PALINDROME
REMOTE SENSING

Testing the influcence of wind turbines on weather radars by generating virtual Doppler-RCS signatures

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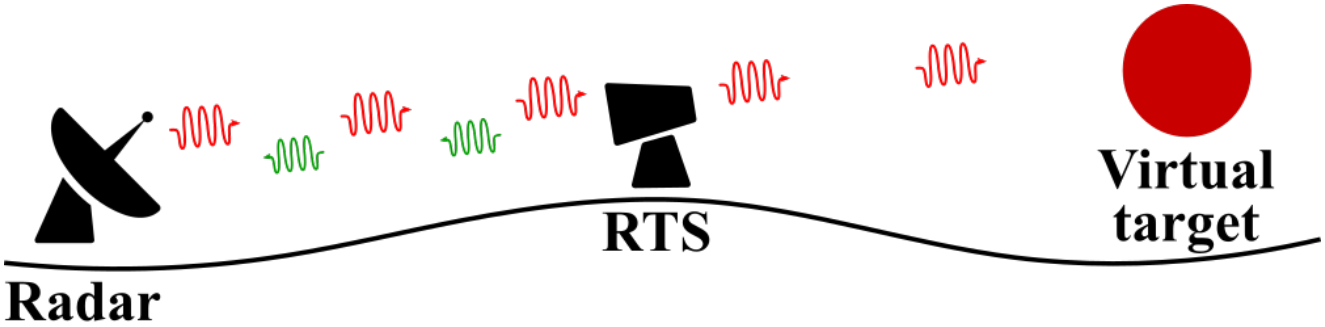
Target Generation

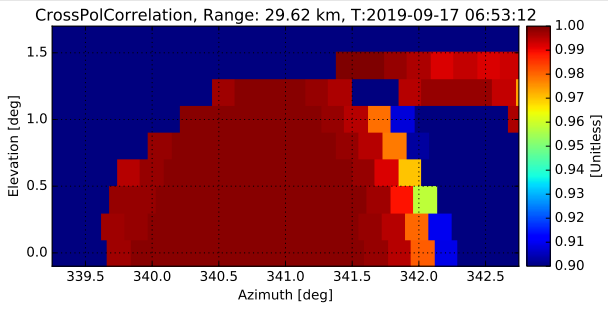


- Generates a calibrated, virtual radar target
- Receives incoming radar pulses
- Every individual pulse is sampled and stored
- Pulses are sent back with predefined amplitude, Doppler shift and time delay
- Full polarimetric (i.e., full phase control on receive and transmit)

