Noise Emission

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Current situation

Locally enforced motorcycle driving ban in Austria [2]

NEMO project identified, i. a., motorized two-wheelers as high emitters [3]

Swiss noise radar study detected LVs as major traffic sound source [1]

Type approval limit values decrease over time

Introduction – Motivation

LVs are a notable contributor to environmental noise in urban and rural environments

A discrepancy exists between noise levels under controlled and real-world conditions

Type approval procedure and limits are adapted over time with the goal to lower noise pollution

The LENS project aims to bridge this gap by developing and validating innovative approaches to measure and assess noise

Additionally, knowledge of loud driving conditions & causes help to assess effectiveness of noise mitigation measures

Introduction – Methodology

- Roadside monitoring and driving simulation
- On-road measurements with on-board system
- Real-world driving patterns
- Test track measurements
- Conclusion

Background

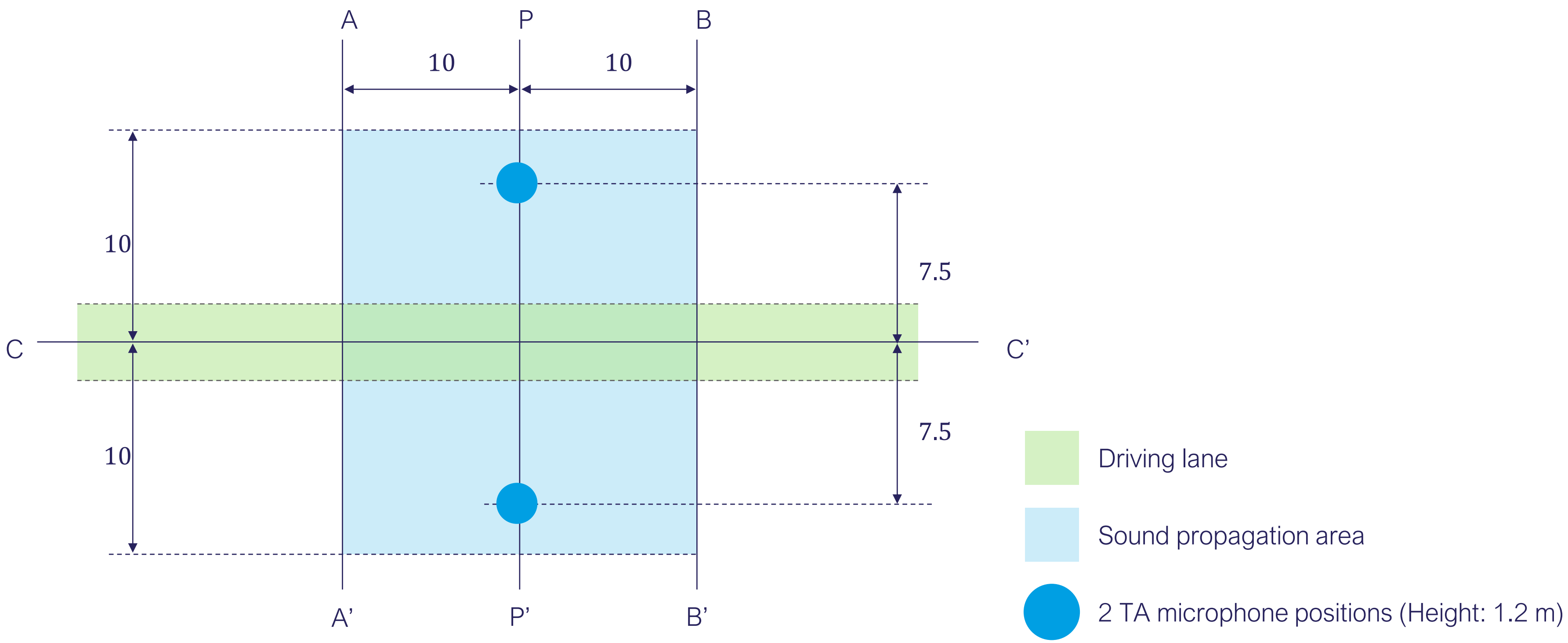
LVs and Noise Type Approval (TA)

Background – Type approval

Vehicle in motion	Stationary noise

• Distinct driving maneuvers on a specified test track
  • Constant speed driving
  • Accelerated driving (L_{wot})
  } L_{urban}
• Measurements in far-field (next slide)
	• Engine speed rising, holding and rapidly releasing
	• Measurements close to vehicle
	• Result: reference value for roadside enforcement w.r.t malfunction/ tampering

Background – Type approval



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Background – UN Regulation

	UN Regulation No. 9	UN Regulation No. 41	UN Regulation No. 63
Vehicle categories	L_2, L_4, L_5, L_6, L_7	L_3	L_1
Vehicle in motion procedure	• Accelerated driving	• Constant speed driving • Accelerated driving	• Accelerated driving
Additional measurements	Additional sound emission provisions (ASEP)	Real driving additional sound emission provisions (RD-ASEP)	–

UN Regulation No. 92
After-market exhaust replacement

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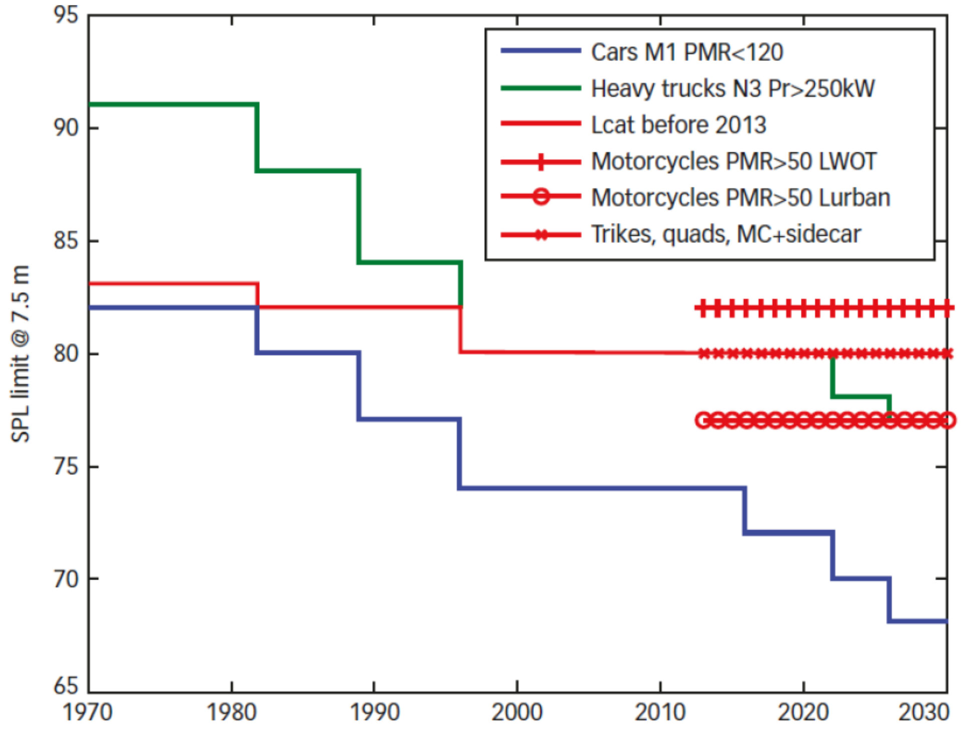
Background – UN Regulation



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Roadside monitoring & driving simulations

Defining loud driving conditions from monitoring and drive cycle simulation

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Roadside monitoring in Utrecht

- Monitoring data at several urban locations including vehicle type, sound and video
- Pass-by sound levels and multiple other sound features
- Assessment of common sound features and driving conditions
- Distance between source and receiver approx. 5m
- Threshold is 80 dB(A)

