Physikalisch-Technische Bundesanstalt
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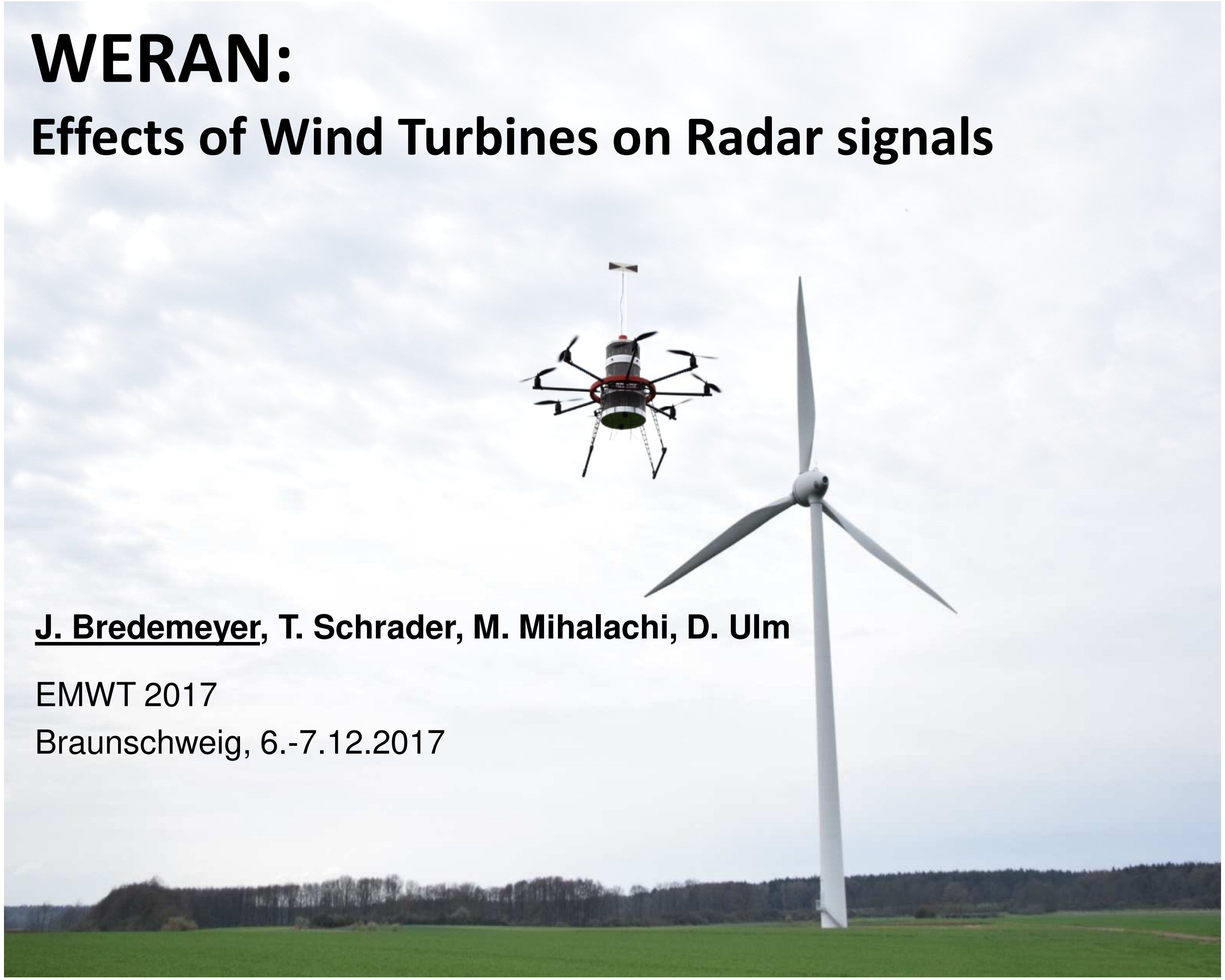
National Metrology Institute

Flight Calibration Services



WERAN:

Effects of Wind Turbines on Radar signals

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EMWT 2017
Braunschweig, 6.-7.12.2017

Gefördert durch:

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

FKZ: 0325644A-D

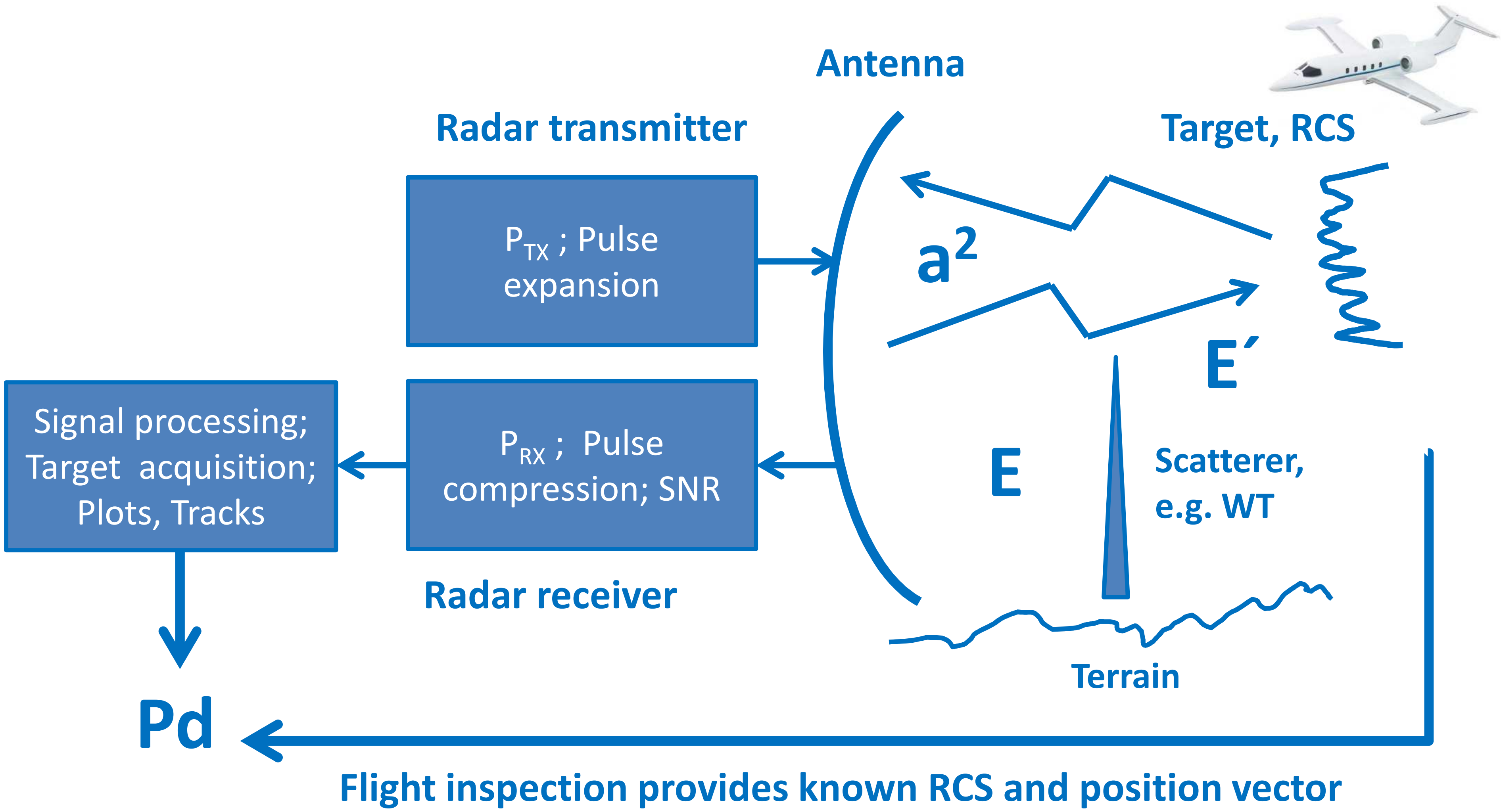
Tasks in WERAN

- Major goal: to improve predictions about the impact of wind turbines on radar

To be achieved by means of

- Measurements of scatter effects
- Separation of single WT contributions
- transfer measures: to provide radar manufacturers with signals-in-space affected by wind turbine scattering
- Data basis for external intercomparisons

Radar and its transmission channel



Breaking down the problem

- „Radar“ implies entire processing chain from signal synthesis/processing, wave propagation and the representation of the situation
- What are the linear parts to analyze and to simulate?
- Where does non-linear signal processing takes action? Where exactly is the interface?
- Which parts of the (linear) system can be measured?
- Any further signal processing is intellectual property of the radar manufacterer; disclosure of details is very unlikely!

