



Simulation and validation of signal interference of a conventional VOR

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Agenda

- › Introduction
- › Modelling of CVOR
- › Validation
- › Simulation Examples



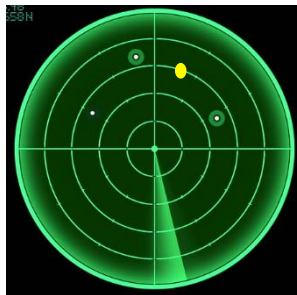
CNS Systems (Communication, Navigation, Surveillance)



Surveillance

Positioning of Aircraft

Radar



Communication

Voice and Data
Communication



Navigation

Providing positioning and
guidance signals

Instrument Landing System ILS

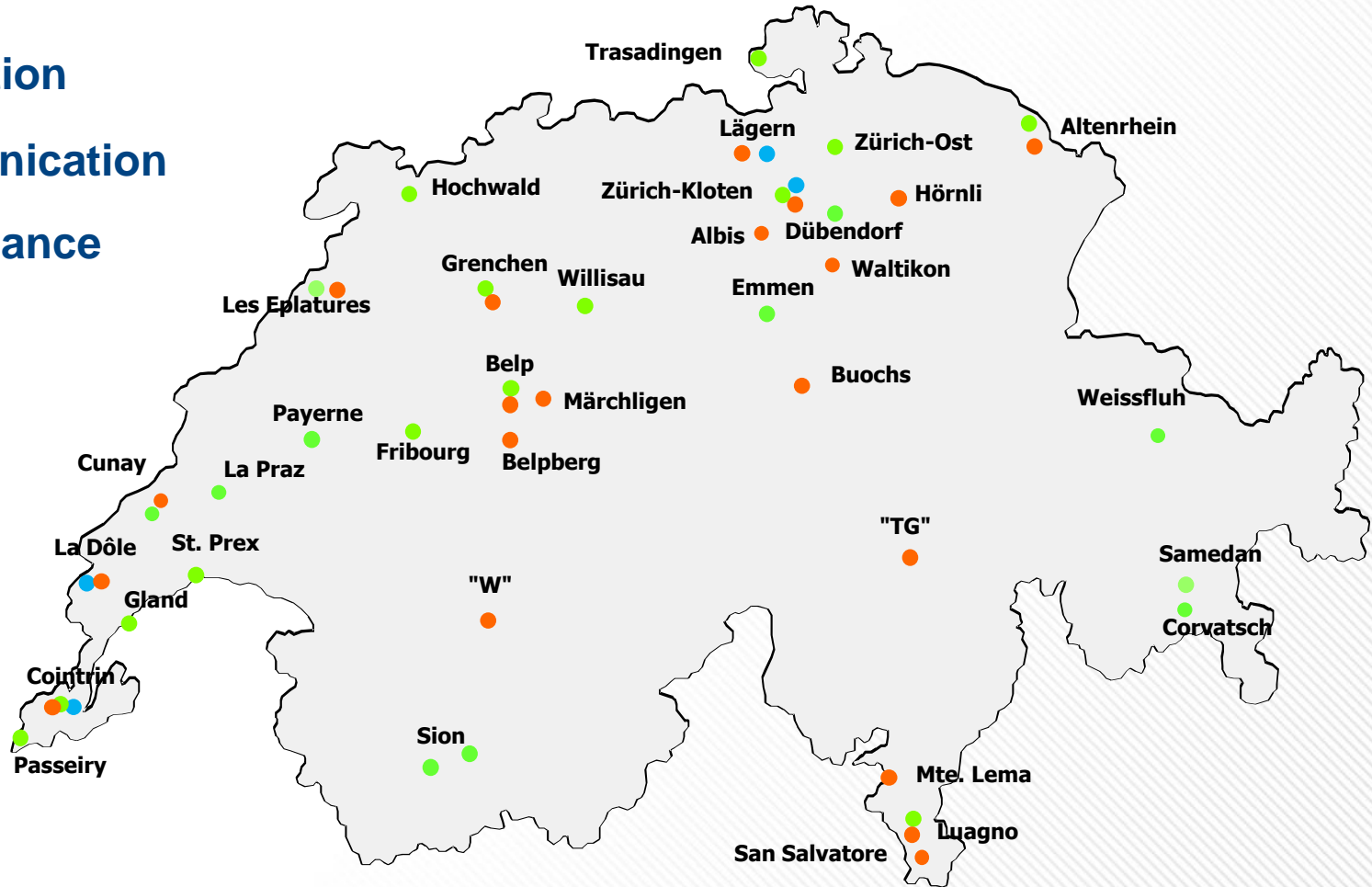


VOR



CNS Installations in Switzerland

- Navigation
- Communication
- Surveillance



Why do Wind Turbines interfere with CNS-Systems?



La Tour Eiffel
300m



Wind Turbine
230m



Zürich Prime Tower
120m



Power Tower
ca. 80m

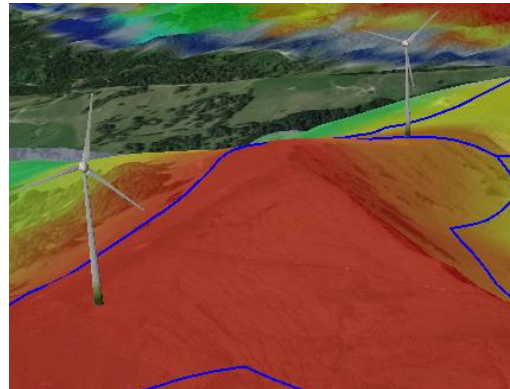
Wind Energy Competence Center (CNS)

Wind Turbines (WT)

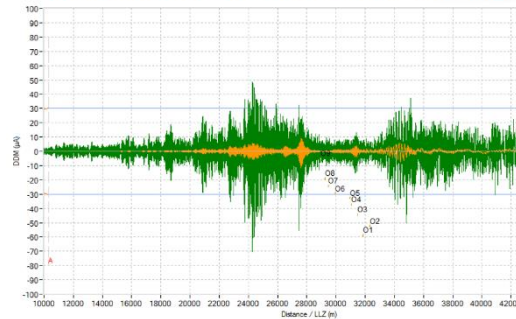


Understand and negotiate technical requirements with regards to CNS
Follow technical evolution

Wind Turbine Assessment



Approach CLR only / COU+CLR 80° Drehung



Assess Compatibility of Wind Turbines with Air Traffic Control

CNS Systems



Understand and follow evolution
Propose wind turbine friendly technology

Methodology, Tools



$$\oiint E \cdot dA = \frac{q}{\epsilon_0}$$

$$\oiint B \cdot dA = 0$$

$$\oint F \cdot ds = -\frac{d\Phi_B}{dt}$$

$$\oint B \cdot ds = \mu_0 i + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$$

Continuously improve evaluation tools

Networking

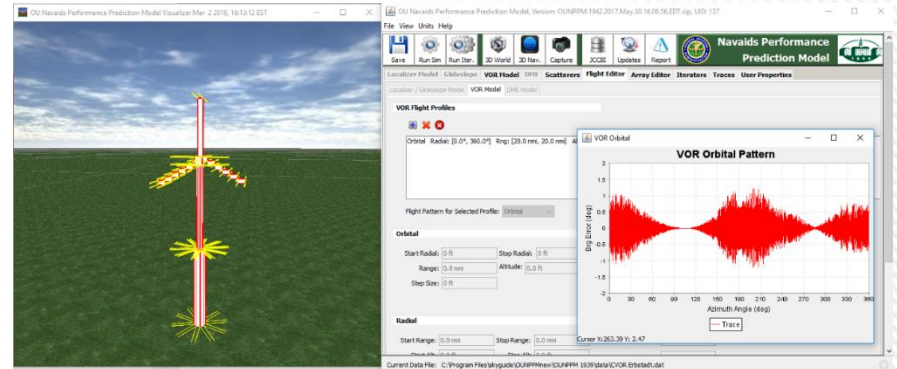


Exchange know how and experience with experts

Electromagnetic Simulation Tools

OUNPPM (OHIO University Navaid Performance Prediction Model)

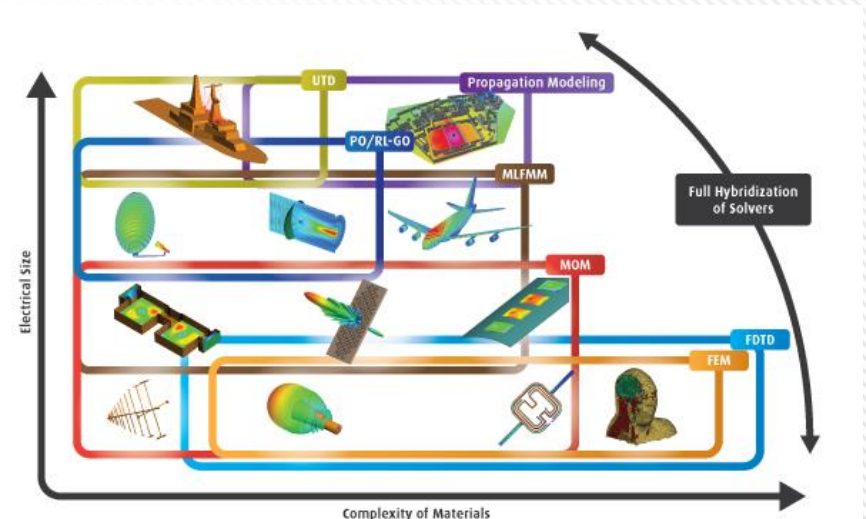
- PO, Standardized Source Model



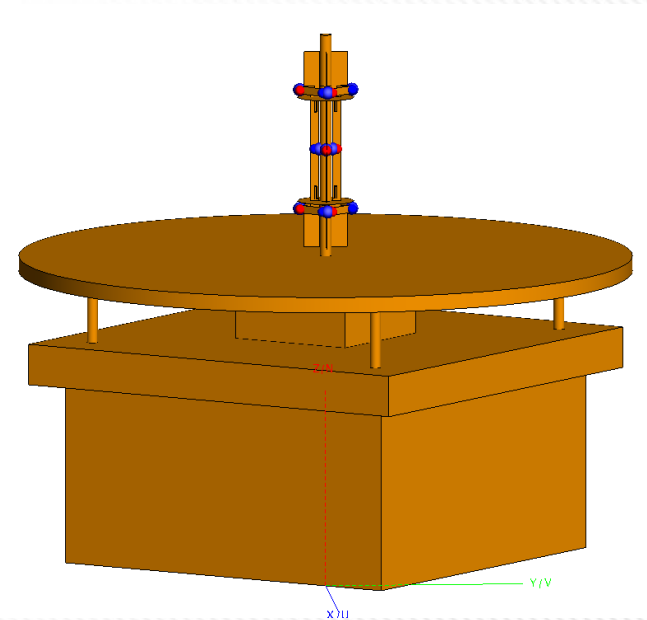
FEKO (Altair)

