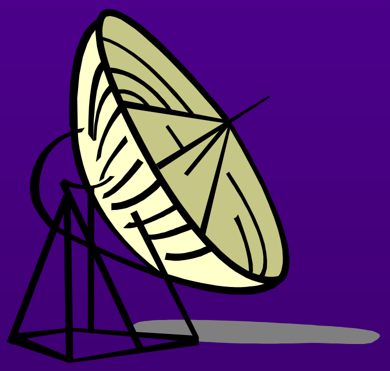
Radar Principles & Systems



Two Basic Radar Types

Pulse

Transmission

Continuous Wave

Pulse Transmission

Pulse Width (PW)

Length or duration of a given pulse

Pulse Repetition Time (PRT=1/PRF)

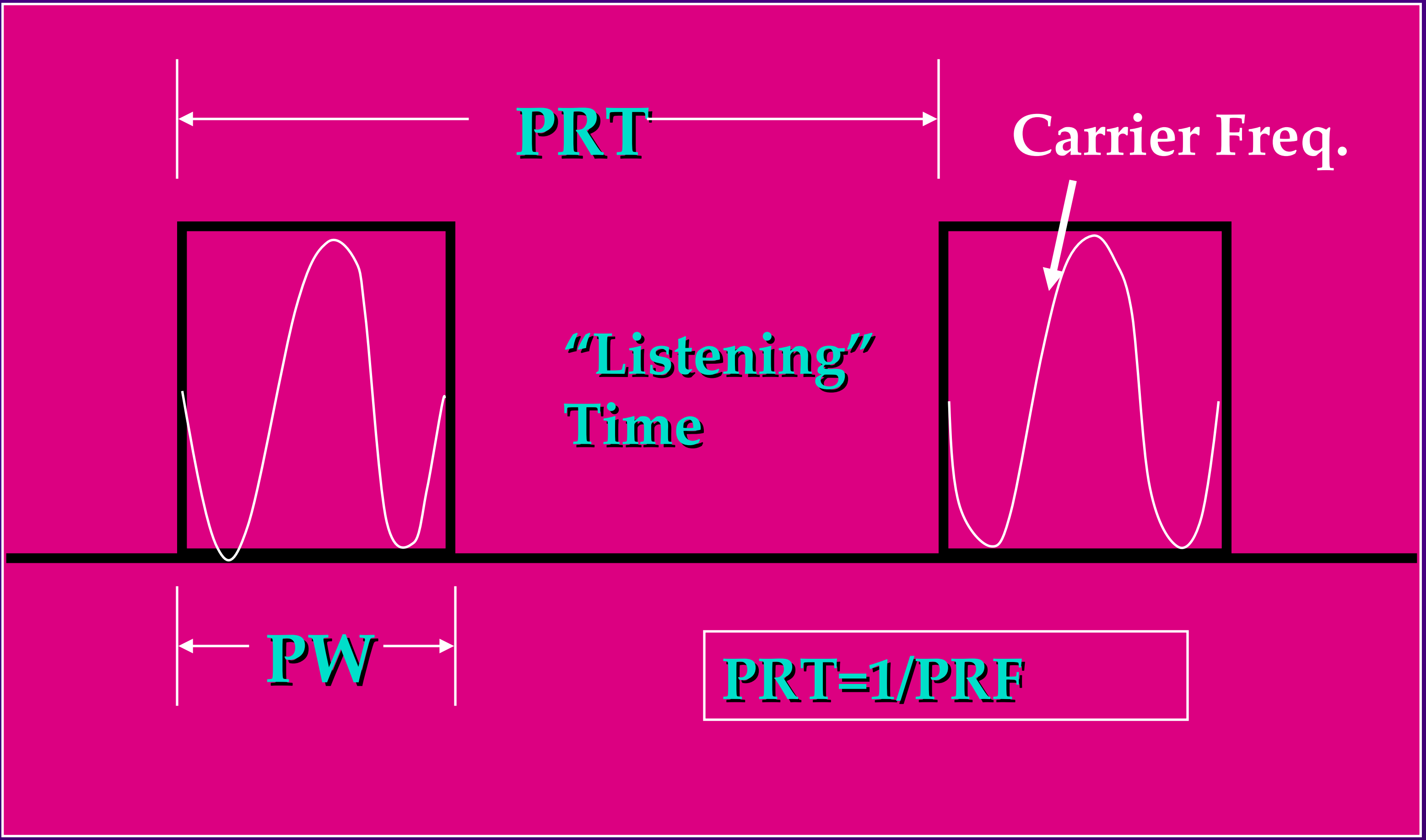
PRT is time from beginning of one pulse to the beginning of the next

PRF is frequency at which consecutive pulses are transmitted.

