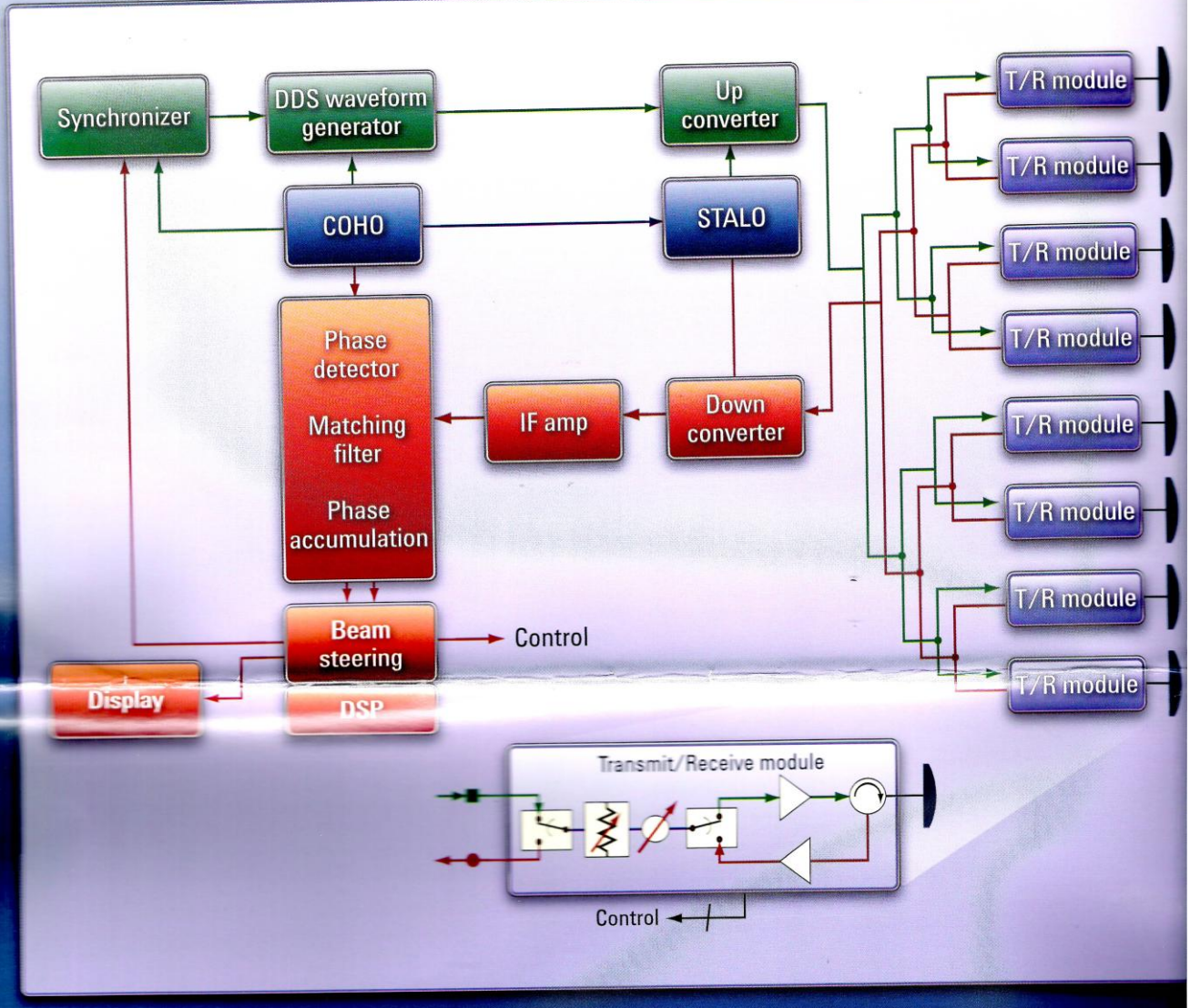
Radar Block Diagram



This block diagram represents a common radar system design. The transmitter generates **a modulated waveform,** upconverts, and transmits using multiple transmit/receive (T/R) **and antenna** elements designed to electronically steer and shape the beam. Radar return **are received** with the same antennas. Receiver processing uses a match filter to **pulse compress** the modulated radar waveform which increases the resolution **and range. The phase** accumulator detects the Doppler shift indicating the target's velocity. **The radar operation is** synchronized with stable and coherent oscillators (COHO) **and stabilized loc oscillators** (STALO) to maximize performance.

