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Sound power level assessment. Is a reference position really reference?

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Abstract

The permitting procedure in the Czech Republic involves a noise study and according to computing result usually a check measurement and a final calculation assessment. Every wind turbine (WT) or farm exceeding circa 35 dB sound pressure level (90% of them) is checked if the theoretical calculation works in the field. Measurement results are used as a validation of wind farm area model.

Measurement consists of single and full WT emission check according to IEC 61400-11, basically. One position is identified as the reference position, next ones are placed at longer distances towards the nearest imission positions downwind. On demand (LF concerns) the measurement inside the dwellings is included. This means that about 4 - 6 sound level meters simultaneously measure WT noise.

Modelling consists of creating 3D model and its calibration by measured values. A ground absorption is a major variable in the calibration process. We choose planned calculated ground absorption 0, default long-term ground absorption estimation 0.2 and real ground absorption calculated by reverse engineering. Ideally, the measured and calculated values at measurement positions coincide. Really, it is not always true.

One of the causes of problems may be sound power level assessment according to IEC. Sound power level shall be calculated from sound pressure level at the reference position. If there is an obstacle in this position, measurement has to be done at different position in the range of inclination angle. If there is not any obstacle widely, we can use more measured values to sound power level assessment. So it may happen that the calibration process is better suited for values except for the reference position. Because the imission positions are placed further from the WT, positions rather away from WT seem more appropriate (if there is a low background noise present).

This article describes the phenomenon based on recent measurements.

Introduction

Measurement:

SLMs: BK2250, 2260 and 2270, primary windscreen, third-octave analysis

Reference microphone position (MP): EN 61400-11, lying circle board

Technical MP: EN 61400-11, circle board adjusted to the similar inclination angle ϕ as in the reference MP

Imission MP: EN 61400-11, standing circle board, window sticking, rarely tripod

Wind speed and direction derived from WT anemometer, assumption: logarithmic wind speed profile

Calculation:

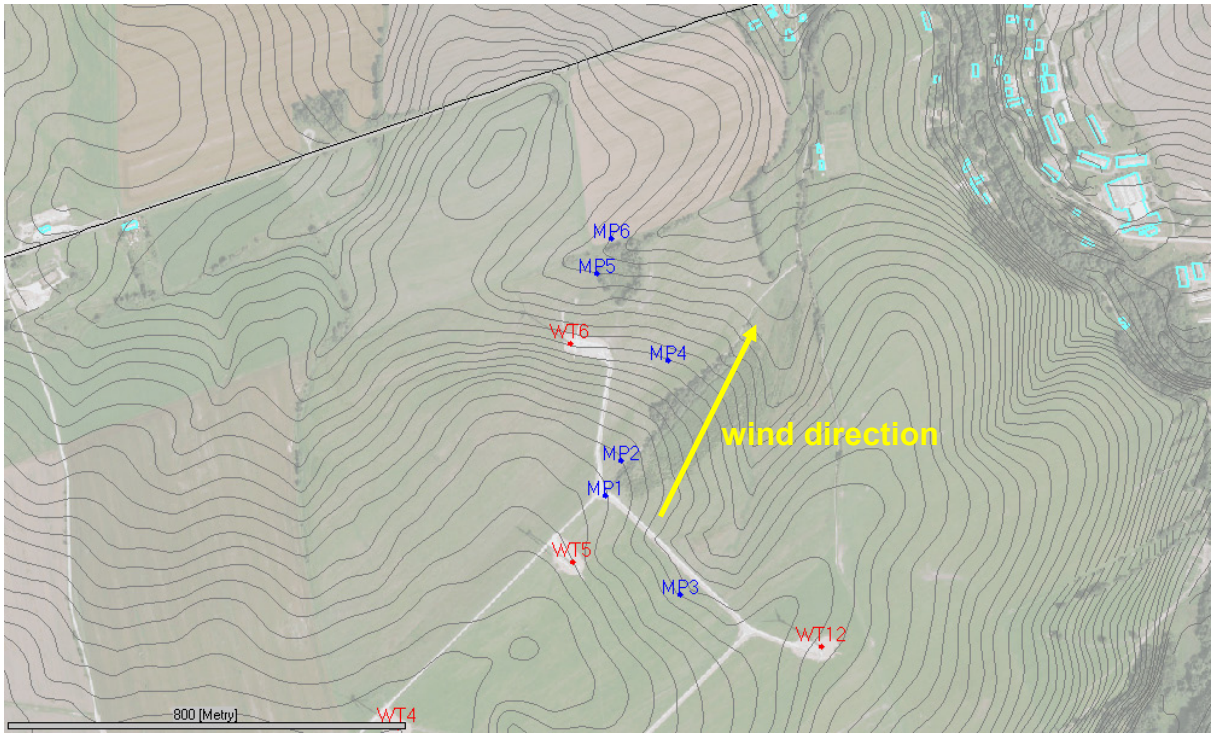
Software: LimA

Method: ISO 9613-2, max. 2 m contour line, constant building height (4.5 - 6 m), omnidirectional point source L_{WA}, third-octave spectra, climate 10 ˚C, 70 %, without meteorological coefficient, relative calculation height 3 m, planned calculated ground absorption 0, real ground absorption calculated by reverse engineering, default long-term ground absorption estimation 0.2

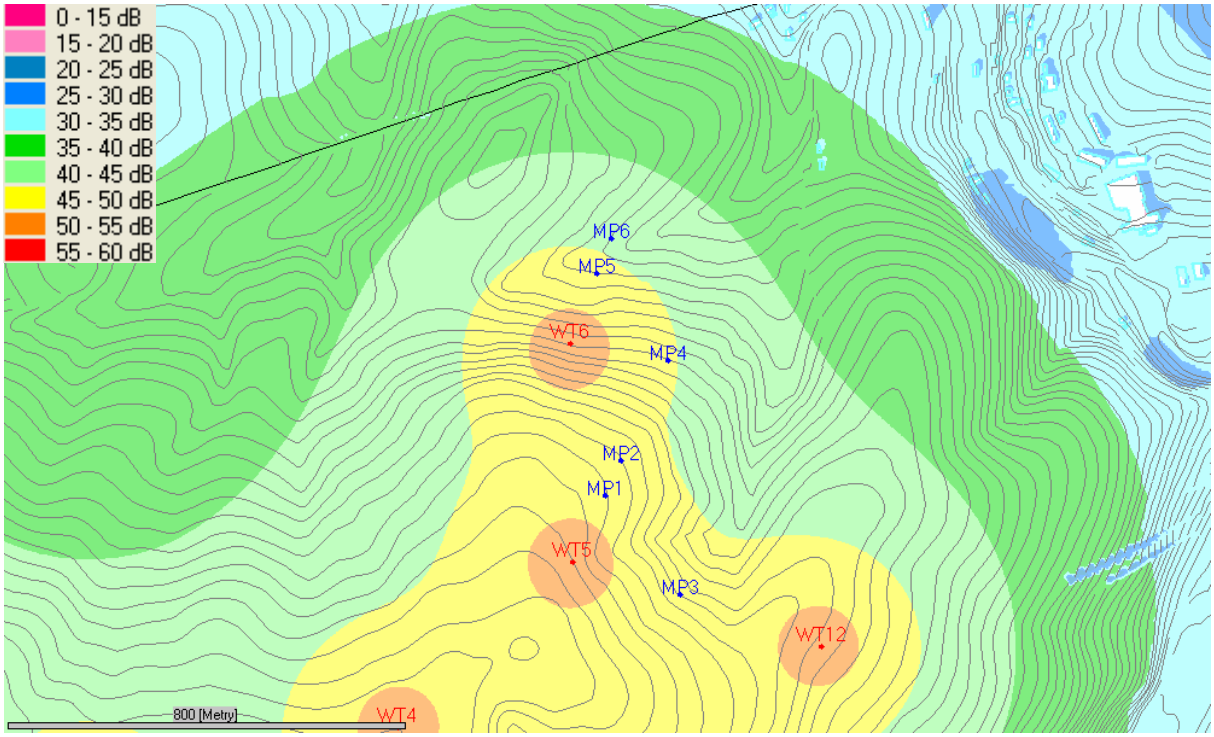
Locality Horní Loděnice - “standard locality”

