Numerical Simulation of low-frequency micro seismic and acoustic emissions of onshore turbines: Comparison with acoustic and seismic measurements

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Patras

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Content

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- Simulation of acoustic-structure and soil-structure interaction
  - Boundary Element Method and Model
  - WT foundation
  - Acoustic source
  - Wave propagation due to acoustic source
  - Micro-seismic source
  - Wave propagation due to seismic source
  - Decay of acoustic and seismic emissions
- Comparison with acoustic and seismic measurements carried out at the wind turbine in Ingersheim
- Conclusions and outlook

Joint Research Project

"Objective criteria for vibration and sound emissions of onshore wind turbines" (TremAc) 2016 - 2019

Partners

- 8 research institutes from 5 universities: Aerodynamics and Gas Dynamics(USt), Wind Energy (TUM), Structural Engineering, Geotechnics and Geophysics (KIT), Psychology (Uni Bielefeld), Environmental Medicine (Uni Halle) and the industrial partner ENERCON
- Associated partners: Ingersheim, Wilstedt (WT)

Motivation

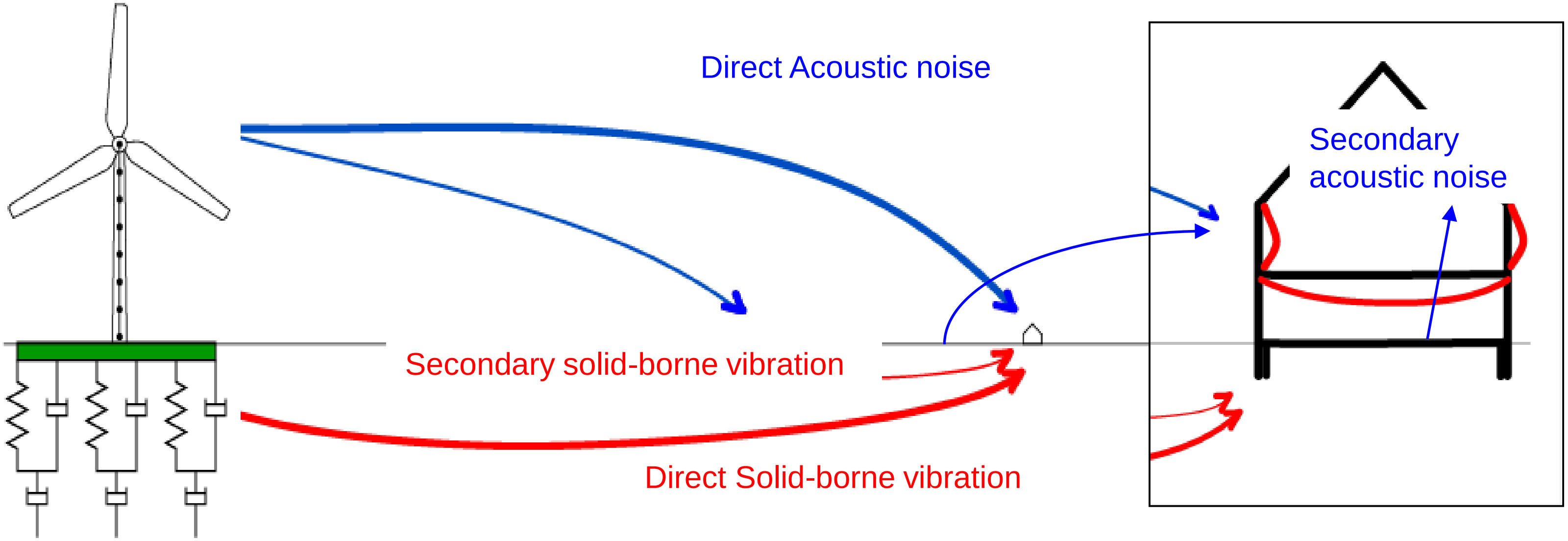
- Microseismic and acoustic noise generated during the operation of wind turbines can be a disturbance for residents

Objective

- Continuous chain of aerodynamic and elastic emission/propagation models from the blades to the resident's homes, validated by measurements, related to health and opinion

Chain of emisions (Simulation and monitoring)

- Acoustic and elastic wave propagation due to dynamic Soil-Structure Interaction
- Secondary effects caused by transmisions on the boundaries between the acoustic and elastic media (secondary noise in nearby building due to the vibration of structural elements and secondary elastic waves in the soil due to acoustic emissions)



Basic Idea of Boundary Element Method (BEM)

- Instead of searching the fundamental solution of the Helmholtz equation in one air domain

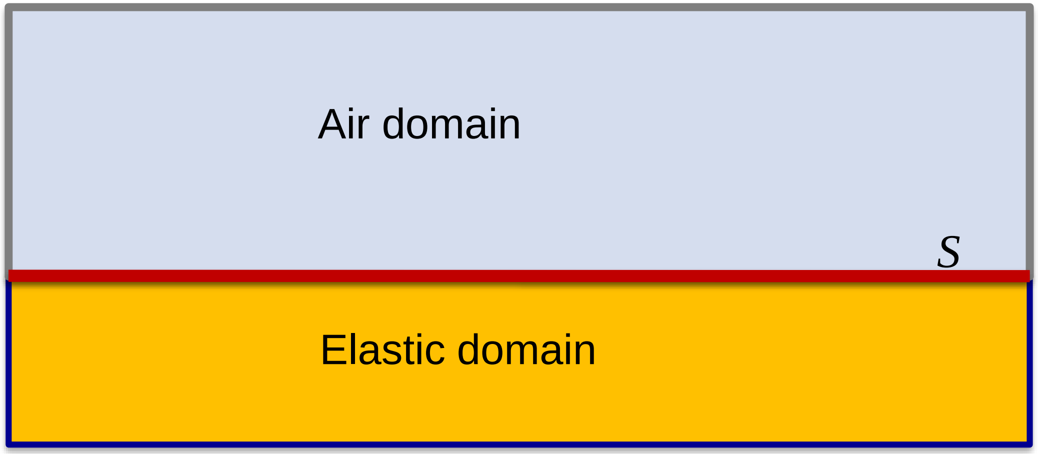
$$\nabla^2 \boldsymbol{p}(\boldsymbol{x}) + \left(\frac{\boldsymbol{\omega}}{\boldsymbol{c}}\right)^2 \cdot \boldsymbol{p}(\boldsymbol{x}) = 0$$

- and the fundamental solution of the Navier-Cauchy equation in one elastic domain

$$\boldsymbol{\mu} \cdot \nabla^2 \boldsymbol{u}(\boldsymbol{x}) + (\boldsymbol{\lambda} + \boldsymbol{\mu}) \cdot \nabla\nabla \boldsymbol{u}(\boldsymbol{x}) + \boldsymbol{\rho} \cdot \boldsymbol{\omega}^2 \cdot \boldsymbol{u}(\boldsymbol{x}) = 0$$

- or in several air domains (layers) or elastic domains (ground layers)

- for N^3 points inside the whole continuum
- search for the solution in **only N^2 points** on the boundary surface *S*



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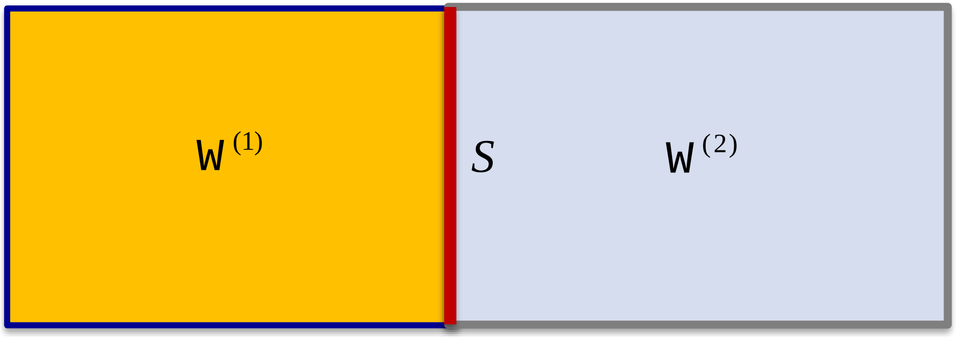
Boundary Element Method (BEM) for coupled elastic-acoustic domains

- Continuity conditions at interface *S:*

$$\boldsymbol{u}^1 = \boldsymbol{u}^2,\ \boldsymbol{t}^1 = -\boldsymbol{t}^2$$

$$p^1 = p^2,\ \partial_n p^1 = -\frac{\rho^1}{\rho^2}\partial_n p^2$$

$$\frac{1}{\omega^2\rho^1}\partial_n p^1 = -\widehat{\boldsymbol{n}}\cdot\boldsymbol{u}^2,\ p^1 = \widehat{\boldsymbol{n}}\cdot\boldsymbol{t}^2$$



- Fundamental solutions G and U of the boundary integral equations

$$\boldsymbol{c}(\boldsymbol{x})\cdot\boldsymbol{p}(\boldsymbol{x}) + \int \boldsymbol{\partial_n G}(\boldsymbol{x},\boldsymbol{y})\cdot\boldsymbol{p}(\boldsymbol{y})\boldsymbol{dS} = \int \boldsymbol{G}(\boldsymbol{x},\boldsymbol{y})\cdot\boldsymbol{\partial_n p}(\boldsymbol{y})\boldsymbol{dS}$$

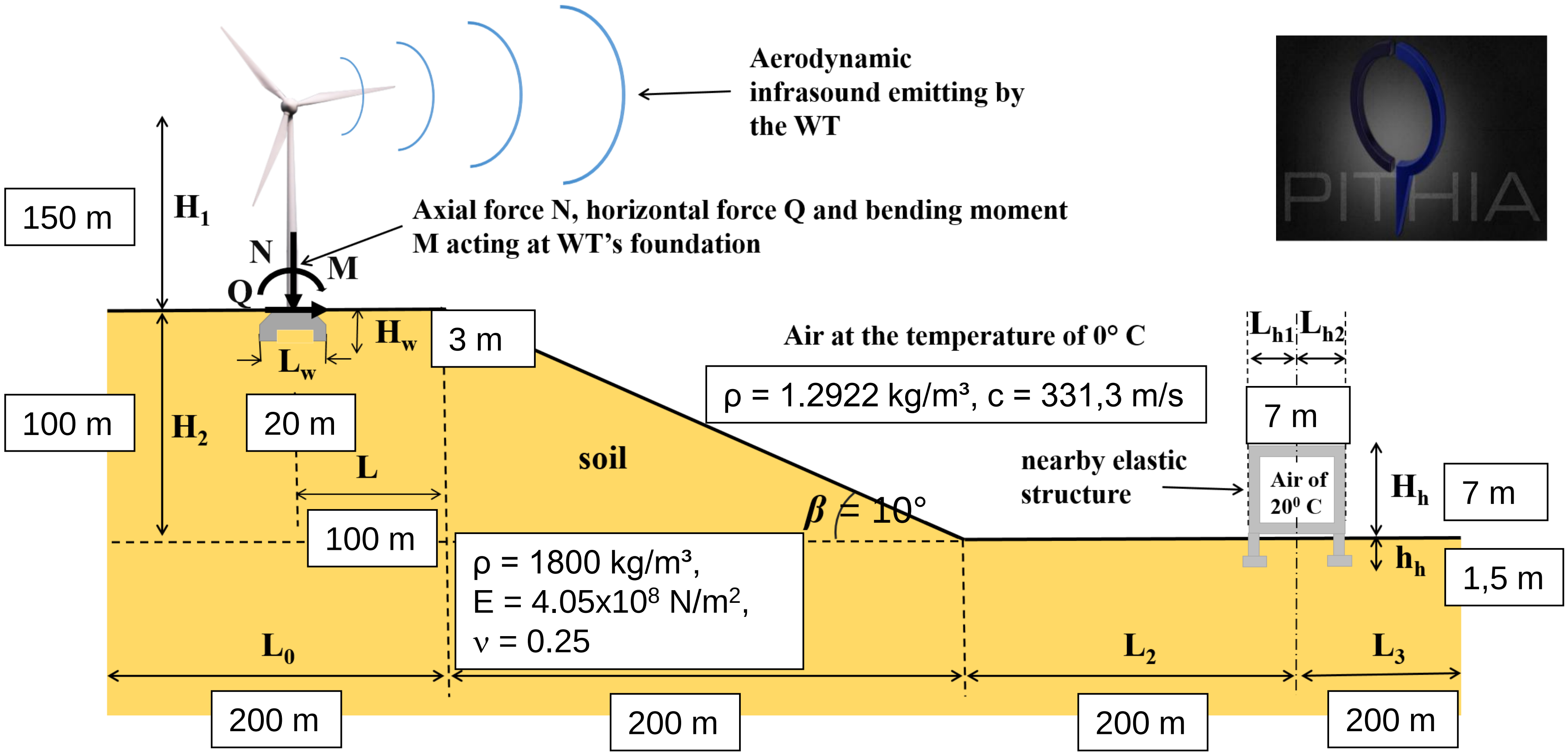
$$\boldsymbol{k}(\boldsymbol{x})\cdot\boldsymbol{u}(\boldsymbol{x}) + \int \boldsymbol{T}(\boldsymbol{x},\boldsymbol{y})\cdot\boldsymbol{u}(\boldsymbol{y})\boldsymbol{dS} = \int \boldsymbol{U}(\boldsymbol{x},\boldsymbol{y})\cdot\boldsymbol{t}(\boldsymbol{y})\boldsymbol{dS}$$

- p acoustic pressure, u displacement, t mechanical traction, ρ density
- Solution of linear systems of algebraic equations

$$\boldsymbol{T}\cdot\boldsymbol{u} = \boldsymbol{U}\cdot\boldsymbol{t} \qquad \boldsymbol{Q}\cdot\boldsymbol{p} = \boldsymbol{G}\cdot\boldsymbol{q}$$

Hierarchical-submatrices (Gkortsas et al., 2017)

Boundary Element Model



- 5 Regions: Granular soil, foundation of WT, building and two air regions
- Soil linear elastic, justified by measurements due to the small disp. amplitudes
- ≈100000 four-node linear boundary elements at all boundaries and interfaces

Acoustic and Microseismic Actions due to WT operation

Load Simulation by UST-IAG:

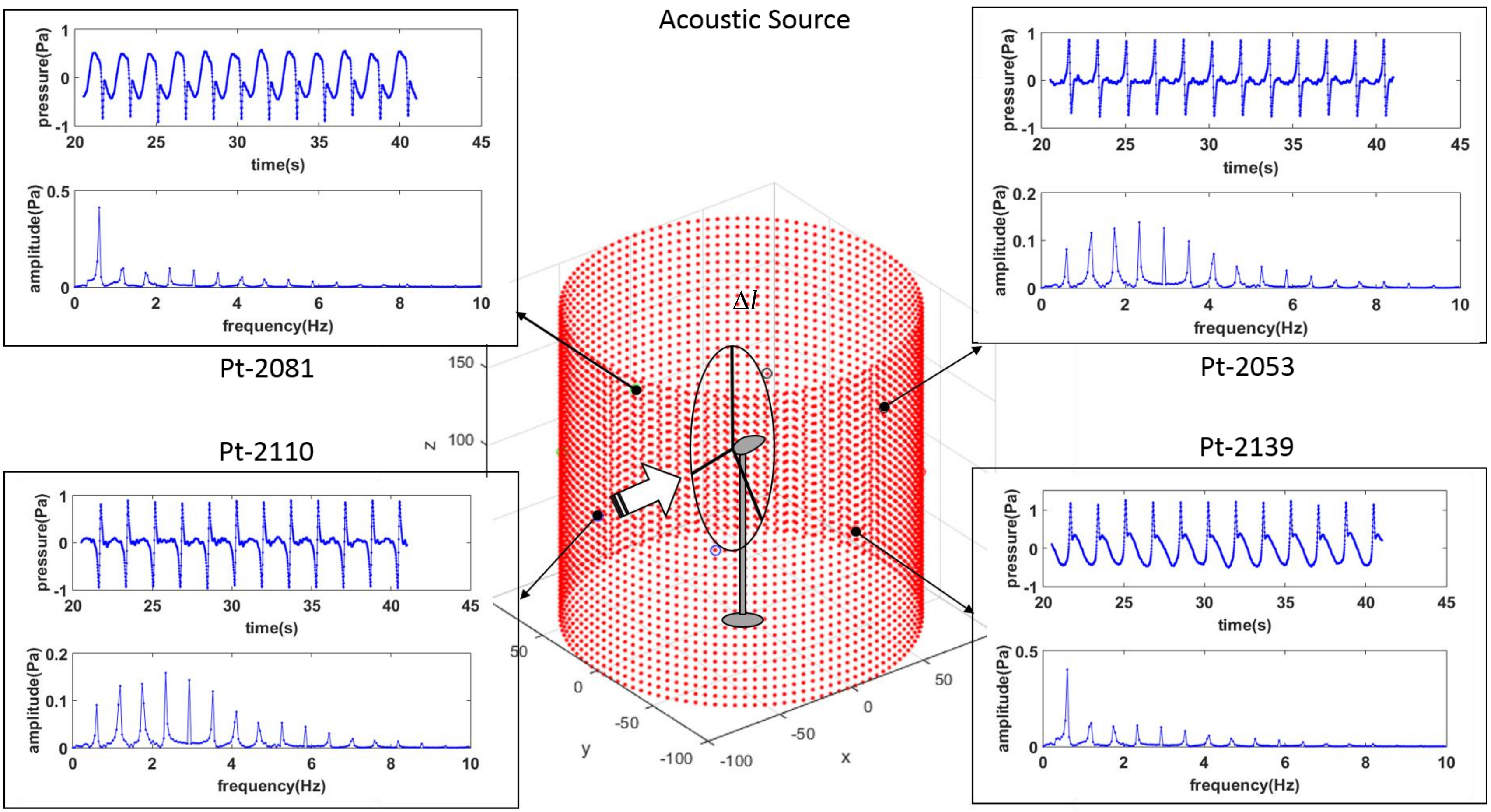
- CFD code FLOWER, uniform or turbulent inflow, delivers acoustic pressure
- Structural code SIMPACK coupled to FLOWER delivers 6 tower base load components
- Simulation of 41 sec. WT operation at 12 m/s wind as time series (aerodynamic and acoustic rotor-tower interaction is taken into account)

Further Proceeding:

- Perform FFT for each time series
- Subtract mean values (due to constant load or steady wind) and irregular amplitudes at the start of simulation
- Identification of dominating frequencies and their amplitudes
- Application to their respective source points as mean-value-free harmonic signals for BEM simulations in the frequency domain.

