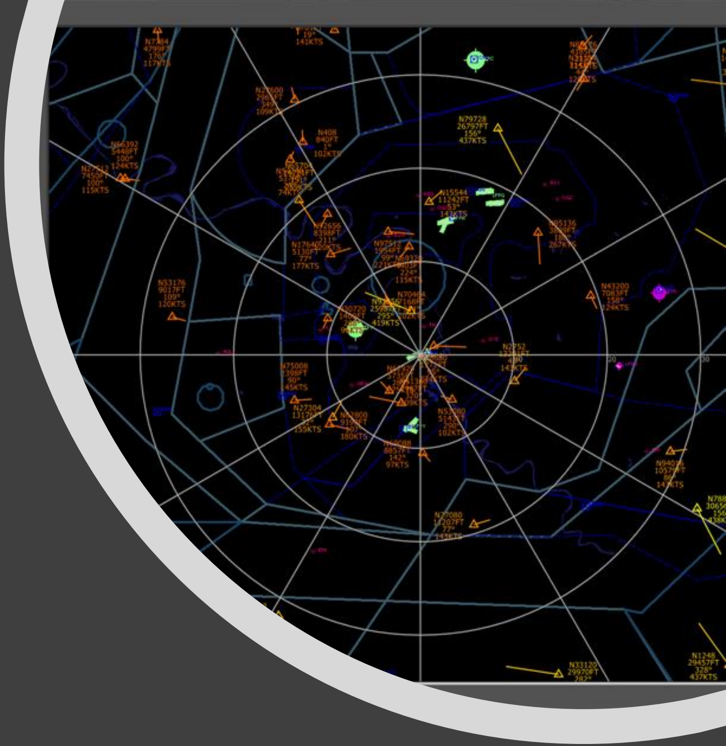
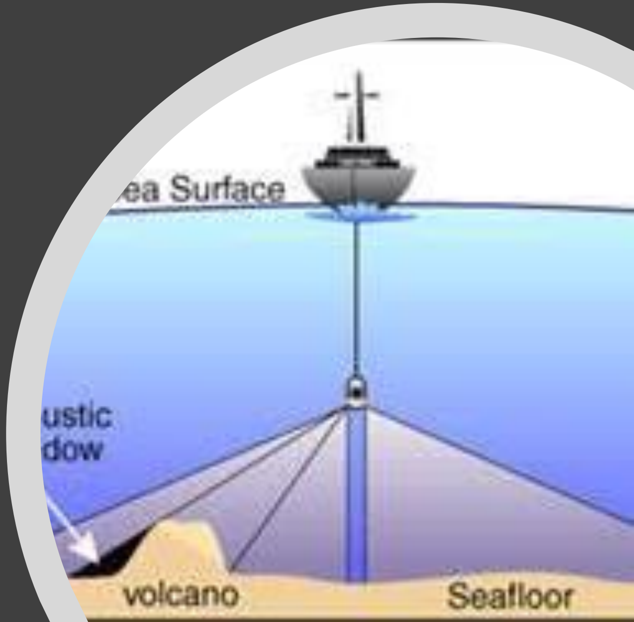
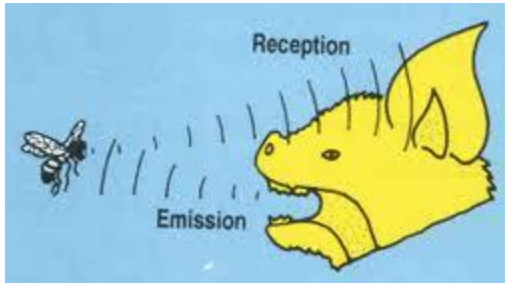


Aviónica & Espaciónica
Módulo 3: Radar Systems



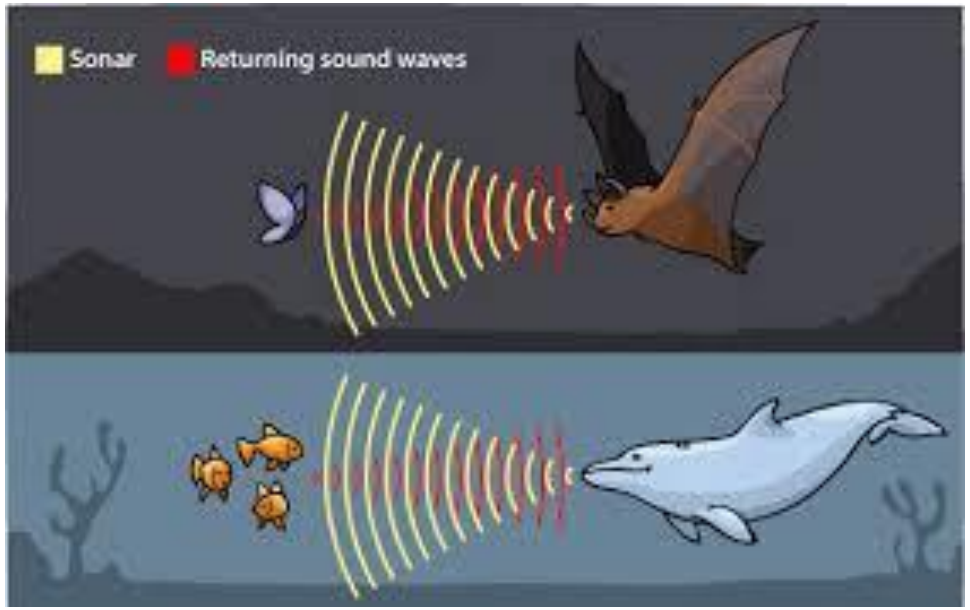
Radar Introduction



- Radar in nature
- Early days or radar, Evolution to our days and in the Future
- The basics
- Course outline

