

Reflections on Radar

Dr Nick Shuley

Radar in a nutshell?

- Primarily an active electromagnetic sensor (as compared to a passive sensor - radiometer).
- Suffers much less attenuation compared to optical (so much larger range).
- Uses the known propagation velocity of light ($3 \times 10^8 \text{ msec}^{-1}$)
- Can use sophisticated antennas (phased arrays to generate beams and process the return signals).
- Huge number of specialized radars.

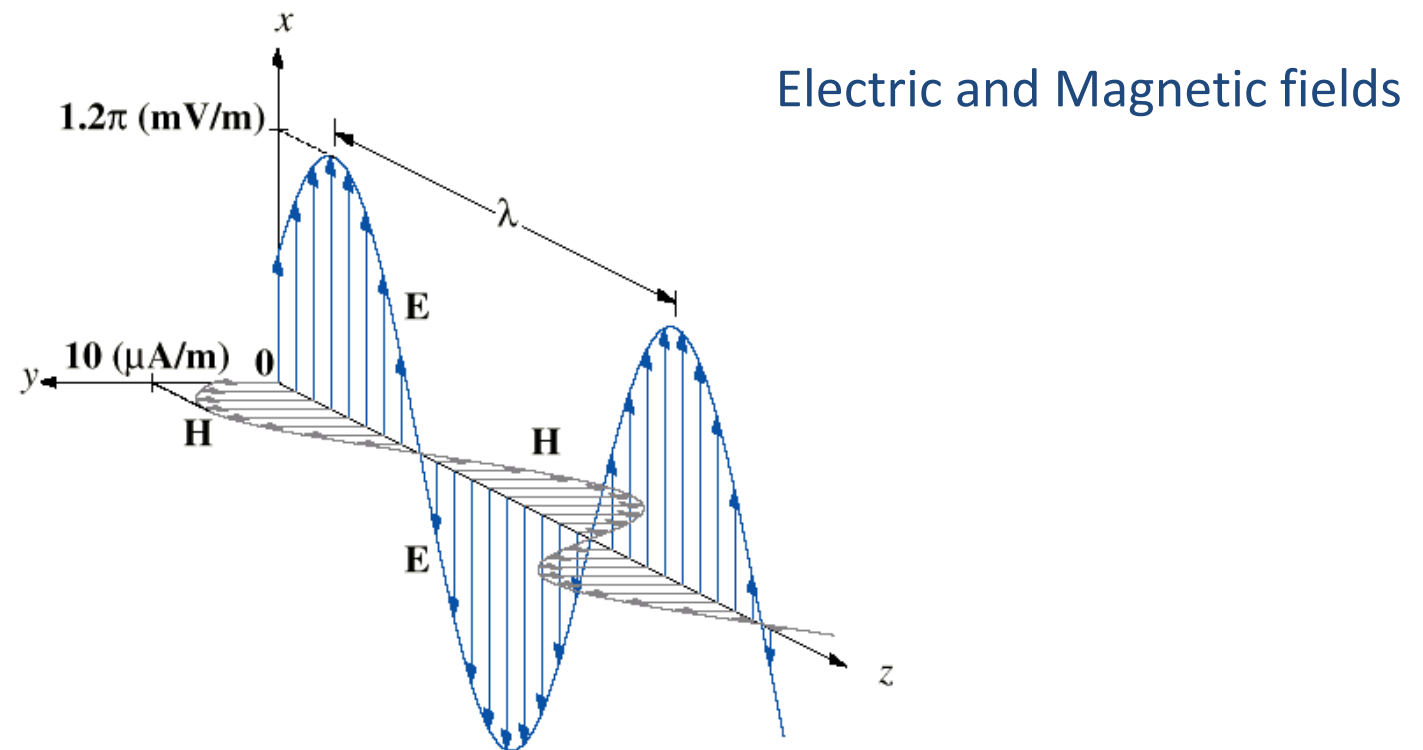
Some radar applications

- Moving Target indicator) MTI.
- Fire control radar
- Rain radars
- Wind Radar (Doppler)
- Ground Probe Radar (GPR)
- Tracking Radar (Monopulse)
- Terrain avoidance Radar
- Police radar (and LIDAR)
- Air Traffic Control radars (ATC)
- Insect radar
- Collision Avoidance Radar
- Synthetic aperture radar (SAR)
- Inverse Synthetic Aperture Radar (ISAR)
- Surveillance radar
- Over The Horizon Radar (OTH).
- Bistatic Radar
- Airborne Early Warning (AEW)
- Slope Stability Radar
- Target acquisition and identification radars

Early beginnings

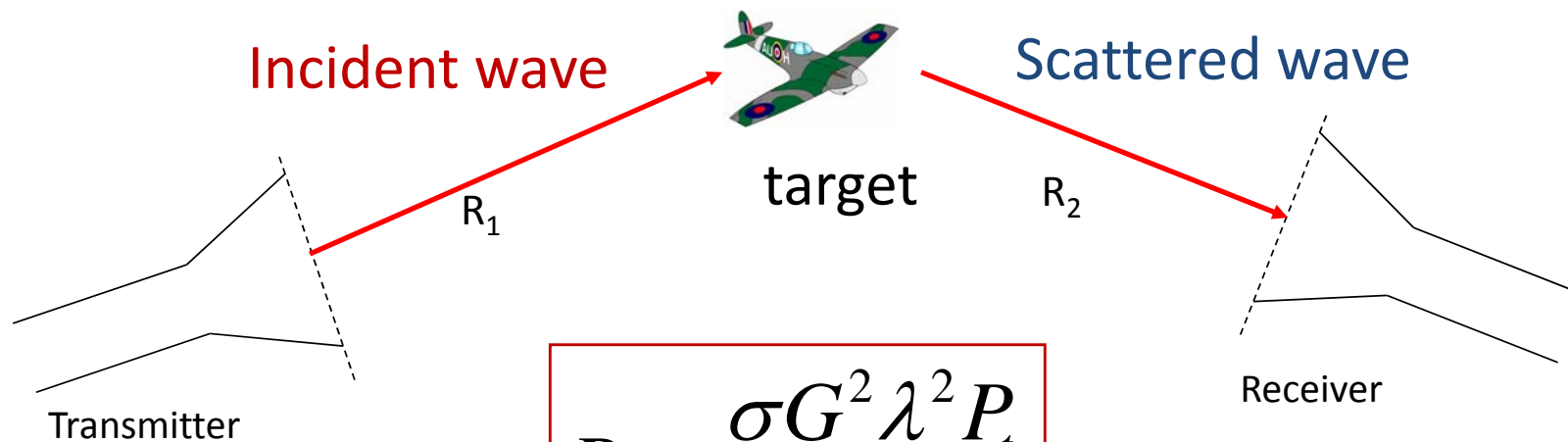
- Need for advance warning systems after WW I
- Churchill leads the way – “Cursed hellish invention and development of war from the air”.
- Watson Watt at Met. Bureau reports that aircraft disturb receivers when flying close.
- Wilkens notes that at a wavelength of 50m (6MHz) a transmitter with a simple antenna could detect an echo from aircraft at 10 miles at 20,000 feet.
- “Detection of Aircraft by Radio Methods” Watson Watt, February 1935.

Electromagnetic Wave



The radar range equation

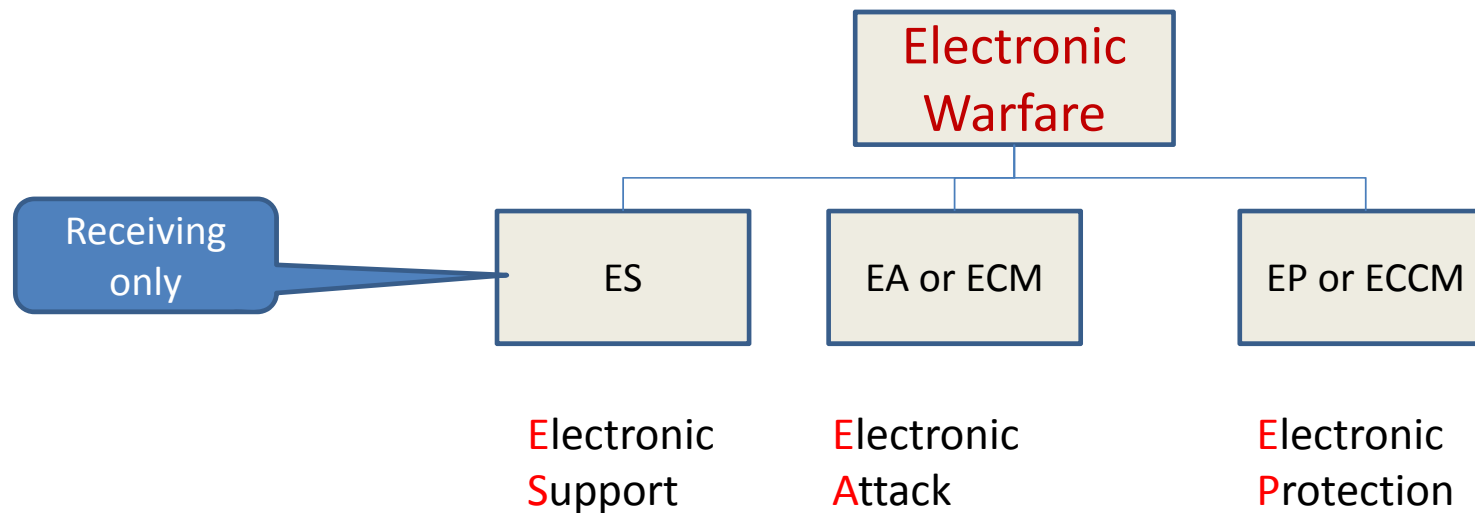
RCS = σ (aspect and polarization dependent)



$$P_r = \frac{\sigma G^2 \lambda^2 P_t}{(4\pi)^3 R^4}$$

Note the 4th power !

