RADAR SYSTEMS COURSE FILE

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GEETHANJALI COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF *Electronics and communications Engineering*

(Name of the Subject / Lab Course) : Radar Systems

(JNTU CODE) : **Programme : *UG***

Branch: ECE **Version No : *01***

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Approved by : (HOD) 1) Name : Dr P Srihari **2) Sign :** **3) Date :**	

2. SYLLABUS

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY

HYDERABAD

IV Year B.Tech. ECE. I-Sem **T P C**

4+1* 0 4

RADAR SYSTEMS

UNIT I

Introduction Nature of Radar, Maximum Unambiguous Range, Radar Waveforms, Simple form of Radar Equation, Radar Block Diagram and Operation, Radar Frequencies and Applications. Related Problems.

UNIT II

Radar Equation : Prediction of Range Performance, Minimum Detectable Signal, Receiver Noise and SNR, Integration of Radar Pulses, Radar Cross Section of Targets (simple targets - sphere, cone-sphere), Transmitter Power, PRF and Range Ambiguities, System Losses (qualitative treatment). Related Problems.

UNIT III

CW and Frequency Modulated Radar : Doppler Effect, CW Radar – Block Diagram, Isolation between Transmitter and Receiver, Non-zero IF Receiver, Receiver Bandwidth Requirements, Applications of CW radar.

UNIT IV

FM-CW Radar, Range and Doppler Measurement, Block Diagram and Characteristics (Approaching/ Receding Targets), FM-CW altimeter, Measurement Errors, Multiple Frequency CW Radar.

UNIT V

MTI and Pulse Doppler Radar : Introduction, Principle, MTI Radar with - Power Amplifier Transmitter and Power Oscillator Transmitter, Delay Line Cancellers – Filter Characteristics, Blind Speeds, Double Cancellation, Staggered PRFs. Range Gated Doppler Filters. MTI Radar Parameters, Limitations to MTI Performance. Non-coherent MTI, MTI versus Pulse Doppler Radar.

UNIT VI

Tracking Radar : Tracking with Radar, Sequential Lobing, Conical Scan, Monopulse Tracking Radar – Amplitude Comparison Monopulse (one- and two- coordinates), Phase Comparison Monopulse. Target Reflection Characteristics and Angular Accuracy. Tracking in Range, Acquisition and Scanning Patterns. Comparison of Trackers.

UNIT VII

Detection of Radar Signals in Noise : Introduction, 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 VIII

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.

TEXT BOOKS :

1. Introduction to Radar Systems – Merrill I. Skolnik, SECOND EDITION, McGraw-Hill, 1981.

REFERENCES :

1. Introduction to Radar Systems – Merrill I. Skolnik, THIRD EDITION, Tata McGraw-Hill, 2001.

3. Vision of the Department

To impart quality technical education in Electronics and Communication Engineering emphasizing analysis, design/synthesis and evaluation of hardware/embedded software using various Electronic Design Automation (EDA) tools with accent on creativity, innovation and research thereby producing competent engineers who can meet global challenges with societal commitment.

4. Mission of the Department

i. To impart quality education in fundamentals of basic sciences, mathematics, electronics and communication engineering through innovative teaching-learning processes.
ii. To facilitate Graduates define, design, and solve engineering problems in the field of Electronics and Communication Engineering using various Electronic Design Automation (EDA) tools.
iii. To encourage research culture among faculty and students thereby facilitating them to be creative and innovative through constant interaction with R & D organizations and Industry.
iv. To inculcate teamwork, imbibe leadership qualities, professional ethics and social responsibilities in students and faculty.

5. PEOs and POs

Program Educational Objectives (PEOs):

PEO 1: To prepare students with excellent comprehension of basic sciences, mathematics and engineering subjects facilitating them to gain employment or pursue postgraduate studies with an appreciation for lifelong learning.

PEO 2: To train students with problem solving capabilities such as analysis and design with adequate practical skills wherein they demonstrate creativity and innovation that would enable them to develop state of the art equipment and technologies of multidisciplinary nature for societal development.

PEO 3: To inculcate positive attitude, professional ethics, effective communication and interpersonal skills which would facilitate them to succeed in the chosen profession exhibiting creativity and innovation through research and development both as team member and as well as leader.

Program Outcomes (POs):

At the end of the program graduate is expected to acquire

PO1: An ability to apply knowledge of mathematics, science, and Engineering to solve complex engineering problems of analog/digital electronics and communication systems.

PO2: An ability to model, simulate, design electronics and communication systems, conduct experiments, as well as to analyze and interpret data.

PO3: An ability to design an electronics and communication system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability and sustainability.

PO4: An ability to function on multidisciplinary teams involving interpersonal skills.

PO5: An ability to identify, formulate and solve engineering problems of multidisciplinary nature.

PO6: An understanding of professional and ethical responsibilities involved in the practice of electronics and communication engineering profession.

