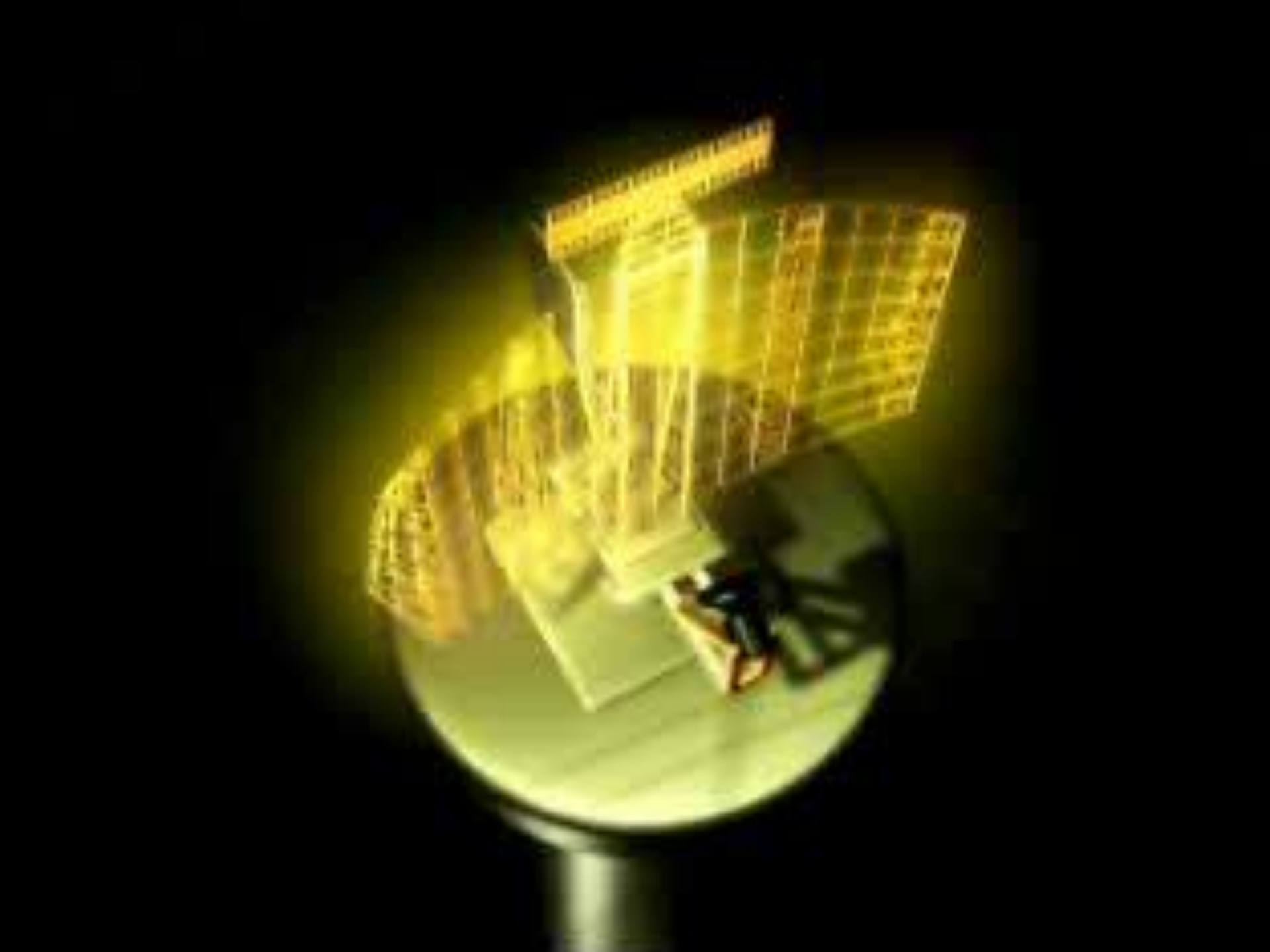

GRAHAM PAYNE

A History and Development of Radar

Personal Background

- 1966
  - 1983 Philips Research Labs
    Microwave Engineer
- 1983
  - 1999 Hewlett-Packard Ltd.
    Microwave Applications
    Engineer
- 1999
  - 2007 Agilent Technologies
    Consultant Microwave
    Engineer

Microwave ‘Engineer’ ??

Personal Background

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  – 1983 Philips Research Labs
  Microwave Engineer
- 1983
  – 1999 Hewlett-Packard Ltd.
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True, Dedicated Microwave Engineer !

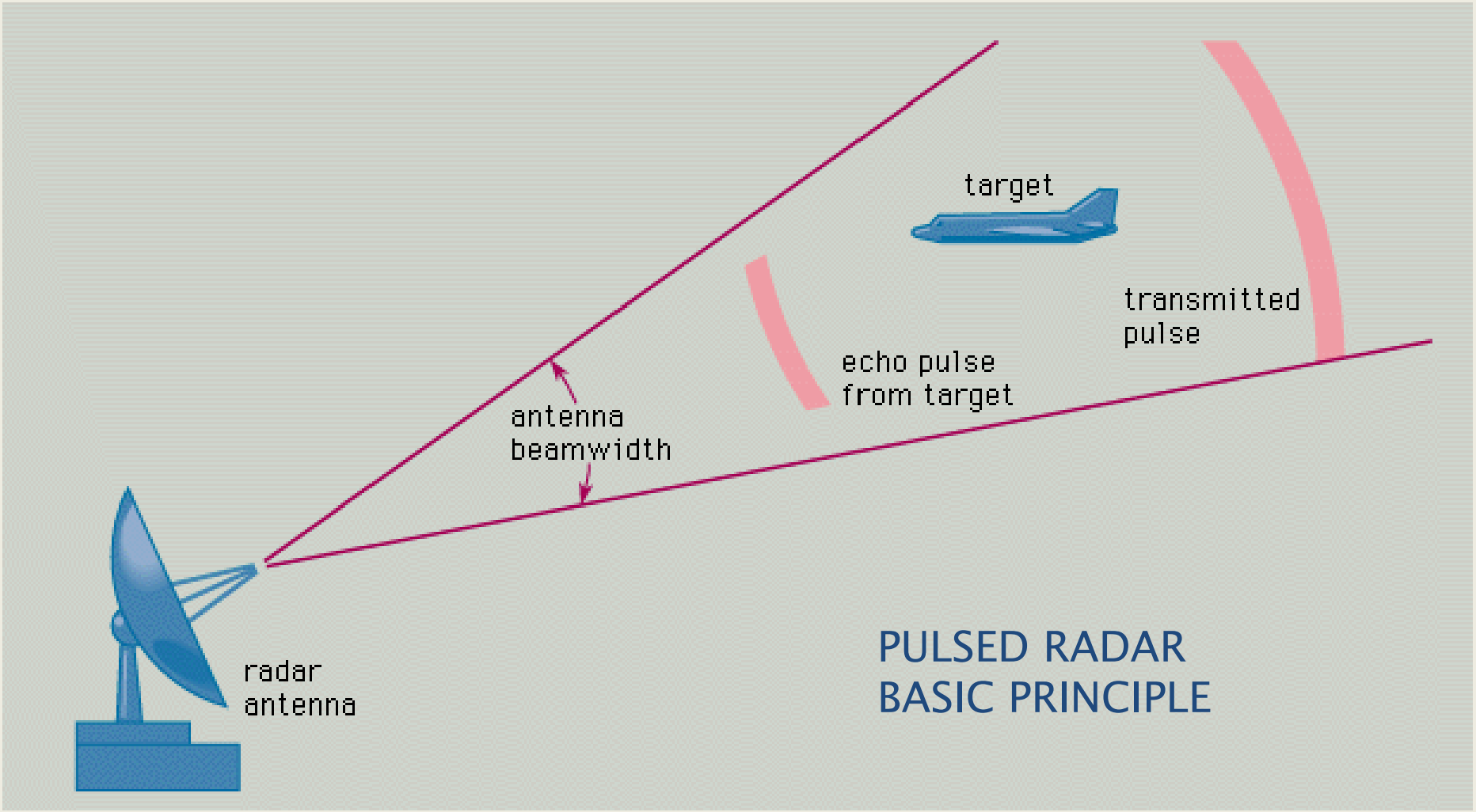
A History of Radar

- Historical Development
- What is Radar?
- Radar Types
- Radar Antennas
- Civilian Radars
- Military Radars
- Future

A History of Radar

- Radio Detection And Ranging
  - Called RDF – Radio detection and Ranging by the British
  - Renamed RADAR by the Americans in 1940

What is Radar ?



A History of Radar

- Early Evolution – Bats!
  - Bats use very similar techniques to modern radar
    - Doppler
    - Monopulse
    - PRF Agility
    - Chirped signals etc
    - But, non electronic !

A History of Radar

QUIZ

- Question 1

When was the first demonstration of a practical radar system

A History of Radar

- 1904

Christian Huelsmeyer

Telemobiloscope

Anti Ship Collision Device

Range 3000m

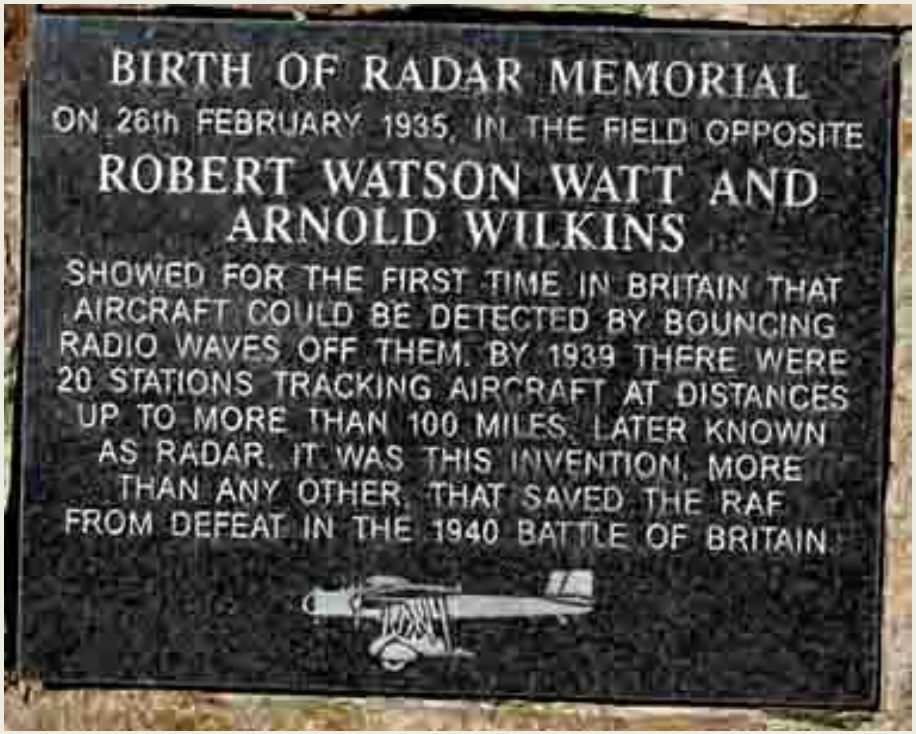
Freq ~ 700 MHz

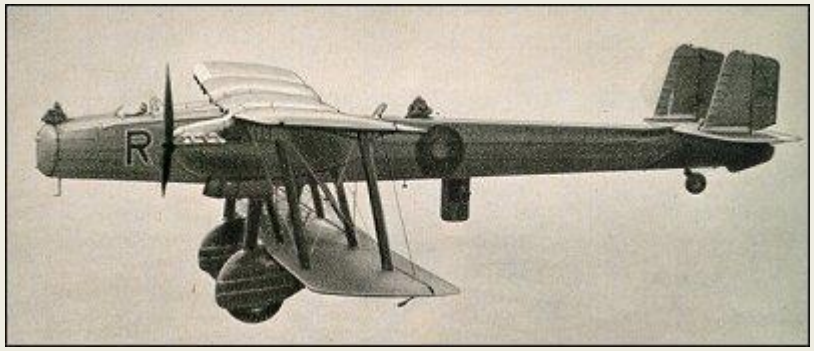
A History of Radar

- 1922/23 Guglielmo Marconi showed his first working device
- 1925/1926 Breit & Tuve, Appleton & Barnett measured Earth's ionosphere using a pulsed technique.
- 1930 US Engineers saw radar like effect at landing strip
- 1928 First UK Patent by HM Signal school by L. S. Alder
- 1922/1930 Page demonstrates the world's first pulsed radar system
- 1935 Watson-Watt and Arnold Wilkens demonstrated successful detection of aircraft – the so called 'Daventry Experiment'

A History of Radar

The Daventry Experiment
Tues 26th Feb 1935, Weedon



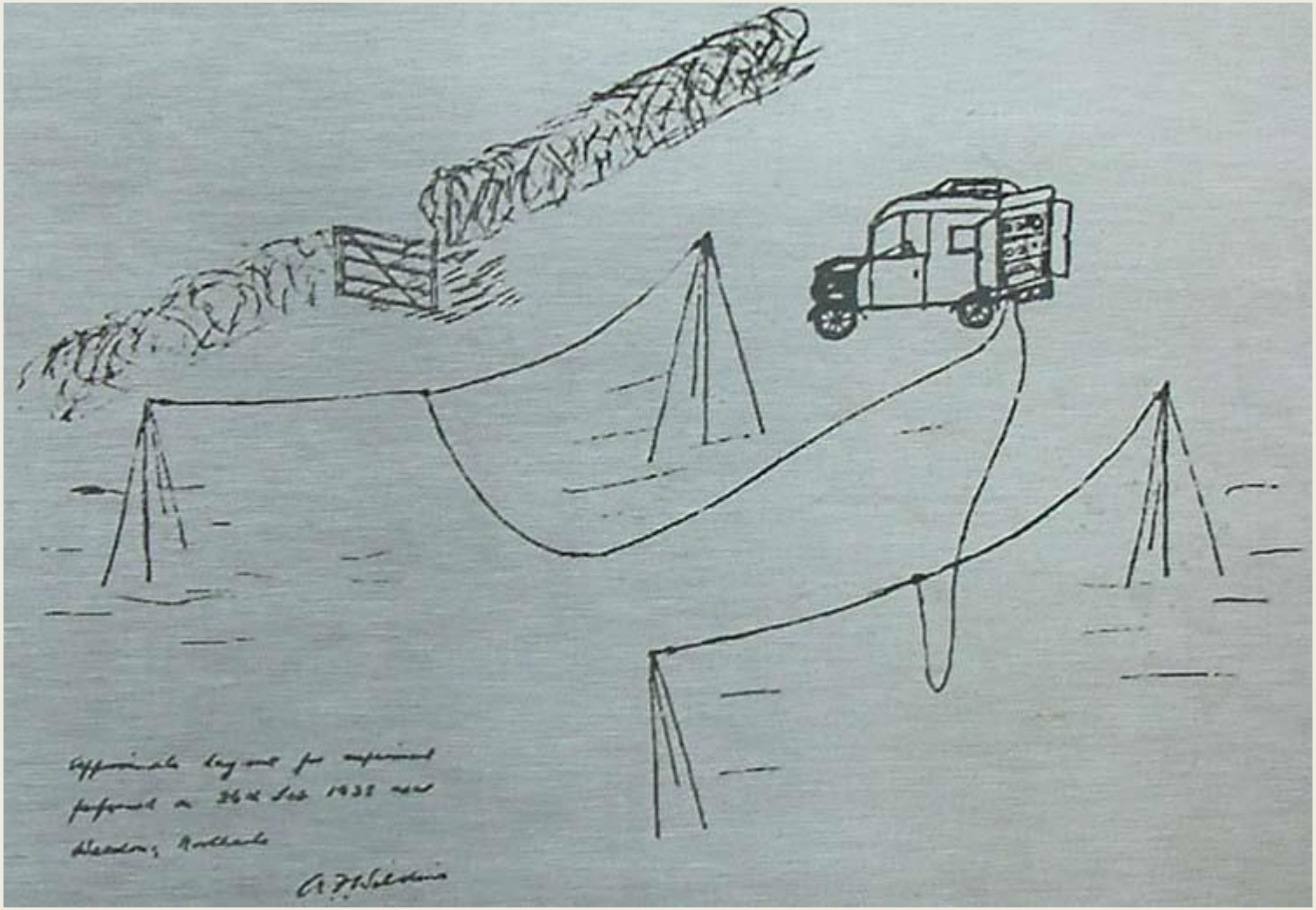


Handley Page ‘Heyford’ Bomber

Morris Van with receiving equipment inside

A History of Radar

The Daventry Experiment
Tues 26th Feb 1935, Weedon



Wilkins's original lab book sketch

A History of Radar

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- 1939/45 Development of Chain Home stations
- 1940 Refinement of Magnetron by Randall & Boot
- 1940 – Jamming, Stealth, Passive Radar, SAR, Phased Arrays etc

A History of Radar

World War 11

Key Developments

- Battle of Britain
  - Chain Home
  - Chain Home Low/Extra Low
- Refinement of the Magnetron
- H2S and Centimetric Radar
- Wurzburg & Bruneval Raid
- Invention of ‘Chaff’ or ‘Window’

A History of Radar

World War 11

Problem

- France is only 22 miles from the South Coast of England
- Aircraft flying at 300 mph will cross in about 7 minutes
- The only warning system that was practical was the eyes and ears or the Royal Observer Corps

Solution

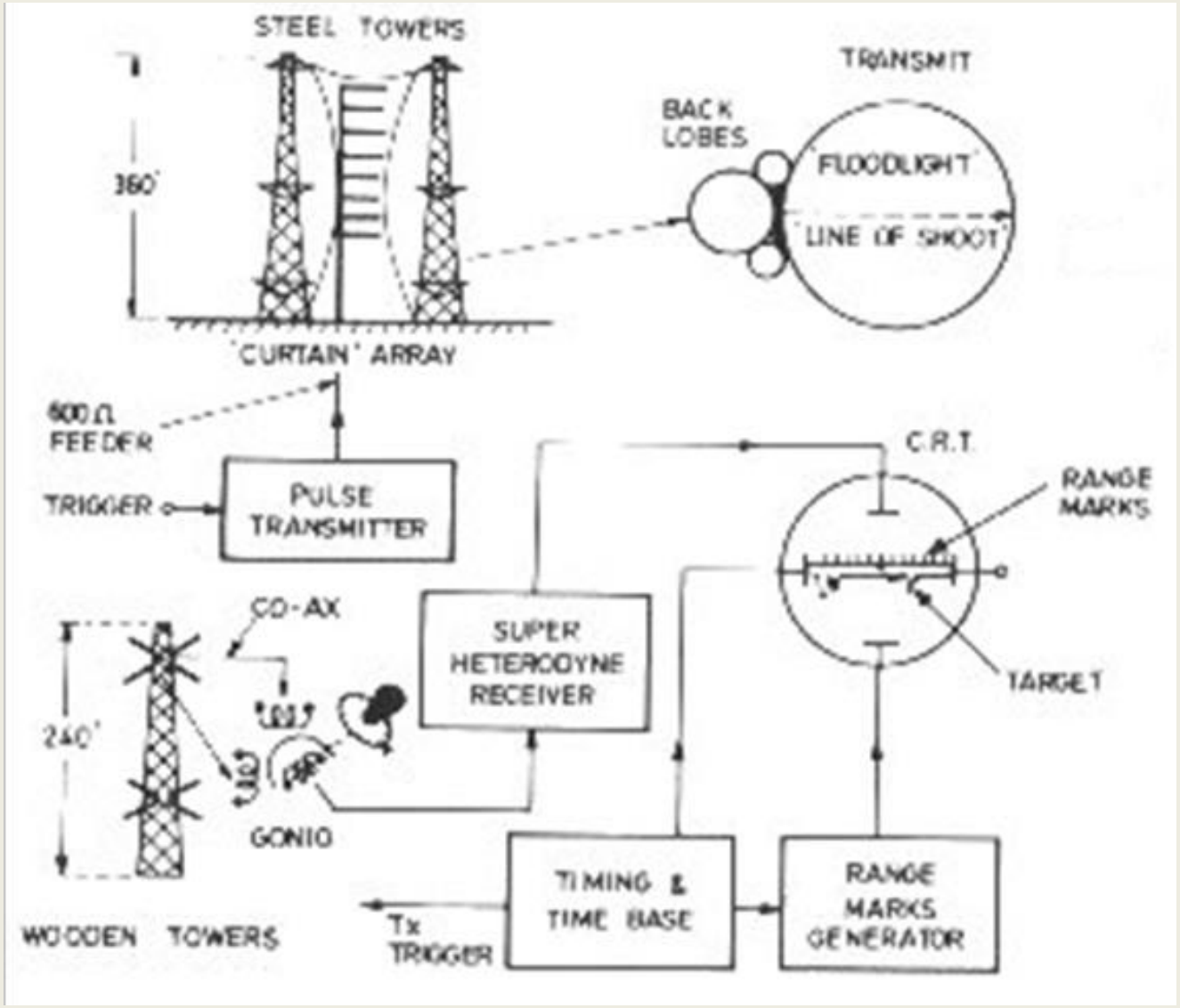
The ‘Chain Home’ Radar Stations

A History of Radar

Chain Home Radar

- Worked at 20 and 70 MHz
- TX Antennas 360 feet high steel masts
- RX Antennae were smaller and used crossed dipoles
- Stations deployed around the coast of UK mainly in the South and East
- Furthest south was Ventnor on the IOW, which opened on Jan 1939. By Easter 1939 all the initial 20 CH were operational
- Stations were attacked many times but rebuilt quickly.