Linear part to be measured

- Superposition of field components E
- Radar „forward scatter“
- to a certain extent: backward or side scatter

Non-Linear parts

- Pulse compression radar: Phase function of expanded pulse
- What is the reference pattern h(k) of the expanded pulse?

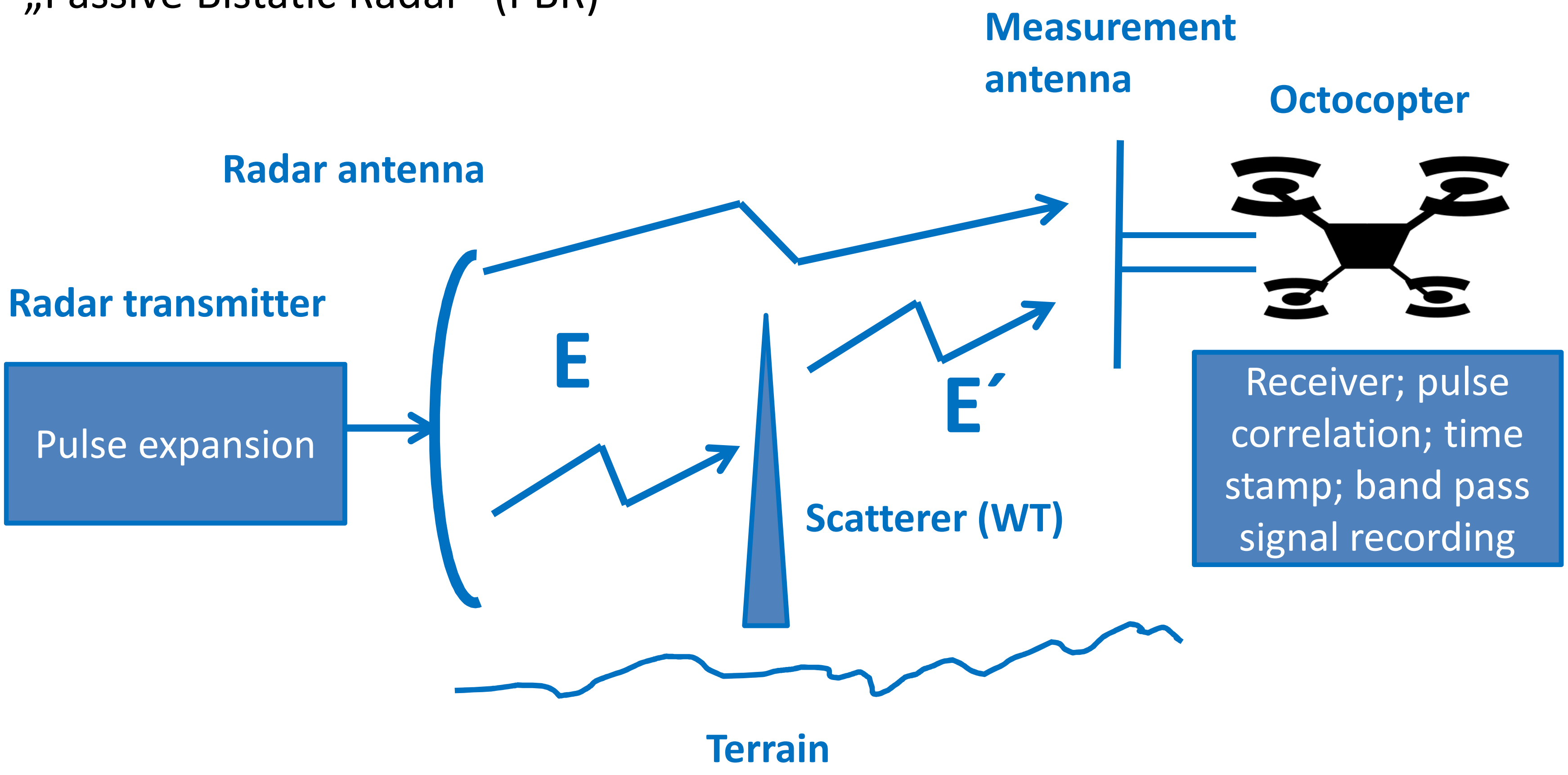
- Thresholds, number of hits
- Parameters of coherent integration
- Weighting functions
- Target detection / acquisition
- Propability of detection
- Tracking

What exactly do we measure and how?

- A radar itself cannot distinguish between single WTs from a large distance, it only detects a bunch of backscatter signals
- Introduction of measurement procedure making use of direct and scattered radar pulses in the time domain (→ „Passive Bistatic Radar")
- For different radar types and frequencies, isolation of the scattering from single WTs
- Measurements at radar sites with numerous WTs of different size and various manufacturers
- „Forward scatter", „backward" or „side" scatter

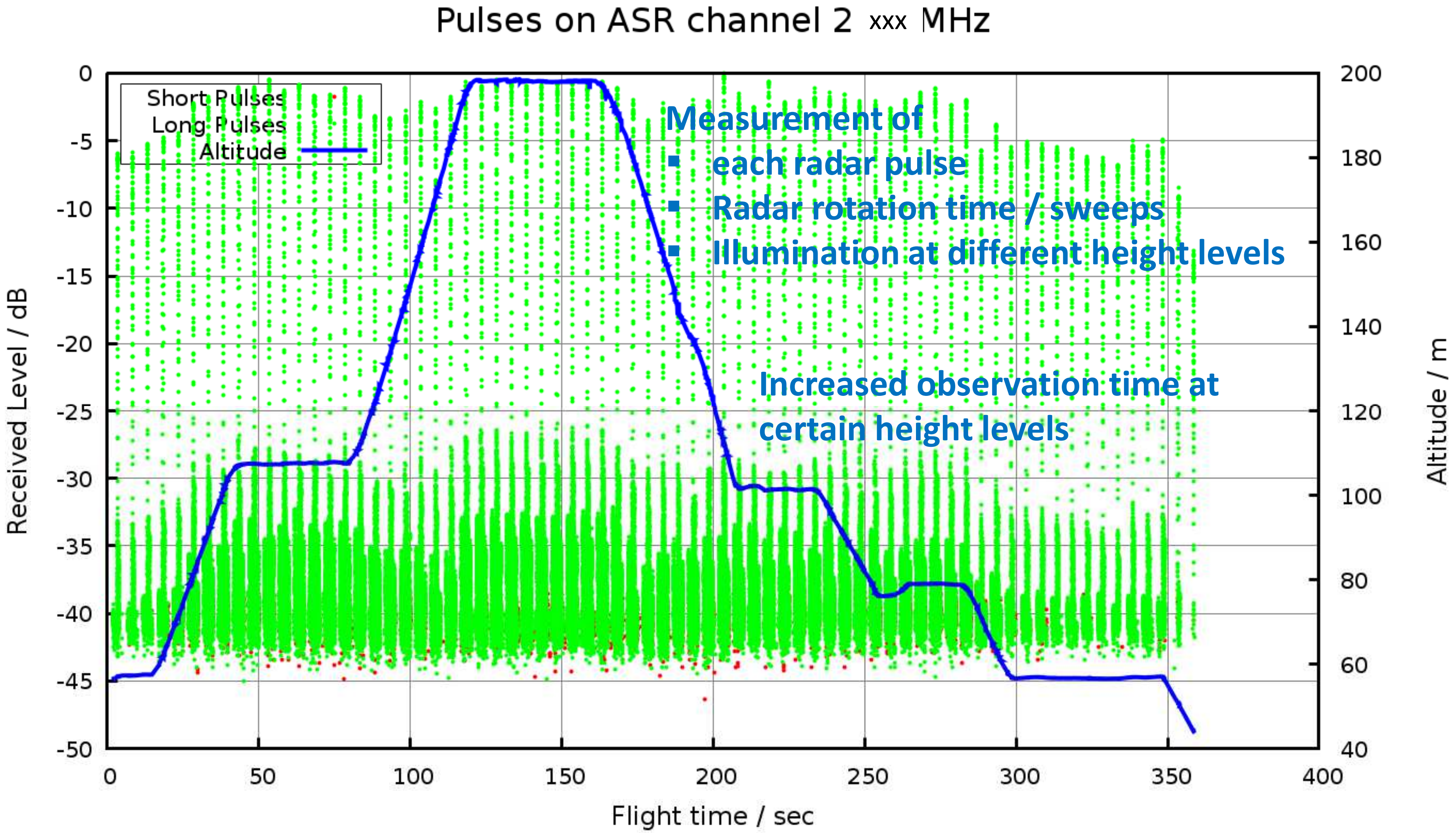
WERAN on-site measurements

„Passive Bistatic Radar“ (PBR)



