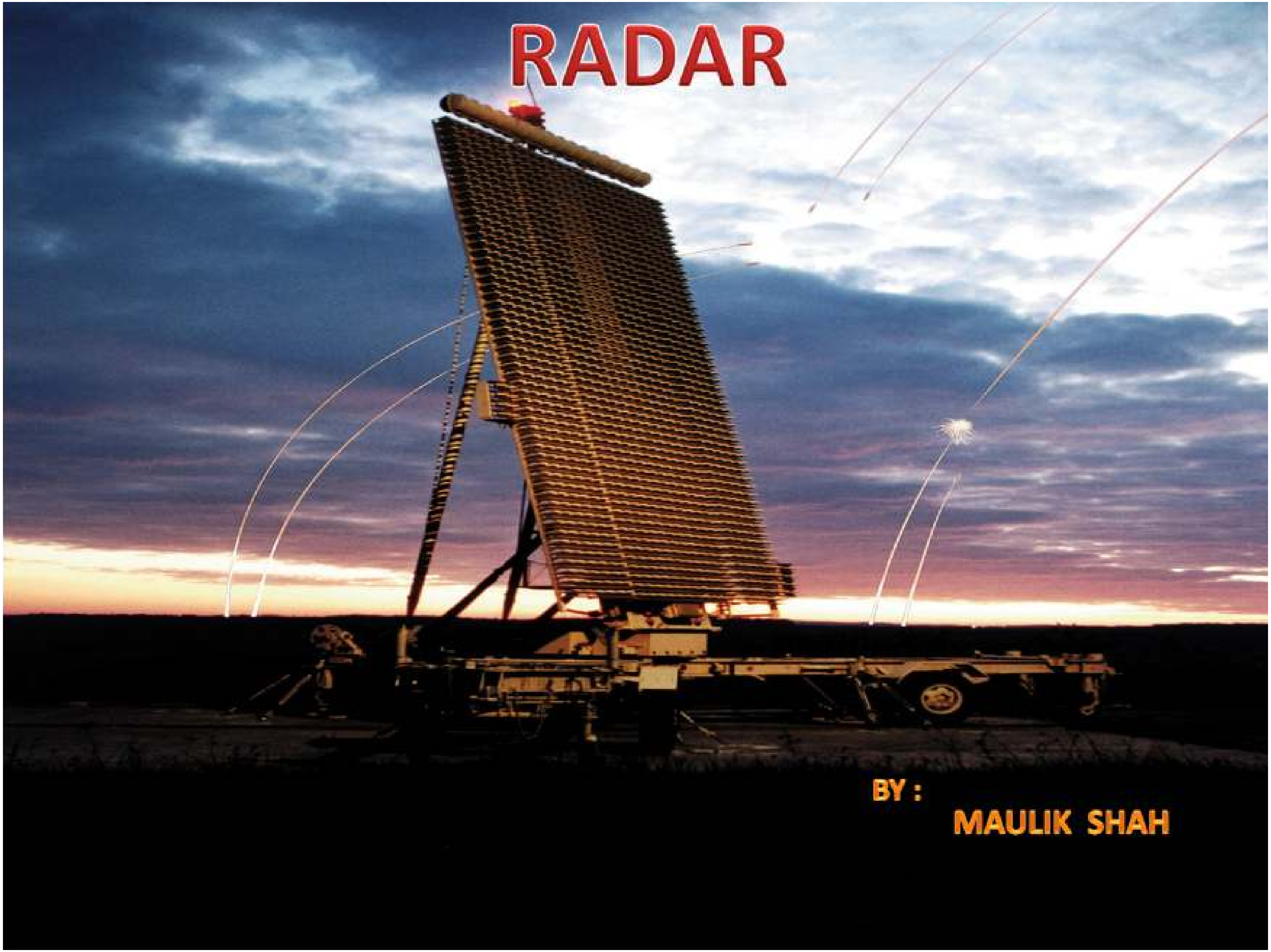
RADAR



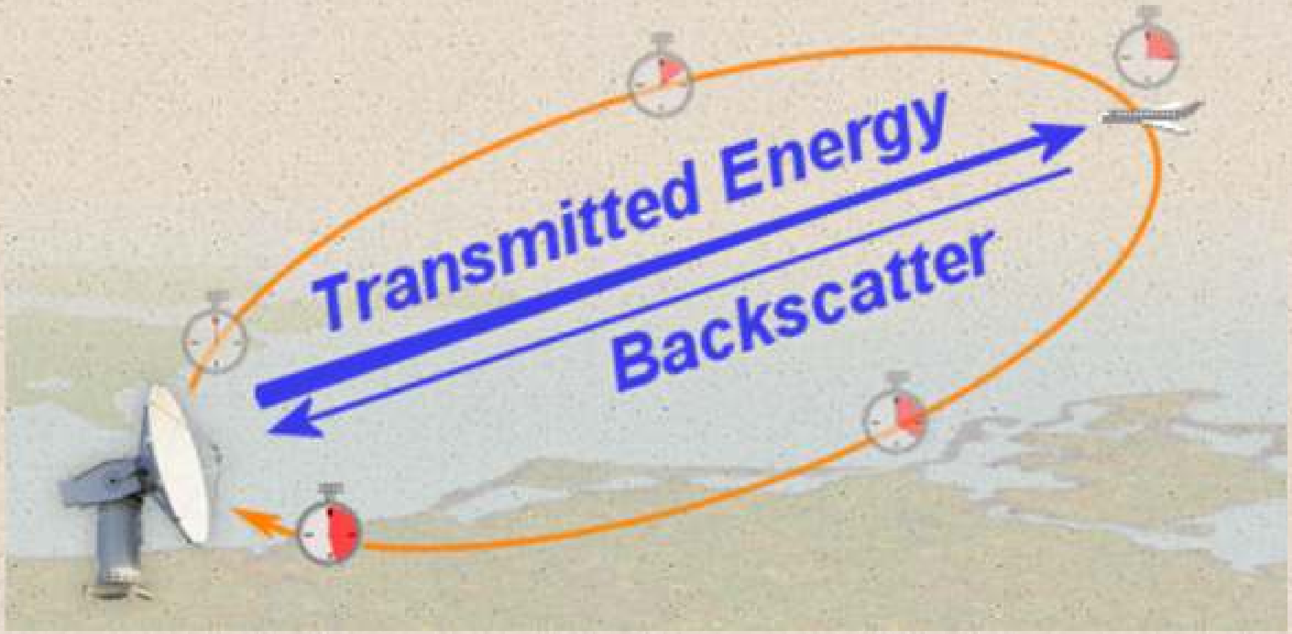
BY :
MAULIK SHAH

What is RADAR ?