9 WT Vestas V90 - 2.0 MW, 1 reference MP behind WT at 150 m distance, 2 MP behind WT at 225 m and 450 m, no imission MP - long distances, nearly flat terrain

WT noise measurement



WT noise calculation



Locality is a rather noisy place near the main road

November 2009, 11:00 - 19:00, overcast, 3.5 - 6.4 °C, 89 - 100 %

Measurement results:

Measurement position 1 - 150 m

wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
5	35.5	44.0	43.3 ± 0.8	99.5 ± 0.8
6	35.7	45.3	44.8 ± 0.8	101.0 ± 0.8
7	36.0	45.9	45.4 ± 0.8	101.6 ± 0.8
8	36.2	45.7	45.2 ± 0.8	101.3 ± 0.8

Measurement position 2 - 225 m

wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
5	33.5	41.1	40.2 ± 0.8	99.1 ± 0.8
6	34.0	42.3	41.6 ± 0.8	100.5 ± 0.8
7	34.5	42.9	42.2 ± 0.8	101.1 ± 0.8
8	35.0	42.8	42.0 ± 0.8	100.9 ± 0.8

Measurement position 4 - 450 m

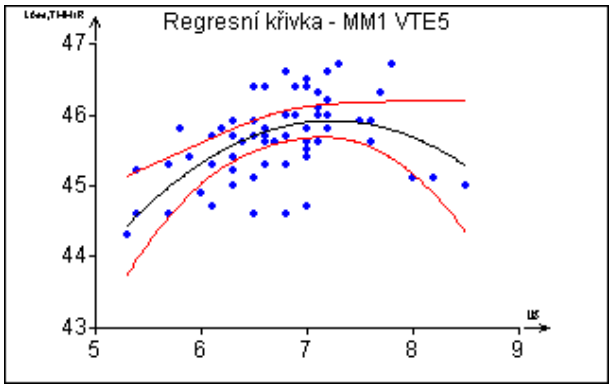
wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
5	34.4	37.4	35.2 ± 0.8	99.5 ± 0.8
6	34.6	37.8	35.6 ± 0.8	99.8 ± 0.8
7	34.8	38.0	35.8 ± 0.8	100.1 ± 0.8
8	35.0	38.1	35.9 ± 0.8	100.2 ± 0.8

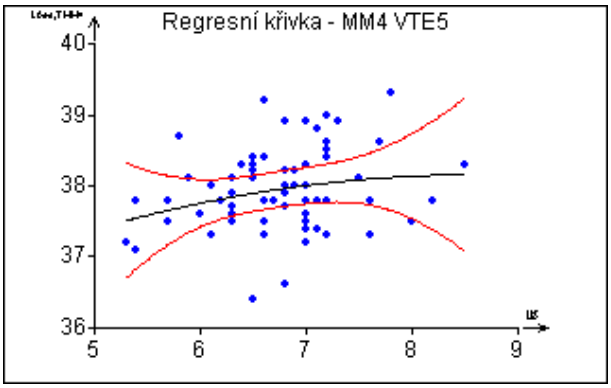
Noise calculation results $L_{Aeq,T}$ [dB] in calculation points:

Measurement position	distance [m]	$L_{Aeq,T}$ backgr. [dB]	$L_{Aeq,T}$ meas. [dB]	$L_{Aeq,T}$ calc.9613-2 [dB]	diff. meas.-calc. [dB]
1	150	36.0	45.4	45.4 (46.9)	0.0
2	225	34.5	42.2	42.3 (45.3)	0.1
4	450	34.8	35.8 *	35.9 (44.0)	**0.1**
-	638	*	*	- (35.5)	-

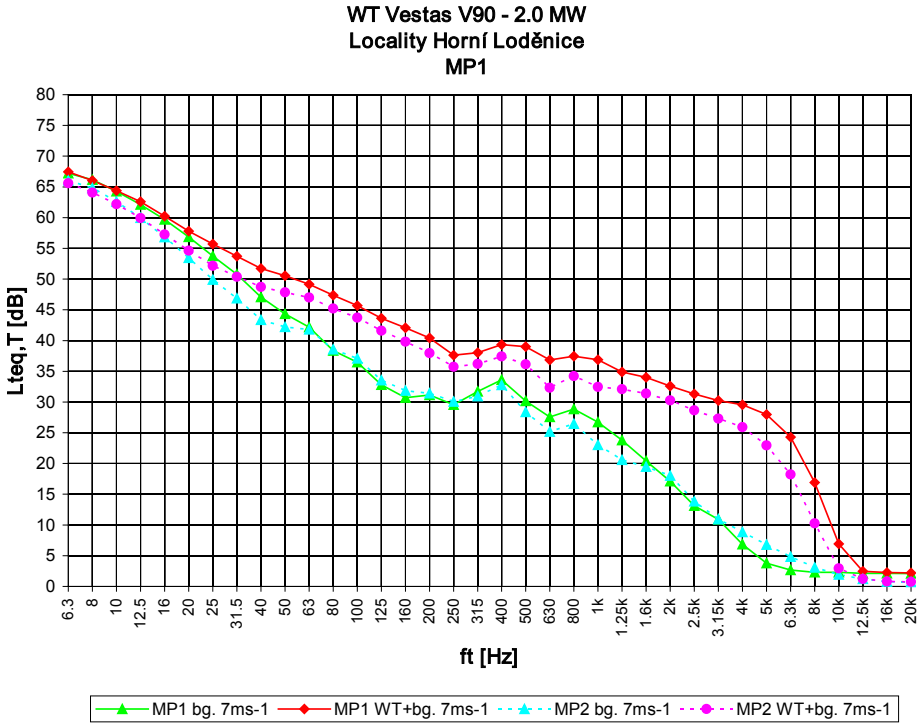
reverse engineering calculated ground absorption 0.32, wind speed 7 ms^{-1}

