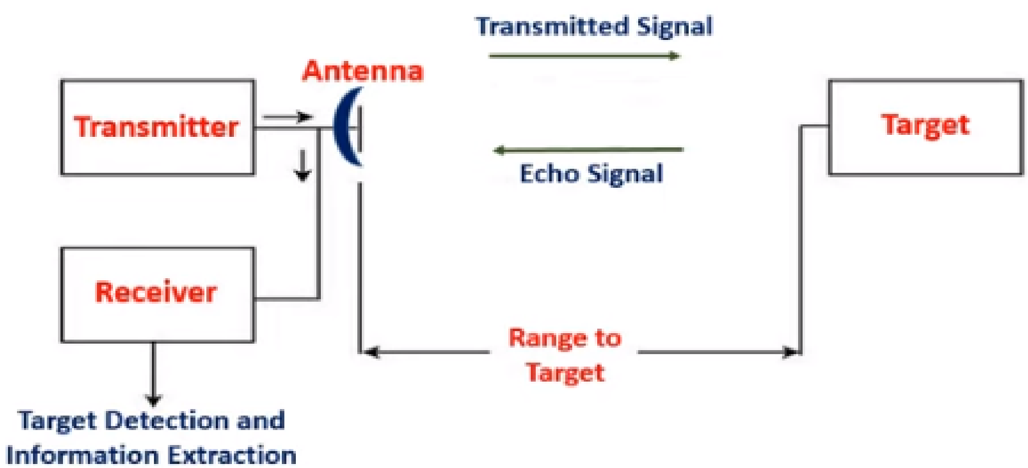
Introduction to RADAR

- RADAR is a construction of words **Radio Detection and Ranging**
- Radio is an Electromagnetic system for detection and location of objects
- Detection refers whether the Target is present or Not, the target can be stationary or Moving
- Ranging refers distance between Radar and Target
- Radar is evaluated just before the world war II and it has given birth to Microwave Technologies
- Radar can see the conditions such as : Darkness, haze, fog, rain and snow which is not possible for human vision

Basic principle of Radar



- Radar mainly consist of a transmitter, receiver, antenna, display device
- It use same antenna for transmitting and receiving the signals
- Radar is used for detecting the objects and locating their location

Important Terms of Radar Systems

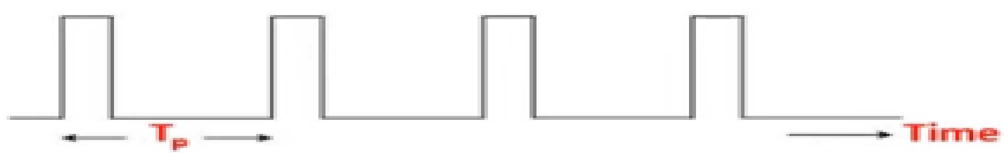
1. Range

2. Pulse Reputation Frequency

3. Maximum unambiguous Range

4. Minimum Range

Pulse Repetition Frequency



- The duration between the two clock pulses must be selected in such a way that the echo signal corresponding to present clock pulse should be received before the next clock pulse
- The number of Radar pulses transmitted per sec is known as Pulse Repetition Frequency , PRF
- The time interval between the successive clock pulses called Pulse Reception Time, PRT

Minimum Range

Minimum range of the target is calculated when the time required for the echo signal to receive at Radar after the signal being transmitted from the radar as pulse width

It is also known as the shortest range of target

Applications of Radar

- Military Applications
- Air Traffic Control (ATC)

- Aircraft Safety
- Ship Safety
- Navigation
- Space
- Remote Sensing

Radar Frequencies

Conventional Radars operate in Microwave Region

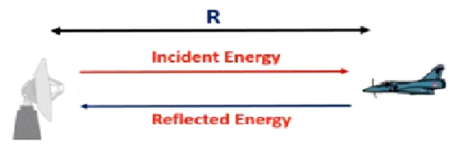
Band Designation	Nominal frequency Range	Specified Frequency Ranges for Radar
VHF	30-300 MHz	138-144 MHz 216-225 MHz
UHF	300-1000 MHz	420-450 MHz 850-942 MHz
L	1-2 GHz	1215-1400 MHz
S	2-4 GHz	2300-2500 MHz 2700-3700 MHz
C	4-8 GHz	5250-5295 MHz
KU	12-18 GHz	13.4-14.0 GHz 15.7-17.7 GHz
KA	27-40 GHz	33.4 – 36 GHz