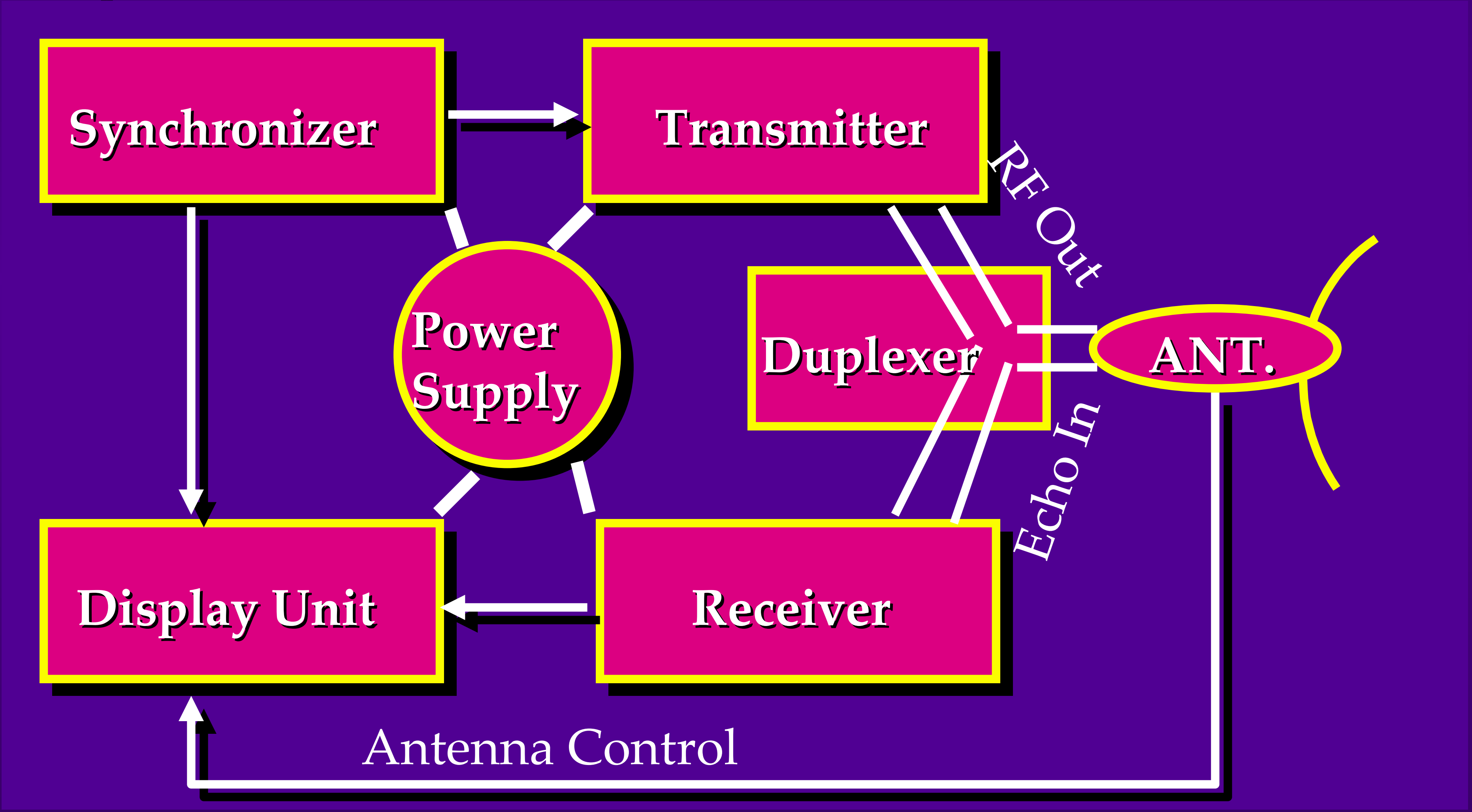
PW can determine the radar's minimum detection range; PW can determine the radar's maximum detection range.

PRF can determine the radar's maximum detection range.