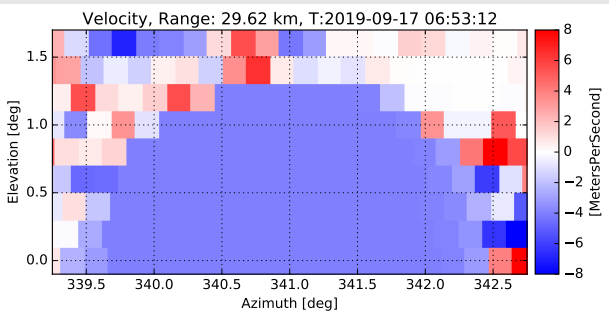
Vienna, 2020

Virtual calibration targets

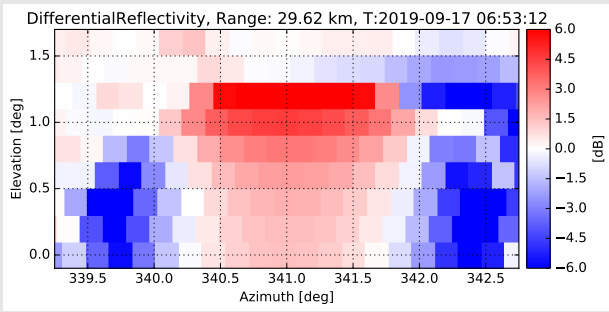
Co-Polar Correlation



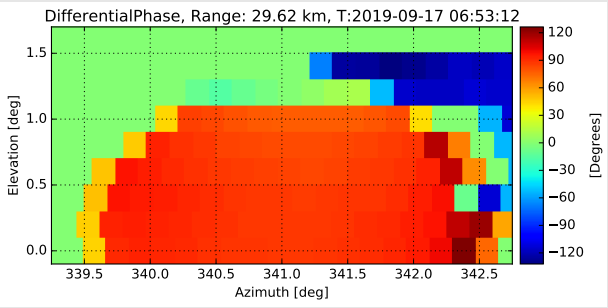
Velocity



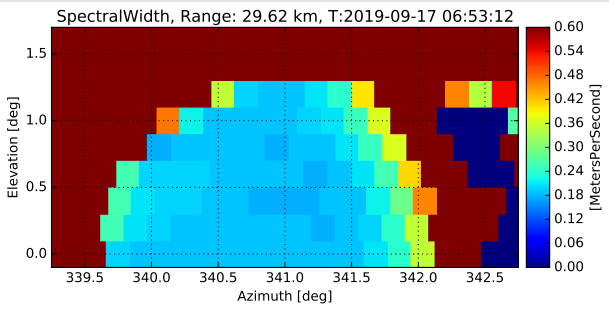
Diff. Reflectivity



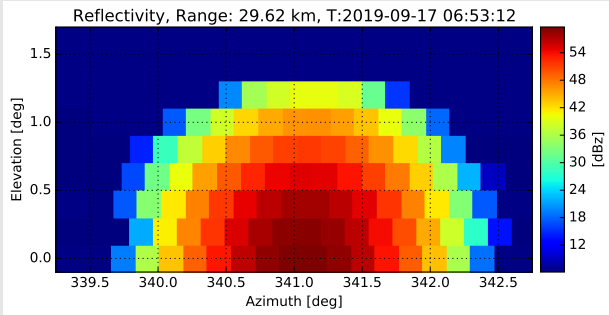
Differential Phase



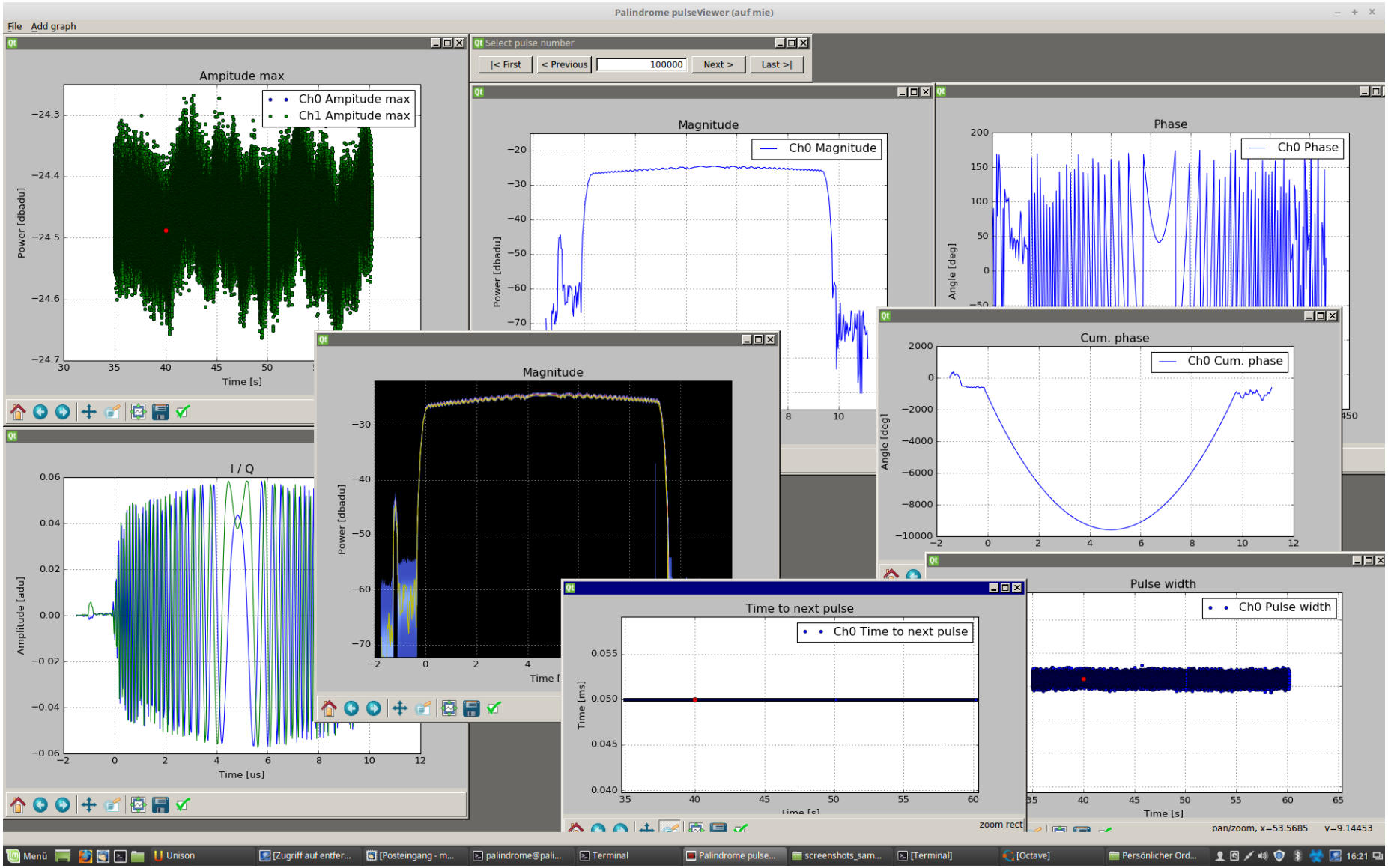
Spectral Width



Reflectivity

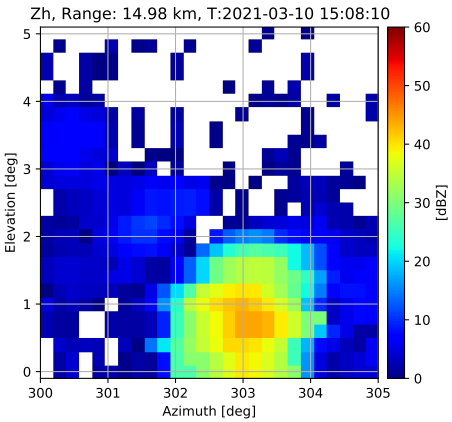