PO7: An ability to communicate effectively with a range of audience on complex engineering problems of multidisciplinary nature both in oral and written form.

PO8: The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context.

PO9: A recognition of the need for, and an ability to engage in life-long learning and acquire the capability for the same.

PO10: A knowledge of contemporary issues involved in the practice of electronics and communication engineering profession

PO11: An ability to use the techniques, skills and modern engineering tools necessary for engineering practice.

PO12: An ability to use modern Electronic Design Automation (EDA) tools, software and electronic equipment to analyze, synthesize and evaluate Electronic and Communication systems for multidisciplinary tasks

PO13: Apply engineering and project management principles to one's own work and also to manage projects of multidisciplinary nature

6. Course Objectives and Outcomes

Course Objectives

To understand the basic subunits of a RADAR system with respect to their functions.

- To derive the basic radar equation and its dependence on various parameters
- To study CW radar system and its application along with FMCW radar system for altimeter applications.
- To study Doppler Effect and its applications with respect to pulsed Doppler radar.
- To understand moving target indicator and to study its application.
- To study and understand the effect of noise on radar signal detection.

To study the various types of Radar Receivers and Transmitter systems

Course Outcomes

- **After completion of the course the student is able to**
- **CO1: Demonstrate the basic principle of RADAR System.**
- **CO2: Solve the RADAR Equation and to calculate Transmitter power.**
- **CO3: Analyze the working principle of CW and Frequency Modulated Radar.**
- **CO4: Draw the block diagram of FM-CW Radar and also calculate Measurement errors.**
- **CO5: Analyze the principle of each and every block of MTI and Pulse Doppler Radar.**
- **CO6: Analyze Tracking Radar principle.**
- **CO7: Demonstrate the basic principle of Receiver and also extraction of signal in Noise.**
- **CO8: Calculate Noise Figure and Noise Temperature in Radar Receivers and can describe antennas used for Radars.**

7. Brief Importance of the Course and how it fits into the curriculum

Radar Systems is offered as a core subject for ECE students in the Second Semester of Fourth Year. This subject is covering the fundamentals of Radars. 4 Credits are allocated for this subject.

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8. Prerequisites if any

Knowledge in the areas of Signals and Systems, Communication Systems and Probability and statistics

9. Instructional Learning Outcomes

UNIT-1

1. Able to know the Introduction to Nature of Radar.
2. Able to calculate Maximum Unambiguous Range, Radar Waveforms.
3. Able to find Simple form of Radar Equation.
4. Able to draw Radar Block Diagram and Operation
5. Able to identify Radar Frequencies.
6. Able to understand Applications.

UNIT-2

1. Able to Predict Range Performance
2. Able to predict Minimum Detectable Signal
3. Able to calculate Receiver Noise and SNR
4. Able to calculate Integration of Radar Pulses
5. Able to find Transmitter Power, PRF and Range Ambiguities
6. Able to predict System Losses (qualitative treatment), Related Problems.

UNIT-3

1. Able to understand the concept of Doppler Effect,
2. Able to draw the block diagram of CW Radar .
3. Able to know the concept of Isolation between Transmitter and Receiver
4. Able to understand the concept of Lidars
5. Able to draw the block diagram of Non-zero IF Receiver.
6. Able to formulate Receiver Bandwidth Requirements.
7. Able to write Applications of CW radar

UNIT-4

1. Able to define FM-CW Radar

2. Able to do Range and Doppler Measurement calculations.
3. Able to draw Block Diagram of (Approaching/ Receding Targets) and know the characteristics.
4. Able to get the concepts of FM-CW altimeter, Measurement Errors
5. Able to understand Multiple Frequency CW Radar
6. Able to assess the information available from a radar

UNIT-5

1. Able to demonstrate MTI Radar with - Power Amplifier Transmitter and Power Oscillator Transmitter.
2. Able to draw the Delay Line Cancellers – Filter Characteristics
3. Able to define Blind Speeds, Double Cancellation, Staggered PRFs.
4. Able to know the concepts of Range Gated Doppler Filters, MTI Radar Parameters
5. Able to comment on Limitations to MTI Performance.
6. Able to define Non-coherent MTI, MTI versus Pulse Doppler Radar

UNIT-6

1. Able to know different types in Tracking with Radar, Sequential Lobing, Conical Scan.
2. Able to know the concept of Mono pulse Tracking Radar – Amplitude Comparison Mono pulse (one- and two- coordinates).
3. Able to know the concept of Phase Comparison Mono pulse.
4. Able to write Target Reflection Characteristics and Angular Accuracy
5. Able to compare and define Tracking in Range, Acquisition and Scanning Patterns. Comparison of Trackers
6. Able to calculate Theoretically accuracy of radar measurements

UNIT-7

1. Able to describe the Introduction to Detection of Radar Signals in Noise
2. Able to derive the expression for Matched Filter Receiver
3. Able to describe Matched Filter Receiver – Response Characteristics and Derivation
4. Able to derive Correlation Function and Cross-correlation Receiver
5. Able to find Efficiency of Non-matched Filters
6. Able to describe Matched Filter with Non-white Noise.