A History of Radar

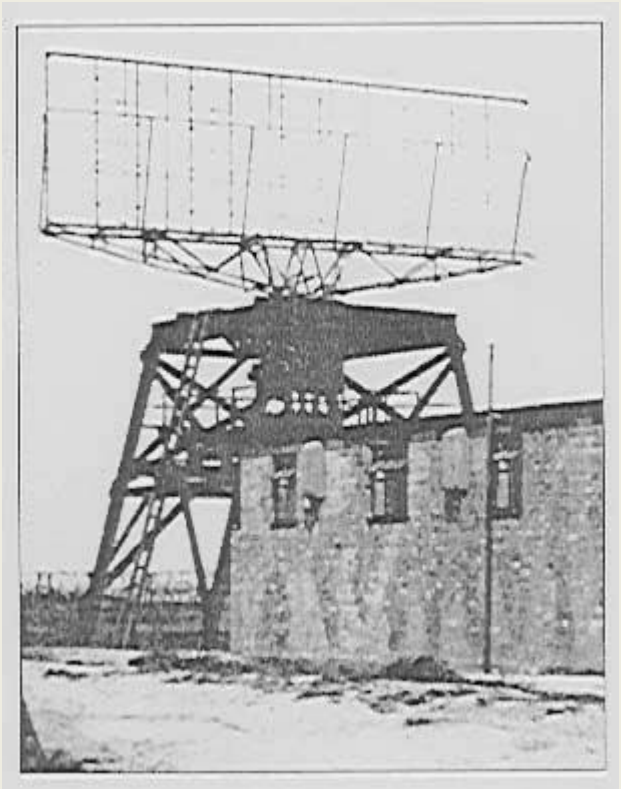


A History of Radar

Unable to detect low flying aircraft due to 'clutter'

A History of Radar

Chain Home Low



- Worked at 200 MHz
- Aircraft 500 feet up and 25 miles away could be detected + 100 mile range at 10,000 ft altitude could be detected
- Much smaller footprint
- Originally built with separate Tx and Rx arrays manually rotated but later integrated into a single array
- Locally Truleigh Hill (CHL) and Poling (CH) worked in tandem feeding data to the Filter Room and Stanmore.

A History of Radar

Chain Home Low

VT98 Power Triode Valve

- Each tube could deliver 100 kW at 200 MHz
- Force air cooling

The filament required 12.6V at 58A !

A History of Radar

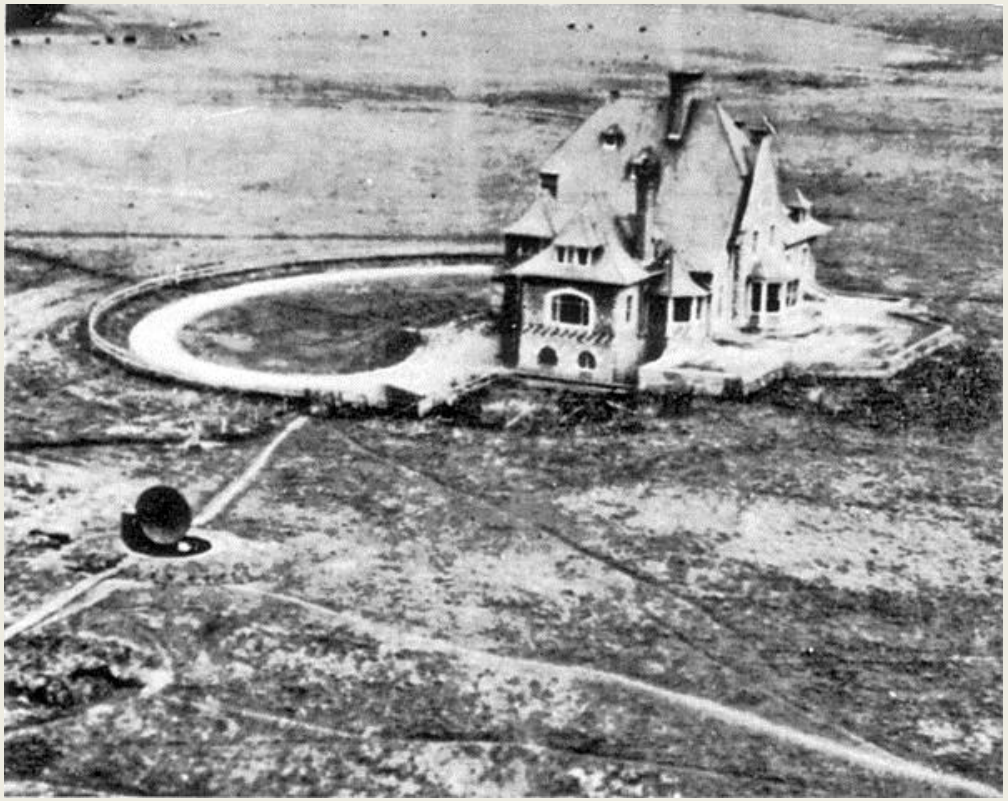
Chain Home Extra Low

- Worked at 3000 MHz (3 GHz)
- Peak Power 500 kWatt
- Pulse length 0.6 or 1.9 uS
- Pulse rate 500 pulses/sec
- Nodding -1 to +20 degrees vertical
- Beam width 7.5 degrees
- Aircraft tracked at 50 ft out to 45 miles

Type 13 CHL Radar

A History of Radar

Operation Biting – The Bruneval Raid



- Feb 1942 Combined Ops raid on Bruneval, Northern France
- 110 Para Commandos led by Maj John Frost
- Technicians dismantled the 'Wurzburg' radar and all returned to UK except for 2 killed and 6 captured
- Led to a greater understanding of German radar technology and capability

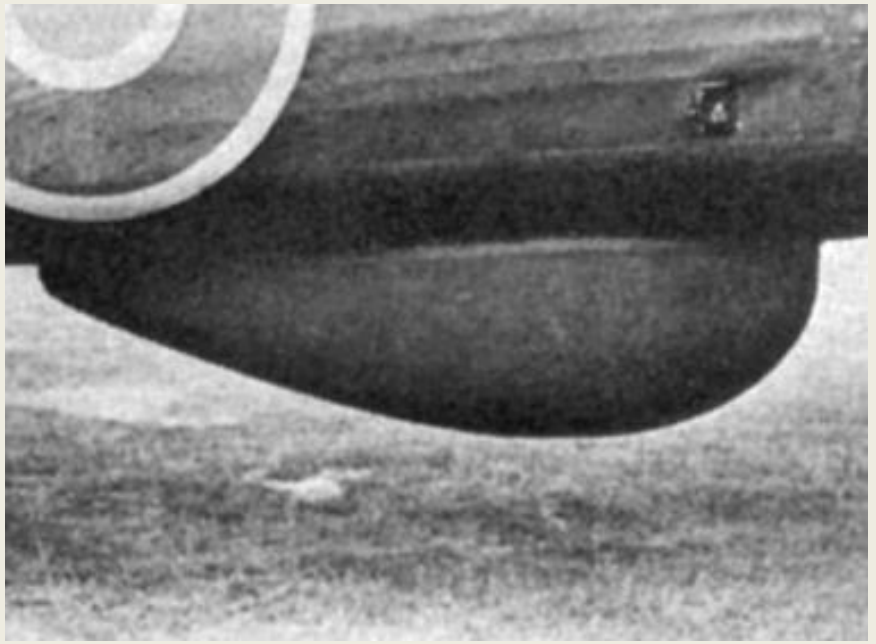
A History of Radar

Development of the Magnetron

- Type of high power valve
- J.T. Randell & H.A.H.Boot at Birmingham Uni in Feb 1940 showed first military version giving 500 watts at 3000 MHz
- Capable of > 12kW peak at 9600 MHz
- Allowed development of radars that could detect submarines
- Higher freq operation allowed airborne radar with scanners

A History of Radar

H2S and Centimetric Radar



- First airborne Ground Scanning Radar and was developed in Britain
- Used the cavity magnetron initially at 3 GHz later 9.6 GHz
- Initially fitted to Stirling and Halifax bombers for nav and night bombing
- In 1943 it was captured by the Germans who developed countermeasures which were then fitted to their night fighters (Naxos Radar Warning Rx)
- US developed the X band version at 9600 MHZ in 1945 (H2X)
- Later versions worked at 20,000 MHZ and used for weather radar

A

T.R.E.

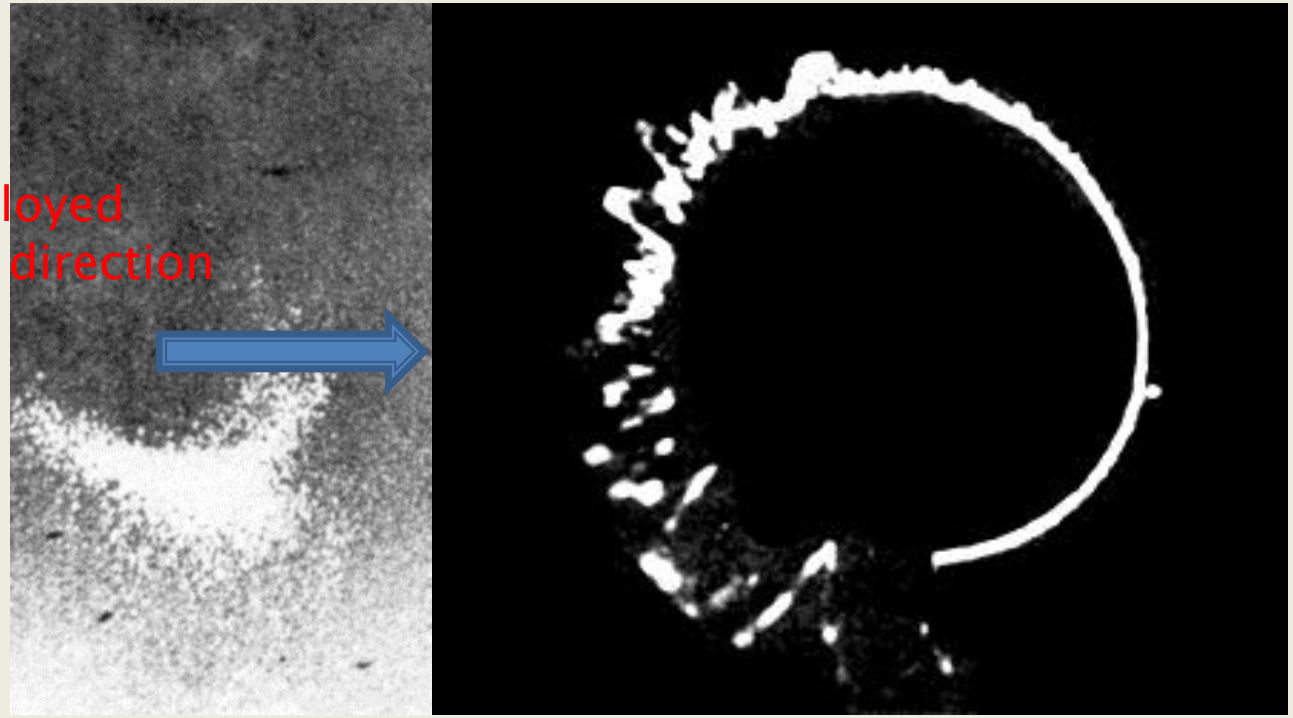
FILM

A History of Radar

'Window ' or Chaff

- Directly developed Robert Cockburn of TRE as result of the Bruneval raid when it was discovered that only 3 frequencies were in use by Germans
- Black paper strip backed with aluminium foil – ½ wavelength long
- Foil acted as an antenna and re-radiated the enemy radar signal

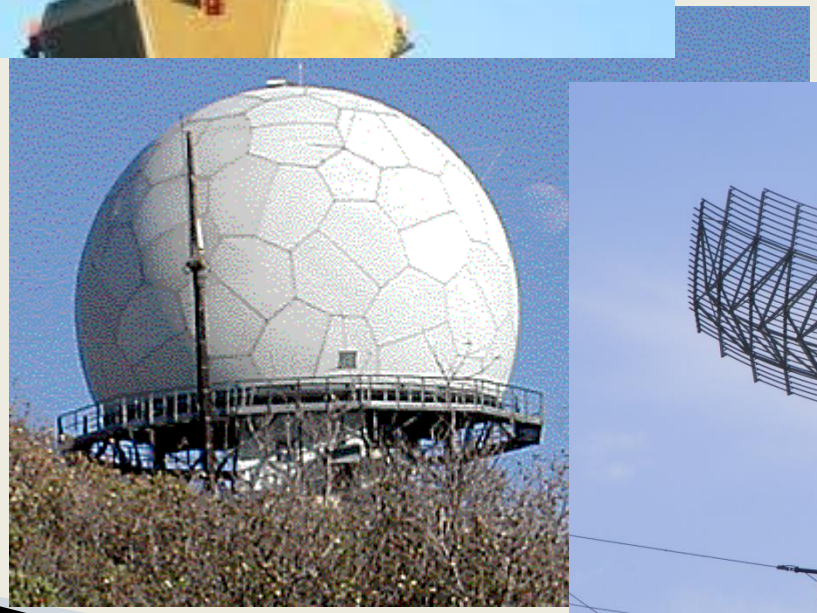
Chaff deployed
From this direction



A History of Radar

- Historical Development
- What is Radar?
- Radar Types
- Radar Antennas
- Civilian Radars
- Military Radars
- Future

What is Radar ?



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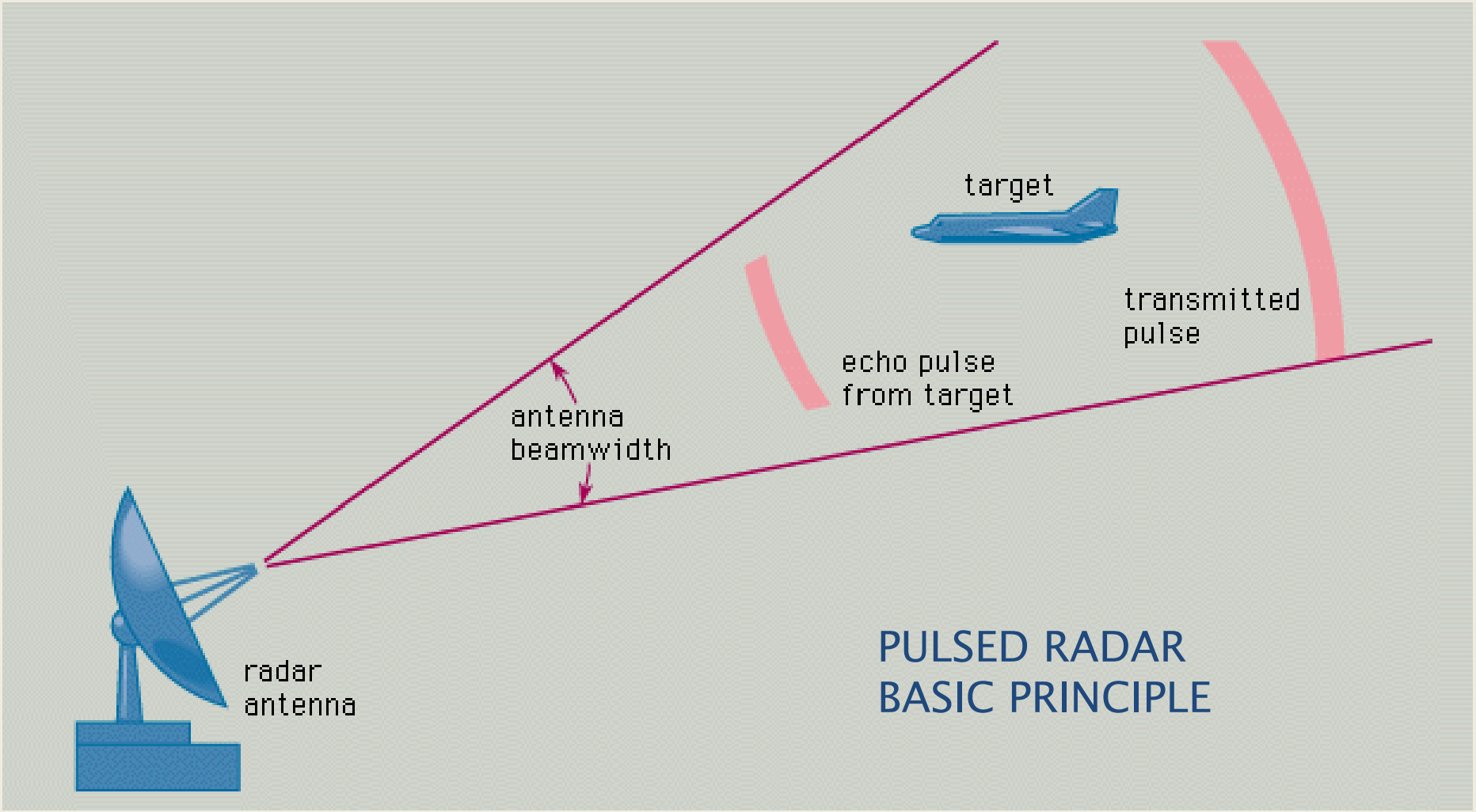
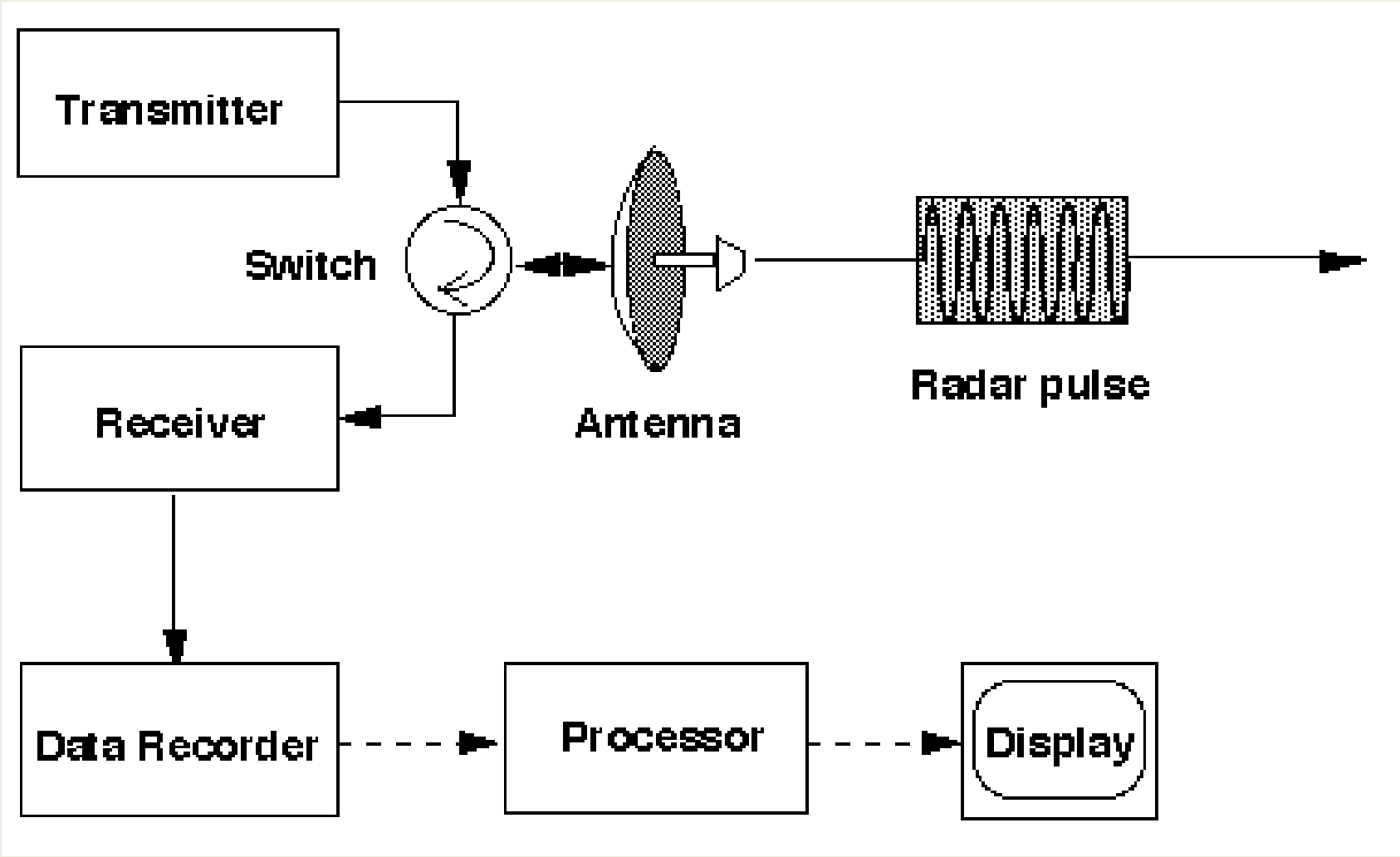