- **RADAR** is an acronym for **RA**dio **D**etection **A**nd **R**anging.

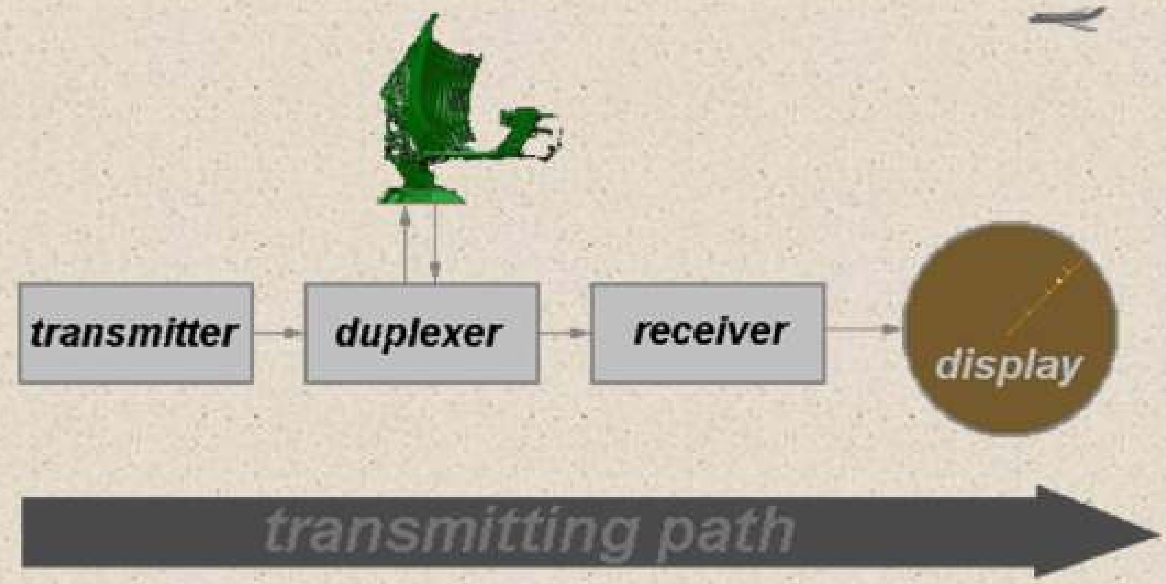
- RADAR is an object detection system that uses electromagnetic waves to identify the range,altitude,direction or speed of both moving and fixed objects such as aircrafts,ships,motor vehicles,weather formations and terrain.

Principle of Operation



- Reflection of electromagnetic waves
- Measurement of running time of transmitted pulses

Radar Basic Principles



- Transmitter
- Duplexer
- Receiver
- Radar Antenna
- Indicator

Principle of Measurement

- Distance Determination.
- Direction Determination.
- Elevation Angle.
- Range Resolution.

Distance Determination

- The distance is determined from the running time of the high frequency transmitted signal and the propagation c_0. The actual range of a target from the radar is known as **slant range**. Slant range is the line of sight distance between the radar and the object illuminated. Since the waves travel to a target and back, the round trip time is dividing by two in order to obtain the time the wave took to reach the target. Therefore the following formula arises for the slant range:

  $R = c_0 \cdot t/2$ where: c_0 = speed of light = $3 \cdot 10^8\ ^m/_s$

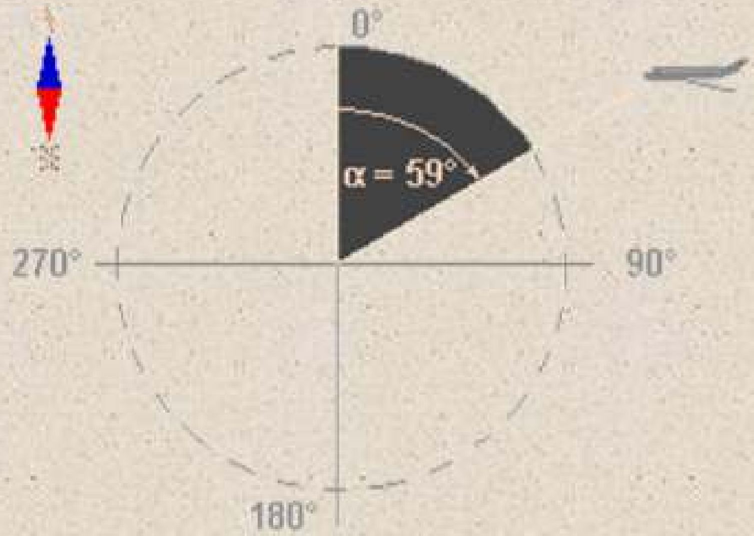
  t = measured running time [s]

  R = slant range antenna - aim [m]

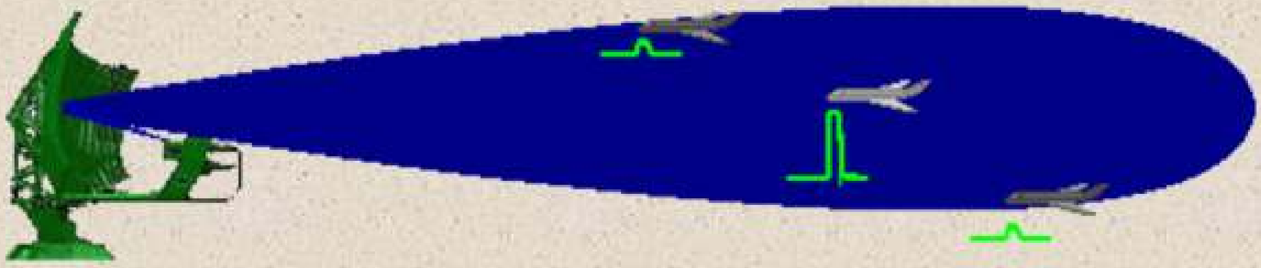
  The distances are expressed in kilometers or nautical miles
  (1 NM =1.852 km).

Direction Determination

- The angular determination of the target is determined by the directivity of the antenna. Directivity, sometimes known as the directive gain, is the ability of the antenna to concentrate the transmitted energy in a particular direction. By measuring the direction in which the antenna is pointing when the echo is received, both the azimuth and elevation angles from the radar to the object or target can be determined.

