Programme Name/s	**: Digital Electronics/ Electronics & Tele-communication Engg./ Electronics & Communication Engg./ Electronics Engineering/ Industrial Electronics/ Electronics & Computer Engg.**
Programme Code	**: DE/ EJ/ ET/ EX/ IE/ TE**
Semester	**: Fifth**
Course Title	**: MICROWAVE ENGINEERING & RADAR SYSTEM**
Course Code	**: 315342**

I. RATIONALE

The knowledge of microwave devices is essential for electronics and communication engineering diploma graduates and they need to assimilate it in order to maintain microwave devices used in telecommunication applications. The basic knowledge of microwave signal generation, propagation, amplification and measurement is vital to maintain RF communication systems. The real-life applications of this course are in point-to-point communication systems on the terrestrial layers, in RADAR, navigation and in space radio communications. This course will help to develop skills to use and maintain the microwave communication system.

II. INDUSTRY / EMPLOYER EXPECTED OUTCOME

The aim of this course is to help students to attain the following industry/employer expected outcome through various teaching learning experiences.
Maintain telecommunication systems which contains microwave components.

III. COURSE LEVEL LEARNING OUTCOMES (COS)

Students will be able to achieve & demonstrate the following COs on completion of course based learning

- CO1 - Select waveguide for given microwave communication system.
- CO2 - Test performance of microwave components.
- CO3 - Construct RF circuits using RF devices.
- CO4 - Interpret working of RADAR based systems for range detection.
- CO5 - Maintain SONAR and various types of RADAR systems as microwave application.

IV. TEACHING-LEARNING & ASSESSMENT SCHEME

Course Code	Course Title	Abbr	Course Category/s	Learning Scheme					Credits	Assessment Scheme											
				Actual Contact Hrs./Week			SLH	NLH		Paper Duration	Theory				Based on LL & TL				Based on SL		Total Marks
															Practical						
				CL	TL	LL					FA-TH	SA-TH	Total		FA-PR		SA-PR		SLA		
											Max	Max	Max	Min	Max	Min	Max	Min	Max	Min	
315342	MICROWAVE ENGINEERING & RADAR SYSTEM	MAR	DSE	4	-	2	-	6	2	3	30	70	100	40	25	10	25#	10	-	-	150

Total IKS Hrs for Sem. : 0 Hrs

Abbreviations: CL- ClassRoom Learning , TL- Tutorial Learning, LL-Laboratory Learning, SLH-Self Learning Hours, NLH-Notional Learning Hours, FA - Formative Assessment, SA -Summative assessment, IKS - Indian Knowledge System, SLA - Self Learning Assessment

Legends: @ Internal Assessment, # External Assessment, *# On Line Examination , @$ Internal Online Examination

Note :

1. FA-TH represents average of two class tests of 30 marks each conducted during the semester.
2. If candidate is not securing minimum passing marks in FA-PR of any course then the candidate shall be declared as "Detained" in that semester.
3. If candidate is not securing minimum passing marks in SLA of any course then the candidate shall be declared as fail and will have to repeat and resubmit SLA work.
4. Notional Learning hours for the semester are (CL+LL+TL+SL)hrs.* 10 Weeks
5. 1 credit is equivalent to 30 Notional hrs.
6. * Self learning hours shall not be reflected in the Time Table.
7. * Self learning includes micro project / assignment / other activities.

