Response to reviewers' comments

We would like to thank both reviewers for their positive assessment of the manuscript and for their helpful comments. The remarks primarily address the applicability of the proposed method under varying boundary conditions, such as different atmospheric situations, topographical settings, and turbine types. This is a valid and important point. These aspects have been added to relevant sections and are additionally identified as areas for future work.

This document provides the answers to the reviewers' comments. The lines used in the answers refer to the new version of the manuscript. The modified paragraphs are marked in the manuscript and are also given in colour in the corresponding responses in this document.

Reviewer 1: (marked blue in the manuscript)

Thank you for the positive assessment and helpful comments.

1. *Maybe some paragraphs may be shortened as the paper is a bit long.*

   Sect. 3.3 (Analysis of listening test) and 5.1 (Application of the detection framework - Statistic of Stage 1) have been shortened. The overall length of the manuscript has been reduced primarily through the reformatting of tables and the removal of empty or non-applicable sections (e.g. "Code availability", "Data availability"). As a result, the manuscript has been shortened by two pages (28 instead of 30). The reductions have not led to any substantive changes to the content.

2. *Maybe some additional details about atmospheric absorption could be of interest. The authors stated that this aspect does not significantly contribute. Is this true also for long listening time when the humidity may change considerably?*

   We agree that atmospheric absorption can vary with changing atmospheric conditions, in particular humidity and temperature. Under particularly favourable atmospheric conditions, atmospheric absorption can affect the detection rate at high frequencies.

   In the revised manuscript, the previous statement has been toned down. Atmospheric absorption is now described as having a minor influence under the present measurement conditions, rather than being negligible. This change reflects the fact that even over the relatively short propagation distance considered here, atmospheric absorption at 2 kHz can have a measurable effect, which under extreme conditions (low temperature, high humidity) can amount to approx. 4 dB. For the third-octave bands below 2 kHz, the effect of atmospheric absorption is considered less relevant, as absorption decreases strongly with lower frequencies. At 1 kHz, atmospheric absorption under extreme conditions is approx. 1.4 dB.

   Sect. 5.1 (lines 480–485) has therefore been revised:
   Due to the relatively short distance of 178 m between the microphone and the wind turbine, atmospheric absorption is expected to have only a minor influence overall. Under standard conditions (20°C, 50% relative humidity), attenuation at 2 kHz is about 1.4 dB per 100 m. Atmospheric absorption may reduce the detection at 2 kHz, while its effect is not pronounced at lower frequencies. However, at greater propagation distances and across a wider range of atmospheric conditions, particularly under low humidity and higher temperatures, atmospheric absorption becomes more significant.

3. *Could also the authors describe a bit the effect of ground in the detection method? Is the ground effect retained in the model?*

   The proposed detection framework is based on measured acoustic time series and does not include an explicit modelling of sound propagation effects. The ground effect is therefore contained in the measured signal and is implicitly considered in the analysis.

   Physically, the ground effect leads to a superposition of direct and ground-reflected sound components, resulting in frequency-dependent interference effects and, consequently, changes in the sound pressure levels of individual frequency bands. In the immediate vicinity of the wind turbine, as in the present case at a distance of 178 m, it is assumed that the direct sound dominates (cf. IEC 61400-11). With increasing distance, ground effects become more significant. The superposition of direct and reflected sound can lead to changes in the spectral characteristics as well as to a reduction in the prominence of the modulation components. In the field, the responsible author observed that at greater distances (approx. 1500 m), the signal often appears less distinctly modulated and more as a broadband noise with a superimposed, less pronounced amplitude modulation.

   The detection method is currently being applied and evaluated using measurement data at distances of up to approx. 1500 m. Initial results show that the wind turbine noise can still be identified even under reduced modulation conditions. At the same time, the reduced modulation leads to a lower detection rate of amplitude modulation in the subsequent identification of WTN components.

   The consideration of the ground effect has been included as part of future work in **Sect. 6 (line 596–597)**:
   The detection capability of the framework will be evaluated with explicit consideration of sound propagation effects, including atmospheric and ground effects.

