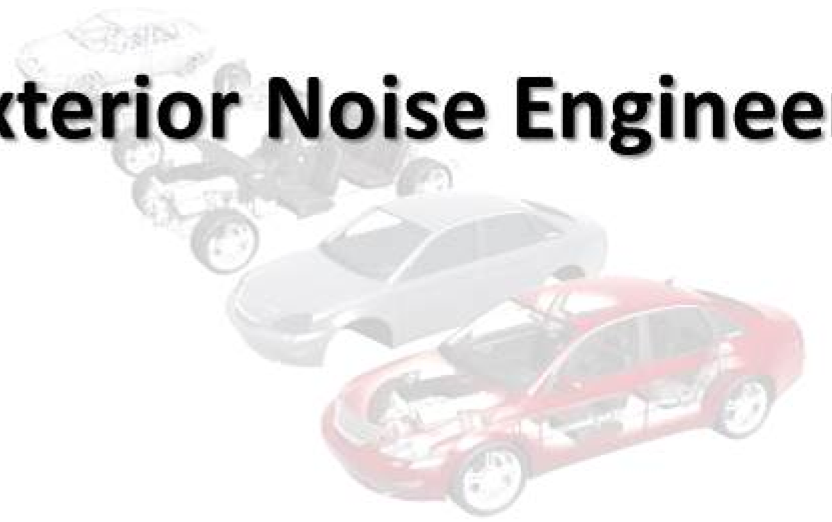
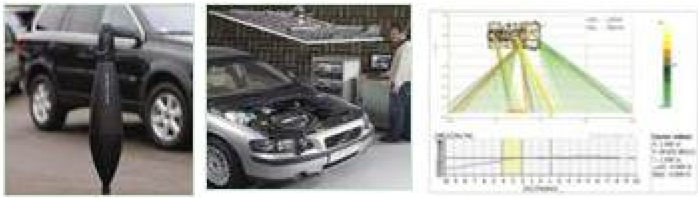
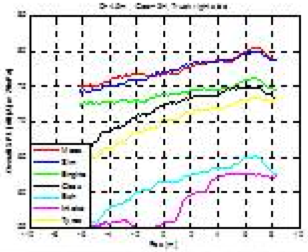
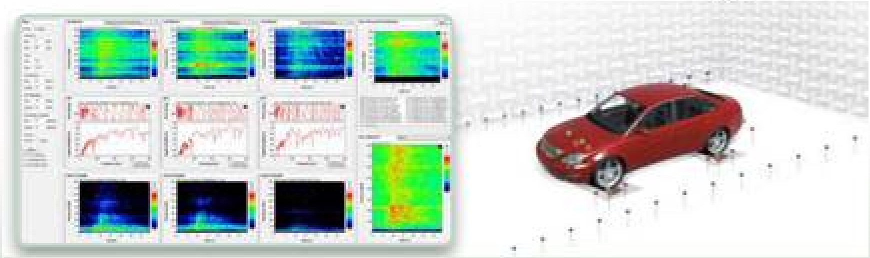
Pass by Noise Regulation as ECE R41 and ECE R51



- Vehicle Exterior Noise Engineering -







June 2015
Yunseon Ryu(Yoo)

Brüel & Kjær

Contents

Vehicle Exterior Noise Engineering

- ”Exterior Vehicle Noise Engineering” is used to ensure, that the vehicle fulfils the legislation requirements on maximum Pass-by noise levels
- The reference test is the standardised Pass-by noise measurement done on a test track fulfilling the standard’s specifications
- The recent update of the ISO 362 Pass-by standard has resulted in a more realistic but also more complex test procedure, so engineering work is more and more done as Indoor tests, where test conditions are highly repeatable
- It should be noted, that the upcoming electrical vehicle has started work on a standard for minimum Pass-by levels, see also section on Hybrid – Electrical vehicles

- Main methodologies used are Pass-by testing (track and indoor), Noise Source Indentification (holography, beamforming) and various Source - and Path trouble-shooting tools used for in-depth contribution analysis

Exterior Vehicle Noise Engineering

Driven by Pass-by legislation

Process:

Initial Investigation
- Field Pass-by
- Indoor Pass-by

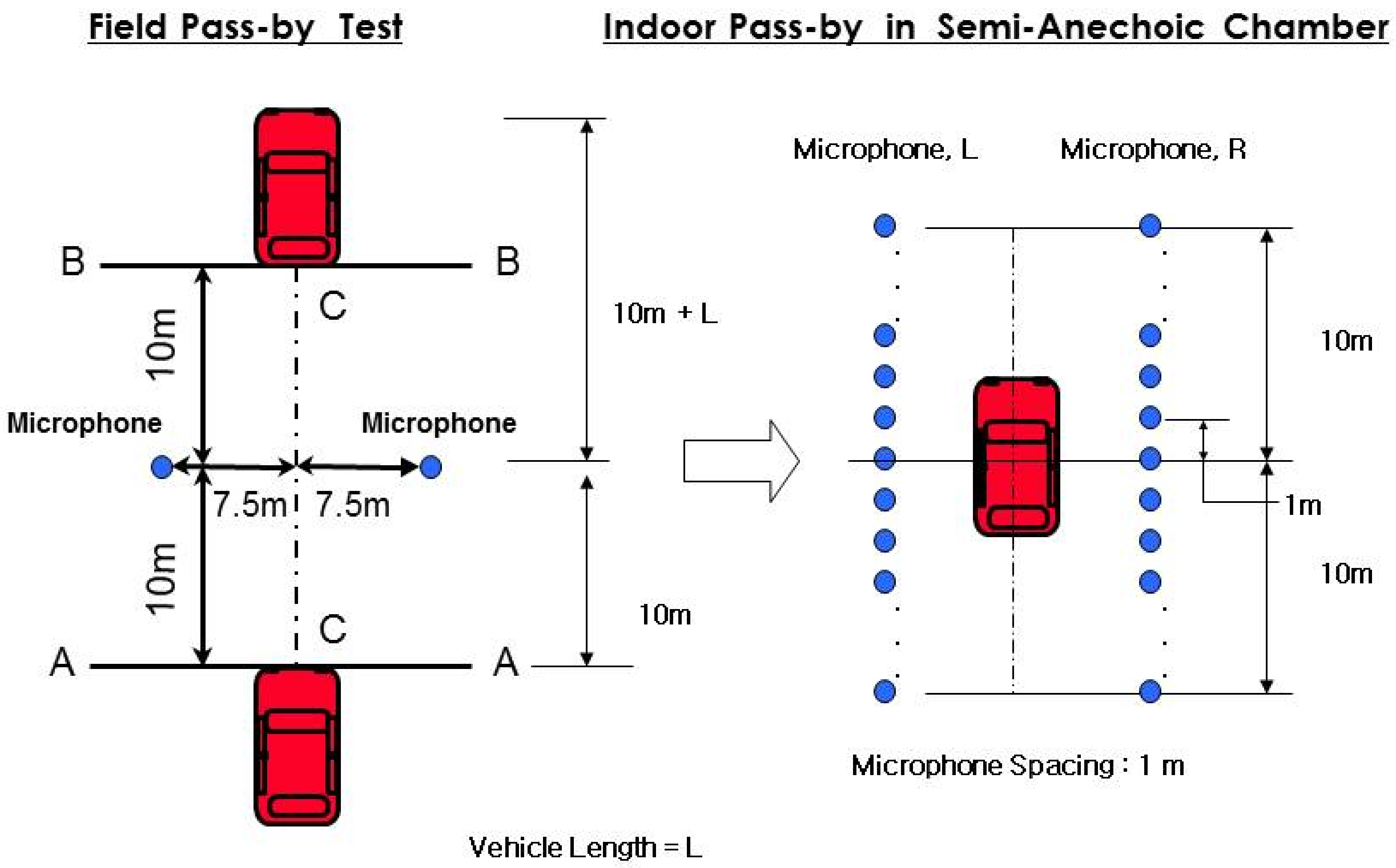
Critical:
Frequency
Position
RPM/Speed

External Source Mapping
- Holography
- Beamforming

Root Source Contribution
- Coherent Contribution
- Indoor Pass-by (modified vehicle)
- Source Path Contribution

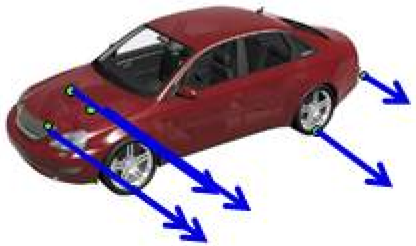
Conformance Validation
- Field Pass-by

Test Layout: Field and Indoor Pass-by

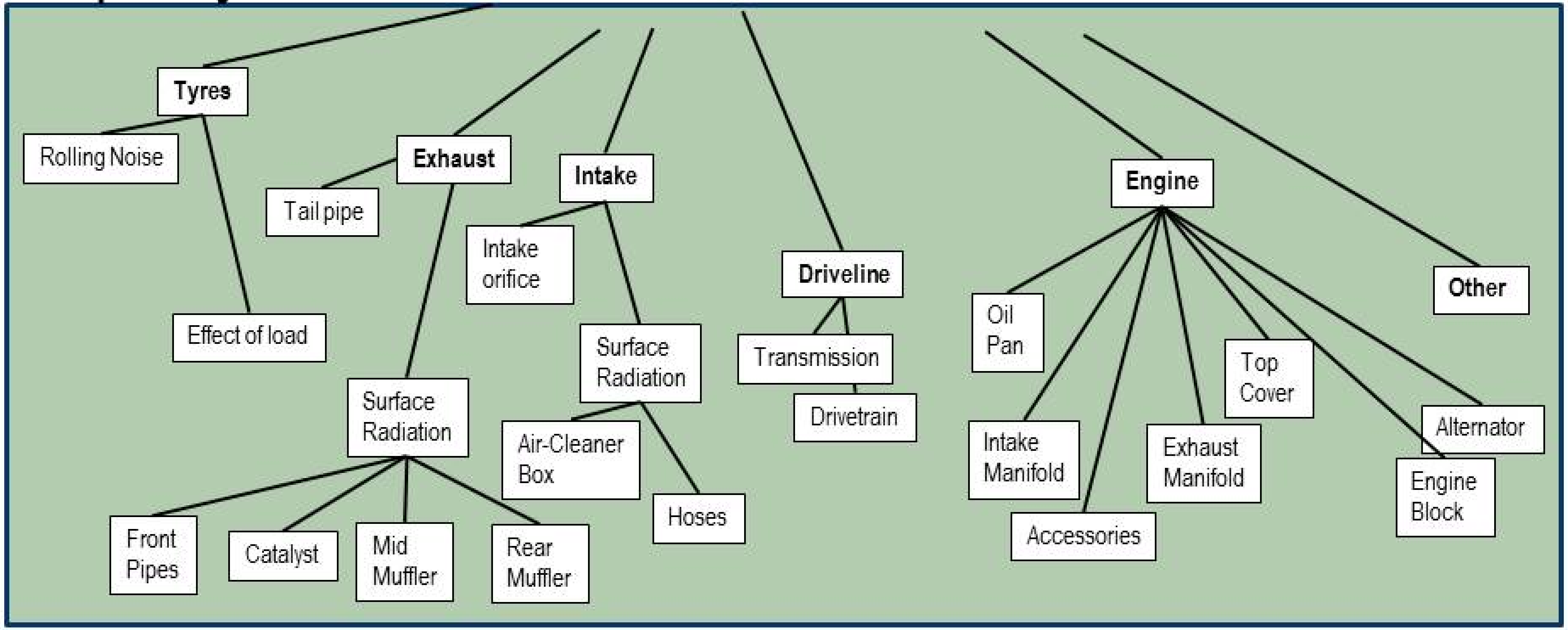


Pass-by noise sources

Increasing noise in the environment drives legislation to require lower pass-by levels



Powertrain (engine, intake, exhaust) is a main contributor to the pass-by noise



Typical sources contributing to Pass-by levels

Relative Contributions of Engine and Rolling Noise

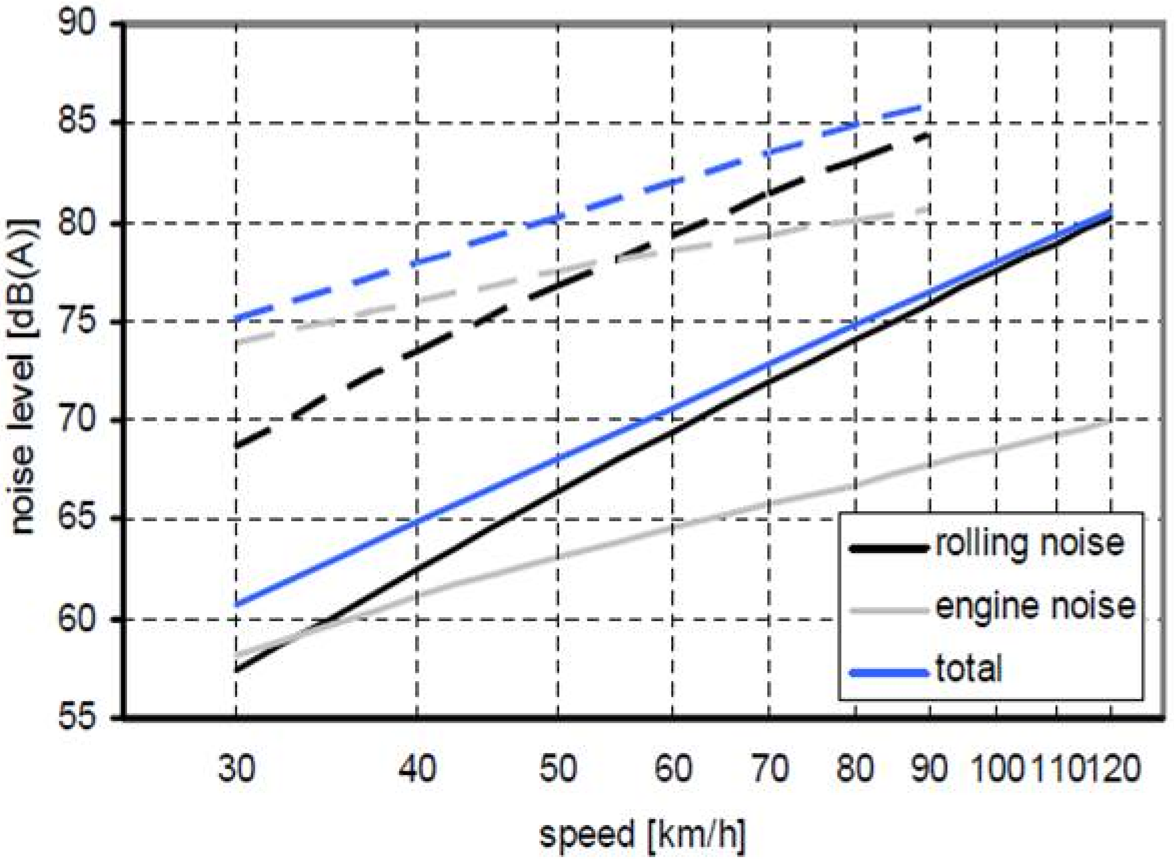


figure 3 respective contributions of propulsion (engine) noise and tyre/road (rolling) noise for light vehicles (continuous line) and heavy vehicles (dashed line) on a dense surface.

Contents

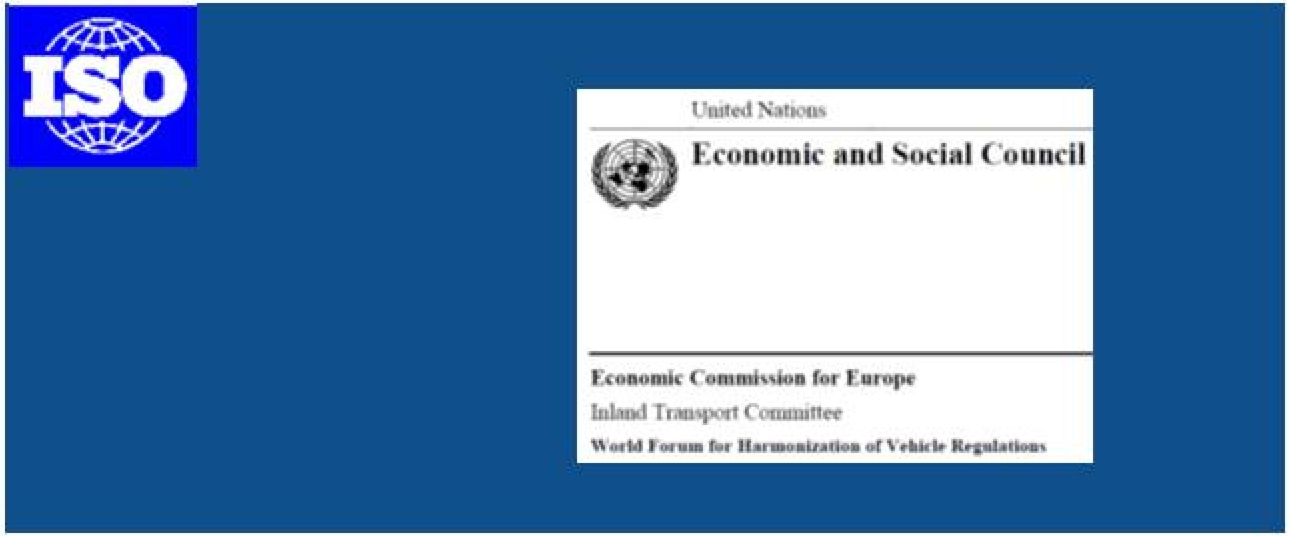
- Vehicle exterior noise engineering overview
- Field Pass-by
  - Standards and regulations
  - Systems for standardised testing
  - Beamforming for Noise Source Identification
- Indoor Pass-by
  - Principle
  - Accuracy
  - Contribution analysis using Source Path Contribution
- Summary, conclusion

Standard and Regulation

Standard : Define how to measure in terms of conditions, facilities, environment, and procedure, i.e. ISO ####
Regulation : Define the noise limits based on the standard, in terms of physical unit, local situation, and requirement, i.e. UNECE/R ##

"ISO 362 defines the Pass-by test procedure as standard measurement, and R51/41 regulates the limits of sound level of the vehicle exterior noise, measured by ISO 362 standard procedure."

