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Internal Assessment Test 1 – Sept. 2025

Subject/Code: RADAR COMMUNICATION				Code: BEC714D
Date:	Duration: 90 mins	Max. Marks: 50	Semester: 07	Branch: ECE

Sl.	**Answer any FIVE FULL Questions**	**Marks**	**CO**	**RBT**
1	Explain with an illustrative example the relation among Pt, Rmax, Run and duty-cycle in a pulse radar	10	CO1	L2
2	Briefly explain RADAR system losses	10	CO1	L2
3	List and explain five applications of radar.	10	CO1	L1
4	Calculate the maximum range of a radar system which operates at 4cm with a peak pulse power of 600kW if its minimum receivable power is 10-13 W, the capture area of its antenna is 6 m2 and the radar cross sectional area of the target is 30m2	10	CO1	L2

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5	Explain amplitude comparision monopulse in one angle coordinate with a neat block diagram	10	CO2	L2
6	With neat block diagram explain single delay line canceller	10	CO2	L2
7	With a neat block diagram explain the MTI Radar with power amplifier transmitter.	10	CO2	L2

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3.

Air Traffic Control (ATC)

Application: Monitoring and managing aircraft movements.
Explanation:
Radar systems are widely used in airports and by air traffic control authorities to:

Track aircraft positions in the sky and on runways.

Ensure safe separation between planes.

Guide aircraft during takeoff, flight, and landing (especially in poor visibility).
Example: Secondary surveillance radar (SSR) provides aircraft identification and altitude information.

Weather Monitoring and Forecasting

Application: Detecting and tracking weather conditions.
Explanation:
Weather radar (Doppler radar) is used to:

Measure precipitation intensity and movement.

Detect storms, hurricanes, and tornadoes.

Estimate rainfall and predict severe weather events.
Example: Doppler weather radar can determine wind speed and direction within a storm system.

Military and Defense

Application: Surveillance, target detection, and missile guidance.
Explanation:
Radar plays a vital role in defense systems by:

Detecting enemy aircraft, ships, and missiles.

Guiding missiles and interceptors toward their targets.

Supporting battlefield surveillance and reconnaissance.
Example: Airborne Early Warning and Control (AEW&C) radar systems provide long-range detection of threats.

Marine Navigation

Application: Ensuring safe navigation for ships and boats.
Explanation:
Marine radar helps vessels:

Detect other ships, buoys, and landmasses, especially in fog or at night.

Avoid collisions and navigate safely through narrow waterways.
Example: Ship-mounted radar systems display the surroundings on a radar screen, enhancing safety at sea.

Automotive and Traffic Management

Application: Collision avoidance and vehicle control systems.
Explanation:
Modern vehicles use radar sensors for:

Adaptive cruise control (maintains safe distance from other vehicles).

Automatic emergency braking.

Blind-spot detection and parking assistance.
Example: Millimeter-wave radar in cars detects obstacles and adjusts vehicle speed automatically.

Summary Table:

Application Area	Radar Use	Example System
Air Traffic Control	Aircraft tracking and guidance	ATC radar, SSR
Weather Monitoring	Rainfall and storm detection	Doppler weather radar
Military & Defense	Surveillance and missile guidance	AEW&C, ground-based radar
Marine Navigation	Ship safety and collision avoidance	Marine radar systems
Automotive Systems	Vehicle safety and automation	Adaptive cruise control radar

2.RADAR System Losses

In a practical radar system, not all transmitted power contributes to target detection.
Various **losses** occur due to imperfections in components, propagation, and processing.
These are collectively called **Radar System Losses**.

Transmission Losses

These occur in the **transmitter and antenna system** before the signal is radiated.
Causes:

Power lost in cables, connectors, and waveguides.

Imperfect antenna efficiency.
Example: If antenna efficiency = 0.8, then 20% power is lost.

Propagation Losses

During propagation through the atmosphere, part of the signal energy is lost.
Causes:

Atmospheric absorption (due to water vapor, oxygen).

Scattering and refraction.
Effect: Reduces the signal strength reaching the target and returning to radar.

Receiver Losses

These occur in the **receiver section** due to electronic components.
Causes:

Noise figure of receiver amplifiers.

Mismatch losses in transmission lines.

Non-ideal filters and mixers.

Signal Processing Losses

Losses introduced during **detection and filtering** of radar signals.
Causes:

Non-coherent integration (loss of phase information).

Finite pulse integration time.

Thresholding and quantization effects.

Miscellaneous Losses

Other practical losses that affect radar performance, such as:

Scanning losses (beam not continuously on target).

Polarization mismatch (improper antenna alignment).

Radome losses (attenuation through the radar's protective cover).

