Nor848A Acoustic Camera

Use of the Nor848A acoustic camera on wind turbines

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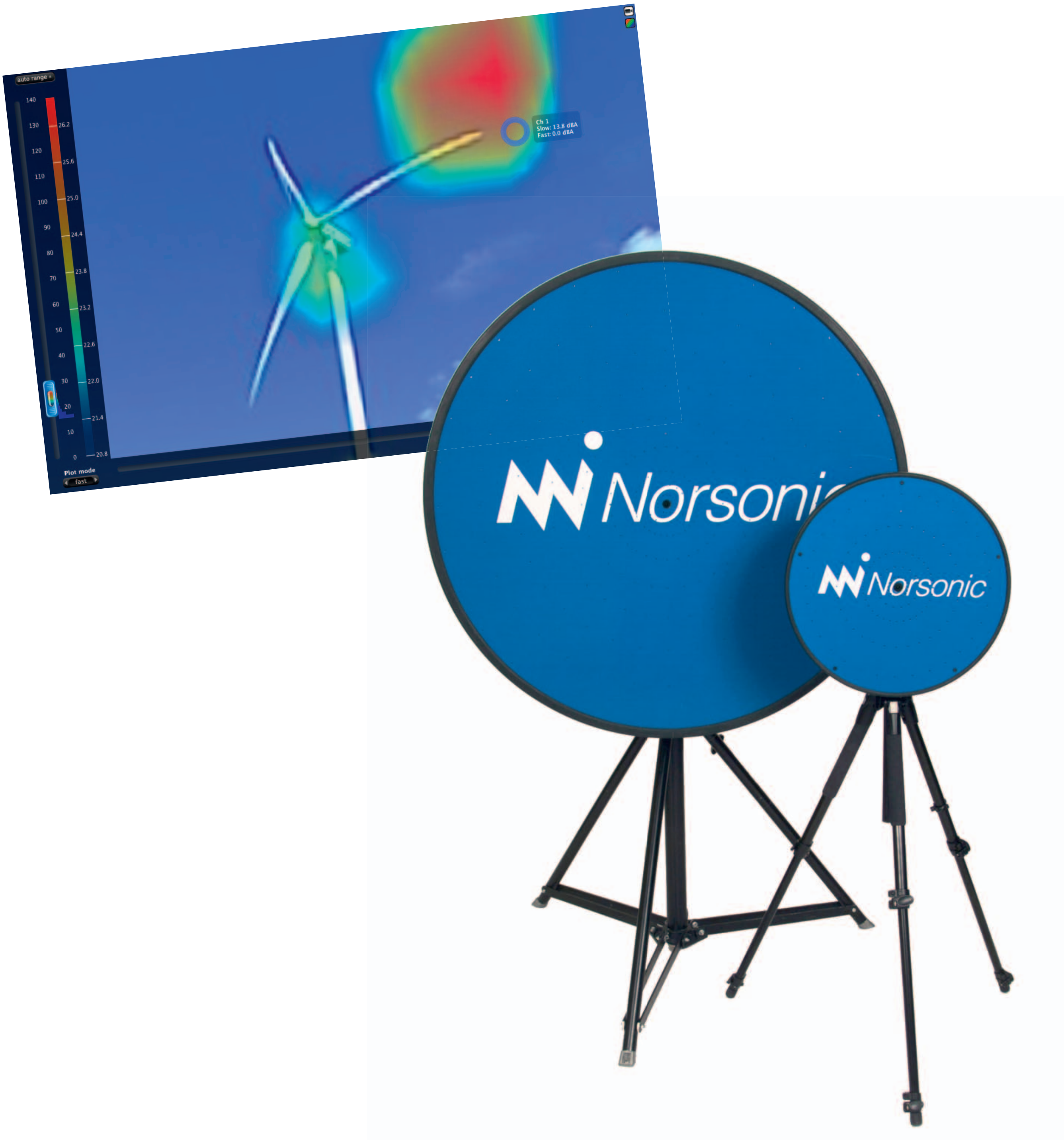


The acoustic camera system Nor848 is a powerful tool to investigate noise sources. In realtime you listen to a beamformed audio signal so that you can hear individual sources one by one. Immediately you can identify the strongest over all noise source in a multisource environment, and you can do the same analysis for single frequencies, 1/3 or 1/1 octave bands or any given frequency range.

