GREWUS GmbH

Measurement Report

Ambient Noises and Audible Reverse Warning Devices

Christopher Pagel / Ralf Hinnerichs
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Contents

High, middle and low ambient noise levels

For a general definition of “typical quiet areas (low level areas)”, normal level and high level areas, measurements are needed. Therefore, we did a couple of measurements in our neighbourhood.
The SPL values (LAFmax, LAeq) for „Low Level“, „Normal Level“ und „High Level“ has been determined at different representative locations. We believe blue marked location are normal, red marked location are loud and green marked are low.

1. Frequently used normal road
    a. typical normal, but even loud area from time to time could be used
    b. the average SPL is just below 75dBA (attached details could be seen in the diagrams)
    c. This kind of street could be a good example as a “maximum” normal area

2. Entrance area of warehouse
    a. Still a typical normal area, but even as quiet area from time to time could be used
    b. The average SPL is in the area of 65dBA but in some periods it is even less than 55dBA
    c. This kind of area could be a good example as “minimum” normal area

3. Supermarket parking space
    a. It is clearly a normal area the measurements are showing it as expected

4. Freeway service station
    a. It is a typical area where trucks need to move backward. That’s why we consider it as an important measurement.
    b. It is not needed to switch to loud area even the SPL is in average higher than the middle SPL of normal area definition
    c. The SPL only in peaks will increase to higher values than 70dBA

5. Logistics center
    a. A typical area for trucks to load and unload. So it is an important area to be considered
    b. After measurement we consider it as a normal area. The average SPL is below 60 dBA

6. Construction site beside a road
    a. The measurement has been taken at a long distance from the construction (about 25m) see picture.
    b. During work time even in long distance the SPL increased over 75dBA and calculated for a shorter distance an average of 85 dBA can be assumed.
    c. 75dBA seems to be a good level for loud areas

7. Industrial park parking space
    a. It is absolutely a normal area the measurements are clearly showing it as expected

8. Forest
    a. Surely to be defined as a quiet area.
    b. The SPL only increase during abnormal situation as an Aircraft is flying over (see diagram)
    c. The SPL does not exceed 55dBA

9. Construction site city area
    a. It is a typical area that can be regarded as a loud environment
    b. The average SPL is 77dBA with peaks up to 90dBA caused by construction work

<u>Recommendation</u>

Based on these results the three ambient sound levels should be considered as following:

Low Level:	< 55 dBA
Normal Level:	>= 55 dBA and <= 75 dBA = 65 dBA +/-10 dB
High Level:	> 75 dBA

Component specification

After the specification of the ambient noise levels the SPLs of the audible reverse warning device must be considered. To define the SPL in regard of the ambient noise levels a look to existing standards and to the measurements is needed.

According ISO7731 the audibility of danger sounds must be ensured. The effective masked threshold shall be distinctly exceeded. To ensure its audibility, the A-weighted sound-pressure level of the danger signal shall not be lower than 65 dBA at any position in the signal reception area. And the ambient noise level has to be exceeded by certain values.

Following SPL for danger signals are defined according ISO7731:

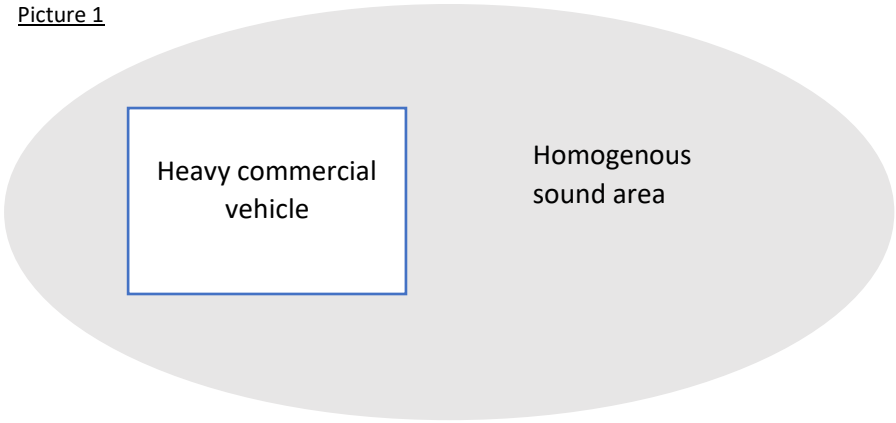
A-weighted sound-pressure level	>15 dB above ambient noise level
1/3 octave-bands	>= 13 dB above ambient noise level

To define the SPLs of the audible reverse warning device, the following three aspects must be taken into account:

1. The three typical ambient noise classifications for low, high and normal sound as explained before
    a. Low Level: < 55 dBA
    b. Normal Level: >= 55 dBA and <= 75 dBA = 65 dBA +/-10 dBA
    c. High Level: > 75 dBA

2. A homogenous sound area over all positions around the heavy commercial vehicle must be presumed. At all points in the as homogenous area marked field the SPL is the same.