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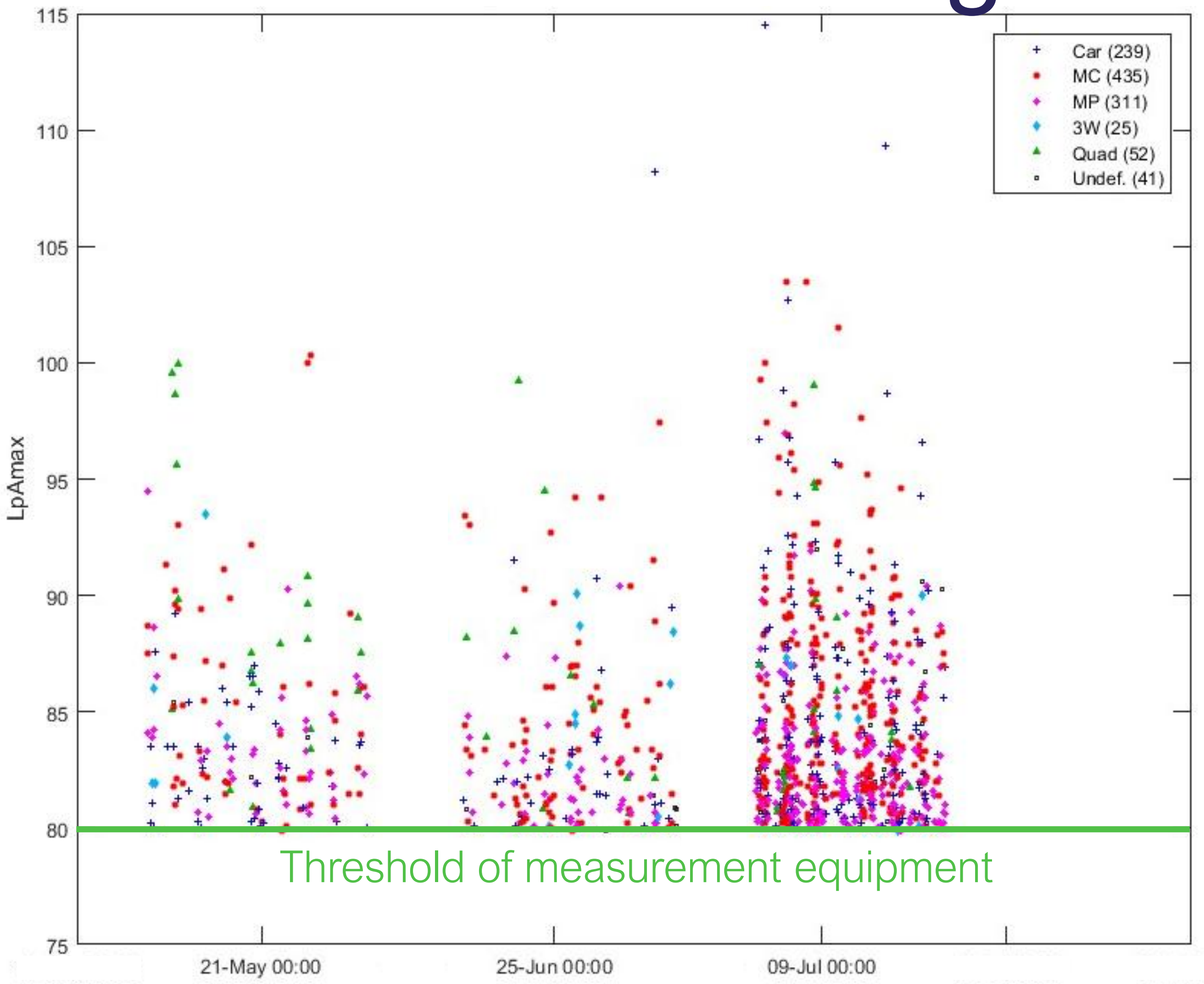
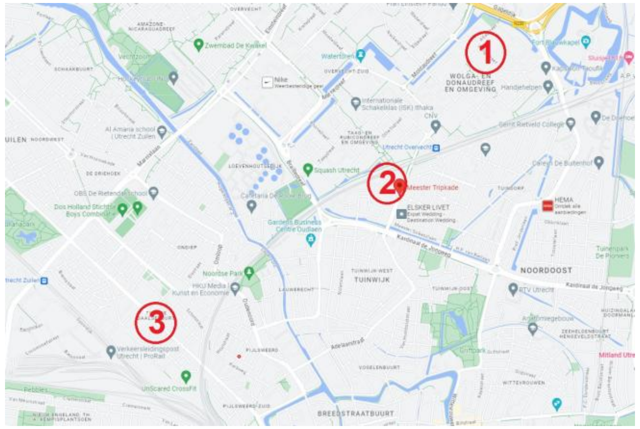
Roadside monitoring in Utrecht





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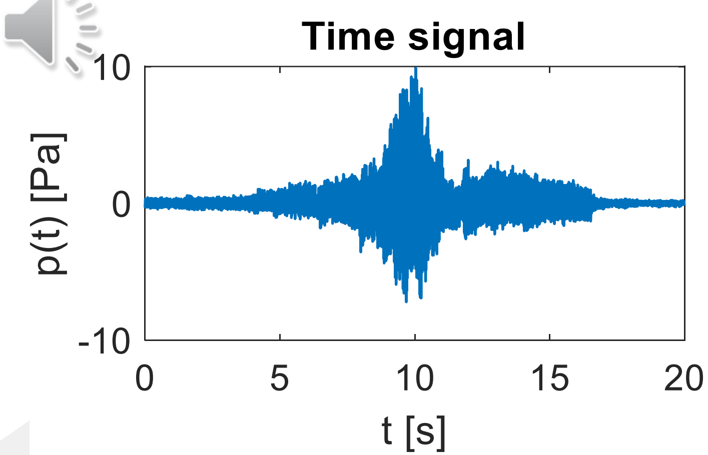
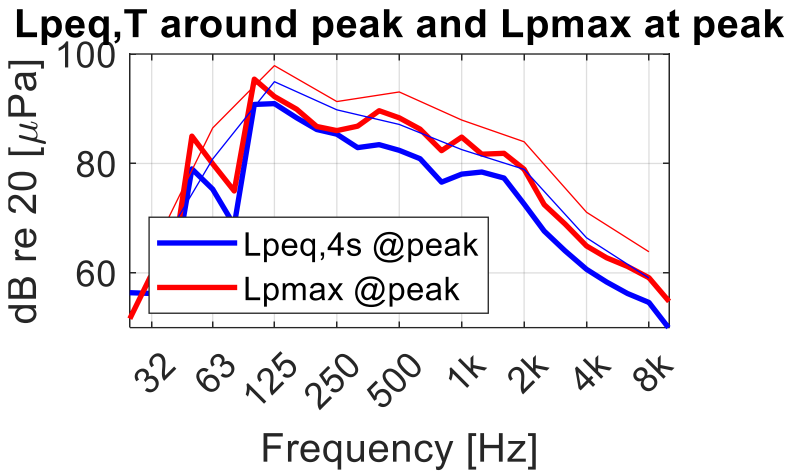
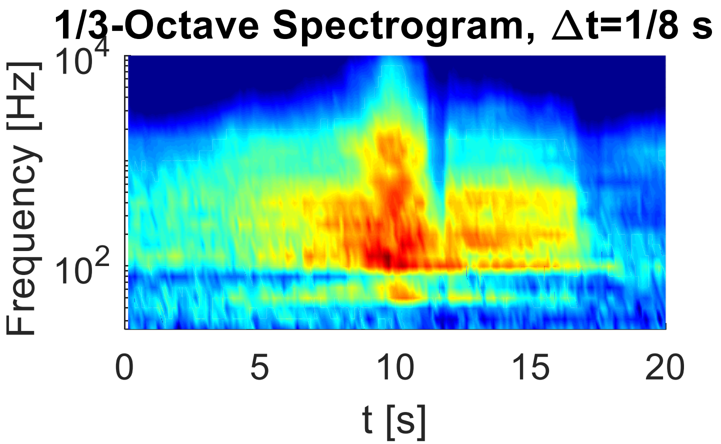
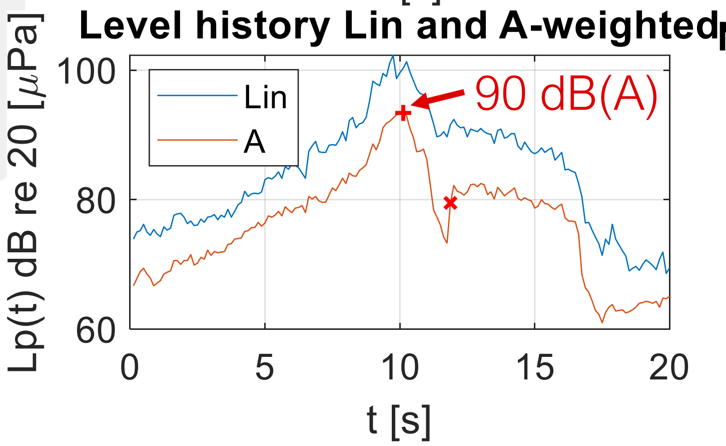
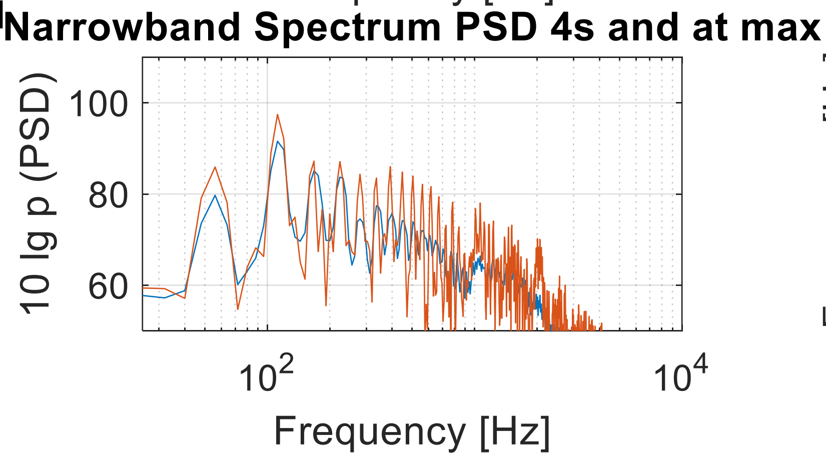
Sound features – High rpm moped

