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Wind turbine noise measurement : an efficient and reliable method for extracting the wind turbine noise out of the background noise

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Summary

Wind turbines are mostly implanted in the countryside where the background noise is usually low and at typical distances of 350 to 500 meters from the nearest neighboring dwellings. As a result, their specific noise is about the level of the background noise (typically 35 to 50 dBA) and as such difficult to extract from it. However one can take advantage of the typical wind turbine sound modulation. The method consists first in measuring and storing the time history of the short LAeq(1s) every second in continuous over the period of investigation (typically not less than 1 month if a statistical figure is to be obtained). Then the diagram of occurrences (step 0.5 dB) of these LAeq(1s) is to be plotted for each consecutive period of 10 minutes. On each graph the specific contribution of the wind turbine noise appears out of the background noise, as a group of five consecutive bands that correspond to the typical 2 to 3 dB wind turbine sound modulation. The wind turbine noise over the 10 minutes period is then the value of the fourth band. This method has been applied and validated on 5 different sites during more than 500 measuring days in continuous.

1. Introduction

When setting-up noise limits it is important to be able to control them afterwards and as such, to make sure to have a reliable and an efficient measurement method.
The case of wind turbines is specific because their noise is usually low in the neighborhood and is often close to, or partly covered by the background noise.
It is therefore important to be able to extract the specific noise of the wind turbine, out of the background noise, without stopping the machines.
This article presents such a measurement method, describing the measurement parameters, the measurement protocol and the results of the validation campaigns.

2. Why Wind Turbine Noise is close to the background noise

The situation is that wind turbines need wind to run. And this feature has two direct consequences : the (big) size of the machines and the place (countryside) where they are best implanted.
Wind turbines are of (very) big size in order to get the maximum of the wind gradient (the higher, the better – typically a tower height of 100 meters) and in order to get the maximum of the wind flow (the bigger the rotor surface, the better – typically a rotor diameter of about 100 to 130 meters).
For the same reasons wind turbines are further best implanted in the countryside, away from obstacles and at the top of the hills (in order to fully benefit from the best possible “linear” wind gradient).
As a result the machines are quiet intrusive in the landscape, especially when viewed from the direct neighborhood. This leads to force a minimum distance with respect to the first dwellings, in an attempt to reduce/minimize this visual landscaping intrusion on the neighborhood population. This minimum (landscaping) distance is commonly set to 3 to 4 times the total height of the machine, i.e. typically 350 to 500 meters (or even more).
From the noise point of view such distances (about 500 meters away) provide a certain amount of attenuation which is nearly exclusively due to the distance effect.
Indeed the size of the machine forces the noise to be generated (very) high above ground, typically from 50 to 150 meters in altitude as the blades repeatedly cut the wind gradient. At this altitude no ground effect is accounted for. In turn, this “high in altitude” generated sound can freely propagate over large distances since the machines are overlooking the surroundings from the top of the hills down to the houses.
Such configuration does not lead to significant ground attenuation so that the sound attenuation is about 60-62 dB (distance effect) over the typical 500 meters (that is the minimum visual landscaping distance between the wind turbines and the nearest dwellings). As a result the specific noise level comes up to be less than or maximum 45 dBA at the façade of the nearest dwellings as table 1 shows – depending on the wind speed (at 10 m height) and on the specific noise power curve of the wind turbine.
Typical background noise levels are of the same order of magnitude as the ones induced by wind turbines – making it necessary to derive a specific noise measurement procedure in order to extract the specific wind turbine noise out of the background noise, without stopping the machines.

Table 1 – Specific wind turbine noise level at a distance of 500 m

Wind speed at 10 m height, m/s	Sound power level, dBA	SPL at 500 m, dBA
4	97	35
5	101	39
6	103	41
7	104	42
8	104	42