TX Path: Pulse Shape and Phase

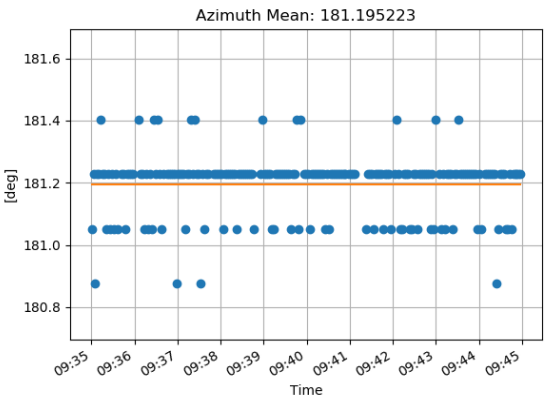


Measurement examples

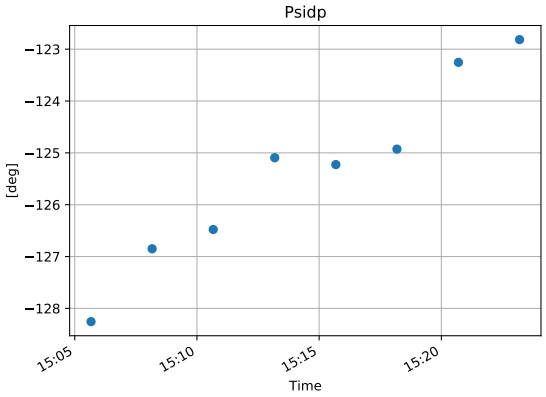
Z_h



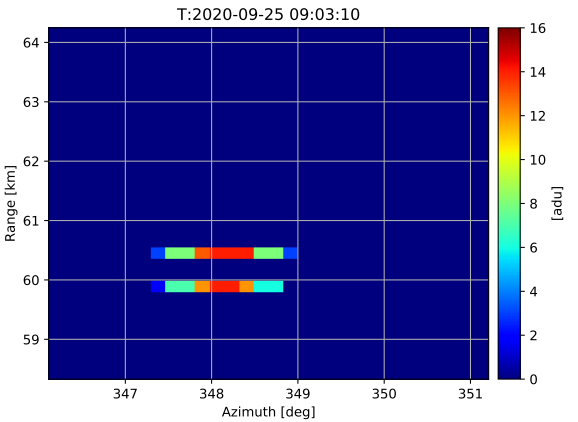
Pointing



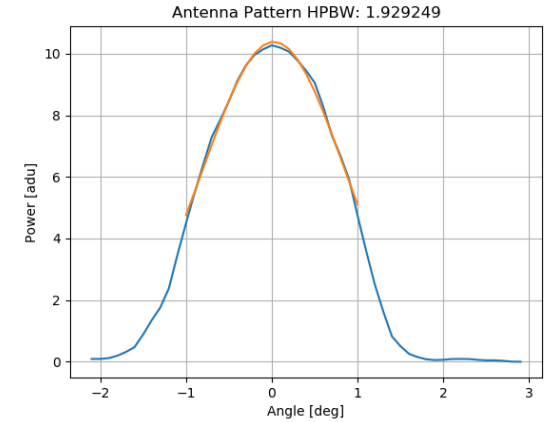
Diff. Phase



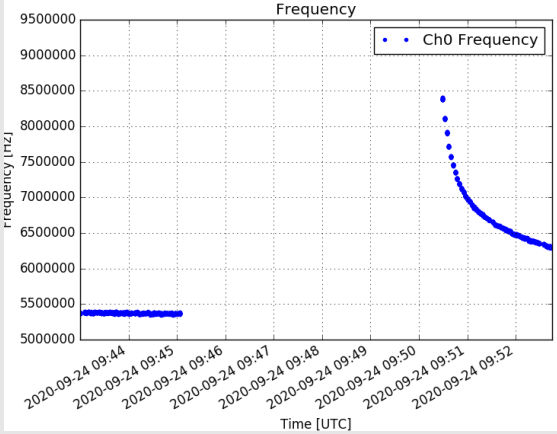
Range



HPBW

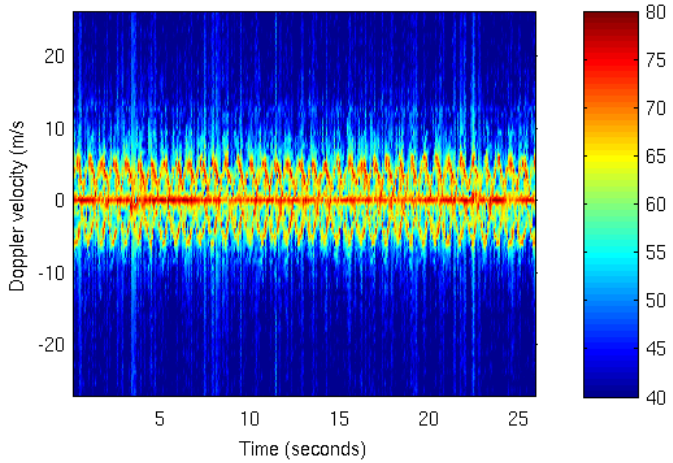


Frequency

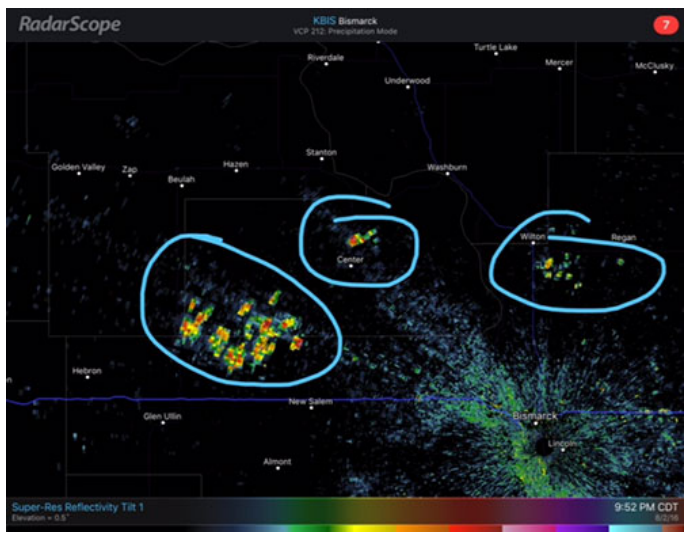


Wind turbine influence on weather radar

- Wind turbines are strong scatterers.
- Doppler broadending, range broadening.
- Doppler velocities from 0 to 60 m/s.
- Set-up locations in the area of interest of weather radars.
- Influence on radars is difficult to predict.
- 23% of wind turbine projects are rejected because of the concerns of radar operators. → This number increases with the number of already installed wind turbines.