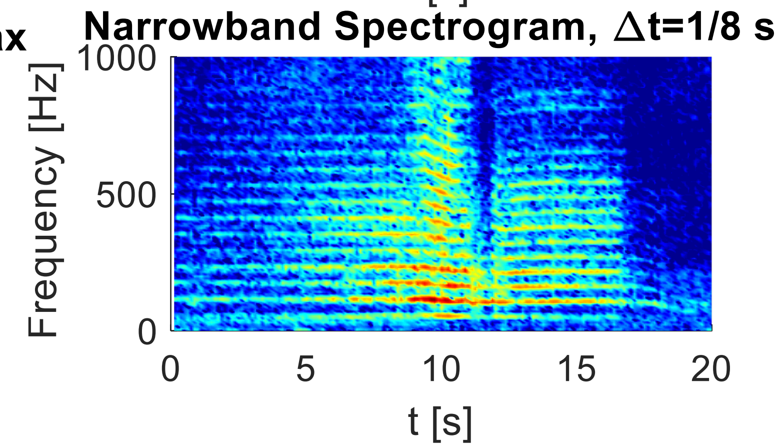




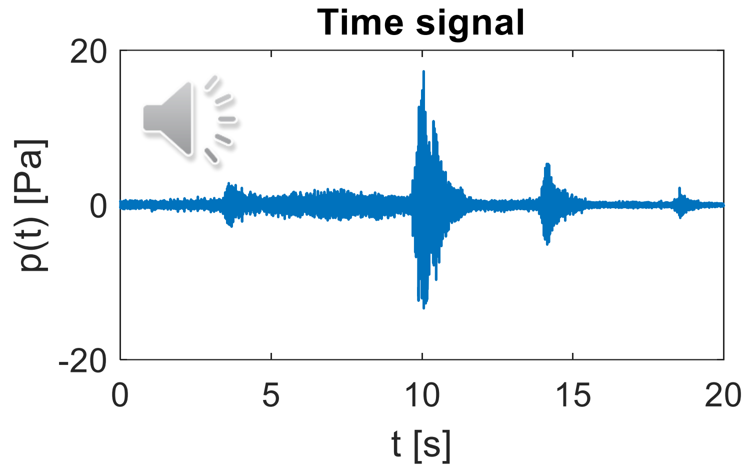


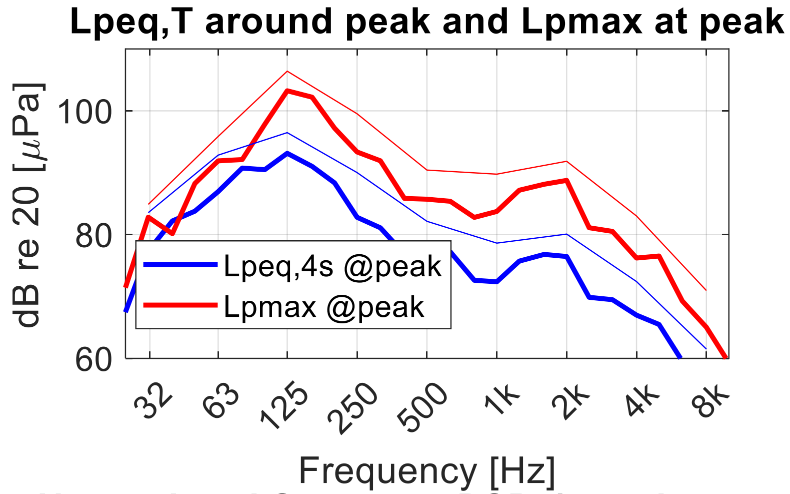


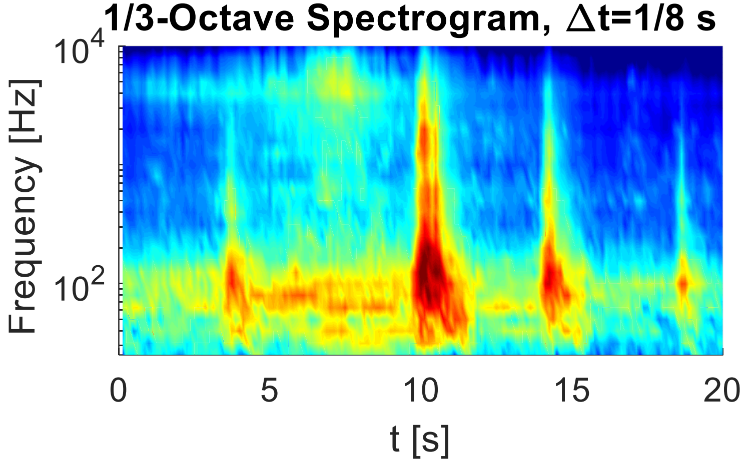


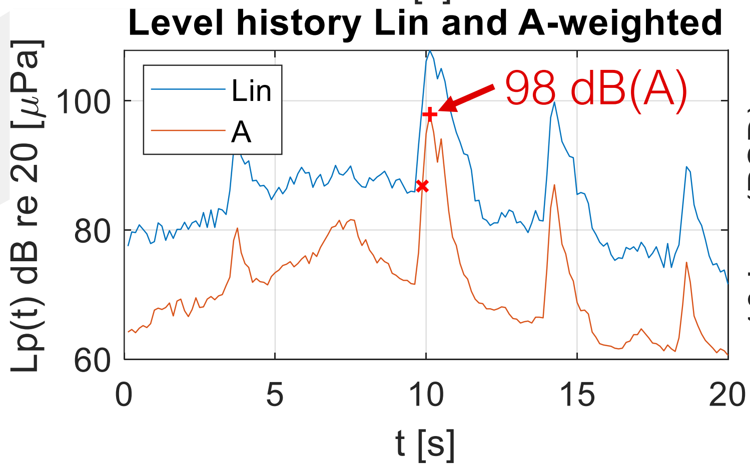


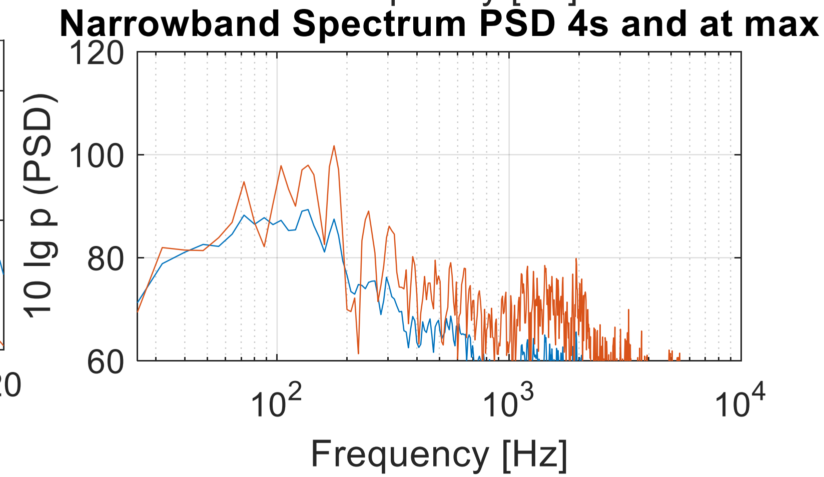
Sound features – Revving

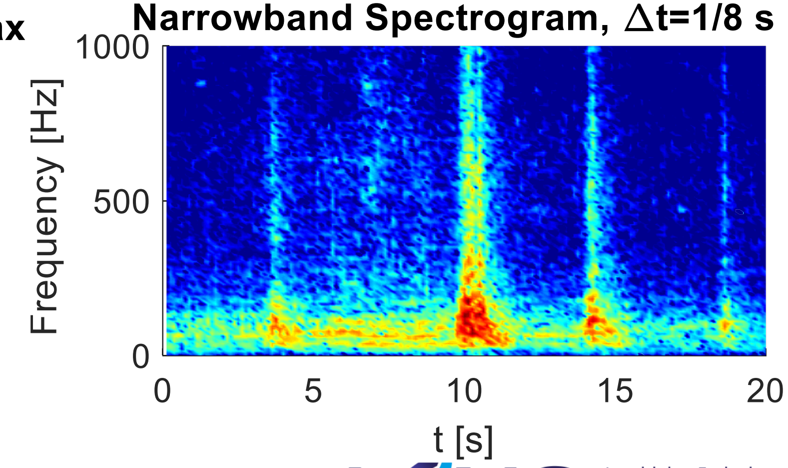












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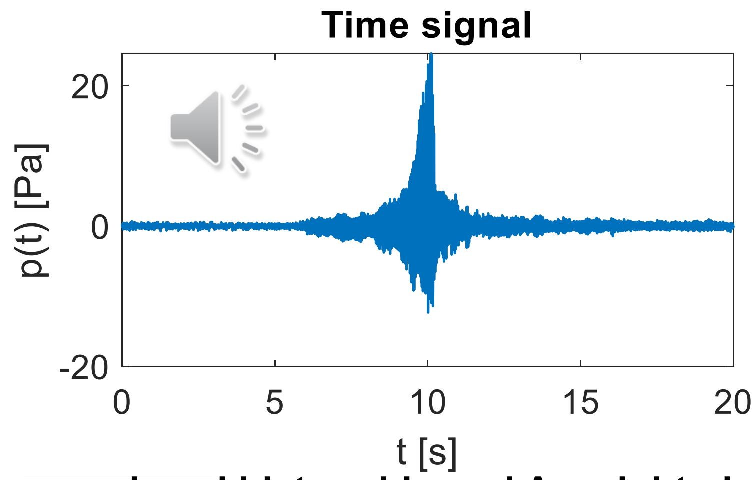
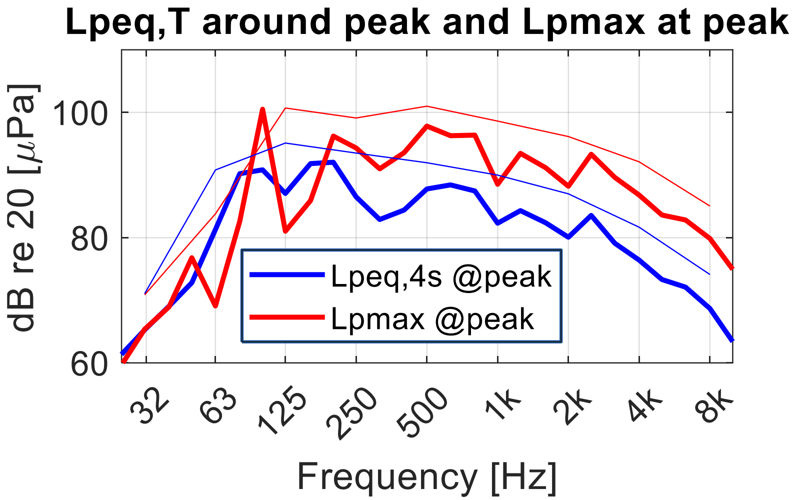
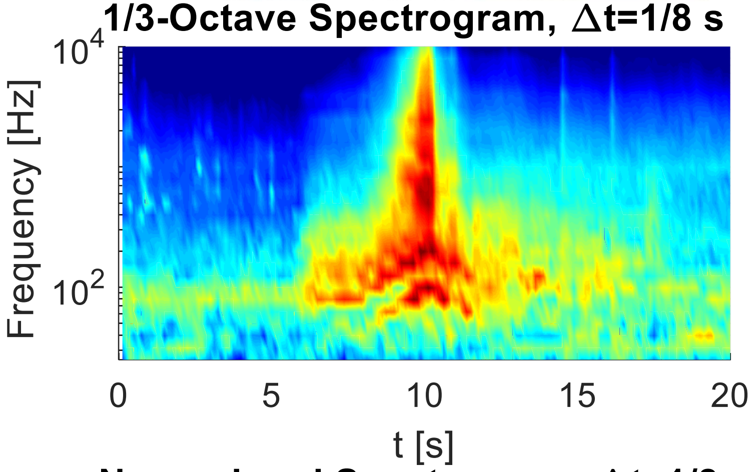
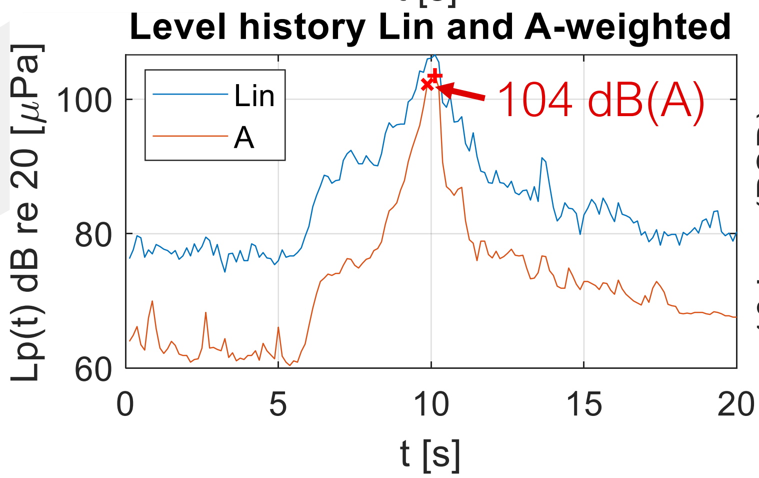
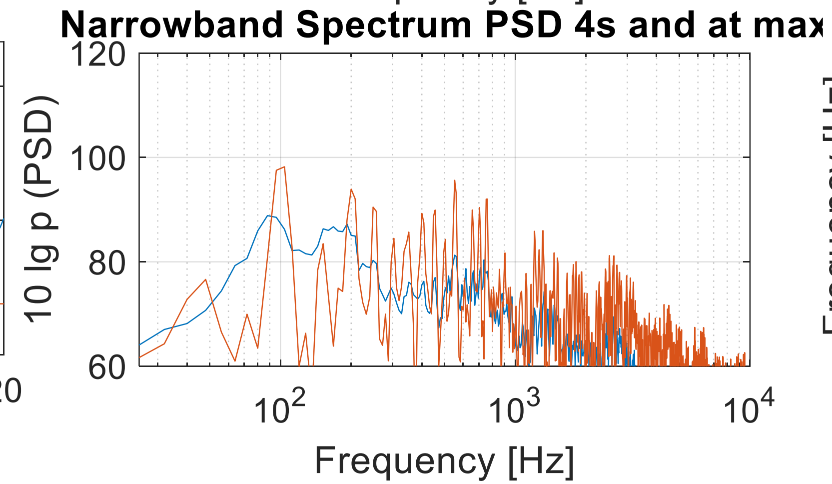