    Picture 1



3. The warning signal has to follow the ISO rules
    a. A-weighted sound-pressure level >15 dB above ambient noise level
    b. 1/3 octave-bands >= 13 dB above ambient noise level

These aspects lead to the recommended warning sound SPLs in 2m distance as followed:

For low level ambient noise the maximum of the low level warning signal is

70 dBA (55 dBA + 15 dB) for tonal and 68 dBA (55 dBA + 13 dB) for 1/3 Octave sound
In a low level mode typically the ambient noise should not exceed 55dBA. That's why it is the MAXIMUM SPL in LOW modus

For high ambient noise level the danger warning sound must be

minimum 90 dBA (75 dBA + 15 dB) for tonal and 88 dBA (75 dBA + 13 dB) for 1/3 Octave sound
In a loud area the SPL will be typically higher than 75dBA. That's why it is the MINIMUM SPL in loud mode

For normal ambient noise level the danger warning sound will be

80 dBA (65 dBA + 15 dB) for tonal 78 dBA (65 dBA + 13 dB) for 1/3 Octave sound
The normal mode should be just between Loud and quiet areas.

Furthermore, an audible reverse warning device is typically specified with a tolerance of +/- 3dB. This belongs to measurement and production tolerances. Many suppliers of alarms define the SPL at 1m instead of 2m, so we consider both values and define the following table:

		2m distance			1m distance		
Ambient noise SPL		**Tonal warning sound** Offset: 15 dB above ambient noise			**Tonal warning sound** Offset: 15 dB above ambient noise		
		Min	Typ	Max.	Min	Typ	Max.
Low Level	55	64	**67**	70	70	**73**	76
Normal Level	65	77	**80**	83	83	**86**	89
High Level	75	90	**93**	96	96	**99**	102
Ambient noise SPL		**1/3 Octave warning sound** Offset: 13 dB above ambient noise			**1/3 Octave warning sound** Offset: 13 dB above ambient noise		
		Min	Typ	Max.	Min	Typ	Max.
Low Level	55	62	**65**	68	68	**71**	74
Normal Level	65	75	**78**	81	81	**84**	87
High Level	75	88	**91**	94	94	**97**	100

Table 1

The selfadjustable acoustic warning device should consider exactly the same SPL requirements as the non-selfadjustable system. This means, the selfadjustable system should switch automatically between the 3 different sound levels (normal, high, low) automatically. But the levels for the automatic switching must be defined.
We propose to fix the settings as follows:

Ambient noise	**Selfadjustable alarm setting**	**Remark**
SPL < 45dBA	Low	The system has to switch in low sound mode
SPL < 55dBA	Low	The system can switch in low but it is allowed to stay in normal sound
SPL 55- 75dBA	Normal	The system should stay in normal sound
>70 dBA	High	The system can switch in high sound but is allowed to stay in normal
>80dBA	High	The System has to switch in high modus

Table 2

The hysteresis for switching into different modes is recommended to reflect a normal use. Similar to the manual use, the driver will also not switch permanently between different cases. The SPL of the ambient noise is changing permanently (see measurements), The self-adjustable will respect different conditions faster than a driver, but it is not needed and recommended to have a dynamic change over all ambient noise levels, e.g. 15dB above the ambient noise. The sound would not be stable and the specification can't be done in a practical manner.

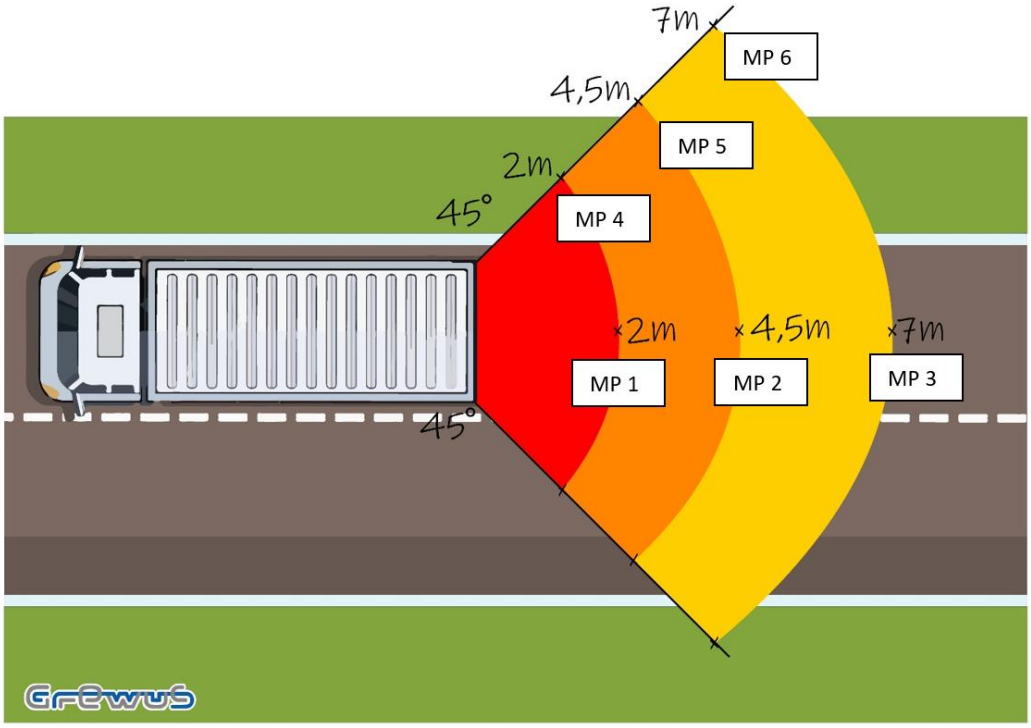
Measurements regarding mounted devices / specification “part II. Audible reverse warning signals of motor vehicles”