- Standard Test Procedure of ISO 362-1:2014, ISO 362-2:2014
- UNECE/R51, R41 Test Conditions & Limitations



Classification of Vehicles

- Category L : 4 wheels or less

- Category M : 4 wheels or more (passenger vehicles)
  - M1 : less than 8 seats except driver's seat
  - M2 : more than 8 seats except driver's, max. 5 tons
  - M3 : more than 8 seats except driver's, max. 5 tons or more

- Category N : 4 wheels or more (cargo vehicles)
  - N1 : maximum allowance load 3.5 tons or less
  - N2 : maximum allowance load 3.5 tons to 12 tons
  - N3 : maximum allowance load 12 tons or more

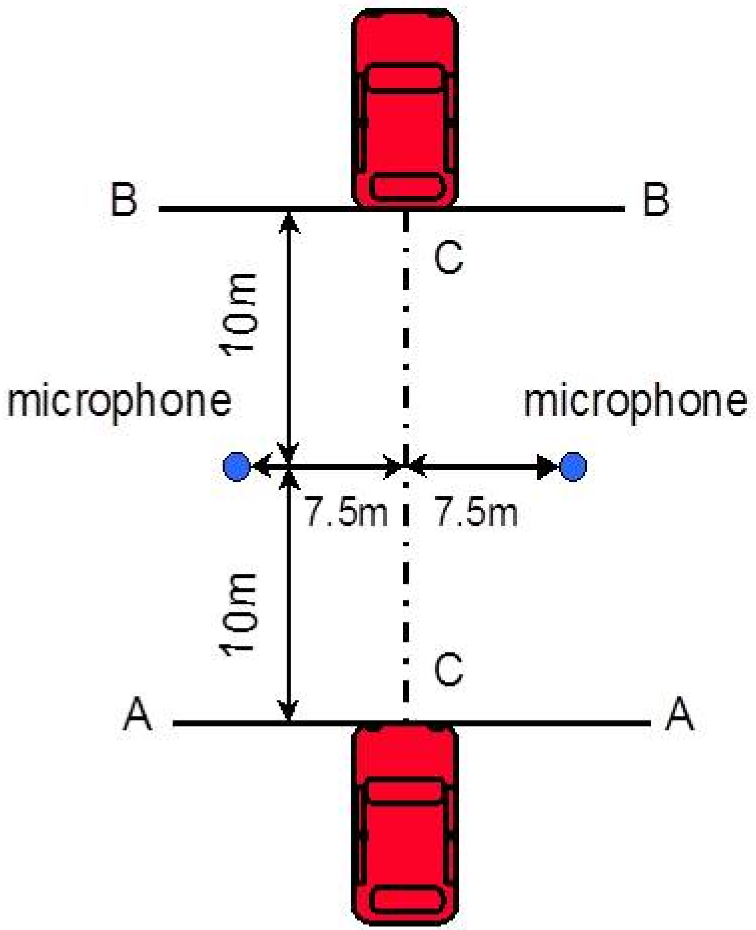
ISO 362-1 : Category M, N

ISO 362-2 : Category L

Category L

- **L1, L2** : Mopeds – ISO 9645
- **L3** : two-wheeled motor vehicles with an engine cylinder capacity greater than 50 cm^3 or maximum speed greater than 50 km/h
- **L4** : three-wheeled motor vehicles with an engine cylinder capacity greater than 50 cm^3 or maximum speed greater than 50 km/h, the wheels being attached asymmetrically along the longitudinal vehicle axis
- **L5** : three-wheeled motor vehicles with an engine cylinder capacity greater than 50 cm^3 or maximum speed greater than 50 km/h, having a gross vehicle mass rating not exceeding 1 000 kg and wheels attached symmetrically along the longitudinal vehicle axis
- **L6** : four-wheeled vehicles whose unladen mass is not more than 350 kg, not including the mass of the batteries in the case of electric vehicles, whose maximum design speed is not more than 45 km/h, and whose engine cylinder capacity does not exceed 50 cm^3 for spark (positive) ignition engines, or whose maximum net power output does not exceed 4 kW in the case of other internal combustion engines, or whose maximum continuous rated power does not exceed 4 kW in the case of electric engines
- **L7** : four-wheeled vehicles, other than those classified for the category L6, whose unladen mass is not more than 400 kg (550 kg for vehicles intended for carrying goods), not including the mass of the batteries in the case of electric vehicles, and whose maximum continuous rated power does not exceed 15 kW

ISO 362 Test Method



Meteorological conditions
5 ~ 40 ℃, < 5 m/sec

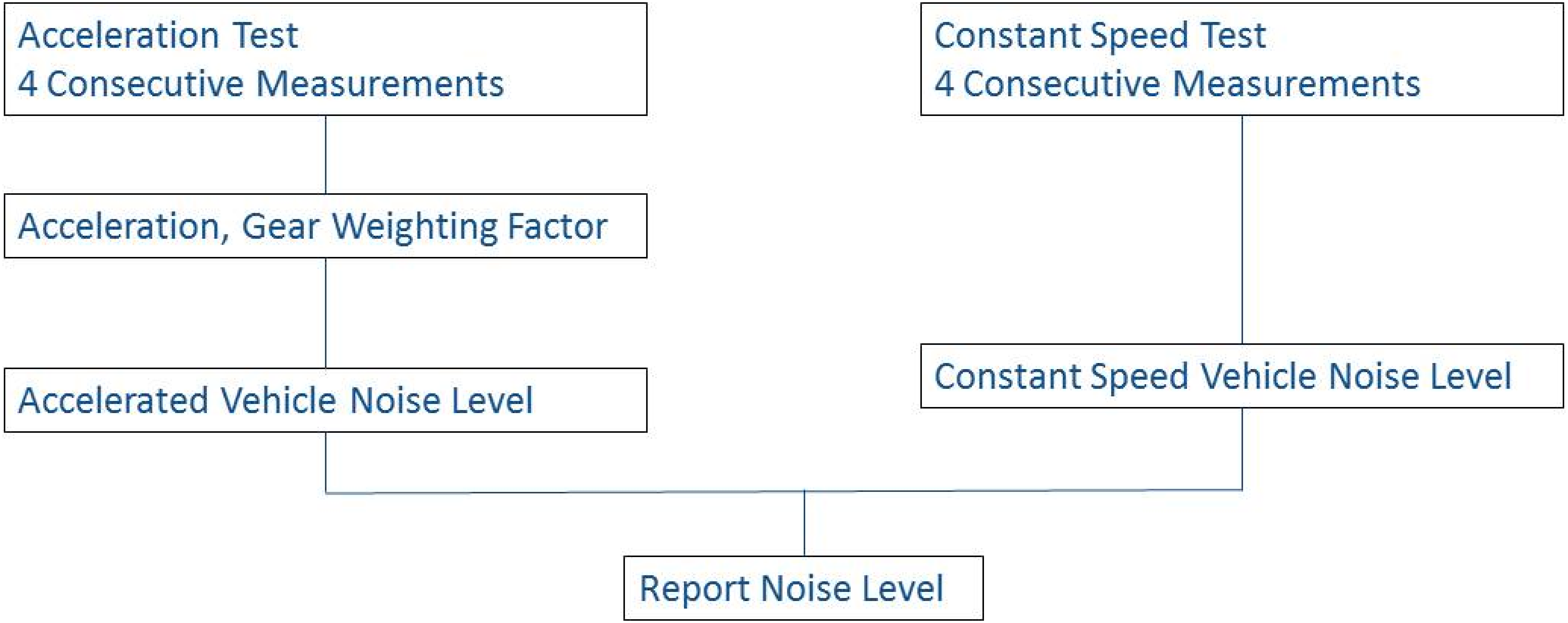
Background noise
less 10 dB (15 dB recom.)

Table 1 — Correction applied to an individual measured test value

Background sound pressure level difference to measured sound pressure level, in dB	10	11	12	13	14	greater than or equal to 15
Correction, in dB	0,5	0,4	0,3	0,2	0,1	0,0

Number of measurements
four consecutive measurements

ISO 362:2014 Test Procedure



Regulations & Limit Values

Regulation 41, Noise emissions motorcycles (L Category)

Regulation	Test Description	Standard
ECE R41.04 Noise Emission Motorcycle (L Category)	Measurement of Noise of Vehicles in Motion	ISO 362-2:2007
	Measurement of Noise Emitted by Stationary Vehicles	ISO 5130
	ASEP: Additional Sound Emission Provisions (L_3 Category)	

Noise Limit Values in Regulation R41

Power-to-mass ratio index (PMR)	Limit value for L_{urban} in dB(A)
PMR ≤ 25	73
25 < PMR ≤ 50	74
PMR > 50	77

Regulations & Limit Values

Regulation 51, Noise emissions of M and N Categories of vehicles

Regulation	Test Description	Standard
ECE R51.03 Noise Emission Vehicles	Measurement of Noise of Vehicles in Motion	ISO 362-1:2014
	Measurement of Noise Emitted by Stationary Vehicles	ISO 5130
	ASEP: Additional Sound Emission Provisions (M_1, N_1 Category)	

Noise Limit Values in Regulation R51

Vehicles	Limit values (dB(A))
Passenger's car no more than 9 seats	74
Passenger's car no more than 9 seats, engine power less than 150kW Engine power of 150kW or above	78 80
Passenger's car no more than 9 seats, goods-carrying car less than 2 tons Greater than 2 tons, not exceeding 3.5 tons	76 77
Goods-carrying car, exceeding 3.5 tons, engine power less than 75kW Engine power greater than 75kW or above but less than 150kW Engine power greater than 150kW or above	77 78 80

Regulation 51, Noise emissions of M and N categories of vehicles Future Limits

Cate gory	Description of Vehicle Category	Limit Values expressed in dB(A) (decibel (A))		
		Phase 1 from July 2016	Phase 2 from July 2022	Phase 3 from July 2026
M	vehicles used for the passengers			
M_1	power to mass ratio ≤ 120kW/1000kg	72	70	68
M_1	120kW/1000kg < power to mass ratio ≤ 160kW/1000kg	73	71	69
M_1	power to mass ratio > 160kW/1000kg	75	73	71
M_1	power to mass ratio > 200kW/1000kg, seat ≤ 4	75	74	72
M_2	mass ≤ 2500kg	72	70	69
M_2	2500kg < mass ≤ 3500kg	74	72	71
M_2	3500kg < mass ≤ 5000kg, engine power ≤ 135kW	75	73	72
M_2	3500kg < mass ≤ 5000kg, engine power > 135kW	75	74	72
M_3	engine power ≤ 150kW	76	74	73
M_3	150kW < engine power ≤ 250kW	78	77	76
M_3	engine power > 250kW	80	78	77

Cate gory	Description of Vehicle Category	Limit Values expressed in dB(A) (decibel (A))		
		Phase 1 from July 2016	Phase 2 from July 2022	Phase 3 from July 2026
N	vehicles used for the carriage of goods			
N_1	mass ≤ 2500kg	72	71	69
N_1	2500kg < mass ≤ 3500	74	73	71
N_2	engine power ≤ 135kW	77	75	74
N_2	engine power > 135kW	78	76	75
N_3	engine power ≤ 150kW	79	77	76
N_3	150kW < engine power ≤ 250kW	81	79	77
N_3	engine power > 250kW	82	81	79

From :

REGULATION (EU) No 540/2014 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 16 April 2014

on the sound level of motor vehicles and of replacement silencing systems, and amending Directive 2007/46/EC and repealing Directive 70/157/EEC

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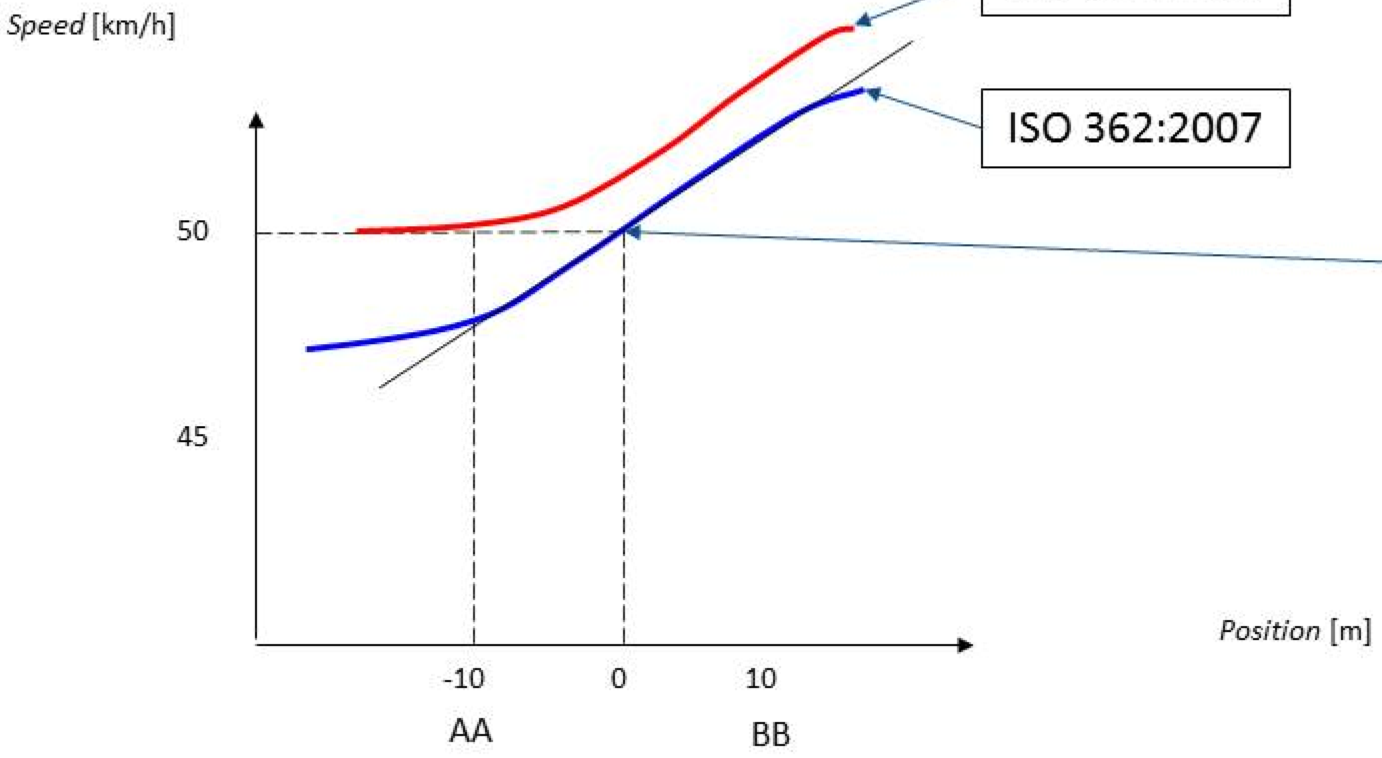
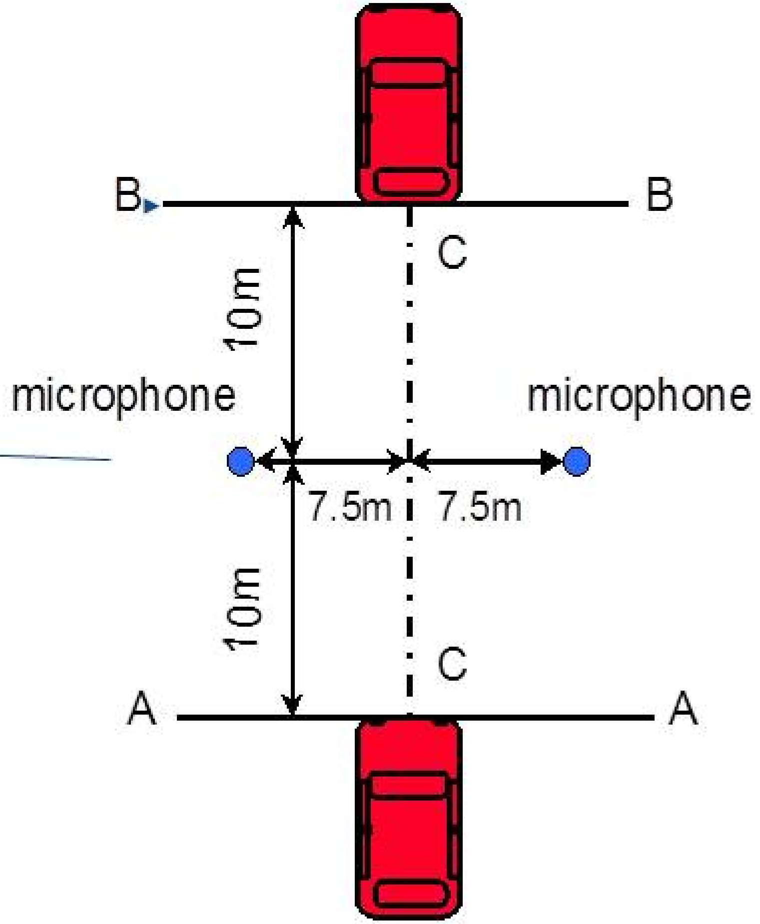
BEYOND MEASURE

Acceleration Test

50 km/h at 0 meter





ASEP(Additional Sound Emission Provisions)

- ASEP is introduced to ensure pass by compliance in relevant driving scenarios

- ASEP is only applicable for the vehicles of categories M_1, N_1, L_3

Example of ASEP procedure for Regulation 51 (see Reg. 51, Appendix 7 for details):

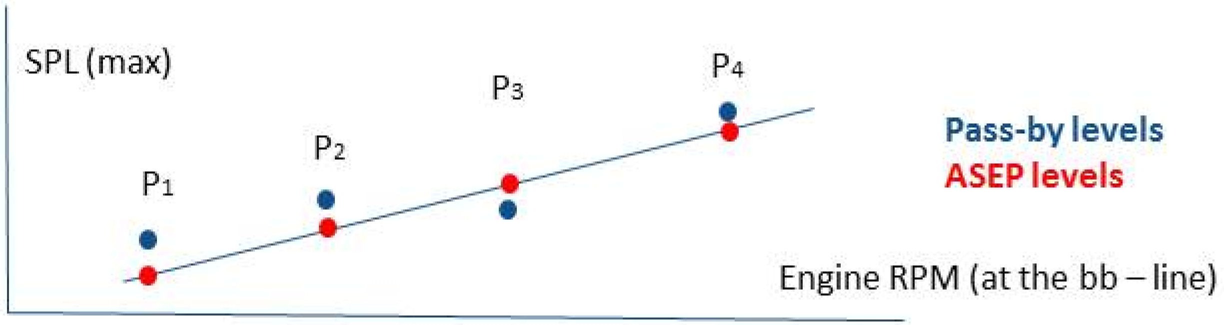
- 4 additional pass-by runs are required for every gear ratio, that leads to acceptable test results

Run 1: P_1	V_{aa} = 20km/h (min) stable acceleration (no gearshift) (if not stable then +5 km/h)
Run 4: P_4	V_{bb} = 80km/h (max)
Run 2,3: P_2, P_3	$V_{bb\_j} = V_{bb\_1} + ((j - 1) / 3) * (V_{bb\_4} - V_{bb\_1})$ for j = 2 and 3

- The results of each run Lkj, where k is gear selection and j is run no, shall not exceed the limits below:

$L_{kj} \leq L_{ASEP\_kj} + 2$ dB(A)

where, $L_{ASEP\_k.j}$ is the standard pass by run SPL corrected for engine RPM – and gear ratio slopes