3. Noise Amplitude Modulation

Wind turbine noise is characterized by a continuous variation in its sound level amplitude. This phenomena is due to the size of the machine. The noise is indeed generated (very) high above ground (typically from 50 to 150 meters in altitude) and the modulation of the sound level amplitude comes each time one blade repeatedly cuts the wind gradient in the upper part of the rotor.
This phenomena can be best observed when measuring at the foot of the machine with a time integration less than 1 second, ideally less than 100 ms. The typical rotation speed of the machine is about 15 rounds/minute so that one blade passes every 1,33 second at the bottom of the rotor. The measuring time constant should therefore be less than 1 second if the phenomena is to be observed.
Figure 1 below shows 11 “peaks” each of which corresponds to the repeated passage of each successive blade – leading to 44 “peaks” in one minute, i.e. 15 rounds per minute (since there are 3 blades).
The figure is obtained with a measurement time constant of 100 ms. It clearly shows the sound level amplitude modulation (about 4 to 5 dB – when considering a measuring time constant of 100 ms – and about 2 to 3 dB – when considering a measuring time constant of 1 second) each time a blade is passing. This is the typical “waouh” “waouh” wind turbine sound characteristic. This characteristic can be used at large distance (at about 500 m from the machine) to extract the specific wind turbine noise level out of the background noise.

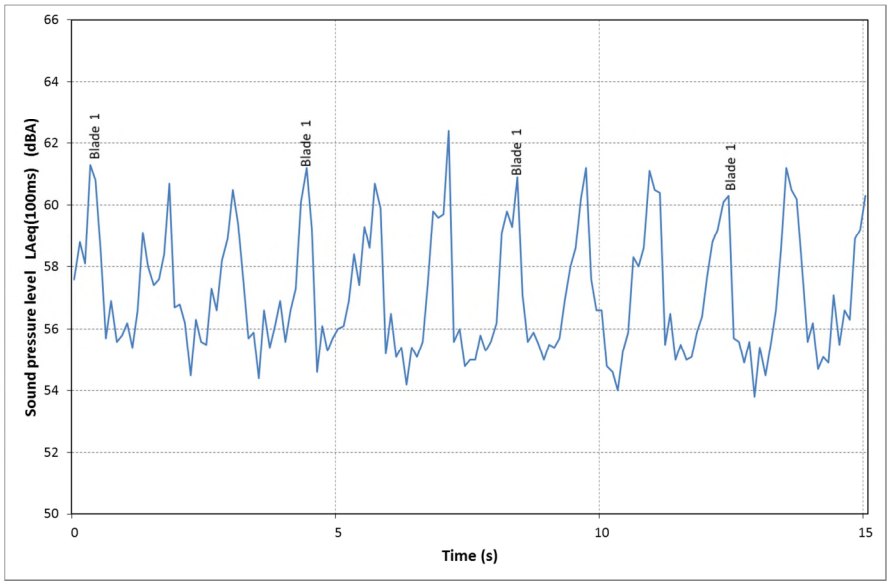
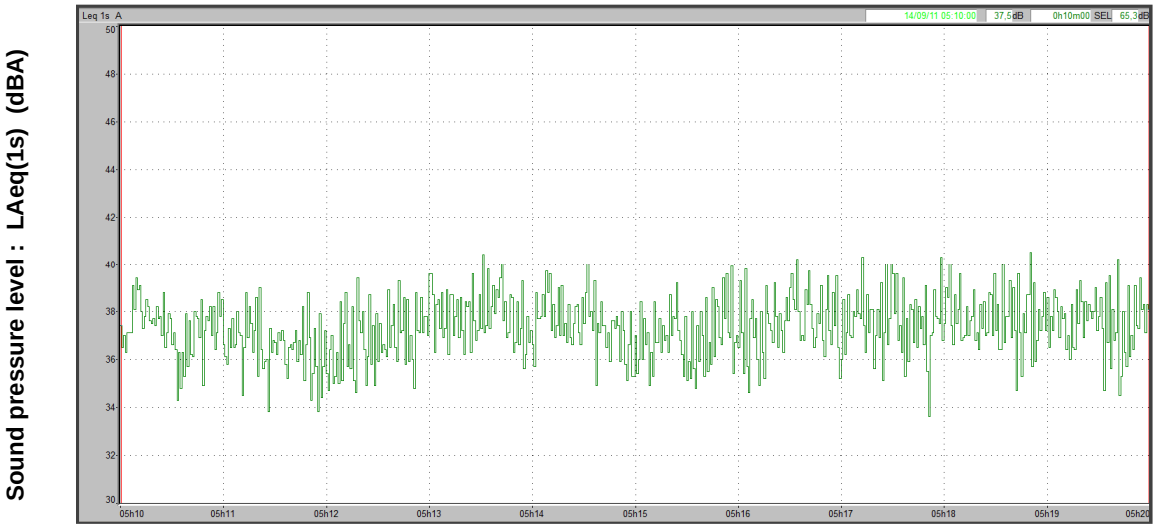


Figure 1 – Wind turbine sound amplitude modulation (15 rounds/minute)

4. Measurement protocol and signal processing

The measurement procedure is first to measure and to store the time history of the short LAeq(1s) every second in continuous over a long period of investigation (for statistical purposes) – typically 1 to 2 months, 24 hours per day, 7 days per week. Figure 2 shows an example of such a time history over a period of 10 minutes where the typical wind turbine noise amplitude modulation (here about 2 to 4 dB) can be seen.