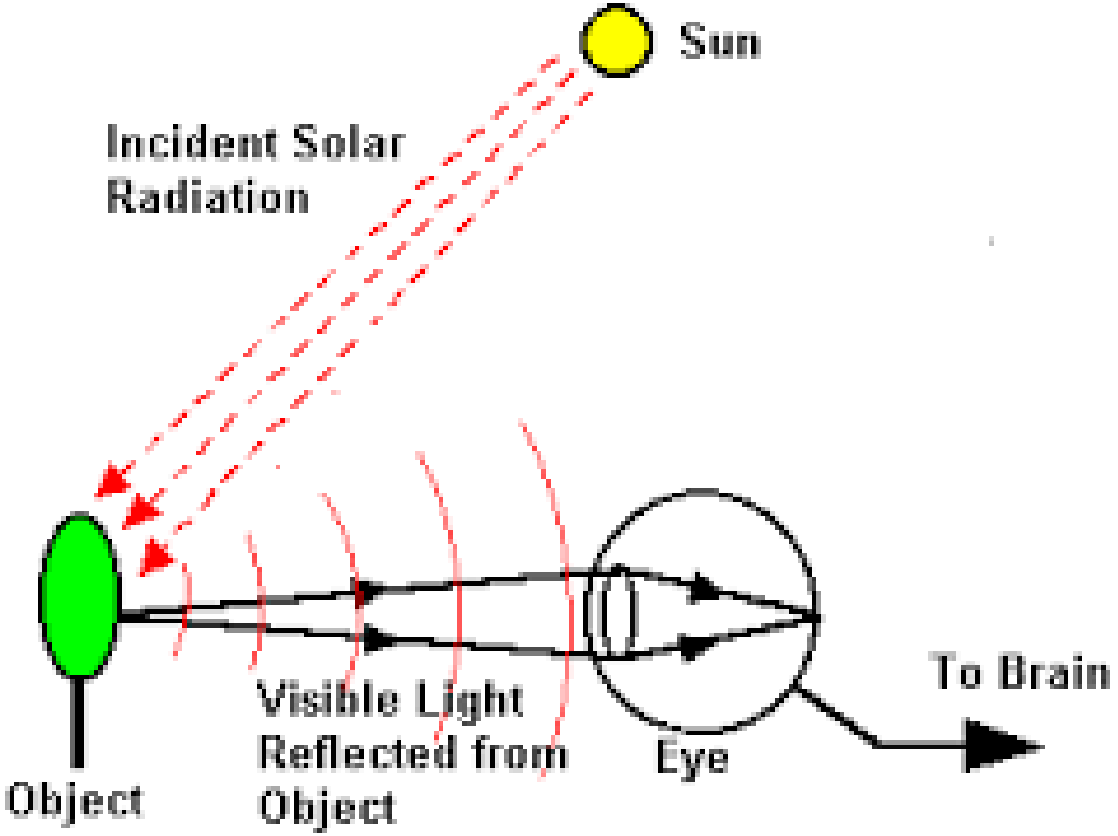
Sonar in nature

- Animal sensing



Radar in nature

- Is our vision a part of a radar system?



Brief History

1886
- **Heinrich Rudolf Hertz**
  - ondas de radio refletem-se em objetos

1904
- **Christian Hülsmeyer**
  - deteção de objetos metálicos distantes

1916
- **Robert Watson-Watt**
  - sistema de aviso de trovoadas

1922
- **Leo Crawford Young e Albert Hoyt Taylor**
  - sistema de deteção de navios

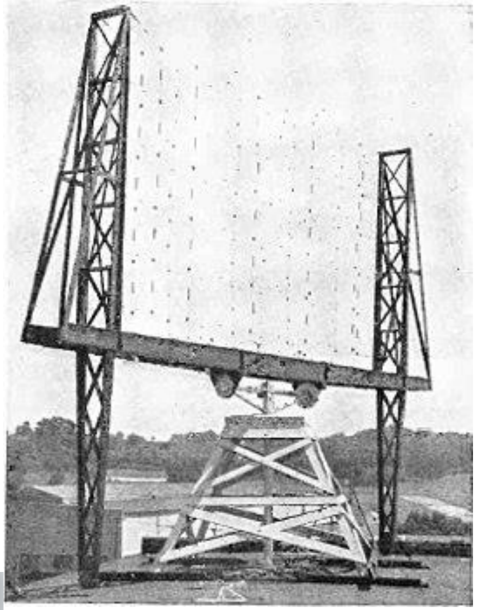
1930
- **Lawrence A. Hyland**
  - sistema de deteção de aviões

1934
- **Antes do início da Segunda Guerra Mundial**
  - Alemanha; Inglaterra; EUA; França; Itália; Japão; Holanda; URSS;