Pass-by levels
ASEP levels

V_{aa}: entry speed
V_{bb}: exit speed
V_{bb_1}: exit speed of first test run

Measurement Conditions of ASEP for M1, N1

Vehicle Speed : $V_{aa_ASEP} \leq 20$km/h
Acceleration : $a_{WOT_ASEP} \leq 4$m/sec^2
Engine Speed : $n_{bb\_ASEP} \leq 2.0 * pmr^{-0.222} * s$ or $n \leq 0.9 * s$, which is lowest
pmr = the power to mass ratio in kW/t
s = the rated engine speed
Vehicle Speed :
if n_{bb_ASEP} is reached in one gear $V_{bb_ASEP} \leq 70$km/h
in all other cases $V_{bb_ASEP} \leq 80$km/h
Gears : $k \leq$ highest gear measured in Annex II
k not first gear

Covering 99% of all the urban driving conditions

Measurement Procedure of ASEP

Four Runs of Each Gear
P_1, P_2, P_3, P_4

$L_{anchor,i} = L_{WOTi,annex\ II}$
$n_{anchor,i} = n_{bb,woti,\ annex\ II}$
$V_{anchor,i} = V_{bb,WOTi,\ annex\ II}$

Determination of Anchor Point (L_{anchor} , n_{anchor})

$L_{ASEP\_k,j} = L_{anchor\_k} + (Slope_k - Y) * (n_{bb\_k,j} - n_{anchor,k})/1000$
$L_{ASEP\_k,j} = L_{anchor\_k} + (Slope_k + Y) * (n_{bb\_k,j} - n_{anchor,k})/1000$

Calculation of $L_{ASEP,kj}$
Measurement j, Gear k

Evaluation of L_{kj}

Calculation of $L_{urban\ ASEP}$

$L_{kj} \leq L_{ASEP\_kj} + x$

$k_{P\ ASEP} = 1 - (a_{urban} / a_{WOT\ test\ ASEP})$

$L_{urban\ measured\ ASEP} = L_{WOT\ ASEP} - k_{P\ ASEP} * (L_{WOT\ ASEP} - L_{CRS})$

$L_{urban\ normalized} = L_{urban\ measured\ ASEP} - L_{urban}$

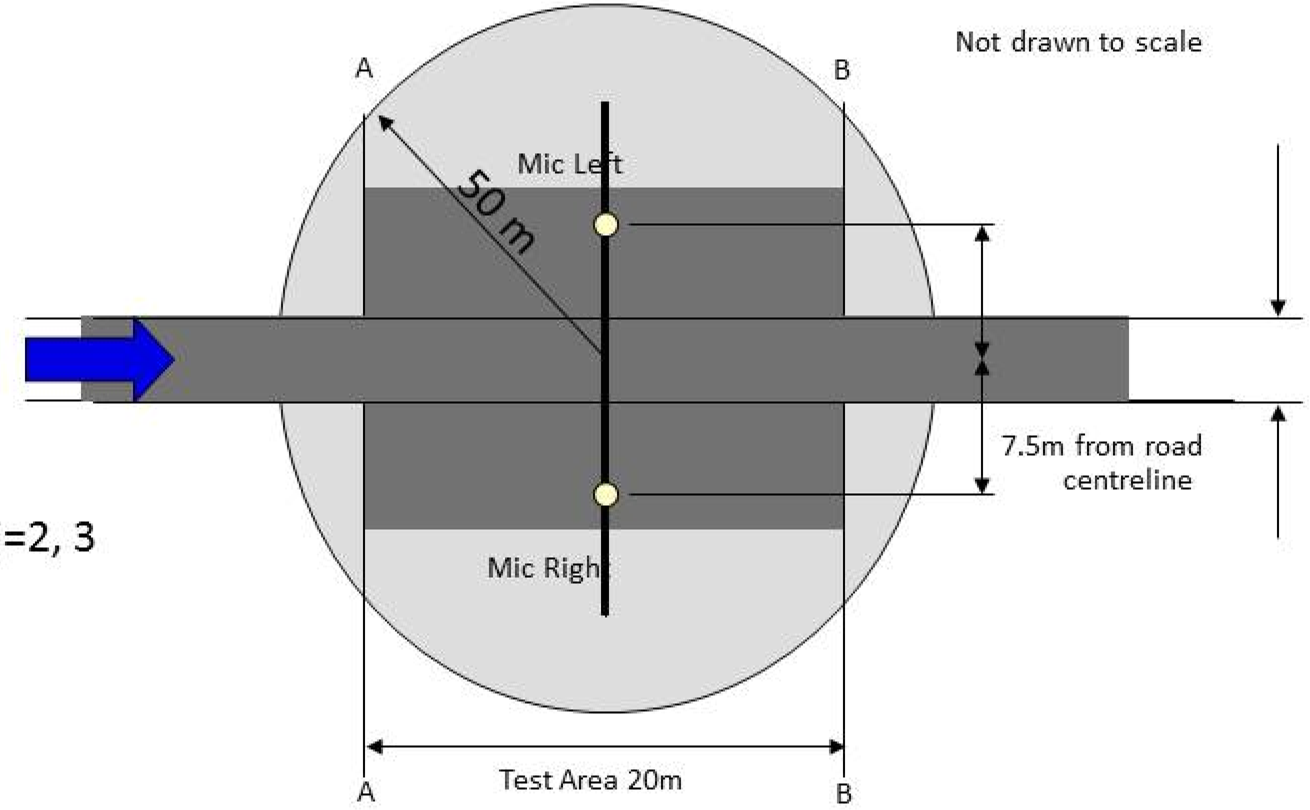
$L_{urban\ ASEP} = L_{urban\ normalized} - (0,15 * (V_{bb\ ASEP} - 50))$

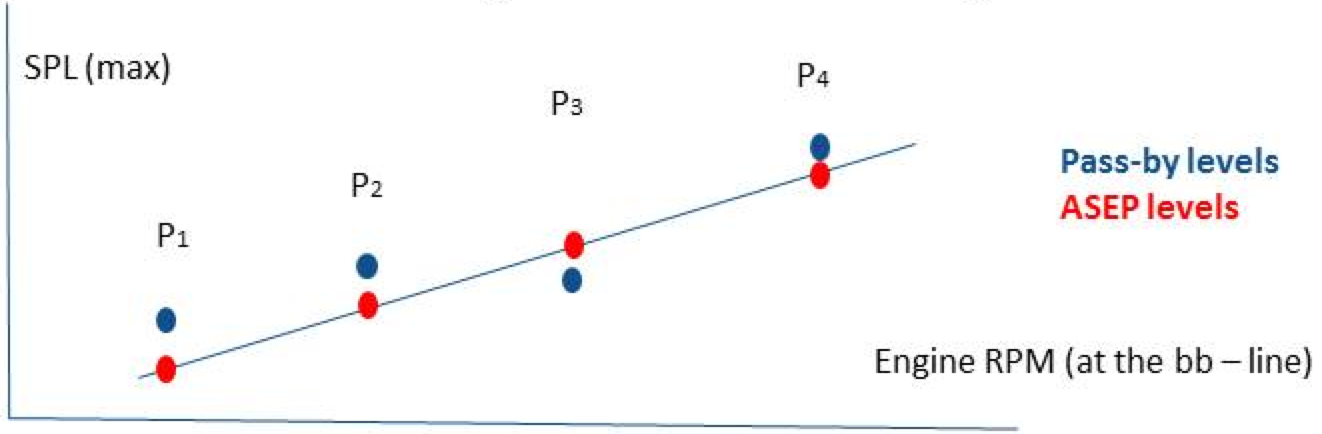
Target Conditions

- Four test runs in each gear selection
- P1 with V_{aa_1} = 20km/h
- P4 with V_{bb_4} = 70km/h or 80km/h
- P2, P3 Runs are;

$$V_{bb\_j} = V_{bb\_1} + ((j-1)/3)*(V_{bb\_4} - V_{bb\_1}),\ j=2, 3$$

Where, V_{bb_1} = Vehicle Speed at BB of test run P1
V_{bb_4} = Vehicle Speed at BB of test run P4
Tolerance for V_{bb_j} = ±3km/h





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Measurement Procedure of ASEP

For every separate test run the following parameters shall be determined and noted:

- The maximum A-weighted sound pressure level of the both sides of the vehicle indicated during each passage of the vehicle between the two lines AA and BB, mathematically rounded to the first decimal place. ($L_{wot,kj}$). If a sound peak obviously out of character with the general sound pressure level is observed, the measurement shall be discarded. Left and right side may be measured simultaneously or separately.

- The vehicle speed readings at AA and BB shall be reported with the first significant digit after the decimal place. ($V_{aa,kj}$; $V_{bb,kj}$)

- If applicable, the engine speed readings at AA and BB shall be reported as a full integer value. ($n_{aa,kj}$; $n_{bb,kj}$)

- The calculated acceleration shall be determined in accordance to the formulas in annex II ($a_{WOT,test,kj}$).

Determination of Anchor Points in each Gear selection

Lower Anchor Point : Measurement in gear i, the maximum sound level L_{WOTi}, the reported engine speed n_{WOTi} and vehicle speed V_{WOTi} at BB of gear ratio i of the acceleration test in Annex II.

$L_{anchor,i} = L_{WOTi,annex\ II}$

$n_{anchor,i} = n_{bb,WOTi,\ annex\ II}$

$V_{anchor,i} = V_{bb,WOTi,\ annex\ II}$

For measurements in gear ratio i+1 the anchor point consists of the maximum sound level L_{WOTi+1}, the reported engine speed n_{WOTi+1} and vehicle speed V_{WOTi+1} at BB of gear ratio i+1 of the acceleration test in Annex II.

$L_{anchor,i+1} = L_{WOTi+1,annex\ II}$

$n_{anchor,i+1} = n_{bb,WOTi+1,\ annex\ II}$

$V_{anchor,i+1} = V_{bb,WOTi+1,\ annex\ II}$

Calculation of Slope

$$Slope_k = \frac{\sum_{j=1}^{5}(n_j - \bar{n})(L_i - \bar{L})}{\sum_{j=1}^{5}(n_j - \bar{n})^2} \quad \text{(in dB/1000 rpm)}$$

With $\bar{L} = \frac{1}{5}\sum_{j=1}^{5} L_j$;

$\bar{n} = \frac{1}{5}\sum_{j=1}^{5} n_j$;

where n_j = engine speed measured at line BB

Calculation of the linear noise level increase expected for each measurement

The sound level $L_{ASEP,kj}$ for measurement point j in gear k shall be calculated using the engine speeds measured for each measurement point, using the slope relative to the specific anchor point for each gear ratio.

$L_{ASEP\_k,j} = L_{anchor\_k} + (Slope_k - Y) * (n_{bb\_k,j} - n_{anchor,k})/1000$, for $n_{bb\_k,j} \leq n_{anchor,k}$

$L_{ASEP\_k,j} = L_{anchor\_k} + (Slope_k + Y) * (n_{bb\_k,j} - n_{anchor,k})/1000$, for $n_{bb\_k,j} > n_{anchor,k}$

Y=1

Interpretation of Result

Every individual noise measurement shall be evaluated.

The sound level of every specified measurement point shall not exceed the limits given below:

$L_{kj} \leq L_{ASEP\_k.j} + x$

$x = 3$ dB(A) for vehicle with a non-lockable automatic transmission or non-lockable CVT
$x = 2$ dB(A) + limit value – L_{urban} of Annex II for all other vehicles

If the measured sound level at a point exceeds the limit, two additional measurements at the same point shall be carried out to verify the measurement uncertainty. The vehicle is still in compliance with ASEP, if the average of the three valid measurements at this specific point fulfils the specification.

Calculation of $L_{urban\ ASEP}$

(a) calculate $a_{WOT\ test\ ASEP}$

(b) determine the vehicle speed ($V_{bb\ ASEP}$) at BB during the $L_{WOT\ ASEP}$ test;

(c) calculate $k_{P\ ASEP}$ as follows: $k_{P\ ASEP} = 1 – (a_{urban} / a_{WOT\ test\ ASEP})$ Test results where $a_{WOT\ test\ ASEP}$ are less than aurban shall be disregarded.

(d) calculate $L_{urban\ measured\ ASEP}$ as follows: $L_{urban\ measured\ ASEP} = L_{WOT\ ASEP} – k_{P\ ASEP} * (L_{WOT\ ASEP} – L_{CRS})$
For further calculation, use the Lurban from Annex II without rounding, including the digit after the decimal (xx.x).

(e) calculate $L_{urban\ normalized}$ as follows: $L_{urban\ normalized} = L_{urban\ measured\ ASEP} – L_{urban}$

(f) calculate $L_{urban\ ASEP}$ as follows: $L_{urban\ ASEP} = L_{urban\ normalized} – (0,15 * (V_{bb\ ASEP} – 50))$

(g) compliance with sound level limits: $L_{urban\ ASEP}$ shall be less than or equal to 3,0 dB.

Measurement Procedure of ASEP

Four Runs of Each Gear
P_1, P_2, P_3, P_4

$L_{anchor,i} = L_{WOTi,annex\ II}$
$n_{anchor,i} = n_{bb,WOTi,\ annex\ II}$
$V_{anchor,i} = V_{bb,WOTi,\ annex\ II}$

Determination of Anchor Point (L_{anchor} , n_{anchor})

$L_{ASEP\_k,j} = L_{anchor\_k} + (Slope_k - Y) * (n_{bb\_k,j} - n_{anchor,k})/1000$
$L_{ASEP\_k,j} = L_{anchor\_k} + (Slope_k + Y) * (n_{bb\_k,j} - n_{anchor,k})/1000$

Calculation of $L_{ASEP,kj}$
Gear k, Measurement j

Evaluation of L_{kj}
$L_{kj} \leq L_{ASEP\_k.j} + x$

Calculation of $L_{urban\ ASEP}$

$k_{P\ ASEP} = 1 – (a_{urban} / a_{WOT\ test\ ASEP})$

$L_{urban\ measured\ ASEP} = L_{WOT\ ASEP} – k_{P\ ASEP} * (L_{WOT\ ASEP} – L_{CRS})$

$L_{urban\ normalized} = L_{urban\ measured\ ASEP} – L_{urban}$

$L_{urban\ ASEP} = L_{urban\ normalized} – (0{,}15 * (V_{bb\ ASEP} – 50))$

Measurement Conditions of ASEP for L3 (PMR>50)

Vehicle Speed : $V_{aa_ASEP} \geq 20$km/h, $V_{bb_ASEP} \leq 80$km/h

Engine Speed : $n_{aa\_ASEP} \geq 0.1 *(s-n_{idle})+n_{idle}$

n_{bb_ASEP} shall not exceed

$0.85 *(s-n_{idle})+n_{idle}$ pmr ≤ 66

$3.4* \text{pmr}^{-0.33}*(s-n_{idle})$ pmr > 66

pmr = the power to mass ratio in kW/t

s = the rated engine speed

- Automatic Transmission with non-lockable gear ratio exempted

Target Conditions

- Two additional test runs
- P1 with V_{pp_1} = 50km/h
- P2 with V_{bb_2} Corresponding to (≤ 80km/h)

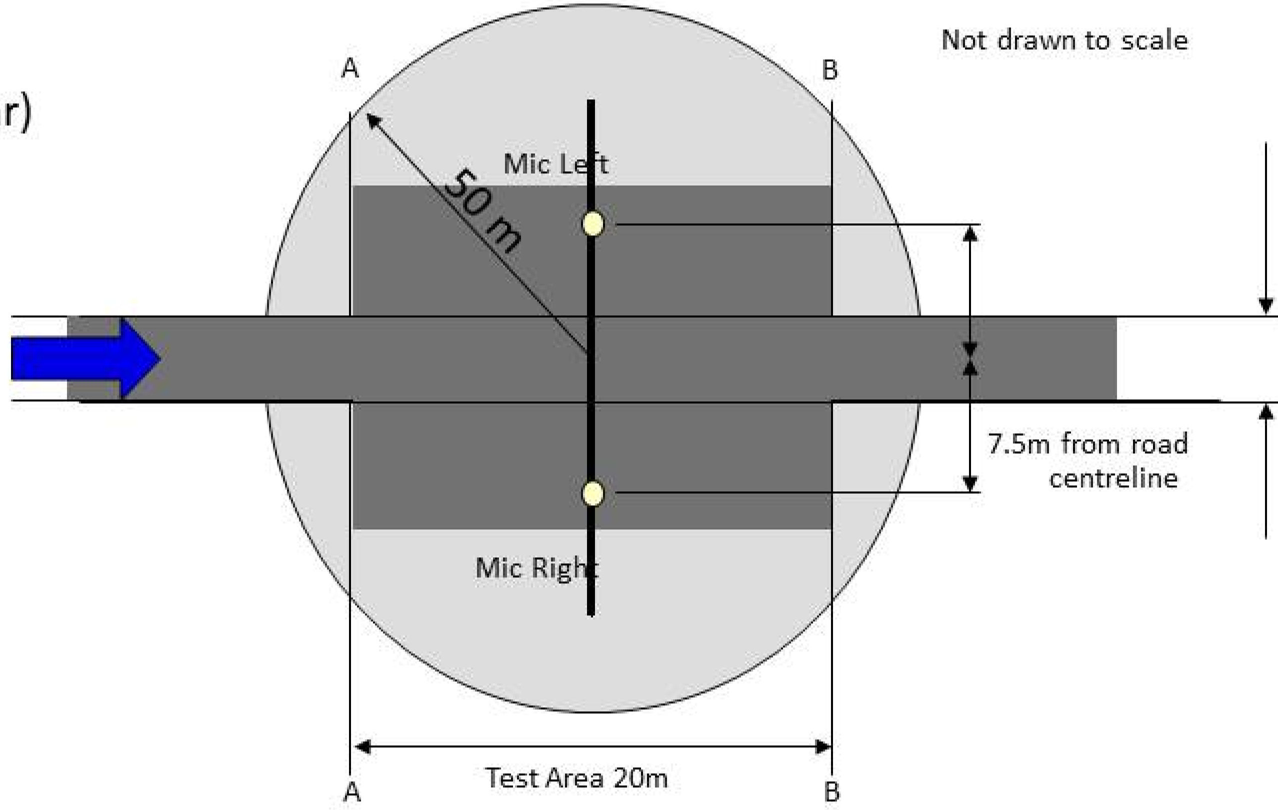
n_{bb_ASEP} shall not exceed (applicable 2nd, 3rd, 4th gear)

$0.85 * (s - n_{idle}) + n_{idle}$ pmr ≤ 66

$3.4 * pmr^{-0.33} * (s - n_{idle})$ pmr > 66

pmr = the power to mass ratio in kW/t

s = the rated engine speed



Limit Levels

- $L_{wot,(i)} + (0*(n_{pp} - n_{wot,(i)})/1000) + 3$ for $n_{pp} < n_{wot,(i)}$
- $L_{wot,(i)} + (5*(n_{pp} - n_{wot,(i)})/1000) + 3$ for $n_{pp} \geq n_{wot,(i)}$

From 2017 January

- $L_{wot,(i)} + (1*(n_{pp} - n_{wot,(i)})/1000) + 3$ for $n_{pp} < n_{wot,(i)}$
- $L_{wot,(i)} + (5*(n_{pp} - n_{wot,(i)})/1000) + 3$ for $n_{pp} \geq n_{wot,(i)}$

*ISO 362-3 : Measurement of noise emitted by accelerating road vehicles - Engineering method – Indoor Test Method

- M, N Category
- **Test room requirements**

- General

Hemi-anechoic space with the same effective propagation characteristics as an open space.