Figure 2 – Time history of LAeq(1s) over a period of 10 consecutive minutes, at night



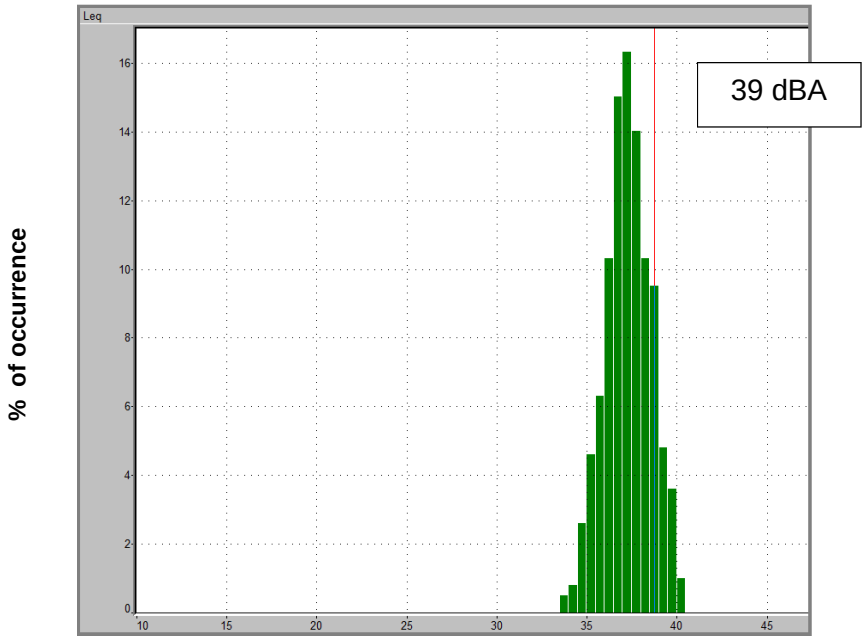
time : 10 minutes period starting 05h10 until 05h20

Then the diagram of occurrences (for each class of 0,5 dB) is plotted for each consecutive period of 10 minutes over the total measurement period. In other words the number of occurrences of each class of 0,5 dB is counted over each period of 10 consecutive minutes. Figure 3 shows the resulting histogram of occurrences that corresponds to the Figure 2 time history.

The wind turbine noise amplitude modulation always appears on the diagram of occurrences as a bundle of 5 consecutive bands of 0,5 dB (see Figure 3) corresponding to the 2 to 4 dB amplitude modulation.

In the study the specific wind turbine noise level has been set to the band “just above” these 5 systematic consecutive bands (to account for the typical wind turbine noise amplitude modulation). The specific wind turbine noise level has therefore been set to 39 dBA for the corresponding 10 minutes of Figures 2 and 3.

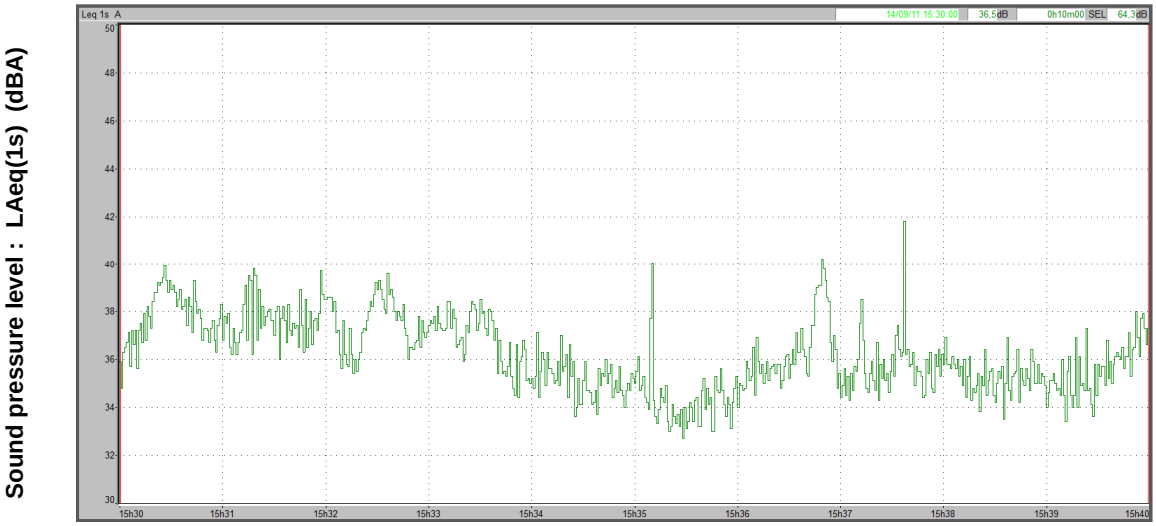
Figure 3 – Histogram of occurrences corresponding to the time history of Figure 2