V. THEORY LEARNING OUTCOMES AND ALIGNED COURSE CONTENT

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
1	TLO 1.1 Define the given parameters of waveguide and transmission lines. TLO 1.2 Identify the relevant frequency band for microwave communication. TLO 1.3 Calculate the cut off wavelength, cut off frequency, characteristic wave impedence, group and phase velocities of the given rectangular waveguide. TLO 1.4 Describe with relevant sketch the field pattern of the given mode of rectangular waveguide. TLO 1.5 Distinguish rectangular waveguide and circular waveguide.	**Unit - I Fundamentals of Transmission Lines and Microwaves** 1.1 Transmission lines: Definitions of standing waves, VSWR, reflection coefficient 1.2 Microwave frequency spectrum, IEEE and OSHA (Occupational Safety And Health Administration) standards and band designations, advantages and disadvantages of microwave signals 1.3 Rectangular waveguide: Cut off wavelength, cut off frequency, characteristic wave impedance, group and phase velocities (Definitions, formulae and Simple numerical) structure, advantages, disadvantages and applications of rectangular waveguide 1.4 Rectangular waveguide modes :TE, TM, TEM, dominant mode, field patterns of TE10, TE20, TE11 modes only 1.5 Circular waveguide: Structure, advantages, disadvantages and applications of circular waveguide, field pattern of TE11 mode only	Lecture Using Chalk-Board Video Demonstrations Flipped Classroom Presentations

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
2	TLO 2.1 Suggest suitable microwave accessories for given application. TLO 2.2 Describe the procedure to build the microwave test bench setup to test given microwave passive component. TLO 2.3 Compare the performance of the given ferrite components. TLO 2.4 Describe with sketches working principle of microwave cavity resonators, phase shifters, Wilkinson power divider.	**Unit - II Microwave Components** 2.1 Microwave accessories: Rotating coupler, bends and corners, tapers and twists (only use and physical structure) 2.2 Multiple junctions: Construction, working principle and applications of E-plane tee, H-Plane tee, magic Tee (Hybrid Tee), rat race junction (Hybrid Ring) and directional couplers (directivity, coupling factor and isolation) 2.3 Ferrites components: Construction, working principle and applications of isolator, circulator and gyrator 2.4 Construction, working principle and applications of Microwave cavity resonators, phase shifters, Wilkinson power divider	Lecture Using Chalk-Board Model Demonstration Video Demonstrations Hands-on Collaborative learning
3	TLO 3.1 Describe frequency limitations of vacuum tubes at microwave frequency. TLO 3.2 Describe working of RF oscillators and amplifiers with neat sketches. TLO 3.3 Compare the performance of different types of microwave diodes. TLO 3.4 Explain the working of heterojunction bipolar transistors and high electron mobility transistor. TLO 3.5 Describe hazards of microwave radiation.	**Unit - III Microwave Tubes and Microwave Semiconductor Devices** 3.1 Limitations of vacuum tubes at microwave frequencies 3.2 Microwave tube oscillators and amplifiers: Reflex klystron, magnetron, gyrotrons, backward wave oscillator, Travelling wave tube 3.3 Microwave diodes: Varactor diode, Gunn diode, tunnel diode, PIN diode, IMPATT diode, TRAPATT diode, BARITT diode (Construction, working principle and applications) 3.4 Construction, working principle and applications : Heterojunction Bipolar Transistors (HBT's), High Electron Mobility Transistors (HEMT's) 3.5 Microwave radiation hazards: Types (HERO,HERP,HERF) and preventive measures from hazards	Lecture Using Chalk-Board Video Demonstrations Case Study Hands-on