Summary Table

Type of Loss	Cause / Description
Transmission Loss	Waveguide, connector, and antenna inefficiency
Propagation Loss	Atmospheric absorption and scattering
Receiver Loss	Component noise, impedance mismatch
Signal Processing Loss	Detection and integration inefficiencies
Miscellaneous Loss	Scanning, polarization, radome losses

4.
Answer — Maximum range (monostatic radar, ideal)

Use the monostatic radar range equation expressed with antenna effective area A_e. For a single (transmit = receive) antenna:

$$P_r = \frac{P_t\, A_e^2\, \sigma}{4\pi\, \lambda^2\, R^4}$$

Solve for R when $P_r = P_{r,\min}$:

$$R \;=\; \left(\frac{P_t\, A_e^2\, \sigma}{4\pi\, \lambda^2\, P_{r,\min}}\right)^{1/4}$$

Now substitute the given values:

- $P_t = 600\ \mathrm{kW} = 6.00 \times 10^5\ \mathrm{W}$
- $A_e = 6\ \mathrm{m}^2$
- $\sigma = 30\ \mathrm{m}^2$
- $\lambda = 4\ \mathrm{cm} = 0.04\ \mathrm{m}$
- $P_{r,\min} = 10^{-13}\ \mathrm{W}$

Compute:

$$R = \left(\frac{6.00 \times 10^5 \times 6^2 \times 30}{4\pi \times (0.04)^2 \times 10^{-13}}\right)^{1/4} \approx 7.53 \times 10^5\ \mathrm{m}$$

Maximum range ≈ 7.53×10^5 m ≈ 7.53×10^2 km ≈ 753 km.

1.

1. Radar Range Equation

$$R_{\max} = \left(\frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 P_{\min}} \right)^{1/4}$$

From this, $R_{\max} \propto P_t^{1/4}$.

👉 **Meaning:** Increasing peak power P_t increases the maximum range, but only to the fourth-root — so doubling P_t increases range by only $2^{1/4} = 1.19$ times.

---

2. Unambiguous Range

For pulse radar, the radar must receive the echo before the next pulse is transmitted:

$$R_{\text{un}} = \frac{cT}{2} = \frac{c}{2f_p}$$

👉 **Meaning:** As PRF increases, the unambiguous range decreases.
So there's a trade-off between **Rmax** (wants high PRF) and **Run** (wants low PRF).

3. Duty Cycle

$$\text{Duty cycle } D = \tau f_p$$

Average transmitted power:

$$P_{\text{avg}} = P_t \times D = P_t \tau f_p$$

👉 **Meaning:**
Higher duty cycle = more average power (better detection),
but also higher PRF (reduces R_{un}).

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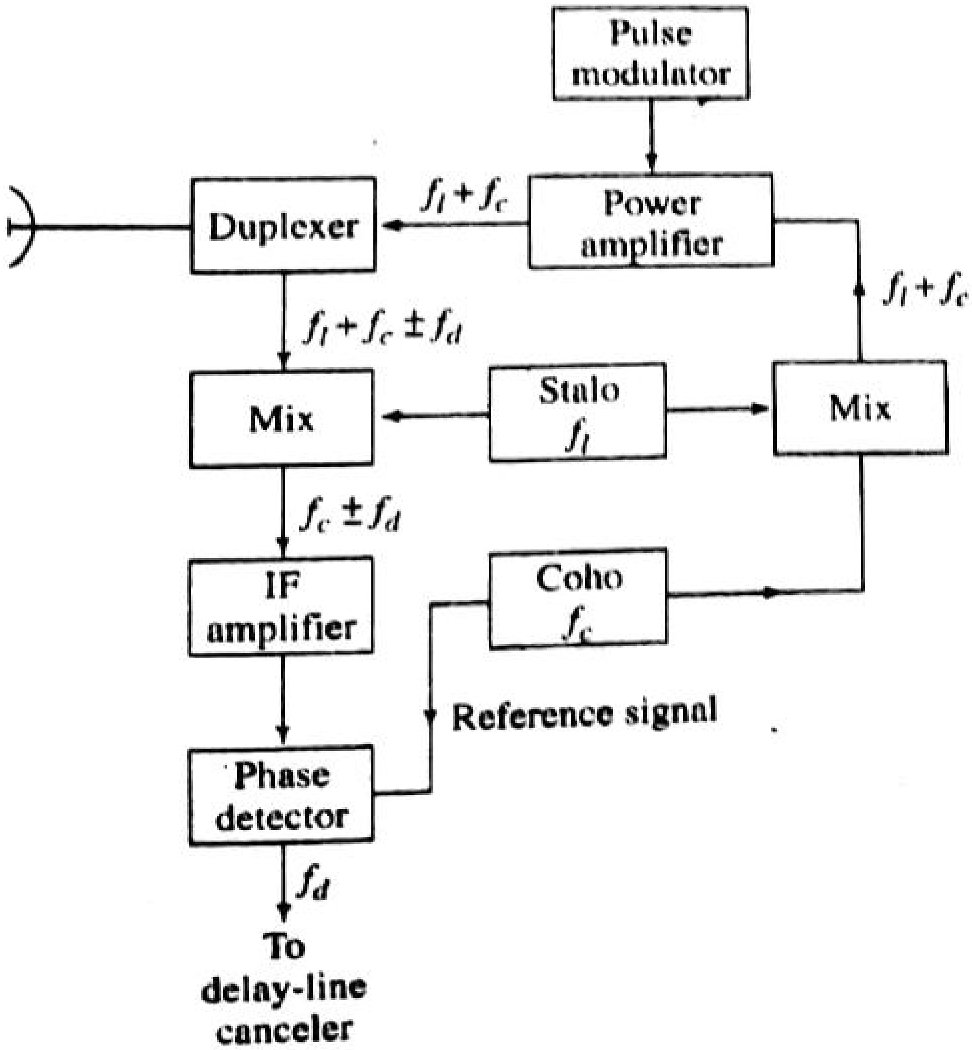
4. Relationship Summary