Pulse Width and Pulse Repetition Frequency (PRF)

Basic Equations for Primary Monostatic Radar

$$\text{Range}_{(max)} = \sqrt[4]{\frac{P_t G_t A_e \sigma}{(4\pi)^2 S_{min}}}$$

$$\text{Power}_{(receiver)} = \frac{P_t G_t A_e \sigma}{(4\pi)^2 R^4}$$

$$\text{Range to target} = \frac{cT_r}{2} \approx 150\ m/us$$

$$\text{Maximum unambiguous range} = \frac{cT_r}{2} = \frac{c}{2F_p}$$

$$\text{Average power} = \frac{P_p \tau}{T_p} = P_p \tau F_p$$

$$\text{Doppler frequency} = \frac{2F_t v_r}{c}$$

$$\text{Target radial velocity} = \frac{F_d c}{2F_t}$$

$$\text{Pulse duty cycle} = \frac{\tau}{T_p}$$

$$\text{Pulse repetition frequency} = \frac{1}{T_p}$$

Where

- A_e = antenna effective aperture, m^2
- c = speed of light ($\approx 3 \times 10^8$ m/s)
- F_d = Doppler frequency
- F_p = pulse repetition frequency
- F_t = transmitter frequency
- G = antenna gain
- P_t = peak power
- P_p = average peak power
- R = range, m
- S_{min} = minimum detectable signal, W
- T_p = pulse repetition period
- T_r = time to and from target
- v_r = radical velocity of target
- σ = radar cross section of target, m^2
- τ = pulse width

Cross correlation: Gxy (f) = Sx (f) S*y(f)

Where

Sx (f) = Fourier transform of the windowed receive pulse
S*y (f) = Fourier transform of transmit pulse

$$\text{Noise factor} \equiv \frac{S_i/N_i}{S_o/N_o} = \frac{N_a + GN_i}{GN_i}$$

$$\text{Noise factor (system)} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_n - 1}{G_1 G_2 \ldots G_{n-1}}$$

$$\text{Noise figure} = 10\ LOG_{10}\ (\text{noise factor})$$

Where

- G = DUT gain
- $G_1, G_2, G_3 \ldots G_n$ = gain of stages 1, 2, 3....n
- $F_1, F_2, F_3 \ldots F_n$ = noise factor of stages 1, 2, 3....n
- N_a = added DUT noise
- N_i = input noise at 290° K
- N_o = noise at the output at 290° K
- S_i = signal at the input
- S_o = signal at the output

Constants

$$kTB = -174.1\ dBm = -204.1\ dBW$$

Where

- k = Boltzmann's constant
- T = at 290° K
- Bandwidth = 1 Hz

Boltzmann's constant: $1.3806505 \times 10^{-23}$ J/K

Speed of light in a vacuum: 299,792,458 m/s ($\approx 3 \times 10^8$ m/s)

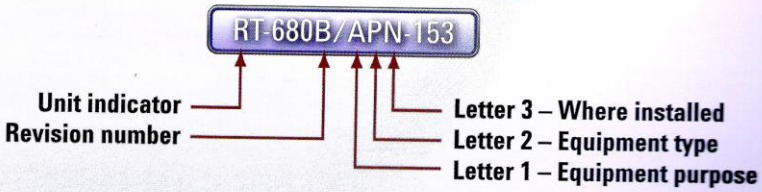
Speed of light in air: 299,705,543.39 m/s

Vacuum	Statute	Nautical
Radar km	6.67128 µs	
Radar mile	10.73639 µs	12.35521 µs
Air	**Statute**	**Nautical**
Radar km	6.67322 µs	
Radar mile	10.7395 µs	12.35879 µs

Military Nomenclature and Designation

Example of the AN/APN-153 (V) Doppler navigational radar system

Joint Army Navy (JAN) designations



Letter 1 – Indicates installation location

- A Piloted aircraft
- B Underwater, mobile (submarine)
- C Cryptographic equipment
- D Pilotless carrier (missile, drone, UAV)
- F Ground, fixed
- G Ground, general
- K Amphibious
- M Ground, mobile
- P Portable (by man)
- S Surface ship
- T Ground, transportable
- U General utility or combination
- V Ground, vehicle
- W Water surface/underwater combination
- Z Piloted/pilotless airborne combination