Full 3D Modelling

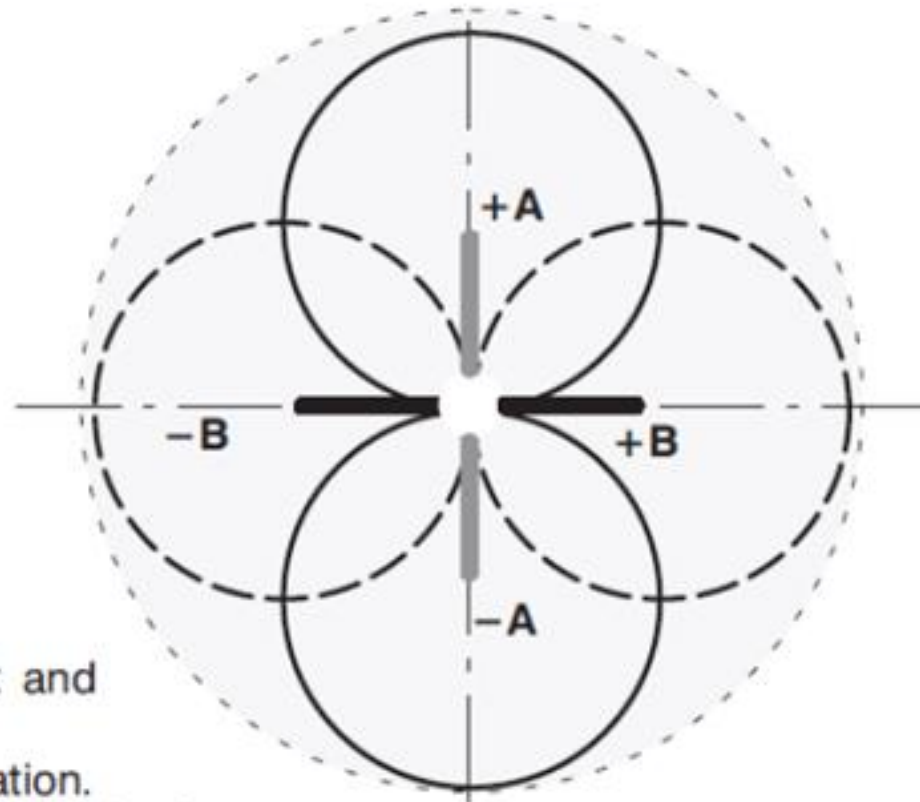
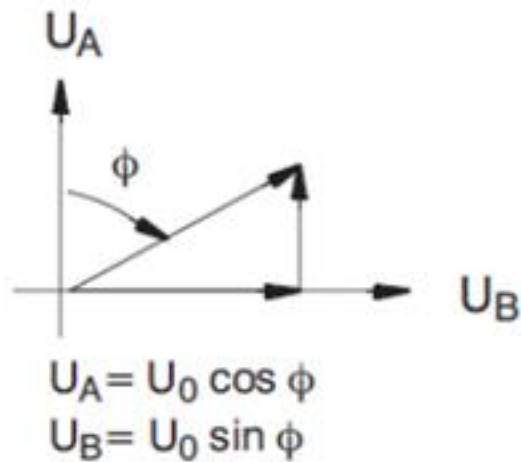
- MoM, MLFMM
- PO, GO
- UTD



Conventional VOR



AM Field Components of VOR



The signals

$$U_A = U_{RF} \cdot \cos \Omega t \cdot \cos \phi \cdot \cos \omega t \text{ and}$$

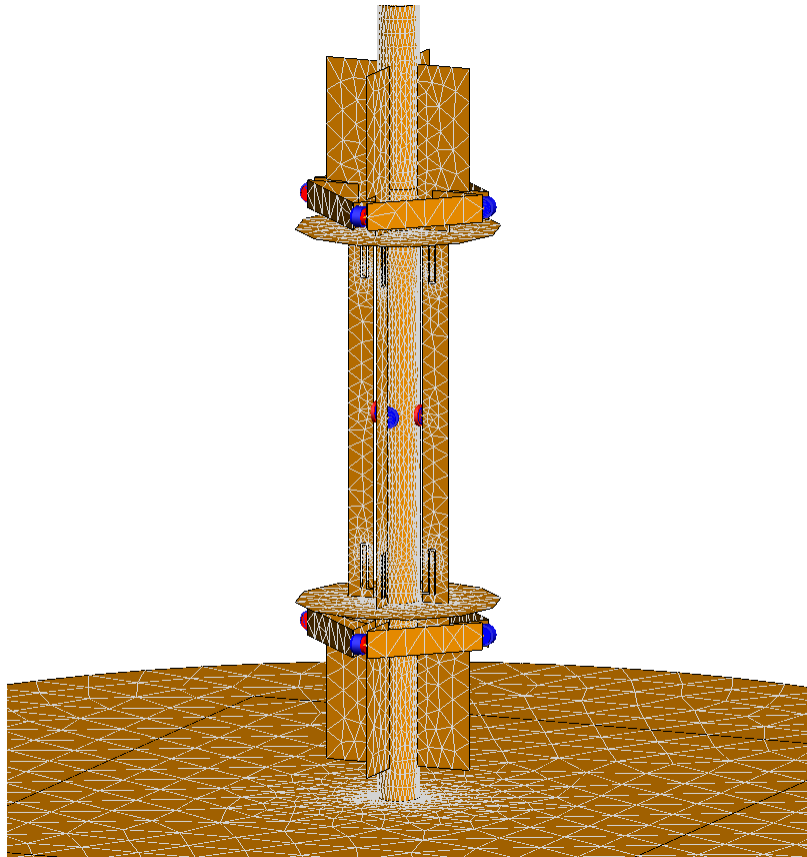
$$U_B = U_{RF} \cdot \cos \Omega t \cdot \sin \phi \cdot \sin \omega t$$

vary with time and angle of observation.

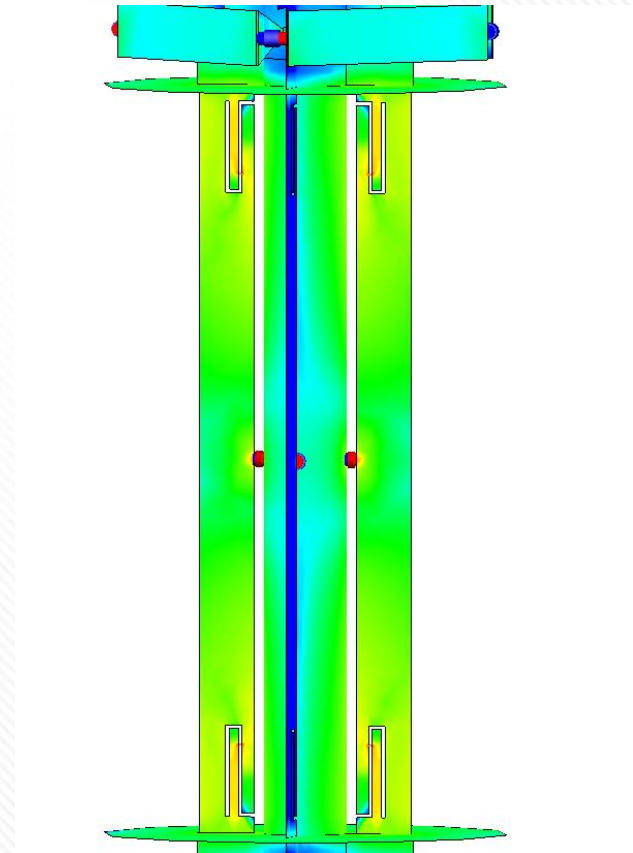
$\Omega = \text{carrier frequency}$; $\omega = 30 \text{ Hz modulation frequency}$

CVOR Antenna

Antenna Model



Currents



A NEW VOR-ANTENNA IN SLOT-TECHNOLOGY

G.Greving,⁺ H.Würth⁺

A B S T R A C T

The general necessity for an improved VOR-antenn related specifications are summarized. The development of a new VOR-antenna is described. The basic radiating elements are discussed and the hardware of staggered loop antennas and interlaced double slots outlined. Specific details are presented. The adjusting technique is described. A vertical compression of more than 20 dB and a bearing error achieved up to 60°-elevation without the need for a cone of silence is reduced to $\pm 30^\circ$.