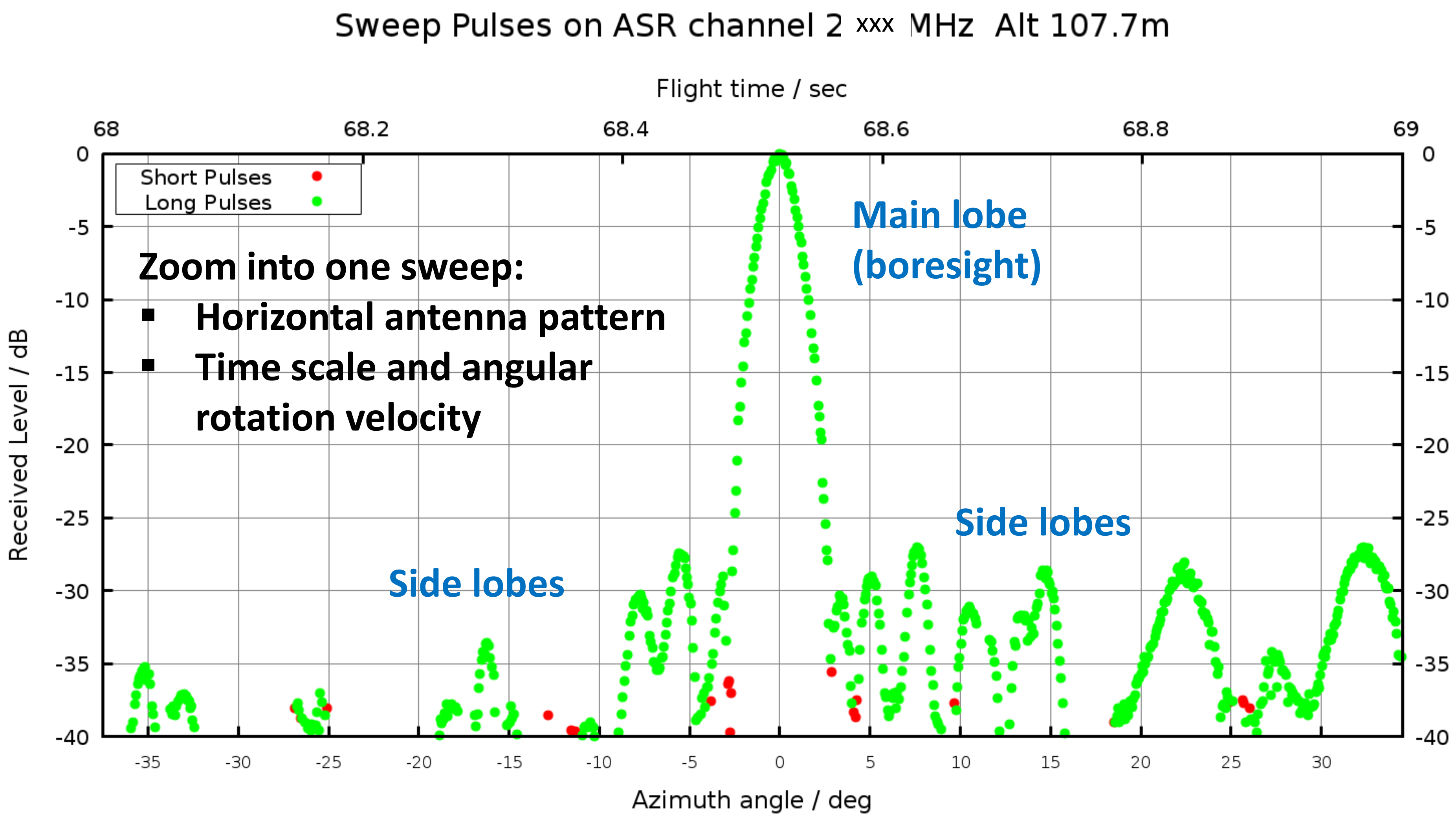
Vertical profile measurement at ASR site