Sound features – Fast acceleration

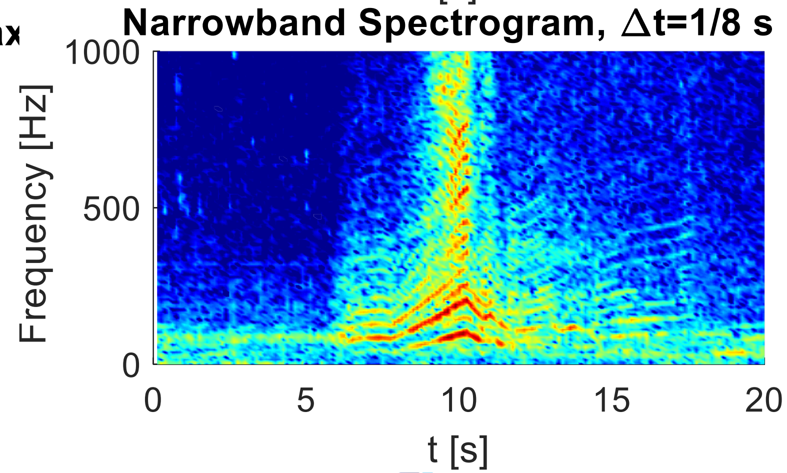












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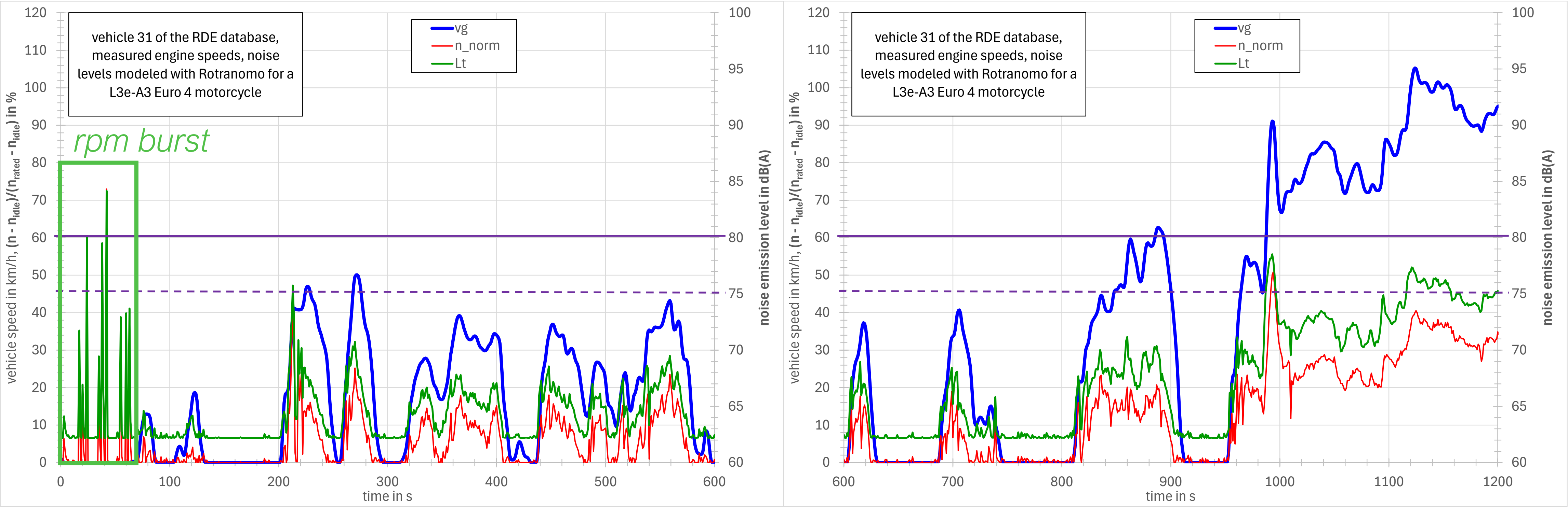
Simulation – real drive emission

- Simulation of noise levels from vehicle speed and engine speed
- Simulation tool is ROTRANOMO, simulating for a distance of 7.5m
- Vehicle speed and engine speed were measured during measurement campaigns

Simulation – real drive emission



75 dB(A) is exceeded for normalized engine speeds above 40%
80 dB(A) is exceeded for normalized engine speeds above 60%

