

Comparing predicted and measured time-variant DVOR bearing errors in presence of wind turbines

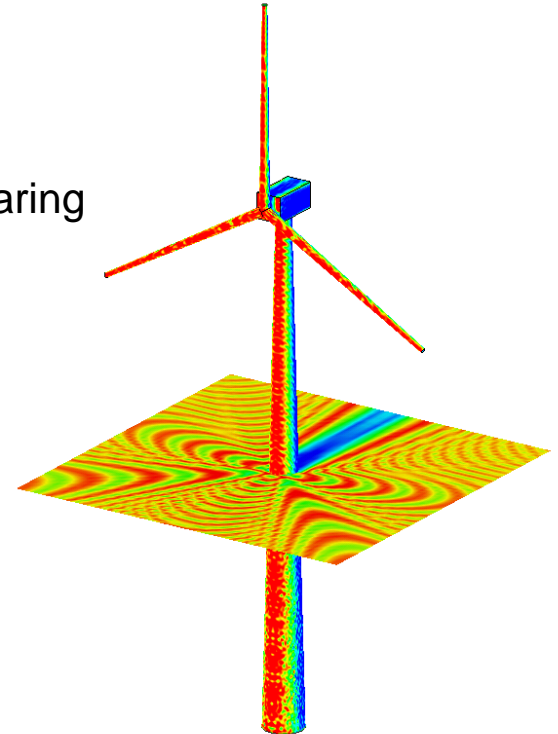


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www.geml.uni-hannover.de

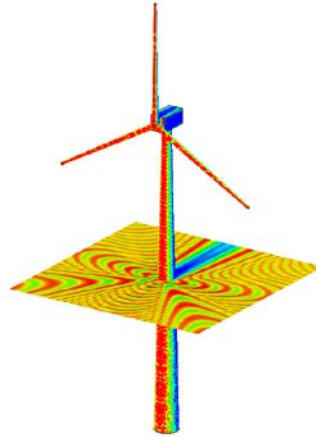
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- Brief introduction in a novel prediction method for DVOR bearing
- Validation example 1
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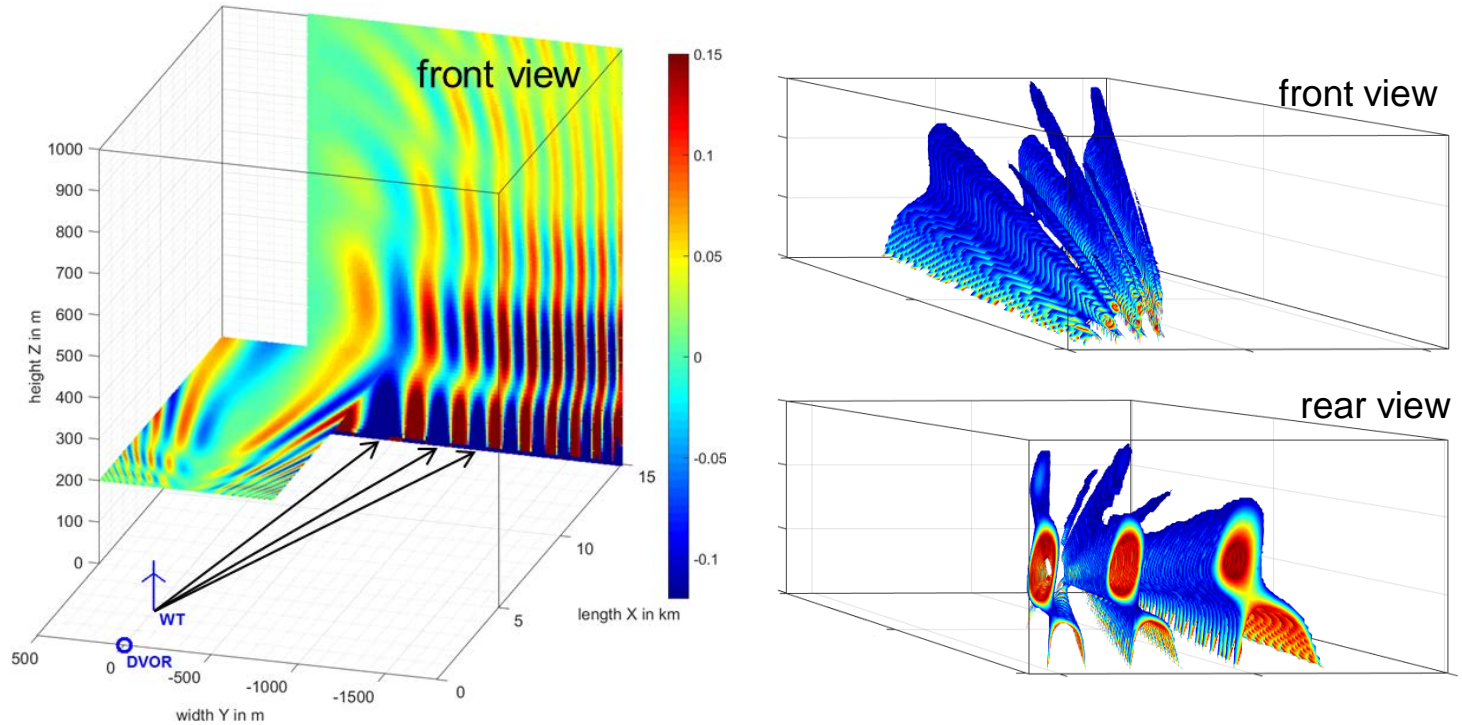
Motivation

- high promotion of renewable energy sources
 - large increase of wind turbine quantity



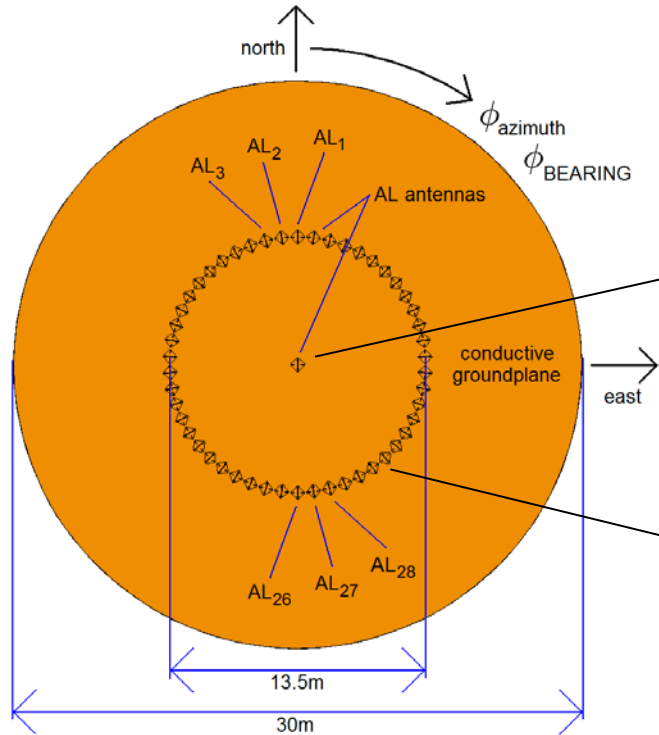
- large surfaces of wind turbines reflecting EM waves
 - operational problems with radio navigation aids like DVOR
 - **disturbance prediction required!**