- Room dimensions

The minimum-room-length (external dimension) should be chosen as follows: 20m (original length of test track) + length of longest vehicle to be tested + 2 x thickness of absorbing elements + 2 x ¼ of the wavelength of the cut-off frequency (2 x distance from the outer microphones to the absorbing walls)

The width of the room is dependent on whether it is a single-sided facility or a dual-sided facility.

- Acoustical qualification of the room

The free field should meet the demands of ISO 3745. The low-frequency cut-off is dependent of the lowest frequency of interest. Additional to ISO 3745 the free field conditions along the measuring microphones must be fulfilled and documented.

level being measured in the test cell (see 8.5).

* NOT RELEASED YET, Coming soon

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*ISO 362-3 : Measurement of noise emitted by accelerating road vehicles - Engineering method – Indoor Test Method

- Condition of the floor

The absorption-coefficient of the floor must be less or equal as defined in ISO 10844.

Acoustical coupling of cavities must be avoided.

- Cooling, ventilation, air temperature, exhaust gas management

The room-temperature must be within the limits as defined in ISO 362-1 (5° - 40°C).

Vehicle-cooling must be managed in a way that the measurements are not influenced by noise emitted by the cooling-system.

The exhaust system of the vehicle must be fully exposed to the acoustic space.

- Background noise

In accordance with ISO 362 the unit should be designed to be quiet enough to be 15 dB below the lowest maximum

* NOT RELEASED YET, Coming soon

*ISO 362-3 : Measurement of noise emitted by accelerating road vehicles - Engineering method – Indoor Test Method

- **Dynamometer requirements**

- Type of texture (rollers)

The texture of the rollers must be rough enough to transfer the torque of the tested vehicle under the required conditions.

- Diameter of the rollers

The diameter of the rollers of a 4-wheel-dyno is limited by the shortest wheelbase of the objects to be tested.

- Reproducibility of the pass-by-dynamic

The response time of the dyno must be equal or lower than the response time of the vehicle under testing conditions.

- 2-wheel-operation or 4-wheel-operation

Under discussion

- Noise emission limit under operating conditions

The noise, emitted by the roller bench under operating conditions (without vehicle on the rollers) inclusive the noise caused by air handling, vehicle cooling, etc.. must be low enough not to influence the expected noise levels of interest.

* NOT RELEASED YET, Coming soon

*ISO 362-3 : Measurement of noise emitted by accelerating road vehicles - Engineering method – Indoor Test Method

- **Test procedures**

  - General

Acoustic data from each of the measuring microphones are acquired and stored to computer memory as time histories. At the same time, data are acquired to quantify the vehicle speed and engine speed during the test. These various sources of information are combined, based on a trigger signal relating to line AA' of the test track when the accelerator throttle is applied.

  - Microphone array – Hard- and Software

It must be ensured that the calculating method of the Overall Sound Pressure Level is able to deliver values within certain accuracy every 0.2m along the test track (the minimum requirement is 30 readings per second). Therefore the density of the microphones must be coordinated with the algorithm of the calculation method.

  - Test-object fixing system

The fixing system should be small enough to avoid disturbance of the sound field

  - Conditions of the vehicle

Same as ISO 362

* NOT RELEASED YET, Coming soon

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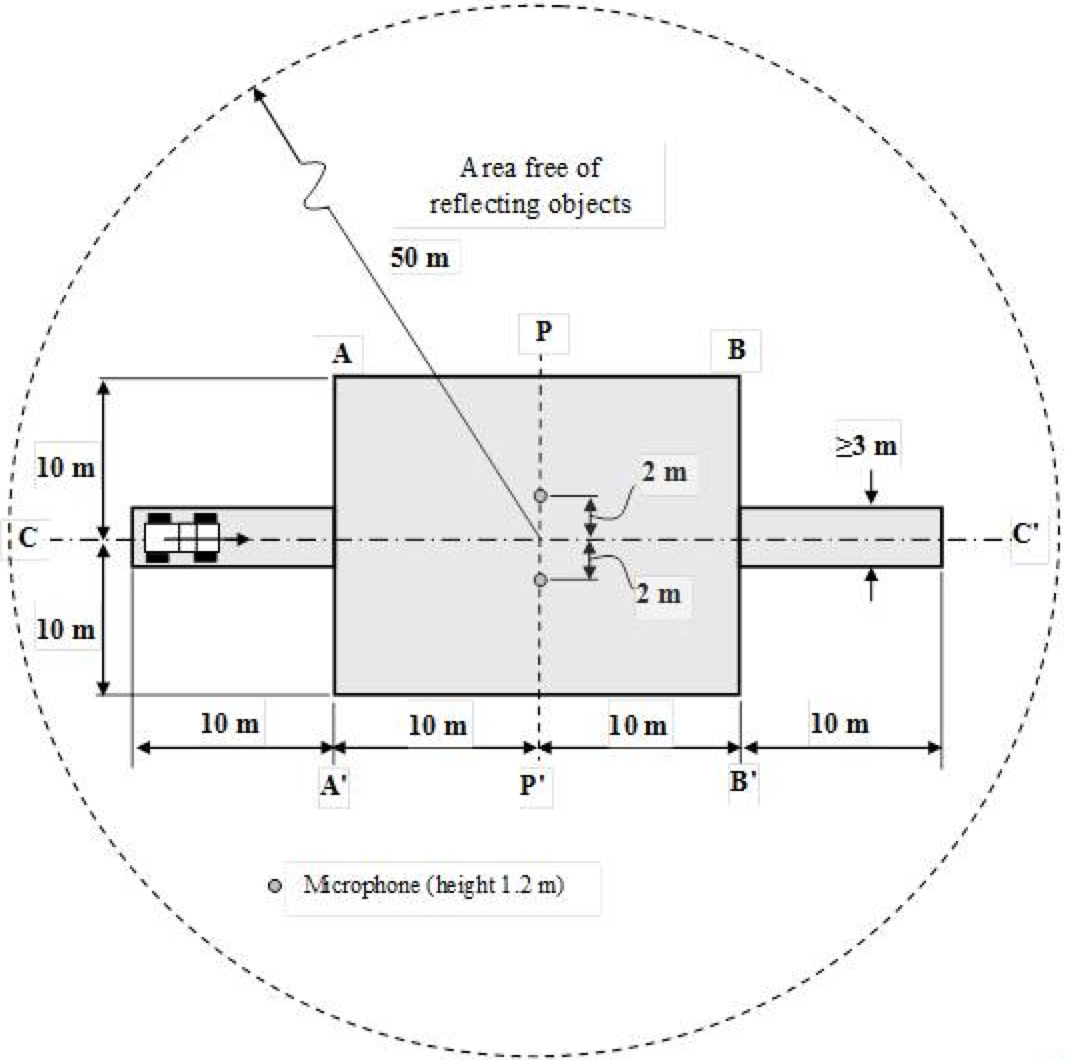
*ISO 16254 : Acoustics — Measurement of Minimum Noise Emitted by Road Vehicles

- **Field Test**
- **Full vehicle indoor hemi anechoic testing**

Cut-off frequency of 100 Hz or lower. The test facility shall meet requirements of ISO 3745, Annex A, or ISO 26101, when published.

In the vicinity of the microphone, there shall be no obstacle that could influence the acoustic field and no person shall remain between the microphone and the noise source. The meter observer shall be positioned so as not to influence the meter reading.



* NOT RELEASED YET, Coming soon

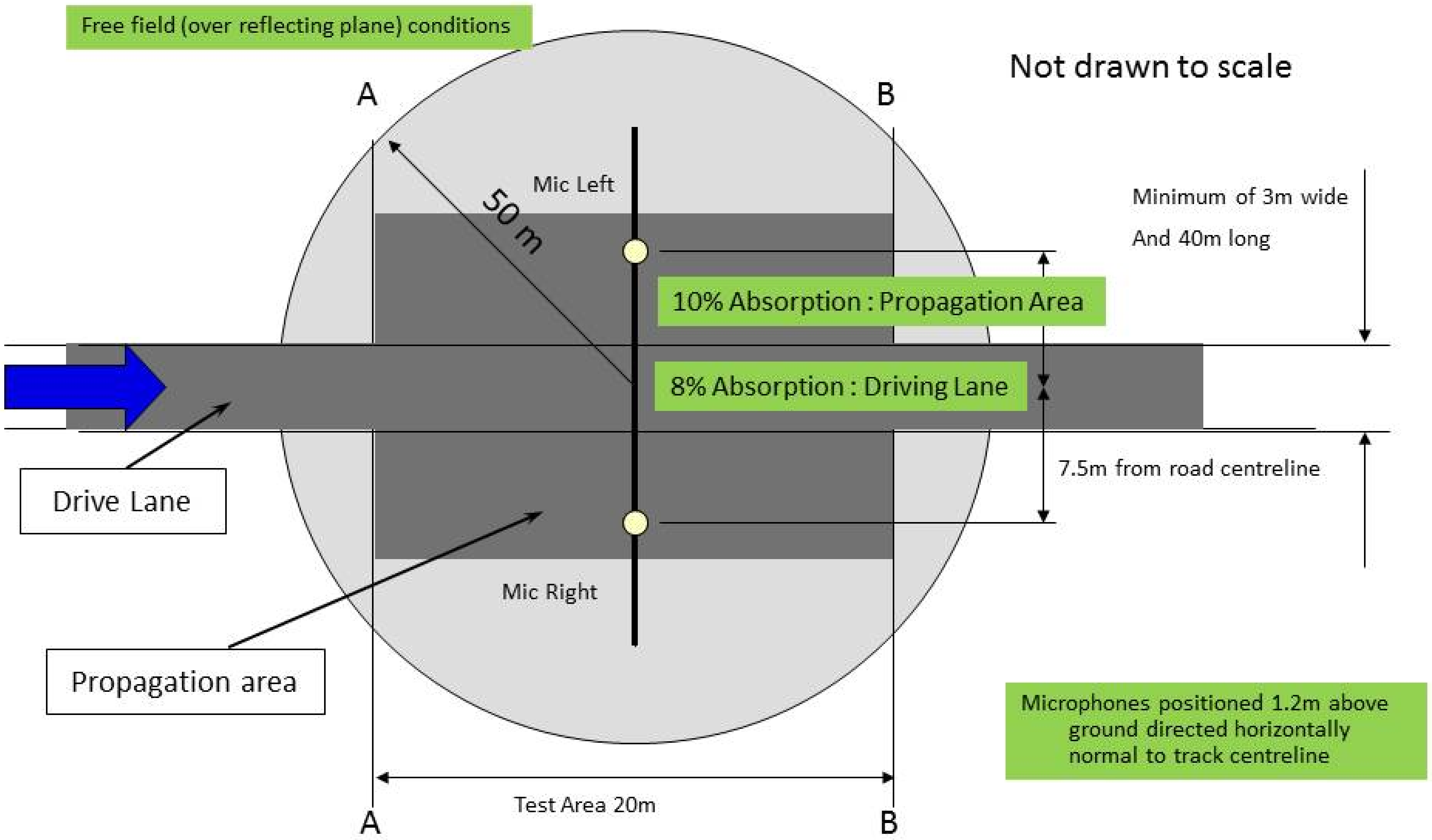
*ISO 16254 : Acoustics — Measurement of Minimum Noise Emitted by Road Vehicles

Test Report

- Reference to this International Standard;
- Details of the test site, site orientation and weather conditions including wind speed, air temperature, wind direction, barometric pressure, and humidity; or if an indoor facility is used, description of the facility including dimensions and cut-off frequency of facility;
- The type of measuring equipment, including the windscreen;
- The A-weighted sound pressure level typical of the background noise;
- The identification of the vehicle, its engine, its transmission system, including available transmission ratios, size and type of tires, tire pressure, tire production type, power, test mass, vehicle length and location of the reference point;
- The auxiliary equipment of the vehicle, where appropriate, and its operating conditions;
- All valid A-weighted sound pressure level values measured for each test, listed according to the side of the vehicle and the direction of the vehicle movement on the test site;
- All valid frequency measurements for each test;
- The technology content of the vehicle's propulsion system (e.g. internal combustion engine, stop/start, battery electric, hybrid, plug-in hybrid, extended-range electric, fuel cell);
- Any special test or vehicle conditions or settings reflective of the technology content listed in above.

* NOT RELEASED YET, Coming soon

ISO 10844 : Acoustics — Specification of test tracks for measuring noise emitted by road vehicles and their tyres



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ISO 10844 : Acoustics — Specification of test tracks for measuring noise emitted by road vehicles and their tyres

4.4 Proving the requirements

..

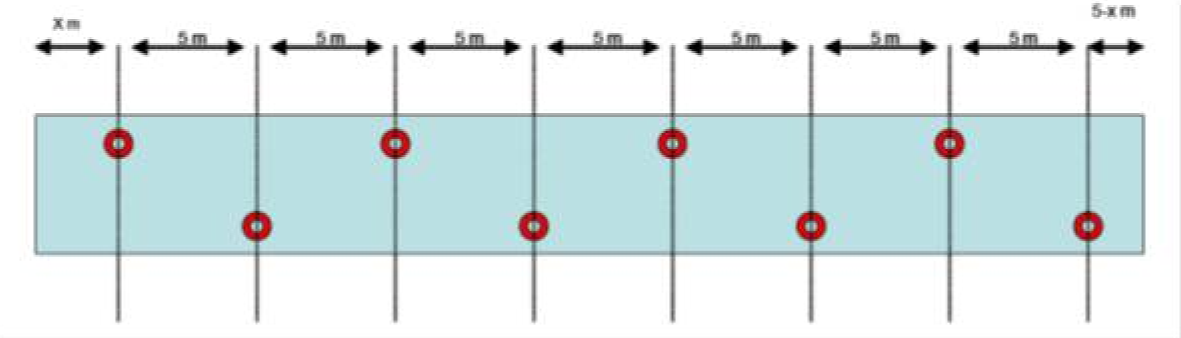
For sound absorption, texture, geometrical and stiffness compliance, the first point shall be chosen randomly (not on the same axis) and the subsequent measurements shall be performed at 5 m intervals to cover the whole track.

..

All measurements shall be made along the total length of the drive lane in each wheel track.

For checking the surface properties of the propagation area, take at least two measurements randomly chosen on each side.

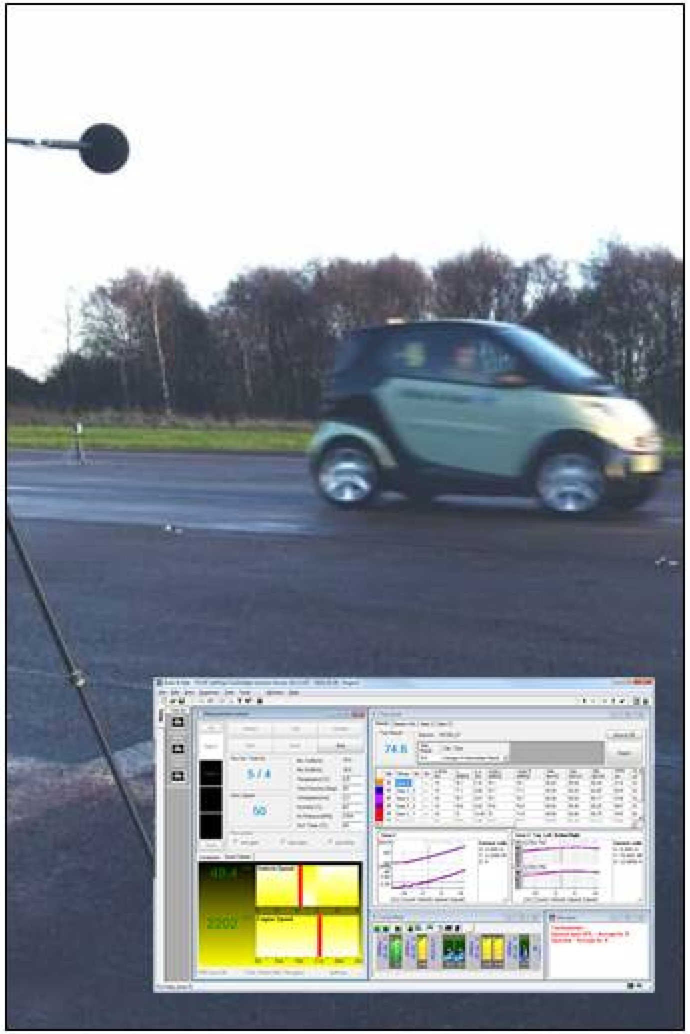
In addition, sound absorption of the propagation area shall be measured at both sides of the drive lane at half way of the microphone location in the vicinity of the line PP'.



