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Metrological validation of the DIN ISO 9613-2 propagation model concerning wind turbine noise

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Summary

Wind turbines can cause harmful effects by noise on the environment resp. humans in the neighbourhood. Sound propagation calculations for wind turbine projects in Germany are usually carried out by using the alternative calculation method of DIN ISO 9613-2.

Within the research project “Metrological validation of the DIN ISO 9613-2 propagation model concerning wind turbine noise” reliable data was collected and evaluated to figure out the difference between the calculated and the real sound propagation of wind turbines in order to consequently improve the forecast quality.

Two wind turbines of the two megawatt class with a hub height of 100 metres and a rotor diameter of 80 metres were used as emission source. All sound pressure level measurements at distances between about 500 metre and 1000 metre to the wind turbines were performed synchronously to the emission measurements at the wind turbines.

The calculations of the sound propagation were performed according to the alternative method of DIN ISO 9613-2 for A-weighted sound pressure levels by taking all relevant parameters such as temperature, humidity and geometrical data in account.

The investigations show that the calculation methods of DIN ISO 9613-2 do not reflect the real sound propagation situation concerning the noise of high wind turbines. Further consideration are needed to adapt the calculation methods of DIN ISO 9613-2 concerning noise exposure of modern wind turbines.

1. Introduction

Wind turbines can cause harmful effects by noise on the environment resp. humans in the neighbourhood. In Germany, the Federal Immission Control Act [1] lays down by law that wind turbines have to be build and operated without causing these harmful effects.

Criteria concerning the determination of the noise immissions in Germany are described within the Technical Instructions on Noise Protection, TA Lärm [2]. Due to this guideline, calculations of sound propagation have to be done according to DIN ISO 9613-2 [3].

The scope of DIN ISO 9613-2 is limited to ground near noise sources thus information on the accuracy is just related up to an average height between sender and receiver of about

30 metre. Consequently, modern wind turbines whose hub-heights meanwhile exceed 100 metre are not included.

Sound propagation calculations for wind turbine projects in Germany are usually carried out by using the alternative calculation method of DIN ISO 9613-2. This implies a non-frequency-selective approach concerning the attenuation due to the atmospheric absorption A_{atm} and the attenuation due to the ground effect A_{gr}.

By taking the standard deviation of the propagation model within DIN ISO 9613-2 with 1,5 dB in combination with a significance level of 10 % into account, the confidence interval is calculated to be 1,9 dB.

The North Rhine Westphalian State Agency for Nature, Environment and Consumer Protection invited tenders for the research project “Metrological validation of DIN ISO 9613-2 propagation model concerning wind turbine noise”. The project wanted to collect reliable data to figure out the difference between the calculated and the real sound propagation of wind turbines in order to consequently improve the forecast quality.

2. Measurement Concept

2.1 Measurement mode

Basically, a metrological validation of the propagation conditions of wind turbine noise is influenced by multiple parameters which are motivated by the typical noise characteristics of wind turbines.

The central point is the fact that wind turbines reach their maximum sound power level at wind speeds at about 8 m/s at a height of 10 meters. This wind speed comes along with a high amount of background noise. Measurements at large distances to wind turbines therefore face the problem of an insufficient signal-to-noise ratio.

In cooperation with the manufacturer of the wind turbines, the rotor speed was increased by manipulating the blade pitch angle which led to fairly high sound power levels in the “measurement mode” even at low wind speeds. Thereby, the measured wind speeds met the scope of DIN ISO 9613-2.

2.2 Meteorology and weather conditions

In addition to the factor wind speed, meteorological conditions have a substantial influence on the sound propagation in the considered distance range. Using a SODAR-RASS system, average readings of the wind vector, the wind speed, the diffuseness and the temperature in heights between 30 metres and 300 metres above ground level were collected.

Near the ground temperatures varied from 5 °C to 10 °C. There was at no time the risk of soil frost. Air pressure was measured between 100,0 kPa and 102,0 kPa, humidity between 70 % and 90 %. The weather conditions largely correspond to the framework of DIN ISO 9613-2.

2.3 Layout

Two wind turbines of the two megawatt class with a hub height of 100 metres and a rotor diameter of 80 metres were used as emission source. The apparent sound power levels were determined by parallel emission measurements according to IEC 61400-11 [4].