all beam dwells across time; each point is one received pulse

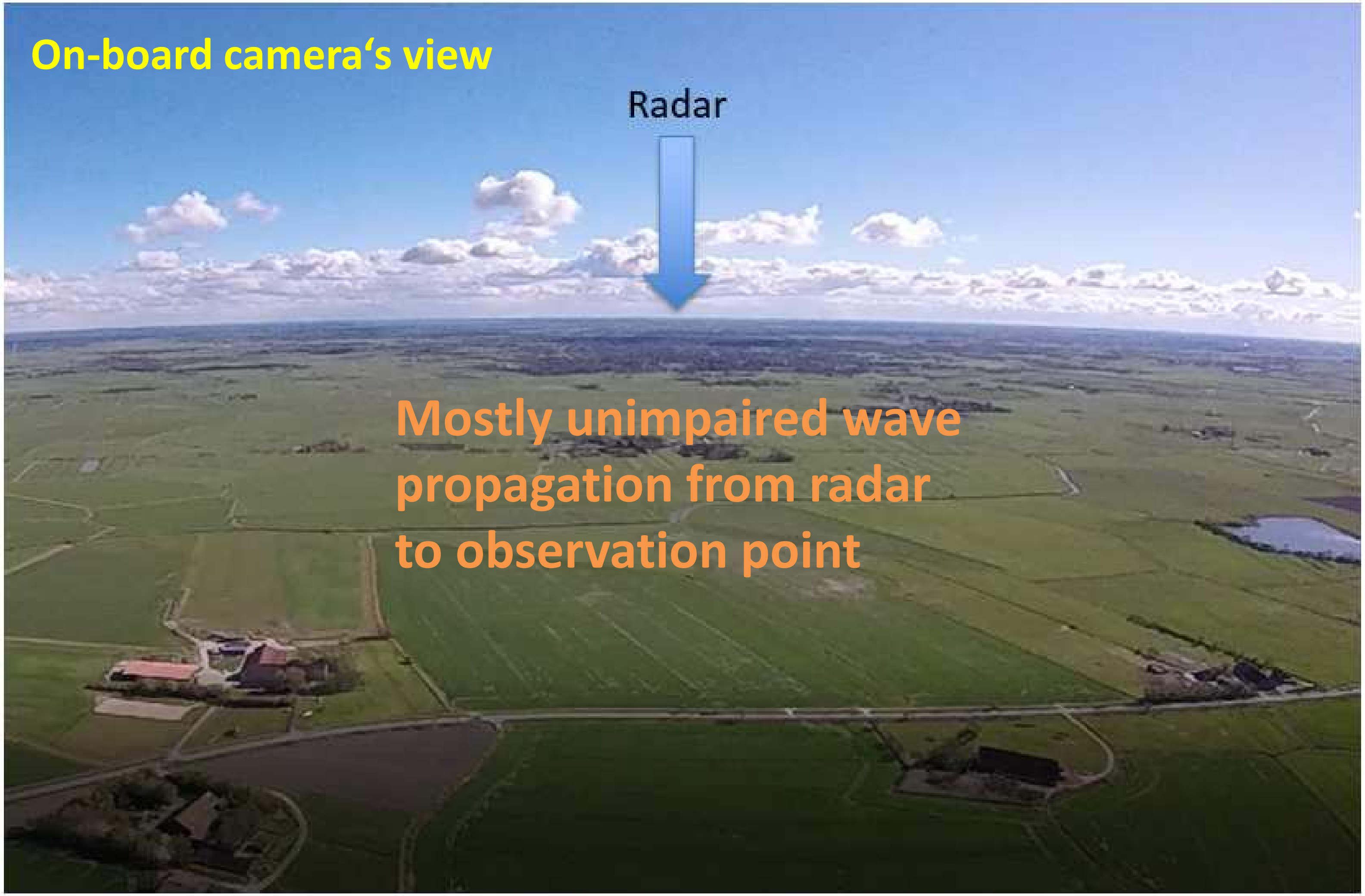


Vertical profile measurement at ASR site

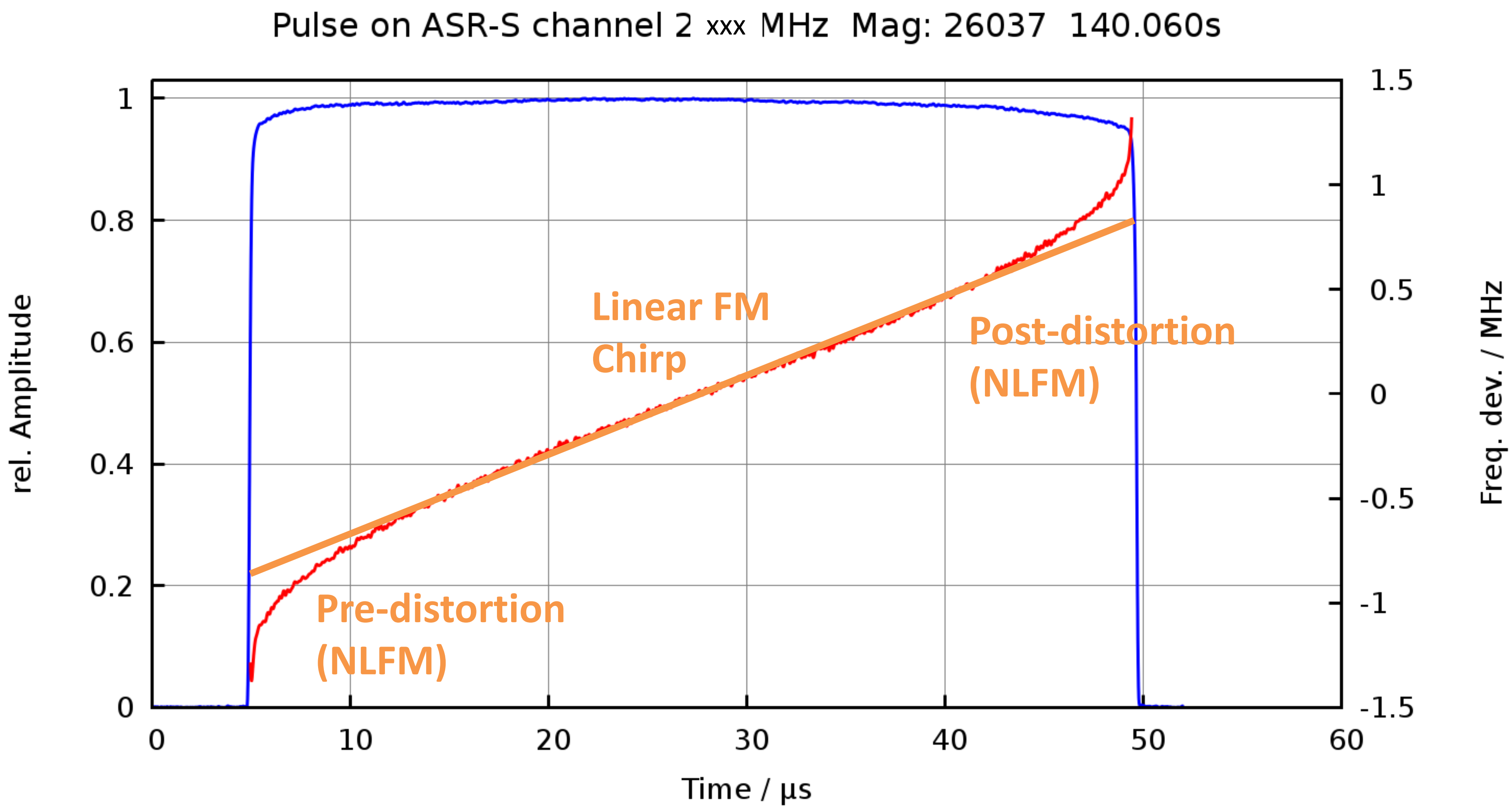
Zoom into single beam dwell



Capturing the radar‘s reference pulse pattern