UNIT-8

1. Able to comment on different types in display systems.
2. Able to calculate Noise Figure and Noise Temperature.
3. Able to differentiate different types in Duplexers – Branch type and Balanced type, Circulators as Duplexers
4. Able to describe Phased Array Antennas – Basic Concepts, Radiation Pattern, Beam Steering and Beam Width changes
5. Able comment on Series versus Parallel Feeds

6. Able to find Applications, Advantages and Limitations radar receiver models.

10. Course mapping with PEOs and POs

Mapping of Course with Programme Educational Objectives:

S.No	Course component	code	course	Semester	PEO 1	PEO 2	PEO 3
1	Electronics		RS	1	√	√	

Mapping of Course outcomes with Programme outcomes:

POs	1	2	3	4	5	6	7	8	9	10	11	12	13	
RADAR SYSTEMS	**2**	**2**	**2**	**1**	**2**			**1**	**1**		**1**		1	**RADAR SYSTEMS**
CO1: Demonstrate the basic principle of RADAR System.	**2**				**2**									
CO2: Solve the RADAR Equation and to calculate Transmitter power.	**2**		**2**		**2**			**1**			**1**		1	
CO3: Analyze the working principle of CW and Frequency Modulated Radar.	**2**	**2**	**1**		**2**						**2**	**2**		
CO4: Draw the block diagram of FM-CW Radar and also calculate Measurement errors.	**2**	**1**	**1**		**1**				**1**					
CO5: Analyze the principle of each and every block of MTI	**2**	**1**	**1**		**2**								1	

and Pulse Doppler Radar.														
CO6: Analyze Tracking Radar principle.	**2**	**2**	**1**		**2**			**1**					1	
CO7: Demonstrate the basic principle of Receiver and also extraction of signal in Noise.	**2**	**2**			**2**				**1**				1	
CO8: Calculate Noise Figure and Noise Temperature in Radar Receivers and can describe antennas used for Radars.	**2**	**2**	**1**		**2**			**1**			**2**	**1**	1	

11.Time table of concerned class

12. Individual time table

13. Lecture schedule with methodology being used / adopted

S. No	Date	Topic covered	No. of hrs
UNIT-I		**Introduction Nature of Radar**	**8**
1.		Introduction Nature of Radar	1
2.		Maximum Unambiguous Range, Radar Waveforms	1
3.		Simple form of Radar Equation	1
4.		Radar Block Diagram and Operation	1
5.		Radar Frequencies and Applications.	1
6.		Related Problems.	1
7.		Tutorial	1
8.		**University questions**	1
UNIT-II		**Radar Equation**	**8**
9.		Prediction of Range Performance	1
10.		Minimum Detectable Signal	1
11.		Receiver Noise and SNR	1
12.		Integration of Radar Pulses	1
13.		Transmitter Power, PRF and Range Ambiguities	1
14.		System Losses (qualitative treatment), Related Problems.	1
15.		Assignment Test	1
16.		Tutorial	1
UNIT-III		**CW and Frequency Modulated Radar**	**8**
17.		Doppler Effect, CW Radar – Block Diagram	1
18.		Isolation between Transmitter and Receiver	1
19.		Isolation between Transmitter and Receiver	1
20.		Lidars	1
21.		Non-zero IF Receiver, Receiver Bandwidth Requirements	1
22.		Non-zero IF Receiver, Receiver Bandwidth Requirements	1
23.		Applications of CW radar	1
24.		Tutorial	1
UNIT-IV		**FM-CW Radar**	**8**
25.		FM-CW Radar	1
26.		Range and Doppler Measurement	1
27.		Block Diagram and Characteristics (Approaching/ Receding Targets)	1
28.		FM-CW altimeter, Measurement Errors	1
29.		Multiple Frequency CW Radar	1
30.		Information availablefrom a radar	1
31.		Assignment test	1
32.		Tutorial	1
UNIT-V:		**MTI and Pulse Doppler Radar**	**8**
33.		MTI Radar with - Power Amplifier Transmitter and Power Oscillator Transmitter	1
34.		Delay Line Cancellers – Filter Characteristics	1