Greving G., Würth H.,
“A new VOR-antenna in slot technology”,
13th EUMW, Nürnberg Sept 1983, pp.
395-400

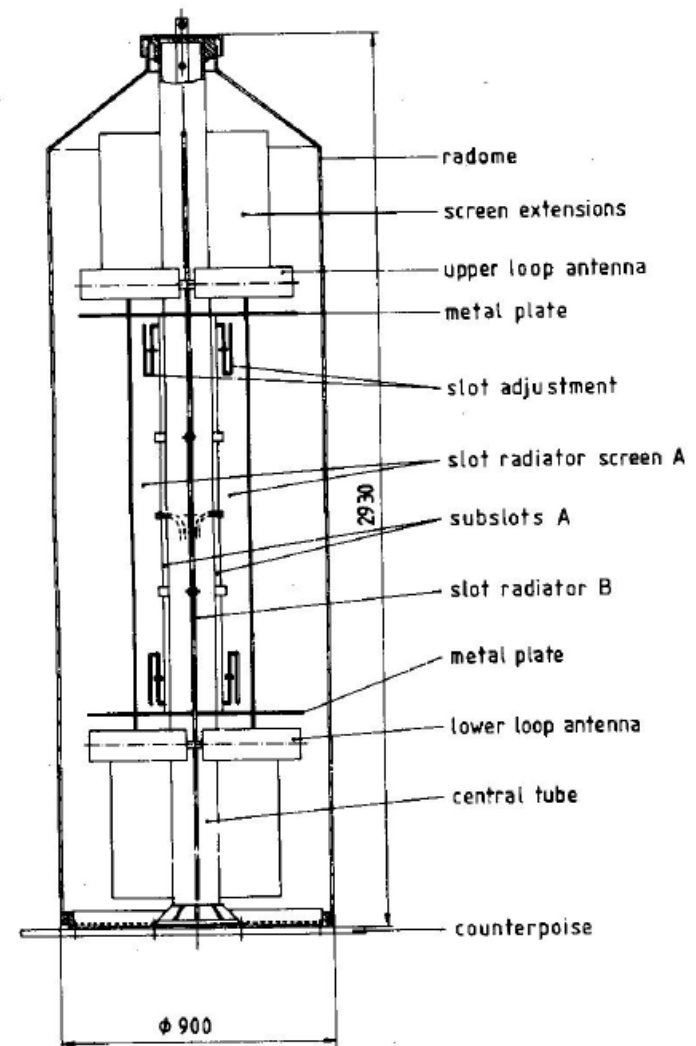
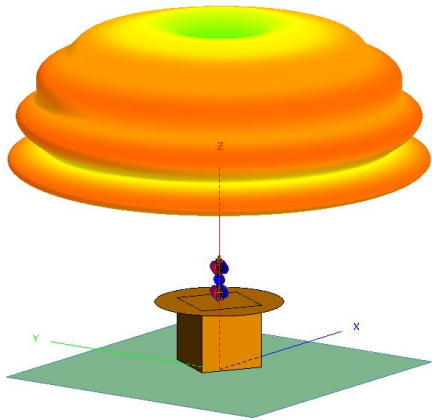


Figure 8 : Principal constructional view of the VOR-antenna with some details

AM Signal Generation

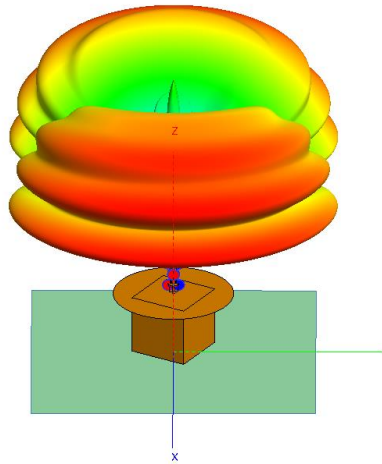
Omnidirectional

Omni

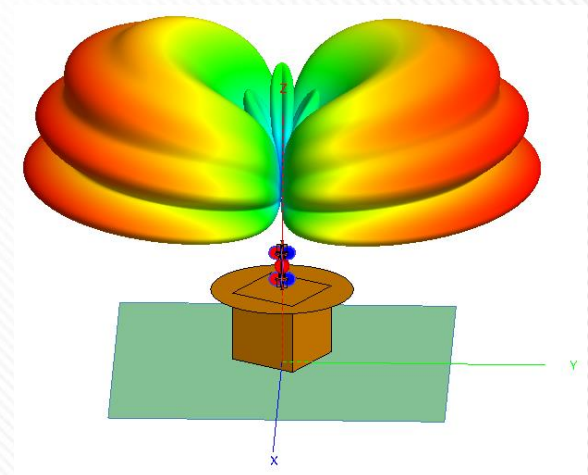


Directional

Dir00



Dir90

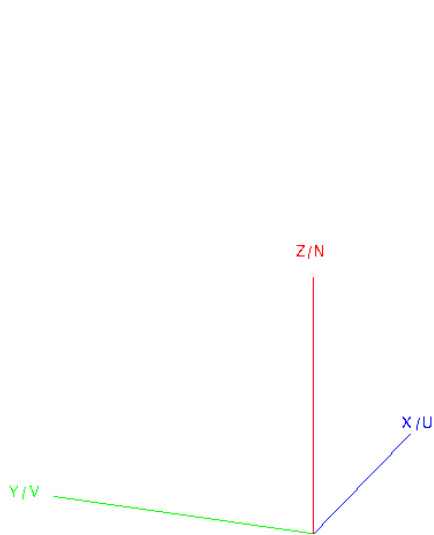


$$U(t) = (\mathbf{Omni} + \mathbf{Dir00} * \cos\omega t + \mathbf{Dir90} * \sin\omega t) \cos\Omega t$$

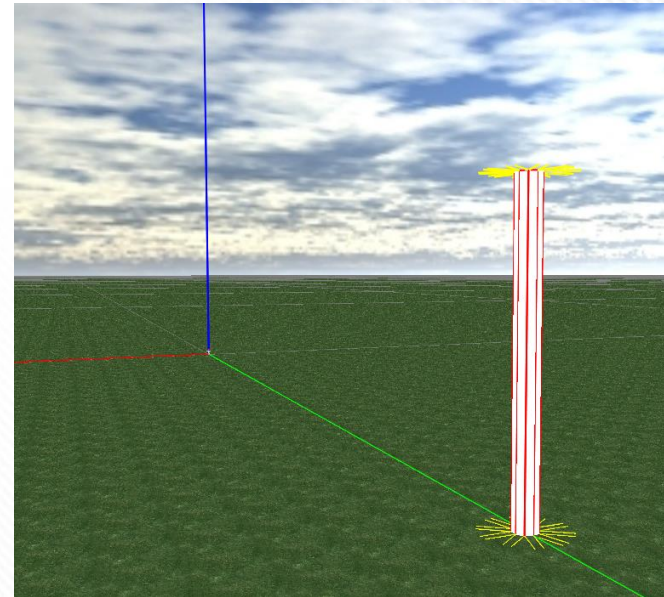
Ω = Carrier frequency; ω = Modulation frequency $2\pi 30\text{Hz}$

Verification with Cylinder Scatterer

FEKO



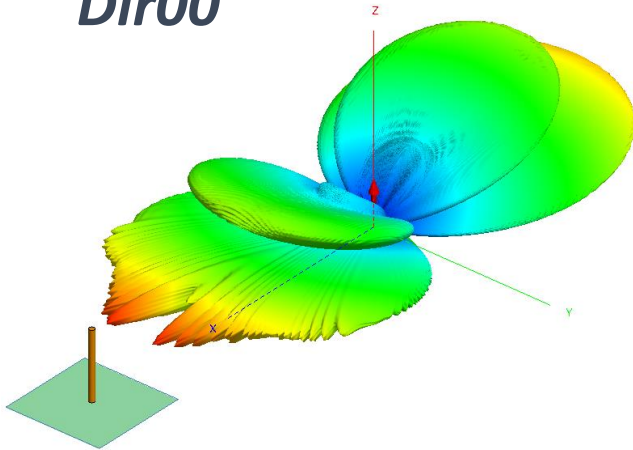
Ohio Tool (OUNPPM)



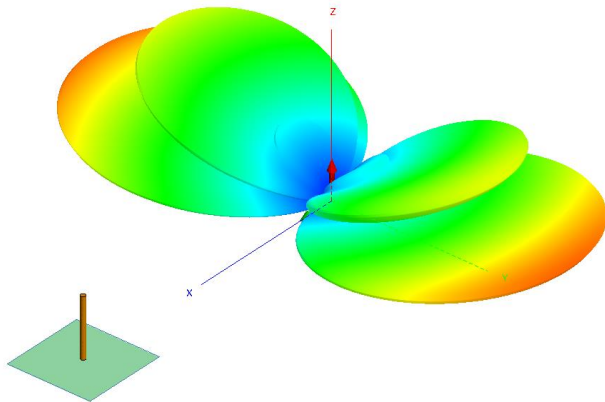
Cylindrical Scatterer: Distance 500m North, Radius 4m, Height 100m

