's and Pocklington's equations) into matrix equations for radiation and scattering problems, using appropriate basis and testing functions for wire antennas and planar microwave structures
CO4:	Develop Finite Element Method (FEM) formulations for waveguide and cavity problems using variational principles and Galerkin's method, incorporating nodal/edge elements, mesh generation strategies, and higher-order shape functions.
CO5:	Analyze and compare the strengths, limitations, computational complexity, and error characteristics of FDM/FDTD, MoM, and FEM, and select the most appropriate numerical technique for a given microwave engineering problem.
CO6:	Demonstrate hands-on proficiency by implementing numerical integration techniques, FDM/FDTD/MoM/FEM solvers in a programming environment, and utilizing commercial computational electromagnetics software for practical microwave component simulation and validation.

Content:

Theory:

Review of Electromagnetic Theory: Maxwell's equations in differential and integral forms; Constitutive relations and boundary conditions; Wave equations and time-harmonic fields; Classification of EM problems: solution regions, differential equations, and boundary conditions; Superposition principle and uniqueness theorem.

Analytical Methods: Orthogonal functions and eigenfunction expansions; Sturm-Liouville problems; Separation of variables in rectangular, cylindrical, and spherical coordinate systems; Green's functions: free-space Green's functions, Green's functions for domains with conducting boundaries; Contour integration and conformal mapping techniques; Fourier transform methods and plane-wave spectrum representations.

Finite Difference Method (FDM): Finite difference schemes: forward, backward, and central differences; Finite differencing of elliptic PDEs (Laplace's and Poisson's equations); Band matrix method and iterative solution techniques (Gauss-Seidel, SOR); Finite differencing of parabolic and hyperbolic PDEs; Accuracy and stability of finite difference solutions.

Finite Difference in Time Domain (FDTD) Method: Yee's finite difference algorithm for Maxwell's equations; Numerical stability and dispersion analysis; Lattice truncation conditions and absorbing

boundary conditions (ABC); Source modeling and initial field specifications; FDTD in cylindrical and spherical coordinate systems; Application to guided structures: transmission lines and waveguides; Wave scattering problems using FDTD.

Numerical Integration: Newton-Cotes rules - Euler's rule, Trapezoidal rule, Simpson's rule; Gaussian quadrature and multiple integration.

Integral Equation Formulations: Classification of integral equations: Fredholm and Volterra types; Connection between differential and integral equations; Green's functions for free space and domains with conducting boundaries.

Method of Moments: Basic principles of MoM and method of weighted residuals; Expansion functions (basis functions) and weighting (testing) functions; Transformation of integral equations to matrix equations (discretization); Evaluation of matrix elements; Solution of the matrix equation; Quasi-static problems; Scattering problems: scattering by conducting cylinder and arbitrary array of parallel wires; Radiation problems: Hallen's and Pocklington's integral equations for wire antennas; Electromagnetic absorption in the human body; Spectral domain MoM for planar microwave structures.

Finite Element Method (FEM): Basic concepts and steps in finite element analysis; Variational principles and Galerkin's method; Nodal and edge elements; Solution of Laplace's equation: finite element discretization, element governing equations, assembly of elements, and solving the resulting system; Solution of Poisson's equation; Solution of the wave equation for waveguide and cavity problems; Automatic mesh generation for rectangular and arbitrary domains; Bandwidth reduction techniques; Higher order elements: Pascal triangle, local coordinates, shape functions, and fundamental matrices.

Comparative Analysis: Strengths and weaknesses of FDM/FDTD, MoM, and FEM; Criteria for selecting appropriate numerical techniques for specific problems; Time-domain vs. frequency-domain analysis; Computational resources and error estimation.

Practical:

1. Implementation of numerical integration techniques
2. FDM implementation for solving Laplace's equation in 2D
3. 1D FDTD implementation for wave propagation; 2D FDTD implementation with absorbing boundary conditions
4. MoM implementation for thin wire antenna (Pocklington's equation)
5. FEM implementation for 1D waveguide problem
6. Comparative study of numerical methods for a given microwave problem
7. Commercial software hands-on session.

Internal Assessment:

Internal Assessment would be based on periodical Assignments; Seminar Presentation and Regularity in Classes.

Suggested Reading:

1. Garg, R., *Analytical and Computational Methods in Electromagnetics*. Artech House
2. Sadiku, M. N. O., *Numerical Techniques in Electromagnetics*, CRC Press

3. Peterson, A. F., Ray, S. L., and Mittra, R., *Computational Methods for Electromagnetics*. IEEE Press
4. Jin, J. M., T*he Finite Element Method in Electromagnetics*, Wiley-IEEE Press
5. Taflove, A. and Hagness, S. C., *Computational Electrodynamics: The Finite-Difference Time-Domain Method*, Artech House
6. Harrington, R. F., *Field Computation by Moment Methods*, IEEE Press
7. Booton, R. C. Jr.. *Computational Methods for Electromagnetics and Microwaves*, John Wiley & Sons
8. Davidson, D. B., *Computational Electromagnetics for RF and Microwave Engineering*, Cambridge University Press
9. Commercial software documentation (HFSS, CST, FEKO)

Course Articulation Matrix (CAM) & Course-Level Mapping

COs	PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	3	2	3	1	1	2
CO2	3	2	3	1	1	3
CO3	3	2	3	1	1	3
CO4	3	2	3	1	1	3
CO5	3	3	3	1	1	3
CO6	3	3	3	1	1	3
Average	**3.00**	**2.33**	**3.00**	**1.00**	**1.00**	**2.83**

PG2MTMW1012 (Microwave and mm-Wave Circuits)

Course Type: Core Course (Th & Pr)

Credit: 06

L-T-P: 3-1-2

Marks Distribution: 40 (Th) -20 (Pr) -15 (IA)

Pre-requisites: Electromagnetic Field Theory, Basic Network Theory, Transmission Line Fundamentals, Engineering Mathematics, Introductory Microwave Engineering.

Course Outcome:

CO1:	Formulate and solve distributed transmission line problems using the telegrapher equations, analyze lossy/ lossless lines under various terminations, and apply Foster's reactance theorem to microwave network synthesis.
CO2:	Apply microwave network analysis techniques including S-parameters, ABCD matrices, and signal flow graphs to characterize, cascade, and evaluate two-port and multi-port microwave junctions.
CO3:	Utilize the impedance and admittance Smith chart proficiently to perform complex

	impedance/admittance conversions and design intricate impedance matching networks (single/ double stub, quarter-wave transformers) while applying the Bode-Fano criterion and binomial/ Chebyshev synthesis for broadband matching.
CO4:	Analyze the performance parameters (unloaded, loaded, and external Q, resonant frequency, and coupling coefficients) of various microwave resonators including transmission line, waveguide cavity, dielectric, and stepped-impedance resonators and design distributed microwave filters using synthesis techniques.
CO5:	Synthesize and design planar microwave components including power dividers, directional couplers, branch-line hybrids, and rat-race couplers using microstrip coupled-line theory, even-odd mode analysis, and electromagnetic modeling of discontinuities.
CO6:	Experimentally characterize microwave passive components and non-reciprocal ferrite devices (isolators, circulators, magic-Tees, and attenuators) using WR-90 waveguide test benches and VNA-based measurements to quantify insertion loss, isolation, coupling, VSWR, and attenuation characteristics.

Content:

Theory:

Network Theorem at Microwave Frequencies: Foster's reactance theorem.

Transmission Line Theory: lumped element circuit model; the telegrapher equations; terminated lossless transmission line; generator and load mismatches; lossy transmission lines.

Microwave Network Analysis: the scattering matrix; the transmission matrix; ABCD matrix techniques; signal flow graph.

Smith Chart: Impedance and admittance Smith chart; applications.

Guided Transmission: Waveguides; coaxial line; stripline; microstrip; wave velocities and dispersion; excitation of waveguides; coplanar waveguides; microstrip bends and discontinuities.

Impedance Matching and Tuning: matching with lumped elements; single-stub tuning; double stub tuning; the quarter wave transformer; theory of small reflections; binomial and Chebyshev matching transformer; tapered lines; the Bode-Fano criterion.

Microwave Resonators: series and parallel resonant circuits; loaded, unloaded and external Q, transmission line resonators; waveguide cavities; dielectric resonators; stepped impedance resonators; excitation of resonators.

Elements of Microstrip Coupled Lines: introduction; analysis methods; introduction to multi conductor transmission line.

Planner Microwave Components: power dividers and couplers; branch line coupler; rat race hybrid coupler.

Microwave Filters: synthesis and design.

RF Behavior of Passive Components: microwave lumped elements: basic lumped elements; model extraction; scalable models.

Ferrite Materials and Non-reciprocal Circuit Components.

Practical:

1. Measurement of WR-90 waveguide.
2. Measurement of standing-wave pattern.
3. Measurement of insertion loss and isolation of an isolator
4. Measurement of insertion loss and isolation between different ports of a circulator.
5. Measurement of insertion loss and isolation between different ports of a magic-Tee.
6. Measurement of attenuation characteristics of an attenuator.

Internal Assessment:

Internal Assessment would be based on periodical Assignments; Seminar Presentation and Regularity in Classes.

