

# 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)

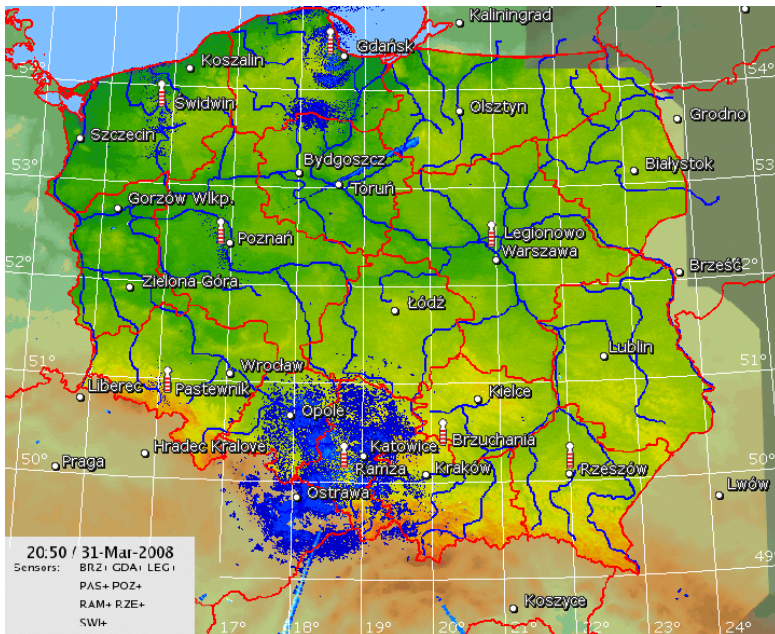
Search or tracking mode.

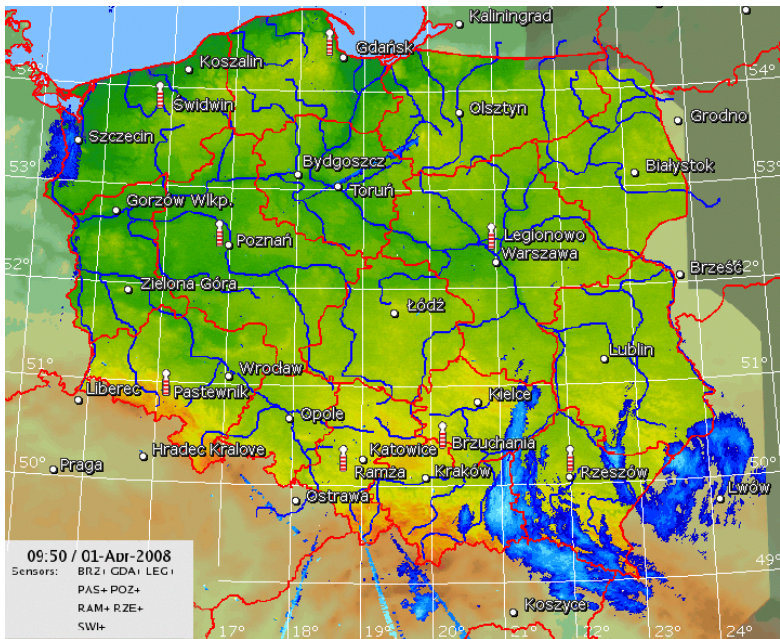
# Meteo radar

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

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







# Velocity measurement

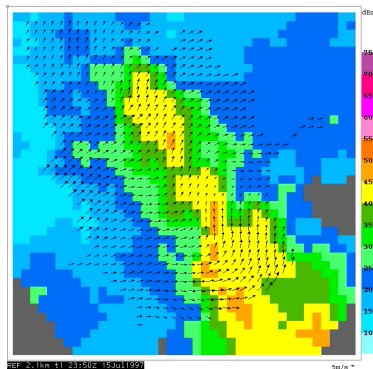
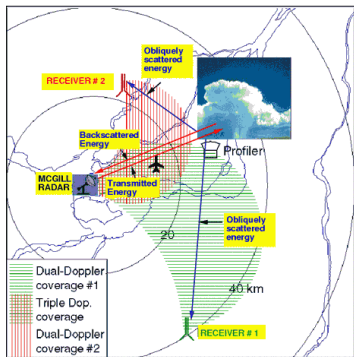
→ Doppler shift measurement

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

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.  $1\text{mm}^6\text{m}^{-3}$  (number of drops per unit volume and the sixth power of drop diameter).

