GENERAL SIR JOHN KOTELAWALA DEFENCE UNIVERSITY

Faculty of Engineering

Department of Electrical, Electronic and Telecommunication Engineering

BSc. Engineering Honours Degree

Semester 8 Examination – November 2025

(Intake 39 – EE/ET)

ET 4212 – RADAR ENGINEERING

Time allowed: 3 Hours 26 November 2025

ADDITIONAL MATERIAL PROVIDED

None

INSTRUCTIONS TO CANDIDATES

This paper contains 4 questions on 9 pages

Answer ALL questions

This is a closed book examination

This examination accounts for 70% of the module assessment. The marks assigned for each question and parts thereof are indicated in square brackets

If you have any doubt as to the interpretation of the wordings of a question, make your own decision, but clearly state it on the script

Assume reasonable values for any data not given in or provided with the question paper, clearly make such assumptions made in the script

All examinations are conducted under the rules and regulations of the KDU

DETAILS OF ASSESSMENT

Learning Outcome (LO)	Questions that assess LO	Marks allocated (Total 70%)
LO1	Q1	25
LO2	Q2	15
LO3, LO4	Q3	20
LO5	Q4	10

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Question 1 **[Total 25 marks]**

a) Explain the key differences between Bistatic radar and Monostatic radar, also stating possible vulnerabilities each type. [02]

b) Derive the Bistatic Radar Equation, steps stating derivation also, indicating all assumptions clearly and show that: [05]

$$P_r = \frac{P_t G_t G_r \lambda^2 \sigma}{(4\pi)^3 R_1^2 R_2^2}$$

Hence, approximate the Monostatic radar equation and show that: [02]

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4}$$

c) At the edge of a vast desert lies the Aquila Border Security Station, a remote outpost responsible for early detection of Large scale UAV approaching from distant air routes. To strengthen its surveillance capability, engineers are tasked with designing a ground-based **L-band search radar** that will operate day and night under harsh weather and terrain conditions. The radar system operates at a **frequency of 1.3 GHz** and must reliably detect incoming targets out to a **maximum range of 200 km**.The expected intruders small reconnaissance aircraft typically have a **Radar Cross Section (RCS) of 1 m²**.The station uses a rectangular **horn antenna** that is **12 m wide** (azimuth dimension) and **4 m high** (elevation dimension).The measured **antenna gain is 17 dB**.To ensure stable surveillance, the radar receiver has a **sensitivity of -100 dBm**. Additionally, for safety reasons, the radar should not detect or process very close objects. Therefore, the **minimum detection range** is required to be **300 m**.

$R_{min} = \frac{CT}{2}$

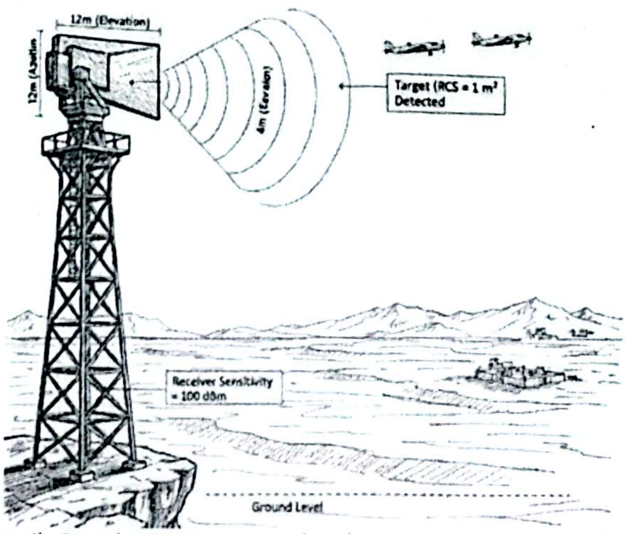


Figure 1: Aquila Boarder Security L Band Radar System: Conceptual Design

Determine the following:

(a) Peak transmitter power (P_t) required for target detection. [02]

(b) Pulse Repetition Frequency (PRF) to achieve a maximum unambiguous range of 200 km. $C/2f_r$ [01]

(c) Average transmitter power. [01]

(d) Range resolution of the radar. [01]

(e) Azimuthal beamwidth of the antenna. [01]

(Assume free-space propagation and use standard radar equations as necessary)

d) Imagine you are designing a surveillance radar for an airport located near a mountain range. The radar receives strong echoes from the mountains (Clutter) that are significantly higher in power than the weak echoes from approaching aircraft. Since the mountains are stationary, their phase remains constant from pulse to pulse, whereas the moving aircraft induces a phase shift (Doppler effect).To filter out the mountains and see only the aircraft, the radar signal processor uses Delay Line Cancellers.