1934

- **Robert Morris Page**
  - first demonstration of a radar for target detection



1935

- **Robert Watson-Watt**
  - first functional prototype of a radar

1945

- **End of World War II**
  - Large surplus of RADAR

Army

Naavy

Air Traffic

Meteorology

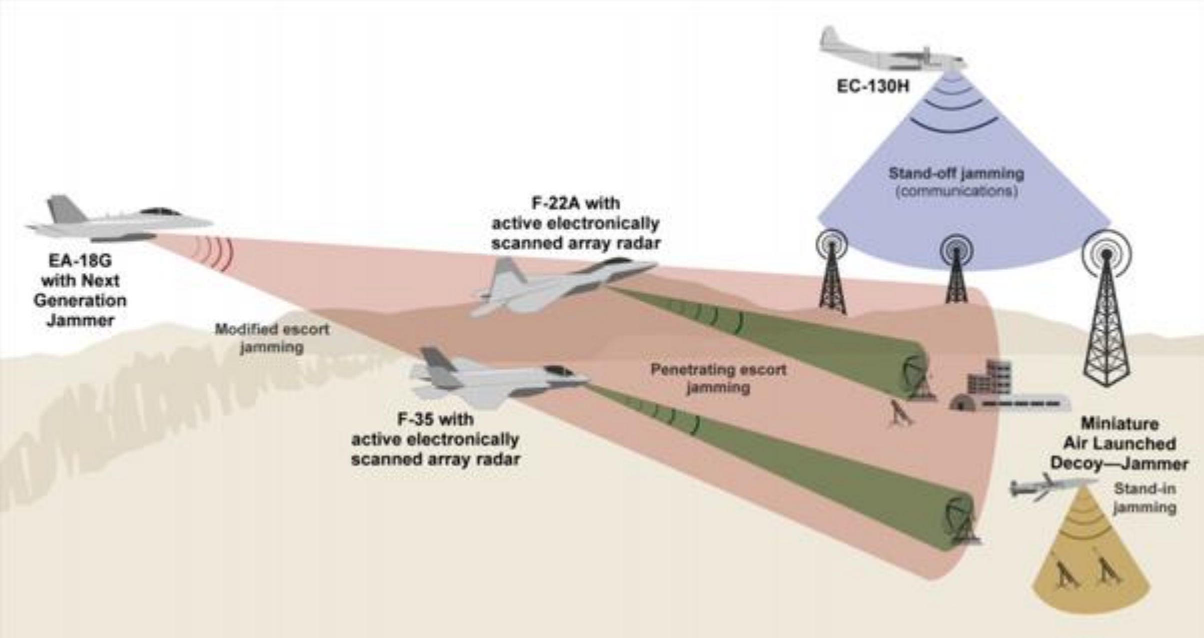
Scienc

Trafic

Militart Means of Sensing

	Optical/IR	Radar	Acoustic	Other
Applications	• Ground surveillance/ reconnaissance/ID • Laser targeting • Night vision • Space surveillance • Missile seekers	• Surveillance • Tracking • Fire control • Target ID/ discrimination • Ground surveillance/ reconnaissance • Ground mapping • Moving target detection • Air traffic control • Missile seekers	• Sonar • Blast detection • Troop movement detection	• Chem/Bio • Radiological
Attributes		• Long range • All-weather • Day/night • 3-space target location • Reasonably robust against countermeasures		