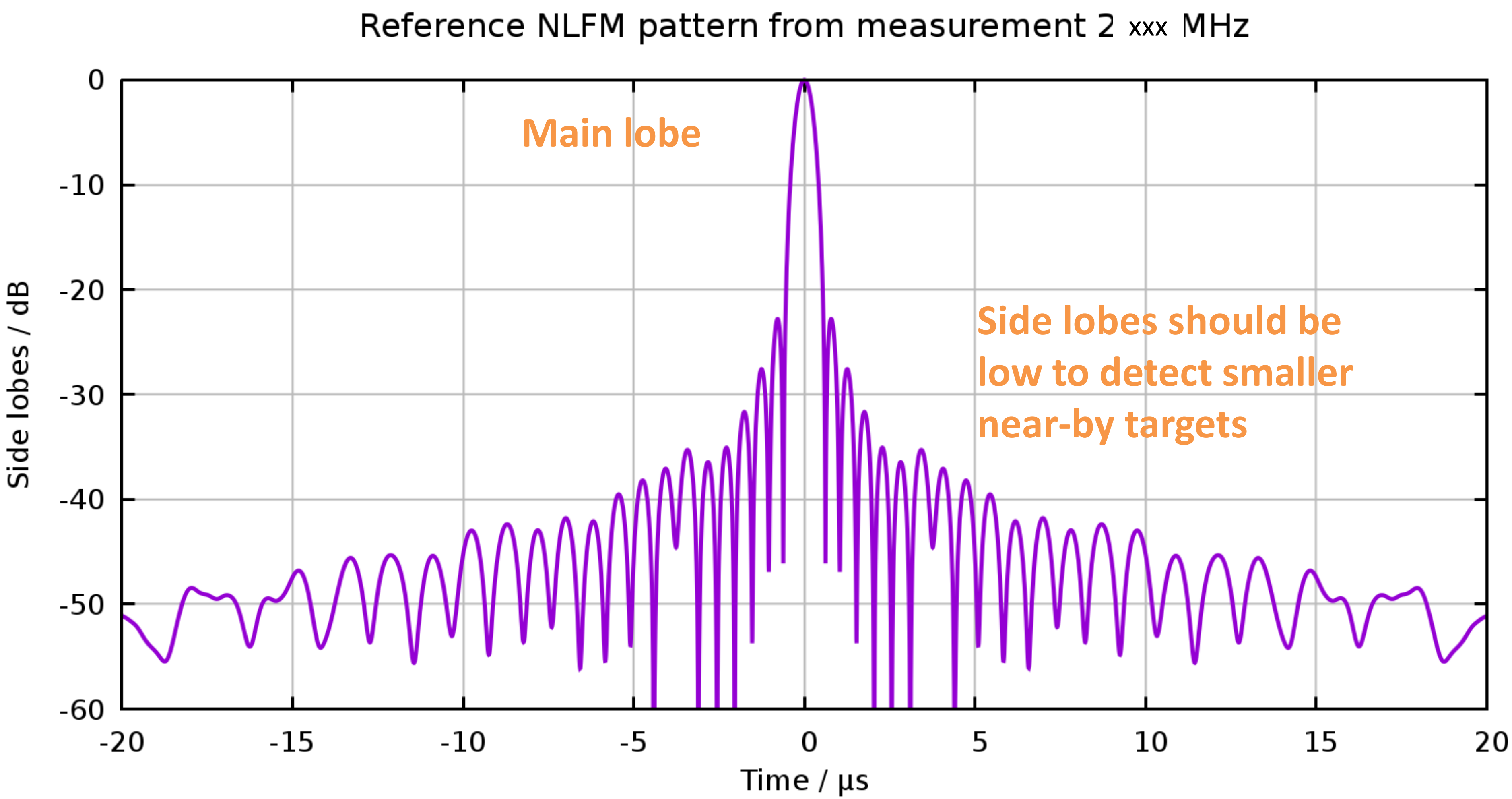


Capturing the radar‘s reference pulse pattern

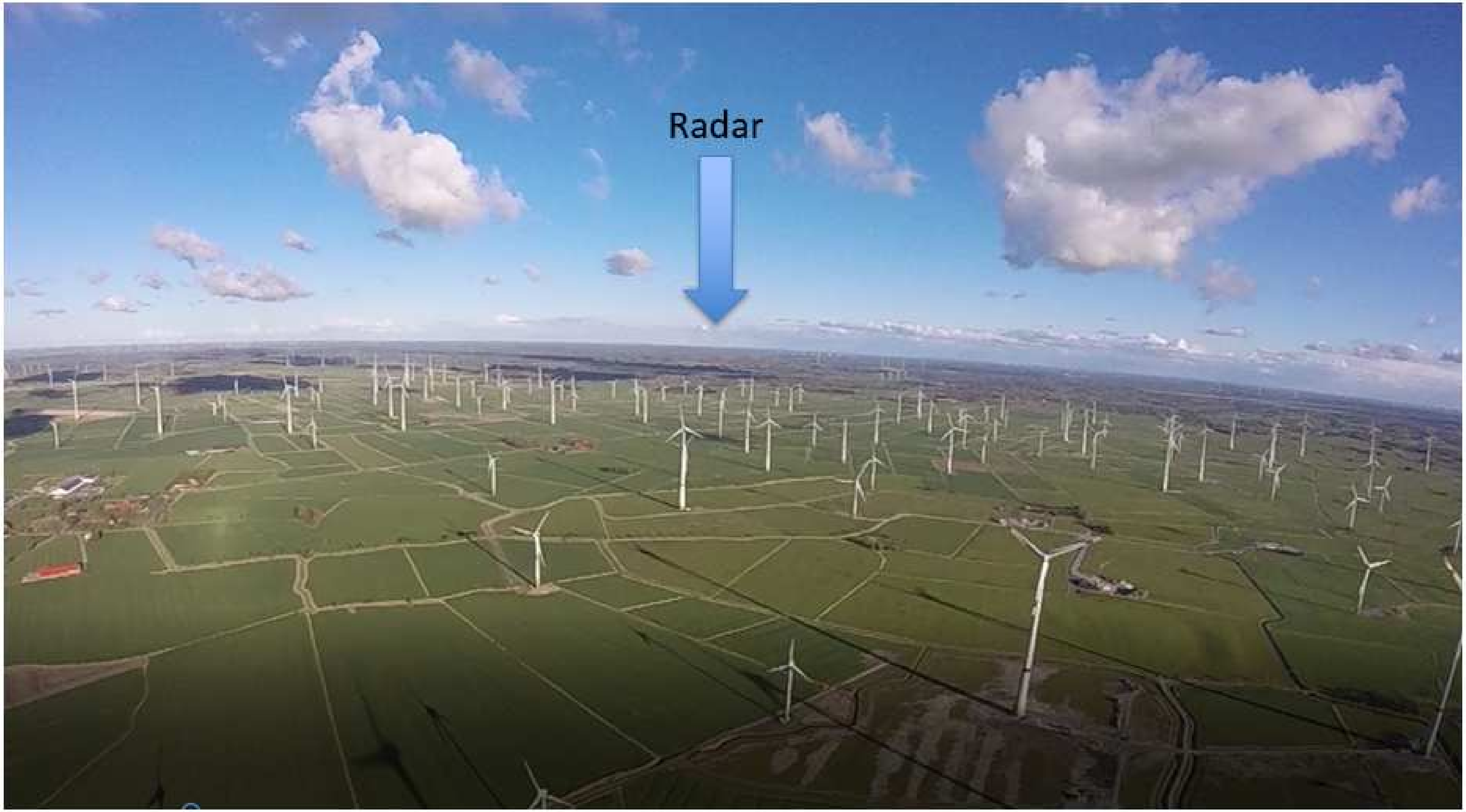


Capturing the radar's reference pulse pattern

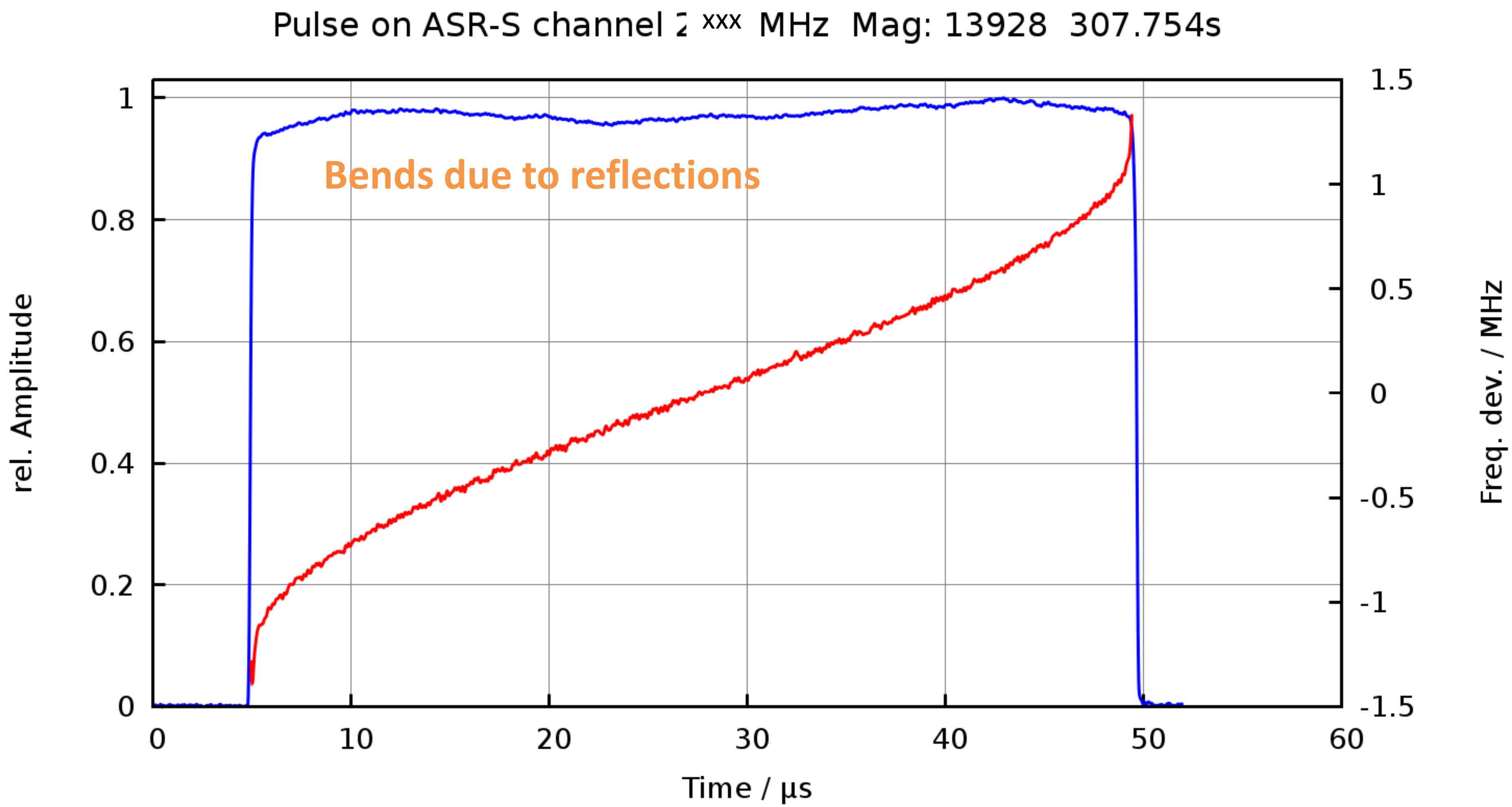
Autocorrelation of h(k): pulse compression → "matched filter"