Defeating Radar



Hostile radiations are:

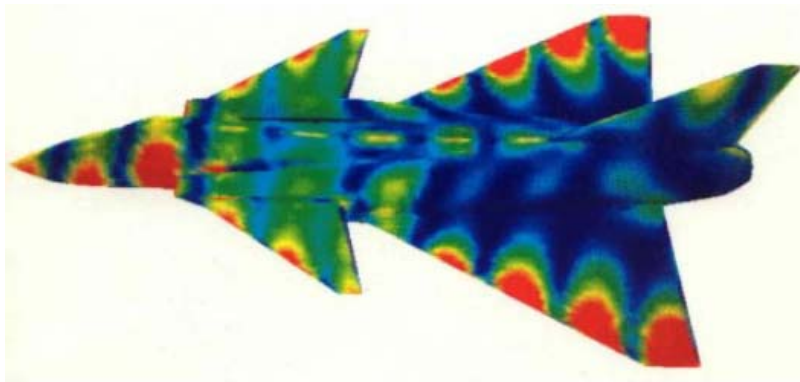
- ❖ Searched for
- ❖ Intercepted
- ❖ Located
- ❖ Analysed
- ❖ Identified

- ❖ Primarily, Jamming
- ❖ Deception
- ❖ IFF
- ❖ Decoys

- ❖ Low Probability of Intercept (LPI)
- ❖ Low sidelobes
- ❖ Monopulse
- ❖ PRF agility

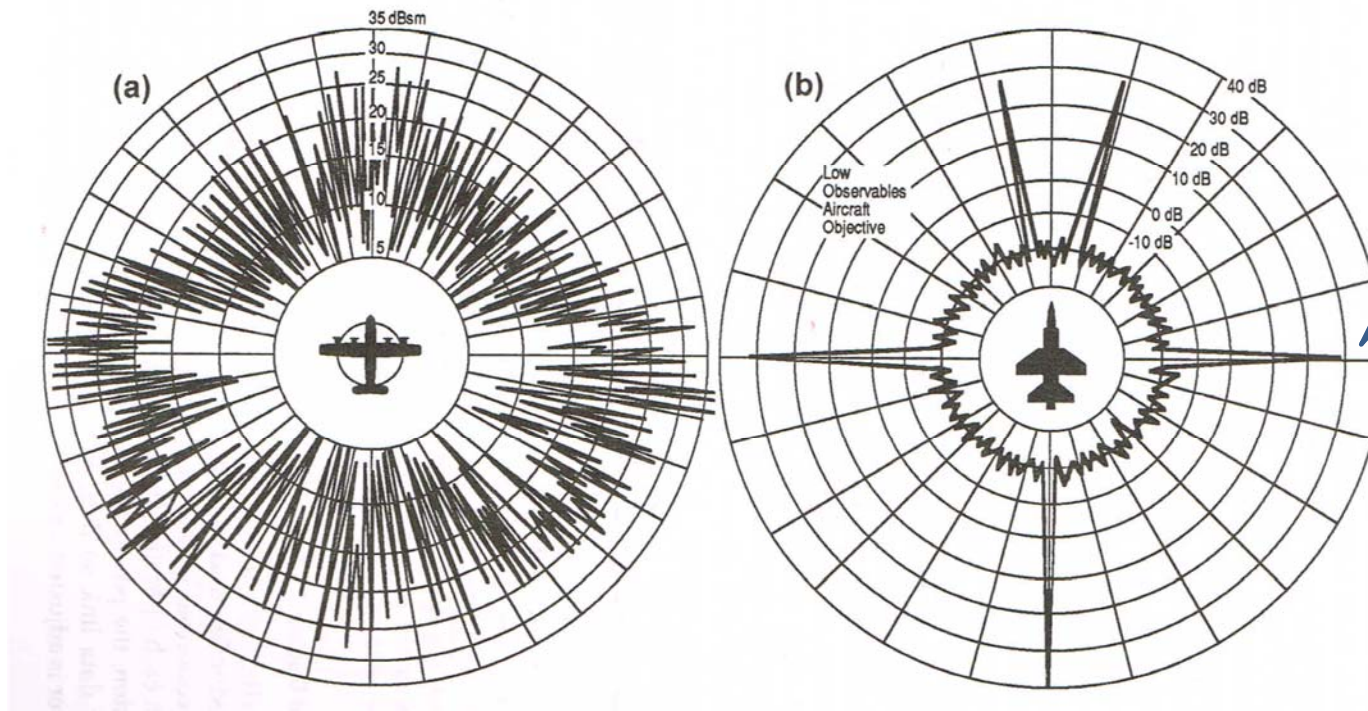
Induced Currents on a radar target

Calculated using computational electromagnetic (CEM) software designed to numerically solve Maxwell's equations.



Single frequency illumination from the LHS

Stealth strategy for RCS

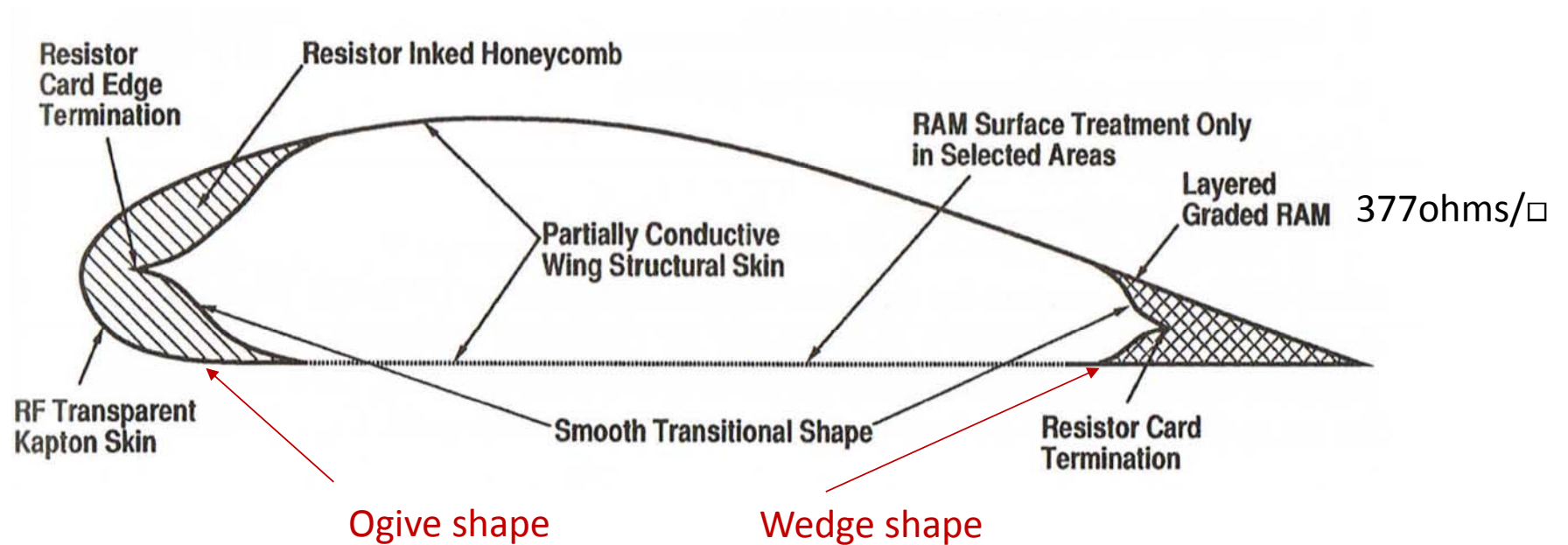


Conventional Aircraft RCS

Stealth Aircraft RCS

Radar cross section reduction (RCSR)

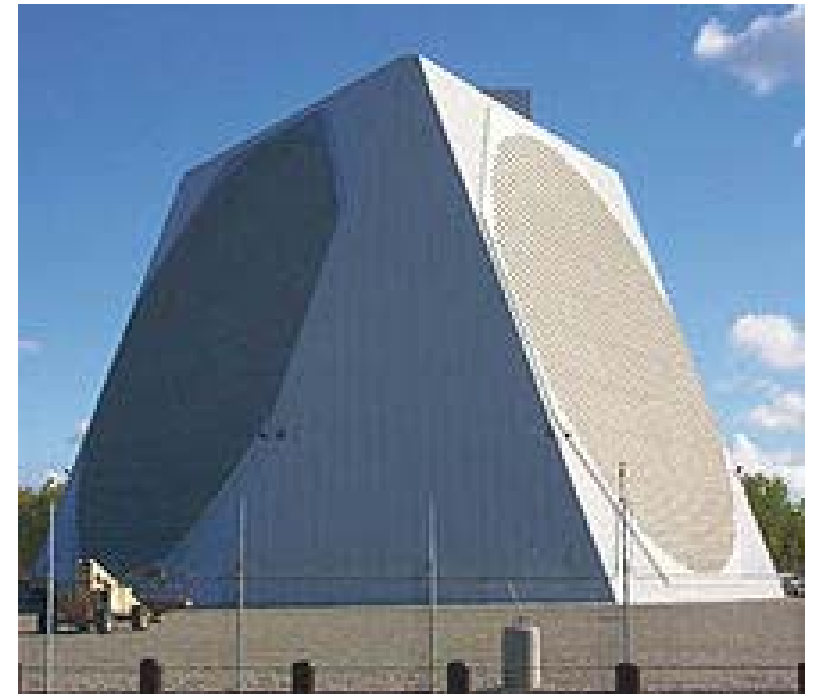
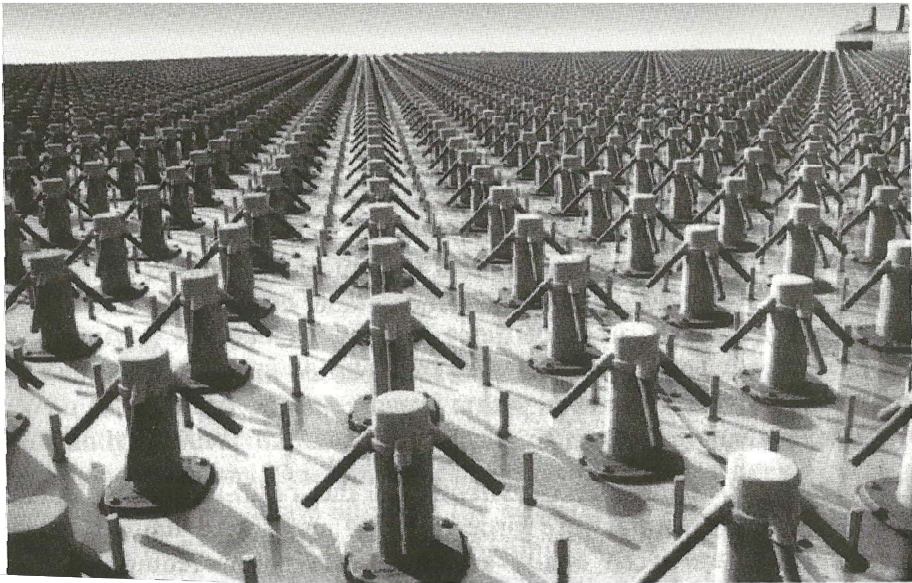
One method uses RAM (radar absorbing materials)