Suggested Reading:

1. D. M. Pozar, *Microwave Engineering*, Wiley
2. A. Das and S. K. Das, *Microwave Engineering*, McGraw Hill Education.
3. S. Das, *Microwave Engineering*, Oxford University Press.
4. K. C. Gupta, *Microwaves*, New Age International
5. N. Marcuvitz, *Waveguide Handbook*, McGraw-Hill Book Company Inc
6. K. Kurokawa, *An Introduction to the Theory of Microwave Circuits*, Academic Press

Course Articulation Matrix (CAM) & Course-Level Mapping

COs	PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	3	2	3	2	2	2
CO2	3	2	3	3	2	2
CO3	3	2	3	3	2	2
CO4	3	2	3	3	2	2
CO5	3	2	3	3	2	3
CO6	3	3	3	3	3	2
Average	**3.00**	**2.17**	**3.00**	**2.83**	**2.17**	**2.17**

PG2MTMW1013 (Microwave and mm-Wave Vacuum and Solid-State Devices)

Course Type: Core Course (Th & Pr)

Credit: 06

L-T-P: 3-1-2

Marks Distribution: 40 (Th) -20 (Pr) -15 (IA)

Pre-requisites: Semiconductor Physics, Analog Electronic Circuits, Electromagnetic Field Theory, Microwave Circuits, Basic Programming and Math

Course Outcome:

CO1:	Differentiate and analyze the fundamental physical mechanisms including beam-wave interaction (velocity/current modulation), transit-time effects, avalanche multiplication, and transferred-electron phenomena governing the operation of O-type, M-type, and solid-state microwave devices, while evaluating their power-frequency limitations.
CO2:	Analyze the operational dynamics, gain-frequency response, efficiency, and tuning characteristics of non-relativistic vacuum electron devices, including multi-cavity/ reflex klystrons, helix/ coupled-cavity TWTs, and crossed-field devices (magnetrons, carcinotrons), and understanding the basic principles of relativistic gyrotrons and FELs.
CO3:	Apply high-frequency equivalent circuit models to analyze the performance of microwave control diodes (Schottky, Varactor, PIN, and Tunnel diodes) for applications in mixers, detectors, phase shifters, switches, limiters, and parametric amplifiers and evaluating their bias-stability criteria.
CO4:	Apply two-valley and impact-ionization theories to explain the negative-resistance characteristics of Gunn and IMPATT diodes, determine their optimum oscillation modes (Gunn, LSA, IMPATT, TRAPATT), and quantify the impact of avalanche/ transit-time noise on radar and communication system phase noise.
CO5:	Extract and interpret small-signal equivalent circuit models to evaluate figures of merit and justify the advantages of wide bandgap devices and MMIC technology for high-power/ high-frequency microwave subsystems.
CO6:	Select appropriate microwave devices for specific transmitter/ receiver subsystems using power-frequency selection matrices, apply power combining and thermal management principles, and experimentally characterize Gunn diode I-V/tuning characteristics, reflex klystron modes, and FET/ HEMT S-parameters using waveguide test benches and VNA.

Content:

Theory:

Fundamentals of Microwave Device Physics: Review of energy bands, carrier transport, and quantum-mechanical tunneling in microwave contexts; Beam-wave interaction physics: Velocity modulation, current modulation, and kinetic energy conversion (electronic efficiency); Power-frequency limitations of conventional tubes (transit time, inter-electrode capacitance, lead inductance); Universal classification of microwave sources: O-type (Linear Beam) vs. M-type (Crossed Field) vs. Solid-State.

Non-Relativistic Vacuum Electron Devices – O-Type: Klystrons - Multi-cavity klystron – bunching theory, output gap loading, gain-bandwidth product; Reflex Klystron - mode patterns, electronic tuning, and Rieke diagrams; Traveling Wave Tubes (TWTs) - Helix TWT: slow-wave structures, forward-wave amplification, gain-frequency response, and oscillation conditions; Coupled-cavity TWT for high power; Twystrons (hybrid devices); Performance characterization - AM/ PM conversion, intermodulation distortion, and harmonic content.

Non-Relativistic Crossed-Field (M-Type) and Relativistic Tubes: Magnetrons - Hull cutoff condition, Hartree resonance, spoke formation, mode separation (strapping), and frequency pushing/pulling factors;

Crossed-Field Amplifiers (FWCFA) and Carcinotrons (Backward Wave Oscillators) – tuning mechanisms; Relativistic Tubes: Gyrotrons – Cyclotron Resonance Maser (CRM) mechanism, mode competition; Free Electron Lasers (FEL) – concept of wigglers and tunability (introductory only).

Microwave Diodes and Control Devices: High-frequency equivalent circuits of p-n junctions (depletion and diffusion capacitances); Schottky Barrier Diodes; Metal-semiconductor junctions; hot-carrier effects, and application as mixers (conversion loss) and detectors; Varactor Diodes - Voltage-variable capacitance, parametric amplification principles (non-degenerate/idler circuits); PIN Diodes - Carrier lifetime, intrinsic region impedance, and application as high-power RF switches, phase shifters, and limiters; Tunnel Diodes - Negative resistance region, equivalent circuit, and bias-stability criteria for oscillators.

Avalanche and Transit-Time Solid-State Devices: IMPATT Diodes - Impact ionization, avalanche delay, transit-time effect; Read diode model; Small-signal negative-resistance analysis (impedance vs. frequency); large-signal effects and efficiency limitations; TRAPATT and BARRITT Diodes - Operational principles, trapping of plasma, and comparative performance metrics; Noise phenomena in avalanche devices (FM noise and AM noise) and their impact on radar phase noise.

Transferred Electron Devices (Gunn Diodes): Two-valley model of GaAs/InP – differential negative resistance; Modes of operation - Transit-time (Gunn oscillation), LSA (Limited Space-Charge Accumulation), and quenched-domain modes; Design of waveguide-cavity Gunn oscillators – cavity coupling, bias circuits, and frequency tuning (YIG-tuned oscillators).

Three-Terminal Solid-State Devices & MMICs: Microwave BJTs: Hybrid-π model, f_T and f_{max}, maximum stable/ available gain; MESFETs - Operation, parasitic resistance/capacitance extraction, and small-signal equivalent circuit (Curtice model); HEMTs & HFETs: Modulation doping, 2-DEG formation, enhanced mobility; High-frequency noise parameters (NFmin, Γopt); Wide Bandgap Devices (GaN/SiC) - Physics, high-power/high-temperature advantages, and current state of the art; Introduction to MMIC (Monolithic Microwave Integrated Circuit) design philosophy and layouts.

Power Combining, Reliability, and System-Level Selection: Device selection matrices - Power vs. Frequency charts for vacuum vs. solid-state; Power combining techniques (corporate vs. spatial combining); Thermal management and reliability (MTTF, junction temperature derating); Guest lecture/Case Studies: Real-world selection for VSAT transmitters, radar front-ends, and space TWTs.

Practical:

1. Measurement of I-V characteristics of Gunn diode in a WR-90 waveguide set up.
2. Measurement of mechanical tuning characteristics of waveguide-cavity Gunn oscillator in WR-90 waveguide.
3. Measurement of bias tuning characteristics of waveguide-cavity Gunn oscillator in WR-90 waveguide.
4. Measurement of reflex klystron characteristics in a WR-90 waveguide set up.
5. Simulation of FET/ HEMT s-parameters.

Internal Assessment:

Internal Assessment would be based on periodical Assignments; Seminar Presentation and Regularity in Classes.

Suggested Reading:

1. Gilmore, R., & Besser, L., *Practical RF Circuit Design for Modern Wireless Systems, Vol. II (Active Circuits),* Artech House
2. A. S. Gilmour, *Microwave Tubes*, Artech House
3. Kroll, K. (Ed.), *Gyrotrons: High-Power Microwave and Millimeter Wave Technology*, Springer
4. Chang, K., *RF and Microwave Solid-State Power Amplifiers. Encyclopedia of RF and Microwave Engineering*, Wiley
5. Carter, R. G., *Microwave and RF Vacuum Electronic Power Sources*, Cambridge University Press
6. S. Y. Liao, *Microwave Devices and Circuits*, Pearson Education
7. R. E. Collin, *Foundations for Microwave Engineering*, Wiley
8. S. Das, *Microwave Engineering*, Oxford University Press
9. M. L. Sisodia, *Microwave Active Devices: Vacuum and Solid State*, New Age Publishers.
10. K. C. Gupta, *Microwaves*, New Age International

Course Articulation Matrix (CAM) & Course-Level Mapping

COs	PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	3	2	3	3	2	2
CO2	3	2	3	3	2	2
CO3	3	2	3	3	3	2
CO4	3	2	3	3	3	2
CO5	3	2	3	3	2	3
CO6	3	3	3	3	3	2
Average	**3.00**	**2.17**	**3.00**	**3.00**	**2.50**	**2.17**

PG2MTMW1014 (Microwave and mm-Wave Communication Systems)

Course Type: Core Course (Th & Pr)

Credit: 06

L-T-P: 3-1-2

Marks Distribution: 40 (Th) -20 (Pr) -15 (IA)

Pre-requisites: Microwave Engineering Fundamentals, Analog & Digital Communication Theory, Probability and Random Processes, Electromagnetic Theory, Microwave Circuits.