Radar Range Equation

- Radar Range Equation is useful to calculate theoretical range of the Target

- Power density at distance, R from the Radar from the isotropic antenna is written as

$$P = \frac{P_t}{4\pi r^2} \text{ ------(1)}$$



➤ Mostly Directional Antennas are used to radiate most of the power P_t in a particular direction

- The power density from a Directional Antenna is

$$P = \frac{P_t G}{4\pi r^2} \text{ ------(2)}$$

➤ The ability of the target to reflect energy is characterized by Radar cross section σ then the re radiated density back at radar is

$$P' = \frac{P_t\, G}{(4\,\pi r^2)}\,\frac{\sigma}{(4\pi r^2)}$$

➤ The receiving antenna captures a portion of echo energy incident on it.if effective area of the antenna is A_e then P_r is

$$P_r = P' A_e$$

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

$S_{min} =$

$R_{max} =$

Fundamental form of Radar Range Equation (or) Range Equation (or) Radar Equation

Modified form1 of Radar Range Equation

The relation between Gain of directional antenna (G) and Effective aperture (A_e) is written as $G = \frac{4\pi A_e}{\lambda^2}$

We know $R_{max} =$

$R_{max} =$

$$\boxed{R_{max} =}$$

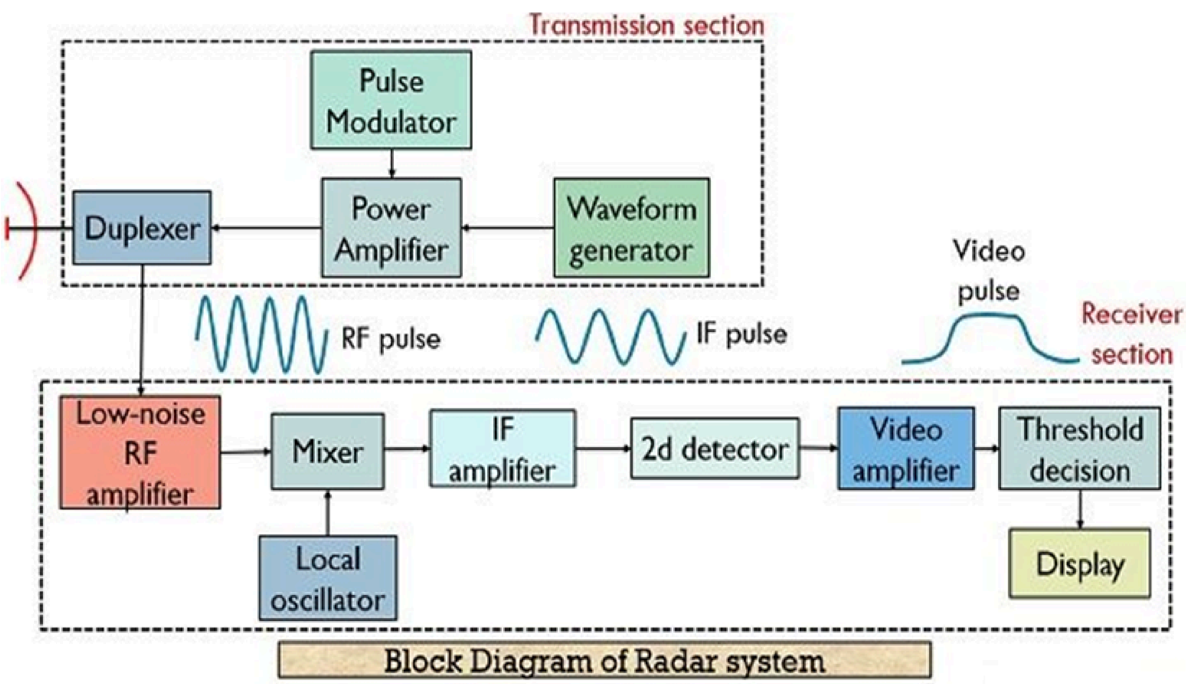
Modified form 2 of Radar Range Equation

$A_e =$

$R_{max} =$

$R_{max} =$

Radar Block Diagram



The function of each block of Pulsed 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 repetitive pulses