1) Draw the block diagram of a Single Delay Line Canceller. In your diagram, clearly label and state in equations the following system parameters using the notations given below: [01]

Input Signal: x(t)
Output Signal: y(t)
Impulse Response: h(t)
Delay Time: T

$2(1-\cos\omega T)$

2) To further improve SDLC (Single delay line canceller) filter performance, Single delay line canceller with feedback is introduced. Consider the below block diagram of a Recursive MTI Filter with a feedback gain coefficient K and find the followings.

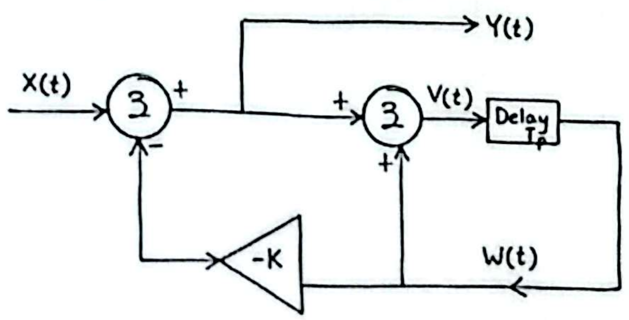


Figure 2 : MTI recursive filter block diagram

a) Write a expressions in time domain to Y(t) , W(t) and V(t) separately. [03]

b) Find the Z transformation of each above and write the expressions again in terms of Y (z), W(z) and V (z) respectively. [03]

c) Then find the H (z) = Y(z) / X (z) and show that transfer function [02]

$$H(z) = \frac{1 - z^{-1}}{1 - Kz^{-1}}$$

3) Calculate the number of pulses required to achieve the desired output (widens the rejection notch) to avoid the blind speeds using the following plot of Power spectrum density of MTI filter with respect to Normalized doppler frequency [01]

$\frac{1}{k = 1-k}$

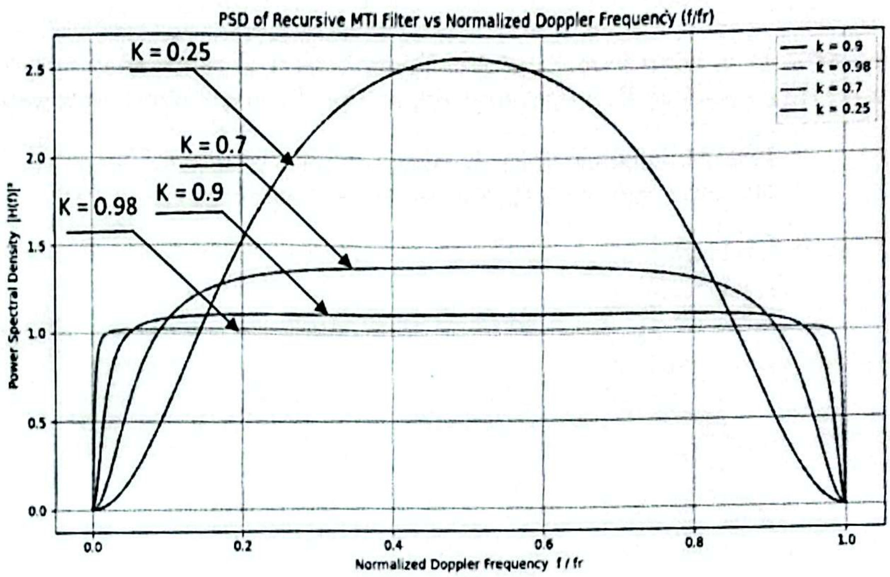


Figure 3: PSD of recursive MTI Filter vs Normalized Doppler Frequency

Question 2 **[Total 15 marks]**

a) You have been appointed as the Chief Systems Engineer for a remote surveillance outpost on a small, off-grid island. Your mission is to stop a smuggling ring known for two distinct behaviors:

1. They park large "motherships" up to **200 km offshore** (stationary targets) to offload cargo.

2. They use small, high-speed **"go-fast" boats** to run the cargo to shore, often hiding inside **heavy storm waves** (high sea clutter).