Synchronously measurements concerning sound pressure level and wind speed were carried out in down- and upwind direction at distances of about 500 metres, 750 metres and 1000 metres to the wind turbines at a height of five meters (Figure 1).

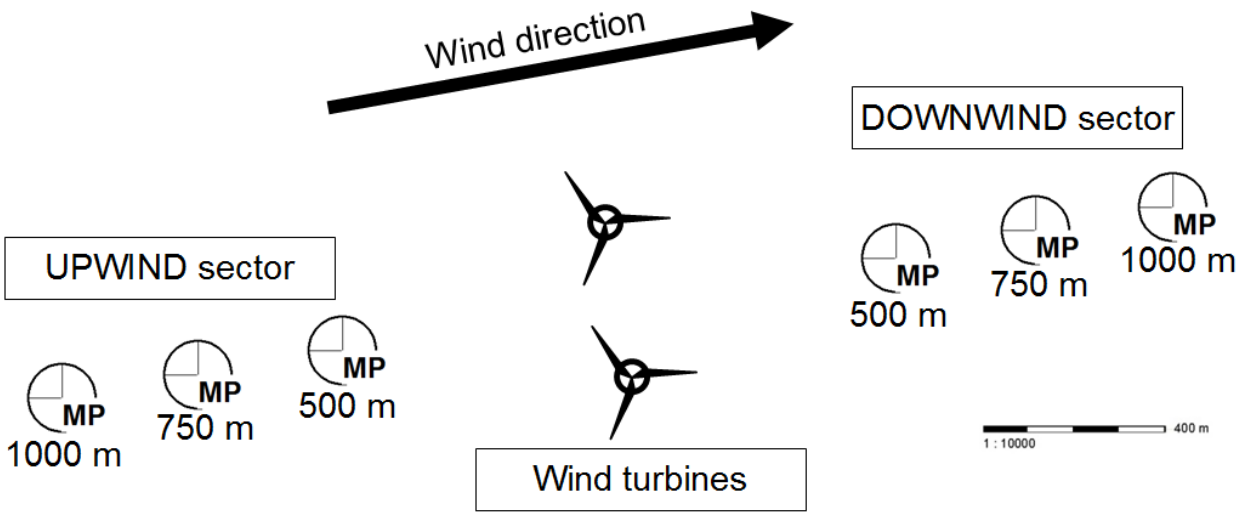

Figure 1: Exemplary measurement constellation on site

The investigation site is located within a region which is characterized by agricultural land (fields and meadows) as well as small pieces of forest. In addition to agricultural roads, main roads run at distances of about two kilometres and county road are a fair way off, too. If a piece of forest prevented the setup of a measuring point, it was moved slightly aside. This procedure leads to measured values between 450 metres and 1100 metres to the wind turbines.

2.4 Data sets

The measurements were performed in ten nights. In the years 2012 and 2013, investigation periods were realized in October and November with five nights each period. Within every night the data sets contain 30 minutes background noise measurements and 30 minutes of total noise measurements. The averaging time was set to 10 seconds.

3. Evaluating the measurements

3.1 Acoustical emissions by the wind turbines

For the determination of the sound power levels of both wind turbines the measurement positions were established in accordance with the requirements of IEC 61400-11. An

interaction between both emission measurement positions could not be excluded due to the short distance between them.

