EINSTEIN TELESCOPE

Geophysical Imaging and Monitoring | Physics Institute III B | RWTH AACHEN UNIVERSITY

Mitigating the Impact of Wind Turbines on the Einstein Telescope

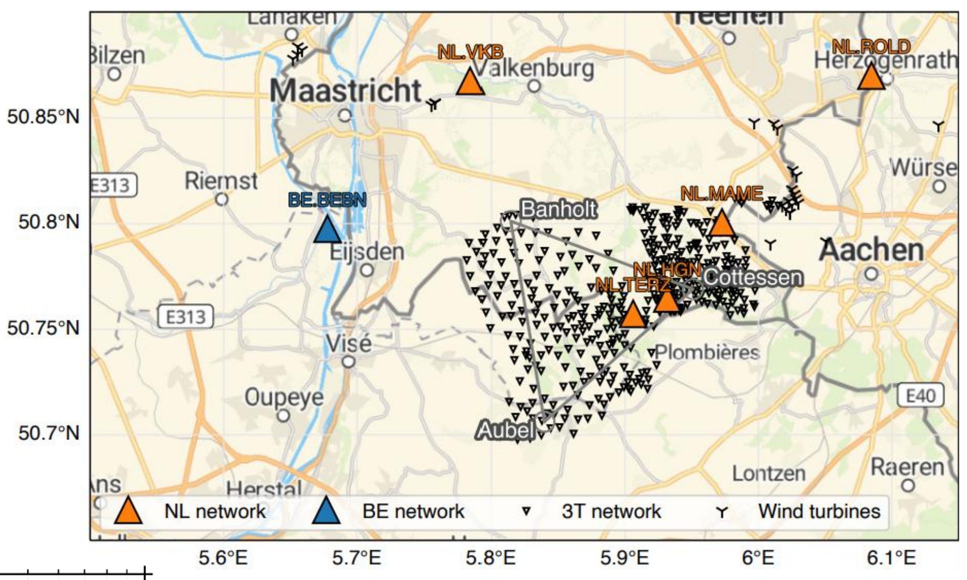
Marc Boxberg[2], Tom Niggemann[1], Niklas Nippe[1], Achim Stahl[1], Florian Wagner[2]

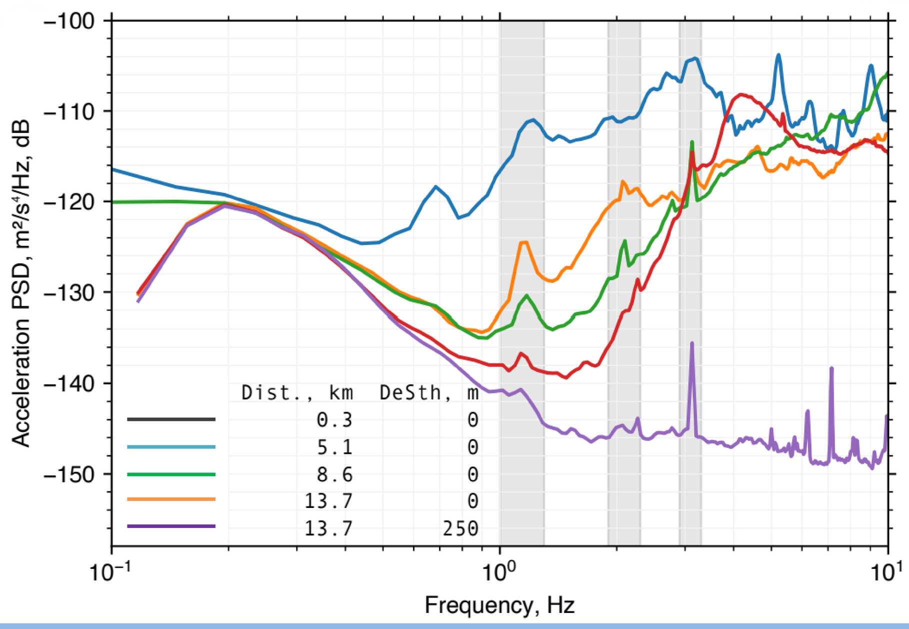
1 Physics Institute III B, RWTH Aachen University

