

RADAR METEOROLOGY

Lecture 1

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Radar for meteorology: why?

ACTIVE SENSOR

Hydrometeors measurements: raindrops, snowflakes, hail, ice particles and drizzle

The radar electromagnetic waves can propagate through consecutive media without severe attenuation

**Focus → ground-based weather/atmospheric radar
and rain ($\lambda = 3-10$ cm)**

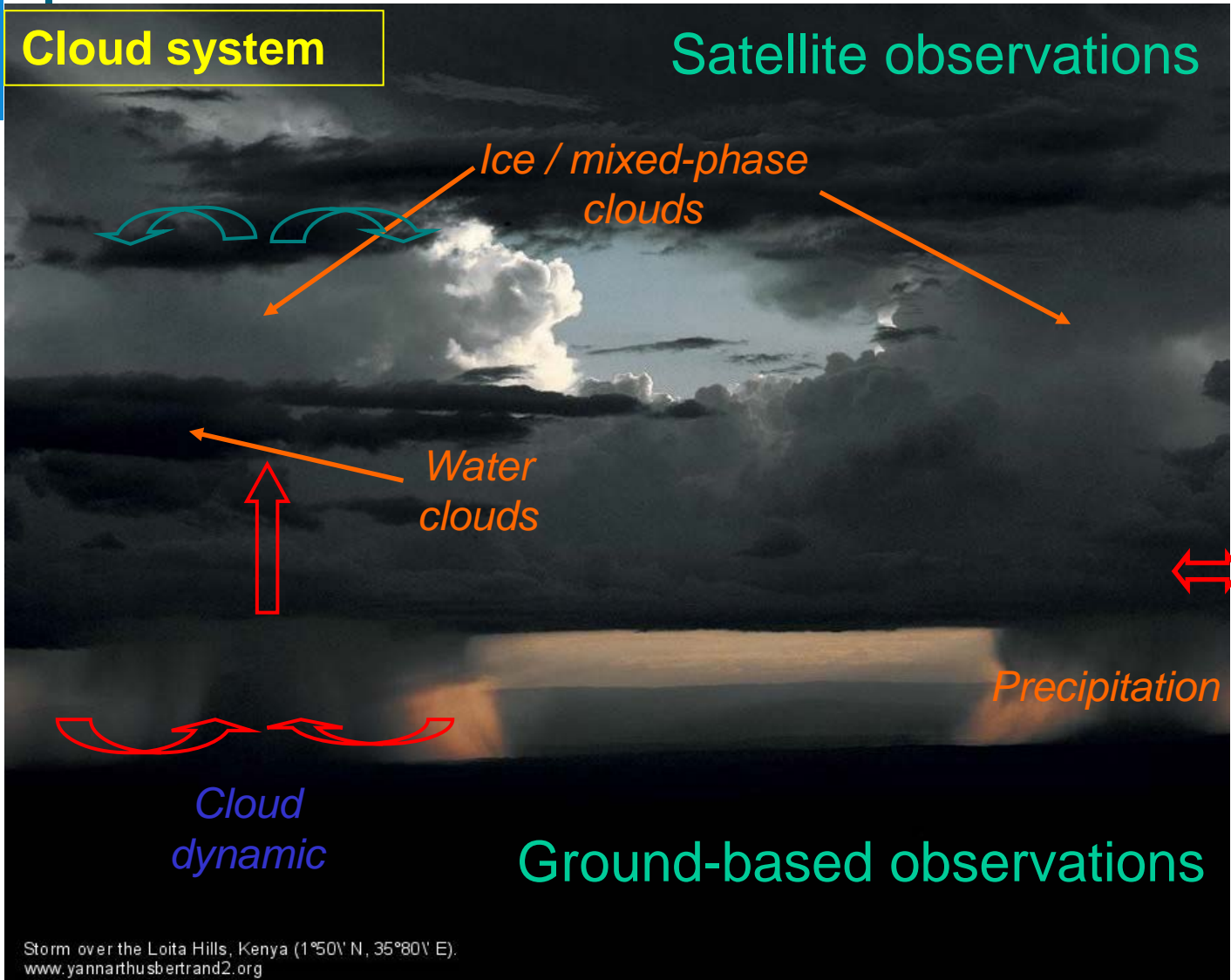


Radar for meteorology: why?

- ❖ horizontal or vertical profiles of the atmosphere with good spatial (10-100 m) and temporal resolution (1 s – 1 min) (particles must be present to reflect back the transmitted signal)
- ❖ good spatial coverage (horizontal scanning radar with maximum range of 300 km, 15 km vertical profiling of the troposphere)
- ❖ possibility of diverse measurements (power, phase, Doppler, polarization) at different frequencies



Radar for meteorology: why?



Studies
Microphysics of particles present in the cloud system
 +
Motion of the particles - dynamic

Storm over the Loita Hills, Kenya (1°50' N, 35°80' E).
www.yannarthusbertrand2.org

Weather/atmospheric ground-based radar for precipitation observation

Larger
radar
↑

	Wavelength	Frequency	Maximum range for rain
S-band	15-8 cm	2-4 GHz	100-130 km
C-band	8-4 cm	4-8 GHz	100-130 km
X-band	4-2.5 cm	8-12 GHz	30-60 km