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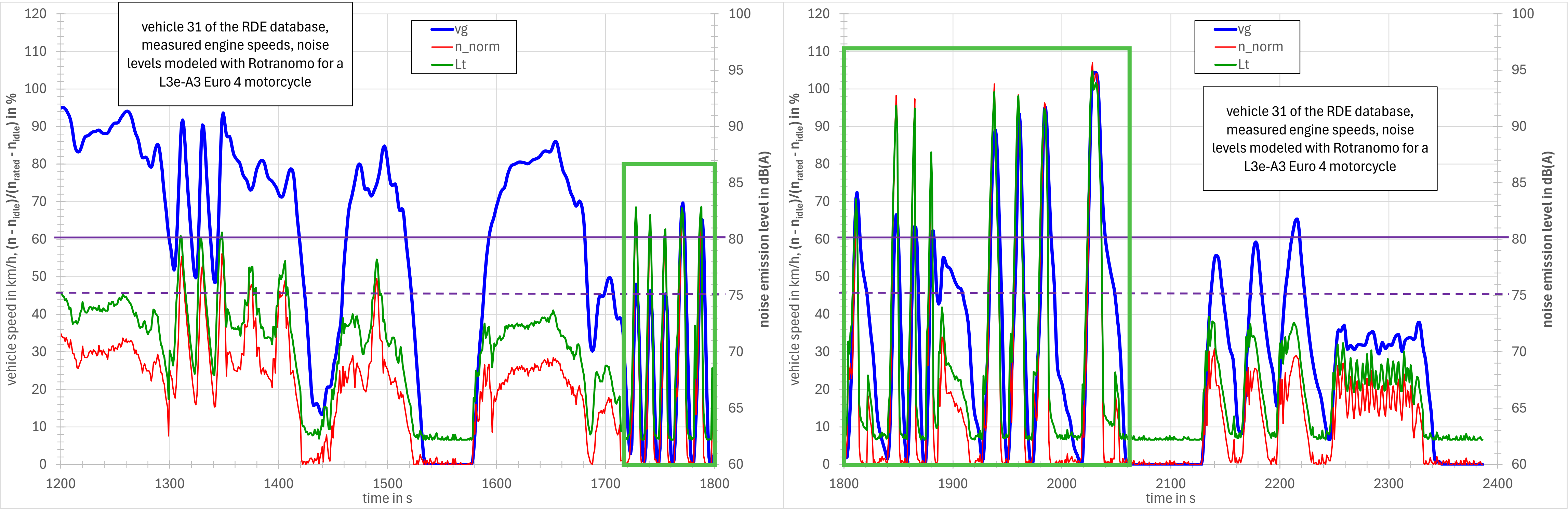
Simulation – real drive emission

Accelerations from standstill



80 dB(A) is exceeded for accelerations from standstill to target speeds of 50 km/h and above

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Roadside monitoring and simulation

Summary

- A total of nine driving patterns were derived from monitoring & simulation
- The most important in terms of noise level and occurrence are shown on the right

No	Condition	Vehicle operation	Already in TA?
2	rpm burst	Stationary, short activation & release of accelerator	No
3	Acceleration from standstill	Acceleration, late gear change	No
6	Maximum acceleration from standstill	Acceleration	No
9	Backfire	Multiple gear changing or manual operation	Only in R41

On-road measurements with on-board system

Acoustic on-road measurements with a newly developed on-board noise sensor

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On-road on-board measurements

On-board measurement system

- Goal: Gathering longer time periods from one vehicle to correlate driving maneuver and noise level

- High-sampled noise level and GPS coordinates are necessary

On-road on-board measurements

On-board measurement system

- Mounting Position
  - An empirical study of four different sensor positions was conducted with a mid-rear position being determined as the most suitable position
  - A documentation for each vehicle measured was mandatory

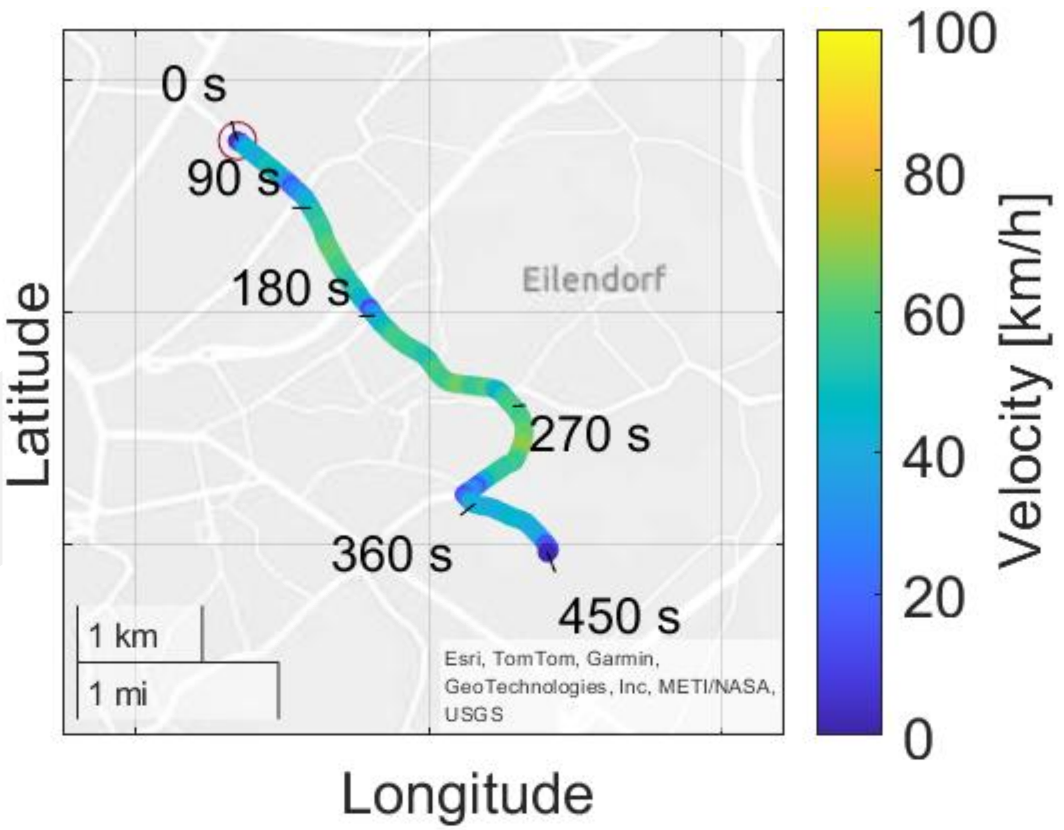
On-road on-board measurements

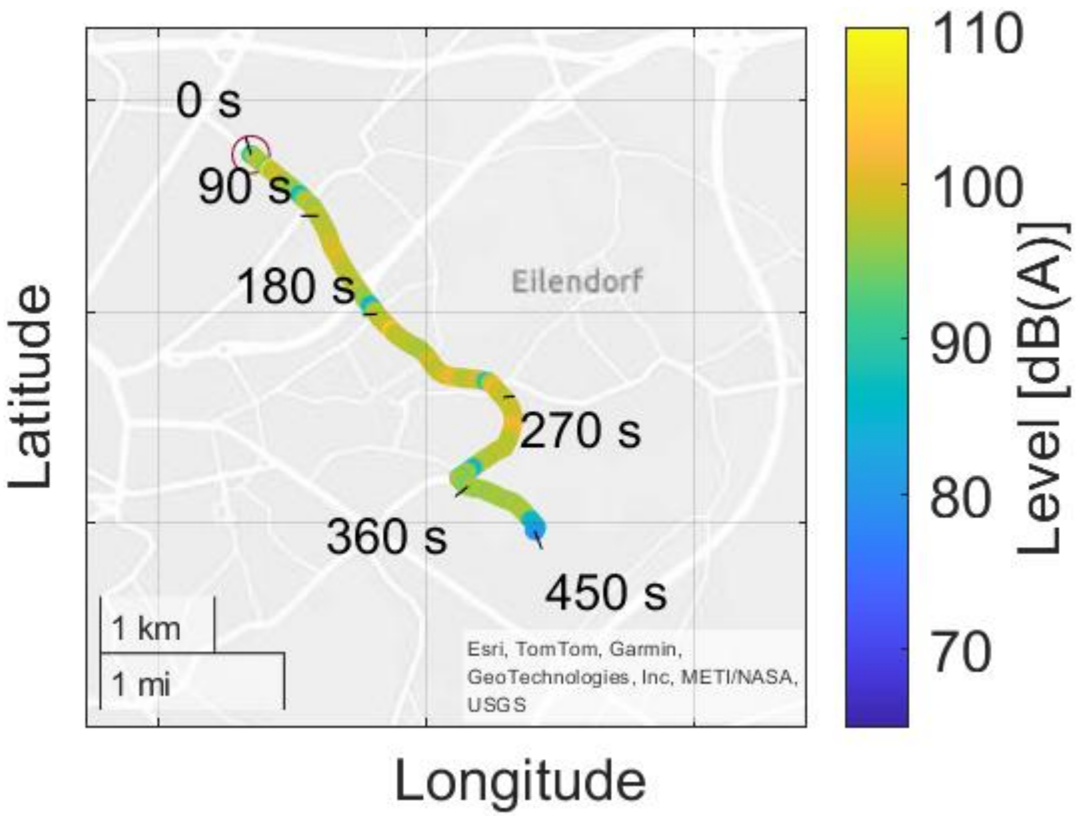
Procedure

- Measurement of 15 LVs with 27 different routes
- Routes lasted from 5-7 minutes up to over 40 minutes
  - Routes in Germany, Austria, Greece, Spain & France

On-road on-board measurements

Exemplary results





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On-road on-board measurements

Summary

- Noise-intensive driving maneuvers <u>outside</u> of (RD-) ASEP were detected
- Noise emission detection in real traffic is highly complex
  - Position of the sensor
  - Wind noise
  - Etc.

