INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal, Hyderabad -500 043

ELECTRONICS ANDCOMMUNICATION ENGINEERING

COURSE DESCRIPTOR

Course Title	**RADAR SYSTEMS**				
Course Code	**AEC521**				
Programme	B.Tech.				
Semester	VI	ECE			
Course Type	Core Elective				
Regulation	IARE - R16				
Course Structure	**Theory**			**Practical**	
	Lectures	**Tutorials**	**Credits**	**Laboratory**	**Credits**
	3	-	3	-	0
Chief Coordinator	Dr. M V Krishna Rao, Professor				
Course Faculty	Dr. M V Krishna Rao, Professor				

I. COURSE OVERVIEW:

The course teaches the operating principles of various types of radar systems, and discusses the detection and estimation of target parameters (mainly range and velocity) used in different radars. The course also discusses about the transmitters and receivers of various types of radars. At the end of the course, the student will be able to appreciate the preliminary design aspects of various radars. The student will also be able to appreciate the processing techniques of radar signals. This course has several prerequisites, but the course itself is independent and forms the basis for in-depth understanding of several ranging applications such as Electronic Warfare, Navigation Systems, Missile Terminal Guidance and Landing systems of Air and Space vehicles.

II. COURSE PRE-REQUISITES:

Level	Course Code	Semester	Prerequisites	Credits
UG	AEC003	III	Probability Theory and Stochastic Processes	4
UG	AEC005	IV	Analog Communications	4

III. MARKSDISTRIBUTION:

Subject	SEE Examination	CIA Examination	Total Marks
Radar Systems	70 Marks	30 Marks	100

IV. DELIVERY / INSTRUCTIONAL METHODOLOGIES:

✔	Chalk & Talk	✔	Quiz	✔	Assignments	✘	MOOCs
✔	LCD / PPT	✔	Seminars	✘	Mini Project	✘	Videos
✘	Open Ended Experiments						

V. EVALUATION METHODOLOGY:

The course will be evaluated for a total of 100 marks, with 30 marks for Continuous Internal Assessment (CIA) and 70 marks for Semester End Examination (SEE). Out of 30 marks allotted for CIA during the semester, marks are awarded by taking average of two CIA examinations or the marks scored in the make-up examination.

Semester End Examination (SEE): The SEE is conducted for 70 marks of 3 hours duration. The syllabus for the theory courses is divided into five units and each unit carries equal weightage in terms of marks distribution. The question paper pattern is as follows. Two full questions with "either" or "choice" will be drawn from each unit. Each question carries 14 marks. There could be a maximum of two sub divisions in a question.

The emphasis on the questions is broadly based on the following criteria:

50 %	To test the objectiveness of the concept.
50 %	To test the analytical skill of the concept OR to test the application skill of the concept.

Continuous Internal Assessment (CIA):
CIA is conducted for a total of 30 marks (Table 1), with 25 marks for Continuous Internal Examination (CIE), 05 marks for Quiz/ Alternative Assessment Tool (AAT).

Table 1: Assessment pattern for CIA

Component	**Theory**		**Total Marks**
Type of Assessment	CIE Exam	Quiz / AAT	
CIA Marks	25	05	30

Continuous Internal Examination (CIE):
Two CIE exams shall be conducted at the end of the 8th and 16th week of the semester respectively. The CIE exam is conducted for 25 marks of 2 hours duration consisting of two parts. Part–A shall have five compulsory questions of one mark each. In part–B, four out of five questions have to be answered where, each question carries 5 marks. Marks are awarded by taking average of marks scored in two CIE exams.

Quiz / Alternative Assessment Tool (AAT):
Two Quiz exams shall be online examination consisting of 25 multiple choice questions and are be answered by choosing the correct answer from a given set of choices (commonly four). Marks shall be awarded considering the average of two quizzes for every course. The AAT may include seminars, assignments, term paper, open ended experiments, five minutes video and MOOCs.