USA
Europe
cities

Maximum range S-/C-band: 300 km

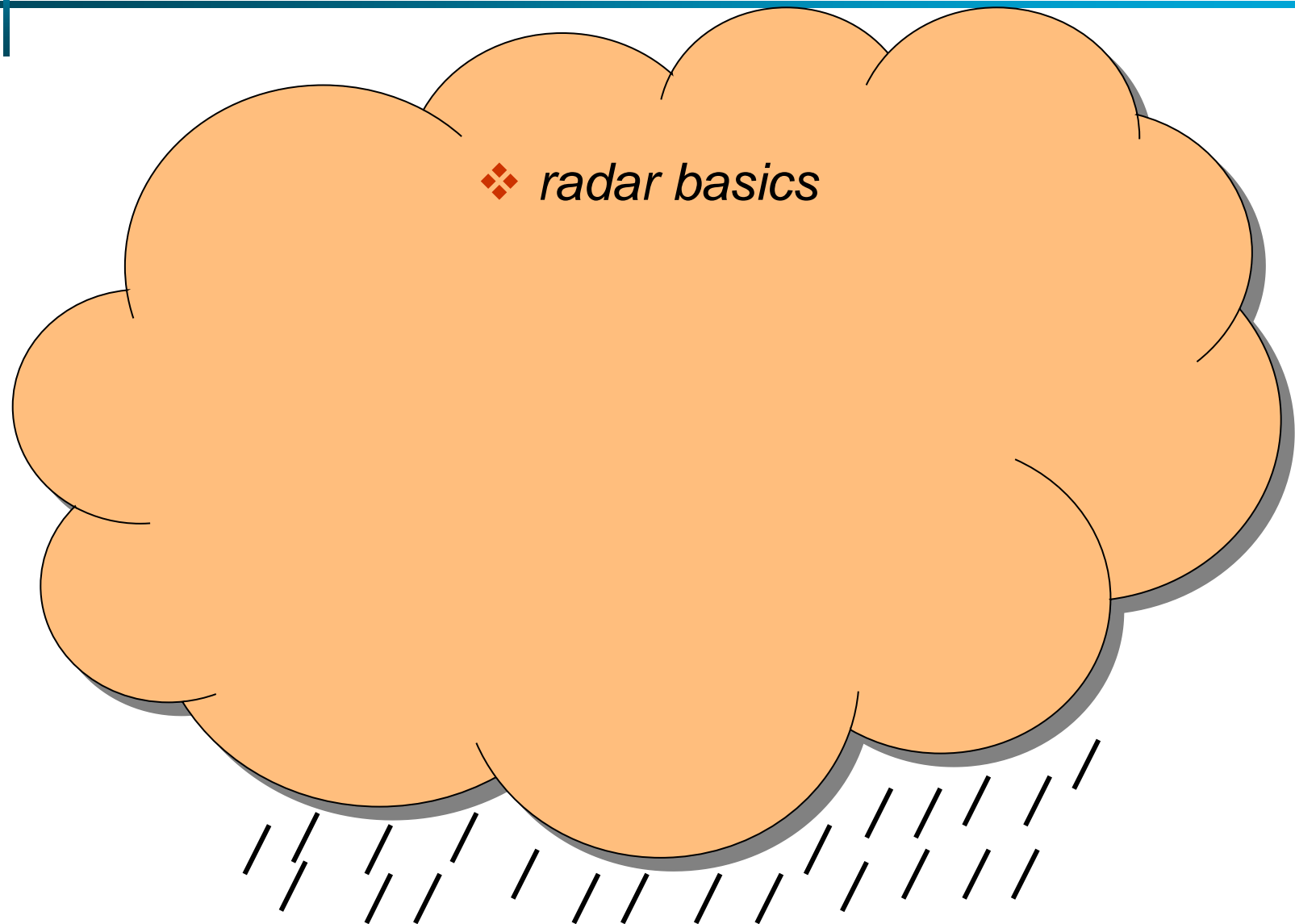


Contents

- ❖ *radar basics*
- ❖ *weather radar measurement modes*
- ❖ *radar equation*
- ❖ *radar cross-section*
- ❖ *Rayleigh scattering*