Sr.No	Theory Learning Outcomes (TLO's)aligned to CO's.	Learning content mapped with Theory Learning Outcomes (TLO's) and CO's.	Suggested Learning Pedagogies.
4	TLO 4.1 Define various terminologies with respect to RADAR. TLO 4.2 Calculate the maximum RADAR range for the given data. TLO 4.3 Explain with relevant sketches the given types of scanning and tracking methods used for RADAR. TLO 4.4 Describe properties and applications of surface clutter, sea clutter, land clutter with respect to RADAR. TLO 4.5 Describe display methods used in RADAR.	**Unit - IV RADAR Fundamentals** 4.1 Basic block diagram of RADAR system, Doppler effect, Definitions : Radar range, pulse width, Pulse Repetition Frequency (PRF), duty cycle 4.2 RADAR range equation derivation (simple numerical), significance of RADAR range, factors affecting RADAR range 4.3 Antenna Scanning types : Working principle of Horizontal, vertical, helical and spiral, Antenna Tracking types : Working principle of sequential, conical and mono pulse 4.4 Radar clutter : Properties and applications of surface clutter, sea clutter, land clutter 4.5 Display Methods: A-scope, PPI, RHI, RADAR Beacons	Lecture Using Chalk-Board Video Demonstrations Presentations Hands-on Site/Industry Visit
5	TLO 5.1 Describe the given application of microwave in detail. TLO 5.2 Describe basic principle of SONAR with neat sketch. TLO 5.3 Compare different types of RADARs for given application. TLO 5.4 Illustrate given microwave application in real life.	**Unit - V Microwave and RADAR System Applications** 5.1 Working principle of Microwave applications: Biomedical applications of microwaves, Remote Sensing RADAR, MST RADAR, RADAR Radiometer, RADAR based Navigation - Omni-directional ranges and Tactical Air Navigation System (TACAN), Instrument Landing System (ILS), Long Range Navigation system (LORAN) 5.2 SONAR system: Working principle and applications 5.3 Basic pulse RADAR system, CW Doppler RADAR, MTI RADAR (Block diagram, operation and applications) 5.4 Working principle of RADAR applications: Vehicle speed detection, Self-driving cars, Vehicle parking assistance system, Air traffic control system, Weather surveillance RADAR	Lecture Using Chalk-Board Presentations Case Study Site/Industry Visit Hands-on

VI. LABORATORY LEARNING OUTCOME AND ALIGNED PRACTICAL / TUTORIAL EXPERIENCES.

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 1.1 Calculate VSWR and reflection coefficient for given length of transmission line.	1	Measurement of VSWR and reflection coefficient for the given length of transmission line	2	CO1
LLO 2.1 Use the frequency meter with microwave test bench setup to determine the frequency and wavelength of waveguide for TE10.	2	* Determination of the frequency and wavelength of rectangular waveguide for TE10 mode	2	CO1

Practical / Tutorial / Laboratory Learning Outcome (LLO)	Sr No	Laboratory Experiment / Practical Titles / Tutorial Titles	Number of hrs.	Relevant COs
LLO 3.1 Test the output of microwave test bench setup to ensure power division in microwave tees E- plane, H- plane and E-H plane. LLO 3.2 Interpret the result from reading.	3	* Measurement of power division in microwave tees E- plane, H- plane and E-H plane using microwave test bench setup	2	CO2
LLO 4.1 Evaluate coupling factor and insertion loss of given circulator. LLO 4.2 Evaluate coupling factor and insertion loss of given Isolator.	4	* Determination of coupling factor and insertion loss of the given circulator and isolator	2	CO2
LLO 5.1 Calculate various parameters to test performance of microwave phase shifter.	5	Measurement of phase shift of microwave phase shifter	2	CO2
LLO 6.1 Test the performance of Reflex Klystron Microwave Tube. LLO 6.2 Calculate tuning range.	6	* Determination of tuning range of Reflex Klystron Microwave Tube	2	CO3
LLO 7.1 Test the performance of Gunn diode. LLO 7.2 Calculate output power and frequency.	7	Determination of output power and frequency of Gunn diode and plot its V-I characteristics	2	CO3
LLO 8.1 Use Doppler RADAR to detect maximum range.	8	* Determination of the maximum range of Doppler RADAR	2	CO4
LLO 9.1 Calculate the rotations per minute of a moving object (e.g., Fan, Pendulum,etc) based on RADAR.	9	Determination of the rotations per minute (RPM) of a moving object using RADAR	2	CO4
LLO 10.1 Investigate the effect of pulse repetition frequency on Radar range equation and observe the waveform. LLO 10.2 Observe the waveform of effect of radial velocity of the target on doppler frequency generation for various frequency bands. LLO 10.3 Test the effect of blind speed on the performance of MTI RADAR. LLO 10.4 Investigate the effect of pulse repetition frequency on clutter attenuation.	10	* Simulation of RADAR based practicals using any freeware/open-source simulation software	2	CO4 CO5

Note : Out of above suggestive LLOs -

- '*' Marked Practicals (LLOs) Are mandatory.
- Minimum 80% of above list of lab experiment are to be performed.
- Judicial mix of LLOs are to be performed to achieve desired outcomes.