35.		Blind Speeds, Double Cancellation, Staggered PRFs.	1
36.		Range Gated Doppler Filters, MTI Radar Parameters	1
37.		Limitations to MTI Performance.	1
38.		Non-coherent MTI, MTI versus Pulse Doppler Radar	1
39.		**Assignment**	1
40.		**Tutorial Class**	1
UNIT-VI:		**Tracking Radar**	**8**
41.		Tracking with Radar, Sequential Lobing, Conical Scan	1
42.		Monopulse Tracking Radar – Amplitude Comparison Monopulse (one- and two-	1
43.		Phase Comparison Monopulse.	1
44.		Target Reflection Characteristics and Angular Accuracy	1
45.		Tracking in Range, Acquisition and Scanning Patterns. Comparison of Trackers	1
46.		Theoretically accuracy of radar measurements	1
47.		**Assignment**	1
48.		**Tutorial class**	1
UNIT-VII:		**Detection of Radar Signals in Noise**	**8**
49.		Introduction to **Detection of Radar Signals in Noise**	1
50.		Matched Filter Receiver	1
51.		Matched Filter Receiver – Response Characteristics and Derivation	1
52.		Correlation Function and Cross-correlation Receiver	1
53.		Efficiency of Non-matched Filters	1
54.		Matched Filter with Non-white Noise.	1
55.		**Tutorial class.**	1
56.		**Tutorial class**	1
UNIT-VIII:		**Radar Receivers**	**8**
57.		Noise Figure and Noise Temperature. Displays – types	1
58.		Duplexers – Branch type and Balanced type, Circulators as Duplexers	1
59.		Introduction to Phased Array Antennas – Basic Concepts, Radiation Pattern, Beam	1
60.		Series versus Parallel Feeds	1
61.		Applications, Advantages and Limitations.	1
62.		**University Papers Solving**	1
63.		**Assignments**	1
64.		**Tutorials**	1
			64

TEXT BOOKS :

1. Introduction to Radar Systems – Merrill I. Skolnik, SECOND EDITION, McGraw-Hill, 1981.

REFERENCES :

1. Introduction to Radar Systems – Merrill I. Skolnik, THIRD EDITION, Tata McGraw-Hill, 2001

14. Detailed Notes

--Available Separately—

15. ADDITIONAL TOPICS

1. **Light Detection and Ranging**
2. **Optical Radars**
3. **Weather Radars**
4. **Imaging / mapping Radars/Lidars**

16. University previous Question papers

Code No: R41044 **R10** **Set No. 1**

IV B.Tech I Semester Regular/Supplementary Examinations, Nov/Dec - 2014

RADAR SYSTEMS

(Electronics and Communication Engineering)

Time: 3 hours **Max. Marks: 75**

Answer any FIVE Questions

All Questions carry equal marks

*****

1 a) Define maximum unambiguous range of radar and derive the expression for radar equation. [8]

b) What should be the pulse repetition frequency of a radar in order to achieve a maximum unambiguous range of 60 nmi and if the radar has a peak power of 800 kW, what is its average power with a pulse width of 1.5 μs. [7]

2 a) Explain the significance of integration of radar pulses and derive the expression for integration efficiency. [8]

b) A radar operates at a frequency of 1.35 GHz has an antenna of width 32 feet, a maximum unambiguous range of 220 nmi, and an antenna scan time of 10s. What is the number of echo pulses per scan received by the radar from a point target? [7]

3 a) Explain the principle of operation of CW radar with the help of a neat diagram. [8]

b) Describe the principle of multiple frequency CW radar with necessary equations. [7]

4 a) Explain the advantages of using staggered pulse repetition frequencies in the design of MTI Doppler filters. [7]

b) Draw the block diagram of MTI radar using range gates and filters and explain its operation. [8]

5 a) Explain the principle of sequential lobing tracking radar with the help of neat diagrams. [8]

b) Describe the comparison of various tracking radars. [7]

6 a) Explain the principle of phased array antenna with the help of a neat diagram. [8]

b) Describe the various types of radiators used for phased arrays. [7]

7 a) Explain the frequency response characteristics of a matched filter receiver with necessary equations. [8]

b) Draw the block diagram of a cross correlation receiver of radar and explain. [7]

8 a) What is the function of a duplexer in radar? Explain the operation of balanced duplexer with a neat diagram. [8]

b) Explain how the circulator can be used as a duplexer in radar system. [7]

Code No: R41044 **R10** **Set No. 2**

IV B.Tech I Semester Regular/Supplementary Examinations, Nov/Dec - 2014

RADAR SYSTEMS

(Electronics and Communication Engineering)

Time: 3 hours **Max. Marks: 75**

Answer any FIVE Questions

All Questions carry equal marks

*****

1 a) Explain the basic principle of operation of radar with a neat block diagram. [8]

b) Explain the various applications of radar. [7]

2 a) What are the various methods for representing the fluctuations of radar targets? Explain any one in detail. [8]

b) What are the various system losses in a radar system? Explain in detail. [7]

3 a) Explain the operation of CW Doppler radar with non-zero IF receiver with a neat diagram. [8]

b) Describe the bandwidth requirements and applications of CW radar. [7]

4 a) Draw the block diagram of MTI radar with power oscillator transmitter and explain its operation. [8]

b) Describe the parameters and limitations of MTI radar. [7]

