MISS – Project

Minderung der Störwirkung von Windenergieanlagen auf seismologische Stationen

Teilprojekt WWU:
Mitigation of effects on the travel path – a theoretical approach

Rafael Abreu, Christine Thomas

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Understanding the seismic noise generated by Wind Parks

DIN 4150-1:2001-06 (2001)

$$\text{NOISE LEVEL} \sim \sqrt{N}$$

total number of operative WTs

- Is this true for all WPs?
- Is there a way to reduce seismic noise by different wind park (WP) configurations?

Schofield (2001)

Neuffer (2020); Neuffer and Kremers (2017)

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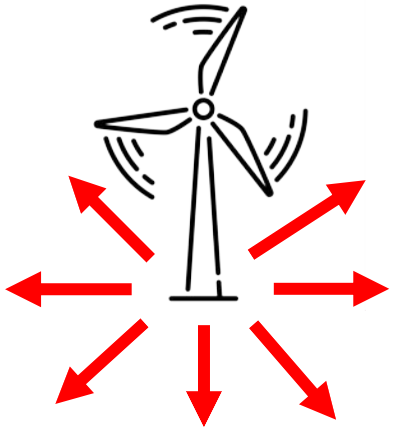
MISS: Mitigation of induced seismic signals

Two types of source can be considered

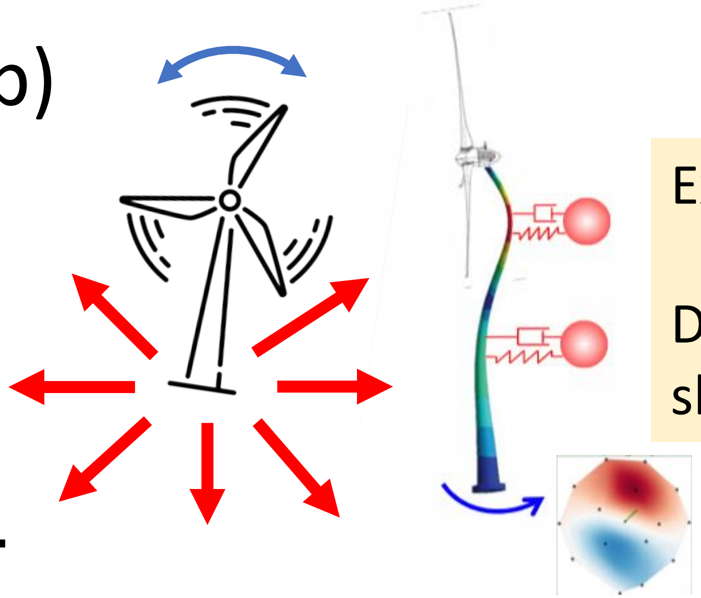
a)



Explosion source (no bending)

Different sources are phase shifted or in phase

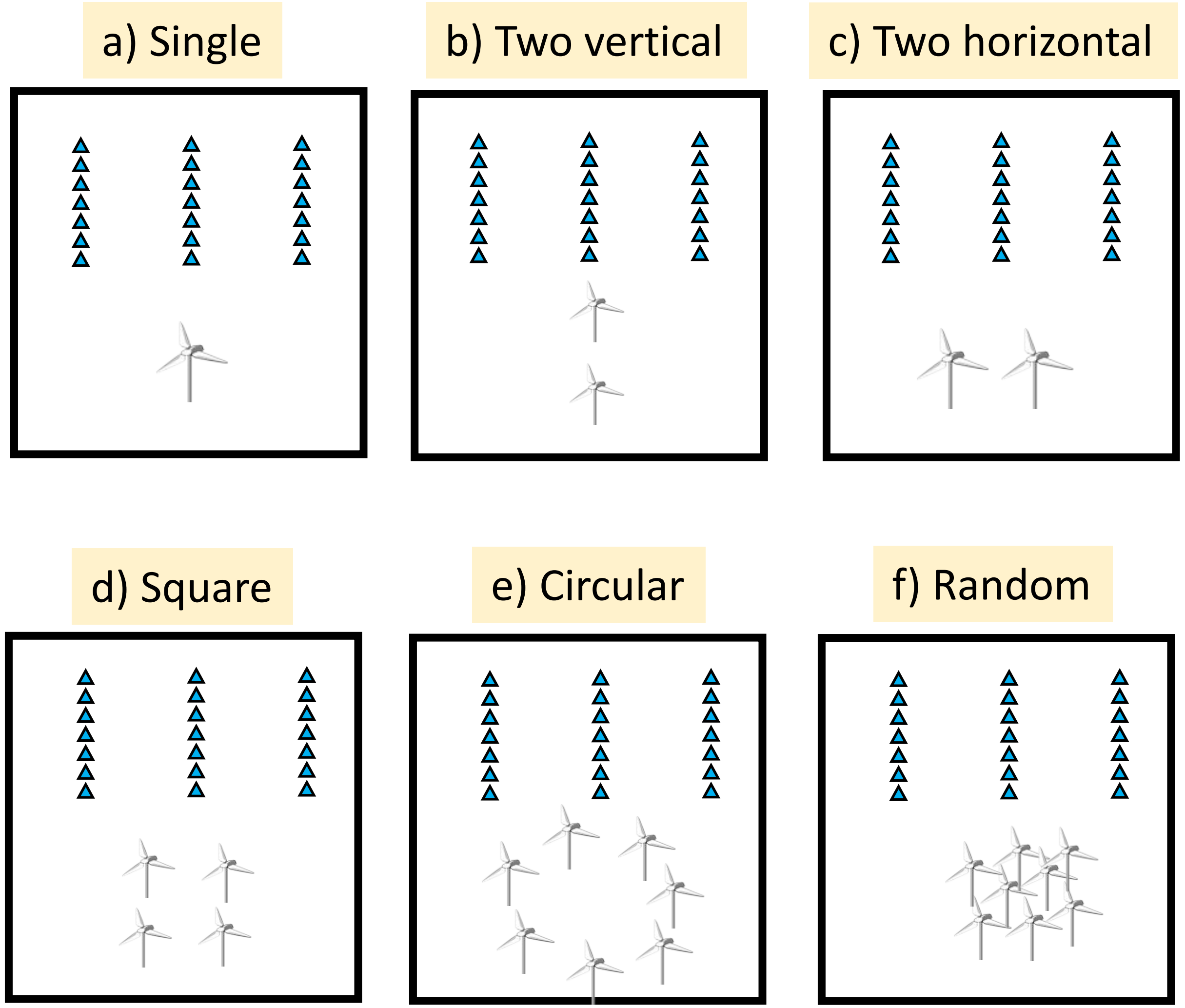
b)