The SPL for the installed alarm needs to be defined. A lot of different parameters influences the resulting SPL. For a variety of these parameters we made measurements to have a more detailed look at their influence.

A first the theoretical aspect:
The SPLs for different distances can be calculated to the following rule under normal conditions:
L2 = L1 - 20 x LOG (d1/d2).
While d1 is the reference distance with the reference SPL L1, d2 is the distance and L2 is the SPL we examine now. Based on these parameters an alarm under normal conditions (e.g. no reflection) which is generating an SPL L1 of 80dBA at 2m distance will generate a sound at 7m distance of
80dBA – 20 x log (7m/2m) = 69dBA.
For a definition of acoustical requirements for the device mounted on the vehicle a couple of considerations are needed:

1. There are different “danger zones” behind a vehicle. We recommend an approach like picture 2 shows with different zones marked in red, orange and yellow:

   Picture 2



   The red area up to a distance of 2m behind the vehicle can be regarded as a high risk area, up to 4.5m as medium risk and up to 7m as low risk area for affected persons.

2. The mounting position will have a serious impact on the warning sound (e.g. behind the bumper, left, middle or right side of the truck etc.).
3. Reflections, caused by the street, walls, etc., reflections caused by the truck itself and the mounting position of the warning device. So, a realistic definition is complicated.

To examine some of these aspects we made measurements in realistic situations. For this we test the SPL results at defined measurement points MP 1 to MP 6 (picture 2). The measurement height of the audible warning device and the microphone was 1.5m.
We tested the following audible warning devices as an example:

1. Tonal 2200Hz, 89dBA / 1m
2. 1/3 octave, 1600Hz, 84dBA / 1m

	Measured SPL [dB(A)]						**Calculated SPL [dB(A)]**		
Type of warning sound	MP1	MP2	MP3	MP4	MP5	MP6	MP1	MP2	MP3
Tonal	87,8	78,8	80,2	76,0	79,7	77,3	83	76	72
1/3 Octave	78,9	75,5	72,9	71,6	66,8	65,1	78	71	67

Table 3

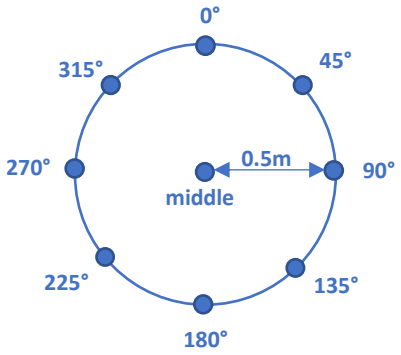
As a result, the SPL for the tonal sound does not correspond to the mathematical expectations. The measured SPL is much higher than the theoretical calculated SPL for certain distances and the reason for that are of reflections. The differences between theory and measurement are up to 8dB.

For measurements of mounted audible reverse warning devices we recommend at least 4 measurement points to ensure appropriate SPLs in considered areas. These measurement points should cover the high risk area and the low risk area. In the high risk area the values must at least meet the minimum values of table 1 minus 3 dB and in low risk areas the maximum values of table 1 plus 3 dB must not be exceeded.

With the tonal sound a second special effect was seen during the measurements. We measured at 2m distance to the alarms on different heights/angles the SPL of different types of warning sound, see results in table 4:

	LAFmax [dBA]	
measurement position	Tonal sound	1/3-octave sound
Middle	85,9	80,0
0°	89,6	79,3
45°	91,5	79,8
90°	89,0	79,1
135°	90,9	79,7
180°	88,8	80,3
225°	90,7	79,6
270°	81,8	79,1
315°	90,1	79,8
Average	88,7	79,6
maximum deviation	9,7	1,2

Table 4



measurement positions

Slight changes (less than 45°) showed SPL changes up to 9dB for the tonal sound while the 1/3-octave sound transmits sound uniformly. So this is a phenomenon of the tonal sound itself. We regard that mainly as a measurement issue and not relevant for everyday situations: If a truck is moving and a person in danger is moving, the SPL will not stay in this kind of acoustic holes. But the consideration for the specification of the measurements is important: A method mentioned for example in TFRA-04-06 under point 14.3.6. is important and will eliminate this problem:

TFRA-04-06: 14.3.6.