Contents

Field Pass-by

- Turnkey system for pass-by measurements
- Scalable solution from Low cost Conformance Test System to advanced solution with complete data collection in one pass-by measurement:
  - noise and vibration spectra, orders, position, velocity, RPM and throttle (gas pedal) position along with other parameters
- Fulfils the latest ISO 362 revision
- Simple 3 step operation makes the systems very easy to use:
  - Acquisition Setup, Session Setup, Measure



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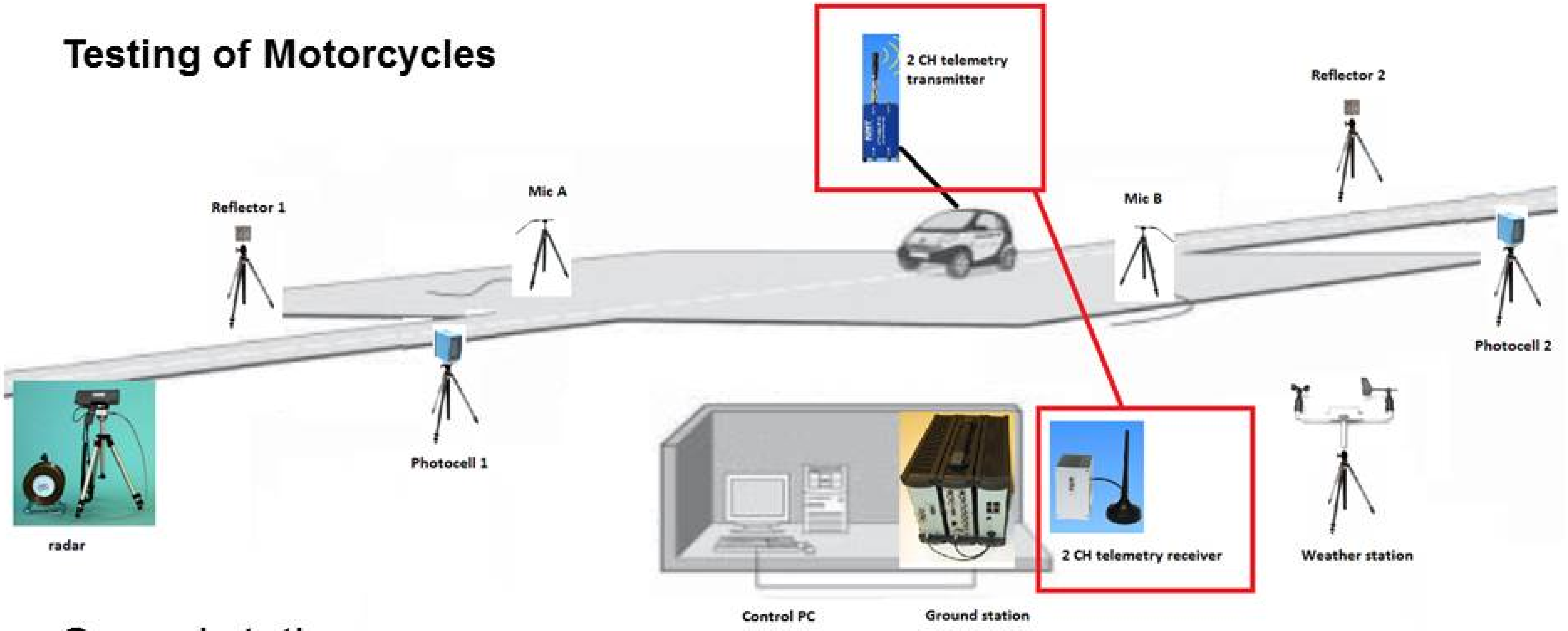
Field Pass-by 2: Ground station with 2 Channel telemetry

Testing of Motorcycles



Ground station

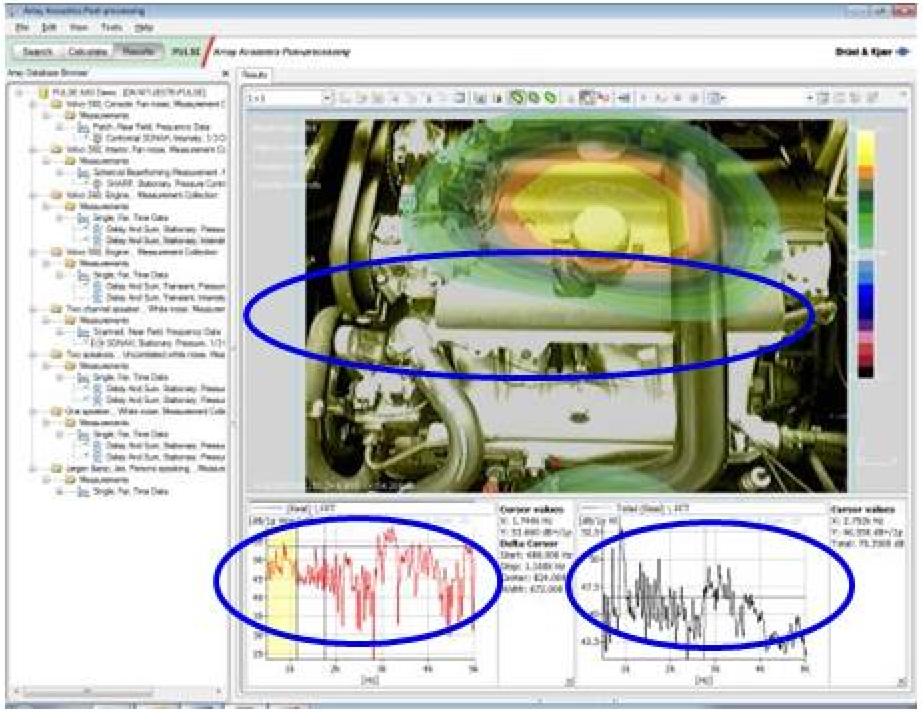
2 Signals from the vehicle via telemetry

Also available with LAN-Xi front-end

Contents

Noise Source Identification (NSI) Introduction

- The objective of NSI is to identify the major noise sources on an object in terms of:
  - Position
    - From where is noise radiated?
  - Frequency content
    - What are the characteristics of the noise?
  - Quantify contributions
    - How important is it?
  - Root causes
    - What is its origin?
  - Impact
    - What effect does it have?



Using an accelerometer or HATS reference for correlation

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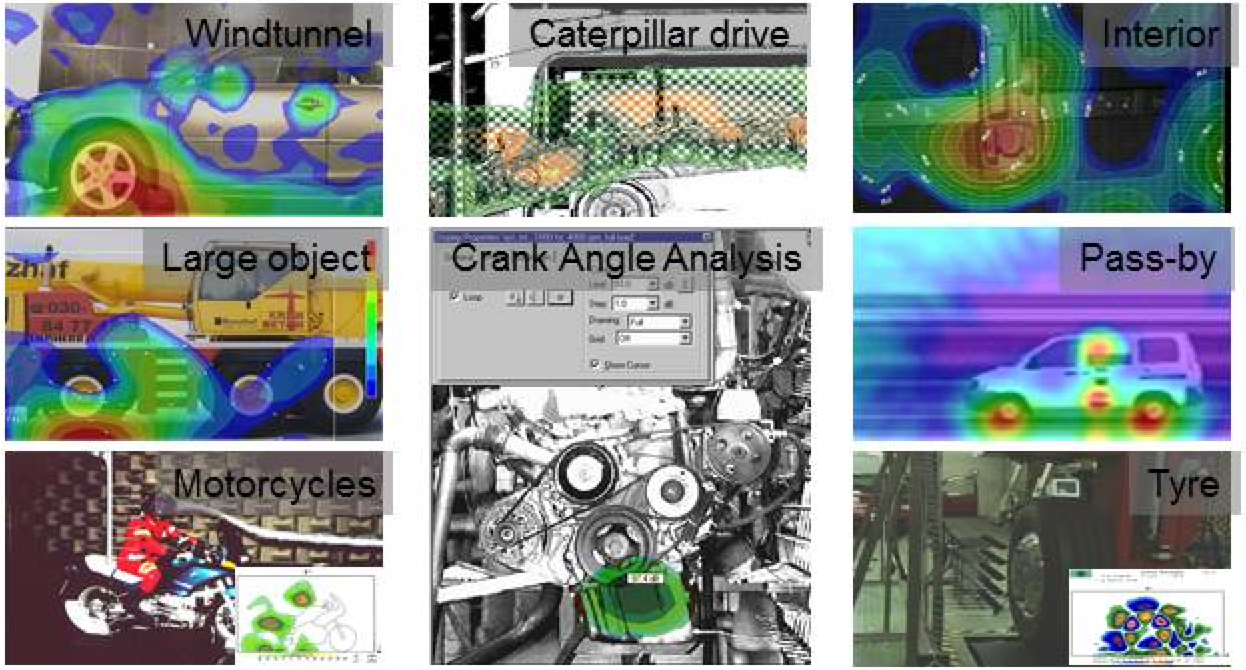
Noise Source Identification: technologies and uses

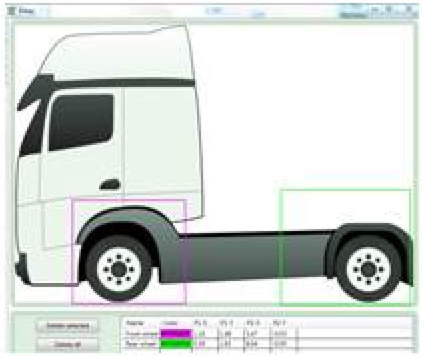
- The versatile PULSE Array Acoustics Suite supporting a number of acoustic Beamforming and Holography technologies covers a wide range of use cases:
  - large and small test objects
  - stationary and moving noise sources
  - analysis at stationary conditions; vs rpm/speed/position/crank angle
  - mapping of sound pressure/ power/intensity/ Sound Quality Metrics

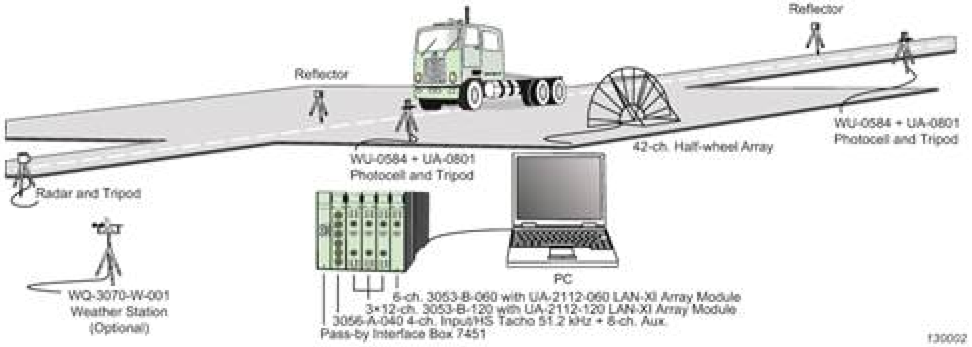
- Exterior noise engineering applications
  - Moving Source Beamforming ("Pass-by")
  - Holography investigations of powertrains
    - Analysis vs rpm, crank angle etc
  - Holography investigations of tyres



Road Vehicles, Moving Source Beamforming Introduction

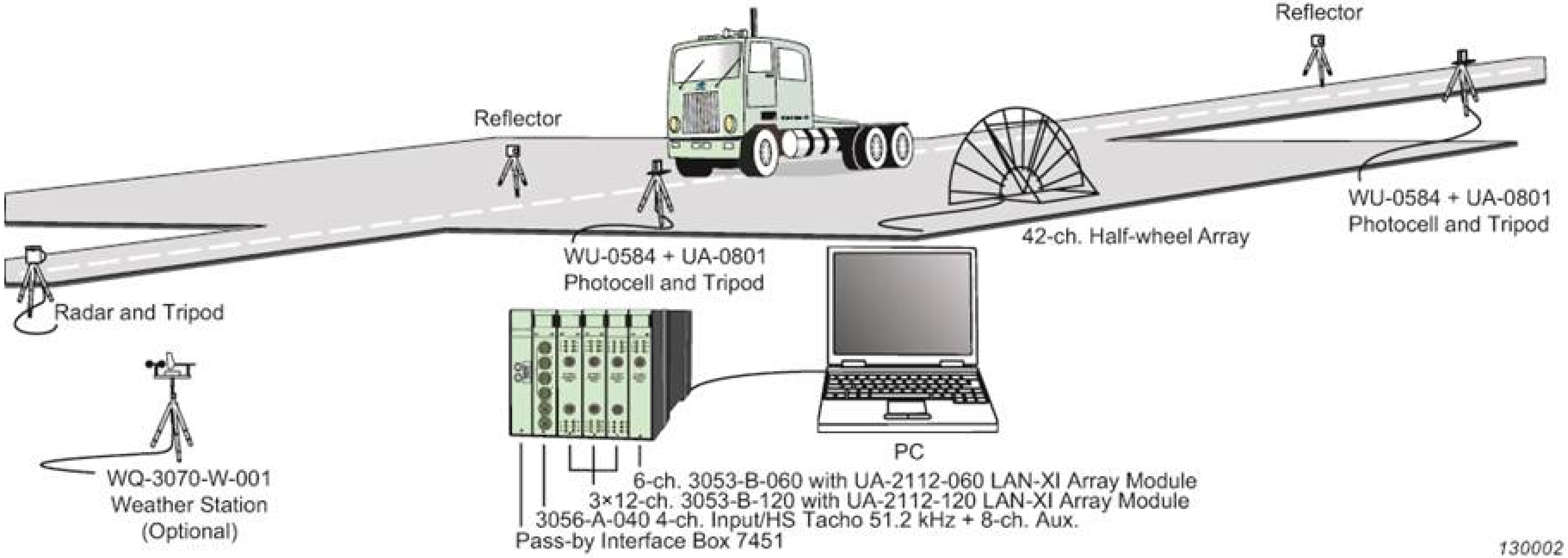
- ISO SPL vs Position calculation from an array microphone
- Contour plot showing sound pressure level as a function of vehicle position on track
- Preview in calculation Setup speeds up the analysis process
- Validation of Total Contribution vs ISO SPL
- A-weighting both in calculation and in display
- Line diagram showing maximum sound pressure levels as a function of vehicle position on track
- Multiple planes showing 3D mapping of data. This representation is only relevant for vehicles with open structures such as trucks





Road Vehicles, Moving Source Beamforming: System setup

- Road Vehicle Moving Source Beamforming used as a stand-alone system
- Can also be combined with standardised Pass by test



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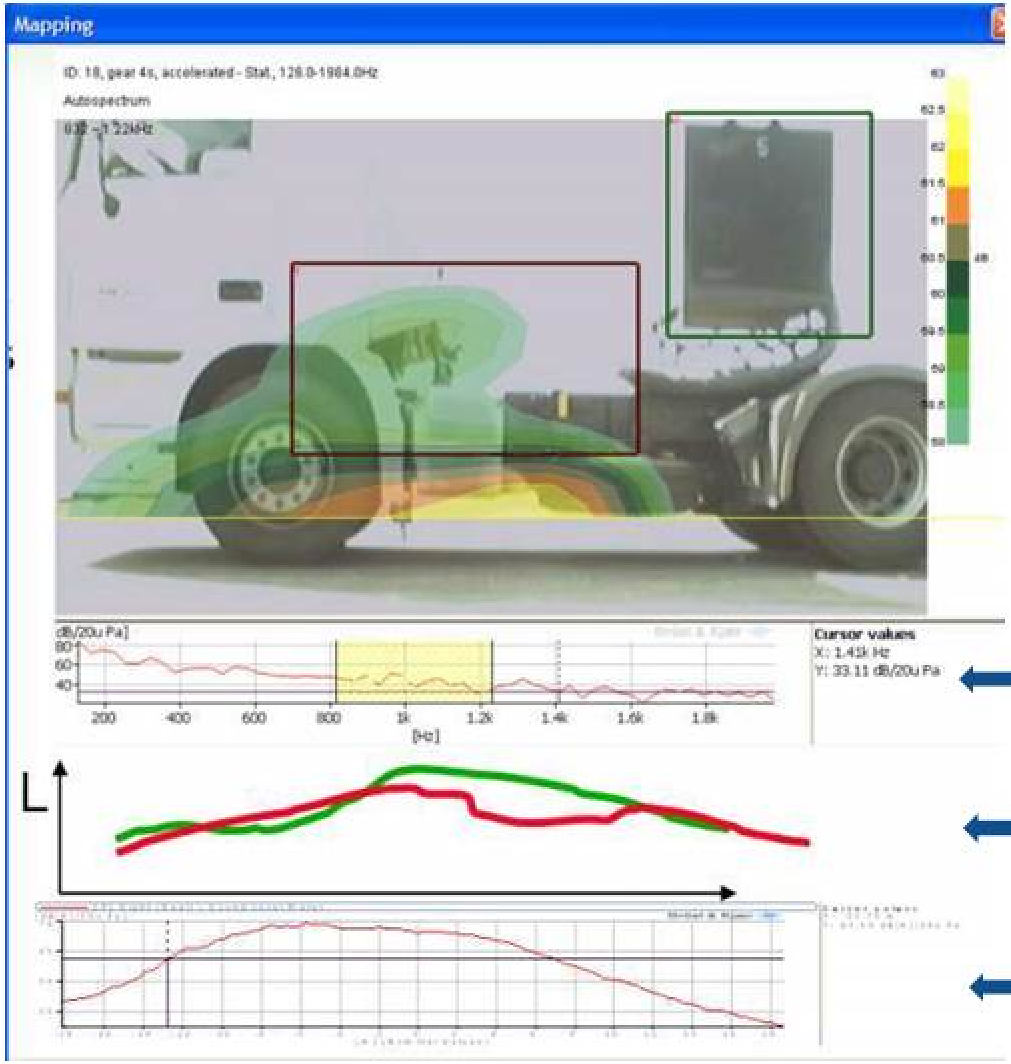
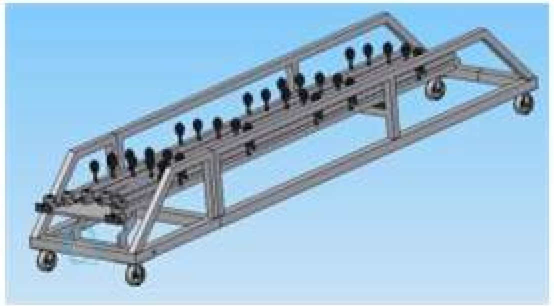
Example: Mapping versus Position

Test Process

- Prepare system incl. easy to carry and set up lightweight array system
- Record microphone signals as vehicle is passing by
- Process and analyze data
  - Inspect spectrum at max SPL
  - Select critical frequency range
  - Select important radiation areas
  - Map noise radiation in critical frequency range of selected areas vs position





Frequency selection

Contribution analysis

ISO reference curve

Moving Source Beamforming Summary

Noise Mapping versus vehicle position

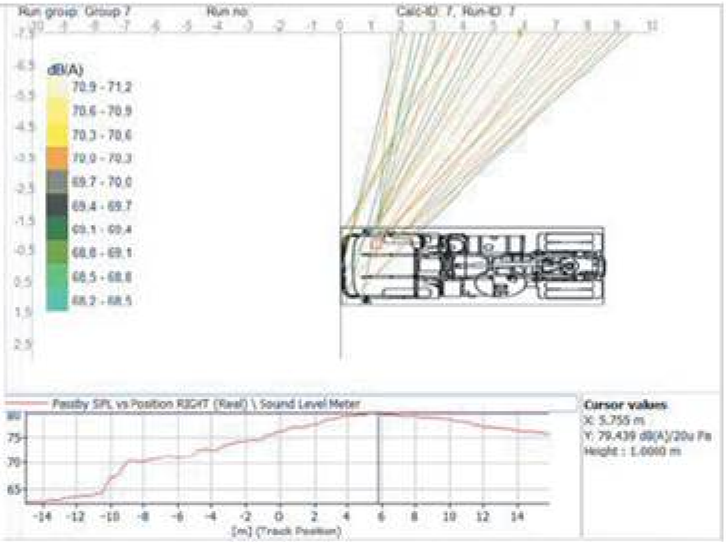
Mapping of planes from the side, front and top of the vehicle

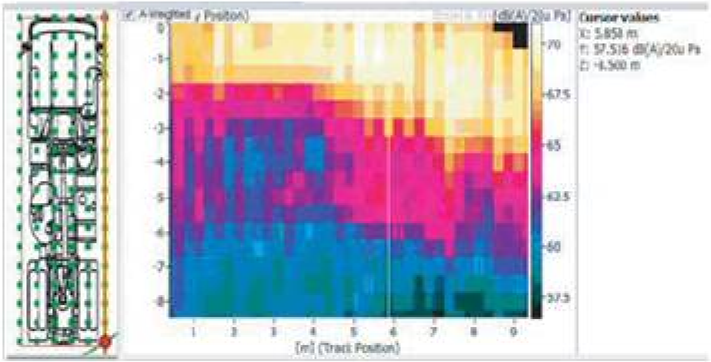
Time domain implementation of beamforming

Doppler corrected results

Component Contribution analysis

Easy comparison with pass-by ISO 362 measurements





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Contents

Indoor Pass-by testing

Purpose

To make a simple and reliable tool for development, troubleshooting

Function

Must also be available in rooms where the size does not allow to set up the microphones in 7.5m distance from the center-line