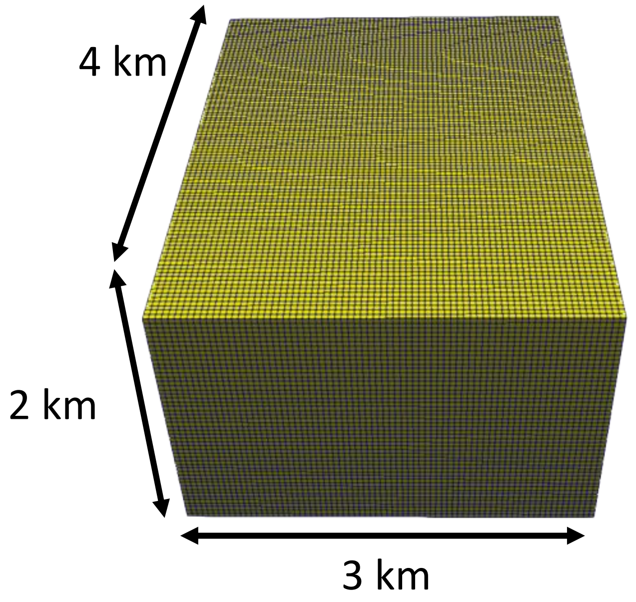
Explosion source + bending

Different sources are phase shifted or in phase

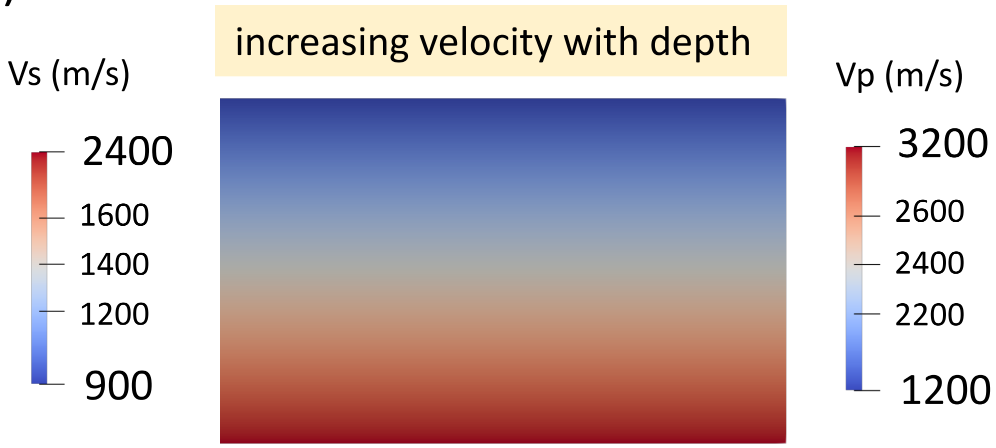
Influence of wind-turbine locations



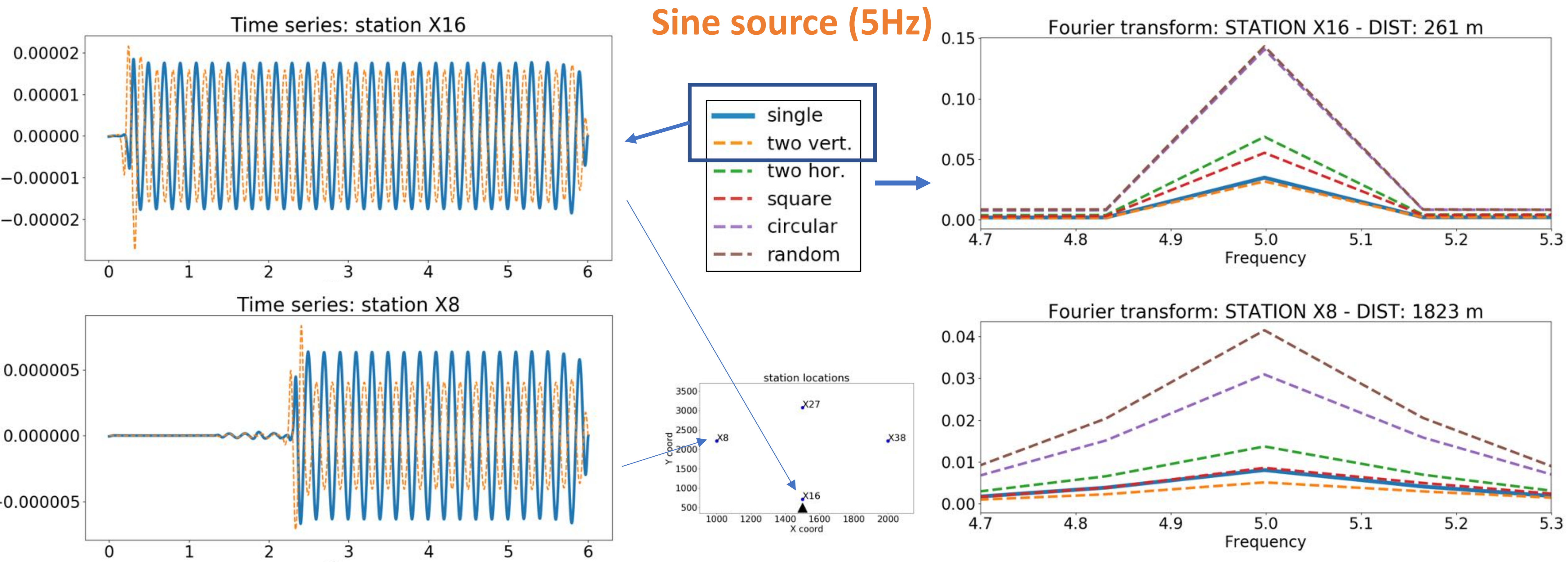
g)



