HBK – Hottinger Brüel & Kjær

EXTERIOR NOISE IN NVH

Finn Kryger Nielsen

December 6 2023

Welcome to today's session

Exterior Noise in NVH

- This Webinar will present solutions related to Exterior Noise in NVH
- This will focus on Exterior Noise from vehicles mainly Cars and trucks.
- This includes
  - Pass by Solutions: Field Pass-by, Indoor Pass-by
  - Minimum noise for Quiet Road Transportation vehicles (EV, HEV, FCEV
  - Moving Source Beamforming
  - Source Path Contribution (Source ranking)
  - Noise Source Identification

Introduction of Finn Kryger Nielsen

- Master of Science EE 1983
- Master of Leadership and Innovation 2008

- 40 Years With (H)BK
  - Marketing
  - Innovation
  - R&D
  - .....

- Solution Architect in Customer Project Sound & Vibration Group

- Family, Bird watching and photographing, Music Playing in a band,

HBK
HOTTINGER BRÜEL & KJÆR

Urban Noise

ROAD TRAFFIC NOISE IS DOMINANT CONTRIBUTOR TO URBAN NOISE POLLUTION

European Environmental Agency report (EEA) Report No. 22/2019 published 5th March 2020…

- “At least 20% of the EU population lives in areas where traffic noise levels are harmful to health”

Regulatory authorities demand reduced noise emissions from road vehicles

ISO 362 pass-by noise test is mandatory under UN/ECE regulations for homologation of road vehicles

- Noise limits, set by regulation, are increasingly strict

UN/ECE R51 limits getting stricter

2016 2020 2024

- M1: Passenger cars
- M2: Small buses
- M3: Large buses

- N1: Pick-up Truck, Van
- N2: Commercial Trucks 3.5t - 12t
- N3: Heavy Trucks >12 tonnes

- L category: motorcycles covered separately by R41

Vehicle category	*Vehicles used for the carriage of passengers*	*Limit Values (dB(A))*		
		Phase 1	*Phase 2*	*Phase 3*
M_1	PMR ≤ 120	72	70	68
	120 < PMR ≤ 160	73	71	69
	PMR > 160	75	73	71
	PMR > 200, no. of seats ≤ 4, R-point height < 450mm from the ground	75	74	72
M_2	$M \leq$ 2.5 t	72	70	69
	2.5 t < M ≤ 3.5 t	74	72	71
	M > 3.5 t; $P_n \leq$ 135 kW	75	73	72
	M > 3.5 t; P_n > 135 kW	75	74	72
M_3	$P_n \leq$ 150 kW	76	74	73
	150 kW < $P_n \leq$ 250 kW	78	77	76 2026
	P_n > 250 kW	80	78	77
Vehicle category	*Vehicles used for the carriage of goods*	*Phase 1*	*Phase 2*	*Phase 3*
N_1	$M \leq$ 2.5 t	72	71	69
	M > 2.5 t	74	73	71
N_2	$P_n \leq$ 135kW	77	75 2022	74
	P_n > 135 kW	78	76	75
N_3	$P_n \leq$ 150 kW	79	77	76 2026
	150 kW < $P_n \leq$ 250 kW	81	79	77
	P_n > 250 kW	82	81	79

HBK HOTTINGER BRÜEL & KJÆR

Pedestrian Safety

MINIMIZE THE RISK POSED BY SILENT CARS (HEV AND EV)

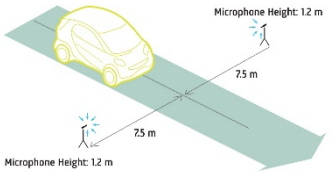
It seems that Quiet Road Transportation Vehicles (HEV,FCEV,BEV) is responsible for more injuries compared to conventional ICE due to lower noise

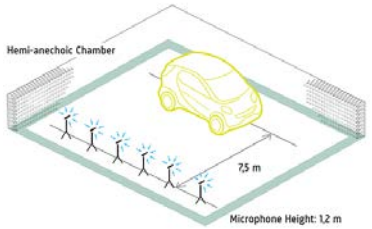
Regulatory authorities demand increased sound emissions from from QRTV.

- R138 is mandatory to minimum noise under UN/ECE re gulations for homologation of road vehicles
- US has adopted a slightly different Regulation in yhe US called FMVSS 141

Vehicle Exterior Noise Engineering Solutions

	Homologation CoP	R&D Testing

Field 	• Traditional Pass By
	  • Single track
	  • Multi vehicle pass-by
	• QRTV testing
	  • R138
	  • FMVSS 141
		• Traditional Pass By
		  • Single track
		  • Multi vehicle pass-by
		• Moving Source Beamforming

Indoor 	Now allowed to be used for homologation and conformity of production	• Indoor pass-by system
		  • ISO-362-3
		  • Can be <7.5 m but at least 5.5 m
		  • Contribution analysis
		• Noise Source Identification
		  • Beamforming
		  • Wide band Holography

HBK HOTTINGER BRÜEL & KJÆR

Exterior Noise

FIELD PASS-BY TESTING

Solutions designed for high productivity Pass-by testing

- according to current ISO standards
- and UN/ECE regulations

Maximum noise

Simple telemetry-based solutions

- Single car transmitting vehicle parameters to Ground station

Advanced /Multivehicle) testing

- Testing one many cars on same track
- Scalability of In-vehicle sound and vibration measurement channels

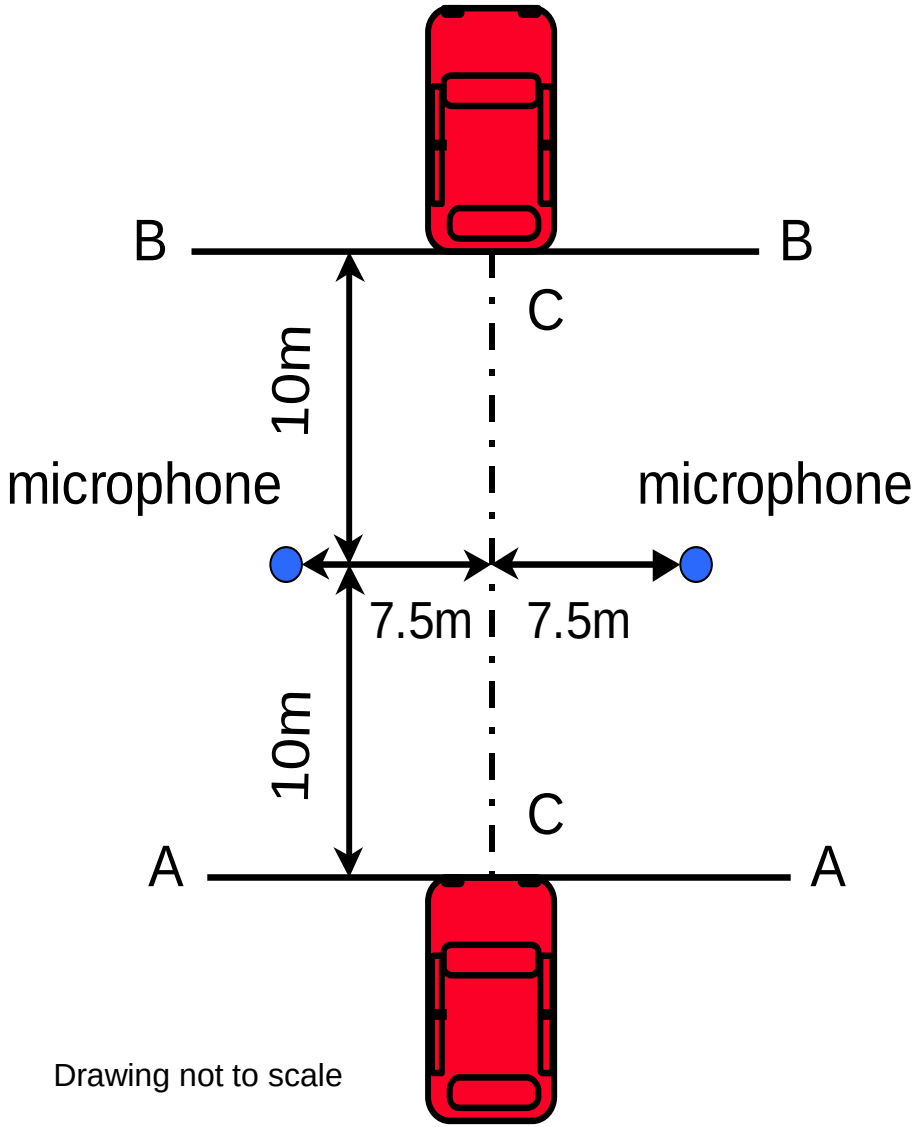
Minimum

QRTV testing on EV/HEV/FC according to QRTV Regulations

- Outdoor and Indoor

HBK HOTTINGER BRÜEL & KJÆR

ISO 362-1 Pass-by Noise Test Method



Meteorological conditions:
Temperature range 5 to 40 °C
Wind speed < 5 m/s
Road-surface temperature 5 to 60 °C

Track surface must conform to ISO 10844

Background noise must be greater than 10dB below measured level (15dB recommended)

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

4 consecutive, consistent measurements

HBK HOTTINGER BRÜEL & KJÆR

ASEP: Aditional Sound Emission Provisions

- ASEP will be included in the type-approval procedure and the existing derogations for certain vehicle types revised
- ASEP are preventive requirements intended to cover driving conditions of the vehicle in real traffic outside the type-approval driving cycle
- These driving conditions are environmentally relevant and it needs to be ensured that the sound emission of a vehicle under street driving conditions does not differ significantly from the vehicle tested.

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):

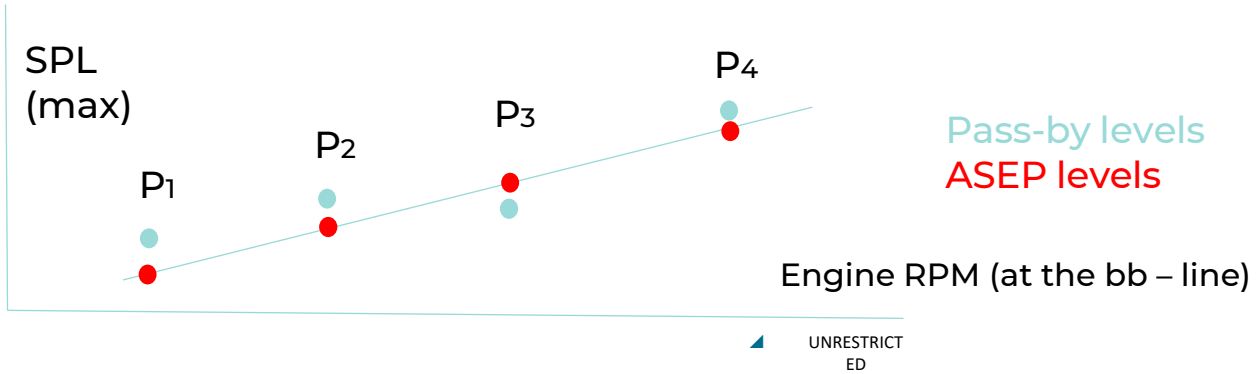
- 4 additional pass-by runs are required for every gear ratio, that leads to acceptable test results

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)

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



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

HBK HOTTINGER BRÜEL & KJÆR

Real Driving - Additonal Sound Emmision Provision

- an internal combustion engine (ICE) for propulsion of the vehicle, or
- any other propulsion technology fitted with an exterior sound enhancement system.

- A measurement for RD-ASEP is valid, if all parameters are within the specifications of the table below during the test run between lines AA' and BB'.

Parameter	*Minimum*	*Maximum*
Vehicle Speed	> 0 km/h at line AA'	100 km/h at line BB'
Acceleration	0 m/s²	4 m/s²
Performance	0 m²/s³	35 m²/s³
Gear	ANY for forward driving	
Mode	ANY	

- In any operation condition, the engine speed of a vehicle, which can be propelled with an ICE operating, is limited to 80% of engine rotational speed at maximum power

HBK
HOTTINGER BRÜEL & KJÆR

RD ASEP

- The target operation condition for a single test run is randomly selected by the authority present during the tests carried out for type approval.
- The operation condition during measurements per run is defined by
  - the gear selector position,
  - the vehicle mode,
  - the vehicle entry speed at line AA'
  - the percentage of accelerator depression, either for constant speed or in steps of 25 % acceleration depression.

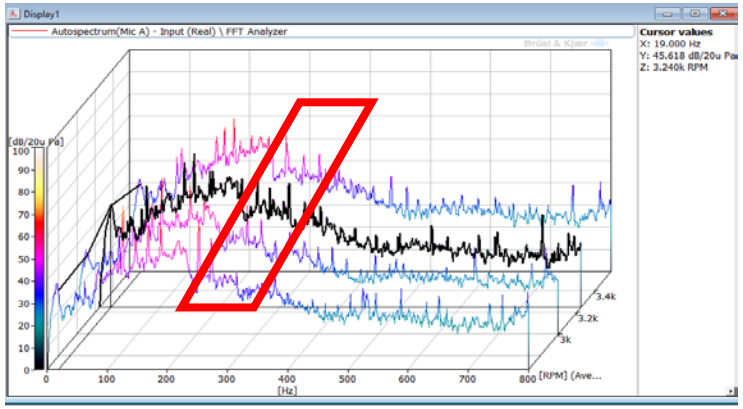
- RD-ASEP measurements are compared to the Sound Expectation Model depending on Car type; ICE, HEV, FCEV, BEV based on the WOT and CRS measurements from Annex 3 plus FRN corrected.

Minimum Noise - R 138 QRTV (Quiet Road Transp. Vehicle)

- Aim
  - to minimize the risk posed by silent cars (HEV and EV), without creating a disturbing level of traffic noise

- Including:
  - Minimum AVAS (Acoustic Vehicle Alerting System) sound levels
  - Frequency shift

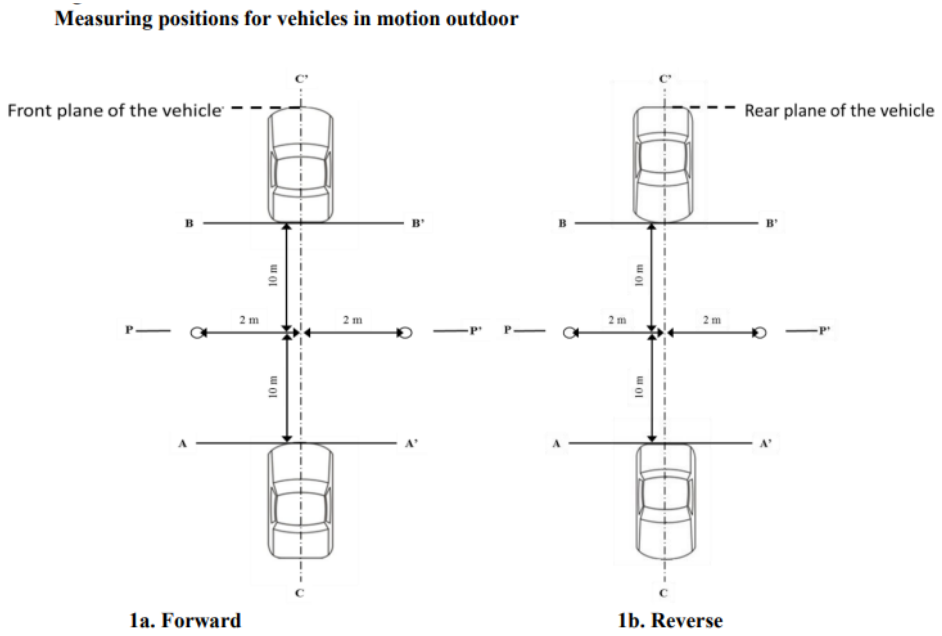
- Outdoor facility and vehicle in motion
  - 5 km/h to 20 km/H in steps of 5 km/h
- Outdoor/Indoor facility and vehicle in standstill
  - Signal to AVAS corresponding to speeds for vehicle in motions
- Indoor facility and vehicle in motion
  - 5 km/h to 20 km/h in steps of 5 km/h
- AVAS mounted rigidly in an indoor facility
  - microphone of the measuring instrument shall be placed at 1 m distance from the AVAS in the direction where the subjective sound level is greatest



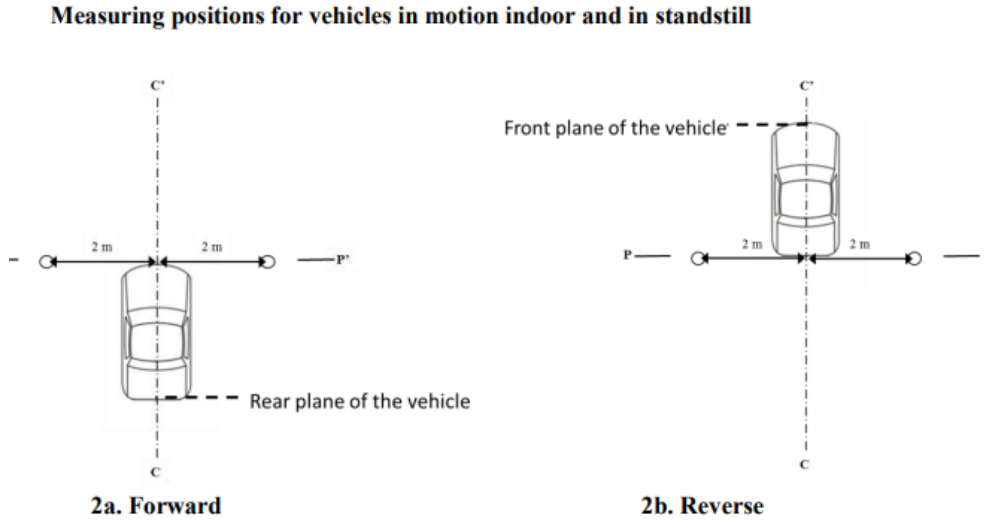
R138 QRTV

Measurements positions in Motion and Standstill

Outdoor



Indoor and Standstill outdoor



FMVSS 141 - Minimum Sound Requirements for HEV and EV

- Aim
  - Ensure that electric vehicles (EV) or hybrid vehicles (HEV) produce sounds so both blind and sighted pedestrians can more easily detect and recognize by hearing these vehicles avoiding accidents
- Conduct compliance testing outdoors
- Audible noise must be produced when reversing or at forward speeds of up to 19 miles (30 kilometres) per hour.
  - Stationary
  - Directivity
  - Reverse
  - Volume Change
- Audible alerts are not required above the said speed, chiefly because tire and wind noise at higher speeds provide adequate warning to pedestrians.