Pulse Diagram



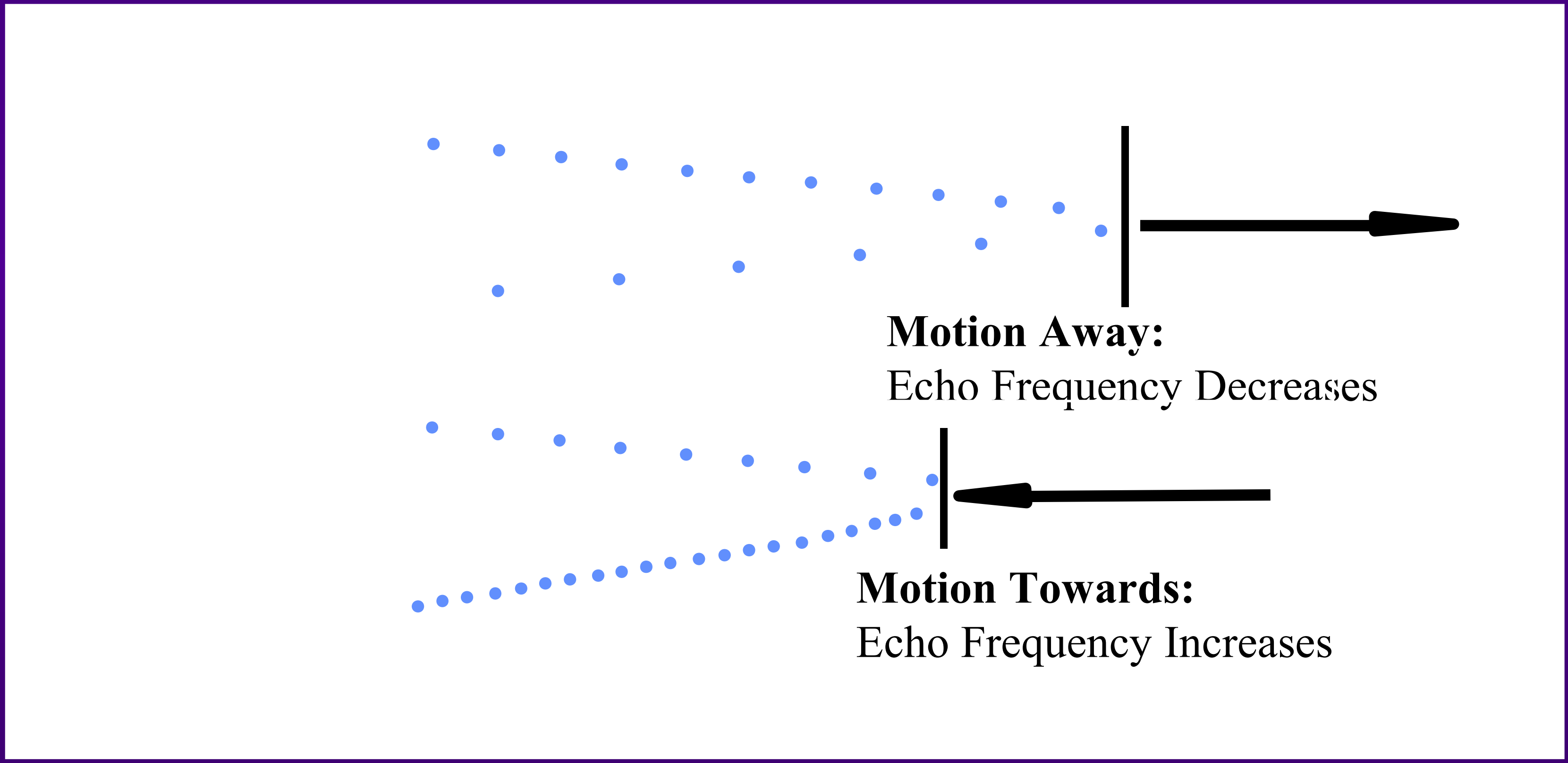
Pulse Radar Components



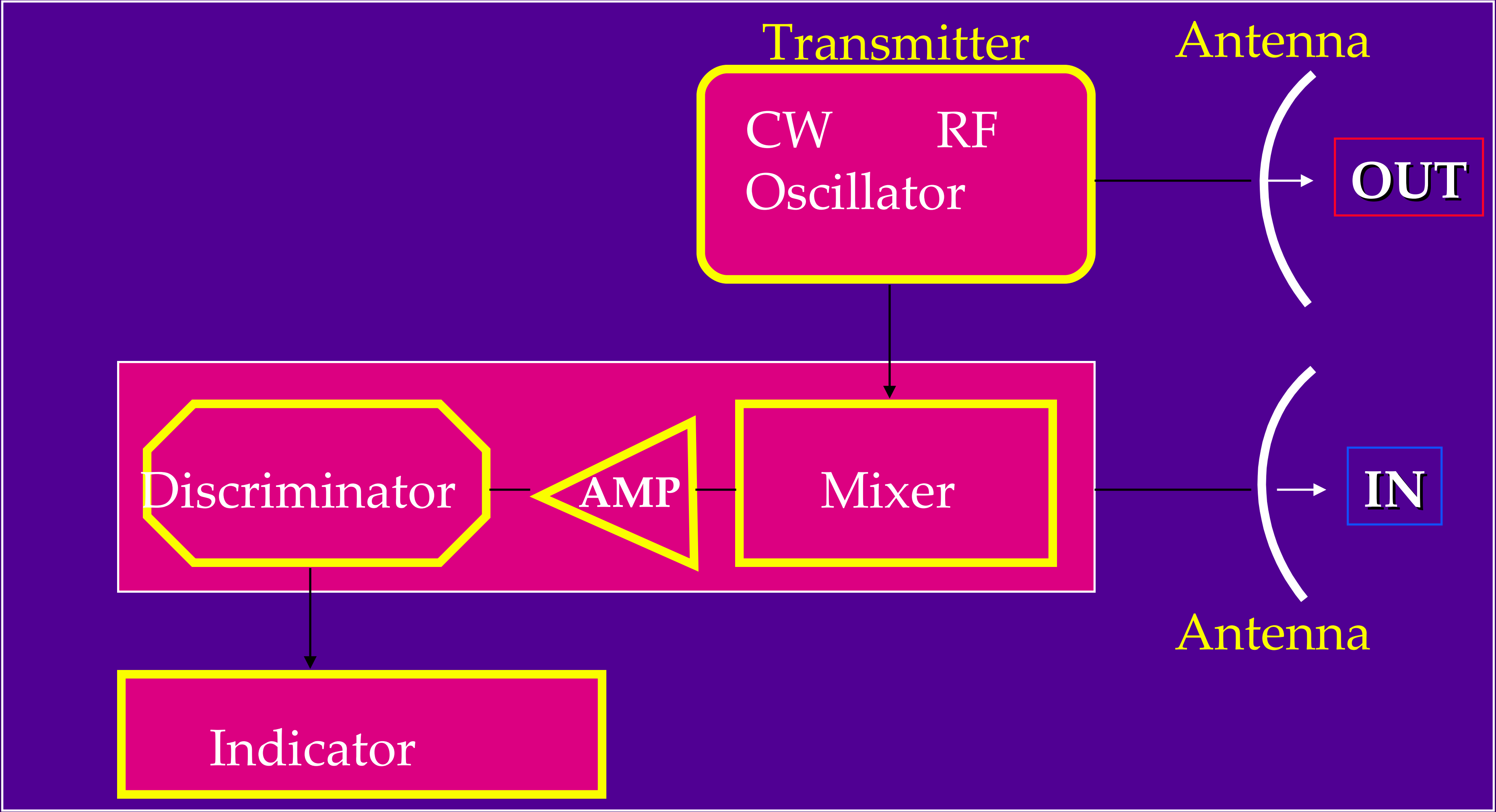
Continuous Wave Radar

- Employs continual RADAR transmission
- Separate transmit and receive antennas
- Relies on the "DOPPLER SHIFT"

Doppler Frequency Shifts



Continuous Wave Radar Components



Pulse Vs. Continuous Wave

Pulse Echo

- Single Antenna
- Gives Range, usually Alt. as well
- Susceptible To Jamming
- Physical Range Determined By PW and PRF.