h)



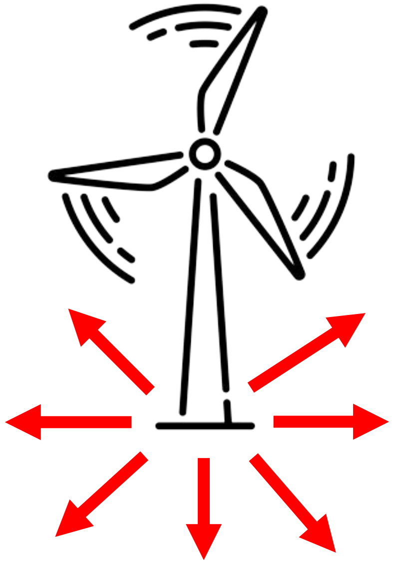
Influence of wind-turbine locations



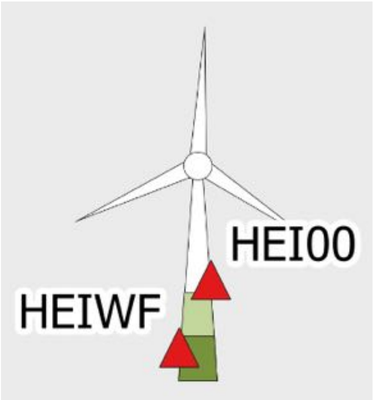
- ✓ Two WTs seem to attenuate the seismic energy in some cases compared to a single WT (blue) but depending on arrangement of WTs
- ✓ The $\sqrt{N}$ assumption does not necessarily hold

Noise sources from DMT

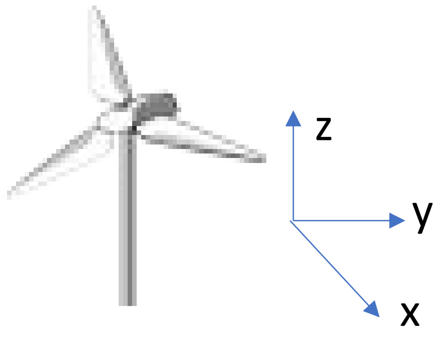
explosion source (no bending)



Seismic stations at the wind turbine (HEI00)