Sound pressure level LAeq(1s) per class of 0,5 dB

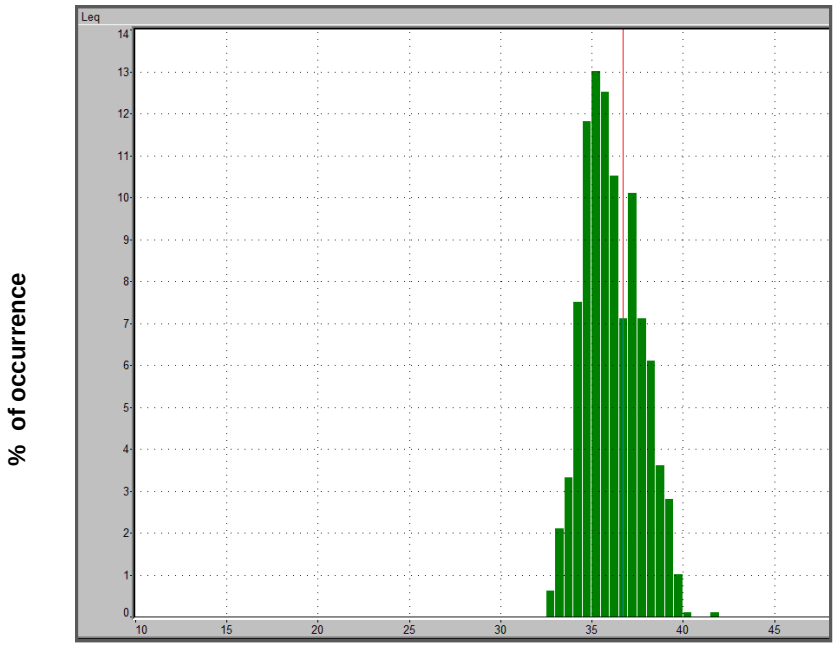
Figures 4 and 5 show how the background noise is filtered and how the wind turbine noise is extracted over the corresponding LAeq(1s) 10 minutes time history.

Figure 4 – Time history of LAeq(1s) over a period of 10 consecutive minutes during the day



