EE3-27: Principles of Classical and Modern Radar

Introductory Concepts

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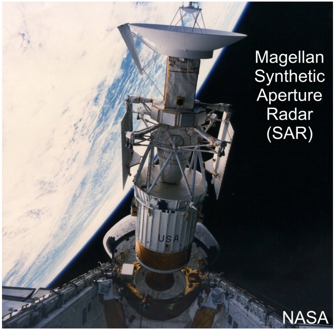
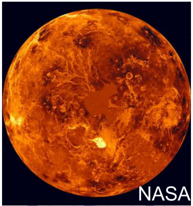


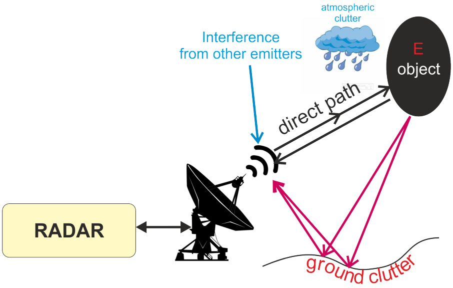
Magellan SAR Map of Venus



Introduction: Traditional Radar Functions

- to detect the presence of targets
- to estimate target parameters, for instance:
  - R, range obtained from pulse time delay
  - v_r, relative radial velocity obtained from the Doppler frequency shift $\mathcal{F}_D$ (if the target or radar is moving)
  - angles θ (azimuth) or ϕ (elevation) or both (θ, ϕ), of the target obtained from antenna pointing
- to carry our signature analysis, inverse scattering and imaging for estimating:
  - target size
  - target shape and components
  - moving parts
  - material composition
- Note: the complexity of the radar increases with
  - the extent of the functions that the radar performs and
  - the sophistication of the algorithms employed.

Introduction: Radar Operational Environment



- Radar return depends on:
  - target orientation (aspect angle) and distance (range)
  - target environment (other objects nearby; location relative to the earth's surface)
  - propagation characteristics of the path (rain, snow or foliage attenuation)
  - antenna characteristics (polarization, beamwidth, sidelobe level)
  - Tx and Rx characteristics

Joint Electronics Type Designation Systems

- In the joint Army-Naval Nomenclature Systems, known as *Joint Electronics Type Designation Systems* (JETDS) the Radar is represented by the letter "P". Examples of this list are given below while a more complete list is given in Appendix-B.

Examples (JETDS)

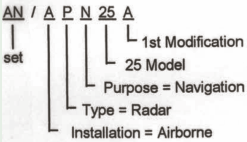
TABLE 1-2 ■ Some Elements of the Joint Electronics Type Designation System (JETDS)[a]

Platform (1st letter)	Equipment Type (2nd letter)	Application (3rd letter)
A – Airborne	L – Countermeasures	G – Fire control or searchlight directing
F – Ground fixed	P – Radar	N – Navigation
M – Ground mobile	Y – Processing	Q – Special or multipurpose
S – Surface ship	B – Communications security	Y – Surveillance
T – Ground transportable	Q – Sonar	R – Receive (passive) only
U – Ground utility	W – Armament	S – Detecting, range and bearing, search
B – Underwater		
G – Ground		
K – Amphibious		
P – Man portable		

[a]The Joint Army–Navy Nomenclature System was previously used to catalog electronic equipment.

Examples (JETDS, cont.)

Examples



SYSTEM	PURPOSE	CONTRACTOR
ALQ–137(V)4	Repeater Jammer	Sanders
ALQ–144(V)	IR Countermeasures Set	Sanders
ALQ–153	Tail Warning Set	Westinghouse
ALQ–155	B–52 ECM Power Management Systems	Northrop
ALQ–157(V)	Navy Infrared Jammer	Loral
ALQ–161	B–1B Integrated ECM System	AIL
ALQ–162(V)1	Navy Countermeasures Set	Northrop
ALQ–162(V)2	Army Countermeasures Set	Northrop
ALQ –165	Self-Protection Jammer	ITT/Westinghouse
ALQ –171	Tactical countermeasures	Northrop
ALQ –172	B–52G/H, C–130 Countermeasures Set	ITT
ALQ –172/155	B–52G/H Sensor Integration	—
ALQ –176(V)	ECM Pod	Hercules
ALQ –184(V)	ECM Pod (Modified ALQ–119)	Raytheon
ALQ –188	Countermeasure System	Northrop QRC Division
ALQ –196	Jammer	Sanders
ALR–20A	B–52 Panoramic receiver	RCA
ALR–46	Radar Warning Receiver (4 Versions)	Dalmo Victor
ALR–56	Radar Warning Receiver (4 Versions)	Loral
ALR–62(V)	Radar Warning, Countermeasures Sets	Dalmo Victor
ALR–69	Radar Warning receiver	ATD/Dalmo/Litton
ALR–72	Threat Panel	Dalmo Victor
ALT–6B	Jammer	GE
ALT–16	Jammer	Motorola
ALT–28	Jammer	Northrop
ALT–32	Jammer	Multiple
APM–427	Radar Simulator	AAI
APR–38	Radar Attack Warning System	WJ/IBM/Microphase
APR–39(V)1	Radar Warning Receiver	Dalmo Victor
APR–39(V)2	Radar Signal Detecting Set	Dalmo Victor
APR–44(V)	Radar Warning System	AEL

Types and Uses of Radar

- **Search radars** scan a large area with pulses of short radio waves
- **Targeting radars** use the same principle but scan a smaller area more often
- **Navigational radars** are like search radar, but use short waves that reflect off hard surfaces. They are used on commercial ships and long-distance commercial aircraft
- **Mapping radar** scans a large regions for remote sensing and geography applications
- **Wearable radar** which is used to help the visually impaired as a substitute to eye.
- **Air traffic control** uses radar to reflect echoes off of aircraft
- **Weather radar** uses radar to reflect echoes off of clouds
  - Weather radars use radio waves with horizontal, dual (horizontal and vertical), or circular polarization
  - Some weather radars use the Doppler effect to measure wind speeds

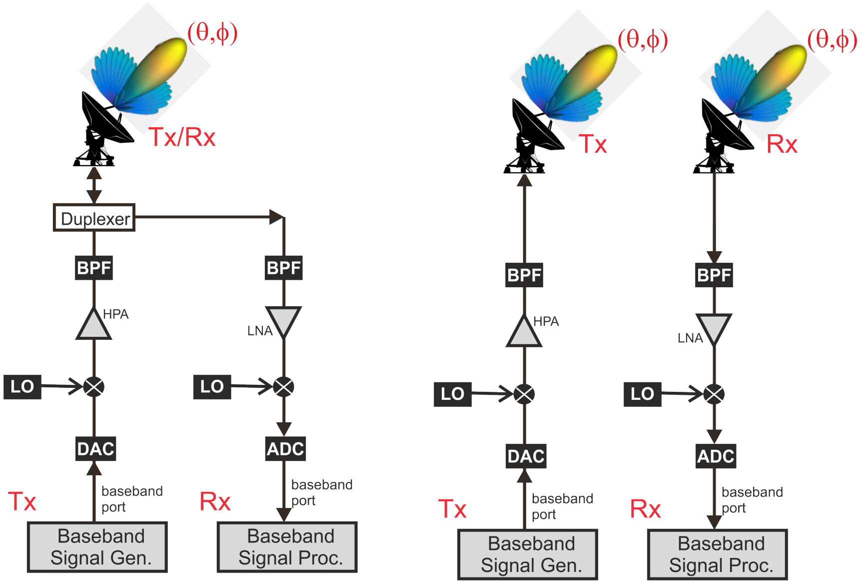
- Appendix-A gives a wider list of types and uses of radar and can be used to classify radar system according to their "applications".