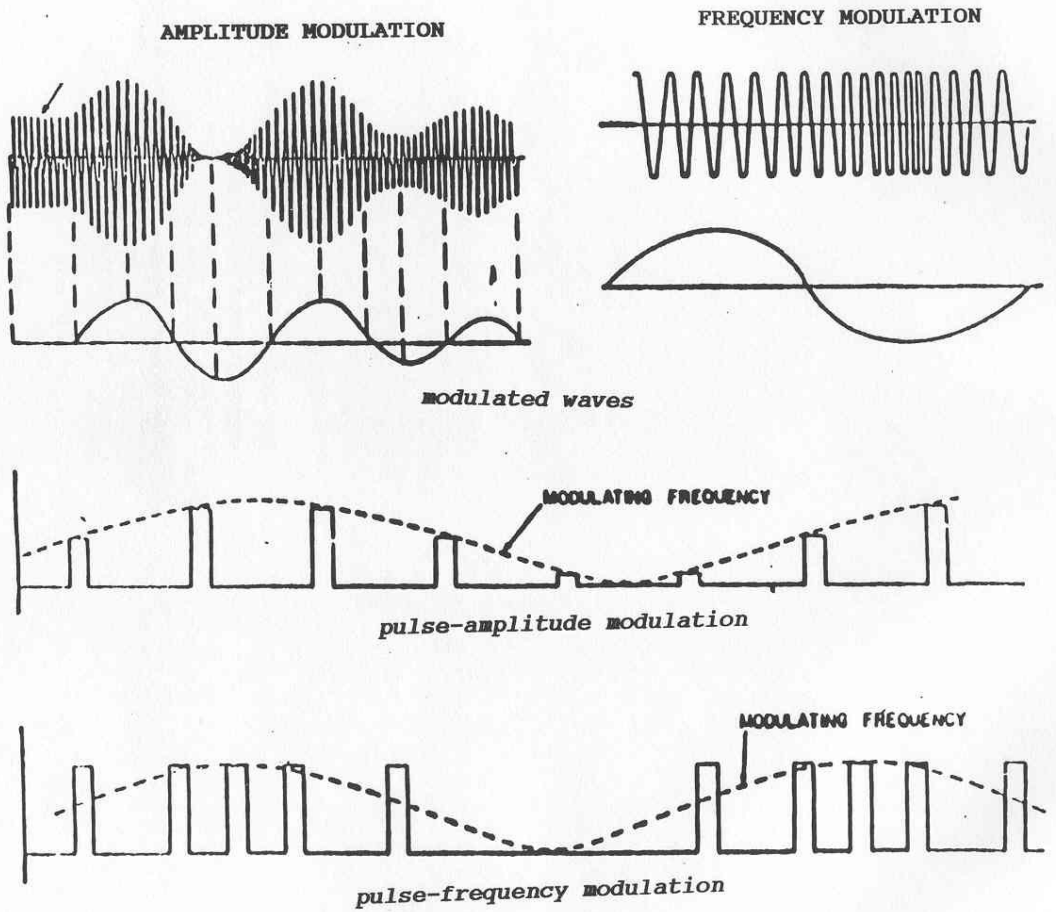
Continuous Wave

- Requires 2 Antennae
- Range or Alt. Info
- High SNR
- More Difficult to Jam But Easily Deceived
- Amp can be tuned to look for expected frequencies

RADAR Wave Modulation

- **Amplitude Modulation**
  - Vary the amplitude of the carrier sine wave
- **Frequency Modulation**
  - Vary the frequency of the carrier sine wave
- **Pulse-Amplitude Modulation**
  - Vary the amplitude of the pulses
- **Pulse-Frequency Modulation**
  - Vary the Frequency at which the pulses occur

Modulation Types



Electromagnetic energy modulation techniques.

Antennae

Two Basic Purposes:

Radiates RF Energy

Provides Beam Forming and Focus

Must Be 1/2 of the λ for the maximum λ employed (Depends on f spectrum)

Wide Beam width pattern for Search, Narrow for Tracking

Concentrating Radar Energy or Beam-forming

Linear Arrays

- Uses the Principle of wave summation (constructive interference) in a special direction and wave cancellation (destructive interference) in other directions.
- Made up of two or more simple half-wave antennas.

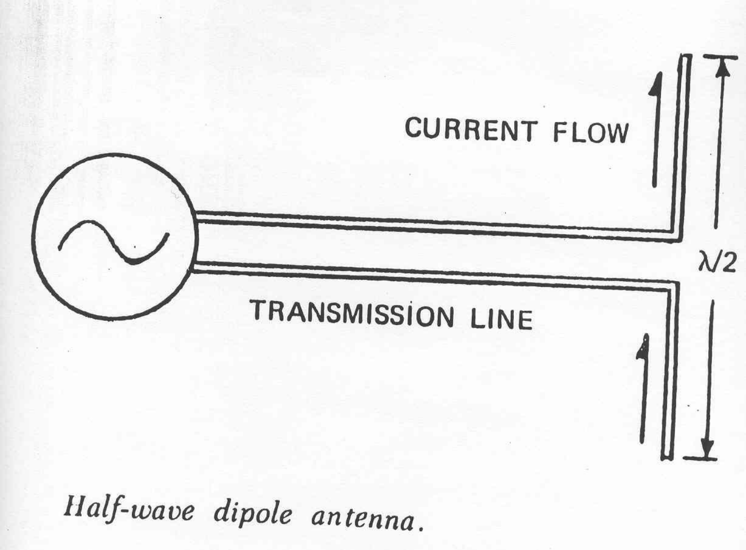
Quasi-optical

- Uses reflectors and “lenses” to shape the beam.

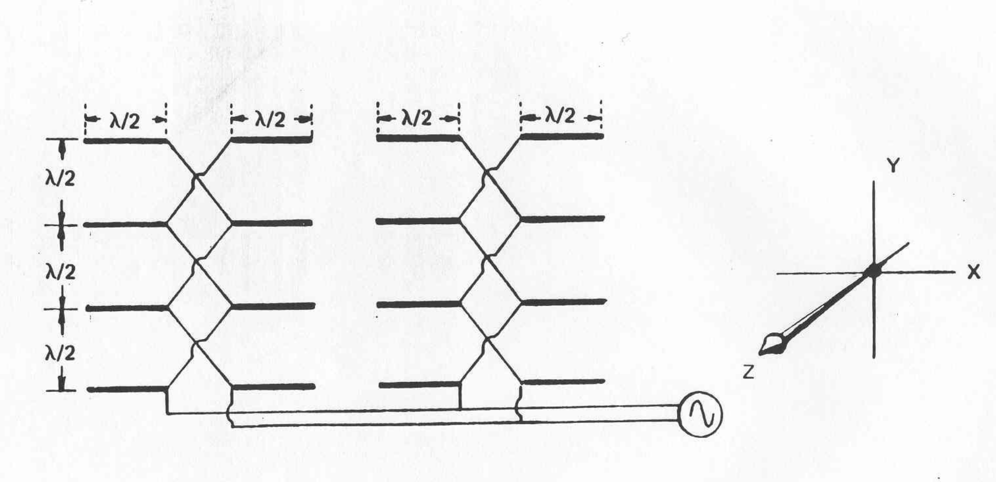
Reflector Shape

- Paraboloid - Conical Scan used for fire control - can be CW or Pulse
- Orange Peel Paraboloid - Usually CW and primarily for fire control
- Parabolic Cylinder - Wide search beam - generally larger and used for long-range search applications - Pulse

