Unit - 4

1.) Radar range equation (no deviation) ...

- The radar range equation represents the physical dependences of the transmit power, which is the wave propagation up to the receiving of the echo signals.
- The power P_e returning to the receiving antenna is given by the radar equation, depending on the transmitted power P_s, the slant range R, and the reflecting characteristics of the aim (described as the radar cross section σ).
- At the known sensibility of the radar receiver, the radar equation determines the achieved by a given radar theoretically maximum range.
- Furthermore one can assess the performance of the radar set with the radar range equation (or shorter: the radar equation).

$$R_{MAX} = \left[\frac{P_t G A_e \sigma}{(4\pi)^2 S_{min}}\right]^{\frac{1}{4}} = \left[\frac{P_t A_e^2 \sigma}{4\pi \lambda^2 S_{min}}\right]^{\frac{1}{4}}$$

Where,

P_t is the peak power transmitted by the Radar.

G is the gain of transmitting Antenna.

σ is the Radar across section of the target.

A_e is the effective aperture of the receiving Antenna.

S_{min} is the power of minimum detectable signal.

Factor influncing the Radar Range...

▸ Frequency :-

The higher the frequency of a radar (radio) wave, the greater is the attenuation (loss in power), regardless of weather. Lower radar frequencies (longer wavelengths) have, therefore, been generally superior for longer detection ranges.

▸ Peak Power :-

The peak power of a radar is its useful power. Range capabilities of the radar increase with peak power. Doubling the peak power increases the range capabilities by about 25 percent.

▸ Pulse Length :-

The longer the pulse length, the greater is the range capability of the radar because of the greater amount of energy transmitted.

▸ Pulse Repetition Rate :-

The pulse repetition rate (PRR) determines the maximum measurable range of the radar. Ample time must be allowed between pulses for an echo to return from any target located within the maximum workable range of the system. Otherwise, echoes returning from the more distant targets are blocked by succeeding transmitted pulses.

This necessary time interval determines the highest PRRR that can be used. The PRR must be high enough, however, that sufficient pulses hit the target and enough echoes are returned to the radar.

▸ Beam Width :-

The more concentrated the beam, the greater is the detection range of the radar.

▸ Receiver sensitivity :- The more sensitive receivers provide greater detection ranges but are more subject to jamming.

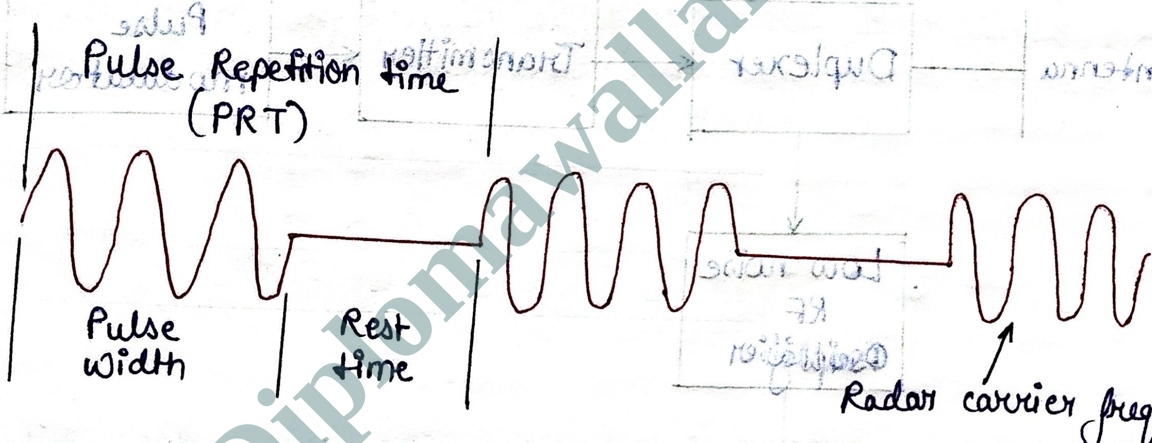
▸ Target characteristics :-

▸ Antenna Rotation Rate :-

2.) Pulsed Radar System ...