Letter 2 – Equipment type

- A Invisible light, heat radiation (i.e. infrared)
- B Comsec (secure communications)
- C Carrier (electronic wave or signal)
- D Radiac (radioactivity detection, identification, and computation)
- E Laser
- F Fiber optics
- G Telegraph or teletype
- I Interphone and public address
- J Electromechanical
- K Telemetering
- L Countermeasures
- M Meteorological
- N Sound in air
- P Radar
- Q Sonar and underwater sound
- R Radio
- S Special or combination
- T Telephone (wire)
- V Visual, visible light
- W Armament (only used, if no other letter applies)
- X Fax or television
- Y Data processing
- Z Communications

Letter 3 – Defines purpose of equipment

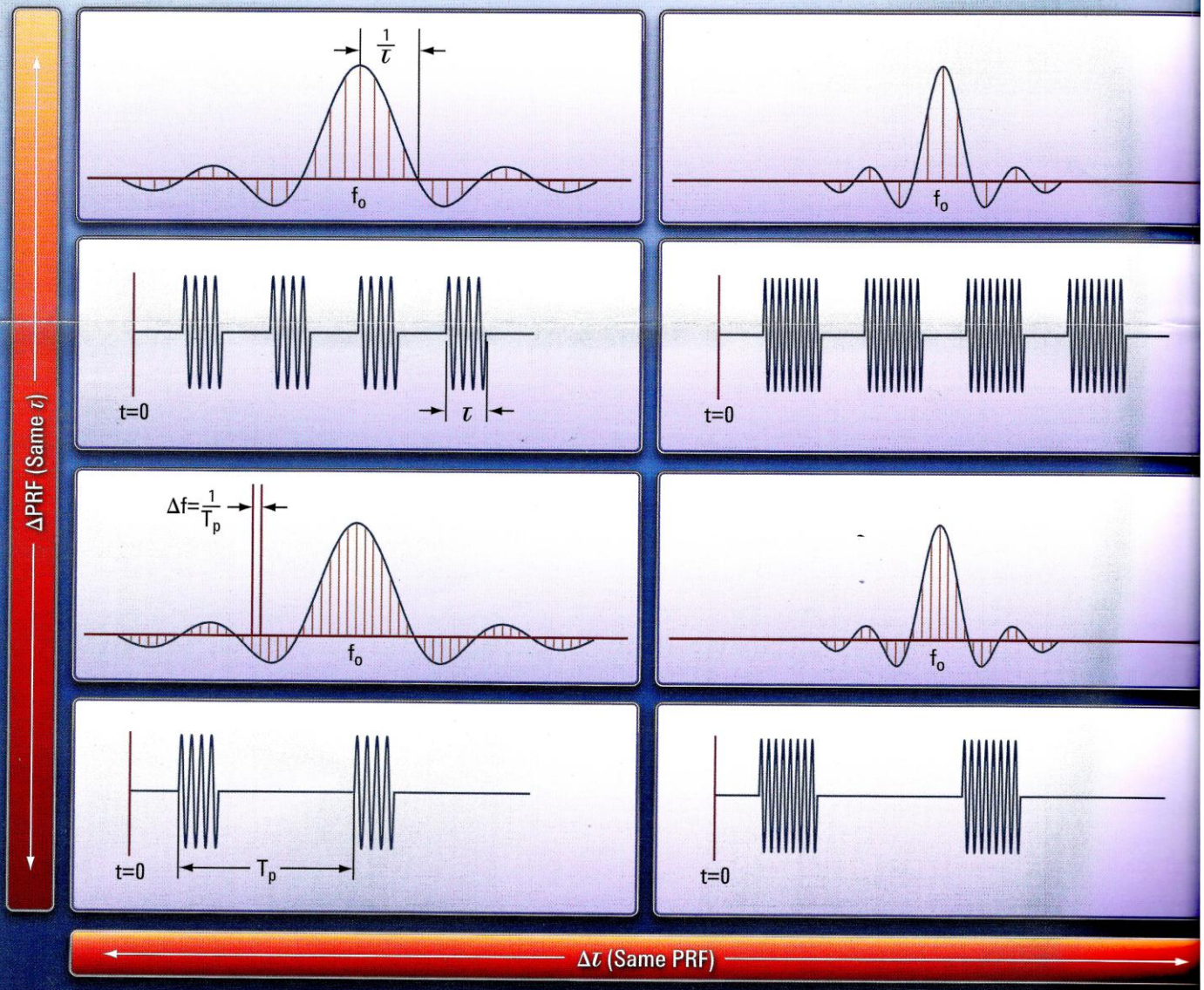
- A Auxiliary assembly
- B Bombing
- C Communications
- D Direction finding, reconnaissance and surveillance
- E Ejection and/or release
- G Fire control or searchlight directing
- H Recording and/or reproducing
- K Computing
- *L Searchlight control; removed from the system; purpose now covered by "G"*
- M Maintenance or test
- N Navigation Aid
- *P Reproducing; removed from the system; purpose now covered by "H")*
- Q Special or combination
- R Receiving or passive detecting
- S Detecting, range and bearing, search
- T Transmitting
- W Automatic flight or remote control
- X Identification or recognition
- Y Surveillance (target detecting and tracking) and control (fire control and/or air control)
- Z Secure