Assumptions

The noise is coming from one point(i.e. acoustical center) independent of frequency

Microphones are placed in the far field so the distance law can be used i.e. for every doubling of distance the level will decrease with 6dB

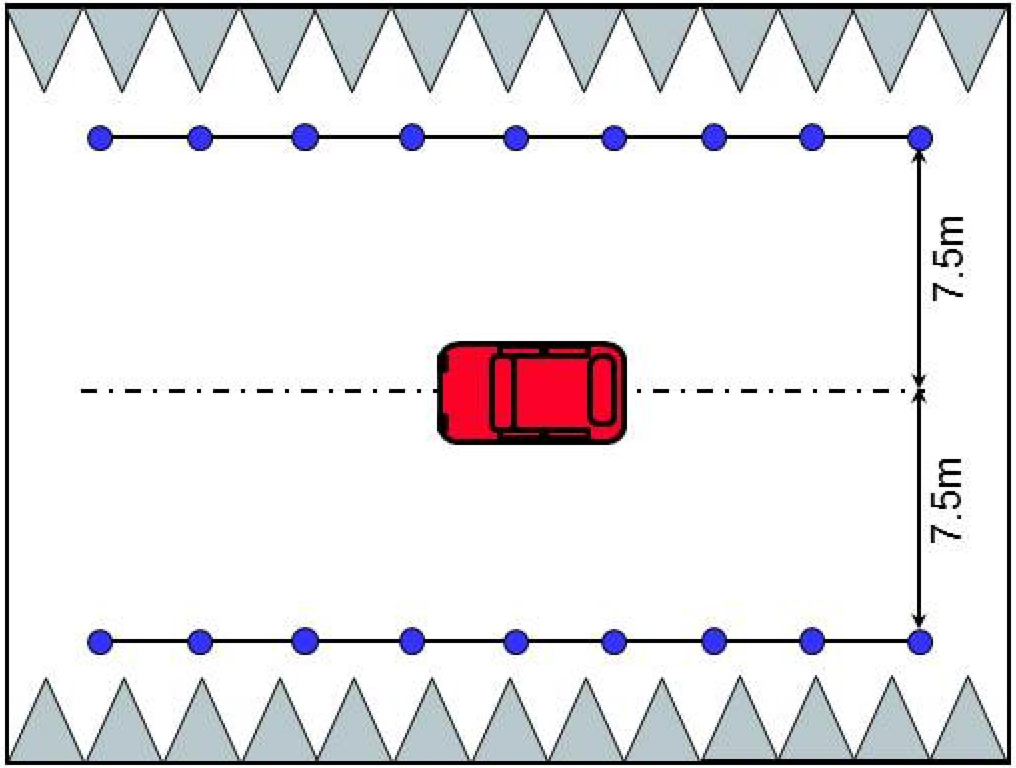
Corrections

To make better comparison with the real measurement Doppler effect correction is used

Tyre noise correction delivers more accurate representation of tyre noise

Conventional Indoor Pass-by

- Large hemi-anechoic room
- Pass-by result: Total vehicle vs position (level or spectra)



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Indoor Pass-by using Simple Vehicle Model

- Smaller hemi-anechoic room
- Pass-by result: Total vehicle vs position (level or spectra)

Assumptions:

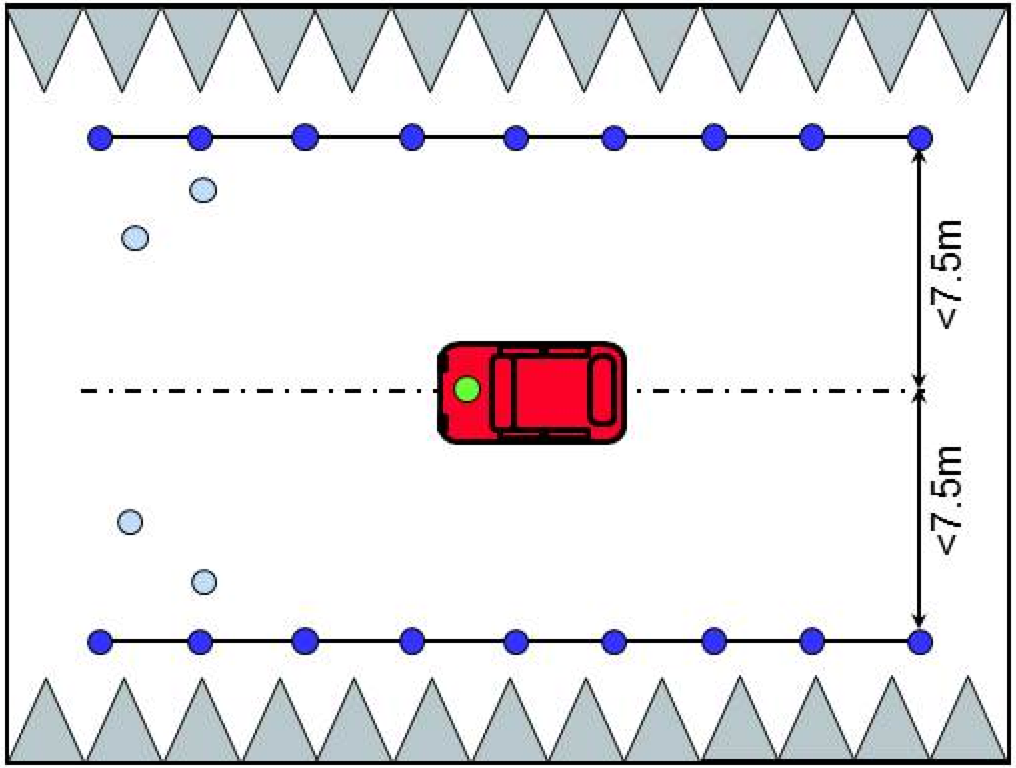
1)

Noise coming from one acoustical center – can be one center per side - independent of frequency

2)

Microphone arrays placed in far-Field

Arrays can be straight lines or curved ◯ to support room geometry



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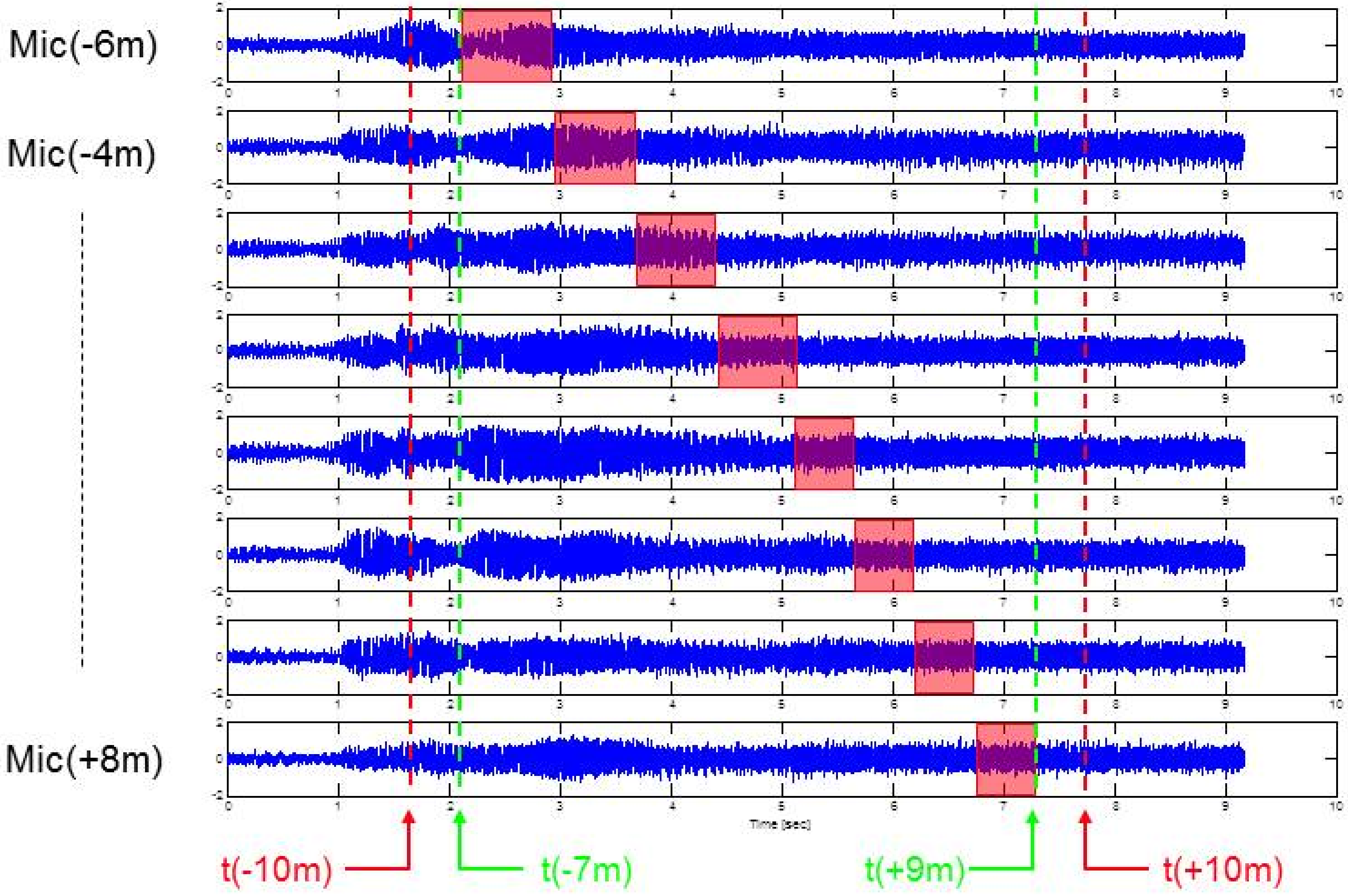
Synthesizing Time Signals

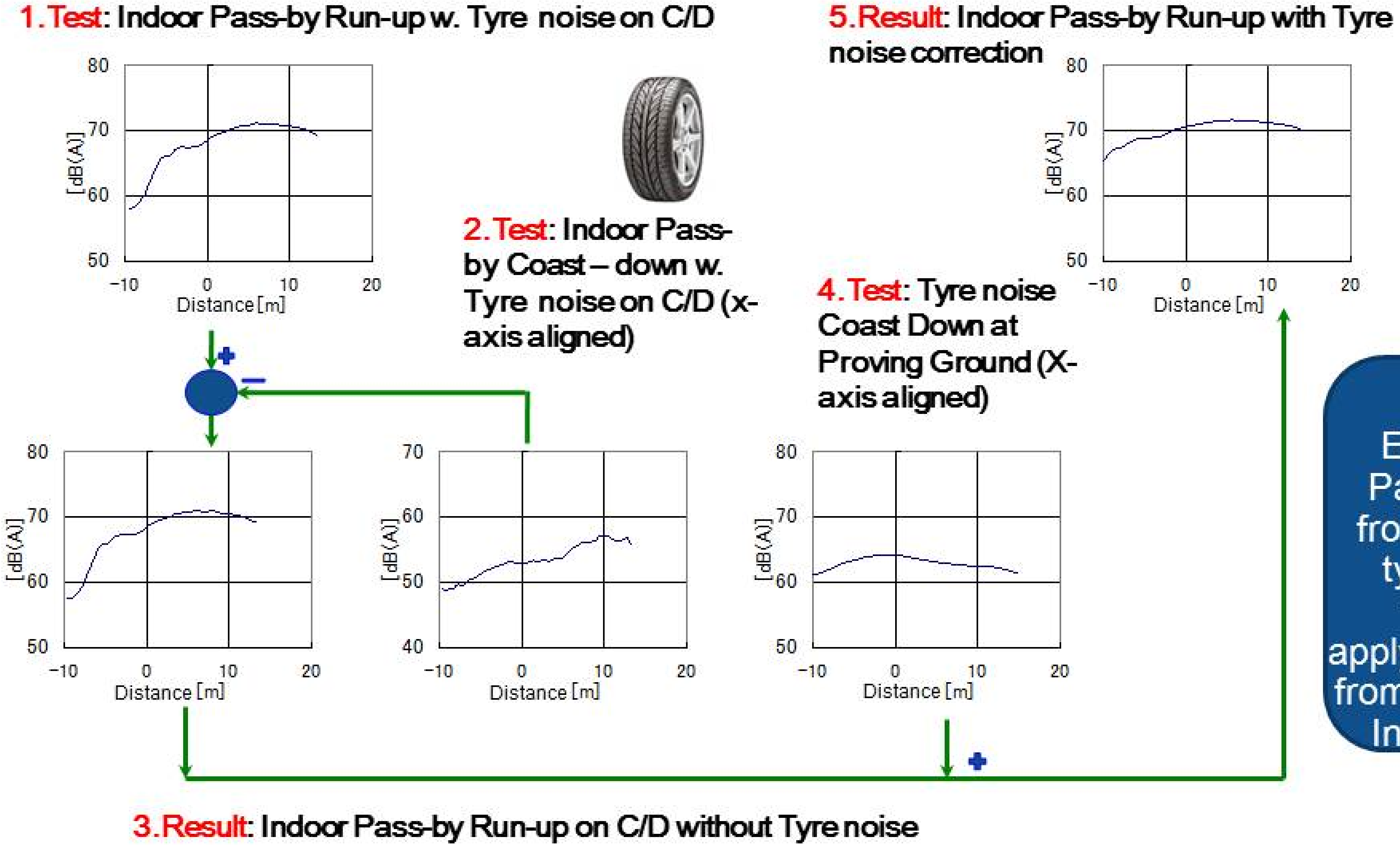


The time signals from the individual pass-by array microphones are added together and Doppler corrected to synthesize the two (left and right) ISO microphone signals

A normal Pass-by calculation is subsequently done on the synthesized signals

Tyre Noise Correction of Indoor Pass-by data

The tyre noise measured on the chassis dyno is replaced with tyre noise measured on the test track



Benefit:

Evaluate the Pass-by noise from a range of tyres on one vehicle by applying tyre noise from track tests to Indoor results

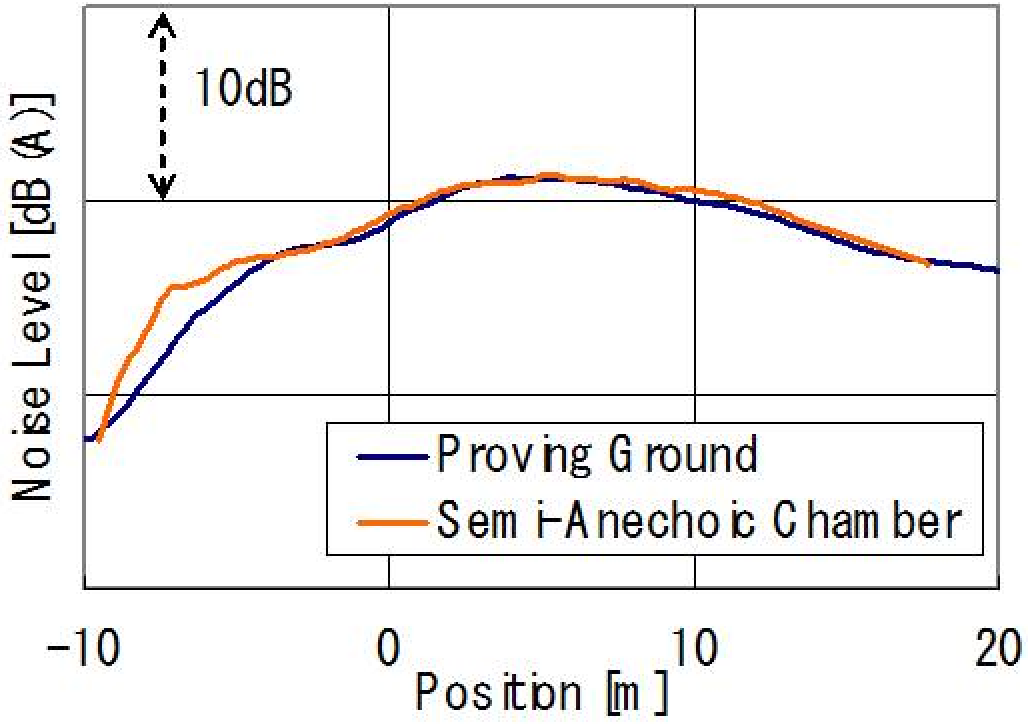
Why Indoor Pass-by testing

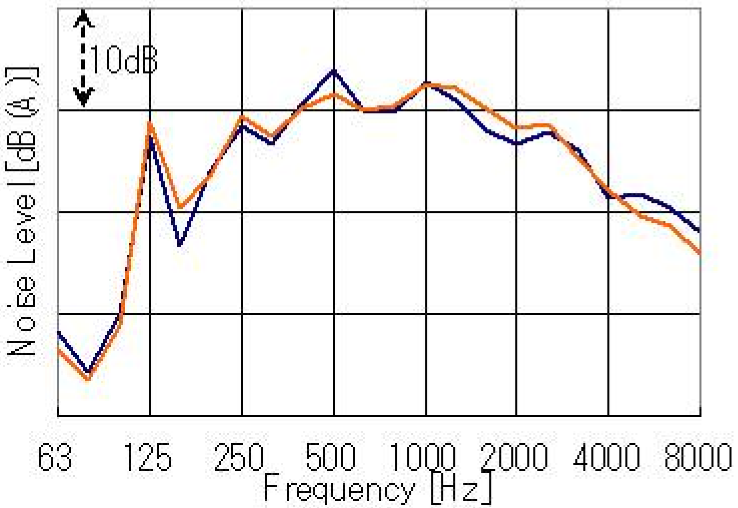
- Indoor Pass-by testing cannot yet replace the field conformance test, but the method offers a number of advantages in the product development phase
  - Repeatable
  - Flexible
  - Fast
  - Easy to use
  - Precise Test Condition, Engine and Vehicle conditions
  - Stable Test Environments
  - Easy Comparison
  - Contribution Analysis of Vehicle Components
  - …and Indoor !