- However, in the remainder of this topic (but also in Topics 2-10) we will focus on
  - basic radar system architectures and
  - radar classifications

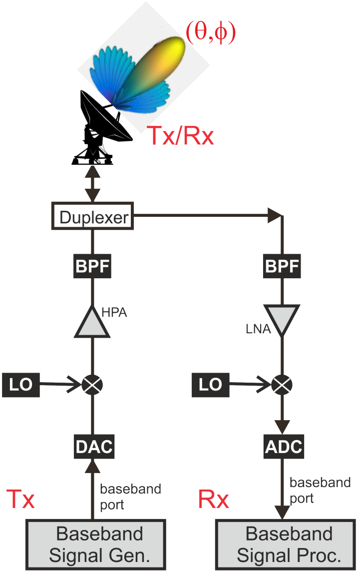
  which are independent[1] of the radar's "application" and based on the
  - radar signals and their properties and
  - radar's system structure employed.

[1] i.e. can be used in any required application

Radar Generic Architecture



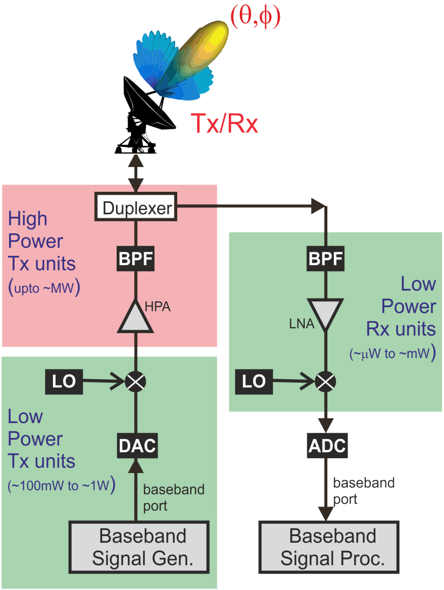
Radar Generic Architecture (cont.)



Example

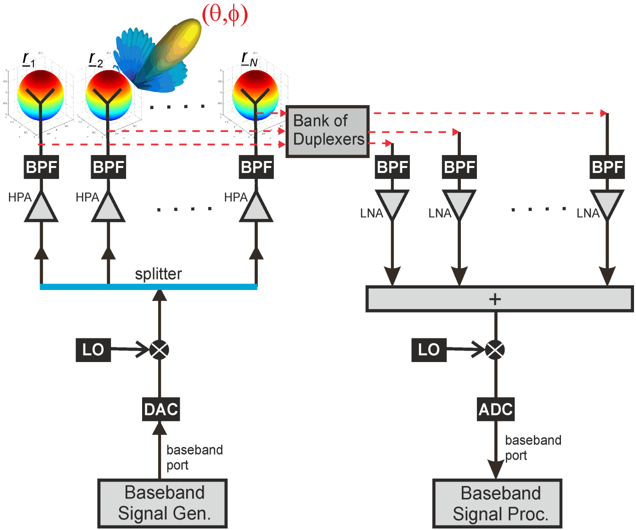
BPF: Band Pass Filter
HPA: High Power Amplifier
LNA: Low Noise Amplifier
LO: Local Oscillator
ADC: Analogue-to-Digital Converter
DAC: Digital-to-Analogue Converter

Radar Architecture: Low and High Power Subsystems

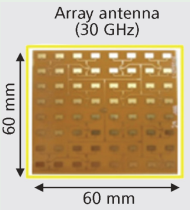


- Radar transmitter and receiver can be divided into two major subsystems:
  - Low power transmit and receive subsystem (Radar waveform generator and receiver)
  - High power transmitter subsystem

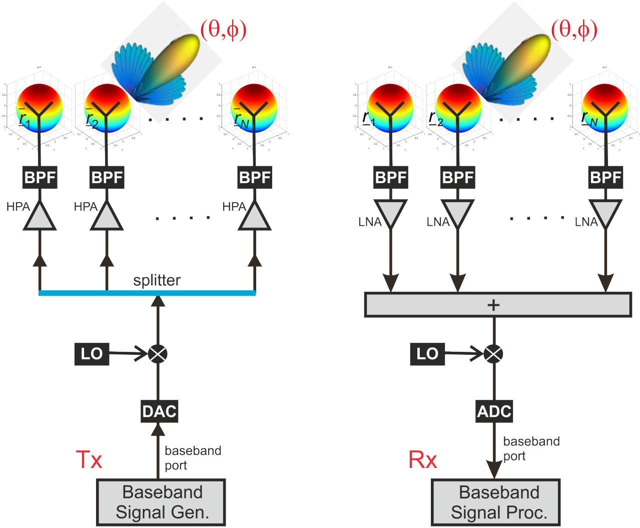
Radar Architecture with Single Antenna Arrays



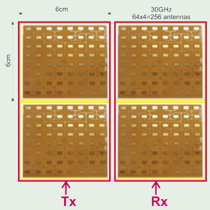
Example



Radar Architecture with Two Antenna Arrays



Example

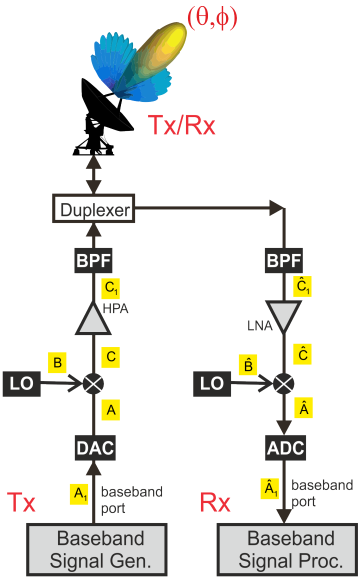


Basic Parts of a Radar

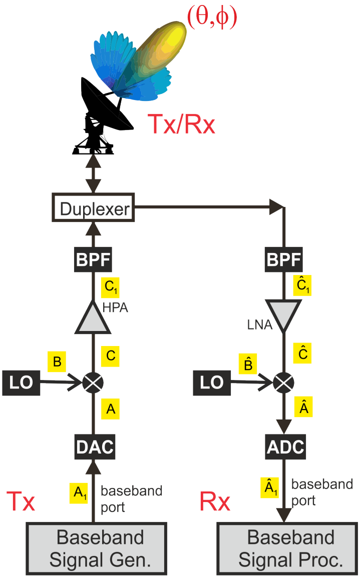
- **Antenna**
- **Duplexer**
- **Tx**
  - Local Oscillator (LO) $\triangleq$ Carrier Generator
    Note: LO + multiplier $\triangleq$ up-converter
  - DAC, HPA, BPF
  - Baseband Signal Generator
- **Rx**
  - Local Oscillator (LO) $\triangleq$ Carrier Generator.
    Note: LO + multiplier $\triangleq$ down-converter
  - ADC, LNA, BPF
  - Baseband Signal Processor
- Synchroniser[1]: common clock for Tx and Rx
- Display unit[1]: This is connected to the Baseband Signal Processor
- Power supply[1]

[1] not shown in the various radar architectures.