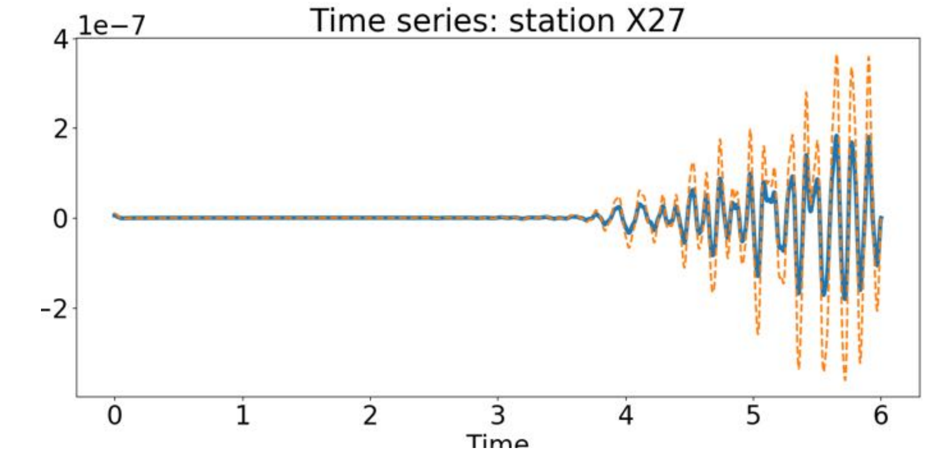


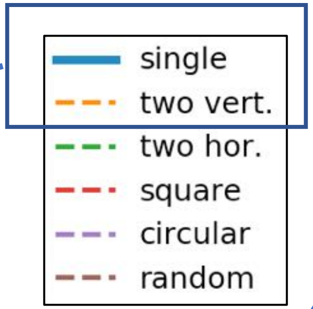
Source of noise

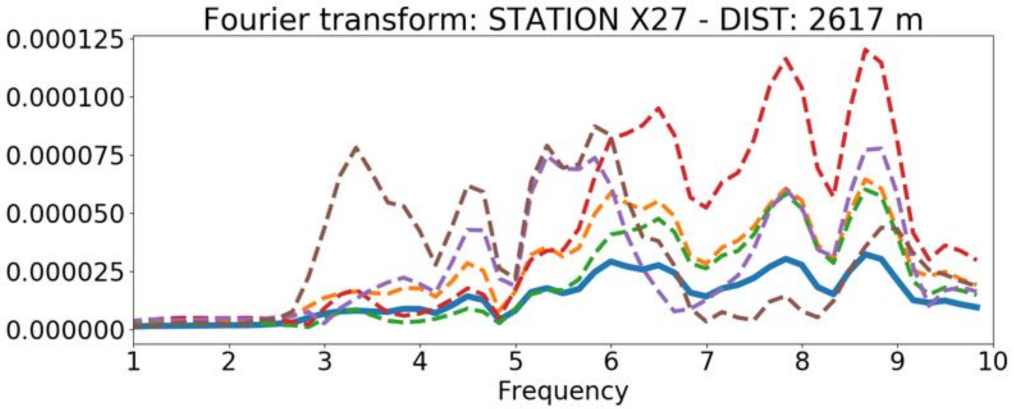


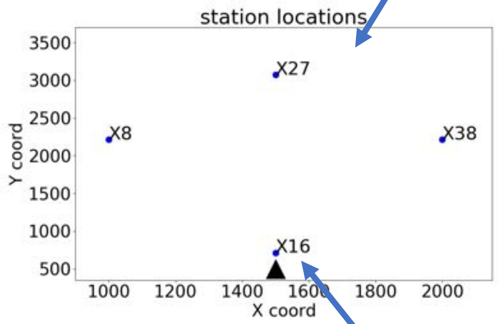
- ✓ Realistic source measured by DMT is used instead of a Ricker wavelet.
- ✓ Ricker wavelet limited in frequencies
- ✓ Real signal contains frequencies in the range [1-10] Hz with frequency peaks as send out by the WT

Influence of wind-turbine locations

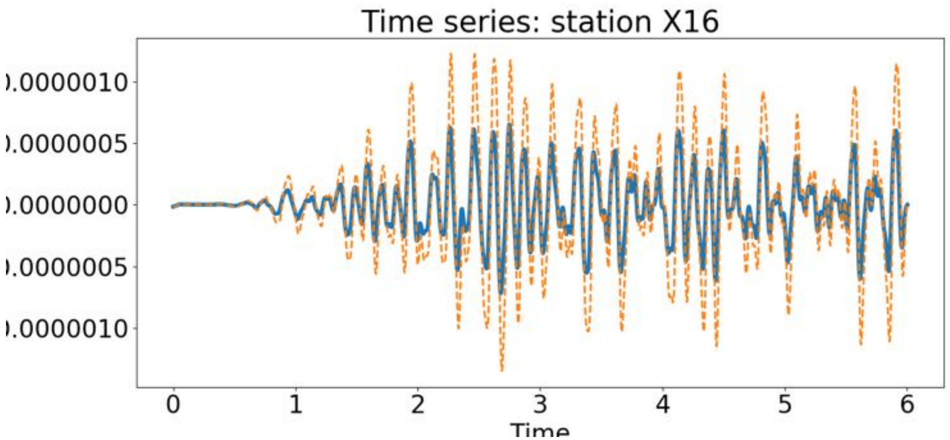


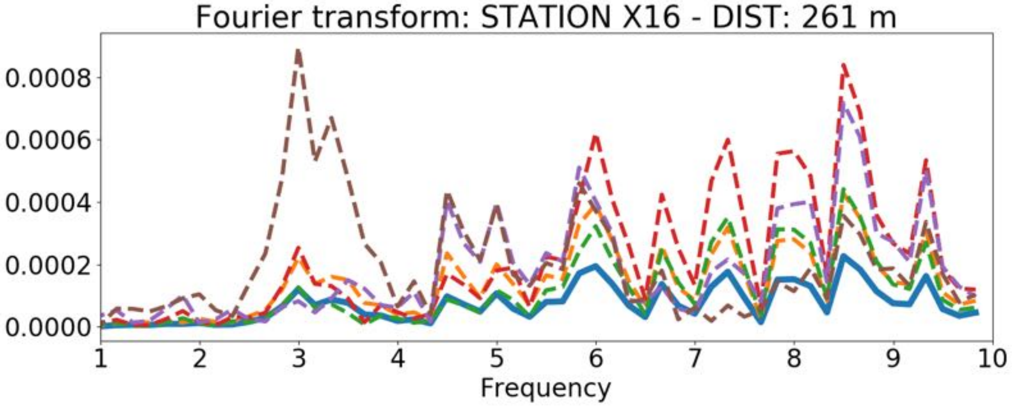






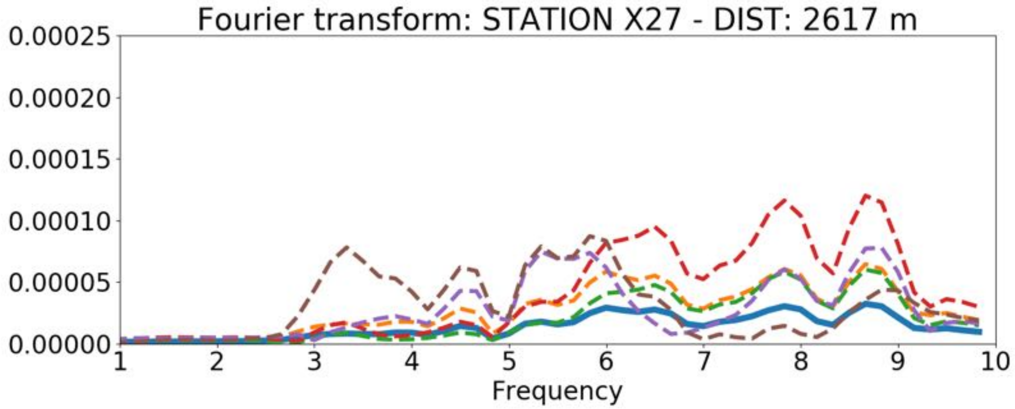
Attenuation of particular frequency amplitudes but also increase of amplitudes is possible Depending on arrangement of WTs in WP