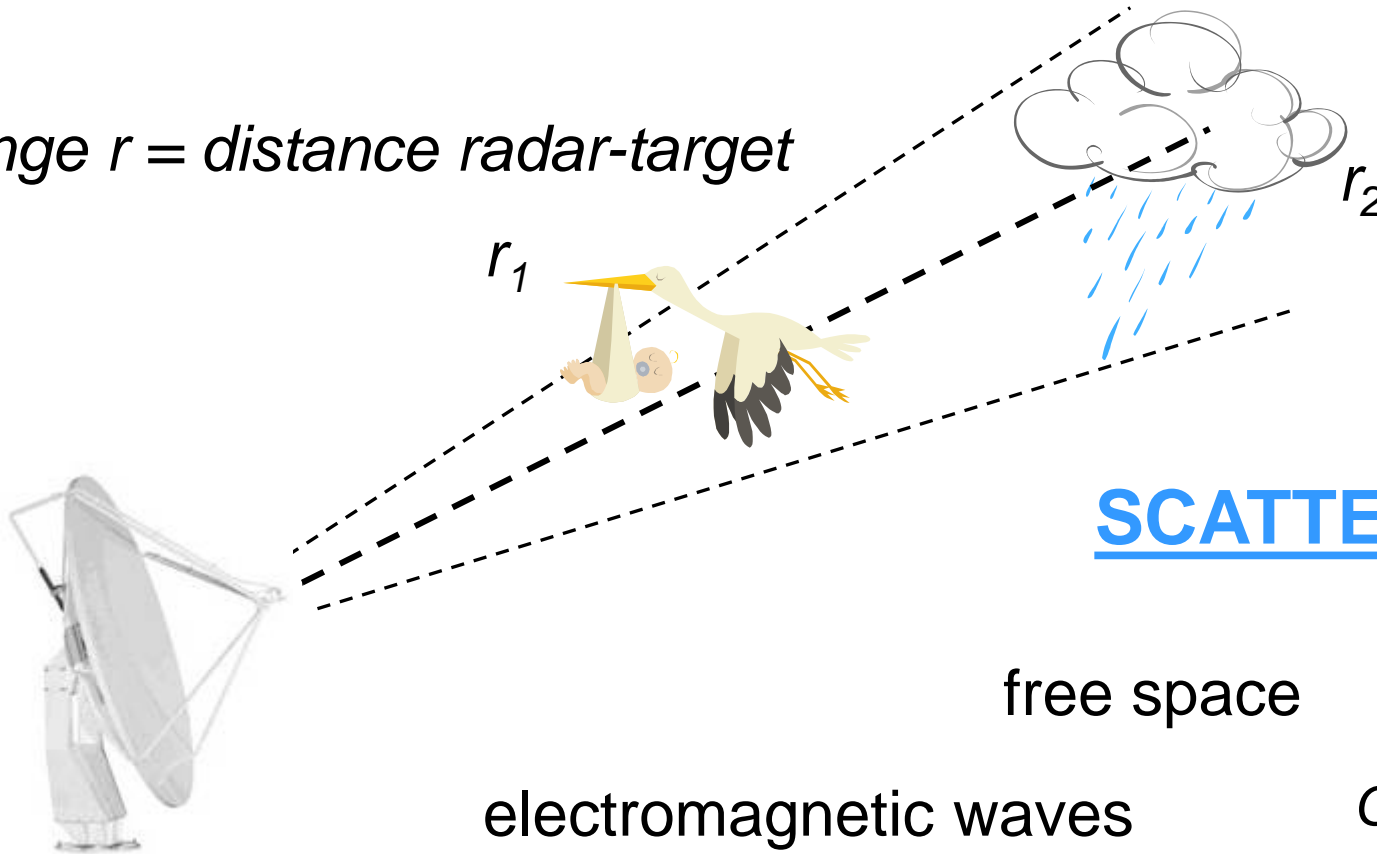


Contents



Radar: Radio Detection and Ranging

Range $r =$ distance radar-target



SCATTERING

free space

electromagnetic waves

$$C = 3 \cdot 10^8 \text{ m s}^{-1}$$

radar wavelength λ [10–3–0.3] cm

$$\lambda = \frac{c}{f_c}$$

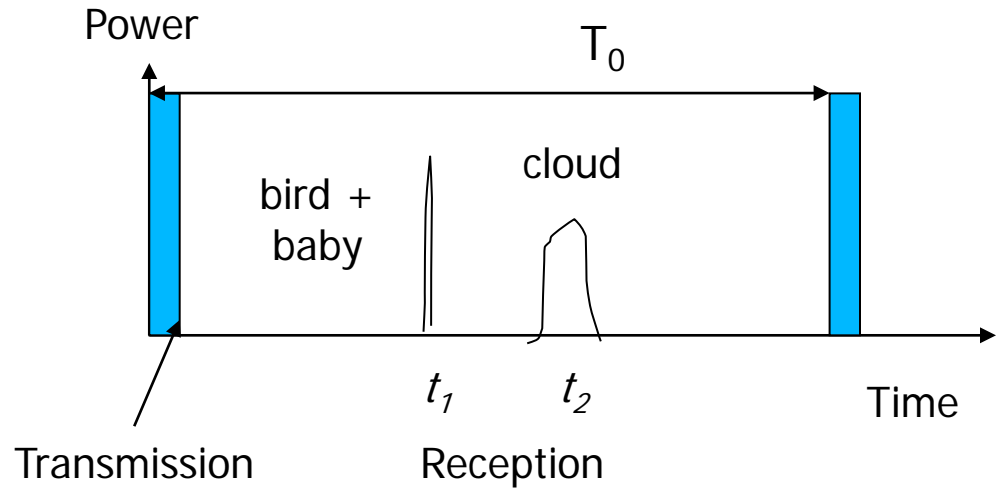
radar frequency f_c [3–10–100] GHz



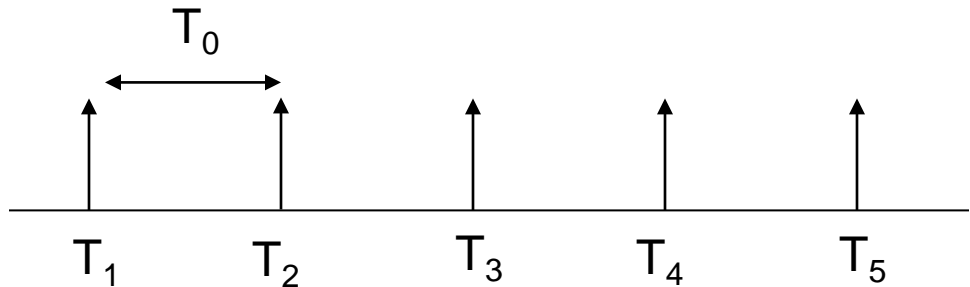
Radar: Radio Detection and Ranging

The ranges of objects (targets) are measured

$$r = \frac{ct}{2}$$



T_0 pulse repetition time

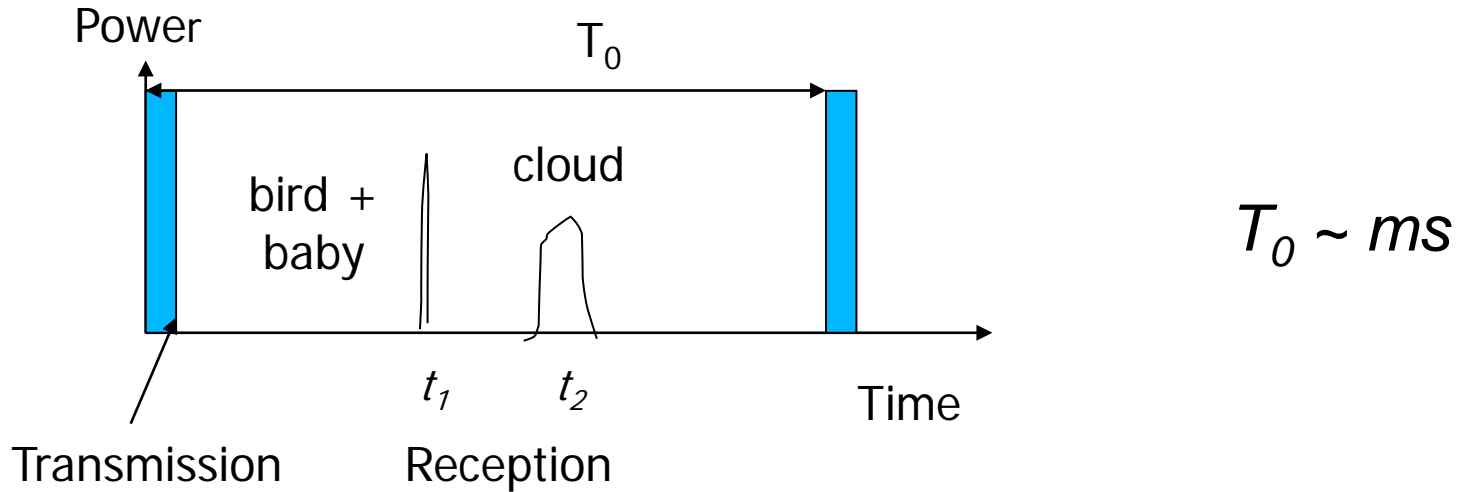


Large T_0 : large r_{max}

$$r_{max} = \frac{cT_0}{2} \quad T_0 \sim ms$$



Radar: Radio Detection and Ranging



But the time resolution is of the order of the second or more, it means that time-averaging is carried out to reduce the variance of the measured power

What else do we measure with a radar?

Signals

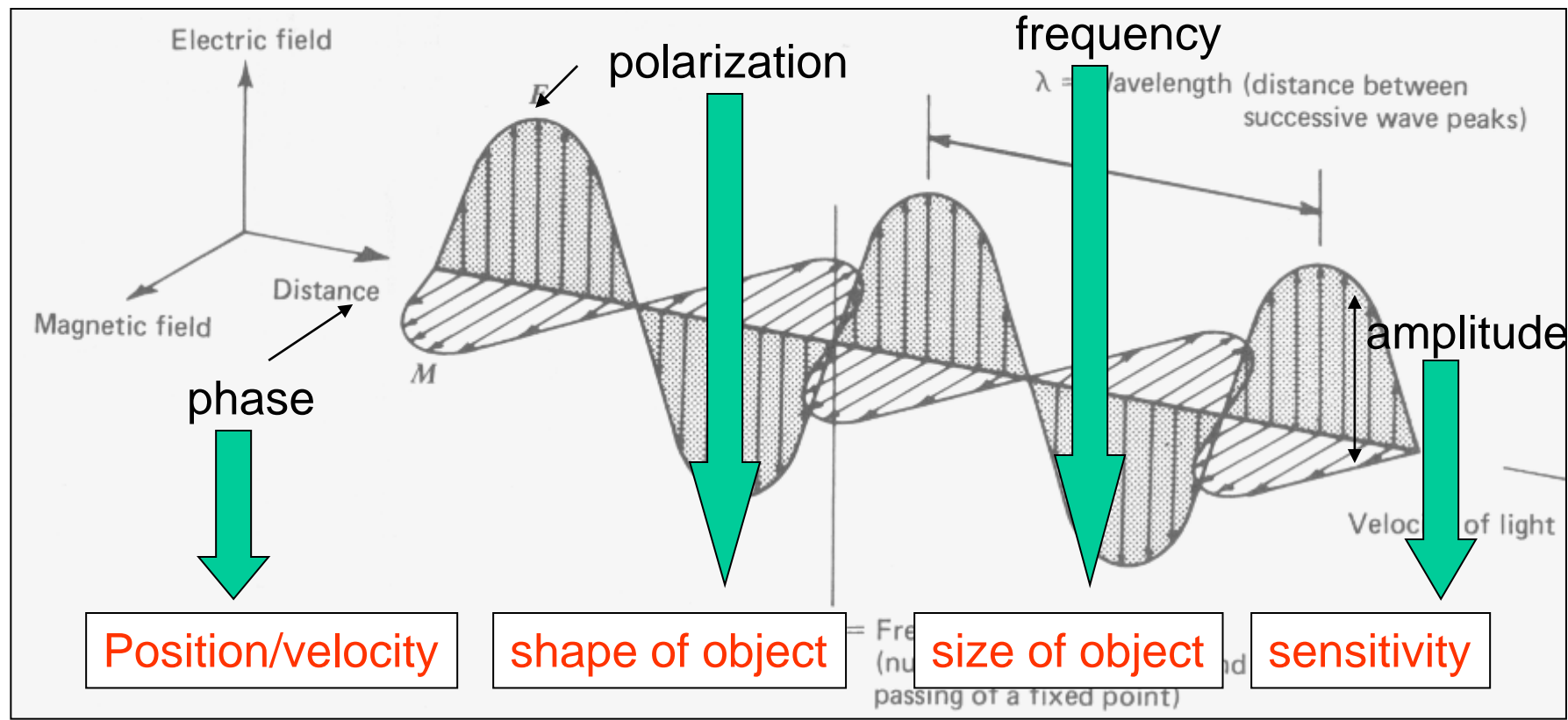
amplitude
phase
polarization
frequency

Without interpretation meaningless parameters!

For remote sensing: we want to derive the physical properties of system earth

How can we use EM-waves?

$$\vec{E}^i(r, t) = E_0 \hat{e}_i \exp[j(\omega t - k_0 r)] \quad k_0 = 2\pi / \lambda$$