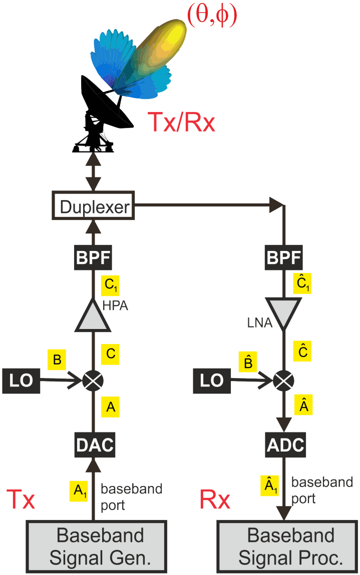
Radar Signal Flow - Tx



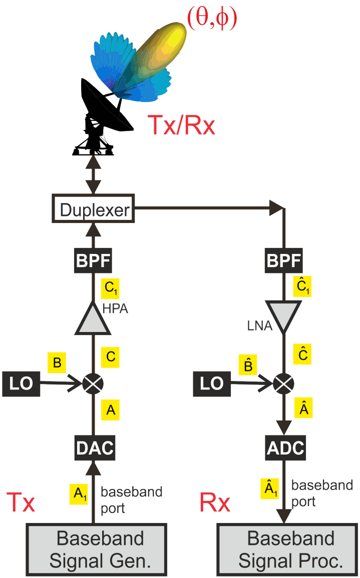
- **Tx, Point-A1**: the baseband signal generator, generates at Point-A1 a sequence of samples $b(t_l)$ of a suitable baseband signal $b(t)$ for the particular job the radar is to perform. It also controls the *timing*, *frames* or *modulation scheme* depending on the configuration. Note that t_l is the time instant of the l-th sample, with $l = 1, 2, ...,$.
- **Tx, Point-A:** at Point-A the DAC will produce the *time continuous* baseband signal $b(t)$ [without any loss of generality, unity power is assumed]



- **Tx, Point-B**: the carrier $\exp(j2\pi F_c t)$ is generated, where F_c is the carrier frequency.
- **Tx, Point-C**: the bandpass signal $b(t).\exp(j2\pi F_c t)$ is produced.
- **Tx, Point-C_1**: the signal at Point-C is amplified by HPA to produce at Point-C_1 the bandpass signal $\sqrt{P_{Tx}}.b(t).\exp(j2\pi F_c t)$ that might have an average power (P_{Tx}) as small as mWatts or as large as MWatts.



- **Tx/Rx, Duplexer**: The function of the duplexer is to allow a single antenna to be used by
  - protecting the sensitive receiver from burning out while the transmitter is "ON", and
  - directing the received echo signal to the receiver rather than to the transmitter.
- **Tx-Antenna**: The Tx-antenna will transform the electrical signal at Point-C_1 to electromagnetic (EM) waves that will propagate in our 3D-dimensional physical space.



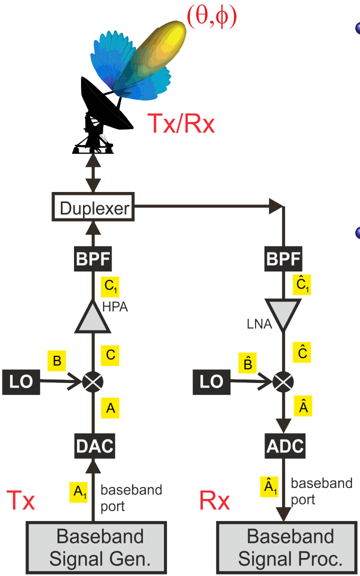
- Some of the radiated energy may be intercepted by a reflective object (usually known as target) located at a distance from the radar.

Examples (Radar Targets)

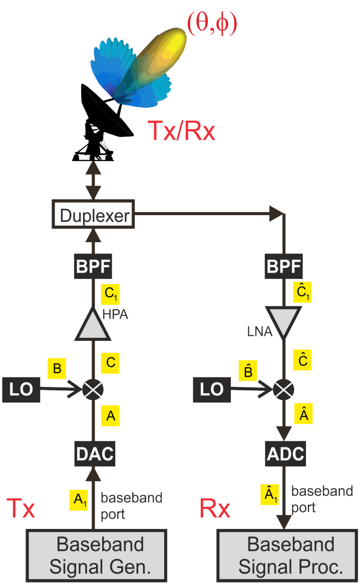
Radar targets might be:

- drones, aircraft, ships, or missiles;
- people, animals, birds, insects;
- precipitation, clear air turbulence, ionized media, land features (vegetation, mountains, roads, rivers, airfields, buildings, fences, and power-line poles);
- sea, ice, icebergs, buoys, underground features;
- meteors, spacecraft & planets.

Radar Signal Flow - Rx



- **Rx, Point-$\hat{\mathbf{C}}_1$**: At the output of the Rx-antenna, and consequently at Point-$\hat{C}_1$, a bandpass signal is received which may include the echoes from targets (if present), clutter and bandpass noise.
- **Rx, Point-$\hat{\mathbf{C}}$**: The LNA amplifies the weak received signal at Point-$\hat{C}_1$, to produce at Point-$\hat{C}$ the bandpass signal $x(t)\exp(j2\pi F_c t)$, where $x(t)$ has a level where its presence can be detected later on.
  - Because noise is the ultimate limitation on the ability of a radar to make reliable detection decision and extract information about the target, care is taken to ensure that the receiver produces very little noise of its own. Thus, LNA = essential.

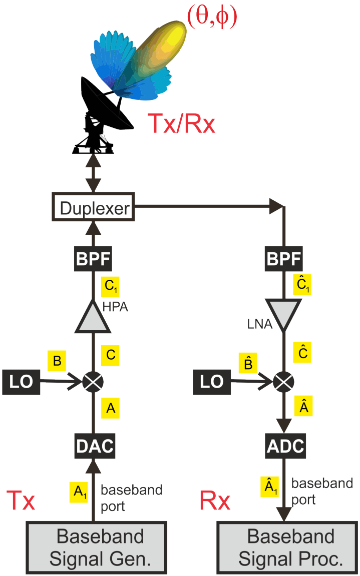


- **Rx, Point-$\hat{\mathbf{B}}$**: the carrier signal $\exp(-j2\pi F_c t)$ is generated at Point-$\hat{B}$ and is used to down-convert the bandpass signal at Point-$\hat{C}$ to the baseband signal at Point-$\hat{A}$, where F_c is the same carrier frequency.

- **Rx, Point-$\hat{\mathbf{A}}$**: at Point-$\hat{A}$ we get the baseband signal $x(t)$, i.e. the carrier has been removed.

- **Rx, Point-$\hat{\mathbf{A}}_1$**:The signal at Point-$\hat{A}$1 is the discretised version of $x(t)$. That is, $x(t_l), \forall l$, where, again, t_l is the time instant of the l-th sample with $l = 1, 2, \ldots$

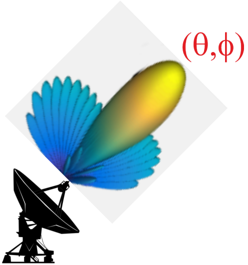
Based on the signal received at Point-$\hat{A}_1$, the radar aim is to characterise & identify (study) "targets" aiming at solving 5 generic technical problems:



1. The "Detection" Problem: detecting the presence of objects/targets;
2. The "Estimation" Problem: measuring (estimating) certain set of parameters associated with objects/targets;
3. The "Tracking" Problem;
4. The "Classification" Problem: identification of the type of the object/target, that is, getting its "electronic signature". This can be used, for instance, to identify the type of the object by comparing this with an existing database of signatures.
5. The "Reception" Problem ("passive" radar)

Radar Antennas.