VI. HOW PROGRAM OUTCOMES ARE ASSESSED:

Program Outcomes (POs)		Strength	Proficiency assessed by
PO1	**Engineering knowledge**: Apply the knowledge of mathematics, science, engineeringfundamentals, and an engineering specialization to the solution of complex engineering problems.	3	Quiz
PO2	**Problem analysis**: Identify, formulate, review research literature, and analyze complexengineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences	2	Assignments
PO3	**Design/development of solutions**: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	3	Assignments
PO4	**Conduct investigations of complex problems**: Use research-based knowledge and researchmethods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.	3	Seminars

3 = High; 2 = Medium; 1 = Low

VII. HOW PROGRAM SPECIFIC OUTCOMES ARE ASSESSED:

Program Specific Outcomes (PSOs)		Strength	Proficiency assessed by
PSO 1	**Professional Skills:** An ability to understand the basic concepts in Electronics & Communication Engineering and to apply them to various areas, like Electronics, Communications, Signal processing, VLSI, Embedded systems etc., in the design and implementation of complex systems.	3	Seminars and Assignments
PSO 2	**Problem-solving skills:** An ability to solve complex Electronics and communication Engineering problems, using latest hardware and software tools, along with analytical skills to arrive cost effective and appropriate solutions.	3	Quiz and Assignments
PSO 3	**Successful career and Entrepreneurship:** An understanding of social-awareness & environmental-wisdom along with ethical responsibility to have a successful career and to sustain passion and zeal for real-world applications using optimal resources as an Entrepreneur.	-	-

3 = High; 2 = Medium; 1 = Low

VIII. COURSE OBJECTIVES (COs):

The course should enable the students to:	
I	Learning and understanding of operation of basic types of radar systems.
II	Learning and understanding of detection and processing of radar signals
III	Learning and understanding of various types of targets, interferences, noises and losses encountered in radars.
IV	Learning and understanding of some important aspects radar transmitters and receivers

IX. COURSE OUTCOMES (COs):

COs	Course Outcome	CLOs	Course Learning Outcome
CO 1	Learning and Understanding of Pulse radar systems.	CLO 1	Learning of the operating principles of Pulse radars
		CLO 2	Understanding of various types of radar targets: point and fluctuating .
		CLO 3	Appreciate various types of clutters, noises, losses involved in radar systems.
		CLO 4	Preliminary System design of Pulse and Pulse Compression radars
CO 2	Understanding of CW and FMCW radar systems.	CLO 5	Preliminary System design of CW and FM-CW radars
		CLO 6	Appreciatevariousinterferences encountered in radar target detection
CO 3	Exploration of Moving Target Indication and Pulse Doppler Radar systems	CLO 7	Understanding of the operating principles of MTI & Pulse Doppler radars
		CLO 8	Preliminary System design of MTI and Pulse Doppler radars
CO 4	Analysis of Target detection techniques and Understanding of Tracking Radar	CLO 9	Understanding of the operating principles of search and tracking radars
		CLO 10	Understanding & Analysis of detection techniques of target echo signal
		CLO 11	Understanding of tracking techniques of target echo signal
CO 5	Discussion of subsystems of a typical Radar Transmitter and Receiver	CLO 12	Understanding of different subsystems of a typical Radar transmitter
		CLO 13	Appreciate the concept of Noise Figure and the estimating the performance of radar receivers
		CLO 14	Understanding of different subsystems of a typical Radar Receiver

X. COURSE LEARNING OUTCOMES (CLOs):

CLO Code	CLO's	At the end of the course, the student will have the ability to:	POsMapped	Strength of Mapping
AEC521.01	CLO1	Learning of the operating principles of Pulse radar	PO1	3
AEC521.02	CLO2	Understanding of various types of radar targets: point and fluctuating	PO1, PO2	3
AEC521.03	CLO3	Appreciate various types of clutters, noises, losses involved in radar systems	PO2, PO4	2
AEC521.04	CLO4	Preliminary System design of Pulse and Pulse Compression radars	PO3, PO4	3
AEC521.05	CLO5	Preliminary System design of CW and FM-CW radars	PO3	3