2 Geophysical Imaging and Monitoring, RWTH Aachen University

Wind Turbine Seismic Noise in the EMR

- Seismic measurements performed by Shani-Kadmiel et al. in the Euregio Meuse-Rhine (EMR) in 2021 [1]
- ~ 400 geophones deployed west of the Aachen wind park
- Modelling of the geology and Newtonian Noise estimate



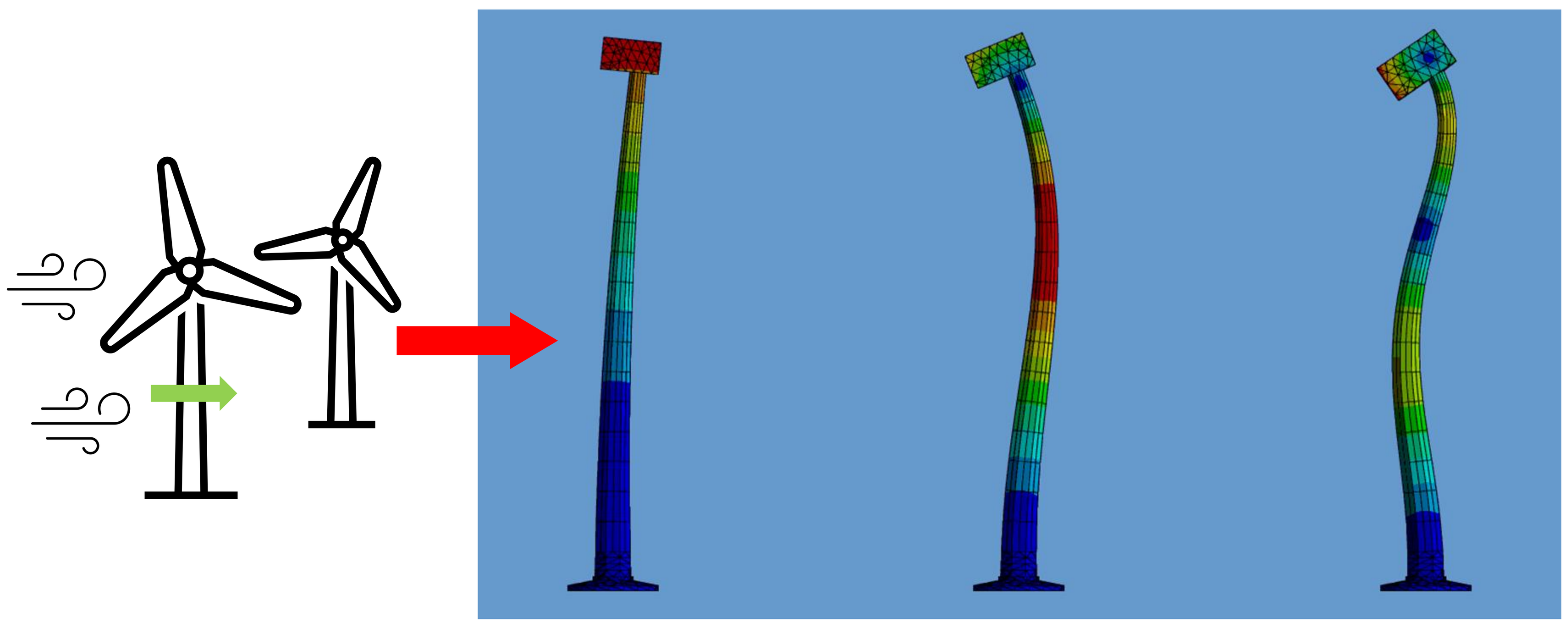


- Power spectral density dependency on the distance to the Aachen wind park [1]
- Spectral peaks are visible independent of distance
- The amplitude decreases with distance → **Peaks correspond to wind turbine tower eigenmodes**

