ECE 514E – RADAR & SATELLITE ENGINEERING

MOVING TARGET INDICATOR (MTI) RADAR – STUDY GUIDE/REVISION

---

1. INTRODUCTION TO MTI

1. What is Moving Target Indicator (MTI) Radar?

Moving Target Indication (MTI) radar is designed to detect and track moving targets while filtering out stationary objects like buildings or terrain which are referred to as clutter.

2. Core Concepts & Terminology

1. **Clutter**: Unwanted echoes (ground, weather, buildings).
2. **Doppler Effect**: Frequency shift due to target motion:

$$f_d = \frac{2v_r}{\lambda}$$

   Key variables: Radial velocity (v_r), wavelength (λ).

3. **MTI Goal**: Suppress clutter (near-zero f_d) while detecting moving targets.
4. **Critical Terms**: PRF (Pulse Repetition Frequency), Blind Speeds, Cancellation Ratio.

II. HOW MTI WORKS: SIGNAL PROCESSING CHAIN

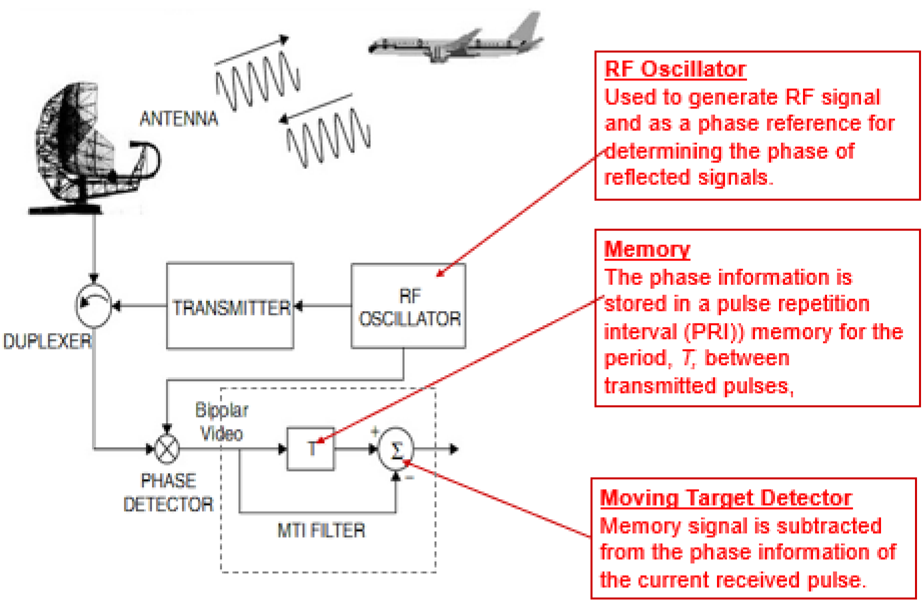

Figure 1. Block diagram of MTI Radar System

1. **Phase-Sensitive Detection**
    - Uses a **coherent oscillator (COHO)** to preserve phase data in echoes.
2. **Pulse Cancellation**
    - **Delay-Line Cancellers**: Subtract consecutive pulses.
        - *Single Canceller*: $y(t) = x(t) - x(t - T)$
        - *Double Canceller*: Two single cancellers in cascade.
    - **Frequency Response**:

      $$|H(f)| = \left|2sin\left(\frac{\pi f T}{2}\right)\right|$$

      (Nulls at $f = 0, \frac{2}{T}, \frac{4}{T} \dots$ …. Which suppress clutter.

III. MATHEMATICAL FOUNDATIONS

1. **Doppler Frequency**:

   $$f_d = \frac{2v_r f_{tx}}{C}$$

   Where f_{tx} is the transmit frequency.
2. **Blind Speeds**:

   $$v_{blind} = \frac{n\lambda PRF}{2}$$

   When $v_r = v_{blind}$, the target is undetectable.
3. **Cancellation Ratio (CR)**:

   $$CR = \frac{Clutter\ Power\ Input}{Residual\ Clutter\ Power\ Output}$$

   For ideal canceller, CR → ∞

IV. LIMITATIONS & SOLUTIONS

1. **Blind Speeds**:
    - **Solution**: Staggered PRF → shifts blind speeds.
2. **Clutter Fluctuations**:
    - Causes imperfect cancellation → **limit CR**.
3. **Equipment Instability**:
    - Oscillator phase noise → false targets.
4. **Digital vs. Analogue MTI**:
    - Modern systems use **digital filters** (FIR/IIR) for flexibility.

