Radar Measurements

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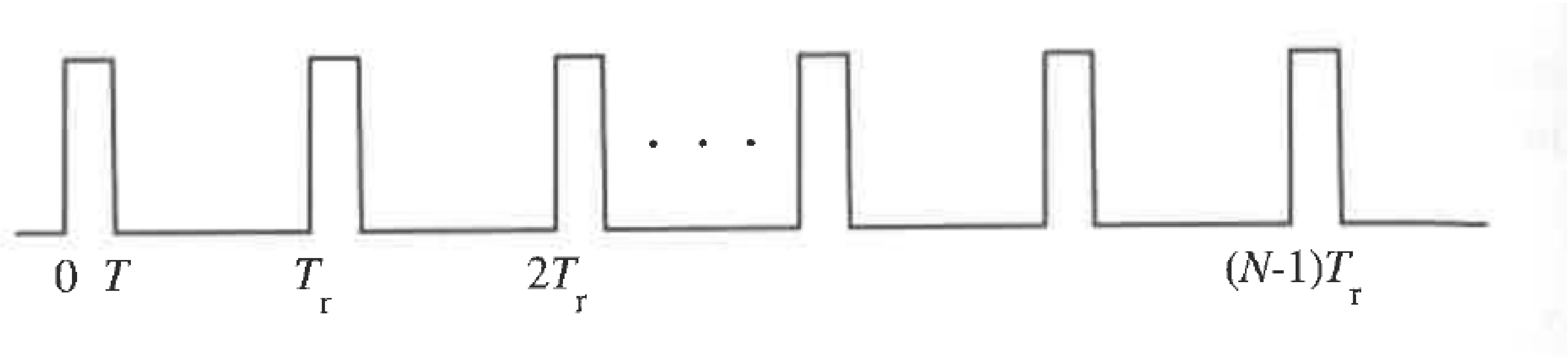
Echo location principle

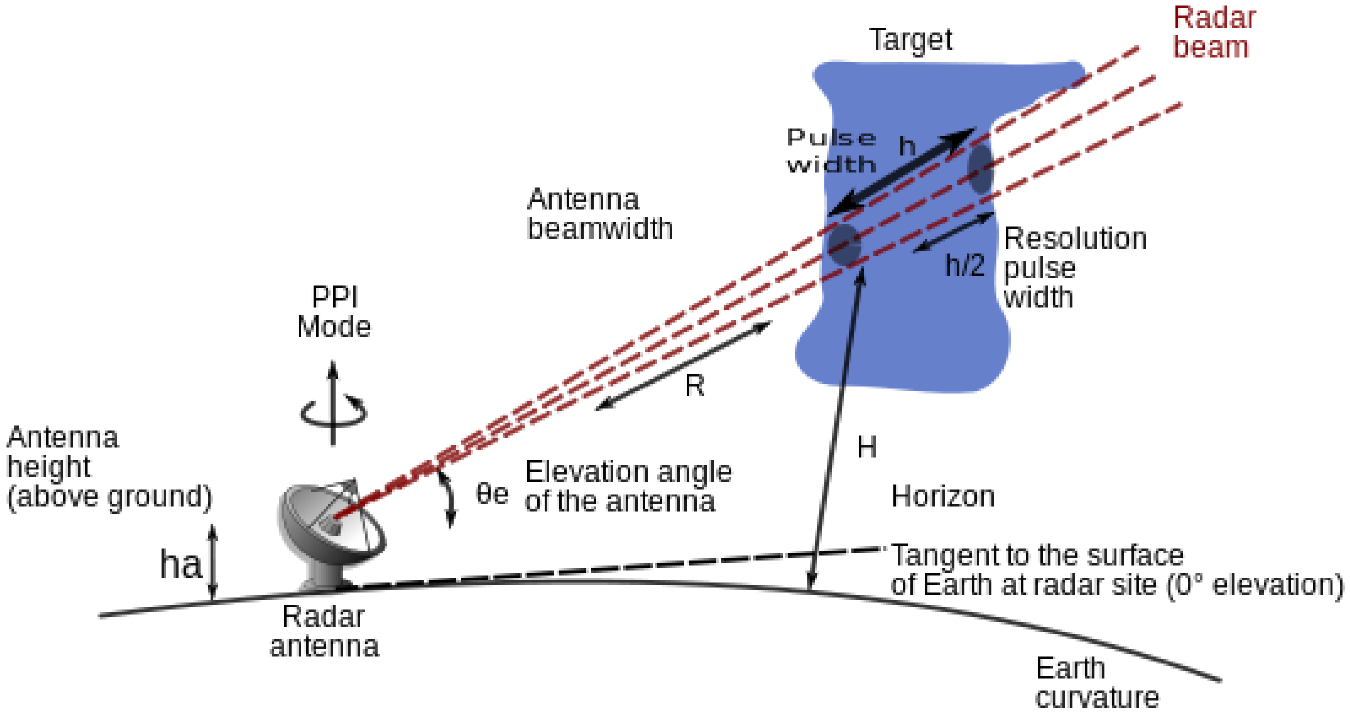
- Radar transmits short µ-wave „rectangular“ pulses with constant emitted frequency (/how/wavelength) and pulse duration („length“, „width“) τ with pulse repetition frequency PRF