Eigenmodes of Wind Turbines

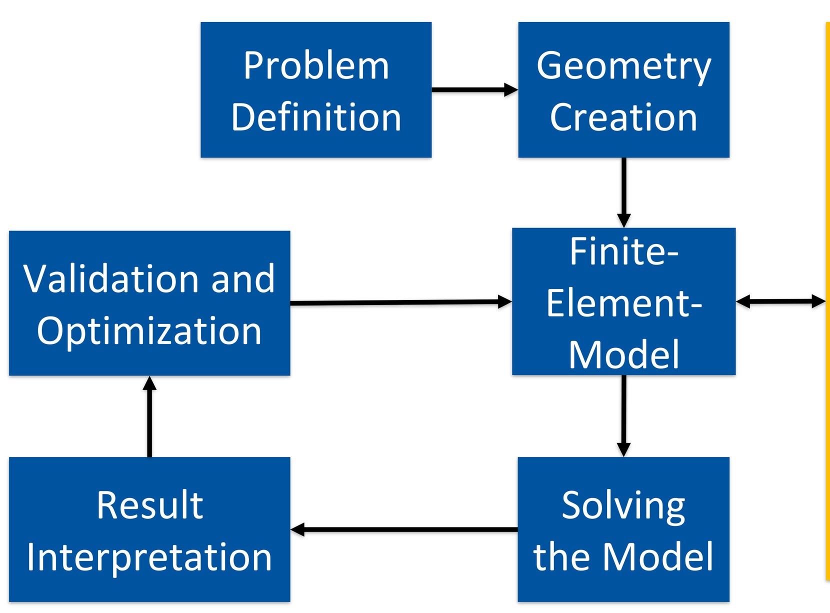
- **Rotor frequency** at about 0.08 – 0.33 Hz or 5 – 20 RPM **below ET's detection range**
- **Tower eigenmodes** are **more relevant** at 0.1 – 10 Hz and above

1. Wind pressure on the tower
2. Rotor blades periodically shield the tower
3. Excitation of tower eigenmodes
4. Vibrations propagate into the ground



Modal analysis with the Finite Element Method

Modal analysis is a fundamental method in structural dynamics for determining the **natural frequencies** and **modes** of a mechanical system. It shows **how** and at **which frequencies** a component or structure naturally vibrates - without any external excitation. Modal analysis uses the **finite element method (FEM)** as a tool to calculate the vibration properties of **complex structures**.



Steps in a FEM:

1. Define material properties
2. Select and assign geometries and elements
3. Meshing
4. Apply boundary conditions (supports)
5. Insert loads
6. Select result form
7. Check the model and repeat the steps if necessary

Mitigation Techniques

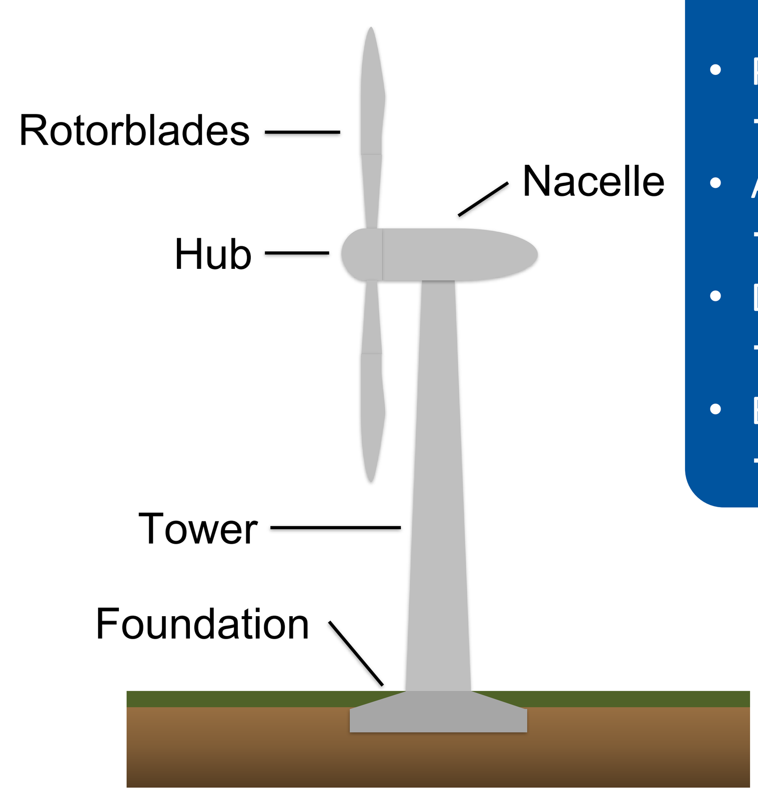
In order to reduce the seismic impact of wind turbines, different mitigation strategies and techniques are investigated.