# Airborne Pulse-Doppler radar

Search radar: AWACS and Bryza-1RM

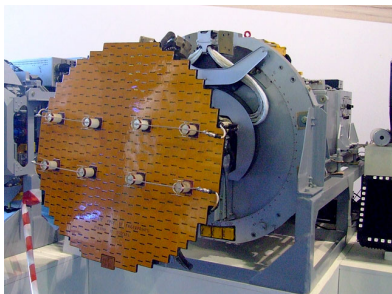


(wikimedia

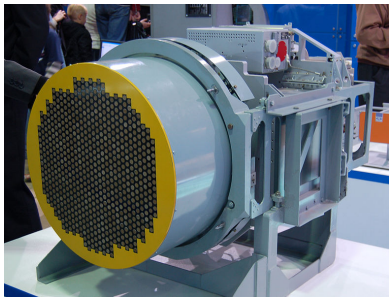


# Airborne Pulse-Doppler radar

Fighter - multifunction radar



Mechanically scanned  
MiG-29 radar



Electronically scanned  
(wikimedia commons)

# ATC radar

Transmitter: Pulsed chirp (or other modulation).

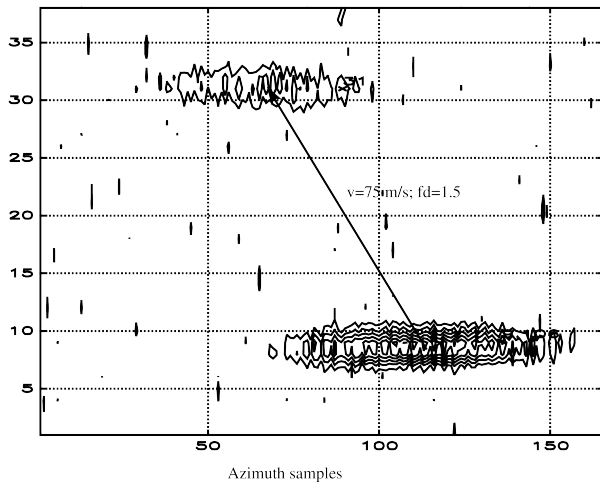
Common: Antenna, scan mechanism, waveguides, rotary joint, T/R switch

Receiver:

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

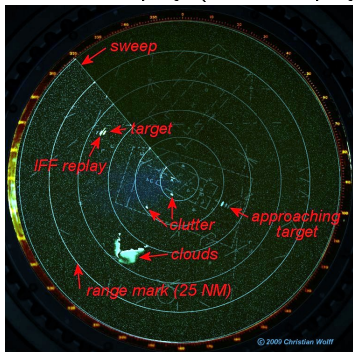
# A target

Raw video (unthresholded) - two scans overlaid



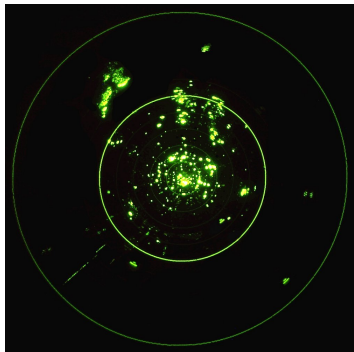
# ATC radar display

→PPI display (other displays are history now)

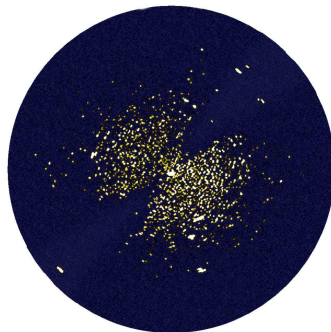


(from radartutorial.eu)

# Clutter



Ground/meteo clutter



Sea clutter

# MTI/MTD

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

MTI pulse-to-pulse stagger

MTD block stagger

Filter characteristics with stagger: poor!