Radiation Pattern including Scatterer

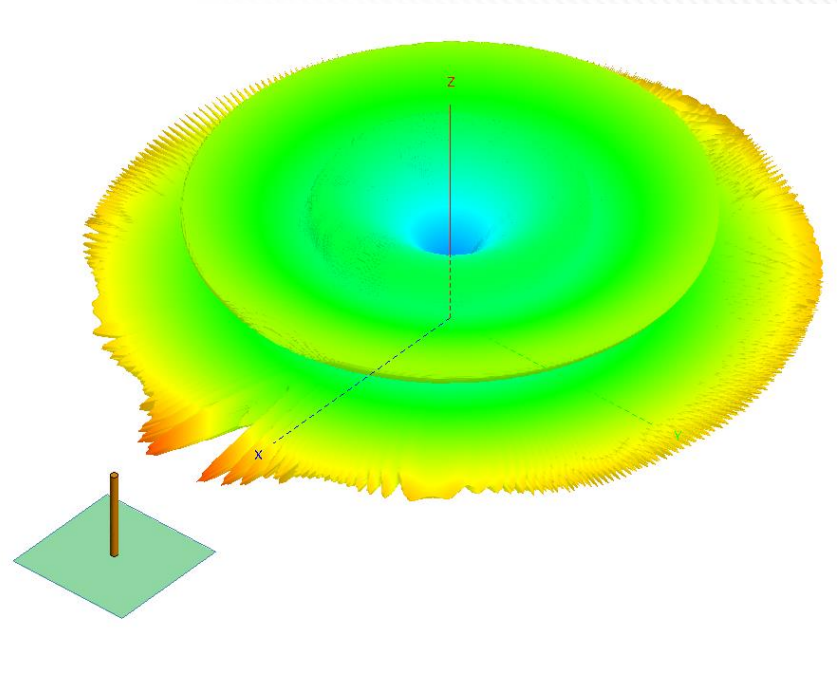
Dir00



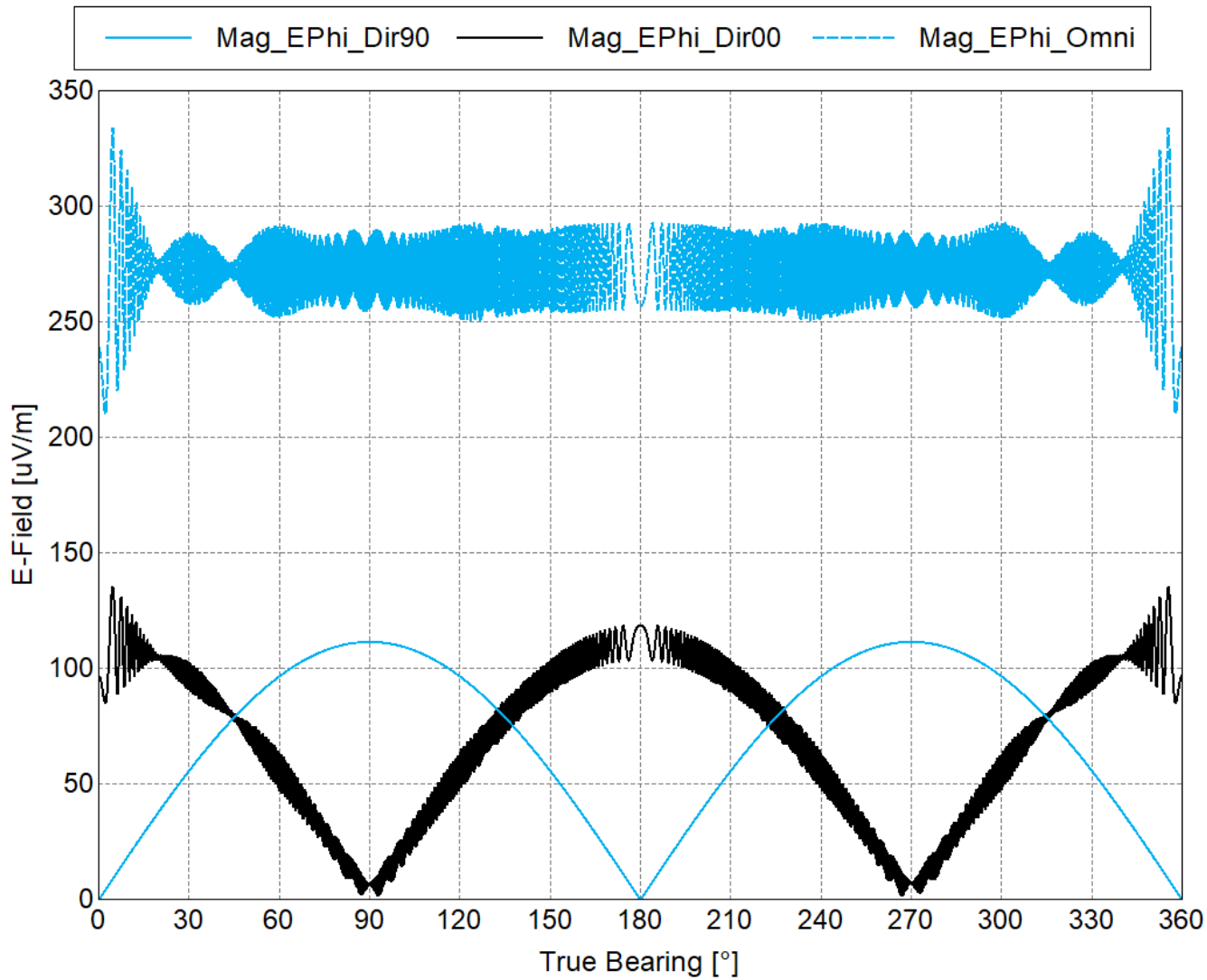
Dir90



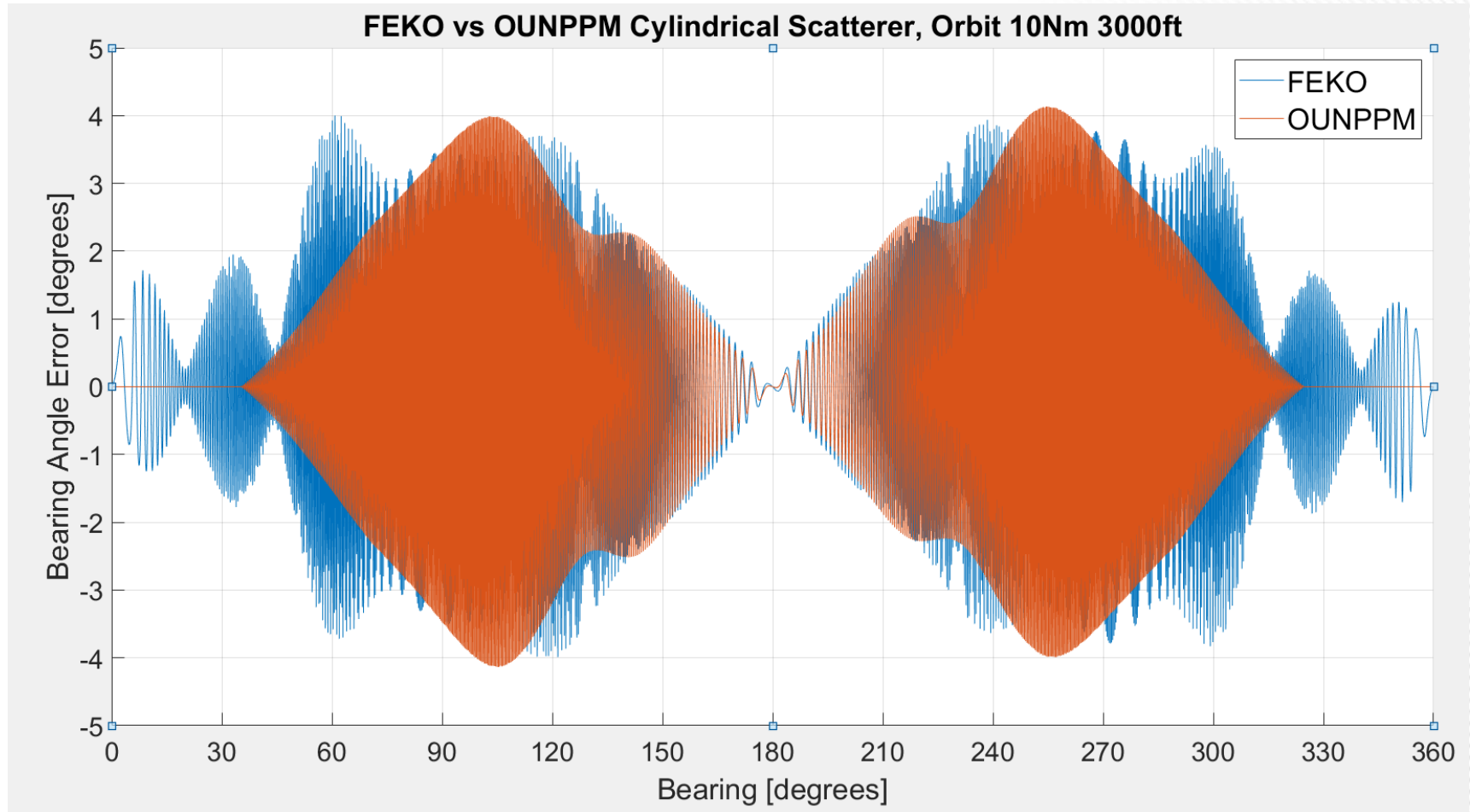
Omni



Magnitude E-Field



Cylindrical Scatterer, FEKO vs. OUNPPM



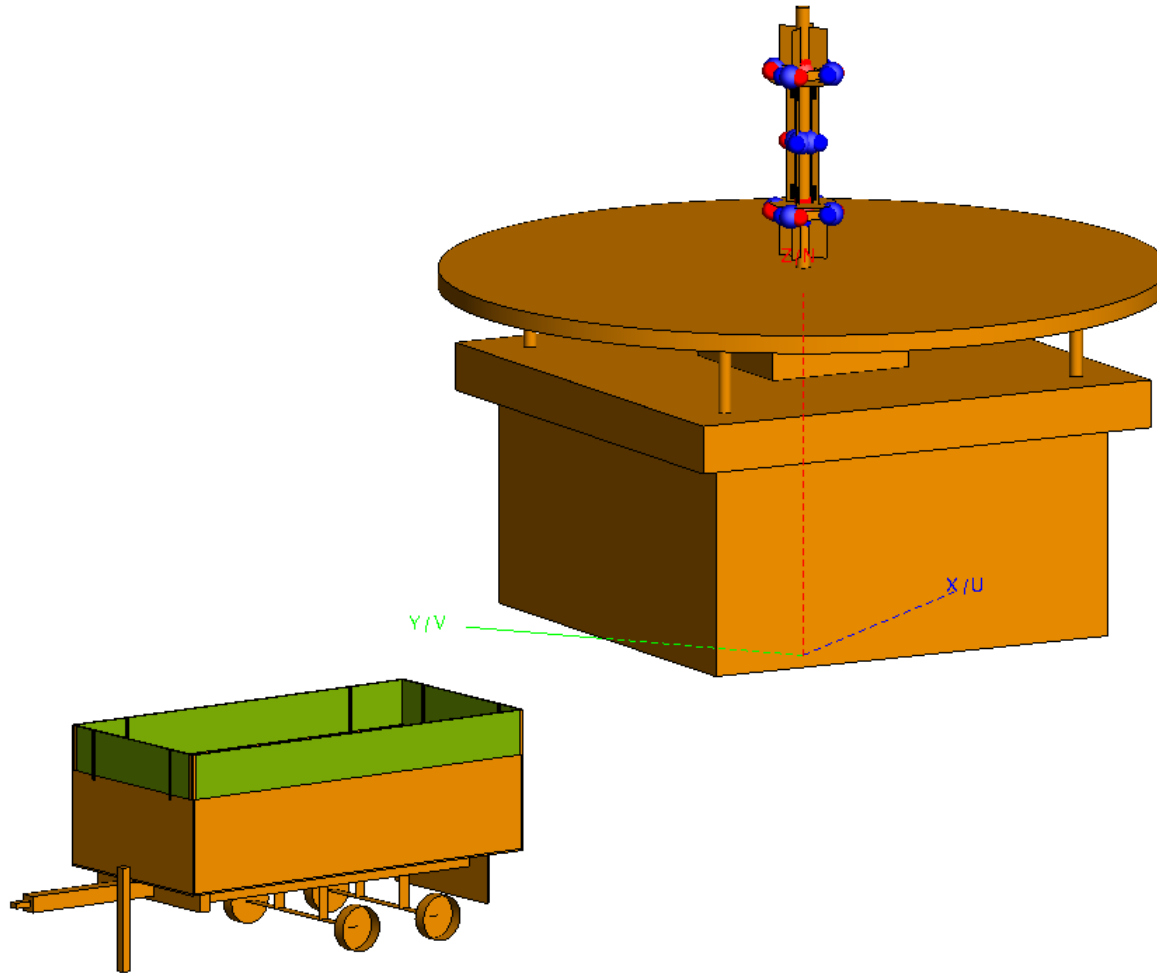
Drone Flight Inspection



