Introduction to RADAR

Introduction

✓ RADAR stands for-

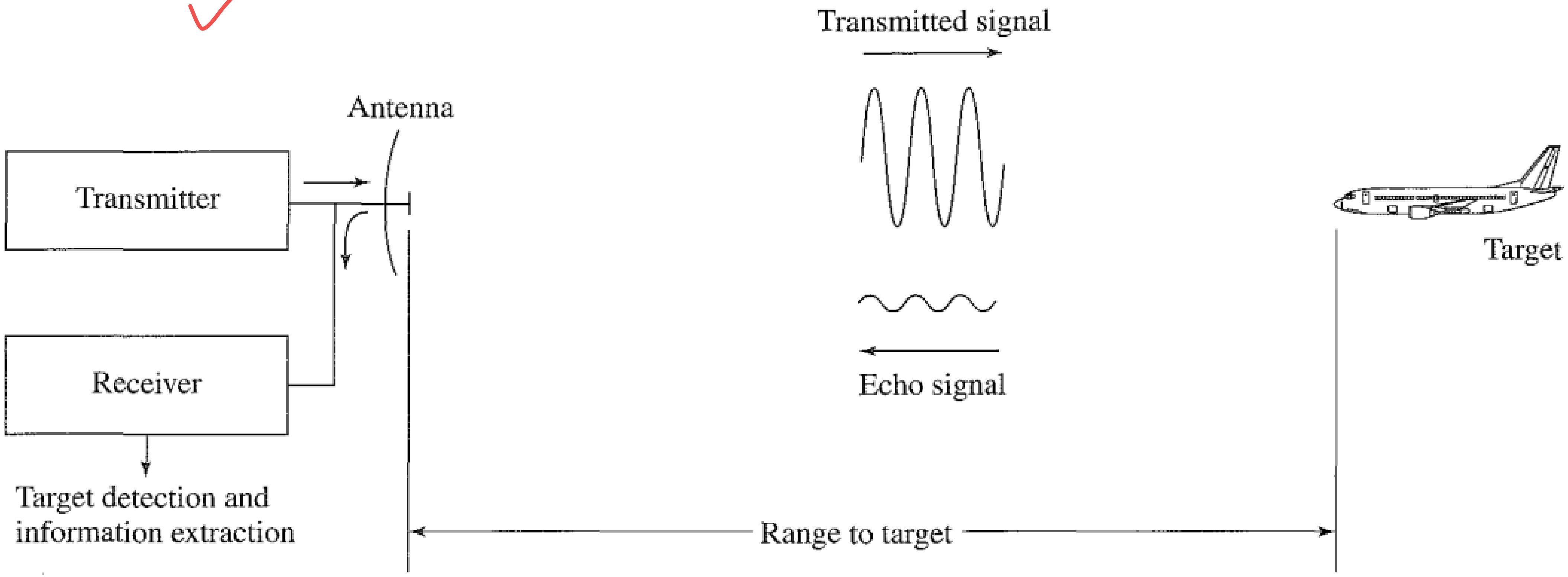
RAdio **D**etection **A**nd **R**anging

✓ It can operate in Darkness, Haze, Fog, Rain or Snow.

✓ RADAR is an electromagnetic sensor for the detection and location of reflecting objects such as aircraft, ships, spacecraft, vehicles, people, and the natural environment.

Ref: Skolnik [3rd Edition]

Introduction



Ref: Skolnik [3rd Edition]

Range to a Target

- Radar engineers use the term range to mean distance.

- Range: The range of the target is observed by measuring the time (T_R) it takes for the radar signal to travel to the target and return back to the radar. Thus the time for the signal to travel to the target located at range (R) and the return back to the radar is 2R/c. The range of the target can be given as:

$$R = \frac{cT_R}{2}$$

with the range in kilometers or in nautical miles, and T in microseconds.