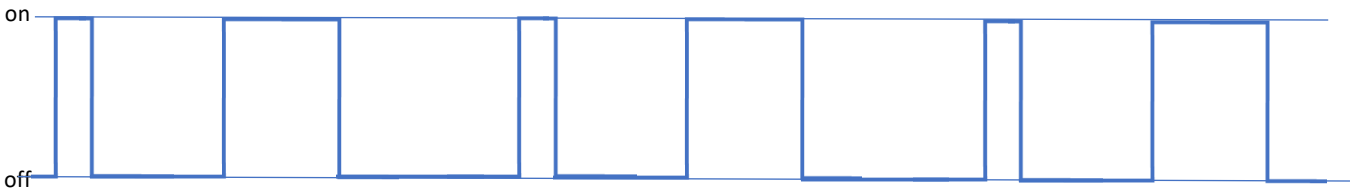
The maximum sound-pressure level shall be sought within the range of 0.5 and 1.5 m above the ground, and the height, at which the maximum sound-pressure level was found has to be fixed for the purpose of taking the measurements prescribed below.

The sound pressure level shall be measured at that fixed height for a duration of at least 3 seconds. The final result shall be the maximum A-weighted sound pressure level of the reading period, rounded mathematically to the nearest integer.

Intermittent Cycles and Duty Ratios of Reverse Warning Devices

To maximize the safety and the warning effect of an audible reverse warning device we also recommend non-uniform temporal structure of reverse warning sounds. ISO 7731 also states recommendations for temporal characteristics, cycles from 0.5 Hz to 4 Hz and an alarm as high distinguishable from ambient sound as possible.

Example:



An example is an alarm with an intermittent sound with two different pulse lengths alternating. Our tests have shown that alarms with these temporal characteristics are more audible and distinguishable from ambient noise in comparison to alarms with a more uniform temporal structure.

The corresponding regulation part

TFRA-04-06: 6.1.1.: *The sound shall be periodical with [50 to 90] cycles per minute and the time sending the sound and sending no sound shall be nearly the same.*

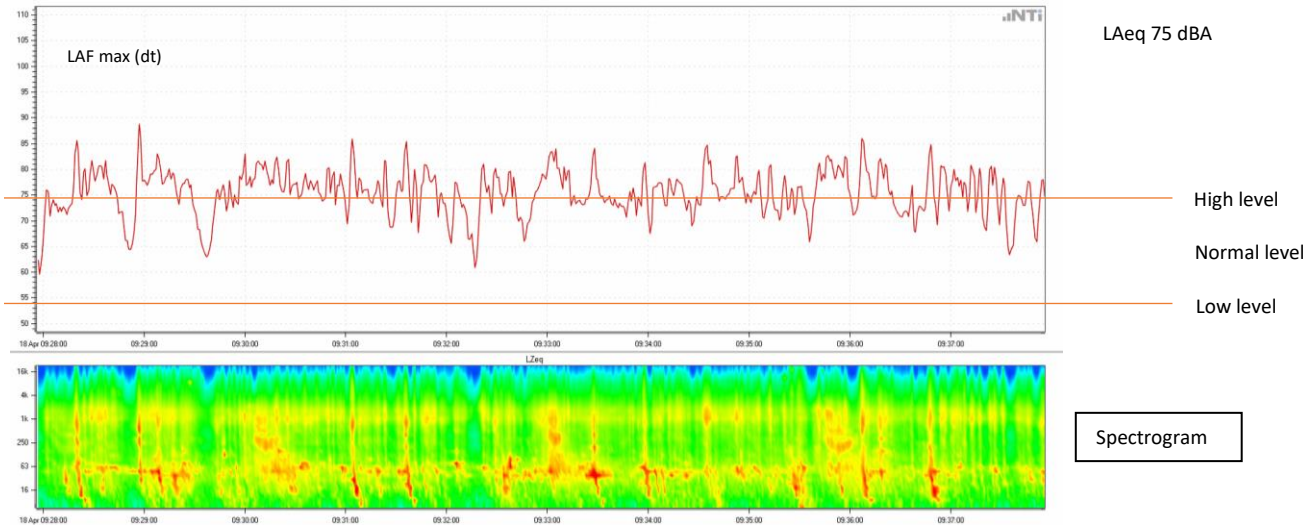
should therefore preferable not only include different amounts of cycles, but also include different pulse lengths for one audible warning device sound. This higher freedom of design could increase the safety and audibility for audible reverse warning devices.

Measurements of different environments

The following test results are showing the pictures where the measurements have been done. We performed the data acquisition always for 10 minutes. Special occurrences can be seen by looking to the peaks in the diagram. The colored diagrams are showing the spectral analysis of the ambient noise. In some cases the dynamic of the sound pressure level and the frequency spectrum explains the need of taking the masked threshold into account.