Examples of Antenna Types

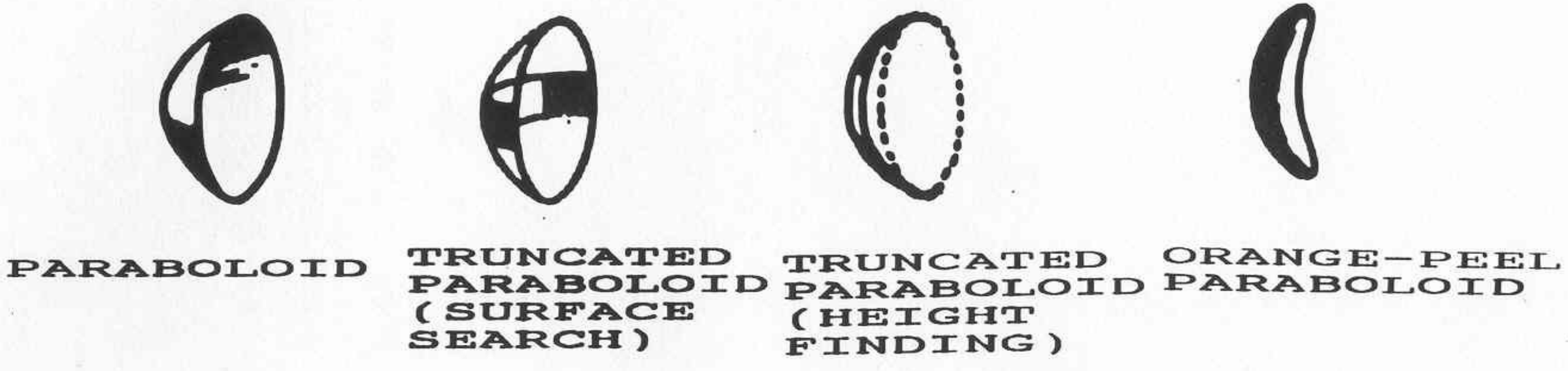


Half-wave dipole antenna.