R(km)=0.15 TR(μs) or R(nmi)= 0.081 TR(μs)

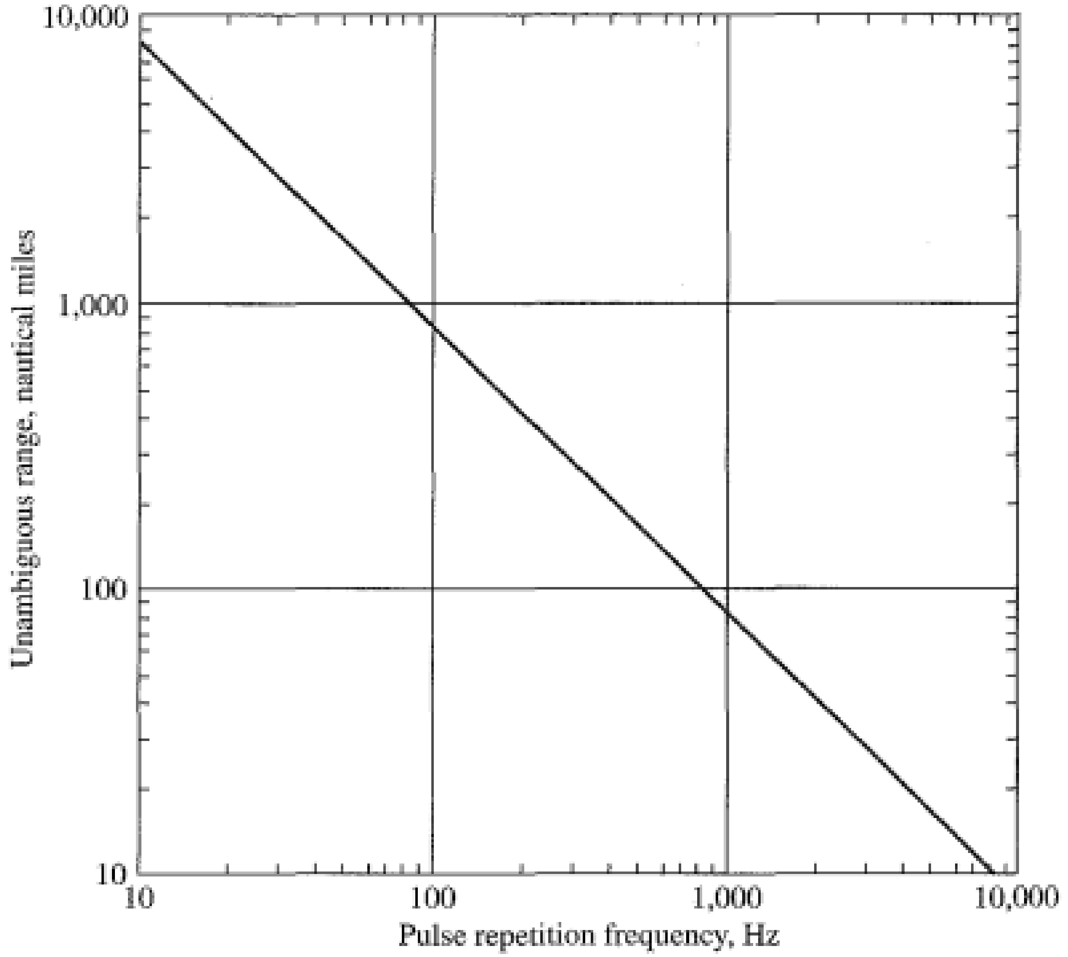
1 nmi = 1.8 km

Ref: Skolnik [3rd Edition]