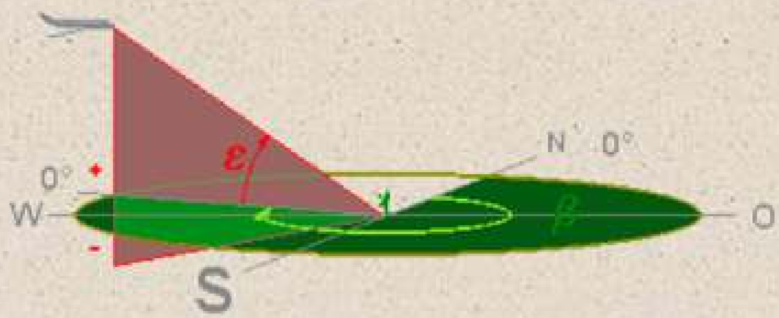


Direction Determination



- The antennas of most radar systems are designed to radiate energy in a one-directional lobe or beam that can be moved in bearing simply by moving the antenna. The point of maximum echo, determined by the detection circuitry or visually by the operator, is when the beam points direct at the target. Weapons-control and guidance radar systems are positioned to the point of maximum signal return and maintained at that position either manually or by automatic tracking circuits.

Elevation Angle



- Altitude or height-finding search radars use a very narrow beam in the vertical plane. The beam is mechanically or electronically scanned in elevation to pinpoint targets.

- The elevation angle is the angle between the horizontal plane and the line of sight, measured in the vertical plane. The Greek letter Epsilon (ε) describes the elevation angle. The elevation angle is positive above the horizon (0° elevation angle), but negative below the horizon.

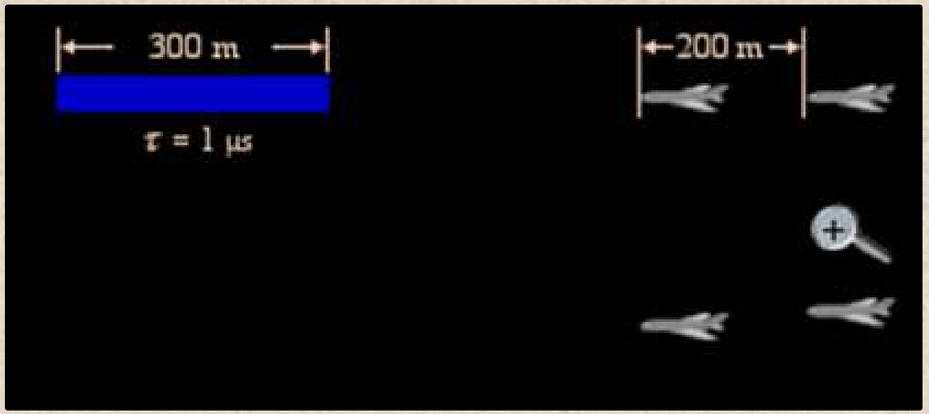
Range Resolution

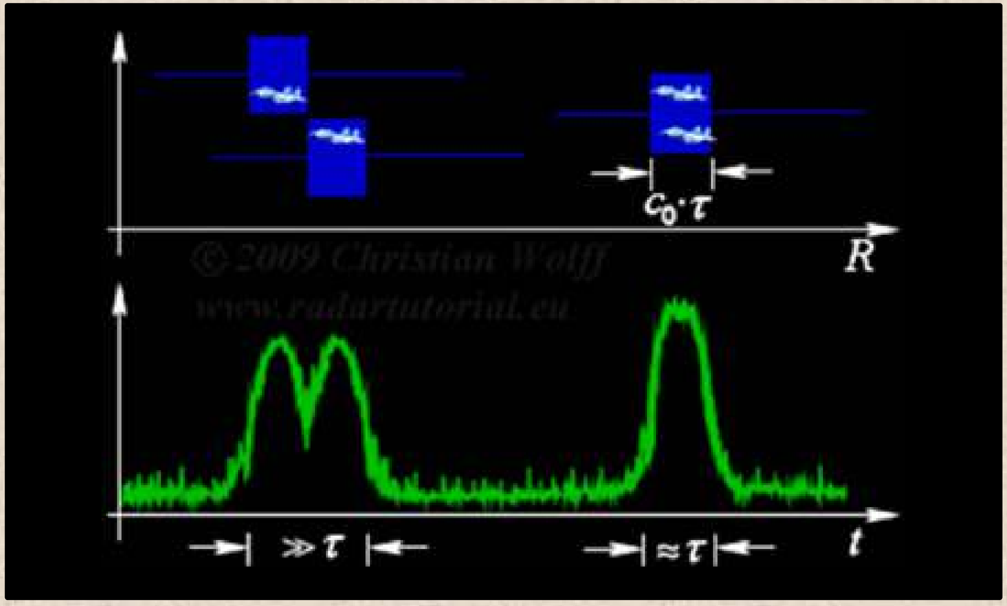
- Range resolution is the ability of a radar system to distinguish between two or more targets on the same bearing but at different ranges. The degree of range resolution depends on the width of the transmitted pulse, the types and sizes of targets, and the efficiency of the receiver and indicator. Pulse width is the primary factor in range resolution. A well-designed radar system, with all other factors at maximum efficiency, should be able to distinguish targets separated by one-half the pulse width time τ. Therefore, the theoretical range resolution cell of a radar system can be calculated from the following equation:

  $\mathbf{S_r \geq c_0 \cdot \tau / 2}$ where: c_0 = speed of light = $3 \cdot 10^8\ {}^{m}/_{s}$