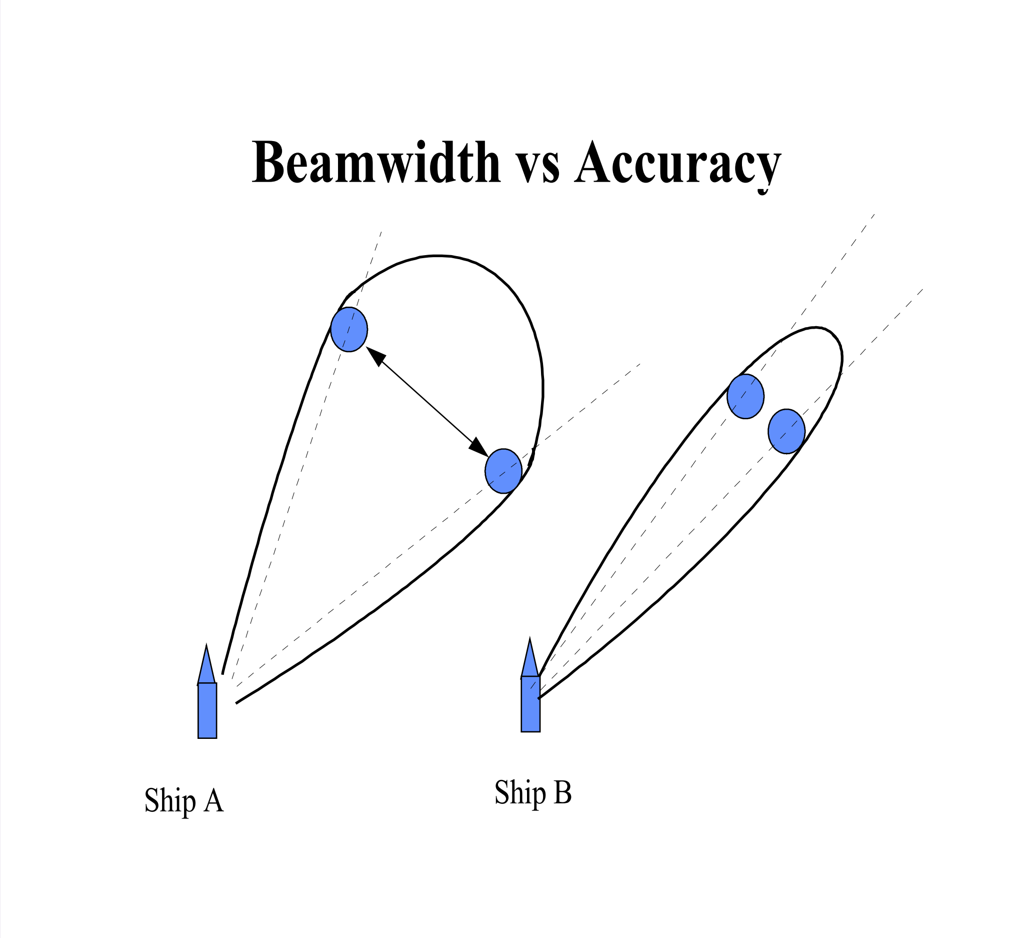


BROADSIDE ARRAY

Quasi-optical Arrays



Beam width Vs. Accuracy

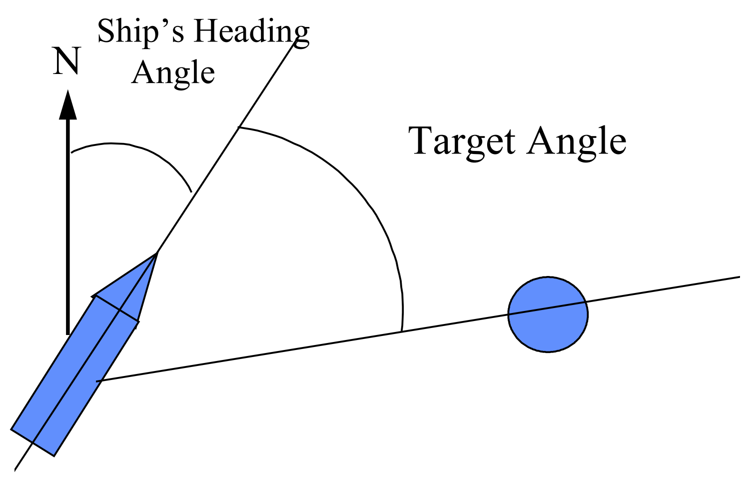


- Beam width= the arc where signal strength varies by ± 3 dB from maximum. (50%)
- Wider beam width = lower accuracy.
- BW α λ / Antenna dimension

Azimuth Angular Measurement

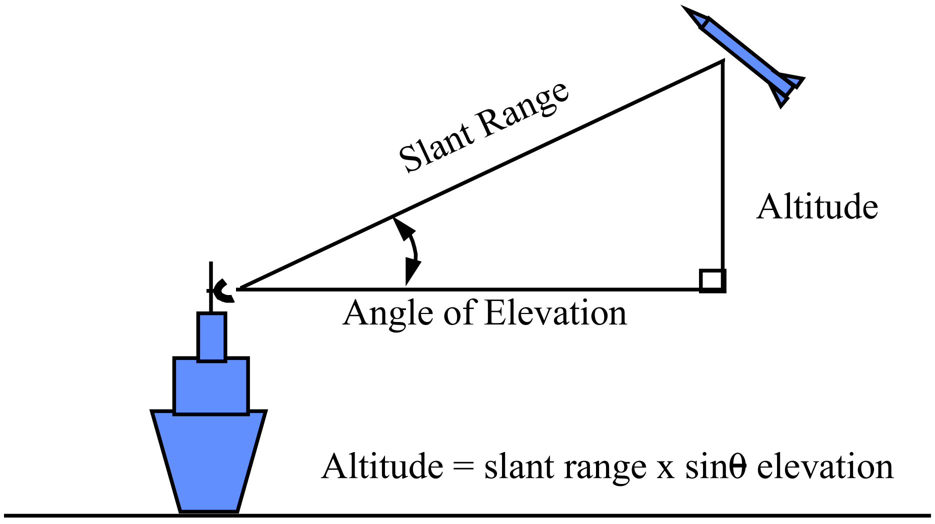
Azimuth Angular Measurement

Relative Bearing = Angle from ship’s heading.
True Bearing = Ship’s Heading + Relative Bearing



Determining Altitude

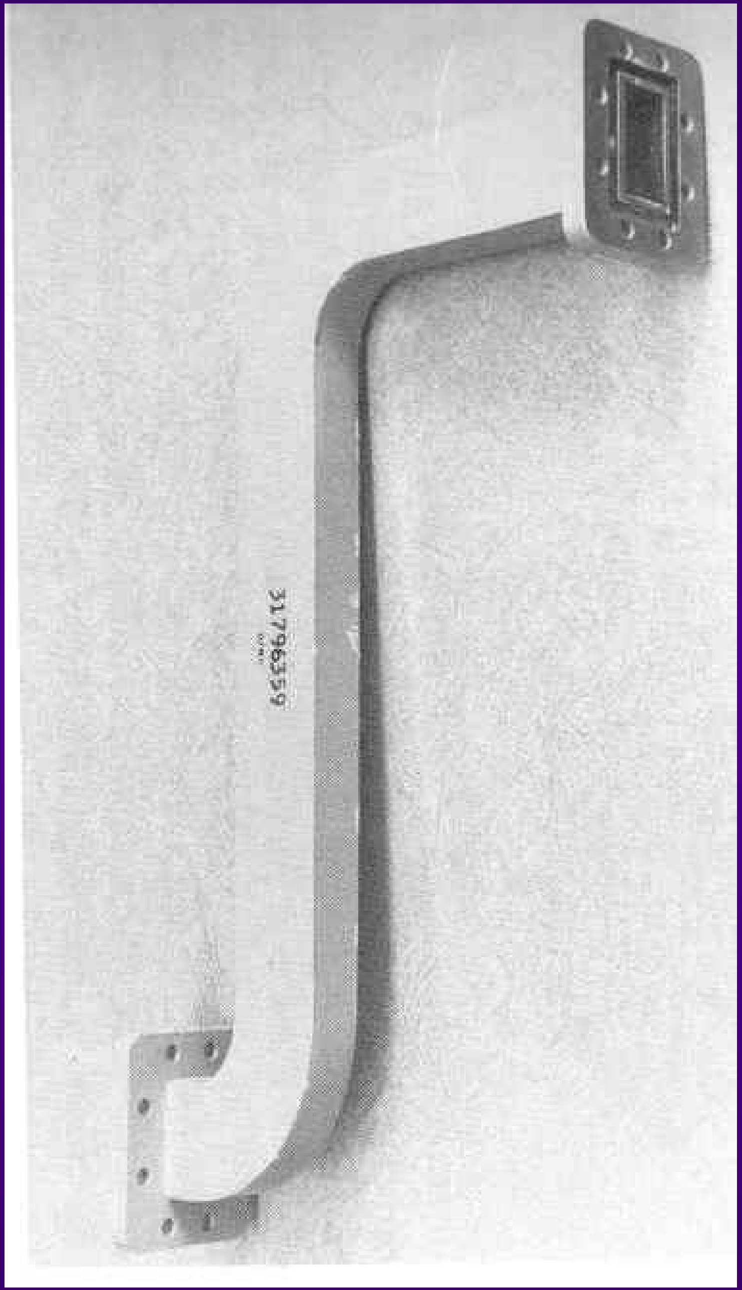
Determining Altitude



Altitude = slant range x sinθ elevation

Wave Guides

- Used as a medium for high energy shielding.
- Uses A Magnetic Field to keep the energy centered in the wave guide.
- Filled with an inert gas to prevent arcing due to high voltages within the wave guide.