This study shows that in addition to document noise emission from a windturbine, the Nor848 can be a useful tool for predictive maintenance. Anomalies in noise emission from the different parts of the turbine will indicate that the given part should be further investigated to avoid later failure or breakdown.

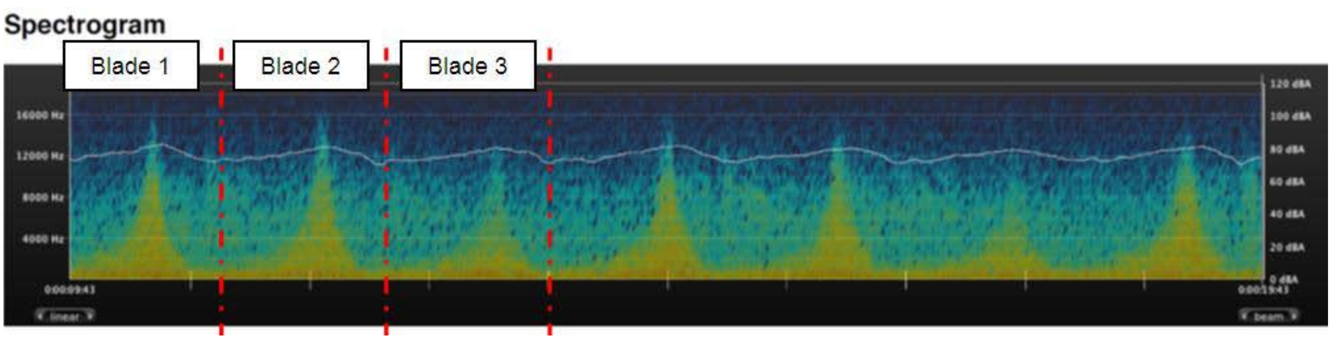
Three different situations are investigated in this paper

1. Different sound pressure level from the different rotor blades. This can indicate damage on a rotor blade that decrease the efficiency of the turbine, and also it can generate damage from asymmetric wear and tear or even accidents if the blade or parts of the blade fall off.
2. Resonances in the tower giving low frequency noise. This is a major nuisance for neighbours as low frequency noise propagates over long distances. Also as we shall see it might be an indication of need of maintenance as it can be caused by abnormal vibration from the gearbox or the generator itself.
3. Tonal noise is another major source of complaints from neighbours of a wind turbine farm. With an acoustic camera you can locate and document the source of the tonal noise

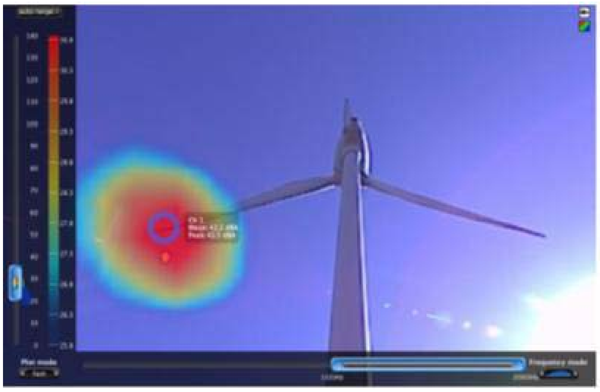
Differences in sound pressure levels of individual rotorblades

By investigating the waterfall spectrogram differences in noise spectra between the individual blades can easily be discovered.