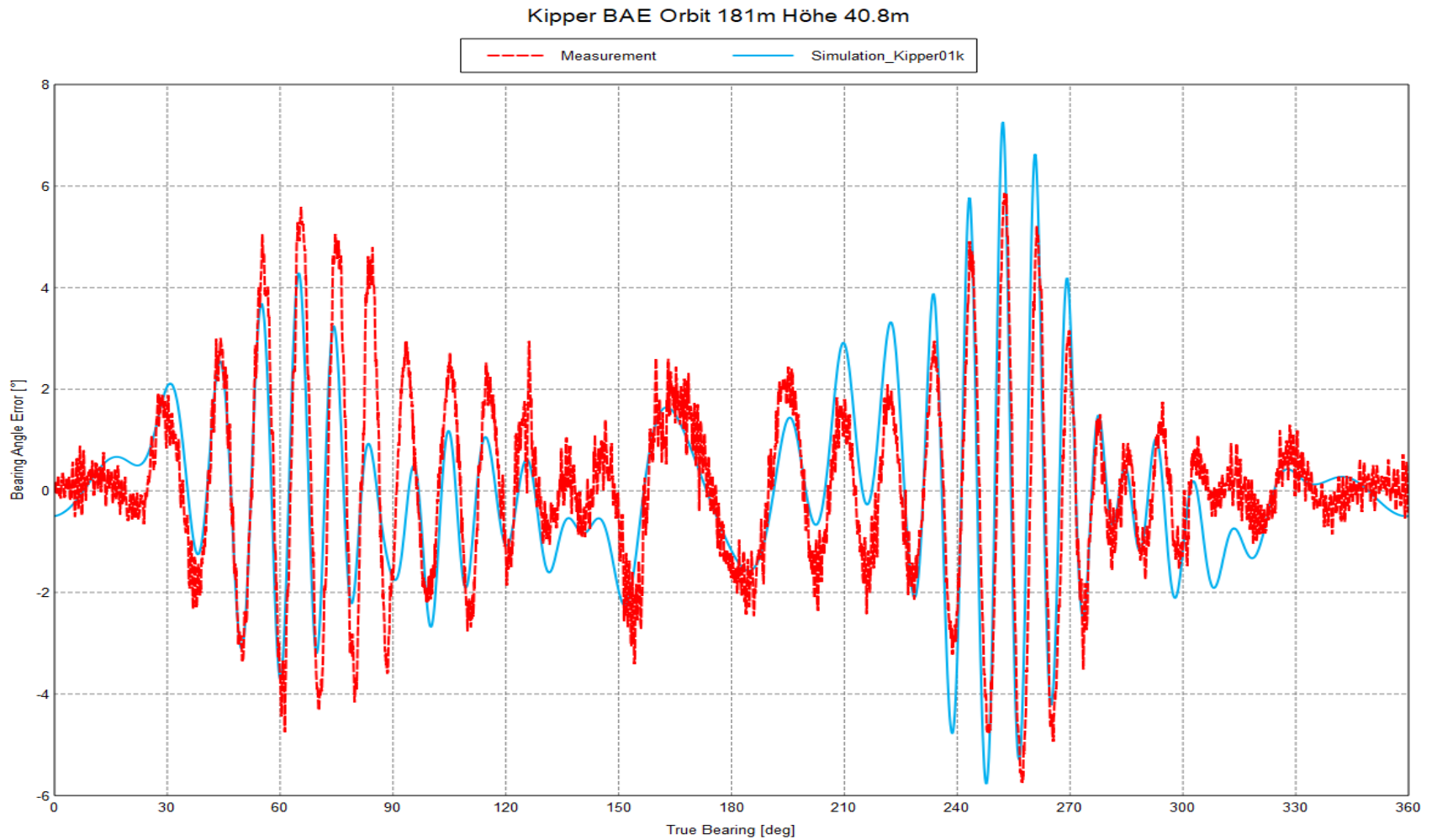
Tipper Wagon Scatterer (Kipper)



FEKO Model of Tipper Wagon Simulation

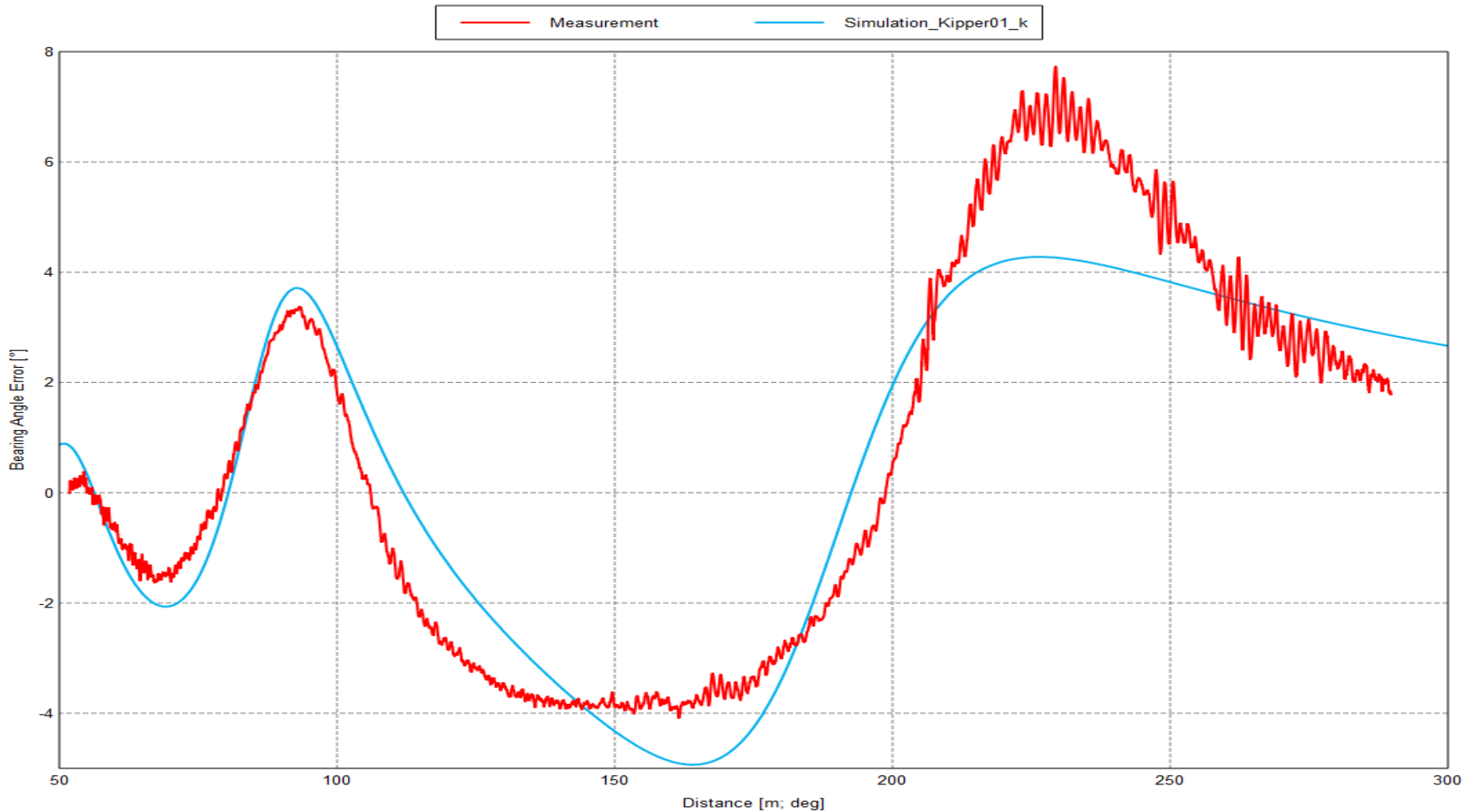


Orbit Radius 180m Height 40m



Radial 255 Distance 50 - 300m Height 40m

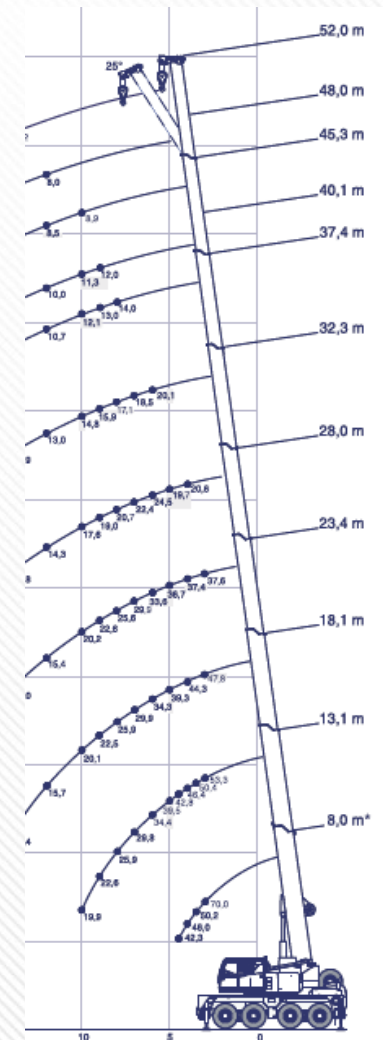
Bearing Angle Error Radial 255.1 Höhe 40.9m mit Kipper