5 a) Explain the principle of amplitude comparison monopulse tracking radar with the help of a neat block diagram. [8]

b) Compare the amplitude comparison and phase comparison monopulse tracking radar. [7]

6 a) Describe the principle of cosecant-squared antenna pattern with the help of a neat sketch. [8]

b) Write short notes on Radomes. [7]

7 What are various detection criteria used to detect weak signals at a radar receiver in the presence of noise? Explain in detail. [15]

8 a) Explain the principle of phased array antenna and derive the expression for radiation pattern. [8]

b) Describe the applications, advantages and limitations of phased arrays. [7]

Code No: R41044 **R10** **Set No. 3**

IV B.Tech I Semester Regular/Supplementary Examinations, Nov/Dec - 2014

RADAR SYSTEMS

(Electronics and Communication Engineering)

Time: 3 hours **Max. Marks: 75**

Answer any FIVE Questions

All Questions carry equal marks

*****

1 a) Describe the various radar frequencies and list out the applications of radar. [8]

b) Derive the expression for simple form of radar range equation. [7]

2 a) Define the radar cross section of targets and explain its significance for various types of targets. [8]

b) What is the maximum radar cross section in square meters of an automobile license plate that is 12 inches wide by 6 inches high, at a frequency of 10.525 GHz. [7]

3 a) Draw the block diagram of FM-CW radar using sideband super heterodyne receiver and explain its operation. [8]

b) Describe the measurement of range and Doppler shift in FM CW radar. [7]

4 a) Explain the principle of double delay-line canceller with necessary equations and waveforms. [8]

b) Determine the highest frequency that a radar can be operated if it is required to have a maximum unambiguous range of 200 nmi and no blind speeds less than 600 kt. [7]

5 a) With the help of a neat block diagram, explain the principle of conical-scan tracking radar. [8]

b) Explain the various target reflection characteristics that can limit the accuracy of tracking radar. [7]

6 a) What are the various types of phase shifters used in phased arrays? Explain anyone with a neat sketch. [8]

b) Describe the principle of lens antenna. [7]

7 a) Describe the characteristics of an envelope detector of a radar receiver with the help of necessary equations. [8]

b) Explain the principle of coherent detector with a neat diagram. [7]

8 a) Explain the various types of displays used in radar. [8]

b) Explain the series and parallel feed arrangements for phased array antennas. [7]

Code No: R41044 **R10** Set No. 4

IV B.Tech I Semester Regular/Supplementary Examinations, Nov/Dec - 2014
RADAR SYSTEMS
(Electronics and Communication Engineering)

Time: 3 hours Max. Marks: 75

Answer any FIVE Questions
All Questions carry equal marks
*****

1 a) Explain the operation of radar with the help of a neat block diagram. [8]
b) Determine the peak power and duty cycle of a radar whose average transmitter power is 200 W, pulse width of 1μs and pulse repetition frequency of 1000 Hz. [7]

2 a) Derive the expression for radar range equation in terms of noise figure. [8]
b) Describe the various system losses in a radar system. [7]

3 a) Explain the principle of FM-CW altimeter with the help of a neat block diagram. [8]
b) Explain how isolation is provided between transmitter and receiver of CW radar. [7]

4 a) Explain the principle of MTI radar that uses a power amplifier as the transmitter with a neat block diagram. [8]
b) Differentiate MTI and pulse Doppler radar. [7]

5 a) Explain the principle of phase comparison monopulse tracking radar and list out its applications. [8]
b) Describe the various scanning patterns that can be employed in tracking radars. [7]

6 a) Explain the principle of Cassegrain antenna with the help of a neat sketch. [8]
b) Describe the various types of feeds used for parabolic reflector antennas. [7]

7 a) Draw the block diagram of a binary moving window detector in a radar receiver and explain its principle of operation. [8]
b) Explain the operation of tapped delay-line integrator with a neat sketch. [7]

8 a) Derive the overall noise figure of a radar receiver with noise figure F, that is preceded by an RF device with a loss L_{RF}. [8]
b) What is the overall noise figure of a transmission line and duplexer, which have a loss of 1.2 dB, connected to a receiver whose noise figure is 2.3 dB. [7]

Code No: R05410404 **Set No.1**

IV B.Tech. I Semester Regular Examinations, November -2008
RADAR SYSTEMS
(Common to Electronics & Communication Engineering and Electronics & Telematics)