Factors That Affect Radar Performance

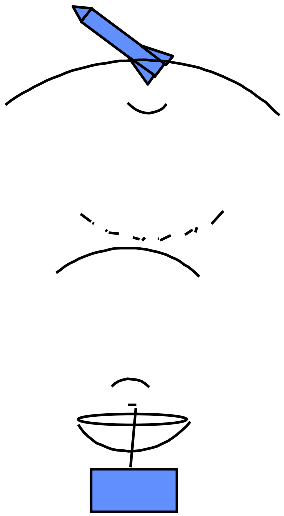
- Signal Reception
- Receiver Bandwidth
- Pulse Shape
- Power Relation
- Beam Width
- Pulse Repetition Frequency
- Antenna Gain
- Radar Cross Section of Target
- Signal-to-noise ratio
- Receiver Sensitivity
- Pulse Compression
- Scan Rate
  - Mechanical
  - Electronic
- Carrier Frequency
- Antenna aperture

Radar Receiver Performance Factors

- Signal Reception
- Signal-to-Noise Ratio
- Receiver Bandwidth
- Receiver Sensitivity

Signal Reception

- Only a minute portion of the RF is reflected off the target.
- Only a fraction of that returns to the antenna.
- The **weaker the signal** that the receiver can process, the **greater the effective range**.



Signal-to-Noise Ratio

- **Measured in dB!!!!!**
- **Ability to recognize target in random noise.**
  - Noise is always present.
  - At some range, noise is greater that target's return.
- **Noise sets the absolute lower limit of the unit's sensitivity.**
- **Threshold level used to remove excess noise.**

Receiver Bandwidth

- **The frequency range the receiver can process**
- **Receiver must process many frequencies**
  - Pulse are generated by summation of sine waves of various frequencies.
  - Must receive with frequency shifts from Doppler
- **Reducing the bandwidth**
  - Increases the signal-to-noise ratio- less broadband component (good)
  - Distorts the transmitted pulse(bad)

Receiver Sensitivity

- **Smallest return signal that is discernible against the noise background**
  - mW range
- **An important factor in determining the unit's maximum range**
- **Lowest return strength that can be detected is denoted S_{min} or <u>Min. Detectable Signal</u>**

Pulse Effects on Radar Performance

- Pulse Shape
- Pulse Width
- Pulse Compression
- Pulse Power

Pulse Shape

- **Determines range accuracy and minimum and maximum range.**
- **Ideally we want a pulse with vertical leading and trailing edges.**
  - Very clear signal – easily discerned when listening for the echo
  - Some receivers reduce rain clutter on displays by discarding pulses that do not change rapidly

Pulse Width

- Determines the range resolution.
- Determines the minimum detection range

  $Rh_{min,\ unambig} = (c\ PW) / 2$

- Can also determine the maximum range of radar.
- The narrower the pulse, the better the range resolution.

Pulse Compression

- Increases frequency of the wave within the pulse.
- Allows for good range resolution while packing enough power to provide a large maximum range.

Pulse Power

- **The means to get the signal out a long way.**
  - High peak power desirable to achieve maximum ranges.
  - Low power results in more compact radar units with less power required to operate.
- **Average power is the time-averaged transmission power for a pulse radar**
- **Duty cycle- the ratio of peak power to average power for pulsed radar**
  - $DC = PW / PRT = P_{ave} / P_{peak}$

Other Factors Affecting Performance

Scan Rate and Beam Width

Narrow beam require slower antenna rotation rate

Pulse Repetition Frequency

Determines radar's maximum range(tactical factor)

Rh_{max}= (c PRT) / 2

Carrier Frequency

Determines antenna size, beam directivity and target size.

Radar Cross-section (α)

Radar Cross Section (What radar can see(reflect))

Function of target:

- Size
- shape
- Material
- Aspect
- Carrier frequency

Theoretical Maximum Range Equation

$$Rh_{max}=[P_t G \sigma A_e]^{1/4}/[(4\pi)^2 S_{min}]^{1/4}$$

P_t= Transmitted power

G= Antenna gain (function of beamforming efficiency & power efficiency)

A_e= aperture (receive area of antenna)

Summary of Factors and Compromises

Summary of Factors and Compromises

Factor	Desired	Why	Trade-off Required
Pulse Shape	Sharp a rise as possible Tall as possible	Better range accuracy More power /longer range	Require infinite bandwidth, more complex Requires larger equipment/more power
Pulse Width	Short as possible	Closer minimum range More accurate range	Reduces maximum range
Pulse Repetition Freq.	Short	Better range accuracy Better angular resolution Better detection probability	Reduces maximum range
Pulse Compression	Uses technique	Greater range Shorter minimum range	More complex circuitry
Power	More	Greater maximum range	Requires larger equipment & power
Beam Width	Narrow	Greater angular accuracy	Slow antenna rate, Detection time
Carrier Frequency	High	Greater target resolution Detects smaller targets Smaller equipment	Reduces maximum range
Receiver Sensitivity	High	Maximizes detection range	More complex equipment
Receiver Bandwidth	Narrow	Better signal-to-noise ratio	Distorts pulse shape

Types of Radar Output Displays

A Scan (amplitude v. range)

- Used for gunfire control
- Accurate Range information

B Scan

- Used for airborne fire control
- Range and Bearing, forward looking

E Scan

- Used for Altitude

PPI

- Most common type
- Used for surface search and navigation
- Displays target bearing and range

Specific Types of Radar

Pulse Doppler

- Carrier wave frequency of return compared with that of orignal pulse in mixer to detect moving targets.
  - Gives bearing, range, and relative motion.
  - Limited by blind speeds- occurs when range changes by ½ λ from pulse to pulse.

