Microphone measurements in the vicinity of wind power plants: Results for the wind park in Gagel, Saxony Anhalt, Germany

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Abstract:

This document compiles the results of a sound measurement campaign in the vicinity of a wind park to provide objective data for a quantitative characterisation of noise emission in the infrasound frequency range. Microphone measurements were carried out at a wind park near Gagel, Saxony Anhalt, Germany and were compared with results obtained with microbarometers nearby. The experimental setup, the data acquisition and the analysis are described, and narrowband and octave band spectra are calculated and depicted. Reference data are given which allow a first assessment of the noise situation.

Introduction

Currently the supply of economy and society with electrical energy mainly relies on conventional sources like coal, oil, and gas. The transformation to renewable and sustainable alternatives is a great challenge and mainly the extension of wind energy is hindered by serious questions concerning the noise emission and the following impact on humans living in the vicinity of wind parks. This includes many issues concerning the measurement of the emitted sound fields as a first step of any noise assessment.

In July and August of 2021, the Bundesanstalt für Geowissenschaften und Rohstoffe (BGR) carried out measurements of infrasound near the wind park Gagel located in Altmärkische Höhe, Saxony Anhalt, Germany. Seven measurement stations equipped with microbarometers were placed in increasing distances to the wind park on a ground mainly covered with trees and closed bushes. These stations continuously recorded the infrasound signals in the environment generated by any source. (Bundesanstalt für Geowissenschaften und Rohstoffe 2021)

In order to compare the results obtained by the microbarometers to those got with measurement microphones, the Physikalisch-Technische Bundesanstalt (PTB) accompanied the measurement campaign by multiple short-term microphone measurements at three of the BGR stations named GAG01, GAG02 and GAG07. For a site map of the station area see (BGR 2021). These experiments enable a direct comparison between the two measurement methods in a realistic field environment.

Measurement setup

For the microphone measurements, two identical microphone sets consisting of a ½” microphone capsule Brüel & Kjær 4964, a low frequency preamplifier GRAS 12AK-S1 and a power module GRAS 12AD were used. One of the microphones, here referred to as “microphone on tripod”, was equipped with a spherical 90-mm windscreen of type GRAS AM0069 and mounted approximately one meter above ground on a tripod. The other microphone, here referred to as “microphone on plywood base”, was equipped with a hemispherical 90-mm windscreen of the same type and mounted in the centre of a circular plywood plate with a diameter of one meter. To further reduce wind noise, a hemispherical hollow windscreen with a diameter of 47 cm was used on top of the plywood plate as a secondary windscreen. The screen was home-made using a faux fur fabric which was brought to a spherical form and stabilized by a wire frame. This setup was based on DIN EN 61400-11 (DIN EN 61400DIN EN DIN EN 61400-11:2012 + A1:2018). The microphones were oriented towards the reference point of Gagel windfarm as shown in (BGR 2021). Figure 1 shows the measurement setup at BGR station GAG07.

The analog voltage signals of both microphones were acquired simultaneously with an analog-to-digital converter (A/D converter) of type Data Translation DT9857E and were stored as .wav files on a laptop using an in-house developed recording software.

Both microphone chains were individually calibrated in a frequency range from 2 Hz to 100 Hz. At the BGR stations microbarometers of type MB2000, MB2005 and MB3d were used (CEA - French Alternative Energies and Atomic Energy Commission 2012)

Figure 1: Setup of the measurement microphones

For a measurement included in this dataset, we arranged the microphones next to one of the BGR microbarometers at the stations as shown in Figure 1. During a time interval of about 45 minutes data was recorded and off-line periods including obvious disturbances and faults were cut out. Finally, a continuous trace of clean, undisturbed data with a length of 30 minutes remains. To compare the microphone data to the results obtained by the microbarometers, the corresponding data was assigned using the noticed timestamp and were downloaded from EIDA data system (Hartmann 2021). The timestamps of the microphone and microbarometer measurements were matched with an accuracy of one second.

Data File format

The voltage output signals of the microphone chains were sampled with a sampling rate of 2000 Hz and saved to individual 32-bit float .wav files. The samples were normalized to a range of ± 10 V to preserve the full dynamic range of the A/D converter.