Course Outcome:

CO1:	Analyze and predict terrestrial microwave propagation impairments including multipath fading, rain attenuation, gaseous absorption, and diffraction using standard ITU-R models (P.530, P.676, P.837, P.526) and professional planning tools.

CO2:	Formulate the functional architecture of modern Digital Microwave Radio (DMR) systems, differentiate between IF/ RF front-end components, antenna systems, and protection switching configurations, and evaluate their impact on link reliability and availability.
CO3:	Design and compute comprehensive point-to-point microwave link budgets including transmit power, antenna gains, feeder losses, free-space path loss, atmospheric/ rain attenuation, and receiver threshold, to determine system gain, fade margin, and link availability for specified performance targets.
CO4:	Formulate path profiles using digital terrain data, apply Fresnel zone clearance criteria and earth-bulging corrections for tower-height calculations, and select appropriate diversity techniques (space, frequency, polarization) and equalization methods to mitigate multipath fading and delay spread.
CO5:	Differentiate between legacy PDH/ SDH transport and modern packet-based technologies (Carrier Ethernet, GFP, MPLS), justify synchronization requirements using Sync-E/ IEEE 1588v2 for mobile backhaul/ fronthaul, and evaluate the challenges and opportunities in millimeter-wave (V/E-band) and hybrid RF/FSO systems.
CO6:	Quantify the impact of noise and co-channel/ adjacent-channel interference on system BER and outage probability using C/I and I/N criteria, apply ITU-R frequency planning and regulatory compliance frameworks (spectrum licensing, channel spacing, emission masks), and execute end-to-end microwave link designs using professional planning software and spectrum analyzers for field validation.

Content:

Theory:

Microwave Propagation Engineering: Review of propagation modes - Line-of-Sight (LOS), Trans-horizon (Troposcatter), and Ducting; Atmospheric effects - Gaseous absorption (oxygen/water vapor peaks), and ITU-R rain attenuation models (specific attenuation, rain rate statistics, and fade slope); Terrain effects - Fresnel zone ellipsoids, knife-edge diffraction (multiple-edge models), and reflection coefficients over rough surfaces; Multipath propagation - Mechanisms (ground/branch reflections and atmospheric layering), frequency-selective fading, and flat fading; Propagation prediction tools - ITU-R Rec. P.530 (terrestrial) and P.676 (attenuation).

System Architecture of Digital Microwave Radio (DMR): Functional block diagram of a modern DMR terminal - IF/RF front-end, up/down converters, local oscillators (synthesizers), High-Power Amplifiers (HPAs) and Low-Noise Amplifiers (LNAs); Antenna systems - Parabolic reflectors, gain/efficiency, radiation patterns, and feeder losses (waveguide vs. coaxial); Hot-standby configurations - 1+1, 2+0, and N+1 protection switching mechanisms (hard-switched vs. hitless).

Modulation Techniques and Spectral Efficiency: Complex I/Q modulation fundamentals and constellation diagrams; Linear modulations - M-ary PSK (BPSK, QPSK, 8PSK) and M-ary QAM (16, 32, 64, 128, 256 QAM); Constant-envelope modulations - GMSK (Gaussian Minimum Shift Keying); Adaptive Coding and Modulation (ACM) - Modulation and coding schemes (MCS) selection based on signal-to-noise ratio (SNR), throughput maximization, and link uptime guarantees; OFDM (Orthogonal Frequency Division Multiplexing) for multi-path resilience in non-LOS scenarios.

Link Budget Engineering and Path Profile Design: Comprehensive microwave link budget - Transmit power (dBm), antenna gains, feeder losses, free-space path loss (FSPL), atmospheric/rain attenuation, and

receiver threshold (Eb/N0 requirement); Calculation of system gain, fade margin, and link availability (percentage uptime); Path profile analysis - Terrain slicing, earth-bulging (k-factor), and clearance criteria (0.6F1 for reliability); Diversity techniques: Space diversity (antenna separation), Frequency diversity, and Polarization diversity – optimal combining vs. switched diversity; Equalization techniques: Time-domain (transversal filters) vs. Frequency-domain equalizers to combat delay spread.

Digital Multiplexing, Synchronization, and Modern Transport: Legacy versus modern transport - T1/E1 to T3/E3 (brief overview), PDH, SDH/ SONET (STM-1/OC-3); Modern packet-based transport - Carrier Ethernet, GFP (Generic Framing Procedure), and MPLS (Multiprotocol Label Switching) over microwave; Synchronization - Sync-E (Synchronous Ethernet) and IEEE 1588v2 (Precision Time Protocol) for mobile fronthaul/backhaul; Hybrid systems - Space-to-ground and high-altitude platforms (HAPS).

Millimeter-Wave and Advanced Systems: V-band (60 GHz – oxygen absorption band) and E-band (70/80 GHz) point-to-point links - challenges, hardware constraints, and regulations; Introduction to massive MIMO and phased-array beamforming for microwave/ mm-wave communication; Free-space optical (FSO) and hybrid RF/ FSO systems (brief).

Noise, Interference, and Performance Analysis: Thermal noise, noise figure, and cascaded system noise temperature; Error performance - BER vs. E_b/N_0 curves for coherent modulations (PSK/ QAM); Interference analysis - Co-channel and adjacent-channel interference, carrier-to-interference (C/I) ratio, and interference-to-noise (I/N) criterion; Outage probability prediction - Combined effects of fading, rain, and interference using ITU-R models.

Frequency Planning and Regulatory Framework: ITU-R frequency allocation bands (6, 7, 8, 11, 13, 15, 18, 23, 26, 28, 32, 38 GHz); National regulatory compliance (spectrum licensing), channel spacing, and emission masks.

Practical:

1. RF propagation measurement campaign (e.g., measuring signal strength in an indoor/outdoor LOS path).
2. Use of Pathloss / Google Earth Pro / open-source tools to plot a terrestrial path profile and compute Fresnel zone clearance.
3. Hands-on configuration of a commercial microwave radio terminal (e.g., DragonWave, Aviat, or Ceragon) – setting TX power, modulation, and channel frequency.
4. Simulation of a point-to-point link budget in MATLAB/ Octave to calculate availability vs. rain rate.
5. Spectrum analyzer measurements of adjacent-channel interference and signal bandwidth.

Internal Assessment:

Internal Assessment would be based on periodical Assignments; Seminar Presentation and Regularity in Classes.

Suggested Reading:

1. Kizer, G. M., *Digital Microwave Communication: Engineering Point-to-Point Microwave Systems*, Wiley-IEEE Press
2. Freeman, R. L., *Radio System Design for Telecommunications*, Wiley-Interscience

3. Anderson, H. R., *Fixed Broadband Wireless System Design*, John Wiley & Sons
4. Pozar, D. M., *Microwave Engineering*, Wiley
5. Lee, W. C. Y., *Mobile Communications Engineering*, McGraw-Hill
6. Sklar, B., *Digital Communications: Fundamentals and Applications*, Pearson.
7. ITU-R P-Series Recommendations:
    a. P.530-18 – Propagation data and prediction methods for terrestrial line-of-sight systems.
    b. P.676-13 – Attenuation by atmospheric gases.
    c. P.837 – Characteristics of precipitation for propagation modelling.
    d. P.526 – Diffraction propagation (knife-edge and rounded obstacles).
8. ETSI EN 302 217, Fixed Radio Systems; Characteristics and requirements for point-to-point equipment and antennas.
9. Pathloss 5.0 (Industry standard planning tool – student version).
10. Google Earth Pro (For terrain profile extraction).

Course Articulation Matrix (CAM) & Course-Level Mapping

COs	PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	3	2	3	2	3	2
CO2	3	2	3	2	2	2
CO3	3	3	3	3	3	2
CO4	3	2	3	3	3	2
CO5	3	2	3	2	2	2
CO6	3	3	3	2	3	3
Average	**3.00**	**2.33**	**3.00**	**2.33**	**2.67**	**2.17**

PG2MTMW1021(Minor-I; To be opted from SWAYAM/ NPTEL)

Course Type: Minor Course (Th)

Credit: 04

L-T-P: 4-0-0

Marks Distribution: 75 (Th) -0 (Pr) -0 (IA)

Course: From the area of Quantum Technology/ Artificial Intelligence & Machine Learning/ Environmental Engineering & Sustainability according to the consultation with the department.

Semester-II

PG2MTMW2011 (Microwave and mm-Wave Test & Measurement)

Course Type: Core Course (Pr.)