$$P^i \propto |\vec{E}^i|^2$$

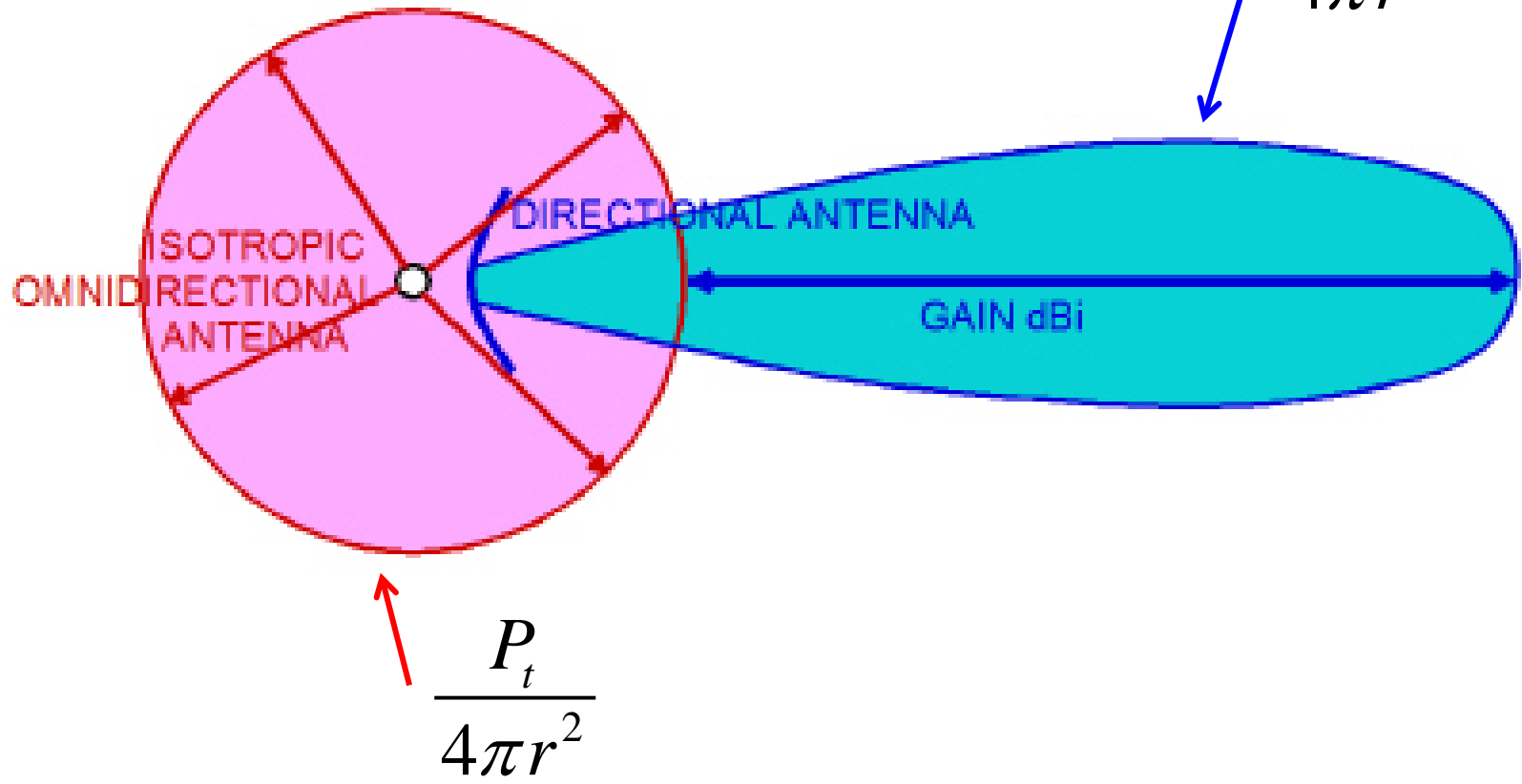
Plane wave

Free space

Transmitted power

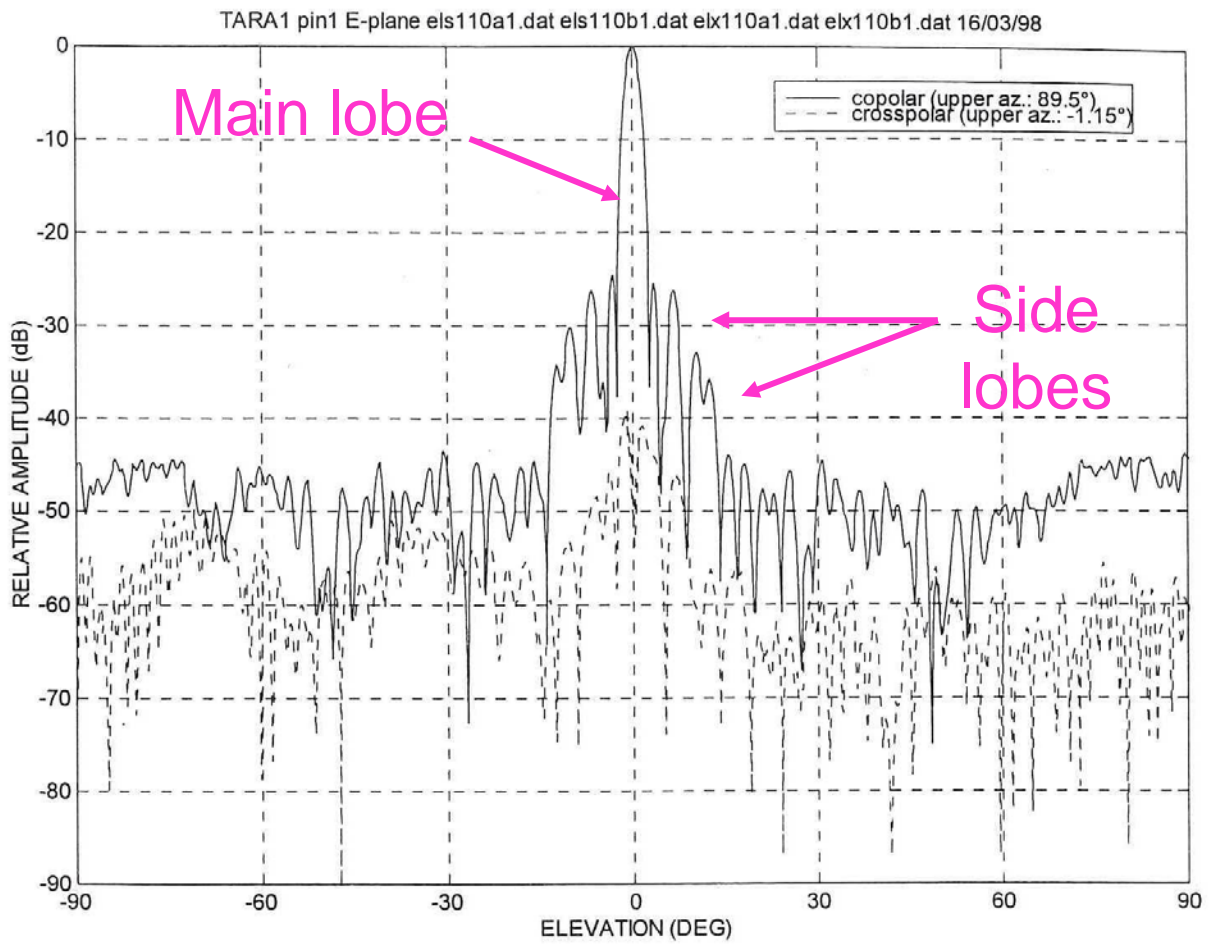
$$P^i \propto |\vec{E}^i|^2$$

$$\frac{P_t G_t(\alpha, \phi)}{4\pi r^2}$$



Example of antenna radiation pattern

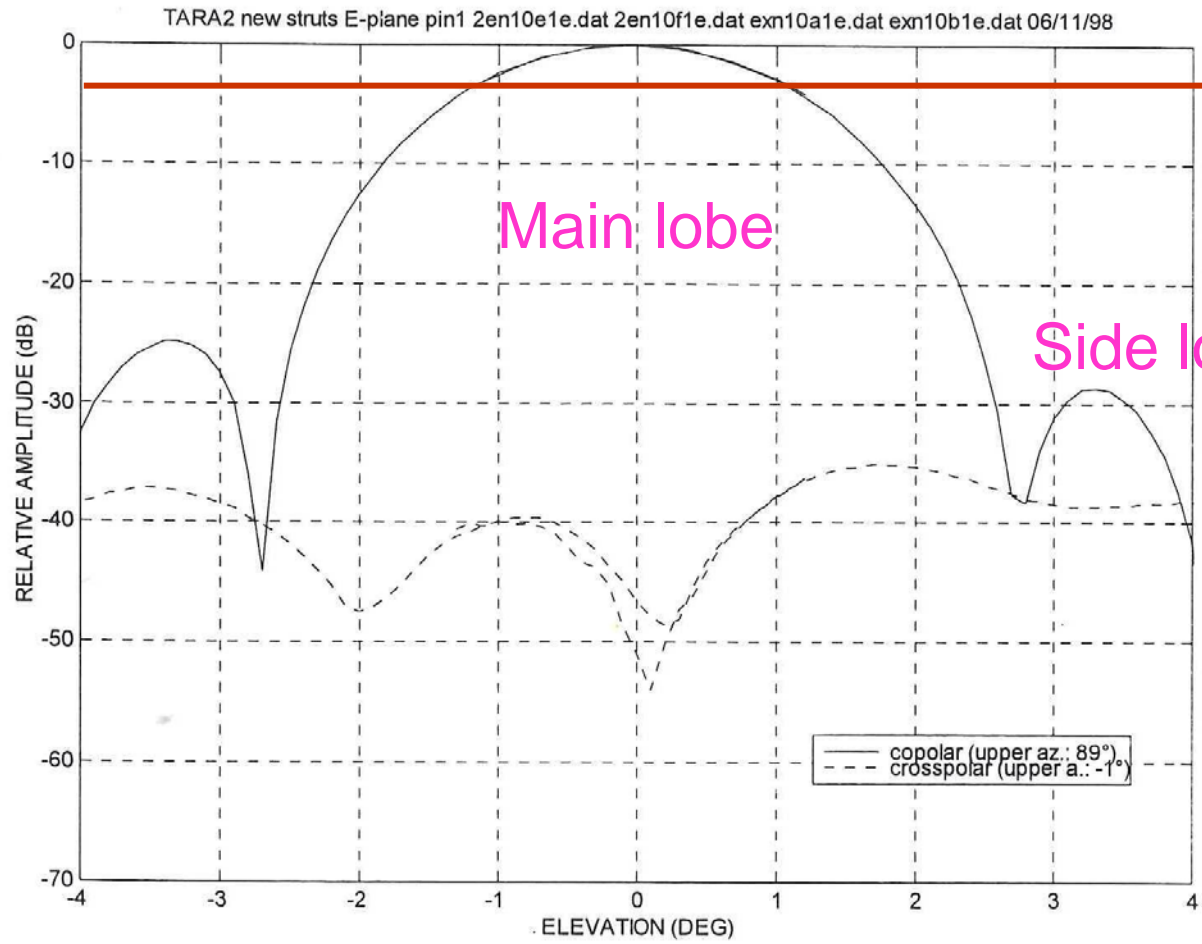
$$\text{Relative antenna gain} = 10\log\left(G(\alpha)/G_{\max}\right)$$



Describes how well antenna directs the radiation

TARA radar