1. Frequently used road

This measurement has been performed on a frequently used road with 4 lanes (2 on each side). The measurement position was right beside a driveway to a gas station. This area has an average basic environment sound pressure level of 75dBA with high peaks up to 90dBA caused by cars and trucks passing by. The spectrogram shows the frequencies of driving noises of cars and trucks.
This environment is regarded as the maximum of normal environment.



XL2 Sound Level Meter Broadband Reporting:

Hardware Configuration

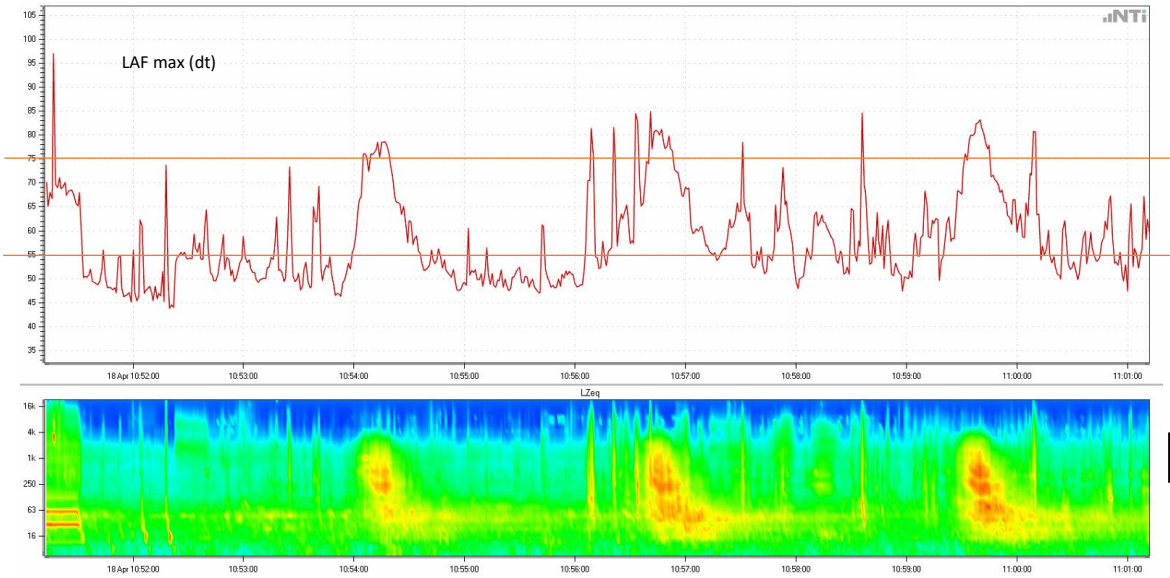
Device Info:	XL2, SNo. A2A-11707-E0, FW4.10
Mic Type:	NTi Audio M4261, SNo. 1013, User calibrated 2019-04-11 08:41
Mic Sensitivity:	16.0 mV/Pa
Time Zone:	UTC+02:00 (Europe/Berlin, DST)

Measurement Setup

Range:	30 - 130 dB

2. Entrance area of warehouse

This measurement has been performed next to the entrance to our warehouse. Usually a quiet area with an average basic environment sound pressure level of 68dBA. Average is 55dBA, but a couple of peaks. During the measurements we had some SPL peaks (95dBA) because of loading sounds and airplanes landing or taking off (85dBA). On the base of the average level with disturbing sounds we would classify this environment as normal level. Without the airplane peaks we would classify this environment as low level.



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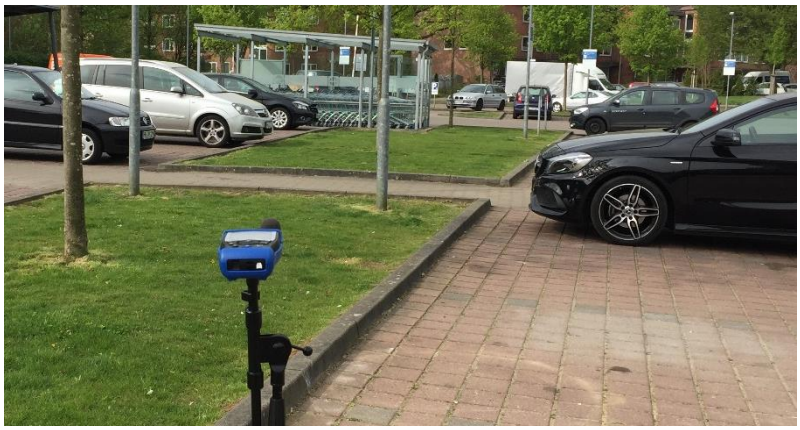
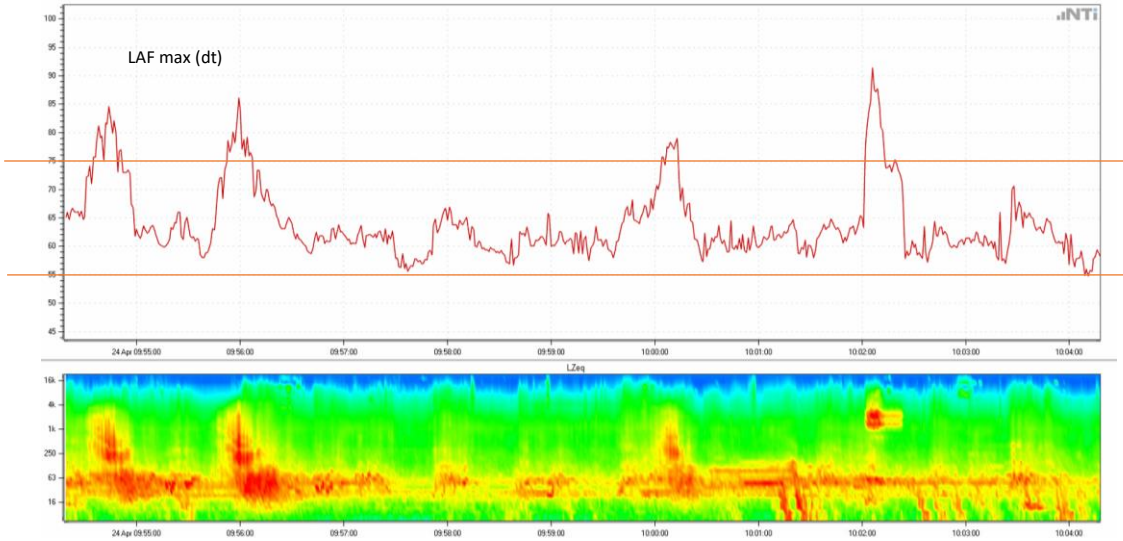
Measurement Setup