The Radar, which operates with pulse signal for detecting stationary targets is called basic pulse radar or simply, Pulse Radar.

The pulse radar system is a type of radar that works by Transmitting high-power, short-duration pulses of electromagnetic waves. These pulses travel through the atmosphere, and when they hit an object (called a target), they reflect back toward the radar. The radar system then detects these reflected signals (echoes) and measures the time taken for the pulse to return. By calculating the time delay between sending and receiving the pulse, the distance to the target can be determined.



★ Principle ...

The principle of a pulse radar system is based on the transmission of short, high-~~frequency~~ energy radio frequency pulses toward target. After sending a pulse, the radar switches to receive mode and waits for the reflected echo from the target. The time interval between the transmitted pulse and the received echo is measured, and this time delay is used to calculate the distance to the target using the formula.

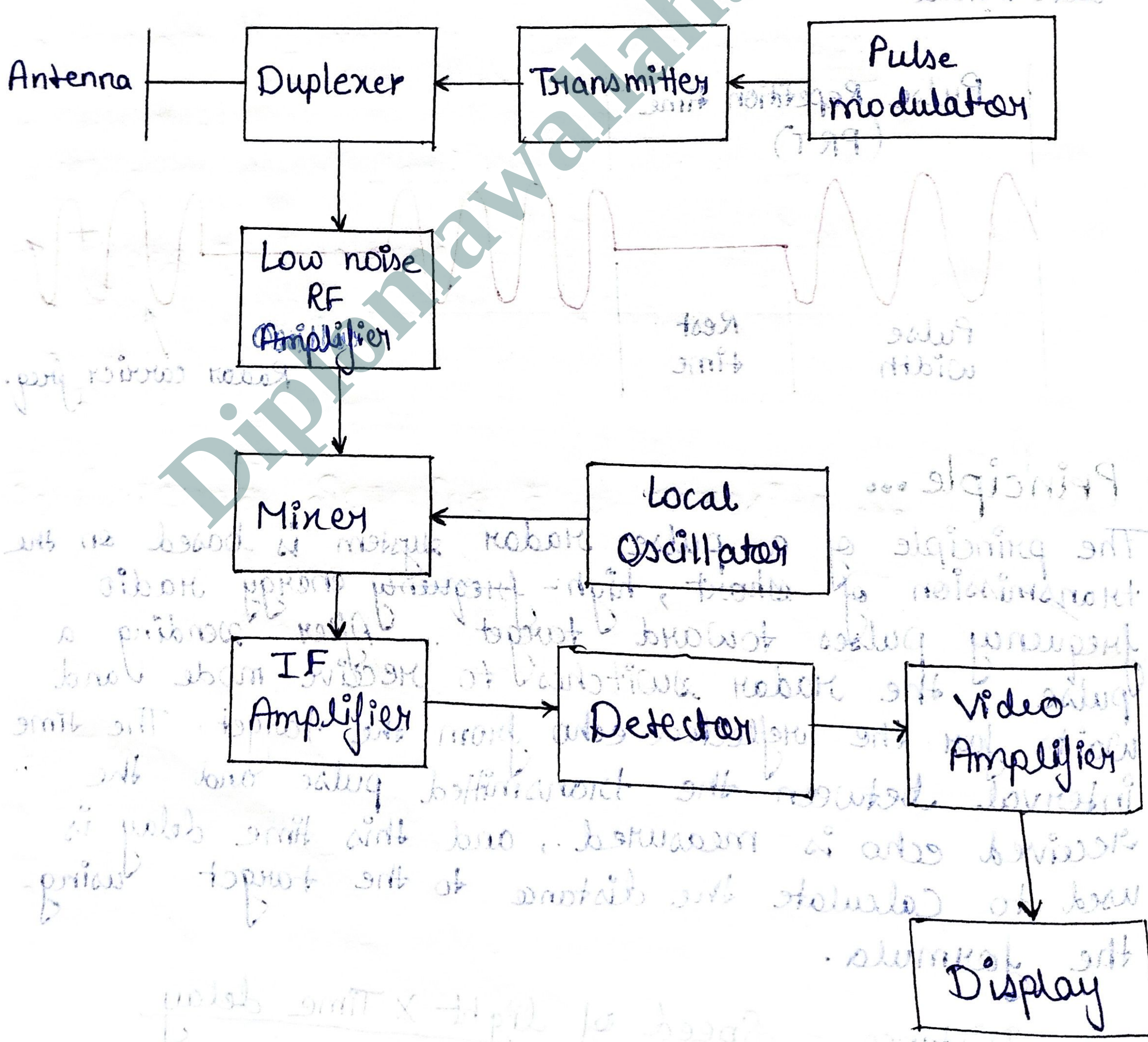
$$\text{Distance} = \frac{\text{Speed of light} \times \text{Time delay}}{2}$$