Surveillance and Defense radars



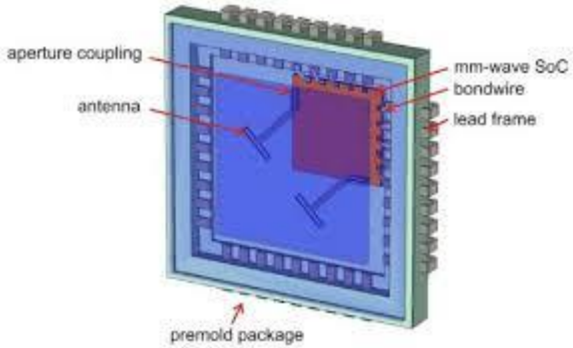
air traffic control radar

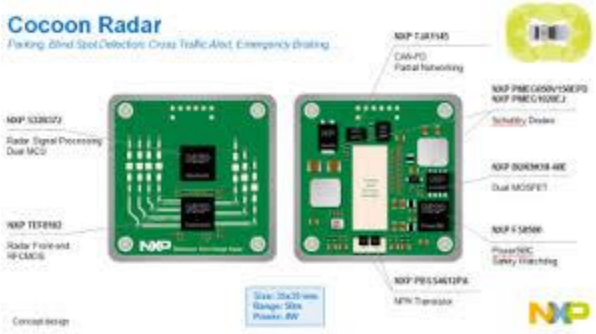
Instrumentation and Scientific radar

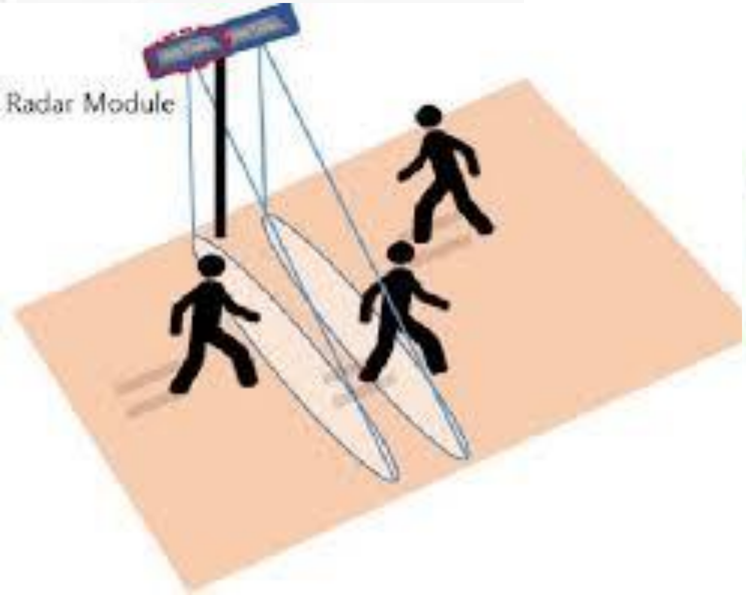





Current Radars







Airborne Radar Overview

Wave Reflection

A fight aircraft uses the same principle, although with electromagnetic waves (in the radio band) to detect distant threats (possible more than 100 km away), even if they are covered by clouds.

Despite these notable characteristics, the principles for detecting objects and their distance are simple, being based on the reflection of electromagnetic waves, rather than pressure waves used by bats.

New US Supersonic Jet

Airborne Radar Overview

Detect, Telemeter, Velocity, Imaging

1.1 wave reflection

In addition to **detecting** and measuring the **distance** to an object, it can also detect its approaching or moving speed **(radial velocity**), as well as the ability to distinguish static objects from moving objects.

Active Electronically Scanned Array - AESA RBE2 radar

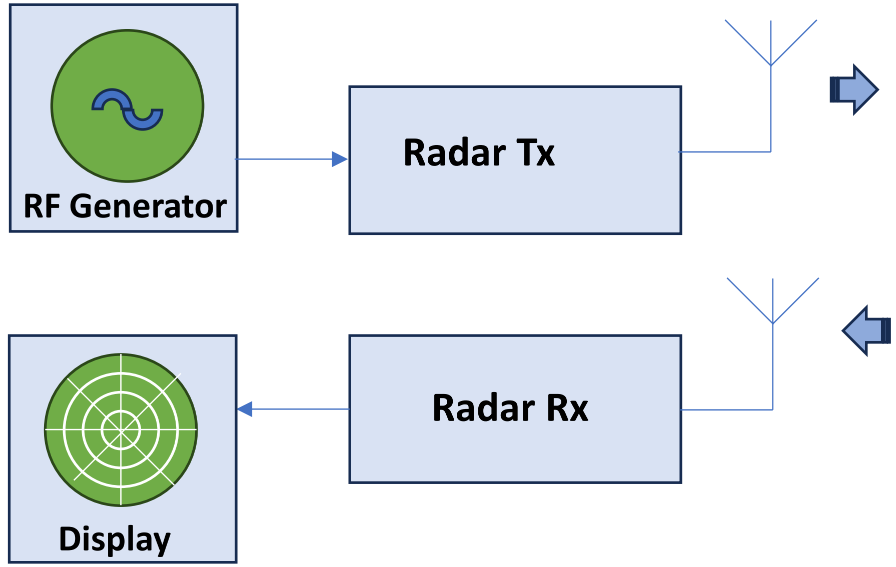
Depending on the desired application, it is possible to filter fixed objects on the ground, such as trees, buildings, etc., or produce High Definition images of the terrain using a technique known as **SAR** (Synthetic Aperture Radar).

At these radio frequencies the atmosphere is completely transparent, making it possible to see objects through the haze fog or Claude night.

Airborne Radar Overview

Radio Detection

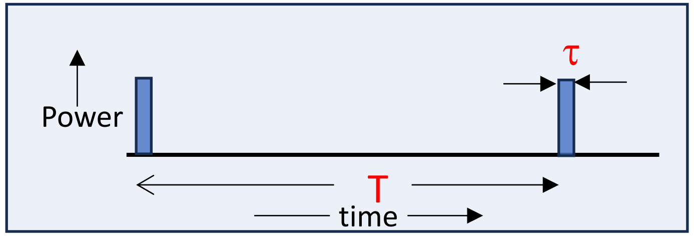
In the early days, radars consisted of 5 elementary blocks visible in the figure.



Currently, in most cases, the transmitting and receiving antenna is the same, and powerful data processing systems are present, mainly in the receiver.
Through this antenna, with possible 360° rotation, it emits and receives the reflection, allowing an obstacle to be indicated on a screen, depending on distance and angle.
To avoid interference problems between the transmitter and receiver, radio waves are normally transmitted in pulses and the receiver is turned off during Transmission and the transmitter is turned off during reception. To switch the emission and reception directions on the antenna, a circulator is used.

Airborne Radar Overview

Radio Detection



The rate at which the pulses are transmitted is called Pulse Repetition Frequency (PRF)
The time between the pulse transmissions is Pulse Repetition Interval (PRI).
So, PRI = 1/PRF.

The term target is used to refer to any element that is intended to be detected, an airplane, a boat, a vehicle, a structure on the ground, anything of the sort.