Credit: 06

L-T-P: 0-0-6

Marks Distribution: 0 - 60 (Pr) - 15 (IA)

Course Outcome:

CO1:	Operate, calibrate, and utilize core microwave instruments like including Spectrum Analyzers, Power Meters, and Vector Network Analyzers to accurately measure frequency, power, S-parameters, insertion loss, isolation, coupling, directivity, and unknown impedances and use Smith chart techniques for passive microwave networks.
CO2:	Characterize the non-linear and dynamic behavior of active microwave devices by experimentally determining injection-locking and angle-modulation characteristics of Gunn oscillators, 1-dB gain compression points of amplifiers, and tuning/ mixing performance of VCOs and mixers using industry-standard measurement protocols.
CO3:	Design and simulate planar microwave components (microstrip patch antennas and branch-line couplers) using full-wave EM simulators, fabricate/ emulate the designs, and critically compare simulated radiation patterns/ S-parameters with measured data to quantify fabrication tolerances and measurement uncertainties.
CO4:	Apply computational tools to calculate Keplerian orbital elements and visibility windows for LEO/ MEO satellites, and execute comprehensive Ku-band link budgets incorporating rain attenuation models to predict C/N ratios and system availability under diverse climatic conditions.
CO5:	Implement advanced array signal processing algorithms by simulating Dolph-Chebyshev tapering for optimal sidelobe control, analyzing beam-squint and grating lobes in phased arrays, and executing radar range equations, pulse compression (matched filtering), and 2D-FFT Doppler processing for moving target detection.
CO6:	Simulate the GPS/GNSS signal acquisition and tracking chain demonstrating proficiency in C/A code correlation and carrier frequency estimation, and synthesize all experimental and simulation results into comprehensive technical reports, effectively quantifying measurement uncertainties, diagnosing system-level anomalies, and defending engineering decisions.

List of Tasks and Experimental Studies:

1. Understanding spectrum analyzer: construction, working and measurement
2. Understanding microwave power meter: construction, working and measurement
3. To estimate the unknown impedance using Smith chart
4. Measurement of insertion loss, isolation, coupling and directivity of a directional coupler.
5. Understanding VNA: construction, working and calibration
6. One-port and Two-port Measurement using VNA
7. Study of injection-locking characteristics of Gunn oscillator.
8. Study of angle modulation using Gunn oscillator
9. Study of synchronized detection of angle modulation using injection-locked Gunn oscillator
10. Study of 1-dB gain compression point of a microwave amplifier
11. Study of microwave VCO characteristics

12. Study of microwave mixer characteristics
13. Measurement of radiation pattern of microwave antenna
14. Design, simulation and measurement of microstrip patch antenna
15. Design, simulation and measurement of microwave branch line coupler
16. Calculation of Keplerian elements and visibility windows for a given LEO/MEO satellite using STK (Systems Tool Kit) or GMAT (open-source).
17. Comprehensive link budget simulation in MATLAB/Excel – plotting C/N vs. rain rate for a Ku-band link.
18. Design and simulation of a 4-element linear phased array – simulation of beam squint and grating lobes with scan angle.
19. Lab 4: Implementation of Dolph-Chebyshev array tapering in MATLAB to achieve a specified sidelobe level.
20. Radar range equation simulation – plotting SNR vs. range and evaluating the impact of RCS fluctuations.
21. Pulse compression implementation (matched filtering) and Doppler processing using FFT on simulated radar returns.
22. GPS/GNSS signal acquisition and tracking simulation

Course Articulation Matrix (CAM) & Course-Level Mapping

COs	PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	3	2	3	2	3	2
CO2	3	2	3	3	3	2
CO3	3	3	3	3	3	3
CO4	3	2	3	2	2	3
CO5	3	2	3	2	2	3
CO6	3	3	3	3	3	3
Average	**3.00**	**2.33**	**3.00**	**2.50**	**2.67**	**2.67**

PG2MTMW2012 (Satellite and Mobile Communication)

Course Type: Core Course (Th)

Credit: 04

L-T-P: 3-1-0

Marks Distribution: 60 (Th) - 0 (Pr) -15 (IA)

Pre-requisites: Microwave Engineering**,** Analog & Digital Communication**,** Electromagnetic Field Theory**,** Microwave Circuits**,** Terrestrial Microwave Systems**.**

Course Outcome:

CO1:	Analyze and predict orbital dynamics, coverage footprints, round-trip delays, and station-keeping requirements for GEO, MEO, and LEO satellite constellations as well as evaluating the impact of

	orbital perturbations, sun transit outages, and eclipse periods on satellite communication availability and power systems.
CO2:	Evaluate the performance of space-segment subsystems—including bent-pipe vs. regenerative transponders, TWTA/ SSPA amplifiers, input-output multiplexers, and shaped/ global-beam reflector antennas along with assessment of their influence on overall satellite capacity, reliability, and link performance.
CO3:	Design of RF front-end of Earth Stations (VSAT, Gateway, TVRO, SNG) by calculating EIRP, G/T, and selecting appropriate LNA/ HPA components (considering noise temperature, linearity vs. efficiency trade-offs, and phase noise requirements), along with justifying antenna diameter, f/D ratio, and tracking system choices.
CO4:	Formulate and compute comprehensive satellite link budgets including EIRP, G/T, free-space path loss, atmospheric attenuation, and rain attenuation at C/ Ku/ Ka/ Q/ V bands using ITU-R P.618, to determine system availability, E_b/N_0, BER performance, and implement uplink power control and fade mitigation techniques for diverse climatic conditions.
CO5:	Apply advanced satellite modulation and multiple-access techniques like DVB-S2X with adaptive/ variable coding and modulation (ACM/VCM), FDMA (SCPC/ MCPC), TDMA, and bandwidth-on-demand (BoD), analyze co-channel/ adjacent-channel interference, polarization isolation (XPD), and interference-to-noise (I/N) ratios while ensuring compliance with ITU-R regulatory frameworks.
CO6:	Model RF propagation for terrestrial cellular systems using Okumura-Hata, COST-231, and ray-tracing models, justify site-engineering choices (tower-mounted amplifiers, remote radio heads, feeder loss optimization, MCL, EMI compliance), and evaluate co-existence challenges and spectrum sharing between 4G/5G terrestrial networks (up to mmWave) and fixed satellite services (FSS) in the context of emerging Non-Terrestrial Networks (NTN) and LEO mega-constellations.

Content:

Theory:

Orbital Mechanics and Spacecraft Environment: Kepler's laws and orbital elements (Right Ascension, Inclination, Argument of Perigee); Geostationary Orbit (GEO), Medium Earth Orbit (MEO), and Low Earth Orbit (LEO) constellations – advantages, coverage footprints, and round-trip delays; Orbital perturbations - Sun/moon gravity, solar radiation pressure, and station-keeping maneuvers; Sun transit outages and eclipse periods – impact on satellite power systems and communication availability.

Space Segment – Subsystem Engineering: Transponders - Bent-pipe (translating) vs. regenerative (on-board processing) transponders, TWTA vs. SSPA amplifiers, input/output multiplexers (IMUX/OMUX); Antenna Subsystems - Reflector antennas (offset-fed vs. center-fed), shaped-beam and global-beam coverage, introduction to phased-array and digitally beamforming antennas for HTS (High-Throughput Satellites); Power and Thermal Subsystems - Solar array sizing, battery capacity for eclipse, thermal balance, and DC-to-RF conversion efficiency.

Earth Station Engineering (Ground Segment): Types of Earth Stations - Gateway stations, TVRO (Television Receive Only), SNG (Satellite News Gathering), and VSAT (Very Small Aperture Terminal) – hub-spoke vs. mesh architectures; Antenna Systems - Parabolic reflector design (diameter, f/D ratio), tracking systems (step-track, monopulse), and radome effects; RF Front-End Design - Low-Noise Amplifiers (LNAs) – noise temperature and cryogenic cooling, High-Power Amplifiers (HPAs) – TWTs

vs. GaN SSPAs, linearity vs. efficiency trade-offs (AM/PM, P1dB); Up/down frequency conversion chains, local oscillator (LO) stability, and phase noise requirements.

Satellite Link Budget Engineering: Comprehensive link budget derivation - EIRP (Effective Isotropic Radiated Power), G/T (Figure of Merit), Free Space Path Loss, and atmospheric (clear-air) attenuation; Rain attenuation modeling at C, Ku, Ka, and Q/V bands using ITU-R P.618; uplink/downlink fade mitigation (Uplink Power Control – UPC); Carrier-to-Noise (C/N), Carrier-to-Intermodulation (C/I), and Carrier-to-Interference (C/I) ratio calculations; End-to-end E_b/N_0 and BER performance; link availability and outage probability analysis.

Modulation, Coding, and Multiple Access Techniques: Advanced satellite modulation - DVB-S2X standards – adaptive coding and modulation (ACM), variable coding and modulation (VCM); spectral efficiency vs. E_s/N_0; Multiplexing techniques - FDMA (SCPC vs. MCPC), TDMA (burst-mode synchronization), and CDMA/random access schemes; Bandwidth-on-Demand (BoD) and dynamic resource allocation in modern HTS networks.

Interference Analysis and Spectrum Management: Co-channel and adjacent-channel interference between adjacent satellites (orbital spacing); Polarization isolation and Cross-Polarization Discrimination (XPD); Interference-to-Noise (I/N) ratio criterion; aggregate interference from terrestrial microwave links into satellite receivers (and vice versa); ITU-R regulatory framework: Article 21 (power-flux density limits), coordination arcs, and frequency filings.

Terrestrial Mobile RF Site Engineering: RF propagation modeling for macro/pico cells - Okumura-Hata, COST-231, and ray-tracing models for urban micro-cells; Tower-mounted amplifiers (TMAs), remote radio heads (RRHs), and feeder loss optimization; Site acquisition, minimum coupling loss (MCL), and electromagnetic interference (EMI) compliance; Co-existence of cellular (4G/5G NR bands up to mmWave) with fixed satellite service (FSS) – sharing and adjacency issues.