Disturbance Prediction

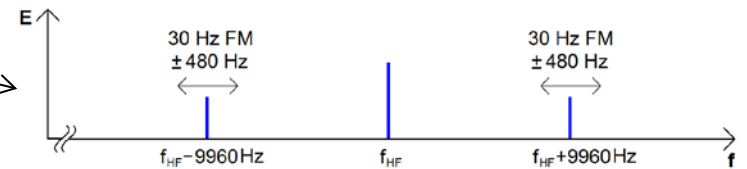
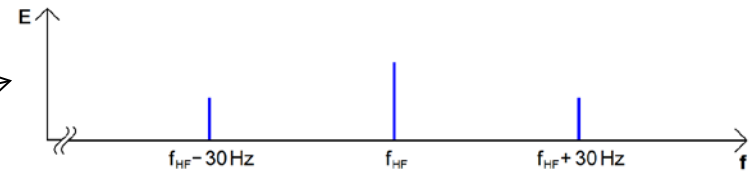


S. Sandmann and H. Garbe: **3D Visualization of Numerically Calculated Bearing Error Texture in Disturbed DVOR Scenarios**
 2019 International Symposium on Electromagnetic Compatibility - EMC EUROPE, Barcelona, Spain, 2019, pp. 294-298. doi: 10.1109/EMCEurope.2019.8872063

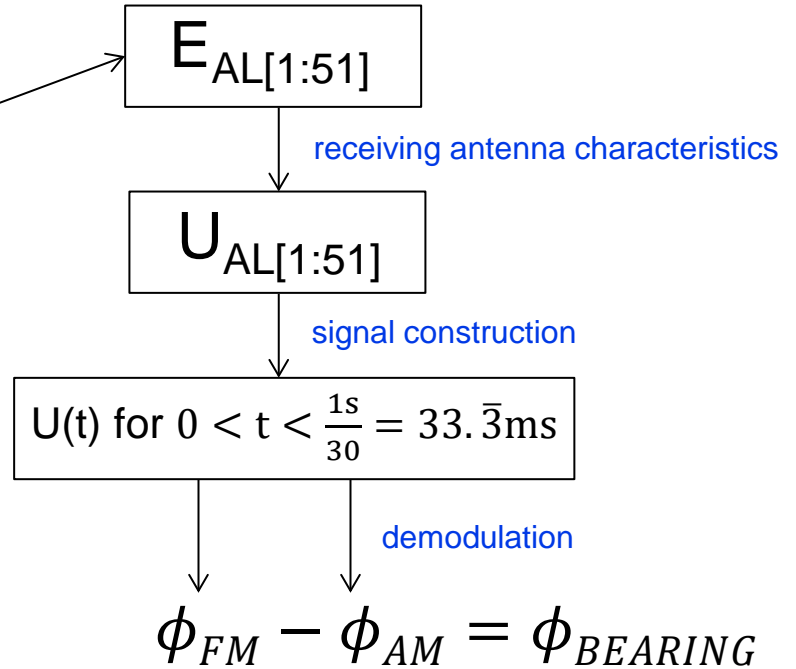
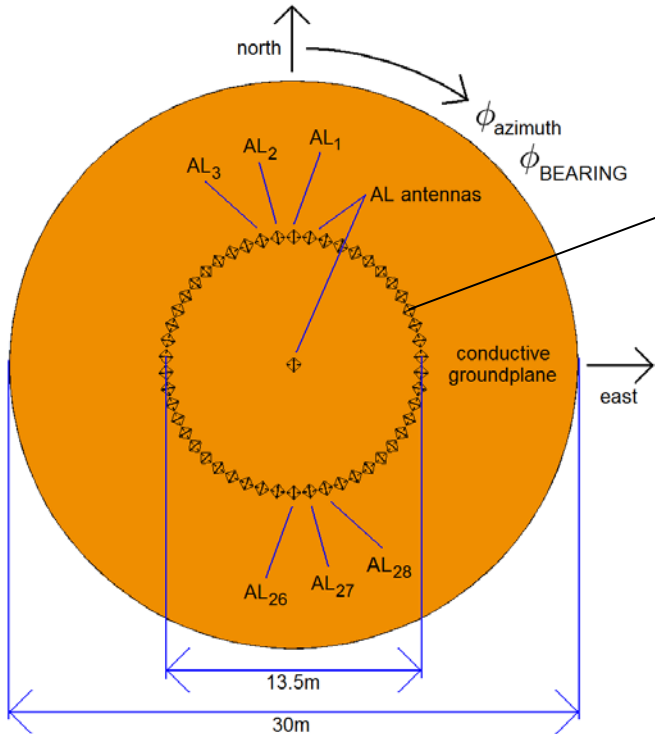
DVOR



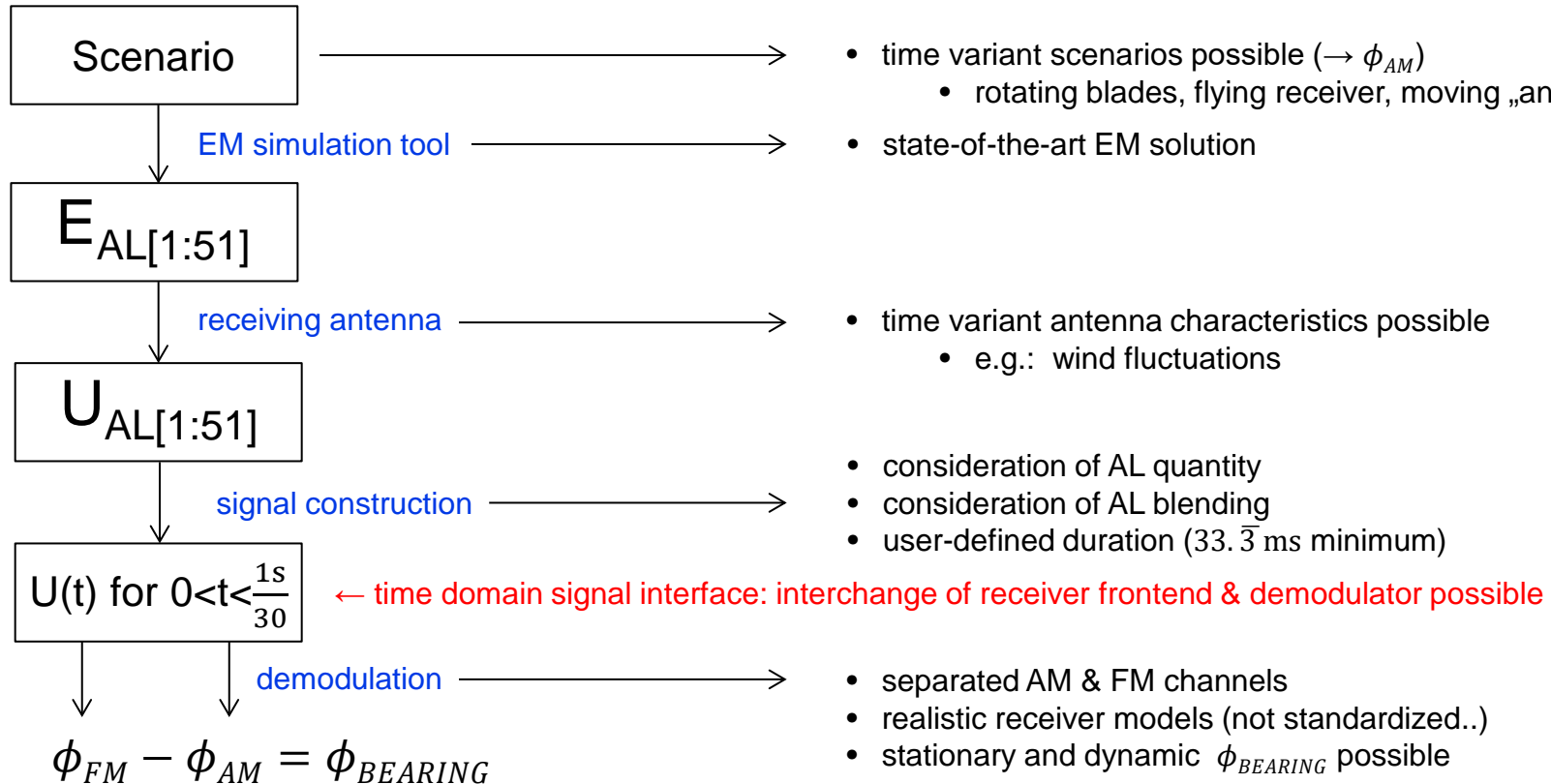
$$\phi_{BEARING} = \phi_{FM} - \phi_{AM}$$