$$PRF = 1/PRT = 1/T_s$$

- Listening period: sampling time or pulse repetition time $T_s - \tau \approx T_s = PRT$
- Several samples N ≈32-50 for statistically reliable measurements



- pulse radial resolution is $\tau/2$
- 1 µs : 150 m
- Distance to scatterer: $r = c\ t/2$
- Maximum time delay of returned echo: $t_{\max} = \ PRT$
- Maximum measurable (unambiguous) distance: $r_{\max} = c\,\frac{PRT}{2}$



Radial resolution

- Volume radial resolution (/where/rscale) is worse than $\tau/2$ due to **range averaging** n_r and possibly different DSP bin size Δr_{DSP}: $\Delta r = n_r\ \Delta r_{DSP}$
- Lisca: 8 bins with 125 m: 1km (too conservative setting)
- P. Ravan: 5 bins with 100 m; 0,5 km;
- Areas with strong Z or V gradients are degraded
- Areas with strong point clutter are enlarged from Δr_{DSP} to Δr

Radial velocity measurements

- Phase delay between consecutive pulses: $\frac{d\varphi}{dt} = -\frac{4\pi}{\lambda} v$
- Unambiguous velocity: $v_{max} = PRF\ \lambda/4$
- Contradictory with unambiguous range (Doppler lemma):
- C band: PRF 600 Hz: 250 km range, max. 8 m/s
- C band: PRF 1200 HZ: 125 km range, max. 16 m/s
- Majority of radars in EU are C-band

Improvements of velocity measurements

- post-festum reconstruction of higher velocity harmonics (Li et al. 2014, AdvAtmSci);
- problematic with high reflectivity and velocity gradients in Cb, with big areas of clear sky
- Improvements of measurement techniques: **dual – PRF**: first half of pulses at PRF1 and second half with PRF2

$$v_{max} = \frac{\lambda}{4(PRT_{lo} - PRT_{hi})}$$

- PRT (or PRF) in 4:3 ratio: v_{max}= 4 $v_{\max(lo)}$

Improvements of velocity measurements

- Example: PRF1=750 Hz, PRF2=1000 Hz; 4:3 ratio; v_{max}= 40 m/s
- Similar technique **dual PRT** (staggered PRT): alternating PRF1-2, same improvement, not supported with all commercial radar SW
- **Triple PRT** : used in Meteo France, supported in Vaisala IRIS .
- All of them **problematic with lower elevations** where big range is required (PRF2: 150 km); second trip echoes appear

Improvements of velocity measurements

- Solution: **phase diversity** (Vaisala IRIS: RPHASE) to eliminate second-trip echoes
- Natural with magnetrons which emit pulses with random phase; each returned pulse is *nearly uniquely phase-signed.* No experience, unknown problems (mangetron phase stability, circuit phase stability)
- Requires phase randomization with klystrons (S-band radars), TWT‘s and SST (newer X,C-band radars with pulse compression)
- Used operationally at FMI