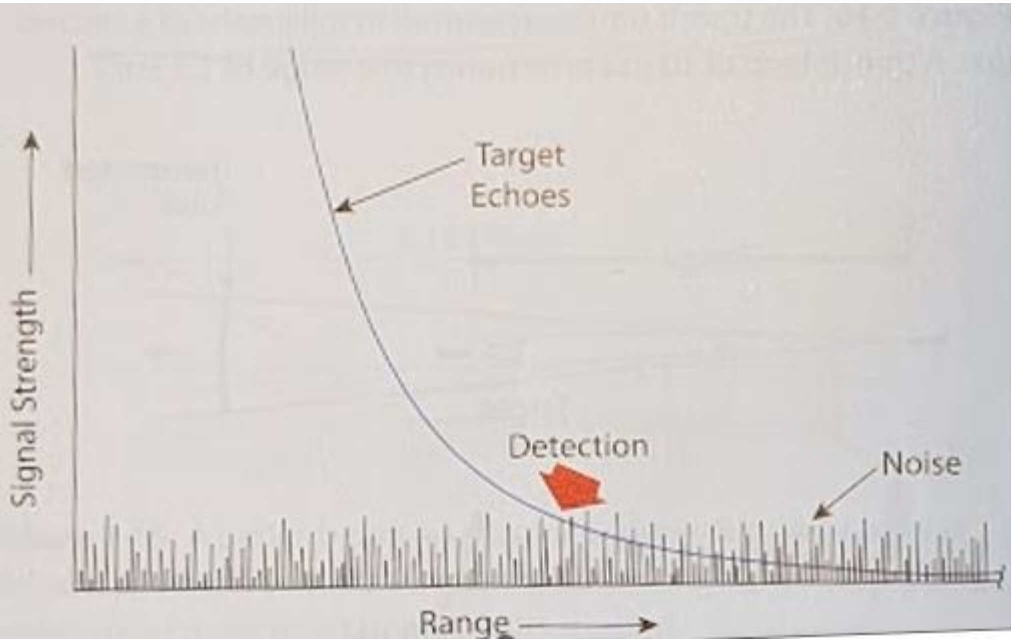
Like light, the radio waves used in most aircraft radars travel in straight lines, so a radar system should be in line of sight to receive an echo from a target.

Airborne Radar Overview

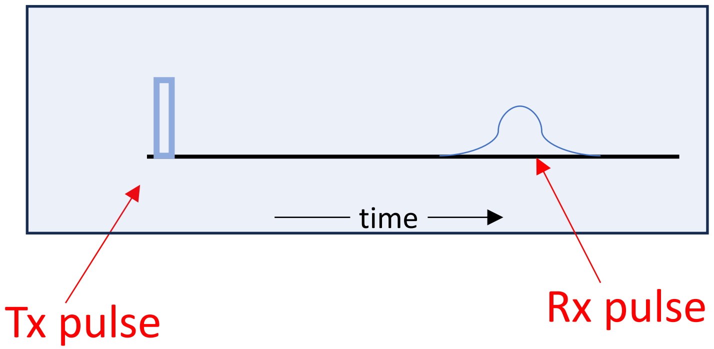
2 Radio Detection

The Target will only be detected if the reflected signal is strong enough to overcome the noise generated in the receiver and the signal echoed by the terrain (Ground clutter).
The strength of a target's echoes is inversely proportional to the target's range raised to the fourth power ($1/R^4$).
The distance at which the target is detected depends on several factors, including:

- The power of the transmitted wave
- the fraction of time during of the pulse
- Antenna gain
- the reflection characteristics of the target
- The interval in which the target is radiated
- The number of scans in which the target appears
- the frequency of radio waves)
- the intensity of background noise or clutter



Airborne Radar Overview



Determining Target Position

Measurig Range

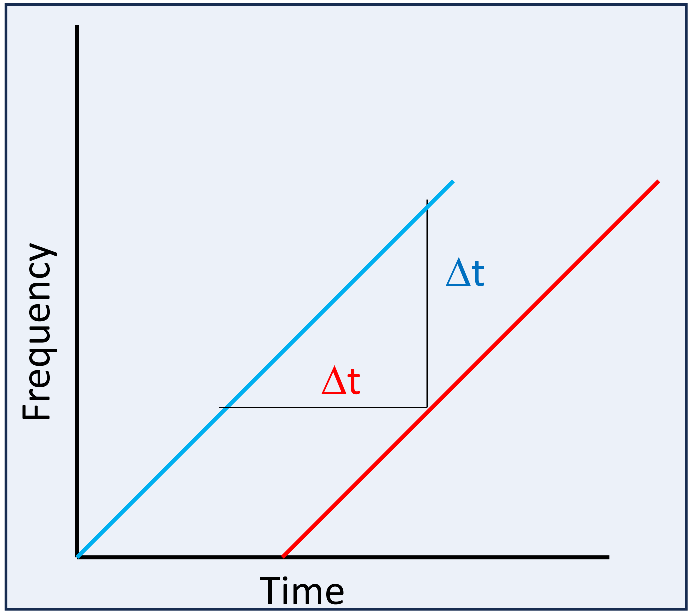
The distance can be determined by measuring the time it takes for the wave to reach the target and return. Radio waves travel at the speed of light 3E08 km/s.

A round-trip transit time of 1 milliseconds corresponds to a range of 150 km.

The transit time is measured by observing the time delay between transmission of a pulse and reception of the echo of that pulse.