The Constraints:

Inventory: You cannot buy new modern radars. You have exactly two legacy units in the warehouse:

Unit A: A High-Power Pulsed Radar (1 μs pulse width).
Unit B: A Continuous-Wave (CW) Doppler Radar (Low power).

Power Limitation: The island runs on a small solar/battery array. You **cannot** sustain the power draw of the High-Power Pulsed Radar continuously 24/7.

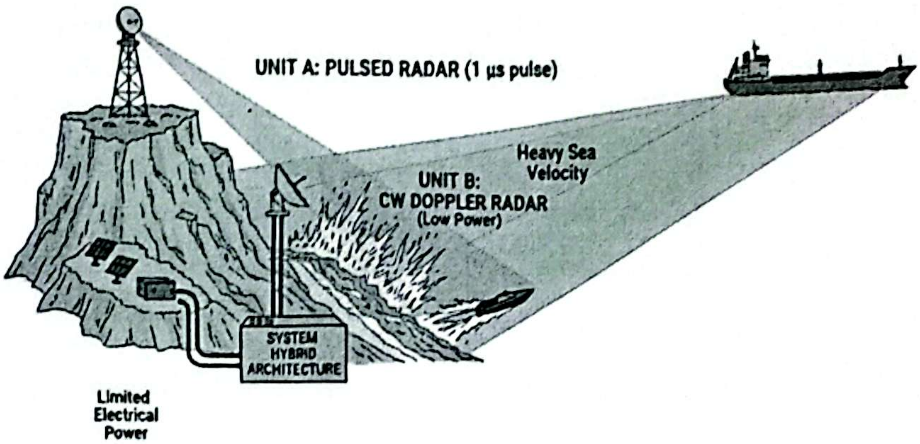


Figure 4: Illustration of the hypothetical terrain

Your Task: Propose a system architecture that ensures 100% mission success. You must determine if one unit is sufficient or if a combination is required.

Answer the following:

1. **The Failure Analysis :** Explain why **Unit A alone** and **Unit B alone** would both result in mission failure. Specifically mention how each unit would fail regarding range, clutter, stationary targets, and power. [03]

2. **The System Solution :** Propose the final operational configuration. Which unit(s) will you deploy? If you use both, explain how they will work together operationally to solve the power constraint while catching both the motherships and the fast boats. [03]

b) You are the Lead Systems Engineer at AeroDef Solutions, currently conducting field trials for a new perimeter defense radar, the *Sentinel-X*. The system relies on FM-CW (Frequency Modulated Continuous Wave) technology using triangular modulation.

System Specifications:
You have calibrated the transmitter to operate at a carrier frequency (f_0) of **10 GHz**. The waveform generator is set to a specific chirp slope: the frequency shifts by exactly **1 kHz** every **1 microsecond.**

The Incident:
During a live test, an unauthorized drone enters the detection zone. Your signal processing unit immediately locks onto the target. You observe the raw data from the mixer output:

- During the **upward frequency sweep** (up-chirp), the beat frequency read-out stabilizes at **5120 Hz.**
- During the **downward frequency sweep** (down-chirp), the beat frequency shifts to **4880 Hz.**

Your Mission:
To configure the tracking software and assess the threat, you must calculate the following parameters based on this snapshot:

1. Threat Velocity: Calculate the drone's **radial velocity**. [03]
2. Threat Vector: Based on the Doppler shift logic, determine if the drone is **closing in** on your radar station or **retreating** away from it. [01]
3. Positioning: Calculate the precise **range** (distance) of the drone at the moment of measurement. $\frac{f_r c}{2f}$ [03]
4. DSP Configuration: The client has requested a software update to separate targets into "range bins" (gates) spaced exactly **300 meters** apart. Based on your current modulation slope, calculate the **frequency bandwidth** required for each of these gates. [02]

Question 3 **[Total 20 marks]**

a) What are the different range frequencies that radar can operate and give their applications? **[04]**

b) A large commercial aircraft may have a physical cross-sectional area of 150 m^2 but its RCS might be significantly larger or smaller depending on the angle of observation.

i. Explain why RCS is NOT the same as the physical geometric area of a target. **[01]**