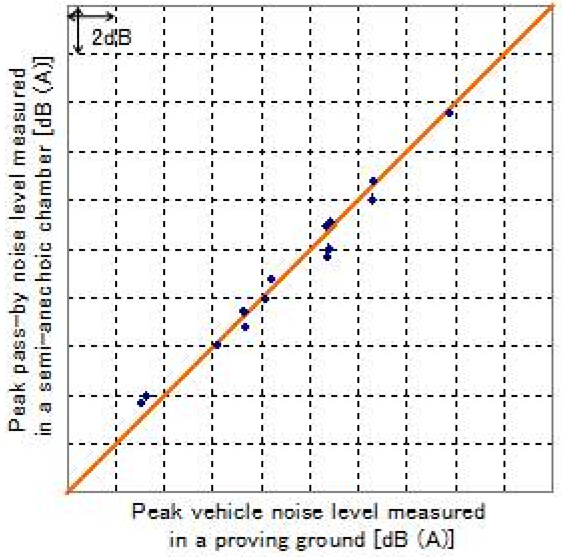
Contents

Pass-by: Comparison of Indoor vs Field Pass-by Results

Similar results is standardised Field Pass-by and Indoor Pass-by Tests







Indoor Pass-by .vs. Field Pass-by

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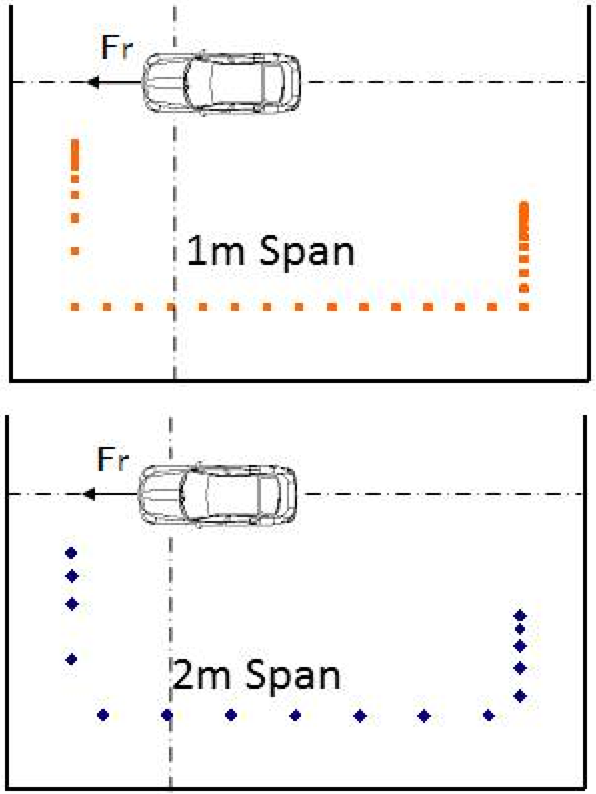
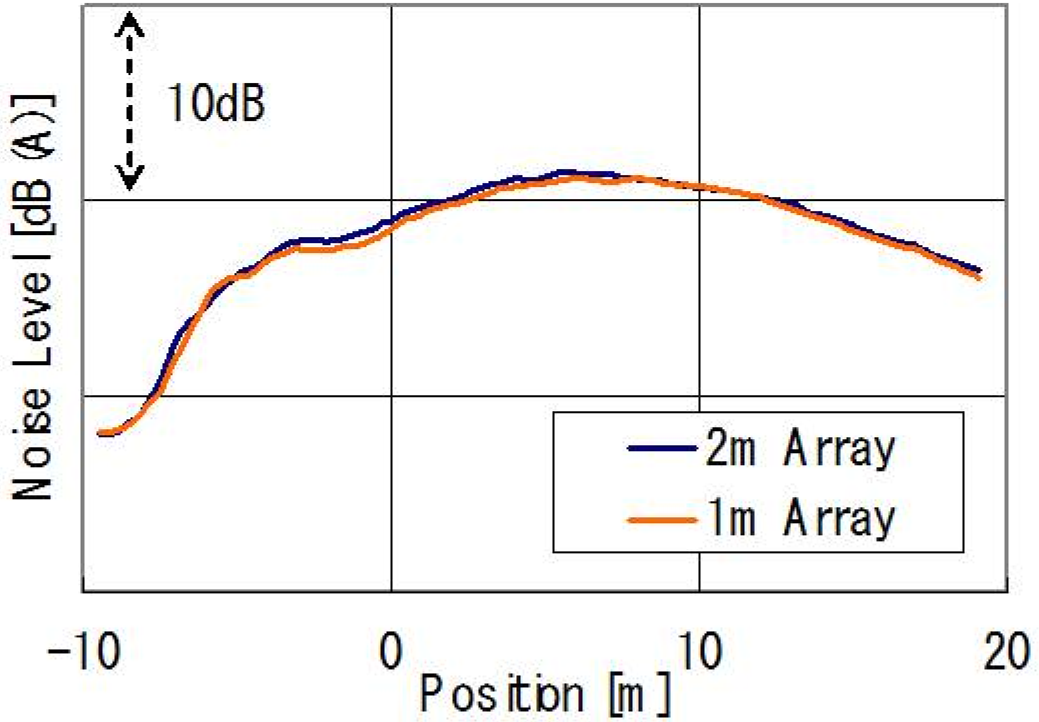
Indoor Pass-by: Comparison of microphone spans

Time domain method:
Same result with half the number of microphones





Microphone Span : 1m vs 2m

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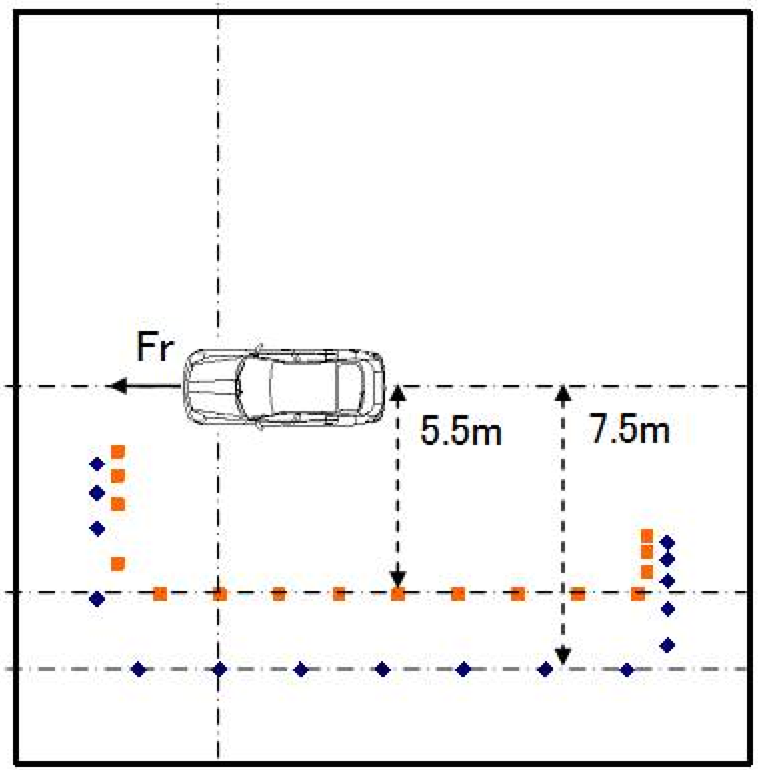
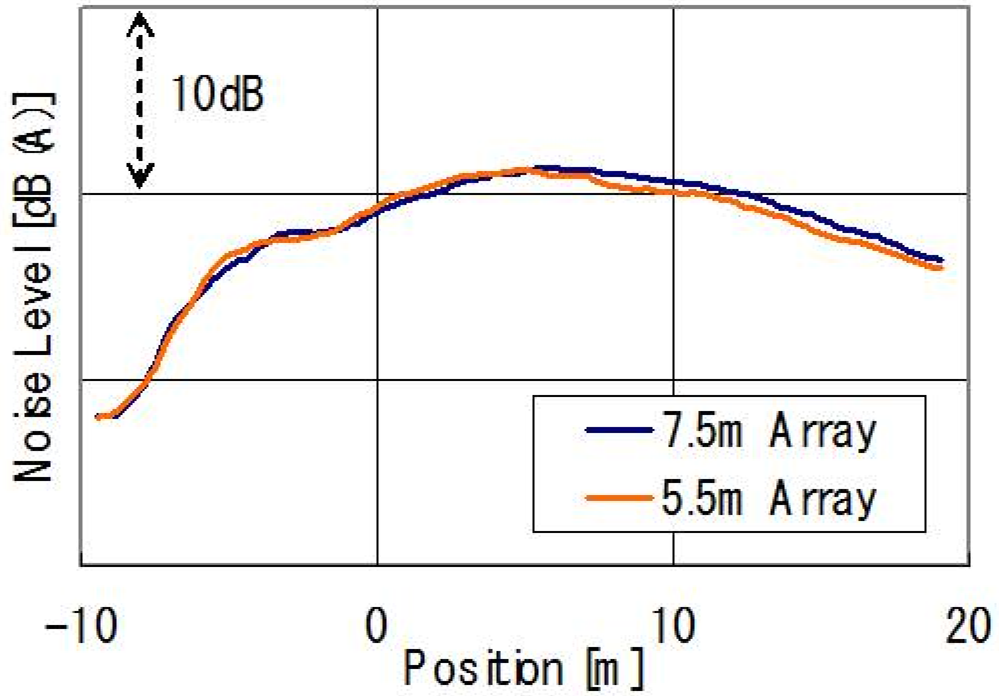
Indoor Pass-by: Validation of Distance Correction

Distance correction using extrapolation

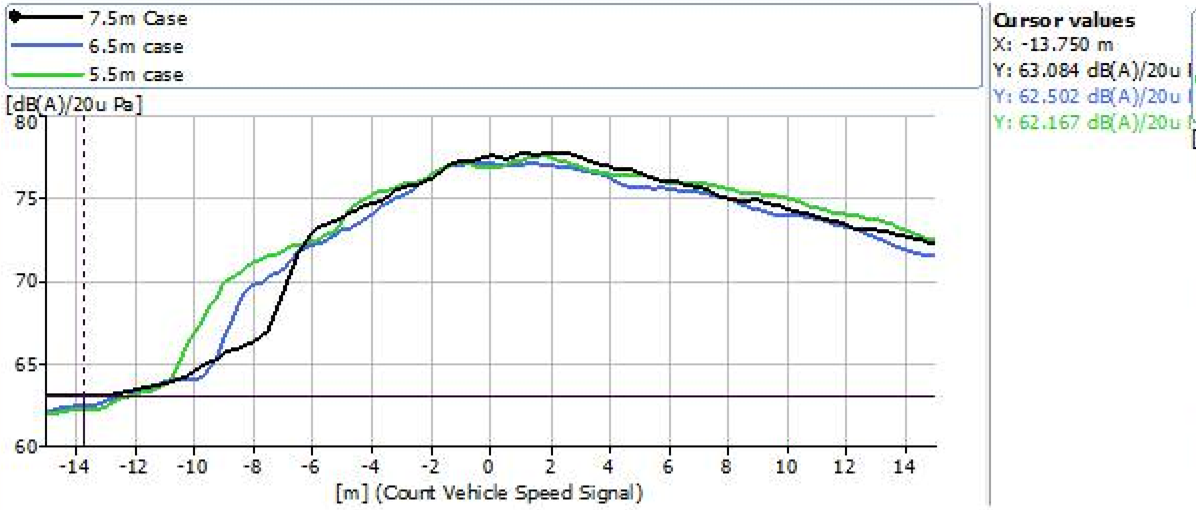




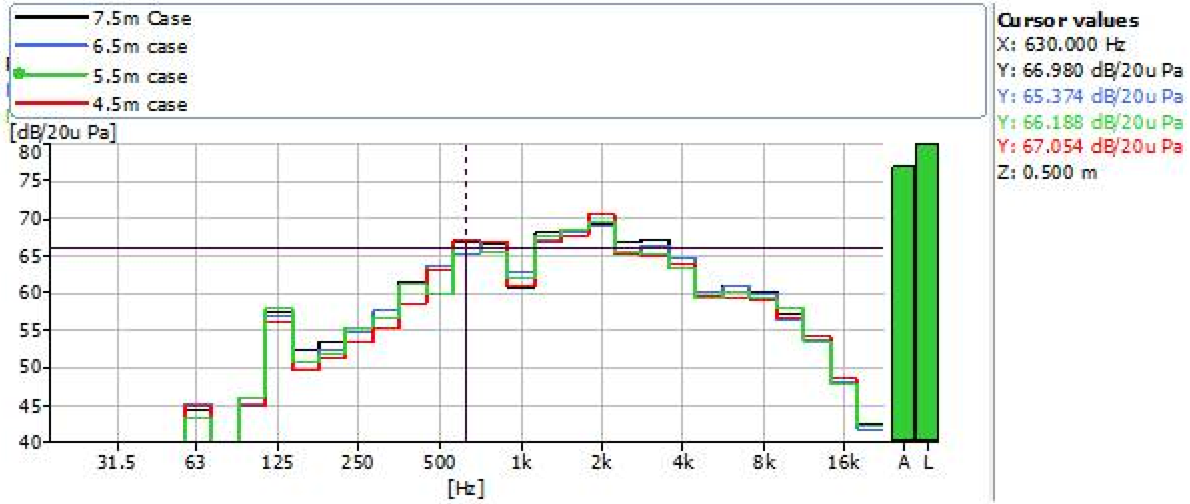
Accurate Results in smaller rooms !

Different Microphone Distances Evaluation (7.5, 6.5, 5.5m, Motorcycle)

SPL Left Side

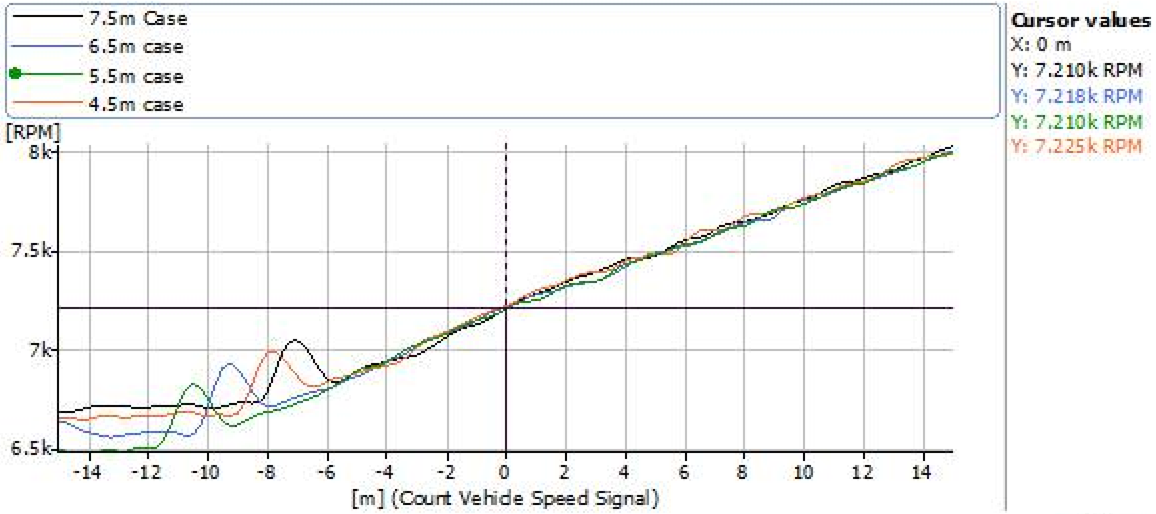


Spectra Left Side



Speed Profile

Engine RPM Profile



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Indoor Pass-by:

- Main conclusions:
  - Indoor system can accurately reproduce results from proving ground tests
  - Indoor system has higher reproduceability of tests
  - High reproduceability is particularly a challenge with the test procedure outlined in the new ISO 362 standard

Development of Pass-by Noise Measurement System on a Chassis Dynamometer

Daisuke Morie Yoshihiro Shirahashi Yunseon Ryu Wataru Narama

Abstract

Vehicle exterior noise levels measured at a proving ground tend to vary owing to the effects of background noise, measurement incapability due to weather conditions and variation in driving styles among test drivers. The test procedure scheduled to be adopted in the next European vehicle noise regulations will be more complicated than the present test method. This change will require much more time for measuring vehicle noise levels in proving ground tests. Therefore, to resolve such problems, we have developed a measurement system that can reproduce proving ground driving on a chassis dynamometer in a semi-anechoic chamber. This paper describes the signal processing procedure and the results of tests conducted to validate the measurement accuracy of the new system.

1 Introduction

The noise emitted by vehicles is generally measured in driving tests conducted at a proving ground according to a test procedure specified by noise regulations or by the ISO 362-1998 international standard. Measured noise levels tend to vary, however, due to the effects of background noise, weather conditions and differences in the driving style of test drivers, among other factors.

The test procedure in the next European vehicle noise regulations is set to be changed and will become more complicated than the current test method.(1)(2) Accordingly, it is expected that much more time will have to be spent to ensure the accuracy of vehicle noise levels measured in proving ground tests.

To resolve such problems and facilitate efficient vehicle noise measurements, we have developed a measurement system that can reproduce proving ground driving on a chassis dynamometer in a semi-anechoic chamber. This paper describes the favorable results obtained in tests that were conducted to confirm the

(2)' and (3)' corresponding to the positions in the proving ground test.(3)

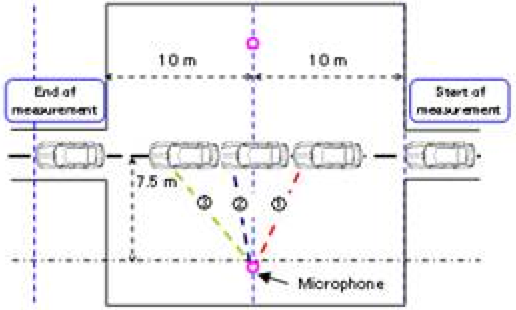
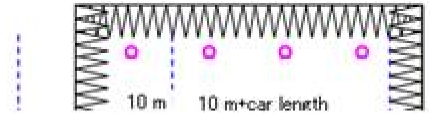


Fig. 1 Schematic diagram of vehicle noise measurement at a proving ground



Joint Paper with Nissan, JSAE 2008

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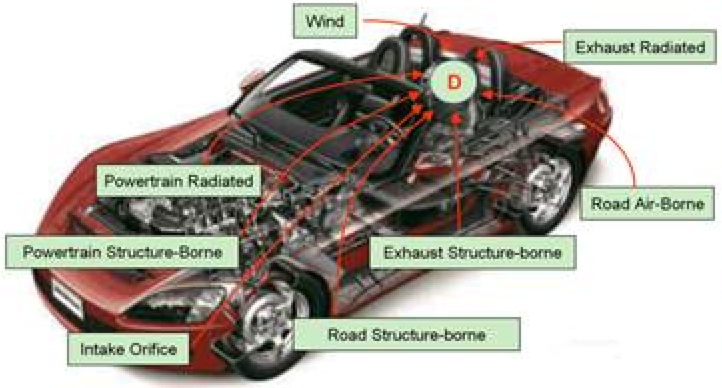
Contents

Source Path Contribution (driver's position):

Determine accurately the NVH contribution at the driver's position

- Source Path Contribution (SPC) is a set of methods for estimating and ranking noise & vibration contributions between sources and receivers by analyzing the source levels and noise paths
- SPC answers these questions:
  - Which inputs are important?
  - Which noise paths are most critical?
  - How do noise paths interact?
  - Is it a system (path) or source problem?