Maximum Unambiguous Range

$$\boxed{R_{um} = \frac{cT_P}{2} = \frac{c}{2f_P}}$$

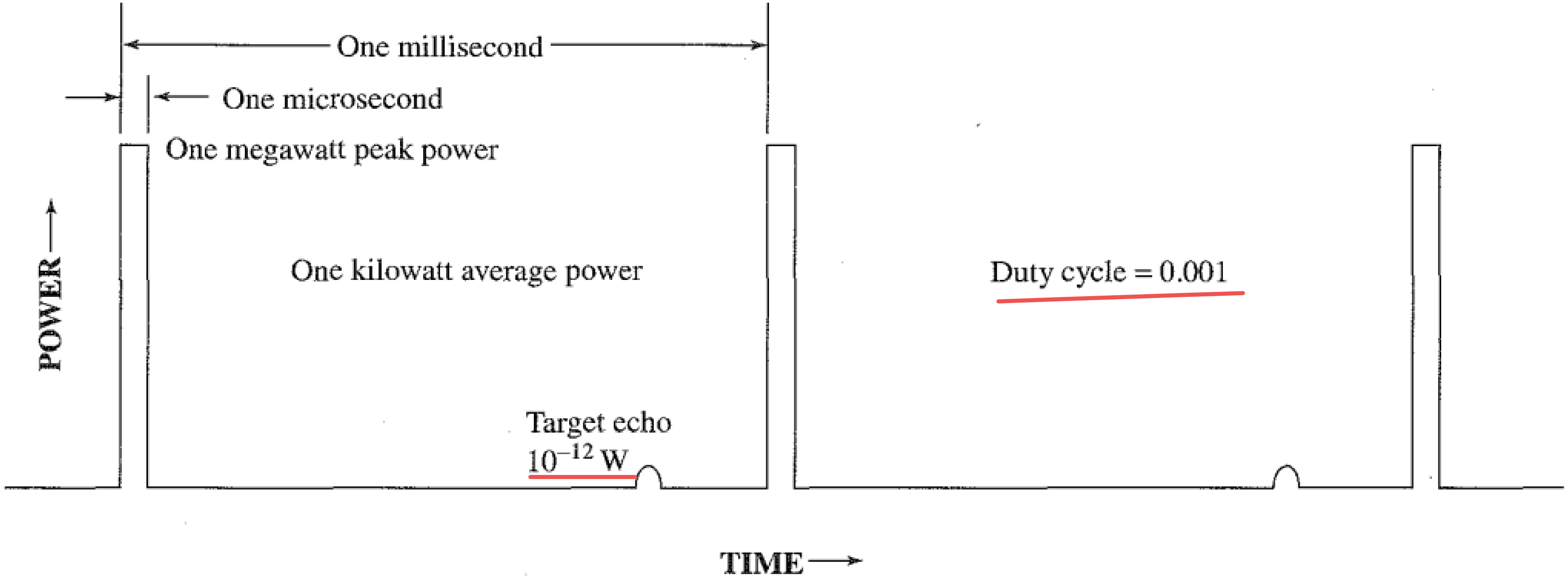
Where,
T_P = pulse repetition period = $1/f_P$,
f_P = pulse repetition frequency (prf), usually given in hertz or pulses per second (pps).



Ref: Skolnik [3rd Edition]

Radar Waveforms

The typical radar utilizes a pulse waveform



Radar Waveforms

Pulse Repetition Frequency (PRF): The rate at which the pulses are transmitted towards the target from the radar is called as the pulse repletion frequency, $\boxed{f_P = 1/T_P}$

Pulse Repetition Period: The time interval at which the pulses are periodically transmitted towards the target from the radar is called as the pulse repletion period, T_P is given by in terms of prf. $\boxed{T_P = 1/f_P}$

Duty Cycle: The duty cycle of the radar waveform is described as the ratio of the total time the radar is radiating to the total time it could have radiated.

$$\boxed{Duty\ Cycle = \frac{\tau}{T_P} = \frac{P_{av}}{P_T}}$$

Where τ is pulse width of the transmitted pulse.

Radar Waveforms

Peak Power of the Radar: The maximum power of the radar antenna, that can be transmitted for the maximum unambiguous range target detection in particular direction.