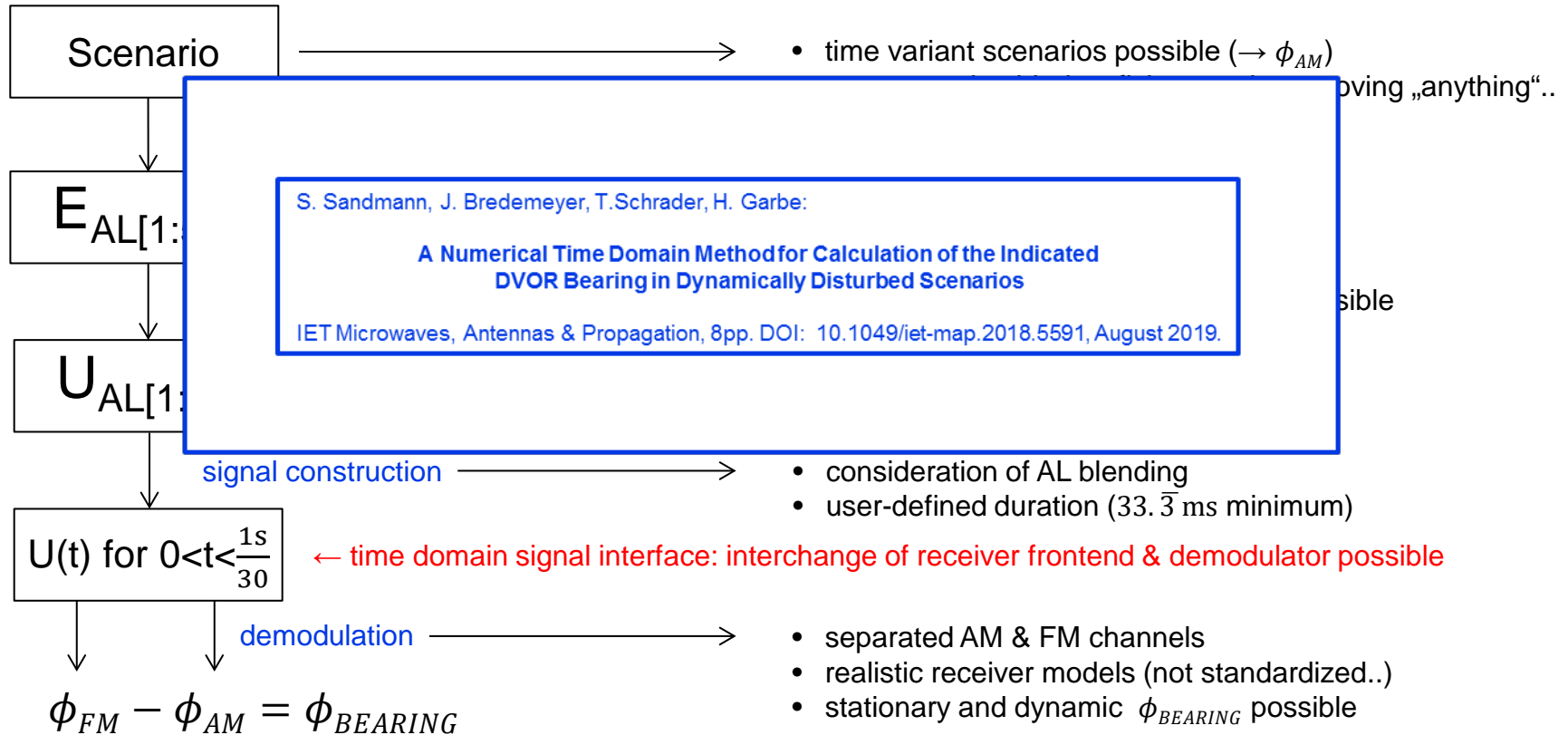
Time Domain Method



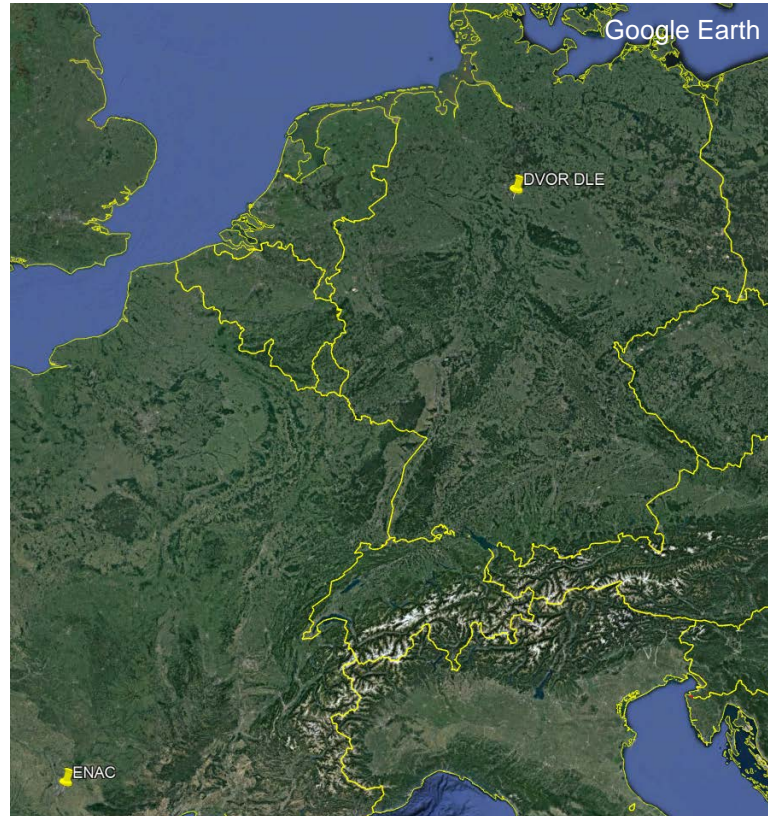
Time Domain Method: Benefits



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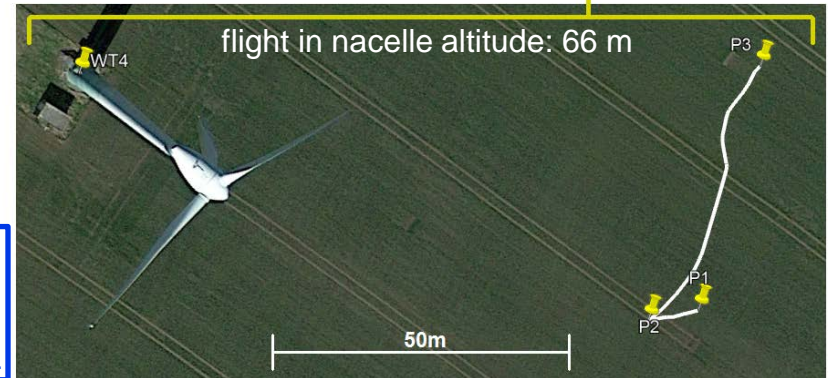


Validation Example 1: DVOR DLE



Validation Example 1: DVOR DLE

National Metrology Institute (PTB), 38116 Braunschweig, Germany.



S. Sandmann, J. Bredemeyer, T. Schrader, H. Garbe:

**A Numerical Time Domain Method for Calculation of the Indicated
DVOR Bearing in Dynamically Disturbed Scenarios**

IET Microwaves, Antennas & Propagation, 8pp. DOI: 10.1049/iet-map.2018.5591, August 2019.

Validation Example 1: DVOR DLE

- dynamic scenario → consideration of:
 - aligning of wind turbines with wind direction
 - real trajectory of octocopter
 - antenna characteristics of octocopter with fluctuations due to wind
 - rotating blades (117 m/s) → scenario increment $\Delta t = 2$ ms

➤ accurate measurement documentation required!

- simulated time span: 36 s → 18001 individual scenarios
- dynamical AM & FM phases calculated
- 90 days x 30 boards x (12 cores & 46 GB RAM)

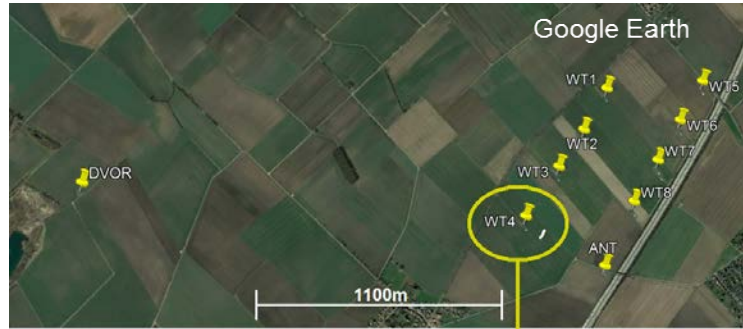
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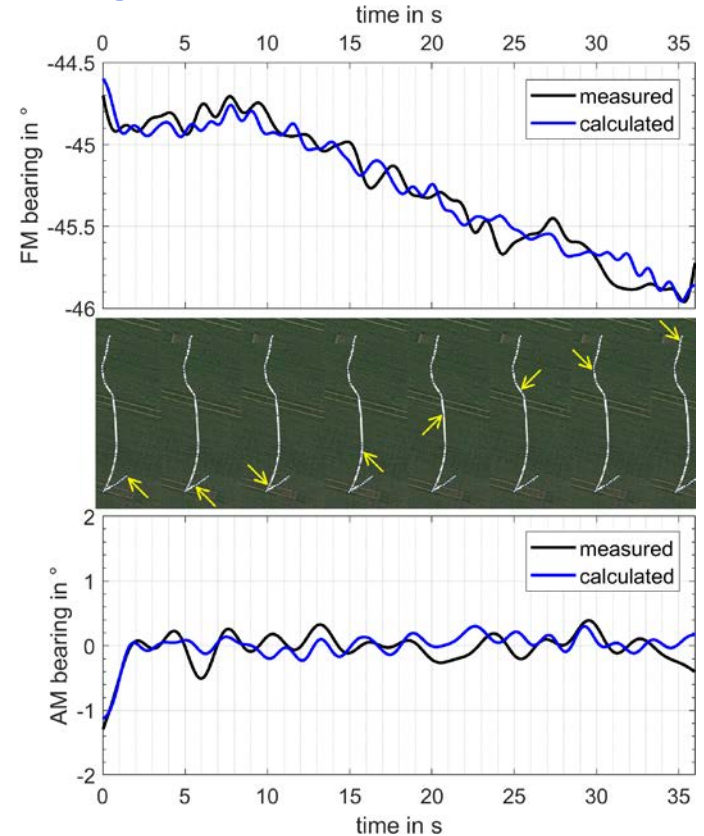
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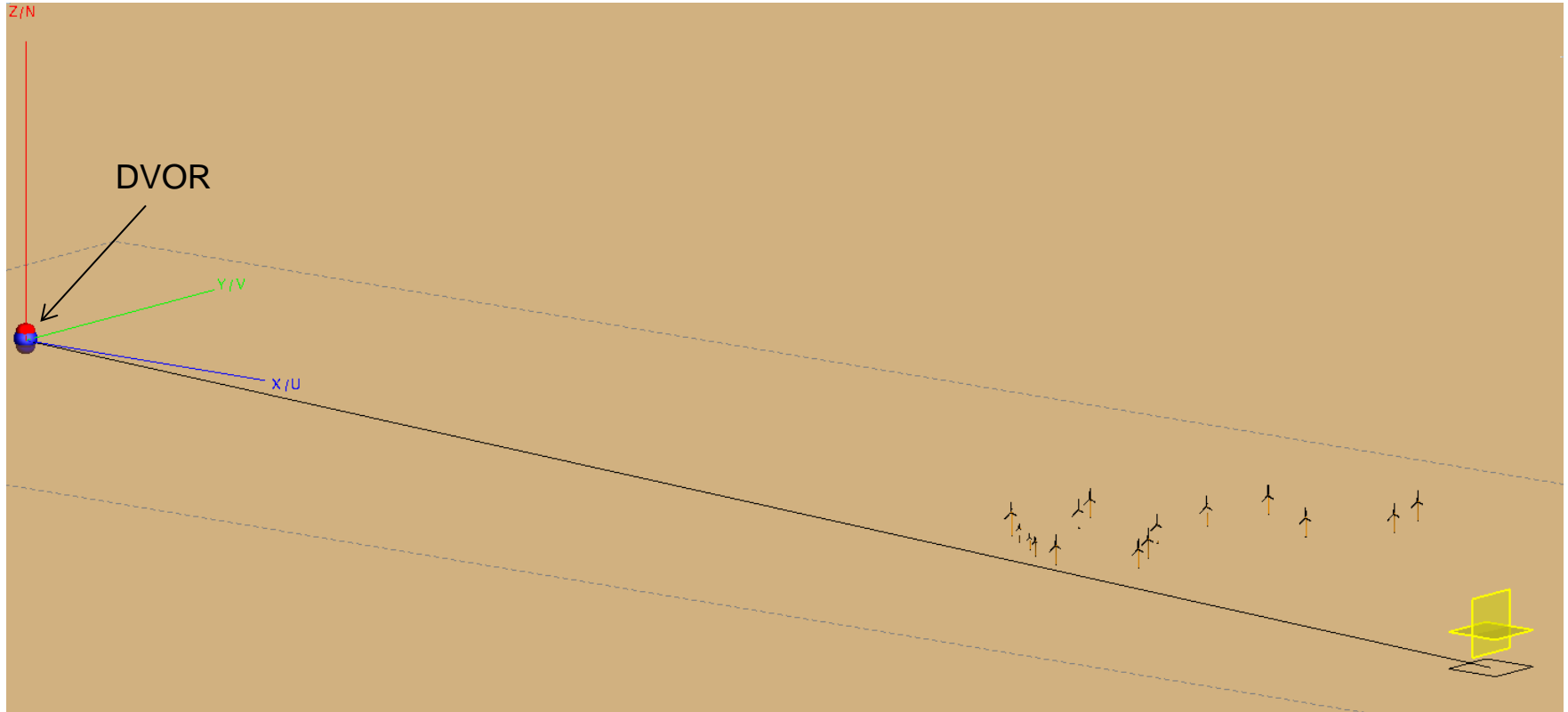
Validation Example 2: DVOR HEZ