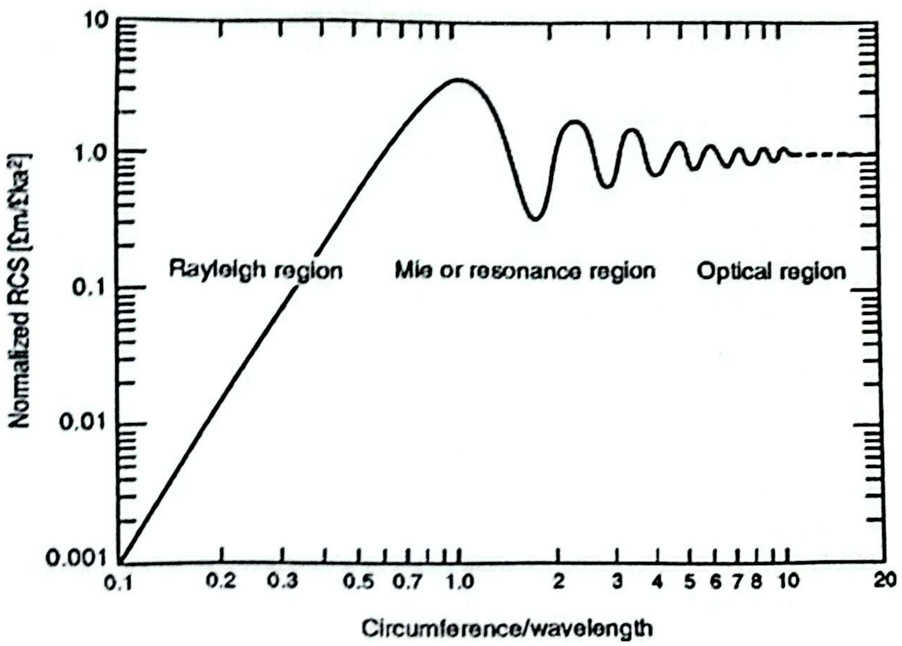
ii. Give one example of a shape that has an RCS larger than its physical size and one example of a shape (or design technique) that produces an RCS smaller than its physical size **[02]**

iii. Apart from the physical size of the target, list **three (3)** other primary factors that determine the magnitude of the Radar Cross Section **[03]**

Shape, ε, μ

c) **Figure 5**, illustrates the Radar Cross Section (RCS) of a spherical target as a function of its electrical size (Circumference / Wavelength). A weather radar operating at **S-band (3 GHz)** is designed to detect rain droplets, while a separate maritime navigation radar operating at **X-band (10 GHz)** is used to detect large spherical marker buoys (radius r = 1 m). Assume speed of light as C = 3 x 10^8

$\frac{\sigma}{\pi a^2}$



$\sim \frac{1\lambda}{2\pi a}$

Figure 5: Normalized RCS graph for a sphere

$\frac{2\pi a}{\lambda}$ $\lambda = 2\pi a$

i. Identify the three distinct scattering regions labeled on the graph (Rayleigh, Mie, Optical). For each region, describe the fundamental relationship between the wavelength (λ) of the incident electromagnetic wave and the physical size (L) of the target. [03]

ii. Explain the behavior of the scattered energy in the Rayleigh region compared to the Optical region. [02]

iii. Why does the RCS drop rapidly as frequency decreases in the Rayleigh region? [02]

iv. Why does the RCS oscillate in the Mie region before stabilizing in the Optical region? both phase and amplitude. [02]

v. Determine which scattering region applies to a **rain droplet** of radius r = 2 mm illuminated by the S-band (3 GHz) radar. [02]

vi. Determine which scattering region applies to the **marker buoy** (r = 1 m) illuminated by the X-band (10 GHz) radar. [02]

Question 4 **[Total 10 marks]**

a) Compare the two major radar jamming techniques, noise jamming and deceptive jamming by clearly explaining how each one interferes with radar performance. [3]

b) Describe the primary operational goal that noise jamming aims to achieve, and state the main objective behind deceptive jamming. [2]

c) For both noise jamming and deceptive jamming, identify one significant tactical advantage and one notable drawback that affect their effectiveness in real combat scenarios. [3]

d) Explain how modern radar systems employ Electronic Counter-Countermeasure (ECCM) techniques to resist, reduce, or neutralize the effects of both noise-based and deception-based jamming. [2]

End of question paper