LPI- Shaping is one strategy

- ❖ Radar Cross Section Reduction (SR71 was an early effort).



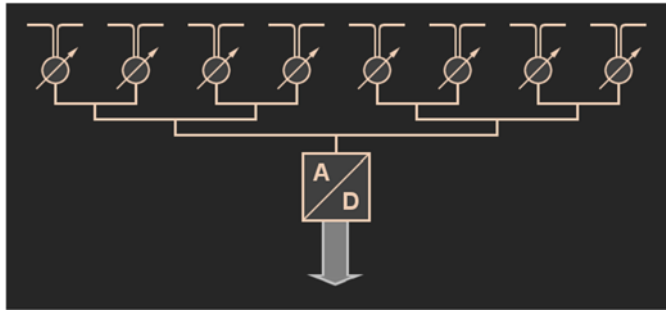


PAVE PAWS RADAR

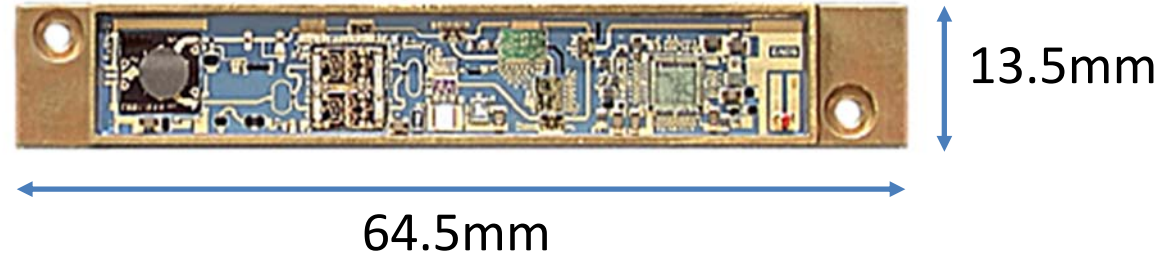
(Phased Array Warning System)

Transmit/Receive (T/R) module

A key component of digital beamforming technology.



Transmitter Receiver
feed network to the
antenna elements



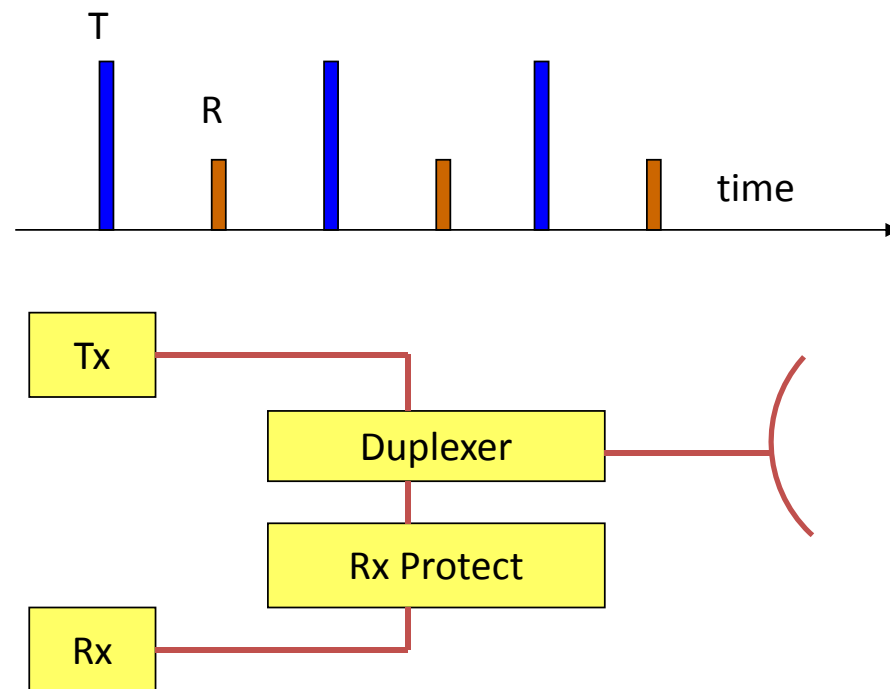
Includes:

- A power amplifier
- A ferrite circulator (connects Tx and Rx)
- Limiter
- Low noise pre-amplifier
- Down converter (mixer)

All in Gallium Arsenide (GaAs) semiconductor technology at RF.

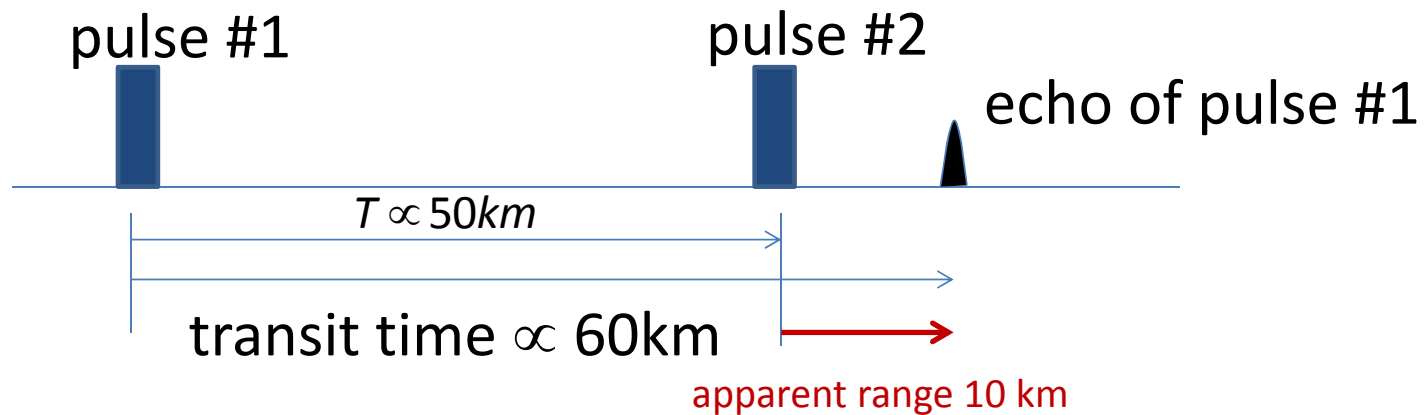
Most Radars are pulsed

- RADAR – **R**Adio **D**etection **A**nd **R**anging



In pulsed radar the transmitted & received signals are separated in time.

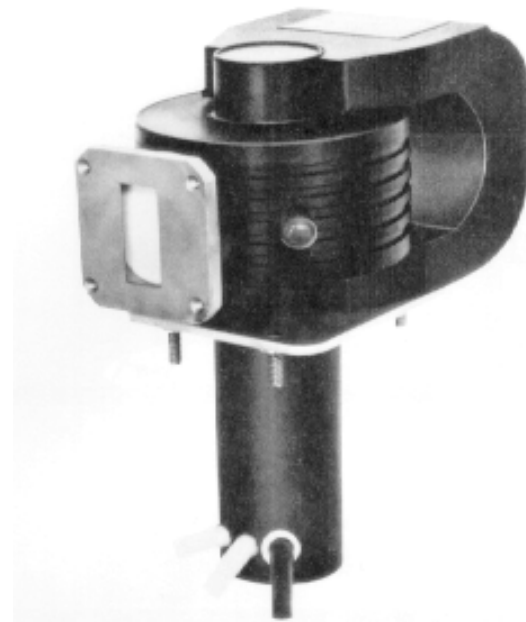
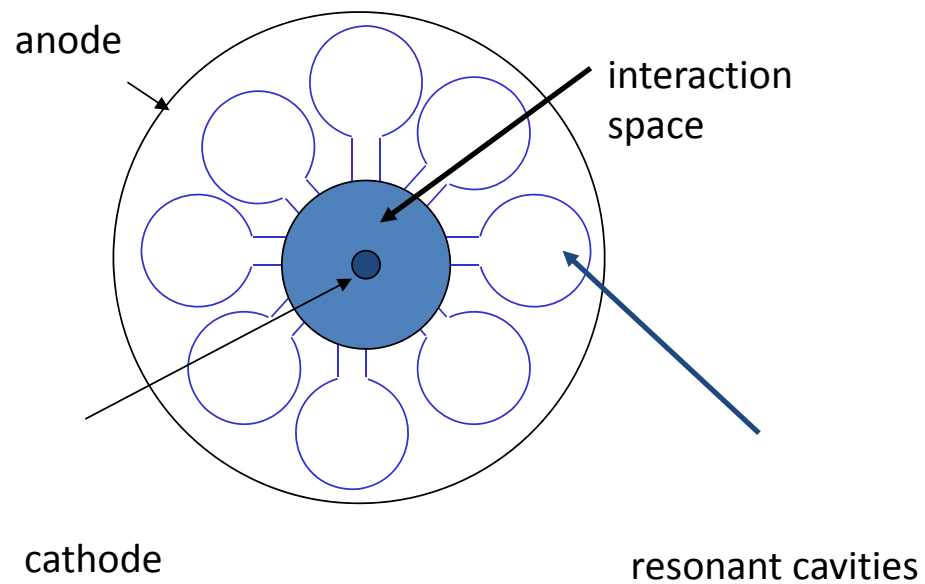
Radar range ambiguities



Did the echo come from Pulse #1 or Pulse #2?

