ESPTR: Pulsed Doppler Radar

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Radar types

By transmit waveform:

- Continuous wave
  - Doppler only (police, toilet, security...)
  - FMCW
  - Noise radars
- Pulsed
- Passive

By usage:

ATC Air Traffic Control

- Maritime: harbour, navigation
- Car mounted: parking, safety...
- Airborne: collision, meteo, fighter, Joint Stars, Bryza
- Satellite (EarthObservation)

By scan: fixed, pivot, rotary, electronic (+ conformal)

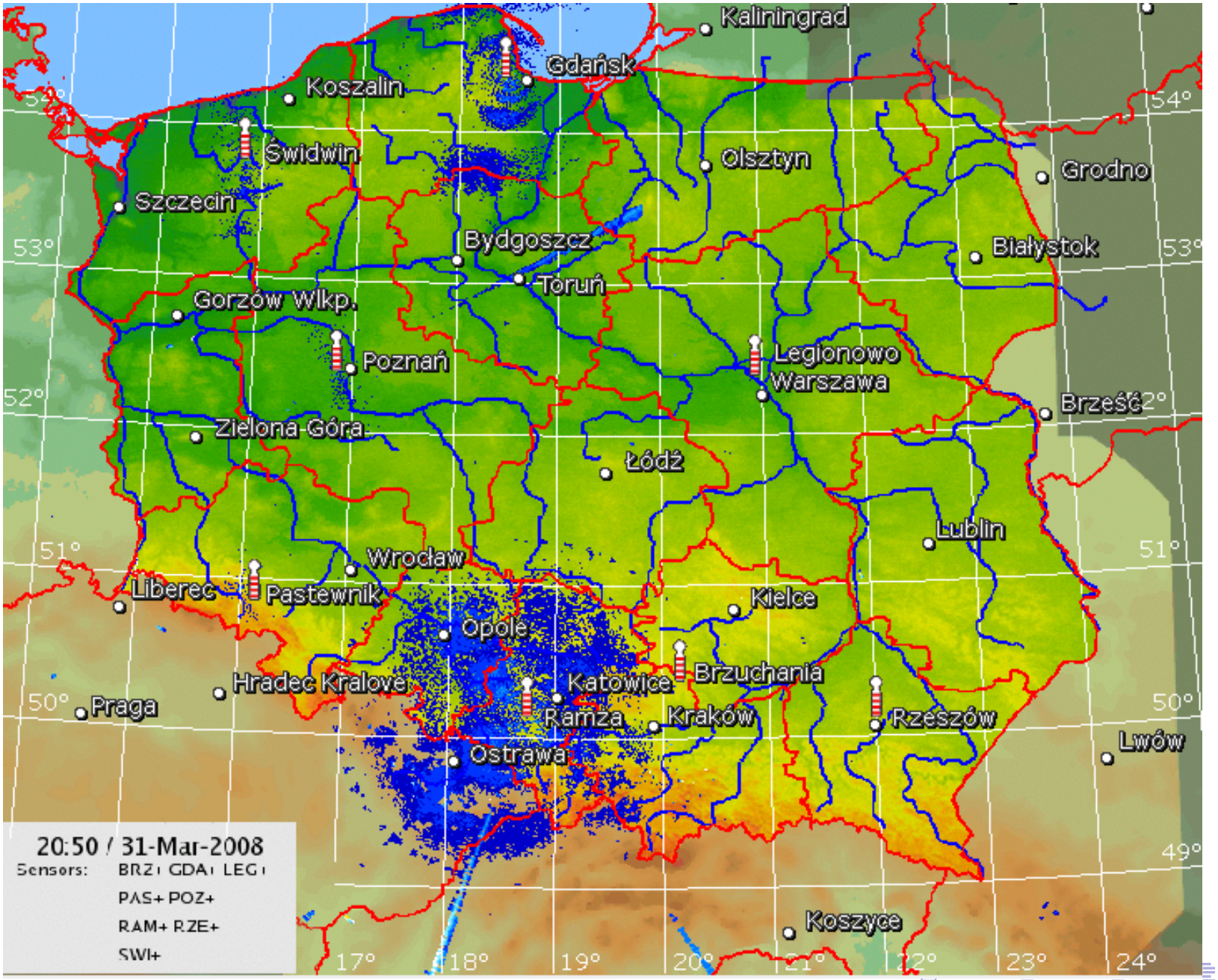
Search or tracking mode.

Meteo radar

- Imaging of water/ice in atmosphere
- Velocity, turbulence, wind profilers (VHF)

Techniques: Doppler, polarimetry, 3D imaging...
Frequency bands:

- L = 1-2 GHz: clear air turbulence study,
- S = 2-4 GHz: far range observation
- C = 5.470-5.725 GHz: medium range (TDWR),
- X = 9-10.5 GHz: small particles (cloud development)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Kielce
Opole
Brzuchania
Hradec Kralove
Katowice
Praga
Ramża
Kraków
Rzeszów
Lwów
Ostrawa
Koszyce
20:50 / 31-Mar-2008
Sensors: BRZ+ GDA+ LEG+
PAS+ POZ+
RAM+ RZE+
SWI+
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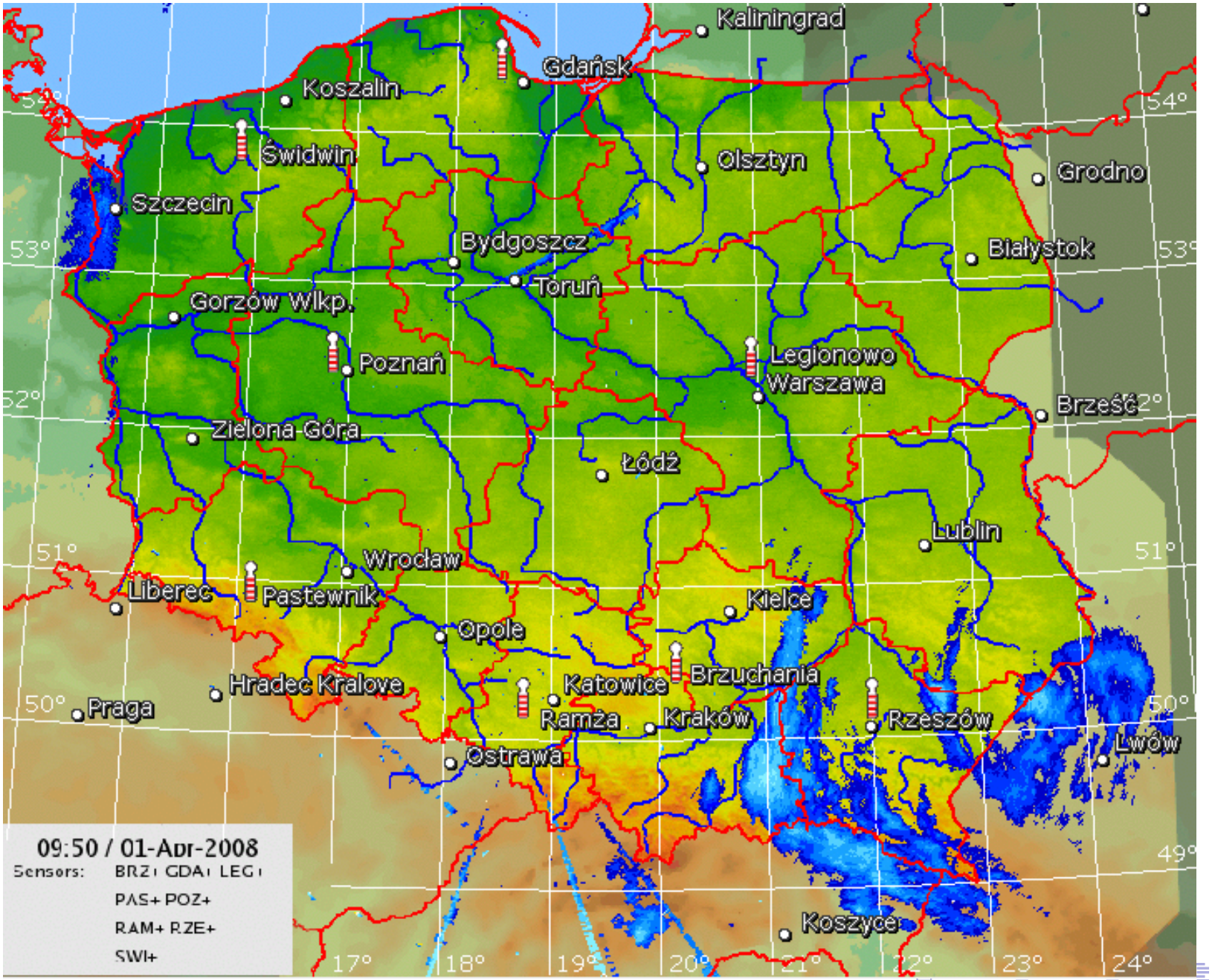
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Velocity measurement

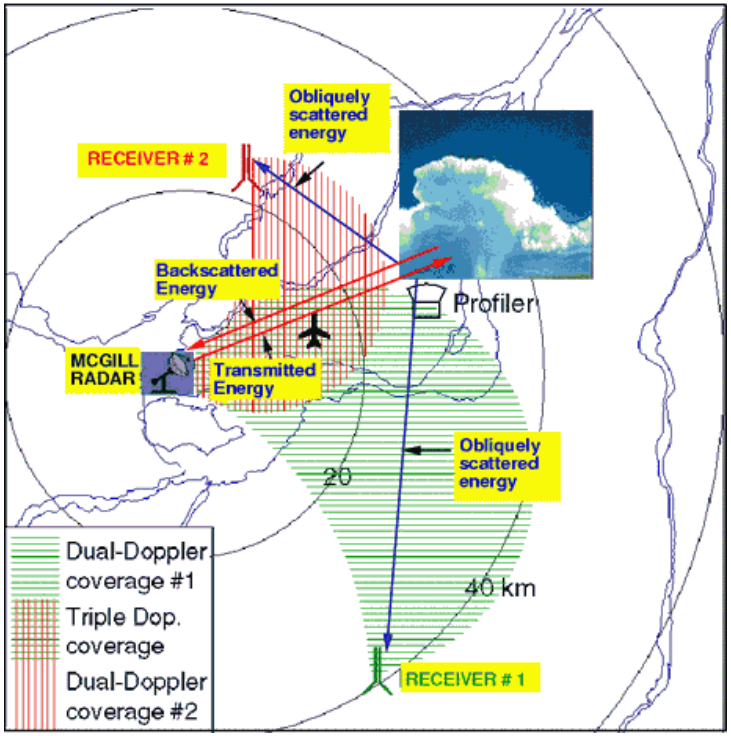
$\longrightarrow$Doppler shift measurement