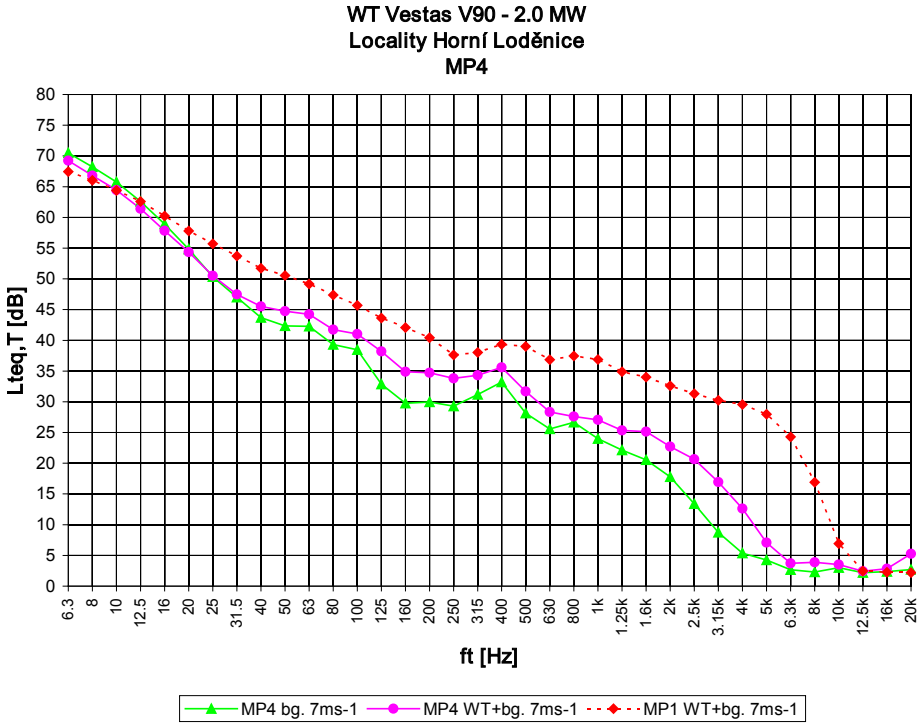
* too high background noise, in parenthesis results for 9 WT





Third-octave spectra:





Locality assessment:

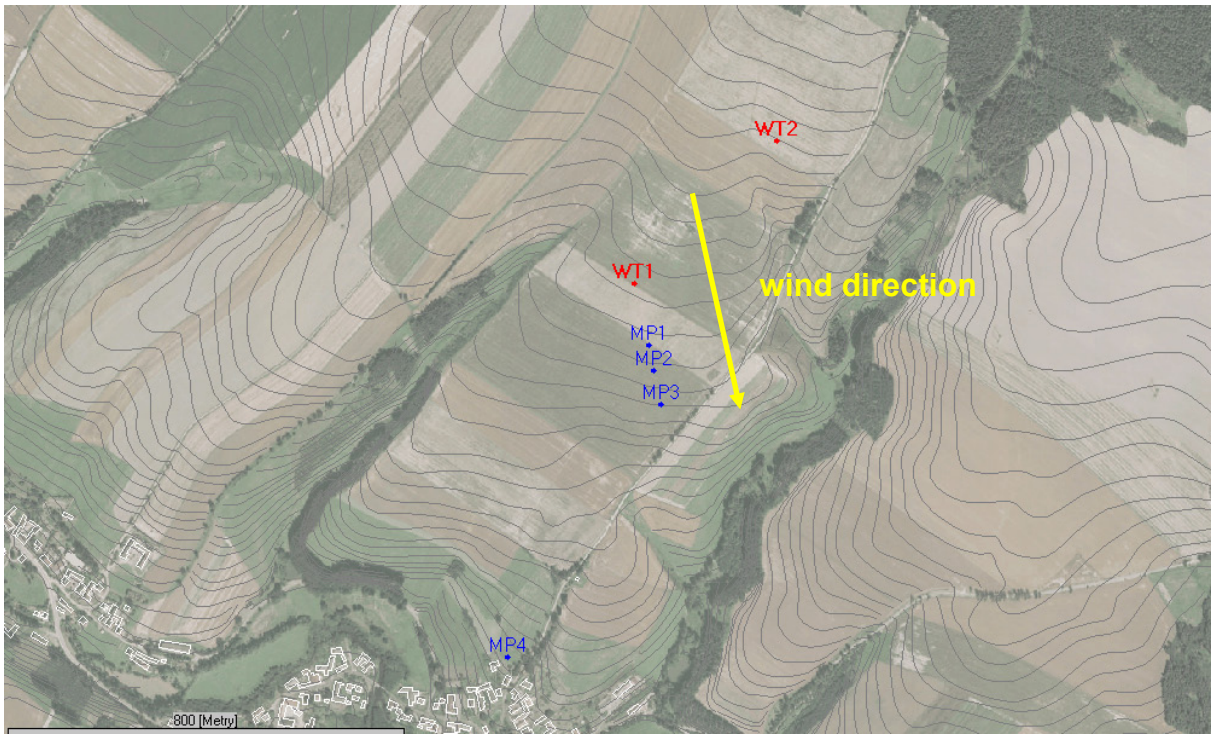
Noise is below the nighttime limit 40 dB, LF noise is minimal, WT got working permission.

Residents haven't complained of WT.

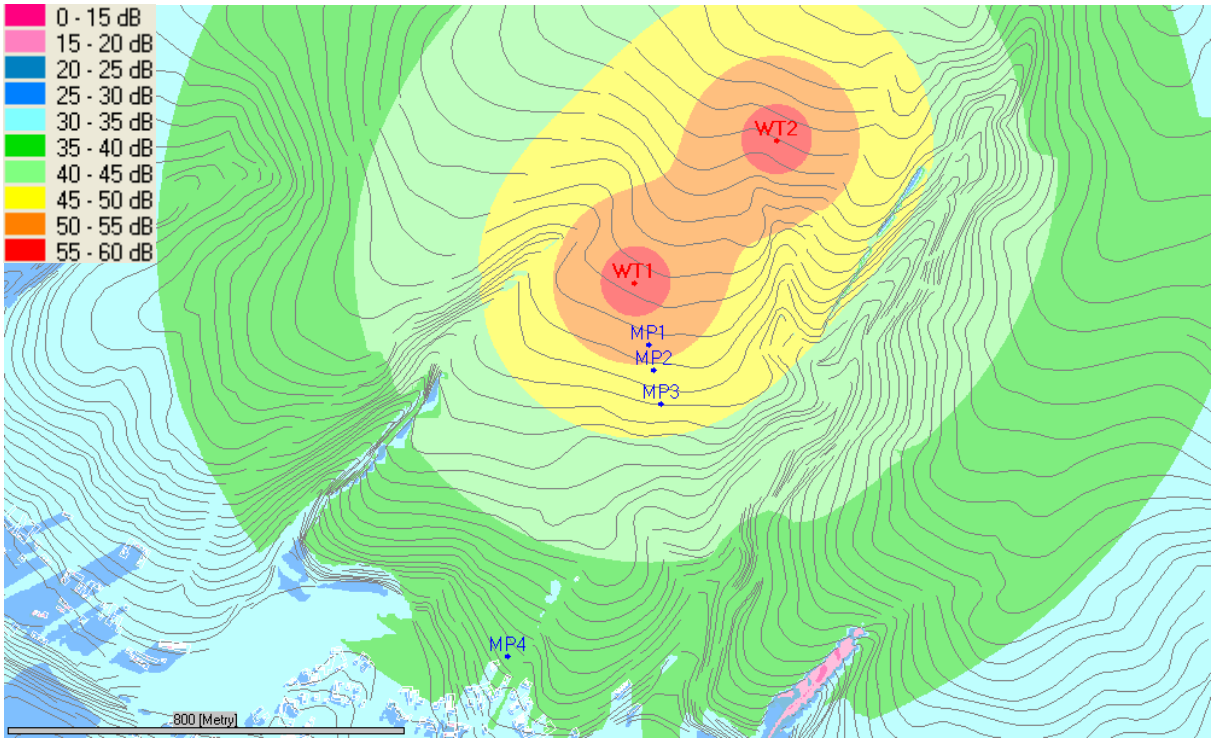
Locality Věžnice - “sound channelling”

2 WT REpower MM92 - 2.0 MW, 1 reference MP behind WT at 126 m distance, 2 MP behind WT at 180 m and 250 m, 2 imission MP - the nearest dwelling downwind at 795 m outside and inside, nearly flat terrain