  τ = pulse width time

Range Resolution

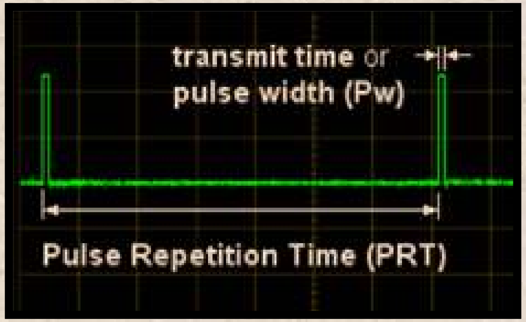




Radar Timing

- **Pulse Repetition Frequency.**
- **Duty Cycle.**
- **Dwell Time.**

Pulse Repetition Frequency

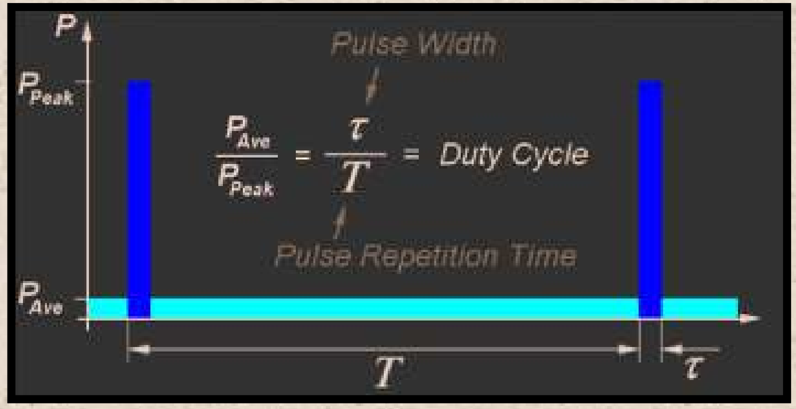


- The Pulse Repetition Frequency (PRF) of the radar system is the number of pulses that are transmitted per second.

- Radar systems radiate each pulse at the carrier frequency during transmit time (or Pulse Width PW), wait for returning echoes during listening or rest time, and then radiate the next pulse..The time between the beginning of one pulse and the start of the next pulse is called pulse-repetition time (prt) and is equal to the reciprocal of prf as follows:

PRT = 1/PRF

Duty Cycle



- The product of pulse width (pw) and pulse-repetition frequency (prf) is called the **duty cycle** of a radar system.

- Duty cycle is the fraction of time that a system is in an "active" state. In particular, it is used in the following contexts: Duty cycle is the proportion of time during which a component, device, or system is operated.

Dwell Time

- The time that an antenna beam spends on a target is called dwell time T_D.
  The dwell time of a 2D–search radar depends predominantly on:
  1) the antennas horizontally beam width Θ_{AZ} and
  2) the turn speed n of the antenna (rotations per minute).
  The dwell time can be calculated using the following equation:

$$\mathbf{T_D = (\Theta_{AZ} \cdot 60)/(360° \cdot n)} \qquad \text{; in [seconds]}$$

Radar Equation

- The power P_r returning to the receiving antenna is given by the radar equation:

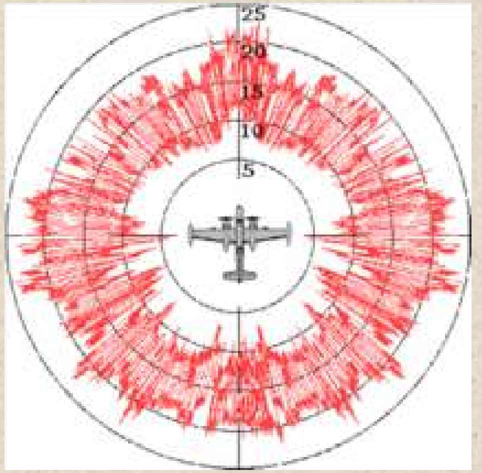
$$P_r = \frac{P_t G_t A_r \sigma F^4}{(4\pi)^2 R_t^2 R_r^2}$$

where
P_t = transmitter power
G_t = gain of the transmitting antenna
A_r = effective aperture (area) of the receiving antenna
σ = radar cross section, or scattering coefficient of the target
F = pattern propagation factor
R_t = distance from the transmitter to the target
R_r = distance from the target to the receiver.

Radar Cross Section

- The size and ability of a target to reflect radar energy can be summarized into a single term, σ, known as the radar cross-section, which has units of m^2. If absolutely all of the incident radar energy on the target were reflected equally in all directions, then the radar cross section would be equal to the target's cross-sectional area as seen by the transmitter. In practice, some energy is absorbed and the reflected energy is not distributed equally in all directions. Therefore, the radar cross-section is quite difficult to estimate and is normally determined by measurement.

- The target radar cross sectional area depends on:
  1) The airplane's physical geometry and exterior features,
  2) The direction of the illuminating radar,
  3) The radar transmitters frequency,
  4) The used material types.



Interference

- **Noise.**
- **Clutter.**
- **Jamming.**

Noise

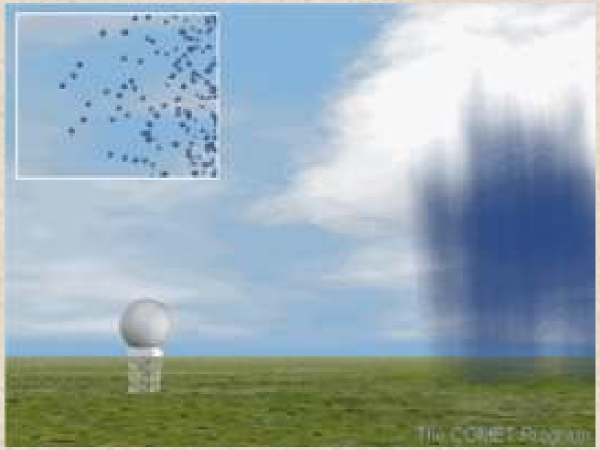
- Signal noise is an internal source of random variations in the signal, which is generated by all electronic components. Noise typically appears as random variations superimposed on the desired echo signal received in the radar receiver. The lower the power of the desired signal, the more difficult it is to discern it from the noise (similar to trying to hear a whisper while standing near a busy road).

- Noise figure is a measure of the noise produced by a receiver compared to an ideal receiver, and this needs to be minimized.

- Noise is also generated by external sources, most importantly the natural thermal radiation of the background scene surrounding the target of interest.

- There will be also flicker noise due to electrons transit, but depending on 1/f, will be much lower than thermal noise when the frequency is high.

Clutter



- Clutter refers to radio frequency (RF) echoes returned from targets which are uninteresting to the radar operators. Such targets include natural objects such as ground, sea, precipitation (such as rain, snow or hail), sand storms, animals (especially birds), atmospheric turbulence, and other atmospheric effects, such as ionosphere reflections, meteor trails, and three body scatter spike. Clutter may also be returned from man-made objects such as buildings and, intentionally, by radar countermeasures such as chaff.

- Clutter may also originate from multipath echoes from valid targets due to ground reflection, atmospheric ducting or ionospheric reflection/refraction.