Most military electronic systems are composed of multiple assemblies or boxes (called black boxes).

Boxes are formally called LRUs (Line Replaceable Units)

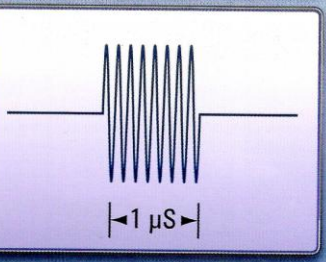
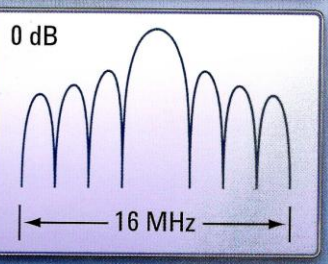
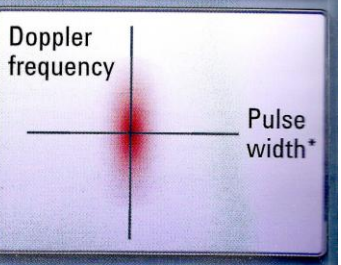
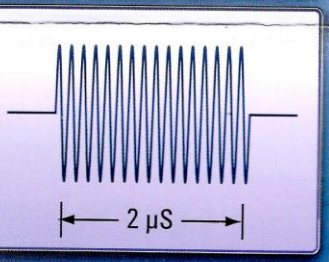
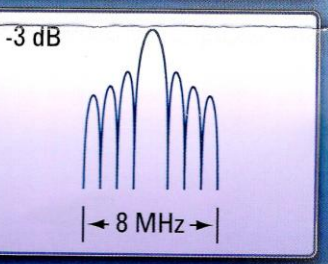
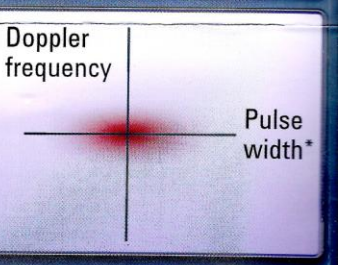
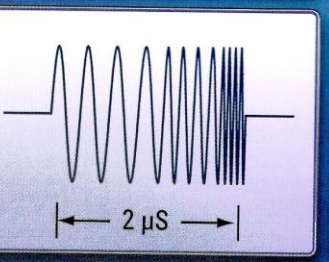
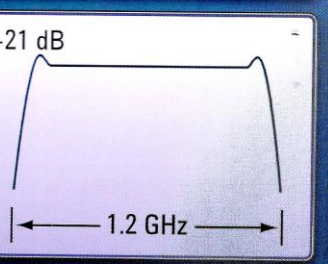
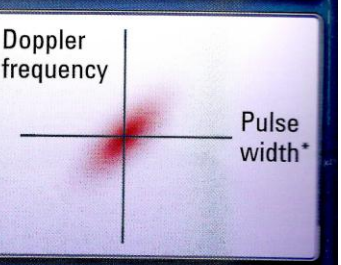
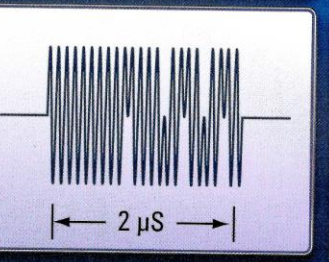
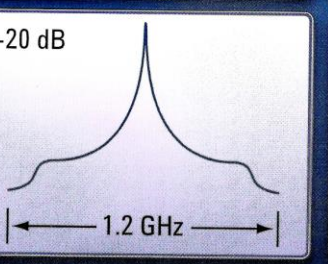
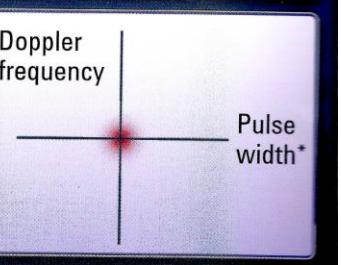
Standard Radar-Frequency Letter Band Nomenclature