FMVSS 141 Tests and evaluations

Only Outdoor

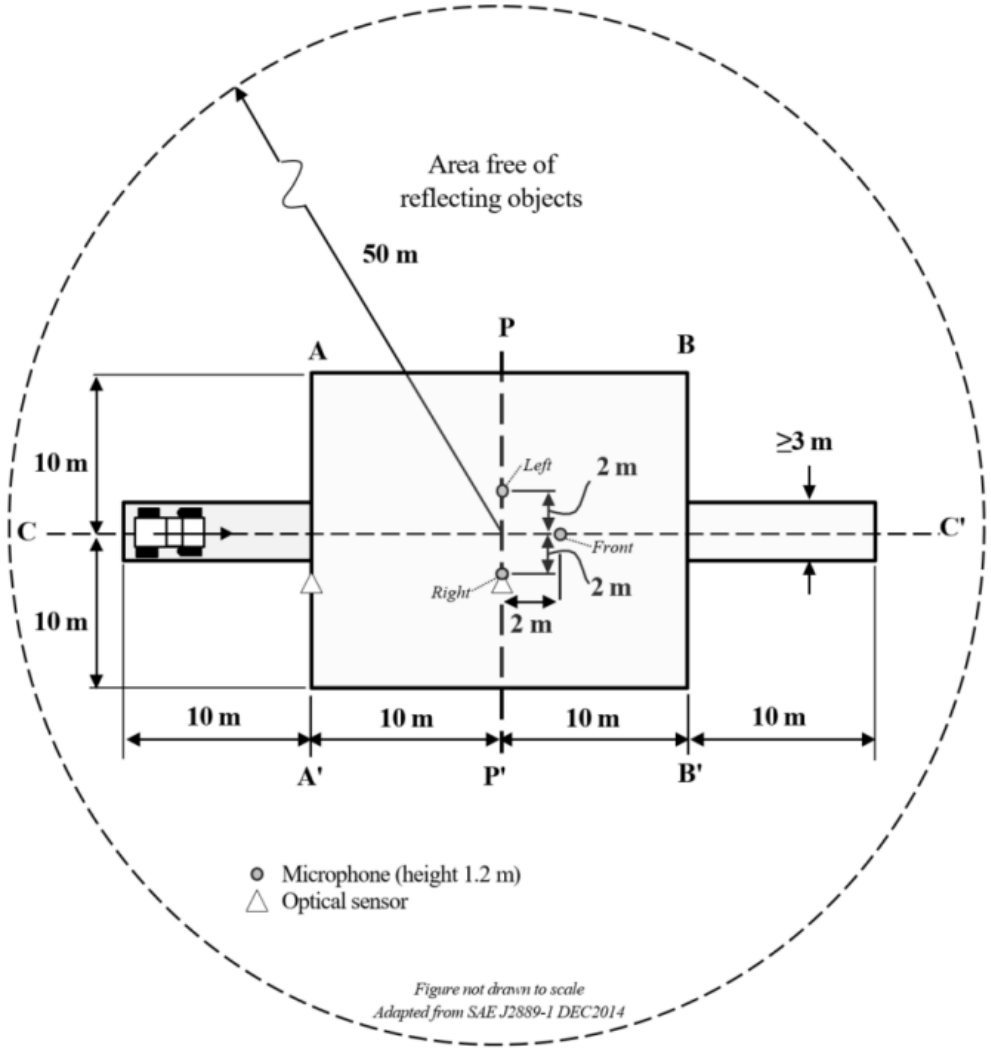
Record Data accoording to spedified conditions

- Stationary Test
- Reverse Test
- Constant speed Pass-by Test - 11 km/h
- Constant speed Pass-by Test - 21 Km/h
- Constant speed Pass-by Test - 31 km/h

Evaluation

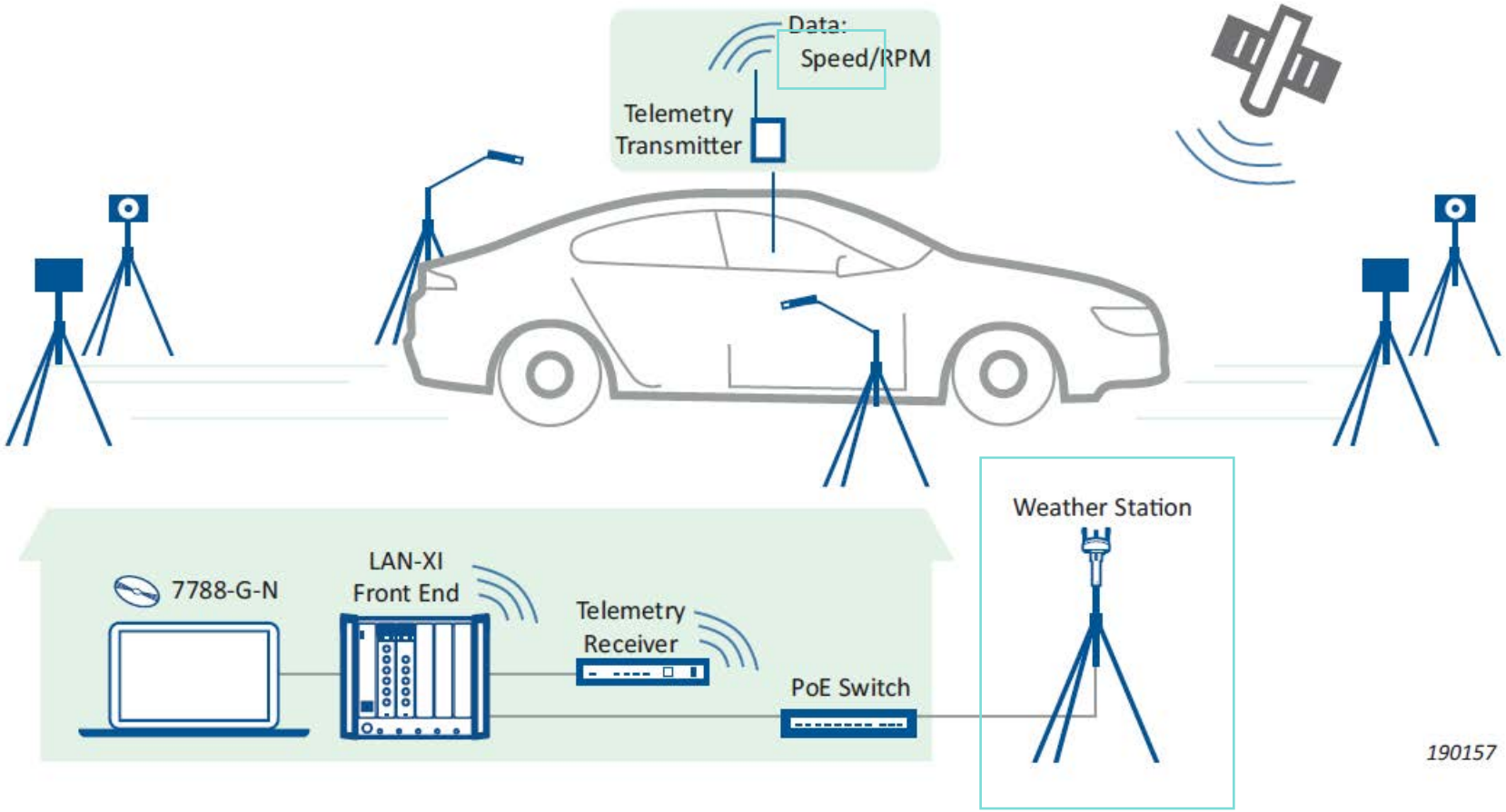
4 1/3 Band or 2 1/3 Octave Band
Relative Volume Change

- Based on Constant Speed pass-by test

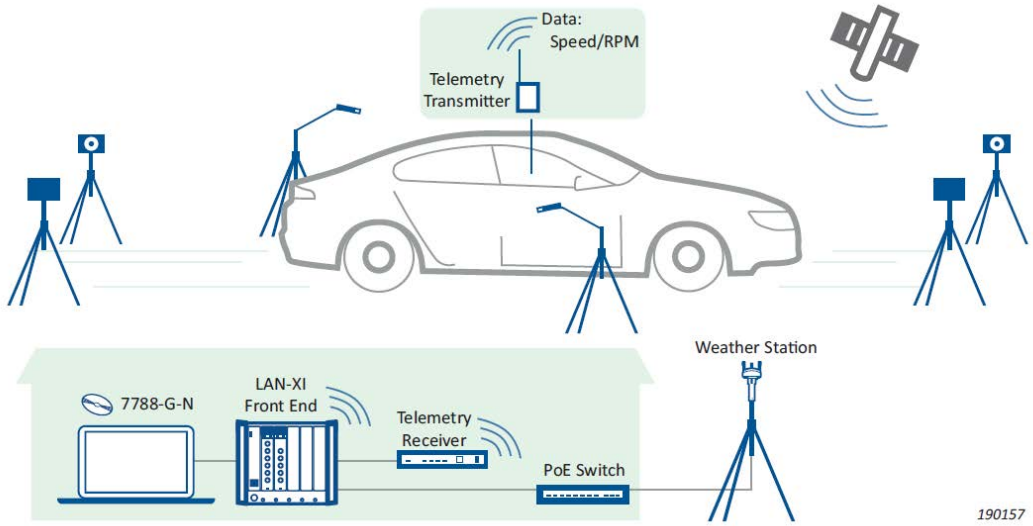


HBK
HOTTINGER BRÜEL & KJÆR

Basic Field Pass-by



Basic Field Pass-by



Field Pass-by system for homologation

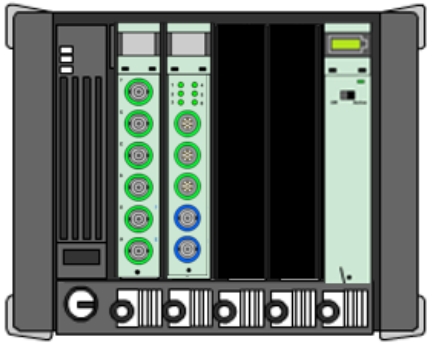
- Measurement controls from ground
- Automatic test plan according to Legislation/Standard
- Simple and fast setup for cars, trucks and motorcycle test
- Radio Telemetry provides
  - Rpm and pedal throttle signals to ground
  - GPS signal from in vehicle measurements as alternative to radar
- Monitors weather data
- Supports bi-directional testing
- Advanced post-processing of stored time data in BK Connect

HBK
HOTTINGER BRÜEL & KJÆR

LAN-XI Ground station with 2 CH (or option for 3CH) telemetry

MM-0256-W-002

UL-1102-X-YYY---



Ground station

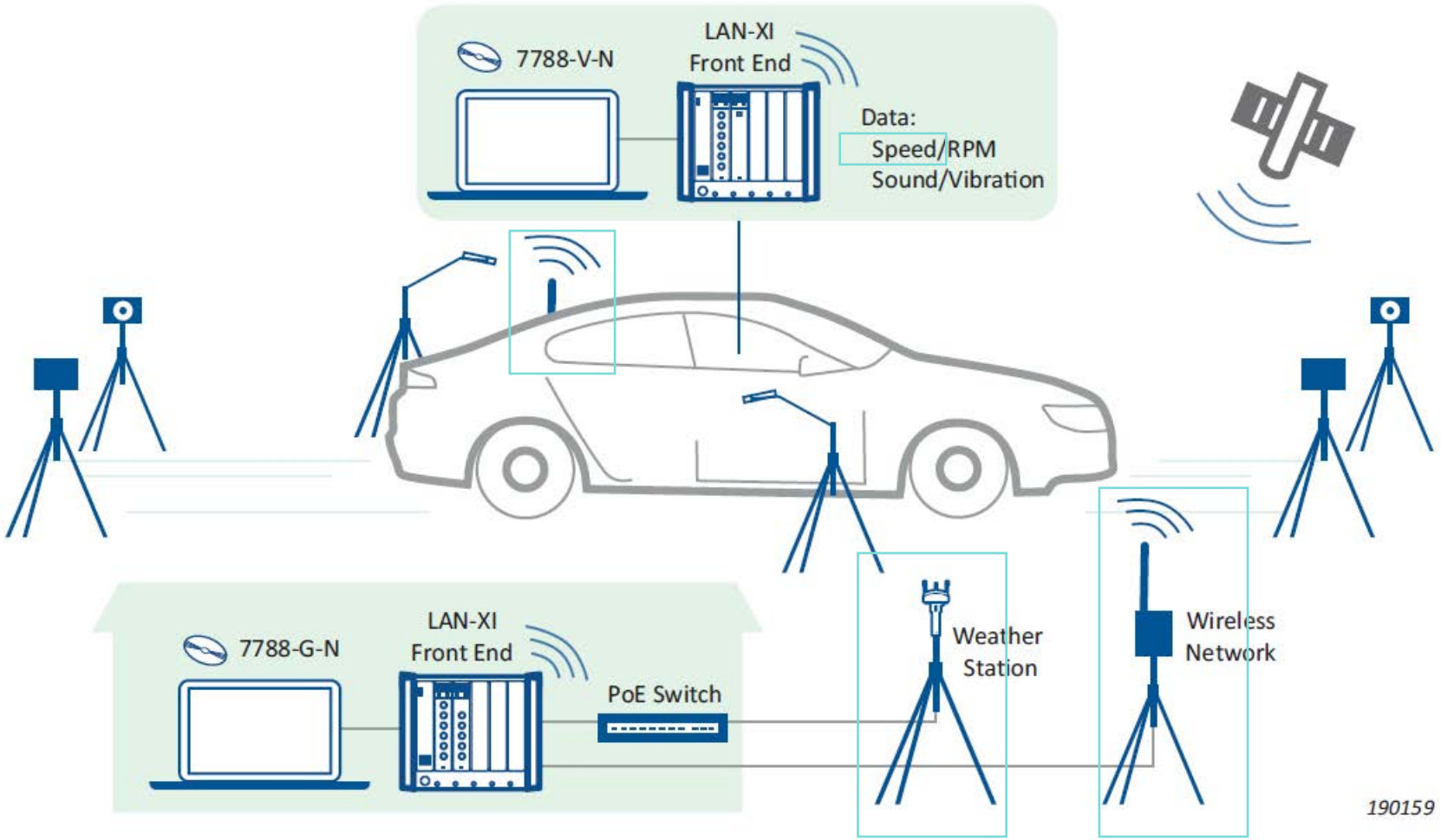
2 CH telemetry

Racelogic GPS Speed sensor

Vehicle station

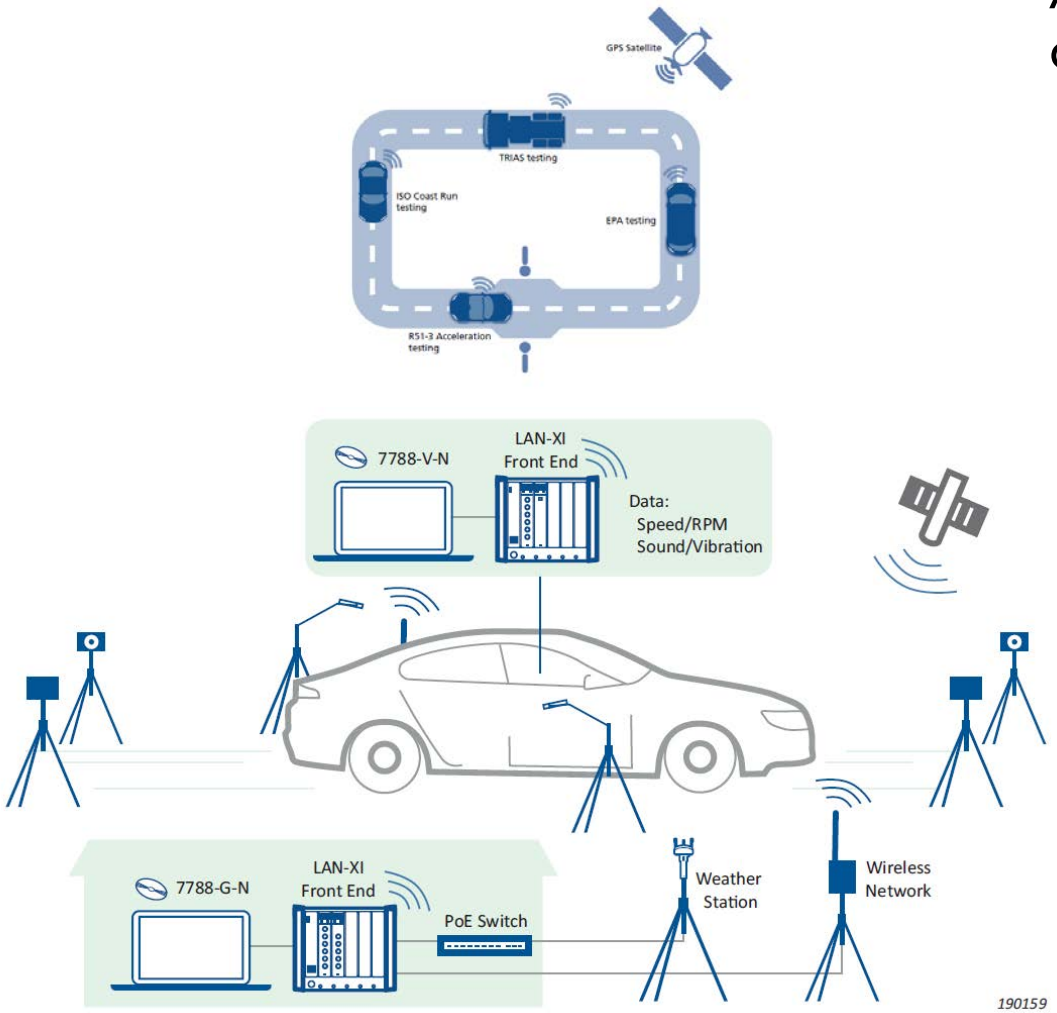
HBK
HOTTINGER BRÜEL & KJÆR

Advanced Field Pass-by



HBK
HOTTINGER BRÜEL & KJÆR

Advanced Field Pass-by



Advanced Field Pass-by system for Product optimization

- Measurement controls in vehicle to guide the driver during test
- Support for multi-vehicle test setup
- On-vehicle sound and vibration measurement channels for correlation with pass-by microphones
- Standard LAN-XI hardware provides
  - Scalability: add more channels as needed
  - Ground – Vehicle data synchronization via built-in GPS support
- Merge of time data/data validation/analysis after test run or later
- Supports bi-directional testing
- Advanced post-processing of stored time data in BK Connect