Example of antenna radiation pattern



beam width $\theta_w =$
 angular width of
 the main beam at
 half power points
 (3 dB below)

In the case of TARA
 radar it is about 2 deg

weather radars:
 $\theta_w = 0.5 - 2$ deg.

Contents



❖ *weather radar
measurement modes*

Height Time Indicator (HTI)

radar resolution volume $V \approx (r\theta_w)^2 \Delta r$

beam width = θ_w

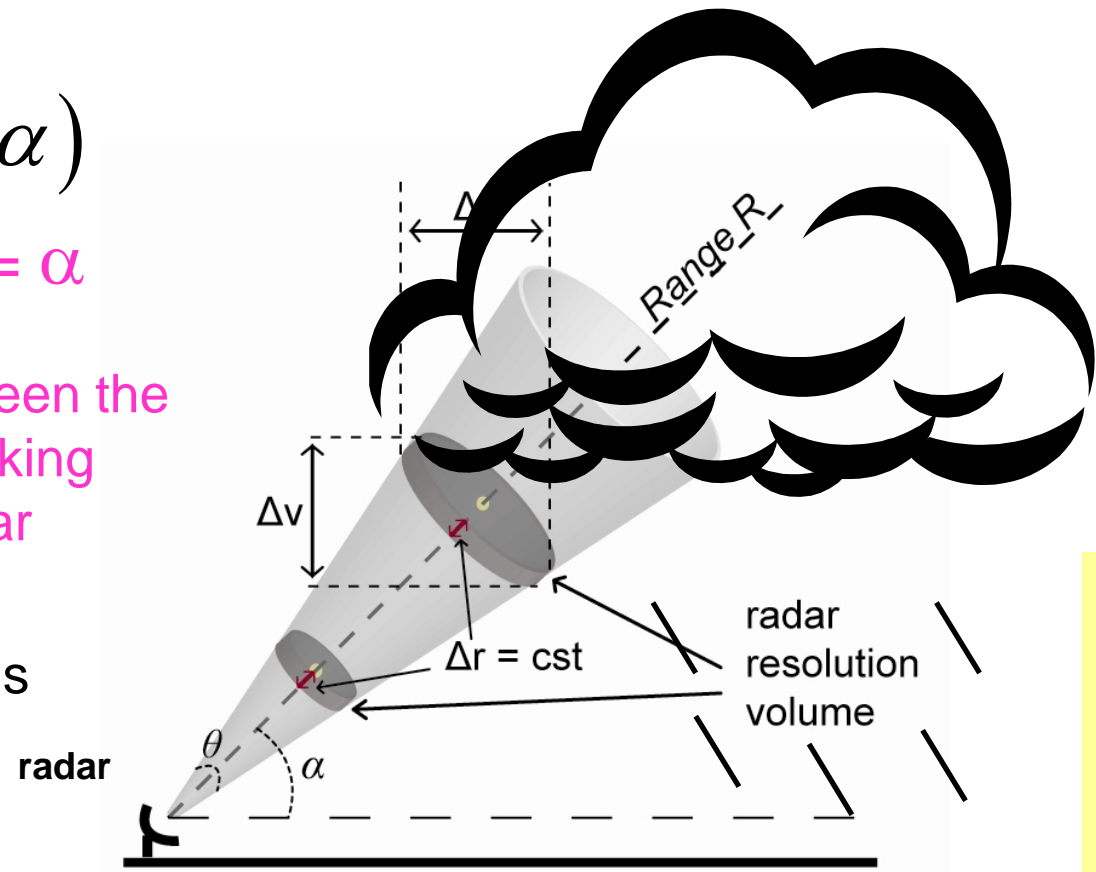
range resolution = $\Delta r = \text{const}$