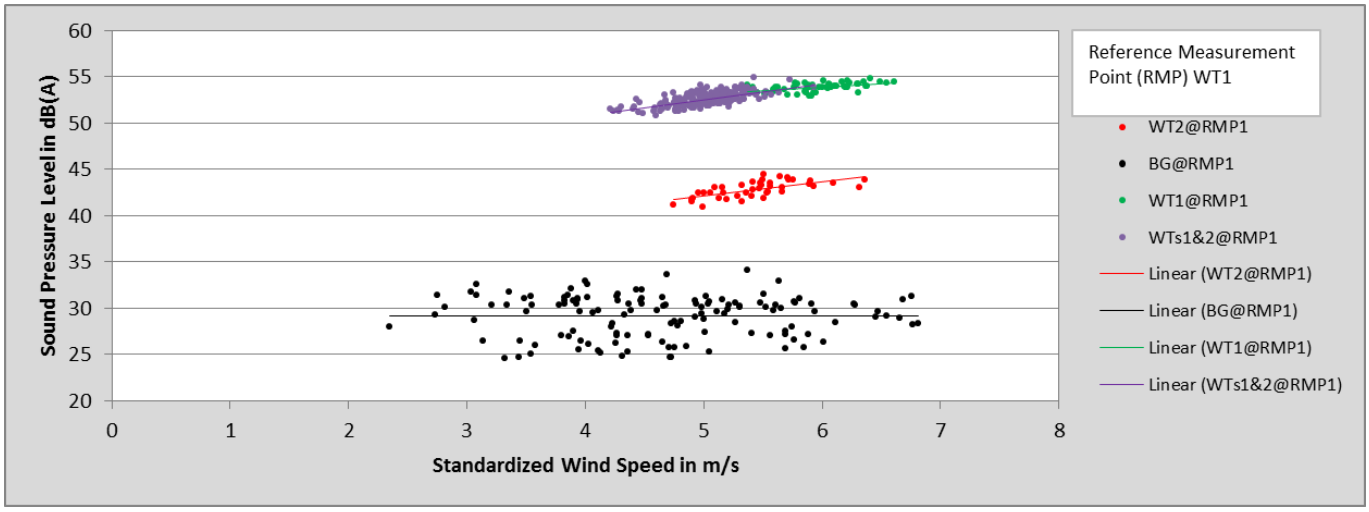

Figure 2: Reference measuring point RMP (WT1)

Consequently, immediately preceding performed non-parallel measurements provided data concerning this interaction. Subsequently, measured sound pressure levels on the measurement board got corrected if necessary (Figure 2, Figure 3).

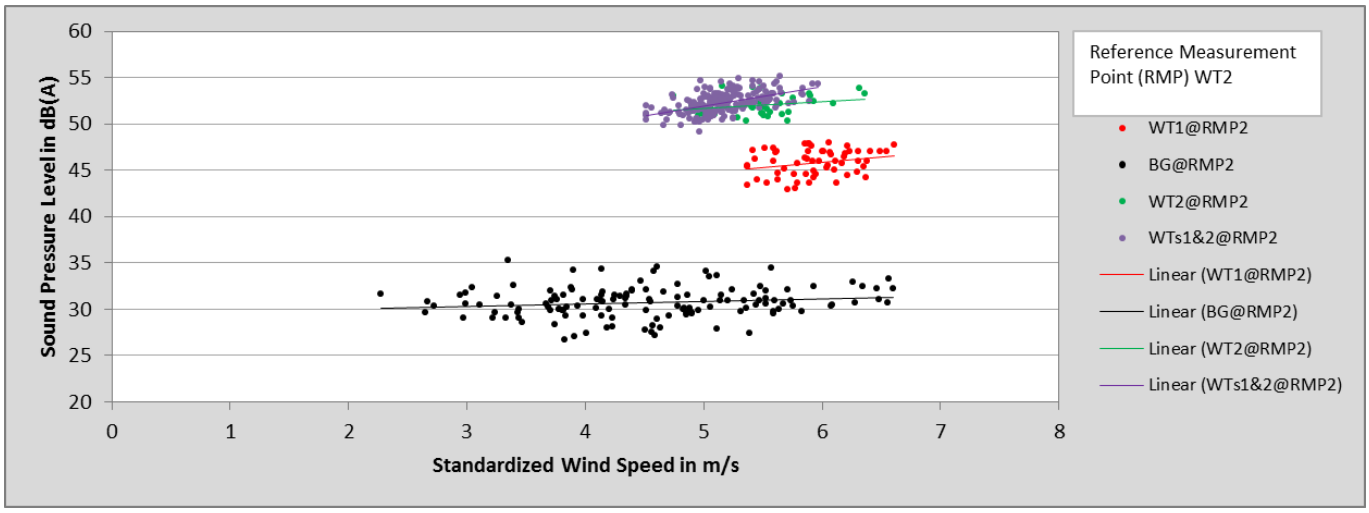

Figure 3: Reference measuring point RMP (WT2)

As can be seen in the exemplary shown figures, the sound pressure level caused by wind turbine 2 at the measurement board 1 (WT2@RMP1) is about 10 dB below the sound pressure level caused by wind turbine 1 at the measurement board 1 (WT1@RMP1). On the other hand, the sound pressure level caused by wind turbine 1 at the measurement board 2 (WT1@RMP2) is only about 6 dB below the sound pressure level caused by wind turbine 2 at the measurement board 2 (WT2@RMP2). In this case, it is necessary to correct the sound pressure level to prevent an overestimation of the sound power level of each wind turbine.