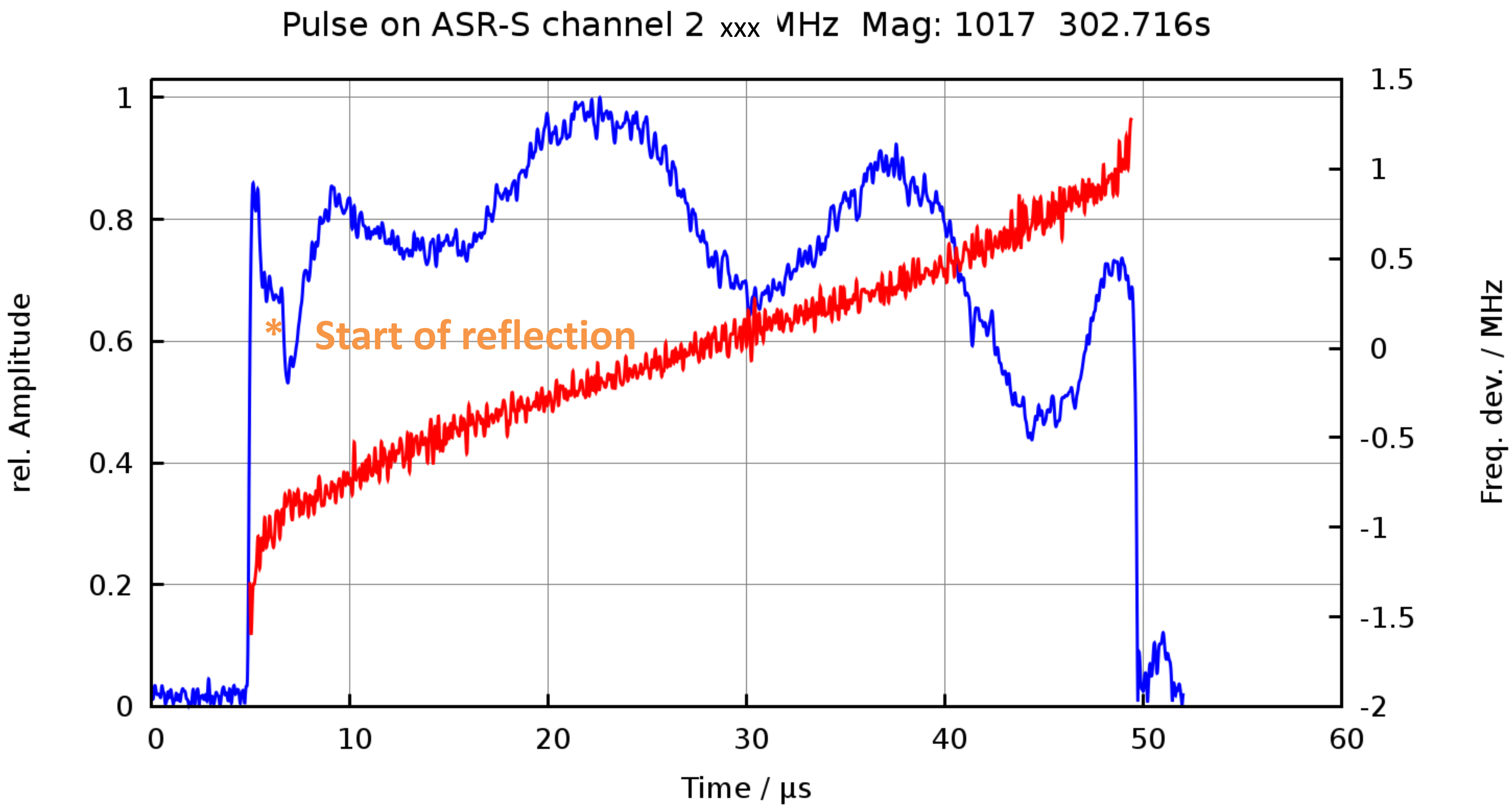
Measurements above wind farm



Pulse form affected by many WTs

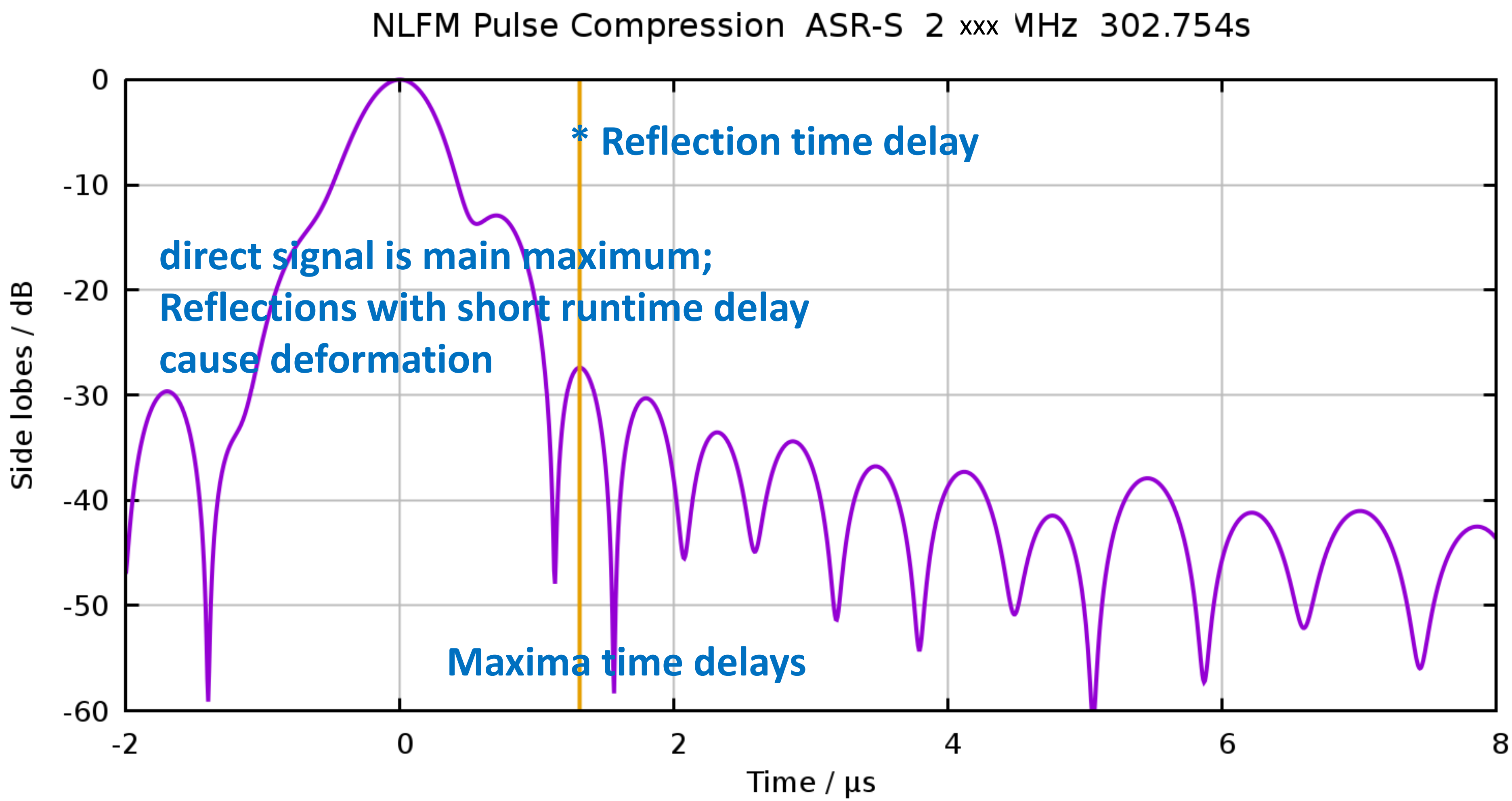


Pulse form affected by many WTs



Scattered signals from various WT (geometry)

Altitude: 108m MSL



Scattered signals from various WT (geometry)