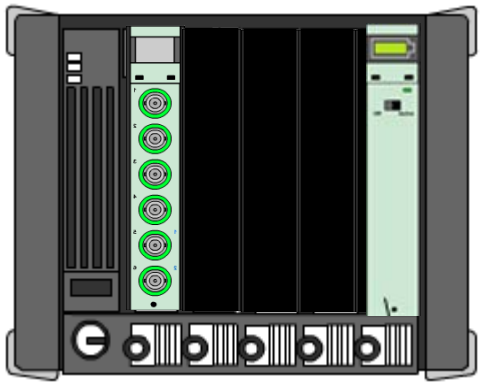
HBK
HOTTINGER BRÜEL & KJÆR

Multi vehicle setup with shared ground station

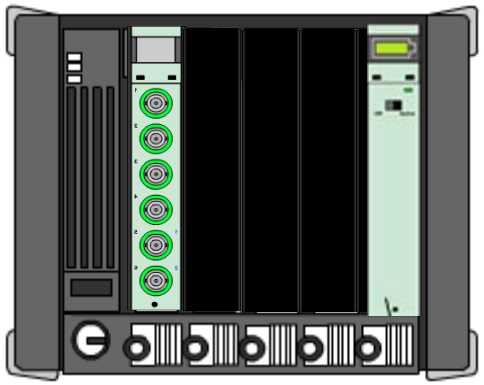
WQ-3207-W-001-

WQ-3207-W-001-

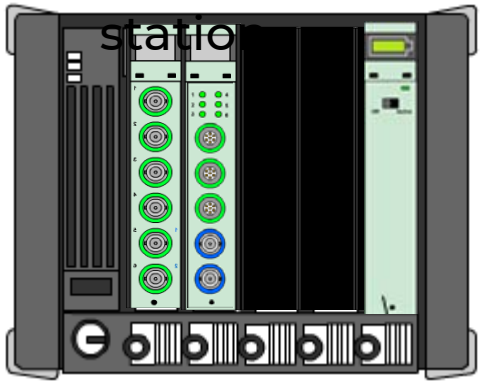
Vehicle 1

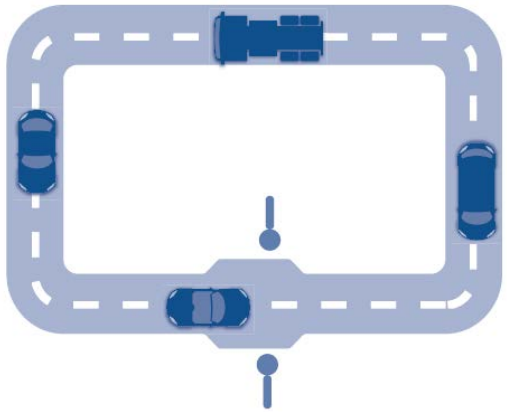


Vehicle 2



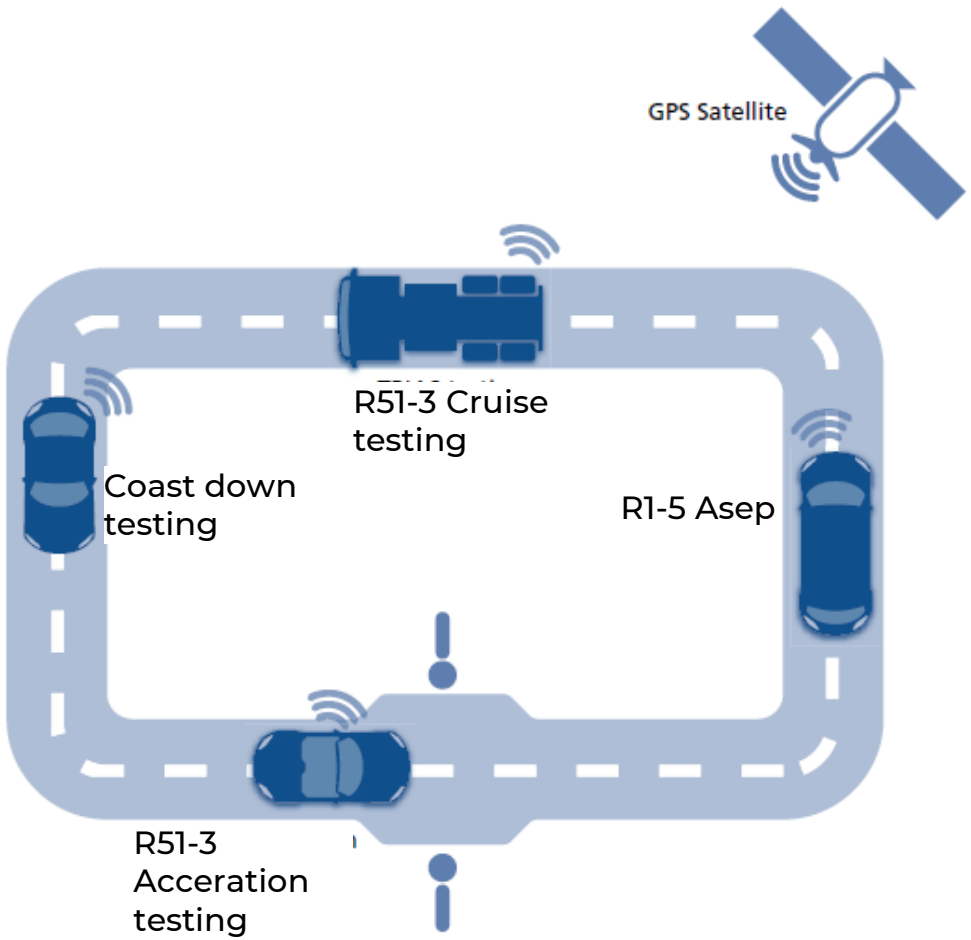
Ground station





HBK
HOTTINGER BRÜEL & KJÆR

Advanced Field Pass-by Multi-vehicle testing

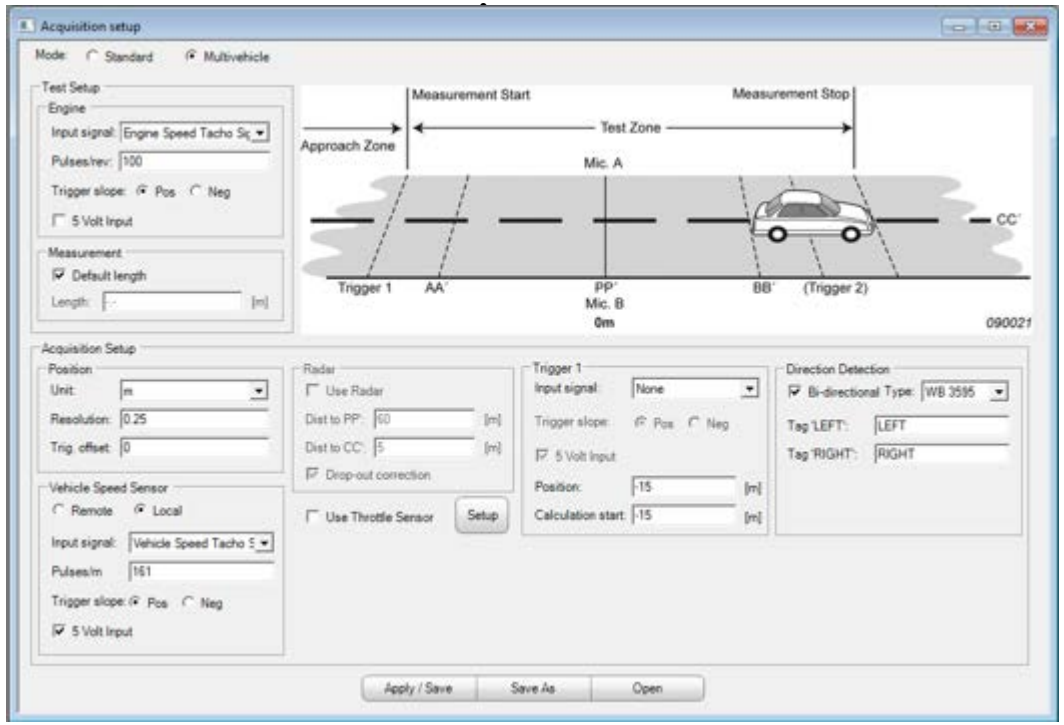


- Multiple vehicle stations can exist and be operational at the same time on the same course using the same single ground station
- Each vehicle can be measured based on different standards or regulations
- System supports bi-directional testing !
- No need for the Ground Station Operator

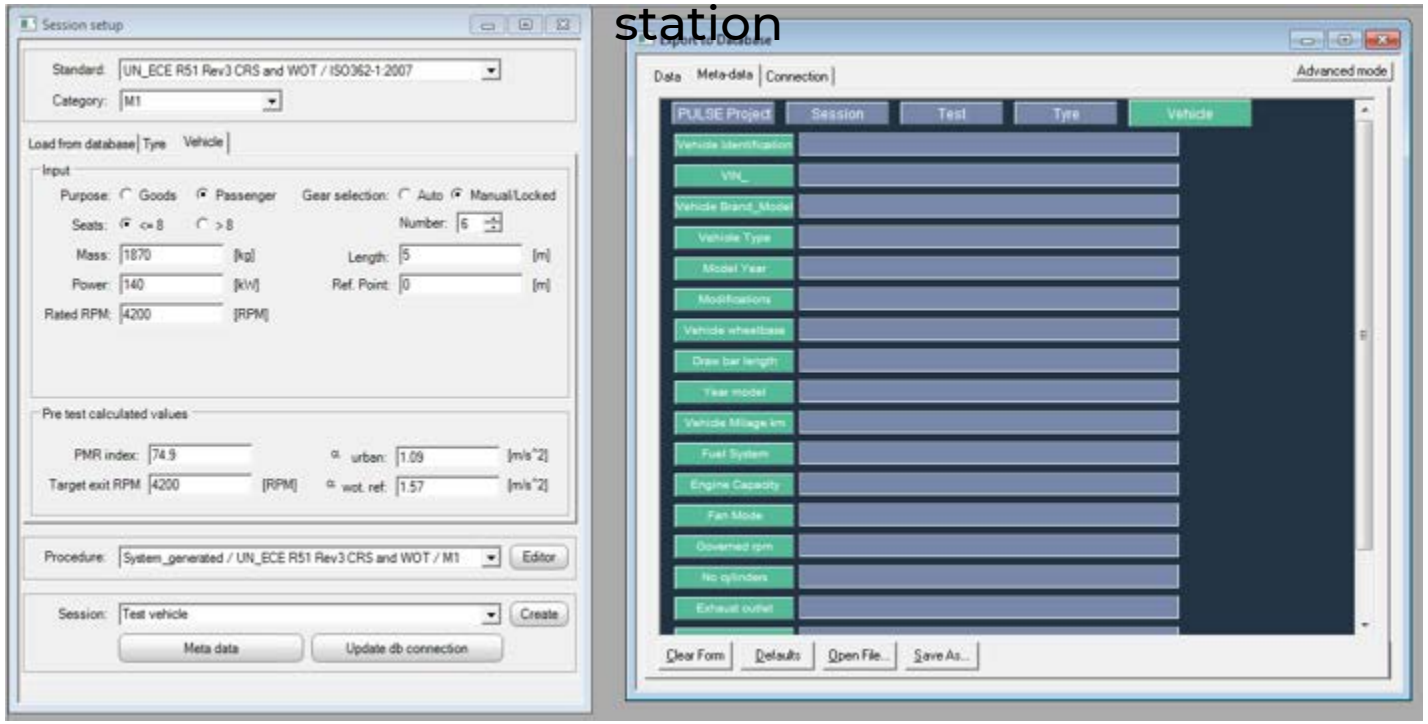
HBK
HOTTINGER BRÜEL & KJÆR

In-vehicle system setup

Vehicle



Vehicle station



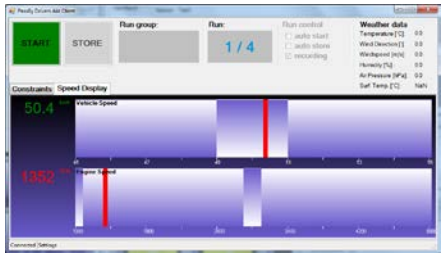
1. Acquisition setup
   - GPS speed , photocells, engine speed etc

2. Session setup
   - Select standard/Reulation and define metadata (vehicle, test)

Analysis results display

Vehicle station

Drivers aid

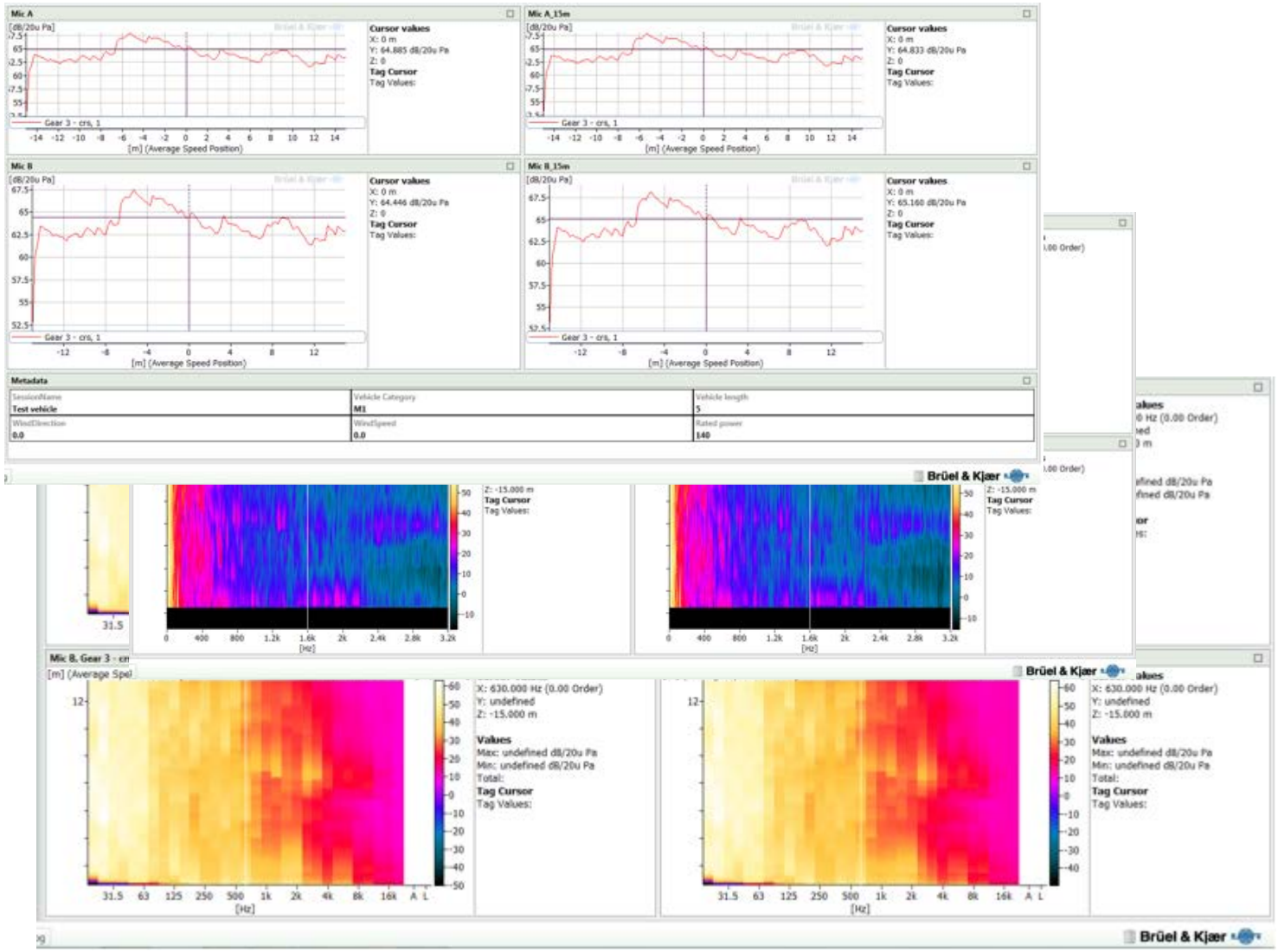


Ground station

- After the data merge and analysis, the results are displayed for validation in the vehicle:
  - Constraints table
  - SPL, vehicle/engine speed vs position
  - Total test results

Post-processing of pass-by data in BK Connect

- Pass-by data (Overall, FFT, CPB vs position)
- User-definable averaging of runs in Result Matrix
- General post-processing
  - Order analysis
  - Data comparison



HBK HOTTINGER BRÜEL & KJÆR

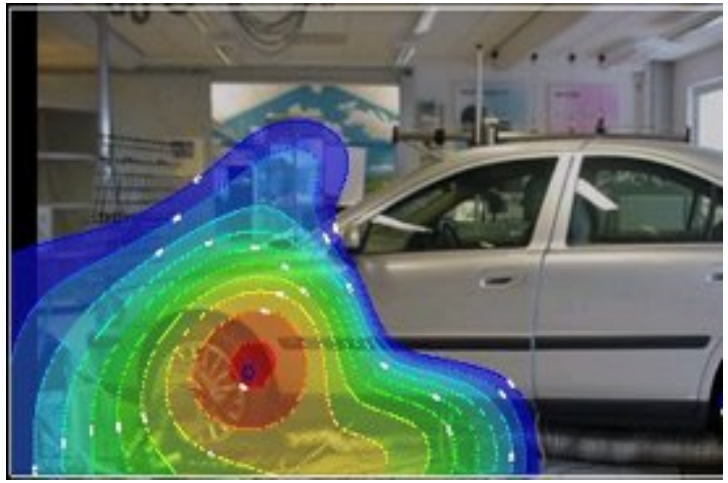
Pass-by: Short Summary

- Simple Telemetry – based system for two – wheelers and homologatio and conformance of production
- Multi-vehicle: High productivity, single person operation
  - For homologation and R&D
- Accurate test results available also under adverse WLAN conditions
- LAN-XI: standard front-ends, scalable (add channels as needed)
- Special connection module supporting photocells and radar simplifies cabling
- Highly accurate sample basis GPS synchronization of ground/vehicle time files
- Time data merge after test: accurate, robust
  - Merge data after each run
  - Merge data when feasible
- Step by step procedure makes ASEP testing straightforward
- Advanced post-processing in BK Connect supports comparison of multiple tests, order analysis, reporting

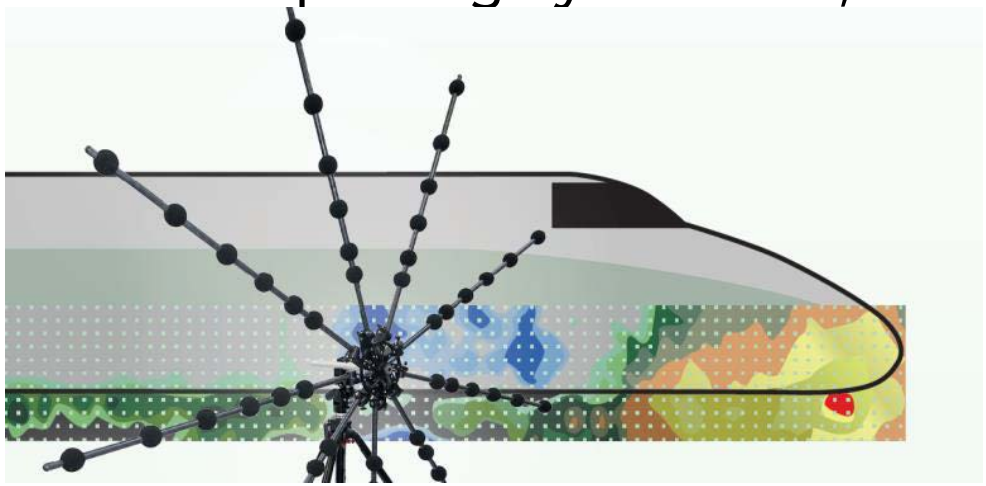
Exterior Noise Engineering

NOISE SOURCE IDENTIFICATION

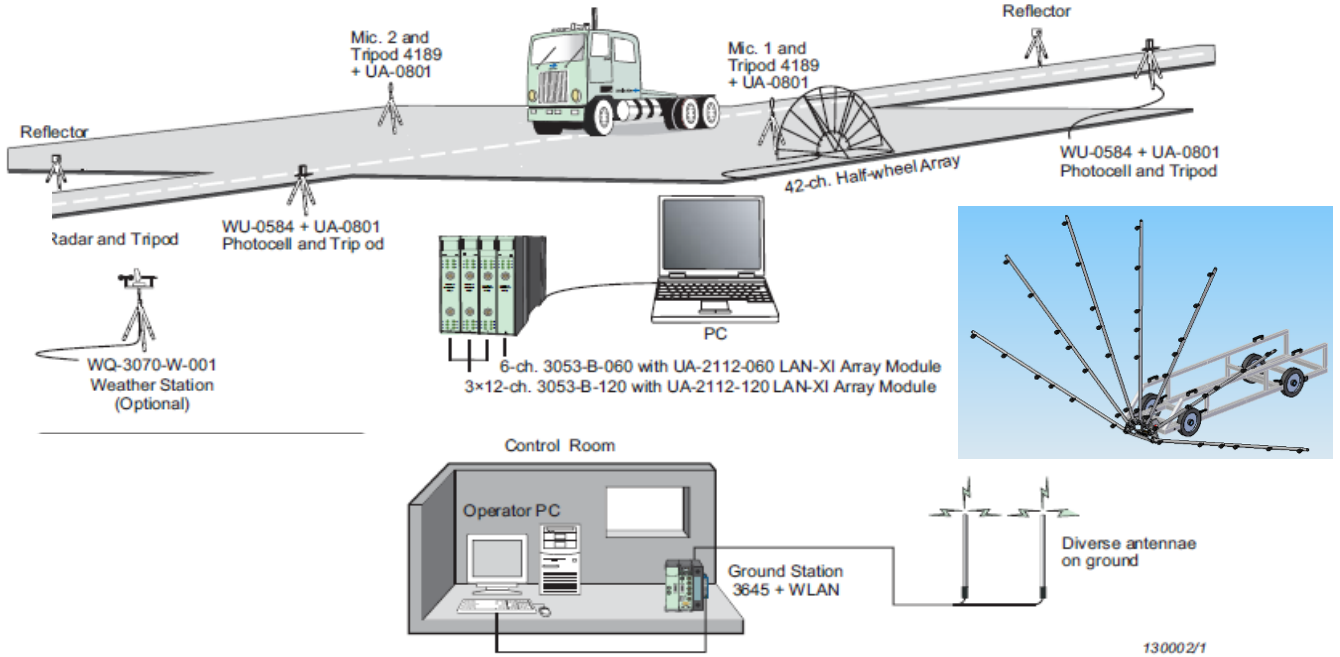
- Position: From where is noise radiated
- Frequency content: What are the characteristics of the noise
- Quantify contributions: How important is it?
- Identify areas to improve



- Identify where noise source emits from the Vehicle
- Moving Sources NSI while passing by: Vehicles, Trains

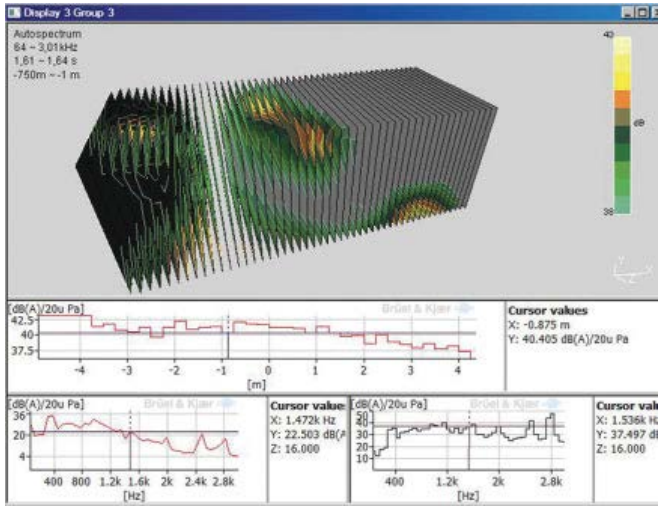


Field Pass-by R&D

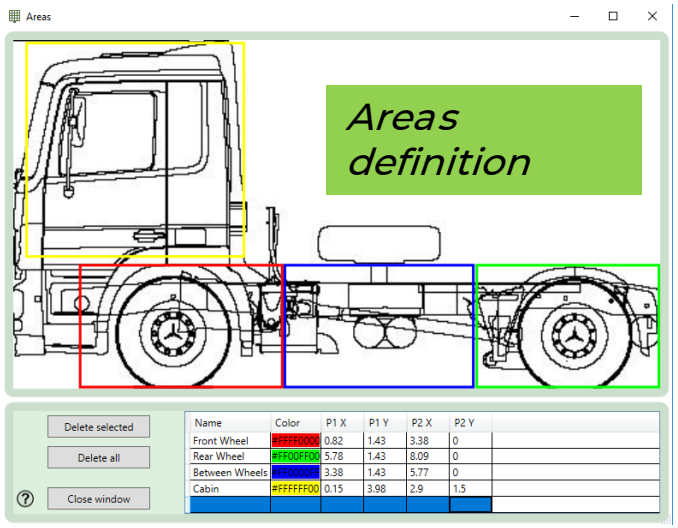


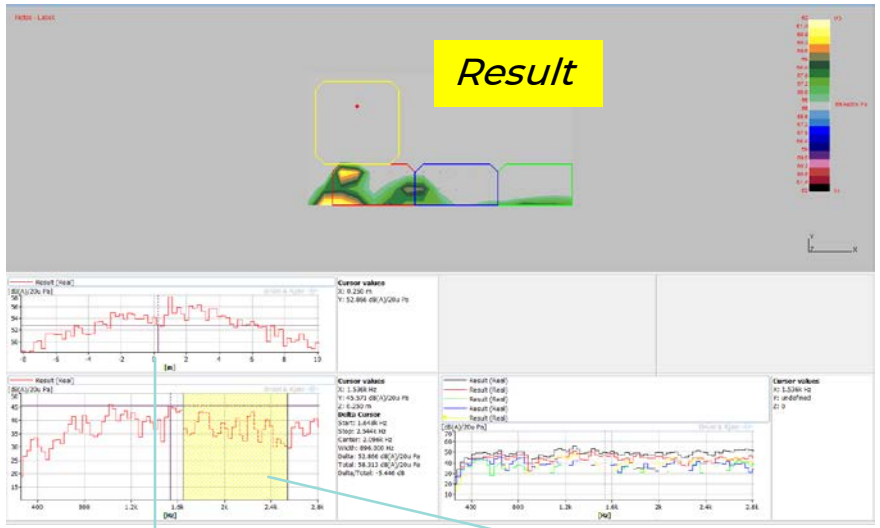
Moving Source (Pass-by) beamforming

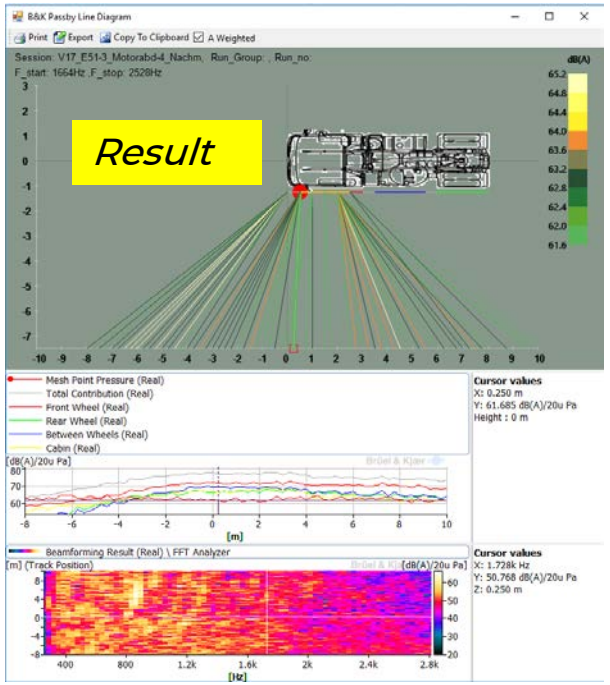
- Helps identify the main noise sources when doing Pass-by testing
- Use stand-alone or integrated with ISO pass-by (same test run)
- Easy setup in the morning/tear down in the evening
- Noise mapping versus vehicle position and contributions from noise sources
- Mapping of planes from the side, front and top of the vehicle
- Line diagram showing sources of maximum sound pressure levels as a function of vehicle position on track
- Easy comparison with ISO Pass-by data