CLO Code	CLO's	At the end of the course, the student will have the ability to:	POsMapped	Strength of Mapping
AEC521.06	CLO6	Appreciate various interferences encountered in radar target detection	PO2	2
AEC521.07	CLO7	Understanding of the operating principles of MTI & Pulse Doppler radars	PO1	3
AEC521.08	CLO8	Preliminary System design of MTI and Pulse Doppler radars	PO3	3
AEC521.09	CLO9	Understanding of the operating principles of search and tracking radars	PO1, PO4	3
AEC521.10	CLO10	Understanding & Analysis of detection techniques of target echo signal	PO1, PO4	3
AEC521.11	CLO11	Understanding of tracking techniques of target echo signal	PO1	2
AEC521.12	CLO12	Understanding of different subsystems of a typical Radar transmitter	PO1, PO3	3
AEC521.13	CLO13	Appreciate the concept of Noise Figure and the estimating the performance of radar receivers	PO1, PO4	2
AEC521.14	CLO14	Understanding of different subsystems of a typical Radar Receiver	PO3	2

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XI. MAPPING COURSE OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES:

Course Outcomes	Program Outcomes and Program Specific Outcomes					
	PO 1	PO 2	PO 3	PO4	PSO 1	PSO 2
CO 1	3	2				
CO 2	2	3	3		2	
CO 3	2	2	3	2		2
CO 4	3		2	2	2	
CO 5			3			2

3 = High; 2 = Medium; 1 = Low

XII. MAPPING COURSE LEARNING OUTCOMES LEADING TO THE ACHIEVEMENT OF PROGRAM OUTCOMES AND PROGRAM SPECIFIC OUTCOMES:

CLOs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO1	3												3		
CLO2	3	3												3	

CLOs	POs												PSOs		
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CLO3		2		2										2	
CLO4	3													3	
CLO5	3			3										3	
CLO6		2												2	
CLO7	3			3										3	
CLO8	2												2		
CLO9	3		3											3	
CLO10	2			2										3	
CLO11			2										2		
CLO12			3	3									3		
CLO13			3										3		
CLO 14			3										3		

3 = High; 2 = Medium; 1 = Low

XIII. ASSESSMENT METHODOLOGIES–DIRECT

CIE Exams	PO1, PO2 PO3, PO4	SEE Exams	PO1, PO2 PO3, PO4	Assignments	PO2 PO3	Seminars	PO4
Laboratory Practices	-	Student Viva	-	Mini Project	-	Certification	-
Term Paper	-						

XIV. ASSESSMENT METHODOLOGIES-INDIRECT

✔	Early Semester Feedback	✔	End Semester OBE Feedback
✘	Assessment of Mini Projects by Experts		

XV. SYLLABUS :

UNIT I	INTRODUCTION
Radar frequencies and applications; Maximum unambiguous range; Radar wave forms; Radar equation; Radar block diagram and operation; Basic pulsed radar system; Moving target indication; Prediction of range performance; Minimum detectable signal; Receiver noise and SNR; Radar cross section of targets; Cross section fluctuations, transmitter power, PRF and range ambiguities; system losses, related problems .	