Future Systems and Non-Terrestrial Networks (NTN): Integration of LEO mega-constellations (Starlink, OneWeb, Kuiper) with terrestrial 5G/6G networks (NTN standards); Free-space optical (FSO) inter-satellite links (ISL); Introduction to Software-Defined Payloads and cognitive spectrum management.

Internal Assessment:

Internal Assessment would be based on periodical Assignments; Seminar Presentation and Regularity in Classes.

Suggested Reading:

1. Maral, G., Bousquet, M., & Sun, Z,. S*atellite Communications Systems: Systems, Techniques and Technology*, Wiley
2. Richharia, M., *Satellite Communication Systems: Design Principles*, McGraw-Hill
3. Ippolito, L. J. Jr., *Satellite Communications Systems Engineering: Atmospheric Effects, Satellite Link Design and System Performance*, Wiley
4. Roddy, D., *Satellite Communications*, McGraw-Hill
5. Freeman, R. L., *Radio System Design for Telecommunications*, Wiley
6. Goldsmith, A., *Wireless Communications*, Cambridge University Press

Course Articulation Matrix (CAM) & Course-Level Mapping

COs	PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	3	2	3	2	3	2
CO2	3	2	3	2	2	2
CO3	3	2	3	3	3	2
CO4	3	2	3	2	3	2
CO5	3	2	3	3	3	2
CO6	3	3	3	2	3	3
Average	**3.00**	**2.17**	**3.00**	**2.33**	**2.83**	**2.17**

PG2MTMW2013 (Antenna, Radar and Navigation)

Course Type: Core Course (Th)

Credit: 04

L-T-P: 3-1-0

Marks Distribution: 60 (Th) - 0 (Pr) -15 (IA)

Pre-requisites: Microwave Engineering**,** Electromagnetic Field Theory**,** Microwave Communications**,** Signals & Systems; Engineering Mathematics

Course Outcome:

CO1:	Formulate radiation integrals using vector potentials and retarded potentials to compute far-field patterns, directivity, gain, radiation efficiency, effective aperture, and polarization properties of microwave aperture, horn, and reflector antennas, as well as analyze mutual coupling effects and noise temperature contributions.
CO2:	Design and analyze rectangular/ circular microstrip patch antennas using transmission line and cavity models (incorporating fringing fields), apply bandwidth enhancement techniques (stacked patches, aperture-coupled feeds, U-slot), and design feed networks (corporate, series, proximity) along with understanding SIW and mm-wave planar array technologies.
CO3:	Synthesize linear and planar antenna arrays using Dolph-Chebyshev and Taylor distributions to achieve optimal sidelobe control, analyze grating lobes, beam-squint effects, and mutual coupling in phased arrays, and differentiate between passive, active (AESA), and digital beamforming (DBF) architectures with adaptive algorithms (LMS, SMI) for interference mitigation.
CO4:	Apply the full Radar equation, incorporating peak/ average power, PRF, system losses, and RCS dependencies to predict maximum detection range, and evaluate detection performance using matched filter theory, probability of detection vs. false alarm, and Swerling fluctuation models, and analyzing the radar ambiguity function for range-Doppler resolution trade-offs.

CO5:	Implement advanced radar signal processing techniques including MTI delay-line cancellers (with blind speed analysis), pulse-Doppler processing, FMCW range-Doppler coupling , and Synthetic Aperture Radar (SAR/ISAR) azimuth resolution principles (chirp scaling, spotlight/ stripmap modes), understanding MIMO and cognitive radar concepts.
CO6:	Analyze terrestrial navigation systems using phase comparison and time-of-arrival principles, evaluate GPS/ GNSS signal structures (L1/ L2/L5, C/A code, P(Y) code) and propagation errors (ionospheric/ tropospheric delays, multipath, DOP), differentiate augmentation systems (WAAS, EGNOS, IRNSS/ NavIC), and understand integrated Radar/ GPS/ IMU sensor fusion for autonomous navigation and LPI/ stealth applications.

Content:

Theory:

Antenna Fundamentals and Radiation Analysis: Vector potentials (A and F), retarded potentials, and the far-field radiation integrals; Antenna parameters in depth - Directivity, gain, radiation efficiency, effective aperture, and noise temperature (including sky noise and ground noise); Reciprocity theorem, antenna impedance, and mutual coupling effects in arrays; Polarization fundamentals: Polarization ellipse, axial ratio, and polarization loss factor (PLF); cross-polarization discrimination (XPD).

Aperture, Horn, and Reflector Antennas for Microwave Systems: Horn Antennas: Rectangular and circular horns – optimum gain, aperture efficiency, and phase error analysis; Reflector Antennas: Parabolic reflectors – aperture field method vs. current distribution method. Cassegrain and Gregorian dual-reflector configurations. Feed blockage, spillover, and edge taper optimization; Frequency Selective Surfaces (FSS) and radome design (brief introduction).

Microstrip and Planar Printed Antennas: Analysis of rectangular and circular microstrip patches – transmission line model and cavity model (including fringing fields); Bandwidth enhancement techniques (stacked patches, aperture-coupled feeds, U-slot); Feeding networks: Corporate, series, and proximity coupling; Introduction to Substrate Integrated Waveguide (SIW) antennas and mm-wave planar arrays.

Phased Arrays, Beamforming, and Smart Antennas: Linear and planar array theory: Pattern multiplication, grating lobes, and mutual coupling (active reflection coefficient); Array synthesis techniques: Schelkunoff polynomial, Dolph-Chebyshev array (optimal sidelobe control), and Taylor distribution (aperture tapering); Phased Array Architectures: Passive vs. Active Electronically Scanned Arrays (AESA); phase-shifter technologies (ferrite, diode, and MMIC-based); Digital Beamforming (DBF): Adaptive algorithms (Least Mean Squares - LMS, Sample Matrix Inversion - SMI) and null-steering for interference mitigation; Massive MIMO arrays for 5G/6G and mm-wave beam-squint effects.

Radar Fundamentals, Equations, and Detection Theory: The Radar equation in its full form: Including peak/average power, pulse repetition frequency (PRF), and system losses (scanning, radome, and signal processing losses); Radar cross-section (RCS): Definition, backscattering dependencies, and reduction techniques (RAM, shaping); Detection theory: Matched filter response, probability of detection (Pd) vs. probability of false alarm (Pfa) – Swerling fluctuation models (Swerling I, II, III, IV); Radar ambiguity function – range and Doppler resolution trade-offs.

Advanced Radar Architectures and Signal Processing: MTI (Moving Target Indication): Delay-line cancellers, blind speeds, and pulse Doppler processing; FMCW (Frequency Modulated Continuous Wave)

Radar: Ramp generation, beat frequency, and range-Doppler coupling; automotive radar applications (77 GHz); Synthetic Aperture Radar (SAR) and Inverse SAR (ISAR): Principle of azimuth resolution, chirp scaling, and spotlight/stripmap modes; Introduction to MIMO Radar (virtual aperture concept) and Cognitive Radar.

Radio Navigation – Terrestrial and Satellite Systems: Terrestrial Navigation: VOR (VHF Omnidirectional Range), DME (Distance Measuring Equipment), and TACAN. Principle of phase comparison and time-of-arrival (TOA); Instrument Landing Systems (ILS) and Microwave Landing Systems (MLS) – localization and glideslope principles (difference of depth of modulation); GNSS/GPS: Space segment, control segment, and user segment. GPS signal structure (L1, L2, L5) – C/A code and P(Y) code; Propagation errors in GNSS: Ionospheric and tropospheric delays, multipath, and Dilution of Precision (DOP); Augmentation systems: WAAS, EGNOS, and IRNSS/NavIC.

Integration, Sensor Fusion, and Contemporary Applications: Combined Radar/GPS/IMU (Inertial Measurement Unit) fusion for autonomous navigation (Kalman filtering perspective); RF Stealth and Low Probability of Intercept (LPI) radar; Radar-based gesture recognition and indoor localization using UWB; EMI/EMC challenges in co-located antennas (radar, comms, and GNSS receivers).

Internal Assessment:

Internal Assessment would be based on periodical Assignments; Seminar Presentation and Regularity in Classes.