Range:	30 - 130 dB

3. Supermarket parking space



This area has an average basic environment sound pressure level of 70dBA. Even though the parking space of this supermarket is very close to a crossroad of a 4-lane road the peaks in SPL are caused by airplanes landing or taking off (85dBA) not by cars passing by. This environment is still classified as normal level



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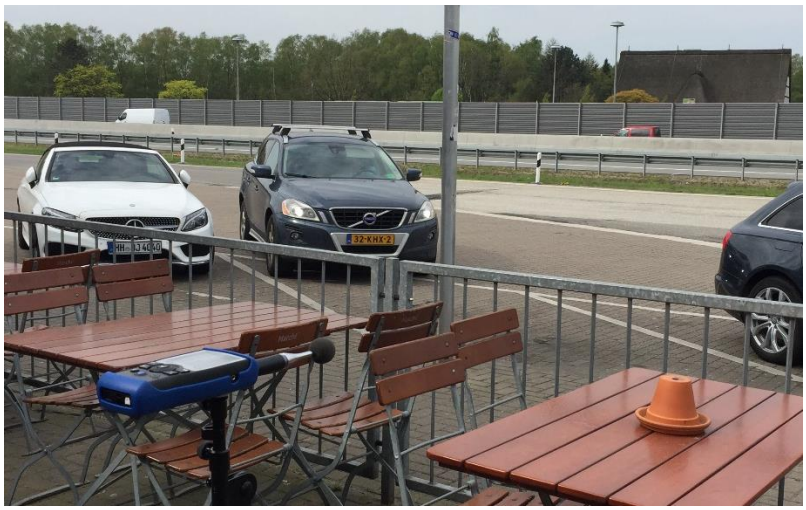
Measurement Setup

Range:	30 - 130 dB

4. Freeway service station



This area has an average basic environment sound pressure level of 68dBA without any “high” peaks. The spectrogram shows constantly driving noise of regularly passing fast driving cars.

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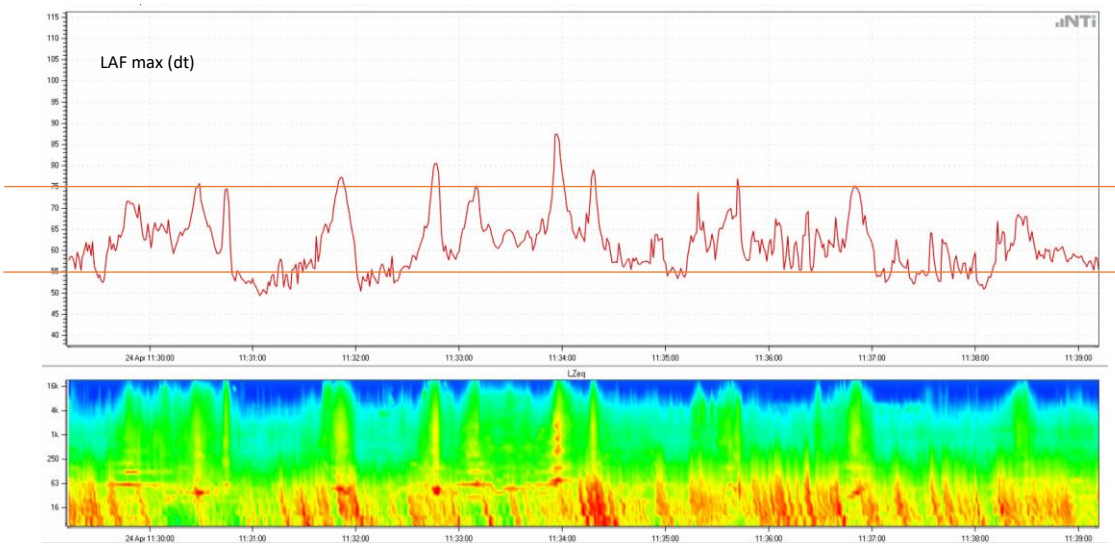
Time Zone:	UTC+02:00 (Europe/Berlin, DST)