Reviewer 2: (marked magenta in the manuscript)

Thank you for the positive assessment and for the constructive comments on the applicability of the proposed method under different conditions.

1. *I would maybe only add a sentence or two on if there might be some difference between different types of turbines in terms of noise production and how this method could be adopted to different types of turbines if there is a difference.*

   Different turbine types can differ in their characteristic parameters (e.g. rotor diameter), operational parameters (e.g. rotational speed ranges), and emission characteristics. The proposed method is based on the physically motivated identification of rotor-synchronous modulation components related to the blade passing frequency. These fundamental relationships are inherent to the operation of three-bladed wind turbines and are independent of the specific turbine type, such that the method is, in principle, transferable to different turbines.

   Within the signal analysis, one of the applied criteria is that at least five out of seven third-octave bands in the range of 200–800 Hz must exhibit a harmonic pattern. This frequency range is typically dominated by aerodynamic noise, in particular trailing-edge noise, and therefore represents a suitable range for detection. For older or future turbine types, the spectral distribution of the emission may shift, such that an adjustment of the considered frequency range might be appropriate. In a preceding processing step, the data are filtered prior to the analysis of modulation components using robust criteria. This preselection can be adapted to different turbine types with relatively little effort. This concerns the definition of the lower limit of the rotor speed range at which the wind turbine is considered to be in operation.

   Overall, the method is therefore considered transferable to different turbine types. An adjustment of parameters within the preselection is recommended and was commented in **Sect. 2.1.1 lines 119 to 121**:
   Note that depending on the turbine type and measurement setup, individual preselection criteria, in particular thresholds related to turbine operation and wind-induced background noise, may require adaptation.
   In special cases with significantly deviating emission characteristics, further adjustments might be required. This was added in **Sect. 2.1.2 lines 177 to 178**:
   For turbines with differing spectral source characteristics, such as future turbine types, the frequency range may require adjustment.

2. *Also, I know they tested the method for a specific set of atmospheric and geographic conditions (geography is set by a study area), but it would be nice to include a few thoughts on how this method could be adopted/changed for different geographies (different vegetation, orography,…) and different atmospheric conditions.*

   The present study is based on measurement data obtained under specific atmospheric and geographical conditions. Changes in boundary conditions, such as different vegetation, orography, or atmospheric stratification, influence sound propagation and might lead in reduced modulation.

   As described previously, the proposed method is based on fundamental physical characteristics of wind turbine noise emission and is therefore not inherently tied to specific site conditions. For applications under different conditions, it may, however, be necessary to adapt the preselection parameters. This particularly concerns the definition of threshold values, for example with regard to wind speed, above which wind-induced vegetation noise dominates and the corresponding data are excluded during the preselection.

   With increasing distance and under more complex propagation conditions, additional sound propagation effects, such as the ground effect or shielding effects due to terrain, become more relevant. These can influence the spectral characteristics of the signal and thus the expression of the modulation components (for details on the ground effect, see the response to Reviewer 1, Part 2).

   The method is currently being applied to four measurement campaigns covering different microphone distances of up to approx. 1500 m. These campaigns were conducted in northern Germany, resulting in similar geographical conditions. However, they cover different seasons and thus varying vegetation states, as well as a high variability of atmospheric conditions. Initial results indicate that the method is capable of detecting wind turbines also under varying atmospheric conditions and vegetation states at larger distances.

   The transferability of the method to more diverse geographical conditions, in particular complex topography and forested areas, constitutes an important subject of future work. In such scenarios, additional sound propagation effects, such as shielding or scattering, play a more significant role, such that further adaptations of the method might be required.

   The consideration of the different geographies and the corresponding effects has been included as part of future work in **Sect. 6 (line 597–601)**:
   The measurements conducted so far have been limited to flat terrain and grassland environments. Further investigations under more complex propagation conditions, such as complex topography and forested areas, are therefore of interest. In such environments, additional effects, including scattering and shielding, may become more significant and may alter the emission characteristics at the receiver, such that adjustments of method parameters may be necessary.