The antenna is what connects the radar to the outside world. It radiates or receives EM energy and performs several functions:

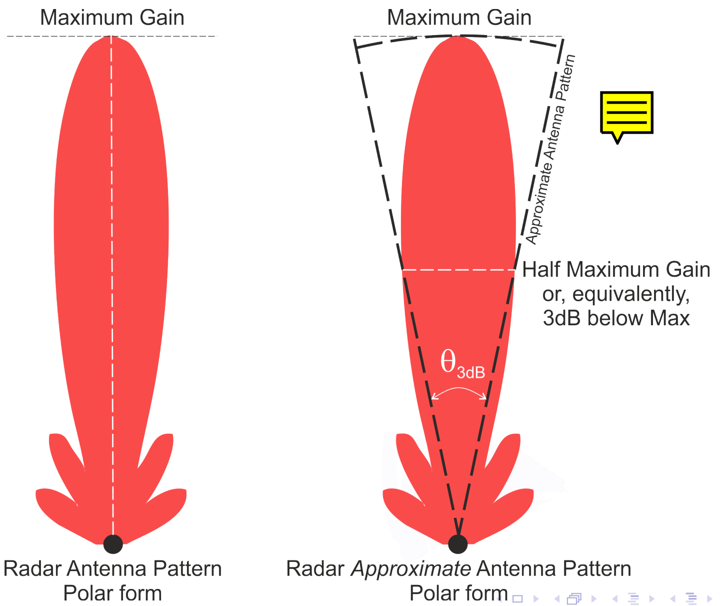


1. concentrates/focuses the radiated energy on transmit; that is, it is "directional" and has, in general, a narrow beamwidth;
2. collects the received echo energy from the target;
3. provides a measurement of the angular direction to the target;
4. provides spatial resolution to resolve (or separate) targets in angle; and
5. "observes" the desired volume of space.

Radar Antennas (cont.)

- $\exists$ many types of antennas. Each type of antenna has its particular advantages and limitations.
  - Generally, the larger the antenna the better, but there can be practical constraints that limit its size
  - Single Antennas are Mechanically Steerable
  - Antenna Arrays are Electronically Steerable
- Must be $1/2$ of the wavelength for the maximum wavelength employed
- Antennas with wide beam: good for "Search"
- Antennas with narrow beam: good for "Track"
- Radar's directional accuracy is a function of the beamwidth.

Radar Antenna Pattern and its Approximation



Radar Antenna Pattern and its Approximation (cont.)

Note:

- In many cases, this radar antenna pattern approximation is tolerable for radar system analysis.
- Thus, the sidelobes are neglected and the gain within the $\theta_{3\text{dB}}$ angle is the maximum antenna gain G_{max}. That is

$$G \simeq \begin{cases} G_{max} & \text{within } \theta_{3\text{dB}} \\ 0 & \text{outside of } \theta_{3\text{dB}} \end{cases} \tag{1}$$

- The gain G of a Tx antenna will be denoted by G_{Tx}
- The gain G of an Rx antenna will be represented by G_{Rx}

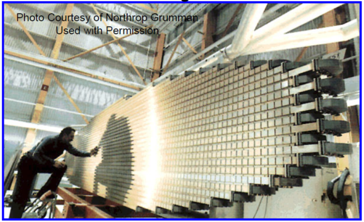
Radar Antennas Come in Many Sizes and Shapes

Examples (Large Radar Antennas)

Electronic Scanning Antenna

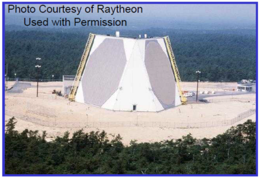
Mechanical Scanning Antenna

Hybrid Mechanical and Frequency Scanning Antenna



Courtesy of MIT Lincoln Laboratory, Used with permission

Mechanical Scanning Antenna

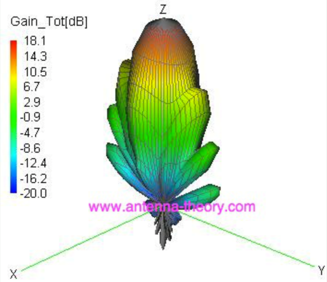


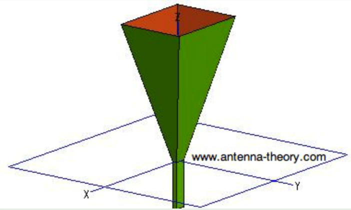
Electronic Scanning Antenna

Photo Courtesy of ITT Corporation Used with Permission

Hybrid Mechanical and Frequency Scanning Antenna

Examples (Single Antennas)



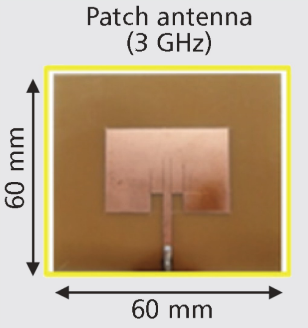


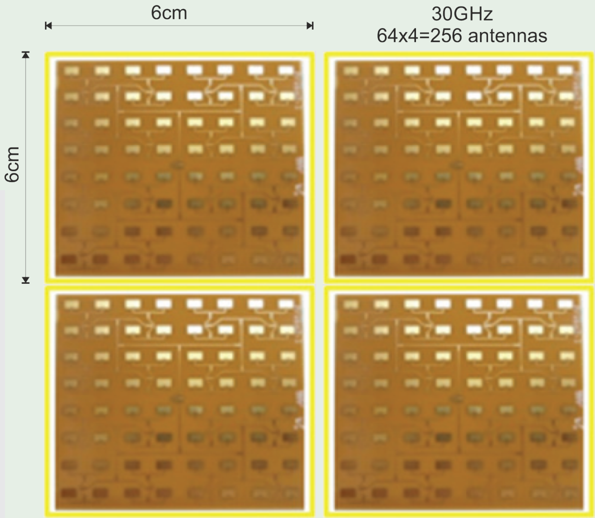
small Horn Antenna

Large Antenna (100m Aperture)

Examples (Large Aperture Antenna Arrays - Radio Telescopes)

Examples (Small Size Radar Antennas)





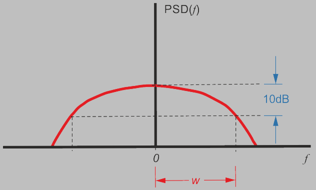
Radar Classification by Spectrum

1. By the Fractional Bandwidth B_{fr}
   - Narrow-Band Radar
   - Wide-Band Radar
   - Ultra-Wide-Band (UWB) Radar
2. By the frequency band at which they operate
   - UHF-Band Radar,
   - L-Band Radar,
   - S-Band Radar,
   - and so on
     (see IEEE Standard Letter Designations for Radar Frequency Bands).