Measurement Setup

Range:	30 - 130 dB

5. Logistics center

This area has an average basic environment sound pressure level of 67dBA but with high peaks up to 89dBA. All the peaks are caused by trucks passing by and loadings sounds at the logistics center. This area has a normal ambient level.



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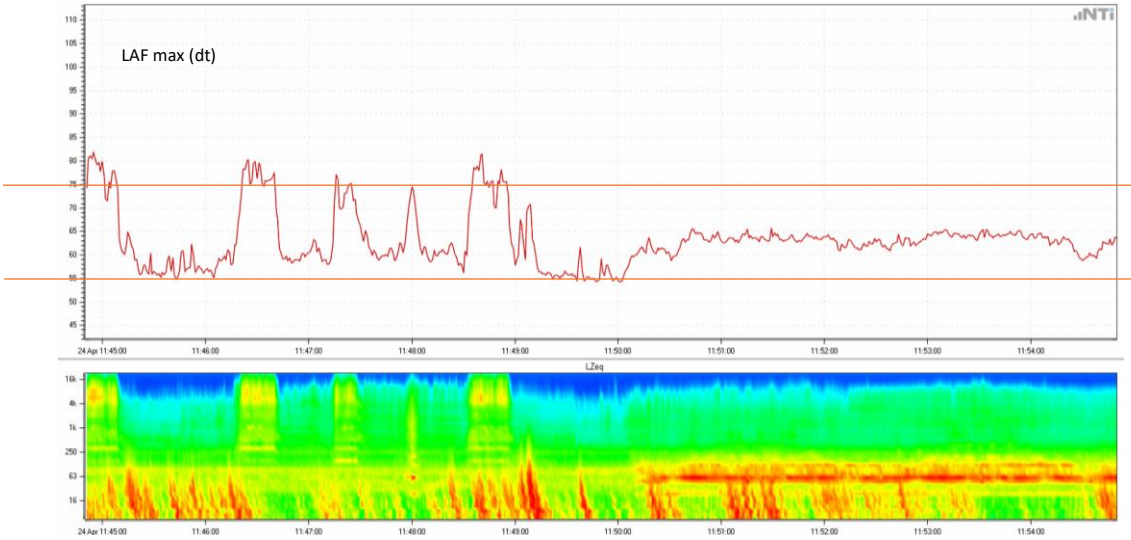
Time Zone:	UTC+02:00 (Europe/Berlin, DST)

Measurement Setup

Range:	30 - 130 dB

6. Construction site beside a road

This area has an average basic environment sound pressure level of 67dBA but with peaks up to 83dBA because of the construction sounds. The test distance is about 25m, so the real average sound should be about 85 dBA in 3m distance. Under this condition the environment can be classified as high level.



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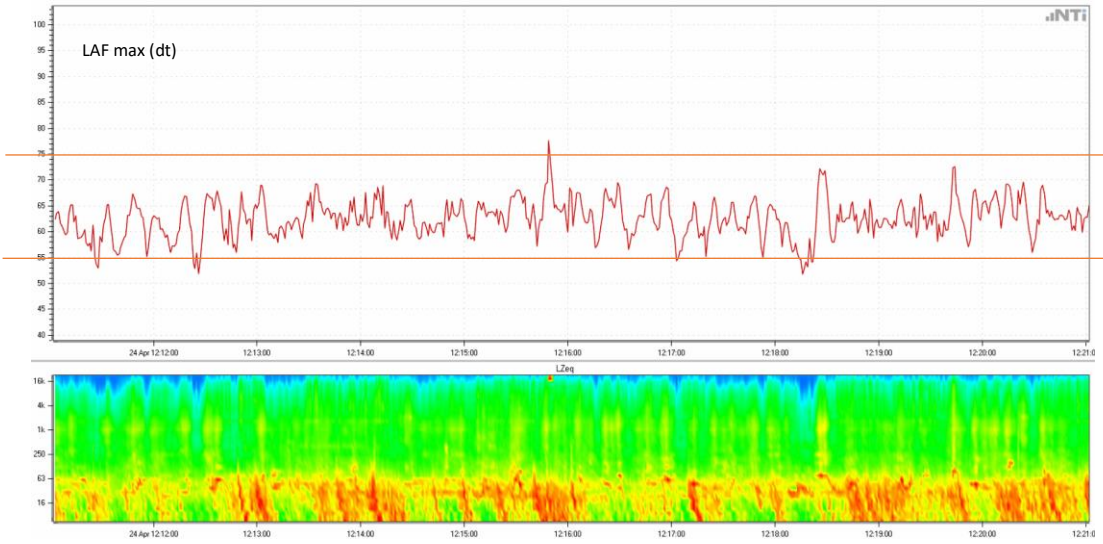
Measurement Setup

Range:	30 - 130 dB

7. Industrial park parking space

This area has an average basic environment sound pressure level of 62dBA. So the environment can be classified as normal area.