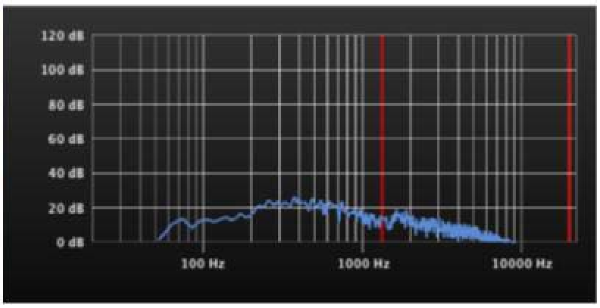
In this case blade one is the one with the highest level. This can be shown with the spectrogram. Therefore the virtuel microphone is set on the bladetips and the spectrogram should be switched from single (standard) to beam. By analyzing the aerodynamic sounds of the blade, we have to look on the frequencies above 1 kHz. For a better overview the time scaling should be increasd up to 10 sec.



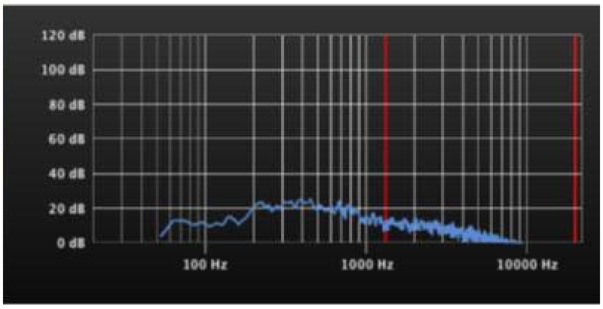
Another possibility to visualize the different sound pressure level of the rotorblades is to switch off the auto range mode. Now we can chose our dynamic range so that the blade with the lower level won't be visuallized.



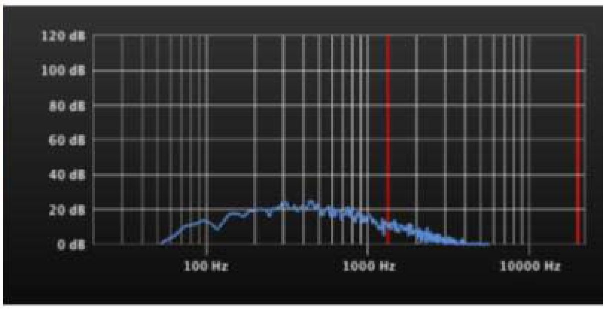
Frequencies at beam focus point



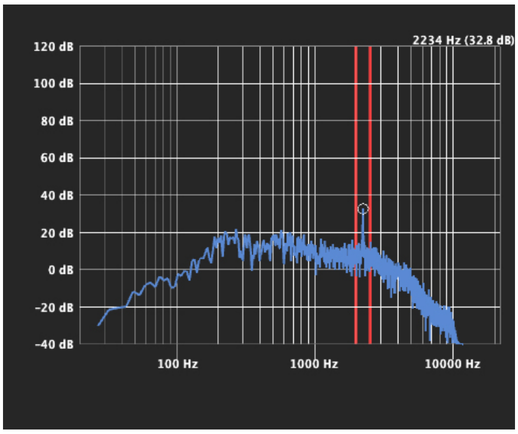
Frequencies at beam focus point



Frequencies at beam focus point

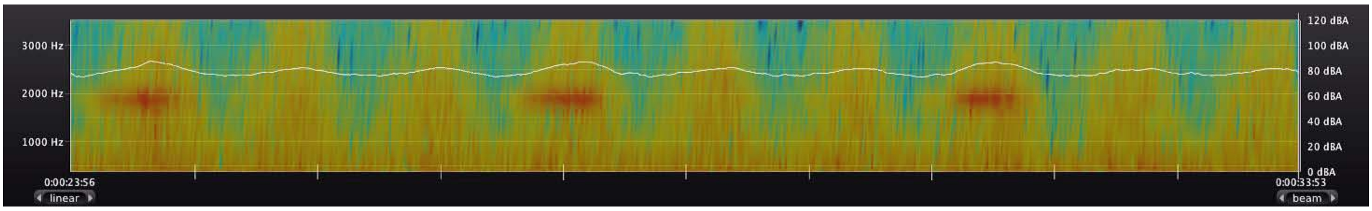


Blade with lightning stroke



In this measurement we detected a blade with a lightning stroke. With the virtual microphone positioned on the blade tips we can see in the red colour in the spectrogram when the damaged blade passes.