WT noise measurement



WT noise calculation



Locality is standard, quiet village place

May 2010, 18:00 - 1:00, overcast, 7.4 - 4.5 °C, 85 %

Measurement results:

Measurement position 1 - 126 m

wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
5	32.5	46.8	46.7 ± 0.8	101.2 ± 0.8
6	33.0	49.3	49.2 ± 0.8	103.7 ± 0.8
7	33.8	49.6	49.5 ± 0.8	103.9 ± 0.8
8	34.8	49.7	49.6 ± 0.8	104.1 ± 0.8

Measurement position 2 - 180 m

wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
5	31.2	45.1	44.9 ± 0.8	101.8 ± 0.8
6	32.1	47.5	47.4 ± 0.8	104.3 ± 0.8
7	33.2	47.9	47.7 ± 0.8	104.6 ± 0.8
8	34.5	47.9	47.7 ± 0.8	104.6 ± 0.8

Measurement position 3 - 250 m

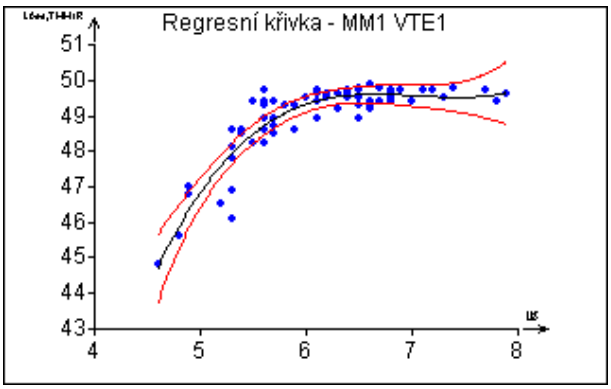
wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
5	31.0	42.9	42.7 ± 0.8	102.0 ± 0.8
6	31.9	45.4	45.2 ± 0.8	104.5 ± 0.8
7	33.3	45.8	45.5 ± 0.8	104.9 ± 0.8
8	35.0	45.9	45.5 ± 0.8	104.9 ± 0.8

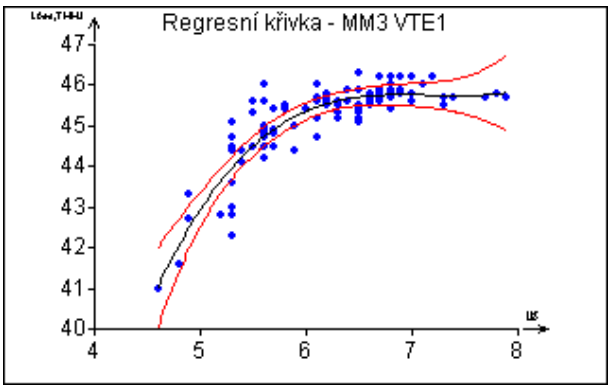
Noise calculation results $L_{Aeq,T}$ [dB] in calculation points:

Measurement position	distance [m]	$L_{Aeq,T}$ backgr. [dB]	$L_{Aeq,T}$ meas. [dB]	$L_{Aeq,T}$ calc.9613-2 [dB]	diff. meas.-calc. [dB]	$L_{Aeq,T}$ calc.13.8log [dB]
1	126	34.8	49.6	50.8 (51.1)	1.2	(49.8)
2	180	34.5	47.7	48.2 (48.7)	0.5	(47.7)
3	250	35.0	45.5	45.5 (46.2)	**0.0**	(45.7)
4	795	38.8	39.7 *	34.8 (35.9)	-	(38.5)

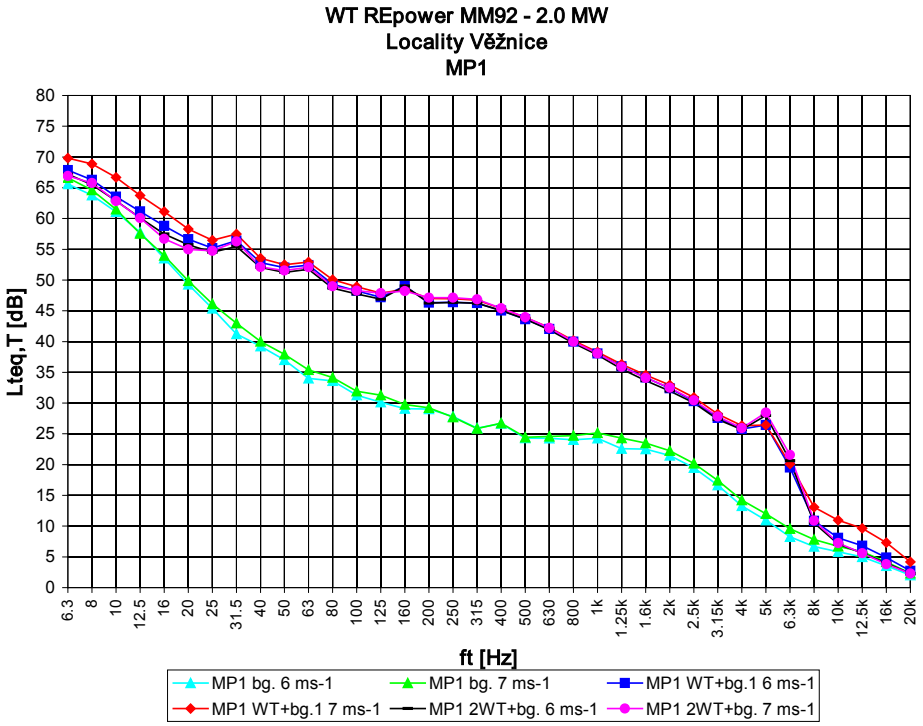
reverse engineering calculated ground absorption 0.16, wind speed 8 ms^{-1}

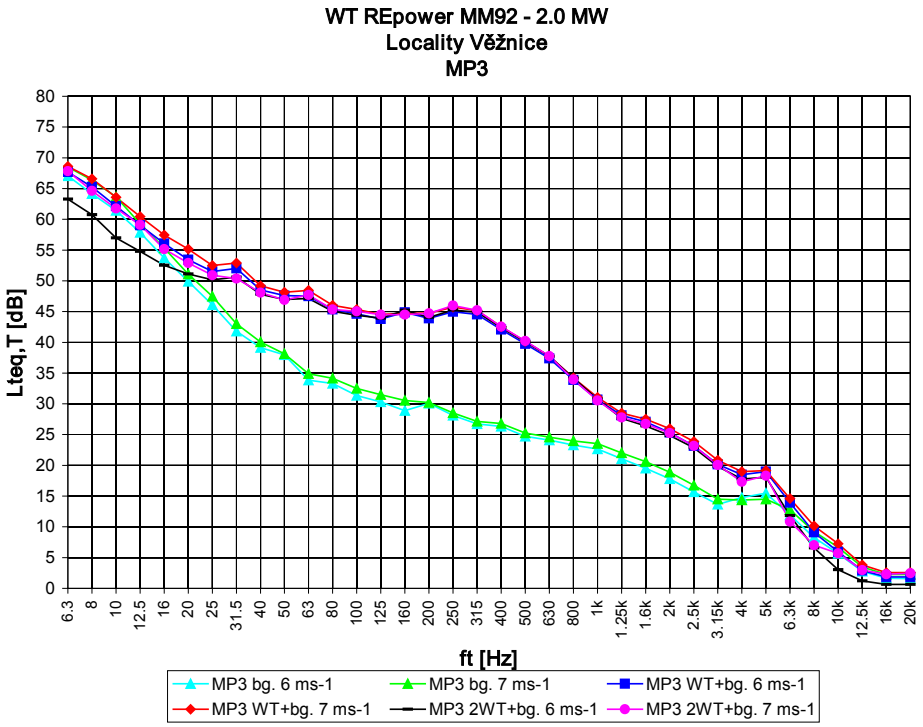
* too high background noise, in parenthesis results for 2 WT