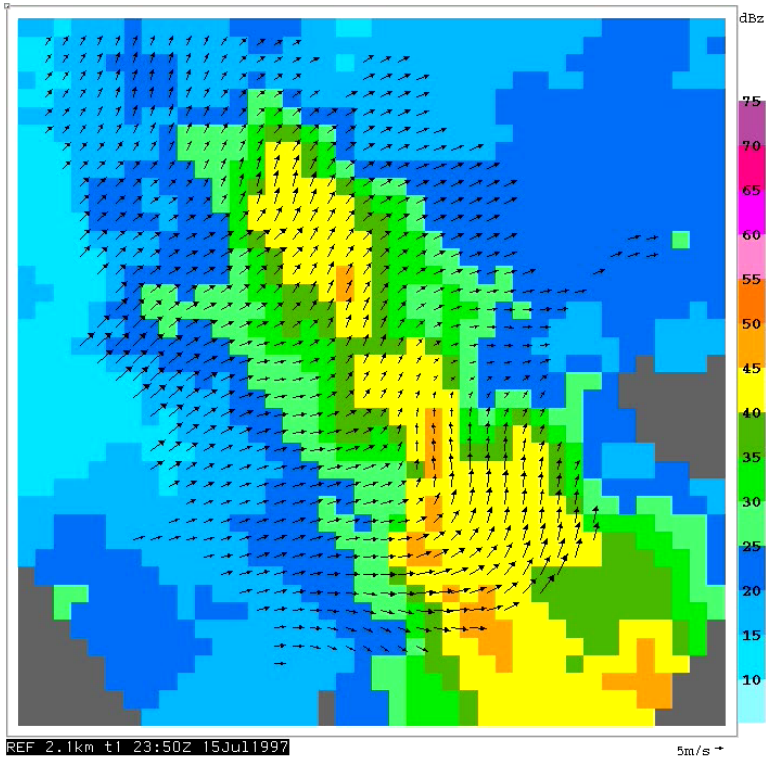
$$x_R(t) = A_T(t - R_0/c - vt/c)e^{j\phi_M(R_0/c+vt/c)}\ e^{j(\omega t)}e^{-j\omega(R_0/c)}e^{-j\omega vt/c}$$

Example: 10GHz, 70 m/s ....

- Min velocity: ground/sea/meteo clutter (ATC), time-on-target (METEO)
- Max velocity (frequency): (inverse of) modulation period

Bistatic radar network





dBZ: dB w.r.t. $1 mm^6 m^{-3}$ (number of drops per unit volume and the sixth power of drop diameter).

