Introduction to Radars
Lecture 1: The Radar Range Equation

By Dr. Sanjay Vidhyadharan

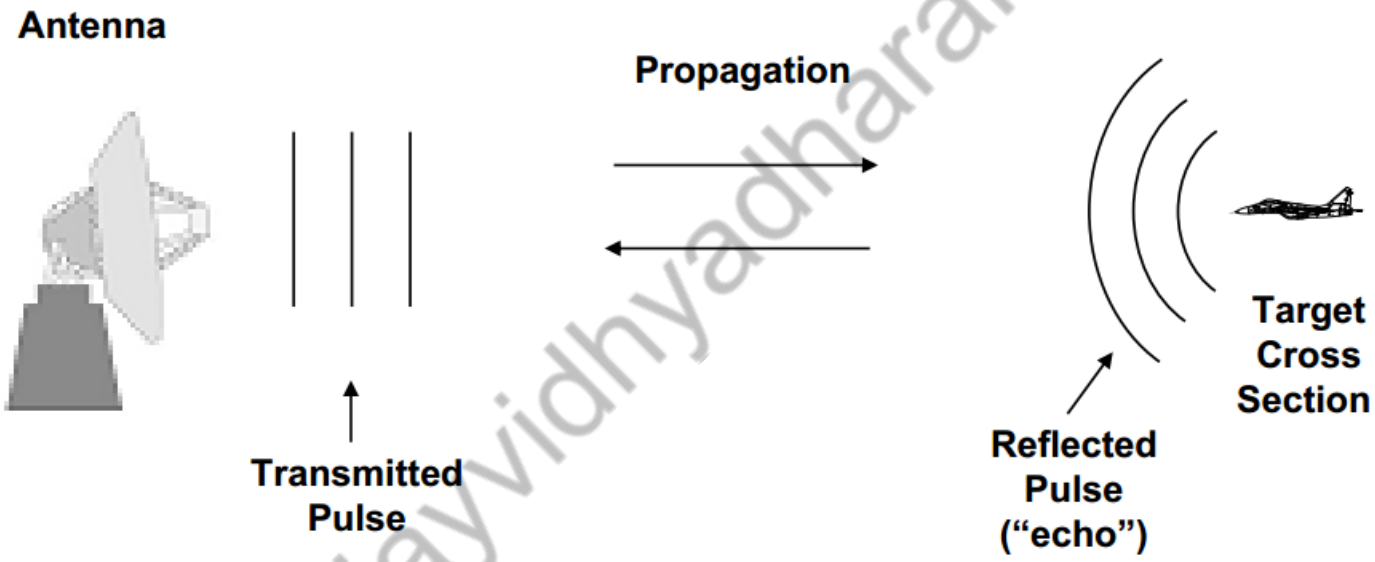
Course Content

INTRODUCTION TO RADAR SYSTEMS
Second Edition **Merrill I. Skolnik**

1. The Radar Range Equation
2. CW and Frequency-Modulated Radar
3. MTI and Pulse Doppler Radar
4. Tracking Radar
5. Electronic Counter-Countermeasures