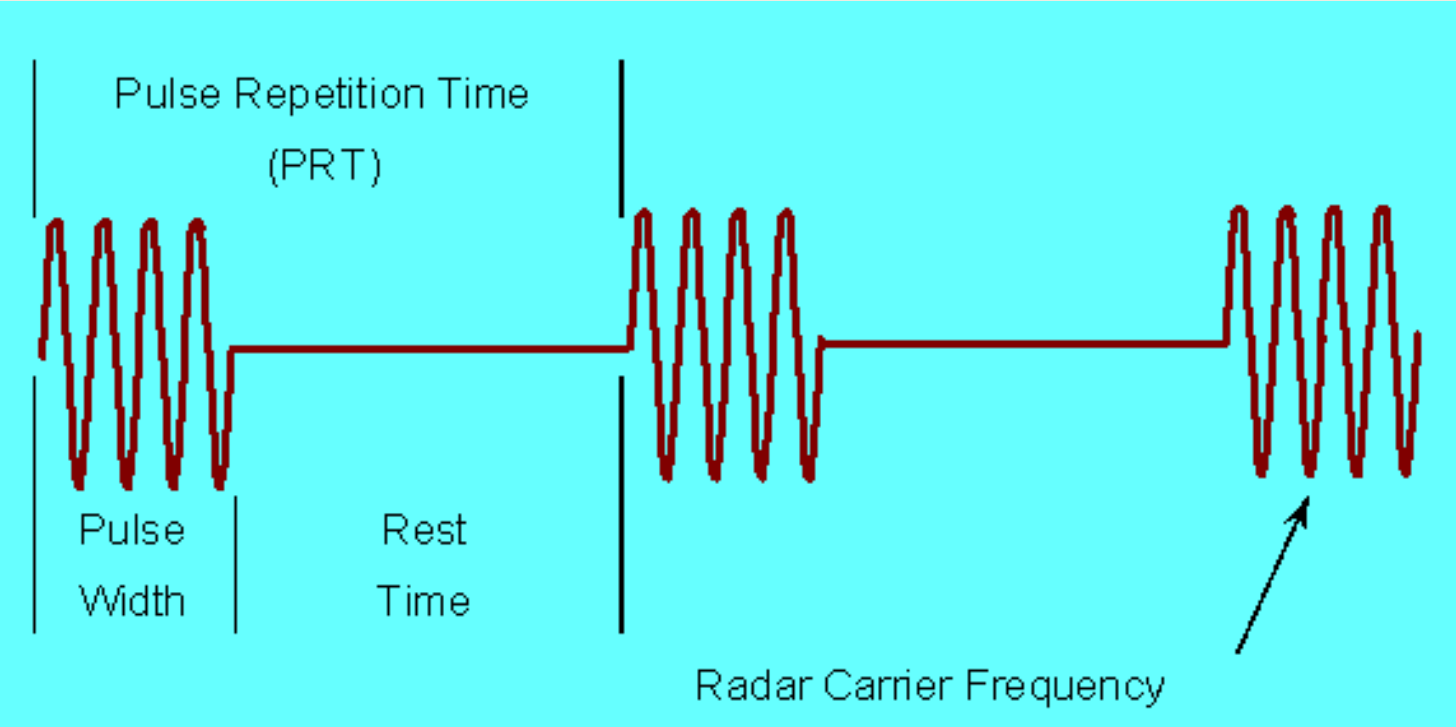
What is Radar ?

Radar Block Diagram



What is Radar ?

Radar Block Diagram



What is Radar ?

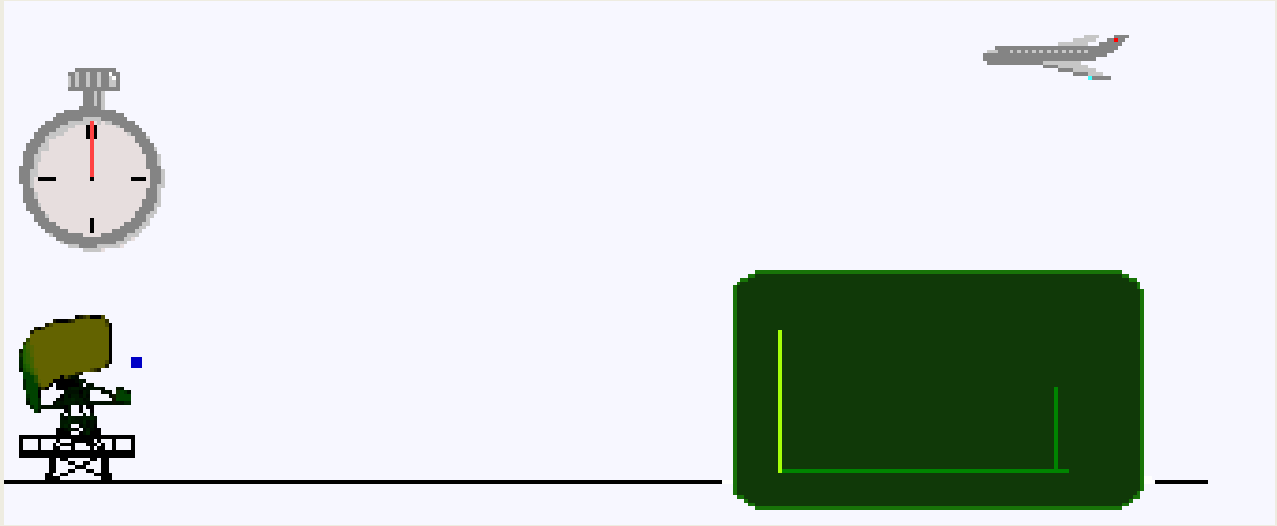
- **Key Questions**:
  - How far away is the target ? “Range”
  - In what direction is the target? “Bearing”

Speed can be calculated from:

$$\text{Speed} = \text{Range}/\text{Time}$$

What is Radar ?

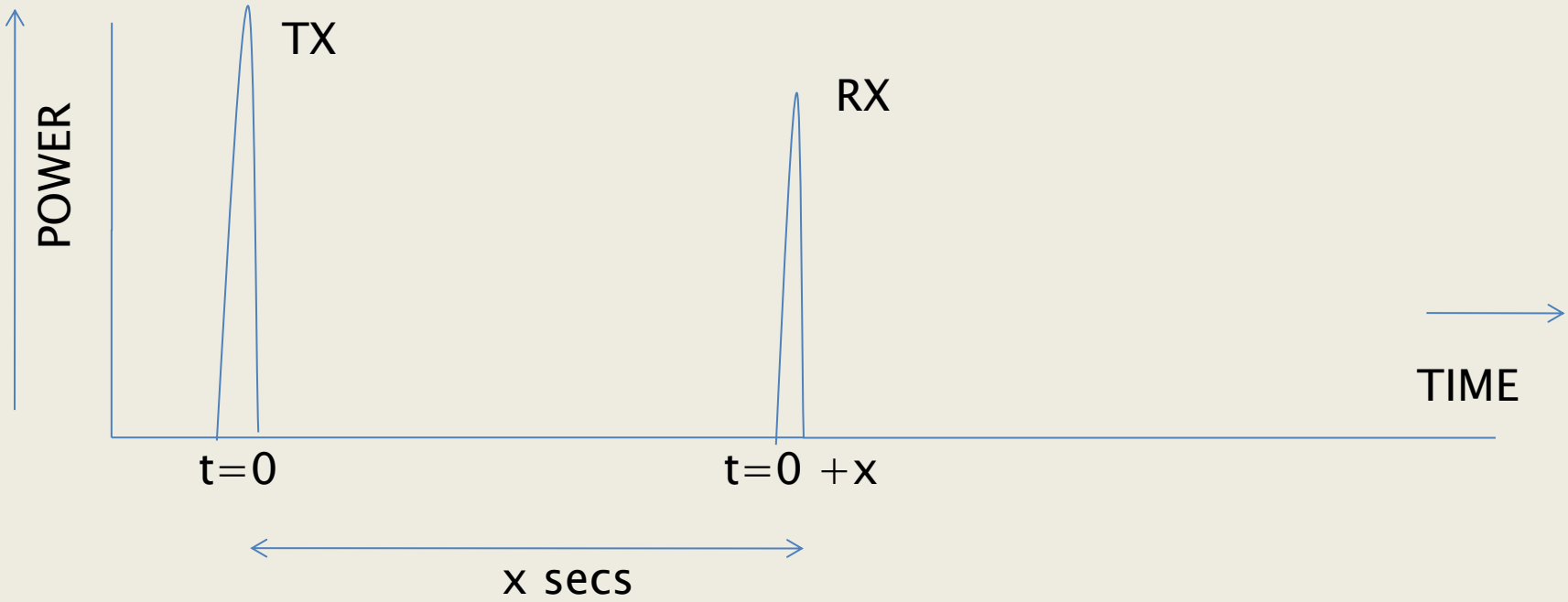
Range:



What is Radar ?

Range:

$$SPEED = \frac{DISTANCE}{TIME} \therefore DISTANCE = SPEED \times TIME$$



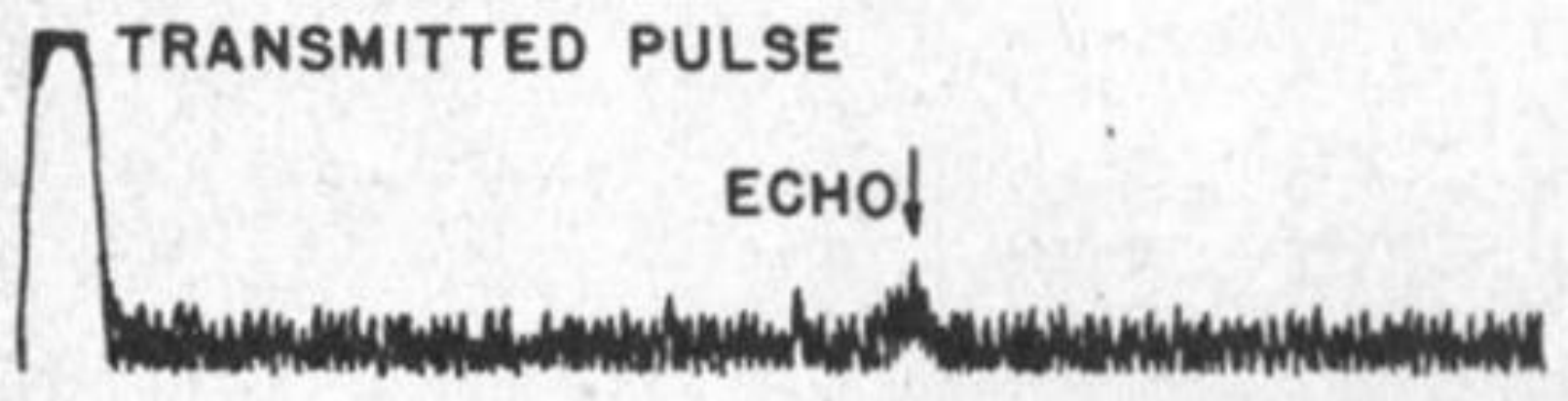
X secs represents the 'there and back' time of the pulse

For example: *If x = 60μS, then x/2 = 30μS*

Distance = 3.10^8 x 30.10^{-6} = 9km

What is Radar ?

Range:

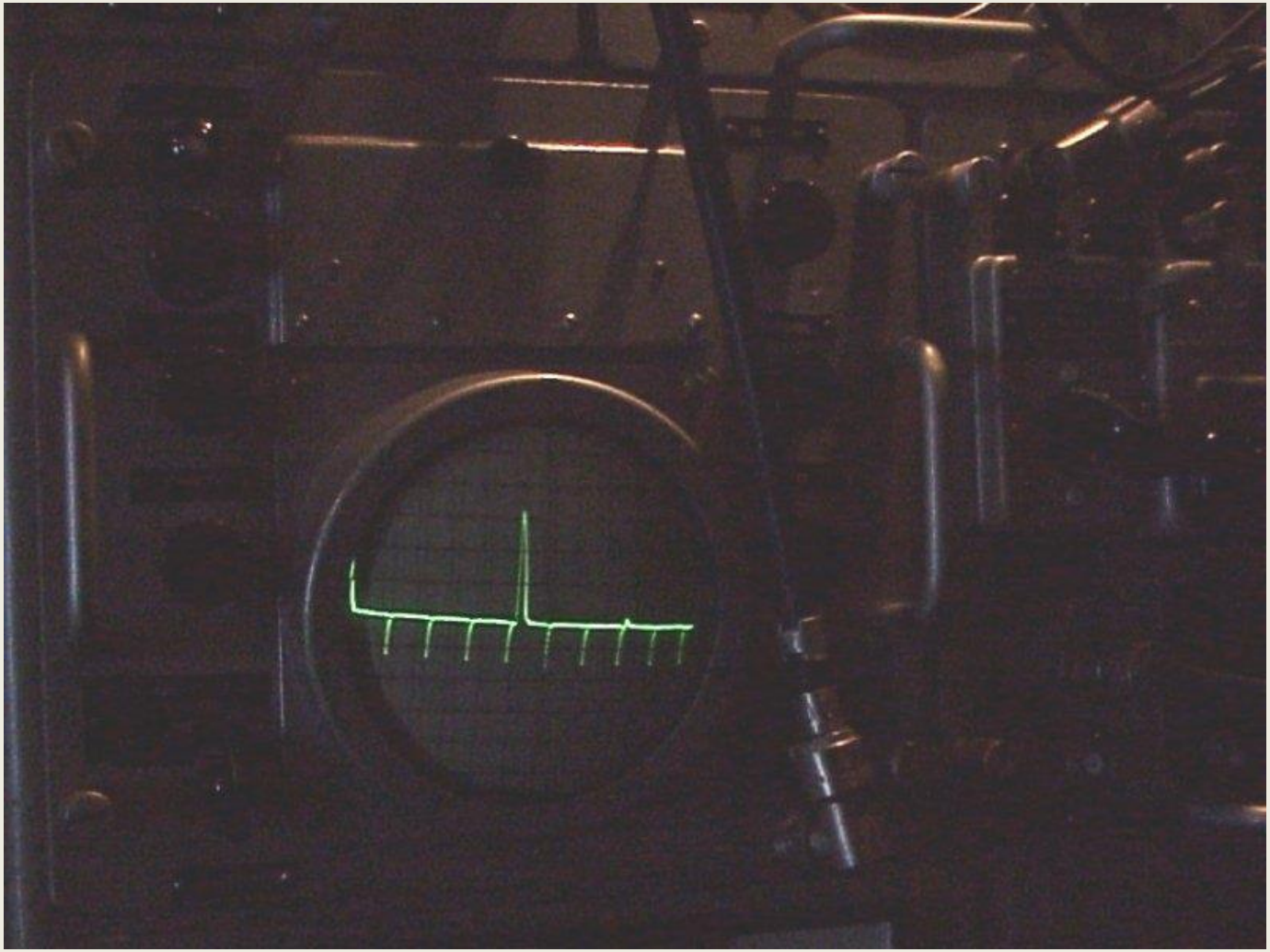


What is Radar ?

Range:

A-Scope Display

Soviet VHF 'Spoon Rest' Radar



What is Radar ?

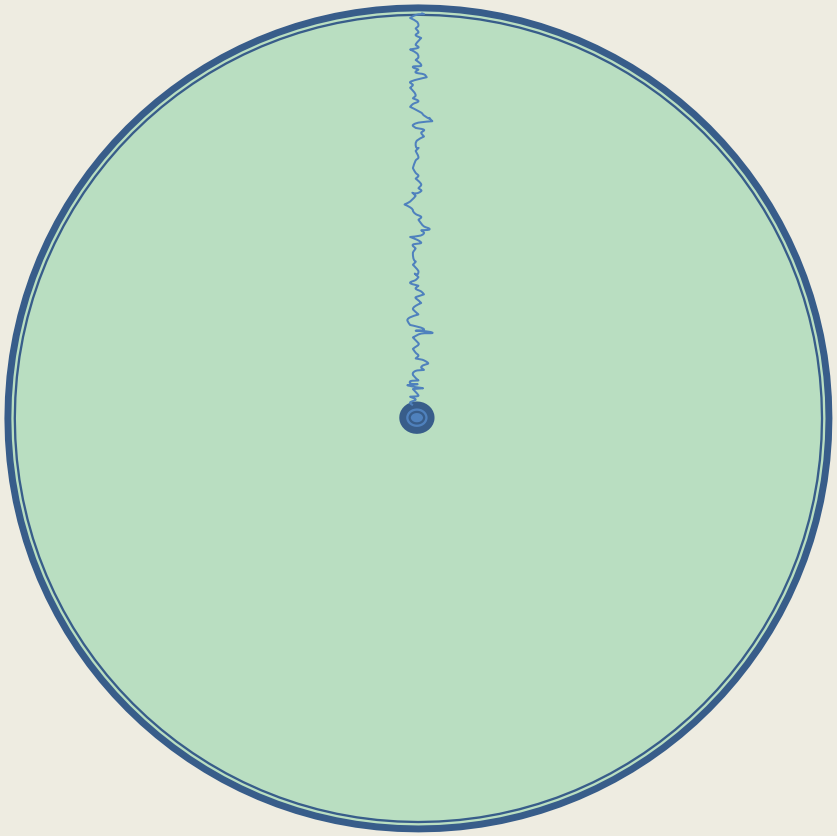
Bearing

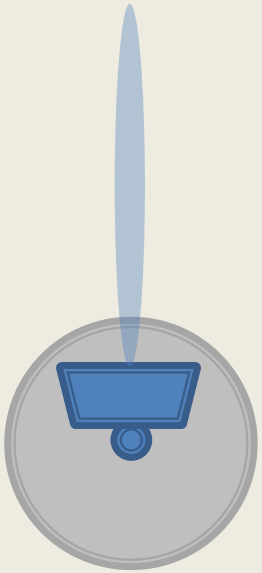
The angular distance of the target compared to some fixed datum

e.g.