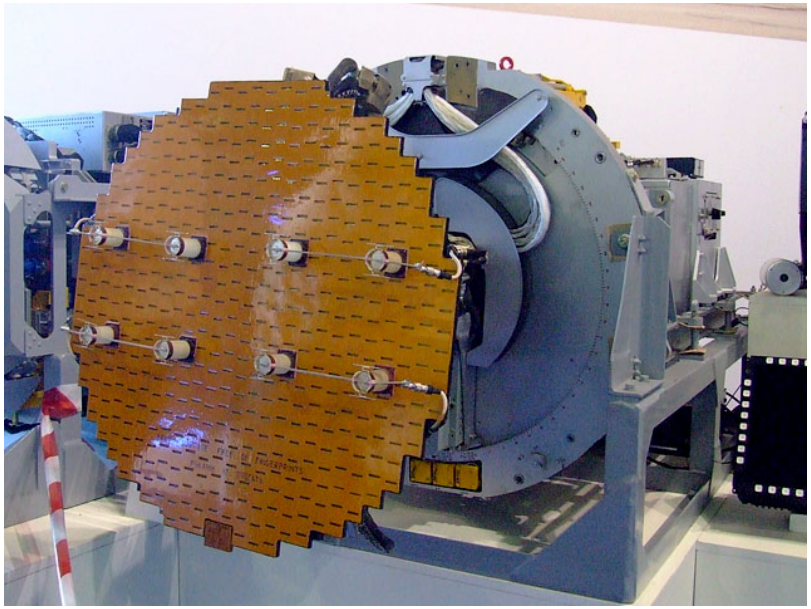
Airborne Pulse-Doppler radar

Search radar: AWACS and Bryza-1RM

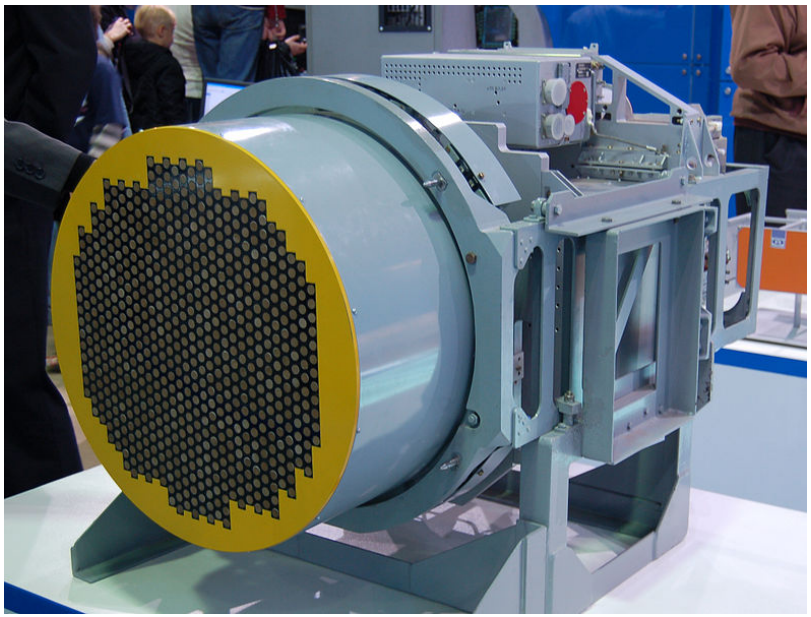
(wikimedia commons)

Airborne Pulse-Doppler radar

Fighter - multifunction radar



Mechanically scanned
MiG-29 radar



Electronically scanned
(wikimedia commons)

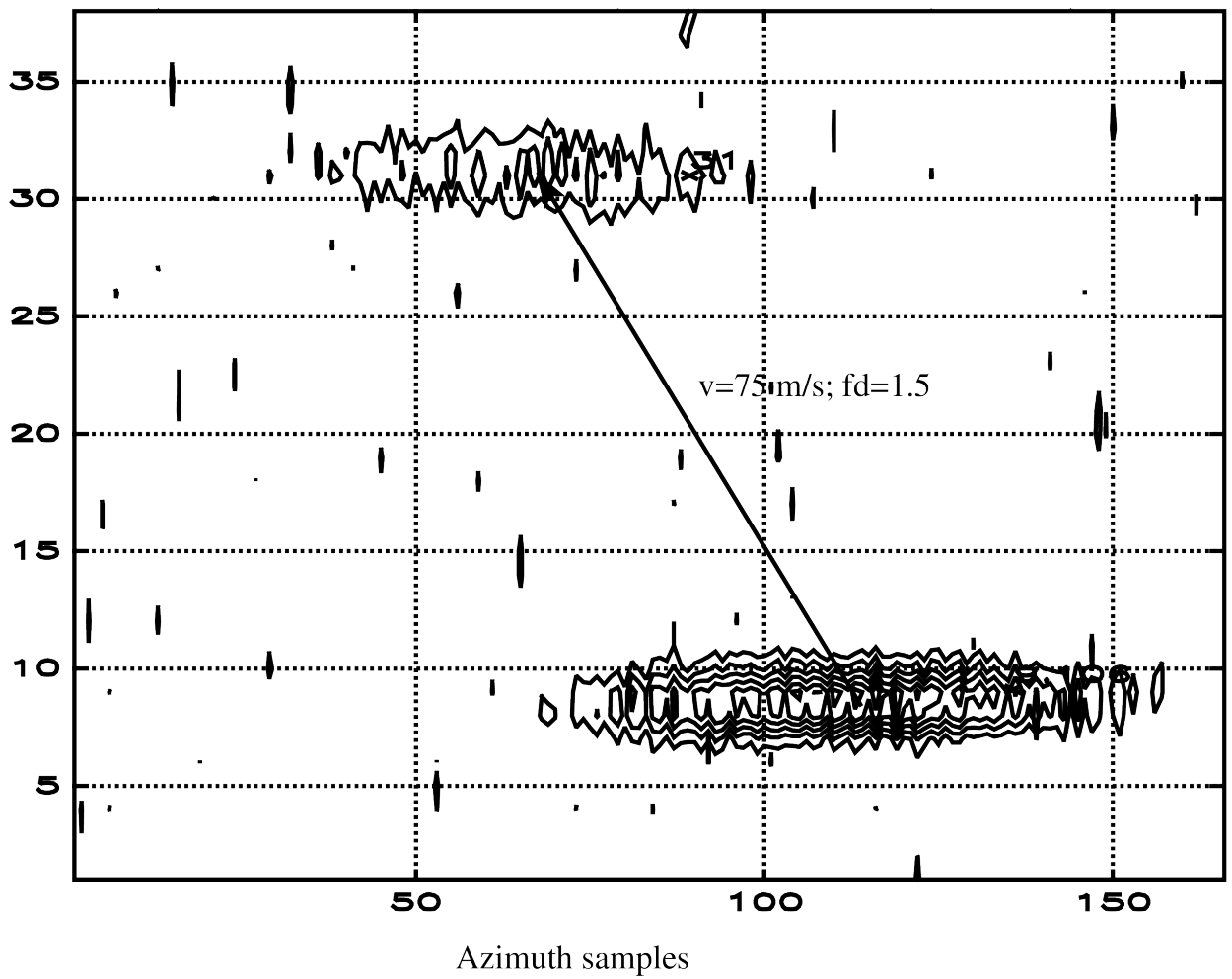
ATC radar

Transmitter: Pulsed chirp (or other modulation).
Common: Antenna, scan mechanism, waveguides, rotary joint, T/R switch
Receiver:

- Protection, LNA, mixer, IF, pulse compression, quadrature demodulation (sin/cos problem $\longrightarrow$@blackboard), range gate $\longrightarrow$range-azimuth plane
- Clutter filter, CFAR, detection, integration, 2nd threshold ($\longrightarrow$raw video)
- Object extraction (clustering raw video "white" areas into $\longrightarrow$plots)
- Track initiation, plot to track association, tracking ($\longrightarrow$tracks)

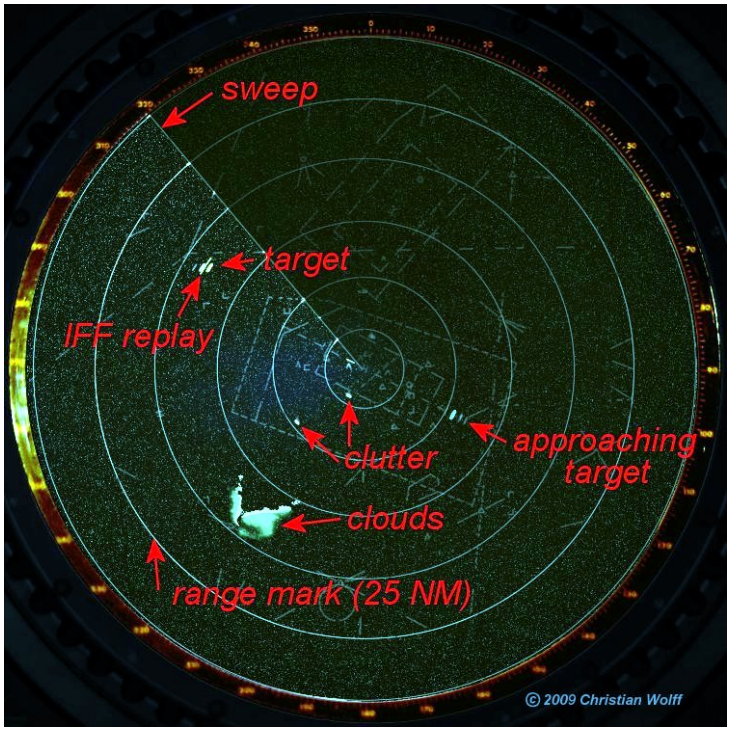
A target

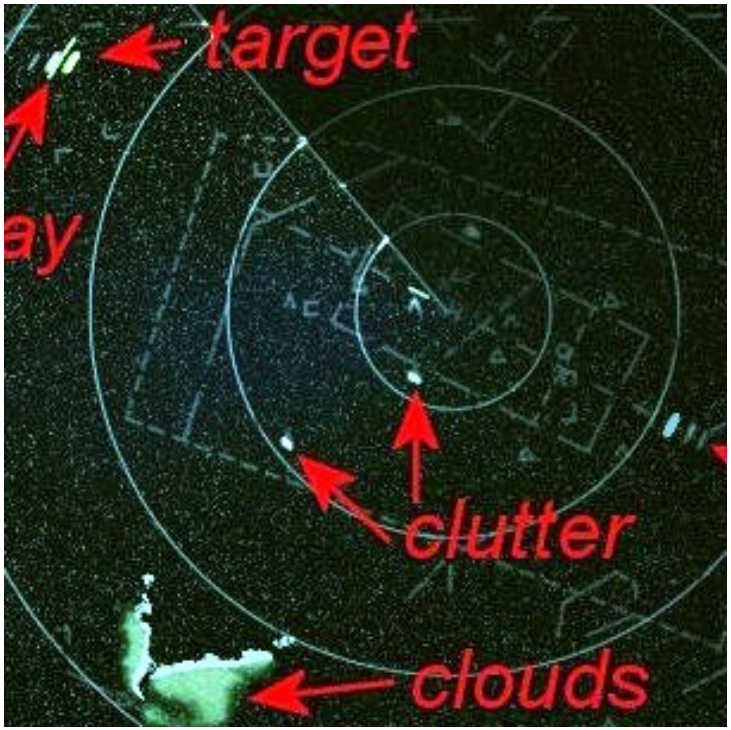
Raw video (unthresholded) - two scans overlaid