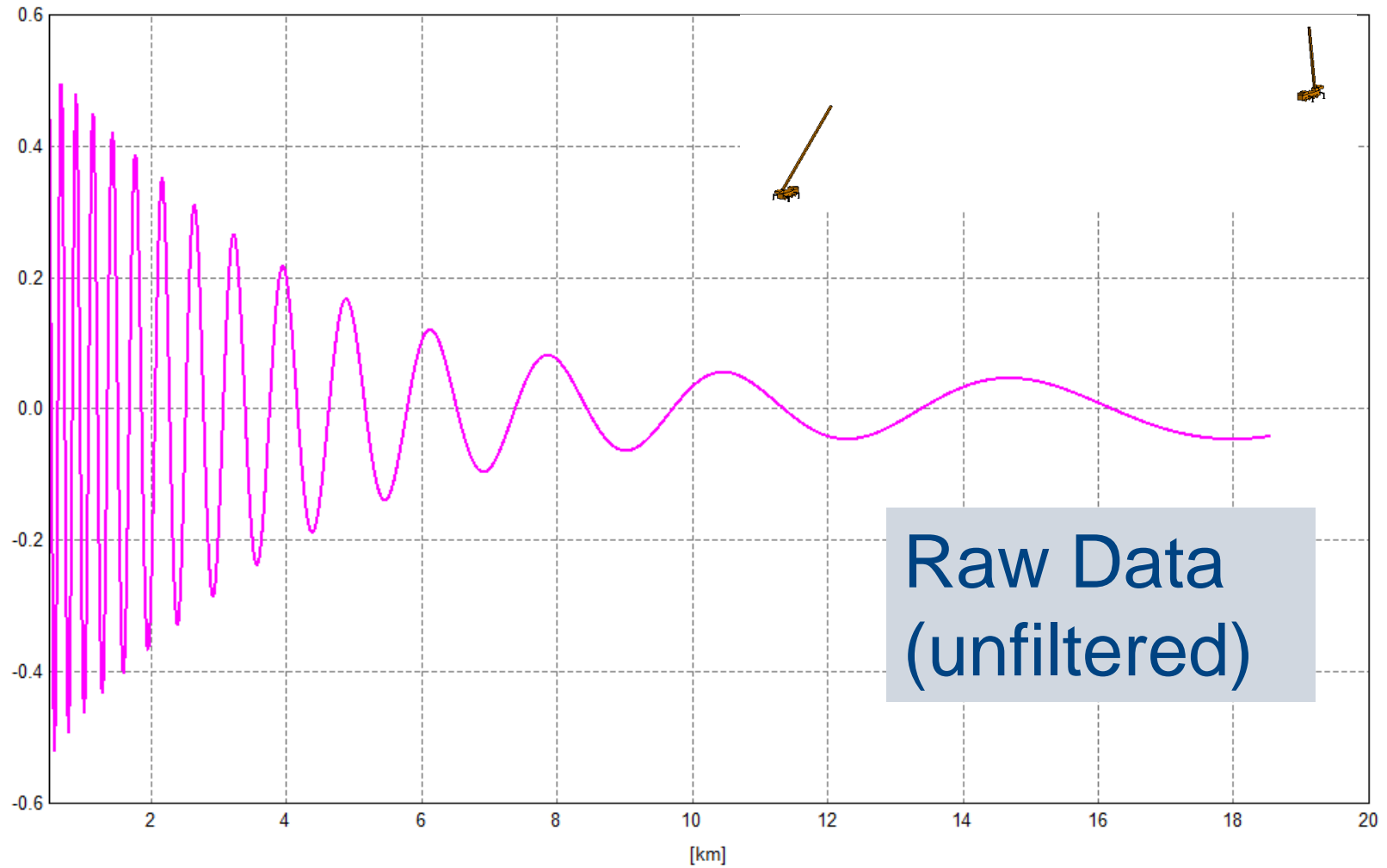
Crane Simulation

- › Distance to VOR: 1175m
- › Radial 99,2
- › Height of crane 39 m
- › Wherefrom 20m are masked by airport building

Illuminated by
VOR

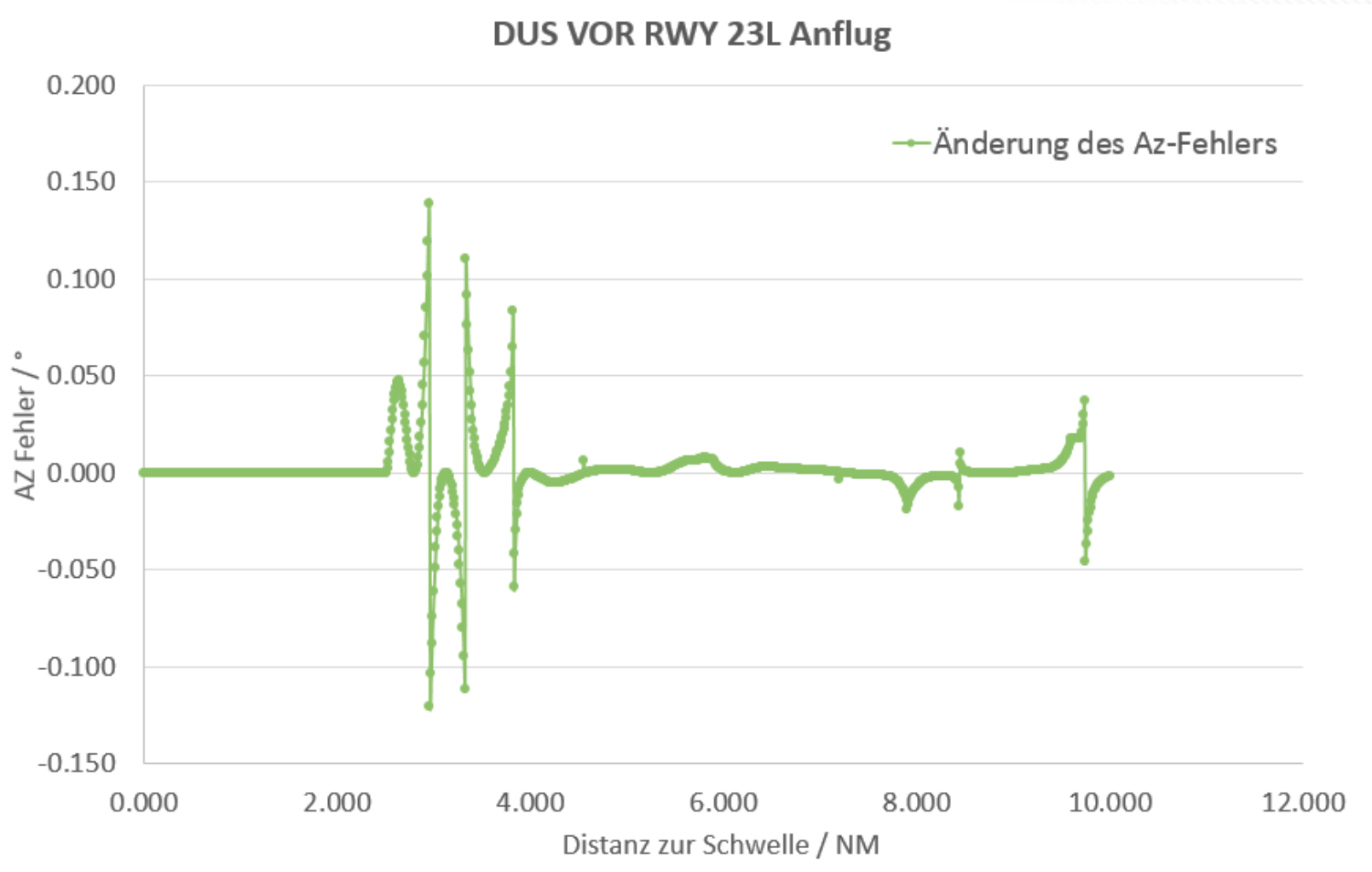


Bearing Angle Error caused by crane



Raw Data
(unfiltered)