- The bearing of the target from nose of the aircraft or ship
  - Bearing Relative
- The bearing of the target from North
  - Bearing True

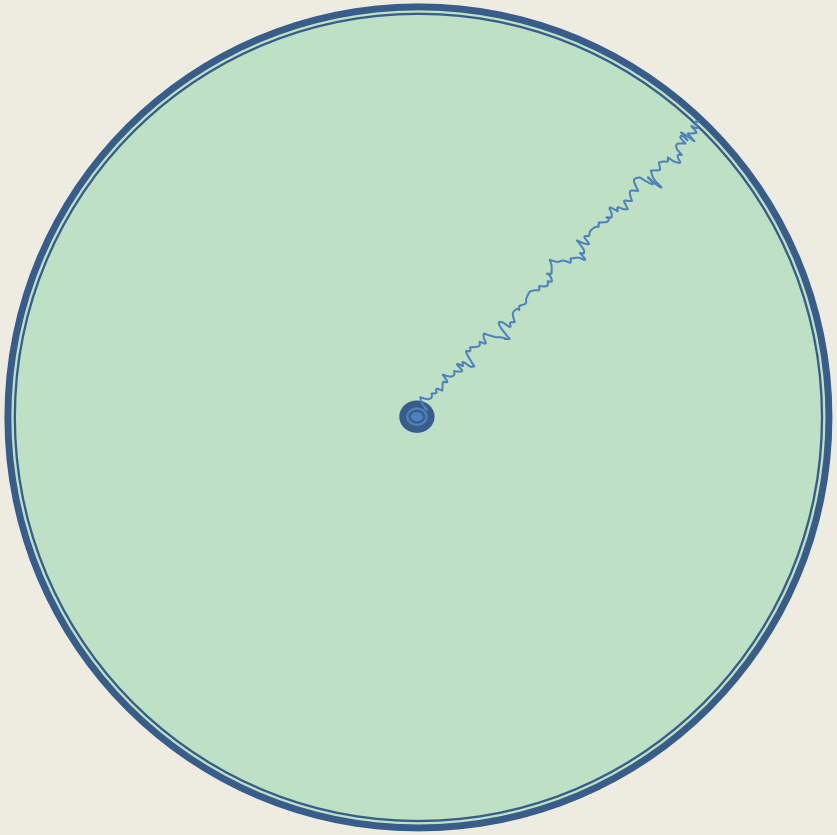
What is Radar ?

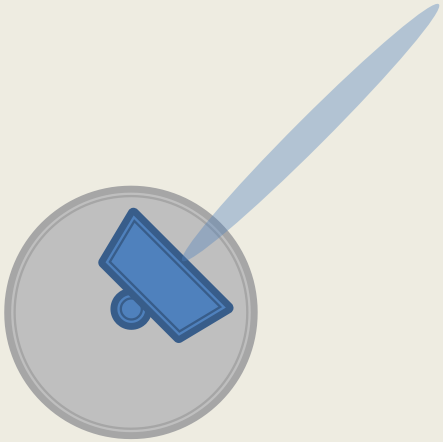




Bearing

What is Radar ?





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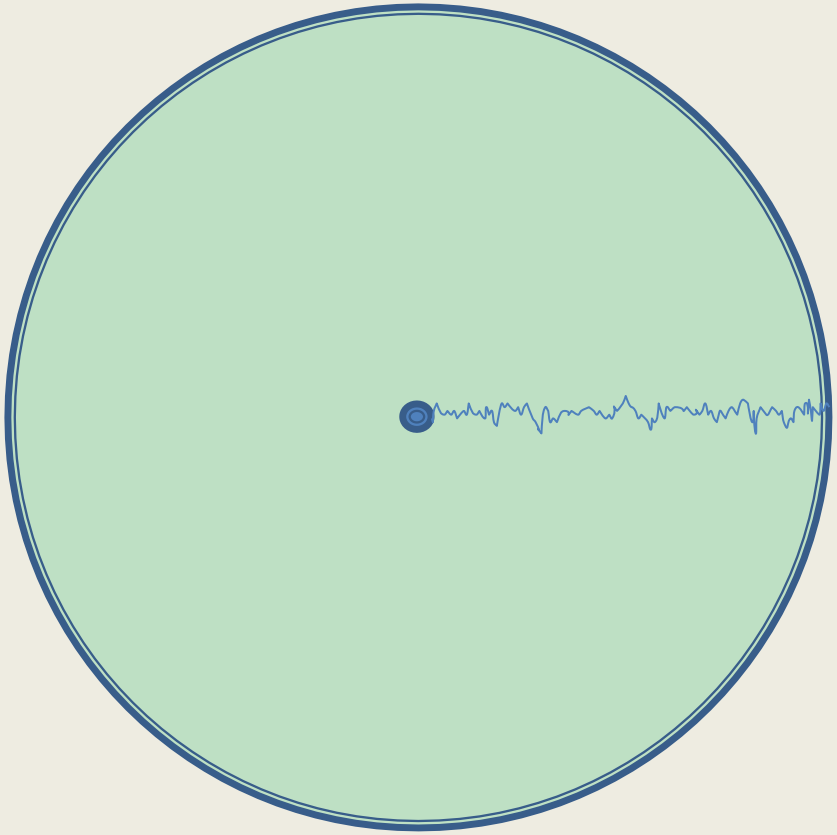

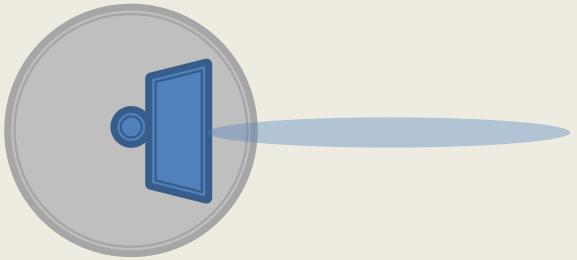

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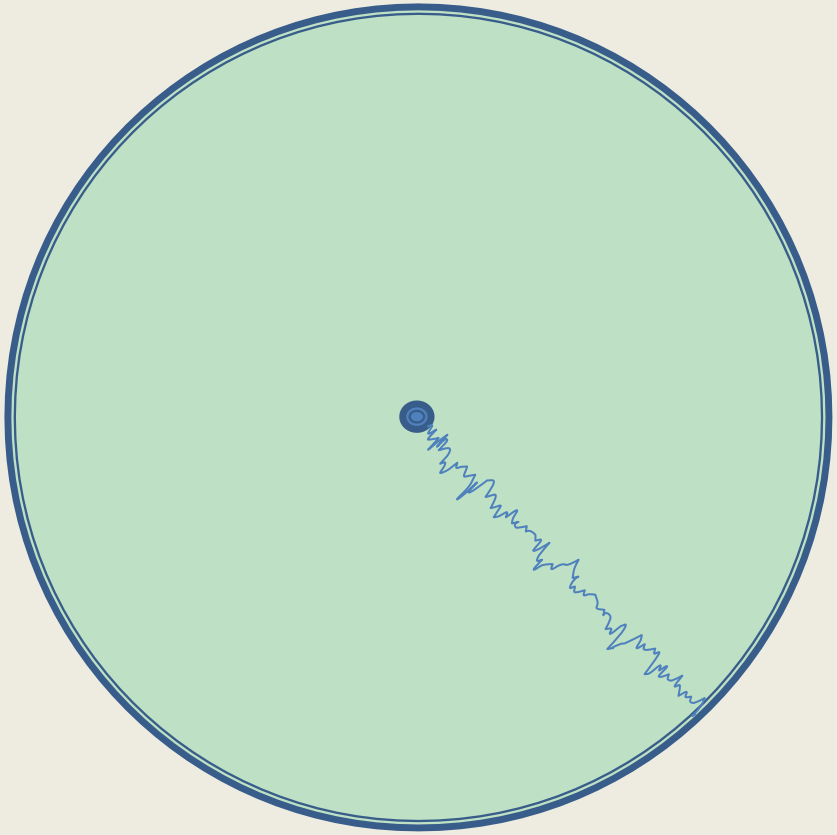

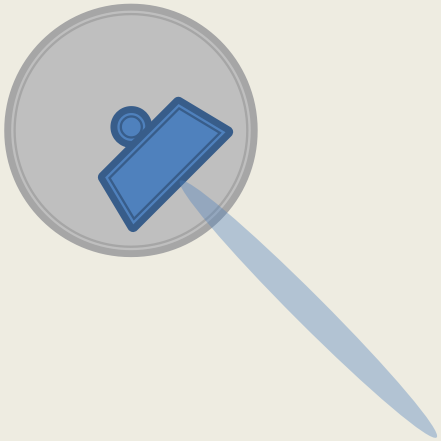

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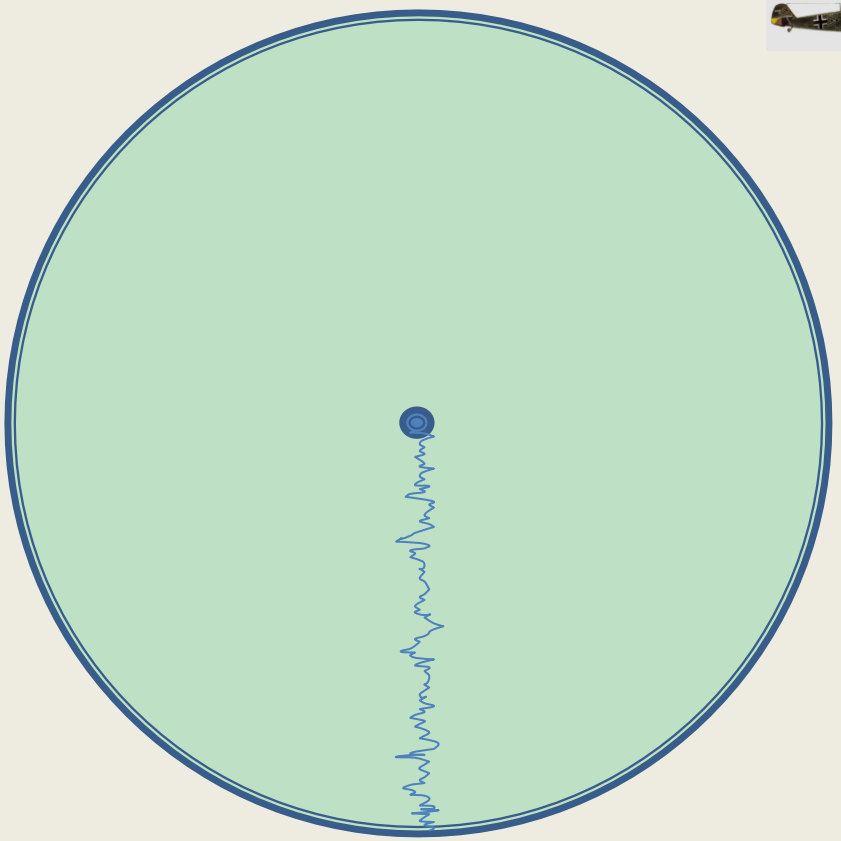

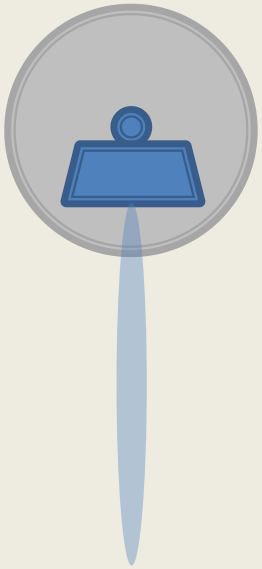

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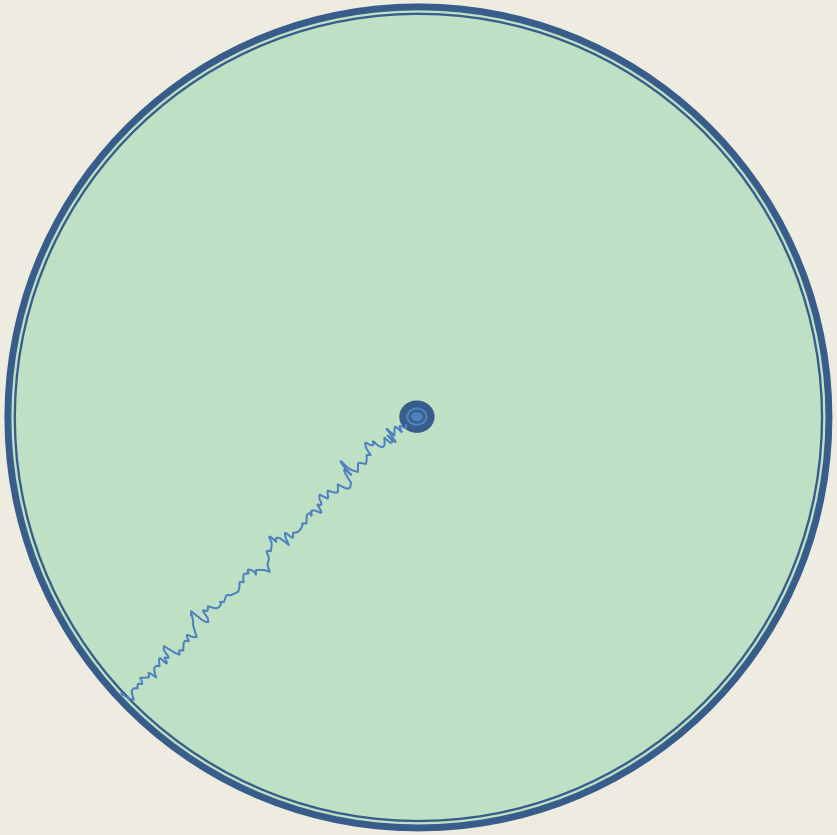

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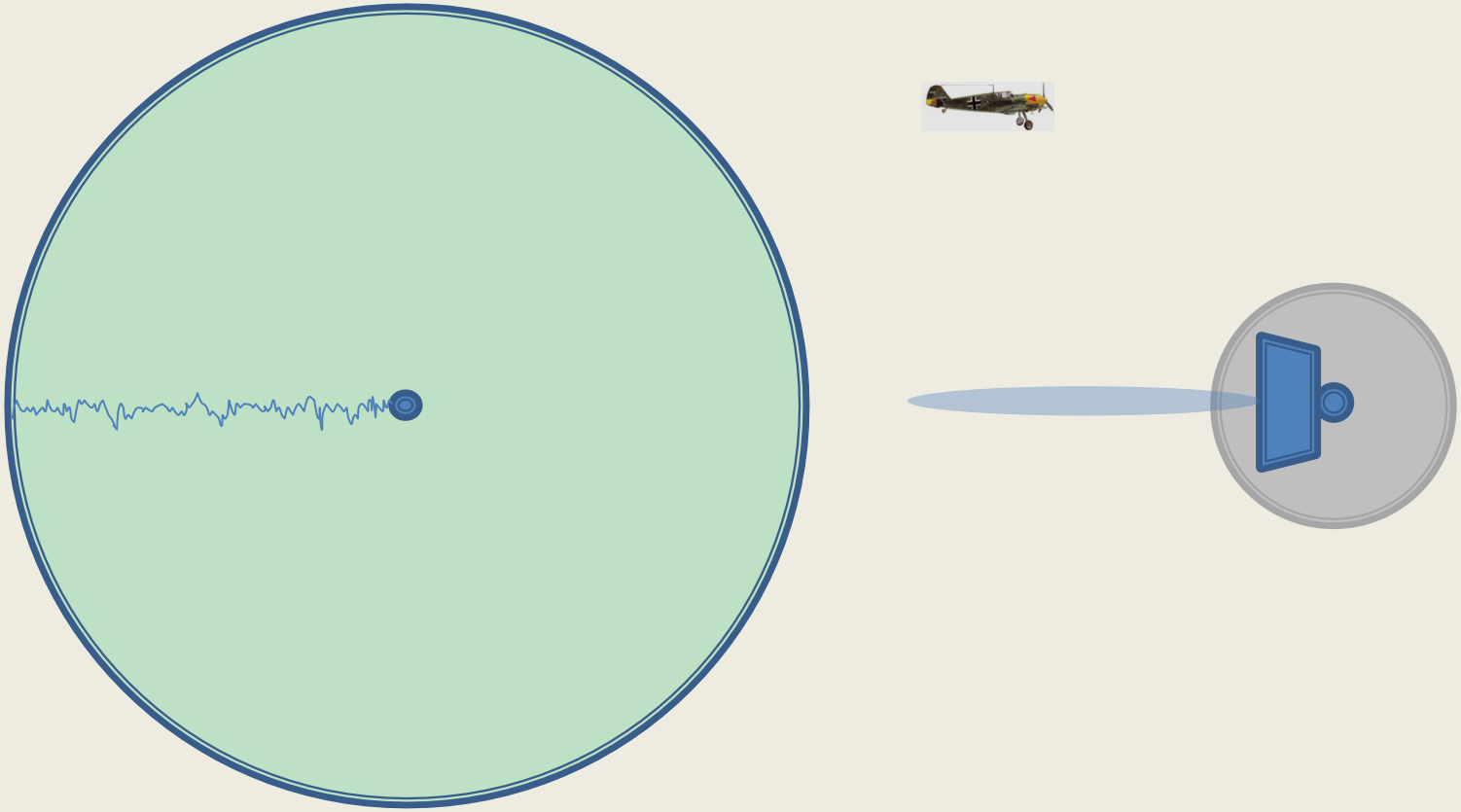

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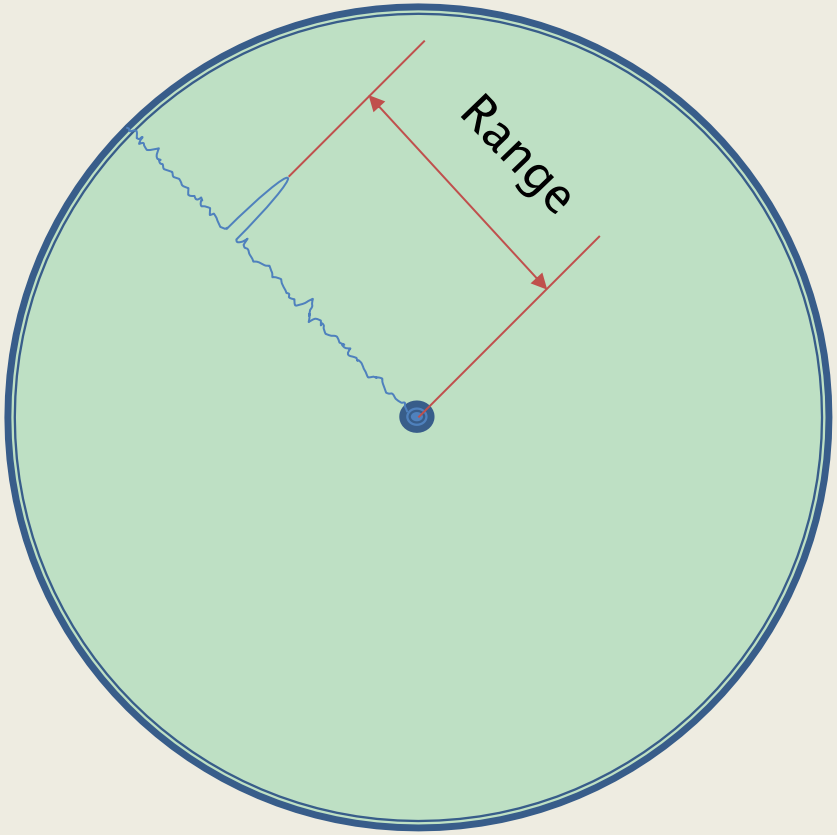