To convert the .wav data to a sound pressure in Pascal (Pa), the samples have to be denormalized by multiplying with a factor of 10 V (corresponding to the original full-scale value of 10 V) and divided by the sensitivity of the corresponding microphone in V/Pa. The sensitivity values for the microphone chains were:

- Microphone on tripod: 0.04915 V/Pa
- Microphone on plywood base: 0.05166 V/Pa

These sensitivity values were valid in the frequency range from 2 Hz to 100 Hz with an uncertainty of 0.6 dB. They resulted from a secondary calibration carried out at PTB before starting the measurement campaign. Inspection of the calibration data revealed an extremely low variation of the sensitivities in the frequency range between 2 Hz and 100 Hz, which allows the application of a single sensitivity value for all samples. The uncertainty given comprises technical contributions from the calibration process as well as an inclusion of the spreading over the frequency range from 2 Hz to 100 Hz. The positioning of the microphones at the measurement points and environmental influences such as wind noise further increase the measurement uncertainty.

To compare the measurements obtained by the microphones to those of the microbarometers, the data of the continuous acquisitions from the microbarometer stations corresponding to the microphone measurement time periods have been taken from the BGR dataset downloaded from the data server. This data has also been converted to normalized 32-bit float .wav files. These acquisitions were taken with a sampling rate of 100 Hz. Since the measured pressure range spans more than 10 Pa, a normalization to ± 20 Pa has been applied to all microbarometer .wav files. To convert the samples from these .wav files back to sound pressure values, the samples have to be denormalized by multiplying with the full-scale value of 20 Pa.

The wav files were named using the convention <Station_name>_<Start_timestamp_UTC>_<measurement_device>.wav, where <Station_name> is the name of the corresponding microbarometer station, <Start_timestamp_UTC> is the date and start time of the microphone data given as UTC time and <measurement_device> describes with which device (microphone or microbarometer) the measurement was conducted.

Data Analysis

For every 30-minutes long data set a narrowband power spectrum and a third-octave band spectrum have been computed. The unit of both spectra is dB (re 20 µPa). While the narrowband spectrum provides a detailed view of the frequency components of the signal, the third-octave band spectrum gives a reliable measure of the sound pressure levels in wider frequency ranges (third-octave fractions). As stated in the standard DIN 45680 (DIN 45680:2011) the third octave band levels can be compared with reference data describing the hearing threshold or a perception threshold for an assessment of infrasound noise. Unfortunately DIN 45680 defines a perception threshold only down to 8 Hz and the measurements presented here stretch to much lower values. To allow a comparison at these lower frequencies, an Excel table is included in this publication which summarizes several potential reference data from various sources for a wider frequency range.

The narrowband spectrum has been calculated as the average of 50 % overlapping power spectra with a window length of 5 minutes. A hann window has been used to decrease spectral leakage. The energy loss caused by the hann window has been compensated, so that the narrowband spectrum contains the same energy as the original time signal. Resulting from the window length, the spectral resolution is 1/300 Hz.

From the narrowband spectrum the third-octave spectrum has been computed in the frequency domain. The energy in every third-octave band has been computed using raised-cosine frequency filters which fulfill the requirements given in DIN EN 61260-1 (DIN EN 61260-1:2014).

For every 30-minutes data set a plot containing the computed spectra for the microphone on a tripod, the microphone on the plywood base and the microbarometer has been created. The frequency range below 2 Hz is included in the plots for comparison purposes but is marked in grey color to indicate that it is outside the microphone calibration range. All computed spectra are attached as .pdf files, following the naming convention "<Station_name>_<Start_timestamp_UTC>_<spectrum_type>.pdf. Furthermore, the third-octave band levels for every third-octave band spectrum have been exported as .csv files using the same naming convention.

The analysis of the influence of wind and positioning is not finished yet. To estimate the disturbances caused by wind noise, the difference in the sound pressure levels obtained by the measurements by the microphone on the tripod and those by the microphone on the plywood base was considered. Recordings where the difference of the third-octave band levels exceeded 10 dB for frequencies above 2 Hz were considered as disturbed by wind noise and, thus, are not included in this dataset. The rationale of this criterium relies on subjective experience from the measurement process. Further experiments will be conducted to develop a better understanding of the influence of wind on infrasound measurements with microphones.

Attachments

The following files are included in this publication:

File type	Naming convention	Number of files
Raw data (.wav)	<Station_name>_<Start_timestamp_UTC>_ <measurement_device>.wav	39
Narrowband spectrum plots (.pdf)	<Station_name>_<Start_timestamp_UTC>_ narrowband_spectrum.pdf	13

Third-octave band spectrum plots (.pdf)	<Station_name>_<Start_timestamp_UTC>_ third_octave_spectrum.pdf	13
Third-octave band spectrum levels (.csv)	<Station_name>_<Start_timestamp_UTC>_ third_octave_spectrum.csv	13
Summary of perception thresholds in the infrasound frequency range (.xlsx)	Thresholds following ISO 226_Moeller_Kühler_DIN 45680.xlsx	1
Summary of perception thresholds in the infrasound frequency range - plot (.pdf)	Thresholds.pdf	1

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