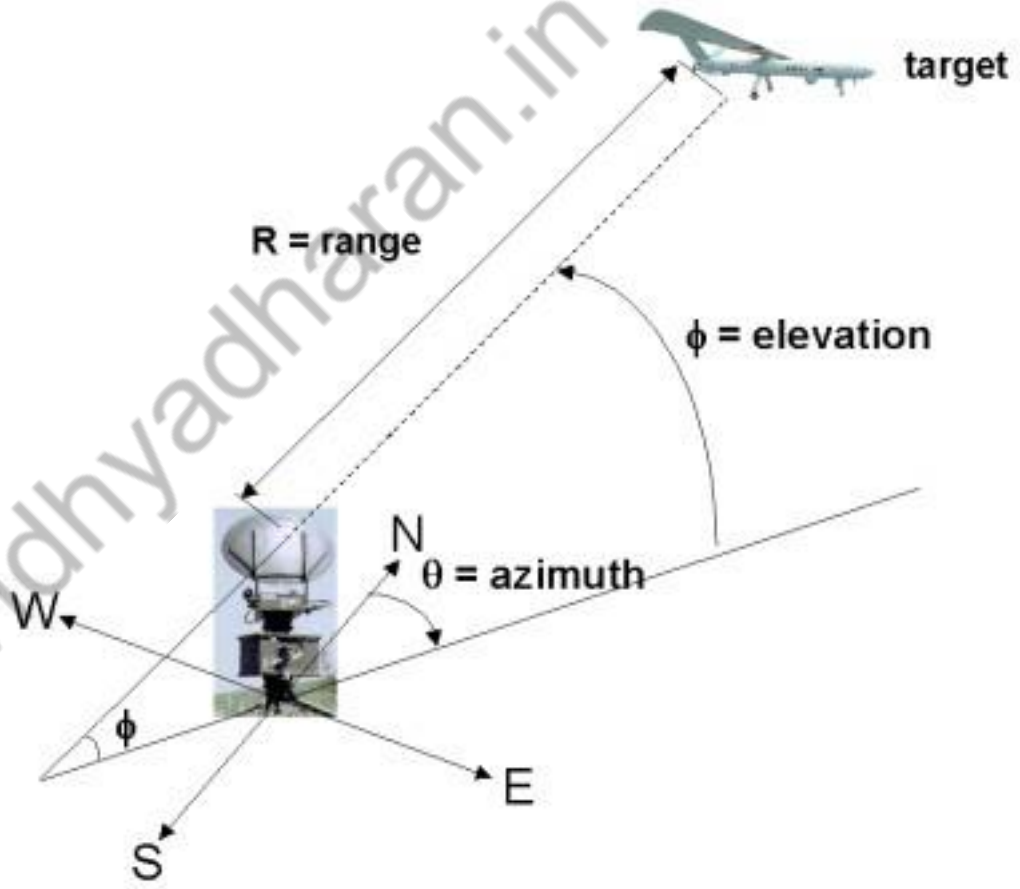
RADAR

RAdio Detection And Ranging



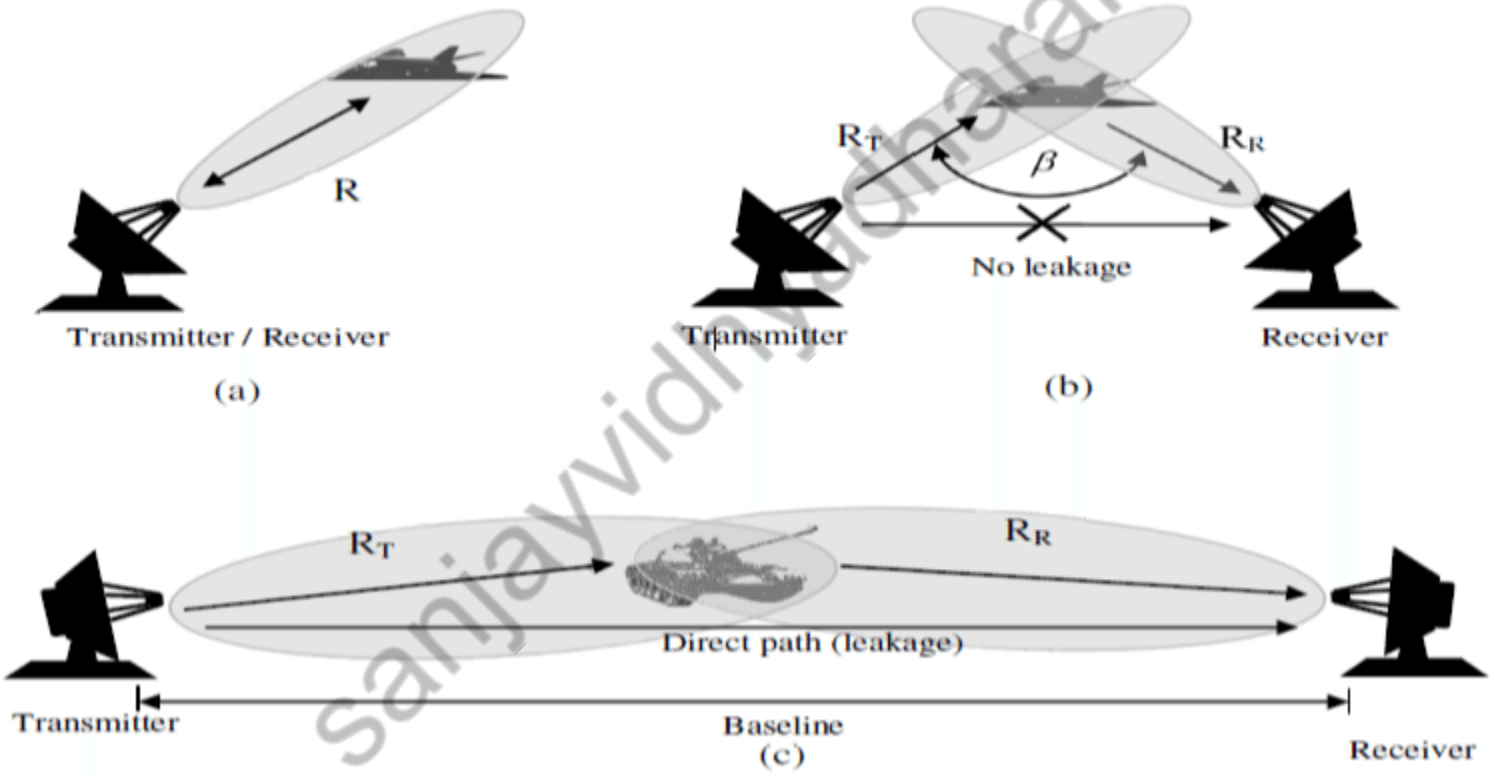
- Target range
- Target angles (azimuth & elevation)
- Target size (radar cross section)
- Target speed (Doppler)