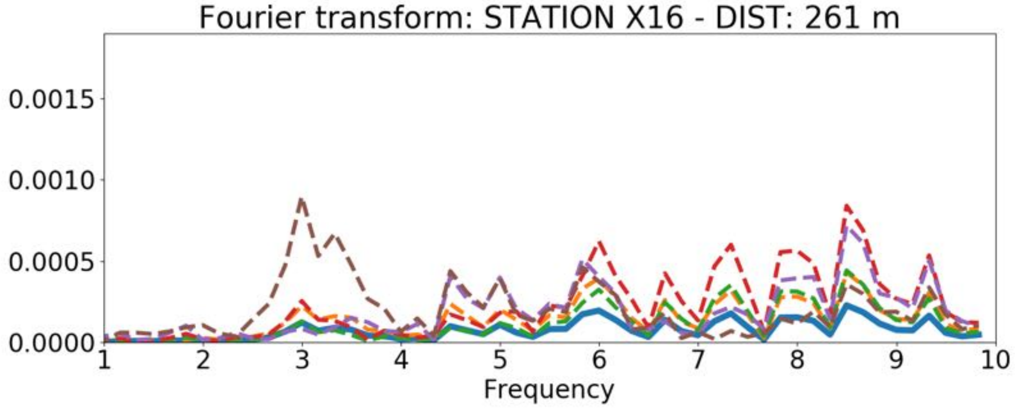


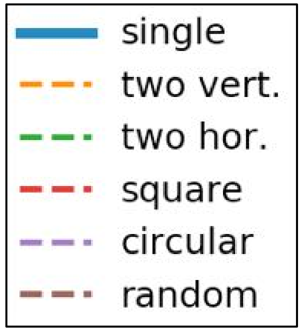


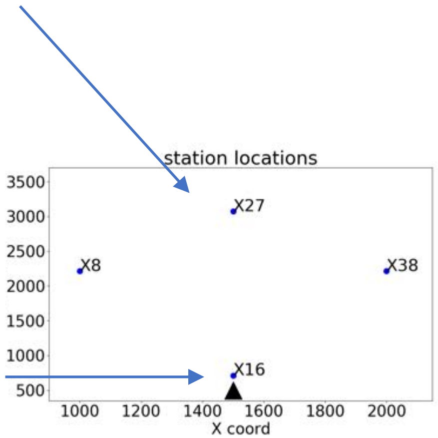
Influence of wind-turbine locations *(with out of phase input signals)*

Input signals in phase

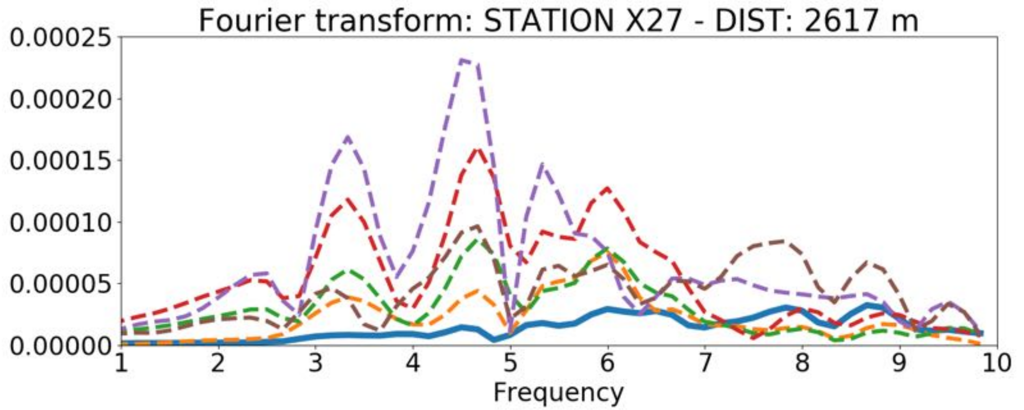


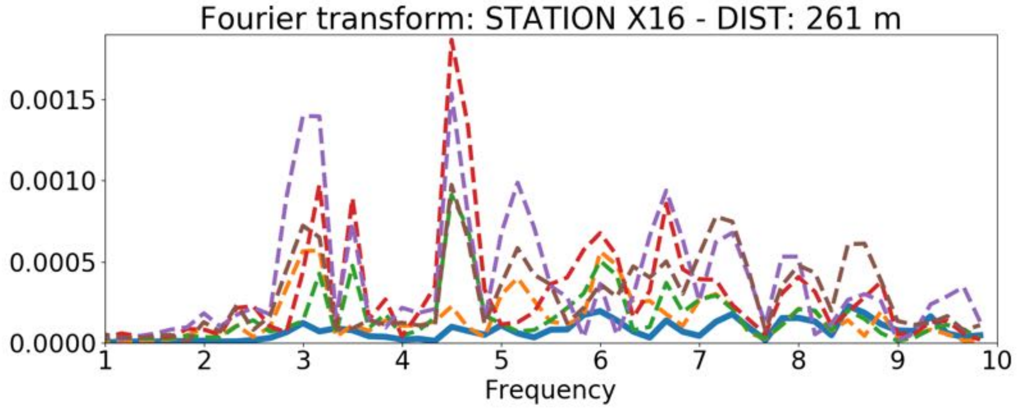






Input signals out of phase



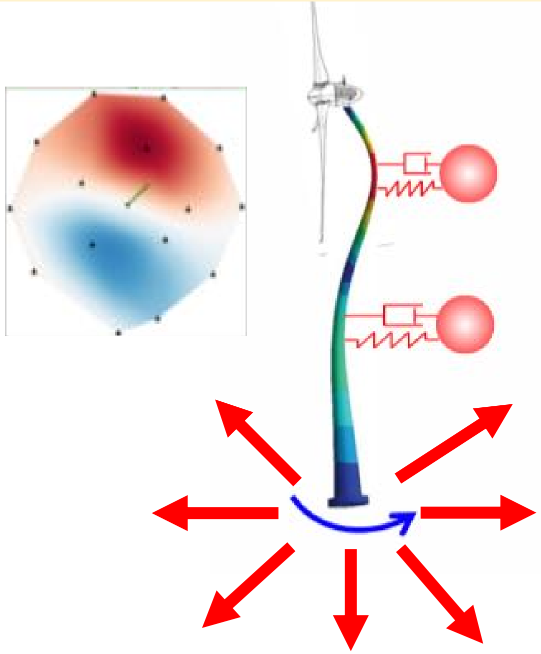


Change in amplitude of particular frequencies
In phase vibrating WTs generate smaller amplitude frequency peaks