VII. SUGGESTED MICRO PROJECT / ASSIGNMENT/ ACTIVITIES FOR SPECIFIC LEARNING / SKILLS DEVELOPMENT (SELF LEARNING)

Micro project

- Build a RADAR working model using Cardboard, Gear motor, Switch, Battery, Color Paper,etc.

- Develop a RADAR working model using Arduino Uno, Servo Motor, Breadboard, Ultrasonic Sensor (HC-SR04), Jumper Wires, etc.
- Measure attenuation of the given attenuator using microwave test bench setup.
- Measure the gain of the Horn antenna using given microwave test bench setup.

Assignment

- Solve given numericals based on Cut off wavelength, cut off frequency, characteristic wave impedance, group and phase velocities of rectangular waveguide.
- Solve given numericals based on RADAR range equation.
- Draw neat sketches of RADAR systems.
- Study microwave components (active and passive) and draw neat sketches.
- Draw field patterns of TE and TM modes of rectangular waveguide.

Student activities

- Prepare a power point presentation on various types of microwave antennas.
- Prepare report on Comparative performance of microwave semiconductor devices/microwave tubes.
- To perform microwave waveguide simulations using freeware/Open source software's.
- Conduct a Library / Internet based survey of RADAR displays and submit detail report of it.
- Conduct a market survey of consumer microwave components and submit detail report of it.
- Prepare a poster on microwave radiation hazards and its protective measures.
- To Illustrate the working principle of the following a. Microwave Tubes b. EM wave propagation prepare /download an animation and share with the class.

Visit

- Visit a place where waveguides are used for microwave communication (such as earth Station, Radio station, telephone exchange, airport. TV broadcast, navigation center) and prepare the report.

Note :

- Above is just a suggestive list of microprojects and assignments; faculty must prepare their own bank of microprojects, assignments, and activities in a similar way.
- The faculty must allocate judicial mix of tasks, considering the weaknesses and / strengths of the student in acquiring the desired skills.
- If a microproject is assigned, it is expected to be completed as a group activity.
- SLA marks shall be awarded as per the continuous assessment record.
- For courses with no SLA component the list of suggestive microprojects / assignments/ activities are optional, faculty may encourage students to perform these tasks for enhanced learning experiences.
- If the course does not have associated SLA component, above suggestive listings is applicable to Tutorials and maybe considered for FA-PR evaluations.

VIII. LABORATORY EQUIPMENT / INSTRUMENTS / TOOLS / SOFTWARE REQUIRED

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number

Sr.No	Equipment Name with Broad Specifications	Relevant LLO Number
1	Microwave Test Bench -X Band (Klystron based) / or any other equivalent, Klystron Power Supply, Klystron tube with Klystron mounts, Frequency meter, Variable attenuator, Detector mount, Wave guide stand, SWR meter and oscilloscope, E Plane Tee, H Plane Tee and Magic Tee Isolator and Circulator, Directional Coupler, Horn Antenna proto type	1,2,3,4,5,6
2	Desktop computer/Laptop, List of software : RF Tool box: MATLAB and SIMULINK or any other open source software like EZNEC, HFSS-CST, VSim, Microwave office	10
3	Microwave test bench -X Band (GUNN Diode based)/ or any other equivalent, Gunn oscillator, Gun power supply, PIN modulator, Isolator, Frequency meter, Variable attenuator, Detector mount, Wave guide stands, SWR Meter. Cables and accessories	7
4	RADAR Trainer Kit (X Band)/or any other equivalent technical specifications: Transmitting Frequency : 10 GHz, Output Power : 10 to 15mW, Operating Voltage : 8.6 V or adjustable, Antenna : Horn and parabolic dish with LNA and mounting , IF Output : Audio range, Power Supply : 230V +/- 10%, 50Hz	8,9