RADAR



- Target range
- Target angles (azimuth & elevation)
- Target size (radar cross section)
- Target speed (Doppler)

Monostatic and Bistatic Radars



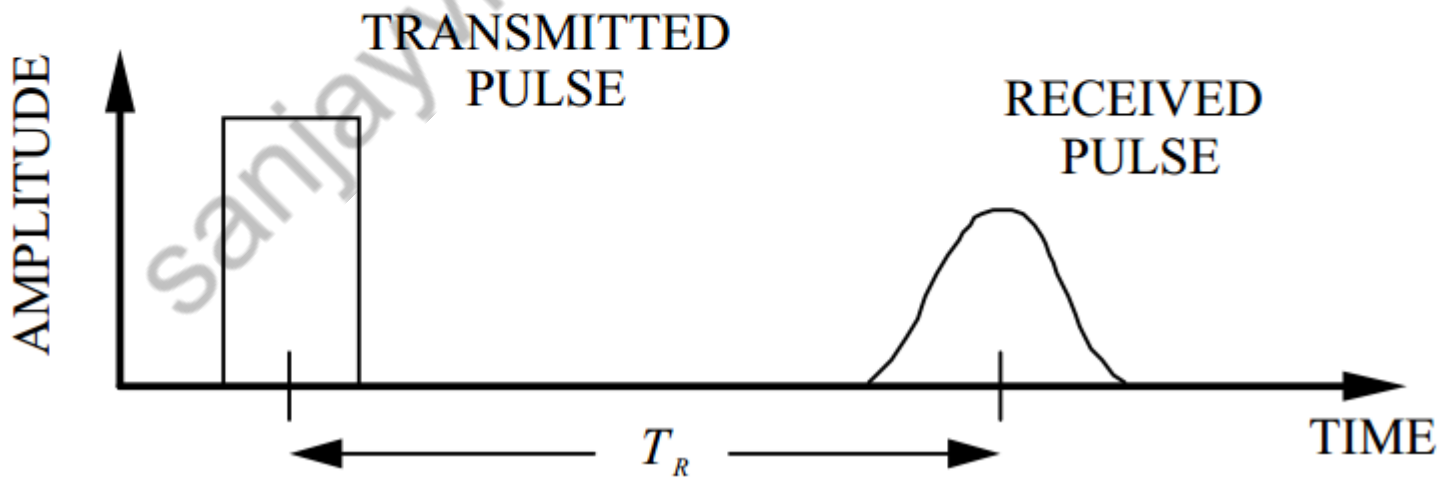
Computation of Range

Range is Computed from round trip travel time of a pulse, TR

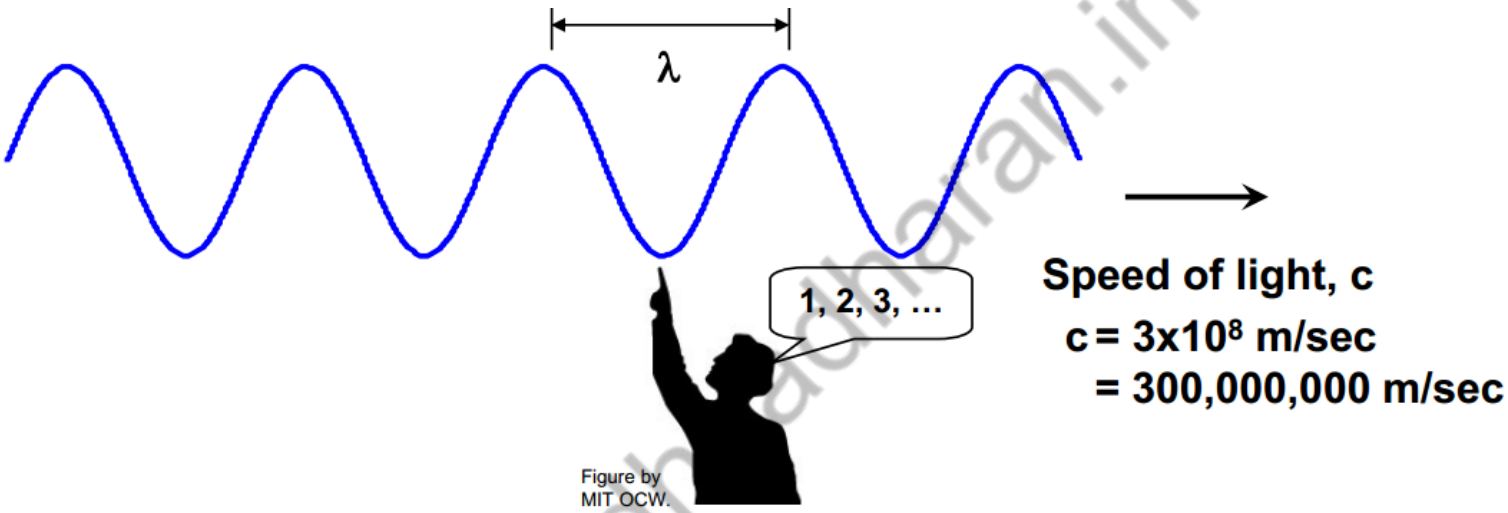
$$\text{Bistatic: } R_t + R_r = cT_R$$

$$\text{Monostatic: } R = \frac{cT_R}{2} \quad (R_t = R_r = R)$$