The sound power level of each wind turbine is calculated as follows:

$L_{WA,WT1}$ = 10*log[10^(0.1*$L_{pWT1\&2@RMP1}$)- 10^(0.1*$L_{pWT2@RMP1}$)- 10^(0.1*$L_{pBG@RMP1}$)]-6+10*log(4*π*R_1^2/S_0)

with:	$L_{WA,WT1}$:	sound power level wind turbine 1 in dB(A)
	$L_{pWT1\&2@RMP1}$:	sound pressure level of both wind turbine at reference measurement position 1 (WT1) in dB(A)
	$L_{pWT2@RMP1}$:	sound pressure level of wind turbine 2 at reference measurement position 1 (WT1) in dB(A)
	$L_{pBG@RMP1}$:	sound pressure level of background noise at reference measurement position 1 (WT1) in dB(A)
	R_1:	slant distance from rotor centre to actual measurement position in m
	S_0:	reference area = 1 m²

3.2 Acoustical immissions at the measuring points

All sound pressure level measurements at distances between about 500 metre and 1000 metre to the wind turbines were performed synchronously to the emission measurements at the wind turbines. All microphones were equipped with a primary and a secondary windscreen to reduce wind-induced noise.

In addition to the sound pressure level of background and total noise the wind speed was documented at a height of 5 m at every measuring point. Based on these wind speeds, the total noise measurements during the wind turbine operating time could be linked with appropriate background noise data.

In a first step of the analysis, all gathered data, total noise and background noise, are presented as a function of the wind speed at the measuring points. Secondly, both types are described with linear regressions (Figure 4).

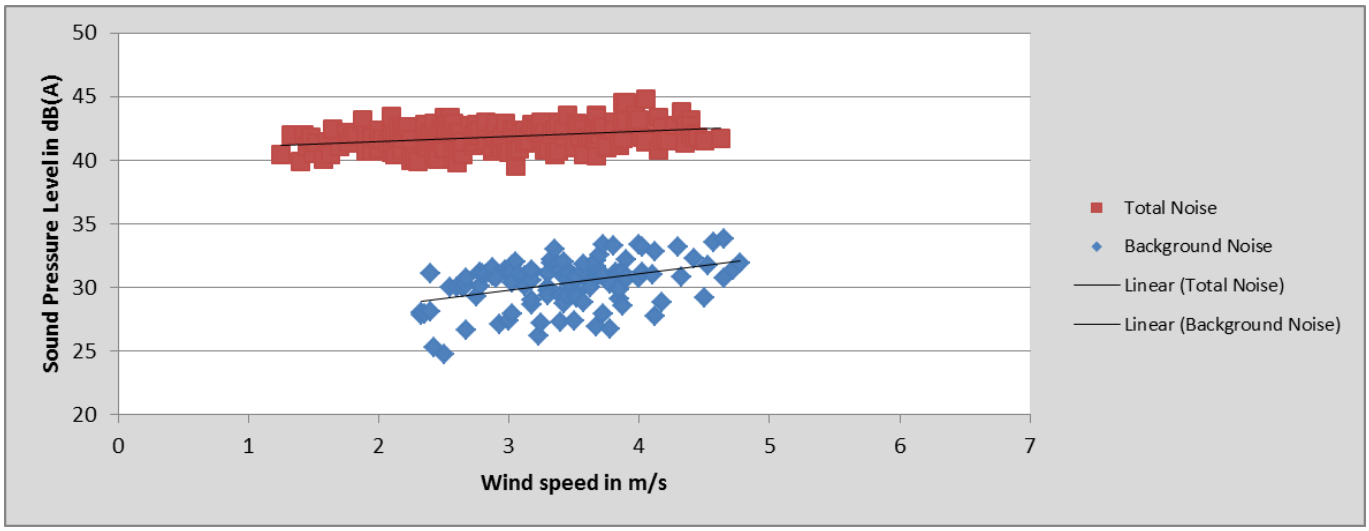

Figure 4: Total Noise and background noise at immission measuring point

The calculation of the sound pressure level caused by the wind turbines is done by taking account of the sound power level of both wind turbines plus the attenuation term for geometrical divergence A_{div} and an iteratively determined constant D_{Const}.