UNIT II	CW AND FREQUENCYMODULATED RADAR
Doppler Effect, CW Radar: Block Diagram; Isolation between transmitter and receiver; Non-zero IF receiver, receiver bandwidth requirements, applications of CW radar, illustrative problems; FM-CW radar, range and Doppler measurement, block Diagram and characteristics (Approaching/ Receding Targets), FM-CW altimeter, multiple frequency CW radar	
UNIT III	**MOVING TARGET INDICATION AND PULSE DOPPLER RADAR**
Introduction to Doppler and moving target indication radar, principle and block diagram of moving target indication, power amplifier transmitter, delay line cancellers, filter characteristics, blind speeds, double cancellation, staggered pulse repetition frequencies, MTI radar parameters, moving target detector; limitations to MTI performance, non-coherent MTI. Pulse doppler radar; radar Equation for pulsed radar; moving target indication versus pulse doppler radar	
UNIT IV	**TRACKING RADAR AND RADAR DETECTION THEORY**
Introduction, single target tracking: range, Doppler and angle measurement, track while scan, angle tracking: sequential lobing, conical scan, monopulse; Tracking radar: Amplitude comparison monopulse (one- and two coordinates), phase comparison monopulse, tracking in range, acquisition and scanning patterns, comparison of trackers. matched filter receiver, response characteristics and derivation, correlation function and cross-correlation receiver, efficiency of non matched filters, matched filter with non-white noise	
UNIT V	**RADAR RECEIVERS**
Noise figure and noise temperature; Displays: Types; Duplexers, branch type and balanced type, circulators as duplexers; Introduction to phased array antennas: Basic concepts, radiation pattern, beam steering and beam width changes, series versus parallel feeds, applications, advantages and limitations.	
TEXTBOOKS:	
1	Merrill I Skolnik , ―Introduction to Radar Systems‖, TMH Special Indian Edition, 2nd Edition, 2007.
2	V.S.Bagad, ―Radar Systems, Technical Publications, 1st Edition, 2009
REFERENCES:	
1	Merrill I Skolnik , ―Radar Handbook, McGraw-Hill Professional Publishing, 3nd Edition, 2008.

XVI. COURSE PLAN:

The course plan is meant as a guideline. Probably there may be changes.

Lecture No.	Topics to be covered	CLOs	Reference
1 - 4	Introducing to Radar &familiarization	CLO1	T1: 1.1-1.6
5-8	Radar power calculations	CLO1, CLO2,CLO3	T1: 2.1-2.5
9-12	Preliminary system design of Pulse Radar	CLO1, CLO12	T1: 2.6-2.12
13-16	Understanding of system design issues of CW Radar	CLO1, CLO13	T1: 3.1-3.2
17-19	Understanding of System design issues of FMCW Radar	CLO1, CLO13	T1: 3.3 & 3.5
20-26	Understanding of Preliminary system design ofMTI radar	CLO4, CLO14	T1: 4.1- 4.3
27-31	Appreciation of design issues of combined range and doppler processing	CLO4, CLO6, CLO7	T1: 4.4 & 4.8-4.10
32-36	Understanding of Search radar design issues	CLO5, CLO8	T1: 5.1-5.4
37-38	Understanding of Tracking radar design issues	CLO5, CLO8	T1: 5.6-5.7 & 5.9

Lecture No.	Topics to be covered	CLOs	Reference
39-42	Understanding of design principles of Radar Receiver	CLO1	T1: 10.1-10.2
43-46	Analysis of Noise performance of radar receiver	CLO3, CLO10	T1:9.1, 9.2, 9.5, 9.6
47-49	Analysis of phased array antennas	CLO11	T1: 8.1-8.2
50-51	Learning about RF feeds and their use in beam steering	CLO9	T1: 8.2 & 8.11

XVII. GAPS IN THE SYLLABUS - TO MEET INDUSTRY / PROFESSION REQUIREMENTS:

S No	Description	Proposed Actions	Relevance With POs	Relevance With PSOs
1	Automatic Detection of radar signals - CFAR receiver (**UNIT IV**)	Additional two (2) Instruction hours	PO2, PO3, PO4	PSO1, PSO2
2	Ambiguity Diagram & its application (**UNIT II**)	Additional two (2) Instruction hours	PO1, PO3, PO4	PSO1, PSO2
3	Pulse Compression Radar: Concept of pulse compression, FM & Phase Coded Radars (**UNIT II**)	Additional three (3) Instruction hours	PO2, PO3, PO4	PSO1, PSO2
4	Radar Clutter: Land and Sea clutter (without mathematical treatment) (**UNIT IV**)	Additional one (2) Instruction hours	PO2, PO3, PO4	PSO1, PSO2
5	Noise Figure due to RF and Mixer stage in Radar Receiver. (**UNIT V**)	Additional two (2) Instruction hours	PO2, PO3, PO4	PSO1, PSO2
6	Phase Shifters (Selective) used in Radar receivers (**UNIT V**)	Additional two (2) Instruction hours	PO2, PO3, PO4	PSO1, PSO2

Prepared by:
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