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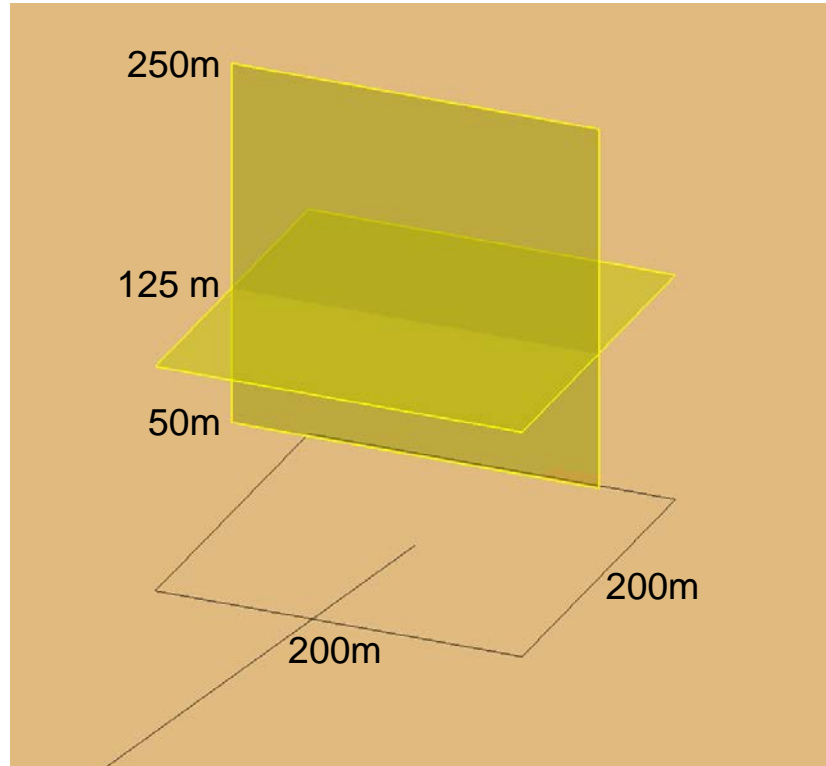


Validation Example 2: DVOR HEZ

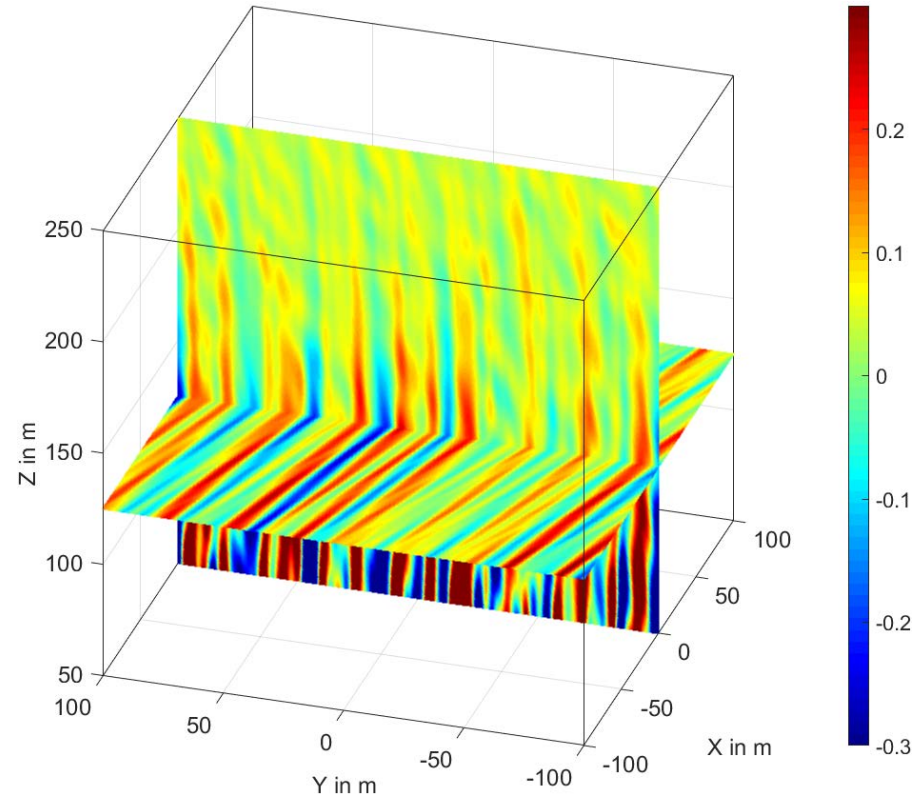
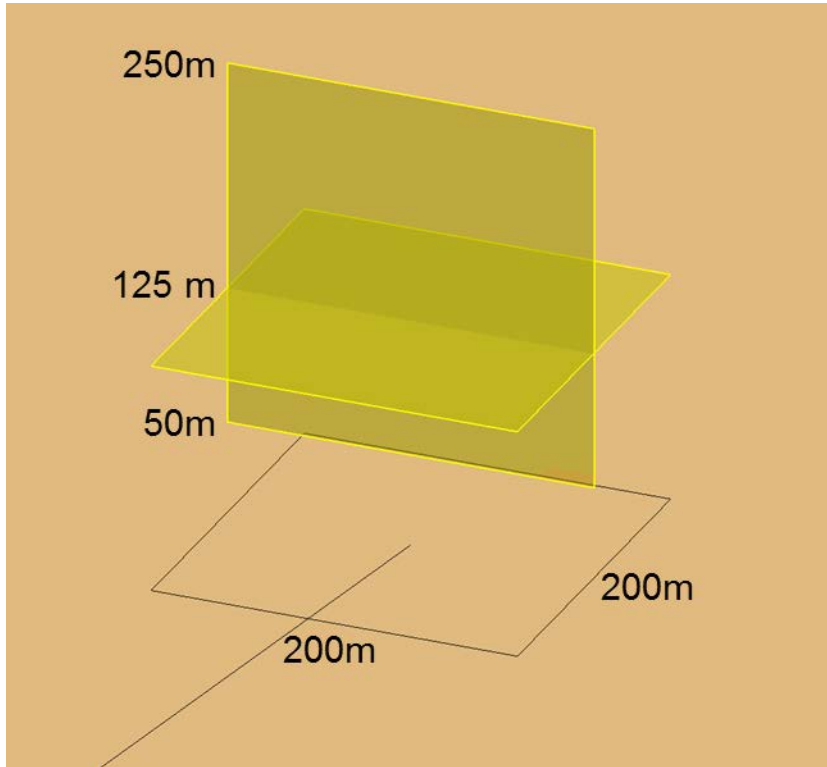