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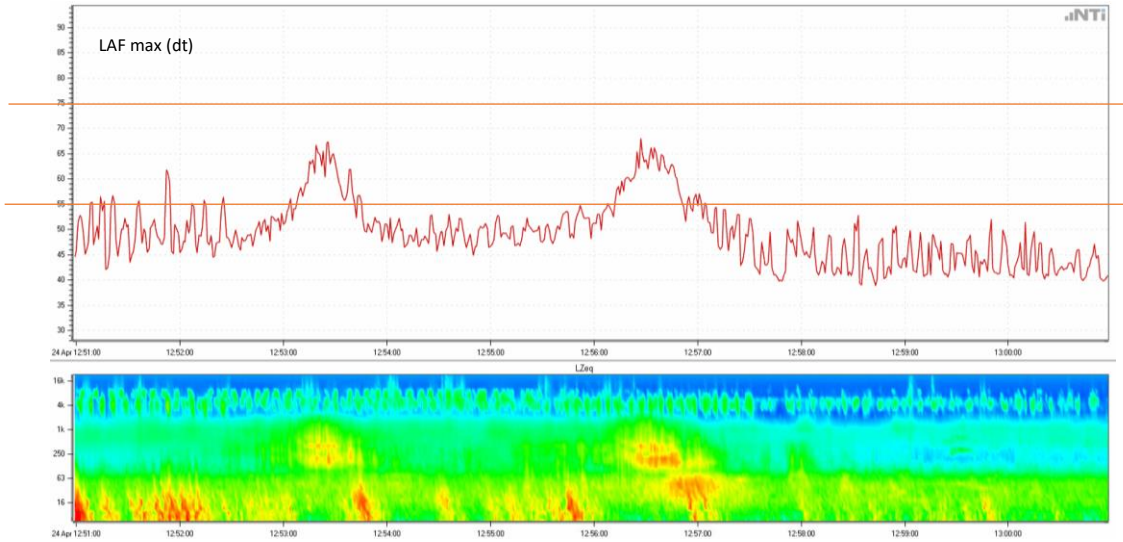
Measurement Setup

Range:	30 - 130 dB

8. Forest

This area has an average basic environment sound pressure level of 53dBA. The only peaks you can see in the graphs are caused by flying airplanes. Therefore the environment can be classified as low level area.



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Time Zone:	UTC+02:00 (Europe/Berlin, DST)

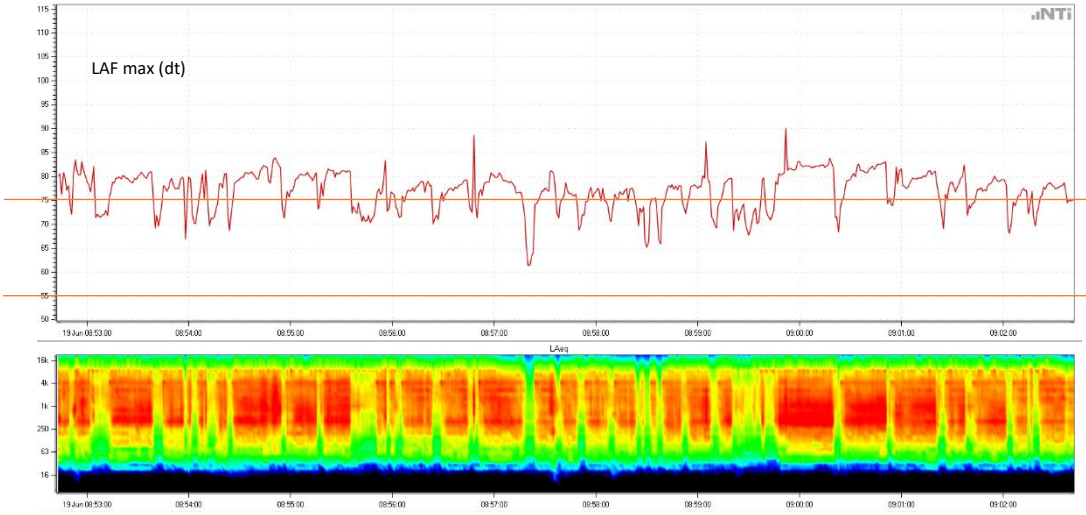
Measurement Setup

Range:	30 - 130 dB

9. Construction site in city area

This area has an average basic environment sound pressure level of 77dBA with peaks up to 90dBA because of the construction sounds.

The environment can be classified as high level.



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