Time vs. Doppler



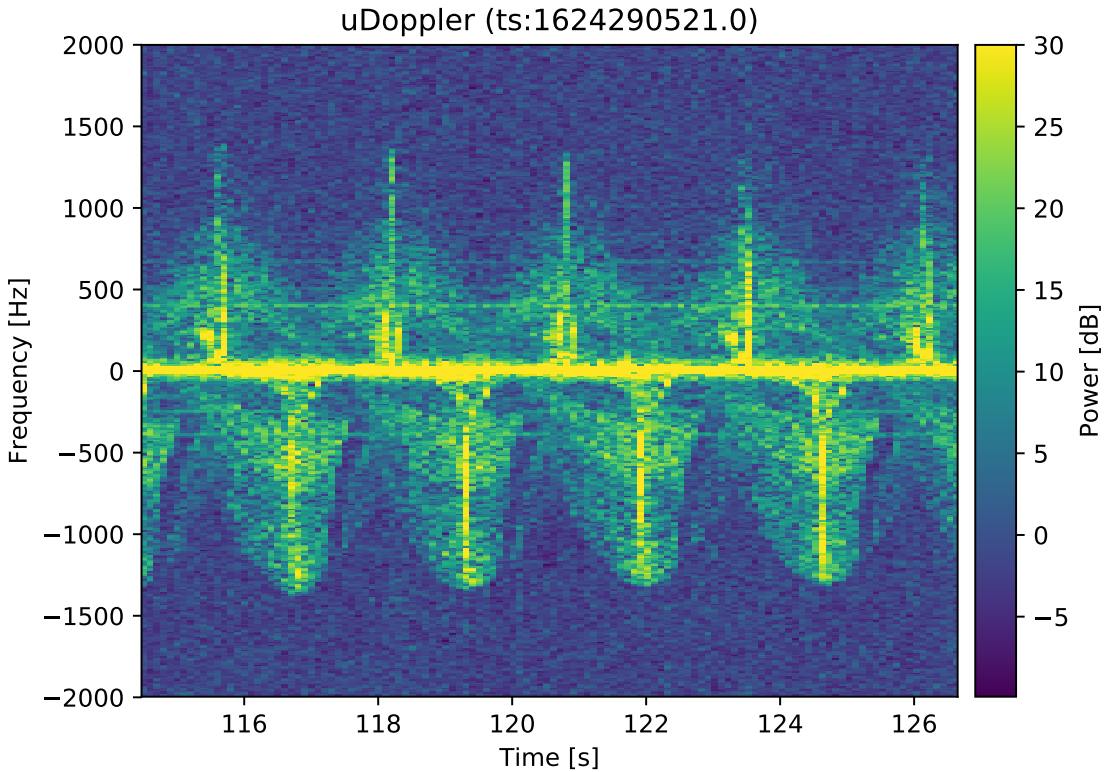
Wind turbine disturbance

Radar Measurements of a Wind Turbine

- Largest wind turbine in Switzerland
- Multistatic C-band radar
- Transmitter: phased array transmitter, chirped pulses, 100 W
- Receiver: digital beamforming, vertical polarization

Measurement Results

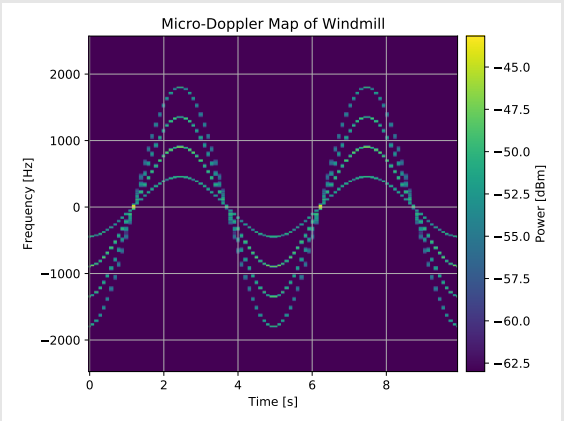
- Maximum Doppler: 1500 Hz $\rightarrow$ 41 m/s
- Shading of the mast
- Blade flashes
- Strong influence of blade pitch angle