Transmitter

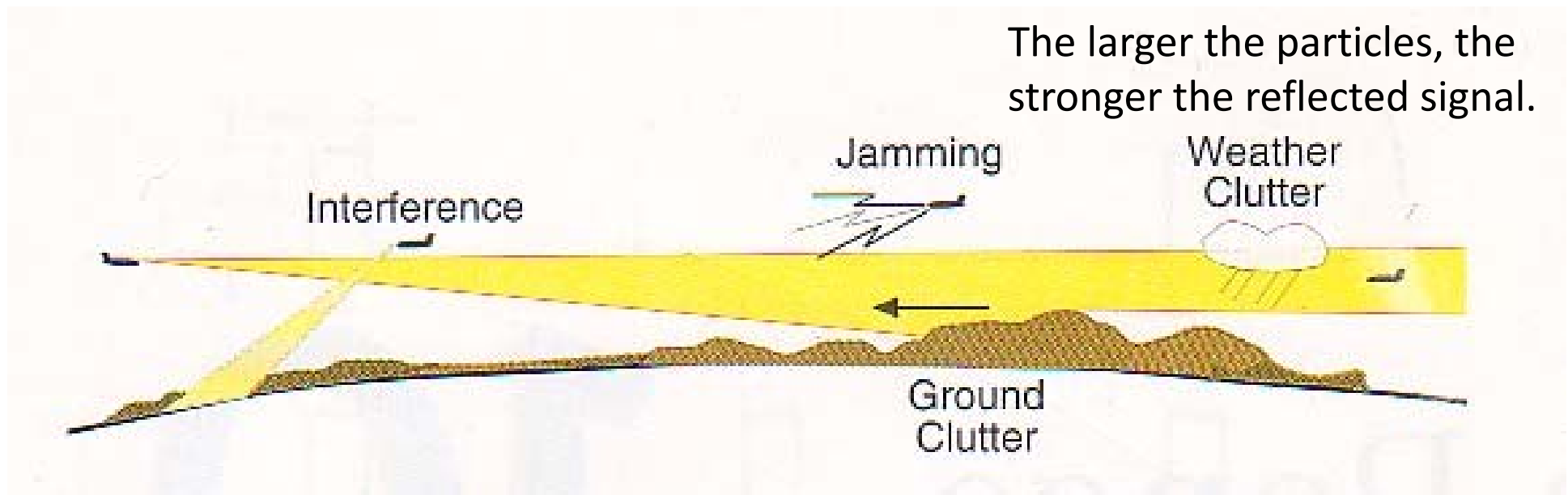
High power magnetron oscillator which is "On" for the duration of the pulse.



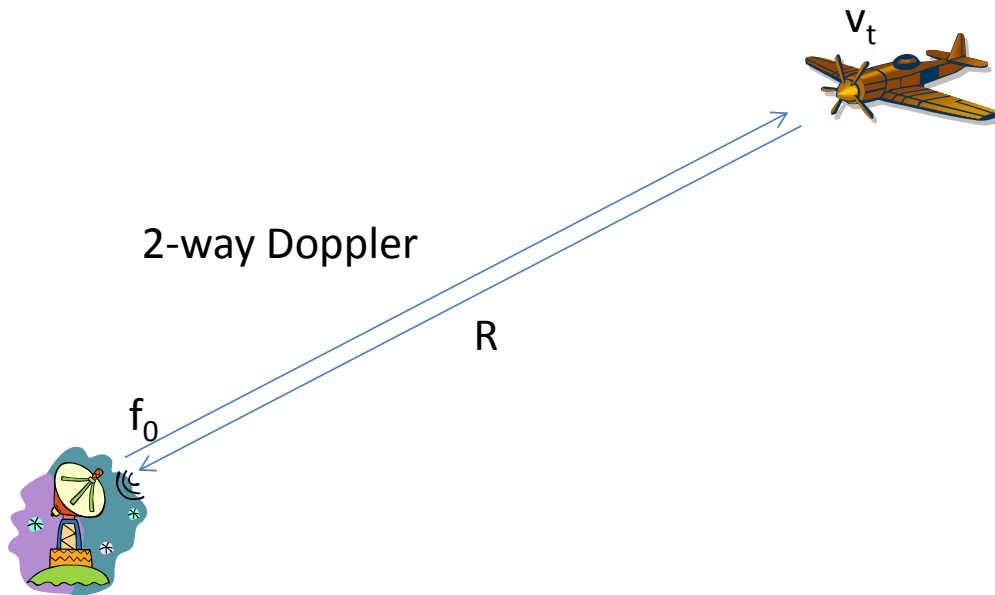
The total Picture

Many Signals can enter the receiver

The larger the particles, the stronger the reflected signal.



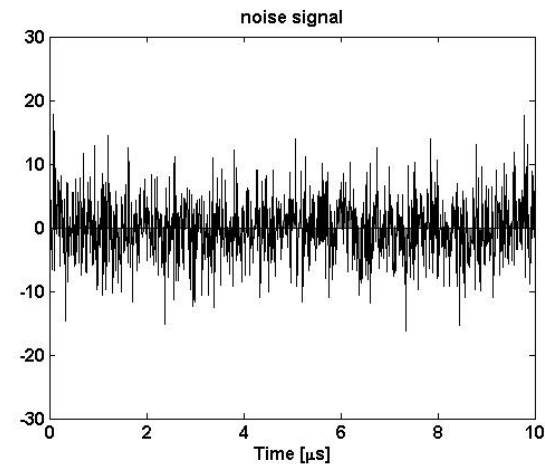
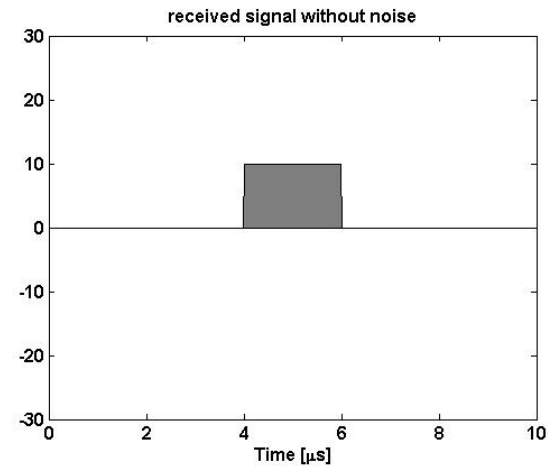
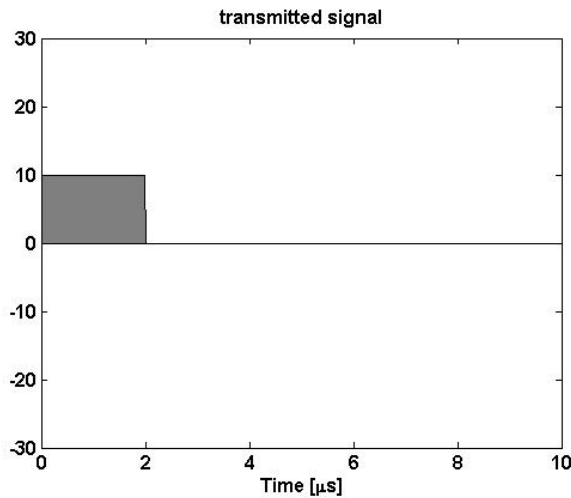
Doppler effect



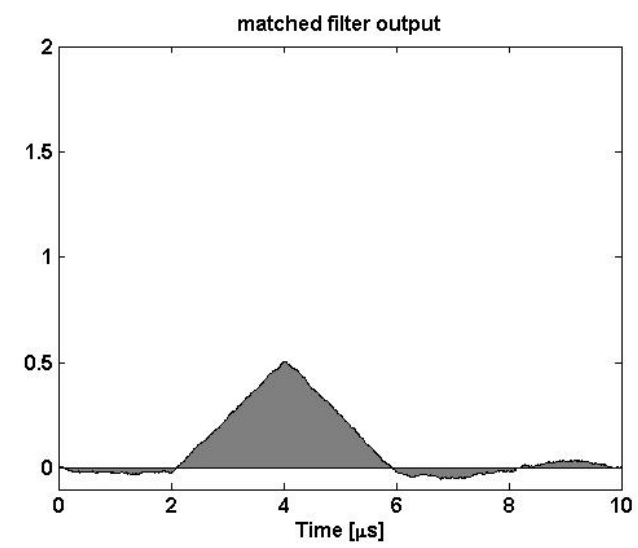
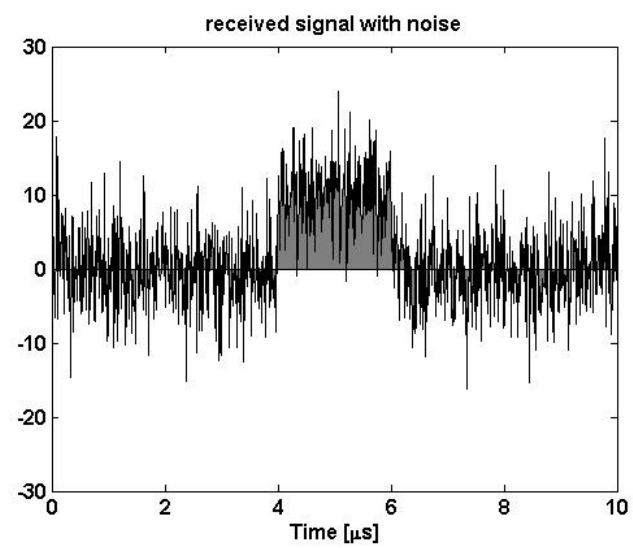
A (small) frequency due to the motion of the target (or the radar). The shift is related to the velocity of the target and may be up (for a closing target) or down for an opening target.