IX. SUGGESTED WEIGHTAGE TO LEARNING EFFORTS & ASSESSMENT PURPOSE (Specification Table)

Sr.No	Unit	Unit Title	Aligned COs	Learning Hours	R-Level	U-Level	A-Level	Total Marks
1	I	Fundamentals of Transmission Lines and Microwaves	CO1	6	4	4	4	12
2	II	Microwave Components	CO2	6	2	4	6	12
3	III	Microwave Tubes and Microwave Semiconductor Devices	CO3	10	2	8	6	16
4	IV	RADAR Fundamentals	CO4	8	4	4	6	14
5	V	Microwave and RADAR System Applications	CO5	10	6	4	6	16
Grand Total				**40**	**18**	**24**	**28**	**70**

X. ASSESSMENT METHODOLOGIES/TOOLS

Formative assessment (Assessment for Learning)

- Two offline unit tests of 30 marks and average of two unit test marks will be considered for out of 30 marks.

Summative Assessment (Assessment of Learning)

- End semester assessment of 70 marks. End semester summative assessment of 25 marks for laboratory learning.

XI. SUGGESTED COS - POS MATRIX FORM

Course Outcomes (COs)	Programme Outcomes (POs)							Programme Specific Outcomes* (PSOs)		
	PO-1 Basic and Discipline Specific Knowledge	PO-2 Problem Analysis	PO-3 Design/ Development of Solutions	PO-4 Engineering Tools	PO-5 Engineering Practices for Society, Sustainability and Environment	PO-6 Project Management	PO-7 Life Long Learning	PSO-1	PSO-2	PSO-3
CO1	2	1	2	1	-	1	2			
CO2	1	2	2	2	-	1	2			
CO3	1	2	2	2	1	2	2			
CO4	2	2	1	2	2	2	3			
CO5	3	3	3	3	2	1	3			

Legends :- High:03, Medium:02,Low:01, No Mapping: -
*PSOs are to be formulated at institute level

XII. SUGGESTED LEARNING MATERIALS / BOOKS

Sr.No	Author	Title	Publisher with ISBN Number
1	D. M. Pozar	Microwave Engineering	John Wiley Publication;4th edition (2013) ISBN: 978-8126541904
2	R. E. Collins	Foundation for Microwave Engineering	Wiley Publication;2nd edition (2007) ISBN: 978-8126515288
3	V. C. Kshirsagar	Microwave and RADAR Engineering	Synergy knowledgeware, Mumbai. ISBN: 978-93-833-5228-9
4	K.K. Sharma	Fundamentals of Microwave and RADAR Engineering	S.Chand and Company New Delhi,2011, ISBN:9788121935371
5	B. Smith and M. H. Carpentier	The Microwave Engineering Handbook (E-Book)	Springer International Publication;1st edition
6	Terman, Frederick Emmons:	Electronic and Radio Engineering	McGraw-Hill,Fourth Edition,ISBN:601421982320:
7	Merrill Skolnik	Introduction to Radar Systems	McGraw-Hill,ISBN-13: 978-0070445338, ISBN-10: 9780070445338

XIII . LEARNING WEBSITES & PORTALS

Sr.No	Link / Portal	Description
1	https://onlinecourses.nptel.ac.in/noc24_ee115/preview	Swayam NPTEL videos on Microwave Engineering
2	https://onlinecourses.nptel.ac.in/noc23_ee133/preview	Swayam NPTEL videos on Principles And Techniques Of Modern Radar Systems
3	https://home.sandiego.edu/~ekim/e194rfs01/	University of San Diego EEE 194 Section 4: RF & Microwave Engineering Spring 2001
4	https://youtu.be/uPXLJfmrCUA?si=OQzaEtDiZeMjrnqV	Design E plane tee using cst microwave studio
5	https://youtu.be/EoWDC4FJK7Q?si=bSJ8Fz8Vb6NsbqG4	Design H Plane Tee using CST microwave studio

Sr.No	Link / Portal	Description
6	https://youtu.be/pGbY59Q9smo?si=QrVy6HUM83g87tdU	Design and analysis of Magic Tee.
7	https://portal.coepvlab.ac.in/vlab/auth/home?dept=2&lab=2	Virtual Microwave Lab (IIT Dayalbagh)

Note :

- Teachers are requested to check the creative common license status/financial implications of the suggested online educational resources before use by the students