Suggested Reading:

1. Balanis, C. A.. *Antenna Theory: Analysis and Design*, Wiley
2. Milligan, T. A., *Modern Antenna Design*, Wiley-IEEE Press
3. Kraus, J. D. & Marhefka, R. J, *Antennas for All Applications*, McGraw-Hill
4. Skolnik, M. I., *Introduction to Radar Systems*, McGraw-Hill
5. Richards, M. A., *Fundamentals of Radar Signal Processing*, McGraw-Hill
6. Parkinson, B. W. & Spilker, J. J., *Global Positioning System: Theory and Applications, Vol. I & II*. AIAA
7. Kayton, M. & Fried, W. R., *Avionics Navigation Systems*, Wiley

Course Articulation Matrix (CAM) & Course-Level Mapping

COs	PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	3	2	3	3	2	3
CO2	3	2	3	3	2	3
CO3	3	2	3	3	2	3
CO4	3	2	3	2	2	3
CO5	3	2	3	2	2	3
CO6	3	3	3	2	2	2
Average	**3.00**	**2.17**	**3.00**	**2.50**	**2.00**	**2.83**

PG2MTMW2014 (Microwave Active Circuits and Transceiver Systems)

Course Type: Core Course (Th)

Credit: 04

L-T-P: 3-1-0

Marks Distribution: 60 (Th) - 0 (Pr) -15 (IA)

Pre-requisites: Microwave Engineering, Analog Electronic Circuits, Electromagnetic Field Theory**,** Microwave Communications**,** Signals & Systems; Semiconductor Physics

Course Outcome:

CO1:	Analyze and quantify noise and distortion in cascaded microwave systems by applying Friis formula for noise figure, cascaded IP3 analysis, and computing spurious-free dynamic range and blocking dynamic range for receiver front-ends.
CO2:	Extract and interpret scattering parameters and noise parameters of microwave and mm-Wave transistors, evaluate unconditional stability, and differentiate small-signal equivalent circuit models from large-signal models.
CO3:	Design and simulate microwave amplifiers using S-parameter techniques including low-noise amplifiers (LNAs) achieving optimal trade-offs between gain, noise figure, and input, and amplifiers for specified gain using unilateral/bilateral design, constant gain circles, and simultaneous conjugate matching with stabilization networks.
CO4:	Apply broadband design techniques (resistive feedback, balanced amplifiers, distributed amplifiers), analyze power amplifier classes (A, AB, B, C) using conduction angles and load-line theory, employ load-pull characterization for optimizing power/efficiency/linearity contours, and evaluate advanced PA architectures (Class F, Inverse-F, Doherty, envelope tracking) while considering thermal management and reliability (MTTF, junction temperature derating) for GaAs/GaN devices.
CO5:	Synthesize negative-resistance (one-port) and feedback (two-port) transistor oscillators using Kurokawa's oscillation condition, design voltage-controlled oscillators with tuning sensitivity and varactor coupling, differentiate Direct Digital Synthesis from Phase-Locked Loops for frequency synthesis, and quantify phase noise using Leeson's model while analyzing its impact on radar/communication system performance.
CO6:	Design and characterize non-linear frequency-conversion circuits (single-ended, single-balanced, double-balanced diode mixers; resistive/ active FET mixers) and control circuits (PIN diode and GaN-based switches, digital step attenuators) by analyzing conversion loss/gain, spurious responses, isolation, and switching speed, integrating all components into complete receiver architectures (superheterodyne, zero-IF, direct-RF sampling) with cascade analysis of total NF, IIP3, gain distribution, and AGC placement using modern CAD tools.

Content:

Theory:

Noise, Distortion, and Dynamic Range Fundamentals: Sources of noise: Thermal, shot, flicker, and partition noise; representation of noisy two-port networks using correlation matrices; Noise Figure (NF) and Noise Temperature (T_e): Definition, measurement techniques (Y-factor method), and NF of cascaded networks (Friis formula) with mismatched source impedances; Non-linearity in RF systems: 1-dB compression point (P1dB), Second-Order Intercept Point (IP_2), and Third-Order Intercept Point (IP_3) – derivation and cascaded IP3 analysis; Spurious-free dynamic range (SFDR) and blocking/ dynamic range.

High-Frequency Transistor Modeling: Scattering parameters: Measurement, de-embedding, and extraction of stability factors (Rollett's K, μ-factor); Small-signal equivalent circuit models: Hybrid-π (BJT) and Curtice/E-Sim (MESFET/ HEMT) models; Noise parameters: Minimum noise figure (NFmin), optimum source impedance (Γ_{opt}), and equivalent noise resistance (R_n) – noise circles; Introduction to large-signal models: Angelov (GaN/ HEMT) and Polyharmonic Distortion (X-parameter) models.

Microwave Amplifier Design (Linear and Low-Noise): Two-Port Power Gain Definitions: Operating Power Gain (G_P), Available Power Gain (G_A), and Transducer Power Gain (G_T); Stability: Unconditional vs. conditional stability; stabilization networks (resistive loading, feedback); Design for Specified Gain: Unilateral and bilateral design; constant gain circles; simultaneous conjugate matching; Low-Noise Amplifier (LNA) Design: Trade-offs between NF, gain, and VSWR; design for minimum NF using Γ_{opt}; source-pull and load-pull simulation principles.

Broadband and High-Power Amplifiers: Broadband Design: Compensated matching networks (resistive feedback, balanced amplifiers, and distributed (traveling-wave) amplifiers); Power Amplifier (PA) Theory: Classes of operation (A, AB, B, C) – conduction angles; load-line theory; Advanced PA Concepts: Class F and Inverse-F (harmonic tuning), Doherty architecture for back-off efficiency, and envelope tracking; Load-Pull Characterization: Contours of power, efficiency, and linearity; introduction to dynamic load-pull; Thermal considerations and reliability (MTTF, junction temperature derating) for GaAs/GaN devices.

Oscillators and Frequency Synthesis: Transistor Oscillators: Negative-resistance (one-port) and feedback (two-port) oscillator design; Kurokawa's oscillation condition; Voltage-Controlled Oscillators (VCOs): Tuning sensitivity and varactor coupling; Frequency Synthesis: Direct Digital Synthesis (DDS) vs. Phase-Locked Loops (PLLs) – loop filters, reference spurs, and lock time; Phase Noise: Leeson's model; impact of phase noise on radar/communication systems; measurement techniques (phase detector and carrier-to-noise ratio).

Non-Linear Circuits (Mixers, Switches, and Attenuators): Mixer Theory: Principles of frequency translation; conversion loss/gain; spurious responses (harmonic mixing) and intermodulation products; Diode Mixers: Single-ended, single-balanced, and double-balanced (ring) mixers; image-reject and sub-harmonic mixers; FET Mixers: Resistive vs. active FET mixers; high IP2/IP3 design techniques; Control Circuits: PIN diode and GaN-based RF switches (SPST, SPDT); digital step attenuators (DSA) – insertion loss, isolation, and switching speed.

Time and Frequency Domain Non-Linear Analysis: Harmonic Balance (HB) vs. Spice transient analysis; convergence issues in non-linear simulations; Envelope (or circuit-envelope) simulation for

modulated signals (modern digital modulations); Introduction to X-parameters (Polyharmonic Distortion) for non-linear behavioral modeling and system-level cascade analysis.

Receiver Architectures and System Integration: Superheterodyne: Image frequency problem; image-reject filtering; channel selection; LO leakage and reciprocal mixing; Zero-IF (Homodyne) and Low-IF Architectures: DC offsets, I/Q imbalance, and flicker noise impact; Direct-RF Sampling: High-speed ADCs/DACs in receivers; alias protection and digital down-conversion; Receiver Cascade Analysis: Total NF, IIP3, gain distribution, and AGC (Automatic Gain Control) placement; Modern CAD Flow: Integration of S-parameter blocks, non-linear models, and system-level behavioral models to simulate a complete transceiver front-end (e.g., 5G mmWave receiver).

Internal Assessment:

Internal Assessment would be based on periodical Assignments; Seminar Presentation and Regularity in Classes.

Suggested Reading:

1. Pozar, D. M., *Microwave Engineering*, Wiley
2. Gonzalez, G., *Microwave Transistor Amplifiers: Analysis and Design*, Prentice Hall
3. Gilmore, R. & Besser, L., *Practical RF Circuit Design for Modern Wireless Systems, Vol. I (Passive) & Vol. II (Active)*, Artech House
4. Cripps, S. C., *RF Power Amplifiers for Wireless Communications*, Artech House
5. Rohde, U. L., Poddar, A. K., & Böck, G., *The Design of Modern Microwave Oscillators for Wireless Applications*, Wiley
6. Maas, S. A., *Microwave Mixers*, Artech House
7. Mishra, D. K., *Radio-Frequency and Microwave Communication Circuits: Analysis and Design*, Wiley
8. Vendelin, G., Pavio, A. M., & Rohde, U. L., *Microwave Circuit Design Using Linear and Nonlinear Techniques*, Wiley
9. Bhal, I. & Bhartia, P., *Microwave Solid State Circuit Design*, Wiley
10. Chang, K., *RF and Microwave Wireless Systems*, Wiley
11. Kurokawa, K., *An Introduction to the Theory of Microwave Circuits*, Academic Press

Course Articulation Matrix (CAM) & Course-Level Mapping

COs	PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	3	2	3	2	2	2
CO2	3	2	3	3	2	3
CO3	3	2	3	3	2	3
CO4	3	2	3	3	2	3
CO5	3	2	3	3	2	3

CO6	3	3	3	3	2	3
Average	**3.00**	**2.17**	**3.00**	**2.83**	**2.00**	**2.83**

PG2MTMW2021 (Minor-II; To be opted from SWAYAM/ NPTEL)

Course Type: Minor Course (Th)

Credit: 04

L-T-P: 4-0-0

Marks Distribution: 75 (Th) - 0 (Pr) -0 (IA)

Course: From the area of Quantum Technology/ Artificial Intelligence & Machine Learning/ Environmental Engineering & Sustainability according to the consultation with the department.