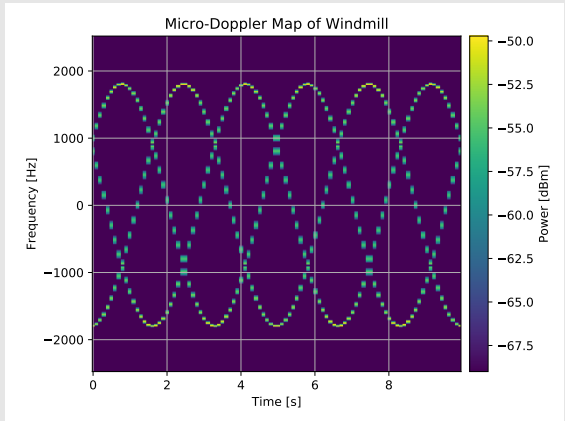
Wind turbine Doppler-RCS signature

Simplified Model

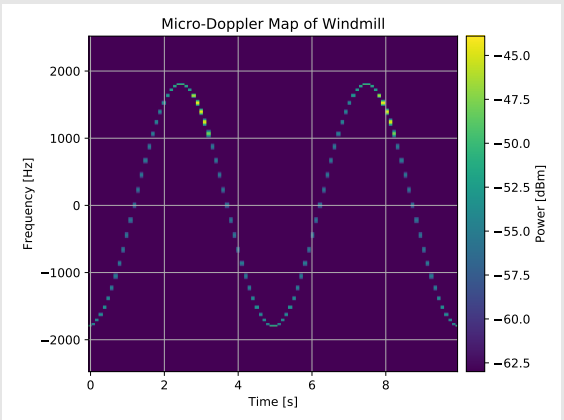
Single blade, multiple radii



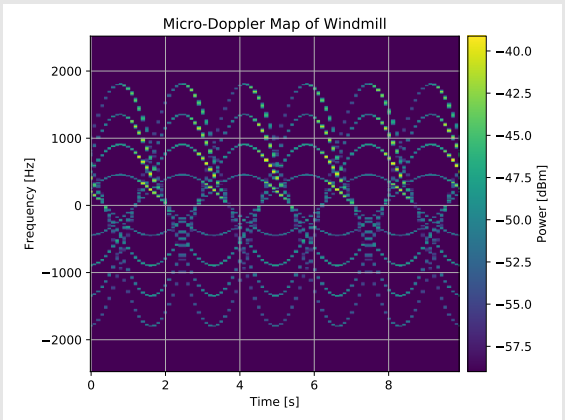
Three blades, one radius



Blade flash, one radius



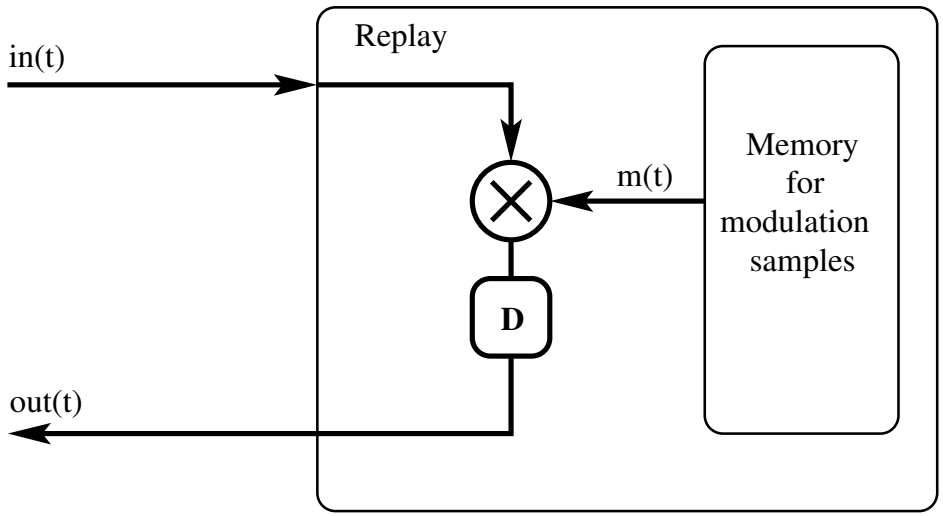
Combination



- Turbine blade implementation: aligned point scatterers
- Parameters: number of blades, number of scatterers, rotation speed, observation angle
- coherent processing interval: 0.1 s $\rightarrow$ discrete measurement points