Source-path-receiver concept

Measurement of acoustical path sensitivities

Reciprocal method using volume velocity source

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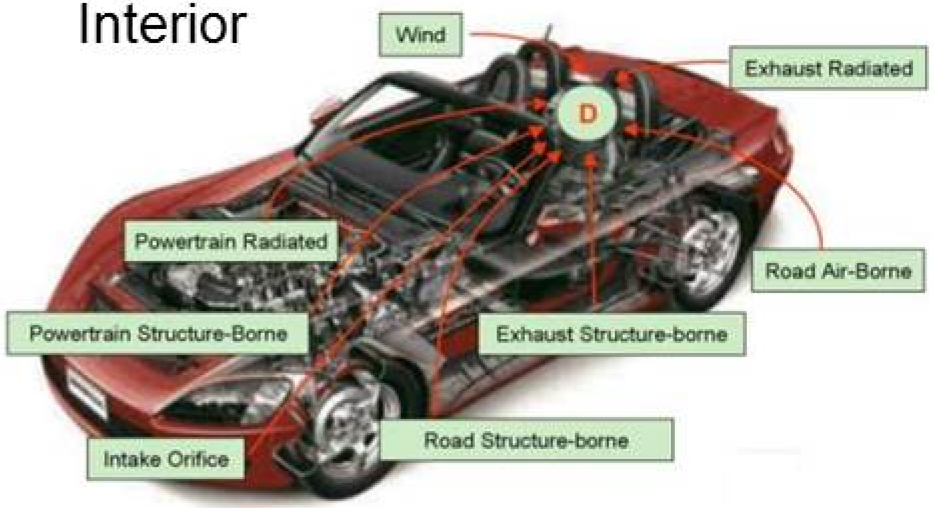
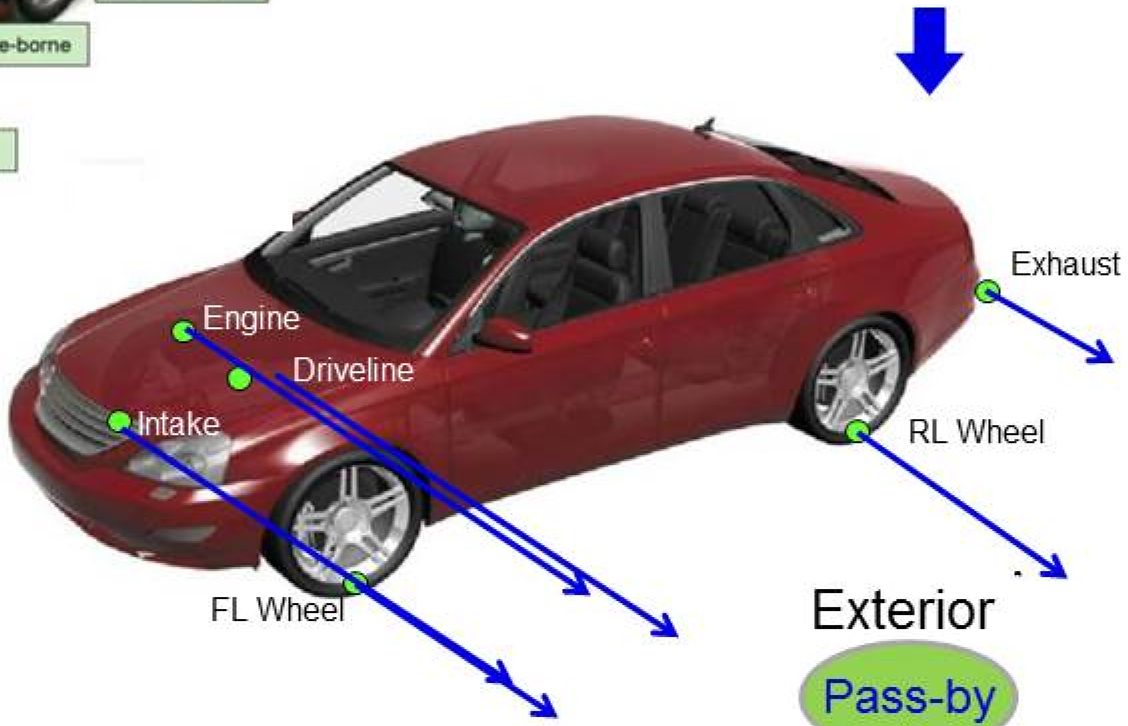
Source Path Contribution (SPC): Pass by position

Interior



Contributions from the noise sources can also be accurately estimated at the ISO Pass-by positions



Exterior

Pass-by

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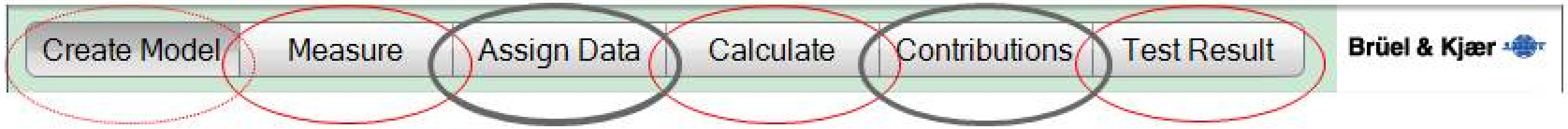
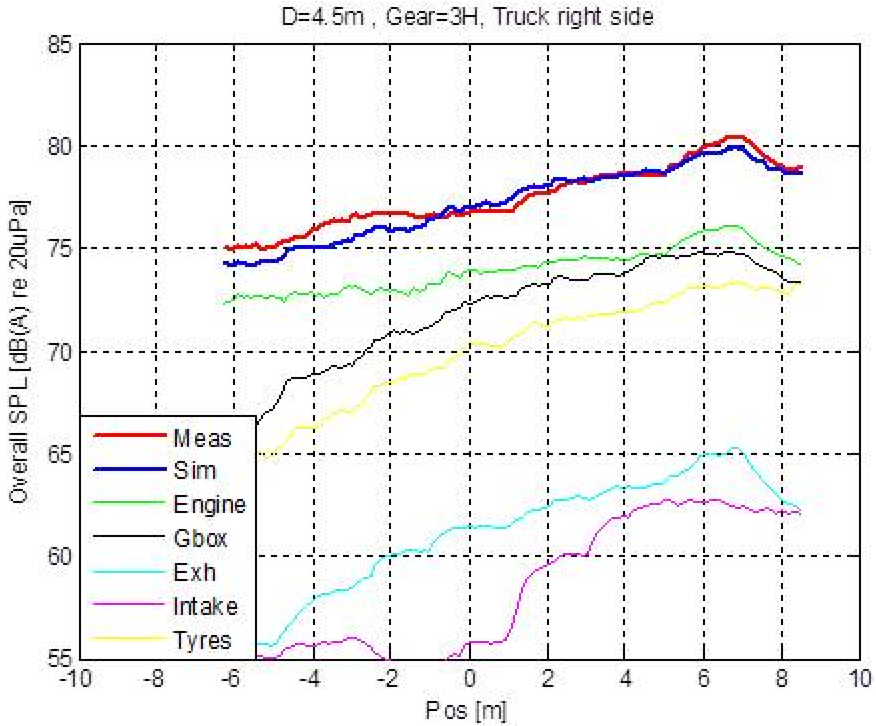
Indoor Pass-by: with optional Contribution analysis

Indoor Pass-by with Contribution Analysis



Contribution Analysis (Exterior Source Path Contribution)

- Perform efficient, year round Pass By development by ranking contributions from the main noise sources
  - Results in the ISO microphone positions vs vehicle position and speed
  - Sum of contributions may be compared with measured total to validate component contributions
  - System designed for routine testing done by technicians



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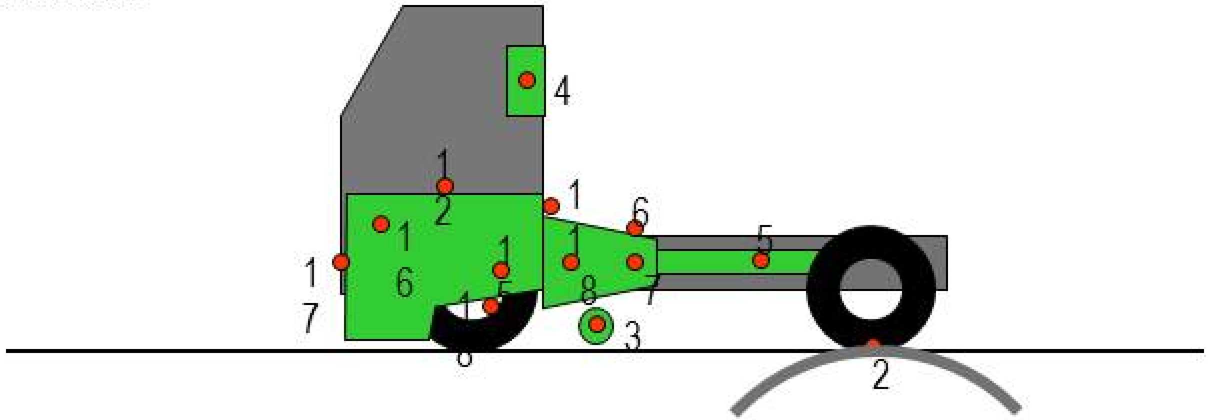
Indoor Pass-by/Contribution Analysis

Truck example:
Noise source contributions to the Pass-by positions

- Exterior noise modeling using SPC (time-domain)
- Pass-by result: Total vehicle level <u>and source contributions</u>

- Source: acoustic point sources model
- Path: airborne path from source to receiver
- Contribution: at PB receivers



Source position

Indoor Pass-by / Contribution Analysis

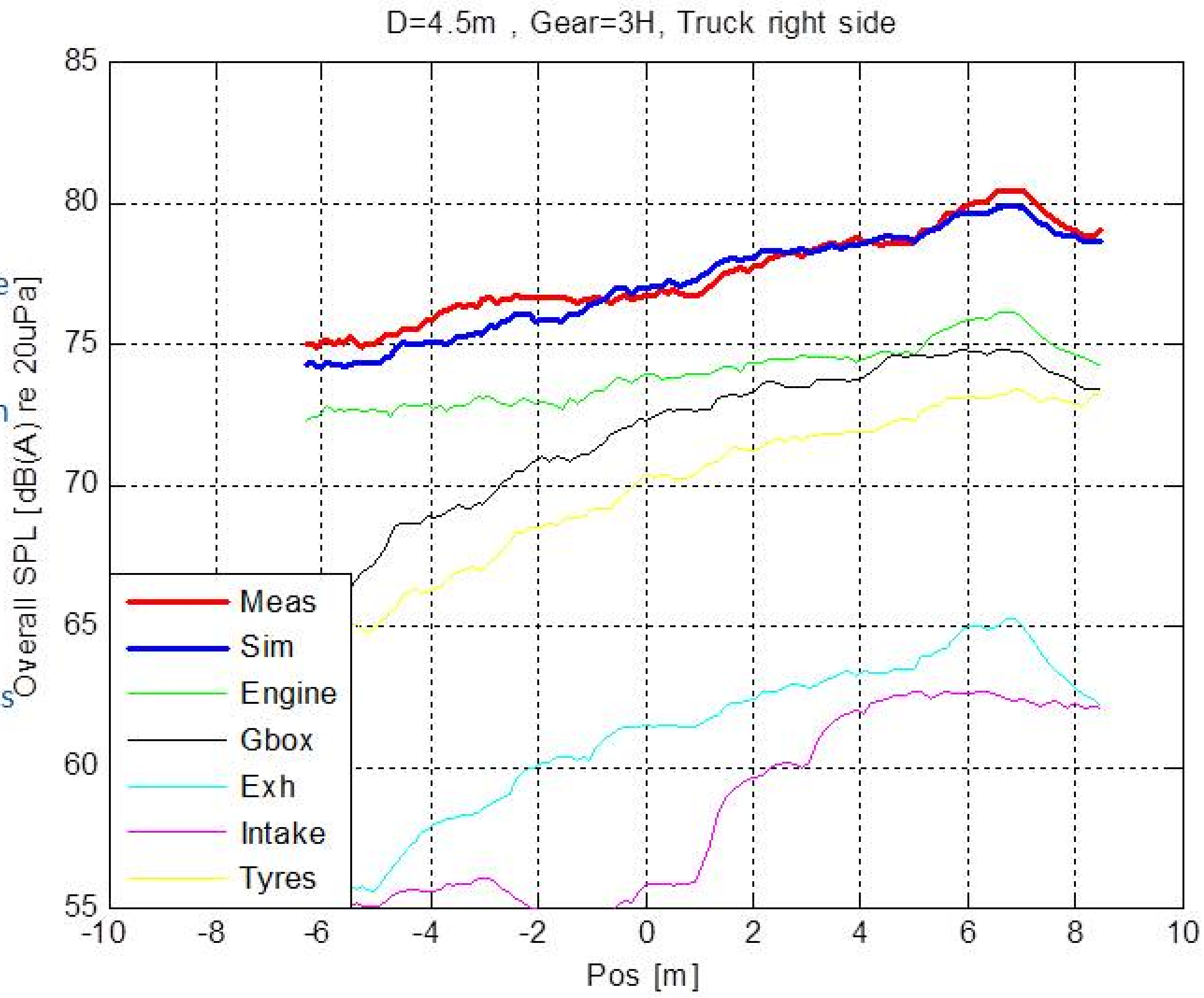
Truck example:

Overall and Individual Source Contributions:

Engine and Gearbox are main contributors at max SPL

Data validation:

Comparison of sum of contributions with total reference measurement gives certainty in results



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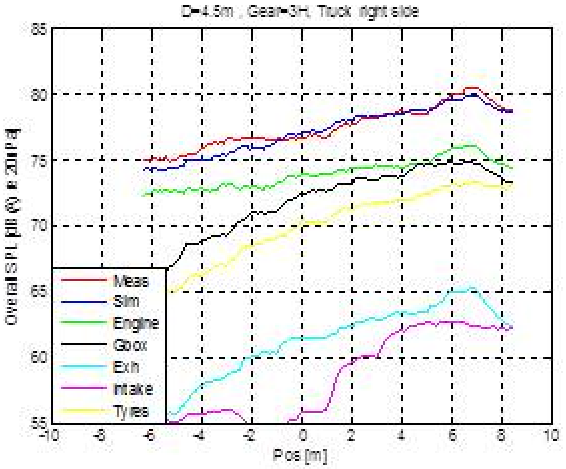
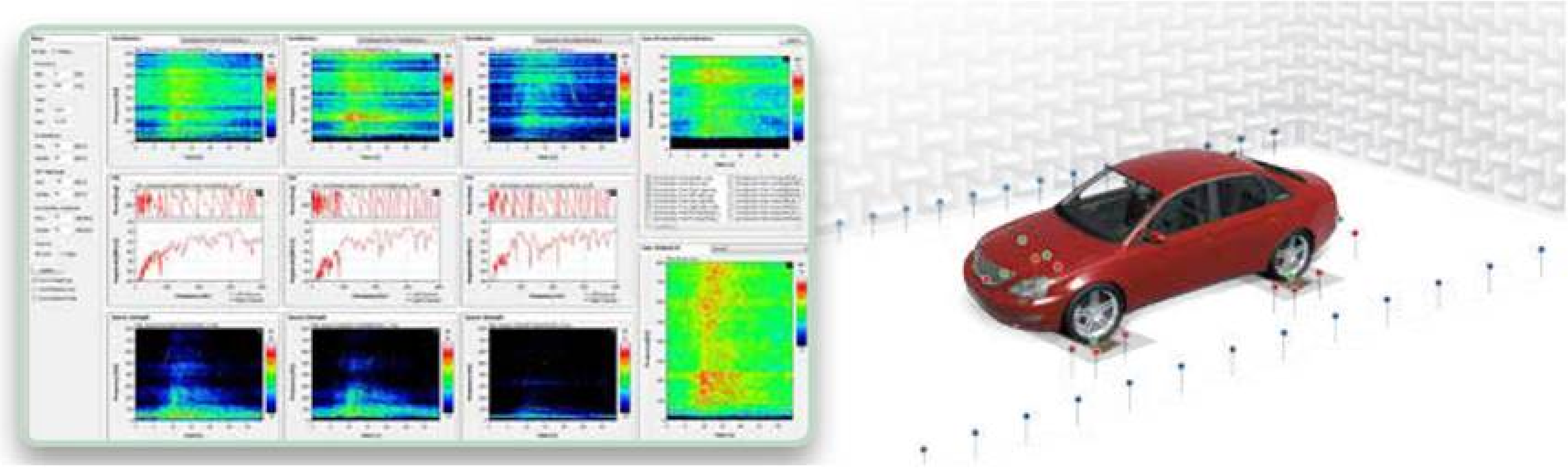
Indoor Pass-by/Contribution Analysis: Summary

- Comprehensive, integrated Indoor Pass-by / Contribution analysis solution
  - Can be configured to various room sizes
  - Tyre Noise Correction allows substitution with tyre noise measured on track
  - Time domain processing allows handling of transients and aural evaluation of contributions
  - Sum of contributions may be compared with measured total to validate component contributions





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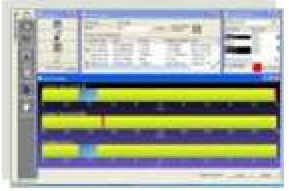
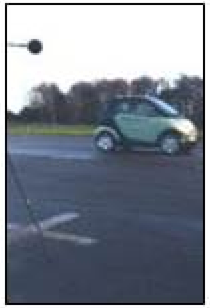
Contents

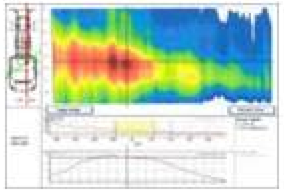
Exterior Noise Summary:
Conformance, Diagnostics, Contribution Analysis, Sound Quality

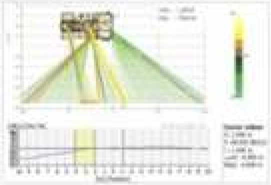
- Field pass-by:
  - 3 steps easy to use, flexible and robust
    - Cars, trucks, motorcycles, tyres…



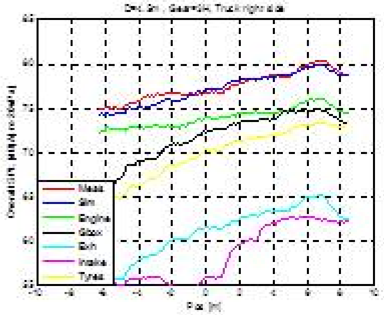


- (Field) Beamforming Pass-by:
  - Fast, Powerful source localisation
    - Developed in cooperation with Truck mfg





- Indoor Pass-by / Exterior SPC:
  - Easy, Accurate contribution analysis
    - developed in cooperation with car mfg
    - Cars, trucks, motorcycles



- Exterior Sound Simulator:
  - When Sound Quality is critical

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BEYOND MEASURE

Conclusion

- Legislation and technology drive the limits for exterioir noise emissions.
- High value business so accuracy and reliability is essential.
- Complex sources to investigate thus different advanced techniques are used to identify them in the Pass-by scenario.
  - Beamforming and Source Path Contribution
- Manufacturers want to know which source is the next problem
  - Not only the primary source is of interest
- With the start of EV/Hybrids exterior noise design is becoming sound quality design, but the approach is used for conventional powertrain vehicles as well.