height = $r \sin(\alpha)$

elevation angle = α

α is the angle between the horizon and the looking direction of the radar

θ_w and α are expressed in radians



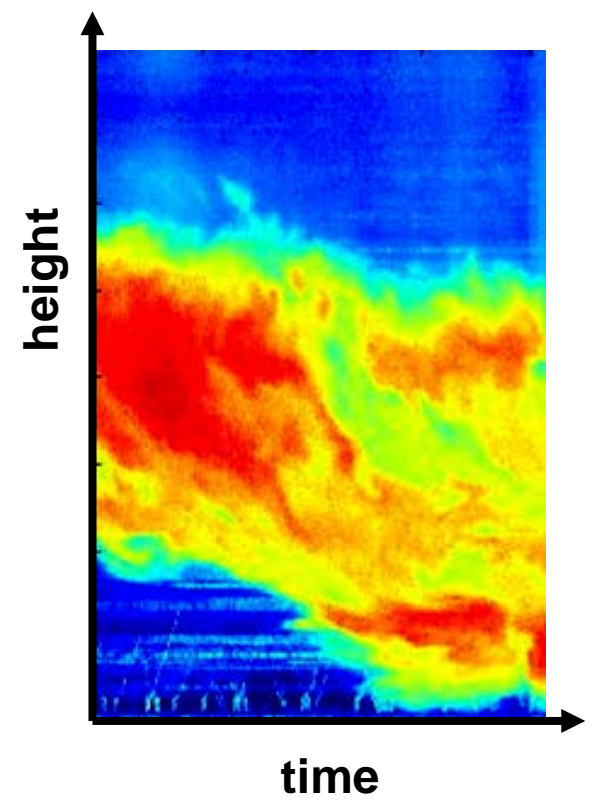
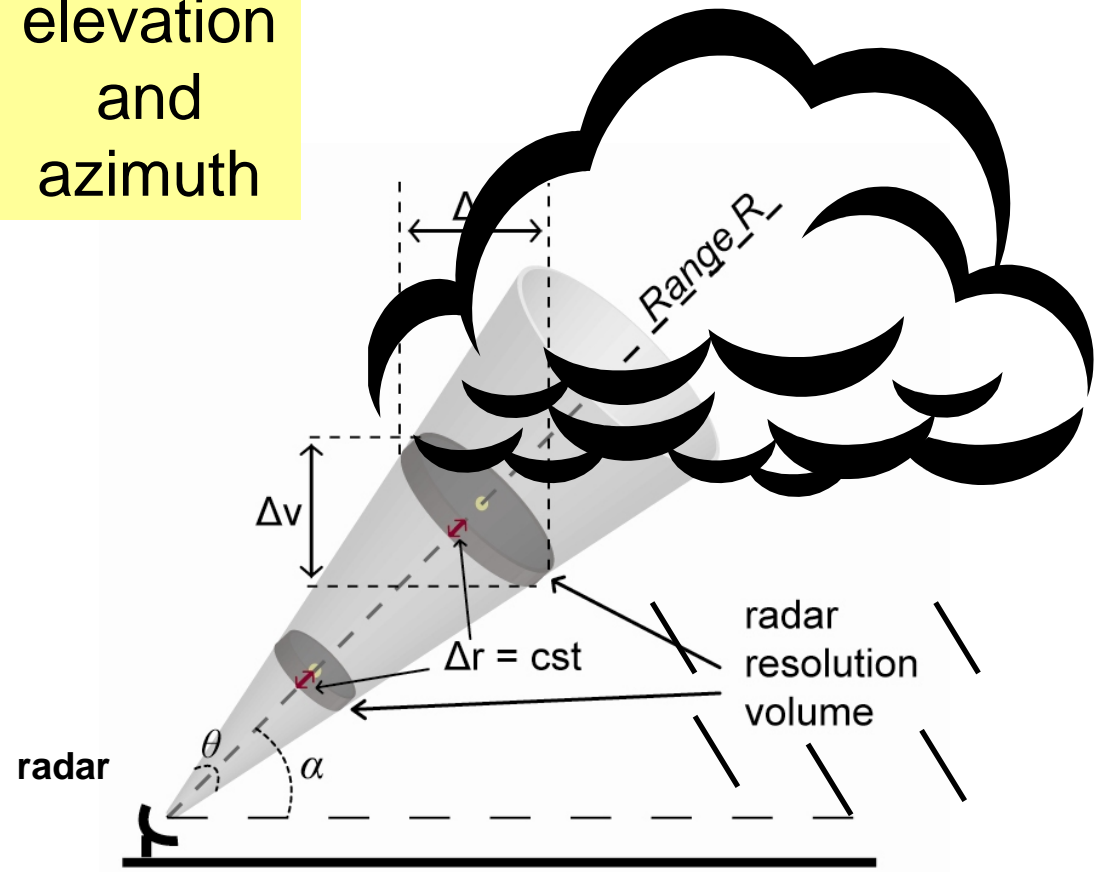
Fixed elevation and azimuth

Height Time Indicator

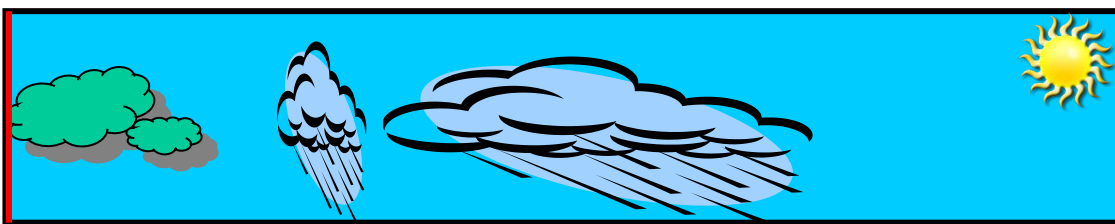
Fixed elevation and azimuth



TARA, TU-Delft



Height Time Indicator (HTI)

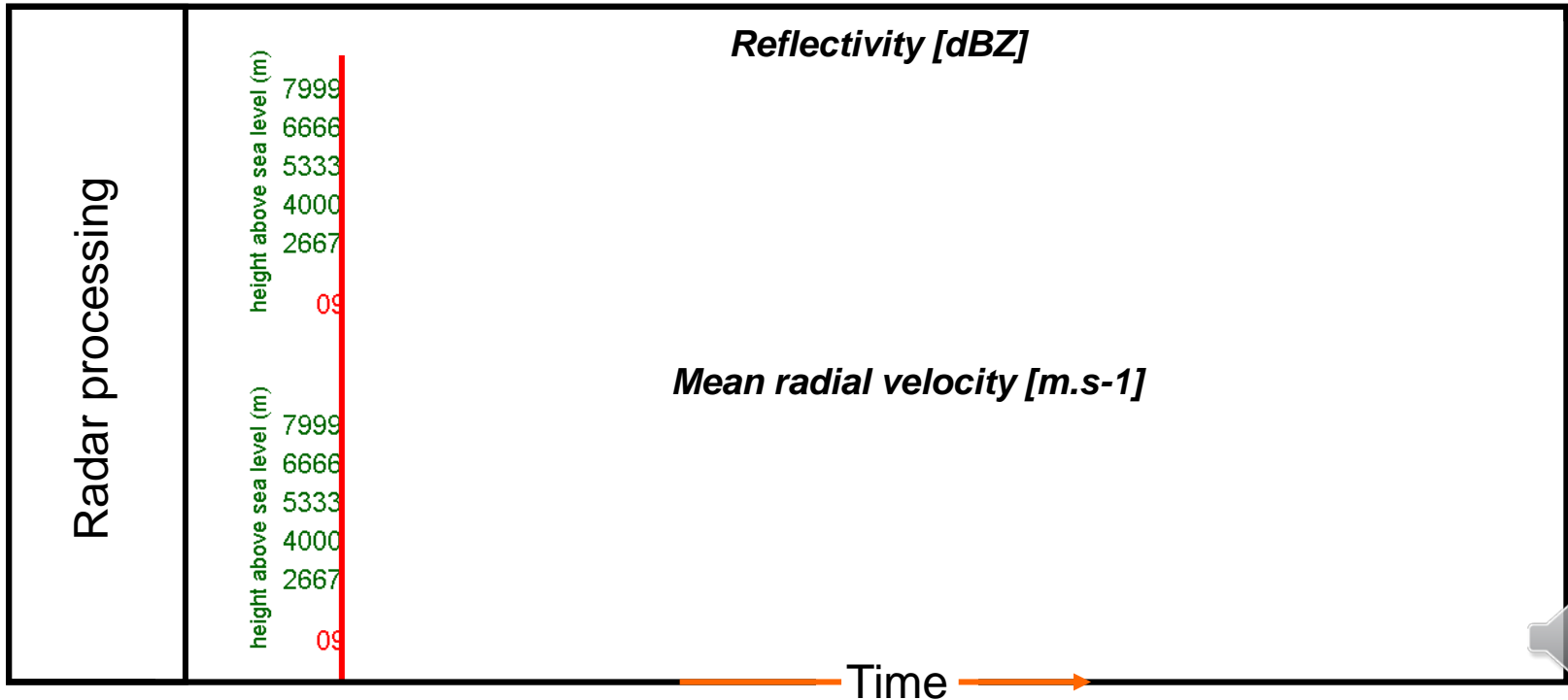


Time ← Current ↑ Cloudy precipitation Clear sky

research radar
TARA



(S Band $\lambda=9.1$ cm)