Acoustic Source around WT

- Acoustic pressure interface: 4218 equidistant points (distance 5 m) on a cylinder (R = 100 m, H = 200 m) around the WT



Acoustic Source around WT

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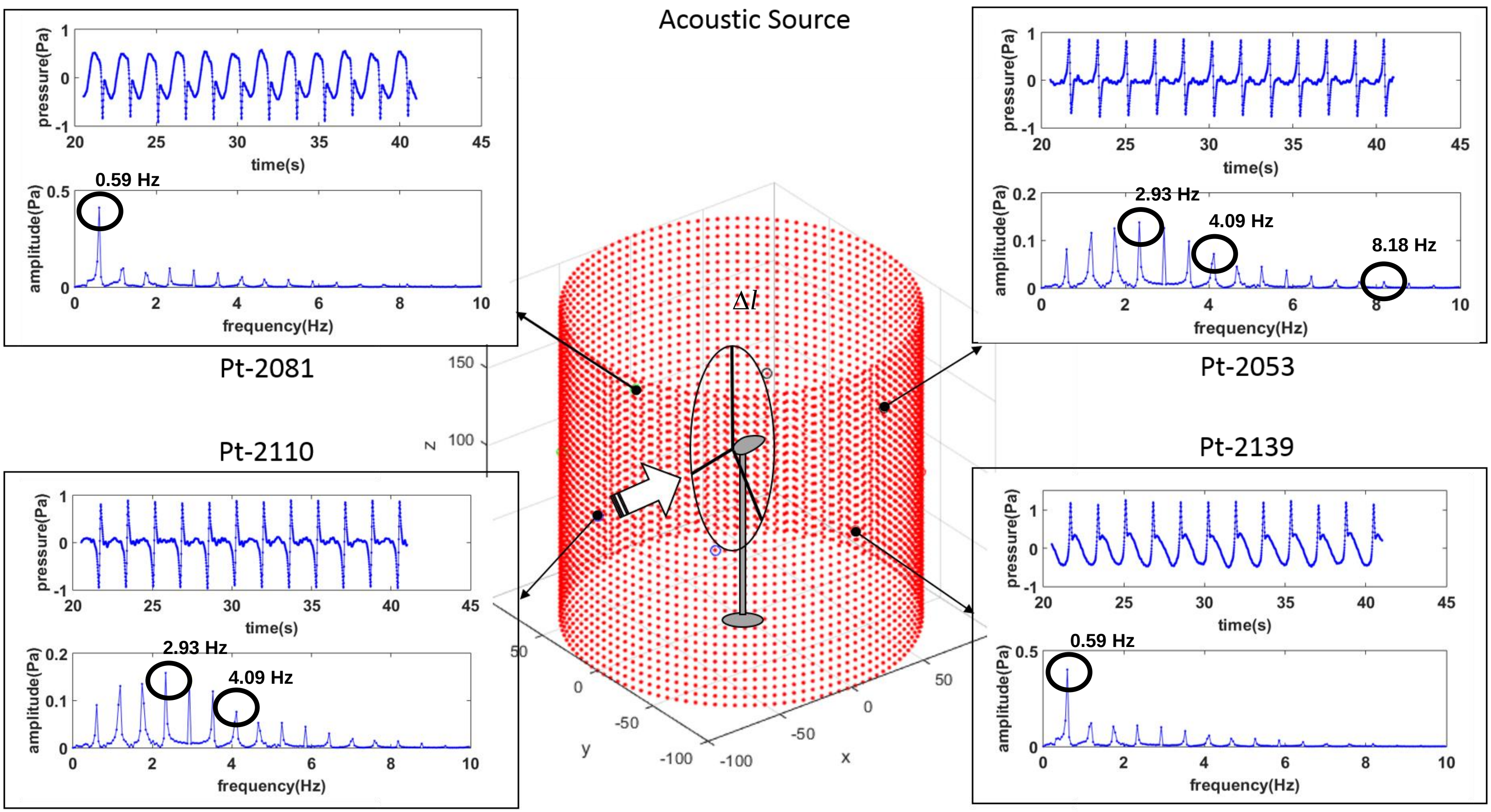
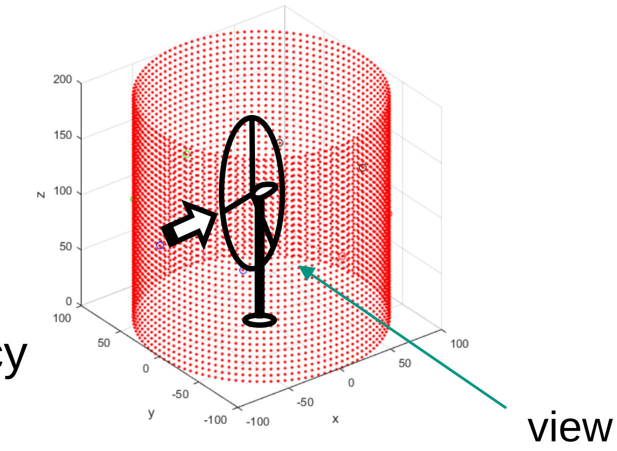
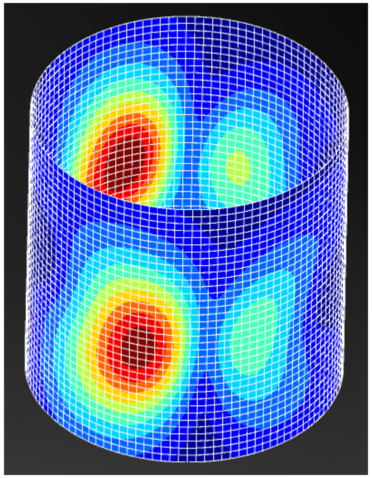


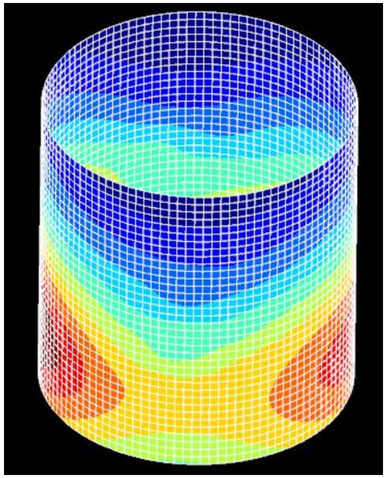
Acoustic Source around WT

- Acoustic pressure distribution on source cylinder for the examined frequencies
- Viewed in rotor plane (y-direction)
- Pronounced directivity change with frequency

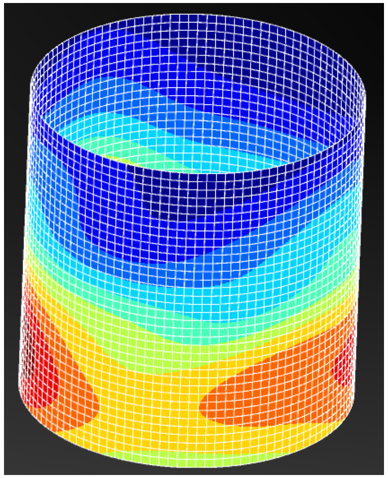




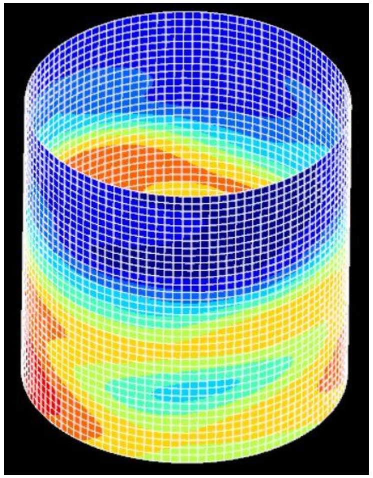
f = 0.59 Hz
|p| = 0.89 Pa



f = 2.93 Hz
|p| = 0.144 Pa



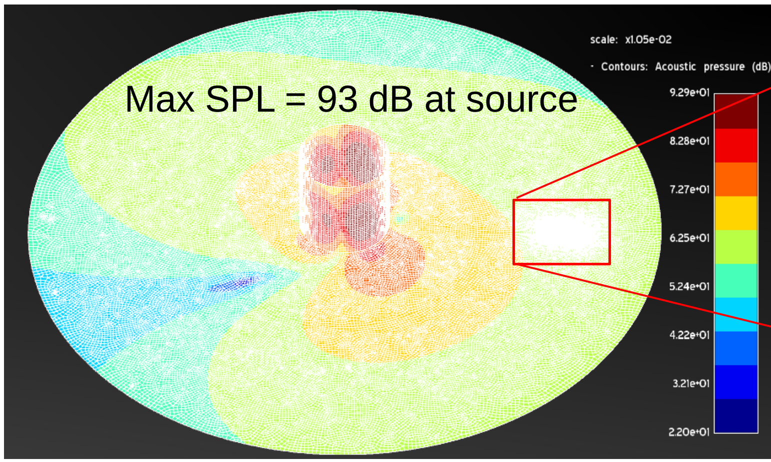
f = 4.09 Hz
|p| = 0.095 Pa

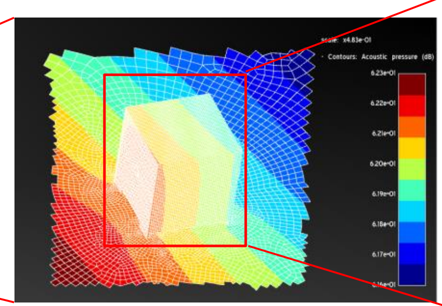


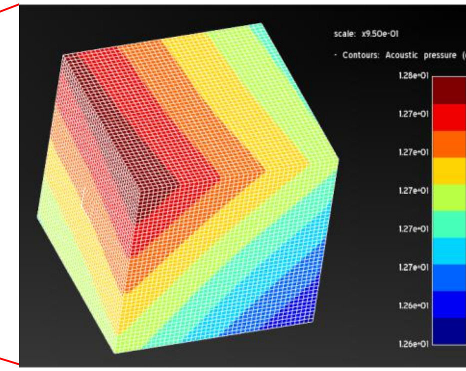
f = 8.18 Hz
|p| = 0.018 Pa

Wave Propagation due to Acoustic Source (uniform inflow)

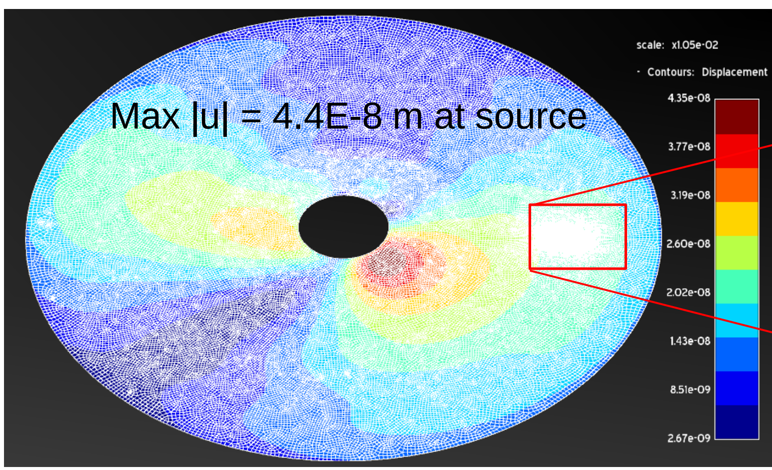
- Acoustic pressure and secondary displacement amplitudes for **f = 0.59 Hz**
- Source 180° rotated (so that main directivity hits building)



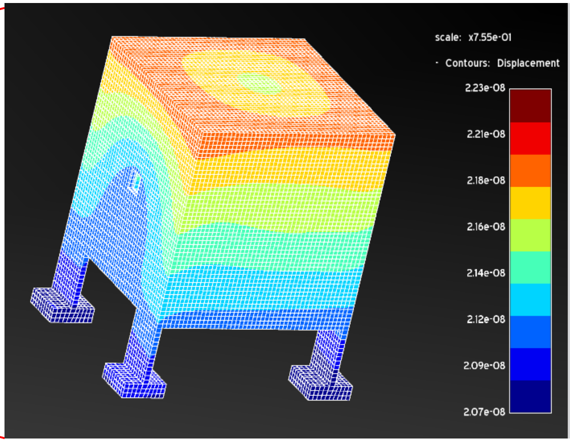




Max SPL = 62 dB outdoor, 12 dB indoor



Max |u| = 2.2E-8 m at building



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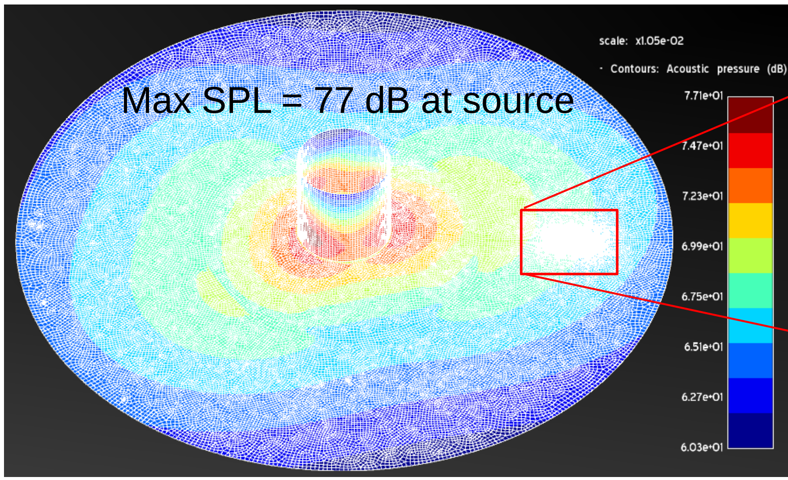
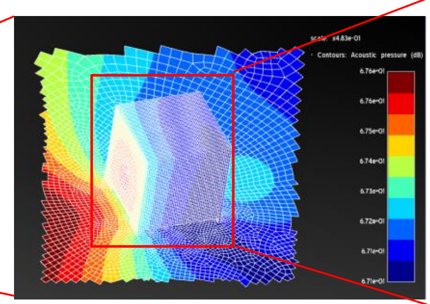
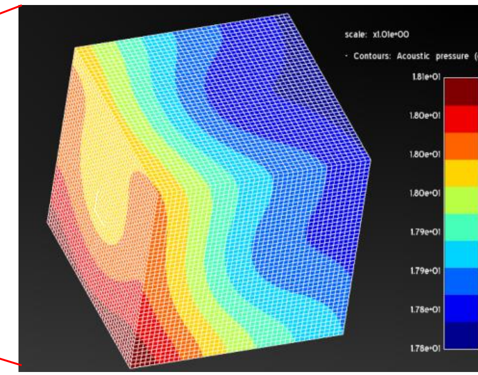
Wave Propagation due to Acoustic Source (uniform inflow)

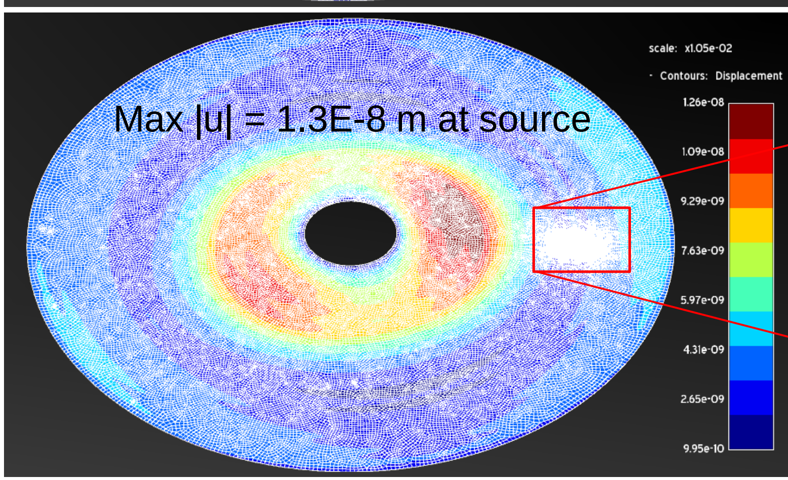
- Acoustic pressure and secondary displacement amplitudes for **f = 2.93 Hz**
- Source 180° rotated (so that main directivity hits building)



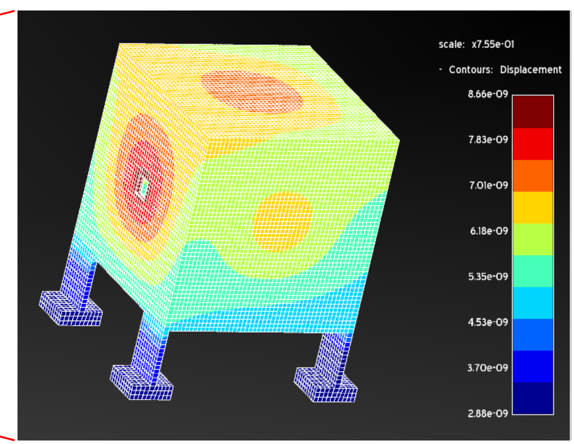




Max SPL = 68 dB outdoor, 19 dB indoor

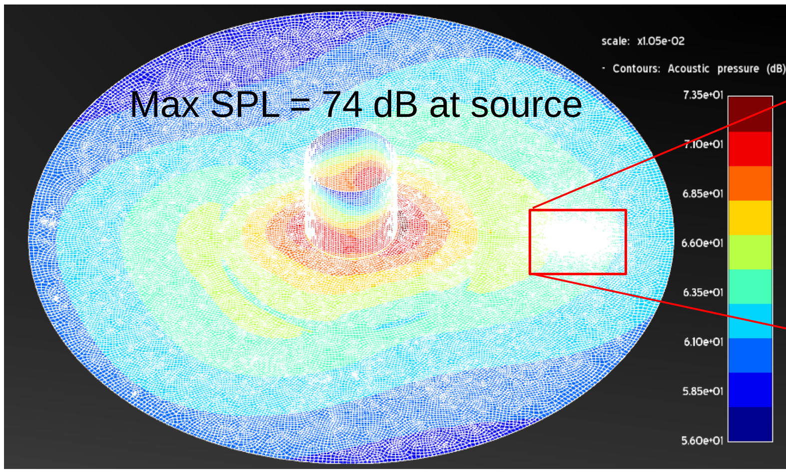


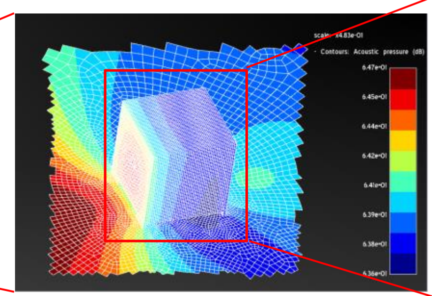
Max |u| = 8.7E-9 m
at building

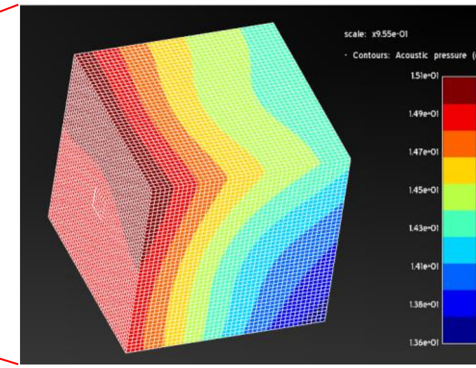


Wave Propagation due to Acoustic Source (uniform inflow)