$L_{p,WT1\&2,calc}$ = 10*log[10^(0.1*($L_{WA,WT1}$-$A_{div,WT1}$-D_{Const}))+ 10^(0.1*($L_{WA,WT2}$-$A_{div,WT2}$-D_{Const}))]

with: $L_{p,WT1\&2,calc}$: calculated sound pressure level caused by both wind turbines in dB(A)
$L_{WA,WT1}$: sound power level wind turbine 1 in dB(A)
$A_{div,WT1}$: attenuation term for geometrical divergence in dB [3]
D_{Const}: iteratively calculated constant in dB

In this case the propagation constant describes unspecified attenuation beyond geometrical divergence. It is calculated providing that the mean square error between the measured and calculated total noise at the measuring points runs to zero.

The calculated level of total noise which occurs at the measuring point is determined by the energetic addition of the linear regression data from the background noise plus the calculated sound pressure level $L_{p,WT1\&2,calc}$.

4. Calculations of the sound propagation

4.1 Calculation procedure

The calculations of the sound propagation were performed according to the alternative method of DIN ISO 9613-2 for A-weighted sound pressure levels.

L_{AT} = 10*log[10^(0.1*($L_{WA,WT1}$+$D_{\Omega,WT1}$-$A_{div,WT1}$-$A_{atm,WT1}$-$A_{gr,WT1}$))+ 10^(0.1*($L_{WA,WT2}$+$D_{\Omega,WT2}$-$A_{div,WT2}$-$A_{atm,WT2}$-$A_{gr,WT2}$))]

with: L_{AT}: average A-weighted sound pressure level in dB(A)
L_{WA}: metrological defined sound power level of wind turbine 1/2 in dB(A)
D_{Ω}: to take account of apparent increase in sound power level [3]
A_{div}: attenuation term for geometrical divergence in dB
A_{atm}: attenuation due to atmospheric absorption in dB
A_{gr}: attenuation due to ground effect in dB

The calculation is performed for every 10 seconds average. Within the calculation all relevant parameters were taken in account such as temperature, humidity and geometrical data.

A meteorological correction C_{met} is not applied which means that only the average A-weighted sound pressure level for downwind situations is calculated.

In a subsequent calculation process the frequency-selective calculation method according to the DIN ISO 9613-2 was used. The metrological determined spectra of the sound power level of both wind turbines were taken into account as well as different ground factors.

4.2 Comparison between measurements and calculations

The comparison of the metrological collected with the calculated immission values bases on the 10-second intervals data. For this purpose all 10 second values out of one measurement period were arithmetically averaged. In addition, the standard deviation was calculated. For the respective data points, the logarithmic regression was calculated either.