- **Reduce excitation, dampen oscillation**
- **Decrease coupling to the ground, alter seismic wave propagation**

- **Criteria** for mitigation techniques are **cost**, **efficiency** and **applicability**
- **Availability** and other interests are also considered

- Firstly, investigation of the **different tower construction designs**
- Tubular tower, hybrid tower and girder masts
- Different forms
- Materials such as **concrete**, **steel** and **wood**

→ **Tower construction design alters eigenmodes and eigenfrequencies of the tower**



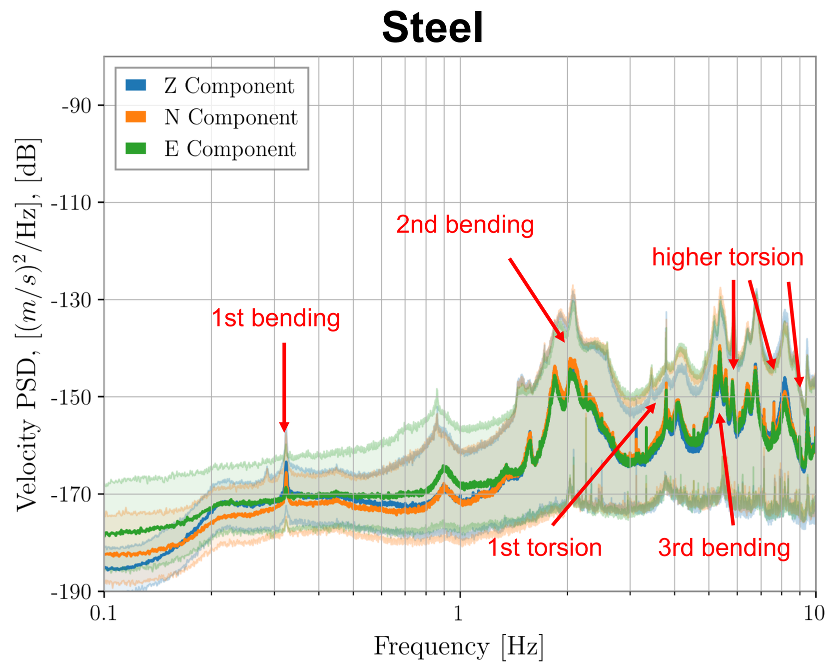
Measures to Reduce Disturbances

- Pitch control
  → Adjusting the angle of the turbine blades
- Active and Passive Vibration Damping
  → Tuned Mass Dampers (TMD)
- Different Tower Construction Designs
  → Girder masts, wooden tower
- Extending the Foundation
  → Increasing size and mass