Real-world driving patterns

Driving patterns based on roadside monitoring, simulations and on-road on-board measurements

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Real-world driving patterns

Approach

- Goal: patterns that capture dynamic noise emission behavior under realistic operating conditions
- A total of 14 standardized driving maneuvers for manual transmission vehicles (13 for CVT) were derived from the investigations done
    - Including a hearing study where participants were supposed to rate sounds
- The defined maneuvers are mainly not included in current TA testing

Real-world driving patterns

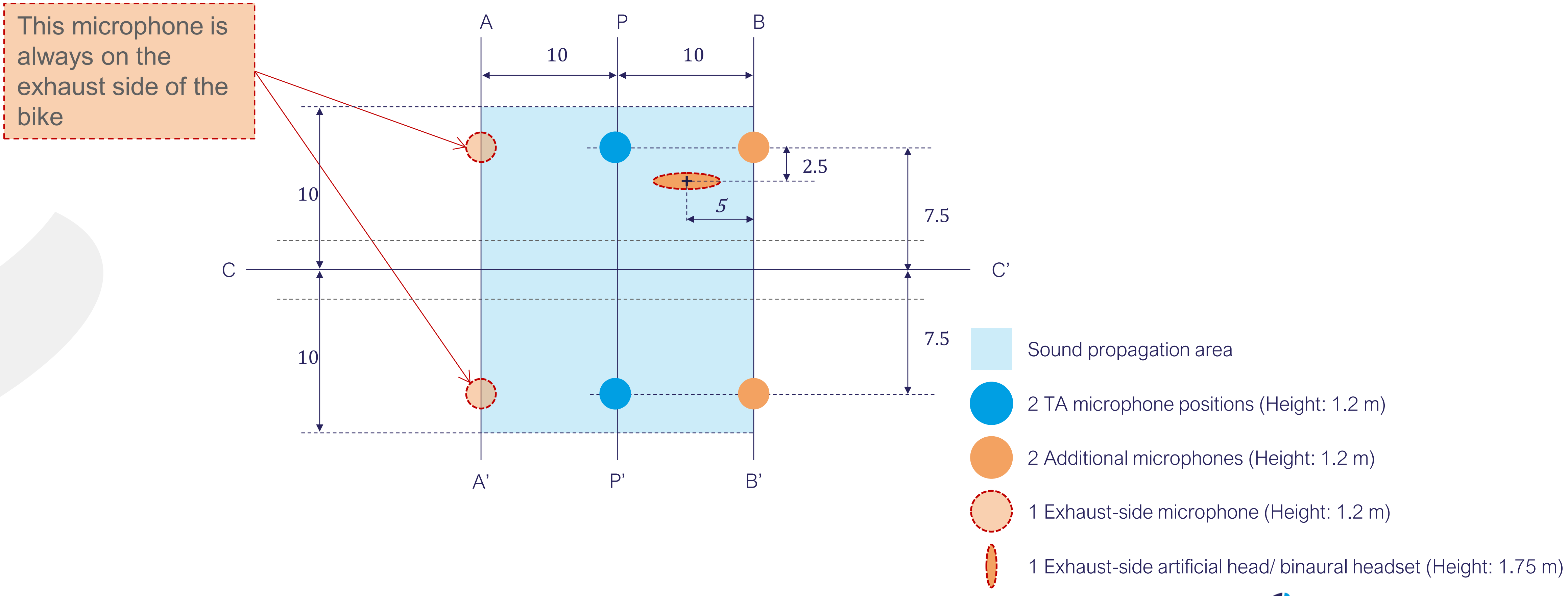
No	Pattern	Description
1	Cold start / engine start	Stationary engine start
2	Throttle control	Shortly activating and releasing throttle control, stationary
3	Aggressive acc. from standstill	Aggressive acceleration from standstill, first gear
4	Moderate acc. from standstill	Moderate acceleration from standstill, first gear
5	Gear shift, first to second, from standstill	Short acceleration in first gear from standstill, shift into second gear, aggressive acceleration
6	Aggressive acc. from const. speed, first gear	Aggressive acceleration from constant speed (< 10 km/h), first gear
7	Gear shift, first to second, const. speed	Short acceleration in first gear from constant speed (< 10 km/h), shift into second gear, aggressive acceleration

Real-world driving patterns

No	Pattern	Description
8	Full/ max. throttle acc., different gears	Full throttle acceleration from constant speed, different gears (e.g. gear 2, 3, 4 if feasible)
9	Gear shift i to i + 1, from const. speed	Short acceleration in gear i from constant speed, shift into gear i + 1, aggressive acceleration
10	Constant speed, gear i, high/max. engine speed	Constant speed in gear i with high/max. engine speed
11	Gear shift, i to i - 1, from const. speed	Constant speed in gear i and downshift to gear i - 1, aggressive acceleration
12	Gear shift, i to i - 2, from const. speed	Constant speed in gear i and downshift to gear i - 2, aggressive acceleration
13	Intermittent throttle control, gear i	Constant speed in gear i, intermittent throttle control, fluctuating engine speed
14	Deceleration, gear i	Constant speed in gear i, releasing throttle control, deceleration

Real-world driving patterns

Measurement setup at test track



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Real-world driving patterns

Summary

- Patterns of high noise emission events were defined to conduct on test tracks
- Measurement setup for higher noise event resolution were defined

Test track measurements

Conduction of TA an RW measurements on extensive fleet

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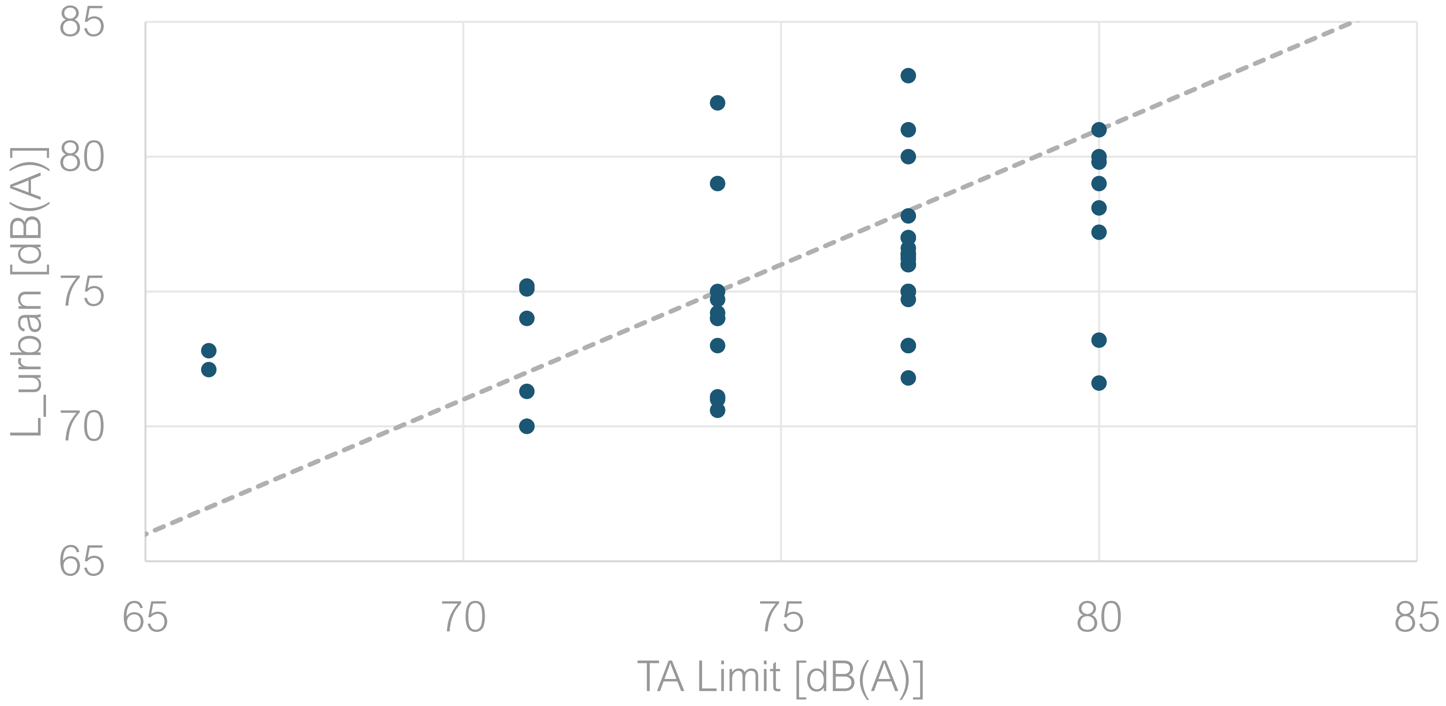
Test track measurements

Type approval

- Type approval testing
  - Own gear selection
- Goal: reproduce TA data and check robustness of TA procedure
- Outcome: highly sensitive procedure