Additional Error due to crane

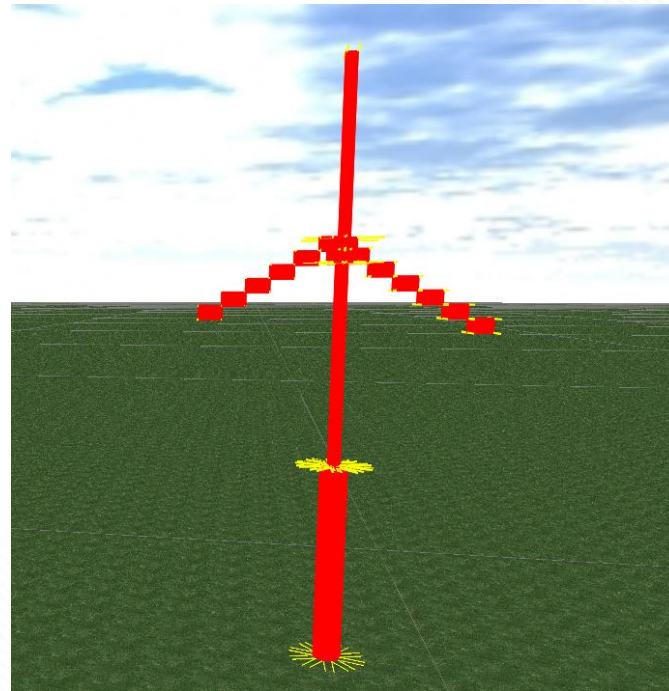


Simulation of Wind Turbines

FEKO

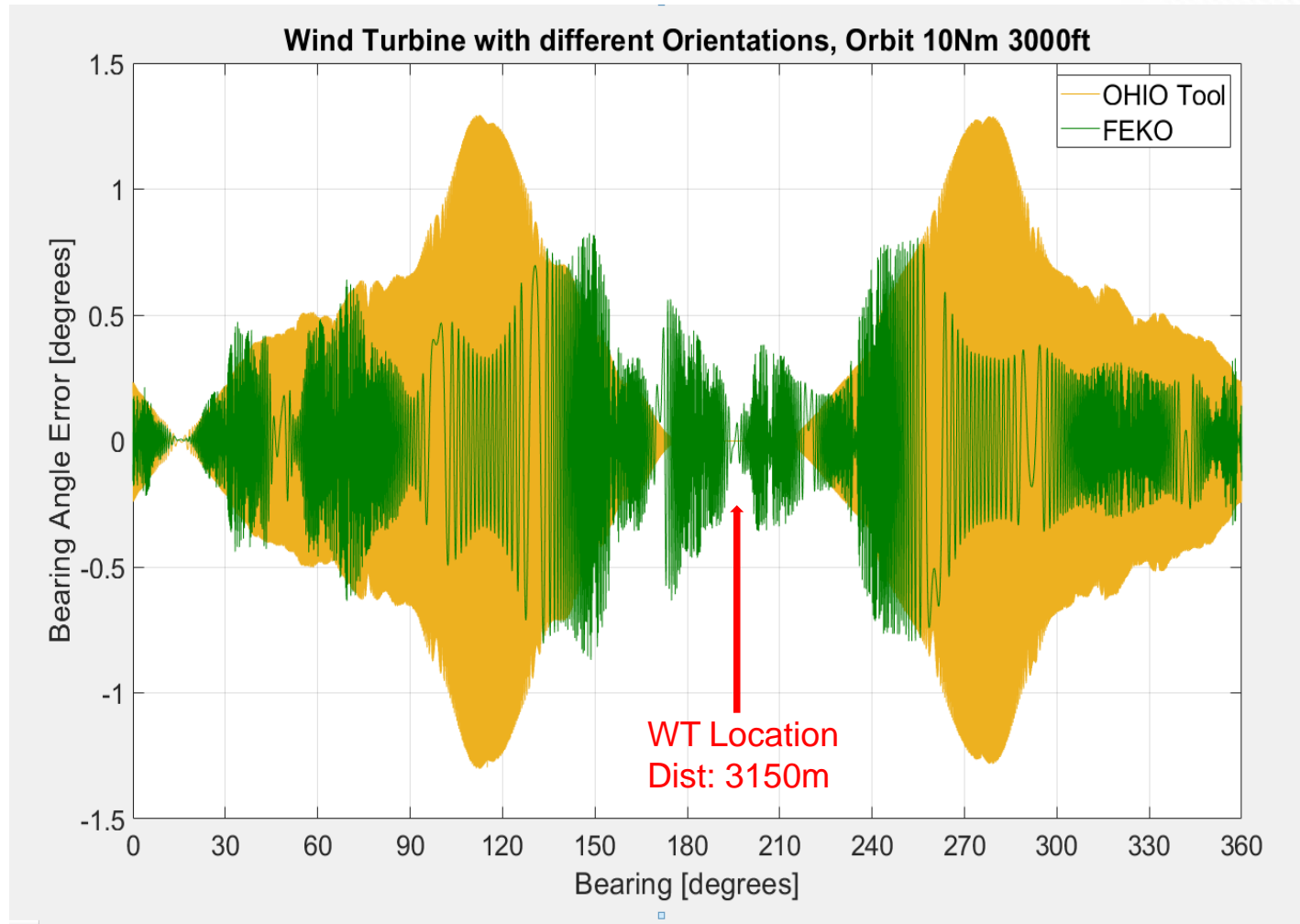


Ohio Tool (OUNPPM)