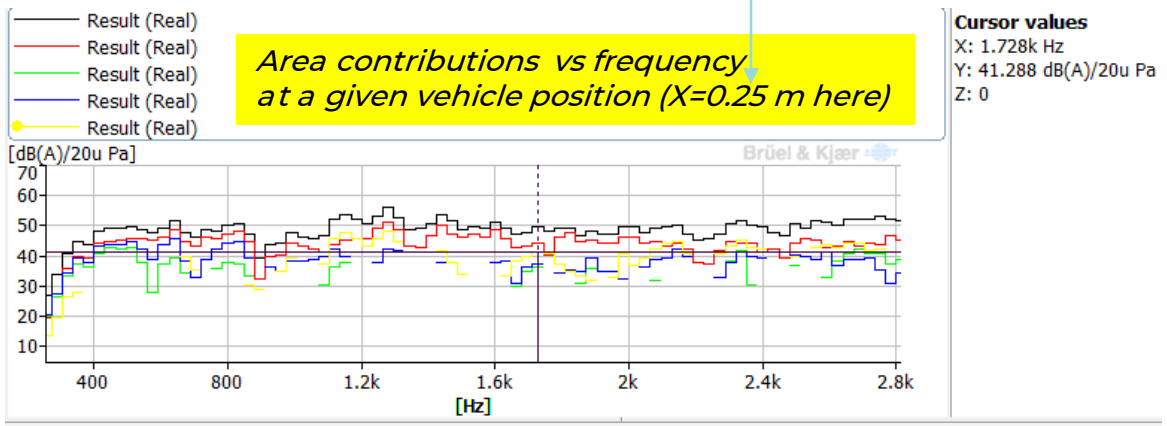


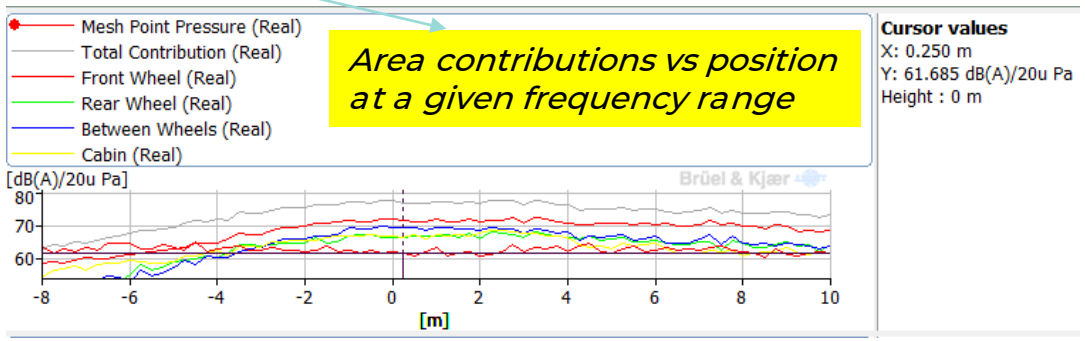
Moving Source (Pass-by) beamforming





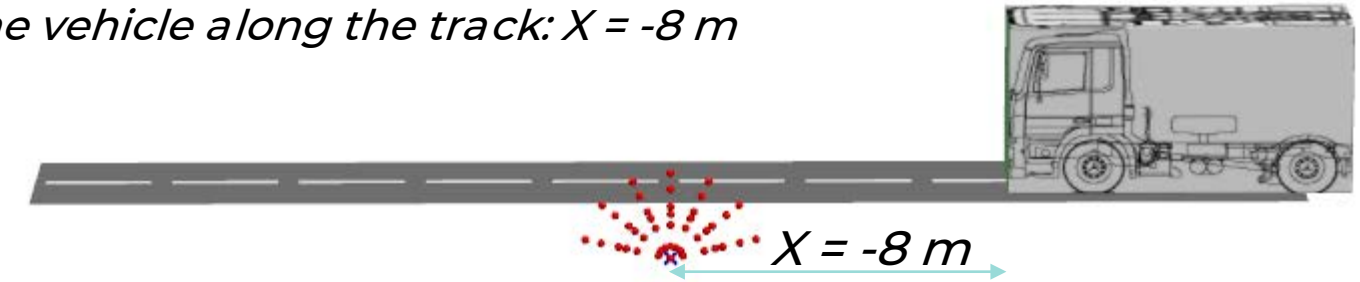


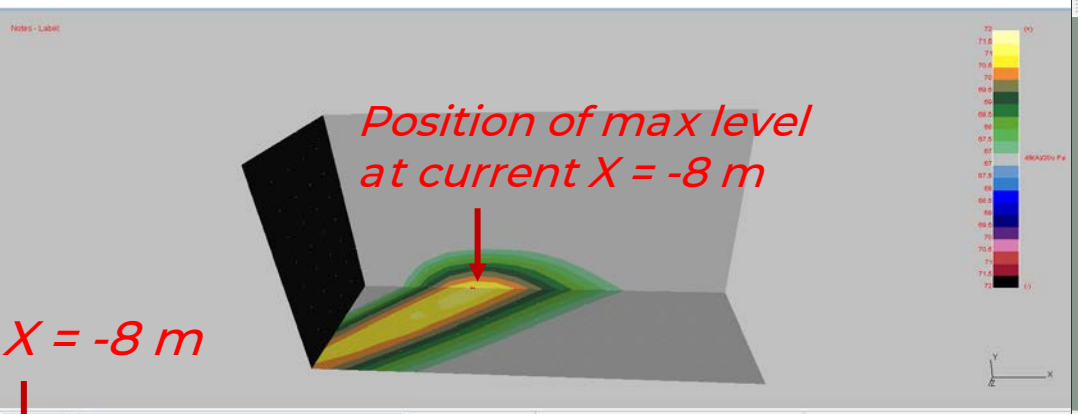


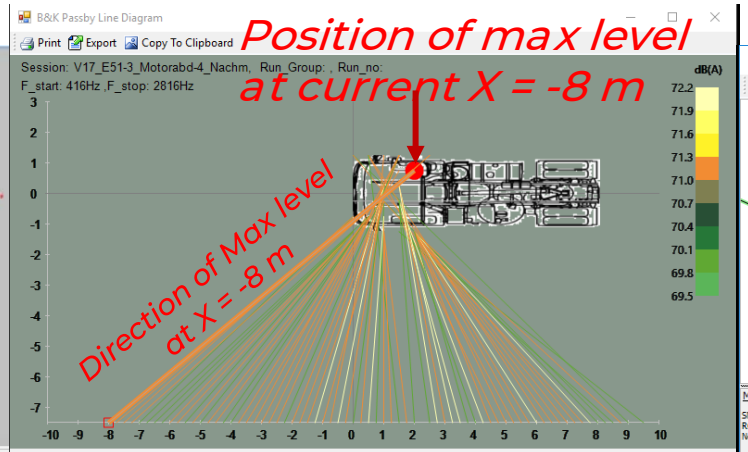


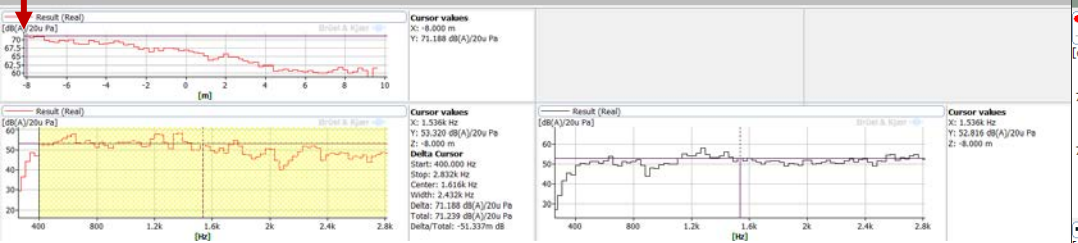
Moving Source Beamforming - example

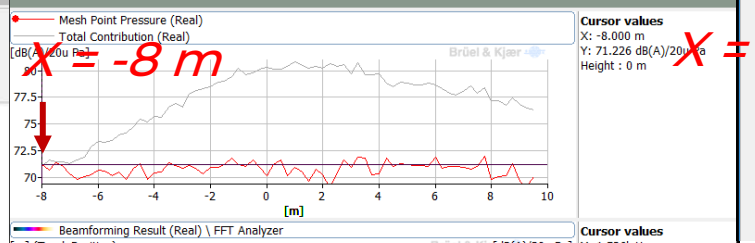
Position of the vehicle along the track: X = -8 m

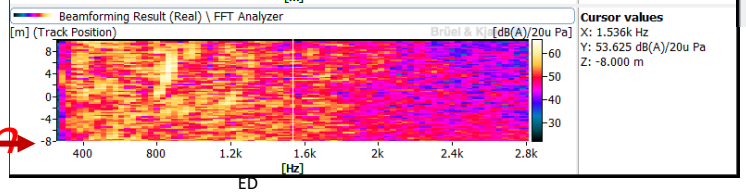


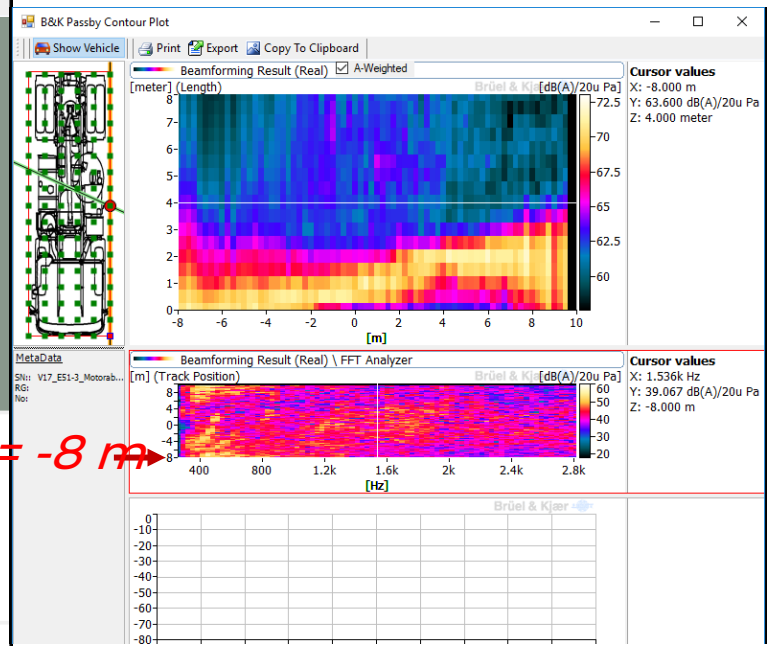








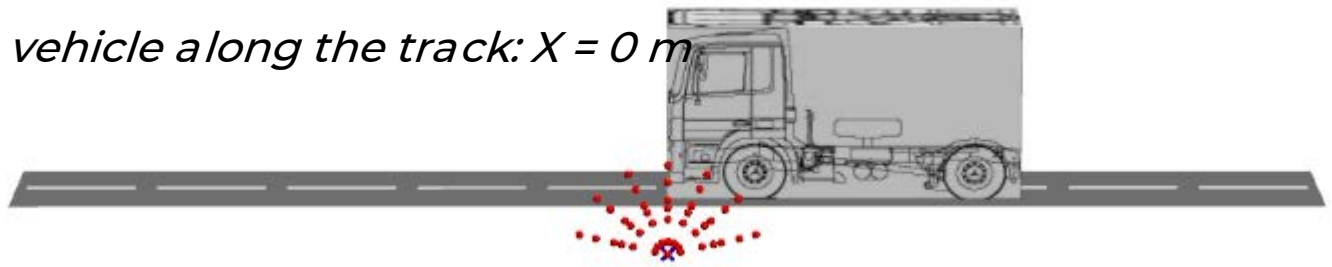


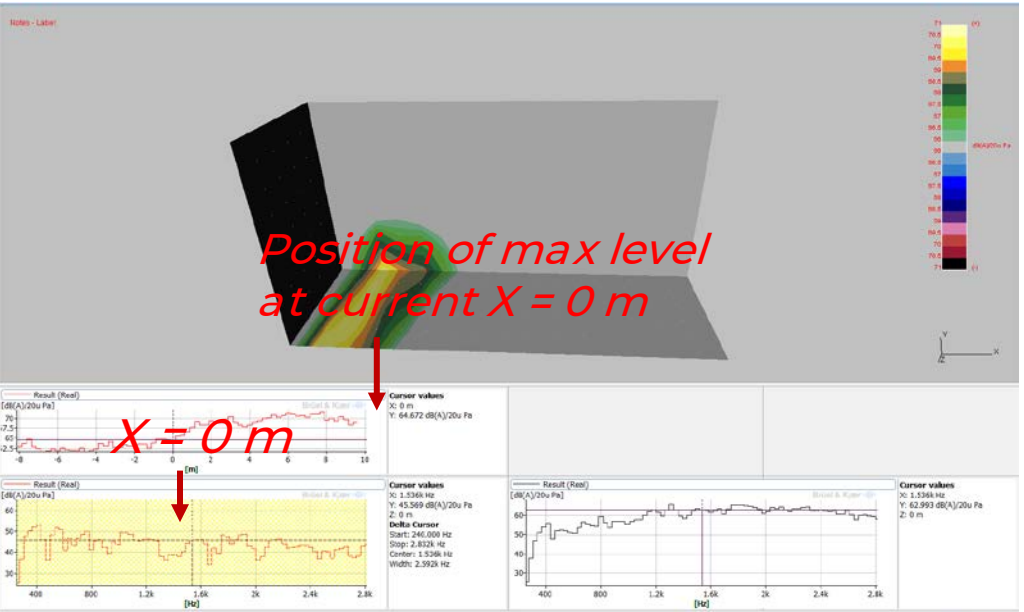


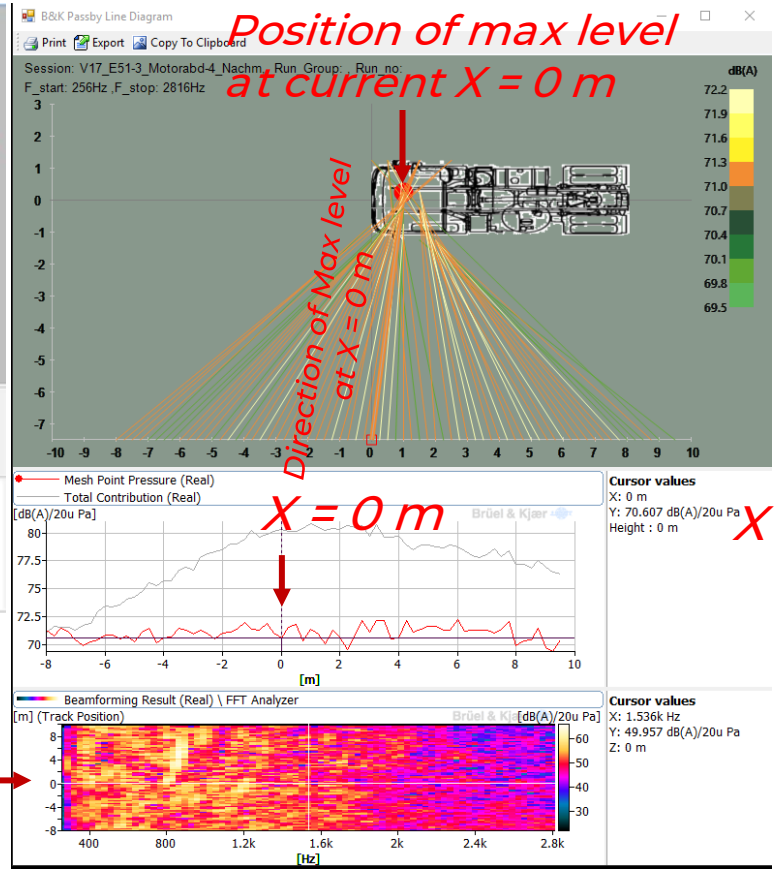
ED

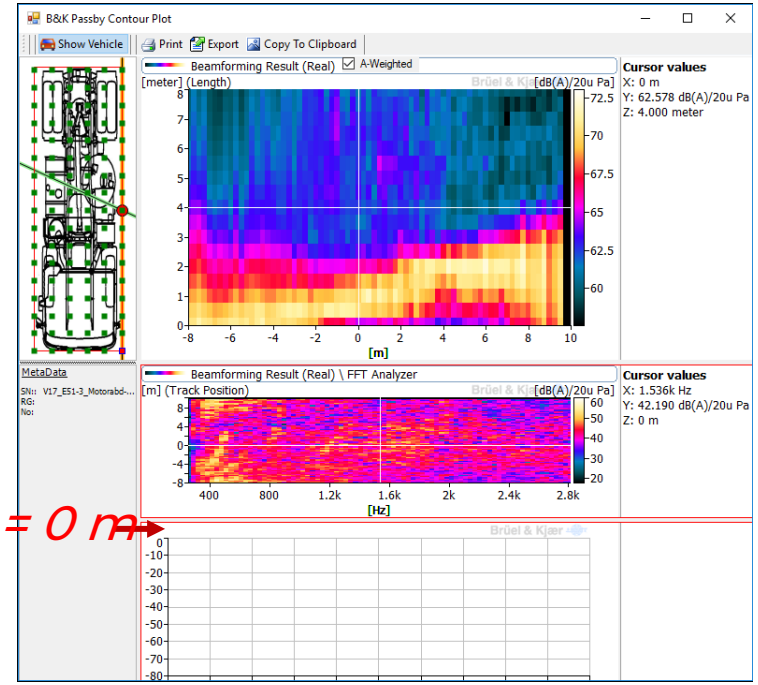
Moving Source beamforming- example

Position of the vehicle along the track: X = 0 m





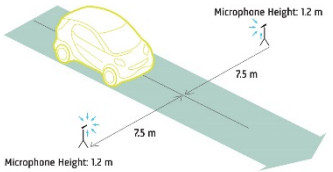


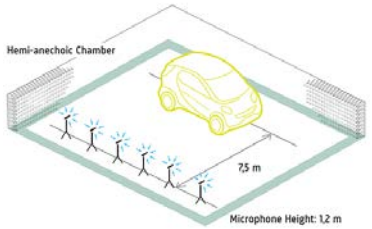


HBK
HOTTINGER BRÜEL & KJÆR

Vehicle Exterior Noise Engineering Solutions

	Homologation CoP	R&D Testing

Field 	• Traditional Pass By
	  • Single track
	  • Multi vehicle pass-by
	• QRTV
	  • R138
	  • FMVSS 141
		• Traditional Pass By
		  • Single track
		  • Multi vehicle pass-by
		• Moving Source Beamforming

Indoor 	Now allowed to be used for homologation and conformity of production	• Indoor pass-by system
		  • ISO-362-3
		  • Can be <7.5 m but at least 5.5 m
		  • Contribution analysis
		• Noise Source Identification
		  • Beamforming
		  • Wide band Holography