time : 10 minutes period starting 15h30 until 15h40

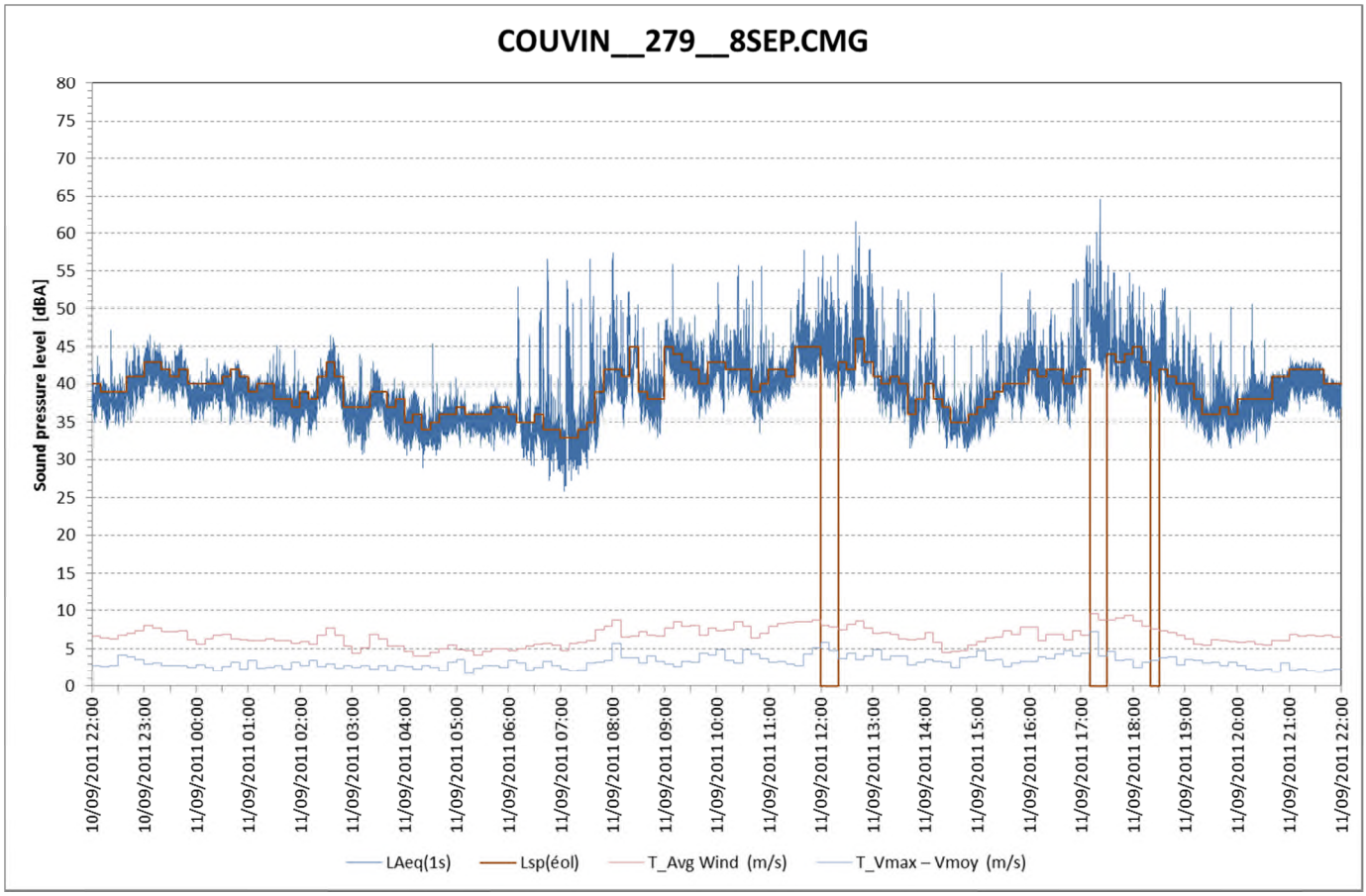
Figure 5 – Histogram of occurrences corresponding to the time history of Figure 4



Sound pressure level LAeq(1s) per class of 0,5 dB

Figure 6 shows how the specific wind turbine noise level (the orange line plotted by steps of 10 minutes) compares to the ambiant noise LAeq(1s) (blue line). See how the “peaks” are filtered over the day and how the specific wind turbine noise level increases/decreases as the average wind speed (at hub height – T_AvgWind m/s) goes up or down.

Figure 6 – Full 24 hours time history showing the measured LAeq(1s) (blue line) and the specific L10min wind turbine specific noise levels (orange line)



5. Statistic validation

The proposed method has been applied with success to about 509 days of permanent LAeq(1s) measurements distributed over 5 different wind farms and at distances from the nearest wind turbine that varied from 450 meters up to 700 meters. The method has been tested over the 4 seasons.

6. Conclusion

This paper presents an efficient and reliable method which extracts the specific wind turbine noise level out of the background noise. It uses the specific wind turbine noise amplitude modulation to do so. Hence the diagram of occurrences (for each class of 0,5 dB) is plotted for each consecutive period of 10 minutes of the continuously measured LAeq(1s). The specific wind turbine noise level modulation always appears as a bundle of 5 consecutive bands of 0,5 dB from which the immediate band “just above” these five is taken as the specific wind turbine noise level. The method has been applied with success to about 509 days of permanent LAeq(1s) measurements distributed over 5 different wind farms and at distances from the nearest wind turbine that varied from 450 meters up to 700 meters. All 4 seasons were tested. All wind parameters were measured in parallel to the noise measurements.

References

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