where $c = 3\text{x}10^8$ m/s is the velocity of light in free space.



EM Waves



Speed of light, c

$c = 3 \times 10^8$ m/sec

= 300,000,000 m/sec

$$\text{Frequency (1/s)} = \frac{\text{Speed of light (m/s)}}{\text{Wavelength } \lambda \text{ (m)}}$$

Examples:

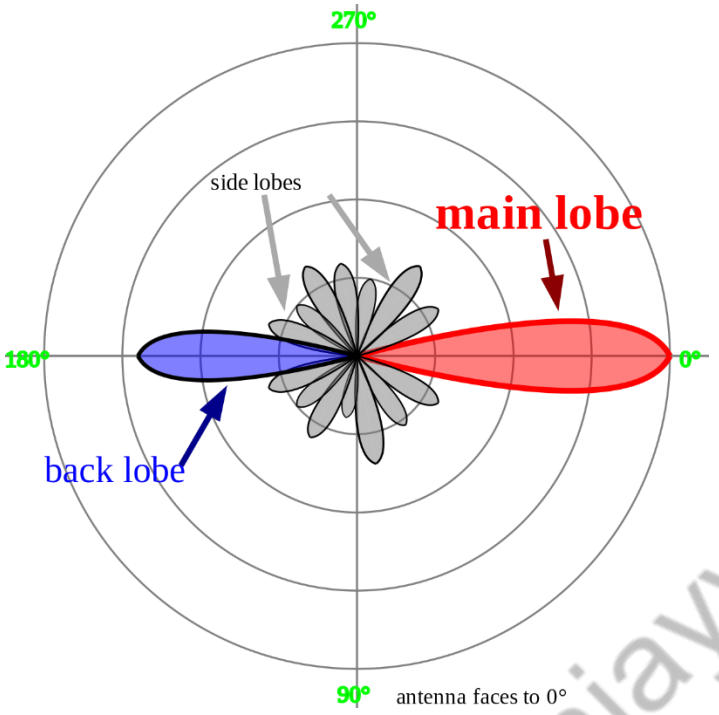
Frequency	Wavelength
100 MHz	3 m
1 GHz	30 cm
3 GHz	10 cm
10 GHz	3 cm