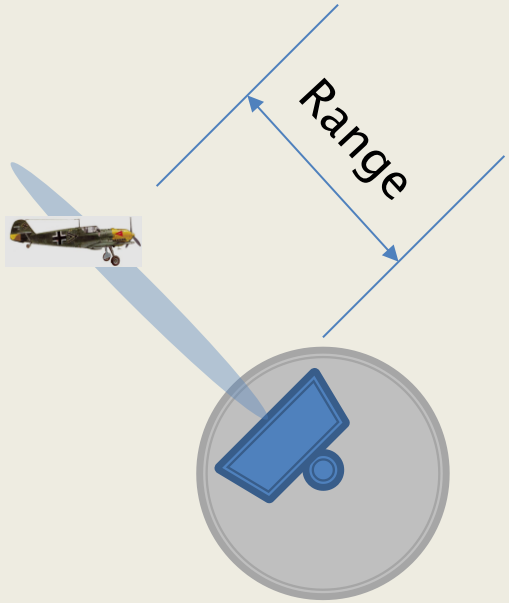

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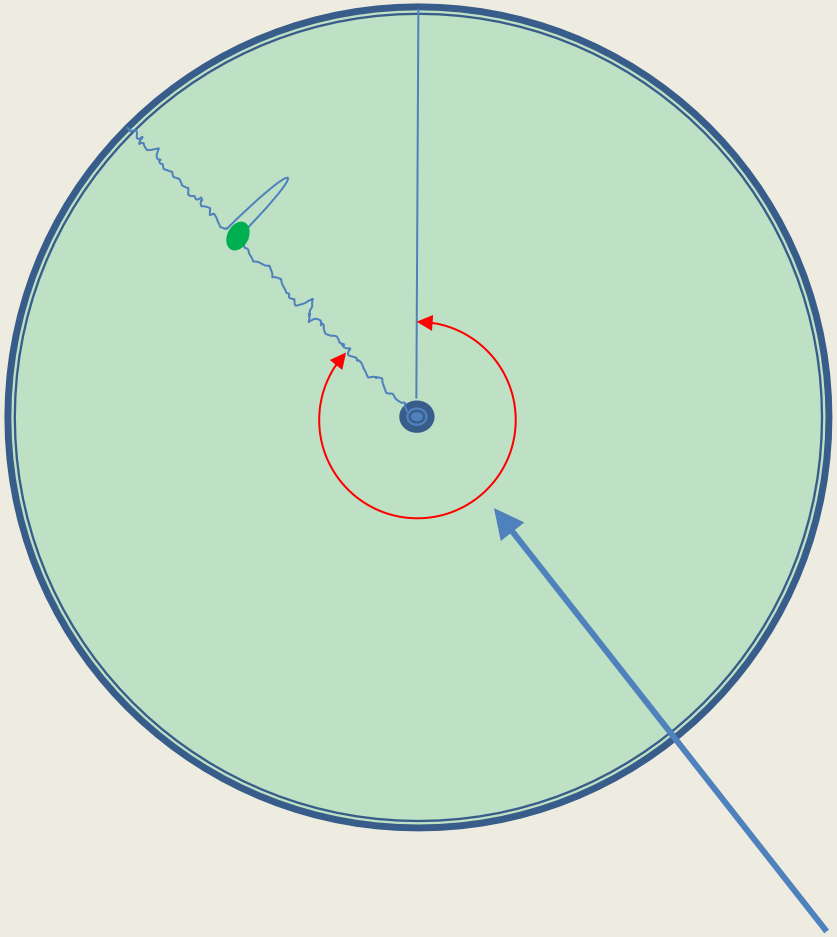

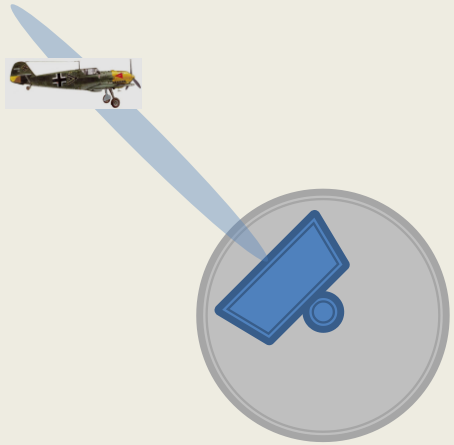

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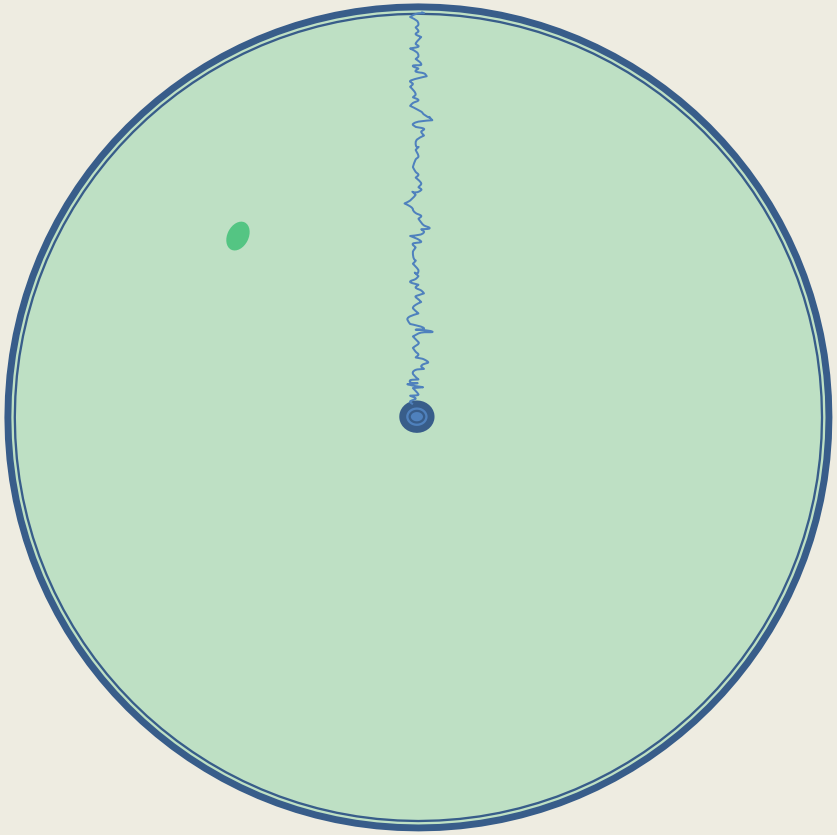

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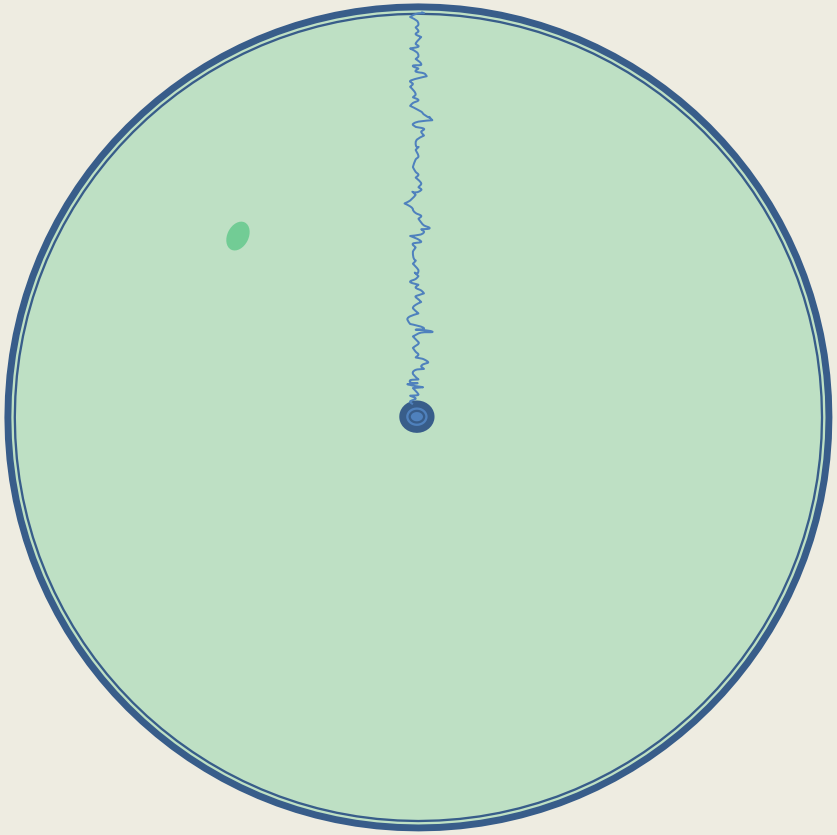

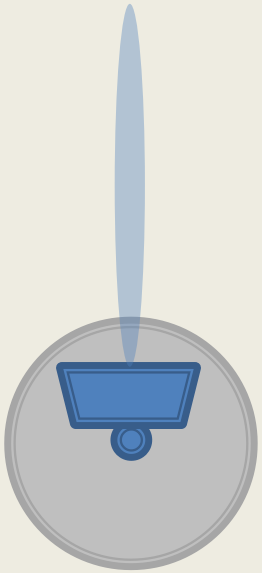

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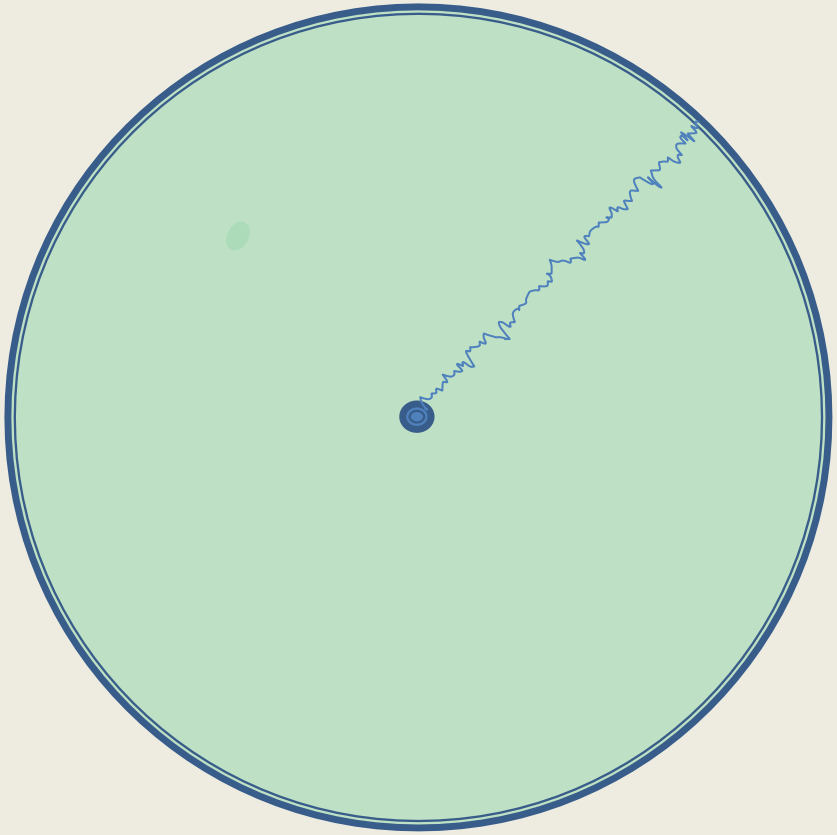

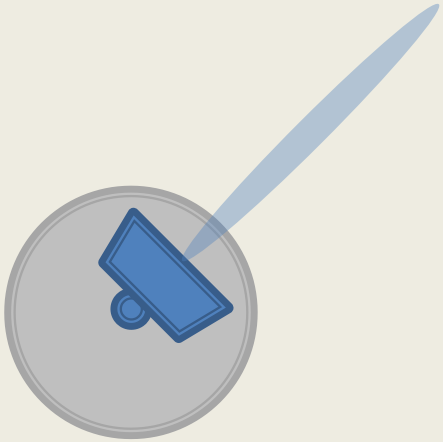

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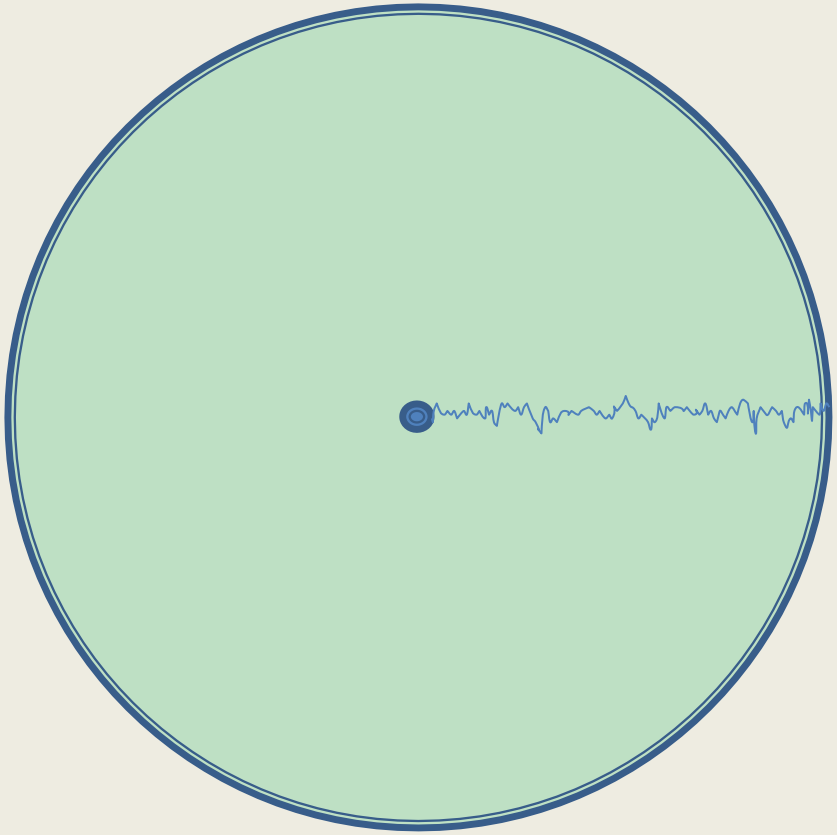

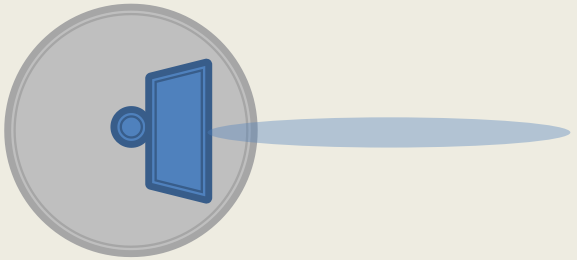

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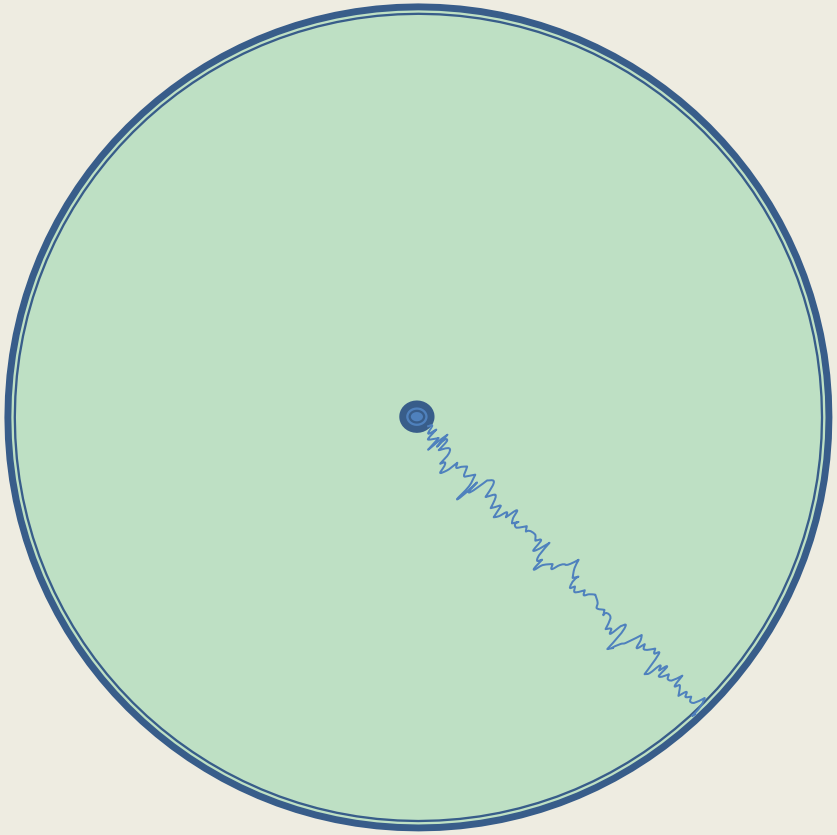