$$f_d = -\frac{2}{\lambda_0} \frac{dR}{dt} = -2 \frac{v_t}{\lambda_0}$$

Radar Signal Processing

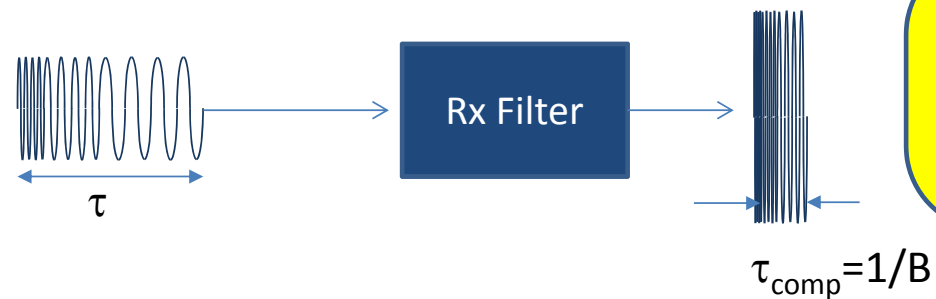


One of the most
important radar
components:
Matched Filter

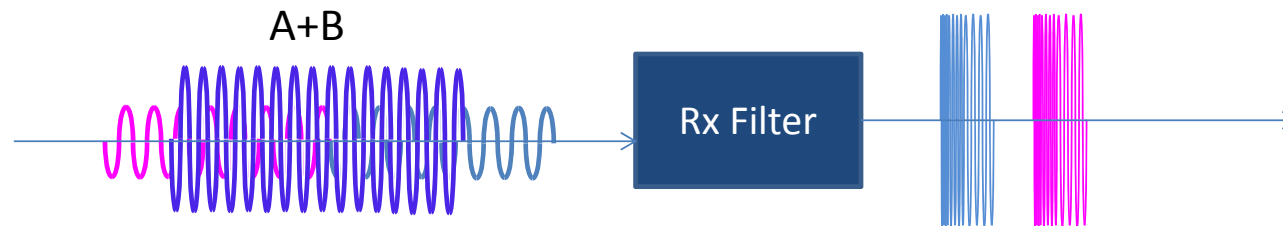


Pulse Compression (Chirp)

Most Radars use
some form of
Chirp!

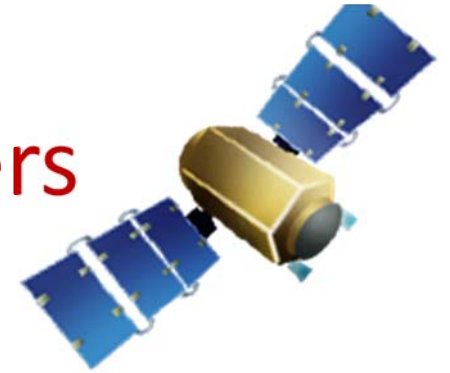


Echoes from closely spaced targets A,B are merged on input but separate on output



So pulses are resolvable if they are separated in time by τ_{comp}

Pulse compression by numbers



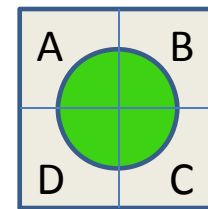
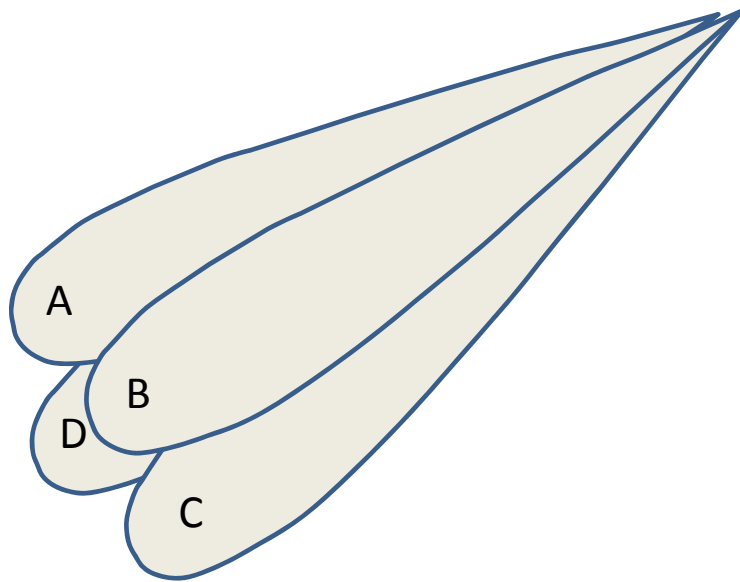
Pulse compression allows huge increases in resolution.

The SEASAT satellite remote sensor without linear chirp pulse compression would have had a range resolution of 14.8km (angle dependent).

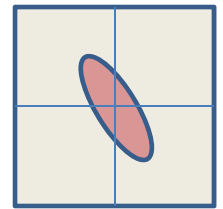
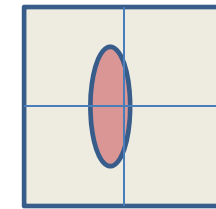
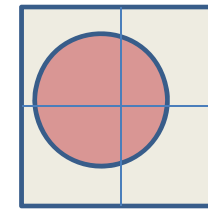
With pulse compression by a factor of 640, the ground resolution is increased down to 20.08m (at 20° look angle).

Monopulse tracking radar

Monopulse uses four squinted beams simultaneously to measure the target's angular position. This requires a special type of feed network so that the four beams are produced using a single pulse. Both phased arrays and reflector based systems are used.

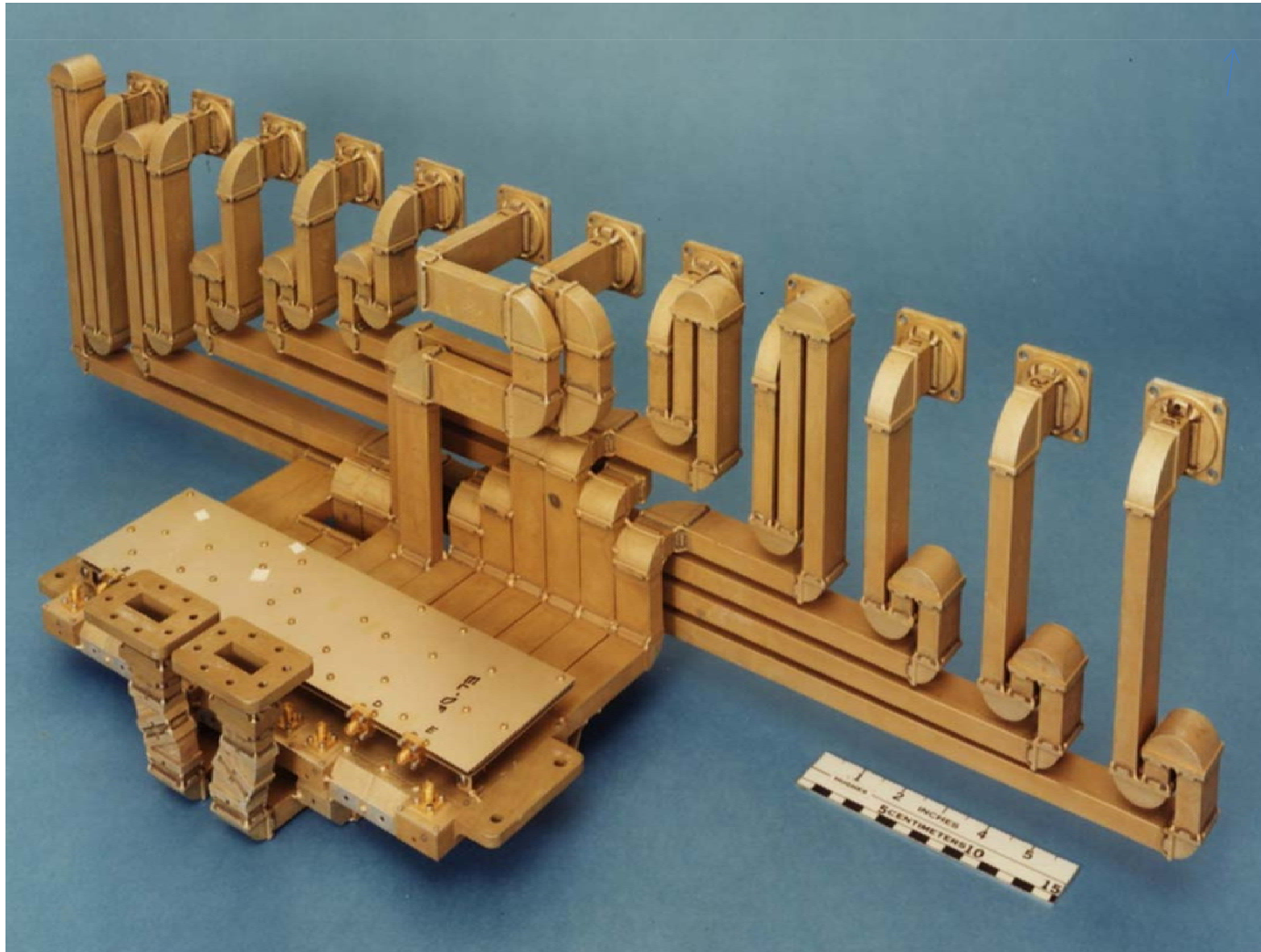


↑
Target echo
signal on
track



↖ ↑ ↗
Target echo off tracking axis

Monopulse feed system



(David Jenn)

Synthetic aperture radar (SAR)

The idea here is to use the forward motion of the vehicle to generate a large aperture. A very short antenna is used (wide beam) to increase illumination duration.