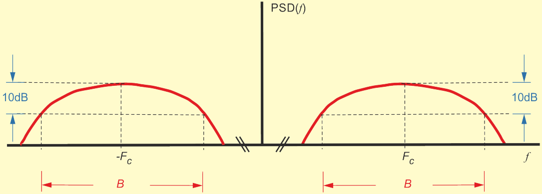
Radar Classification by Spectrum

Spectrum (Power Spectral Density, PSD(f))

at point A: **Baseband**
(Bandwidth$=W$)



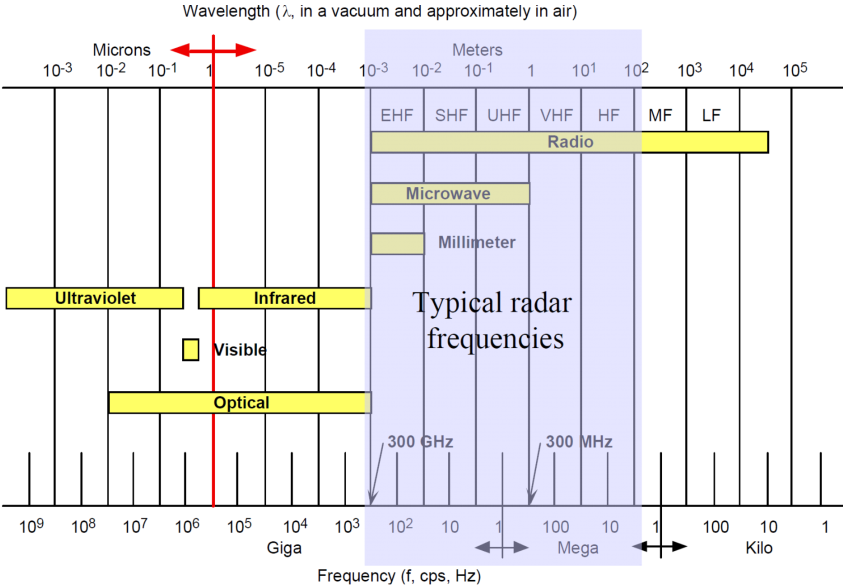
at point C: **Bandpass**
Bandwidth$=B$



Fractional Bandwidth$=\frac{B}{F_c}$

Narrow Band Radar	Wide Band Radar	Ultra Wide Band Radar
$0 < B_{fr} < 0.01$	$0.01 < B_{fr} < 0.25$	$0.25 < B_{fr} < 2.00$

Electromagnetic Spectrum



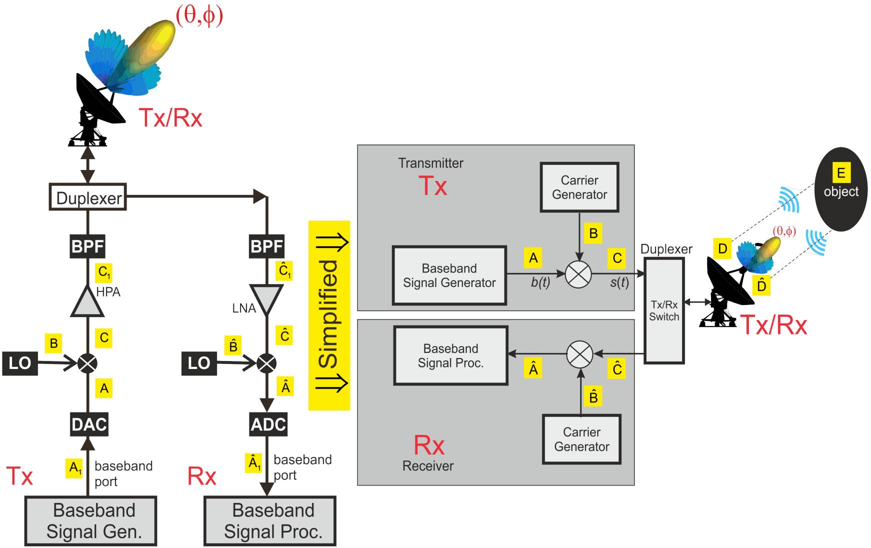
Radar Frequency Bands and Usage[2],[3]

Band Designation	Frequency Range	Usage
High frequency (HF)	3–30 MHz	Ground-penetrating radar, over-the-horizon radar (OTHR), very long range surveillance radar
Very high frequency (VHF)	30–300 MHz	Foliage-penetrating radar, very long range surveillance radar
Ultrahigh frequency (UHF)	300–1,000 MHz	Foliage-penetrating radar, airborne surveillance radar, long range ballistic missile defense radar
L-band	1,000–2,000 MHz	Weapons location radar, air traffic control radar, long range surveillance radar
S-band	2,000–4,000 MHz	Naval surface radar, weapons location radar, weather radar
C-band	4,000–8,000 MHz	Weather radar
X-band	8,000–12,000 MHz	Fire-control radar, air interceptor radar, ground-mapping radar, ballistic missile–tracking radar
Ku-band	12,000–18,000 MHz	Air-to-ground SAR and surface-moving target indication
K-band	18,000–27,000 MHz	Limited due to absorption
Ka-band	27,000–40,000 MHz	Missile seekers, close-range fire-control radar
Millimeter wave (mmw)	40,000–300,000 MHz	Fire-control radar, automotive radar, law enforcement imaging systems, airport scanners, instrumentation radar

[2] IEEE Standard Letter Designations for Radar Frequency Bands

[3] Melvin Sheer, 2014

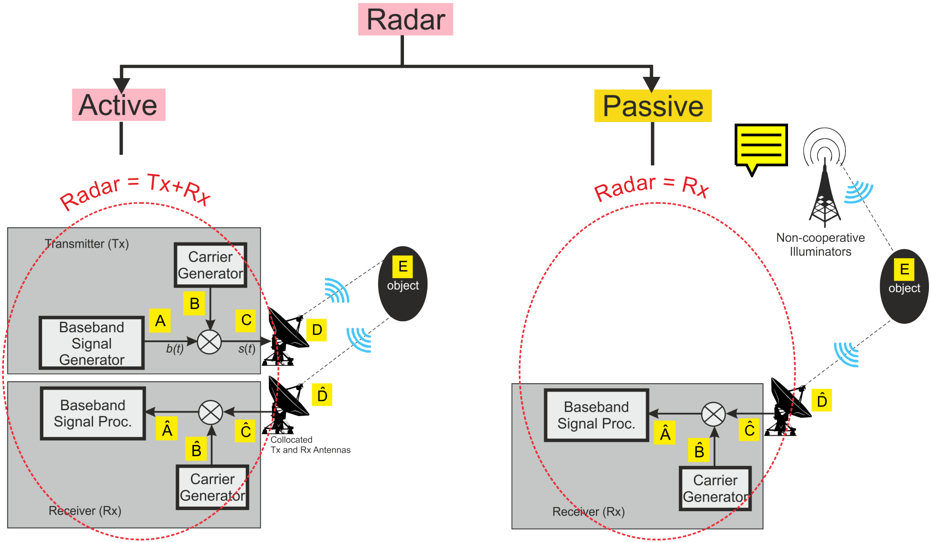
Equivalent Representation of Radar Architecture



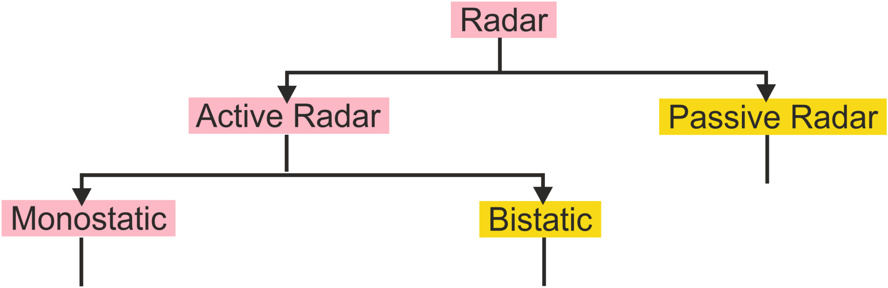
- The LHS figure in the previous slide shows the basic block diagram of a radar architecture with a single Tx/Rx antenna.