The Rx Pulse of two closely spaced in range targets may overlapping. This could be avoided by reducing the width of the pulse. However, when the pulse is reduced the range of distances also becomes smaller. A technique known as echo compression helps resolve this issue.

Airborne Radar Overview

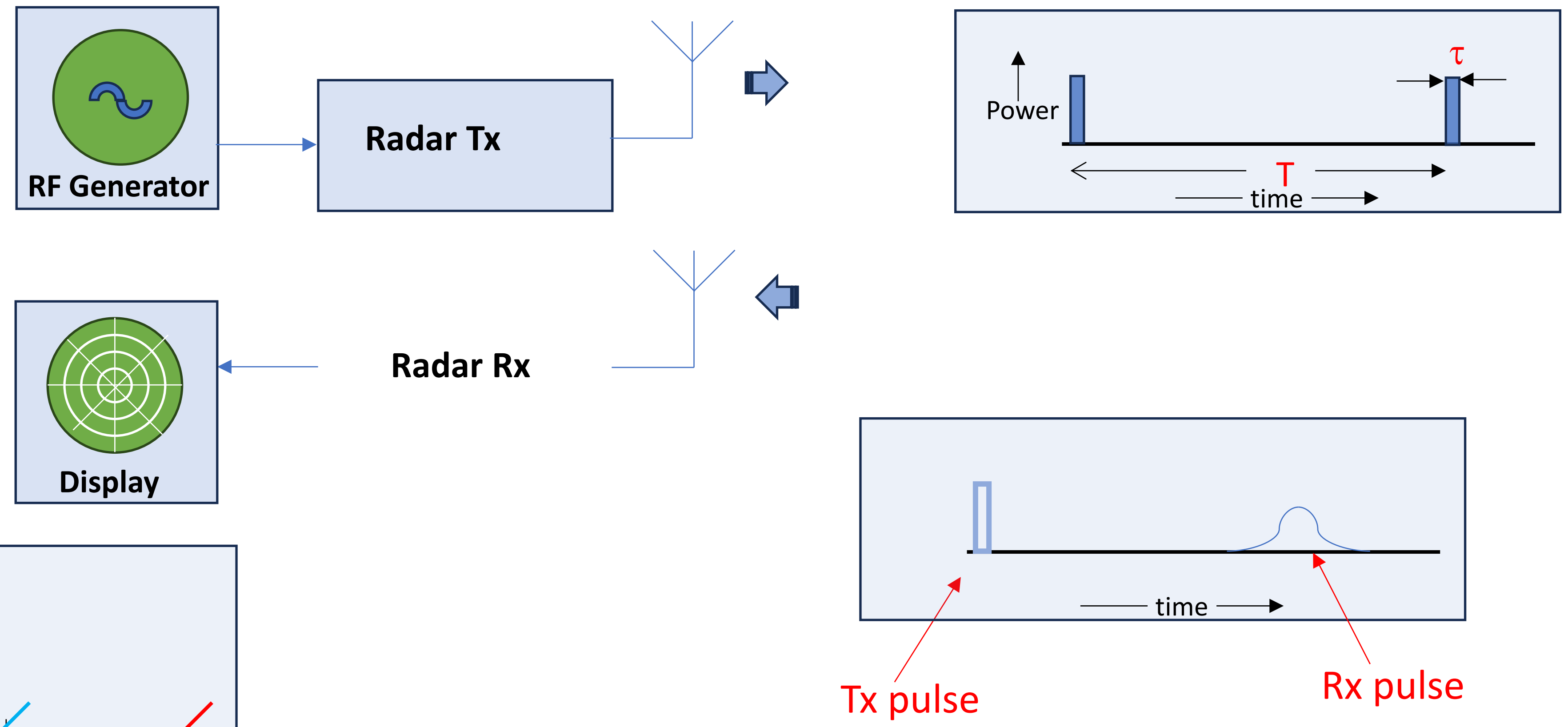


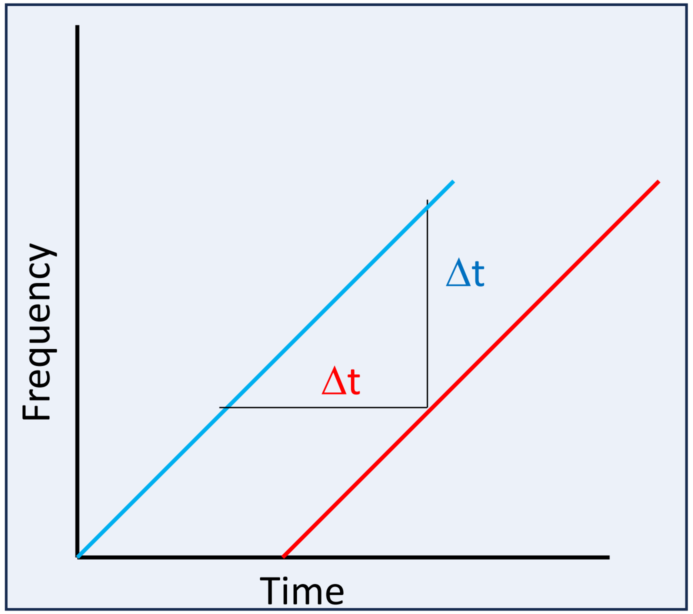