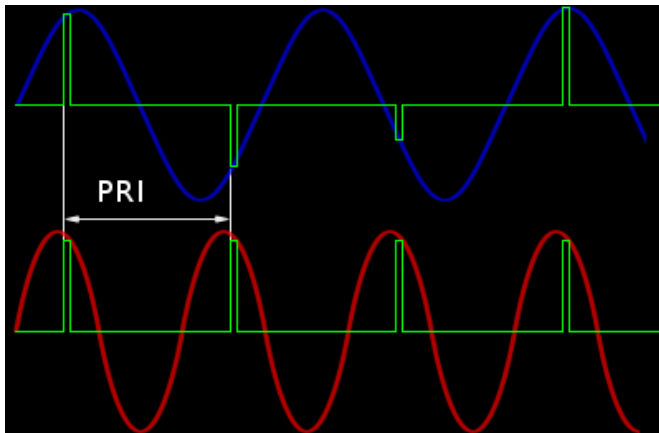
→ variable coefficient filters

MTD: FFT filter bank (or equivalent)

Weather clutter: non-zero Doppler, complex filter coefficients, adaptive filters (MTI)

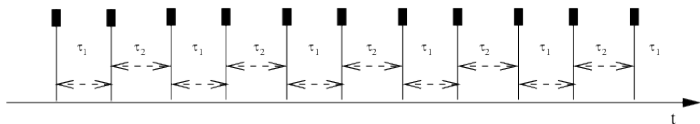
Velocity measurement (CRT with MTI or MTD).

# Blind speed



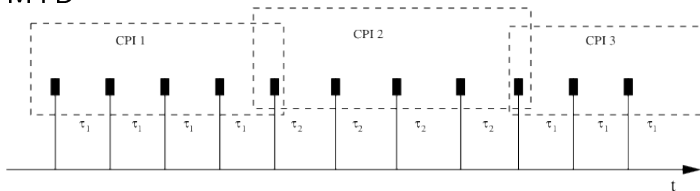
# MTI/MTD sampling

## MTI



Incoherent processing  $\rightarrow$  integration gain by averaging noise

## MTD

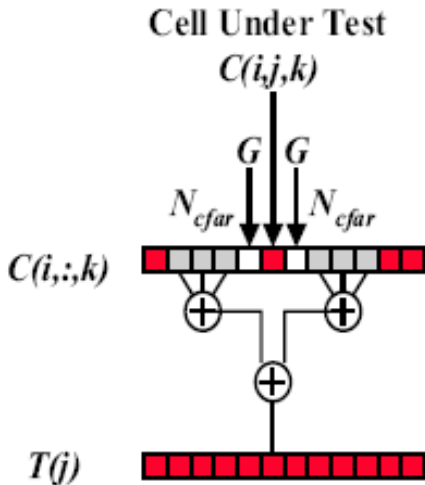


Coherent processing  $\rightarrow$  integration gain by accumulating energy & averaging noise!



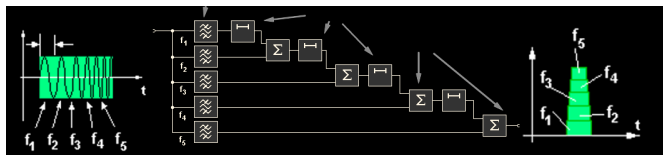
## CFAR

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 (—→compression line, electromechanical filter)
- ▶ Bi- and polyphase
- ▶ Pseudorandom

Range sidelobes.

*Warning: some people use the term “compression” for “deramping”  
—→ see the lecture on FMCW radar*

# ECM/EPM

Electronic Counter Measures

Electronic Protection Measures (a.k.a. ECCM - Electronic Counter-Counter Measures).

Chaff.

Jamming: detection + diversity, agility.

Adaptive jamming/false echoes → pulse coding, pulse stagger