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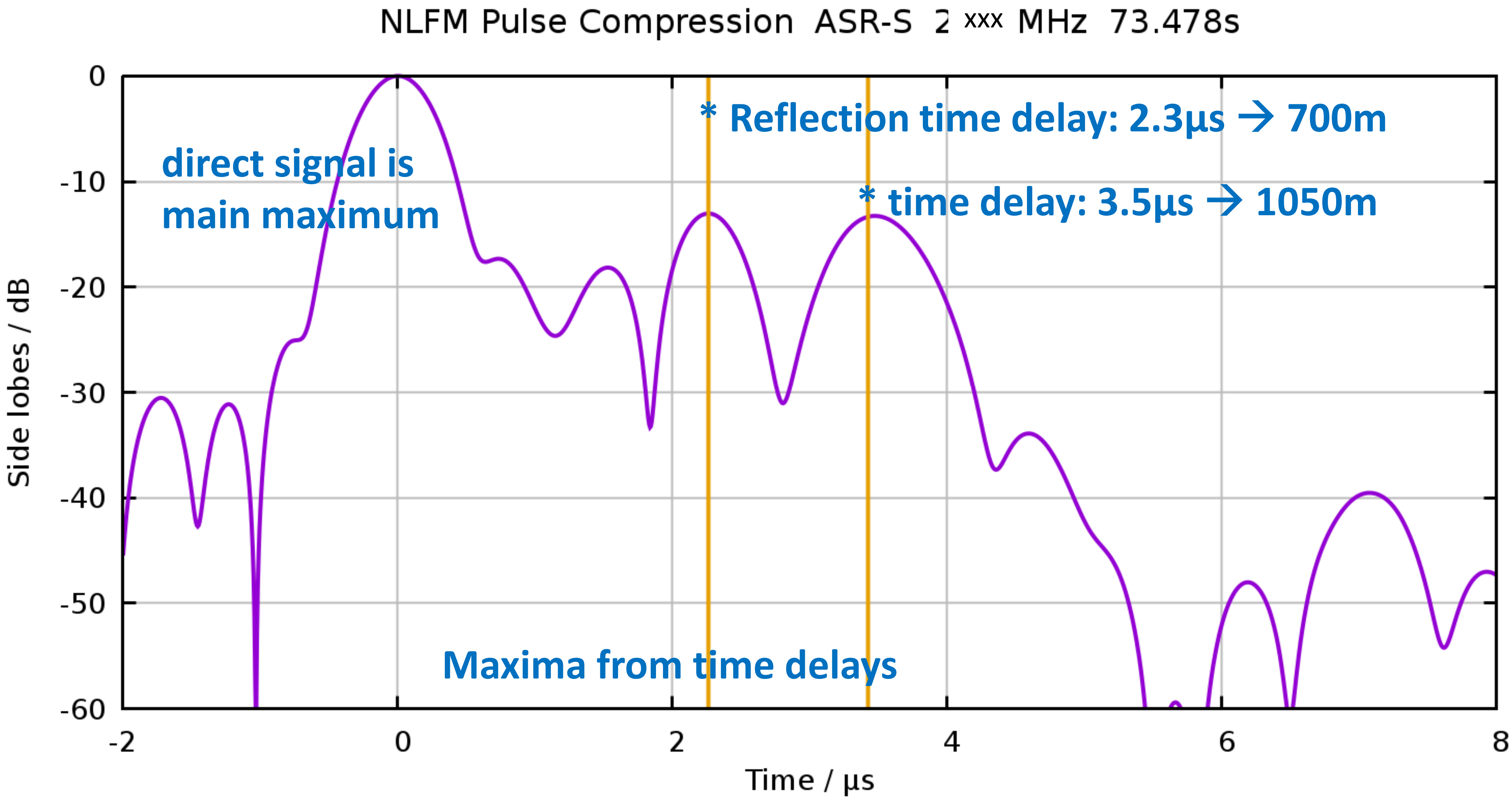
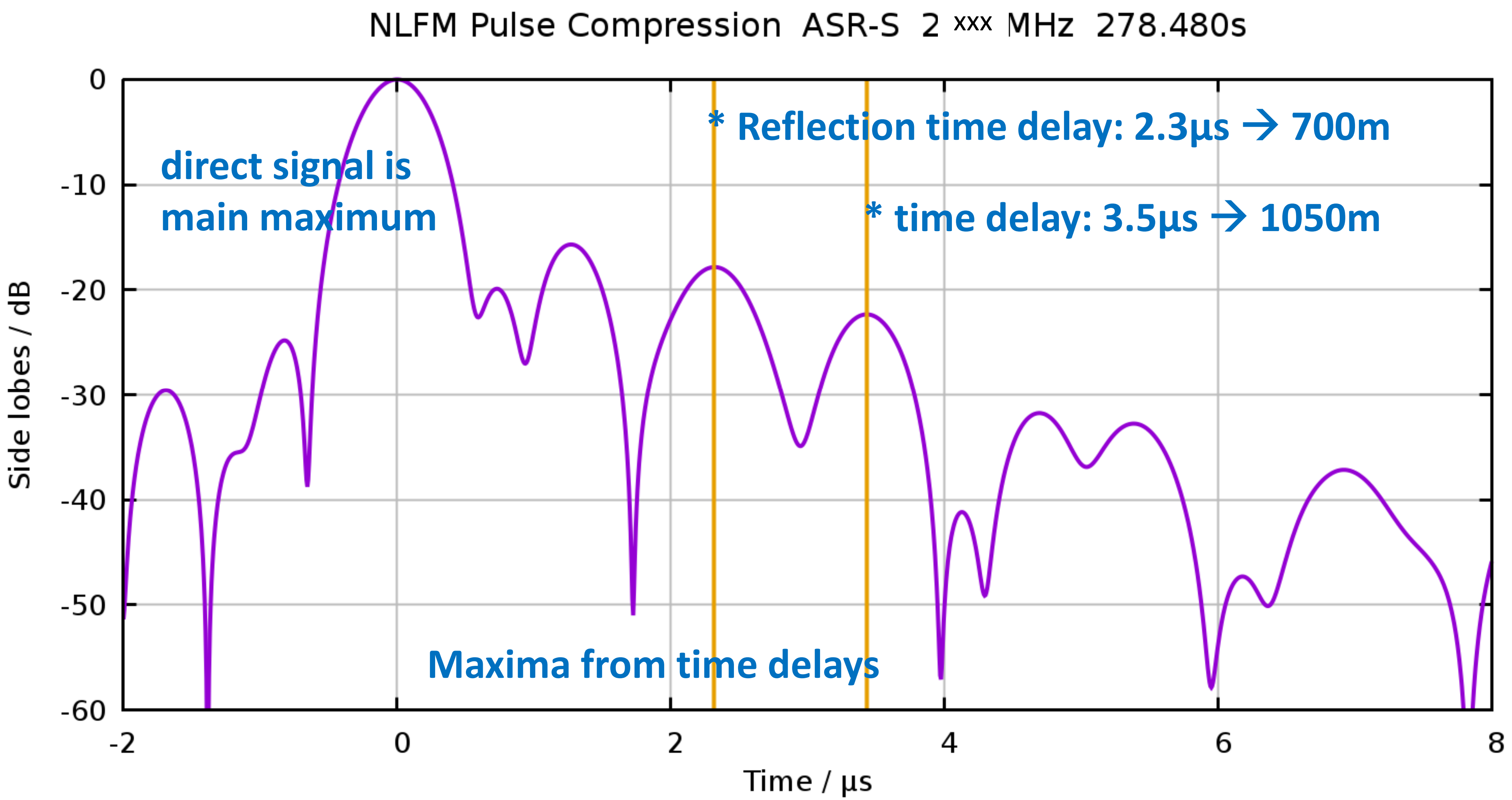


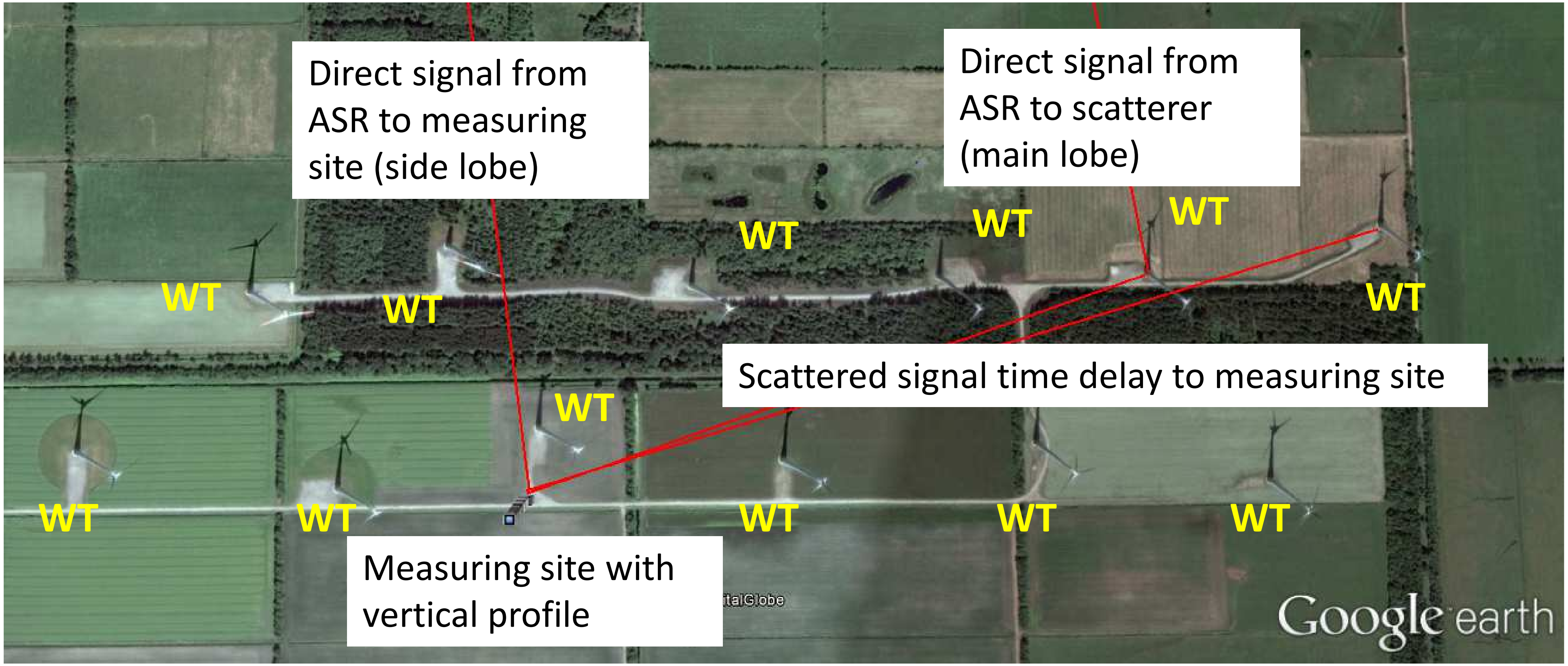
Scattered signals from various WT (geometry)