Determining Target Position

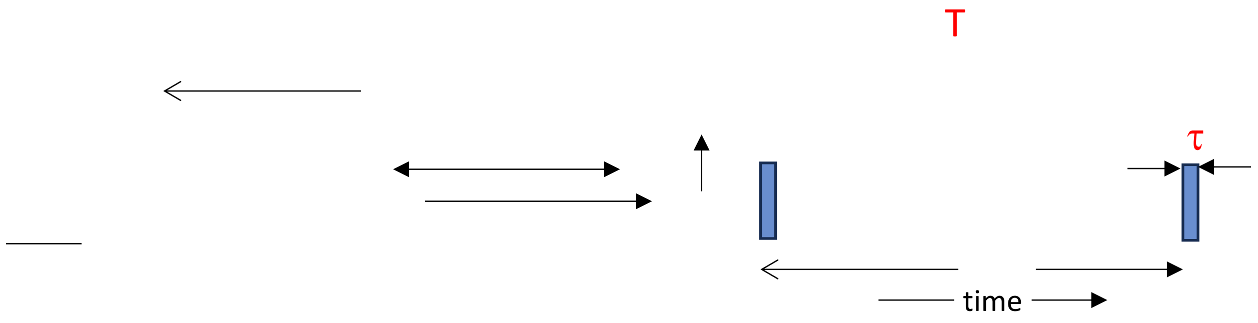
Measurig Range

Primitive continuous wave (CW) radars measured the distance to the target through frequency modulation (CW-FM), varying the frequency as a function of time.

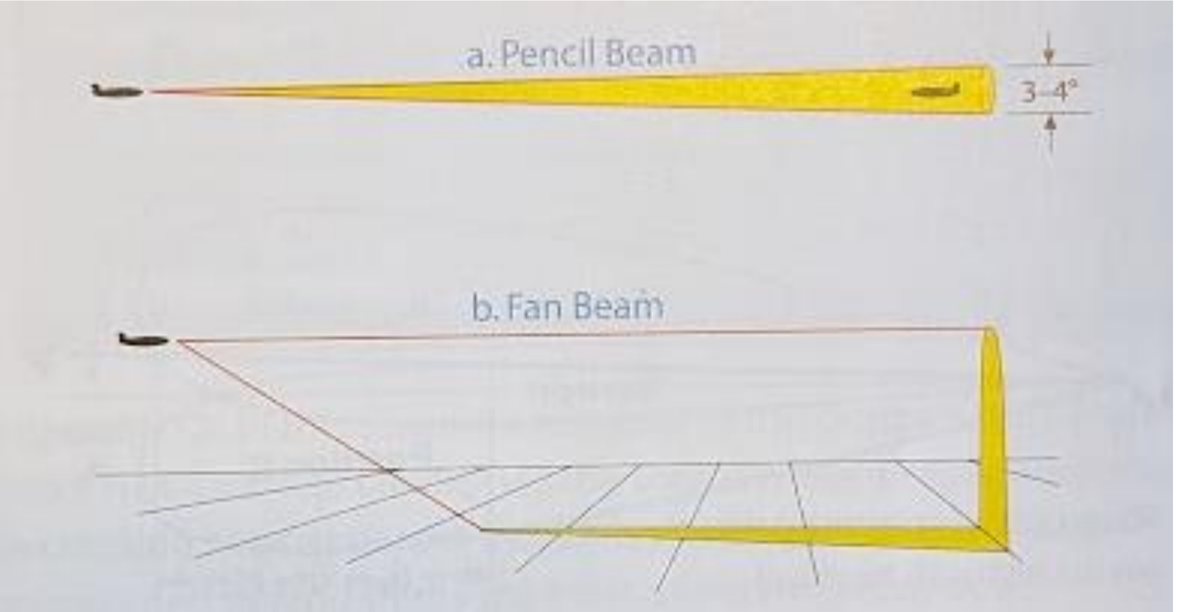
The distance to the target is determined through the delay between waves.