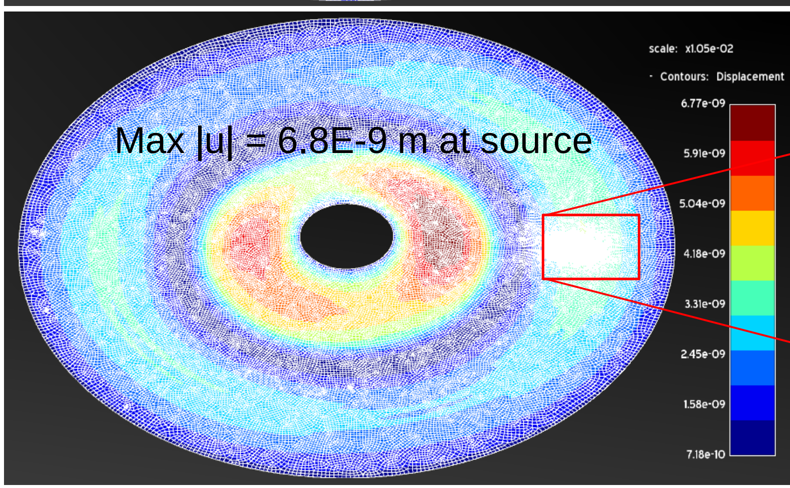
- Acoustic pressure and secondary displacement amplitudes for **f = 4.09 Hz**
- Source 180° rotated (so that main directivity hits building)



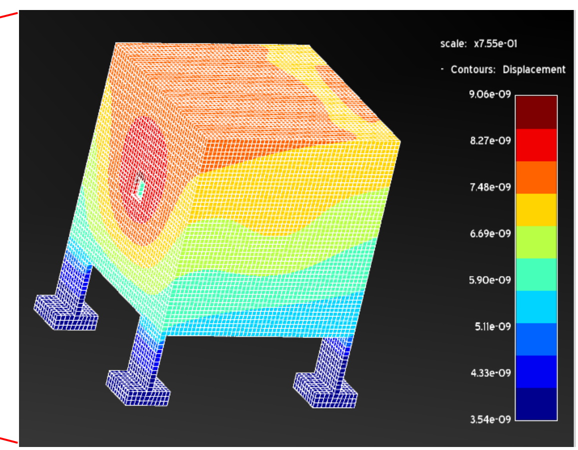




Max SPL = 65 dB outdoor, 15 dB indoor

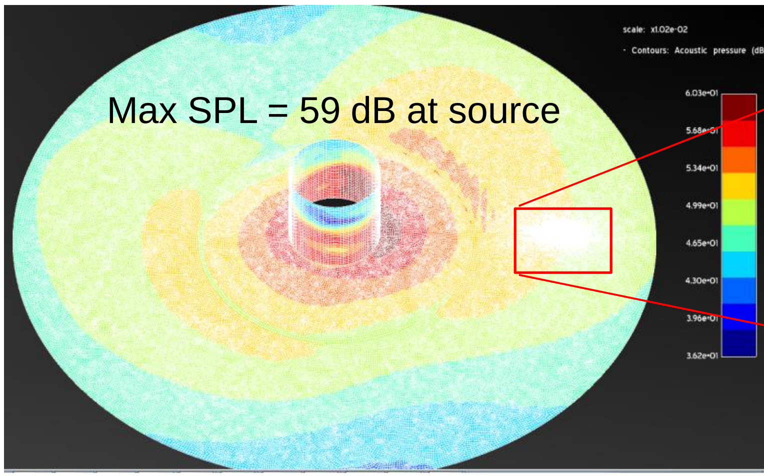


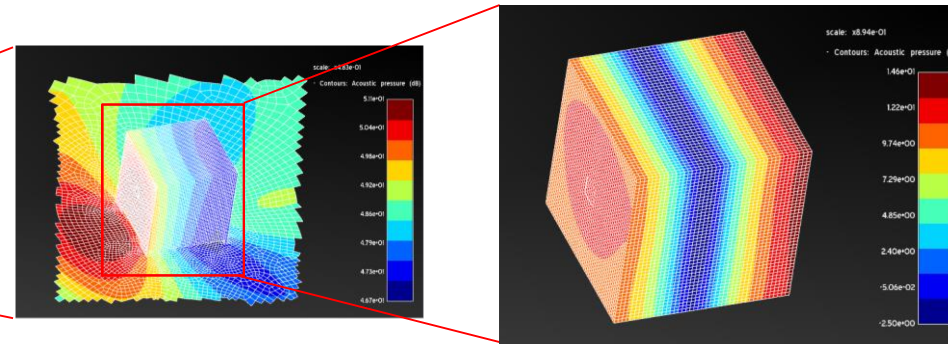
Max |u| = 5.1E-9 m at building



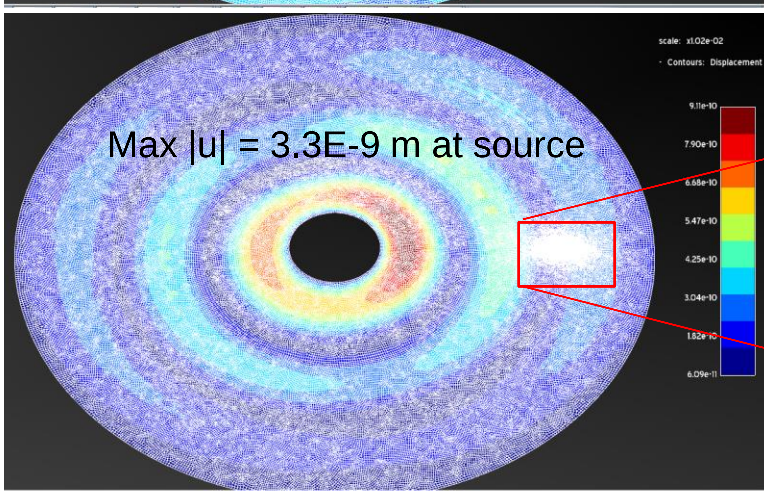
Wave Propagation due to Acoustic Source (uniform inflow)

- Acoustic pressure and secondary displacement amplitudes for **f = 8.18 Hz**
- Source 180° rotated (so that main directivity hits building)

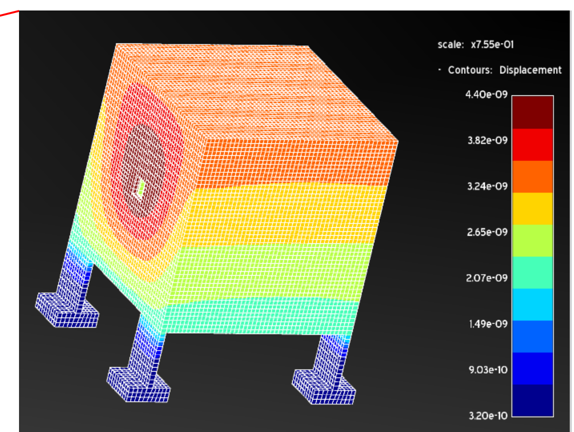




Max SPL = 51 dB outdoor, 15 dB indoor



Max |u| = 2.4E-9 m at building



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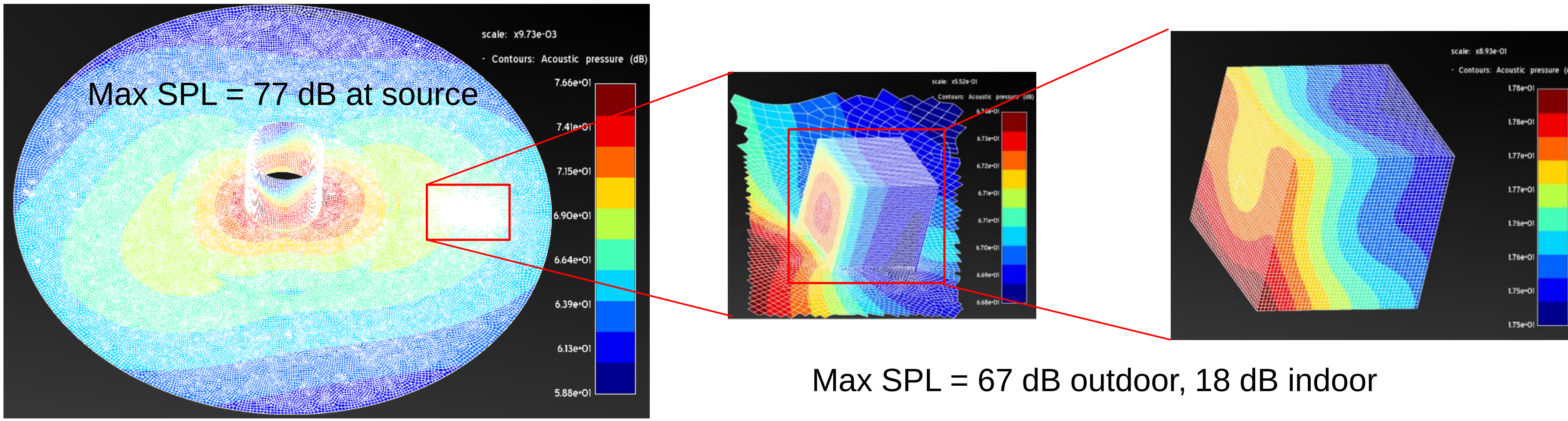
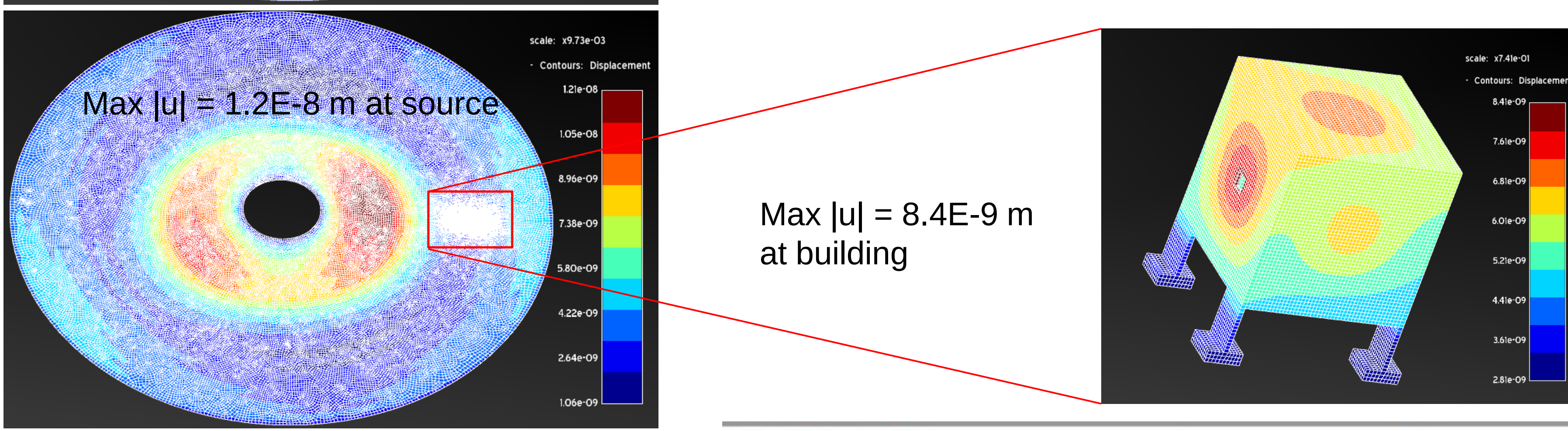
Wave Propagation due to Acoustic Source (turbulent inflow)

- Acoustic pressure and secondary displacement amplitudes for **f = 2.93 Hz**
- Source 180° rotated (so that main directivity hits building)





Acoustic pressure and displacement amplitudes due to Acoustic Source (uniform inflow)

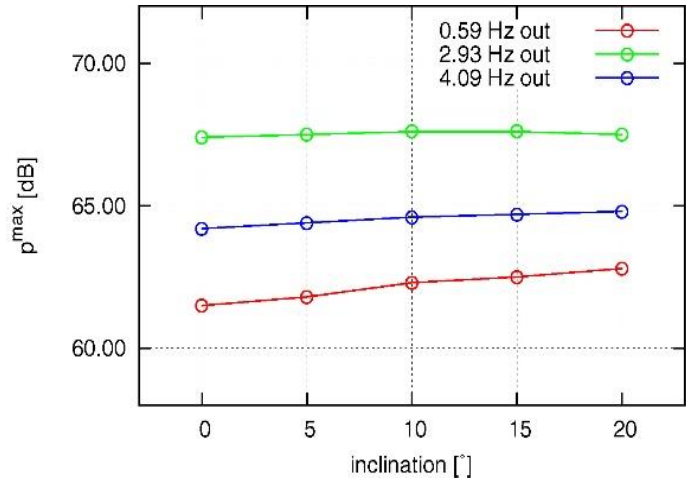
- Variation of building distance

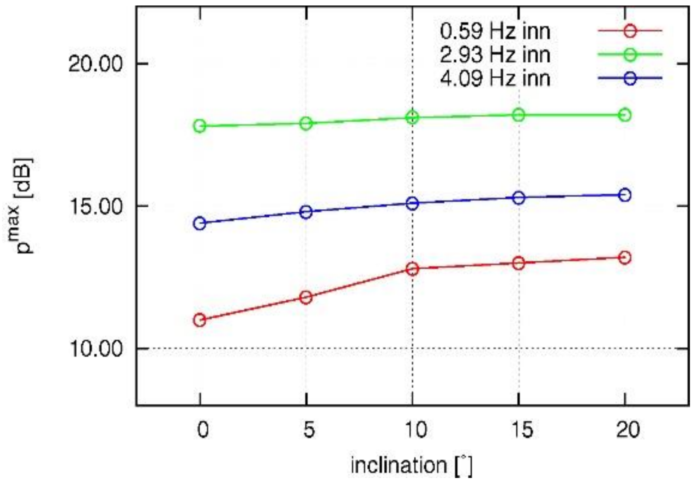
Freq. [Hz]	Pressure level outside building [dB]				Pressure level inside building [dB]			
	Build. at 350 m	Build. at 500 m	Build. at 650 m	Build. at 1 km	Build. at 350 m	Build. at 500 m	Build. at 650 m	Build. at 1 km
0.59	66	62	60	56	16	13	11	5
2.93	70	68	66	62	21	19	16	13
4.09	67	65	63	60	17	15	13	10

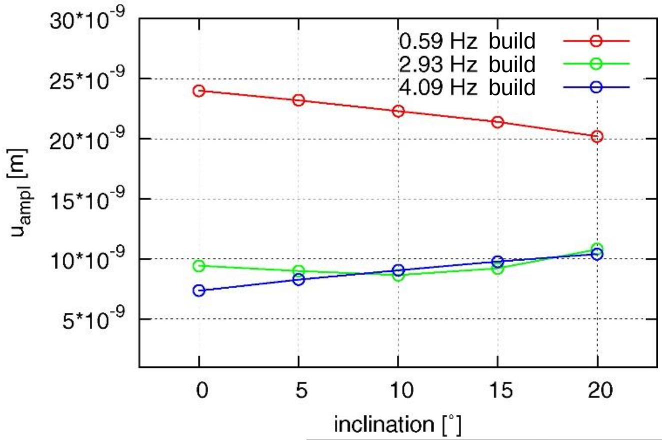
Freq. [Hz]	Displacement amplitude at building [m]			
	Building at 350 m	Building at 500 m	Building at 650 m	Building at 1 km
0.59	2.7E-08	2.2E-08	1.9E-08	1.2E-08
2.93	1.5E-08	8.7E-09	7.0E-09	5.2E-09
4.09	5.7E-09	5.1E-09	3.8E-09	2.8E-09

Acoustic pressure and displacement amplitudes due to Acoustic Source (uniform inflow)