Parameter	Relation	Effect
$R_{\max} \propto P_t^{1/4}$	$\uparrow P_t \rightarrow \uparrow R_{\max}$	Improves detection range
$R_{\text{un}} = c/(2f_p)$	$\uparrow f_p \rightarrow \downarrow R_{\text{un}}$	Reduces unambiguous range

7.

Figure 3.7
Block diagram of an MTI radar that uses a power amplifier as the transmitter.

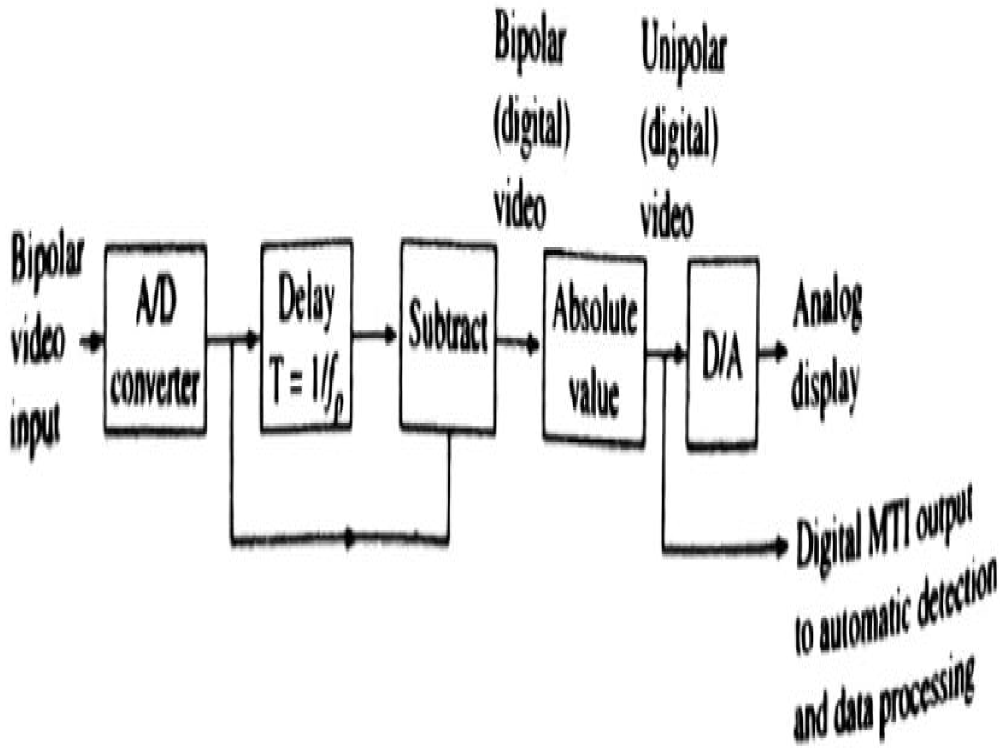


The local oscillator (LO) of an MTI radar's superheterodyne receiver must be more stable than the LO for a radar that does not employ doppler.
If the phase of the local oscillator were to change significantly between pulses, an uncancelled clutter residue can result.
This will appear at the output of the delay-line canceler which might be mistaken for a moving target even though only clutter were present.
To recognize the need for high stability, the LO of an MTI receiver is called the stalo, which stands for stable local oscillator.
The IF stage is designed as a matched filter, as is usually the case in radar.
Instead of an amplitude detector, there is a phase detector following the IF stage.
This is a mixer-like device that combines the received signal (at IF) & the reference signal from the coho.
This is done such that the difference between frequencies of received signal & the reference signal is produced.
This difference is the doppler frequency.
The name coho stands for coherent oscillator to signify that it is the reference signal that has the phase of the transmitter signal.
Coherency with the transmitted signal is obtained by using the sum of the coho & the stalo signals as the input signal to the power amplifier.
Thus the transmitter frequency is the sum of the stalo frequency fl & the coho frequency fc.
This is accomplished in the mixer shown on the upper right side of Fig.3.7.
The combination of the stalo & coho is sometimes called the receiver-exciter portion of the MTI radar.