Third-octave spectra:





Locality assessment:

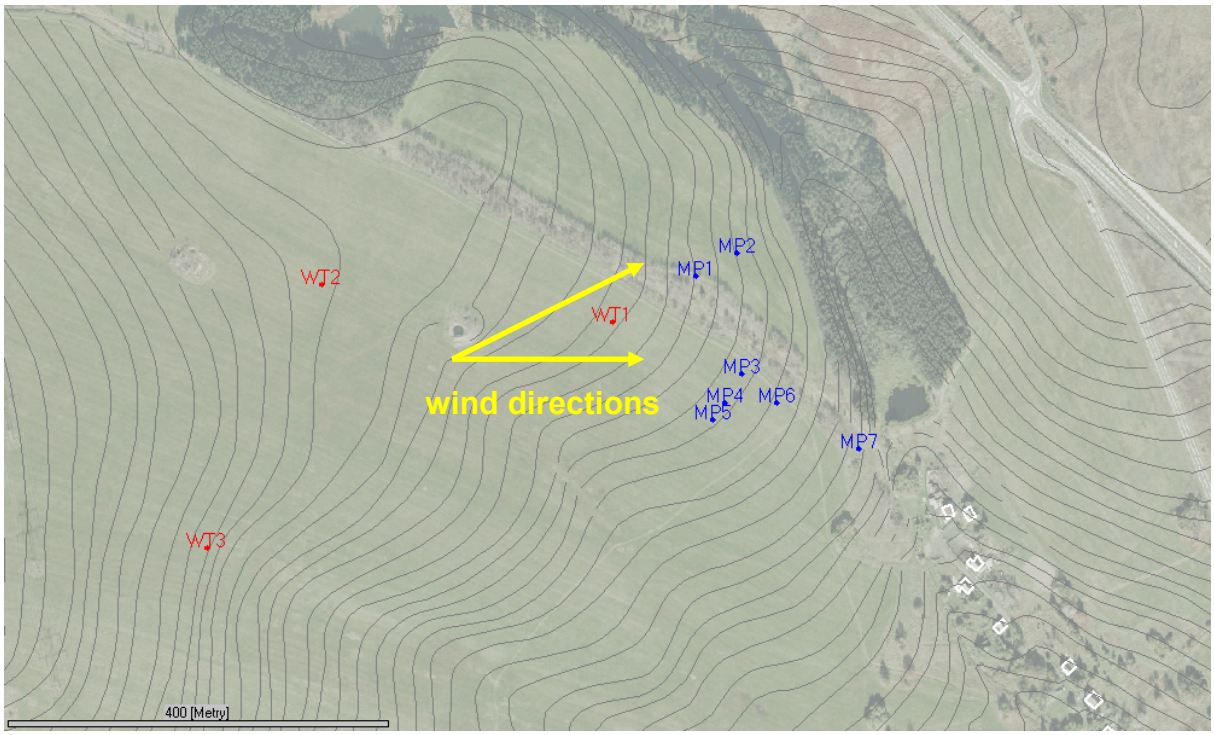
Noise is below the nighttime limit 40 dB, LF noise is minimal, WT got working permission.

Residents haven't complained of WT.

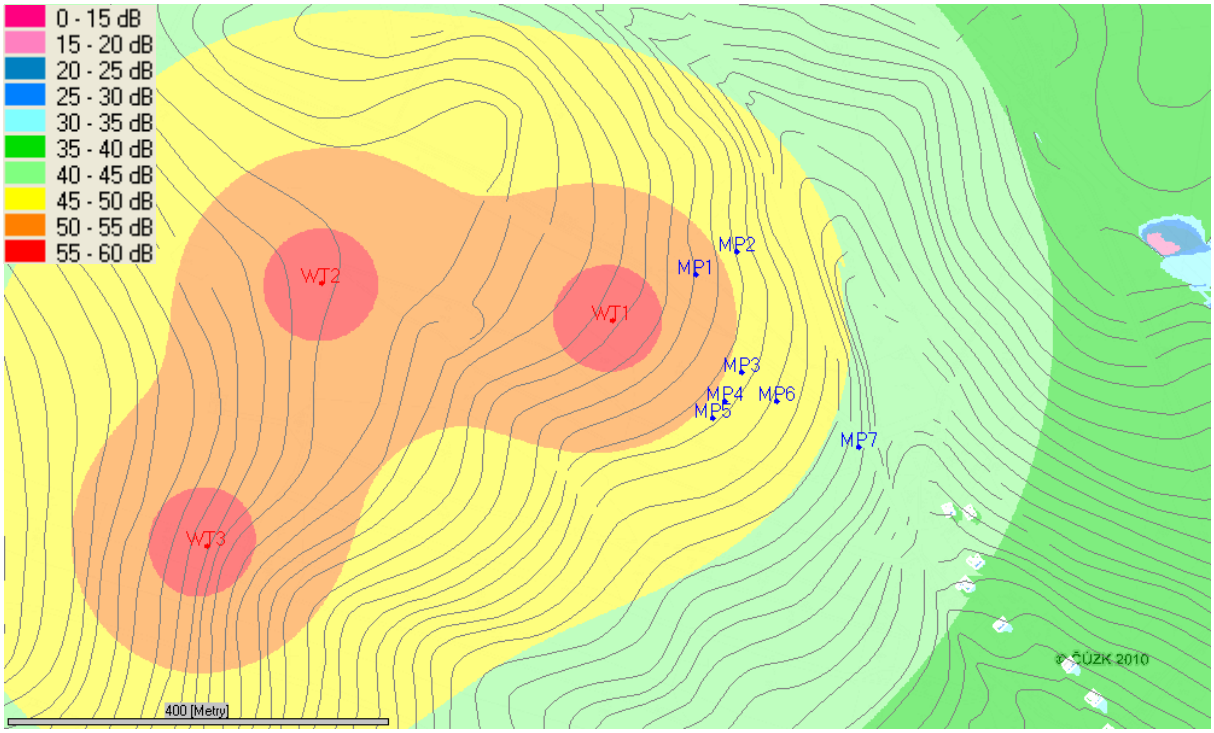
Locality Hora Svatého Šebestiána - “tonality”

3 WT Nordex S70 - 1.5 MW, 1 reference MP behind WT at 100 m distance, 3 MP behind WT at 150, 200 m and 300 m, no imission MP - long distances, nearly flat terrain

WT noise measurement



WT noise calculation



Locality is standard, quiet village place

November 2009, 17:00 - 23:30, clear sky, 4.7 - 6.2 °C, 62 - 77 %

Measurement results:

Measurement position 1 - 100 m

wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
7	36.9	49.8	49.6 ± 0.7	102.1 ± 0.7
8	38.0	50.5	50.3 ± 0.7	102.8 ± 0.7
9	39.1	51.0	50.7 ± 0.7	103.3 ± 0.7
10	40.2	51.4	51.0 ± 0.7	103.5 ± 0.7

Measurement position 2 - 150 m

wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
7	35.3	45.6	45.2 ± 0.8	100.5 ± 0.8
8	35.8	46.0	45.5 ± 0.8	100.8 ± 0.8
9	36.3	46.2	45.7 ± 0.8	101.0 ± 0.8
10	36.7	46.4	45.9 ± 0.8	101.2 ± 0.8