ATC radar display

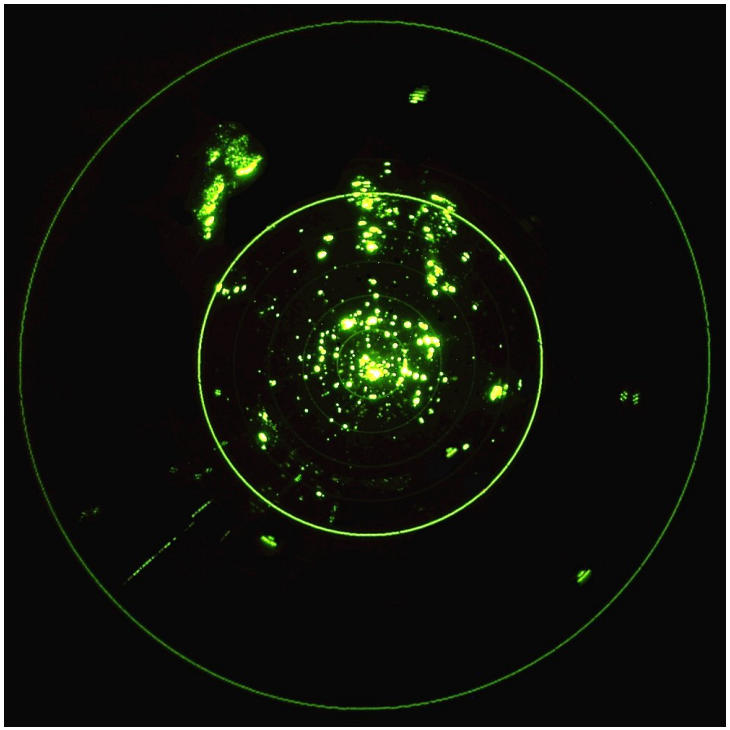
$\longrightarrow$PPI display (other displays are history now)



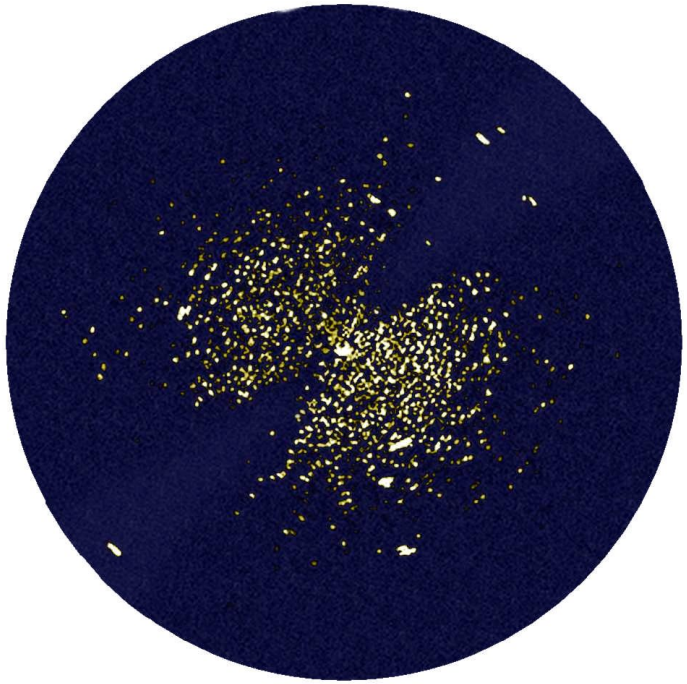


(from radartutorial.eu)

Clutter



Ground/meteo clutter



Sea clutter

from radartutorial.eu

MTI/MTD

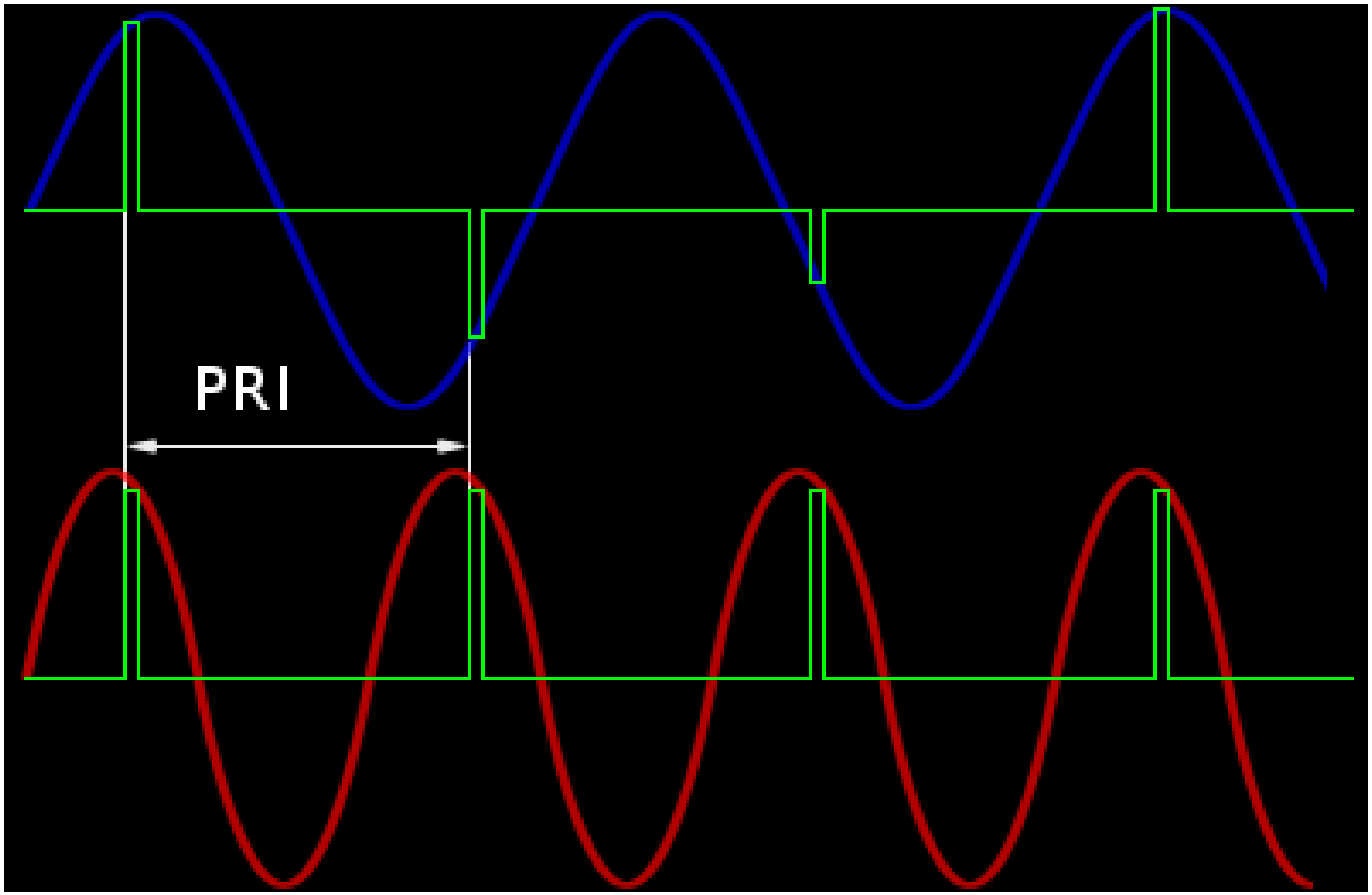
- Clutter is low-pass (in a stationary radar): use a HF filter
- Blind speed problem $\longrightarrow$vary the PRF