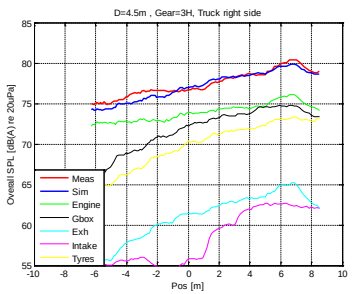
HBK HOTTINGER BRÜEL & KJÆR

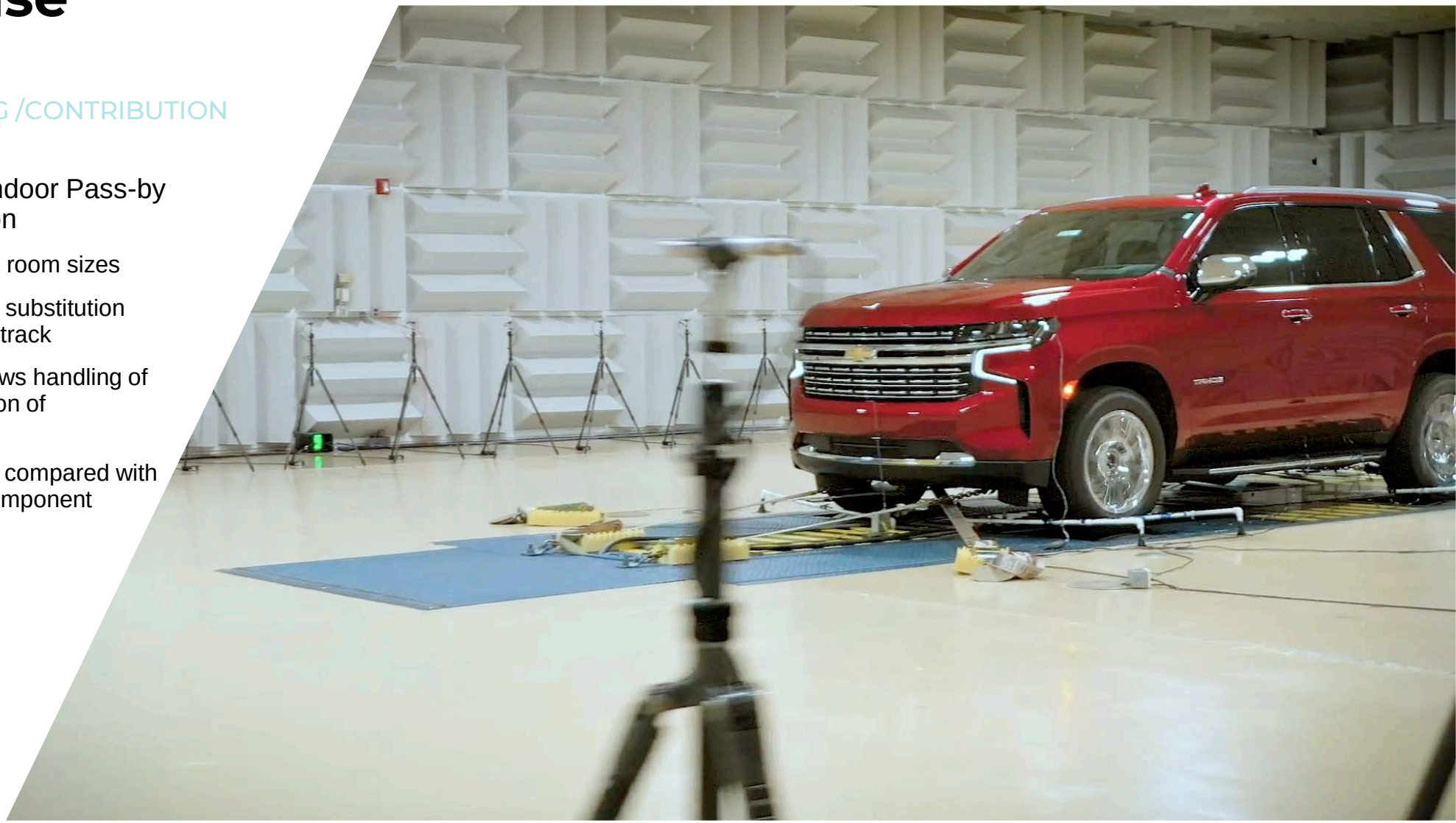
Exterior Noise

INDOOR PASS-BY TESTING /CONTRIBUTION ANALYSIS

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



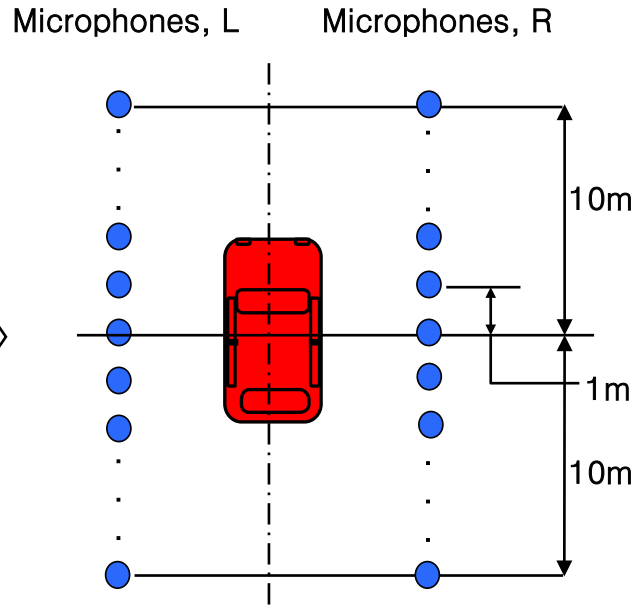


ISO 362-3: Pass-by Noise Test, Indoor Method

ISO 362-1

Field Pass-by on ISO Track

Indoor Pass-by on chassis dyno in Hemi-Anechoic Chamber



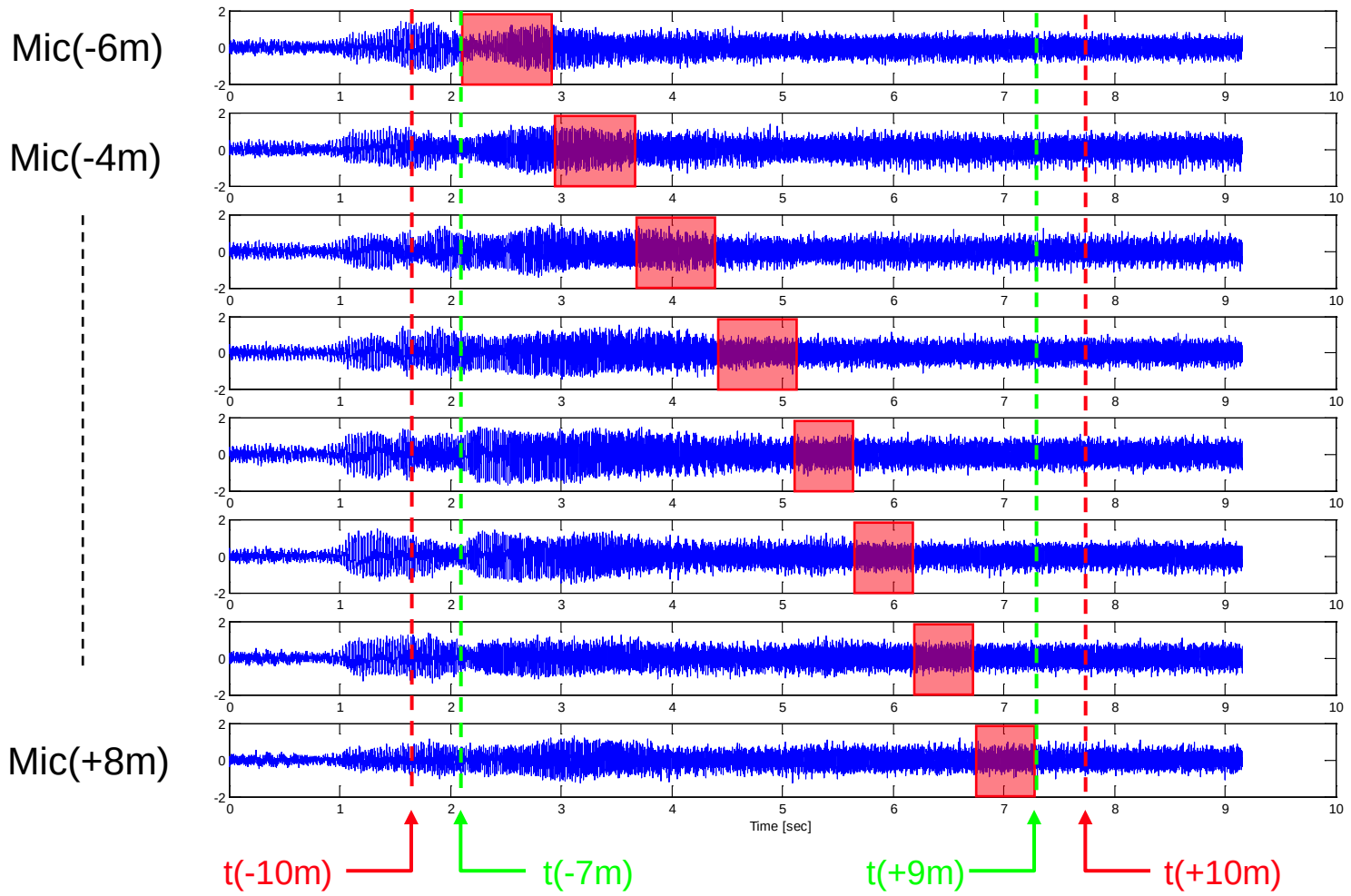
Drawing not to scale

ISO 362-3

- Full control of ambient parameters
- Full operational/driving control
- 24/7 all year-round operation
- Easy vehicle access for added instrumentation & investigative methods

HBK HOTTINGER BRÜEL & KJÆR

Synthesizing Time Signals



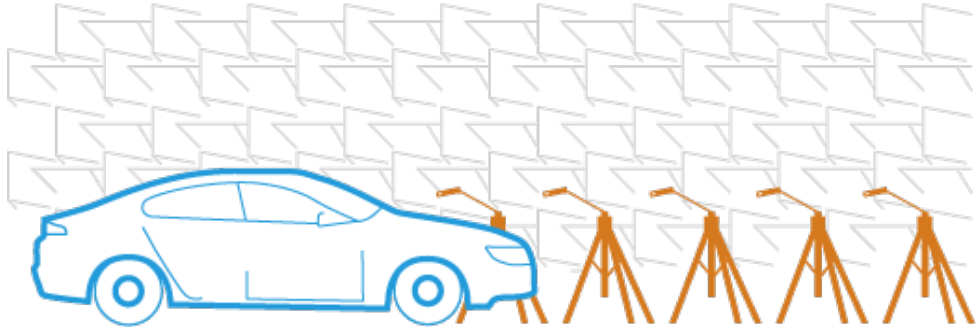
The time signals from the individual pass-by array microphones are added together synthesize the two (left and right) ISO microphone signals

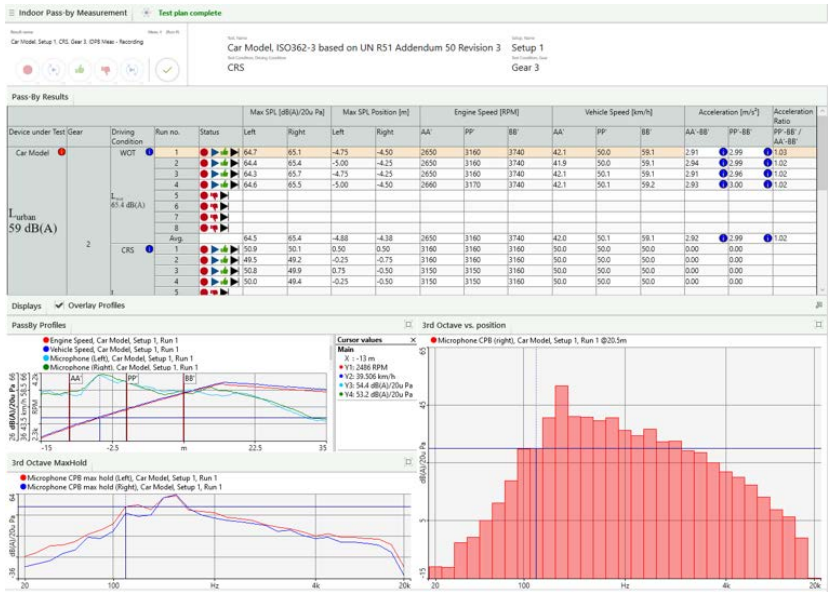
A normal pass-by calculation is subsequently done on the synthesized signals

Homologation at Indoor Pass-by

Indoor pass-by test now allowed to be used for homologation and conformity of production

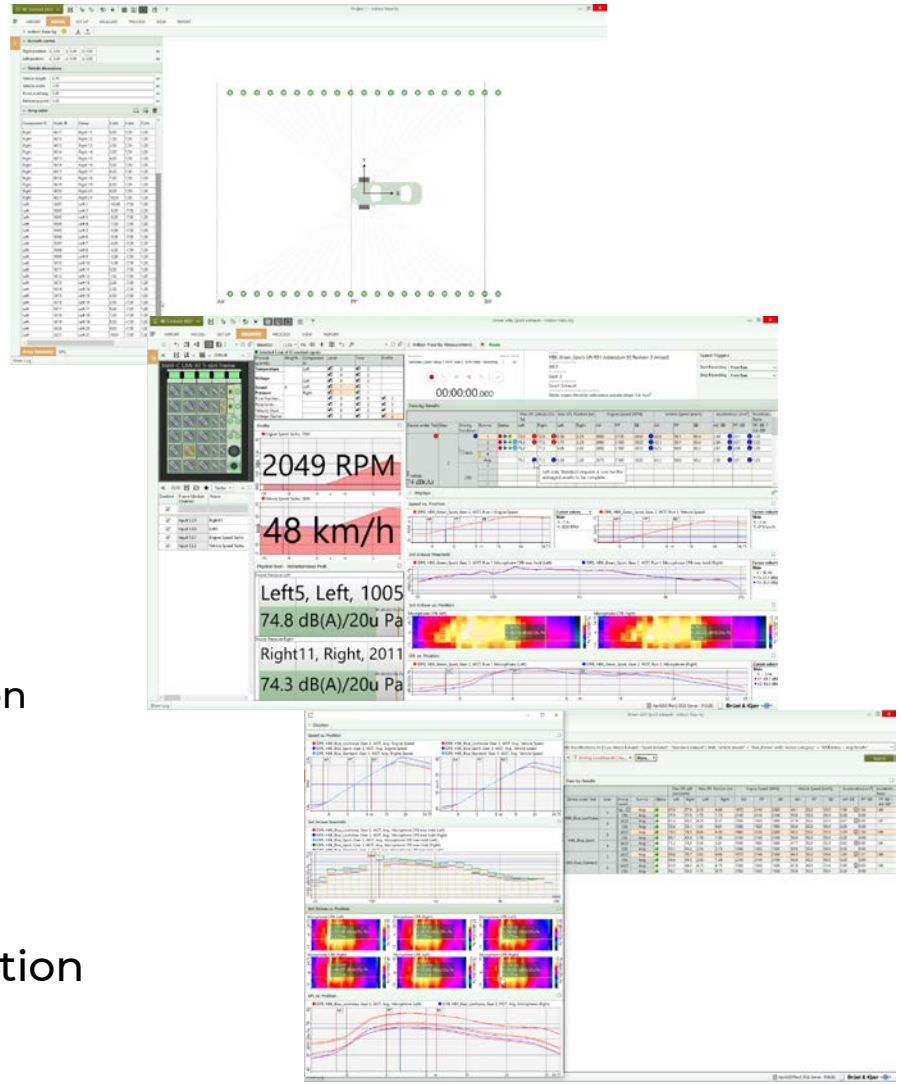
- Automatic test plan according to Legislation/Standard
- Simple and fast setup for cars, trucks according to R51.03
- Includes ASEP and RD-ASEP
- Supports Tyre noise correction as described in IS0 362-3
- Minimum Microphone distance 7.5m
  - (<7.5m for development purposes)
- One- or two-sided array measurements
- Central database for comparison of vehicles and modifications





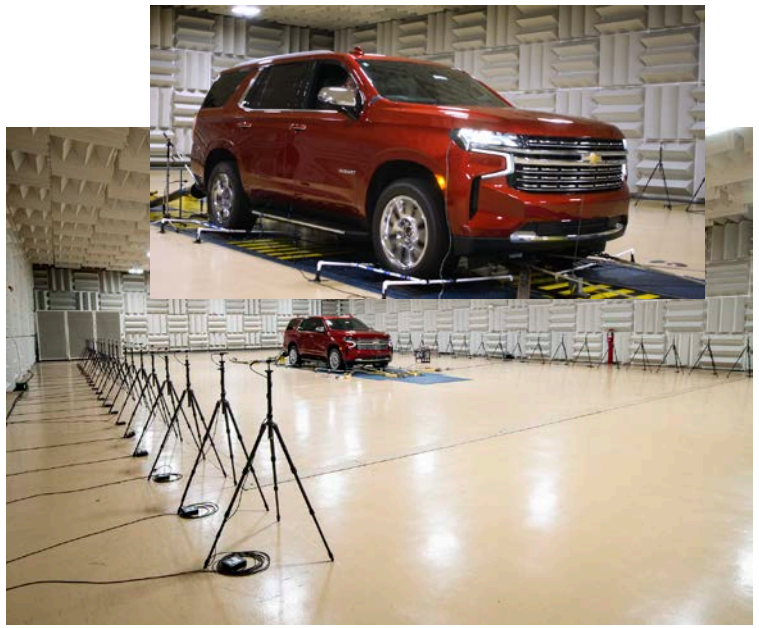
New Indoor Pass-by solution in BK Connect

- Operator-friendly for high productivity
  - Quick start-up using Excel for
    - Geometry model: arrays, sources and indicators
    - Test procedure and vehicle information (metadata)
    - Speed settings (road and engine speed)
    - Auto generate test plan
- Test plan operation for reliable measurements
  - Full test plan visible from the start
    - Integrated real-time monitors
    - Run-by-run validity checks with feedback icons
    - Automatic calculation of total results according to regulation
    - Fast, interactive displays linked to test plan table
- Based on Team Server
  - Data & Results sharing via file-indexing Team Server
  - Easily share, search and view data across the organisation



The need for Tyre Noise Correction (TNC)

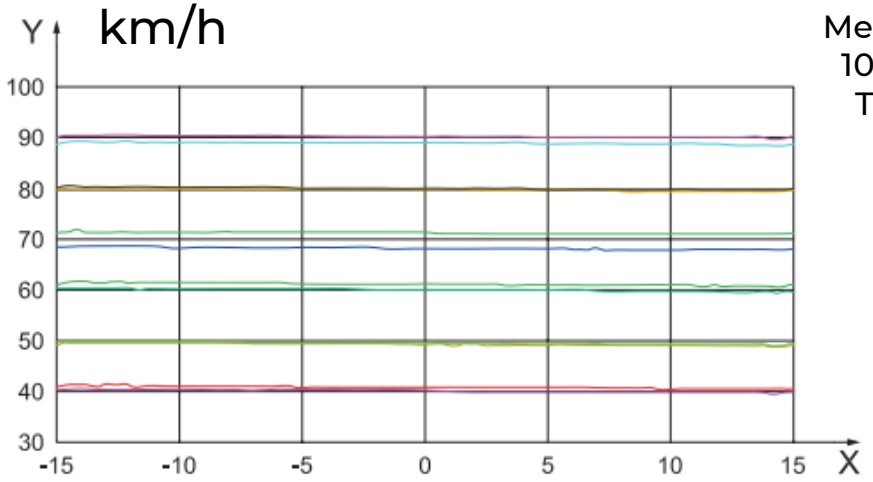
- The tyre noise measured on the chassis dyno is replaced with tyre noise measured on the test track
- The same vehicle, same tyres, produces different pass-by noise owing to different tyre noise contribution:
  - Dyno rollers vs. ISO 10844 road surface
  - Single driven axle vs all axles