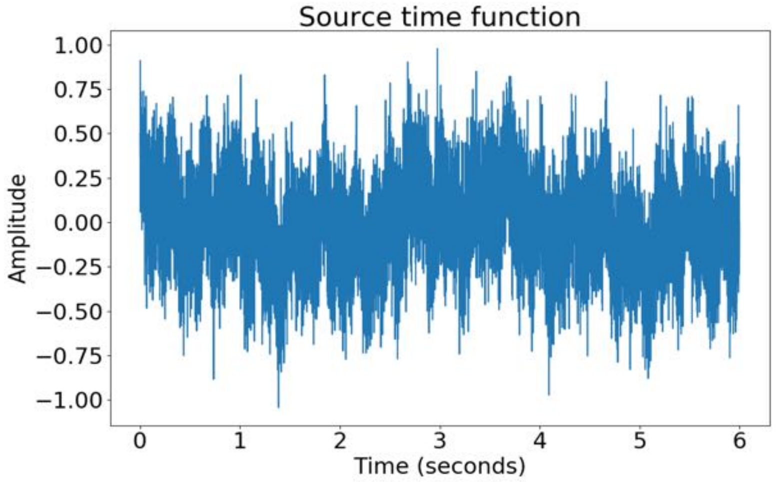
Different types of noise sources from DMT

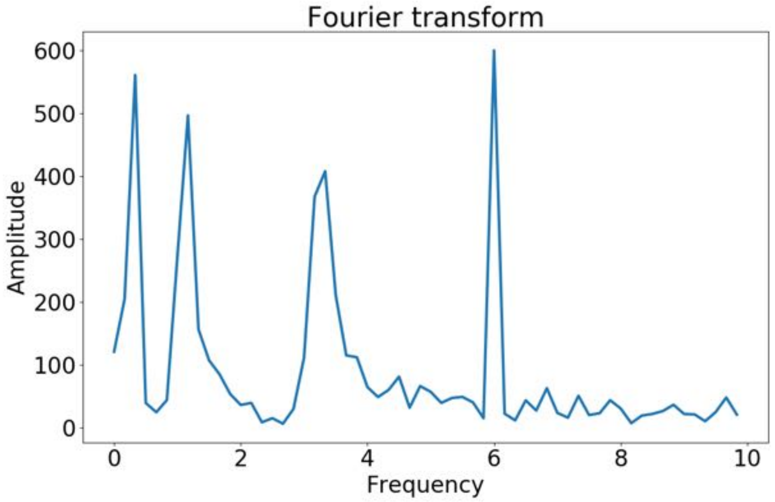
Two sources:
1) Bending
2) Explosion source + bending

$$s(t) = \sum_{i=1}^{4} \cos(2\pi f_i t), \quad \text{with} \quad f_i \in [0.3, 1.1, 3.25, 6]\ [\text{Hz}]$$



more complex source of motion





Seismic source having the main frequency peaks observed in the noise

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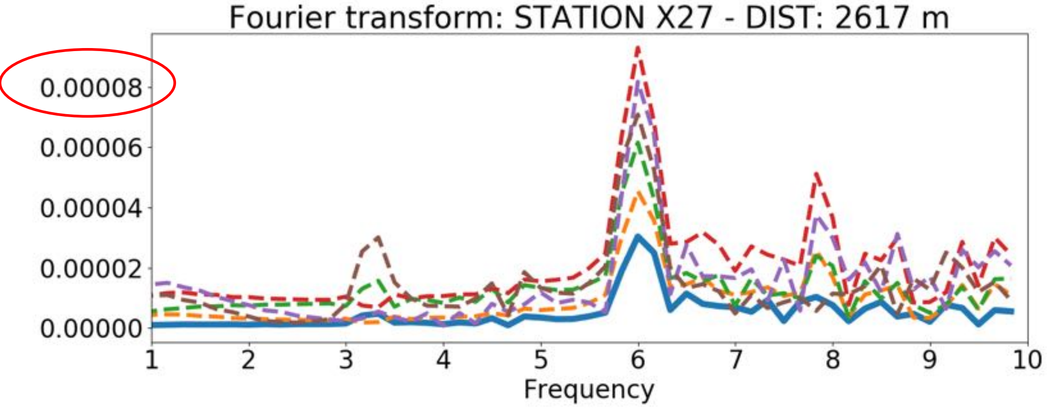
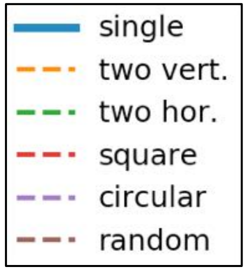
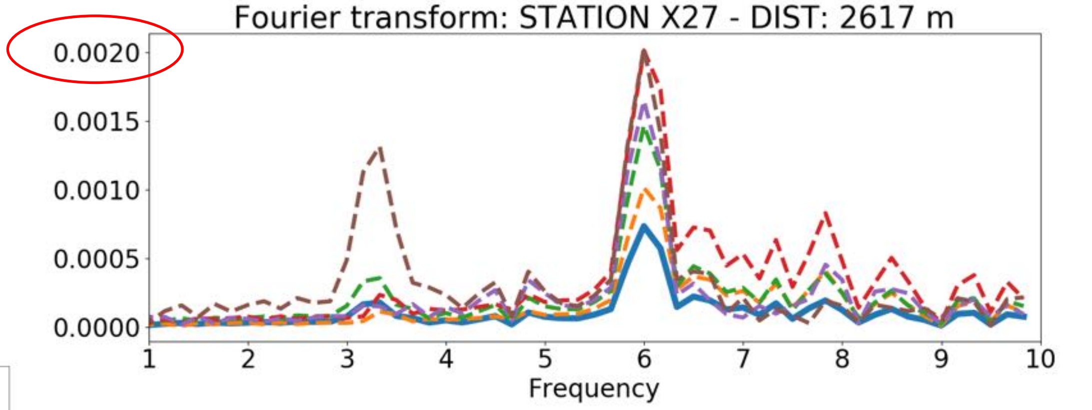
Radiated noise generated by bending vibrational motions of WTs