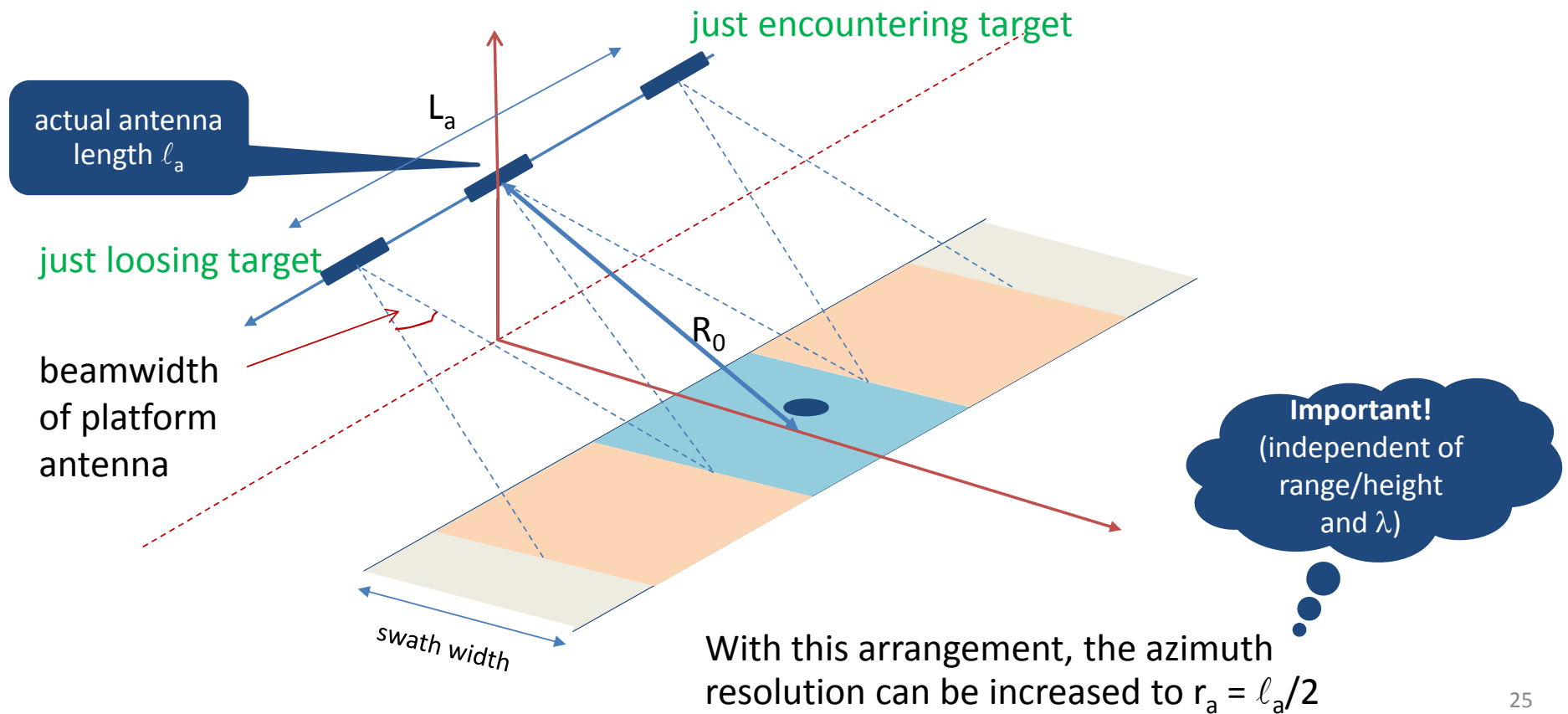
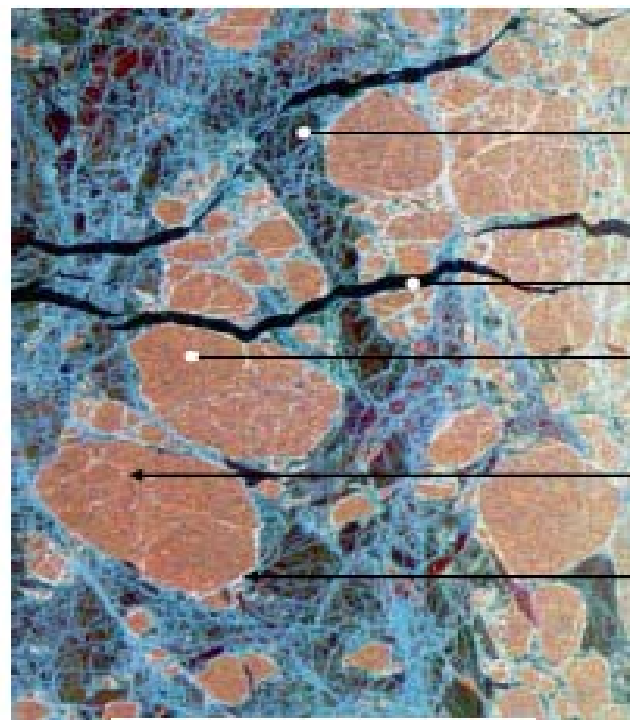


Photo or SAR map? The SAR map was made from a range many times that of the photo.



Monitoring Climate



first year ice coherent, specular (dark)

leads (water covered by very thin ice)

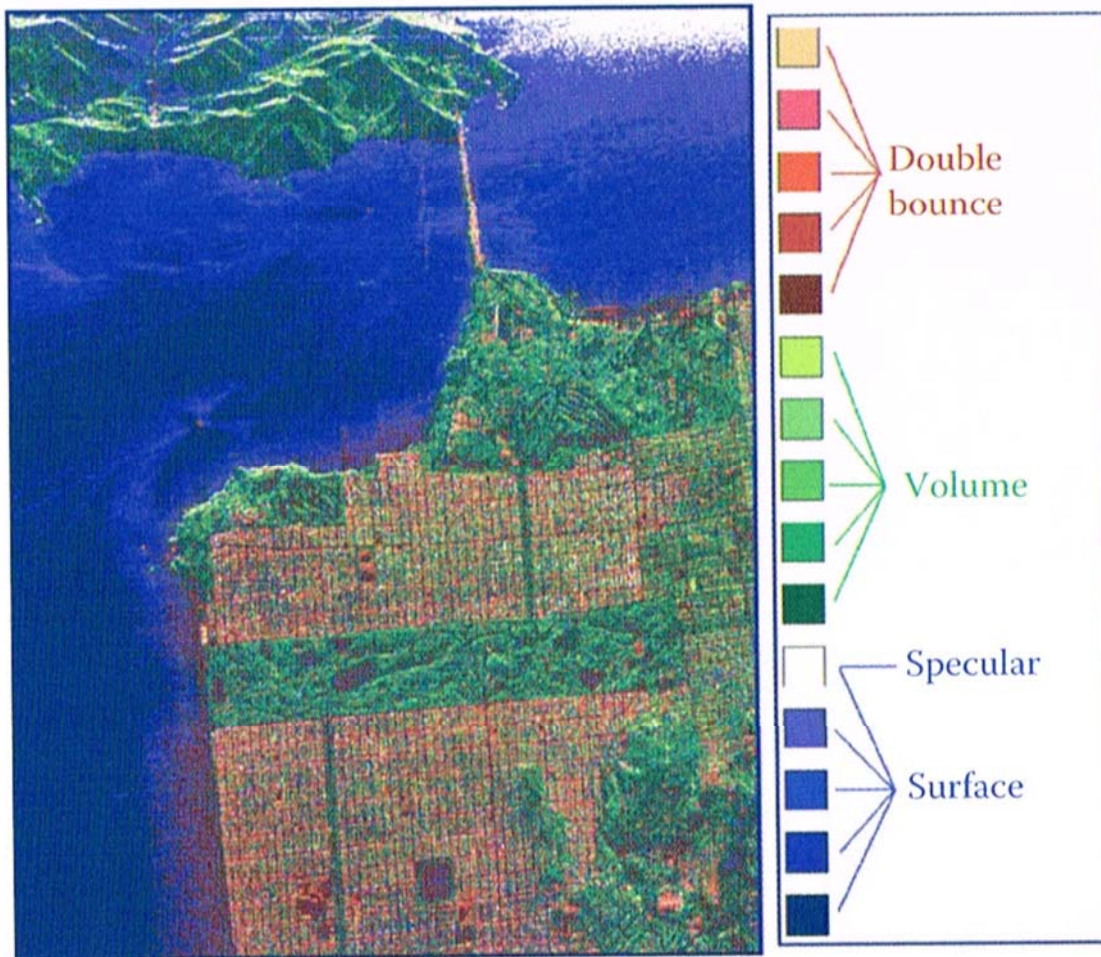
multi-year ice much brighter

pressure ridges Increased roughness

compressed first year ice

52° ← incidence angle range → 27°

Fully Polarized radars (POL SAR)



The decision on each pixel is unsupervised and based on a Wishart classifier

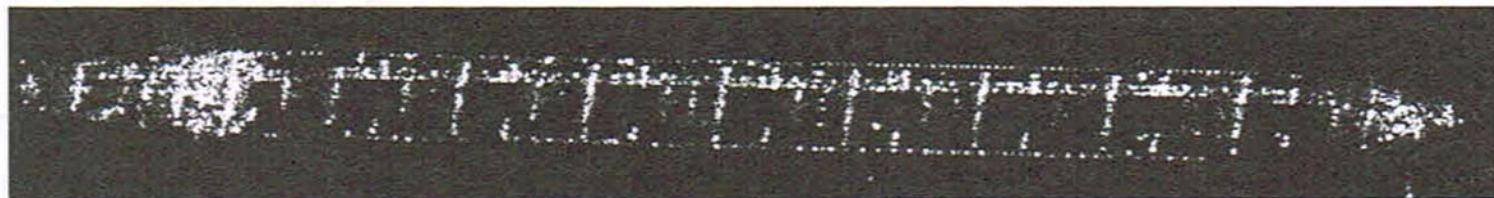
Inverse SAR (ISAR)

A 2D image is used as a basis for identification and recognizing the bulk carrier.