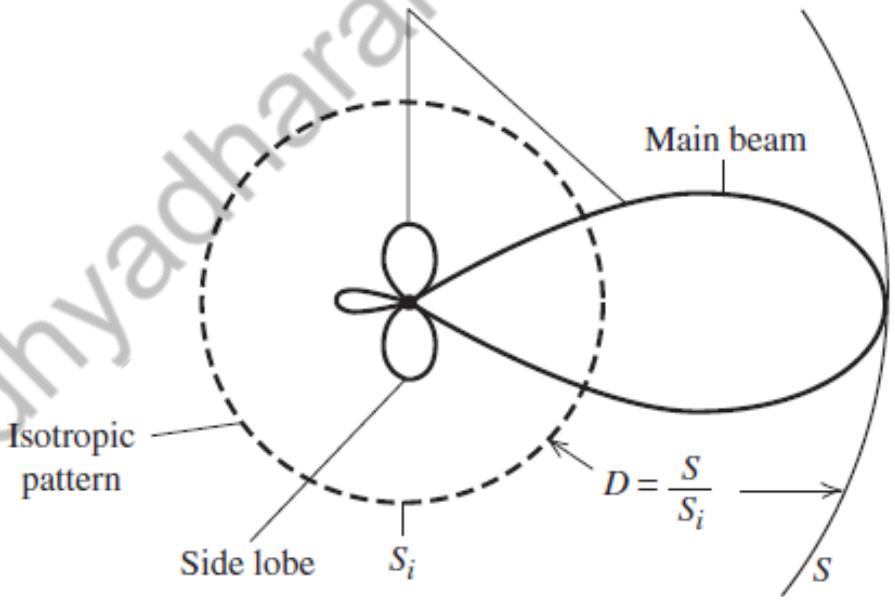
RADAR Operating Frequencies

Band Designation	Frequency Range	Usage
HF	3–30 MHz	OTH surveillance
VHF	30–300 MHz	Very-long-range surveillance
UHF	300–1,000 MHz	Very-long-range surveillance
L	1–2 GHz	Long-range surveillance En route traffic control
S	2–4 GHz	Moderate-range surveillance Terminal traffic control Long-range weather
C	4–8 GHz	Long-range tracking Airborne weather detection
X	8–12 GHz	Short-range tracking Missile guidance Mapping, marine radar Airborne intercept
K_u	12–18 GHz	High-resolution mapping Satellite altimetry
K	18–27 GHz	Little use (water vapor)
K_a	27–40 GHz	Very-high-resolution mapping Airport surveillance
millimeter	40–100+ GHz	Experimental

220 MHz to 35 GHz

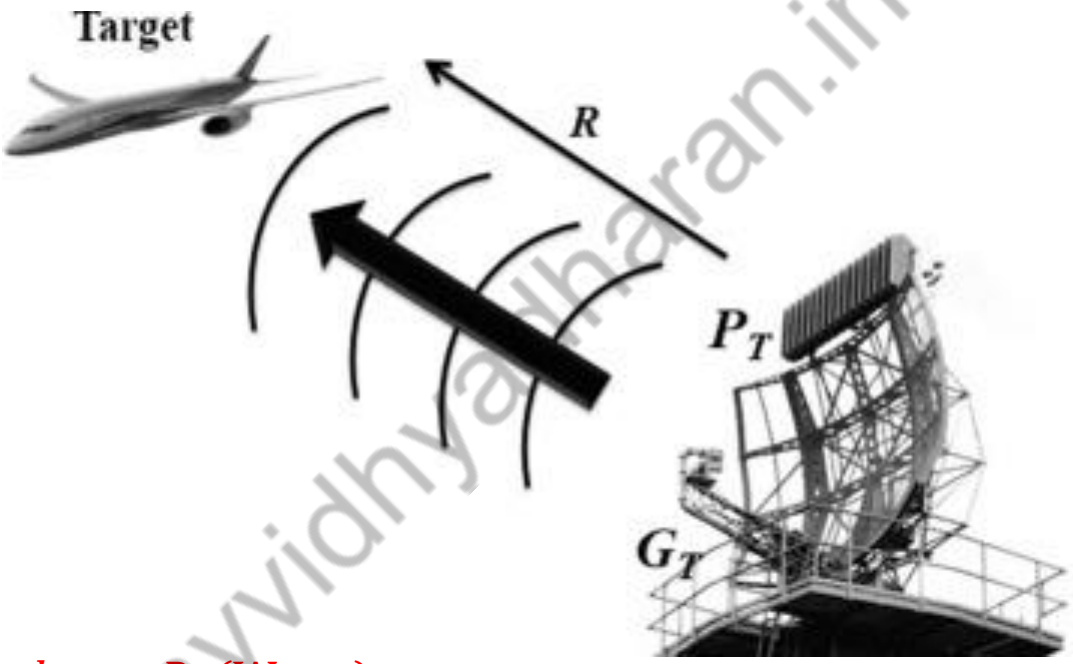
Antenna Directivity





Antenna Directivity It is the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions

Radar Range Equation



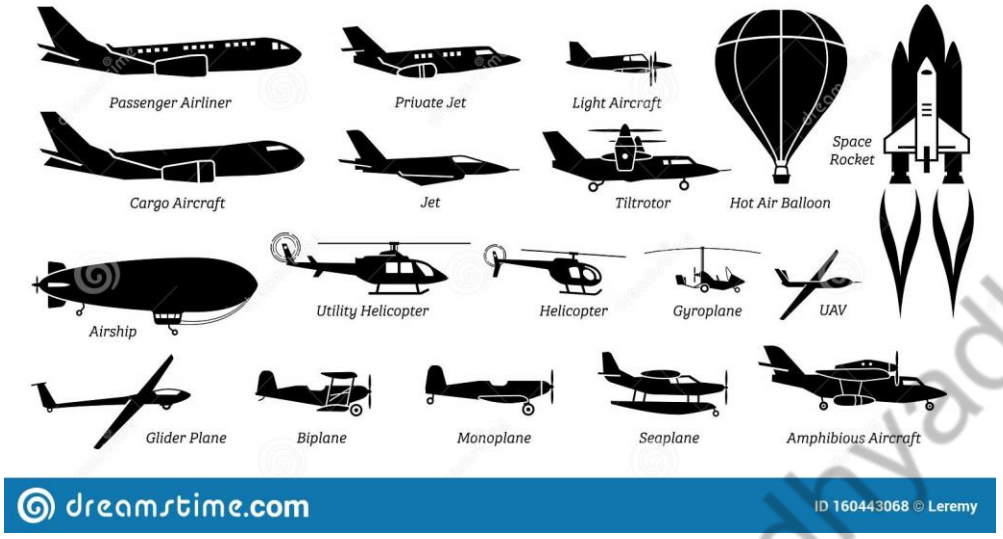
$$Power\ Radiated\ By\ Radar = P_t\ (\text{Watts})$$

$$Power\ Density\ at\ Distance\ R\ if\ Antena\ is\ Isotopic = \frac{P_t}{4\pi R^2} \quad (W/m^2)$$

$$Power\ Density\ at\ Distance\ R\ if\ Antena\ is\ Directional = \frac{P_t G}{4\pi R^2}\ (W/m^2)$$

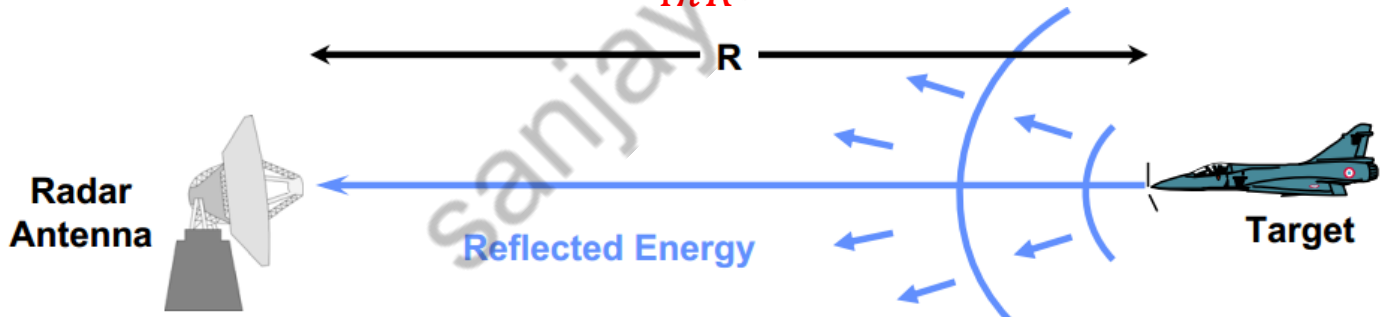
$G\ is\ Directive\ Gain\ of\ Radar\ Antenna$

Radar Range Equation



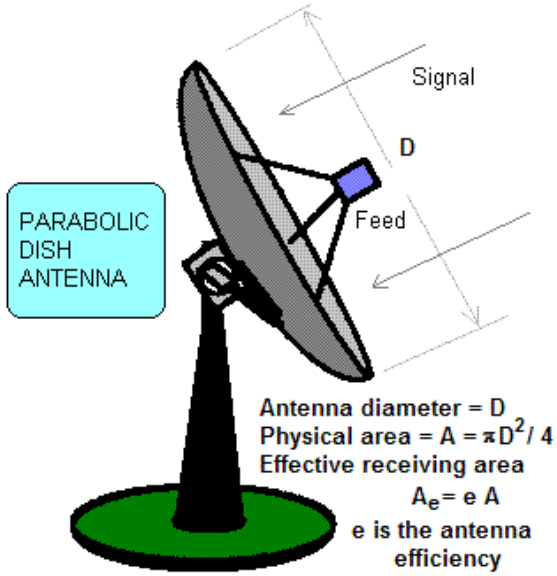
$$Power\ Reflected\ by\ Target = \frac{P_t G \sigma}{4\pi R^2} \quad (W)$$