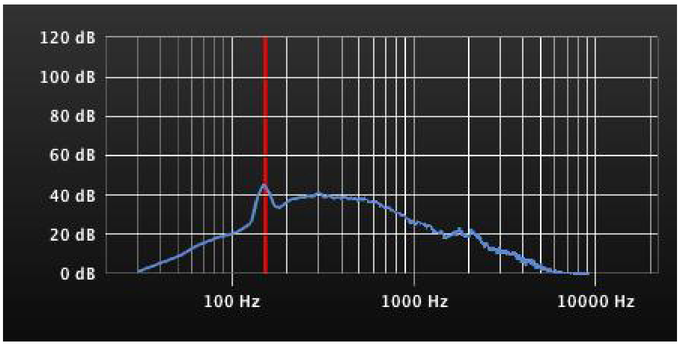
Beam mode:



Example of blade damaged by lightening. (Photo by ARGE WEA, Austria)

Resonances in the tower

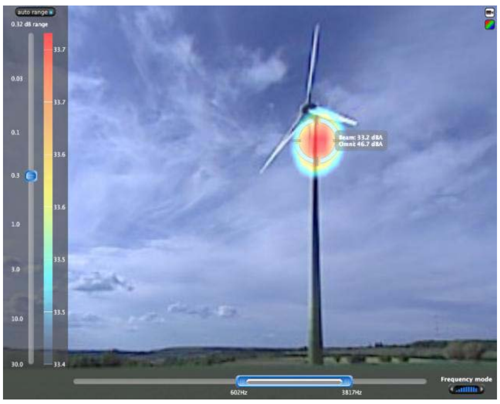
Some wind turbines have problems with structure-borne sound. In the follwing picture we can see that the tower of the wind turbine radiates low frequent sound. In the frequency spectrum we see also that there is a resonance in the tower (ca. 160 Hz). To increase the chance that the localized source actually located at the point shown, we have to increase the integration time. Either by the time constant is set to slow, or averaged over a longer time period. This analysis is done in “frequency mode” which is an optimized adaptive beamforming method that can improve spatial resolution on lower frequencies.

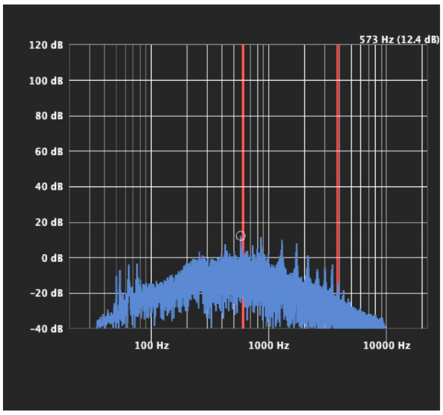


The gearbox or/and the generator are the exciter who set the tower in resonance. In this case the wind turbine (Enercon E70) has only an annular generator and doesn’t use a gearbox. Propably the vibration are produced because of deformation of the lamination stack which can be caused by the influence of a strong electromagnetic field.

Tonal noise of a wind turbine

Two main types of noise sources occur on wind turbines. One of them is the aerodynamic noise which is radiated by the rotor. The other sound source is the machine noise which is radiated by the nacelle and the tower. The main part of the machine noise will be produced by the gearbox and the generator. With enough wind, wind speeds of 8 m/s and more (nominal operation), the noise from the generator and the gearbox can obtain a tonal character that marks itself from the aerodynamic noise. Sometimes other machine parts will be hearable. E.g. the yaw-drive is only hearable when the wind direction has changed and wind turbine turns its nacelle into the wind direction.

