Solid Earth Discussions

Solid Earth Discuss., referee comment RC2
https://doi.org/10.5194/se-2021-21-RC2, 2021

Comment on se-2021-21

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Referee comment on "Seismic radiation from wind turbines: observations and analytical modeling of frequency-dependent amplitude decays" by Fabian Limberger et al., Solid Earth Discuss., https://doi.org/10.5194/se-2021-21-RC2, 2021

The manuscript on *Seismic radiation from wind turbines: observations and analytical modeling of frequency-dependent amplitude decays* is an important contribution to better understand and predict seismic emissions from wind turbines. Measurement results from a well-chosen experiment are presented together with a new approach to model emissions from several wind turbines such as typical wind farm installations.

The two main results are clearly outlined: attenuation factors for a long-term measurement (6 month) and the influence of phase shifts from multiple sources on the emission amplitudes. However, I recommend a revision before publication:

A description of the geology / underground is completely missing (e.g. after line 68). This information is important to understand seismic velocities and quality factors which depend on the physical rock properties.

The influence of wind parks A and B (Fig. 1) must be explained in more details. Are there large wind turbines which may affect the measurements ? What happens if they radiate emissions in phase ?

What is exactly meant by using the 25% quantile (line 81). Does this mean you exclude 75% of the data ? How sensitive is this selection ? Would it make a difference to use the

20% or 40% quantile ? Do you exclude time windows with earthquakes waves ? This should be clarified in the manuscript.

The peaks at relatively high frequencies of 6.0 Hz and 7.6 Hz are the highest ones. How can this be explained ? Which operational modes of the wind turbines are these ? Please explain.

Section 2.2 on amplitude decay: this is on **PSD** amplitude decay as described in lines 104-106. To makes this clear, **PSD** amplitude decay should be written in lines 106, 109 and 121.

It would be helpful to include the amplitude decay for waves in the time domain. Therefore, a conversion should be applied (factor 0.5). Then the resulting b-values can be better compared with typical wave properties, e.g. 0.5 for geometrical spreading of surface waves. In addition: in Fig. 5, the b-values from Lerbs et al. correspond to wave amplitude decays, not PSD decays ! This should be checked also for the values in Neuffer et al. (2019).

Fig. 6 nicely shows the effect of the random phase shifts. Can your observations explain the observation by Neuffer et al. (2019) that the emissions amplitudes increase with the square root of the number of wind turbines ?

Line 165: Quality factor Q: You do not mention seismic scattering. Especially for high frequencies this may contribute to the wave damping.

Equation (3): A constant amplitude A is used. I understand that this is a reasonable start for modelling. However, it should be mentioned that wind turbines emit timely and azimuthally varying signal amplitudes (e.g. Lerbs et al., 2020: Fig. 6-8). This will modify the results below as well as should be considered in real cases.

Section 3.2: It would be helpful to add some sentences on the wave pattern off the profile and add comments for a non-uniform signal amplitude A (eq. 3).

4 Results: The Q value for low frequencies (40) is quite low. Does this fit with the physical properties of the rocks in the subsurface at >100 m depth ? I guess this could be a solid and compact limestone.

Generally, I am missing a comparison of the vs and Q values with the actual rocks along

the profile.

Results and Fig. 13: What requires a third layer (half space below the second layer) ? Why don’t you use a one-layer model with a half-space below ?

Fig. 10 and 11: The gray model curves on the left do not indicate a preference for the average model (black) line. Also the scatter around the black curve is unclear. Better use a colour / gray scale which indicates the actual distribution density of the models. A colour scale for the right part is missing, so it cannot be understood in its current version.

Line 309: use b-values for waves in the time domain; if b is still smaller than 0.5 please explain why the wave amplitude decay is smaller than geometrical spreading

Lines 311-315: make sure that the b-values of the other studies are comparable to your values (PSD decay, wave decay, …)

The discussion should include a paragraph comparing the vs and Q with the rock properties at depth.

Others:

Line 35: were able **to** distinguish

Line 44: Zieger **et al.**, 2020

Line 61: rpm (**rotations** per minute)

Line 84/85: include Hz after the numerical values

Line 234: Explain why you use the square root for the conversion ? Do you want amplitudes in the frequency or time domain ?

Line 238: 6000 **m**

Lines 265: not "until" but "**down to**"

Line 266: Fig. 13 appears in the text before Fig. 10-12 – please re-sort.

Figure 1: Würzburg must be shown (it is cited in the text)

Fig. 12: the black x (better in white) and the red circle (better in orange) can hardly be seen, increase the contrast