Clutter

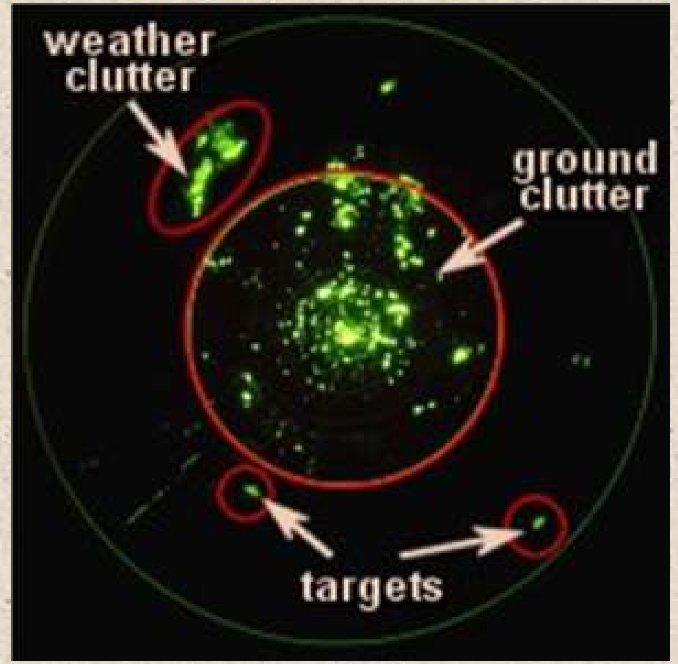
- The basic types of clutter can be summarized as follows:

1) **Surface Clutter** – Ground or sea returns are typical surface clutter. Returns from geographical land masses are generally stationary, however, the effect of wind on trees etc means that the target can introduce a Doppler Shift to the radar return. This Doppler shift is an important method of removing unwanted signals in the signal processing part of a radar system. Clutter returned from the sea generally also has movement associated with the waves.

2) **Volume Clutter** – Weather or chaff are typical volume clutter. In the air, the most significant problem is weather clutter. This can be produced from rain or snow and can have a significant Doppler content.

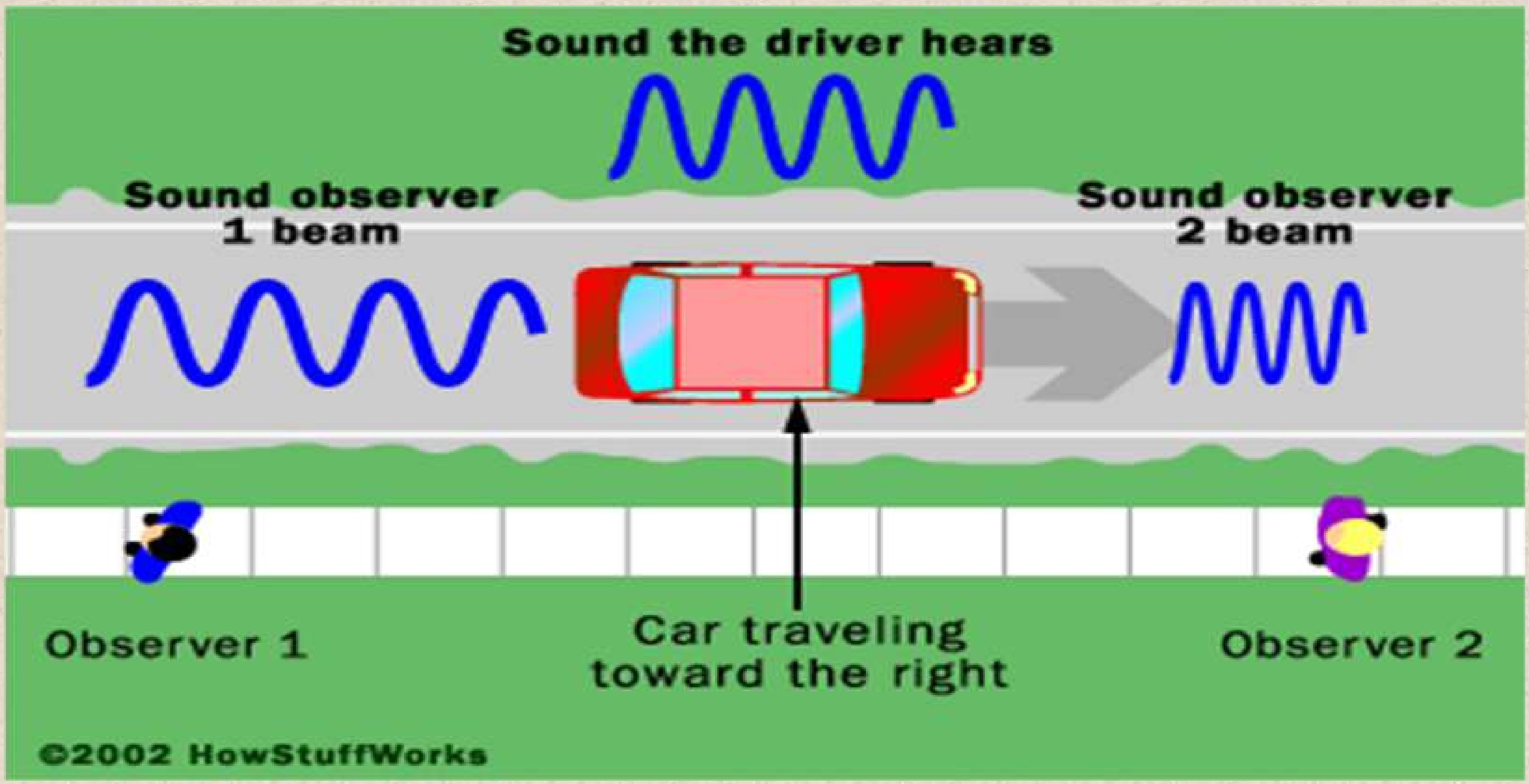
Clutter

3) **Point Clutter** – Birds, windmills and individual tall buildings are typical point clutter and are not extended in nature. Moving point clutter is sometimes described as angels. Birds and insects produce clutter, which can be very difficult to remove because the characteristics are very much like aircraft.