≠

ISO362-3: Speeds and accelerations for FRN and TI

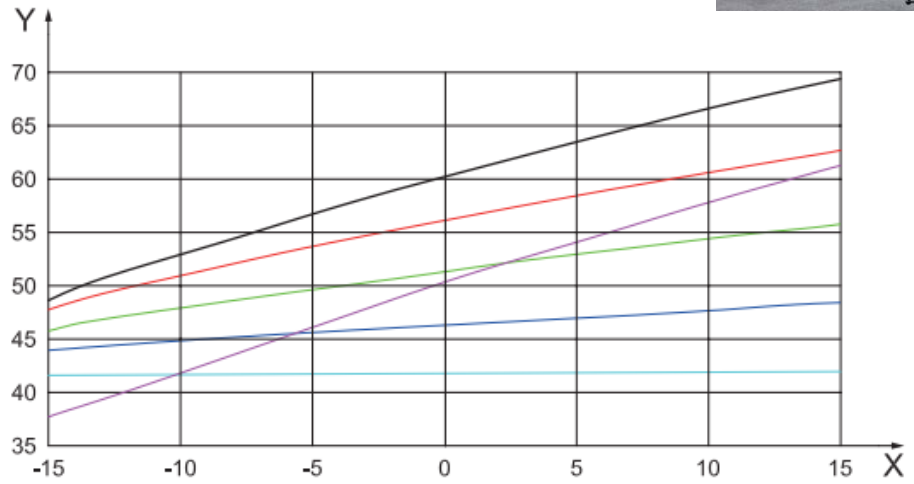
FRN: From 40 to 90 km/h



Key
X *x*-position, m
Y vehicle speed, km/h

Measurements on ISO 10844 surface using Type 7788 Vehicle Pass-by

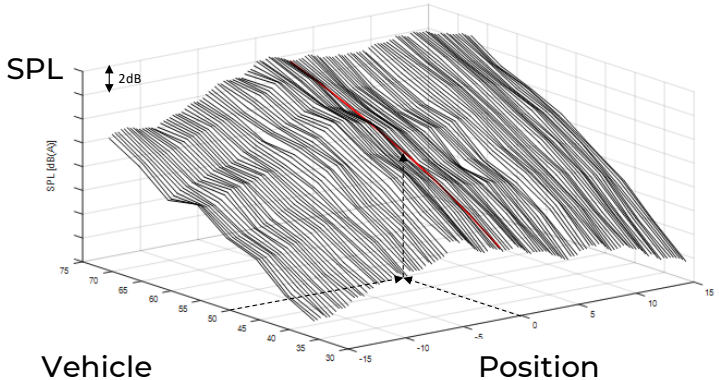
TI: From 0 to 3 m/s²



Key
X *x*-position, m
Y vehicle speed, km/h

FRN: Free Rolling Noise
TI: Torque Influence

Regression analysis on FRN and TI



α, β: FRN coefficients
γ,δ,ε: TI coefficients

HBK HOTTINGER BRÜEL & KJÆR

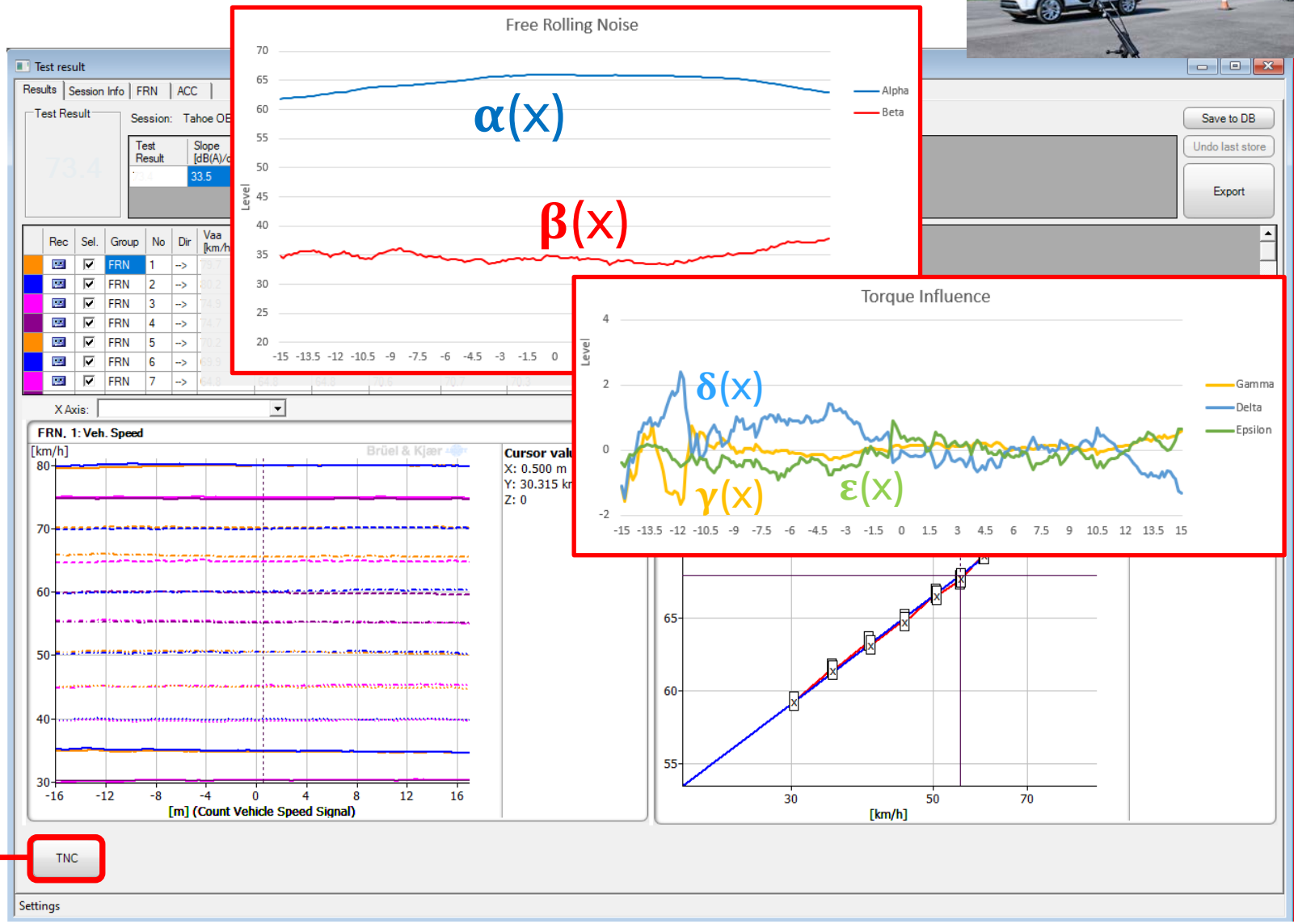
Type 7788: Updates to tyre noise correction (TNC) t

- FRN – free rolling noise: Series of coast-by runs at different speeds (similar to R117)
- TI – torque influence: Series of acceleration runs at different accelerations
- Regression calculations
- Calculate and export TNC coefficients (α,β,γ,δ,ε) as a function of position, x

	A	B	C	D	E
1	Curve 1				
2					
3	Function c	OA-level			
4	label	Overall level - Fast Factor α:Right:S(A)			
5	Number o	201			
6	Point dire	S			
7	Point id	Factor α:Right			
8	Value typ	Real			
9	Weighting	A			
10	X axis unit	m			
11	Y axis unit	TRN			
12					
13	m	TRN			
14	Linear	Real			
15	-15	61.77526			
16	-14.75	61.87986			
17	-14.65	61.90879			
18	-14.5	61.93452			
19	-14.35	61.99974			
20	-14.25	62.04985			
21	-14	62.05577			
22	-13.9	62.07231			
23	-13.75	62.11425			

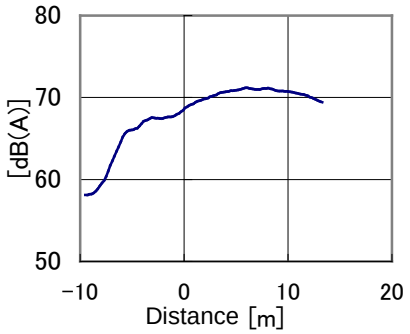
(α,β,γ,δ,ε)

FRN and TI coefficients transported in XML or standardized Excel/CSV file.



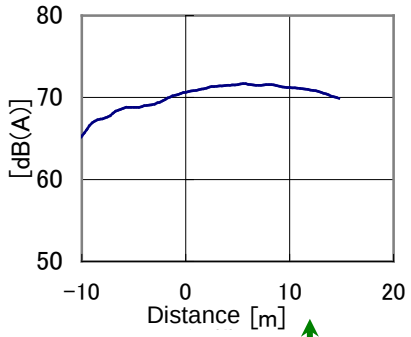
Tyre Noise Correction of Indoor Pass-by data

1.Test: Indoor Pass-by Run-up w. Tyre noise on C/D

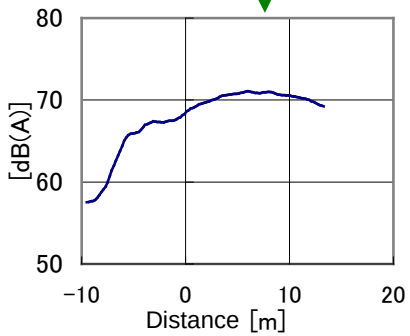


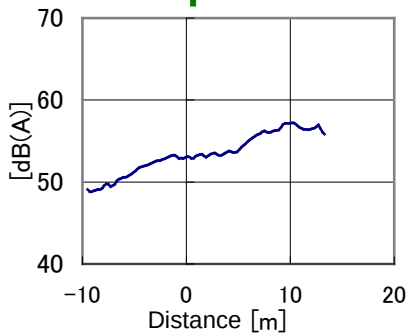
2.Test: Indoor Pass-by Coast – down w. Tyre noise on C/D (x-axis aligned)

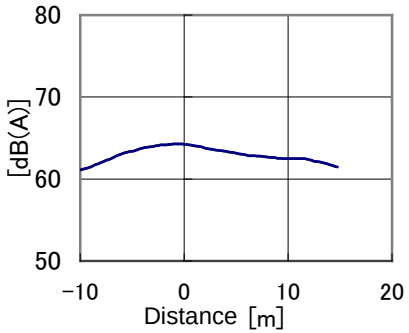
5.Result: Indoor Pass-by Run-up with Tyre noise correction



4.Test: Tyre noise Coast Down at Proving Ground (X-axis aligned)







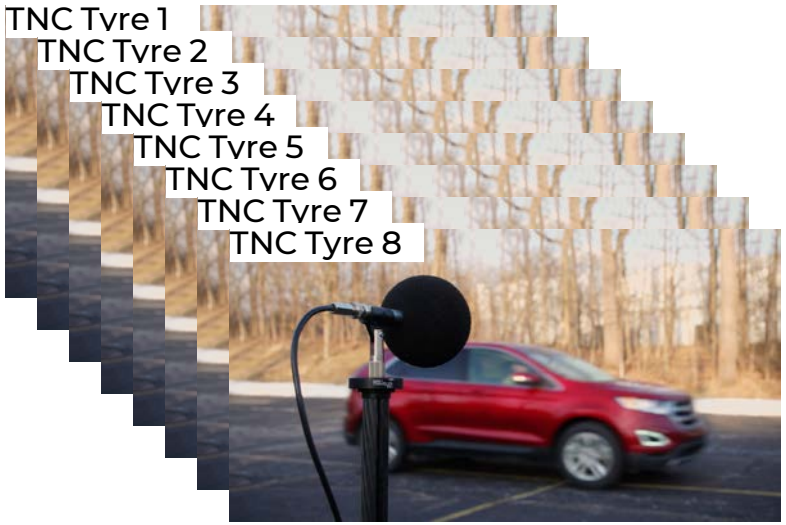
3.Result: Indoor Pass-by Run-up on C/D without Tyre noise

Principles of applying TNC

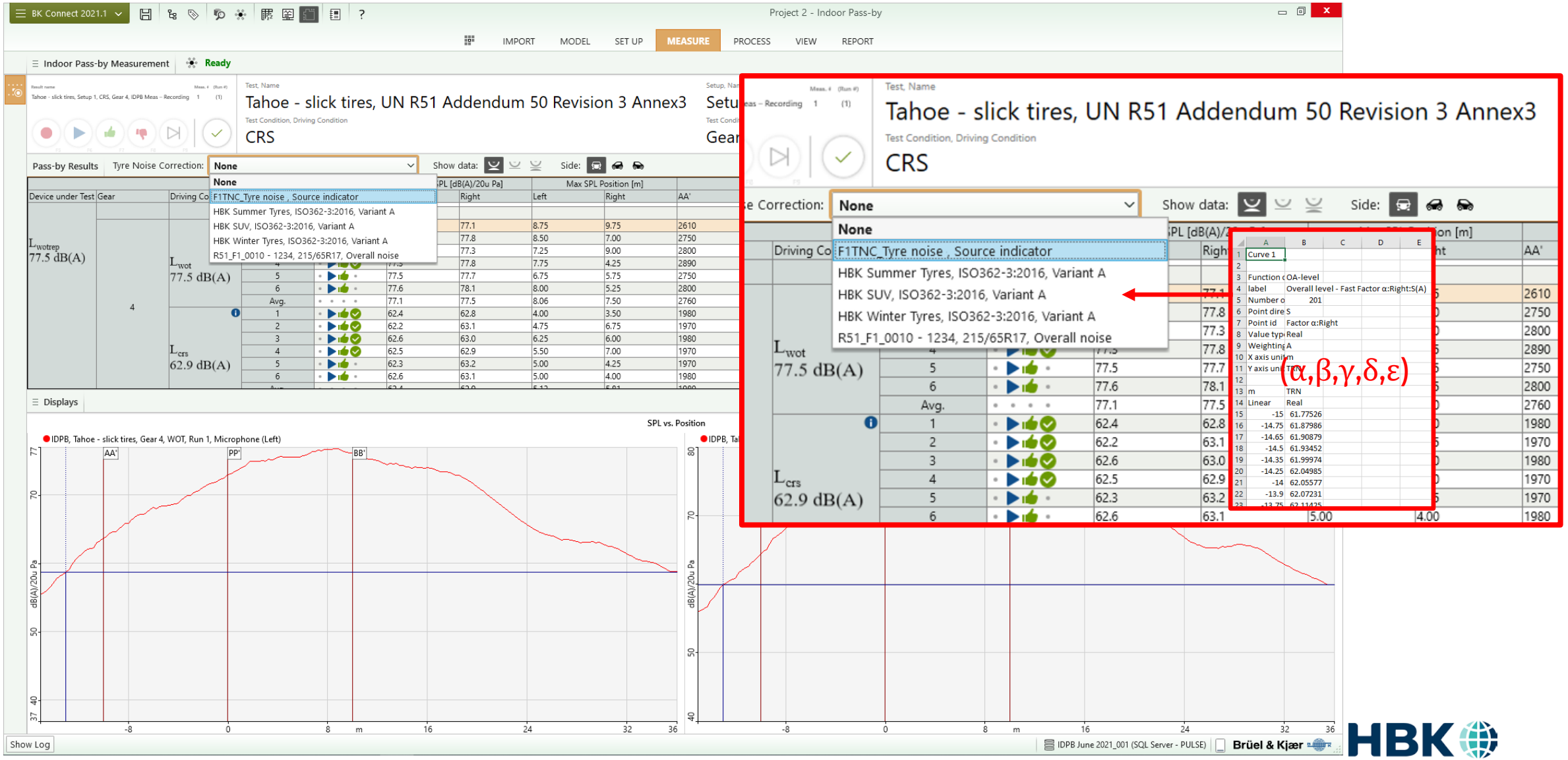
- Measure pass-by noise indoors
  - Minimize tyre/road noise using slicks/low noise tyres (focus on propulsion noise)
- Measure tyre noise (TNC) on ISO 10844 surface using a quiet vehicle; usually with electric propulsion
- Multiple pass-by noise results from single indoor test and multiple tyre noise TNC data sets
- Benefit: Evaluate the Pass-by noise from a range of tyres on one vehicle by applying tyre noise from track tests to Indoor results

Indoor Pass-by propulsion (PTN) noise

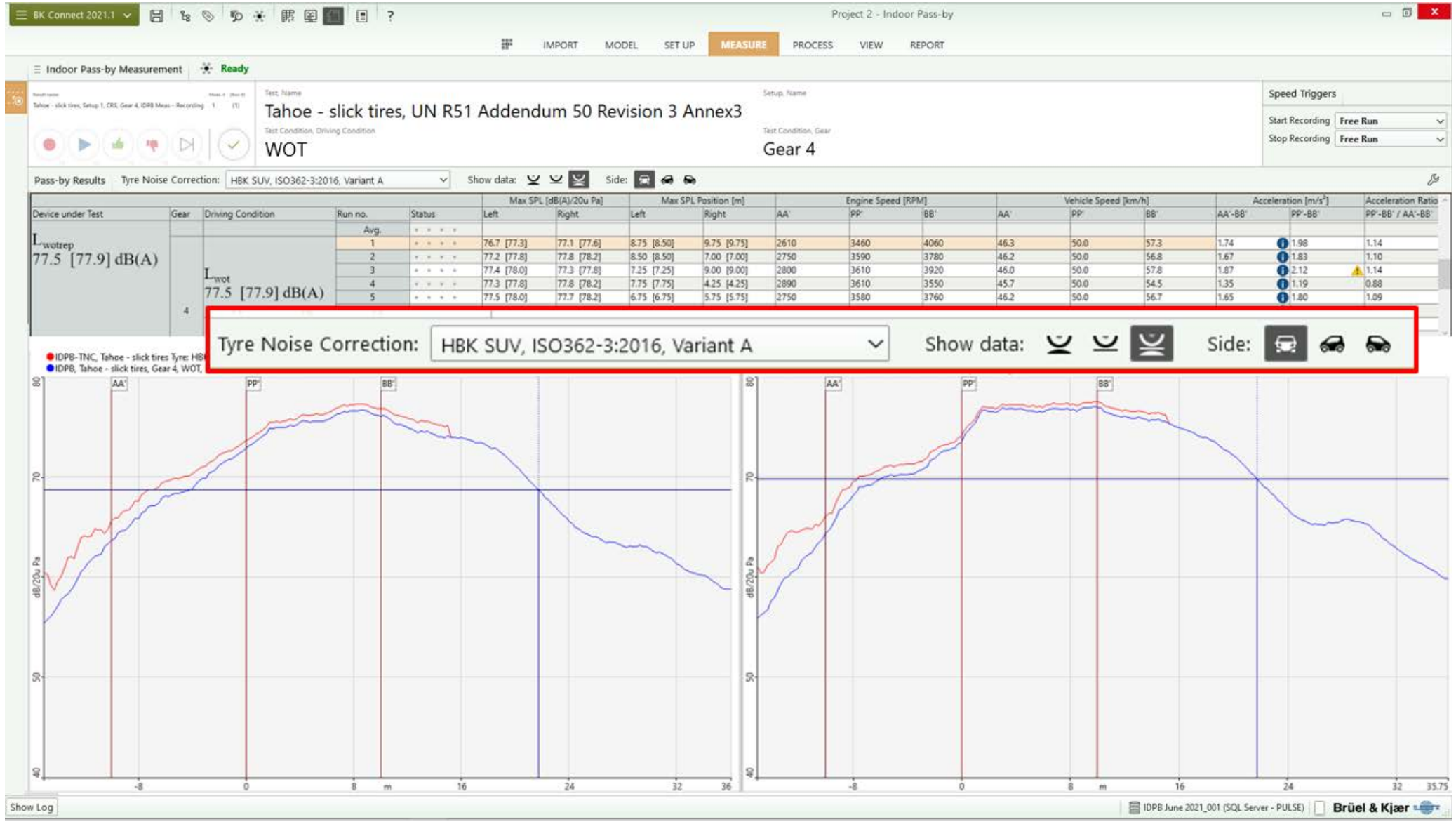
+



BK Connect: Tyre noise correction from TNC tyre library

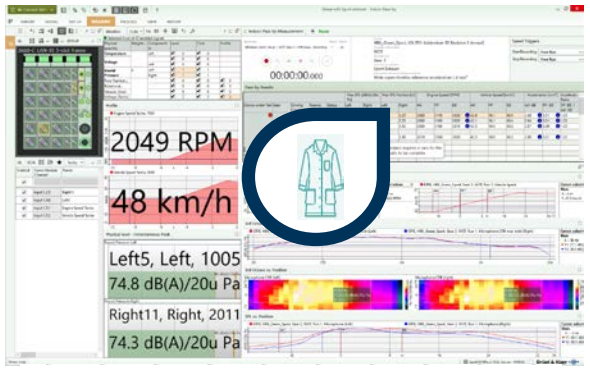


Apply correction – show corrected/uncorrected/both

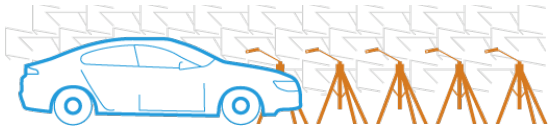


Our data-centric Pass-by solution

Operating measurements for Indoor pass-by/SPC. Calculation of pass-by results according to standards & regulations



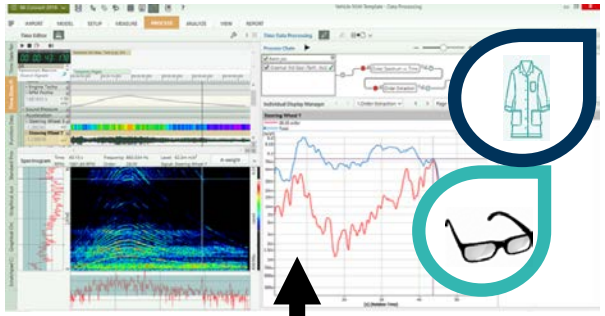
C/D Hemi anechoic room



Tyre Noise correction Results from field pass-by

ISO Track

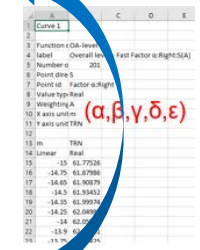
Time Data Processing (Core)