- Variation of slope inclination

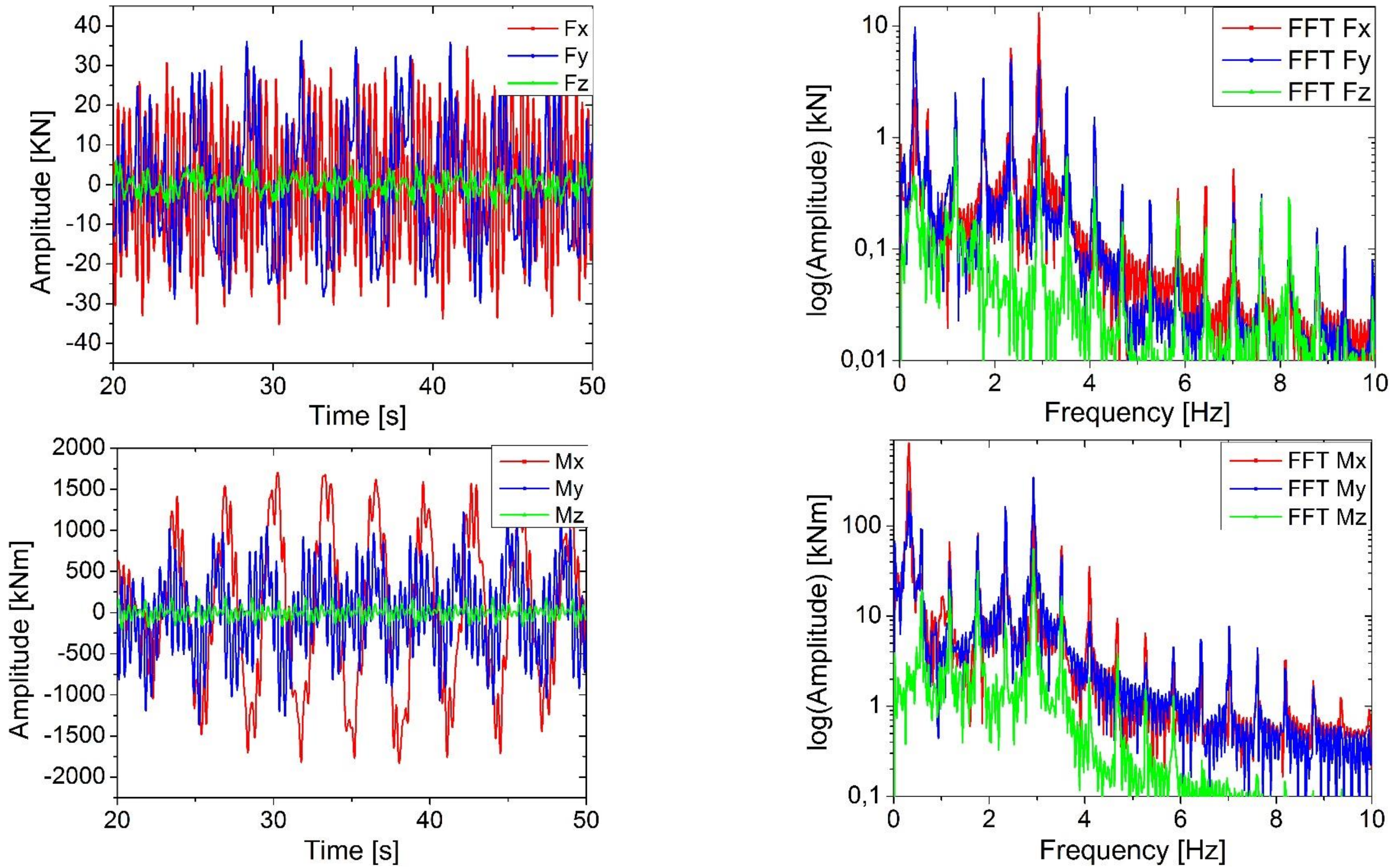






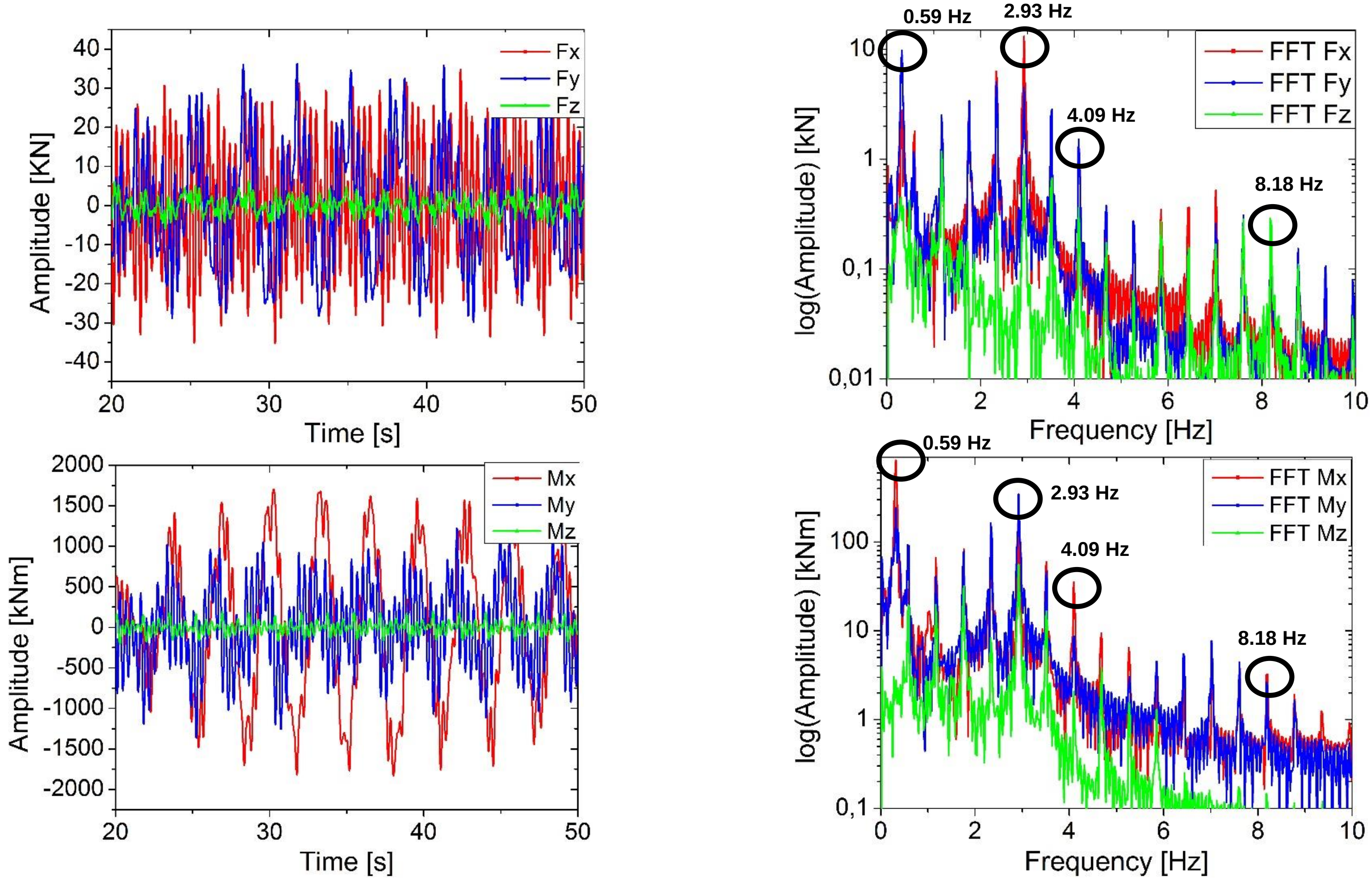
Micro-seismic Source at WT

- Mechanical load interface: foundation base (R = 9.9 m, H = 3.0 m)
- Dominant frequencies also 0.59, 2.93, 4.09, 8.18 Hz



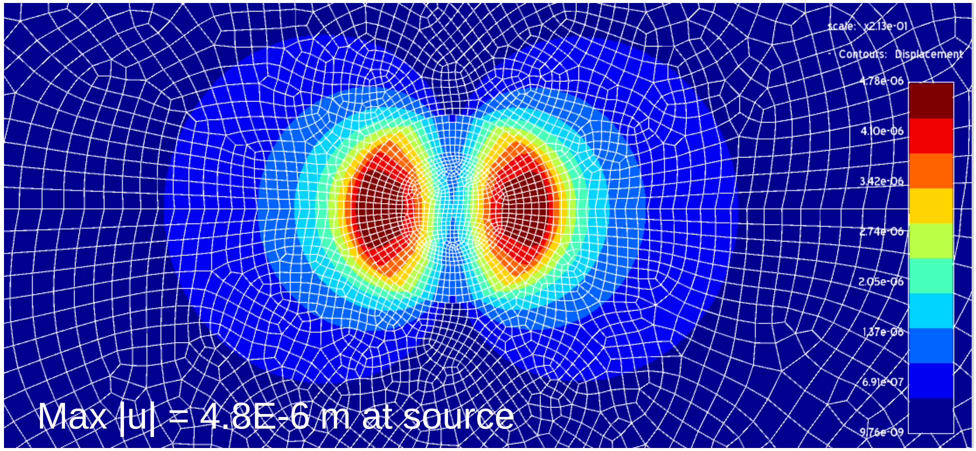
Micro-seismic Source at WT

- Mechanical load interface: foundation base (R = 9.9 m, H = 3.0 m)
- Dominant frequencies also 0.59, 2.93, 4.09, 8.18 Hz

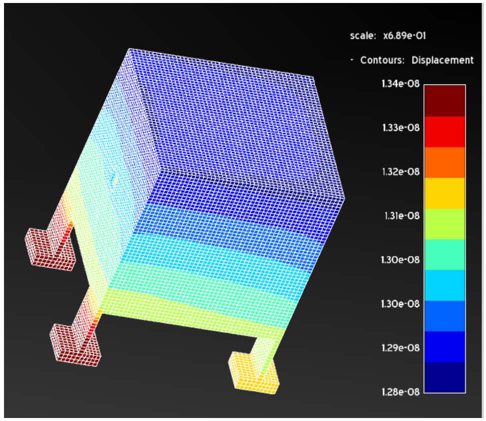


Wave Propagation due to Seismic Source (uniform inflow)

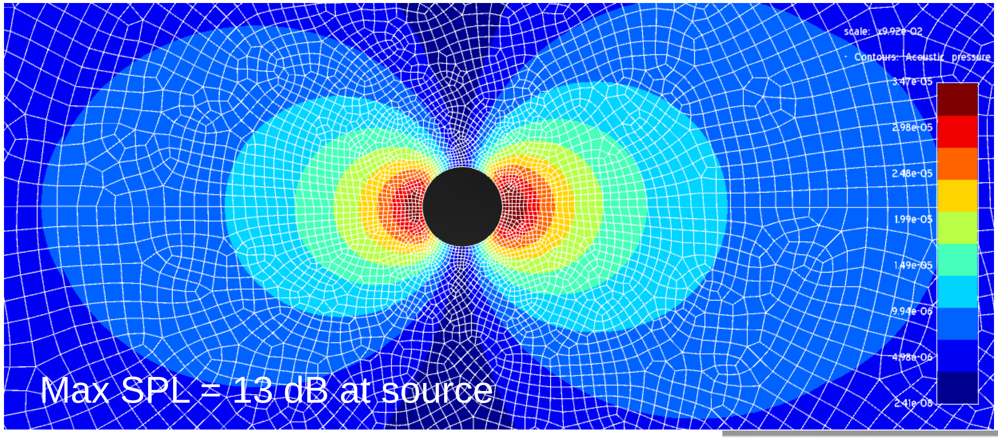
- Displacement and secondary acoustic pressure amplitudes for **f = 0.59 Hz**
- Source not rotated (main directivity hits building)



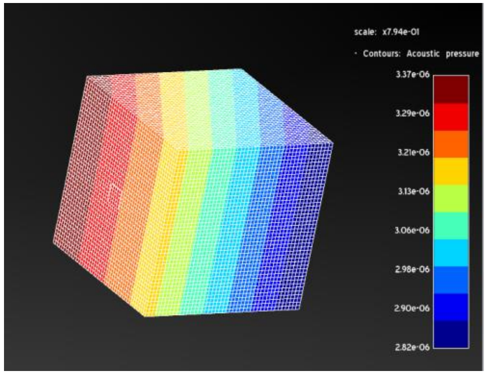
Max |u| = 4.8E-6 m at source



Max |u| = 1.4E-8 m at building



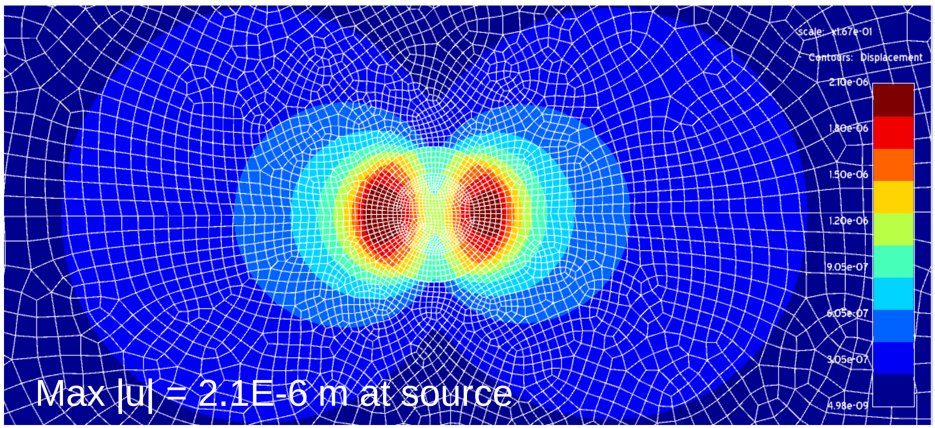
Max SPL = 13 dB at source

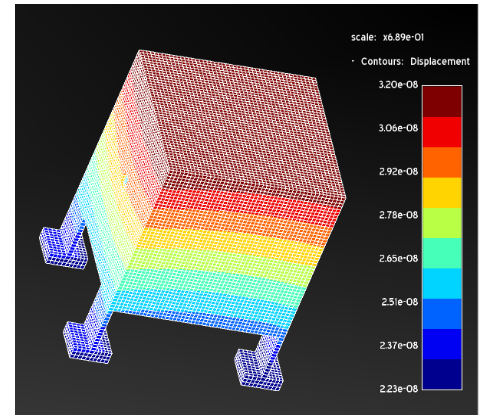


Max SPL = -7 dB outdoor, -15 dB indoor

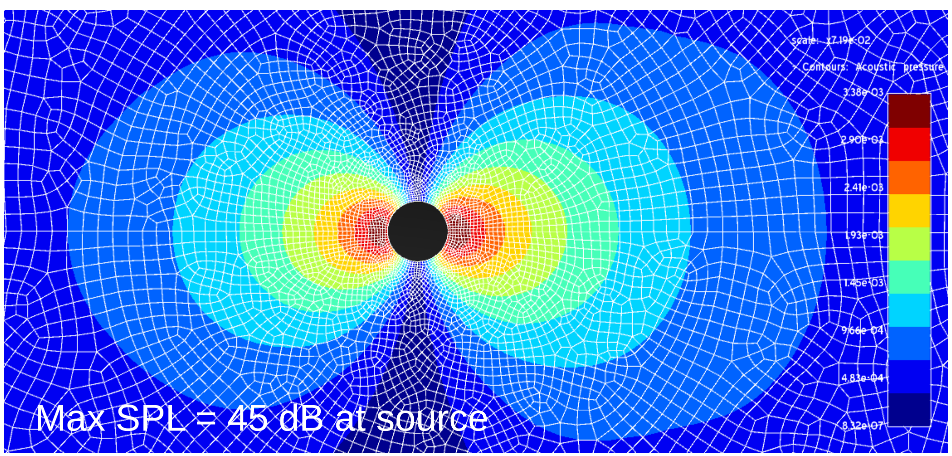
Wave Propagation due to Seismic Source (uniform inflow)

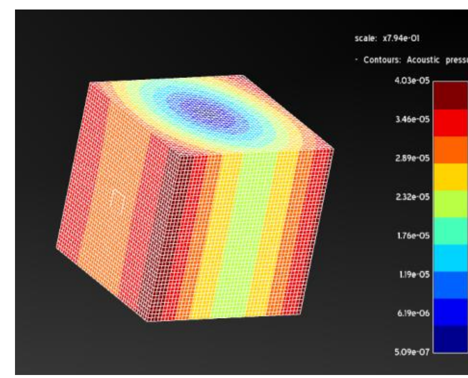
- Displacement and secondary acoustic pressure amplitudes for **f = 2.93 Hz**
- Source not rotated (main directivity hits building)





Max |u| = 3.2E-8 m at building

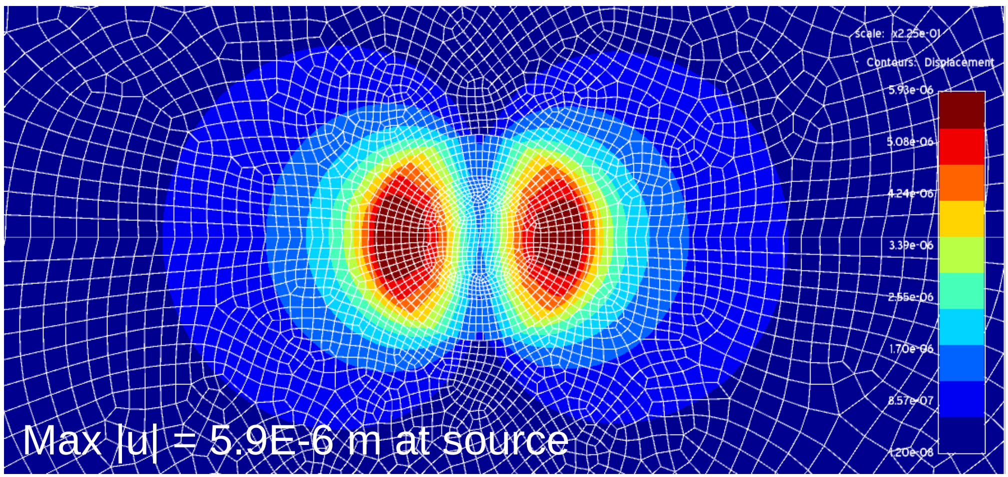




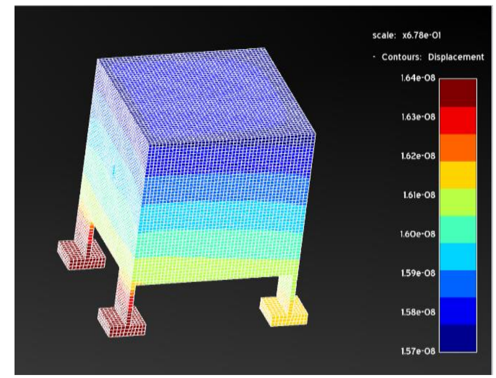
Max SPL = 21 dB outdoor, 7 dB indoor

Wave Propagation due to Seismic Source (turbulent inflow)

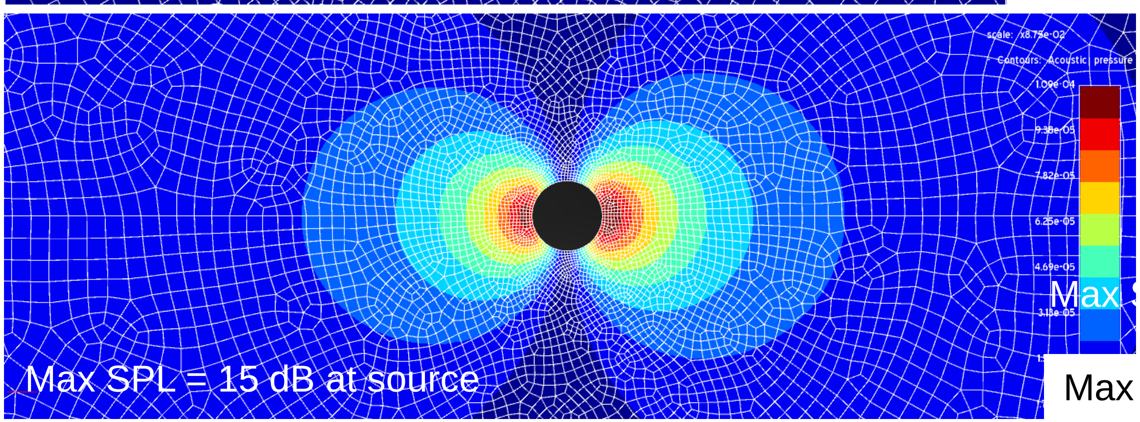
- Displacement and secondary acoustic pressure amplitudes for **f = 0.59 Hz**
- Source not rotated (main directivity hits building)



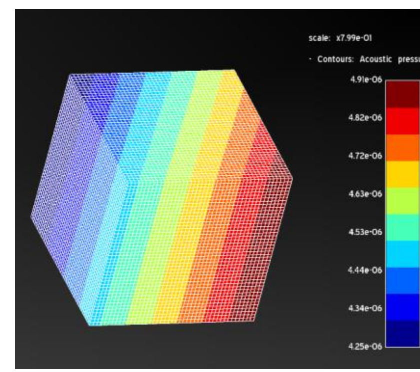
Max |u| = 5.9E-6 m at source



Max |u| = 1.7E-8 m at building



Max SPL = 15 dB at source



Max SPL = -4 dB outdoor, -12 dB indoor

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Acoustic pressure and displacement amplitudes due to Seismic Source (uniform inflow)