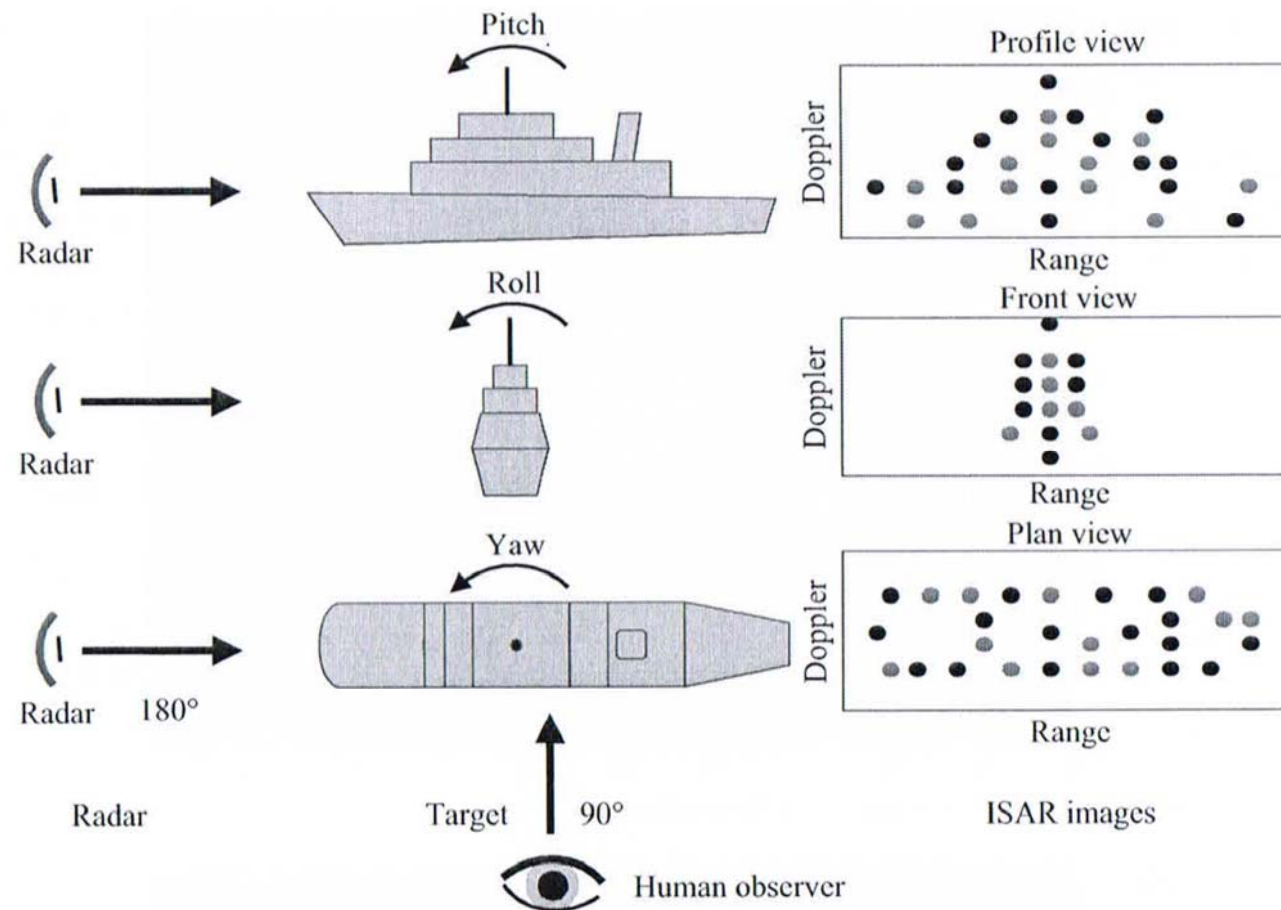
Photo



ISAR image



Differences between ISAR and optical images

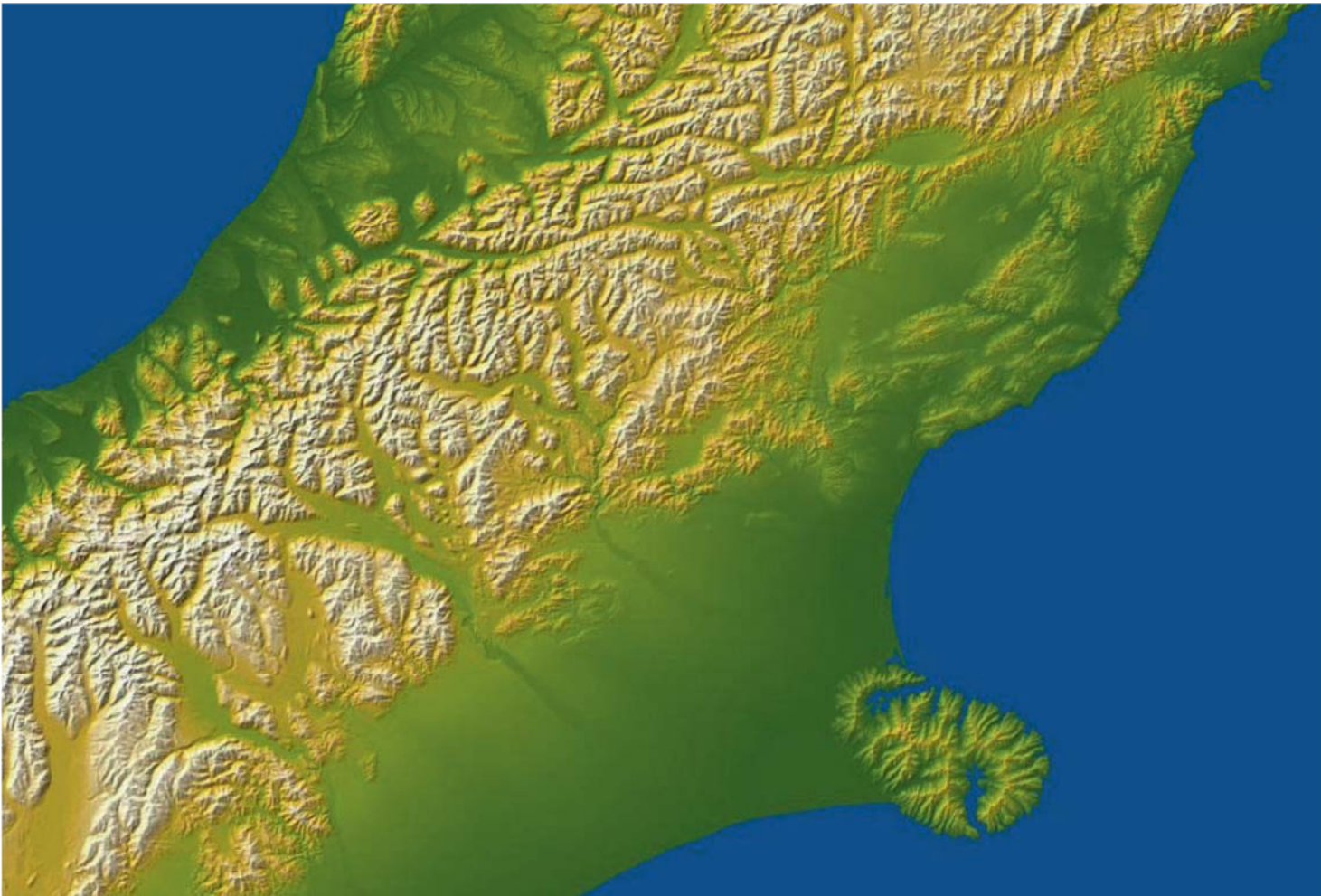


Interferometric SAR

Uses 2 or more SAR images to generate maps of surface information or digital elevation using phases of the waves returning to the platform.