Time data

Shared Data Storage (Team Server)

Pass-by Noise Results

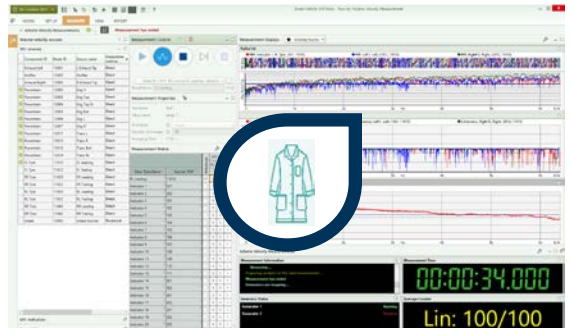


TNC Coefficients

Pass-by data viewer for display and comparison of pass-by results from indoor Pass-by tests

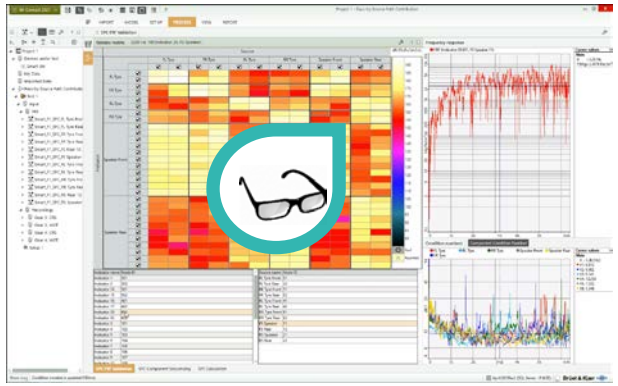
P/Q FRFs

VVS-based Acoustic Transfer Function measurement for SPC analysis



Hemi anechoic room, Outdoor, (C/D Hemi anechoic room)

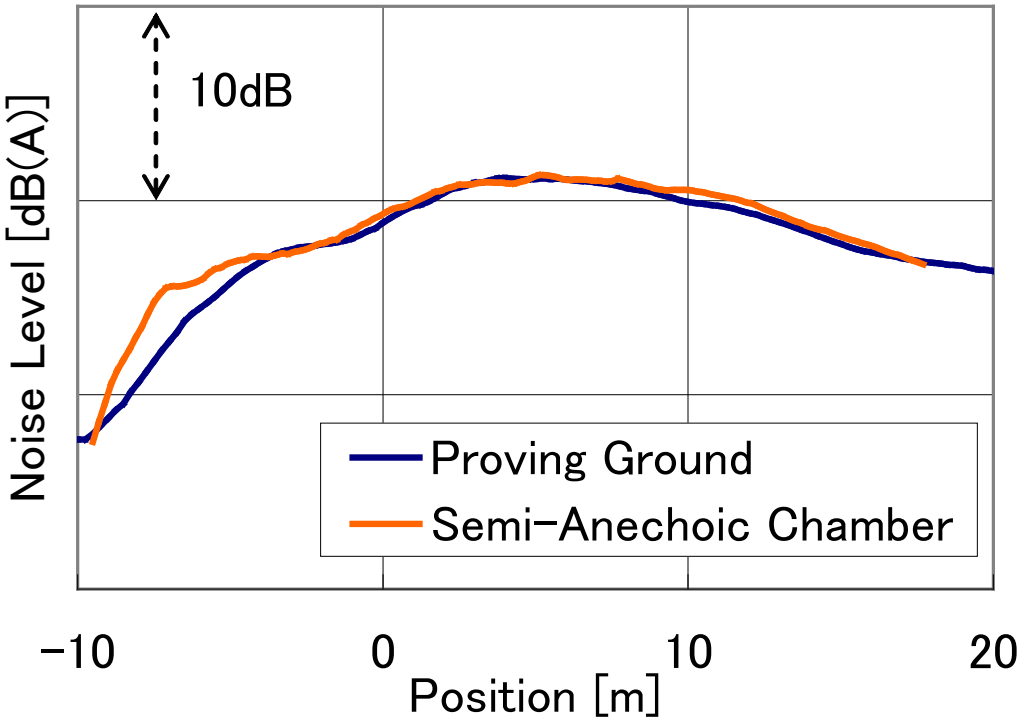
Pass-by SPC with capability for predictive pass-by and evaluation of possible design changes; source & FRF swapping

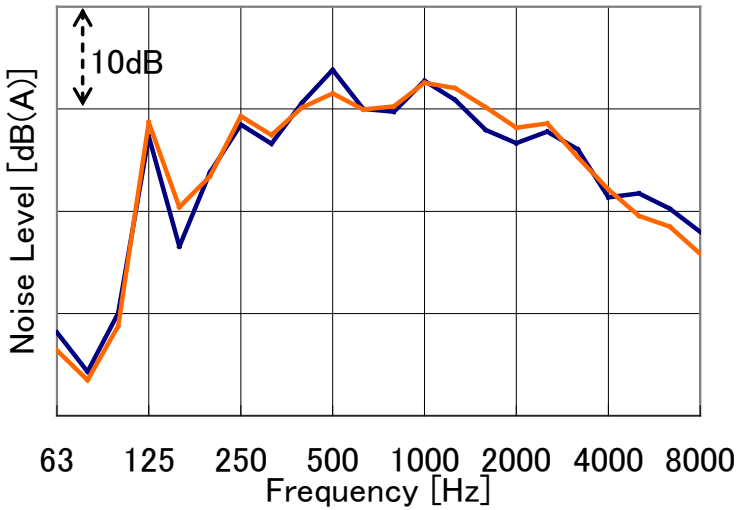


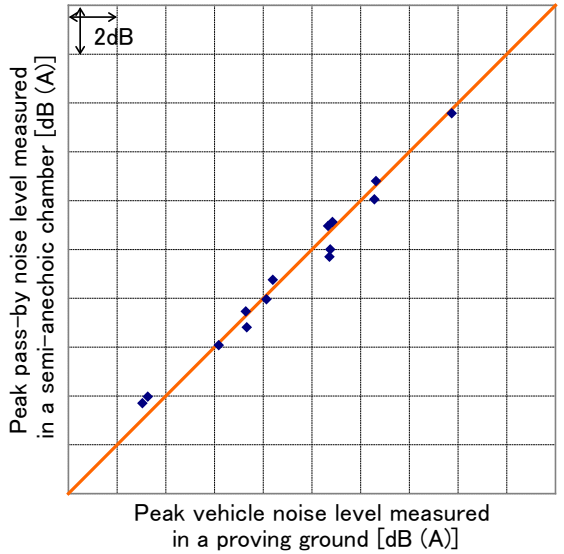
HBK HOTTINGER BRÜEL & KJÆR

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

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



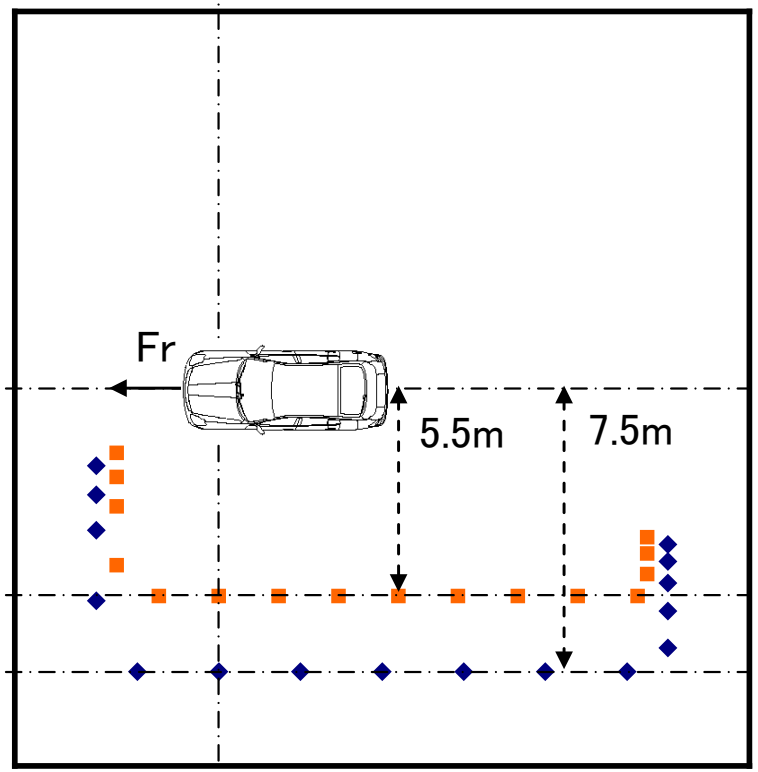


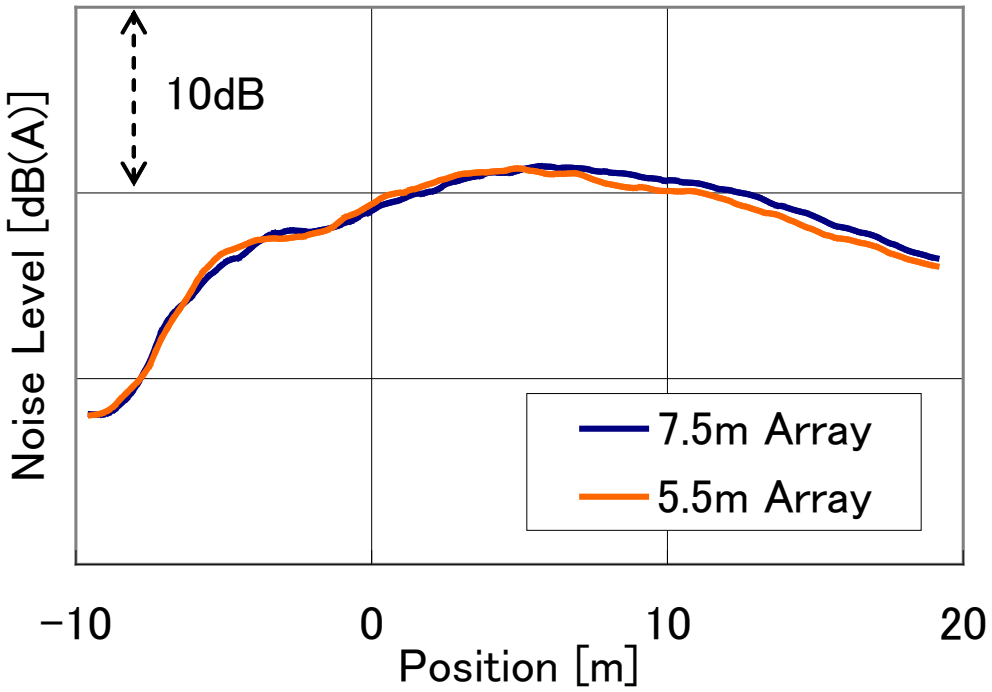


Indoor Pass-by .vs. Field Pass-by

Indoor Pass-by: Validation of Distance Correction

Distance correction using extrapolation (passenger car)





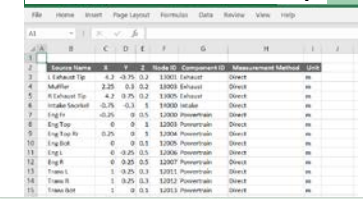
Accurate Results in smaller rooms !

Pass-by Viewer & Indoor Pass-by

Indoor pass-by for homologation, conformity of production or development testing

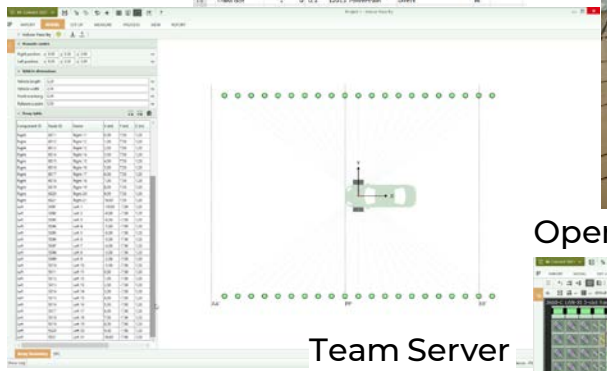
- Excel-based DOF & geometry model plus setup
- Simple and fast setup – regulations built in
- Automatic test plan with constraints and calculations according to ISO362-3 and UN/ECE R51 regulations
- Minimum microphone distance 7.5m for homologation, or <7.5m for development purposes
- One or two-sided array measurements
- Tyre Noise Correction: Standard or Overall
- Central database (Team Server) for data transfer between applications and for comparison of vehicles, vehicle variants, indoor pass-by results

Excel Model/Setup



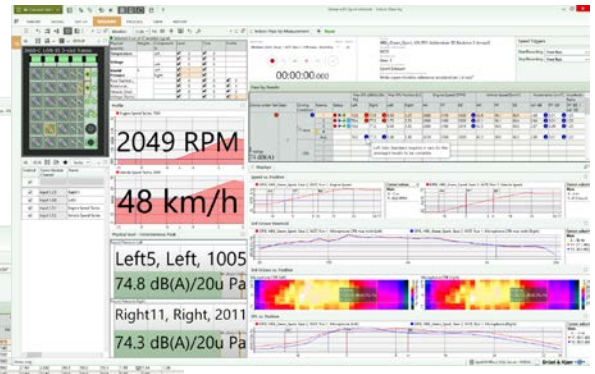
Indoor Pass-by Facility

Model

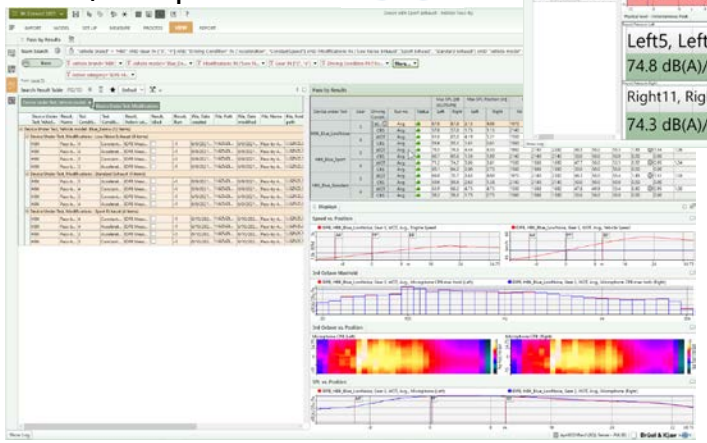


Team Server

Operating Measurements

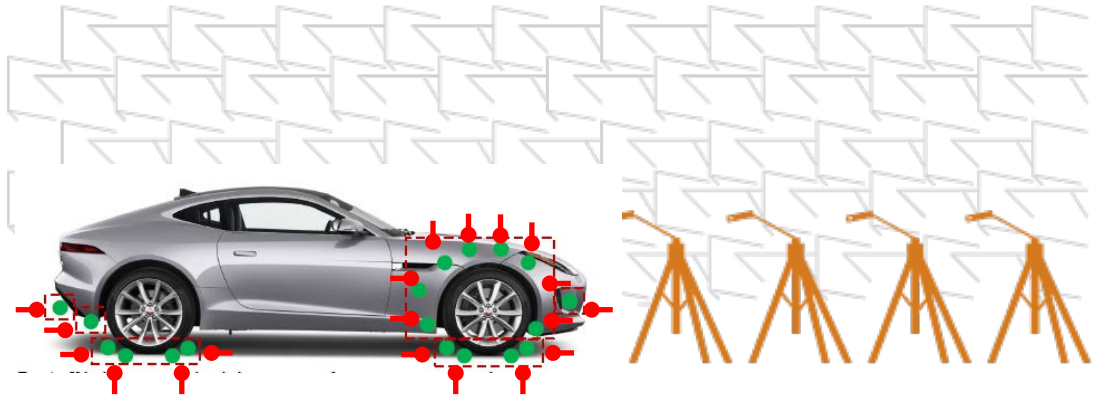


View/compare



HBK HOTTINGER BRÜEL & KJÆR

The benefits of Indoor Pass-by testing

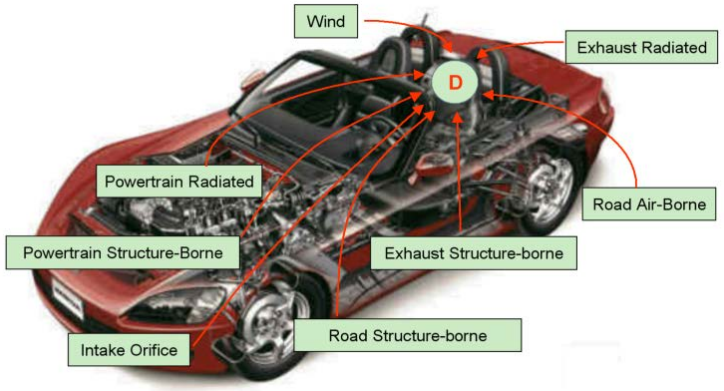


- Fast
- Flexible
- Repeatable
- Easy to use
- Precise test and vehicle conditions
- Stationary vehicle: easy to add instrumentation (cables, power…)
- Stable test environment – temperature, pressure, humidity…
- Easy comparison – test conditions, build variants, different vehicles
- Noise source contribution analysis

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 souces are important?
  - Which noise paths are most critical?
  - How do noise paths interact?
  - Is it a system (path) or source problem?



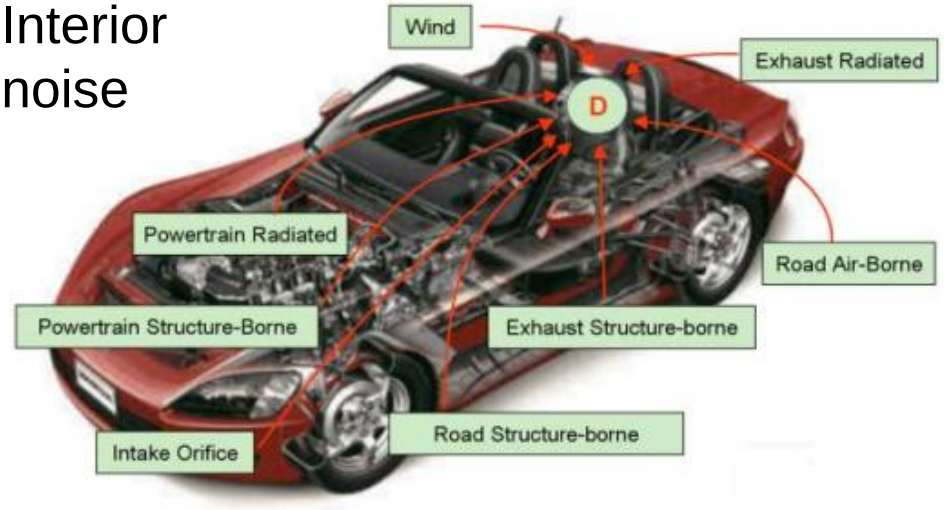
Source-path-receiver concept

Measurement of acoustical path sensitivities

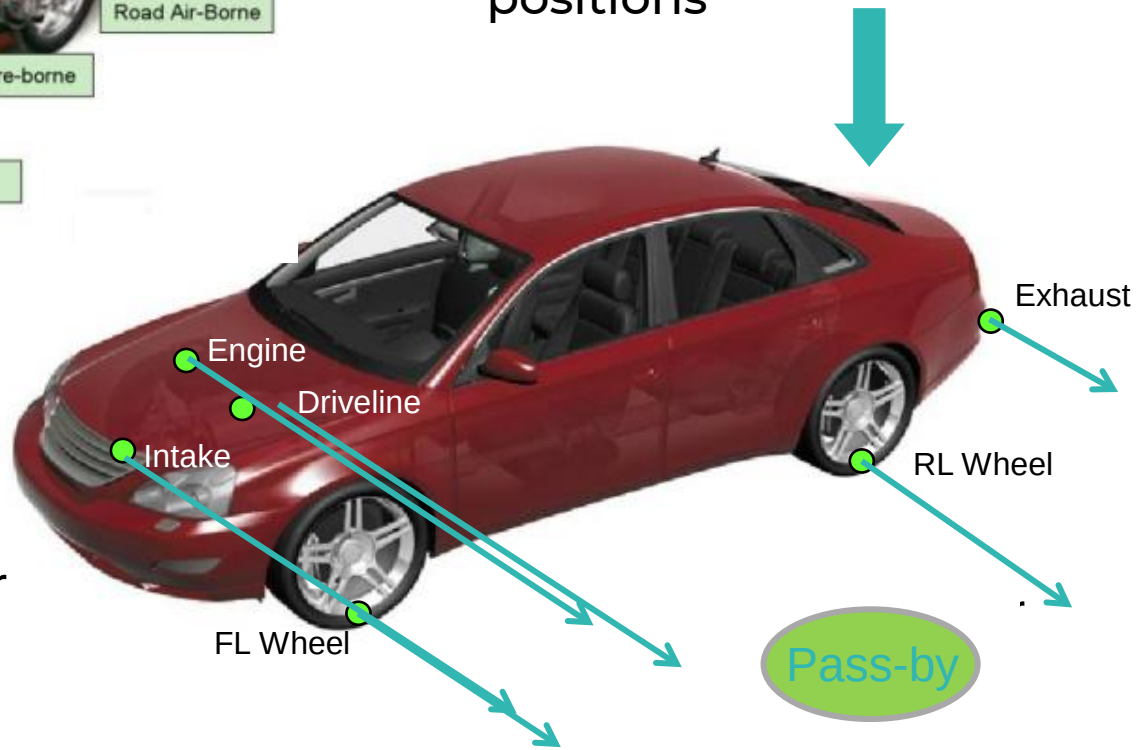
Reciprocal method using volume velocity source