Measurement position 7 - 300 m

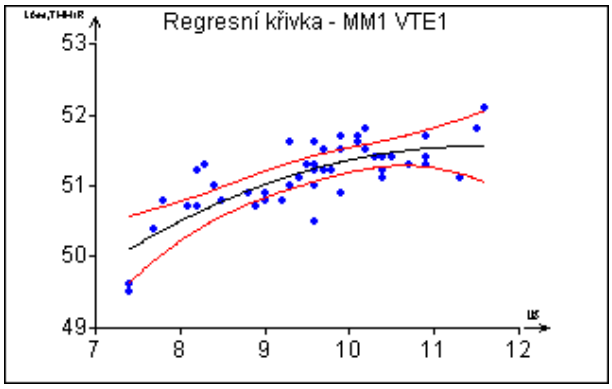
wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
7	34.9	40.0	38.5 ± 1.1	99.2 ± 0.8
8	35.9	41.5	40.1 ± 1.1	100.8 ± 0.8
9	37.0	42.4	41.0 ± 1.1	101.7 ± 0.8
10	38.0	42.8	41.1 ± 1.1	101.8 ± 0.8

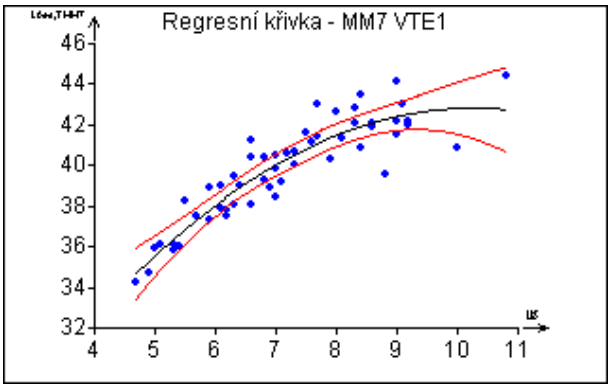
Noise calculation results $L_{Aeq,T}$ [dB] in calculation points:

Measurement position	distance [m]	$L_{Aeq,T}$ backgr. [dB]	$L_{Aeq,T}$ meas. [dB]	$L_{Aeq,T}$ calc.9613-2 [dB]	diff. meas.-calc. [dB]
1	100	40.2	51.0	50.0 (50.4)	-1.0
2	150	36.7	45.9	46.9 (47.5)	1.0
7	300	38.0	41.1	41.1 (42.3)	**0.0**
-	400	*	*	39.7 (41.4)	-

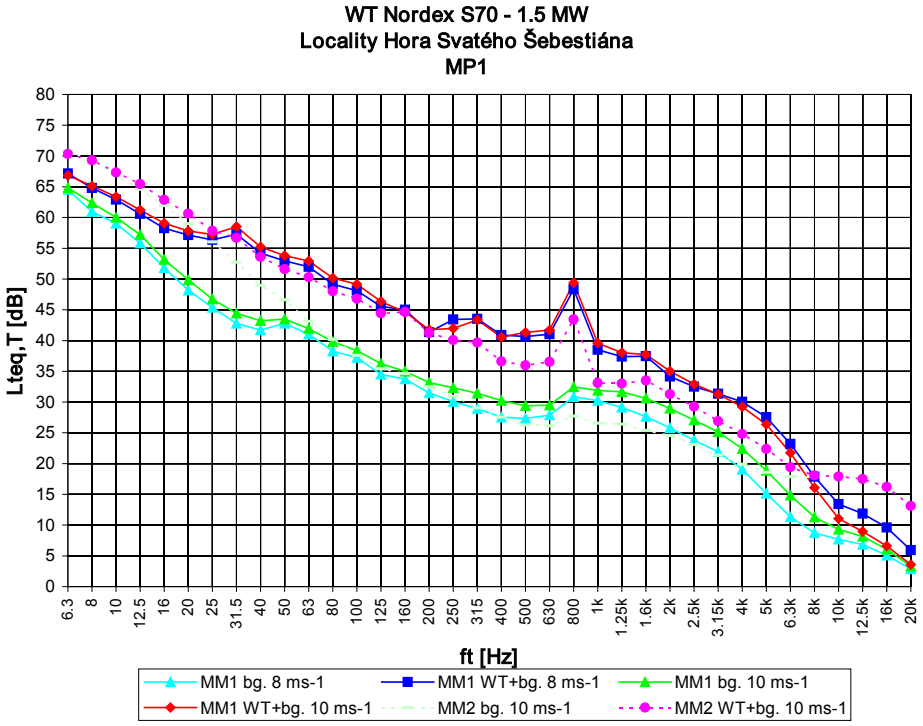
reverse engineering calculated ground absorption 0.64, wind speed 10 ms^{-1}

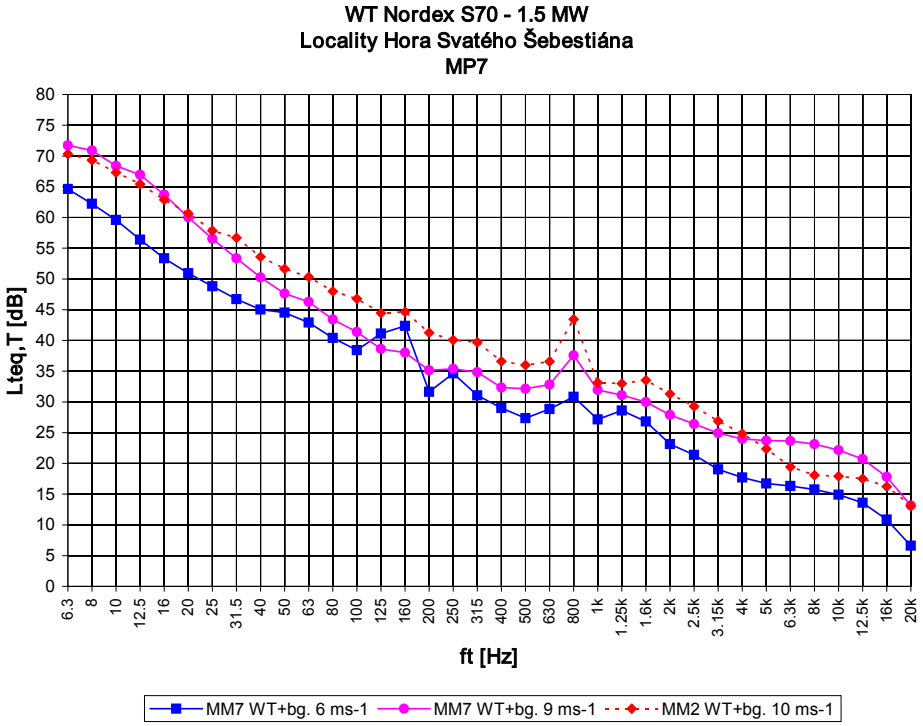
* too high background noise, in parenthesis results for 3 WT





Third-octave spectra:





Locality assessment:

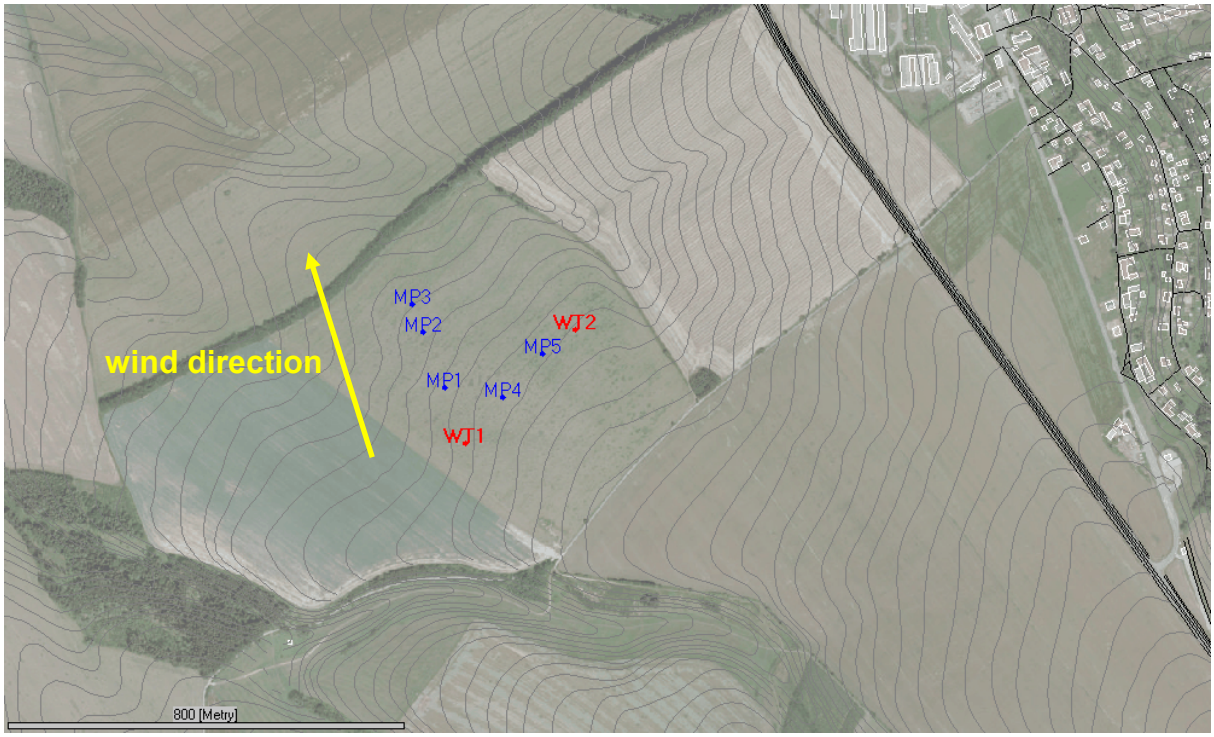
Noise was over the nighttime limit 40 dB. After remedies noise is below the nighttime limit 40 dB, LF noise is minimal, WT got working permission.

Residents complained of WT, after remedies complaints disappeared.

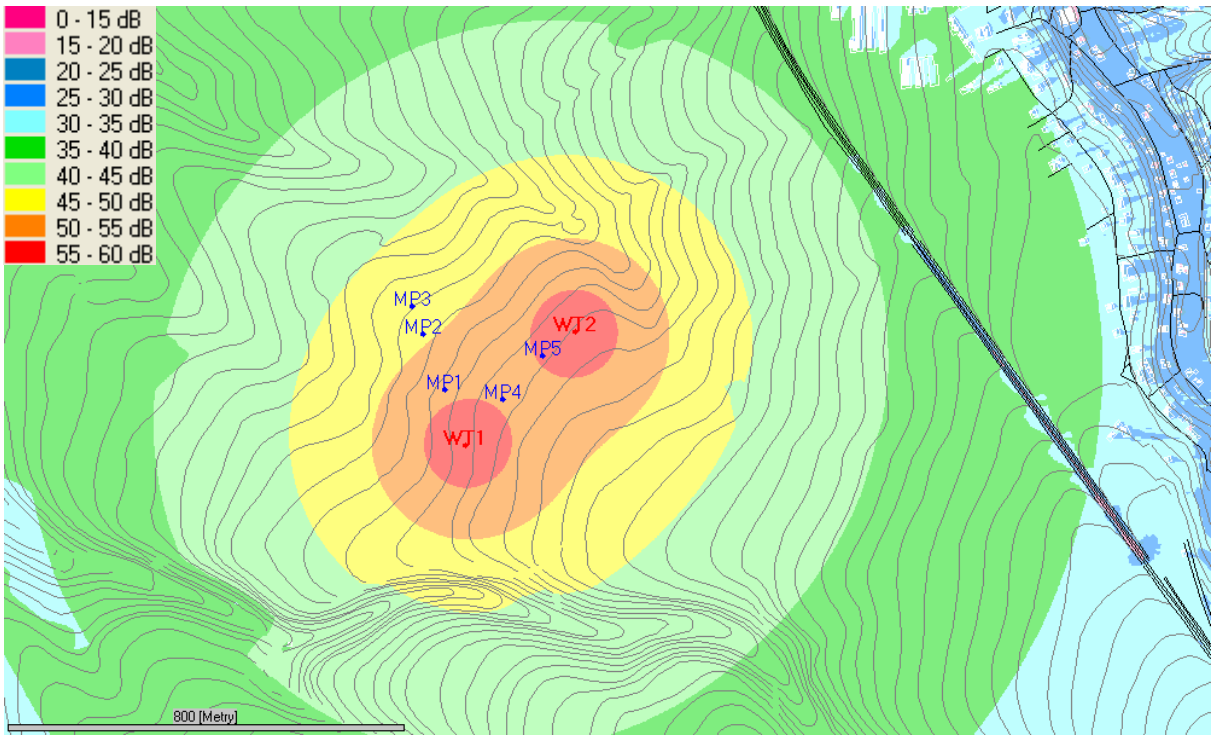
Locality Janov - “low wind speed tonality”

2 WT Wikov W2000spg - 2.0 MW, 1 reference MP behind WT at 120 m distance, 2 MP behind WT at 240 m and 300 m, no imission MP - traffic noise, flat terrain

WT noise measurement



WT noise calculation



Locality is noisy place near the main road

March 2010, 11:00 - 2:00, nearly clear sky, 16.9 - 11.8 °C, 64 - 84 %

Measurement results:

Measurement position 1 - 120 m

wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
5	34.4	51.5	51.4 ± 1.0	105.6 ± 1.0
6	34.7	51.0	50.9 ± 1.0	105.1 ± 1.0
7	35.0	50.7	50.6 ± 1.0	104.7 ± 1.0
8	35.4	50.5	50.4 ± 1.0	104.5 ± 1.0

Measurement position 2 - 240 m

wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
5	33.9	45.6	45.3 ± 0.9	104.3 ± 0.9
6	34.1	45.6	45.3 ± 0.9	104.3 ± 0.9
7	34.4	45.6	45.3 ± 0.9	104.4 ± 0.9
8	34.6	45.7	45.4 ± 0.9	104.4 ± 0.9

Measurement position 3 - 300 m

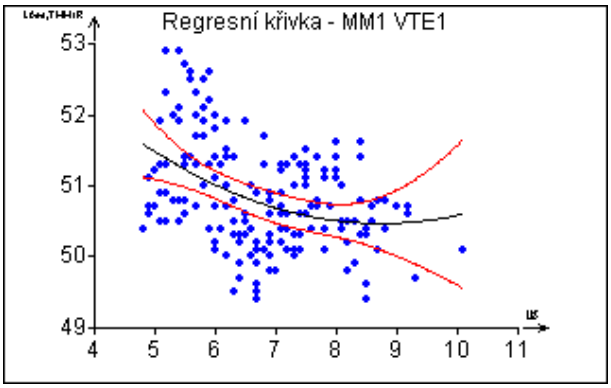
wind speed v_s [ms^{-1}]	$L_{Aeq,T}$ background [dB]	$L_{Aeq,T}$ WT + bg. [dB]	$L_{Aeq,T}$ WT corr. [dB]	sound power level L_{WA} [dB]
5	33.9	43.5	43.0 ± 0.9	103.8 ± 0.9
6	34.2	43.5	43.0 ± 0.9	103.8 ± 0.9
7	34.5	43.6	43.0 ± 0.9	103.9 ± 0.9
8	34.8	43.8	43.2 ± 0.9	104.0 ± 0.9