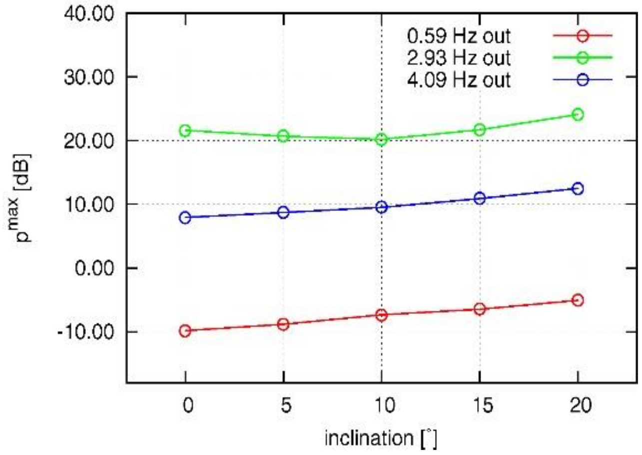
- Variation of building distance

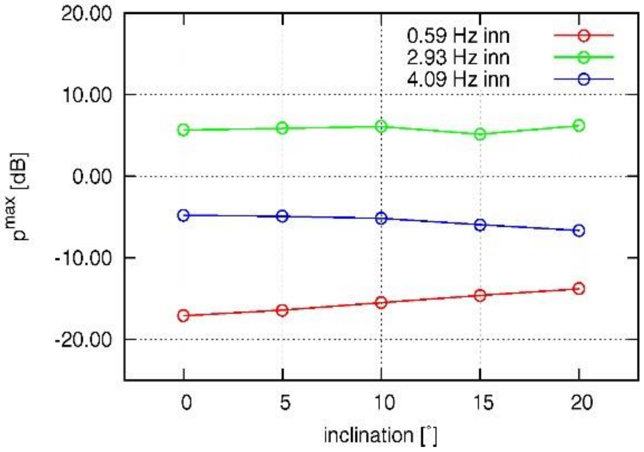
Freq. [Hz]	Pressure level outside building [dB]				Pressure level inside building [dB]			
	Build. at 350 m	Build. at 500 m	Build. at 650 m	Build. at 1 km	Build. at 350 m	Build. at 500 m	Build. at 650 m	Build. at 1 km
0.59	-2	-7	-6	-10	-13	-15	-18	-36
2.93	25	21	20	8	9	7	4	-4
4.09	13	10	4	0	-1	-5	-9	-18

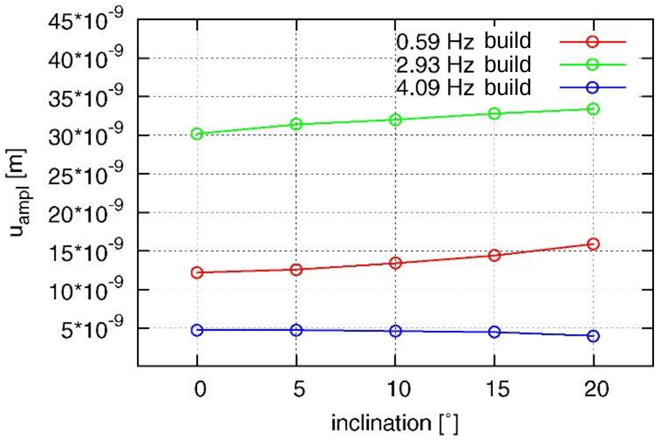
Freq. [Hz]	Displacement amplitude at building [m]			
	Building at 350 m	Building at 500 m	Building at 650 m	Building at 1 km
0.59	2.3E-08	1.4E-08	9.1E-09	5.9E-09
2.93	3.6E-08	3.2E-08	2.2E-08	9.0E-09
4.09	7.4E-09	4.6E-09	3.1E-09	1.0E-09

Acoustic pressure and displacement amplitudes due to Seismic Source (uniform inflow)

- Variation of slope inclination



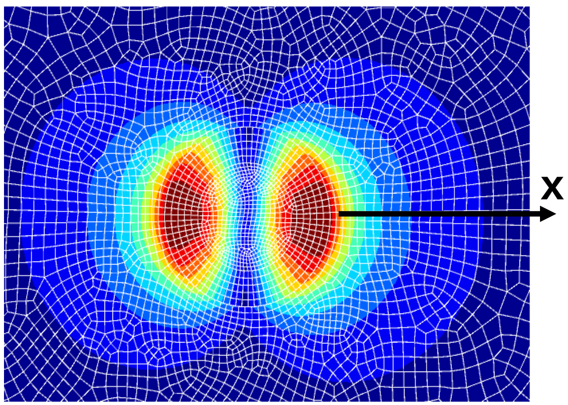




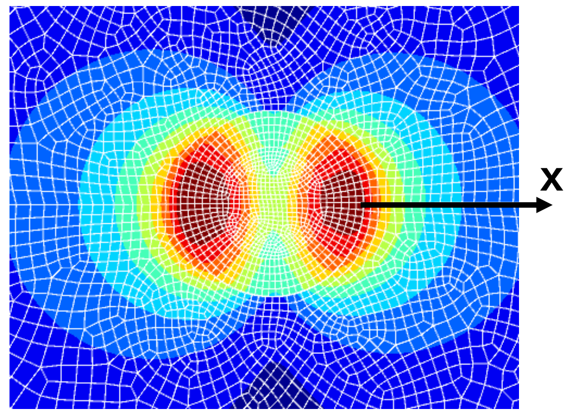
Attenuation of Seismic Noise

Predominant moment load

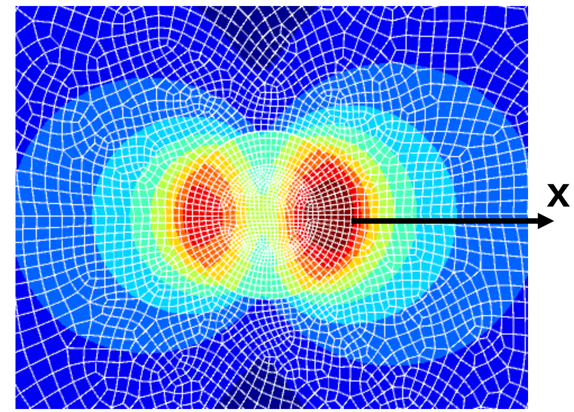
f = 0.59 Hz

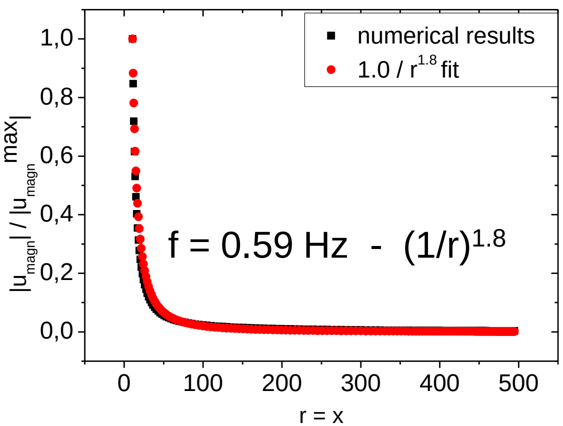


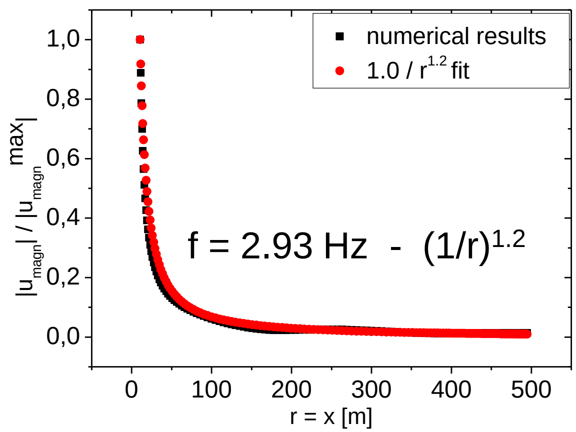
f = 2.93 Hz

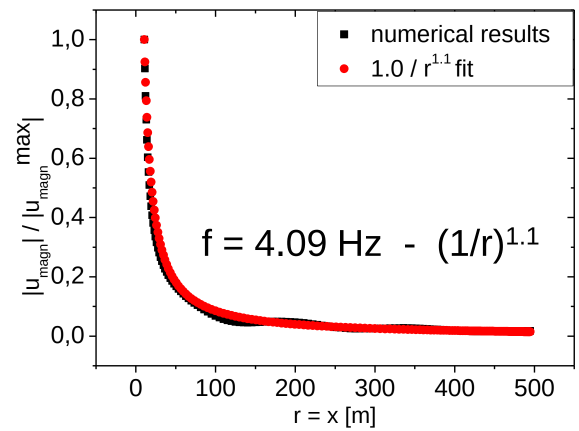


f = 4.09 Hz









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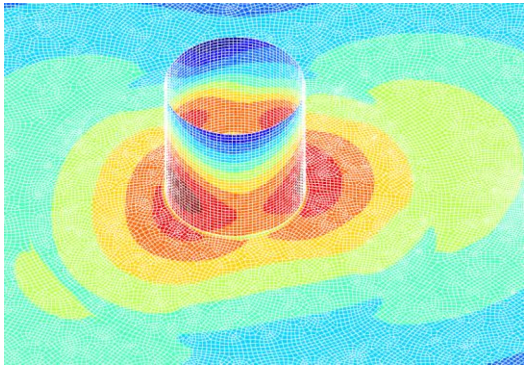
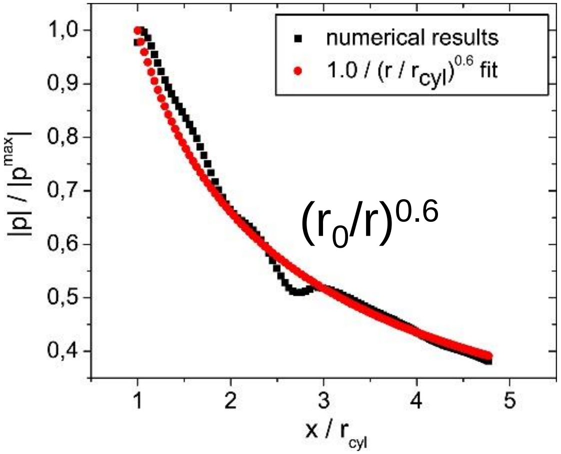
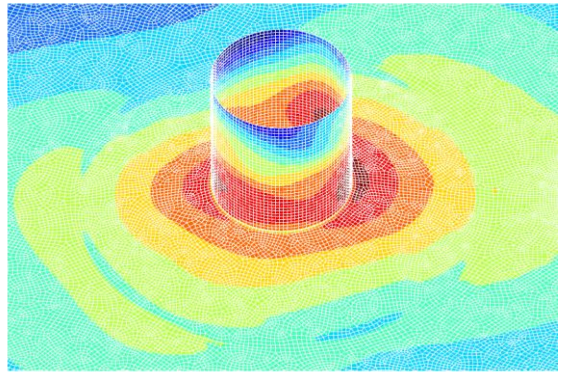
Attenuation of Acoustic Noise

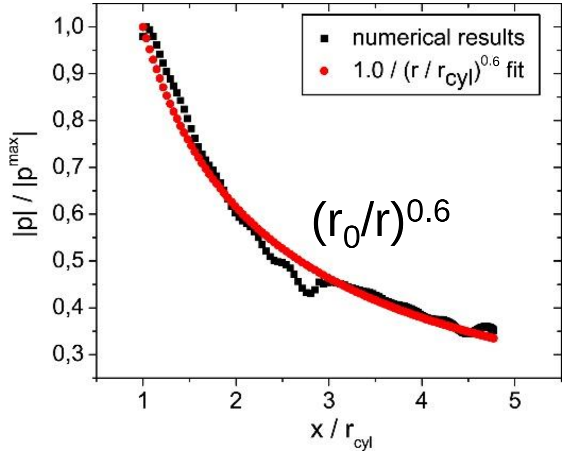
f = 2.93 Hz



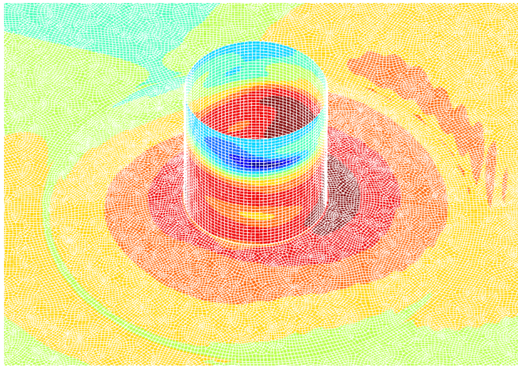


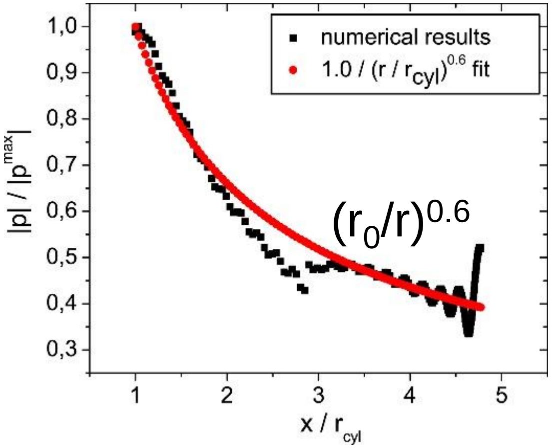
f = 4.09 Hz





f = 8.18 Hz





- Acoustic waves decay slower than the decay of seismic displacement amplitudes

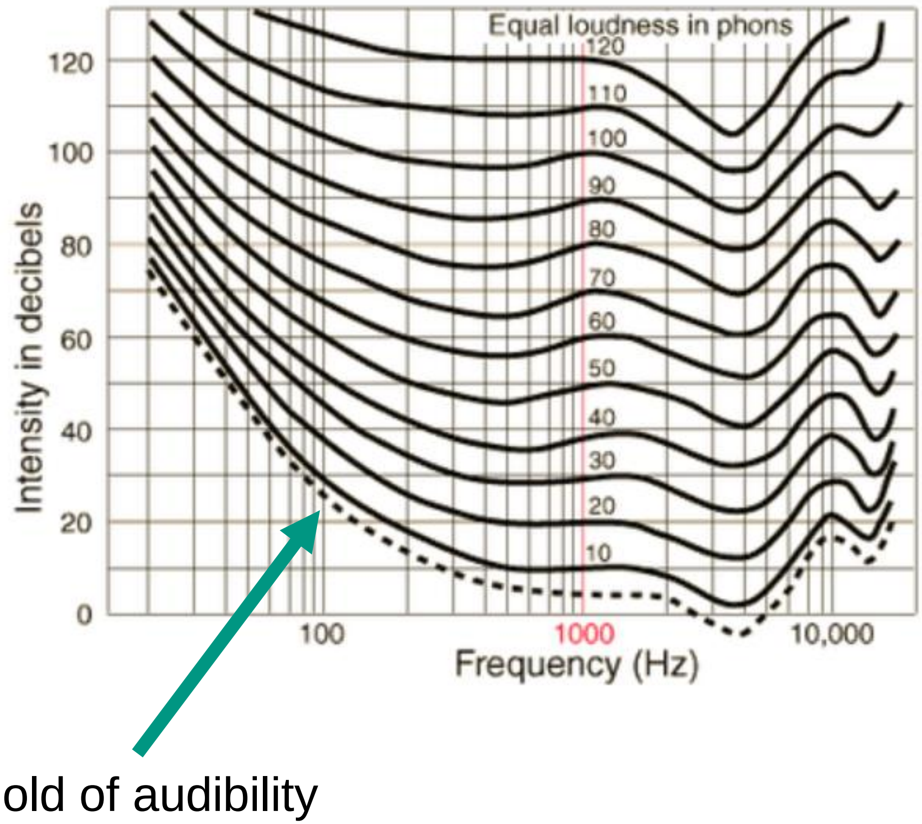
Acoustic pressure and displacement amplitude

Freq. [Hz]	emission	pressure level at source [dB]		Displacement amplitude at source [m]		pressure level outside build. [dB]	Displ. ampl. at build. [m]	pressure level inside build. [dB]
		found.	cylinder	found.	cylinder			
0.59	acoustic		93		4.4E-08	62	2.2E-08	13
	seismic	13		4.8E-06		-7	1.4E-08	-15
2.93	acoustic		77		1.3E-08	68	8.7E-09	19
	seismic	45		2.1E-06		21	3.2E-08	7
4.09	acoustic		74		6.8E-09	65	9.1E-09	15
	seismic	31		2.4E-07		10	4.6E-09	1
8.18	acoustic		59		1.3E-09	54	4.4E-09	15
	seismic	22		3.8E-08		-3	1.3E-09	-5

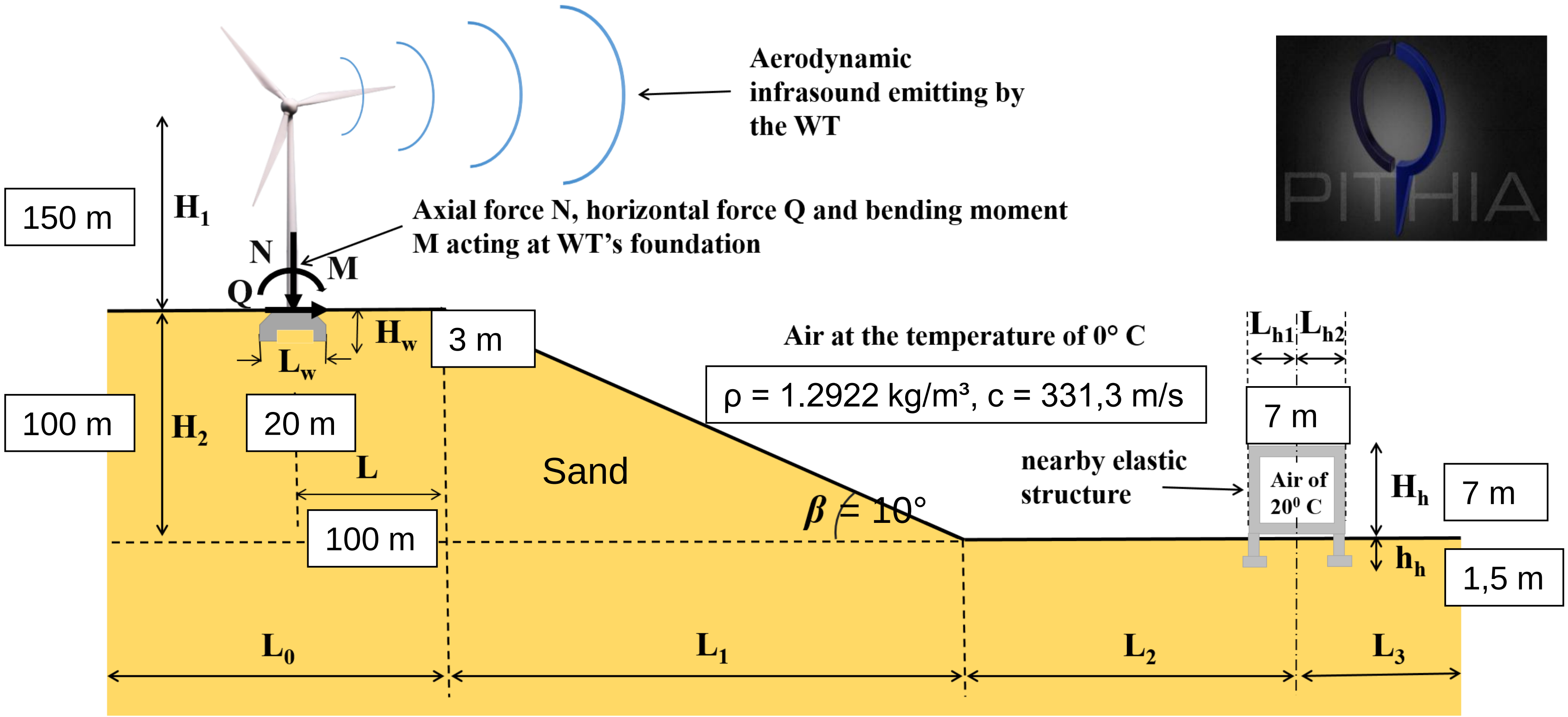
- The small displacements justify the elastic approach
- The displacement amplitudes due to direct seismic emission are greater at source but comparable to those due to secondary acoustic emission at the building
- The acoustic sound is mainly caused by acoustic radiation rather than by seismic effects
- The maximum noise is reached for 2.93 Hz, where the pressure level outside the house is 68+21=89 dB and inside the house is 19+7=26 dB