- **Duplexer** : it is a microwave switch, which connects the Antenna to both transmitter section and receiver section alternatively
- **Low Noise RF Amplifier** : it amplifies the weak RF signal, which is received by antenna
- **Local Oscillator** : it produces a signal having stable frequency
- **Mixer**: it can produce both sum and difference of the frequencies that are applied to it, and the difference of the frequencies will be of Intermediate Frequency (IF) type
- **IF Amplifier** : it amplifies the IF signal ,it improves the signal to Noise Ratio at output
- **Detector**: it demodulates the signal which is obtained at the output of the IF Amplifier
- **Video amplifier** : it amplifies the video signal which is obtained at the output of detector
- **Display**: Generally it displays the amplified video signal on CRT Screen

Detection of signals in Noise

Fundamental form of Radar equation

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

To get Range of Radar maximum

- Peak power of transmitted by Radar P_t should be high
- Gain of the transmitting antenna G should be high
- Radar cross section of the target σ *should be high*
- Effective aperture of the receiving antenna A_e should be high
- minimum detectable signal S_{min} should be low

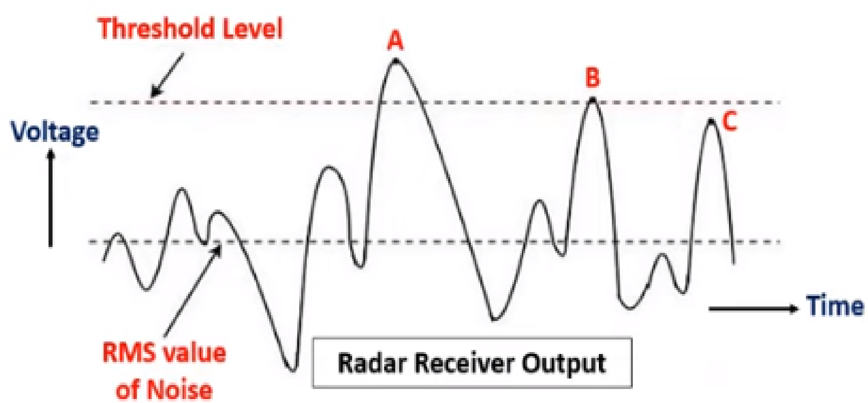
Radar Range is a function of **probability of detection** P_d and **probability of false alarm** P_{fa}

- The **weakest signal** the receiver can detect is called **minimal detectable signal**
- It means **Radar cannot detect** the echo signal if the signal is having less power than that of minimum power
- Generally Radar Receives the echo signal in **addition** with Noise

If the Threshold value is used for detecting the presence of the target from the received signal, the detection is known as **Threshold Detection**

The selection of proper threshold value must be done on the strength of the signal to be detected

- A High Threshold value is chosen when the strength of the signal to be detected is high so that it will eliminate the unwanted noise signal present in it
- A Low Threshold value is chosen when the strength of the signal to be detected is low



A point is valid Detection
B point is valid Detection
C point is Missing Detection

- Noise is the unwanted energy that **interferes** with the ability of the receiver to detect the wanted signal
- It may enter the receiver through the **antenna** along with the desired signal or it may be generated within the receiver
- If the **receiver generates** a noise component into the signal , which is received at the receiver, that type of noise is called Receiver Noise

Noise generated by the **thermal motion** of the **conduction electrons** in the ohmic portions of the receiver input stages is known as **Thermal** or Johnson **noise**