Time: 3 hours **Max Marks: 80**

Answer any FIVE Questions
All Questions carry equal marks
*****

1. (a) Discuss the parameters on which maximum detectable range of a radar system depends.
   (b) Compute the maximum detectable range of a radar system specified below:
   Operating wavelength = 3.2 cm
   Peak pulse transmitted power = 500 kW.
   Minimum detectable power = 10^{-13} W.
   Capture area of the antenna = 5 sq.m.
   Radar cross-sectional area of the target = 20 sq.m. [8+8]
2. (a) Describe how threshold level for detection is decided in the presence of receiver noise for a specified probability of occurrence of false alarms.
   (b) Describe the effect of pulse repetition frequency on the estimated unambiguous range of radar. [8+8]
3. (a) With the help of a suitable block diagram ,explain the operation of a CW Doppler radar in a sideband super heterodyne receiver.
   (b) Calculate the Doppler frequency of stationary CW radar transmitting at 6 MHz frequency when a moving target approaches the radar with a radial velocity of 100 Km/Hour.
   (c) List the limitations of CW radar. [5+5+6]
4. (a) With the help of suitable block diagram, explain the operation of a FM-CW altimeter.
   (b) Discuss all the possible errors in the measurement accuracy of altitudes using a FM-CW radar. [8+8]
5. (a) What is a delay line canceller? Illustrate the concept of blind speeds based on the frequency response of a single delay line canceller.
   (b) Discuss the factors limiting the performance of an MTI system. [8+8]
6. (a) Discuss the effect of surface quality and reflection characteristics of a target on the angular tracking accuracy of a tracking radar.
   (b) Describe the phase comparison monopulse tracking technique in a radar system with the help of necessary block diagram. [8+8]
7. (a) Explain the principle behind the operation of duplexers and receiver protectors.

Code No: R05410404 **Set No.1**

(b) Explain how a circulator can be utilized for a radar receiver protection.
(c) Define noise figure and noise temperature of a receiver system. [5+5+6]

8. Write short notes on the following:
   (a) Displays for visual presentation of radar echo signal.
   (b) Radiation patterns and feed arrangements for array antennas in a radar system. [8+8]

*****

17. Question Bank

1. What are the various unwanted signals which cause errors in FM altimeter?
2. Explain the two frequency CW technique for measuring the Radar range?
3. Write the simplifier version of radar range equation and explain how this equation does not adequately describe the performance of practical radar?
4. What are the specific bands assigned by the ITU for the Radar? What are the
5. Corresponding frequencies?
6. Explain how the sign of the Doppler frequency is found by splitting the received signal in CW radar?
7. Derive the expression for Doppler frequency and plot it as a function of radar frequency and target radial velocity. Assume necessary parameters.
8. A radar is required for a maximum range of 300Km. Calculate the PRF
9. Calculate the range of radar which operates at a frequency of 10 GHz, Peak power of
10. 600KW. if the antenna effective area is 5 m^2 and the area of cross section of the target is 20 m^2, minimum receivable power is 10^{-13} watts
11. Explain about radar cross sections of targets briefly?
12. Explain in detail how range and Doppler measurement is done in FMCW radar
13. Derive the simple form of the radar equation
14. Write short notes on receiver noise in radar systems
15. Explain how the sign of the Doppler frequency is found by splitting the received signal in CW radar?
16. Derive the expression for Doppler frequency and plot it as a function of radar frequency and target radial velocity. Assume necessary parameters.
17. Calculate the maximum range of a radar system which operates at 3 cm with a peak pulse power of 500 kW, if its minimum receivable power is 10^{-13} W, the capture area of its antenna is 5 m^2, and the radar cross-sectional area of the target is 20 m^2.

18. A radar echo is observed after 15μs of the transmitter pulse. Calculate the range of the target
19. What is the beat frequency? How it is used in FMCW radar?
20. Explain how the multipath signals produce error in FM altimeter?
21. What is matched filter? Why it is needed in pulse Radar?
22. How the interference from other radars are reduced in pulse radar?
23. Explain how the Radar is useful for ship safety?

18. Assignment topics/Questions

Radar Frequencies and Applications
Prediction of Range Performance
Receiver Bandwidth Requirements
FM-CW altimeter
Staggered PRFs. Range Gated Doppler Filters
Matched Filter Receiver – Response

19. Unit-wise quiz questions and long answer questions

1. Radar cross section is a measure of _____ as seen by the radar [ ]
   A) frequency B) velocity C) size D) depth

2. _____ are the statistical parameters in radar range equation [ ]
   A) S_{min} B) gain C) A_e D) both A & B

3. The no. of pulses n_B returned from a point target as the radar antenna scans through bandwidth is [ ]
   A) $\theta_B f_p \omega_m/6$ B) $\theta_B f_p/\omega_m 6$. C) $6\omega_m/\theta_B f_B$ D) $6f_B/\theta_B\omega_m$

4. The operator efficiency factor is given by [ ]
   A) $\rho_o = 0.7(\rho_f)^2$ B) $\rho_o = 0.4(\rho_f)^2$ C) $\rho_o = 0.5(\rho_f)^2$ D) $\rho_o = 0.3(\rho_f)^2$