Sound pressure level and threshold of audibility

SPL = 20 log (p/p_0) [dB], with $p_0 = 2 \cdot 10^{-5}$ Pa



Boundary Element Modell



Case 1: Sand

$E = 4{,}05 * 10^5$ kN/m²	: Elastic modulus
$\nu = 0{,}25$	: Poisson's ratio
$\rho = 1800$ kg/m³	: Density

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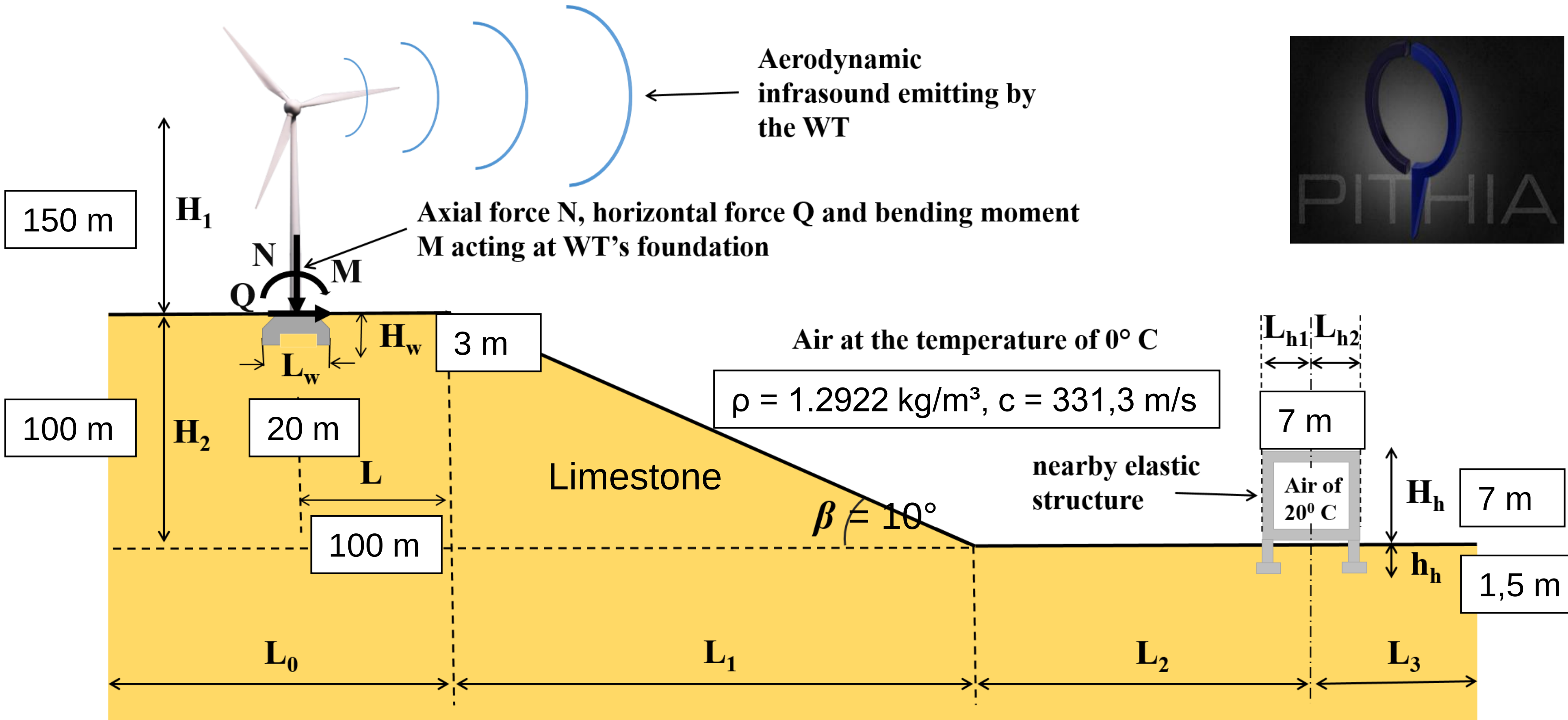
Boundary Element Modell



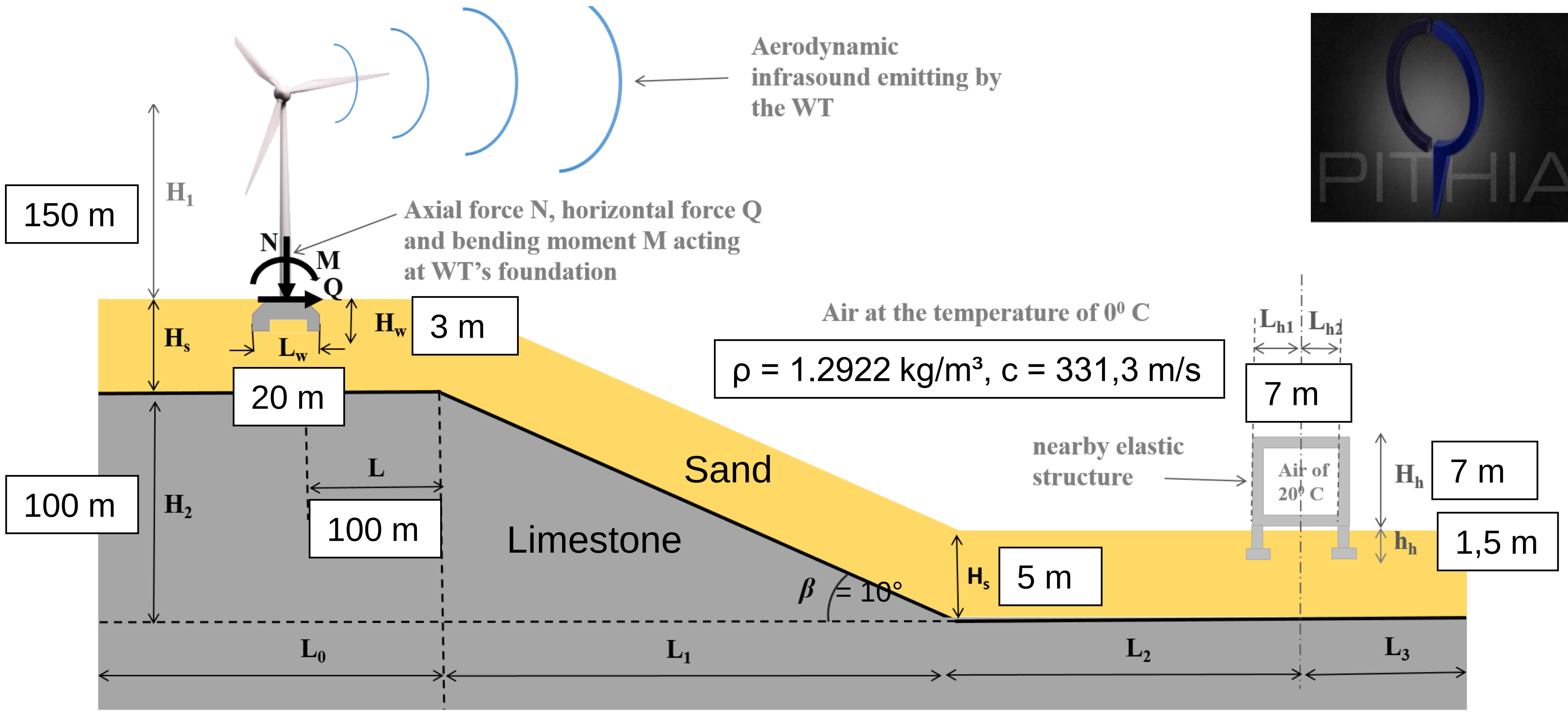
Case 1: Sand

$E = 4{,}05 * 10^5$ kN/m²	: Elastic modulus
$\nu = 0{,}25$	: Poisson's ratio
$\rho = 1800$ kg/m³	: Density

Case 2: Limestone

$E = 3{,}0 * 10^7$ kN/m²	: Elastic modulus
$\nu = 0{,}25$	: Poisson's ratio
$\rho = 2600$ kg/m³	: Density

Boundary Element Modell



Case 3: Sand (Hs = 5m) and limestone

E = 4,05 * 10^5 kN/m²	: Elastic modulus	E = 3,0 * 10^7 kN/m²	: Elastic modulus
ν = 0,25	: Poisson's ratio	ν = 0,25	: Poisson's ratio
ρ = 1800 kg/m³	: Density	ρ = 2600 kg/m³	: Density

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Acoustic pressure and displacement amplitude

Case 2: Limestone

Freq. [Hz]	emission	pressure level at source [dB]		Displacement amplitude at source [m]		pressure level outside build. [dB]	Displ. ampl. at build. [m]	pressure level inside build. [dB]
		found.	cylinder	found.	cylinder			
0.59	acoustic		93		7.5E-10	62	3.2E-10	13
	seismic	-20		3.3E-07		-44	2.8E-10	-55
2.93	acoustic		77		2.0E-10	68	9.2E-11	19
	seismic	10		1.4E-07		-18	2.6E-10	-34
4.09	acoustic		74		1.2E-10	65	4.2E-11	15
	seismic	-4		1.5E-08		-31	3.0E-11	-45
8.18	acoustic		59		2.1E-11	54	2.8E-11	15
	seismic	-10		2.0E-09		-35	1.2E-11	-42

- The displacement amplitudes are much smaller than in Case 1
- The secondary sound pressure level due to seismic emissions are practically negligible
- The direct acoustic sound pressure level is identical to Case 1

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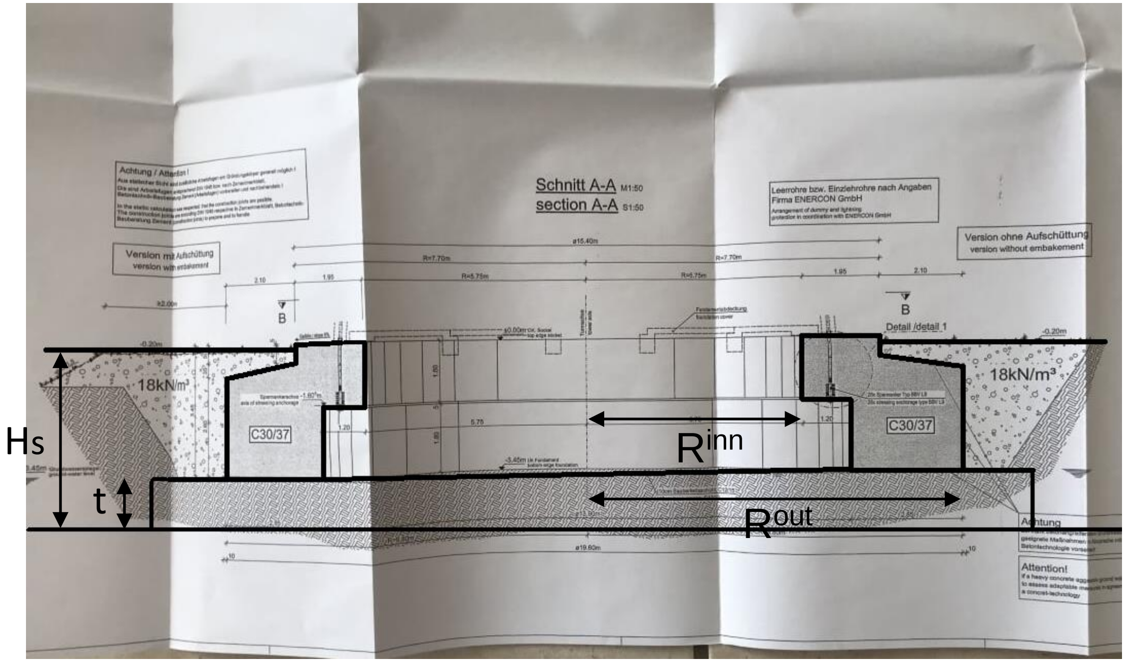
Acoustic pressure and displacement amplitude

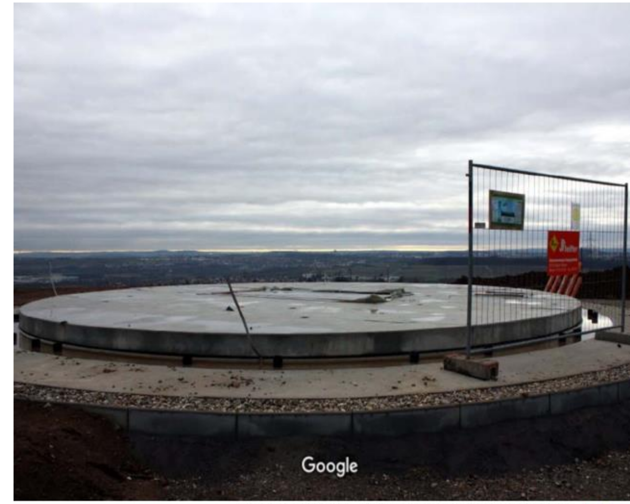
Case 3: Sand (Hs = 5m) and limestone

Freq. [Hz]	emission	pressure level at source [dB]		Displacement amplitude at source [m]		pressure level outside build. [dB]	Displ. ampl. at build. [m]	pressure level inside build. [dB]
		found.	cylinder	found.	cylinder			
0.59	acoustic		93		3.1E-09	62	4.5E-10	13
	seismic	0		3.2E-06		-35	2.4E-10	-44
2.93	acoustic		77		1.5E-09	68	5.1E-10	19
	seismic	31		1.3E-06		-11	2.1E-10	-25
4.09	acoustic		74		1.0E-09	65	3.3E-10	15
	seismic	18		1.4E-07		-21	3.1E-11	-32
8.18	acoustic		59		1.55E-10	54	7.1E-11	15
	seismic	11		2.0E-08		-26	1.4E-11	-34

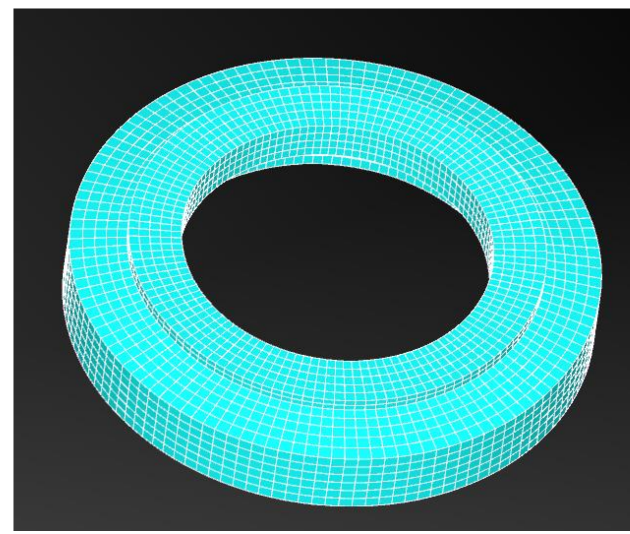
- The values of the secondary acoustic pressure amplitudes lie between the first two cases
- The underlying rocky subsoil leads to a stronger geometric decay of the direct seismic emissions

Foundation of WT and soil stratification (Ingersheim)





Aufnahmedatum: Dez. 2011 Die Bilder sind eventuell urheberrechtlich geschützt. Panoramio



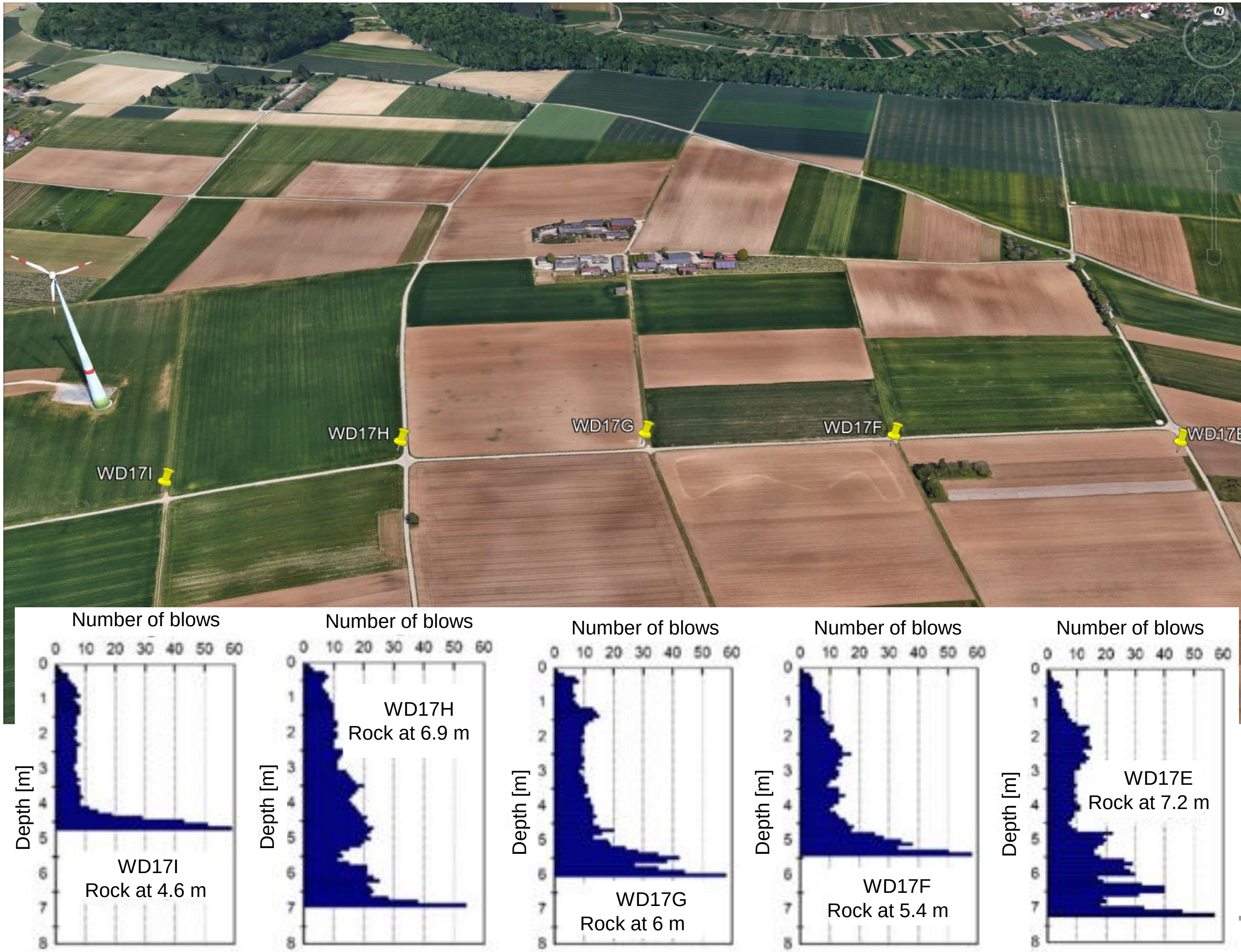
$R^{inn} = 5.75$ m

$R^{out} = 9.8$ m

$t = 1.30$ m

$H_S \approx 4.0 – 6.0$ m

Locations of the pile driving tests (Ingersheim)