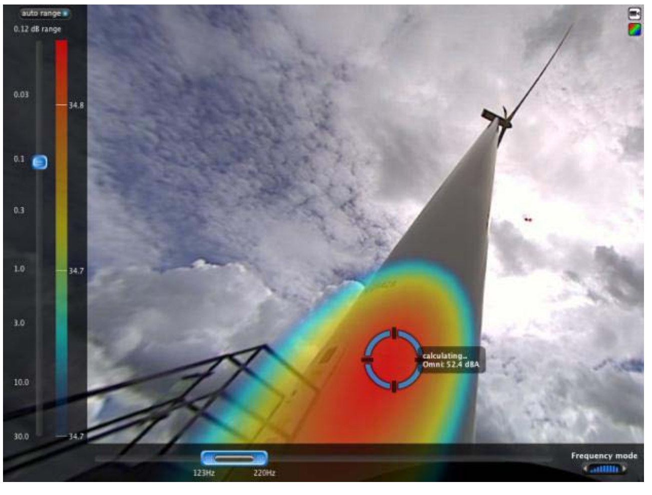


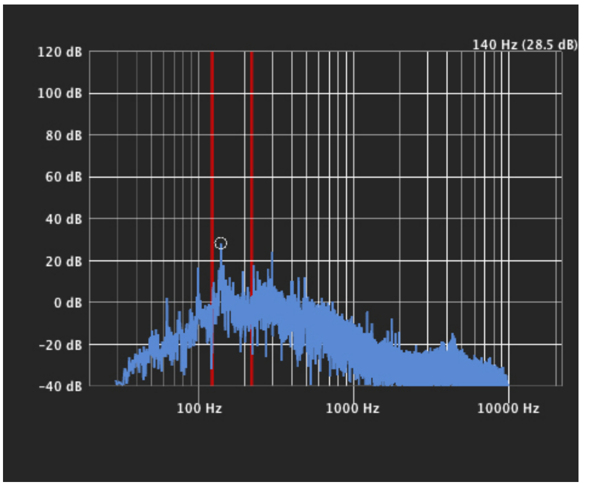


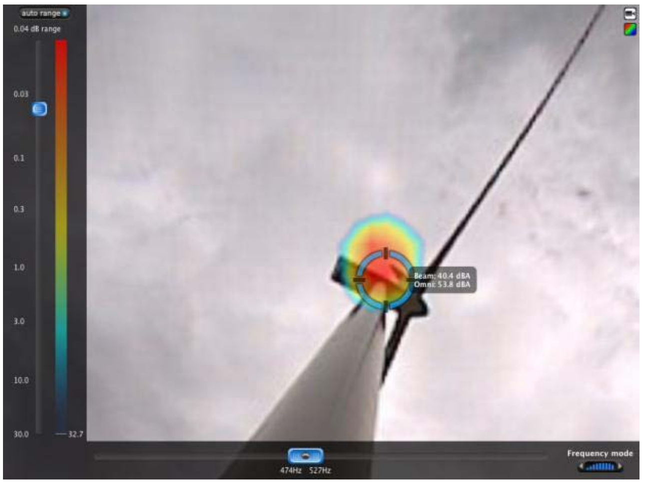
In the picture you can see a Nor848 analysis that shows the noise generated when the yaw drive turns the rotors towards the wind. The yaw drives will radiate vibrations which will be transmitted into the tower and manifest itself as noise.

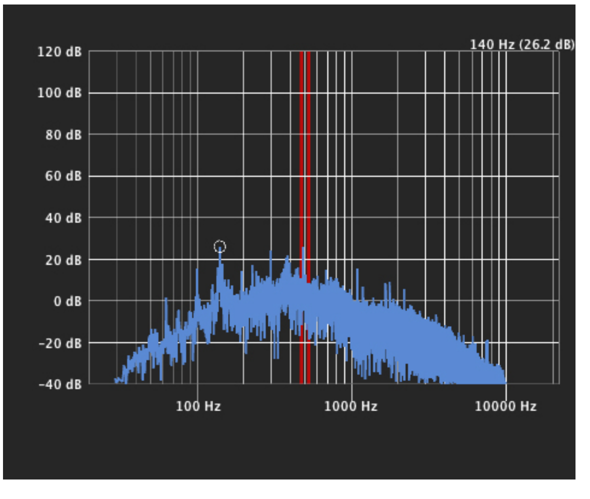
While the wind turbines are operated they sometimes radiate impulsive noise from the hydraulic or electrical break. Pitch controlled wind turbines have an additional noise source: because they are variable in speed they use an inverter, which radiates sounds typically to around 4 kHz. The direct airborne sound of all these sources can be localized on the nacelle, unlike the low frequencies which are transmitted by structure borne sound and so can be localized from the tower.