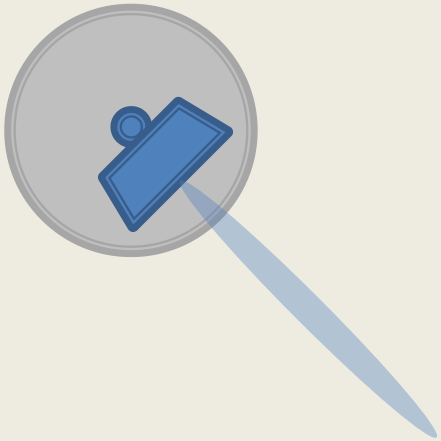

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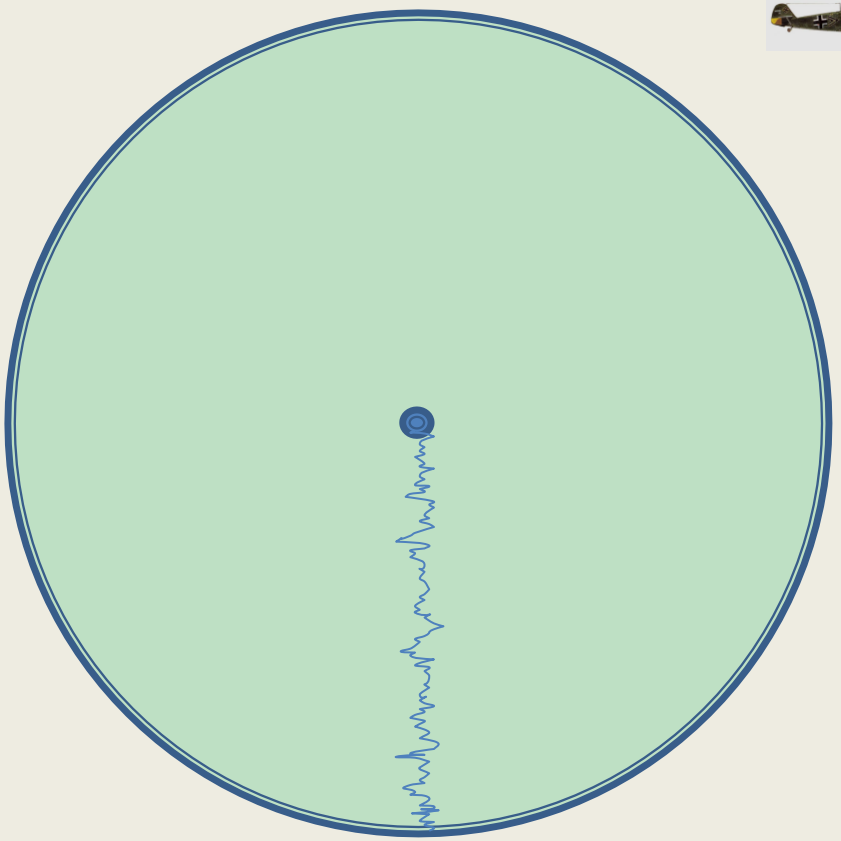
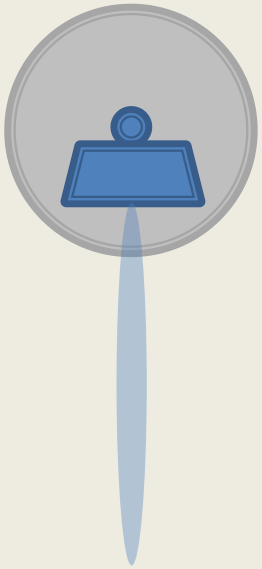
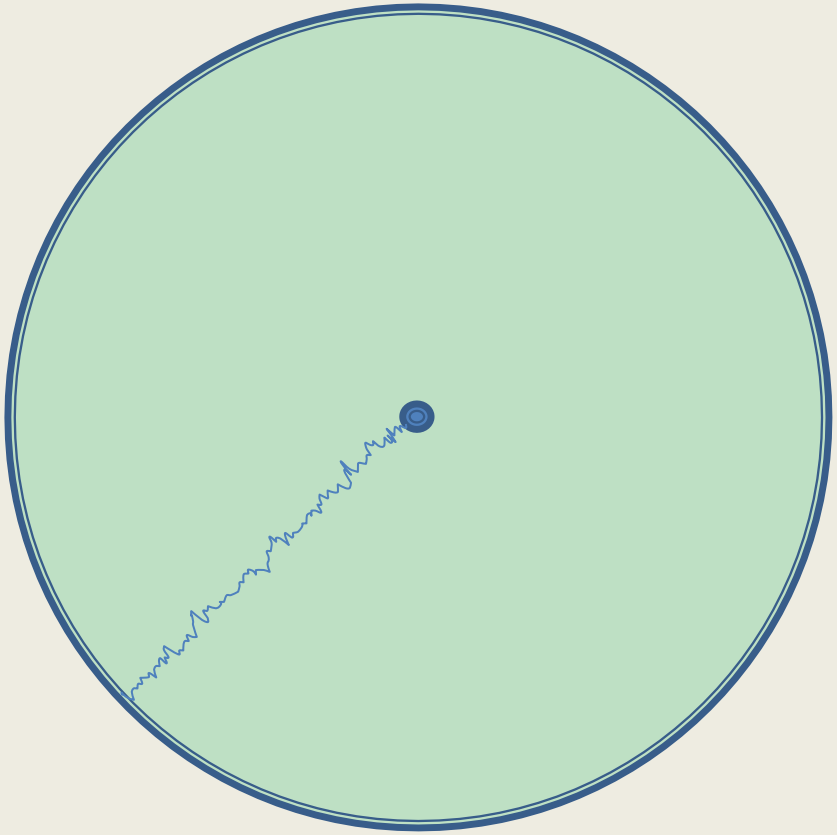
What is Radar ?





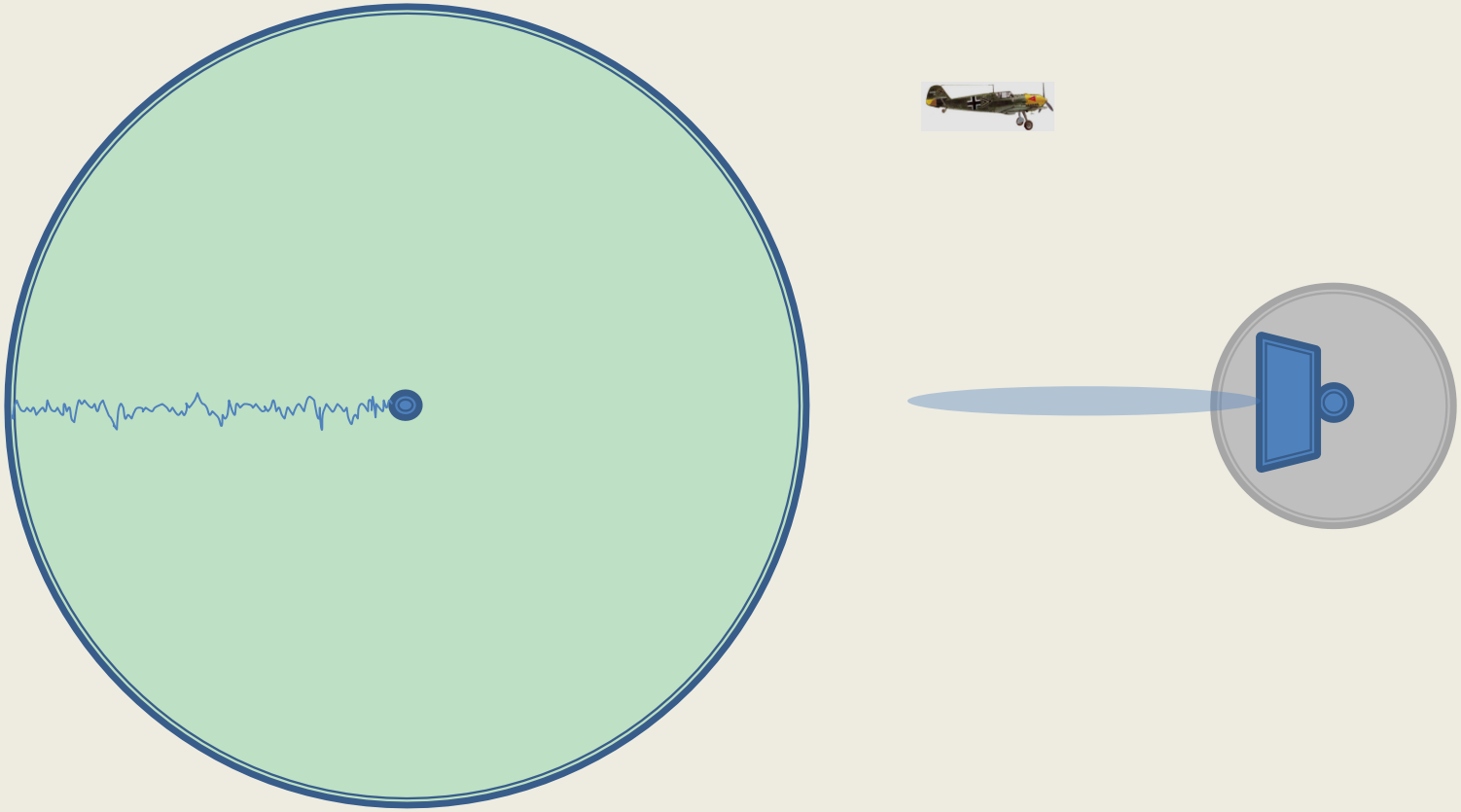
Bearing

What is Radar ?



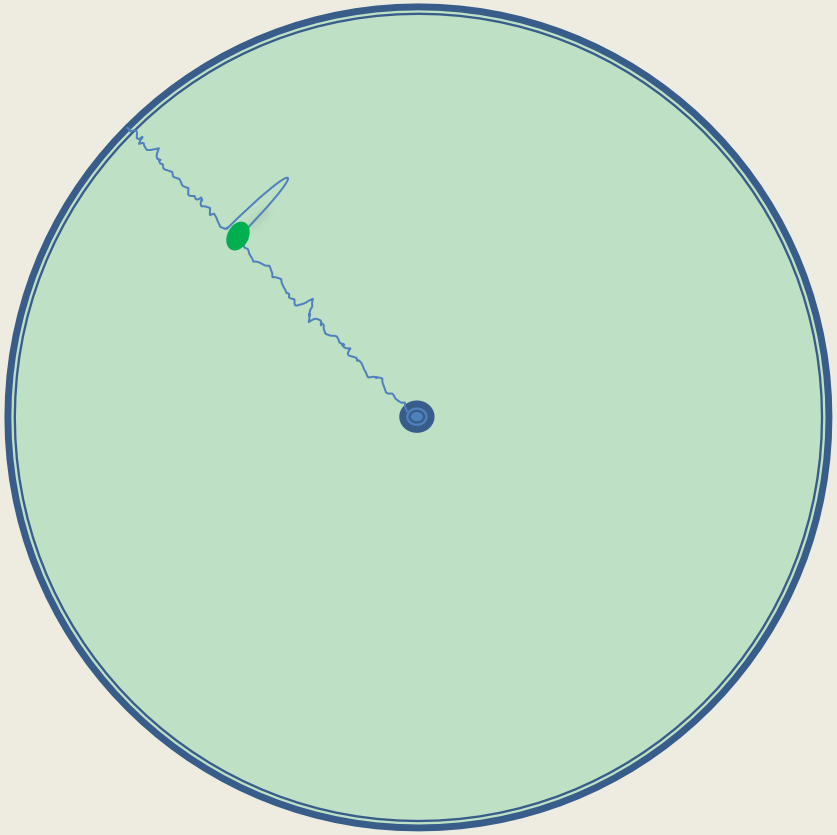
Bearing

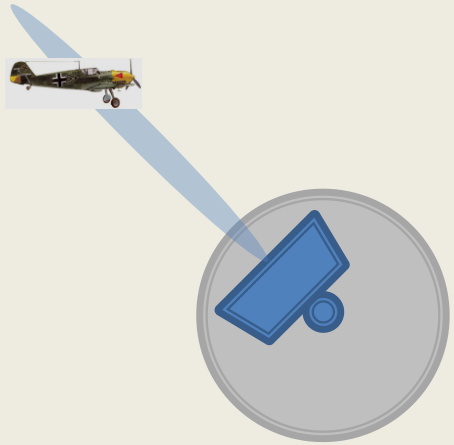
What is Radar ?



Bearing

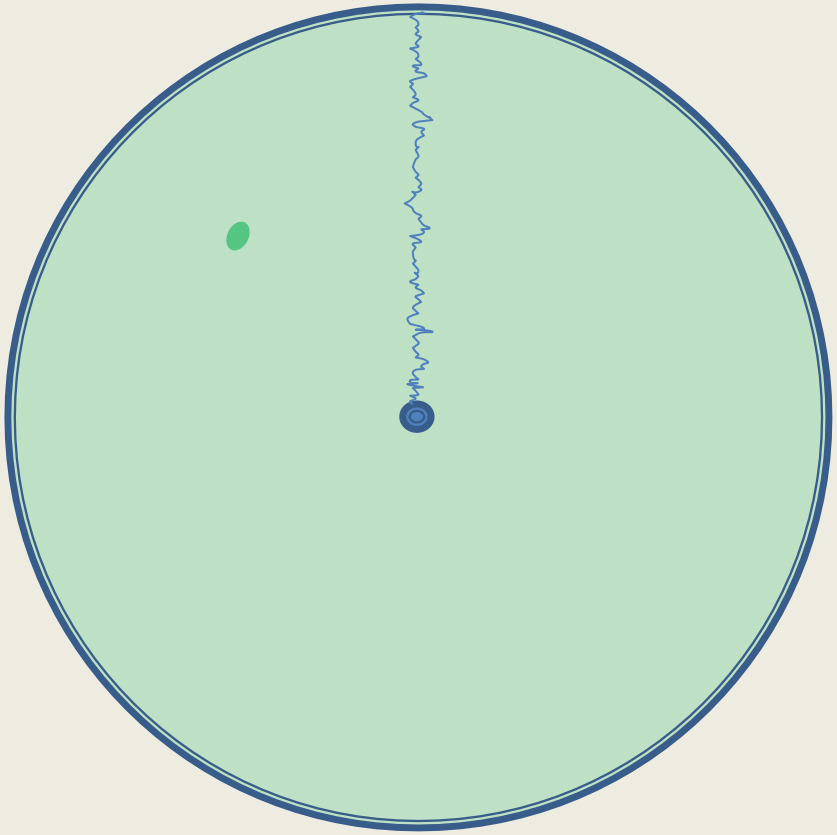
What is Radar ?





Bearing

What is Radar ?



Bearing

What is Radar ?

Bearing

PPI–Scope Display

Note that when a target is detected the brightness of the sweep is increased and appears as a ‘blip’

A History of Radar

QUIZ

Question 2:

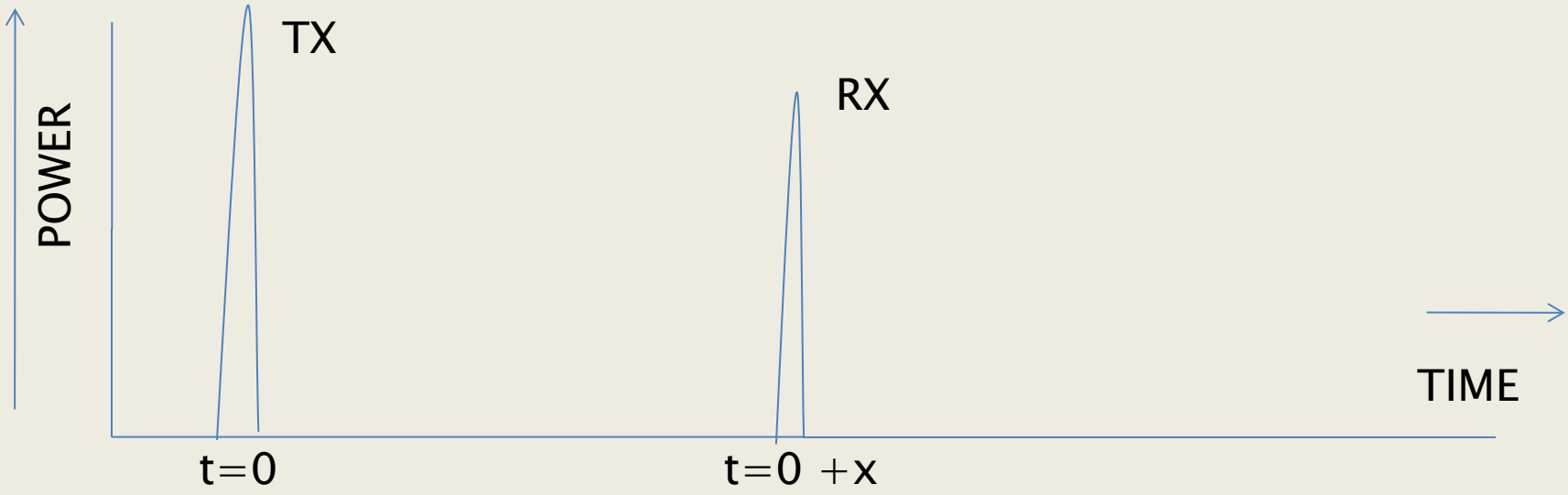
Which is more accurate?

Range or Bearing?

What is Radar ?

Answer: Range

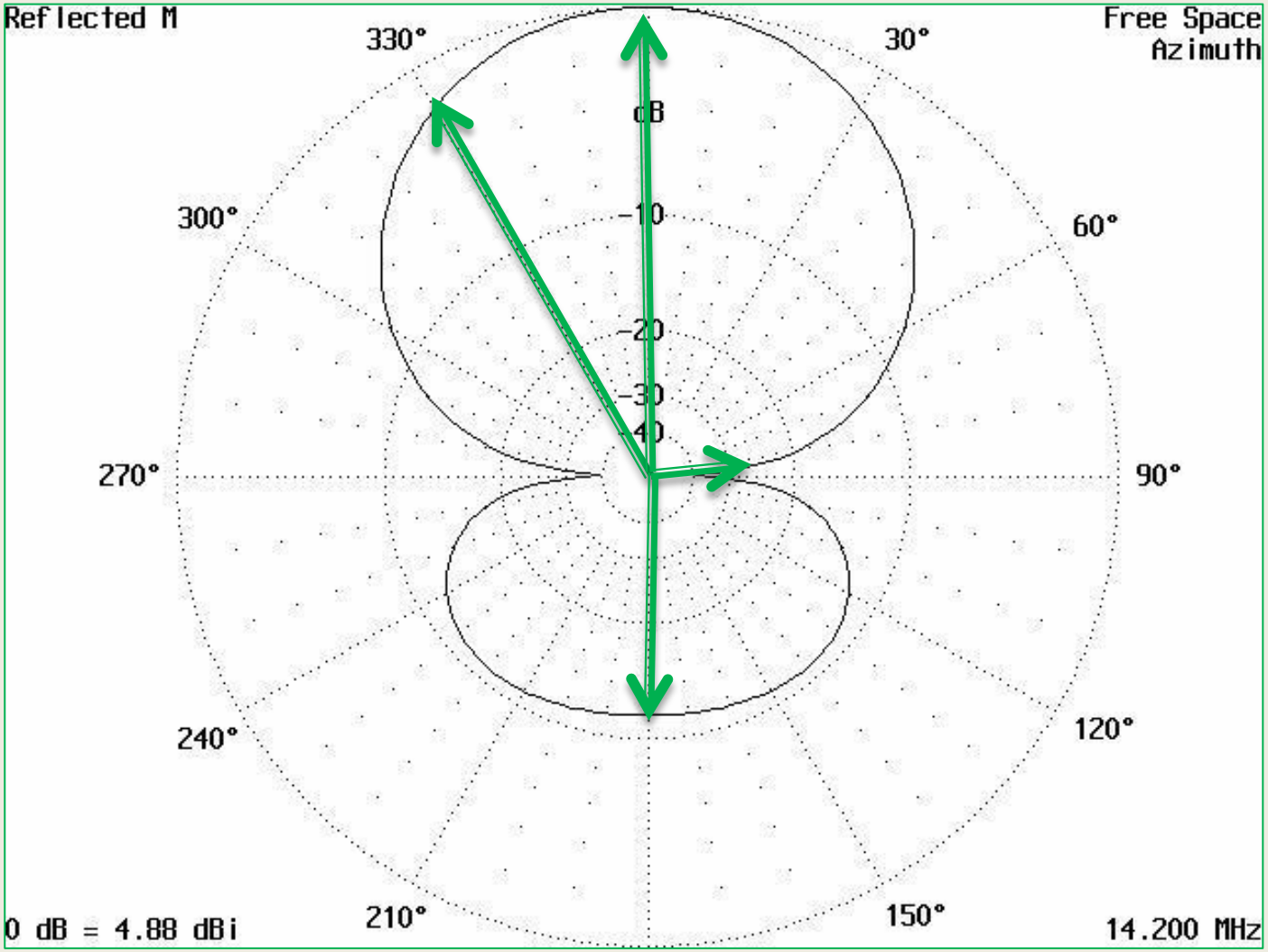
$$SPEED = \frac{DISTANCE}{TIME} \therefore DISTANCE = SPEED \times TIME$$



Remember this ?