Altitude: 79m MSL

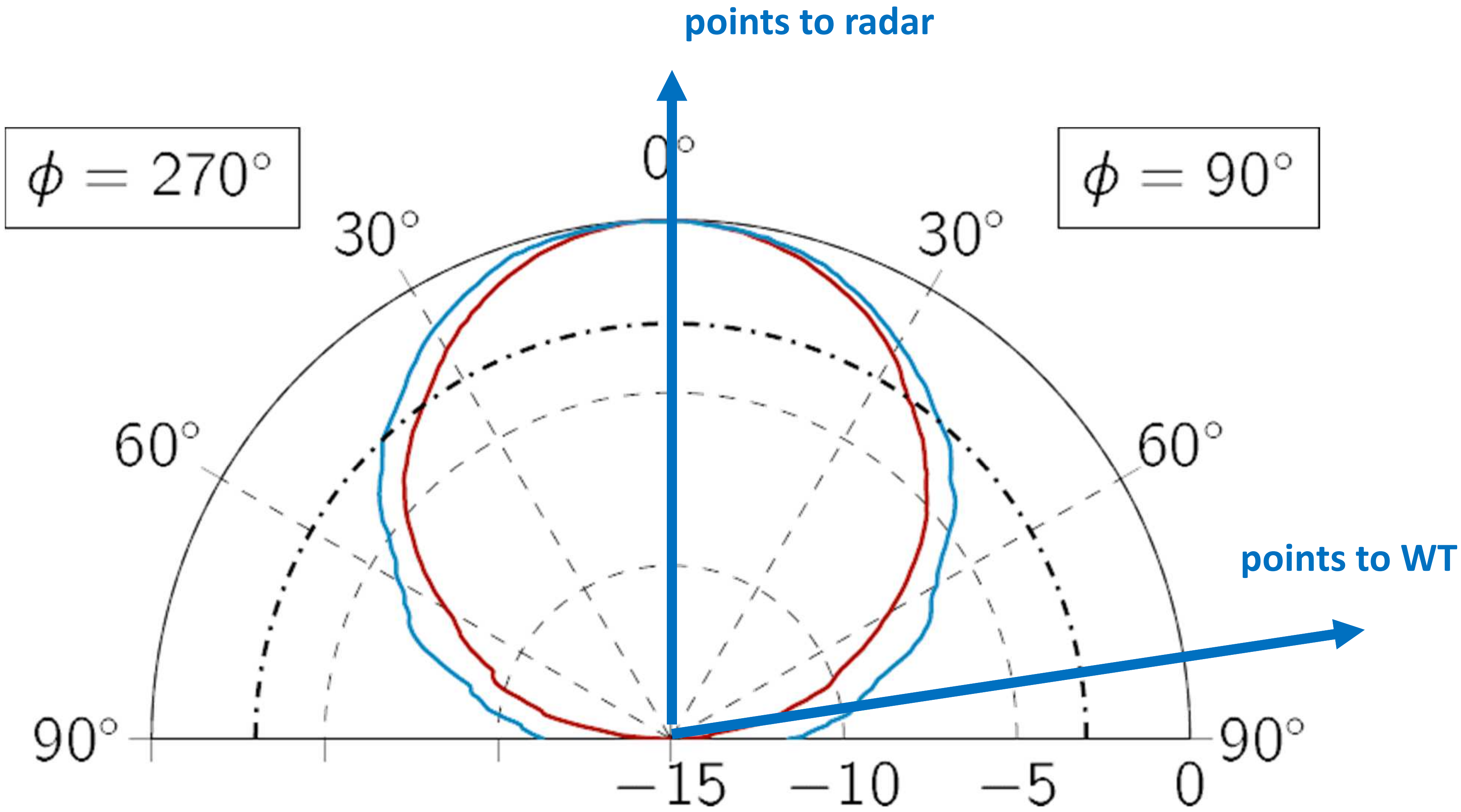


Scattered signals from various WT (geometry)

Wind turbines: Mast height 108m, rotor diameter 82m



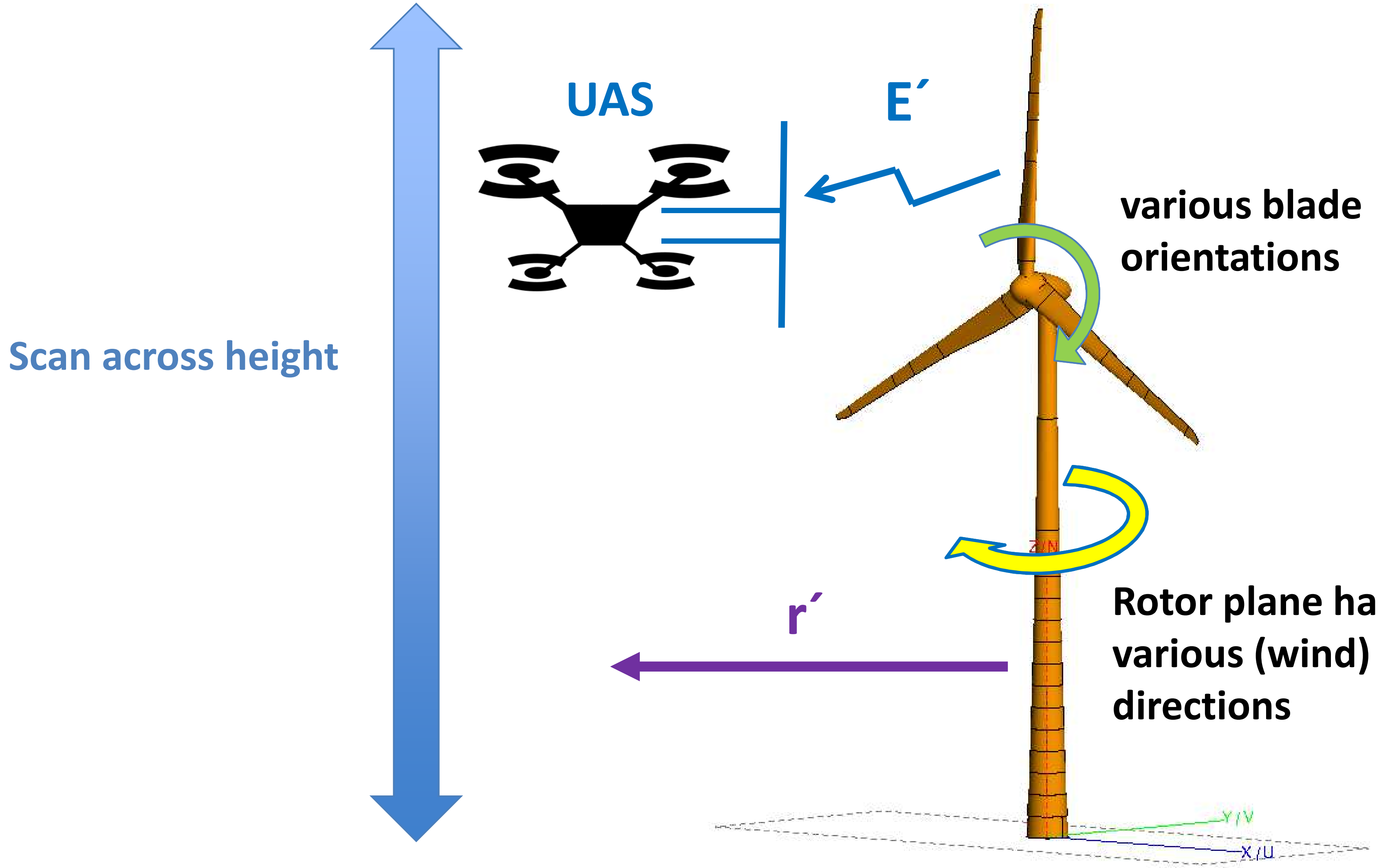
Horizontal patch antenna pattern installed on UAS



Dipole-like reception pattern, with mast (blue), without (red)

Simulation by PTB

Classification of WT reflections



Summary and conclusions (1)

- Pulse compression radar: Deformation of expanded pulses in the vicinity of WTs
- Reflections from many WTs will shift maximum of pulse compression in radar → uncertainty in TOA
- „Matched filter“ analysis of radar‘s transmitted direct pulse and reflection of scatterer (WT) allows for calculation of reflection properties
- Single WTs can be isolated with temporal separation of reflection maxima in pulse compression and corresponding runtime delays
- Radar beam dwell measurements at different heights show nearly homogenous distribution of field strength
- Classification of single WT scatterers for different radar types and frequencies at specific heights, directions

Summary and conclusions (2)

- Octocopter flights were performed at ASR-S and Air Defense Radar (ADR) sites
- Data base of degraded radar pulses available for further analysis
- Data base of WT reflection properties at different S-band frequencies can be derived from these measurements
- The radar manufacturer must take part in further action to evaluate the concrete performance degradation
- There is no simple transformation from electromagnetic field simulations to
  - Range uncertainty
  - angular deviation
  - Probability of detection and losing track of targets