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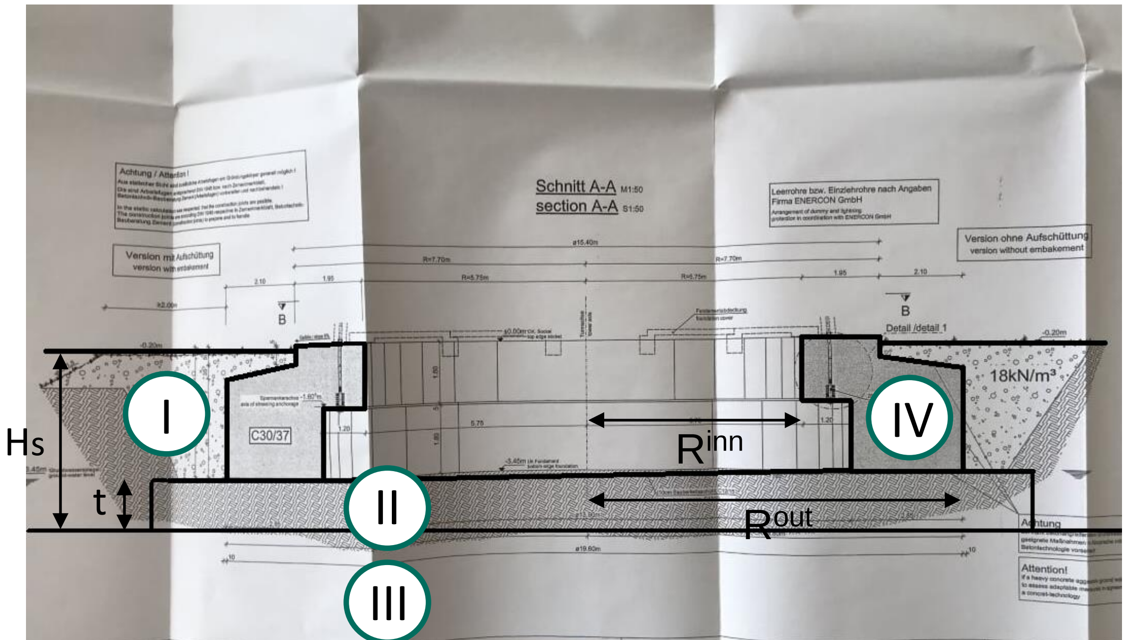
Foundation of WT and soil stratification (Ingersheim)



I Humus

$E = 3{,}12 * 10^4$ kN/m²

$v = 0{,}25$

$\rho = 1800$ kg/m³

II Gravel

$E = 2{,}9 * 10^5$ kN/m²

$v = 0{,}25$

$\rho = 1800$ kg/m³

III Limestone

$E = 3{,}0 * 10^7$ kN/m²

$v = 0{,}25$

$\rho = 2600$ kg/m³

IV Beton

$E = 33 * 10^6$ kN/m²

$v = 0{,}2$

$\rho = 2500$ kg/m³

$R^{inn} = 5.75$ m

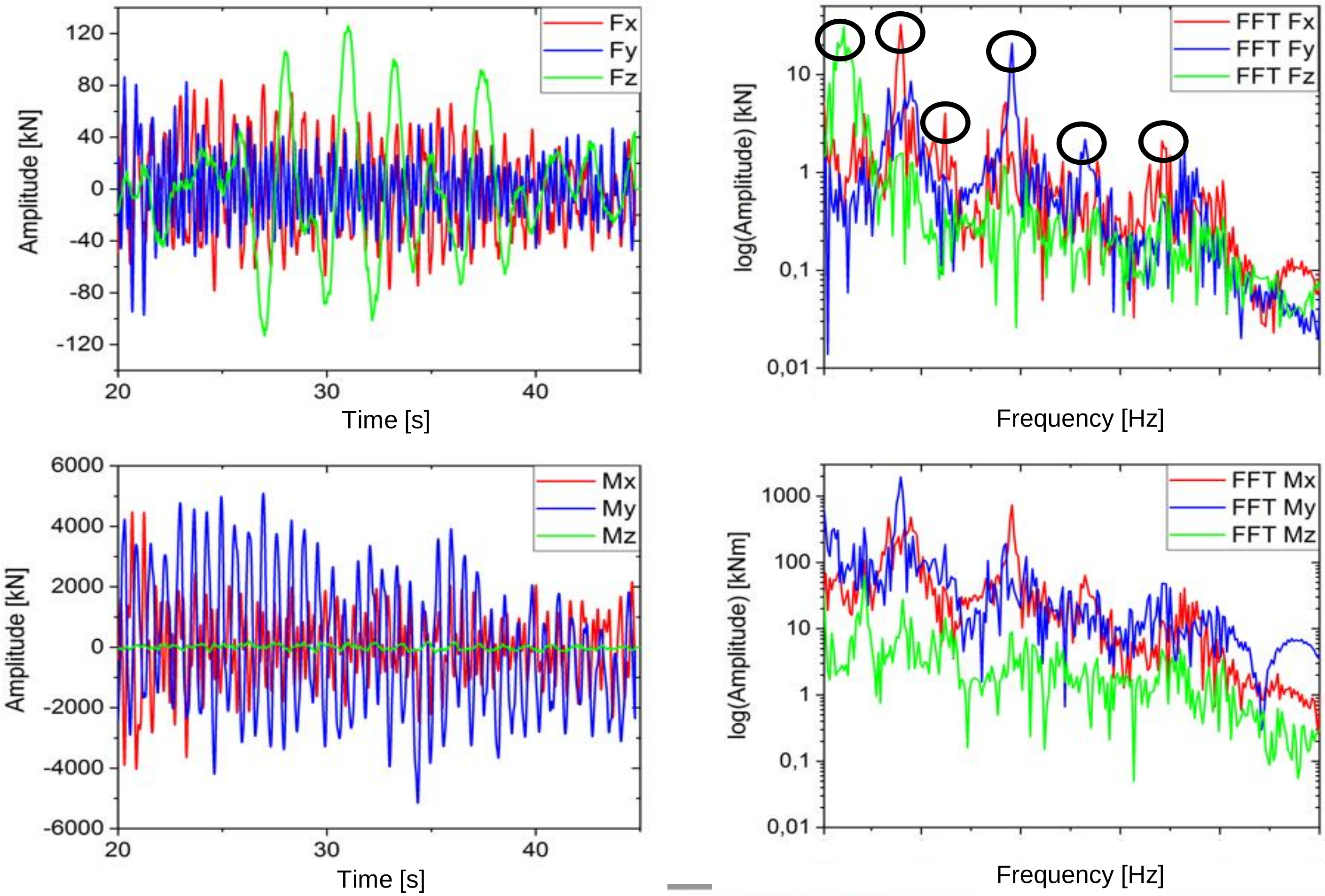
$R^{out} = 9.8$ m

$t = 1.30$ m

$Hs \approx 4.0 – 6.0$ m

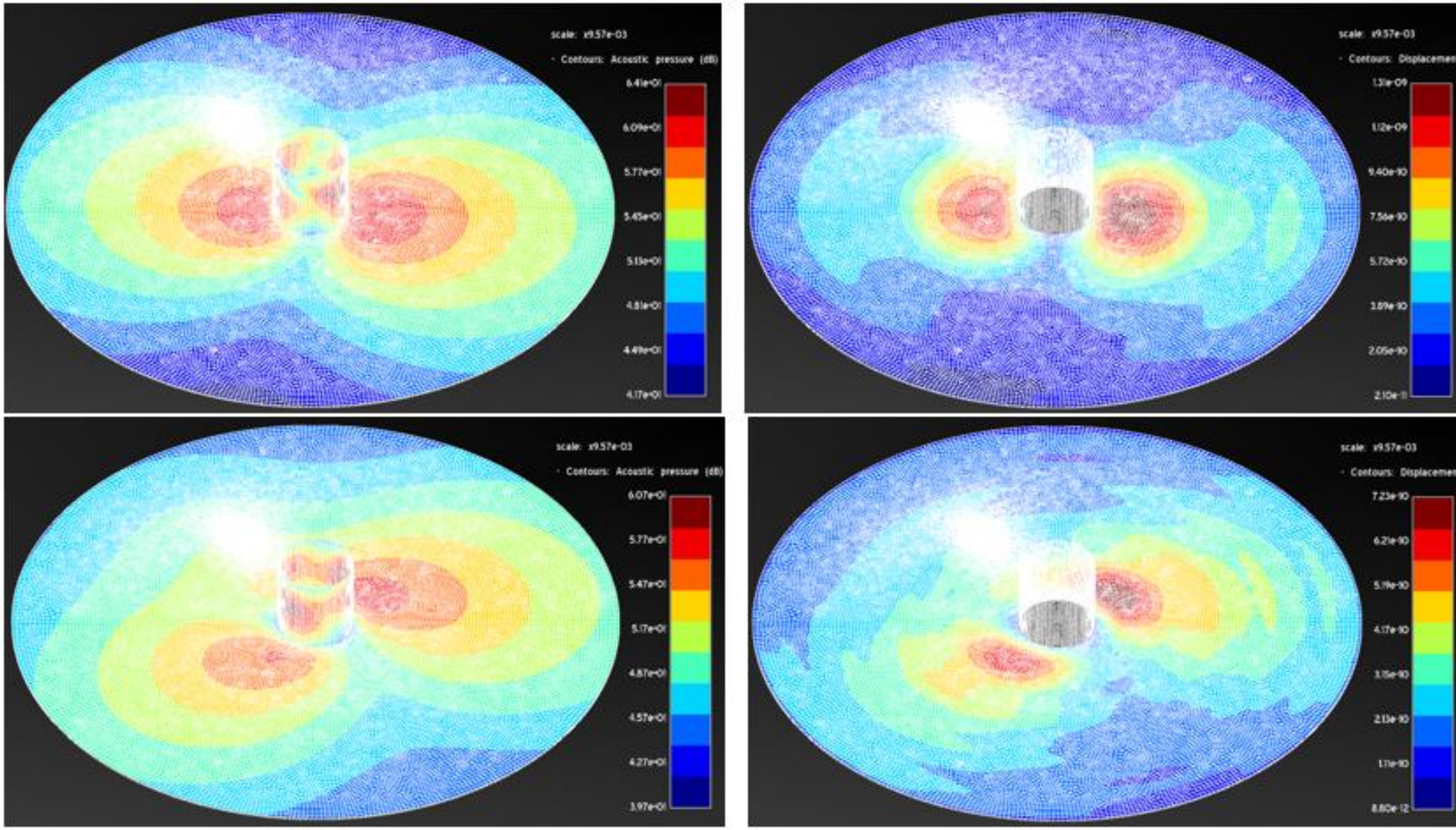
Micro-seismic Source at WT (Ingersheim)

- Time series and FFT of the dynamic parts of all 6 load components acting on the foundation



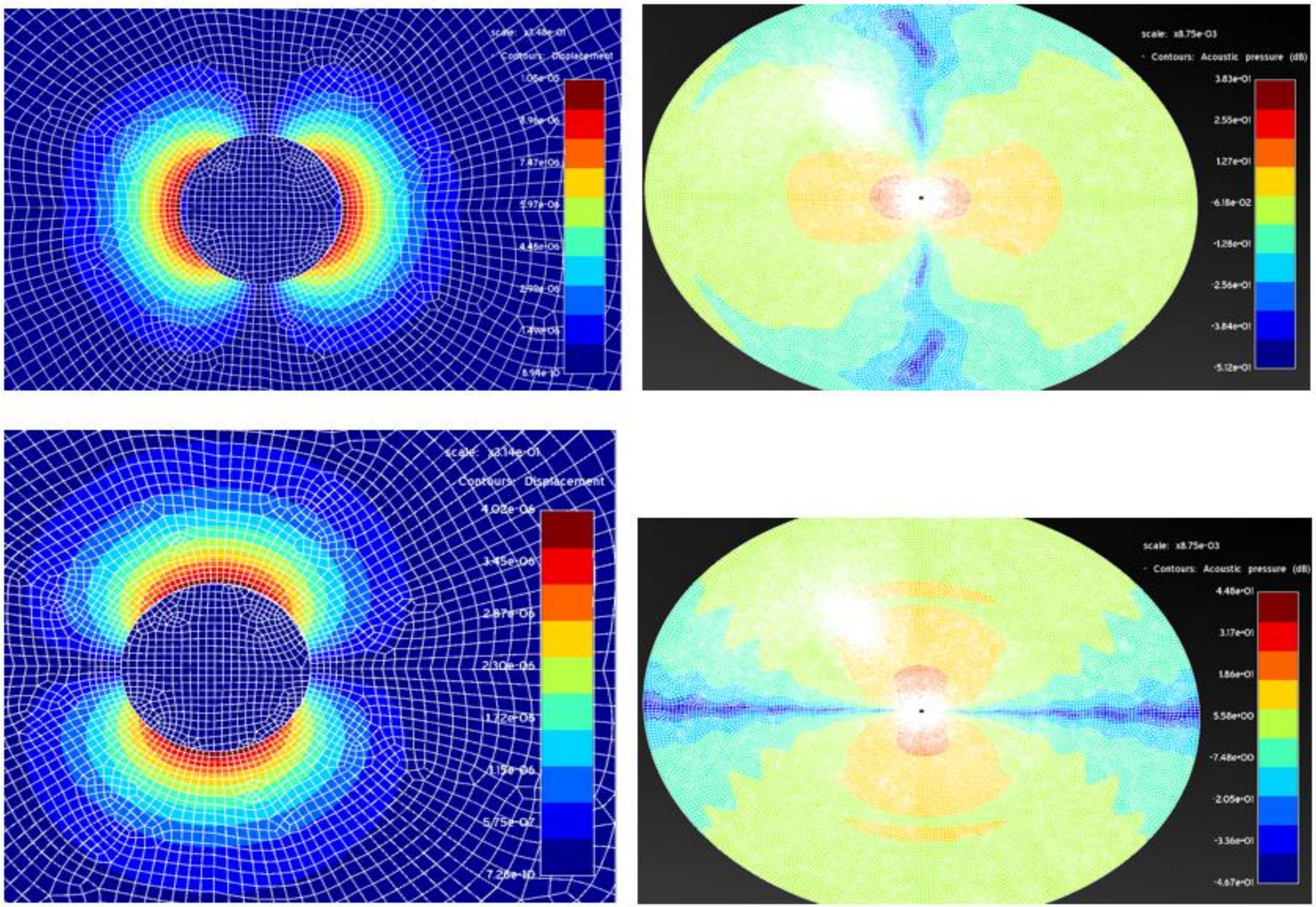
Wave Propagation due to Acoustic Source

- Acoustic pressure (left) and secondary displacement (right) amplitudes for two representative dominant frequencies (2nd and 4th higher harmonics of the BPF)



Wave Propagation due to Seismic Source

- Displacement (left) and secondary (right) acoustic pressure amplitudes for two representative dominant frequencies (2nd and 4th higher harmonics of the BPF)

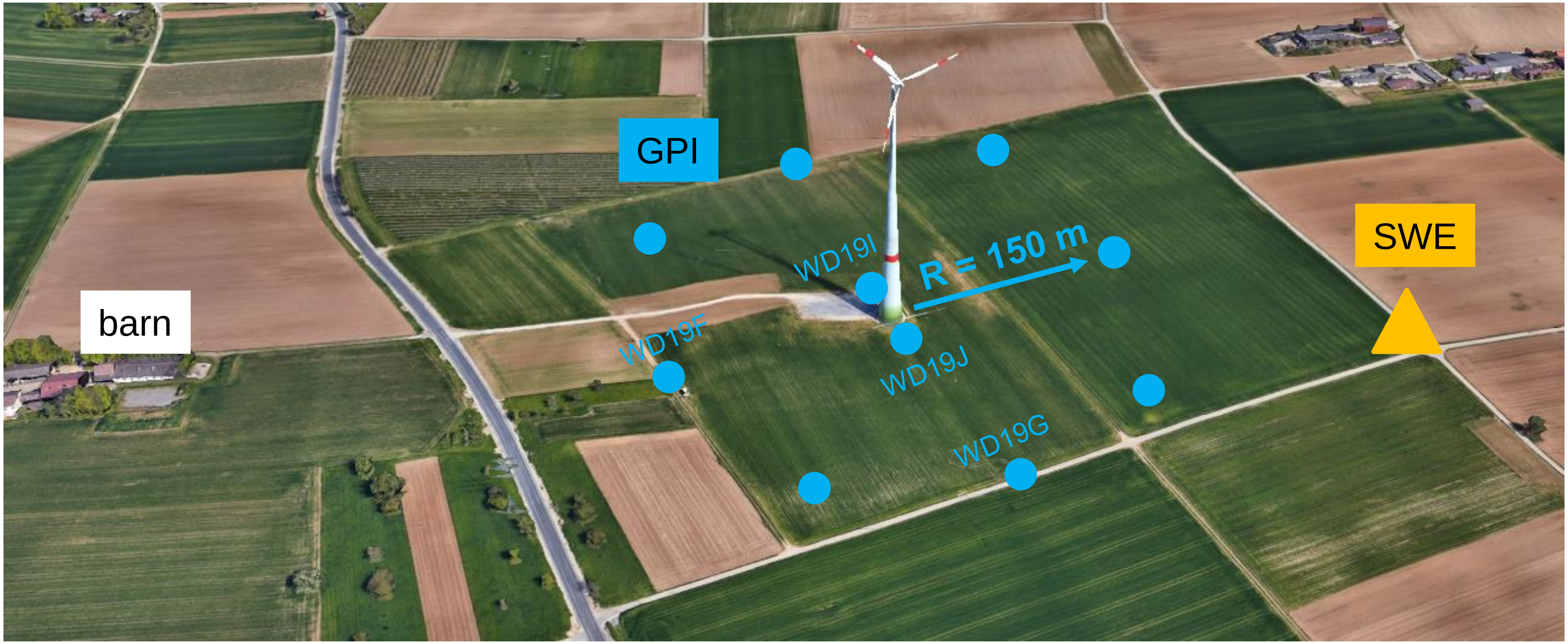


Acoustic pressure and displacement amplitude (acoustic emissions)