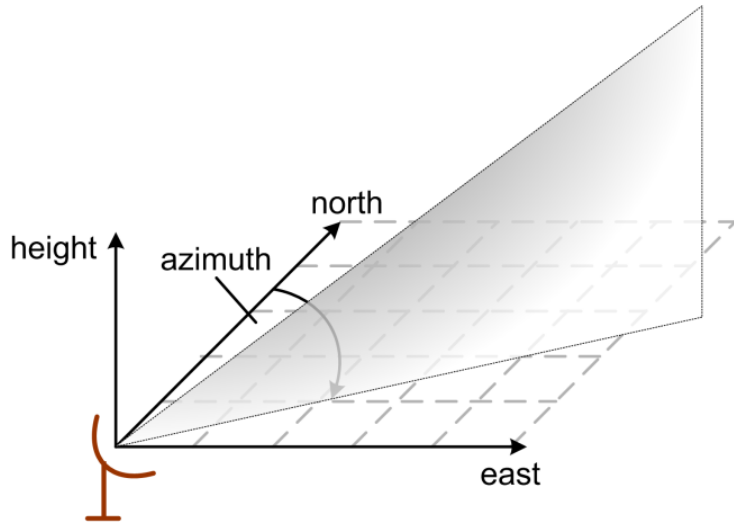


Height Time Indicator (HTI)

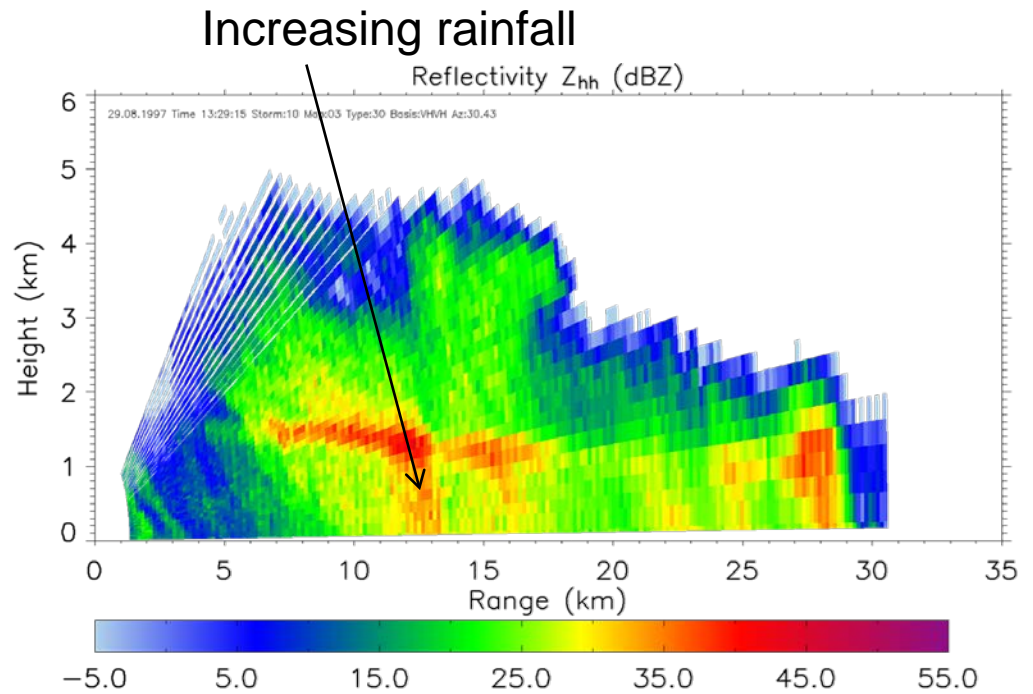
Most common elevation for this display: $\alpha=90^\circ$
(vertical profiling)

RHI: Range Height Indicator

scanning in elevation



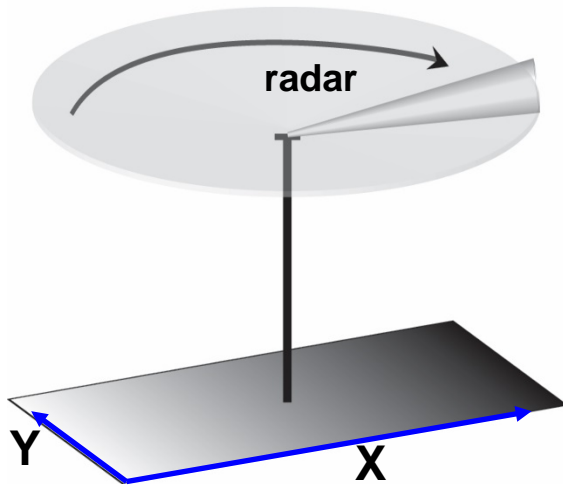
Fixed azimuth



Data: POLDIRAD (DLR, Oberpfaffenhofen, Germany), Prof. Madhu Chandra

PPI: Plan Position Indicator (TU-Delft IDRA radar)

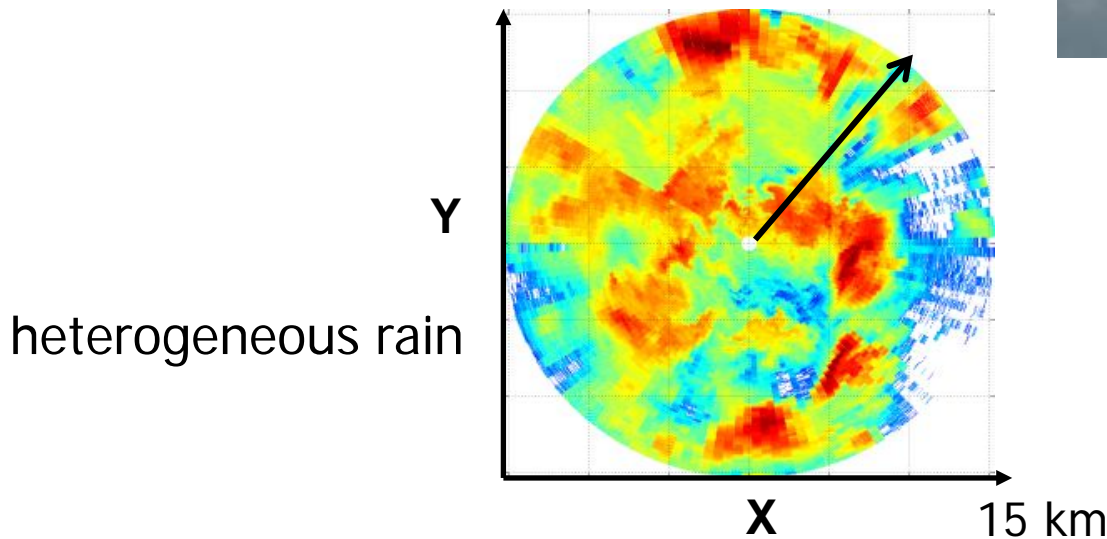
(X Band $\lambda=3.2$ cm)