Average Power of the Radar: The average power of the radar antenna, that can be transmitted for the maximum unambiguous range target detection in all the direction (for isotropic antenna).

Radar Frequencies

Radar Systems Band or Letter Classification

Letter Designation	*Frequency Range in GHz (IEEE Standard)*	*Frequency Range in GHz (NATO or New-Band Designation)*
HF	0.003–0.03	A
VHF	0.03–0.3	A < 0.25; B > 0.25
UHF	0.3–1.0	B < 0.5; C > 0.5
L-band	1.0–2.0	D
S-band	2.0–4.0	E < 3.0; F > 3.0
C-band	4.0–8.0	G < 6.0; H > 6.0
X-band	8.0–12.5	I < 10.0; J > 10.0
Ku-band	12.5–18.0	J
K-band	18.0–26.5	J < 20.0; K > 20.0
Ka-band	26.5–40.0	K
V & W or Millimeter Wave (MMW)	Normally >34.0	L < 60.0; M > 60.0

Ref: Bassem R. Mahafza

Assignment: Applications of different RADAR system band

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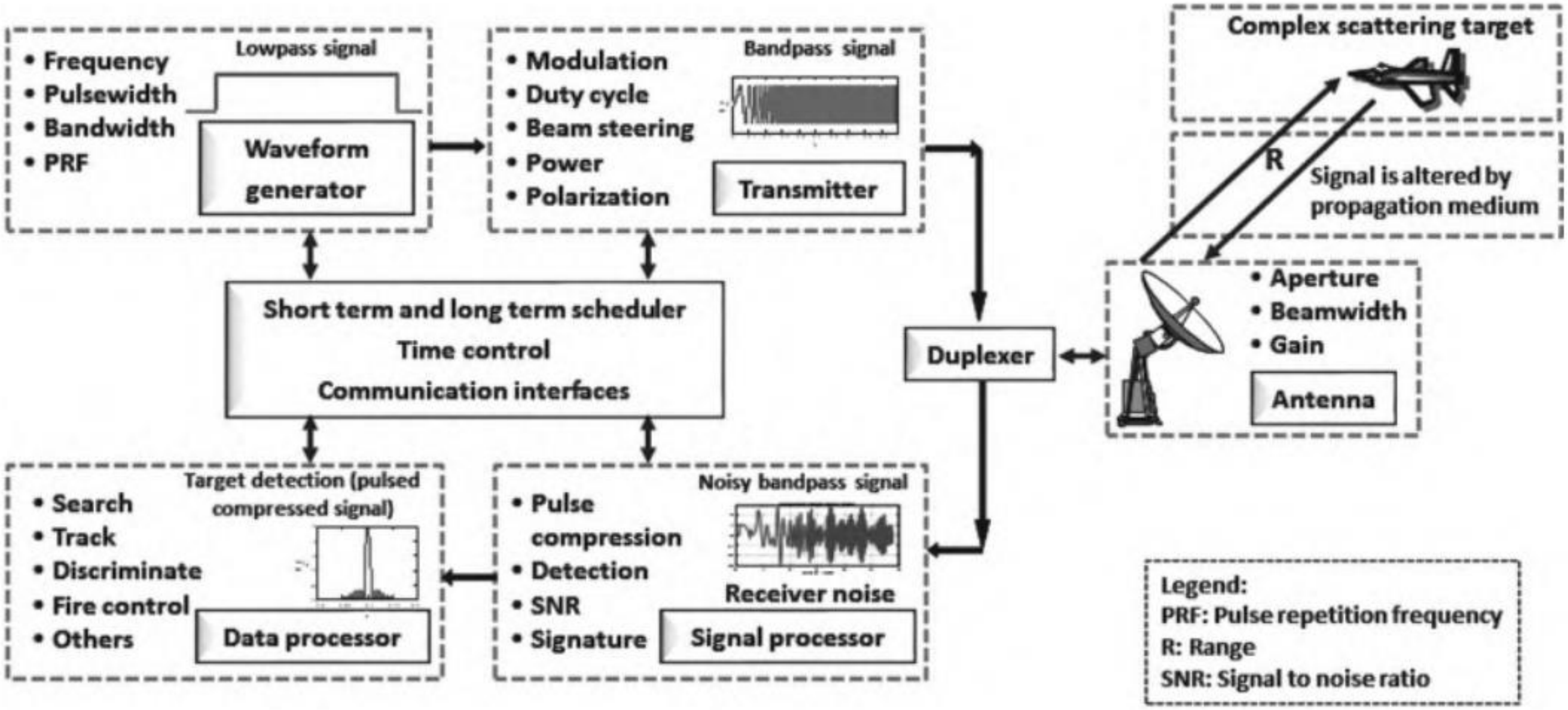
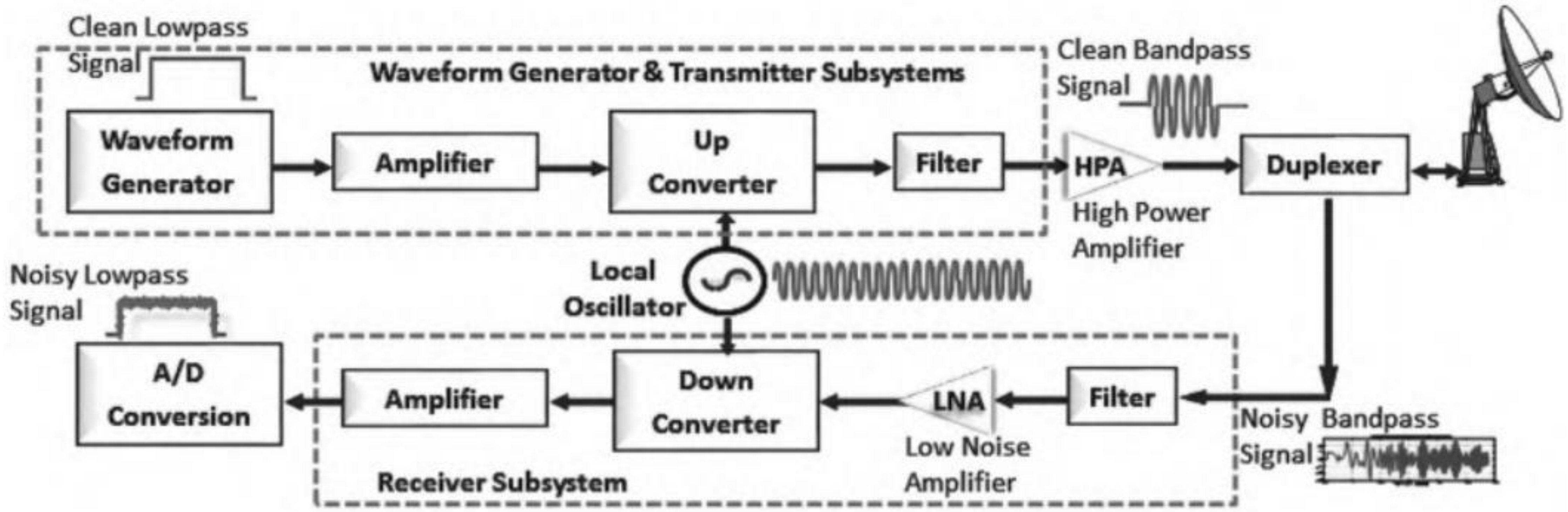
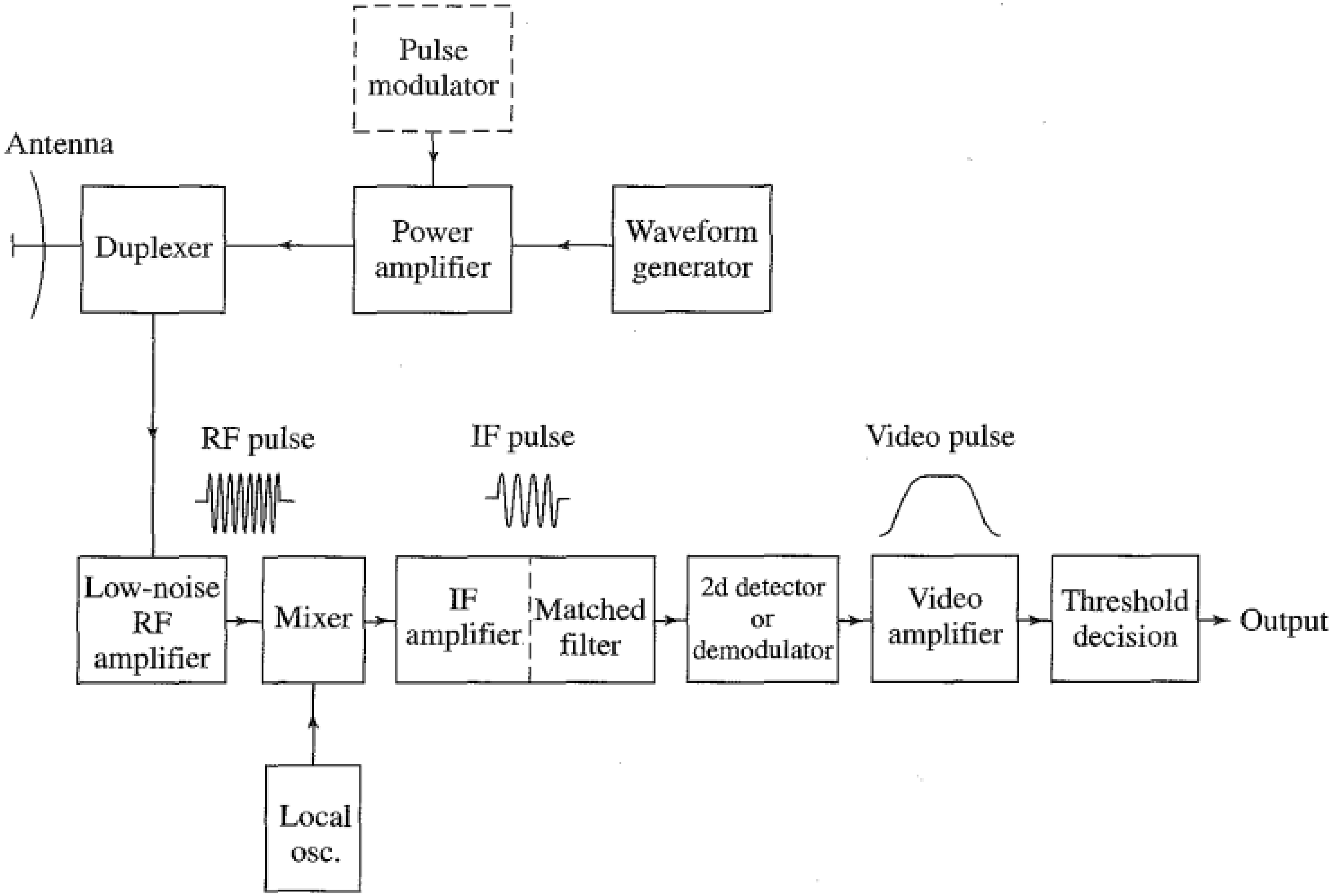
Radar Block Diagram