5. Relation between radial velocity and Doppler frequency is [ ]
   A) $f_d = \frac{1.03\lambda}{V_r}$ B) $f_d = \frac{1.03V_r}{\lambda}$ C) $f_d = 1.03V_r\lambda$ D) none

6. The range beyond which targets appear as second-time around echoes is [ ]
   A) maximum ambiguous range B) maximum unambiguous range
   C) apparent range D) none

7. Relation between acceleration of the target and bandwidth is [ ]

A) $\Delta f_d = \sqrt{\frac{2a_r}{\lambda}}$ B) $\Delta f_d = \sqrt{\frac{2a_r}{\lambda}}$ C) $\Delta f_d = \sqrt[3]{\frac{2a_r}{\lambda}}$ D) $\Delta f_d = \sqrt[3]{\frac{2\lambda}{a_r}}$

8. In the region where , the radar cross section is proportional to [ ]

A) f B) f^2 C) f^3 D) f^4

9. In order to broaden the spectrum of CW radar _____ the carrier [ ]

A) frequency modulate B) amplitude modulate C) Phase modulate D) none

10. _____ is a part of the radar whose function is to pass the desired echo & reject unwanted signal [ ]

A) RF amplifier B) signal processor C) detector D) none

11. Suppressing the clutter at one velocity also suppress the signals at other velocities this process is called as _____

12. Post detection is also called as_____

13. _____ is the wave that travels around the back of the sphere and turns to the radar where it interferes with the reflection from the front of the sphere

14. The weakest signal that a receiver can detect is _____

15. The combination of second detector and video amplifier is said to be_____

16. TDWR stands for _____

17. The transmitter noise that enters the radar receiver via back scatter from the clutter is sometimes called as _____

18. Practically for every $\frac{1^o}{3}$ change in target aspect the aircraft cross section change by _____dB.

19. If the threshold level were set too low, noise might exceed the level and be mistaken for a target. this process is called _____

20. The relation between average power to the peak power if the width of the rectangular pulses is τ is _____

UNIT -I

1. What are the peak power and duty cycle of a radar whose average transmitter power is 200W, pulse width of 1μs and a pulse repetition frequency of 1000Hz?
2. What is the different range of frequencies that radar can operate and give their applications?
3. What are the basic functions of radar? In indicating the position of a target, what is the difference between azimuth and elevation?
4. Determine the probability of detection of the Radar for a process of threshold
5. Draw the block diagram of Basic radar and explain how it works?
6. Write the simplifier version of radar range equation and explain how this equation does not adequately describe the performance of practical radar?

7. Derive the simple form of the Radar equation.
8. What is the duty cycle of this radar ?
9. Describe how threshold level for detection is decided in the presence of receiver noise for a specified probability of occurrence of false alarms.
10. With the help of a suitable block diagram, explain the operation of CW Doppler radar in a sideband super heterodyne receiver.
11. Discuss the results of multiple frequency usage for operating FM-CW radar while mentioning the limitations of multiple frequency usage in CW radars

UNIT -II

12. Compute the maximum detectable range of a radar system specified below:
    Operating wavelength = 3.2 cm
    Peak pulse transmitted power = 500 kW.
    Minimum detectable power = 10^{-13}W.
    Capture area of the antenna = 5 sq.m.
    Radar cross-sectional area of the target = 20 sq.m
13. Describe the effect of pulse repetition frequency on the estimated unambiguous range of radar
14. What is Doppler frequency shift? Establish a relation between Doppler frequency shift and radial velocity of a moving target.

UNIT III

15. Discuss all the possible errors in the measurement accuracy of altitudes using FM-CW radar.
16. Derive fundamental radar range equation governed by minimum receivable echo power $S_{min,}$ in terms of P_t = transmitted power, G = antenna gain, A_e = antenna effective aperture, σ = radar cross section.
17. Describe the effect of (in terms of wavelength of operation) size of a simple spherical target on determination of radar cross section of the sphere.
18. What are multiple-time-around echoes? Explain the relation between unambiguous range estimation and multiple-time-around echoes.
19. Explain how isolation between transmitter and receiver of a radar system can be achieved if single antenna is used for transmission and reception.
20. Discuss the results of multiple frequency usage for operating FM-CW radar while mentioning the limitations of multiple frequency usage in CW radars.

Unit-5

1. (a) Describe the Range gate Doppler filters.
   (b) Differentiate the blind phases from blind speeds.
2. (a) Mention the limitations of MTI radar related to clutter parameters.
   (b) Mention the limitations of improvement factor imposed by pulse-to-pulse in- stability.
3. (a) Draw and explain frequency-response characteristics of an MTI using range gates and filters.
   (b) What is the difference between MTI radar using range gates and an MTI with a single-delay- line canceller?
4. Explain the following limitations of MTI radar.
   (a) Equipment instabilities.
   (b) Scanning modulation.
5. A MTI radar is operated at 9GHz with a PRF of 3000 pps. Calculate the first two lowest blind speeds for this radar. Derive the formula used.