- The RHS figure is the simplified version of the LHS figure, where the DAC, ADC, BPF and the amplifiers HPA and LNA are ignored for simplicity.

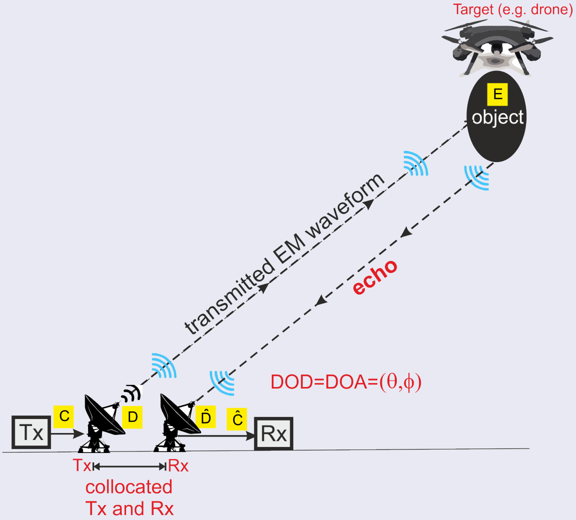
- Similar figures with the same annotation can be produced also for the two-antenna (Tx and Rx) architectures.


Radar
Active
Passive
Radar = Tx+Rx
Radar = Rx
Transmitter (Tx)
Carrier Generator
Baseband Signal Generator
A
B
C
D
b(t)
s(t)
E
object
Baseband Signal Proc.
Â
B̂
Ĉ
D̂
Carrier Generator
Receiver (Rx)
Collocated Tx and Rx Antennas
Non-cooperative Illuminators
E
object
Baseband Signal Proc.
Â
B̂
Ĉ
D̂
Carrier Generator
Receiver (Rx)

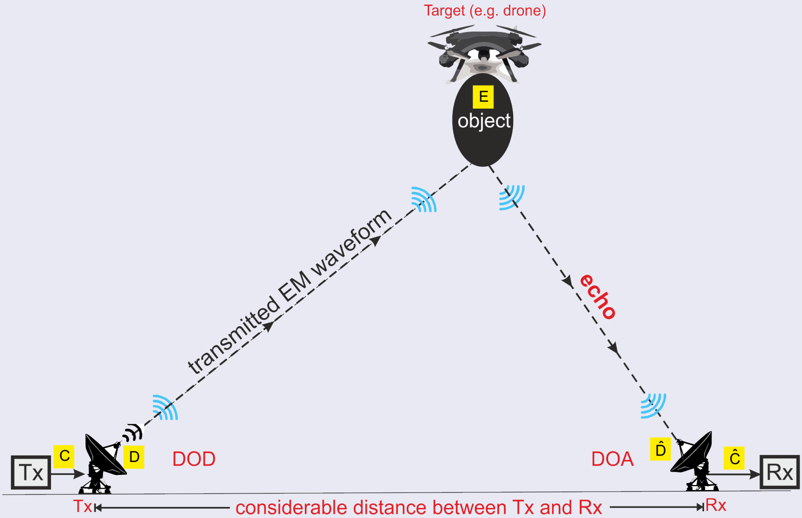
Active and Passive Radar

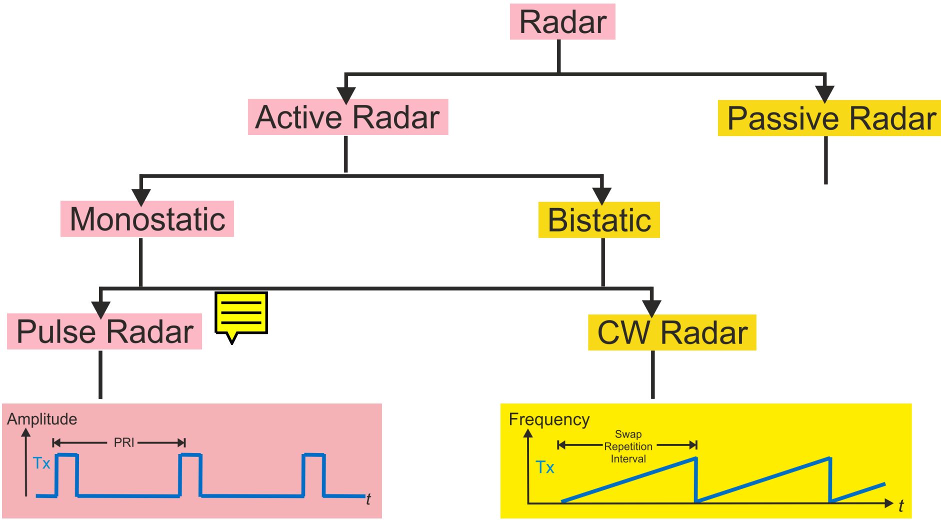


Definition (Monostatic Radar)

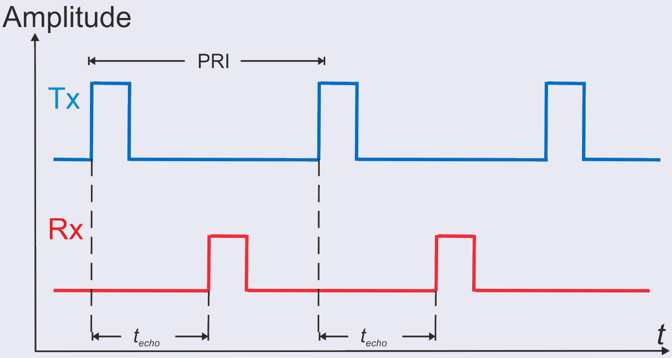


Definition (Bistatic Radar)




Radar
Active Radar
Passive Radar
Monostatic
Bistatic
Pulse Radar
CW Radar
Amplitude
PRI
Tx
t
Frequency
Swap
Repetition
Interval
Tx
t

Definition (Pulse Radar)



$$PRI \triangleq \text{Pulse Repetition Interval (pulse period)}$$

$$PRF \triangleq \text{Pulse Repetition Frequency} = \frac{1}{PRI}$$

$$\text{Duty cycle} \triangleq \frac{\text{Pulse duration}}{PRI}$$

- **Pulse radar**. This is a radar that radiates a repetitive series of almost-rectangular pulses. It might be called the **canonical form of a radar**, the one usually thought of as a radar when nothing else is said to define a radar.

- In particular, a pulse radar is characterized by a high power transmitter that generates an endless sequence of pulses. The rate at which the pulses are repeated is defined as the pulse repetition frequency (PRF).

- Parameter Units:
  - PRF: usually in kHz
  - pulse period, or PRI, or pulse repetition time: usually in msec
  - PRI is the time from beginning of one pulse to the beginning of the next

- N.B.: In the previous slide the Tx (blue) waveform is generated at Point-A and the Rx (red) waveform is received at Point-Â of the basic radar architecture.