A Note on PG2MTMW1021 and PG2MTMW2021 (Minor Courses):

As per the Curriculum and Credit Framework for Postgraduate Programme (CCFPP) under the National Education Policy (NEP) 2020, the M.Tech. in Electronics and Communication Engineering (Microwaves) program includes two Minor Courses, PG2MTMW1021 (Semester I) and PG2MTMW2021 (Semester II), each carrying 04 credits with a total marks distribution of 75 (Theory) and 0 (Internal Assessment).

The following provisions govern the selection and completion of these Minor Courses:

1. **Mode of Delivery:** Students are required to enroll in and successfully complete these courses through SWAYAM (Study Webs of Active-Learning for Young Aspiring Minds) / NPTEL (National Programme on Technology Enhanced Learning) online platforms. The courses offered on these platforms are developed by premier institutions and are recognized for academic credit transfer as per UGC guidelines.
2. **Areas of Specialization:** The Minor Courses shall be chosen from any one of the following interdisciplinary areas, as decided in consultation with the Department:
    - ***A. Quantum Technology***
    - ***B. Artificial Intelligence & Machine Learning***
    - ***C. Environmental Engineering & Sustainability***
3. **Specialized Minor Requirement:** To earn a specialized minor in the chosen area, students must select courses from the same field in both semesters (Semester I and Semester II). For example, a student opting for a Minor in Artificial Intelligence & Machine Learning must take a course in AI/ML during Semester I (PG2MTMW1021) and another AI/ML course during Semester II (PG2MTMW2021). This ensures continuity and depth of learning in the chosen interdisciplinary domain.
4. **Registration and Assessment:** Students are responsible for timely registration on the SWAYAM/ NPTEL platform for the approved courses. The final marks obtained in the SWAYAM/ NPTEL certification examination shall be transcribed as the theory marks for the respective Minor Course. The Department shall provide necessary guidance and approval regarding course selection prior to the commencement of each semester.

5. **Academic Advising:** Students are encouraged to consult with their faculty advisors or the Department Head to select appropriate courses that align with their research interests, career aspirations, and the emerging interdisciplinary demands of the microwave engineering profession.

The inclusion of these Minor Courses reflects the program's commitment to holistic education, interdisciplinary exposure, and the development of versatile engineers capable of addressing complex challenges at the intersection of microwave engineering and emerging technological domains.

Course Outcomes (COs) for Minor Courses (PG2MTMW1021 & PG2MTMW2021):

CO1:	Apply foundational principles of the chosen minor domain (Quantum Technology / Artificial Intelligence & Machine Learning / Environmental Engineering & Sustainability) to analyze contemporary challenges in microwave engineering and related fields.
CO2:	Demonstrate proficiency in utilizing domain-specific tools, algorithms, or frameworks (as applicable) to develop solutions that enhance microwave system design, signal processing, spectrum management, or sustainable engineering practices.
CO3:	Evaluate the impact of emerging interdisciplinary technologies on microwave communication, sensing, and radar systems, and identify opportunities for integration and innovation.
CO4:	Synthesize interdisciplinary knowledge to formulate novel approaches for solving complex real-world problems at the intersection of microwaves and the chosen minor domain.
CO5:	Communicate technical concepts, methodologies, and findings effectively through structured documentation and presentations, demonstrating clarity of thought and technical competence in the interdisciplinary context.
CO6:	Develop a specialized minor competency by integrating learning from two sequential courses in the same domain, demonstrating progressive depth of understanding and application capability.

Course Articulation Matrix (CAM) & Course-Level Mapping for both Minor Courses

COs	PO1	PO2	PO3	PSO4
CO1	3	2	2	3
CO2	3	2	2	3
CO3	3	2	2	3
CO4	3	2	2	3
CO5	2	3	2	3
CO6	3	2	3	3
Average for PG2MTMW1021	**2.83**	**2.17**	**2.17**	**3.00**
Average for PG2MTMW1021	**2.83**	**2.17**	**2.17**	**3.00**

Semester-III and Semester-IV

PG2MTMW3031 (Project-I)

Course Type: Project

Credit: 20

L-T-P: 0-0-20

Marks Distribution: 0-250-0 [Preparation & Submission of Project Report (12 Credits)-150 Marks, Seminar Presentation (4 credits, 50 Marks) & Viva-voce (4 Credits, 50 Marks)]

Course Outcome:

CO1:	Identify and articulate a well-defined contemporary research or development problem in the domain of program with clear industrial, societal, or scientific relevance.
CO2:	Conduct an exhaustive and critical literature survey, evaluate the state-of-the-art, and determine specific research gaps that justify the proposed investigation, while demonstrating familiarity with peer-reviewed journals, conference proceedings, and industry standards.
CO3:	Formulate a robust research methodology, selecting appropriate analytical, computational, or experimental techniques suitable for project work, and develop a detailed project plan with specific objectives, milestones, and a time-bound work schedule.
CO4:	Perform preliminary feasibility studies, including initial simulations, component characterization, test-bed design, or algorithm development, under the guidance of the assigned supervisor, and document preliminary results with proper uncertainty/error analysis.
CO5:	Demonstrate professional technical writing skills by compiling a structured project synopsis/progress report that comprehensively documents the literature review, proposed methodology, preliminary findings, and future work plan.
CO6:	Defend the project proposal, methodology, and initial findings effectively during a seminar presentation before an expert committee, responding to technical queries and justifying the engineering/scientific decisions made during the initial phase.

Course Articulation Matrix (CAM) & Course-Level Mapping

COs	PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	3	2	3	2	2	2
CO2	3	2	3	2	2	2
CO3	3	2	3	3	2	3
CO4	3	3	3	3	3	3
CO5	3	3	3	2	2	2
CO6	3	3	3	2	2	2
Average	**3.00**	**2.50**	**3.00**	**2.33**	**2.17**	**2.33**

PG2MTMW4031 (Project-II)

Course Type: Project

Credit: 20

L-T-P: 0-0-20

Marks Distribution: 0-250-0 [Preparation & Submission of Project Report (12 Credits)-150 Marks, Seminar Presentation (4 credits, 50 Marks) & Viva-voce (4 Credits, 50 Marks)]

Course Outcomes (COs):

CO1:	Execute the complete research methodology formulated in Project-I, conducting exhaustive simulations, advanced measurements, or algorithm development to generate conclusive and reproducible data.
CO2:	Analyze and interpret experimental and/or simulation results critically to assess system/ component performance against initial specifications.
CO3:	Validate the proposed solution by comparing results with theoretical models, standard benchmarks, existing literature, or industry specifications, and justify any discrepancies through rigorous engineering reasoning, error analysis, and uncertainty quantification.
CO4:	Synthesize the entire research journey from problem identification to final results and conclusions into a high-quality, comprehensive final project thesis that demonstrates clarity of thought, logical flow, technical depth, and strict adherence to academic publishing standards.
CO5:	Articulate and defend the research contributions, technical novelty, practical implications, and limitations of the completed work during a final viva-voce examination before the board of examiners.
CO6:	Propose well-justified future research directions, potential commercialization pathways, or technology transfer opportunities based on the limitations, unresolved issues, and novel findings of the completed project work.

Course Articulation Matrix (CAM) & Course-Level Mapping

COs	PO1	PO2	PO3	PSO1	PSO2	PSO3
CO1	3	2	3	3	3	3
CO2	3	2	3	3	3	3
CO3	3	3	3	3	3	3
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3
CO6	3	3	3	3	3	3
Average	**3.00**	**2.60**	**3.00**	**3.00**	**3.00**	**3.00**

NOTE For Project-I and Project-2: The entire third and fourth semesters of one year duration are assigned for the project works at different institutions and laboratories of repute within the country including Burdwan University.

Final Program Articulation Matrix (PAM):

The Program Articulation Matrix provides a comprehensive bird's-eye view of the entire M.Tech. in Electronics and Communication Engineering. (Microwaves) curriculum. Each cell represents the average correlation value (Course-Level Mapping) of the respective course to each PO and PSO.

Sem	Course Code	Course Title	PO1	PO2	PO3	PSO1	PSO2	PSO3	PSO4
I	PG2MTMW1011	Analytical and Computational Methods in EM	3.00	2.33	3.00	1.00	1.00	2.83	-
I	PG2MTMW1012	Microwave Circuits	3.00	2.17	3.00	2.83	2.17	2.17	-
I	PG2MTMW1013	Microwave Vacuum and Solid-State Devices	3.00	2.17	3.00	3.00	2.50	2.17	-
I	PG2MTMW1014	Microwave Communication Systems	3.00	2.33	3.00	2.33	2.67	2.17	-
I	PG2MTMW1021	Minor Course – I	2.83	2.17	2.17	-	-	-	3.00
II	PG2MTMW2011	Microwave Test and Measurement	3.00	2.33	3.00	2.50	2.67	2.67	-
II	PG2MTMW2012	Satellite and Mobile Communication	3.00	2.17	3.00	2.33	2.83	2.17	-
II	PG2MTMW2013	Antenna, Radar and Navigation	3.00	2.17	3.00	2.50	2.00	2.83	-
II	PG2MTMW2014	Microwave Active Circuits & Transceiver Systems	3.00	2.17	3.00	2.83	2.00	2.83	-
II	PG2MTMW1021	Minor Course – II	2.83	2.17	2.17	-	-	-	3.00
III	PG2MTMW3031	Project-I	3.00	2.50	3.00	2.33	2.17	2.33	-
IV	PG2MTMW4031	Project_II	3.00	2.60	3.00	3.00	3.00	3.00	-
Grand Average (Program Level)			**2.96**	**2.27**	**2.86**	**2.47**	**2.30**	**2.52**	**3.00**

Interpretation of the Program Articulation Matrix

1. PO1 (Research & Development):

All courses, including the foundational theory and practical labs, are strongly aligned (average 2.96) with developing independent research and problem-solving abilities. The project courses further consolidate this.