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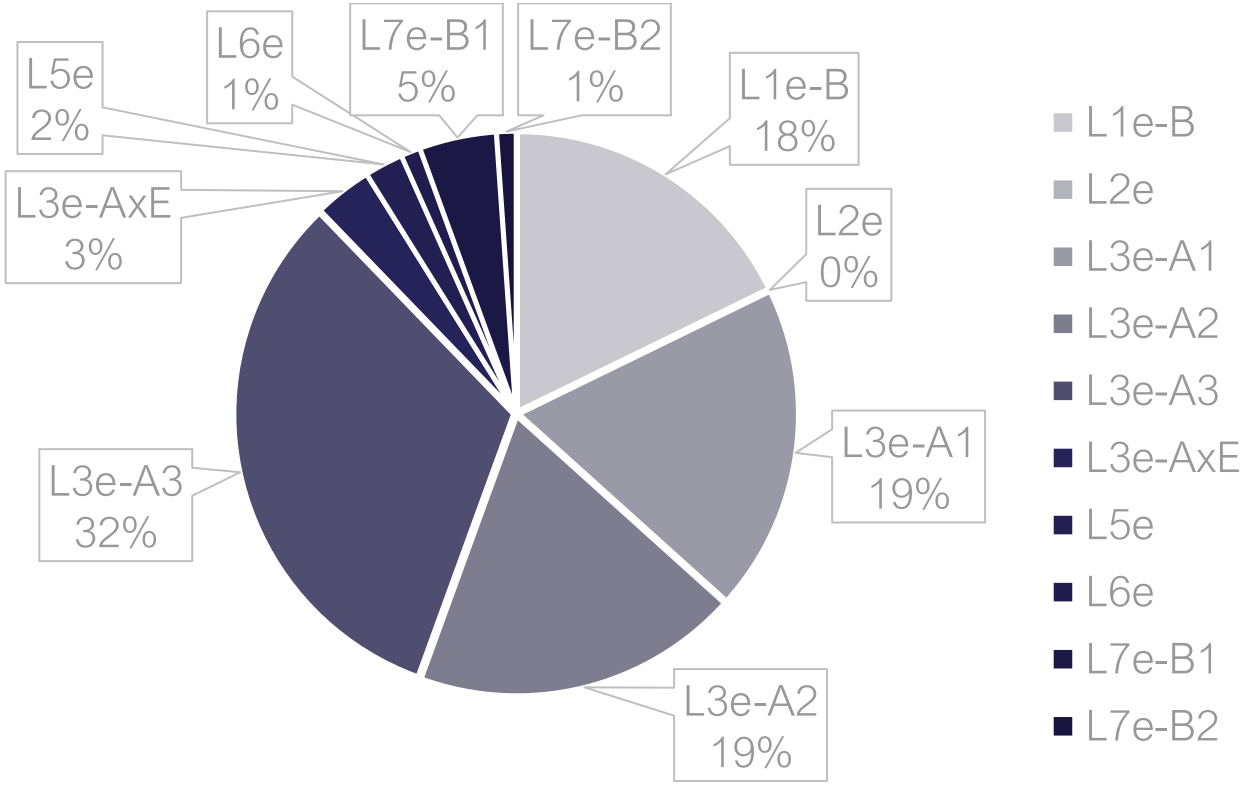
Test track measurements

Real-world driving patterns

- Testing of the newly developed RW driving cycles on 112 vehicles
- The fleet included a wide range of brands, mileages, and technologies



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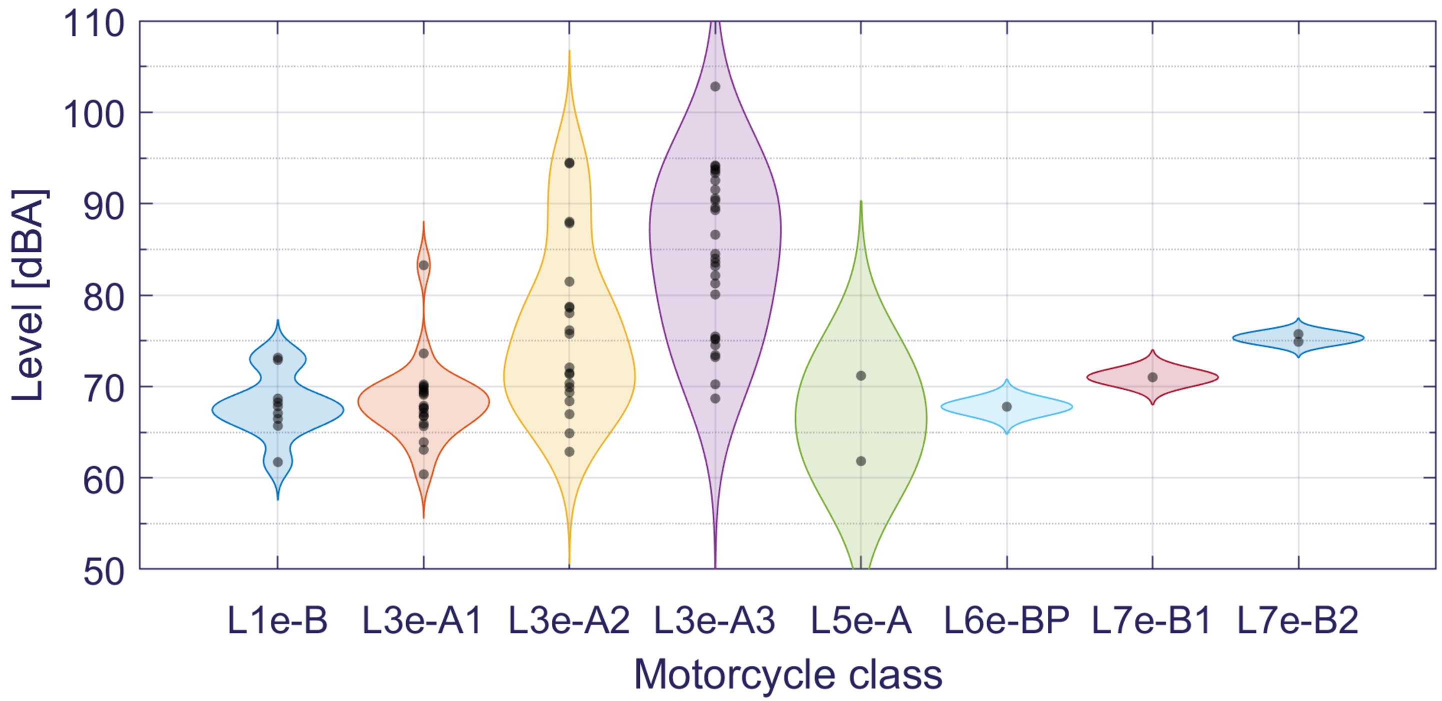
Test track measurements

Real-world driving patterns

- The patterns were conducted if feasible
  - Driver's safety needed to be guaranteed
  - For manual transmission, as many gears as possible were tested
- Close to 2000 Measurements done (compare 14 patterns * 112 vehicles=1568)

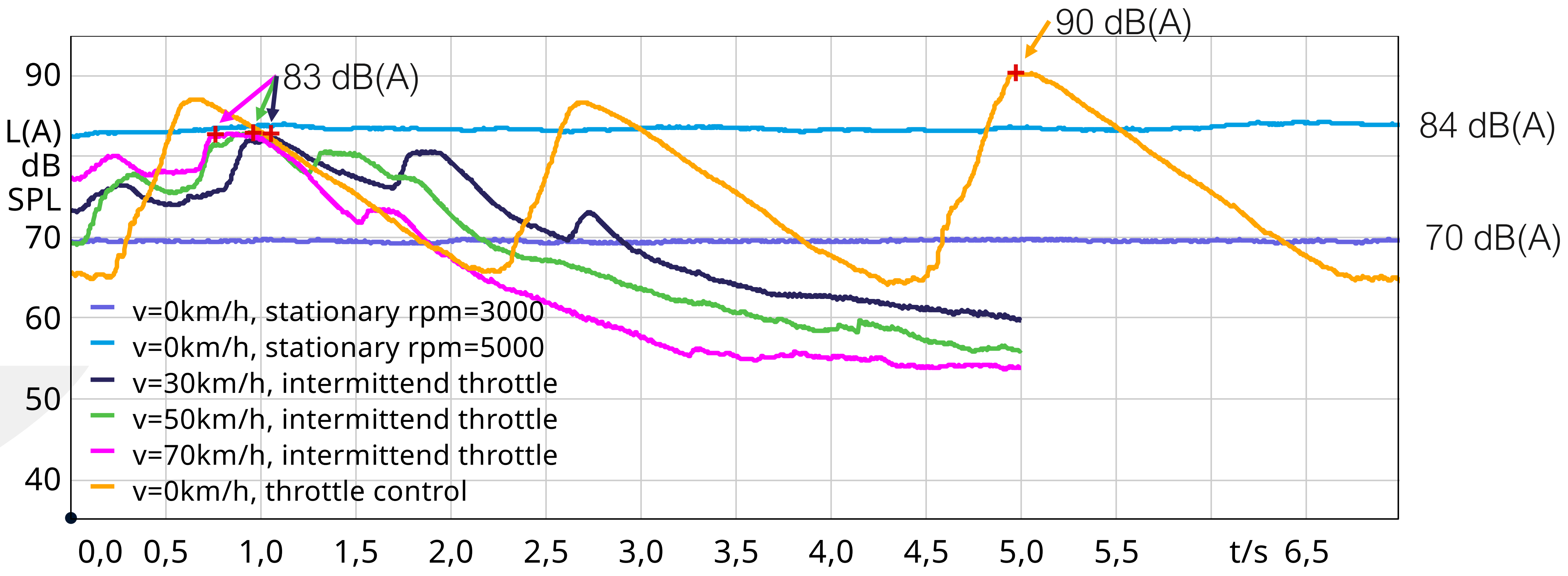
Test track measurements

Real-world driving patterns – High rpm at constant speed [P10]