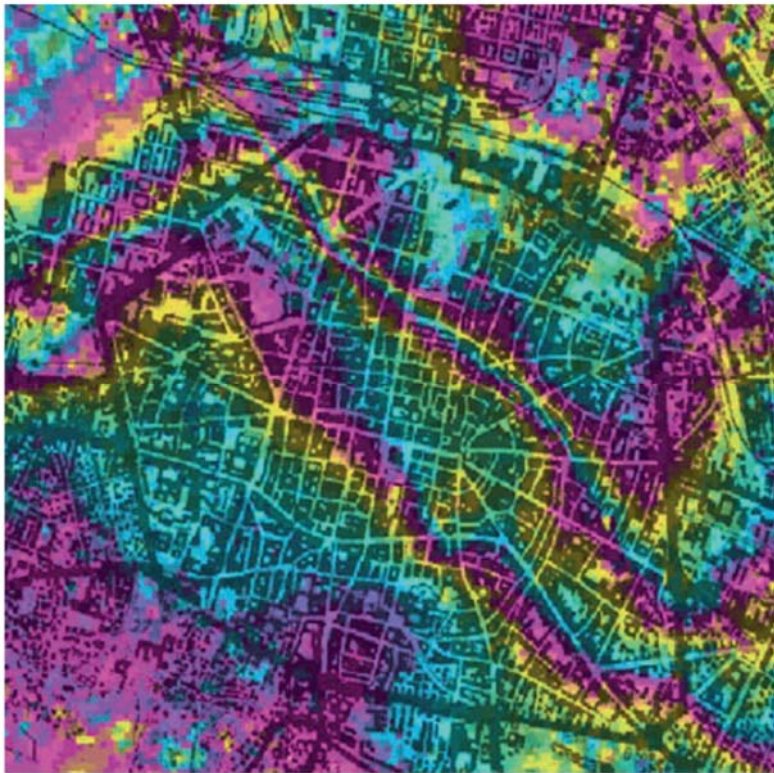
Topological Maps



NASA has released SRTM (Shuttle Radar Topography Mission) data for Australia, and New Zealand comprising 1200 data cells each comprising 1 degree of latitude and longitude. See <http://www2.jpl.nasa.gov/srtm/>

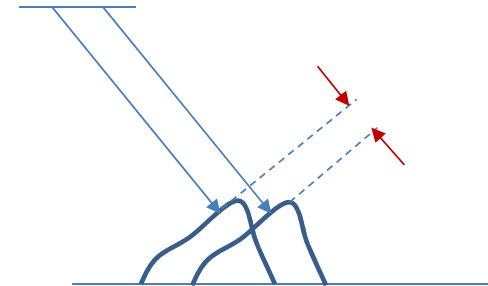
Resolution of the data is 1arc second (30m)

Differential Interferometric SAR (D-InSAR)



ESA Data processing by GAMMA

Can potentially measure millimetre changes in deformation over days or years.

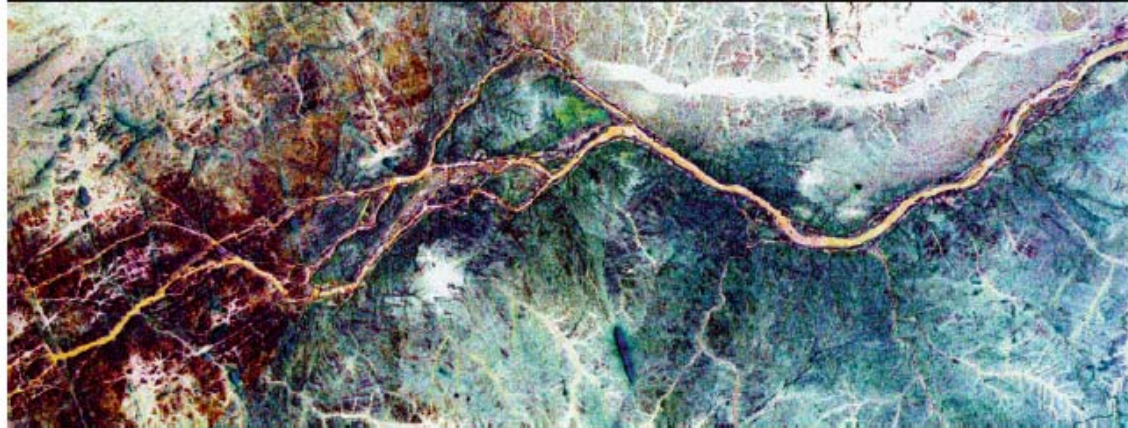


Subsidence in the city of Bologna, Italy at the rate of about 1cm per year using D-InSAR techniques.

Underground mapping



Infrared Photo

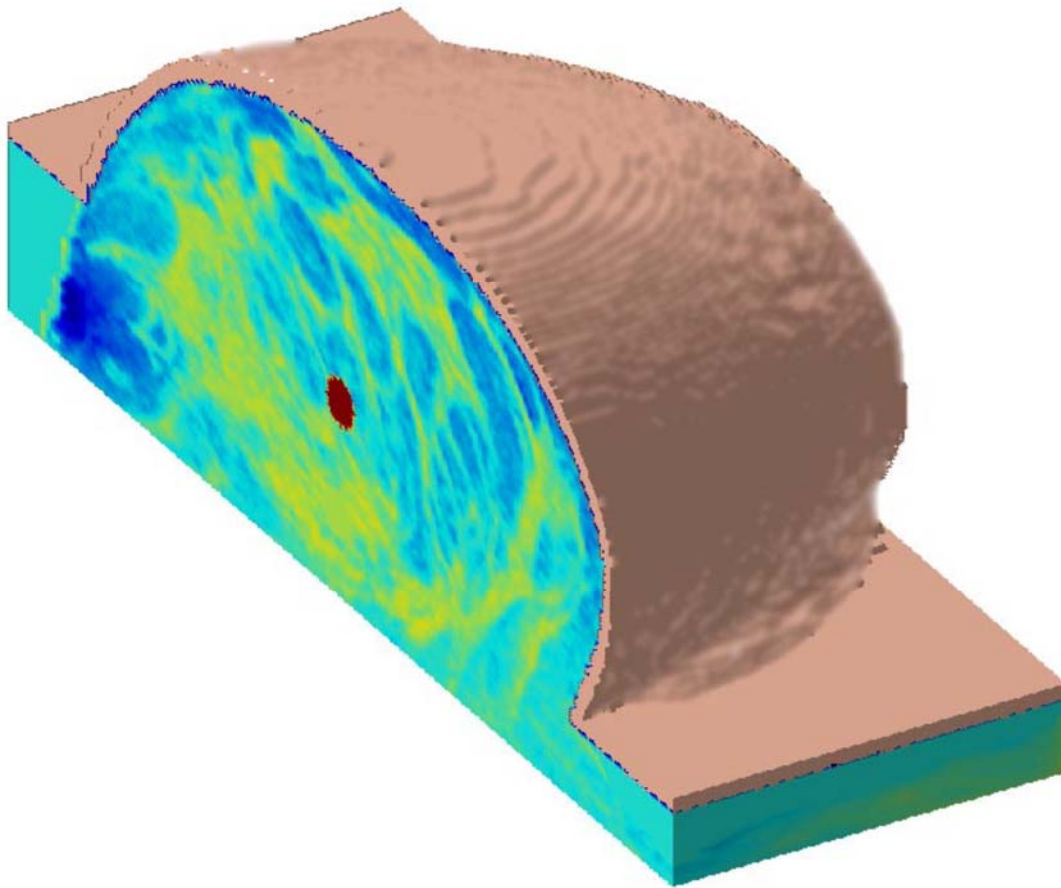


Radar Image

Composite image of various polarizations (different colours) at both C and L band.

Image NASA (JPL)

Imaging of the human body



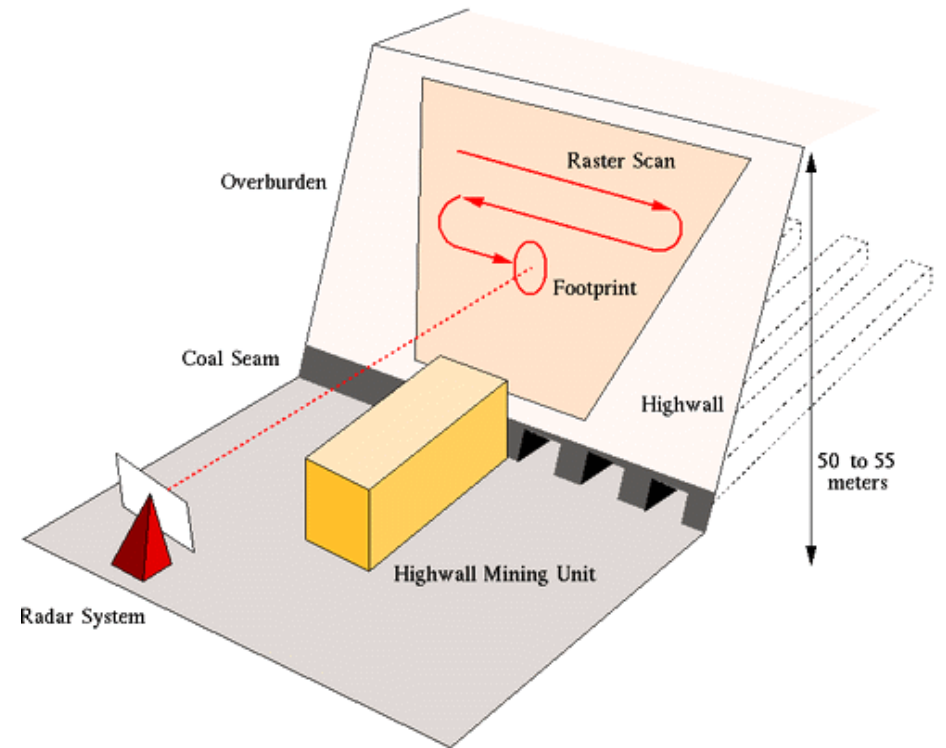
Ultrawideband microwave pulses for early stages of breast cancer detection.

Uses an array of small antennas around the breast and each antenna emits a very short pulse.

Signal processing then used to synthesise the image.

GroundProbe Pty Ltd

- Highwall Mining Radar
Winner of ACARP
Research Prize



Questions?

THANK YOU