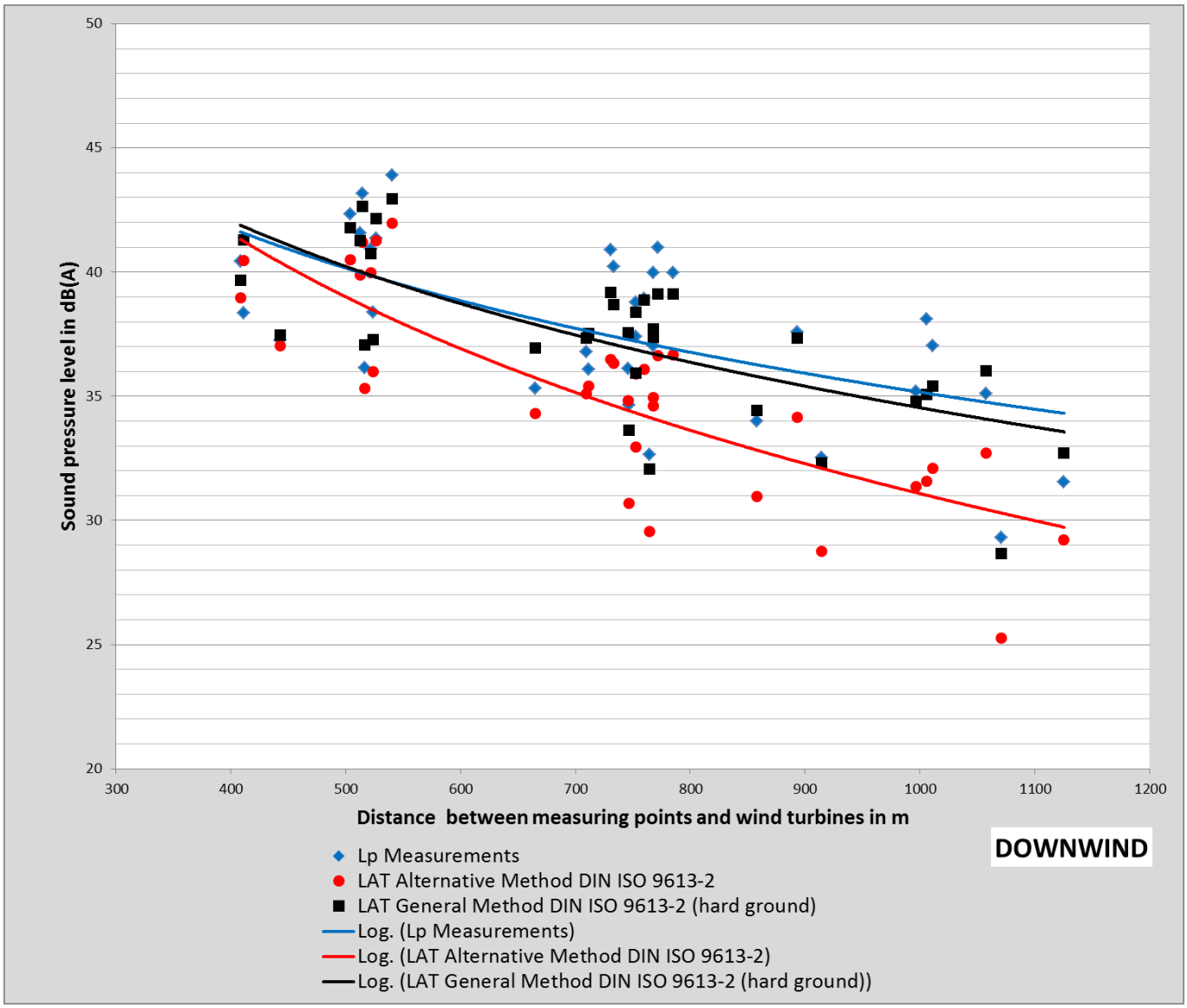

Figure 5: Measured and calculated sound pressure levels in the downwind sector

As shown in figure 5 the metrological collected immission values in the downwind sector and according to the different methods of the DIN ISO 9613-2 calculated, average A-weighted sound pressure level, decrease within the investigated distance.

At small distances of approximately 400 metre to the wind turbines all methods including the measurements provide nearly the same results. With an increasing distance to the wind turbines, the difference between the calculated values and the measured values increases, too, wherein the calculated values are always below the measured values.

At the end of the investigation area at a distance of about 1100 metre to the wind turbines, the difference concerning the alternative method of the DIN ISO 9613-2 grows to about 5 dB while the difference concerning the general method of the DIN ISO 9613-2 (hard ground) stagnates at about 1 dB.