Only bending

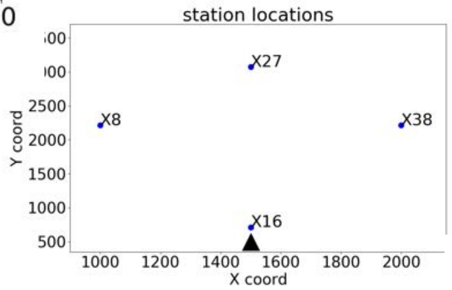




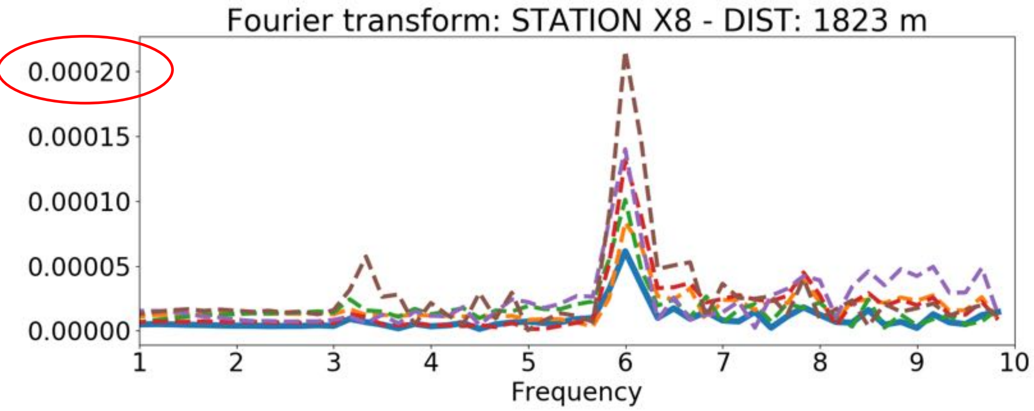
Explosion + bending



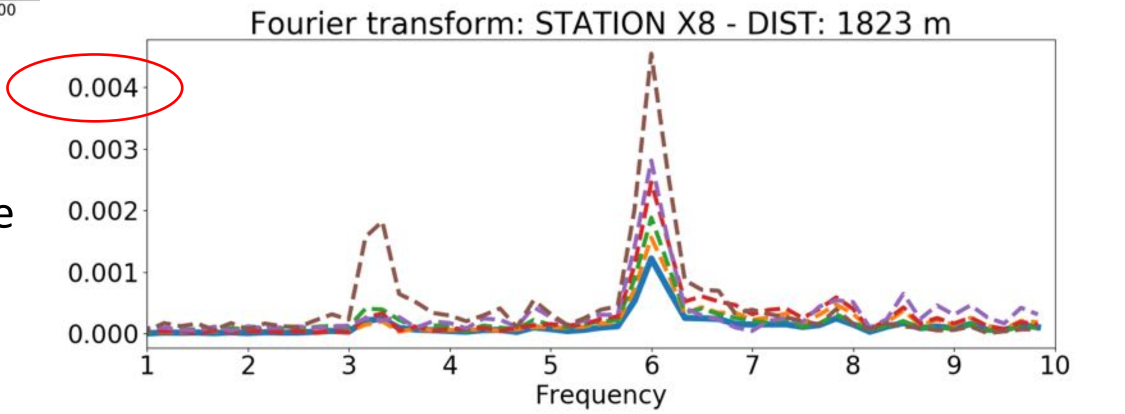
different behaviour is observed



Peaks are visible at long distances
In phase is reduced in amplitude



Note the difference
in the scales



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Summary

- ✓ We cannot find a general rule for arrangements of WTs to reduce the noise radiated at particular frequencies.
- ✓ The excitation of frequency peaks induced by WTs highly depends on the arrangements of WEA in a wind park and the type of source excitation. Noise can be reduced and/or amplified depending on arrangements of WTs.
- ✓ The $\sqrt{N}$ rule relating amplification and number of WTs does not hold (for all frequencies) in our calculations.
- ✓ Influence of geology still needs to be tested.
- ✓ Comparison to real data needs to be carried out for different cases of arrangement of WTs.