Pulse Width and Pulse Repetition Frequency (PRF)



Power, pulse repetition, pulse width, and pulse modulation are traded off to obtain the optimum combination for range and resolution. For simple RF pulses, range resolution varies inversely with pulse width, but narrow pulses drive up peak power requirements. Similarly, the maximum unambiguous range varies inversely with PRF. However, pulse modulation radically affects these relationships.

Pulse Compression Techniques

Pulse type	Time domain	Frequency domain	Ambiguity diagram
Short RF pulse			
Long RF pulse			
Swept RF pulse			
13-bit Barker coded RP pulse			

*The term Pulse width on the Ambiguity diagram refers to the pulse width at the radar detector output

By utilizing pulse compression techniques (modulation), long pulses with lower peak power can be used without sacrificing range resolution. Processing gain in the receiver compresses the received pulse, which restores the high range resolution of narrower pulses and maximizes the detectable range. The ambiguity diagram illustrates location accuracy (horizontal axis) and Doppler frequency shift tolerance (vertical axis).

Standard Radar-Frequency Letter Band Nomenclature

International Table

Band designation	Nominal frequency range	Specific frequency ranges for radar based on ITU assignments		
		Region 1 (Includes all EU countries, the Mideast except Iran, Russia, all of Africa and others)	**Region 2** (Includes the Americas)	**Region 3** (Includes most of Asia, Australia New Zealand and others)
HF	3 to 30 MHz	(There are no official ITU radiolocation bands at HF. So-called HF radars might operate anywhere from just above the broadcast band [1.605 MHz] to 40 MHz or higher)		
VHF	30 to 300 MHz	None	138 to 144 MHz 216 to 225 MHz (Frequencies from 216 to 450 MHz were sometimes called P-band)	223 to 230 MHz
UHF	300 to 1000 MHz (in radar practice)	420 to 450 MHz (216-450 MHz were sometimes called P-band) 890-942 MHz (Sometimes included in L-band)		
L	1 to 2 GHz	1215 to 1400 MHz		
S	2 to 4 GHz	2300 to 2500 MHz		
		2700 to 3600 MHz	2700 to 3700 MHz	
C	4 to 8 GHz	4200 to 4400 MHz (Designated for aeronautical navigation, this band is reserved [with few exceptions] exclusively for airborne radar altimeters)		
		5250 to 5850 MHz	5250 to 5925 MHz	
X	8 to 12 GHz	8.5 to 10.68 GHz		
Ku	12 to 18 GHz	13.4 to 14 GHz		
		15.7 to 17.7 GHz		
K	18 to 27 GHz	24.05 to 24.25 GHz	24.05 to 24.25 GHz 24.65 to 24.75 GHz (The frequency range of 24.65 to 24.75 GHz includes satellite radiolocation [earth to space only])	24.05 to 24.25 GHz
Ka	27 to 40 GHz	33.4 to 36 GHz		
V	40 to 75 GHz	59 to 64 GHz		
W	75 to 110 GHz	76 to 81 GHz		
		92 to 100 GHz		
mm	110 to 300 GHz	126 to 142 GHz		
		144 to 149 GHz		
		231 to 235 GHz 238 to 248 GHz (No ITU allocations are listed for frequencies above 275 GHz)		