MTI pulse-to-pulse stagger

MTD block stagger

Filter characteristics with stagger: poor!
$\longrightarrow$variable coefficient filters
MTD: FFT filter bank (or equivalent)
Weather clutter: non-zero Doppler, complex filter coefficients, adaptive filters (MTI)
Velocity measurement (CRT with MTI or MTD).

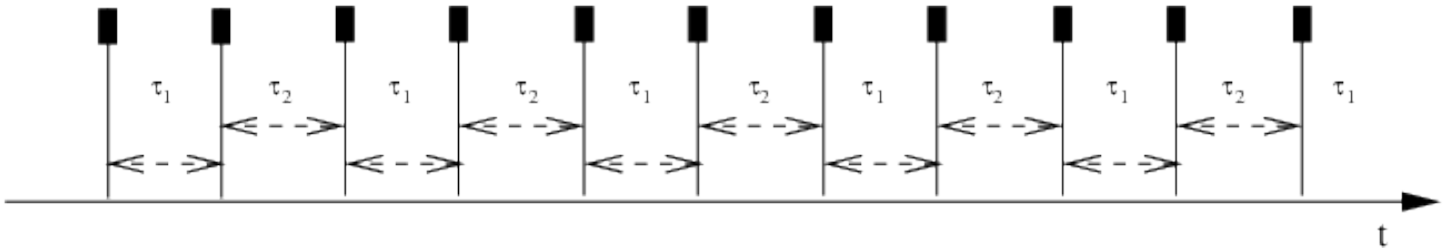
Blind speed



from radartutorial.eu

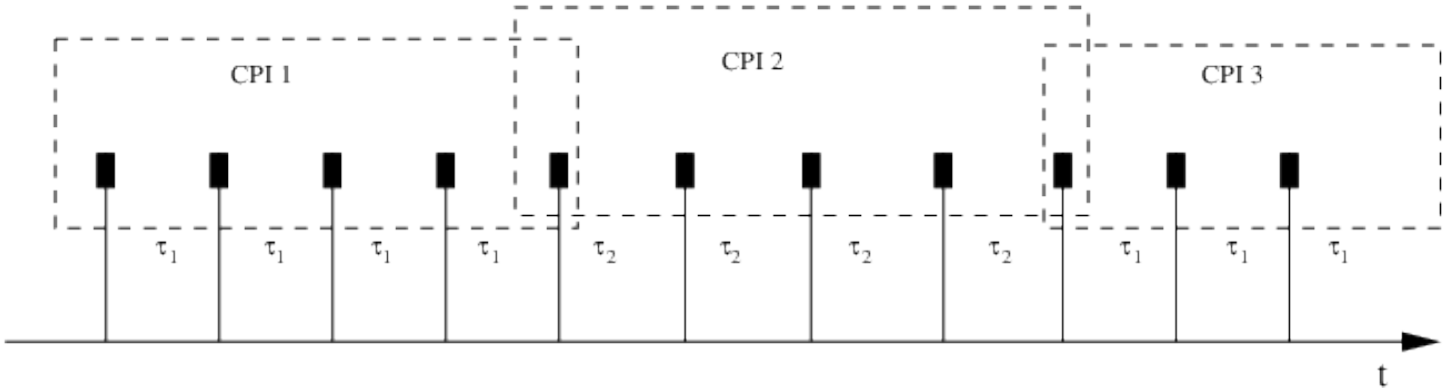
MTI/MTD sampling

MTI



Incoherent processing $\longrightarrow$ integration gain by averaging noise

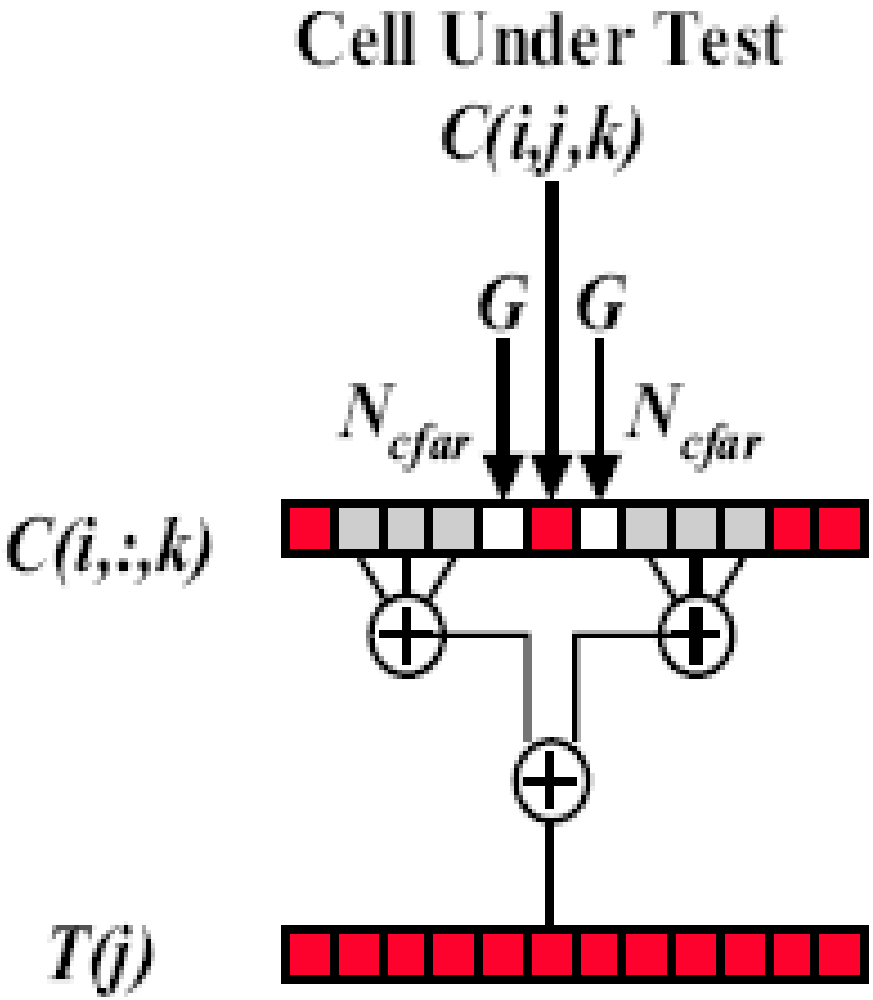
MTD



Coherent processing $\longrightarrow$ integration gain by accumulating energy & averaging noise!

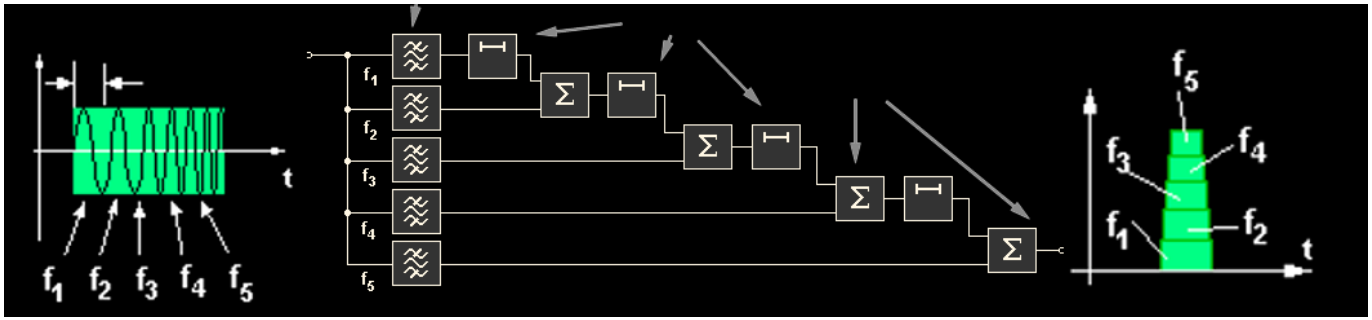
CFAR

Constant False Alarm Rate



Pulse compression

Technically – just a matched filter....



PC with a frequency-dependent delay system (From radartutorial.eu)

Compression ratio: BT product.

- Chirp ($\longrightarrow$compression line, electromechanical filter)
- Bi- and polyphase
- Pseudorandom

Range sidelobes.

Warning: some people use the term "compression" for "deramping"
$\longrightarrow$ *see the lecture on FMCW radar*

ECM/EPM

Electronic CounterMeasures
Electronic Protection Measures (a.k.a. ECCM - Electronic Counter-CounterMeasures).
Chaff.
Jamming: detection + diversity, agility.
Adaptive jamming/false echoes $\longrightarrow$pulse coding, pulse stagger