Validation Example 2: DVOR HEZ

- searching for appropriate flight trajectory:

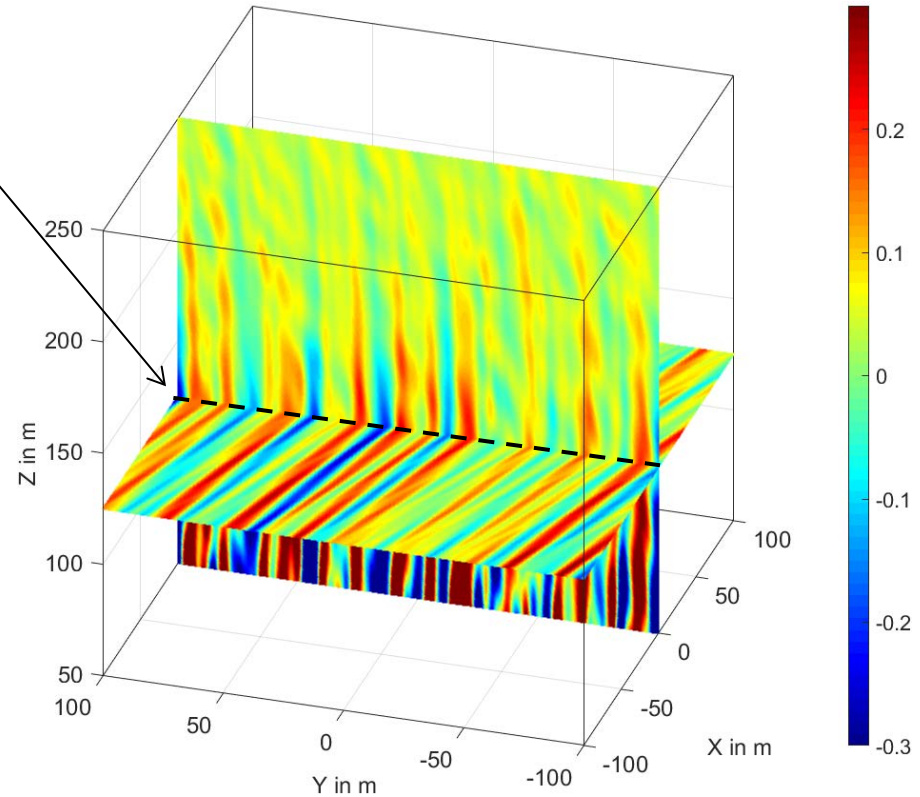


Validation Example 2: DVOR HEZ



Validation Example 2: DVOR HEZ

- chosen flight trajectory for measurements



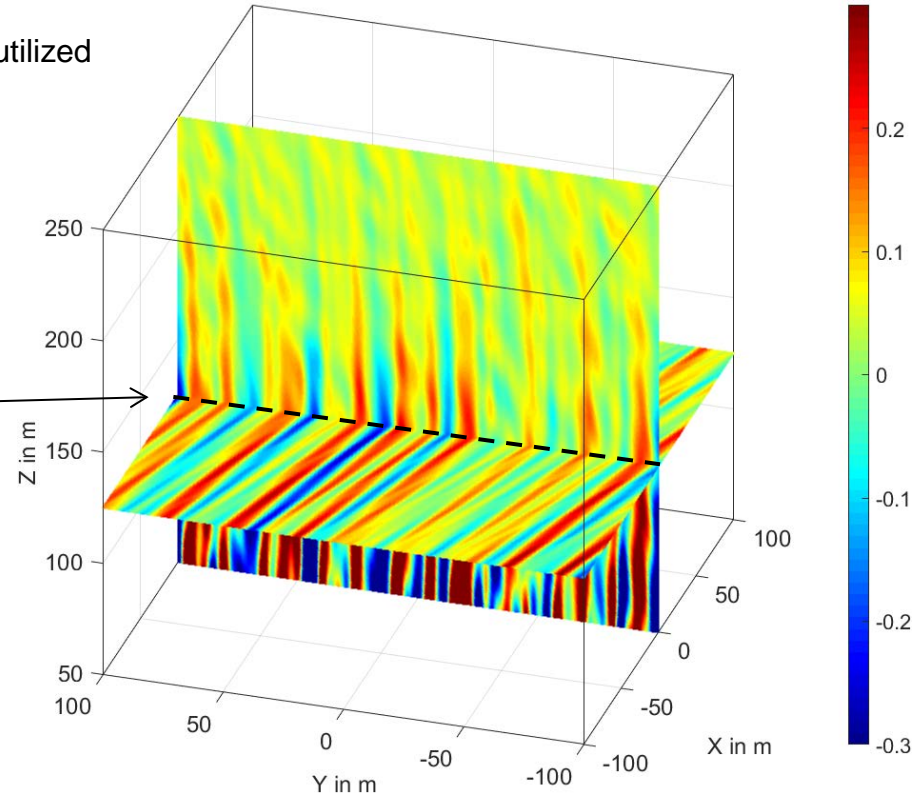
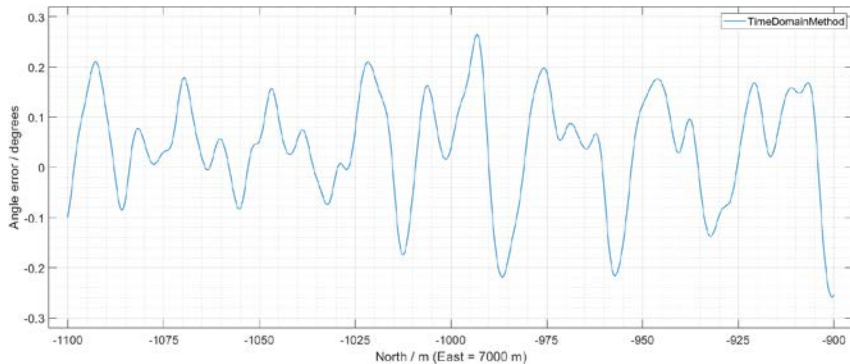
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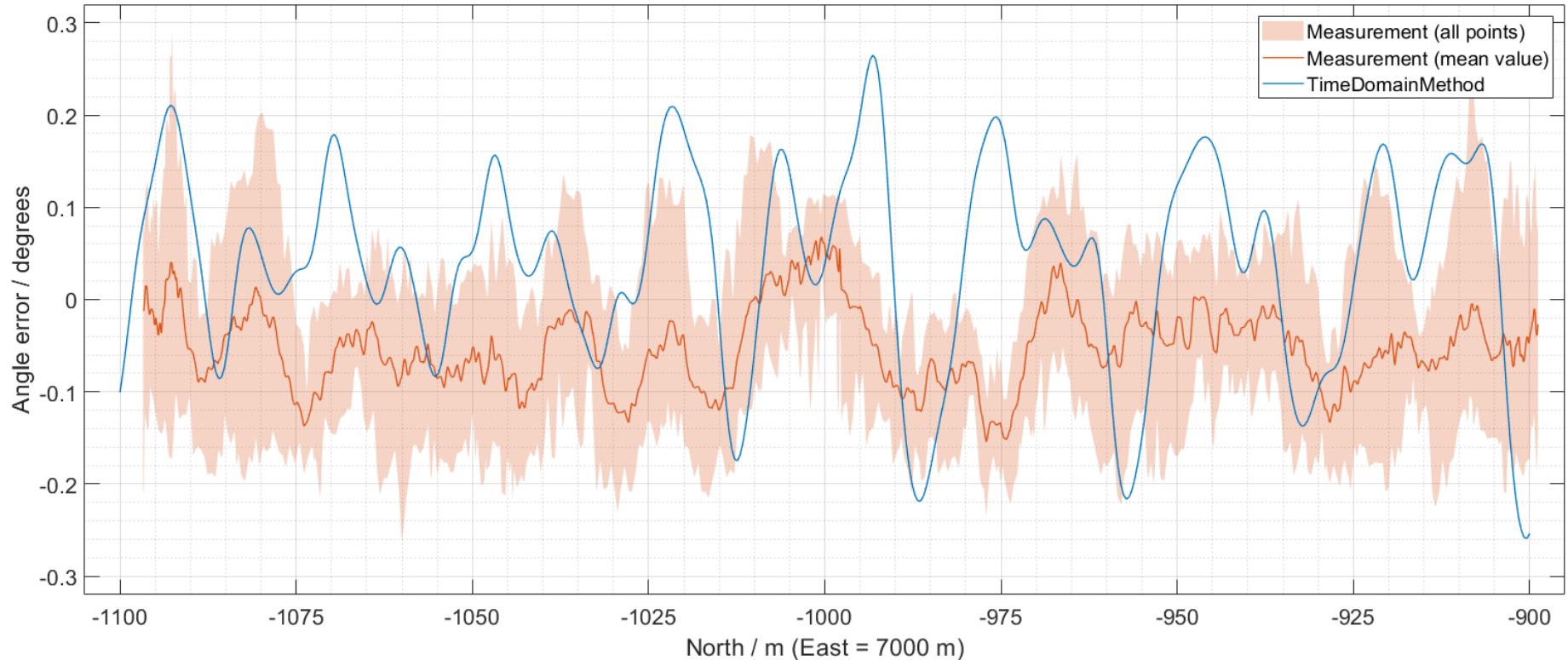
Validation Example 2: DVOR HEZ