2. **PO2 (Technical Reporting):**

   The average mapping (2.27) indicates moderate-to-strong alignment across the curriculum. Courses like Project-I (2.50), Project-II (2.60), Microwave Communication Systems (2.33), and Test & Measurement (2.33) score higher due to their explicit requirements for structured reports, synopses, theses, and seminar presentations.

3. **PO3 (Mastery over Specialization):**

   Consistently mapped with the strong correlation (2.86) across all courses, confirming that the entire curriculum is pitched significantly above the bachelor's level, ensuring deep mastery in Microwaves.

4. **PSO1 (Subsystem Design):**

   Strongly addressed by active/passive circuit courses (1012, 1013, 2014) and the Project-II (3.00), with a program average of 2.47.

5. **PSO2 (Measurement & Validation):**

   Highly addressed by Test & Measurement (2011), Satellite & Mobile (2012), and Project-II (3.00), with a program average of 2.30, reflecting the emphasis on RF instrumentation and ITU-R compliance.

6. **PSO3 (Computational Modeling):**

   This is the strongest PSO in the program (average 2.52), driven by exceptional alignment in Analytical Methods (2.83), Antenna/Radar (2.83), Active Circuits (2.83), and Test & Measurement (2.67), validating the program's heavy reliance on CAD and EM simulation tools.

7. **PSO4 (Minor Courses):**

   The minor courses exhibit the highest correlation (3.00) with PSO4, confirming their direct and substantial contribution to the interdisciplinary application outcome. This validates the program's commitment to holistic education under NEP 2020.

8. **Holistic Development:**

   The inclusion of minor courses with a specialized PSO-M reflects the program's alignment with NEP 2020's vision of flexible, multidisciplinary, and holistic postgraduate education, producing engineers who are not only microwave experts but also versatile thinkers capable of addressing complex challenges at the intersection of multiple technological domains.

Graduate Competencies:

This curriculum ensures that graduates of this program possess:

1. **Technical Depth:**

   Mastery over the physics, design, and characterization of microwave and mm-Wave systems, validated through the strong mapping of all courses to PO3 (average 2.86) and PSOs.

2. **Research Aptitude:**

   The ability to identify problems, formulate methodologies, and contribute novel solutions, as evidenced by the highest correlation of all courses to PO1 (average 2.96).

3. **Professional Competence:**

   Skills in technical documentation, presentation, regulatory compliance, and project management, reflected in the consistent mapping to PO2 (average 2.27).

4. **Computational Proficiency:**

   Exceptional capability in modeling electromagnetic phenomena and executing system-level simulations, as demonstrated by the strongest PSO mapping (PSO3 average 2.52).

5. **Measurement and Validation Skills:**

   Proficiency in precision RF instrumentation and characterization, with PSO2 achieving a program average of 2.30.

6. **Interdisciplinary Expertise:**

   The ability to apply knowledge from Quantum Technology, AI/ML, or Environmental Engineering to augment microwave engineering practice, as reflected in the perfect mapping (3.00) of minor courses to PSO4.

Concluding Remarks:

The M.Tech. in Electronics and Communication Engineering (Microwaves) with Minors in Quantum Technology / Artificial Intelligence & Machine Learning / Environmental Engineering & Sustainability represents a comprehensive, contemporary, and rigorous educational journey designed to produce next-generation microwave engineers and researchers. As we stand at the threshold of the 6G era—characterized by terahertz communication, intelligent reflecting surfaces, ubiquitous sensing, AI-driven network optimization, and quantum-secured communications—the need for engineers who can navigate the complexities of the microwave and millimeter-wave spectrum while integrating interdisciplinary knowledge has never been greater.

It is our expectation that this program will serve as a beacon of excellence in microwave engineering education and contribute meaningfully to the nation's technological self-reliance and global competitiveness in the critical domain of wireless communications, sensing, and emerging interdisciplinary technologies.

M.Tech. in Electronics and Communication Engineering (Microwaves) with Minors in Quantum Technology / Artificial Intelligence & Machine Learning / Environmental Engineering & Sustainability

Curriculum Feedback Form

Preamble:

The Department of Physics, The University of Burdwan, is committed to the continuous improvement and excellence of its postgraduate programs. The M.Tech. in Electronics and Communication Engineering (Microwaves) curriculum has been designed under the Curriculum and Credit Framework for Postgraduate Programme (CCFPP) as per the National Education Policy (NEP) 2020. To ensure the curriculum remains contemporary, industry-relevant, and academically rigorous, we seek your valuable feedback.

Your responses will help us:

- Identify strengths and areas for improvement in the curriculum
- Align program outcomes with industry and research requirements
- Enhance the teaching-learning process
- Ensure graduates are well-prepared for their professional careers

Section A: Respondent Information:

Name: (Optional)	
Designation/ Role:	☐ Outgoing Student ☐ Recruiter / Industry Professional ☐ Project Supervisor ☐ Collaborator / Partner Organization ☐ Academician / Academic Administrator
Organization/ Institution:	
Date of Feedback:	

Section B: Curriculum Structure and Content

Please rate the following aspects of the curriculum on a scale of 1 to 5: (1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree)

S. No.	Statement	Rating
B1.	The curriculum adequately covers the fundamentals of microwave and mm-wave engineering.	
B2.	The balance between theory and practical/ components is appropriate.	
B3.	The curriculum includes contemporary topics	
B4.	The course sequencing (Semester I to IV) is logical and progressive.	
B5.	The credit distribution (90 credits) across semesters is appropriate.	
B6.	The L-T-P structure effectively supports the learning objectives.	
B7.	The minor course specialization options are relevant and valuable.	

B8.	The SWAYAM /NPTEL integration for minor courses is appropriate.	
B9.	The project work (40 credits) adequately prepares students for research/ industry.	
B10.	The curriculum prepares students for careers in microwave engineering.	

Section C: Course-Level Feedback

Course Code	Course Title	Relevance to Program (1-5)	Content Quality (1-5)	Need for Update (Yes/ No)
PG2MTMW1011	Analytical and Computational Methods in EM			
PG2MTMW1012	Microwave and mm-Wave Circuits			
PG2MTMW1013	Microwave and mm-Wave Vacuum and Solid-State Devices			
PG2MTMW1014	Microwave and mm-Wave Communication Systems			
PG2MTMW2011	Microwave and mm-Wave Test & Measurement			
PG2MTMW2012	Satellite and Mobile Communication			
PG2MTMW2013	Antenna, Radar and Navigation			
PG2MTMW2014	Microwave and mm-Wave Active Circuits and Transceiver Systems			
PG2MTMW1021	Minor-I (SWAYAM/ NPTEL)			
PG2MTMW1021	Minor-II (SWAYAM/ NPTEL)			
PG2MTMW3031	Project-I			

PG2MTM W4031	Project-II			

Section D: Program Outcomes (POs) and program Specific Outcomes (PSOs)

Please rate the extent to which the curriculum achieves the following outcomes: (1 = Not Achieved, 2 = Poorly Achieved, 3 = Moderately Achieved, 4 = Well Achieved, 5 = Exceptionally Achieved)

PO/ PSO	Statement	Rating
PO1	An ability to independently carry out research and development work to solve practical problems	
PO2	An ability to write and present a substantial technical report/ document	
PO3	Demonstrate a degree of mastery over the area as per the specialization, at a level higher than the bachelor program	
PSO1	Design and develop advanced passive and active microwave subsystems using S-parameter network theory, impedance matching, and non-linear device physics	
PSO2	Characterize and validate microwave components, communication links, and radar systems using precision RF instrumentation and ITU-R models	
PSO3	Model complex electromagnetic phenomena using computational techniques and execute system-level simulations using CAD platforms	
PSO4	Apply interdisciplinary knowledge from Quantum Technology, AI/ML, or Environmental Engineering to augment microwave engineering practice	

Section E: Overall Assessment and Recommendations:

S. No.	Statement	Rating (1-5)
E1	Overall quality of the M.Tech. (Microwaves) program	
E2	Overall satisfaction with the curriculum	

Section F: Open-Ended Questions:

F1	Which course(s) need revision or removal ?
F2	Are there any emerging topics that should be added to the curriculum?
F3	Which PO/PSO needs improvement? What specific changes would you suggest?

F4	What additional skills or competencies should the curriculum develop?
F5	What administrative or structural improvements would you suggest?
F6	What additional minor specializations should be considered?
F7	What are the top three areas for improvement?
F8.	Any additional comments or suggestions for the department?
Thank you for your valuable time and contribution to the continuous improvement of the M.Tech. in Electronics and Communication Engineering (Microwaves) program at The University of Burdwan.	