RF Generator
Radar Tx
Radar Rx
Display
Power
τ
T
time
time
Tx pulse
Rx pulse


Frequency
Time
Δt
Δt


T
τ
time

Airborne Radar Overview

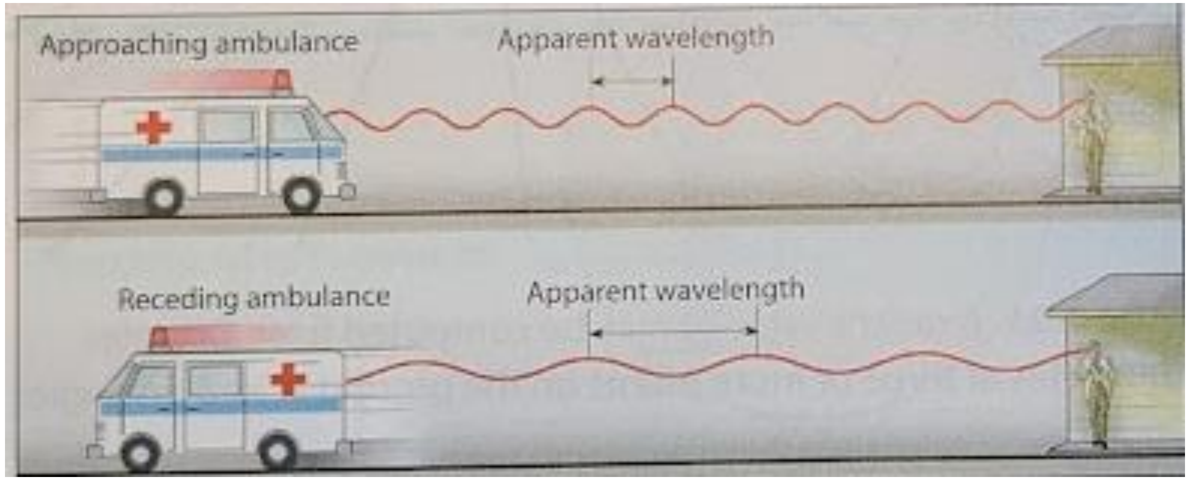


Determining Target Position
Measuring Direction

In most airborne radars, direction is measured in terms of the angle between the line of sight to the target and a reference direction, such as north, or the longitudinal reference axis of the aircraft's fuselage. This angle is usually resolved into a horizontal component called the azimuth and a vertical component called the elevation.

Where both azimuth and elevation are required, the beam is given a more or less conical shape, called a pencil beam. Where only azimuth is required, as for long-range surveillance, mapping, or detecting targets on the ground, the beam may be given a fan shape.

Airborne Radar Overview



The Doppler Effect

A classic example of the Doppler effect is the change in sound of an emergency vehicle. As the vehicle approaches the pitch is increased but as it passes and moves away the pitch is reduced.

Because of the Doppler effect, the radio frequency of an echo received from an object is shifted relative to the frequency of the transmitter in proportion to the object's range rate.

Airborne Radar Overview

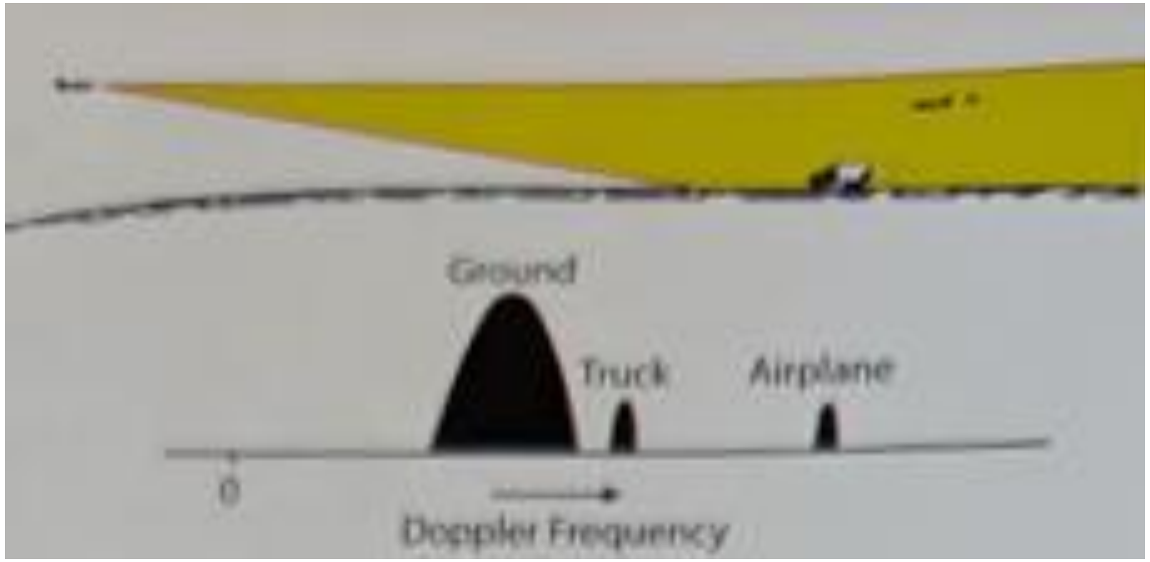
The Doppler Effect

Since the range-rates encountered by radar are a minuscule fraction of the speed of radio waves (i.e., the speed of light), the Doppler shift (or Doppler frequency) of even the most rapidly closing target is so extremely slight that it shows up simply as a pulse-to-pulse shift in the radio frequency phase of the target's echoes.

Like a laser, radar is a coherent sensor, and this allows the phase shift imparted on an echo to be measured. This phase shift is measured by cutting the radar's transmitted pulses from the same position on a continuous signal. The phase of the echo is referenced to the phase of the transmitted pulse, which allows phase changes due to target motion to be measured for only each transmitted pulse.

The rate of change of phase from a sequence of pulses provides a direct measure of the Doppler frequency or radial velocity of a target.

Airborne Radar Overview



The Doppler Effect

By sensing Doppler frequencies, a radar system can differentiate echoes of moving targets from clutter. This is called moving target indication (MTI). Often MTI is separated into airborne moving target indication (AMTI) and ground moving target indication (GMTI).

MTI is of inestimable value in airborne radars that must operate at low altitudes or look down in search of aircraft flying below them.
The antenna beam commonly intercepts the ground at the target's range. Without MTI, the target echoes would be lost in the ground return, as may be seen in figure.

MTI can also be immeasurably important when aircraft must fly at higher altitudes and look straight ahead. Even then, the lower edge of the beam may intercept the ground at long ranges.

Airborne Radar Overview

BOOKs

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