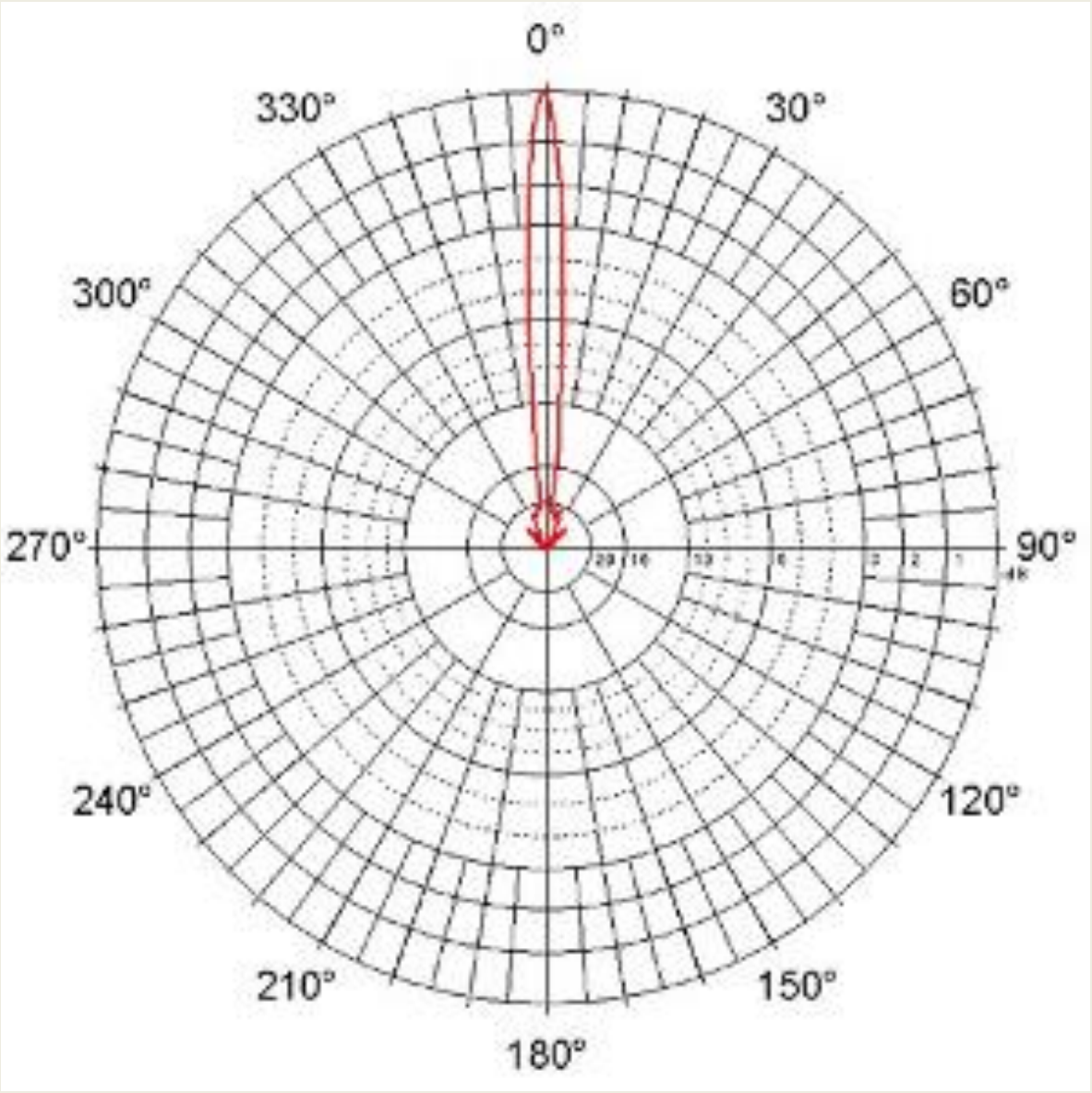
What is Radar ?

Bearing Accuracy



What is Radar ?

Bearing Accuracy



A History of Radar

- Historical Development
- What is Radar?
- Radar Types
- Radar Antennas
- Civilian Radars
- Military Radars
- Future

What is Radar ?

Antenna Types

More gain and a narrower beam
means more elements in the array !

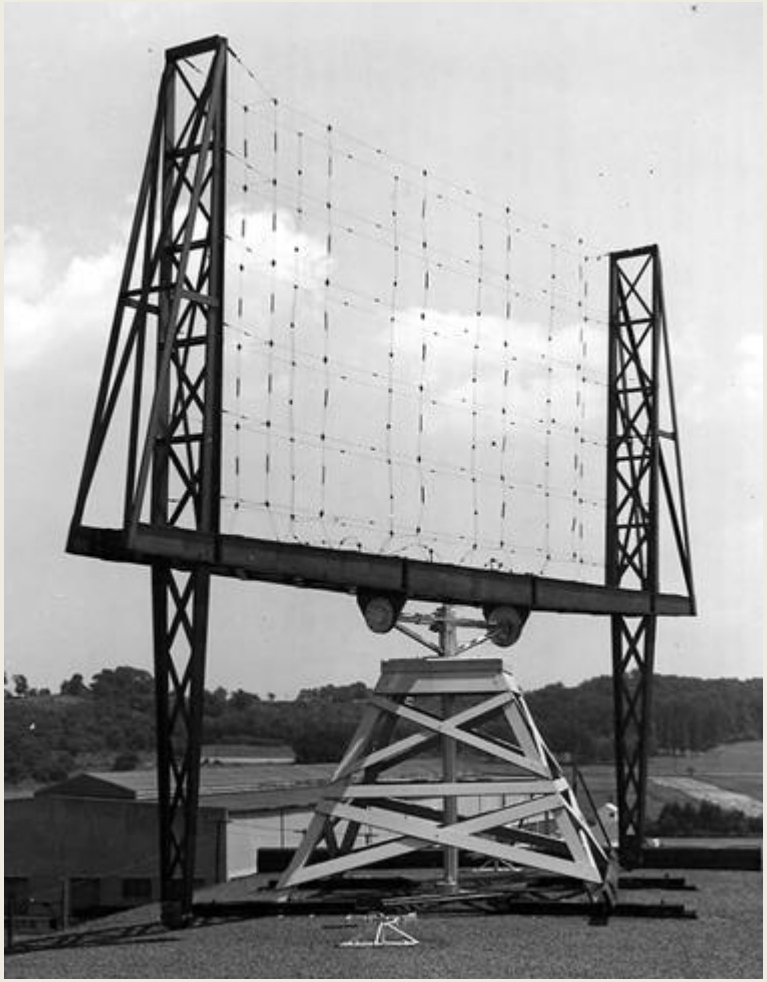
YAGI Antenna

What is Radar ?

Antenna Types

Early WW11 Experiments

Naval Research Labs 1937



What is Radar ?

Antenna Types

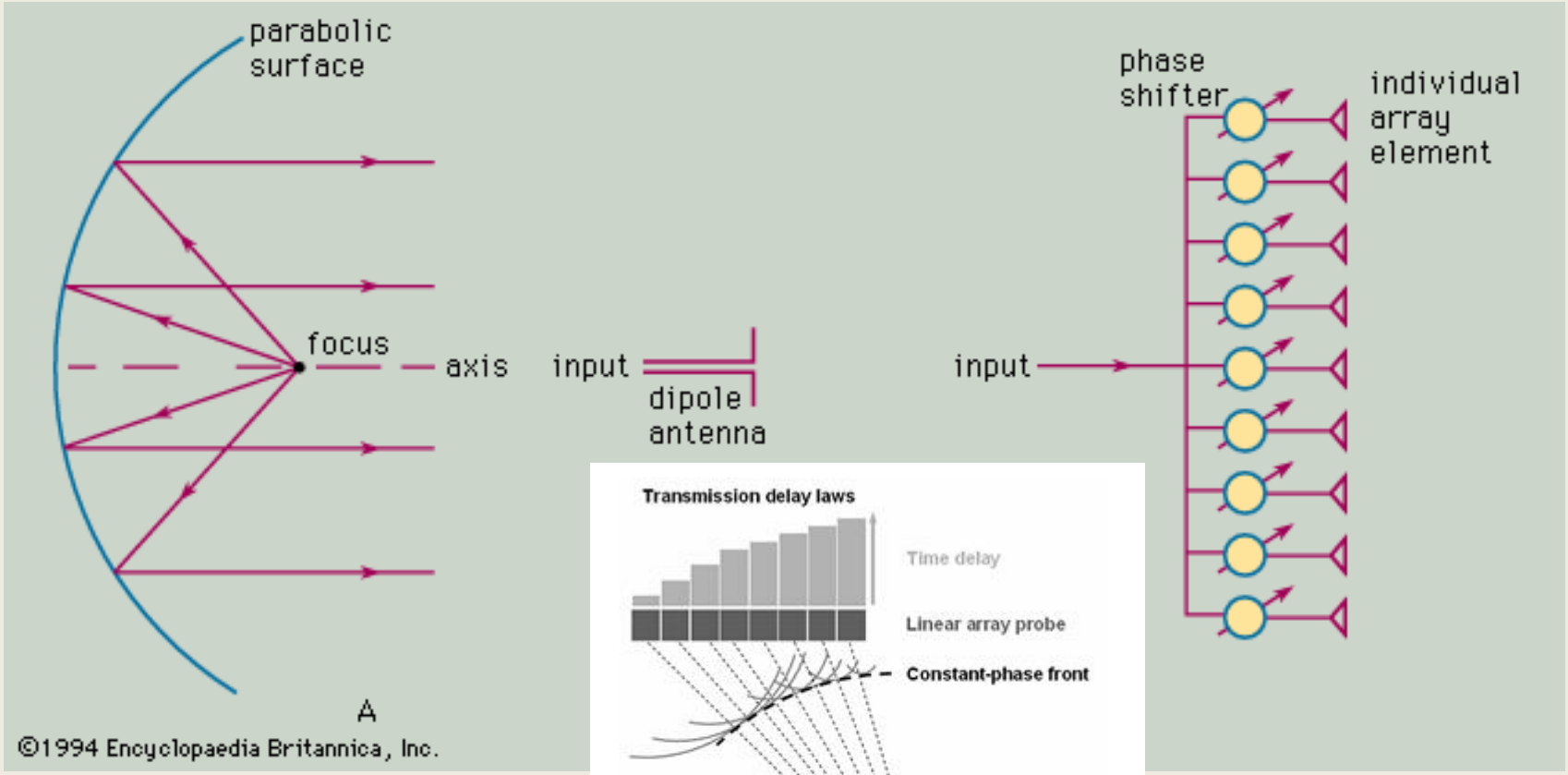
Decca Radar 1963

Approach, Guidance and Weather Radar

Note the use of a parabolic type reflector

What is Radar ?

Phased Array Antenna – Basic Principles



What is Radar ?

Phased Array Antenna – Basic Principles

Remember these ‘golf balls’ just off the A171 to Whitby ??

What is Radar ?

Phased Array Antenna – Basic Principles

- Only 3 sides but 360 deg coverage
- No moving parts
- Height 120 ft
- Each face has 2560 Tx/Rx modules
- Power Output ~2.5 MWatts
- Range ~ 3000 miles
- Part of the US Strategic Defence Initiative

The new Fylingdales Solid State Early Warning Radar,N. Yorkshire

What is Radar ?

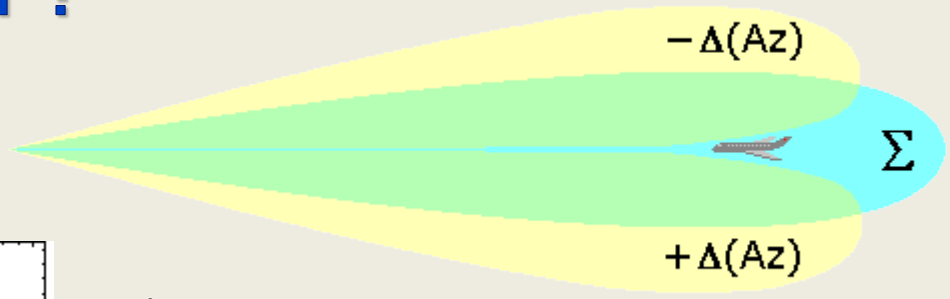
Phased Array Antenna – Basic Principles

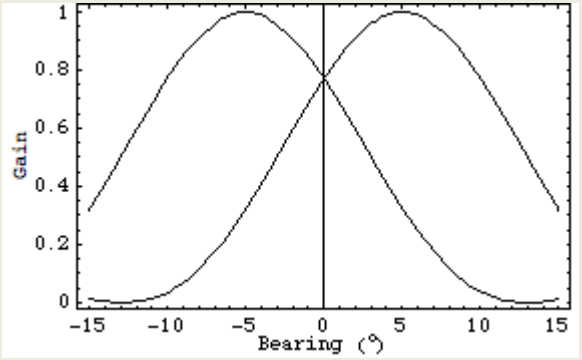
GSM Steerable ‘Smart’ Antenna

Seen now increasingly on motorways

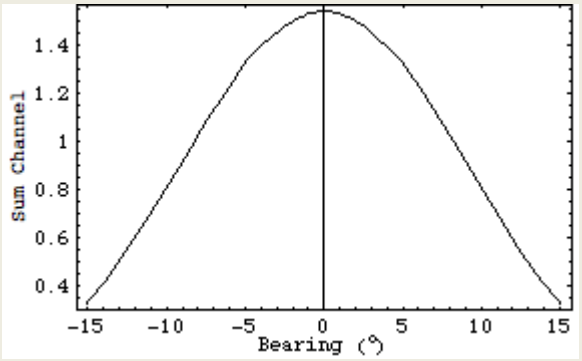
What is Radar ?

Monopulse

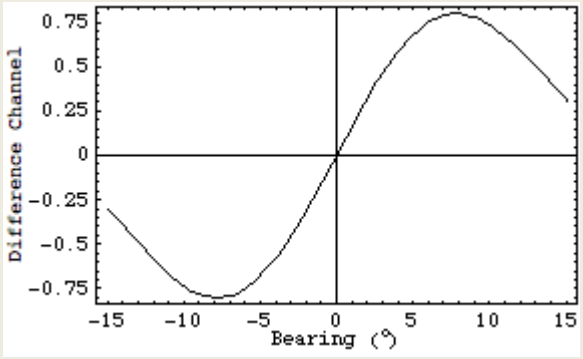




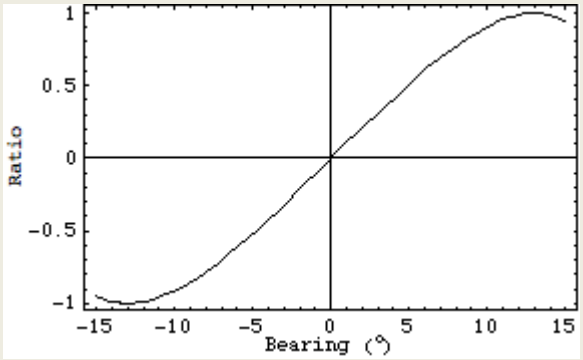
Two beams, steered so that they overlap



Sum of the two beam patterns



Difference of the two beam patterns



Ratio of the sum-difference patterns

What is Radar ?

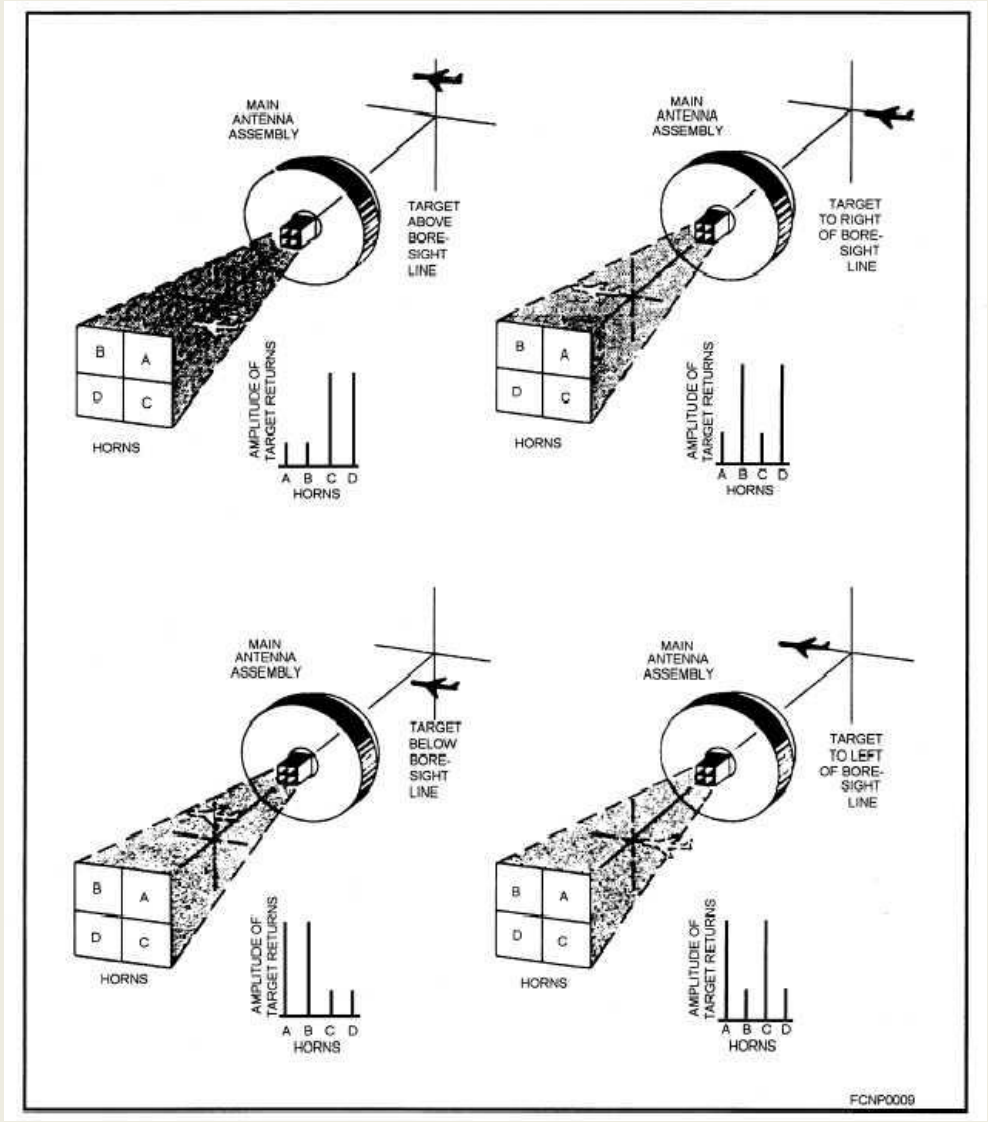
Monopulse

Advantages

- Single Pulse only required
- Difficult to detect
- Difficult to jam
- Accuracy of bearing data

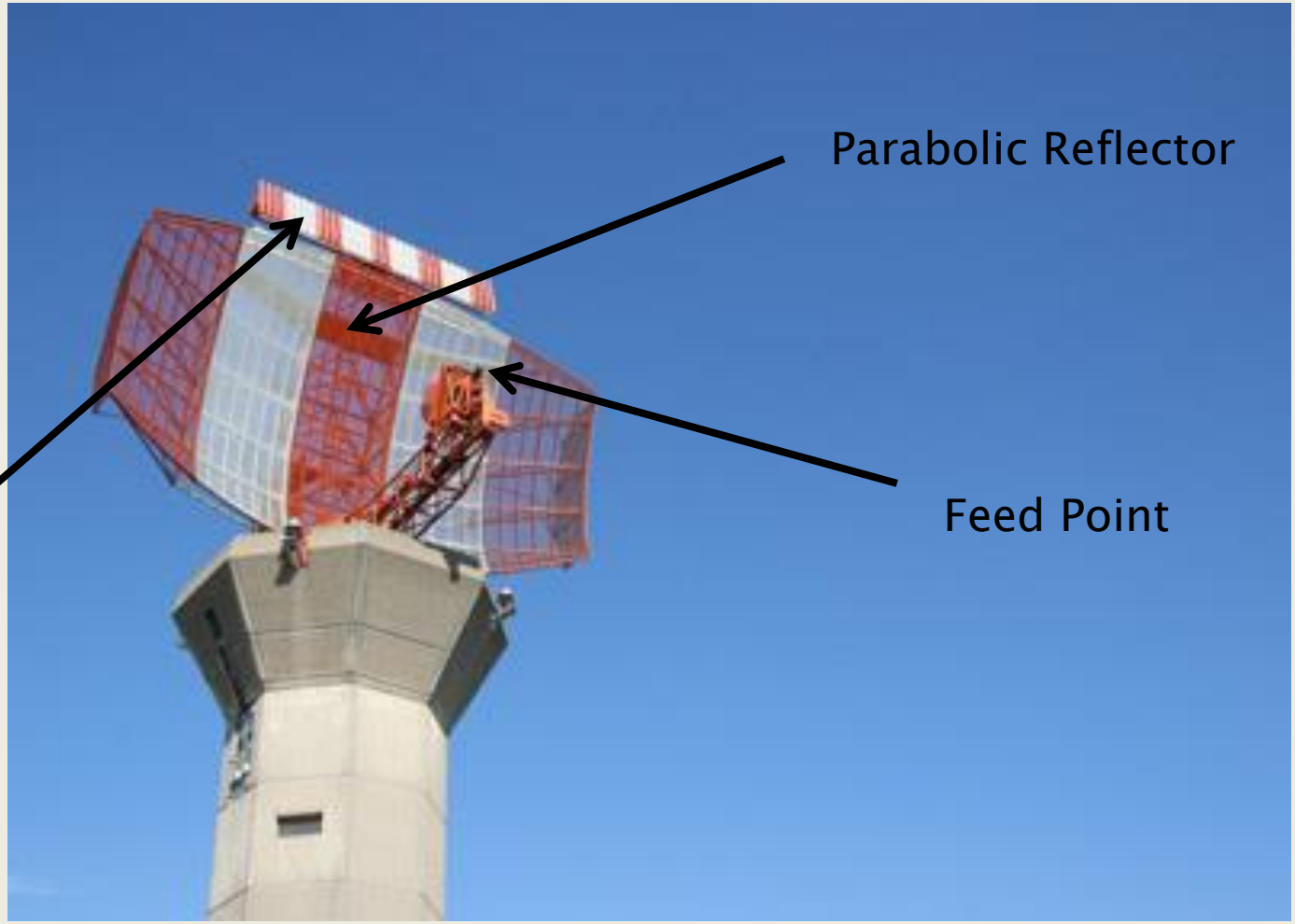
Disadvantages

- Cost
- Complexity



What is Radar ?