- lightweight simulation:
 - no receiving antenna characteristics used → only E_{phi} utilized
 - stationary scenario
 - only ϕ_{FM} calculated
 - simulated duration: 1 DVOR cycle = $\frac{1s}{30} = 33.\bar{3}$ ms
- 4 days x 10 boards x (36 cores & 138 GB RAM)

simulation data extracted along linear trajectory



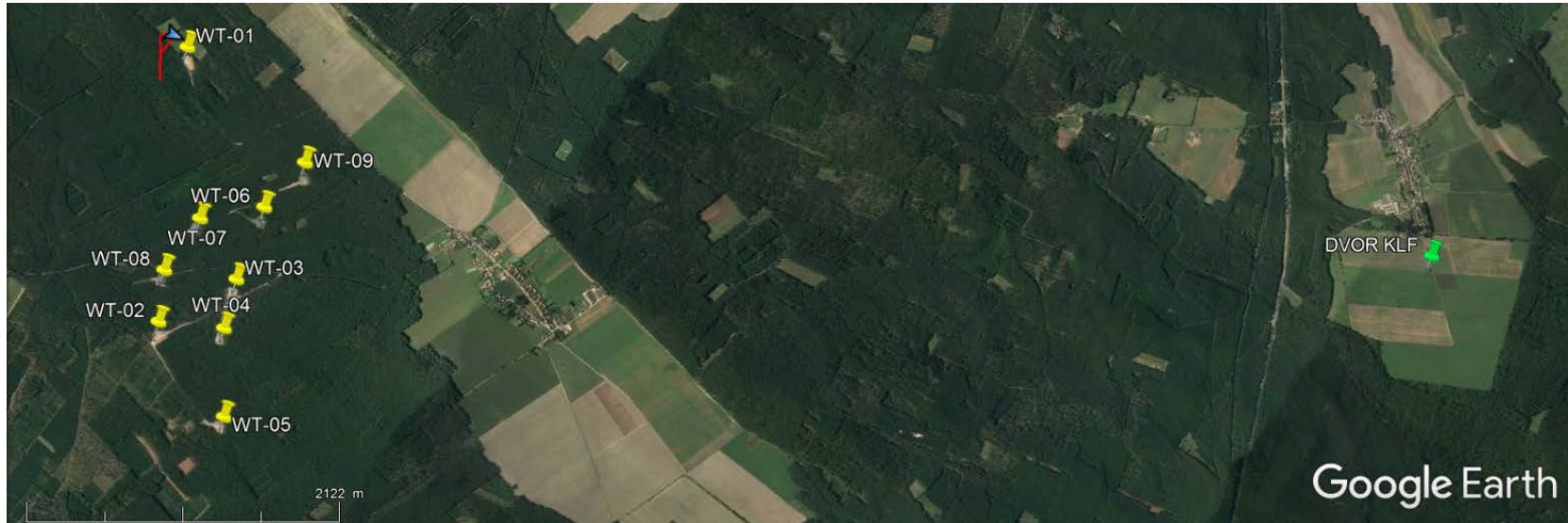
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Validation Example 3: DVOR KLF