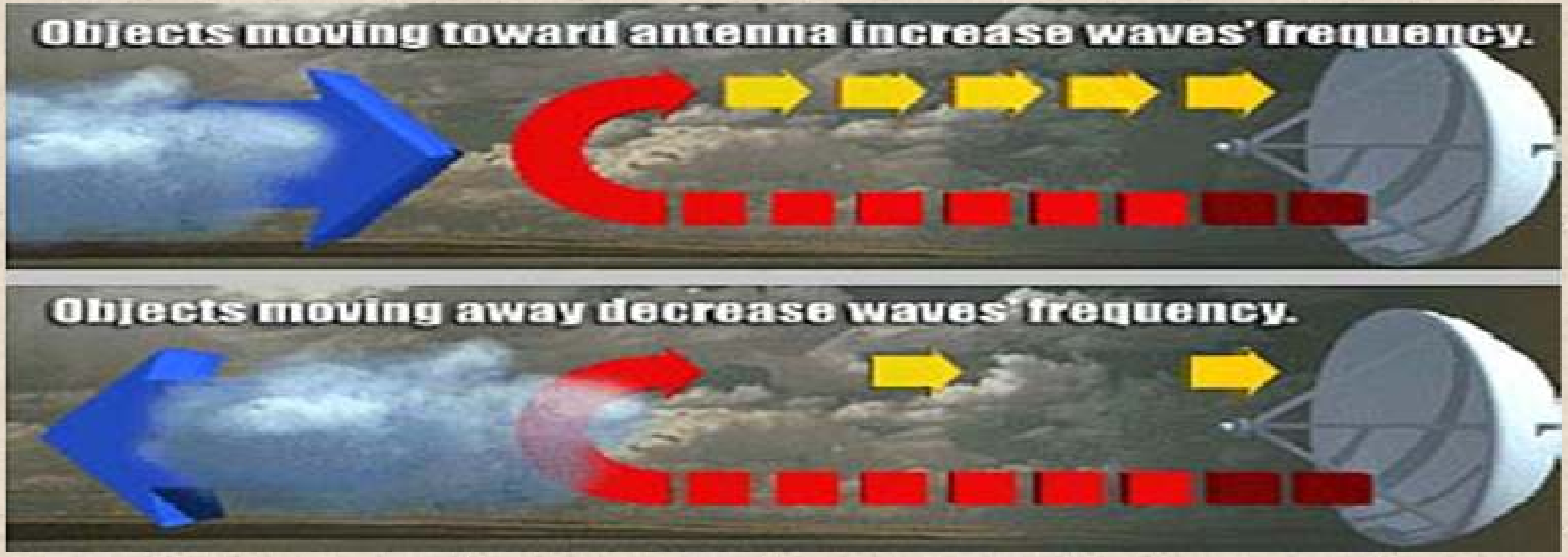


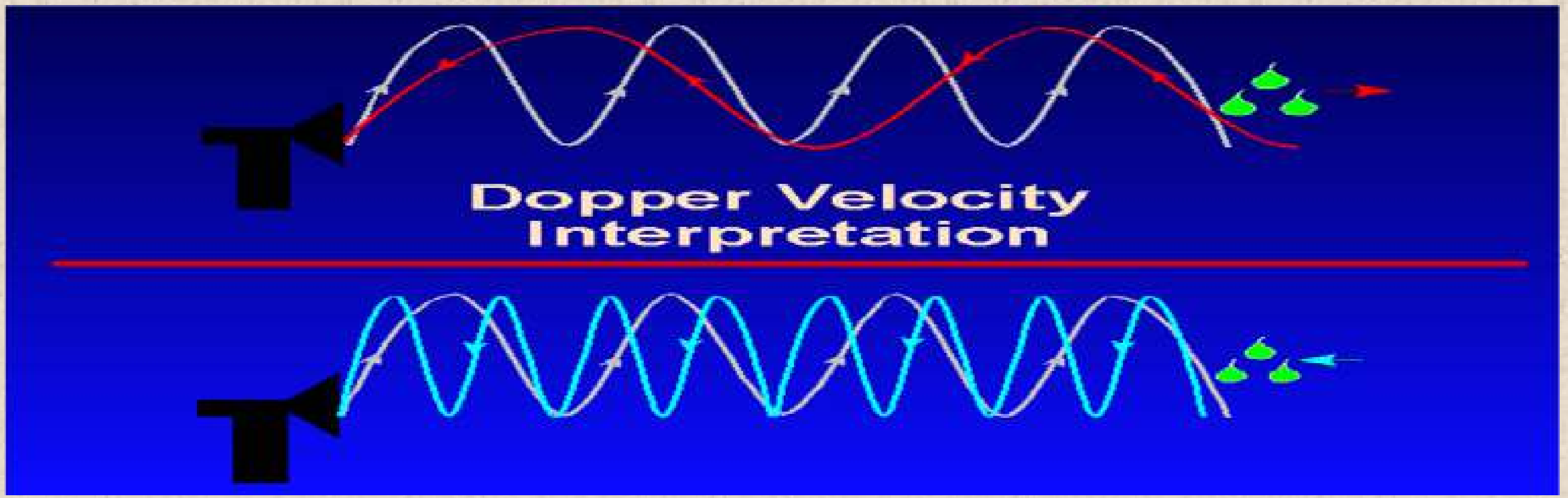
Doppler Effect

- In radar technology the Doppler Effect is using for two tasks:
  1) Speed measuring and
  2) **MTI** - **M**oving **T**arget **I**ndication



Doppler Effect

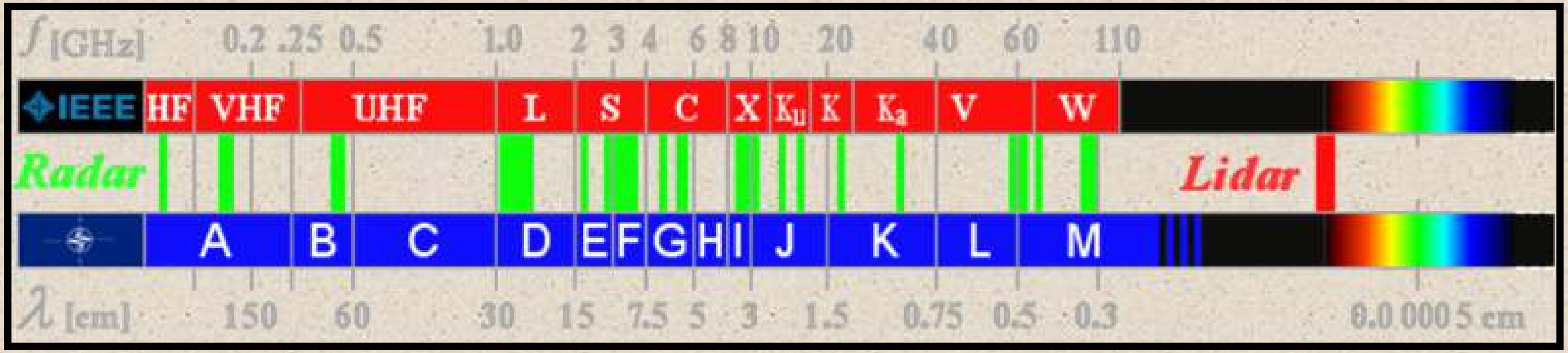




Jamming

- Radar jamming refers to radio frequency signals originating from sources outside the radar, transmitting in the radar's frequency and thereby masking targets of interest. Jamming may be intentional, as with an electronic warfare (EW) tactic, or unintentional, as with friendly forces operating equipment that transmits using the same frequency range. Jamming is considered an active interference source, since it is initiated by elements outside the radar and in general unrelated to the radar signals.