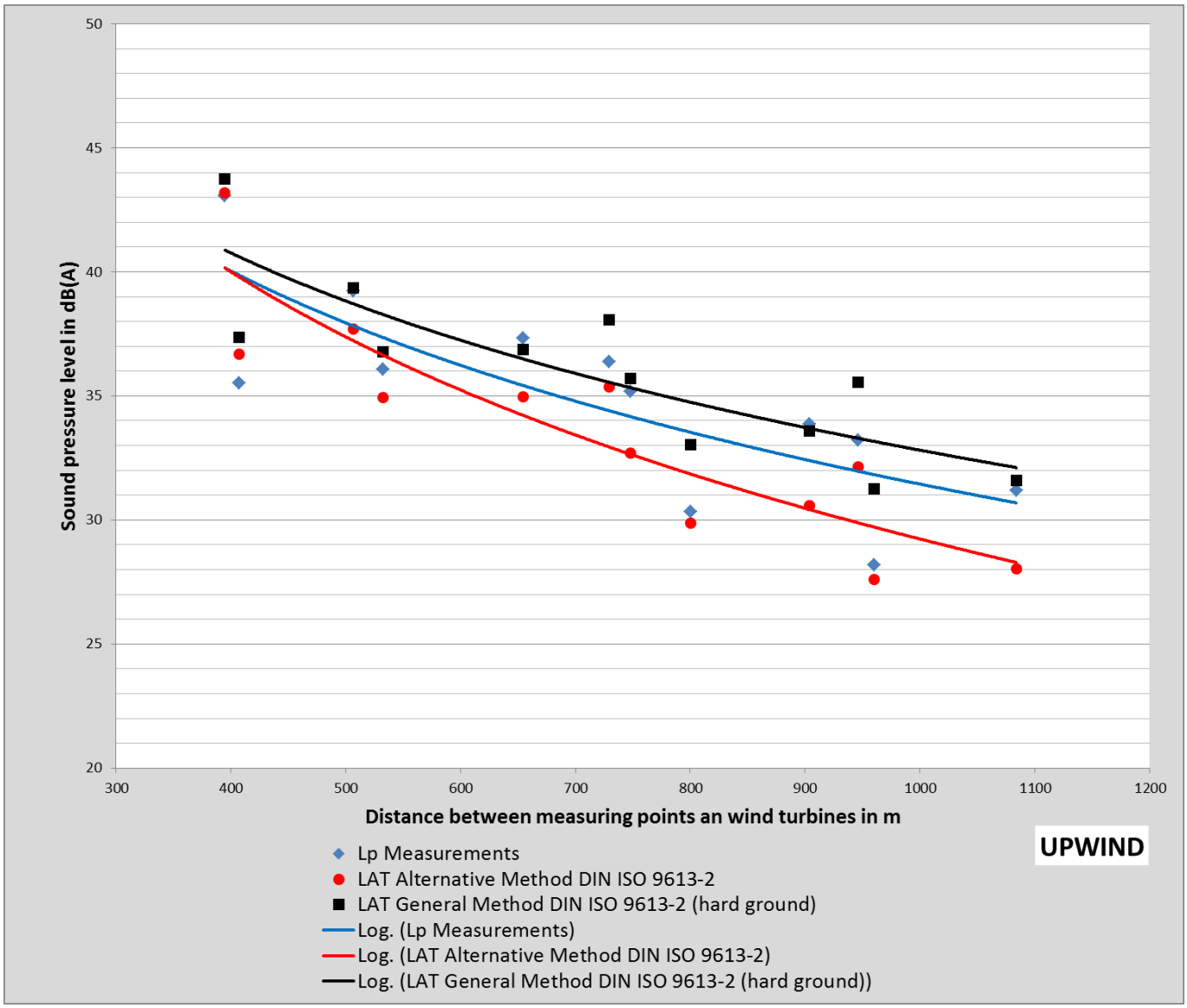

Figure 6: Measured and calculated sound pressure levels in the upwind sector

Figure 6 deals with the upwind sector.

At the beginning of the inspected area calculations according to the alternative method of the DIN ISO 9613-2 provide data which are congruent to the measured values. With the help of the general method of the DIN ISO 9613-2 (hard ground) calculated values are about 1 dB above measured values. With an increasing distance to the wind turbines, the difference between alternative calculated values and the measured values increases, wherein the calculated values are always below the measured values. The difference between the general method of the DIN ISO 9613-2 (hard ground) and the measured values remains nearly the same throughout the entire investigation area.

At the end of the investigation area at a distance of about 1100 metre to the wind turbines, the difference concerning the alternative method of the DIN ISO 9613-2 grows to about 4 dB and thus slightly smaller than in the downwind sector.

5. Conclusions and prospect

Within the research project “Metrological validation of the DIN ISO 9613-2 propagation model concerning wind turbine noise” reliable data was collected and evaluated to figure out the difference between the calculated and the real sound propagation of wind turbines in order to consequently improve the forecast quality.

The investigations show that a confidence interval of 1,9 dB as it is often used in Germany to take the uncertainty of the propagation model of the DIN ISO 9613-2 into account covers the difference up to 550 metre between the wind turbines and the immission points while using the alternative calculation method.

Different reasons lead to the assumption that the alternative method of the DIN ISO 9613-2 is often seen as the preferred calculation method to calculate the sound propagation. An important factor here is in some circumstances the non-frequency selective calculation within this method.

Further consideration therefore should include how to adapt the alternative calculation method of DIN ISO 9613-2 concerning noise exposure of modern wind turbines. In particular it must be determined which parameters such as hub-height, distance between source and receiver and the on this basis calculated attenuation due to the ground effect influence the shown difference.

References

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