Source Path Contribution (SPC): Pass-by mic position

Interior noise



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

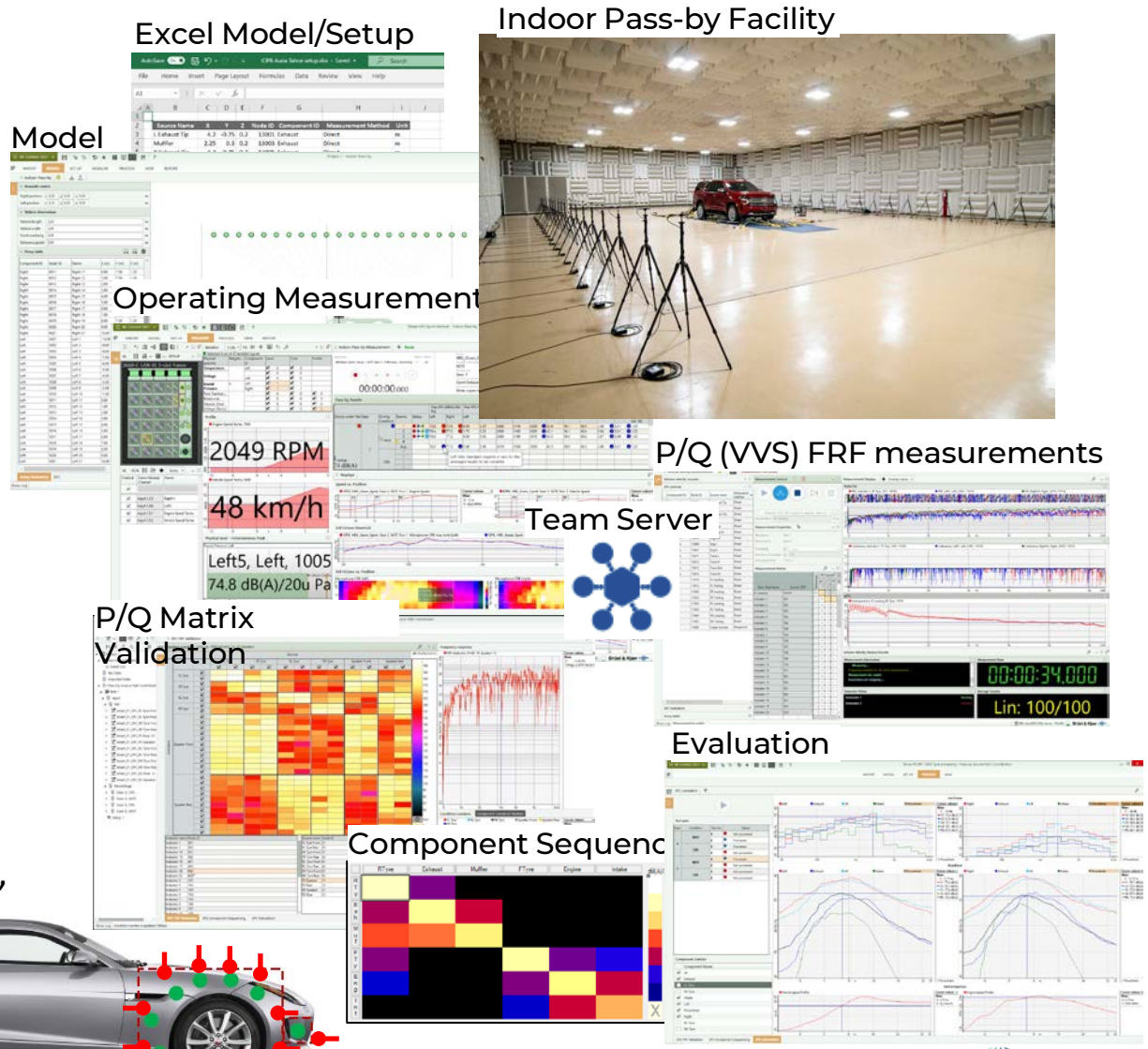


Exterior noise

Indoor Pass-by & Pass-by SPC

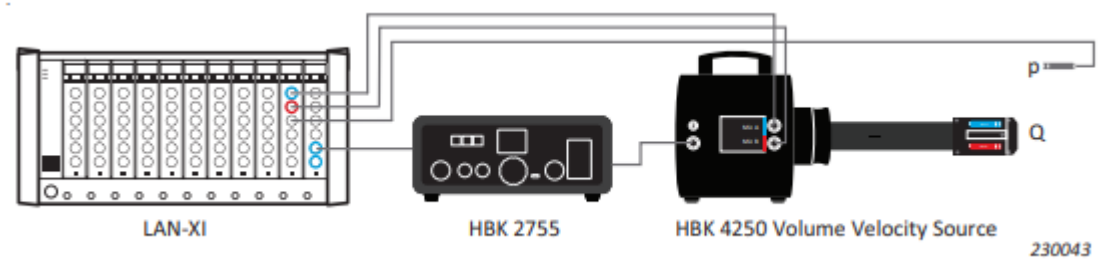
Indoor pass-by, VVS measurements, and source path contribution (SPC) analysis

- Excel-based common DOF model and setup
- Operating measurements (incl. indicators) in Indoor Pass-by
- Tyre Noise Correction: Standard, Overall or Source-Indicator
- Acoustic Transfer Function (VVS) measurements
  - P/Q Source to array (acoustic sensitivity)
  - P/Q Source to indicators (source determination)
- SPC model data completeness feedback
- P/Q matrix validation
- Source grouping, component sequencing
- Sum of contributions compared with measured total to validate component contributions
- Central database (Team Server) for data transfer between applications and for comparison of vehicles, vehicle variants, indoor and field pass-by results



HBK HOTTINGER BRÜEL & KJÆR

Volume Velocity Sources 32 HZ to 16000 Hz



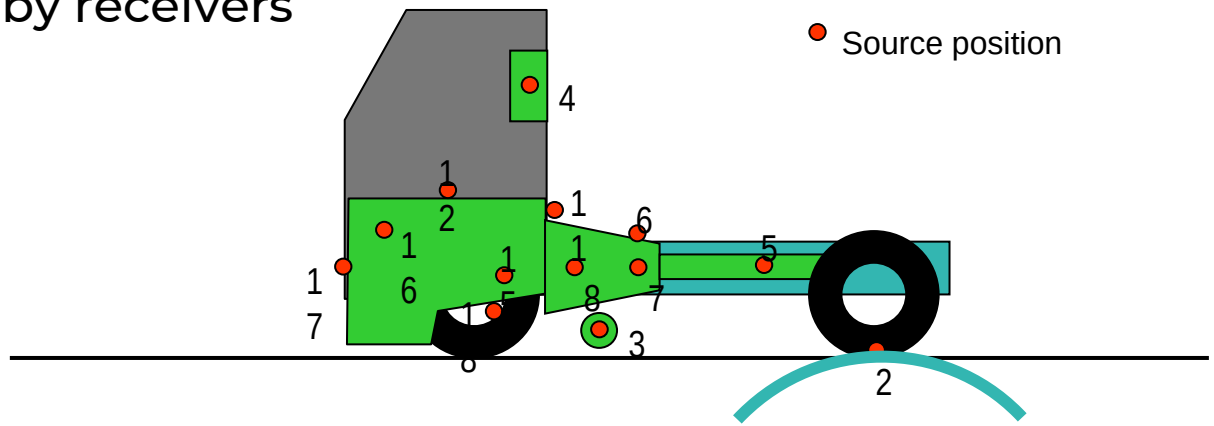
HBK
HOTTINGER BRÜEL & KJÆR

Indoor Pass-by/Contribution Analysis

Truck example: Noise source contributions to the pass-by mic positions

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

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



Indoor Pass-by / Contribution Analysis

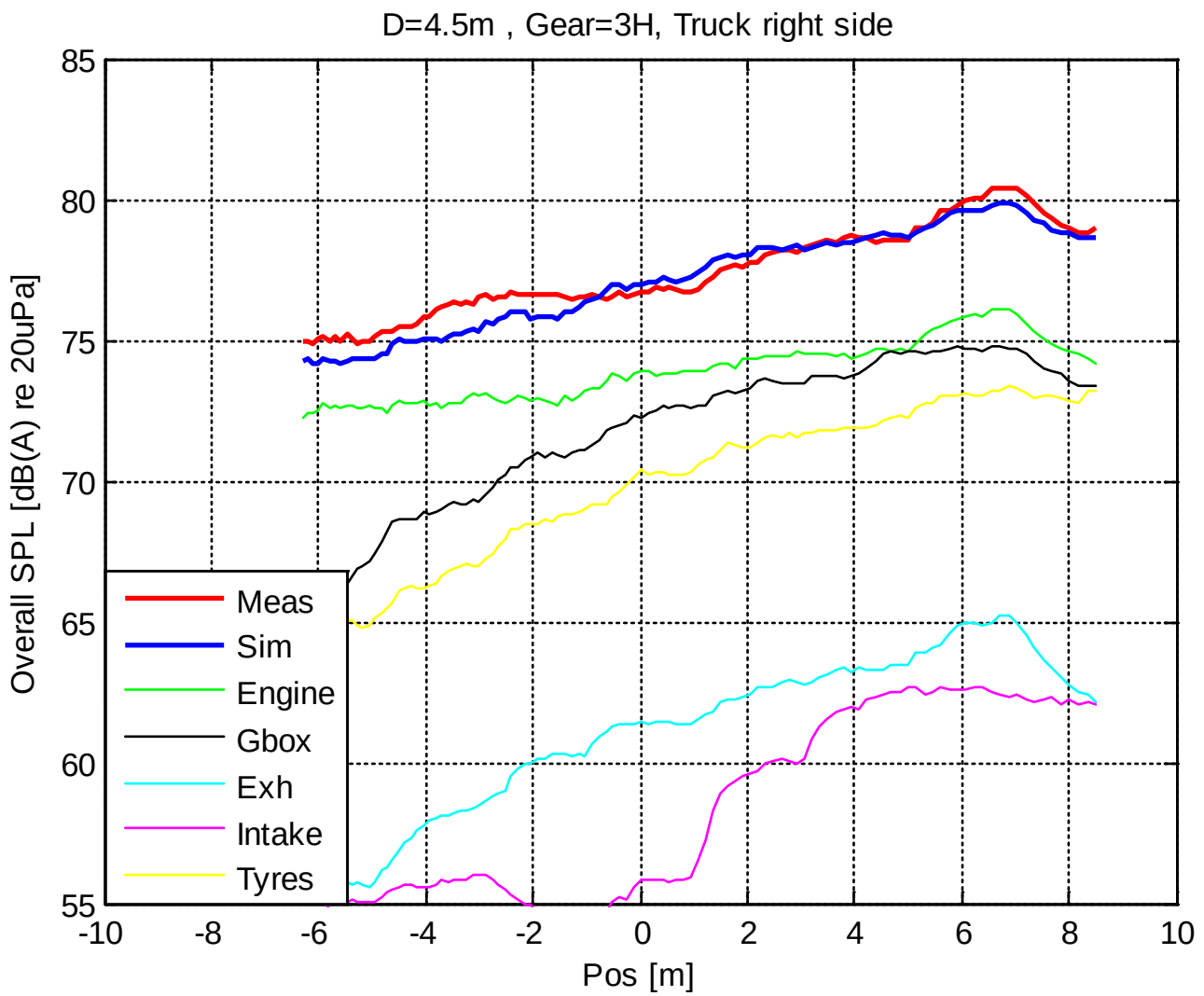
Truck example:

Overall and Individual Source Contributions:

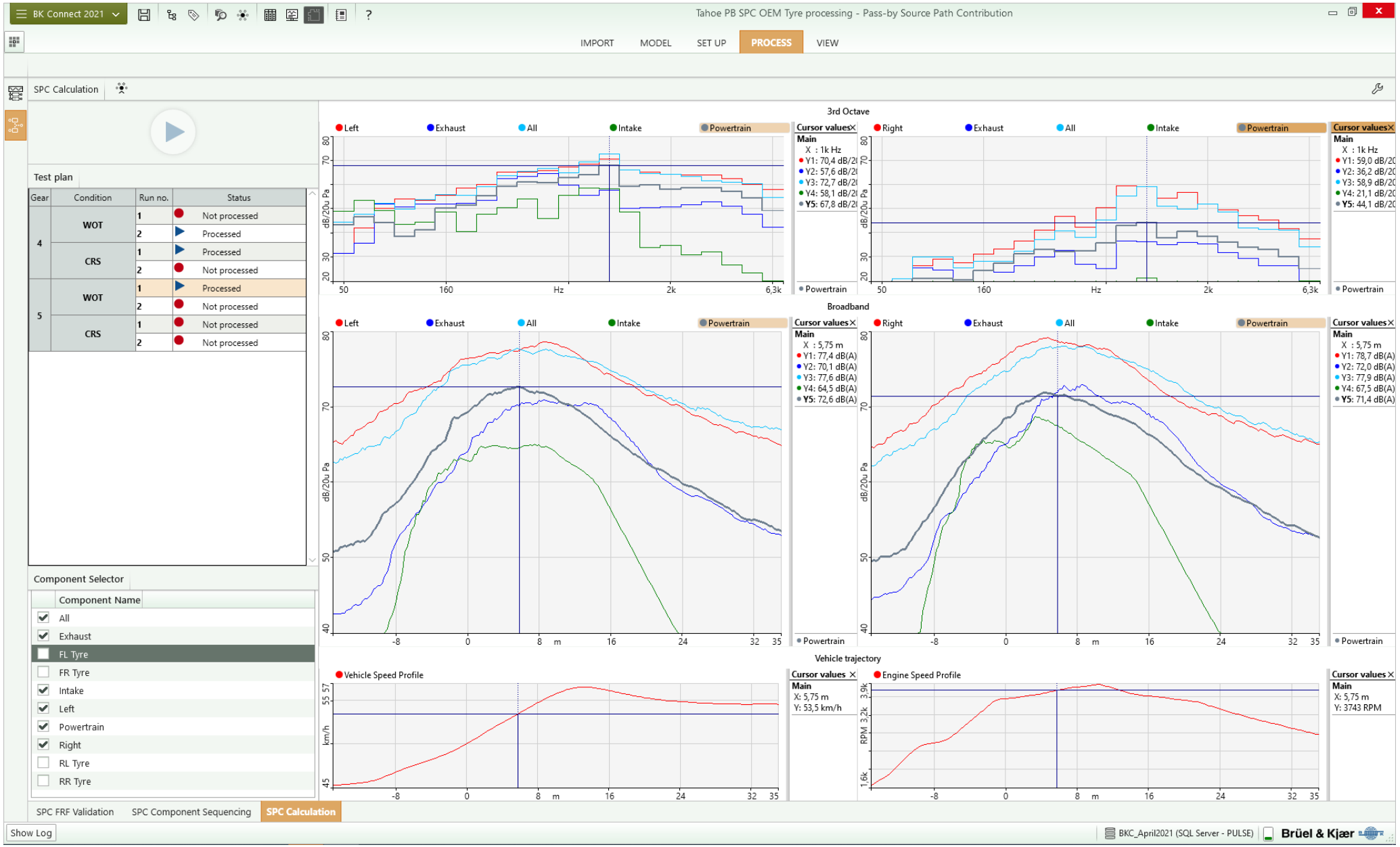
Engine and Gearbox are main contributors at max SPL

Data validation:

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



SPC Calculation – Results



BK Connect Indoor Pass-by and Pass-by SPC

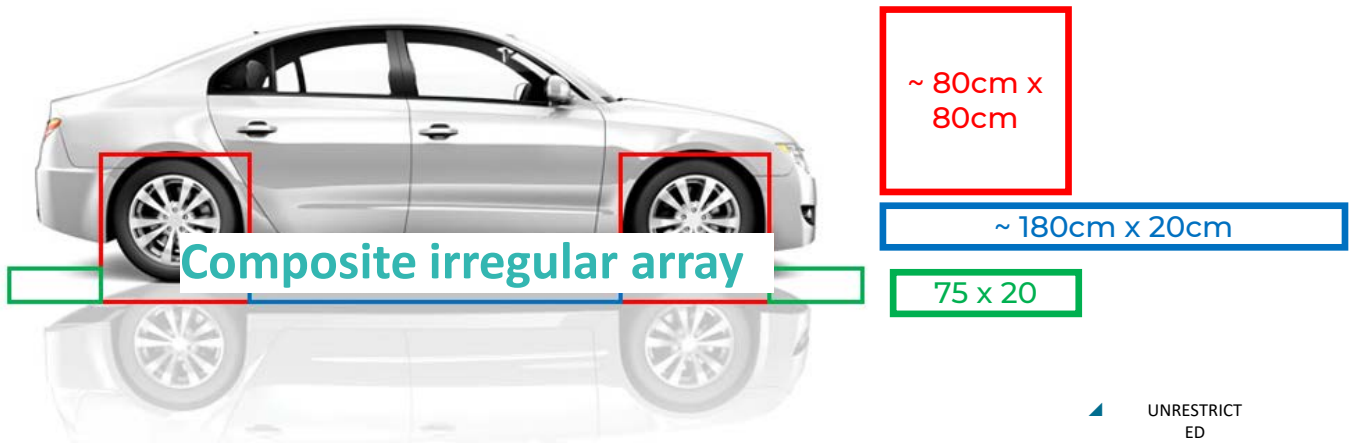
- Indoor Pass-by Measurements – according to ISO standard and UN/ECE regulations
  - Operator-friendly
    - Visual model and test plan for easy setup
    - Standard and regulations built in
    - Test plan measurement GUI with run management and reference data set comparison
  - Data sharing via file indexing Team Server – with local Team Server for results viewing
- Pass-by Data Viewer – both field and indoor pass-by results
  - View and compare results direct from Team Server
- Volume Velocity Source (VVS) Measurements – for acoustic transfer functions
  - Direct & reciprocal measurements
- Pass-by Noise SPC – using pass-by operating measurements and ATFs
  - Contribution analysis for pass-by noise – including source/path swapping for design studies
  - Tyre noise contribution methods

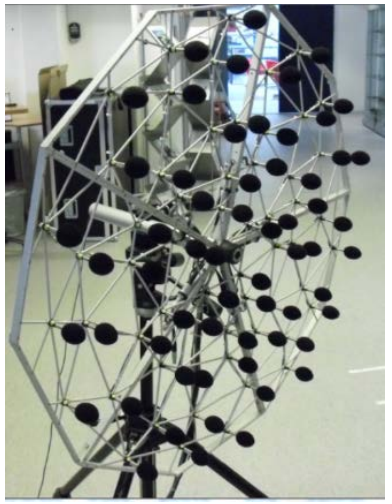
Wideband Holography for full vehicle testing

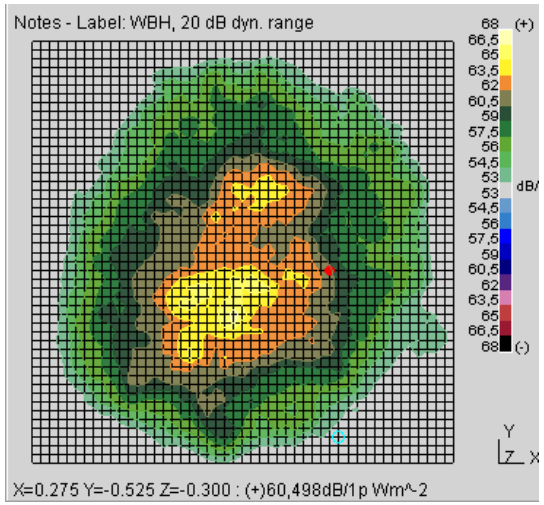
- Higher frequency range demands as engines gets smaller and more lightweight
- Hybrids/electrical vehicles present special challenges from high-frequency sources
- Push for reduced time-to-market requires more efficient testing
- Traditionally a wide frequency range test is done in two steps:
  - Holography at low frequencies and
  - Beamforming at high frequencies

Wideband Holography

- Save time, reduce complexity by using the same array to cover the same frequency range, all in one measurement







WBH 6.3 kHz

- Assumed frequency range: 50 Hz to 4000 Hz
- Measurement distance: 30 cm
- Processing: Pseudo-stationary (time interval avg.)
- Sub-arrays:
  - Wheel arches: 2 x 36 mic
  - Centre area: 24 mic
  - Front and rear: 2 x 10 mic
- Total number of microphones: 116

HBK HOTTINGER BRÜEL & KJÆR

HBK
HOTTINGER BRÜEL & KJÆR

Visit us at www.hbkworld.com