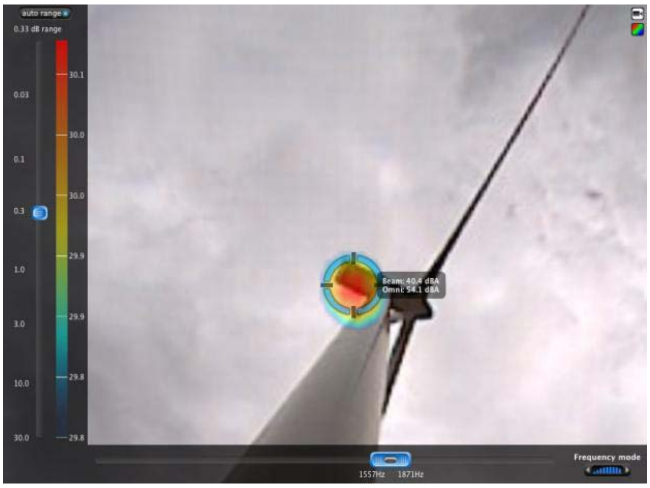
It has to be mentioned that not every tower radiates sound. Some towers are made of reinforced concrete and only the last part on the top of the tower is made of steel. There are also wind turbines where resonances in the tower are reducedby dynamic vibration absorber at the gearbox or/ and the generator.

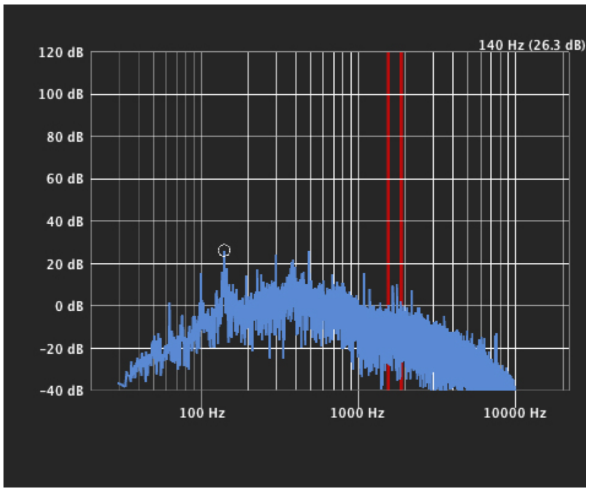












The picture shows how the Nor848 software can be used to locate the loudest noise emitted from a wind turbine – here is indicated the location of the dominant sources for around 200Hz, 500Hz and 2kHz.

Wind turbines energy production capacity is projected to increase by more than 10% each year the next several years. However the development of wind turbine farms are often delayed because of objections to noise or vibration. Modern wind turbines produce significantly less noise than older designs. Turbine designers work to minimize noise, as noise reflects lost energy and output. Only with continuous attention to noise emission during design, installation and operation of wind turbines we can have a chance that ambitious targets for increasing the share of clean energy from wind harvesting can be met. Noise assessments with the assistance of tools like the Nor848 acoustic camera will contribute to this goal.

Unique features for the Nor848 acoustic camera:

Features:

- 3 Sizes Available
- 128 microphones 0.4M array, compact and low cost
- 256 microphones 1M array, only 11 kg weight
- 384 microphones 1.6M array, for lower frequency analysis
- No interface box between array and laptop, direct connection with LAN cable
- Listen to and analyze real time audio from virtual microphone position
- The virtual microphone enables you to listen to the sound contribution from any source real time, filtered with your selected frequency range
- Microphones on a disc reduce the influence of sound and echo from behind
- RPM option for analyzing rotating machinery.
- High-performance optical video camera are included in the camera front-end unit

- The distribution of the high number of microphones ensures high resolving power and reduces the problems due to side lobe effects compared to most other acoustic cameras
- Digital microphones ensure large dynamic range and high stability
- Operated on mains or DC input
- Records the raw signal from every single microphone

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