σ *is Radar Cross Section* (m^2)



$$Received\ \ Power\ Density\ at\ Radar\ Antenna = \frac{P_t G \sigma}{4\pi R^2}\ X \frac{1}{4\pi R^2} \quad (W/m^2)$$

Radar Range Equation



$$Received\ \ Power\ Density\ at\ Radar\ Antenna = \frac{P_t G \sigma}{4\pi R^2}\ X\ \frac{1}{4\pi R^2} \quad (W/m^2)$$

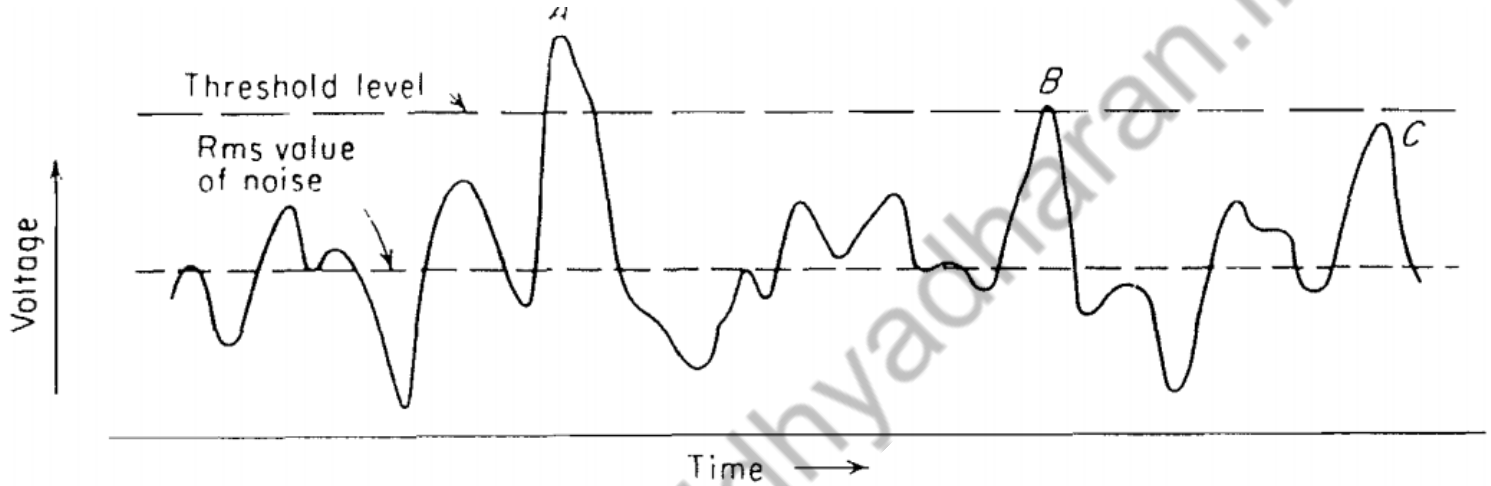
$$Received\ \ Power\ at\ Radar\ Antenna = \frac{P_t G \sigma A_e}{(4\pi)^2 R^4}\ (W) \qquad A_e\ Antenna\ Effcetive\ (m^2)$$

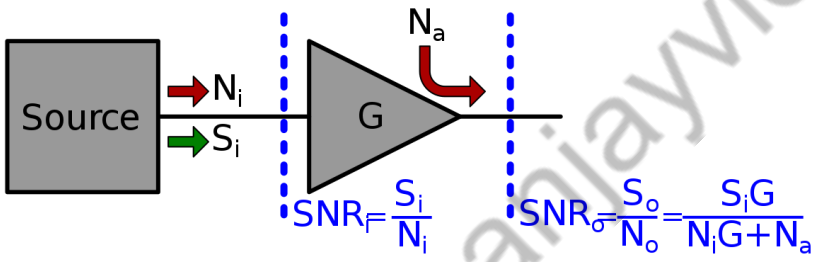
$$Minimum\ Detectable\ Signal\ S_{min} = \frac{P_t G \sigma A_e}{(4\pi)^2 R^4}$$