PSD(f) of a Pulse Radar Tx Signal

- the baseband pulse signal in time domain can be represented as

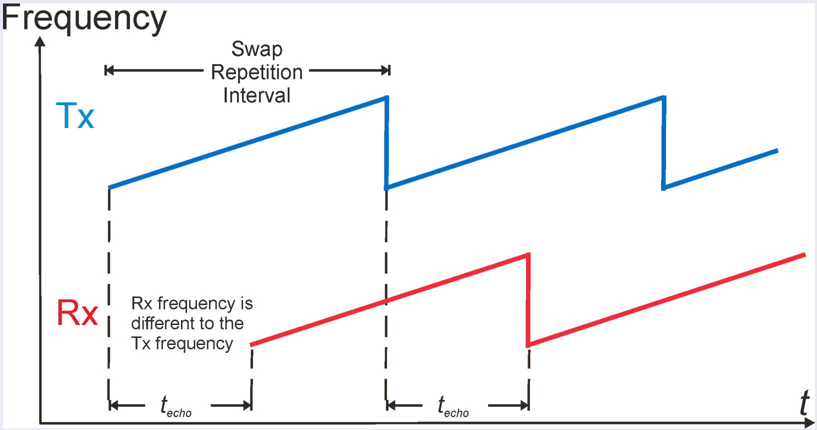
$$b(t) = \text{rep}_{\text{PRI}} \left\{ \text{rect}\left(\frac{t}{T_p} \right) \right\} \tag{2}$$

where T_p represents the pulse duration.

- Using the FT tables (see Appendix-B, Topic-0) we have:

For you ....

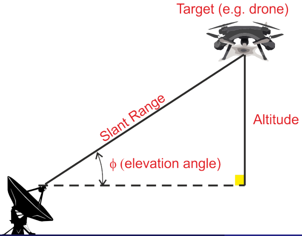
Definition (CW Radar)



- **Continuous wave (CW) radar**. This radar employs a continuous sine wave (continual radar transmission)
- It almost always uses the Doppler frequency shift for detecting moving targets or for measuring the relative velocity of a target (e.g. FMCW radar).
- This CW radar uses frequency modulation of the waveform to allow a range measurement.
- Separate transmit and receive antennas.

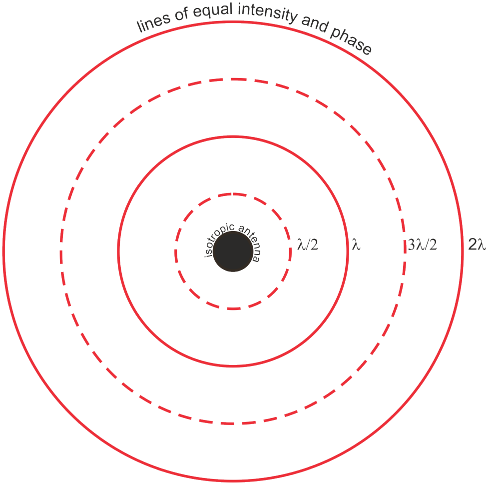
Pulse Radar versus CW Radar

Pulse Radar	**CW Radar**
Pulse signal	CW signal
Single antenna	Requires two antennas
Gives range and altitude	Range or altitude
Susceptible to jamming	more difficult to Jam but easily deceived
High and Low SNR	High SNR



N.B.:The range and the direction of the target determine its location. This is the job for many radar applications such as air traffic control.

Radiation Intensity - Isotropic Antenna



- The isotropic antenna radiates equally in all directions.
- The concentric rings indicate spheres of equal phase and radiation intensity

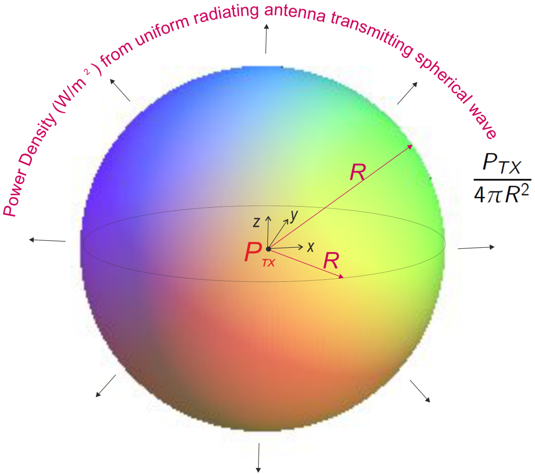
$$\text{Radiation intensity} = I = \frac{P_{Tx}}{4\pi} \tag{3}$$

in W/steradians

where P_{TX} = Radar's Tx-Power

Power Density from Radar Isotropic Antenna

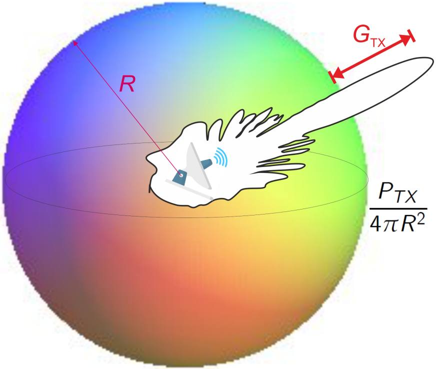
- P_{TX} = Radar's Tx-Power
- $4\pi R^2$ =sphere′s area at distance R from the radar[4]



[4] Radar's Tx-antenna = isotropic (i.e. uniformly radiating)

Power Density from Radar Directional Antenna

- Power Density from directional antenna $= \frac{P_{TX}}{4\pi R^2} G_{TX}$ in $\mathrm{W/m^2}$
- G_{TX} = gain[5]: this is the radiation intensity of the antenna in a given direction over that of an isotropic (uniformly radiating) source



[5]similarly for the Rx-antenna (G_{Rx}).

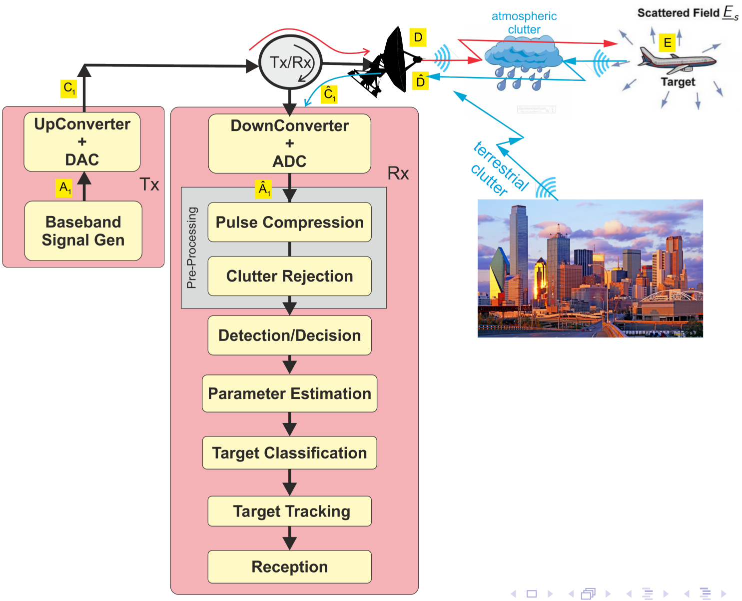
Received Signal Power:

$$
\begin{aligned}
P_{RX} &= \frac{P_{TX}}{4\pi R^2}.G_{TX}.RCS.\frac{1}{4\pi R^2}.A_e \\
&= \frac{P_{TX}}{4\pi R^2}.G_{TX}.RCS.\frac{1}{4\pi R^2}.\frac{G_{RX}\lambda^2}{4\pi} \\
&\Rightarrow \boxed{P_{RX} = \frac{P_{TX}.G_{TX}.G_{RX}.\lambda^2}{(4\pi)^3.R^4}.RCS}
\end{aligned}
\tag{4}
$$