Radar Block Diagram



Radar Block Diagram



Information Given by the Radar

- ✓ The position of the object
- ✓ The distance of objects from the location of radar
- ✓ The size of the object
- ✓ Whether the object is stationary or moving
- ✓ Velocity of the object
- ✓ Distinguish friendly and enemy aircrafts
- ✓ The images of scenes at long range in good and adverse weather conditions
- ✓ Target recognition
- ✓ Weather target is moving towards the radar or moving away
- ✓ The direction of movement of targets
- ✓ Classification of materials

Nature and Types of Radars

- ✓ Speed trap Radars
- ✓ Missile tracking Radars
- ✓ Early warning Radars
- ✓ Airport control Radars
- ✓ Navigation Radars
- ✓ Ground mapping Radars
- ✓ Astronomy Radars
- ✓ Weather forecast Radars
- ✓ Gun fire control Radars
- ✓ Remote sensing Radars
- ✓ Tracking Radars
- ✓ Search Radars
- ✓ IFF (Identification Friend or Foe)

Nature and Types of Radars

- ✓ Synthetic aperture Radars
- ✓ Missile control Radars
- ✓ MTI (Moving Target Indication) Radars
- ✓ Navy Radars
- ✓ Doppler Radars
- ✓ Mesosphere, Stratosphere and Troposphere (MST) Radars
- ✓ Over-The-Horizon (OTH) Radars
- ✓ Mono pulse Radars
- ✓ Phased array Radars
- ✓ Instrumentation Radars
- ✓ Gun direction Radars
- ✓ Airborne weather Radars

Radar Equation

If the transmitted power P_t is radiated by an isotropic antenna,

Power density at range R from an isotropic antenna = $\boxed{\frac{P_t}{4\pi R^2} \text{ (Watt/square meter)}}$

Power density at range R from directive antenna $= \boxed{\frac{P_t G}{4\pi R^2}}$

Here, $G = \frac{\text{max power density radiated by an antenna}}{\text{power density radiated by a lossless isotropic antenna}}$

The target **receives** a portion of the incident energy and **reflected** it in various directions. Thus the radar cross section of the target determines the power density returned back to the radar. The reflected power from the target through its cross section, σ (target cross section) can be given as:

Reflected power from the target towards the radar $= \boxed{\frac{P_t G}{4\pi R^2} * \frac{\sigma}{4\pi R^2}}$

Radar Equation

- ✓ The radar antenna receives a portion of the reflected power from the target cross section. The received power can be given as

$$P_r = \frac{P_t G}{4\pi R^2} * \frac{\sigma}{4\pi R^2} * A_e$$

$$A_e = \rho_a * A$$

- ✓ Where A_e is the **effective area** of the receiving antenna, A is the **physical antenna area** and ρ_a is the antenna **aperture efficiency**. The maximum range of the radar (R_{max}) can be defined as the maximum distance beyond which radar cannot detect the target. So the received signal power can be given as the minimum detectable signal.

$$S_{min} = \frac{P_t G}{4\pi R^2} * \frac{\sigma}{4\pi R^2} * A_e$$

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

❖ This is the fundamental form of the radar range equation / radar equation / range equation

Radar Equation

- ✓ If the antenna is used for both the transmission and receiving purpose, then the transmitted gain (G) can be given in terms of the effective area (A_e).

- ✓ We know that the antenna gain,

$$\boxed{G = \frac{4\pi A_e}{\lambda^2}}$$

- ✓ Now the maximum radar range can be given as follows.

$$R_{max} = \left[\frac{P_t G^2 \lambda}{(4\pi)^3} * \sigma * \frac{A_e}{S_{min}}\right]^{\frac{1}{4}} \quad ; When\ G\ is\ Constant$$

$$R_{max} = \left[\frac{P_t}{(4\pi)^3} * \sigma * \frac{{A_e}^2}{S_{min}}\right]^{\frac{1}{4}} \quad ; When\ A_e is\ Constant$$

Ref: Skolnik [3rd Edition]

References

- ✓ **Introduction to Radar System [2nd Edition]**
  - Merril I. Skolnik
- ✓ **Introduction to Radar System [3rd Edition]**
  - Merril I. Skolnik
- ✓ **Radar Systems Analysis and Design Using MATLAB**
  - Bassem R. Mahafza
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Thank You!