Unit-6

1. (a) Explain the block diagram of amplitude comparison monopulse radar for single angular coordinate and explain its operation.
   (b) Explain the scanning patterns employed with pencil beam antenna.
2. (a) Compare the tracking techniques.
   (b) Explain in detail about limitations to tracking accuracy.
3. (a) What are the advantages of monopulse radar over conical scan radar.
   (b) Explain the block diagram of amplitude comparison monopulse for extracting error signals in both elevation and azimuth.
4. Why is amplitude comparison mono pulse more likely to be preferred over the phase comparison mono pulse and conical scan tracker over sequential lobbing, or lobe switching, tracker? Explain.
5. (a) Draw and explain the following with respect to Tracking in range:
   i. Echo pulse
   ii. Early-late range gates
   iii. Difference signal between early and late range gates.
   (b) Limitation of automatic detection and tracking.

Unit-7

1. Explain the principle and characteristics of a matched filter. Hence derive the expression for its frequency response function.
2. (a) Describe and distinguish between the different types of ECM directed against radar.
   (b) Discuss the relations between the matched filter characteristics and correlation function.
3. Write notes and explain about:
   (a) Passive ECM
   (b) Matched and non-matched filters
   (c) North filter.
   (d) Antijamming techniques.
4. Discuss the relation between the matched filter characteristics and correlation de-tection.
5. Discuss in detail about Matched-filter Receiver with necessary expressions.

unit-8

1. (a) Write notes on various antenna parameters and their significance as applicable to radars.
   (b) Explain and distinguish between the branch-type and balanced duplexers.
2. (a) Explain the different types of feeds and their radiation characteristics, suitable to radar dish antennas.
   (b) List out the merits and demerits of phased array antennas.
3. (a) Discuss about the factors that influence the prediction of Radar range.
   (b) Define noise bandwidth of a radar receiver. How does it differ from 3-dB band width? Obtain the expression for minimum detectable signal in terms of noise bandwidth, noise figure and other relevant parameters.
4. (a) Explain the basic concept of phased array antennas.

(b) Explain characteristics of different radar displays.

5. (a) Draw and explain the radiation pattern of phased array antennas.
   (b) Write notes on various antenna parameters with reference to radar.

20. Tutorial Problems:

1. Compute the maximum detectable range of a radar system specified below:
   Operating wavelength = 3.2 cm

   Peak pulse transmitted power = 500 kW.

   Minimum detectable power = 10^{-3} W

   Capture area of the antenna = 5 sq.m.

   Radar cross-sectional area of the targe t = 20 sq.m.

2. What should be the pulse repetition frequency of a radar in order to achieve a maximum unambiguous range of 60 nmi?
3. How long it take for the radar signal to travel out and back when the target is at the maximum unambiguous range?
4. If the radar has a pulse width of 1.5μs, what is the extent (in meters) of the pulse energy in space in the range coordinate?
5. How far apart in range (meters) must two equal-size targets be separated in order to be certain they are completely resolved by a pulse width of 1.5μs?
6. If the radar has a peak power of 800 kW, what is the average power ?
7. Calculate the Doppler frequency of stationary CW radar transmitting at 6 MHz frequency when a moving target approaches the radar with a radial velocity of 100 Km/Hour.
8. List out the possible errors for measurement of altitudes accurately using a FM-CW altimeter.
9. What is the peak power of a radar whose average transmitter power is 200 W, pulse width of 1μs, and a pulse repetition frequency of 1000 Hz ?
10. What is the range (nmi) of this ground based air surveillance radar if it has to detect a target with radar cross section of 2 m^2 when it operates at a frequency of 2.9 GHz (S band), with a rectangular-shaped antenna that is 5 m wide, 2.7 m high, antenna aperture efficiency ρ_a of 0.6 and minimum detectable signal S_{min} equal to 10^{-12} W (based on P_t in the radar equation being the peak power) ?

21. Known Curriculum Gaps and inclusion of the same in the lecture schedule:

GPS, Navigation systems, Laser Radars

22. Group discussion topics

Military Radars

Radars for remote sensing

Need of Radars for a lay man

Latest developments in Radars

23. References, Journals, websites and E-links

REFERENCES:

1. Introduction to Radar Systems – Merrill I. Skolnik, SECOND EDITION, McGraw-Hill, 1981.

2. Introduction to Radar Systems – Merrill I. Skolnik, THIRD EDITION, Tata McGraw-Hill, 2001

WEBSITES

www.ieeexplore.org

JOURNALS

Journal of applied remote sensing

24. Quality Control Sheets

A. Course End Survey:

Course end survey will be collected at the end of the semester.

B. Teaching Evaluation

Quality control department conducts online feedback, two times in the semester.

25. Students list

26. Group-wise students list for discussion topic:

The Groups will be formed after start of the class work.