Radar Frequency Bands



Air Defense Radars

- The maximum range of Air-Defense Radar can exceed 300 miles, and the bearing coverage is a complete 360-degree circle.

- Another function of the Air-Defense Radar is guiding combat air patrol (CAP) aircraft to a position suitable to intercept an enemy aircraft.

- Major Air-Defense Radar Applications are:
  1) Long-range early warning (including airborne early warning, AEW)
  2) Ballistic missile warning and acquisition
  3) Height-finding
  4) Ground-controlled interception (GCI)

Air Traffic Control Radar

- The following Air Traffic Control (ATC) surveillance, approach and landing radars are commonly used in Air Traffic Management (ATM):
  1) En-route radar systems,
  2) Air Surveillance Radar (ASR) systems,
  3) Precision Approach Radar (PAR) systems,
  4) surface movement radars and
  5) special weather radars.

En-Route Radars

- En-route radar systems operate in L-Band usually. These radar sets initially detect and determine the position, course, and speed of air targets in a relatively large area up to 250 nm.

Air Surveillance Radar

- Airport Surveillance Radar (ASR) is an approach control radar used to detect and display an aircraft's position in the terminal area. These radar sets operate usually in E-Band, and are capable of reliably detecting and tracking aircraft at altitudes below 25,000 feet (7,620 m) and within 40 to 60 nautical miles (75 to 110 km) of their airport.

Precision Approach Radar

- The ground-controlled approach is a control mode in which an aircraft is able to land in bad weather. The pilot is guided by ground control using precision approach radar. The guidance information is obtained by the radar operator and passed to the aircraft by either voice radio or a computer link to the aircraft.

Surface Movement Radar

- The Surface Movement Radar (SMR) scans the airport surface to locate the positions of aircraft and ground vehicles and displays them for air traffic controllers in bad weather. Surface movement radars operate in J- to X- Band and use an extremely short pulse-width to provide an acceptable range-resolution.

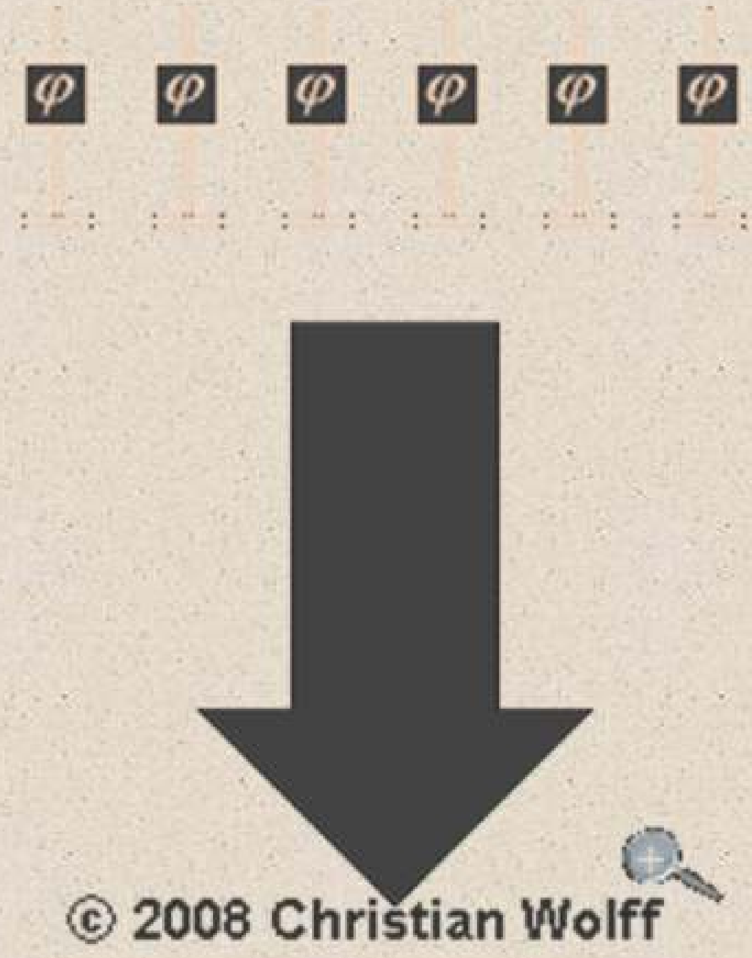
Special Weather Radar

- Weather radar is very important for the air traffic management. There are weather-radars specially designed for the air traffic safety.

Phased array Antenna

Advantages	Disadvantages
•high gain width los side lobes •Ability to permit the beam to jump from one target to the next in a few microseconds •Ability to provide an agile beam under computer control •arbitrarily modes of surveillance and tracking •free eligible Dwell Time •multifunction operation by emitting several beams simultaneously •Fault of single components reduces the capability and beam sharpness, but the system remains operational	•the coverage is limited to a 120 degree sector in azimuth and elevation •deformation of the beam while the deflection •low frequency agility •very complex structure (processor, phase shifters) •still high costs