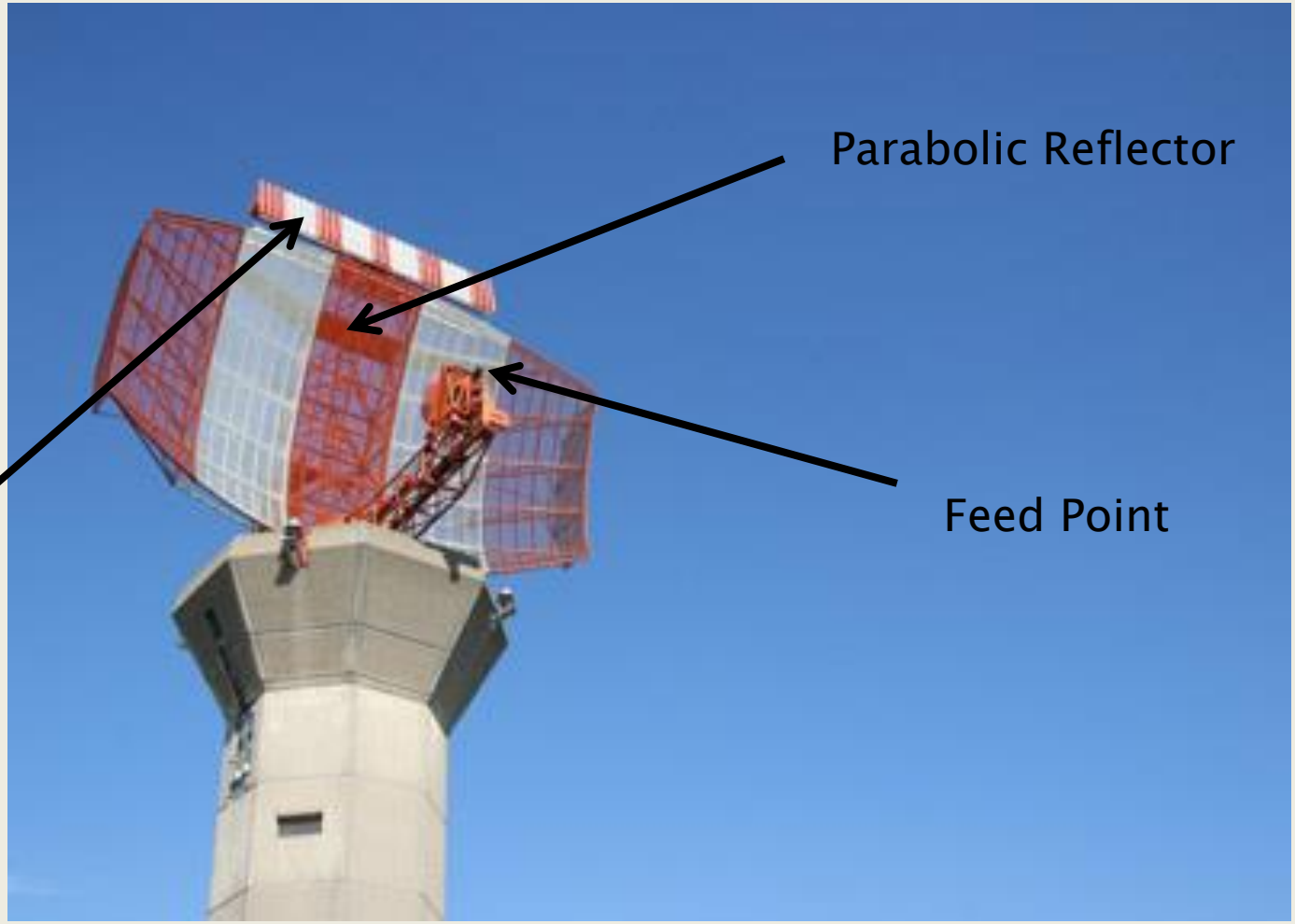
Modern 23cm
(1.3 GHz)
Airport Radar



Heathrow Airport Surveillance Radar

What is Radar ?

Modern 23cm
(1.3 GHz)
Airport Radar



Secondary Radar

Heathrow Airport Surveillance Radar

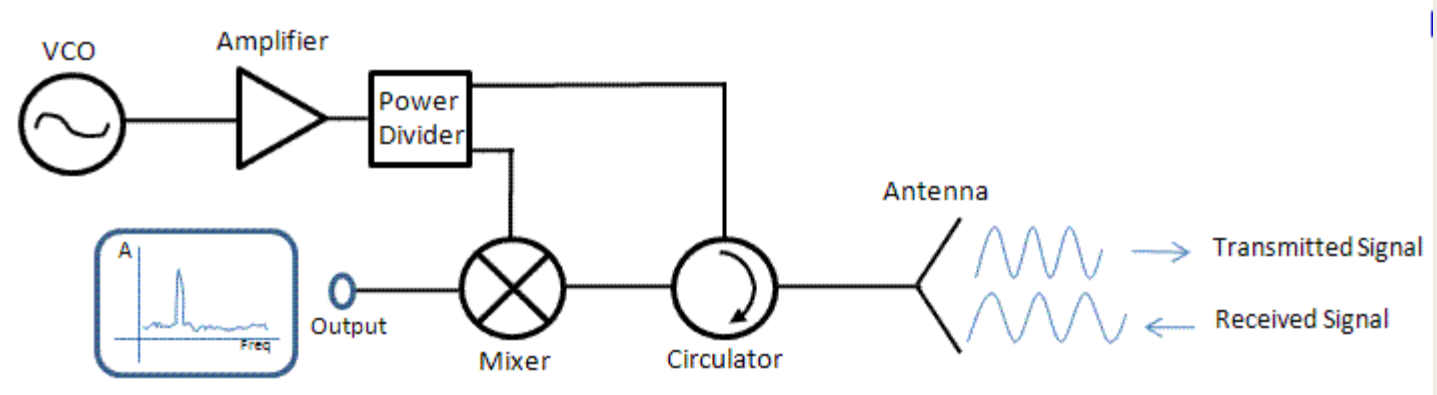
What is Radar ?

Secondary Radar

- Detects and measures aircraft position
- Requests additional information from the target
- Aircraft responds to interrogation sending back encoded data
    - Identity
    - Altitude
- Relies on target having active transponder
- Based on IFF developed in WW II

What is Radar ?

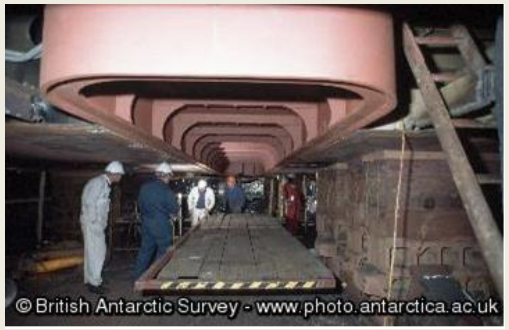
CW Doppler Radar



- Works on the Doppler principle
- Simple design
- Can be low cost
- Can be modified to indicate direction of travel (FM CW)
- Many uses including police speed cameras

Other Radar Applications

- Shipborne – Naval and Civil
- Weather – Balloon tracking and rainfall radars
- Space Resource Mapping
- Ground Penetrating Radar (GPR)
  - Civil, Forensic, Archaeology, Mines etc
- Speed Checking – Police, Harbour Authorities etc
- Ultrasonic
  - Foetal checks
  - Sonar
  - Echo Sounders
- Automobile Anti-Collision using 67 GHz
- Traffic lights, Height Finding etc .. etc ..



Other Radar Applications

Earth Resource Mapping

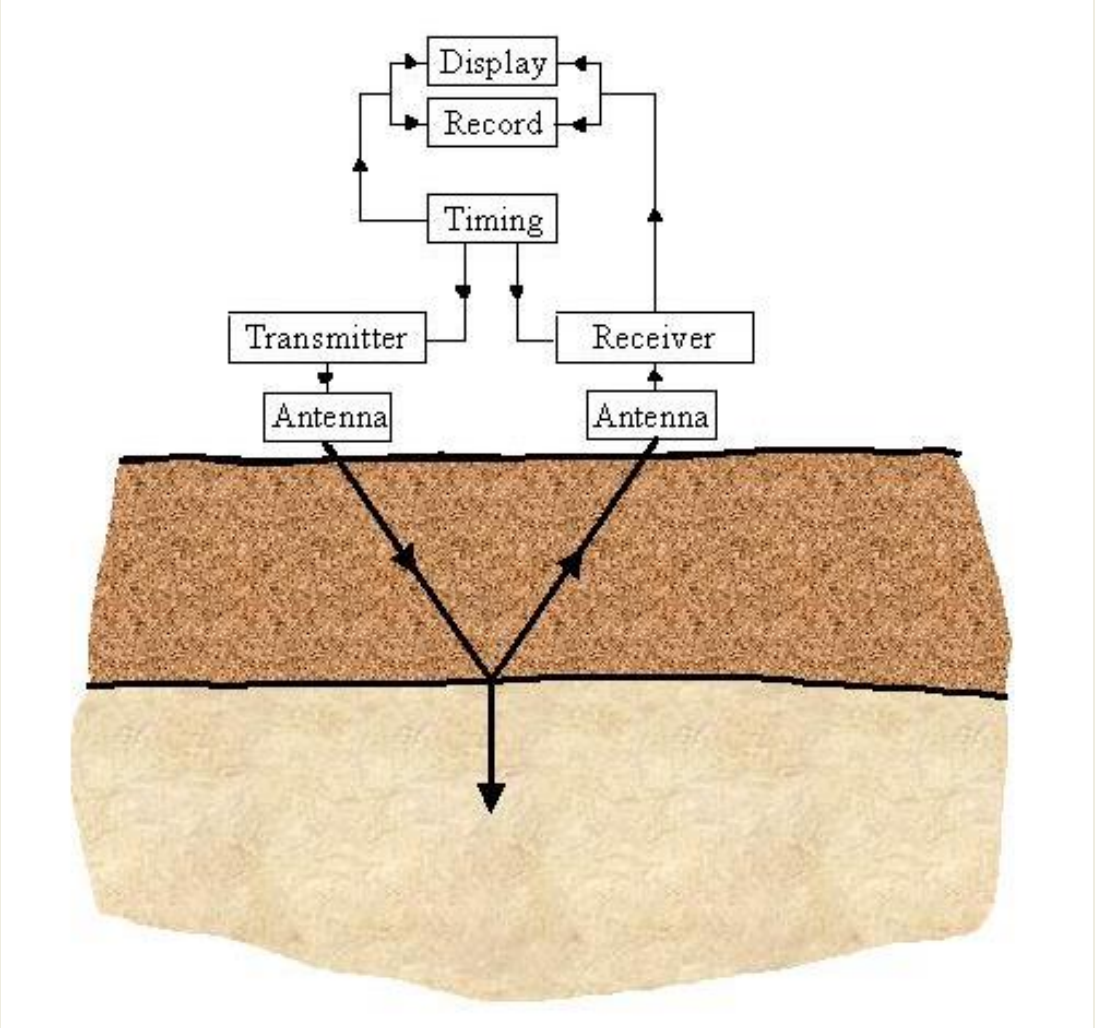
ESA Envisat

- Prime contractor Dornier Germany
- Launched 2002 in a polar orbit
- Provides measurements of atmosphere, ocean, land and ice
- Advanced Synthetic Aperture Radar (SAR)
- Radar Altimeter

Other Radar Applications

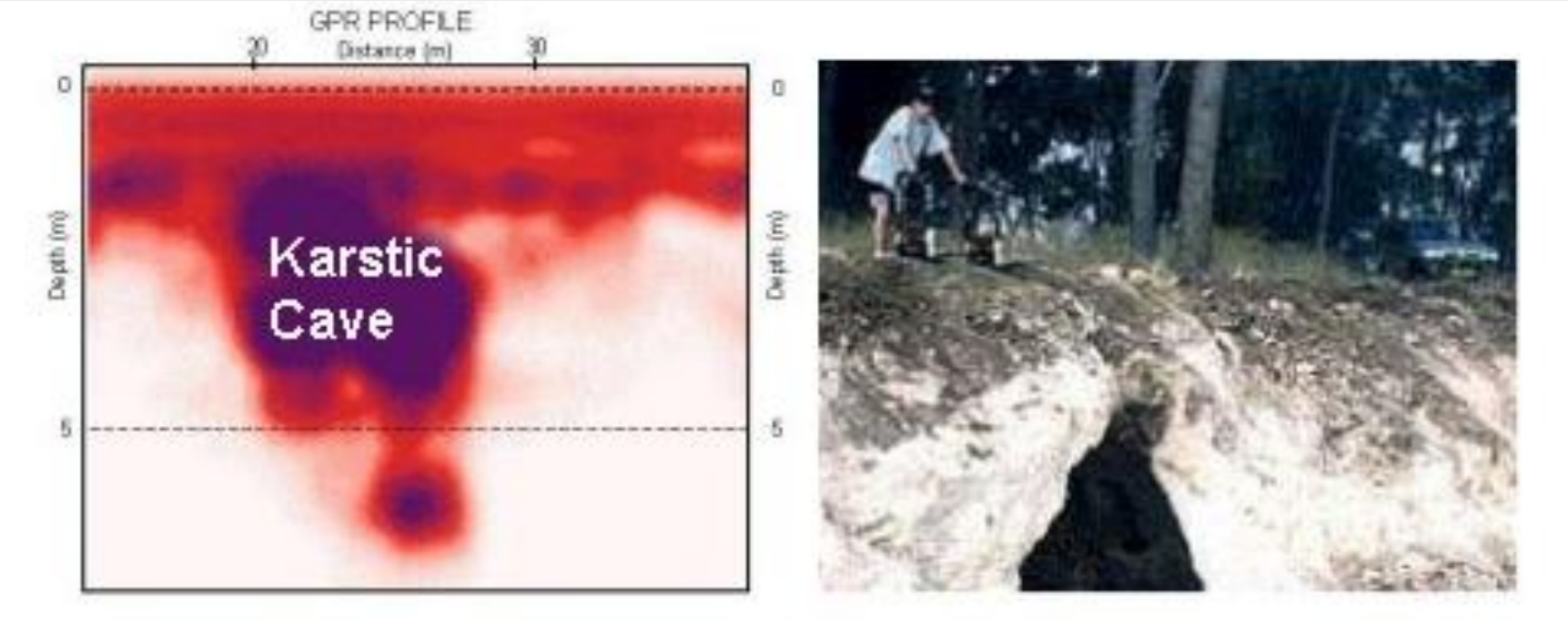
Ground Penetrating Radar

GPR principle



Other Radar Applications

GPR



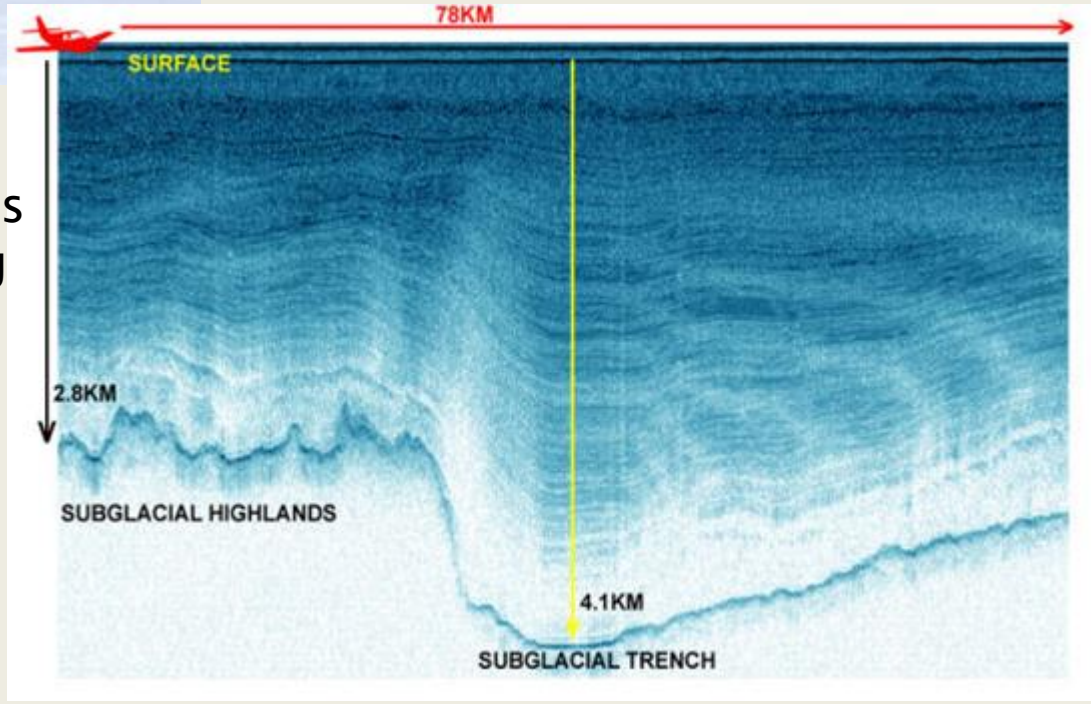
A karstic cave in Israel

Other Radar Applications

GPR with the British Antarctic Survey

Antennas operating at 150 MHz

- Uses pulsed radar techniques with heavy signal processing
- 8m depth resolution
- > 4km depth



Other Radar Applications

Speed Cameras

Operates in K Band ~ 24 GHz

Accuracy < 2% based on photos compared to road markings

Radar used to trigger camera and flash sequence when vehicle detected above a set speed limit

The Future of Radar

- Smaller, lighter hardware
- Extension of the use of digital signal processing
- Better 3D imaging
  e.g. 94 GHz FMCW at St Andrews Uni
- ‘Smart’ control of cars
- …. ??

What is Radar ?

FINALLY !

What is 373.2 ??

What is Radar ?

376.73031346177… Ohms is the Impedance of Free Space

Blame John Wells for giving out false information !

Most of us (ex) engineers are content with 377 ohms !

THANK YOU ALL FOR LISTENING