

# ESPTR: Pulsed Doppler Radar

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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)

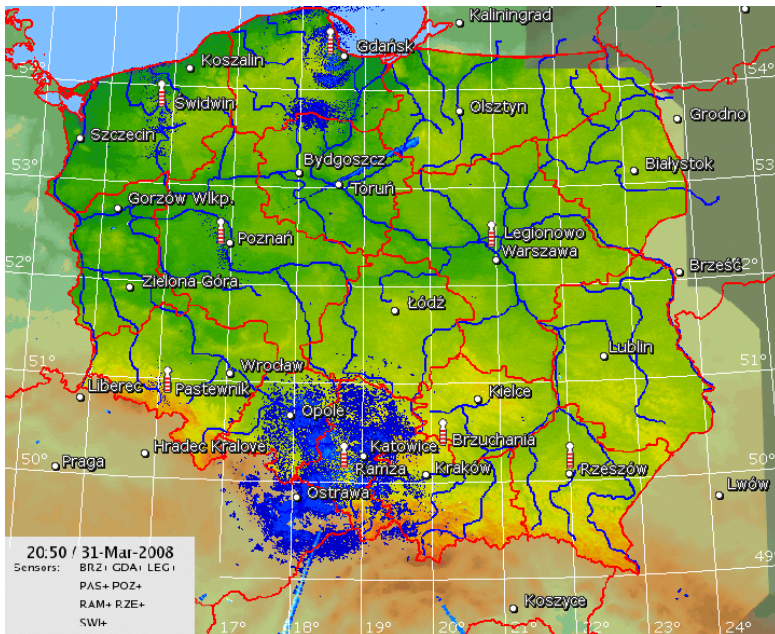
By scan: fixed, pivot, rotary, electronic (+ conformal)

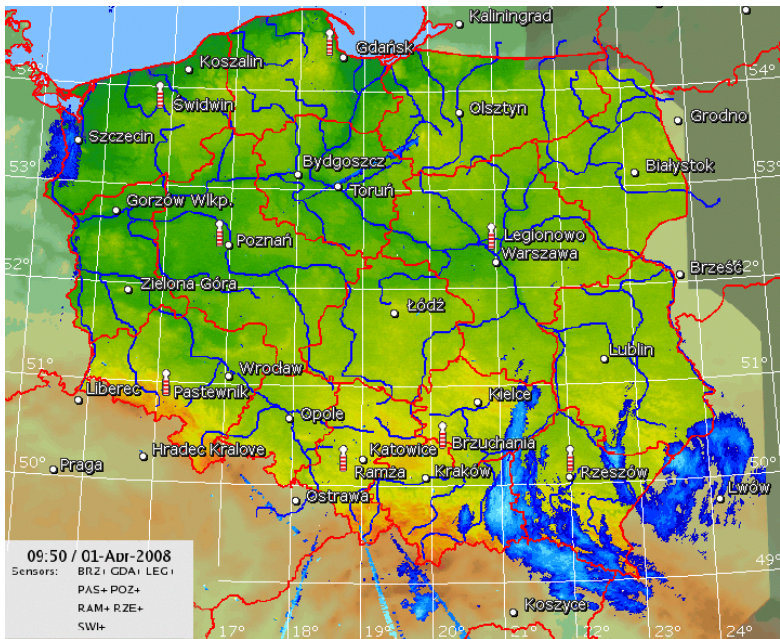
Search or tracking mode.

# Meteo radar

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

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





# Velocity measurement

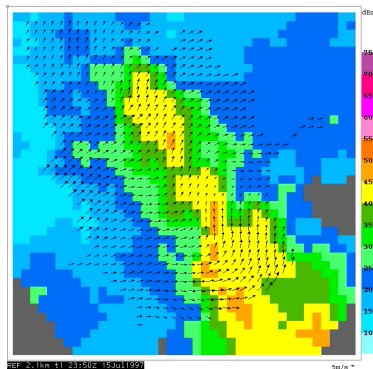
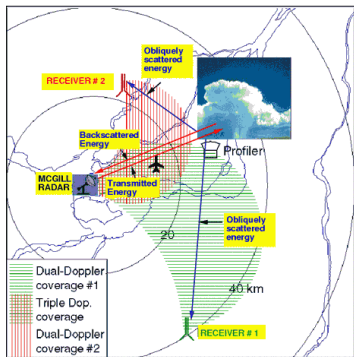
→ Doppler shift measurement

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

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 mm<sup>6</sup> m<sup>-3</sup> (number of drops per unit volume and the sixth power of drop diameter).

# ATC radar

Transmitter: Pulsed chirp (or other modulation).

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

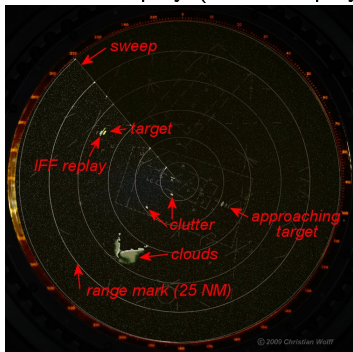
Receiver:

- ▶ 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 (→plots)
- ▶ Track initiation, plot to track association, tracking (→tracks)



# ATC radar display

→PPI display (other displays are history now)



(from [radartutorial.eu](http://radartutorial.eu))

# 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

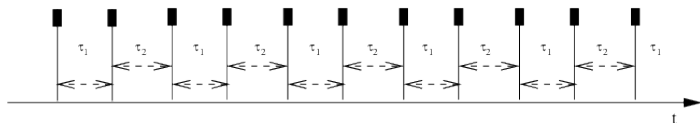
MTD: FFT filter bank (or equivalent)

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

Velocity measurement (CRT with MTI or MTD).

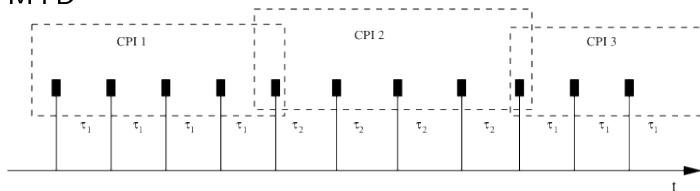
# MTI/MTD sampling

## MTI



Incoherent processing  $\rightarrow$  integration gain by averaging noise

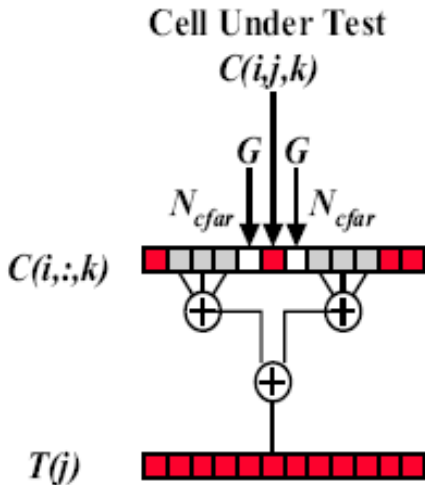
## MTD



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

## CFAR

Constant False Alarm Rate



# Pulse compression

*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/ECCM

Chaff.

Jamming: detection + diversity, agility.

Adaptive jamming/false echoes → pulse coding, pulse stagger