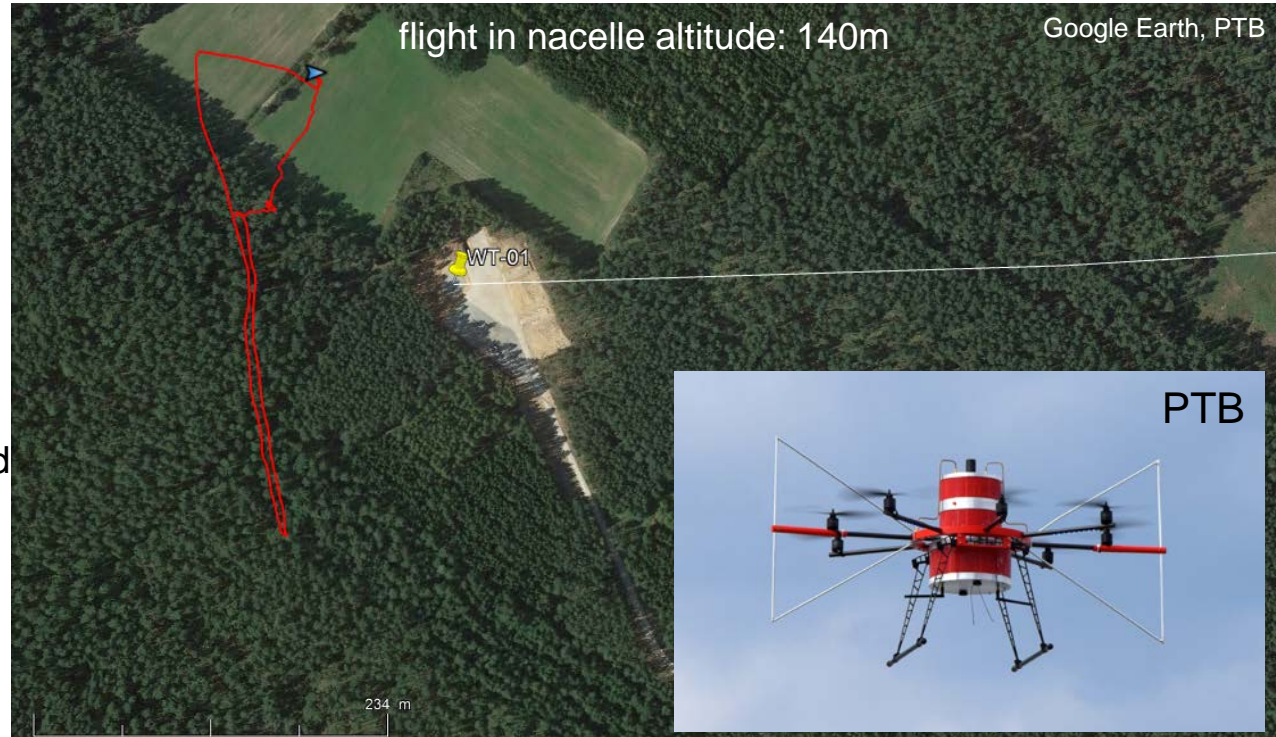


Validation Example 3: DVOR KLF

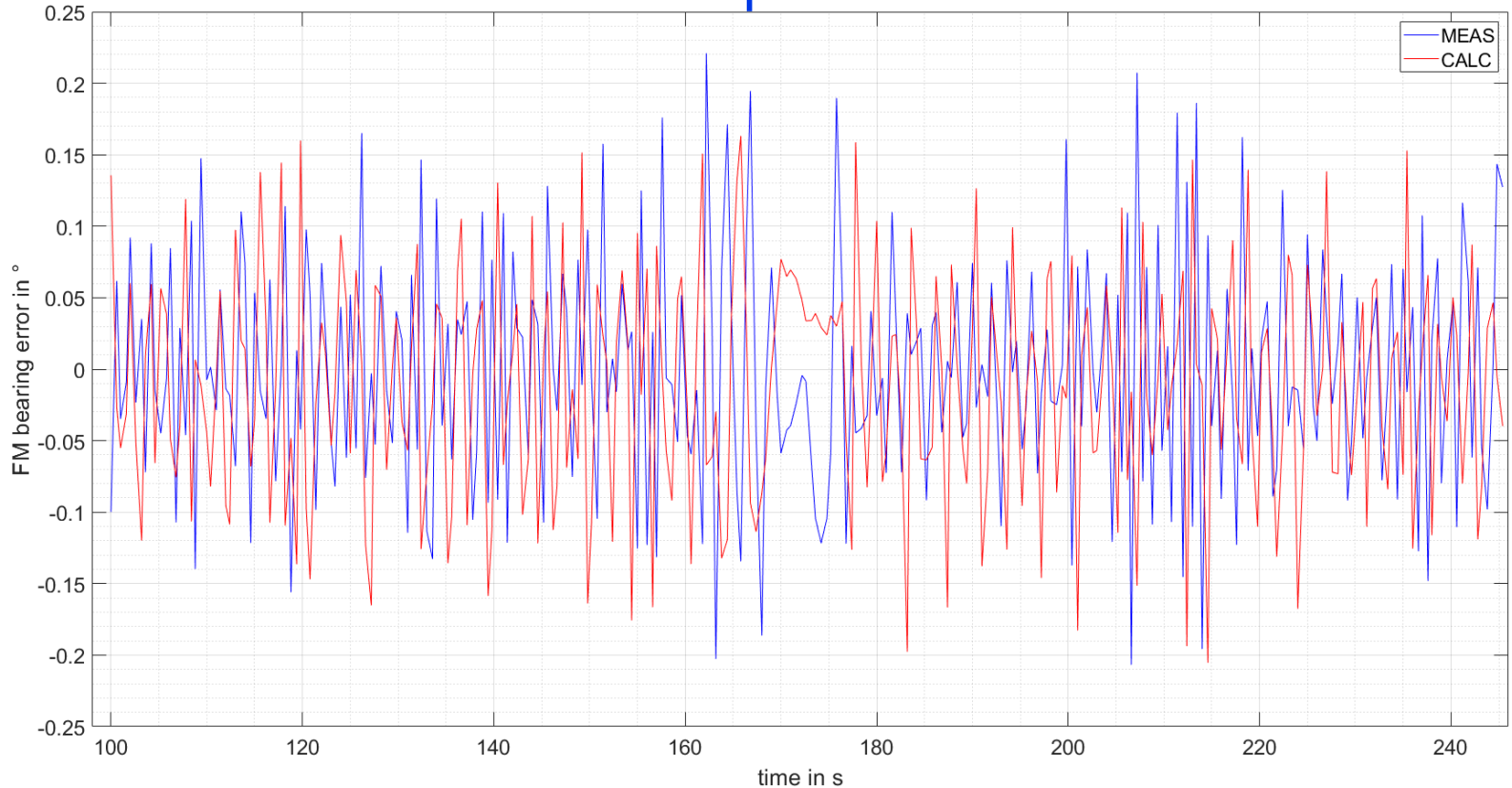


Validation Example 3: DVOR KLF

- WT was already built :)
- lightweight simulation:
 - stationary scenario
 - only ϕ_{FM} simulated
 - simulated duration: $\frac{1}{30}$ s
- no antenna characteristics used
 - only E_{phi} utilized
- 2 days x 10 boards x (36 cores & 138 GB RAM)



Validation Example 3: DVOR KLF



Conclusion

- full consideration of scenario dynamics
- AM & FM phase calculation
- consideration of antenna characteristics of DVOR and receiver
- consideration of DVORs AL quantity & blending
- consideration of individual demodulators

- very good matching between calculations and measurements

- high numerical effort → automatization, parallelization
- simplifications applicable (dynamics & AM phase, antenna characteristics)

Many thanks
for your attention!