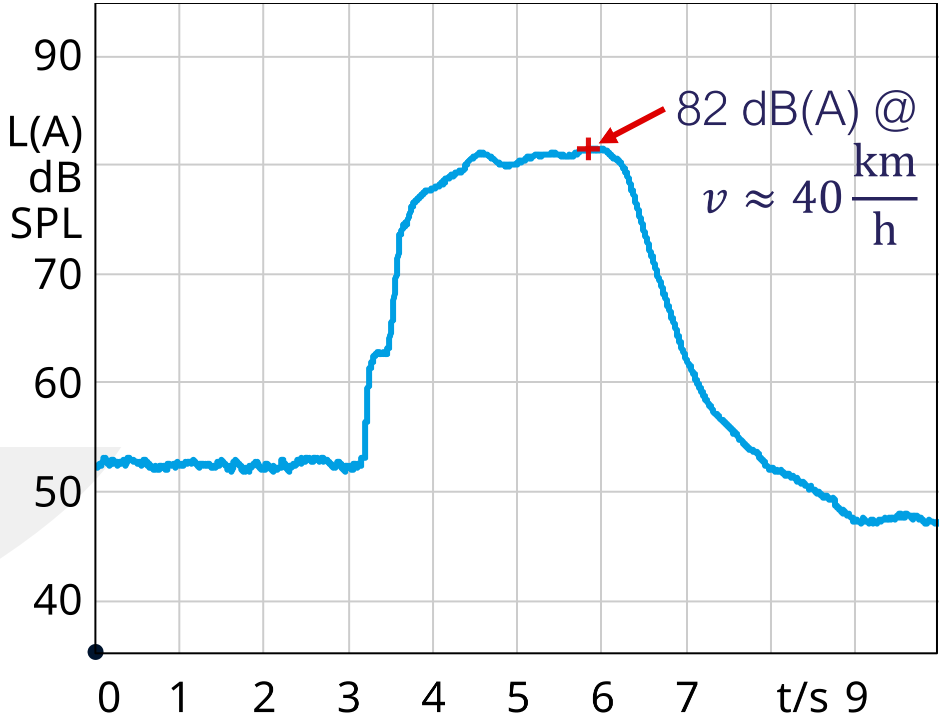
Test track measurements

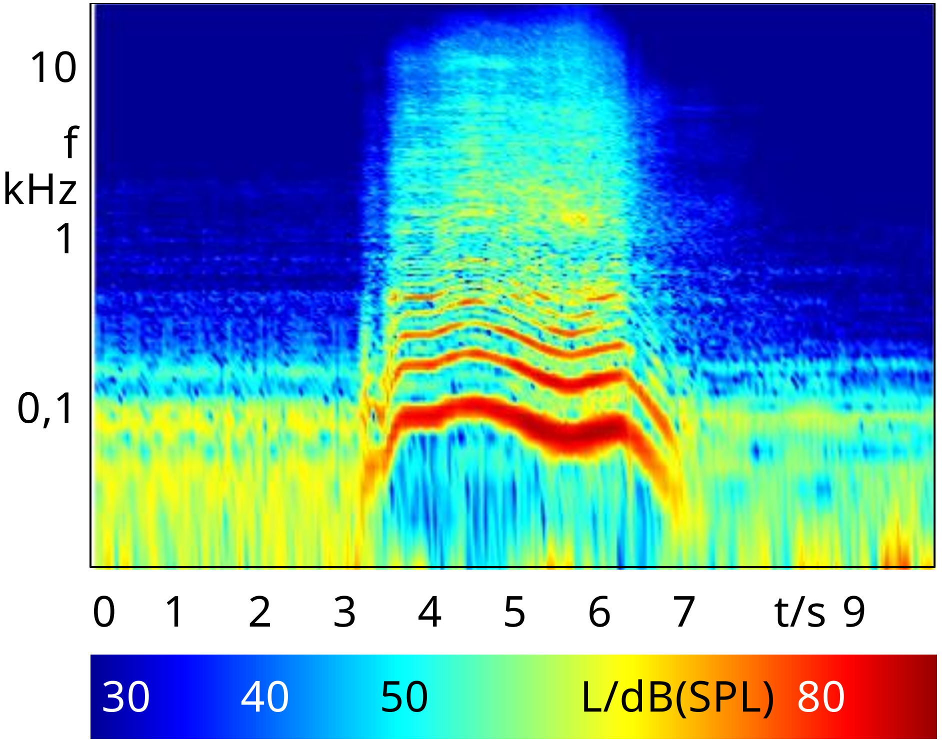
Real-world driving patterns – Revving & throttle control (L3e-A3)



Test track measurements

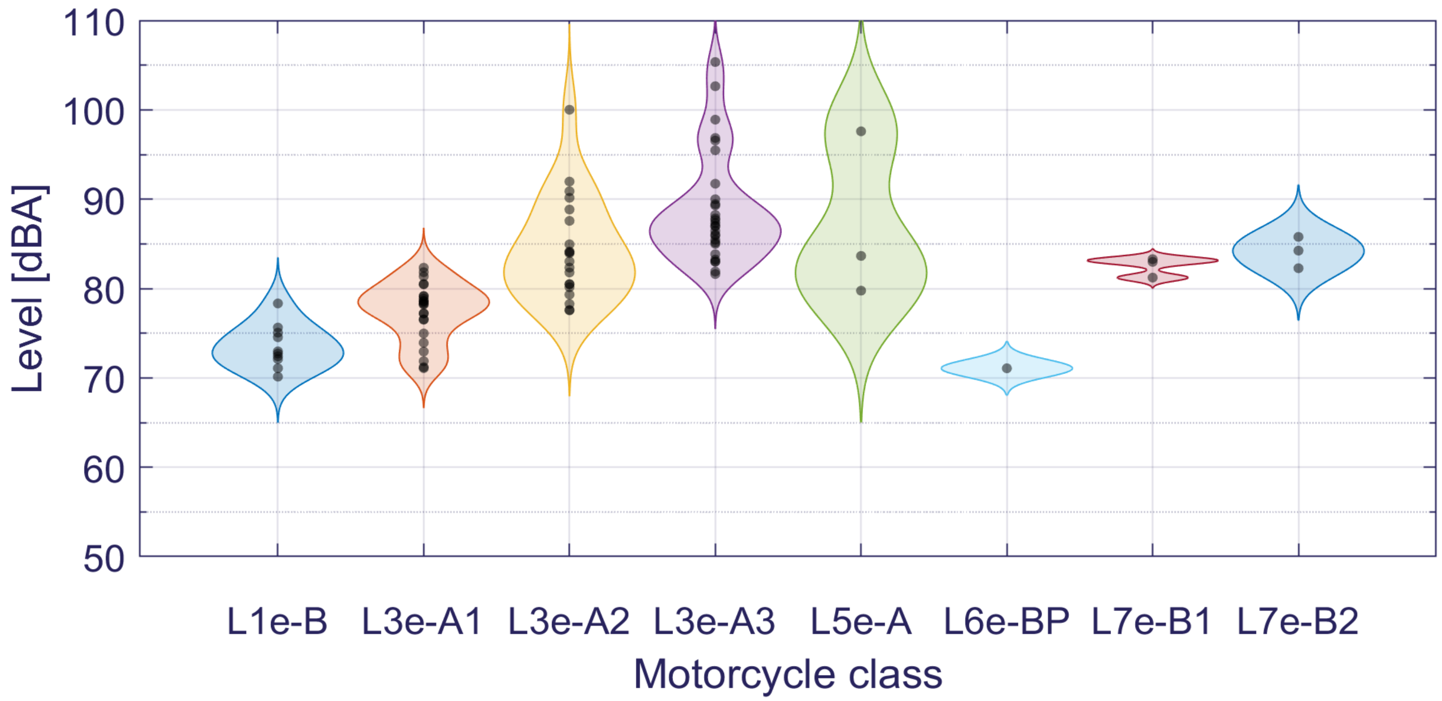
Real-world driving patterns – High acceleration from standstill (L3e-A3) [P3]





Test track measurements

Real-world driving patterns – High acceleration from standstill [P3]



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Test track measurements

Summary

- RW driving patterns were defined based on high noise events
- Levels measured for RW driving patterns lay between 60 dB(A) to over 100 dB(A)
- Feasibility of maneuvers and suitability for integration into TA were examined at a later stage

Conclusion

Conclusion

- High noise events were derived from
  - Roadside monitoring
  - Driving simulation
  - On-road measurements with newly developed on-board sensor
- Noise measurements in real traffic is complex, e.g., due to different noise sources occurring
- Patterns of high noise emission events were defined to conduct on test tracks
  - Levels measured lay between 60 dB(A) to over 100 dB(A)

Literature

[1] Magnin, D., Thomson, R.: Test d'un radar sonore sur 4 tronçons routiers urbains dans le canton de Genève - projet pilote basé sur le système « Hydre » de Bruitparif
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[2] Lechner, C., Schnaiter, D.: Evaluierung der Maßnahmen zum Motorradlärm im Bezirk Reutte
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[3] Noise and Emissions Monitoring and Radical Mitigation
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Thank you for your attention

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