Frequency Agile Systems

- Difficult to jam.

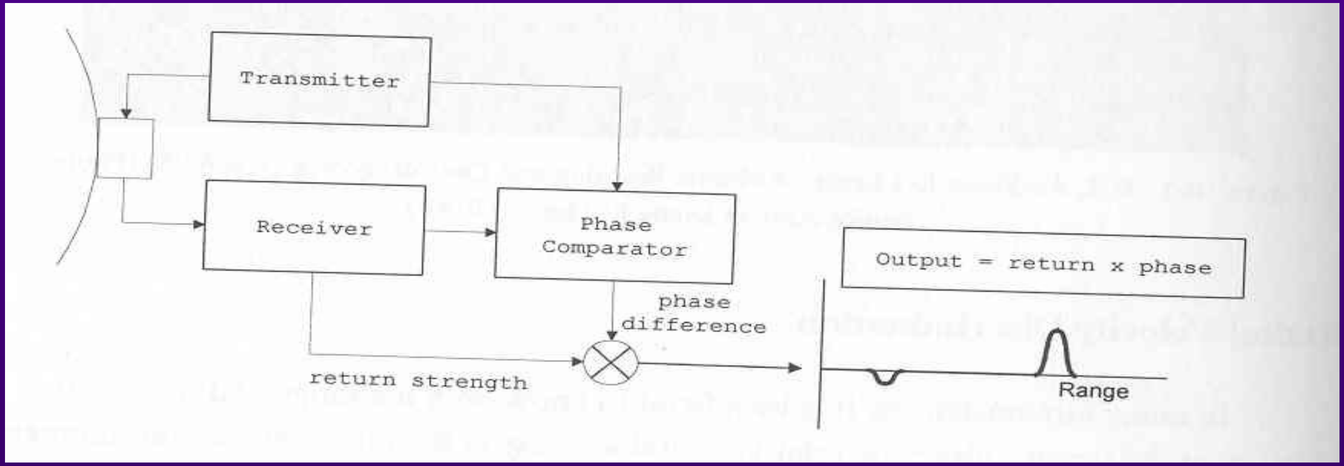
Specific Radar Types

Moving Target Indicator (MTI) System

Signals compared with previous return to enhance moving targets. (search radars)

Stationary targets exhibit no phase shift and can be cancelled in a component known as a canceller.

Moving radar receivers send the platforms speed as a correction to the phase comparator.



FMCW Radar

- **Uses FM pulse to determine range in CW system**
  - Use for radar altimeters and missile guidance.
  - Rh= (cTΔf) / (2(f_2-f_1))

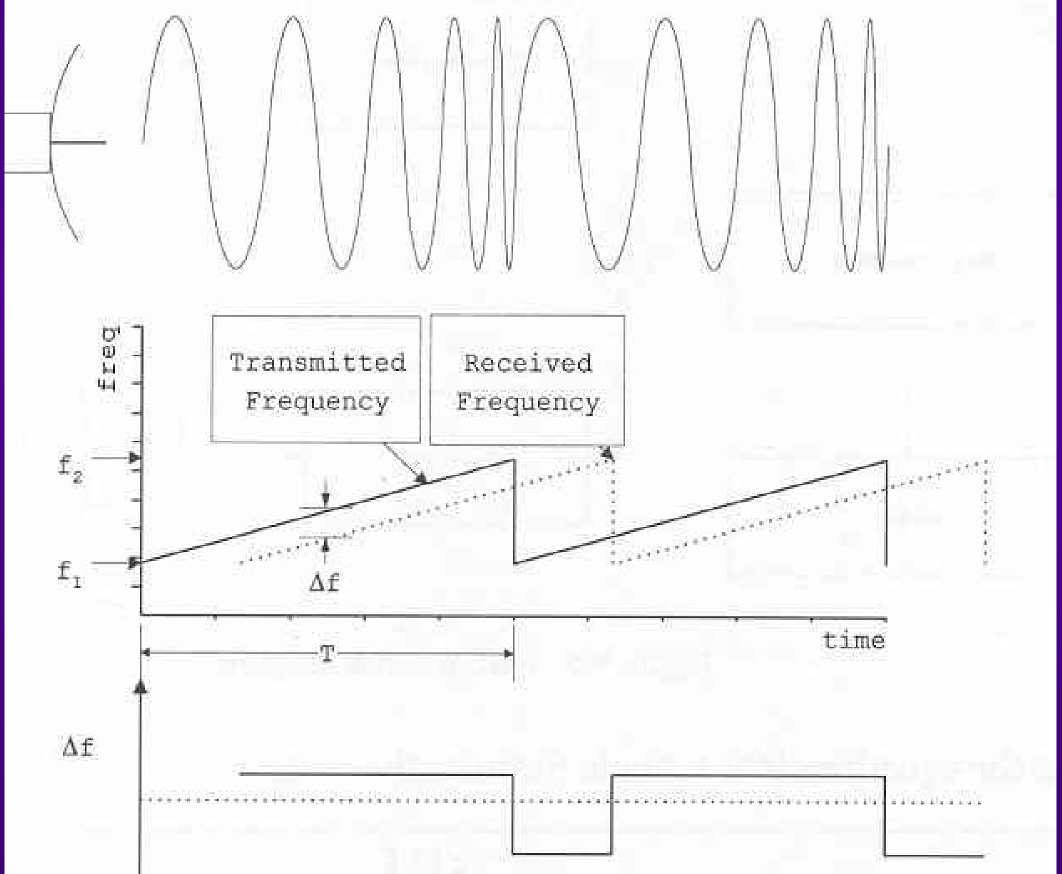


Figure 9-4. FMCW theory of operation.

Questions?