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

Radar Range Equation

Minimum Detectable Signal S_{min}





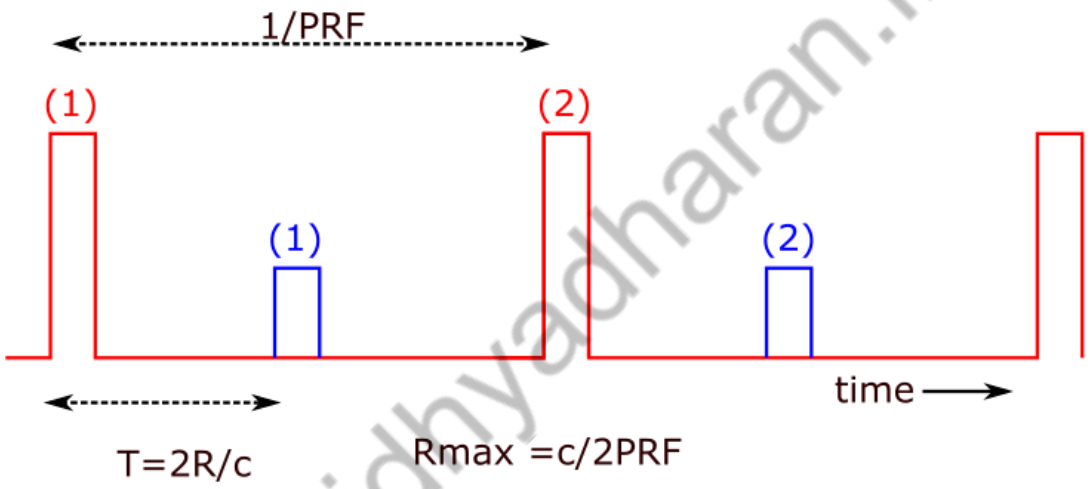
$$N_i = kTB_n$$

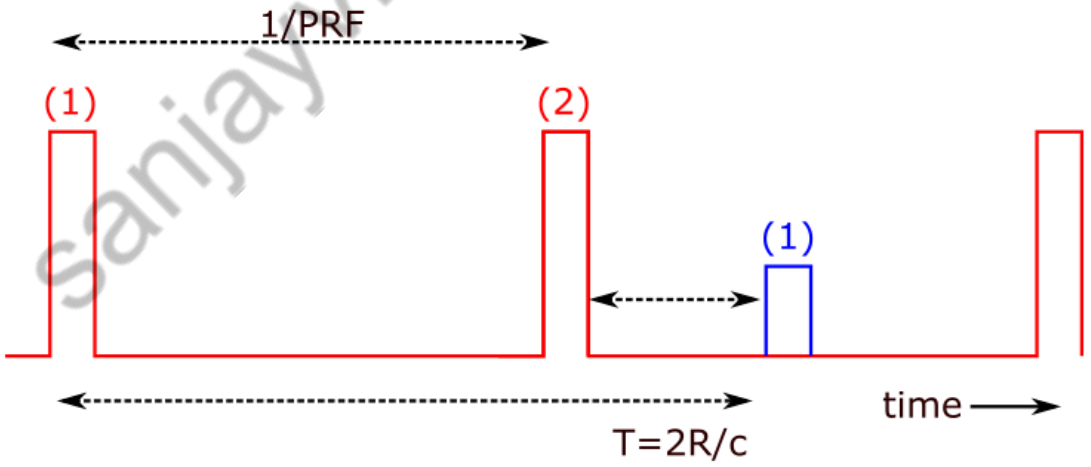
$$F_n = \frac{S_i/N_i}{S_o/N_0} \qquad S_i = F_n kTB_n \left(S_o/N_0\right)$$

$$\text{Max Radar Range } R_{max} = \left[\frac{P_t G \sigma A_e}{(4\pi)^2 F_n kTB_n \left(S_o/N_0\right)_{min}}\right]^{1/4}$$

Max Range and PRF

Pulse Repition Frequency PRF





Pulse Repition Frequency PRF

Low PRF **:** *Below 3 kHz, distance of at least 50 km, ambiguous velocity, civilian aircraft radar and weather radar*

Medium PRF **:** *3 -30 kHz, 5 km to 50 km, Pulse-Doppler radar*

High PRF **:** *Above 3 -30 kHz, Below 5 km, Tracking radar*

Thankyou