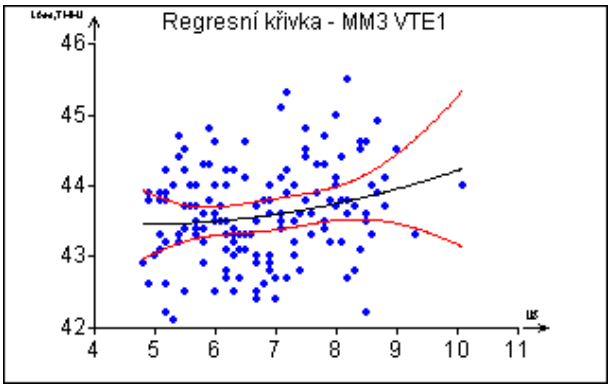
Noise calculation results $L_{Aeq,T}$ [dB] in calculation points:

Measurement position	distance [m]	$L_{Aeq,T}$ backgr. [dB]	$L_{Aeq,T}$ meas. [dB]	$L_{Aeq,T}$ calc.9613-2 [dB]	diff. meas.-calc. [dB]
1	120	35.4	50.4	50.7 (51.6)	0.3
2	240	34.6	45.4	45.3 (47.4)	-0.1
3	300	34.8	43.2	43.3 (45.9)	**0.1**
-	1018	*	*	29.4 (34.0)	-

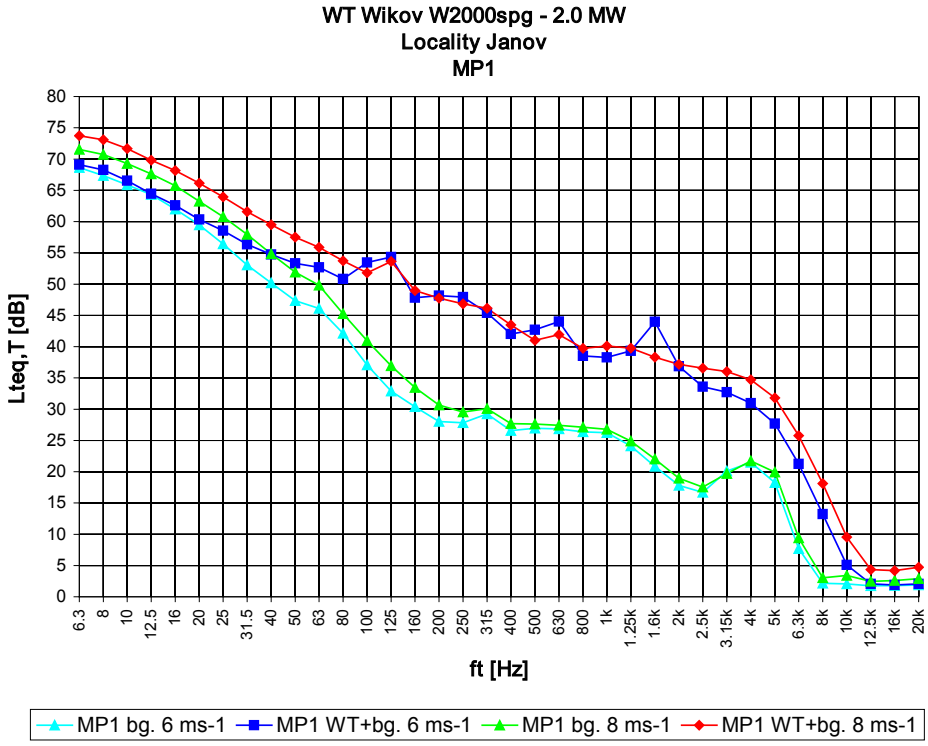
reverse engineering calculated ground absorption 0.28, wind speed 8 ms^{-1}

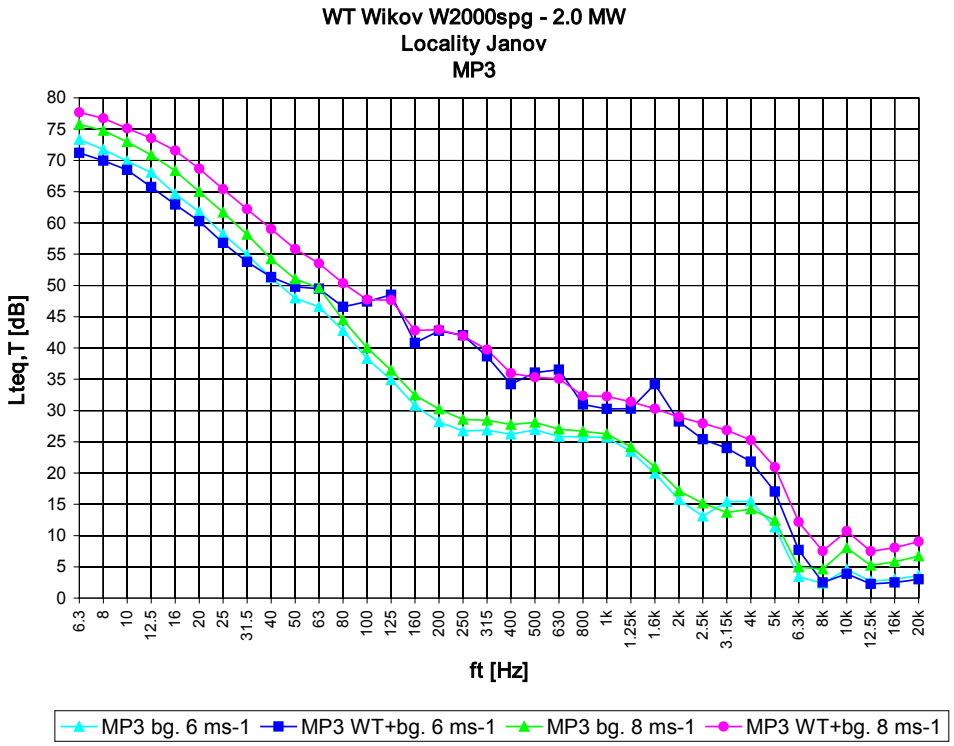
* too high background noise, in parenthesis results for 2 WT





Third-octave spectra:





Locality assessment:

Noise is below the nighttime limit 40 dB, LF noise is minimal, WT got working permission.

Residents haven't complained of WT.

Conclusions

1. Reference MP is very practical, because:
   - it is largely free without obstacles
   - it doesn't require an adjustment
   - other WT's don't interfere with measured one
   - correction for background noise is usually small
2. In some cases sound power level assessment can be burdened with error whether positive or negative effect.

   Probability of error increases with spectral problems (yawing, tonality).

   Magnitude of error isn't big (compared to noise propagation), but it can affect the WT model noise comparison or noise limit compliance.
3. If possible I recommend to measure at longer distance(s) from WT, especially in the case of spectral problems.

   This system should also help identify the tonality at longer distances where it is currently not addressed. A common statement "tonality cannot be transferred directly to longer distances" is true, but useless.

References

IEC 61400-11 ed.2

Measurements in the Czech Republic

Jakobsen J.: Infrasound Emission from Wind Turbines (2005)