The system operates in a cyclic manner transmitting, waiting, and receiving - which allows it to detect objects at various ranges. This principle enables pulse radar to determine the range, direction, and sometimes speed of objects, making it useful in application like defense, aviation, and weather monitoring.

★ Application :-

- Military surveillance
- Air traffic control
- Weather monitoring
- maritime navigation.

★ Block diagram of Pulse Radar ...



The function of each block of pulse RADAR :-

• Pulse Modulator :-
It produces a pulse modulated signal and it is applied to the transmitter.

• Transmitter :-
It transmits the pulse-modulated signal which is a train of repetitives pulses.

• Duplexer :-
It is a device that provides bidirectional flow of signals through a single path. In radar systems, it is used for isolating transmitter and receiver while allowing them to share the same antenna

• Low noise RF Amplifier :-
It amplifies the weak RF signal, which is received by Antenna. the o/p of this amplifier is connected to mixer.

• Local Oscillator :-
It produces a signal having stable frequency. the output of local oscillator is connected to mixer.

• Mixer :-
We know that mixer can produce both sum and difference of the frequency that are applied to it. Among which, the difference of the frequencies will be of intermediate frequency (IF) types.

• IF Amplifier :-
IF amplifier amplifies the Intermediate Frequency (IF) signal. the IF amplifier shown in fig. allows only the Intermediate frequency, which is obtained from mixer and amplifies it. It improves the signal to noise ratio at output.

• Detector :-
It demodulates the signal, which is obtained at the output of detector.

• Video Amplifier :-
As the name suggests, it amplifies the video signal, which is obtained at the output of detector.

• Display :-
In general, It displays the amplified video signal on CRT screen.

Duplexer...

A duplexer is a key component that switches the antenna between the high-power transmitter and the sensitive receiver. Its main functions are:-

• Protect the receiver from high-power pulses.
• Ensures Fast Switching between transmit and receiver modes.
• Minimizes signal loss during switching.

→ Types of Duplexer
• Gas discharge duplexer (TR tubes)
• Circulators
• Electronic switches

3.) Antenna Scanning and tracking...

★ Antenna Scanning...
Antenna Scanning involves moving the radar beam to research for Targets within a certain area.

Types of Scanning

① Mechanical Scanning :-
• The physical movement of the antenna.
• Common in older radar systems.
• slow due to mechanical inertia.

② Electronic Scanning :- (Phased array)

- No moving parts.
- Beam direction changes by altering the phase of the signal at each antenna element.
- Faster and more reliable.

★ Scanning Patterns...

- ▫ Circular Scanning :- The beam rotates 360° horizontally.
- ▫ Sector Scanning :- Limited angle coverage, often used for surveillance in a particular direction.
- ▫ Raster Scanning :- Similar to a TV screen, used for detailed ~~mag~~ mapping.

★ Tracking Methods...

① Lobe Switching :

- Antenna beams switch between two positions.
- Targets is kept in the center by comparing signal strength.

(II) Conical Scanning :

- Beam rotates in a small circle around the targets.
- Allows precise measurement of angle error.

(III) Monopulse tracking :

- Uses multiple beams simultaneously.
- Provides accurate real-time position updates.
- Highly resistant to jamming.

Types of Radar Tracking systems :

(1.) Automatic Tracking Radar : (Auto track).
Computer-controlled, adjusts the antenna to follow making targets.

(2.) Track-While-Scan (TWS) :-

- Allow the radar to continue scanning for new targets while tracking existing ones.
- Widely used in military applications.