Available **thermal noise power** can be written as $N_i = KTB_N$

Where K = Boltzmann's constant $=1.38 \times 10^{-23} \frac{J}{deg}$

T =absolute temperature and it is equal to $290^0 K$

B_N = Receiver Bandwidth

$B_N =$

H (f) = frequency response function of IF Amplifier

Signal to Noise Ratio

- Noise figure may be i**nterrupte**d as a measure of **degradation of** the **signal to noise ratio** as the signal passes through the receiver

$$\text{Noise Figure } F = \frac{(SNR)_i}{(SNR)_0} = \frac{\frac{S_i}{N_i}}{\frac{S_o}{N_0}} = \frac{N_0 S_i}{N_i S_0}$$

$N_i = K$

- Input signal power will be having minimal value, when output SNR is having minimal value (at the output of IF Amplifier)

min

Substitute the s_{min} value in the standard form of Radar Range Equation

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

$$R_{max} = \left[\frac{P_t G^2 \sigma \lambda^2}{(4\pi)^2 F K T_0 B_n \left(\frac{S_0}{N_0}\right) min}\right]^{\frac{1}{4}}$$

The signal to noise ratio is here is the output of the IF Amplifier since maximizing the signal to noise ratio at the output of If is equivalent to maximizing the video output where threshold is made

To get Range of Radar maximum

- Peak power of transmitted by Radar P_t should be high
- Gain of the transmitting antenna G should be high
- Radar cross section of the target σ *should be high*
- Effective aperture of the receiving antenna A_e should be high
- Figure of Merit F should be low
- Receiver Bandwidth is B_n should be low

Radar Cross Section of Targets

- Radar cross section (σ) provides an **indication** of how well a given target **reflects Radar energy**
- It is the **property** of the **scattering object** , or **Target** that is included in the radar equation to represent the **magnitude** of the **echo signal** returned to Radar by the Target
- The Radar cross section of the target is the area intercepting the amount of power which when scattered equally in all directions, produces an echo at the radar equal to that

=

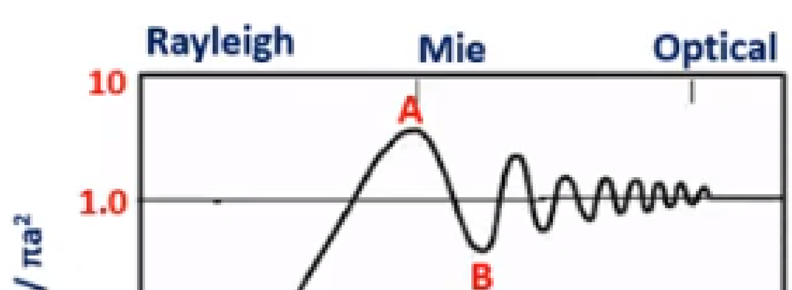
=

Where R: Distance between Radar and Target

E_r = strength of the reflected field at Radar

E_f = Strength of the incident field at Target

Radar Cross Section in a Simple Sphere



- The Radar cross section of a simple sphere is shown in fig . Where a is the radius of a sphere and λ is wavelength

- Three different scattering regions are there

1. Rayleigh Region
2. Mie or Resonance Region
3. Optical Region

<u>Rayleigh Region</u>

- IN Raleigh region size of the sphere is very small compared with wavelength ($\frac{2\pi a}{\lambda}$ << 1)

- This region is interest to radar engineer because cross section of raindrops and meteorological particles fall within this region at the usual radar frequencies

<u>Optical region</u>

- In this region size of the sphere is very large compared with wavelength ($\frac{2\pi a}{\lambda}$ >>1)

- For large $\frac{2\pi a}{\lambda}$ the radar cross section approaches the optical cross section πa^2

<u>Mie or Resonance region</u>

- The cross section is oscillator with frequency within this region

- The maximum range occurs at $\frac{2\pi a}{\lambda}$ = 1 and value is 5.6db greater than its value in optical region

Integration of Radar Pulses

- Many pulses are **returned** from particular target on each radar on each radar scan and can be **used** to **improve detection**
- The number of pulses (n) returned from a point target as the radar antenna scans with a pulse reputation rate of f_p Hz, an antenna beam width θ_B degree and which scans at a rate of θ_S degree per sec is

$$n = \frac{\theta_B f_P}{\theta_S} = \frac{\theta_B f_P}{6\,\omega_r}$$

ω_r = revolution per minute (rpm) for a 360^0 rotating antenna

n = number of pulses received, usually known as **hits per scan** or **pulses per scan**