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EXTRA SLIDES

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Reduction of seismic noise generated by Wind Parks

DIN 4150-1:2001-06 (2001)

$$v_N = \chi v_B \sqrt{N}$$

- v_N: maximum value vibration speed
- χ: correction factor
- v_B: measured maximum value of the vibration velocity at the observation point
- N: total number of (operative and non-operative) WTs

Schofield (2001)

$$A_{LIGO} = A_{1SL} \left(\frac{v}{15}\right)^{1.5} \sqrt{\frac{P_M}{P_{SL}} \frac{r}{R}} \sqrt{N}$$

(much more complicated formulas)

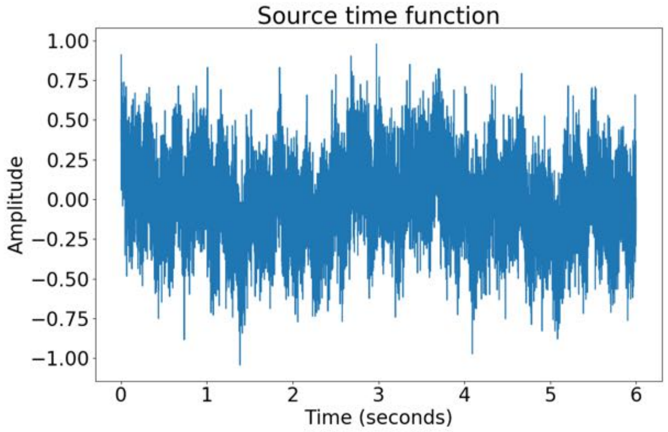
Neuffer (2020); Neuffer and Kremers (2017)

$$\text{NOISE LEVEL} \sim \sqrt{N}$$

- ➢ Is this true for all WPs?
- ➢ Is there a way to reduce seismic noise by different WPs configurations?

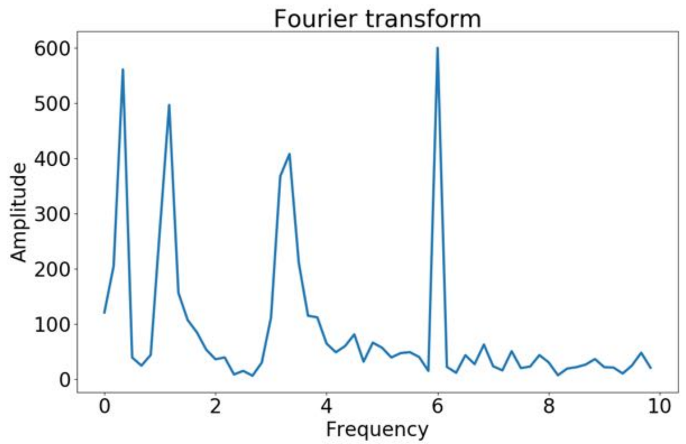
Radiated noise generated by bending vibrational motions of WTs

a) $s(t) = \sum_{i=1}^{4} \cos(2\pi f_i t), \quad \text{with} \quad f_i \in [0.3, 1.1, 3.25, 6]\,[\mathrm{Hz}]$

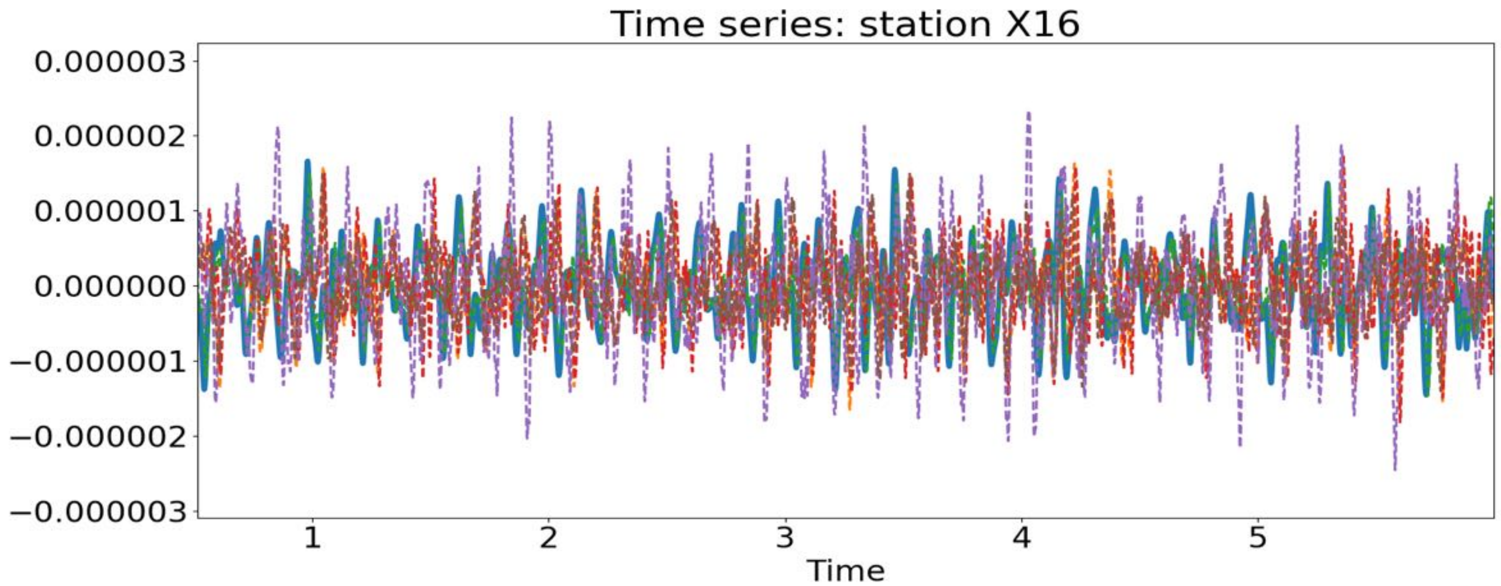


$$M = \begin{pmatrix} 0 & 1 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix} 78.202 \cdot 10^{12}\,[\mathrm{dyne\ cm}]$$

b)



c)



Schofield (2001)

the amplitude of the signal from a WT 18 km far away from the study WT

wind speed

power ratio

is the distance to the WT production the A_{1SL}signal

$$A_{LIGO} = A_{1SL}\left(\frac{v}{15}\right)^{1.5}\sqrt{\frac{P_M}{P_{SL}}}\frac{r}{R}\sqrt{N}$$

amplitude of the signal from a WT 18 km far away from the study WT

average distance from the WP