Higher harmonic to the BFP	pressure level at source [dB]	Displacement amplitude at source [m]	Pressure level at SWE measurement point [dB]	Displ. ampl. at GPI measurement point [m]	Pressure level at barn [dB]	Displ. ampl. at barn [m]
	cylinder	cylinder				
1	0	7.2E-10	-2	2,2E-10	-10	1,2E-10
2	-7	1.3E-9	0	7,2E-10	0	3,7E-10
3	-7	1.1E-9	0	3,5E-10	-2	1,1E-10
4	-10	7.2E-10	-3	4,6E-10	-3	2,7E-10
5	-11	5.9E-10	-4	5,3E-10	-9	1,2E-10
6	-16	4.4E-10	-7	3,2E-10	-7	1,9E-10
7	-17	3.2E-10	-10	3,0E-10	-11	1,3E-10
8	-16	3.4E-10	-9	1,9E-10	-12	8,7E-11
9	-22	2.5E-10	-15	2,3E-10	-20	4,2E-11

- Secondary displacement amplitudes due to acoustic emissions are almost negligible in the immediate vicinity of the WT

Locations of the acoustic and seismic measurement points



- Seismic measurements were carried out at 8 measuring points located on a circle around the WT with a radius of 150m (measurements GPI) and at the barn
- Acoustic measurements were carried out at a measuring point at a distance of about 400 m from the WT (measurement SWE) and also inside the barn

Acoustic pressure and displacement amplitude (seismic emissions)

Higher harmonic to the BFP	pressure level at source [dB]	Displacement amplitude at source [m]	Pressure level at SWE measurement point [dB]	Displ. ampl. at GPI measurement point [m]	Pressure level at barn [dB]	Displ. ampl. at barn [m]
	foundation	foundation				
1	-46	4.9E-7	-32	1,7E-09	-36	7,2E-10
2	-7	1.1E-5	-11	1,1E-08	-11	3,0E-09
3	-23	6.9E-7	-28	1,1E-09	-29	3,3E-10
4	-21	5.2E-7	-22	1,2E-09	-27	4,4E-10
5	-11	1.3E-6	-13	3,4E-09	-17	1,1E-09
6	0	4.0E-6	0	7,4E-09	0	2,4E-09
7	-14	6.7E-7	-19	2,1E-09	-18	6,9E-10
8	-6	4.1E-7	-14	1,7E-09	-15	5,5E-10
9	-16	1.9E-7	-18	6,2E-09	-17	9,3E-10

- The sound pressure level due to the secondary seismic effects is almost negligible at both measurement points

Comparison of simulation and measurement results

Methodology:

- The acoustic and elastic boundary value problem must initially be solved for each frequency of the spectrum
- The obtained results must be converted to the time domain by a common inverse IFFT algorithm
- This method requires the solution of each 3D-boundary value problem for several hundreds of frequencies which is practically impossible

Approximation:

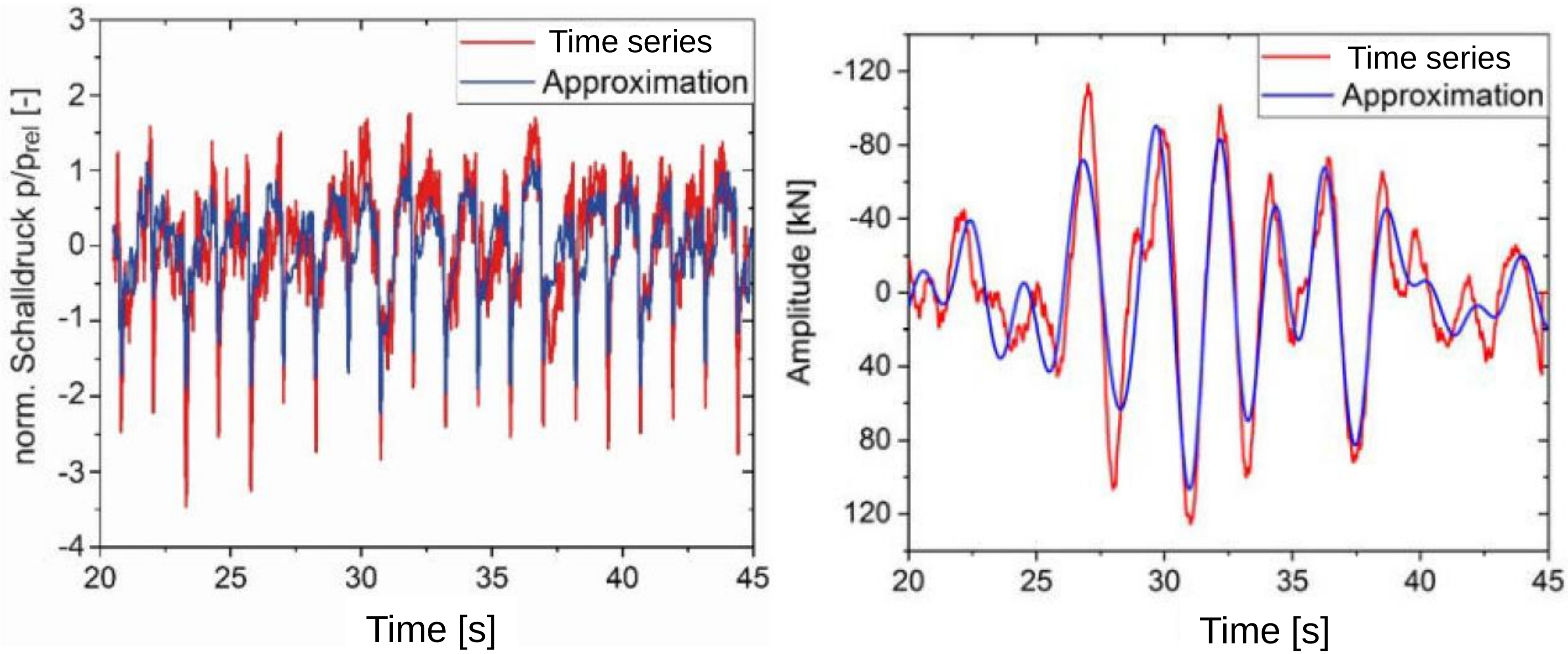
- The IFFT algorithm is carried out only for the solutions of the dominant frequencies

→ All non-dominant frequencies for both the acoustic and elastic boundary value problems have a sound pressure or load amplitude smaller than 15-20% of the corresponding maximum amplitude

Comparison of simulation and measurement results

Verification:

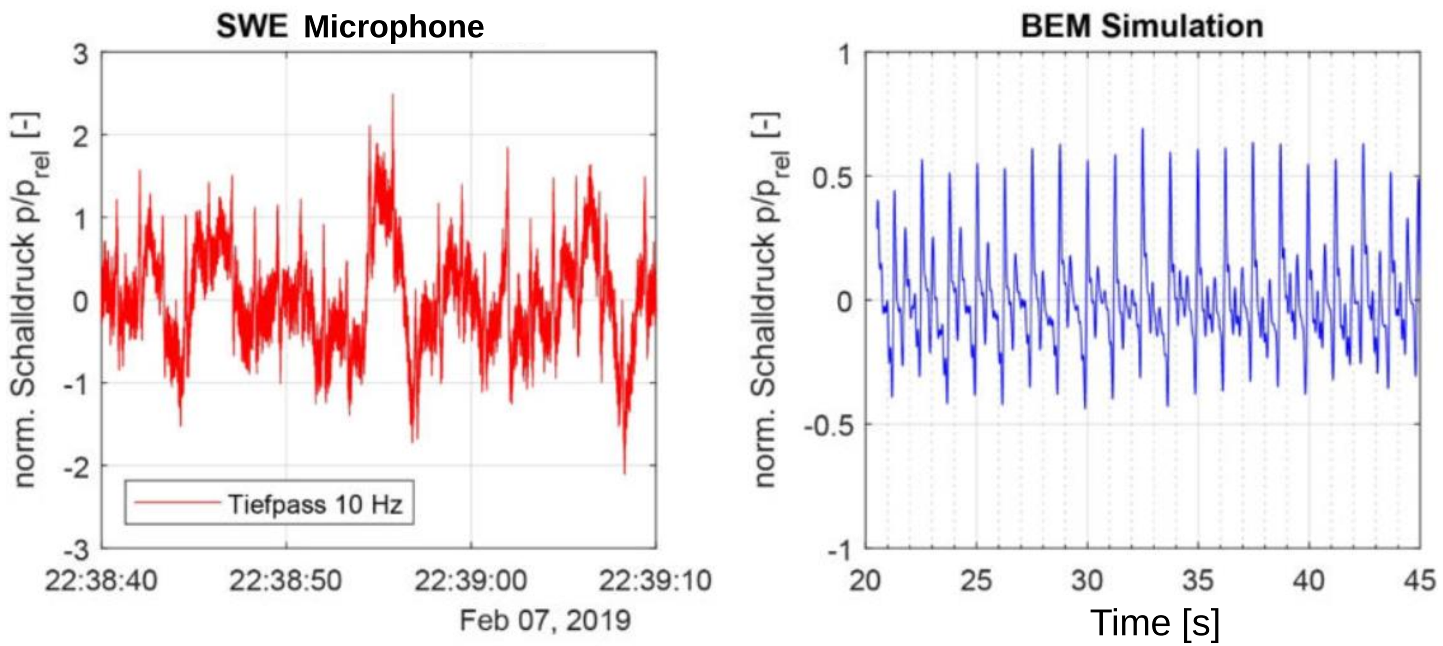
- Calculation of the known boundary conditions at the acoustic and seismic source



- The approximation can satisfactorily reproduce the known time series
- The amplitudes of sound pressure and vertical force component are somewhat underestimated

Comparison of simulation and measurement results

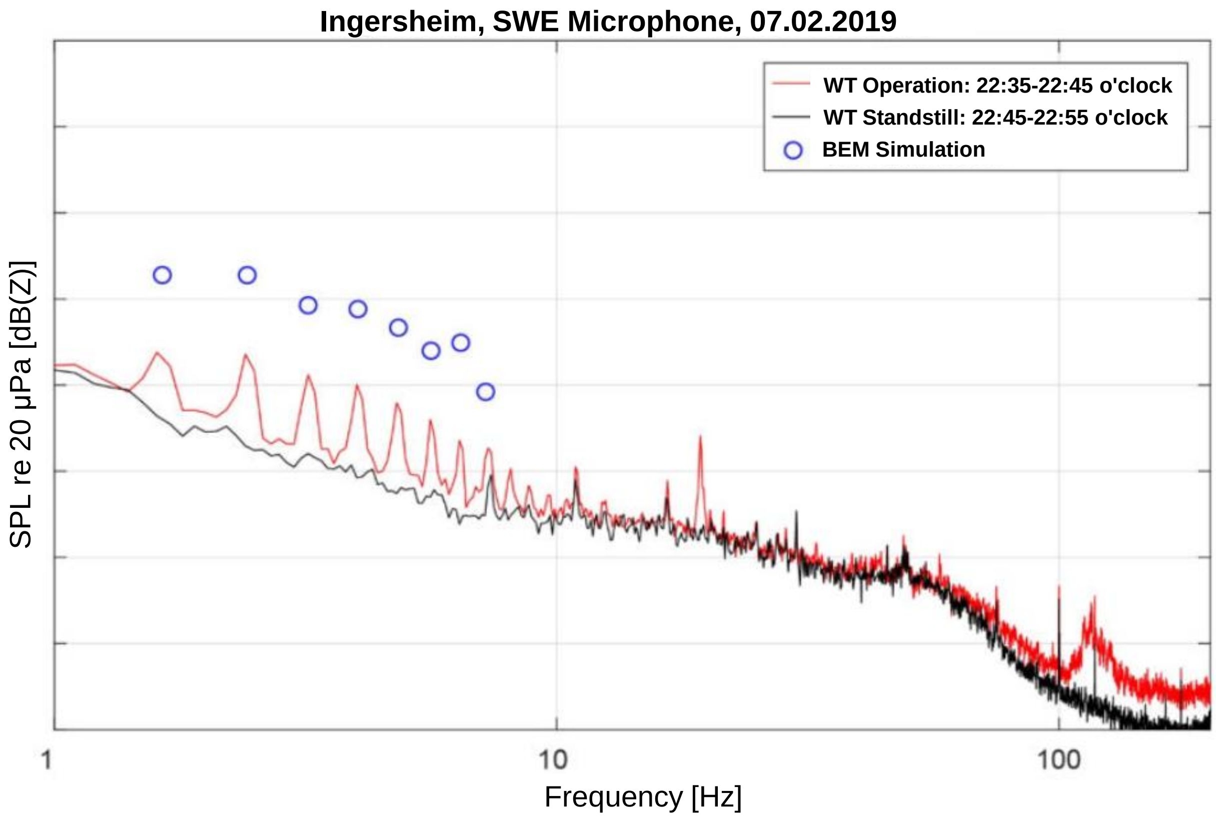
- Evolution of sound pressure at the accoustic measuring point (SWE)



- The predicted sound pressure amplitude is about the half of the measured. This deviation is is not significantly larger than the discrepancy at the source

Comparison of simulation and measurement results

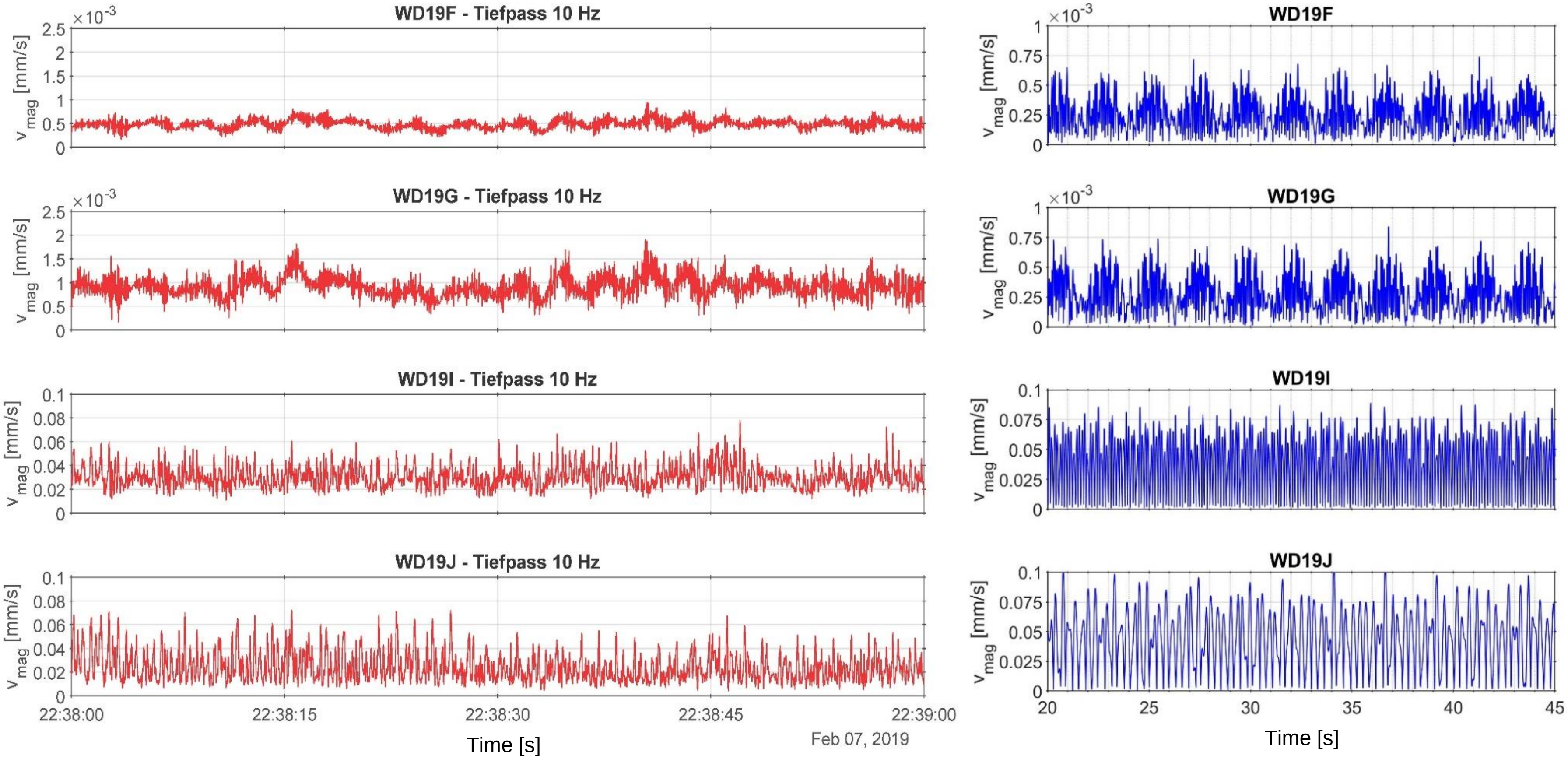
- Amplitude spectrum of the sound pressure level at accoustic measuring point (SWE)



- The sound pressure amplitude decreases with increasing the frequency
- The difference in sound pressure level is less than 10 dB for all dominant frequencies

Comparison of simulation and measurement results

- Evolution of velocity magnitude at the GPI measurement points



Satisfactory agreement between measured and calculated results

Conclusions and outlook

- The WT behaves as a dipole emitter for seismic as well as for acoustic emissions
- The radial attenuation of direct acoustic emission ($r^{0.6}$) is lower than of seismic surface waves ($r^{1.0}$…$r^{2.0}$)
- Outdoor and indoor noise are rather caused by acoustic radiation than by seismic effects.
- The parameters of the subsoil significantly affect the seismic emissions

→ precise knowledge of soil stratification is essential

- Numerical results are able to reproduce the measurements

- No restriction to infrasoung, but the current element mesh size (5-8 m) is not fine enough f > 20 Hz

→ Simulation data from UST-IAG with fine mesh and time resolution at the source

→ Element size must be reduced to less than 1 m

Thank you for your attention!