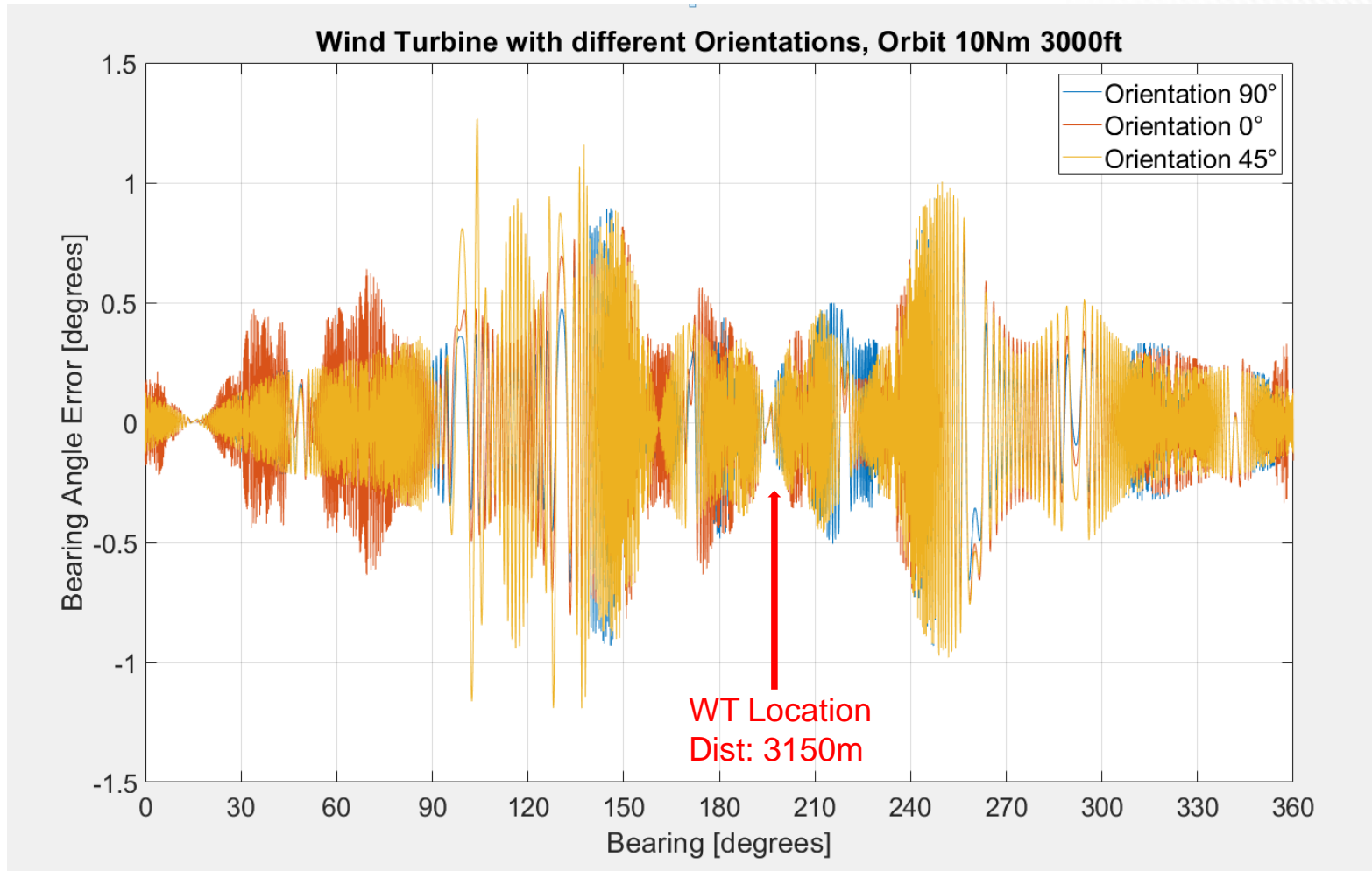


Distance 3100m South, Hub Height 165m

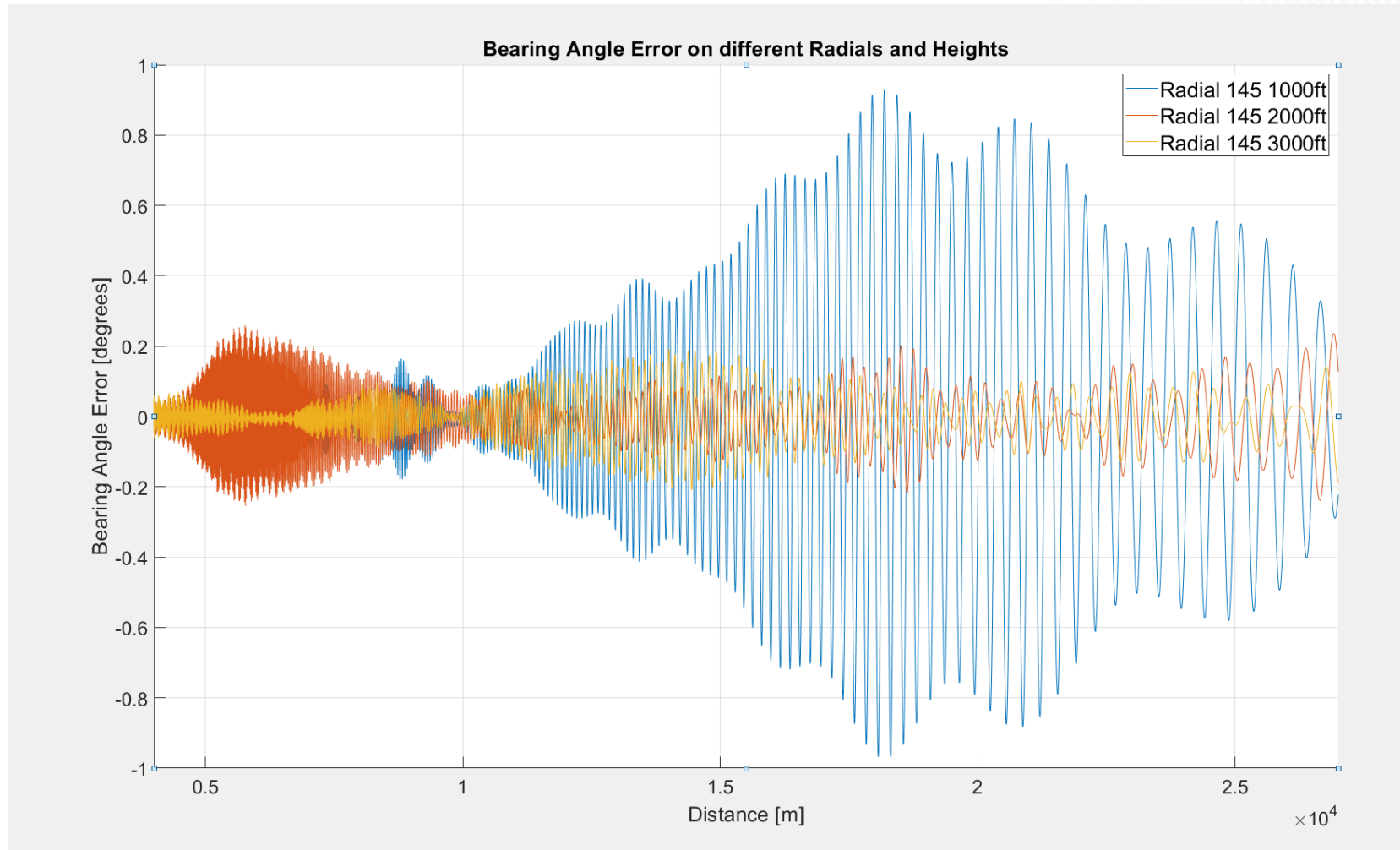
WT Simulation FEKO vs OHIO Tool



Different Orientations of Wind Turbines



Radial, different heights

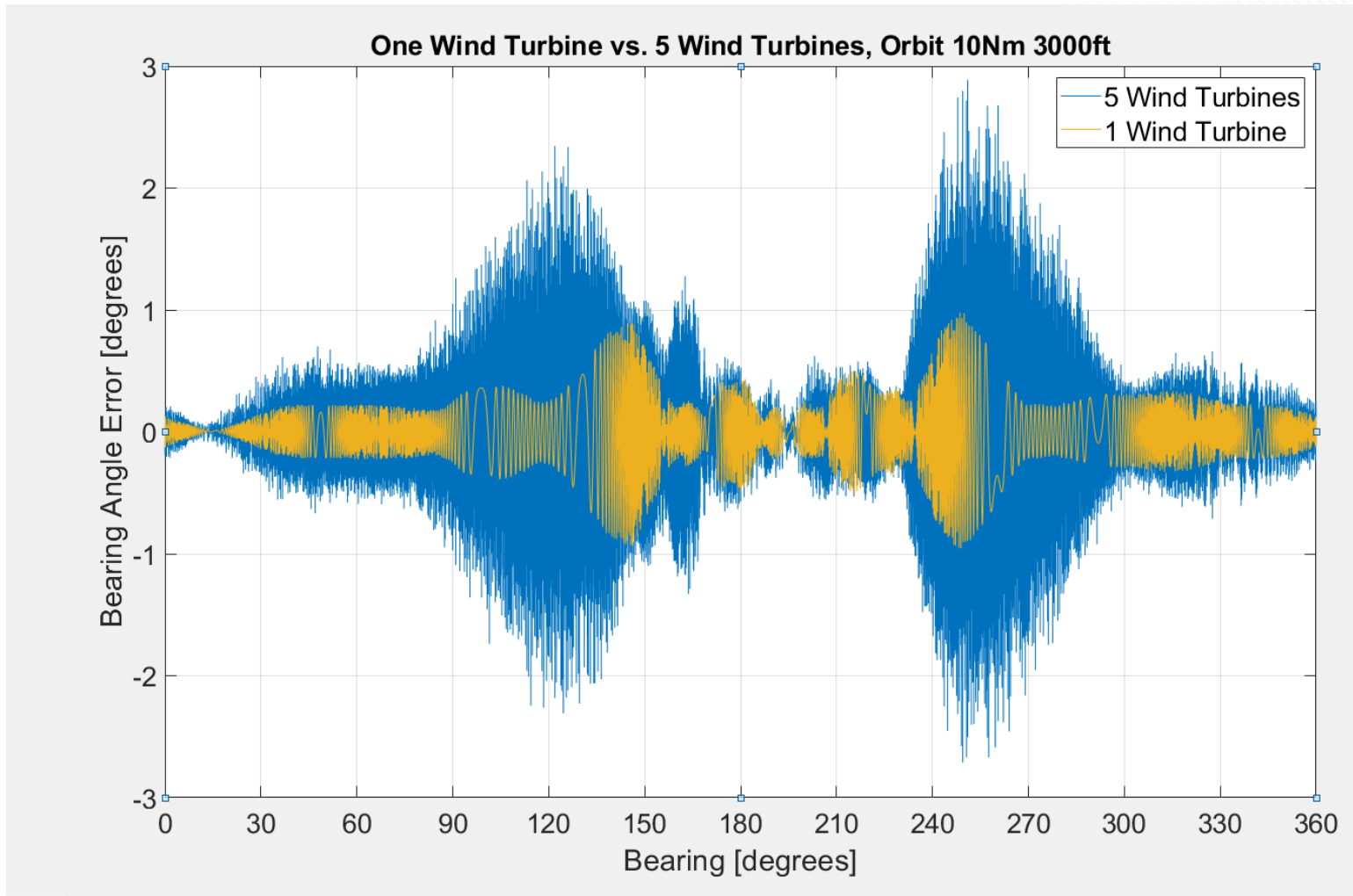


5 Wind Turbines

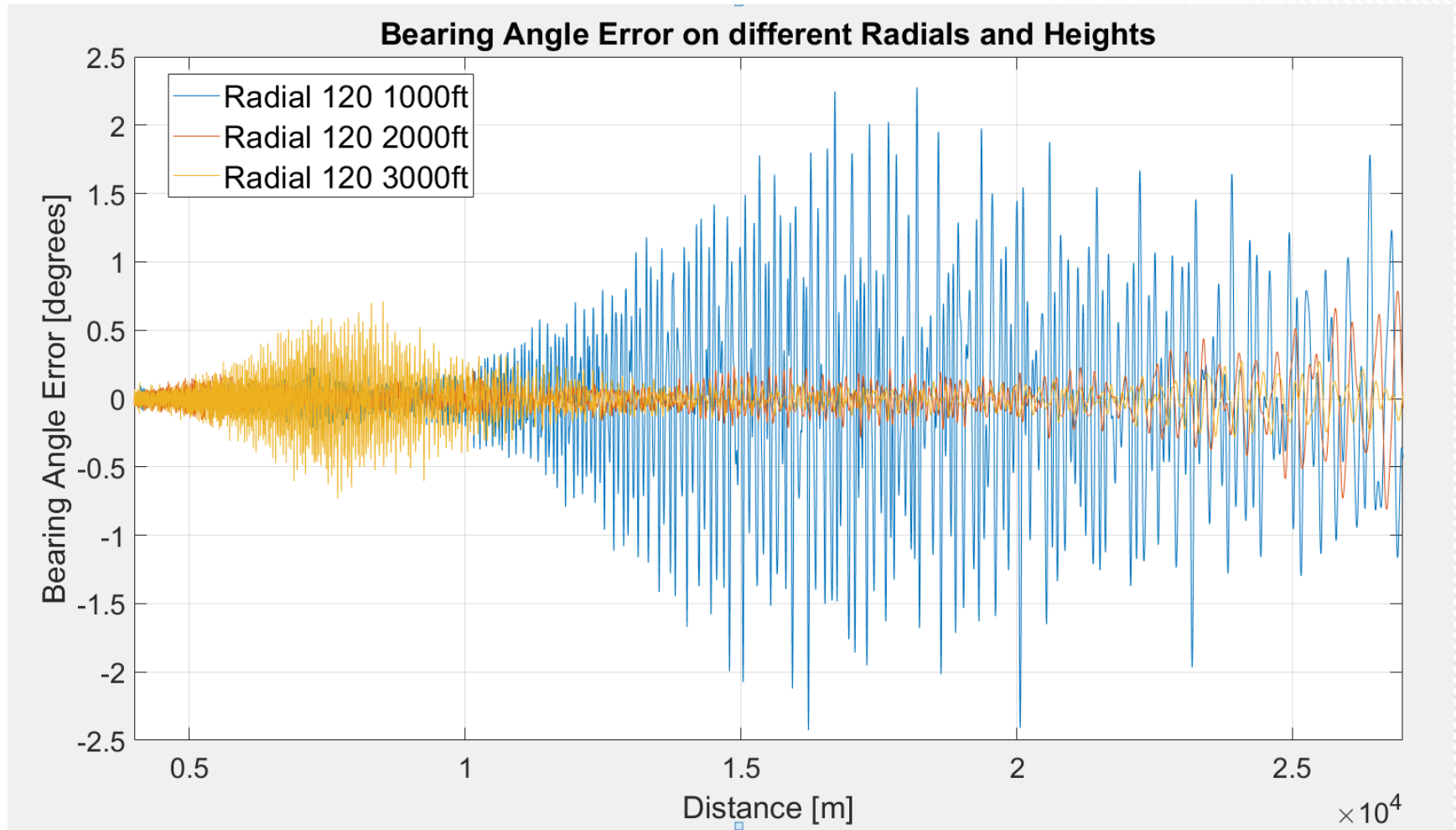


Distance 3100 - 5200m , Bearing 185° - 195°, Hub Height 165m

Orbit Simulations 1WT vs 5WT



Radial , different heights (5 WT)



Conclusion

- › CVOR Model implementation has been presented
- › Simulation approach has been compared with Ohio Tool
- › Validation with Measurement has been shown
- › Simulation studies with Wind Turbines and Crane have been presented



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500px.com/photo/15375671