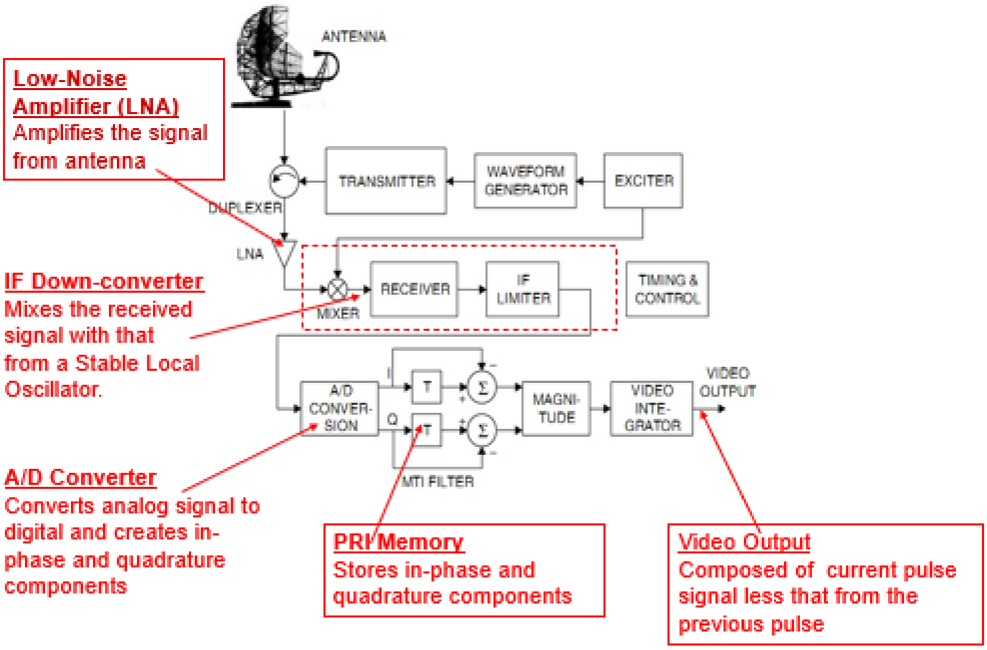

Figure 2. Block diagram of MTI Radar System with digital processing

V. KEY DIAGRAMS TO MASTER

1. **Block Diagram of Coherent MTI Radar**
   (Include: STALO, COHO, Mixer, Canceller).
2. **Frequency Response of Single/Double Canceller**.
3. **Staggered PRF Timing Diagram**.

VI. PRACTICE PROBLEMS

1. Calculate f_d for an approaching car at speed of 30 m/s and $\lambda = 0.03$ m.
2. Find blind speeds for PRF = 1 kHz (λ=0.1 m).
3. Derive the frequency response of a double canceller.
4. Why does staggered PRF reduce blind speeds? Explain mathematically.

VII. REAL-WORLD CONTEXT

- **Applications**: Air traffic control, military surveillance, weather filtering.
- **Tech Evolution**: Analog cancellers → FPGA-based digital filters.
- **MTI vs. Pulse Doppler Radar**: MTI = **low PRF** (range unambiguous), Pulse Doppler = **high PRF** (velocity unambiguous).

IX. SELF-CHECK QUESTIONS

1. Why is phase coherence critical in MTI?
2. How does a single canceller suppress clutter but not moving targets?

3. What happens if PRF is not staggered in clutter-heavy environments?
4. Explain the trade-off between canceller order and velocity response.

EXAM TIPS

Focus on **Doppler math**, **canceller frequency response**, and **blind speed mitigation**. Relate theory to practical limitations (e.g., oscillator stability).

FURTHER EXPLORATION

Study **adaptive MTI** (clutter mapping) and **MTI in automotive radar**.