Using the receiver stalo & coho to also generate the transmitter signal insures better stability than if the functions were performed with 2 different sets of oscillators.
The output of the phase detector is the input to the delay-line canceler, as in Fig.3.6.
The delay-line canceler acts as a high-pass filter.
This is because it is used to separate the doppler-shifted echo signals of moving targets from the unwanted echoes of stationary clutter.

6.

Figure 3.6 Block diagram of a single delay-line canceler.



A **Single Delay Line Canceller** is used in **MTI radar** to **suppress echoes from stationary targets (clutter)** — such as buildings, ground, or sea — and **allow moving targets** to be detected.

It works on the principle of **cancelling two successive received pulses** that have **identical amplitudes and phases** (stationary target returns), while retaining differences caused by **moving targets** (which cause Doppler shift).

Explanation of Each Block

Block	Function
Received Signal Input	Contains echoes from both stationary and moving targets.
Delay Line (Delay = Pulse Repetition Time T)	Stores the previous received pulse for one PRF interval.
Direct Path	Sends the current received pulse directly to the subtractor.
Subtractor (Mixer / Phase	Subtracts the delayed signal (previous pulse) from the current pulse.

Block	Function
Detector)	
Output	The difference signal — stationary target returns cancel (since same amplitude & phase), moving target returns remain (due to phase change caused by Doppler shift).

5.**Concept**

In **monopulse radar**, angular information (target direction) is obtained from a **single pulse** rather than by sequential scanning.
In the **amplitude-comparison monopulse method**, two partially overlapping antenna beams are formed in one angular coordinate (say **azimuth**).

By comparing the amplitudes of the echo signals from these two beams, the **angular position of the target** relative to the antenna boresight is determined.

Antenna and Beam Formation

The antenna system uses **two feed horns** (or subapertures) positioned symmetrically about the radar's boresight.
Their radiation patterns overlap, producing two lobes:

Left (L) beam pattern → maximum slightly to the left of boresight

Right (R) beam pattern → maximum slightly to the right of boresight

At boresight, both beams receive **equal amplitude** returns from a target.

Block Diagram

```
        ┌───────────────────────────────────┐
        │         Antenna Feed        │
        │ (Two Horns / Subapertures) │
        └─────────────────┬─────────────────┘
                  │
     ┌──────────────────────┴──────────────────────┐
     │                        │
     ▼                        ▼
  ┌────────────────┐          ┌────────────────┐
  │  Left (L)   │          │  Right (R)  │
  │  Channel    │          │  Channel    │
  └──────┬─────────┘          └──────┬─────────┘
     │                        │
     ├─────────────────────────┬───────────────────┤
     ▼             ▼
 ┌────────────────────────────────────────────┐
 │   Hybrid Junction (Magic    │
 │   Tee / 90°  Coupler)        │
```

```
└──────────┬───────────────────────┬───────────┘
     │            │
     ▼            ▼
┌─────────────┐   ┌──────────────┐
│ Σ Channel │   │ Δ Channel │
│ (Sum)     │   │(Difference) │
└──────┬──────┘   └───────┬──────┘
     │             │
     ▼             ▼
┌────────────────────┐ ┌──────────────────────┐
│ Detector /     │   │ Detector /     │
│ Video Amplifier │  │ Video Amplifier │
└───────┬────────────┘ └───────┬──────────────┘
    │                │
    └────────────────┬───────┘
           ▼
     ┌──────────────────────────┐
     │ Angle Error     │
     │ Computer /      │
     │ Comparator      │
     └─────────────┬────────────┘
           │
           ▼
     ┌──────────────────────────┐
     │ Servo / Antenna    │
     │ Position Control   │
     └──────────────────────────┘
```

Response Characteristics

Σ Pattern: Maximum at boresight

Δ Pattern: Zero crossing at boresight (changes sign across boresight)

Graphically:

```
Gain
 |
 |         /‾‾‾‾‾‾‾\
 |        /          \
 |       /   Σ Pattern   \
 |      /       /\       \
 |     /       /  \       \
 |----/--------/----\--------\----> Angle
    Left Beam        Right Beam
     \___________/
       Δ Pattern (crosses zero)
```