Measuring & Simulating a Wooden & Steel Tower

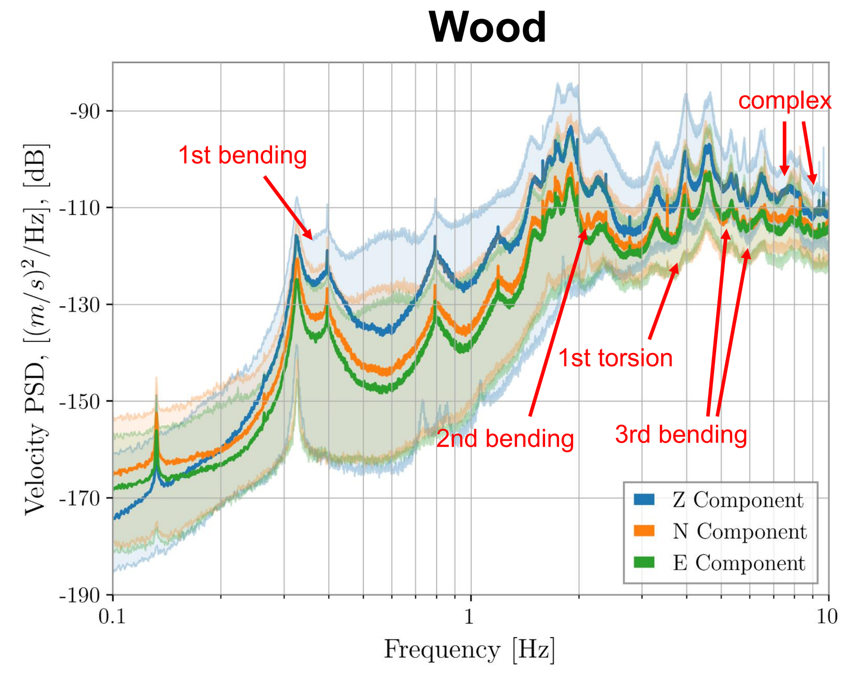
- Measurements at wind turbines of the type Vensys 77 with a hub height of **100 m**, one with a **steel tower**, the other with a **wooden tower**
- Each measurement was taken over a span of **13 days** with the **same 2 Hz geophones** [2]
- The geophones were placed directly next to the foundation of the turbine tower on the surface
- Data are evaluated by computing power spectral densities and identifying spectral speaks caused by the respective wind turbine
- Question: **Do the eigenfrequencies differ for the two materials?**
- **Identification of wind turbine effects via FEM simulations** in Ansys Mechanical [3]

Steel



Mode	Frequency [Hz]	Matching Spectral Peak [Hz]
1st bending	0.26129/0.26172	0.3245
2nd bending	1.8259/1.8412	2.05
1st torsion	3.5619	3.85
3rd bending	5.0113/5.3289	5.3
higher torsion	5.9527/6.2519	5.9
higher torsion	7.1461/7.1596	-
higher torsion	8.2457/8.2457	8.1
higher torsion	8.8961/8.9106	9.4
4th bending	10.021/10.044	-

Wood



Mode	Frequency [Hz]	Matching Spectral Peak [Hz]
1st bending	0.38207/0.38245	0.3269
2nd bending	2.0946/2.1598	2.0
1st torsion	2.9903	3.3
3rd bending	4.345/5.3499	4.6/5.3
complex	7.3235	7.9
complex	8.5885	7.9
complex	9.3646	-

→ **No significant difference in the eigenfrequencies for the two tower materials**

Niklas Nippe
niklas.nippe@rwth-aachen.de

Tom Niggemann
tom.niggemann@rwth-aachen.de

Phone: +49 241 80 27323

References:

[1] Sibilla Di Pace et al. "Research Facilities for Europe's Next Generation Gravitational-Wave Detector Einstein Telescope". In: Galaxies 10.3 (2022)

[2] DiGOS Potsdam GmbH. "Seismic Instruments. Developed for real field applications". 2020

[3] Ansys Mechanical. Finite Element Analysis (FEA) Software for Structural Engineering. https://www.ansys.com/de-de/products/structures/ansys-mechanical

Physics Institute III B
RWTH Aachen University
Otto-Blumenthal-Strasse
52074 Aachen GERMANY
Phone: +49 241 80 27301
Fax: +49 241 80 22244