N.B.:

- $G_{RX} = \frac{4\pi A_e}{\lambda^2} \Rightarrow A_e = \frac{G_{RX}.\lambda^2}{4\pi}$ where A_e = Rx-antenna's effective area
- $G_{RX} = G_{TX} = G$
- RCS = Radar Cross Section

Equivalent Block Diagram of a Radar System



Appendix-A: Radar Classification by Application

Although there is no single way to characterize a radar, here we do so by means of what might be the major feature (or application) that distinguishes one type of radar from another.

- **Weather (meteorological) observation radar**. Such radars detect, recognize, and measure precipitation rate, wind speed and direction, and observe other weather effects important for meteorological purposes. These may be special radars or another function of surveillance radars.
  - *Doppler weather radar*. This is a weather observation radar that employs the Doppler frequency shift caused by moving weather effects to determine the wind; the wind shear (when the wind blows in different directions), which can indicate a dangerous weather condition such as a tornado or a downburst of wind; as well as other meteorological effects
- **Moving target indication (MTI)**. This is a pulse radar that detects moving targets in clutter by using a low pulse repetition frequency (PRF) that usually has no range ambiguities. It does have ambiguities in the Doppler domain that result in so-called blind speeds.
- **Through-the-wall radar**. It is a radar system for detecting the presence and location of people in a closed space in case of no possibility of access.

- **Tracking radar**. This is a radar that provides the track, or trajectory, of a target. Tracking radars can be further classified to STT, ADT, TWS and phased array trackers, as described below:
  - *Single Target Tracker (STT)*. Tracks a single target at a data rate high enough to provide accurate tracking of a maneuvering target. A revisit time of 0.1 s (data rate of 10 measurements per second) might be "typical." It might employ the monopulse tracking method for accurate tracking information in the angle coordinate.
  - *Automatic detection and tracking (ADT)*. This is tracking performed by a surveillance radar. It can have a very large number of targets in track by using the measurements of target locations obtained over multiple scans of the antenna. Its data rate is not as high as the STT. Revisit times might range from one to 12 seconds, depending on the application.
  - *Track-while-scan (TWS)*. Usually a radar that provides surveillance over a narrow region of angle in one or two dimensions, so as to provide at a rapid update rate location information on all targets within a limited angular region of observation. It has been used in the past for ground-based radars that guide aircraft to a landing, in some types of weapon-control radars, and in some military airborne radars.
  - *Phased array tracker*. An electronically scanned phased array can (almost) "continuously" track more than one target at a high data rate. It can also simultaneously provide the lower data rate tracking of multiple targets similar to that performed by ADT.

- **Imaging radar**. This radar produces a two-dimensional image of a target or a scene, such as a portion of the surface of the earth and what is on it. These radars usually are on moving platforms.
  - *Sidelooking airborne radar (SLAR)*. This airborne sidelooking imaging radar provides high resolution in range and obtains suitable resolution in angle by using a narrow beamwidth antenna.
  - *Synthetic aperture radar (SAR)*. SAR is a coherent imaging radar on a moving vehicle that uses the phase information of the echo signal to obtain an image of a scene with high resolution in both range and cross-range. High range resolution is often obtained using pulse compression.
  - *Inverse synthetic aperture radar (ISAR)*. ISAR is a coherent imaging radar that uses high resolution in range and the relative motion of the target to obtain high resolution in the Doppler domain that allows resolution in the cross-range dimension to be obtained. It can be on a moving vehicle or it can be stationary.
- **Weapon control radar**. This name is usually applied to a single-target tracker used for defending against air attack.
- **Guidance radar**. This is usually a radar on a missile that allows the missile to "home in," or guide itself, to a target.

- **Target recognition radar**. In some cases, it might be important
  - to recognize the type of target being observed by radar (e.g., an automobile rather than a bird), or
  - to recognize the particular type of target (an automobile rather than a truck, or a starling rather than a sparrow), or
  - to recognize one class of target from another (a cruise ship rather than a tanker).

  When used for military purposes, it is usually called a noncooperative target recognition (NCTR) radar, as compared to a cooperative recognition system such as IFF (identification friend or foe), which is not a radar.

  When target recognition involves some part of the natural environment, the radar is usually known as a remote sensing (of the environment) radar.

- **Multifunction radar**. If each of the above radars were thought of as providing some radar function, then a multifunction radar is one designed to perform more than one such function-usually performing one function at a time on a time-shared basis.
- **There are many other ways to describe radars, including**
  - land and sea,
  - airborne and spaceborne,
  - mobile and transportable,
  - air-traffic control,
  - ground-penetrating
  - ultrawideband,
  - over the horizon (OTH),
  - instrumentation,
  - laser (or lidar),
  - by their application,
  - and so forth.

Appendix-B: Joint Electronics Type Designation Systems (JETDS)

Platform

First Letter

A – Airborne (installed and operatied in aircraft)
B – Underwater mobile, submarine
C – Air transportable (inactivated, do not use)
D – Pilotless carrier
F – Fixed
G – Ground, general ground use (includes two or more ground-type installations)
K – Amphibious
M – Ground, mobile (installed as operating unit in a vehicle which has no function other than transporting the equipment
P – Pack or portable (animal or man)
S – Water surface craft
T – Ground, transportable
U – General utility (includes two or more general installation classes, airborne, shipboard, and ground)
V – Ground, vehicular (installed in vehicle designed for functions other than carrying electronic equipment, etc., such as tanks)
W – Water surface and underwater

Equipment Type

Second Letter

A – Infrared, heat radiation
B – Pigeon
C – Carrier (wire)
D – Radiac
E – Nupac
F – Photographic
G – Telegraph or teletype
I – Interphone and public address
J – Electromechanical (not otherwise covered)
K – Telemetering
L – Countermeasures
M – Meteorological
N – Sound in air
P – Radar
Q – Sonar and underwater sound
R – Radio
S – Special types, magnetics, etc., or combinations of types
T – Telephone (wire)
V – Visual and visible light
W – Armament (peculiar to armament, not otherwise covered)
X – Facsimile or television
Y – Data processing

Application

Third Letter

A – Auxiliary assempblies (not complete operating sets used with or part of two or more sets or sets series
B – Bombing
C – Communications
D – Direction finder and/or reconnaissance
E – Ejection and/or release
G – Fire control or search light directing
H – Recording and/or reproducing (graphic meteorological and sound)
L – Searchlight control (inactivated, use G)
M – Maintenance and test assemblies (including tools)
N – Navigational aids (including altimeters, beacons, compasses, racons, depth sounding, approach, and landing)
P – Reproducing (inactivated, do not use)
Q – Special, or combination of purposes
R – Receiving, passive detecting
S – Detecting and/or range and bearing
T – Transmitting
W – Control
X – Identification and recognition