Model Implementation

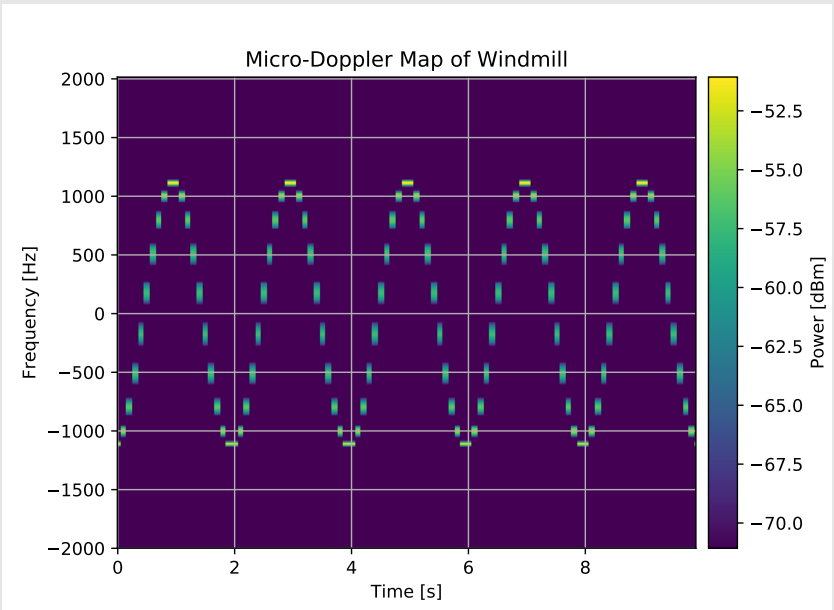
- Doppler-RCS time series simulation $\rightarrow$ stored in the target simulator.
- Target simulator: receives radar pulses.
- Incoming I-Q samples: $\rightarrow$ complex multiplication with pre-stored modulation samples.
- Delay simulation: Modulated samples are buffered and released.
- Upconversion and Transmission.



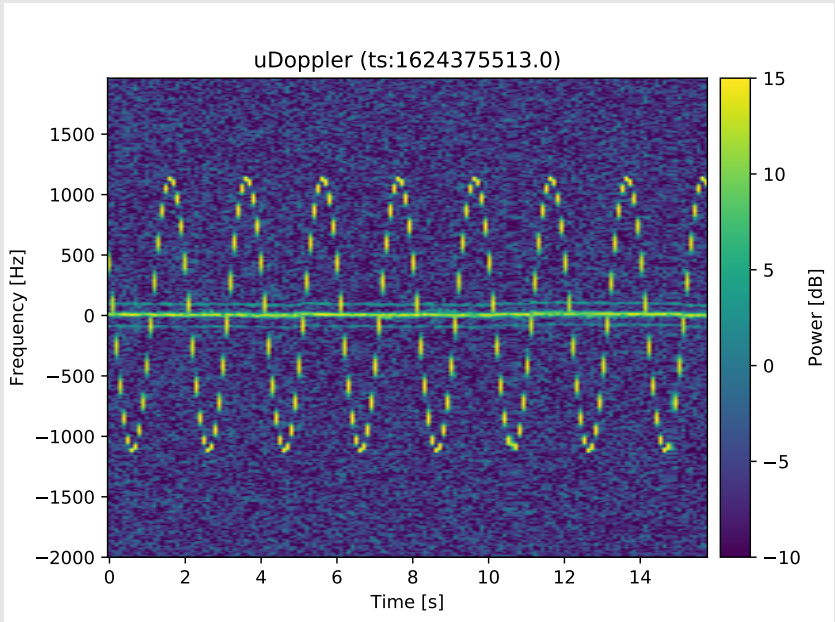
Signal processing for Doppler-RCS modulation

Target Simulator Measurements

Model



Measurements



- Simplified Doppler-RCS pattern.
- The modulation samples can be exactly replayed.
- The radar sees what the model predicts.
- Zero-Doppler (clutter) contamination is missing in the model.

Conclusion

- Wind turbines disturb radars.
- Influence assessment is difficult.
- Virtual wind turbines can be generated with a target simulator.
- Adapt the virtual wind turbine (siting, height) to minimize its influence on radars.
- Optimize the radar's filters to suppress the influence of the wind turbine before construction begins.

Outlook

- More realistic RCS-Doppler patterns.
- 'Record and Play' function.
- Wind park simulation.
- Tests with meteo and ATC radars.
- Facilitate the measurement set-up: $\rightarrow$ Drone-mounted target simulator.

Tetherd drone carrying a target simulator