Fixed elevation



research radar



heterogeneous rain

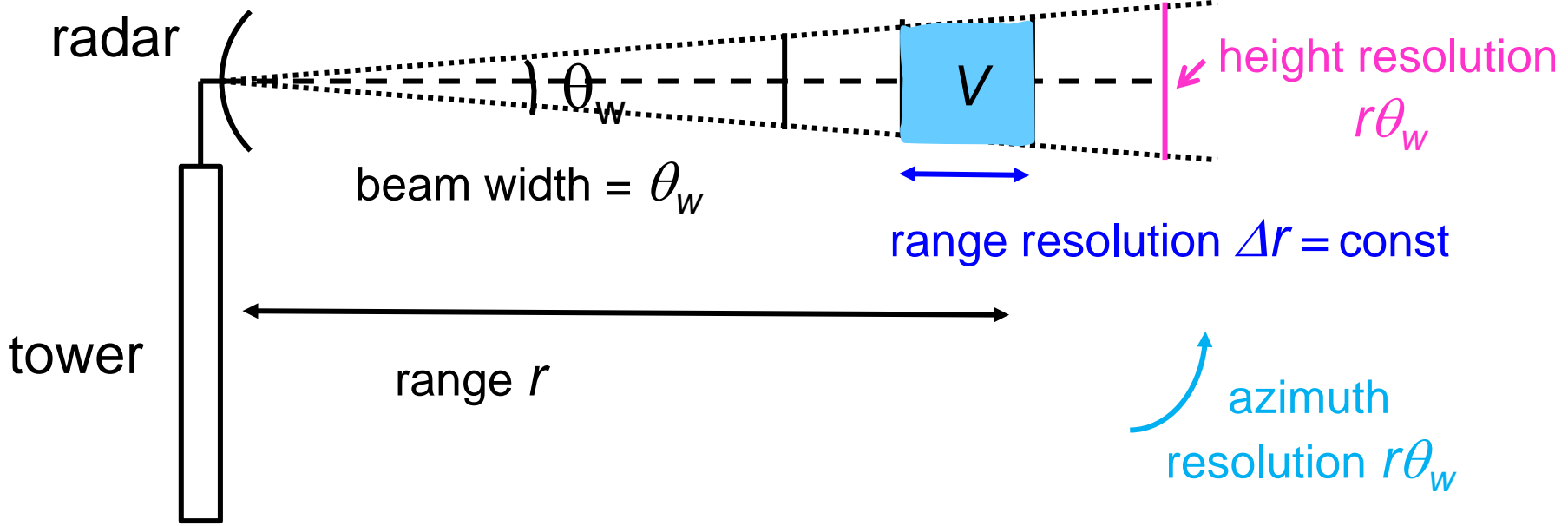
scanning in azimuth

PPI: Plan Position Indicator

Radar looking direction:
horizontal $\alpha=0^\circ$

radar resolution volume

$$V \approx (r\theta_w)^2 \Delta r$$



Rainfall in the city requires high resolution: small $\Delta r, \theta_w, r$

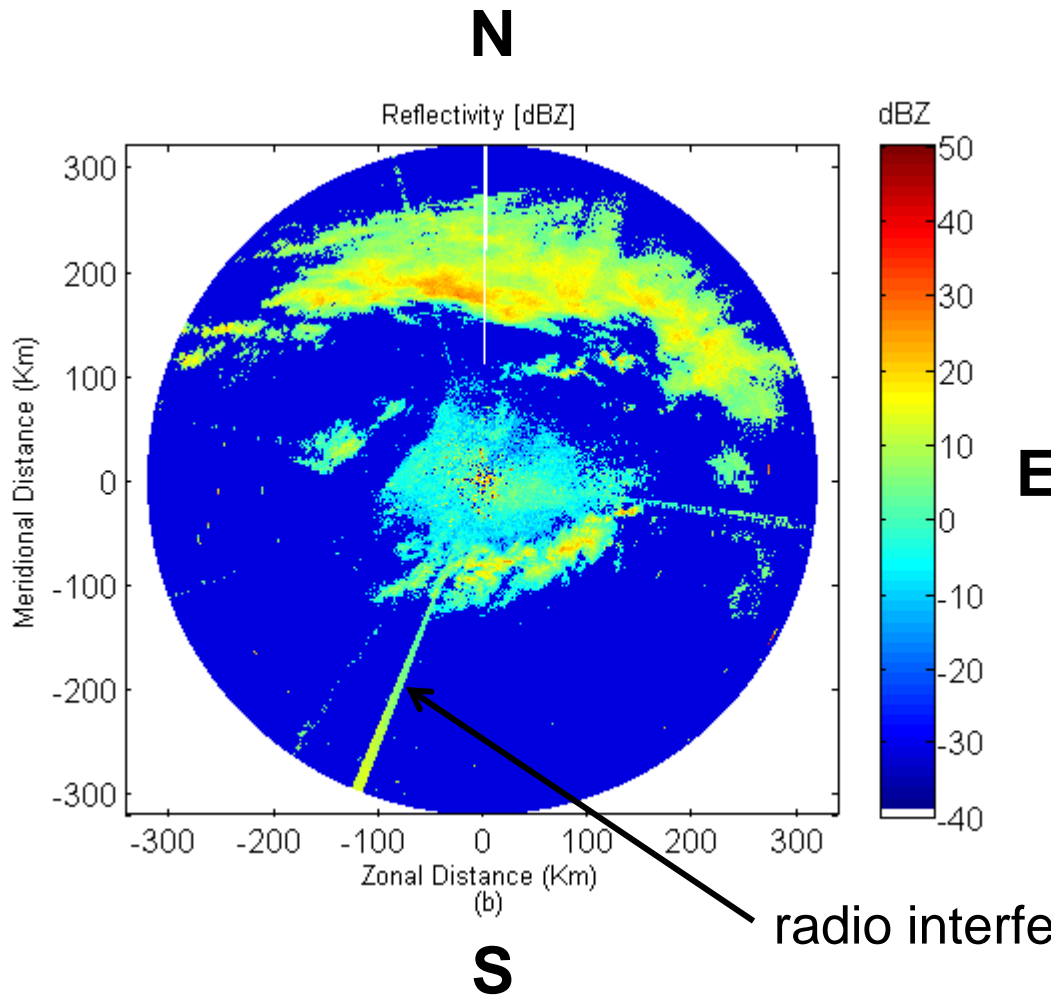
PPI: Plan Position Indicator (KNMI radar)

Preferred elevation: $\alpha=0^\circ$
(horizontal profiling)

(C Band $\lambda=5.3$ cm)



Hans Beekhuis (KNMI)

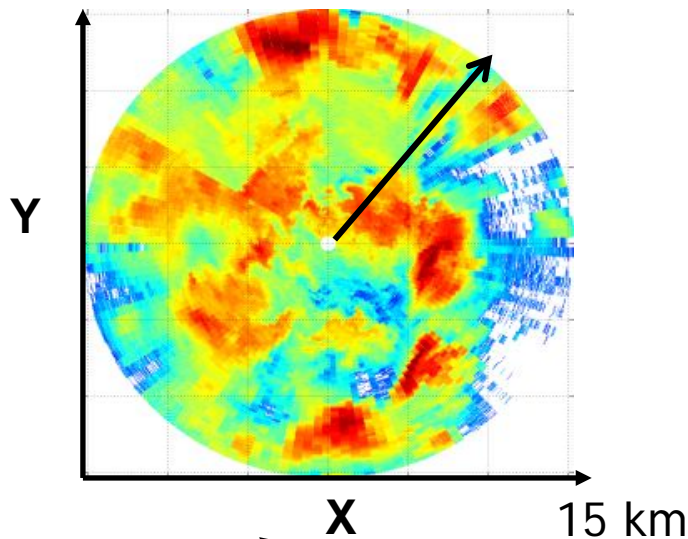


PPI: Plan Position Indicator

Coverage of the city

$$r_{max} = 15 - 60 \text{ km}$$

$$\Delta r = 10 - 30 \text{ m}$$

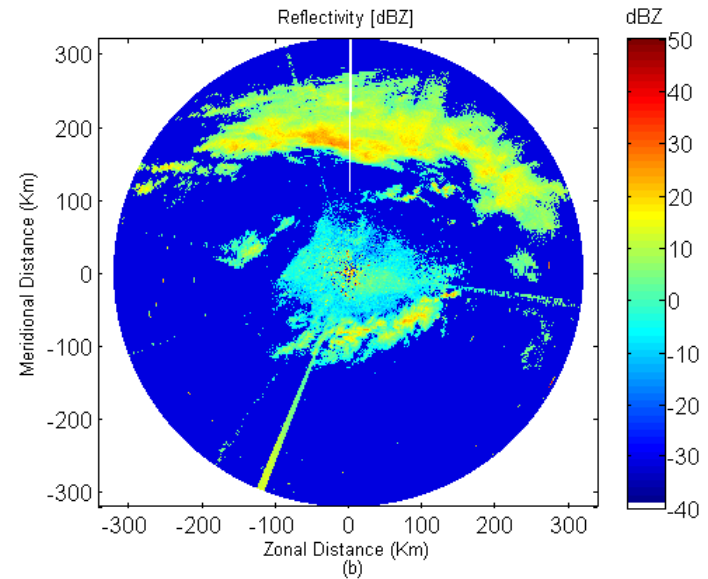


Coverage of the country

Data provided to build website "buienradar" images

$$r_{max} = 200 - 300 \text{ km}$$

$$\Delta r = 100 - 400 \text{ m}$$



Radar beamwidth $\theta_w = 0.5 - 2^\circ$