Phased array Antenna



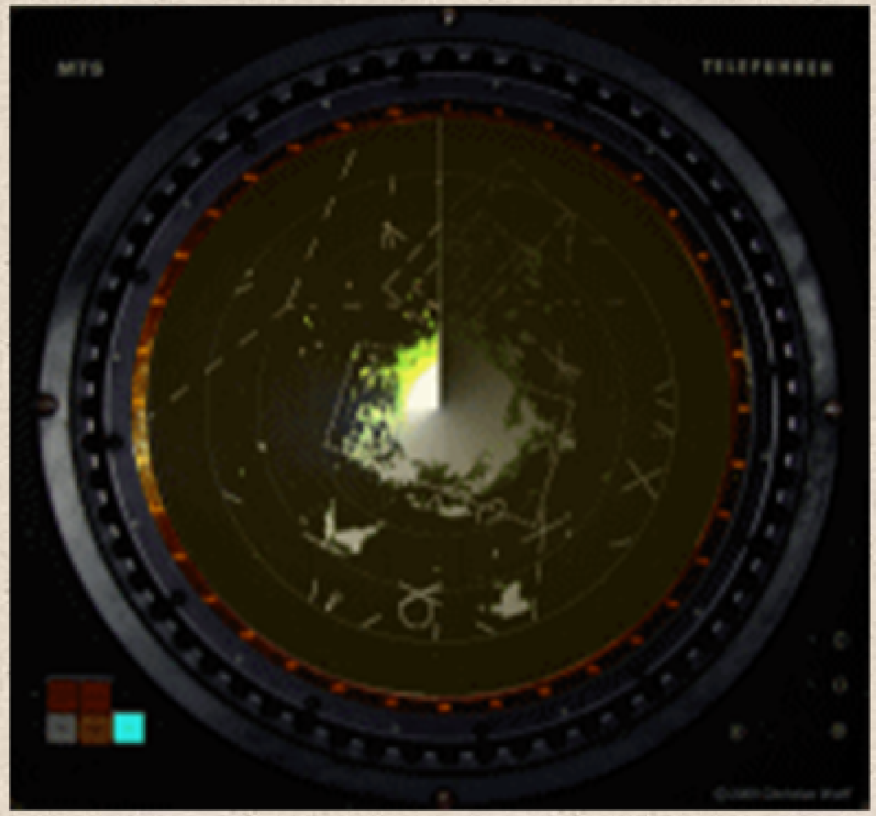
Types of Scan

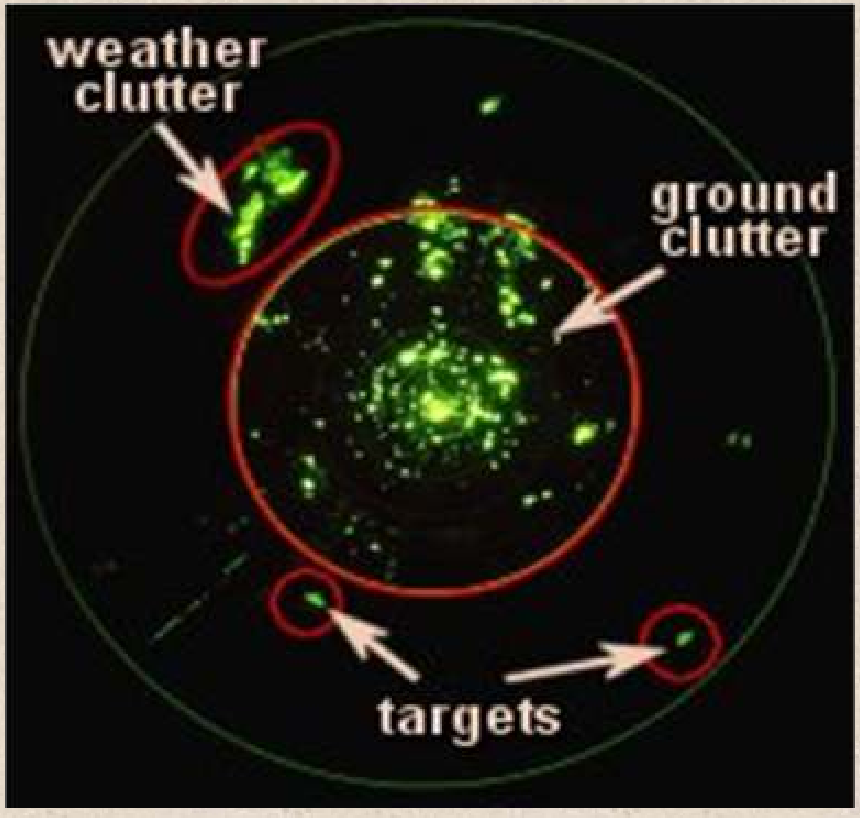
- **Primary Scan**: A scanning technique where the main antenna aerial is moved to produce a scanning beam, examples include circular scan, sector scan etc

- **Secondary Scan**: A scanning technique where the antenna feed is moved to produce a scanning beam, examples include conical scan, unidirectional sector scan, lobe switching etc.

- **Palmer Scan**: A scanning technique that produces a scanning beam by moving the main antenna and its feed. A Palmer Scan is a combination of a Primary Scan and a Secondary Scan.

PPI Scope





Stealth Technology

- **Material.**
- **Shape, Directivity and Orientation.**
- **Active Cancellation.**
- **Radar Absorbent Paint.**

Material

- Materials such as metal are strongly radar reflective and tend to produce strong signals. Wood and cloth (such as portions of planes and balloons used to be commonly made) or plastic and fibreglass are less reflective or indeed transparent to RADAR making them suitable for radomes. Even a very thin layer of metal can make an object strongly radar reflective.

- Submarines have extensive usage of rubber mountings to isolate and avoid mechanical noises that could reveal locations to underwater passive sonar arrays.

Shape, Directivity and Orientation

- The surfaces of the F-117A are designed to be flat and very angled. This has the effect that RADAR will be incident at a large angle (to the normal ray) that will then bounce off at a similarly high reflected angle; it is forward-scattered. The edges are sharp to prevent there being rounded surfaces. Rounded surfaces will often have some portion of the surface normal to the RADAR source. As any ray incident along the normal will reflect back along the normal this will make for a strong reflected signal.

- With **purpose shaping**, the shape of the target's reflecting surfaces is designed such that they reflect energy away from the source.


F-117A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Active Cancellation

- With active cancellation, the target generates a radar signal equal in intensity but opposite in phase to the predicted reflection of an incident radar signal . This creates destructive interference between the reflected and generated signals,resulting in reduced RCS.

Radar Absorbent Paint

- The SR-71 Blackbird and other planes were painted with a special **"iron ball paint“.** This consisted of small metallic-coated balls. RADAR energy is converted to heat rather than being reflected.

- One of the most commonly known types of RAM is iron ball paint. It contains tiny spheres coated with carbonyl iron or ferrite. Radar waves induce molecular oscillations from the alternating magnetic field in this paint, which leads to conversion of the radar energy into heat. The heat is then transferred to the aircraft and dissipated.


SR-71 Blackbird

THANK YOU

References:

- http://en.wikipedia.org/wiki/Radar
- http://www.radartutorial.eu/01.basics/rb01.en.html