- The process of summing all the radar echoes available from a target is known as Integration
- The most common radar integration method is the cathode-ray tube display combined with the integration properties of the Eye and brain of the Radar operator
- Integration may be accomplished in the radar receiver either before the second detector (in the IF) Or after the second detector (in the Video)
- Integration before the detector is called **pre detection or coherent integration** ,while integration after the detection is called **post detection or non-coherent detection**
- Pre detection integration requires that the phase of echo signal is to be preserved if the full benefits is to be obtained from the summing process.

- If n pulses of same SNR is integrated by a lossless pre detection integrator , the integrated SNR will be n times of signal pulse
- Then SNR in Radar equation becomes $(SNR)_n$ =

- n pulses of same SNR is integrated by a post detection integrator ,the integrated SNR will be n times of signal pulse
- The integration efficiency for post detection integration is given by (n) =

Pulse-repetition frequency and range ambiguities

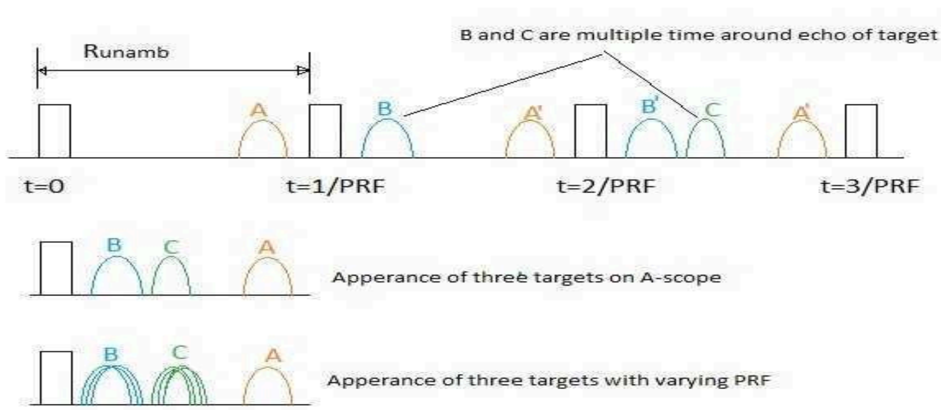
- The pulse repetition freq.(prf) is determined primarily by the maximum range at

which targets are expected

- If the prf is made too high , the likelihood of obtaining target echoes from the wrong

pulse transmission is increased.

- Echo signal received after an interval exceeding the pulse-repetition period are called ***multiple time around echoes.***



Ambiguous and Unambiguous Range

- Target A is located within the maximum unambiguous range R_{unamb} of the radar,

- target B is at a distance greater than R_{unamb} but less than $2R_{Unamb}$
- while target C is greater the $2R_{unabm}$ but less than 3RUnamb The appearance of the three targets on an A-scope is sketched in Fig. c
- The multiple-time-around echoes on the A-scope cannot be distinguished from proper target echoes actually within the maximum unambiguous range.
- Only the range measured for target A is correct; those for B and C are not.
- One method of distinguishing multiple-time-around echoes from unambiguous echoes is to operate with a varying pulse repetition frequency.
- $R_{true} = f_1$ or (f_1+R_{un1}) or (f_1+R_{un2}) or…
- The correct range is that value which is the same with the two PRF, generally three

PRF are often use to resolve range ambiguities.

System Losses

Losses occurs due to,

1. Loss due to integration.

2. Loss due to fluctuating cross section.

3. Loss due to change in radar cross section of target.

4. Losses due to transmission line.

5. Losses due to various mechanical part of radar system

Types of losses:-

1. Microwave plumbing loss.

2. Duplexer loss.

3. Antenna loss.

4. Scanning loss..

5. Collapsing loss.

6. Operator loss.

7. Field degradation.

8. Transmission loss.