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Siemens Digital Industries Software

Simcenter pass-by noise engineering

Providing a complete testing, engineering and certification solution

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Meeting stringent noise emission regulations

In urban areas, traffic noise can be a prominent source of discomfort, affecting the daily lives of millions of people and potentially diminishing their health and well-being. To create a more harmonious living environment and reduce the risks of noise exposure, legislators are working on establishing acceptable emission levels and imposing limits on pass-by noise (PBN) levels.

Pass-by noise testing is a standard procedure that was developed in response to the creation of the International Organization for Standardization (ISO) 362 standard and the United Nations Economic Commission for Europe (UN/ECE) Regulation 51. It measures vehicle emission levels on an exterior test track. The results are used to certify that vehicles comply with established standards. This type of certification is required for all types of road vehicles, including trucks, buses, motorcycles, passenger cars and recreational vehicles.

For hybrid and electric vehicles, new standards are in place for measuring minimum noise emission. For these vehicles an acoustic vehicle alert system (AVAS) adds exterior noise to ensure pedestrian safety.

Versatile PBN engineering techniques

PBN levels are regulated around the world. Most standards adopt test methods and noise levels as prescribed in UN/ECE Regulation 51.03, which lowers levels in three phases.

For passenger cars, the noise limit is being reduced from 74 decibels A-weighted (dB(A)) to 68 dB(A). The first step, which limited the noise to 72 dB(A), became effective on July 1, 2016. The next phases are scheduled for 2020 and 2024.

In parallel, hybrid and electric vehicles require a minimum noise level to ensure pedestrian safety. The UN/ECE community has introduced Regulation 138, while in the U.S. the Federal Motor Vehicle Safety Standards (FMVSS) 141 standard is in place.

This evolving environment demands advanced pass-by noise engineering techniques. Engineers are working at the subsystem level, such as engines, exhaust and tires, to determine their contributions to pass-by noise. By employing such techniques, automotive engineering teams can decide what to focus on to most effectively reduce overall noise levels. This enables them to set noise targets early in the development phase.

Innovative techniques for interior and exterior PBN

Streamlining the approval tests

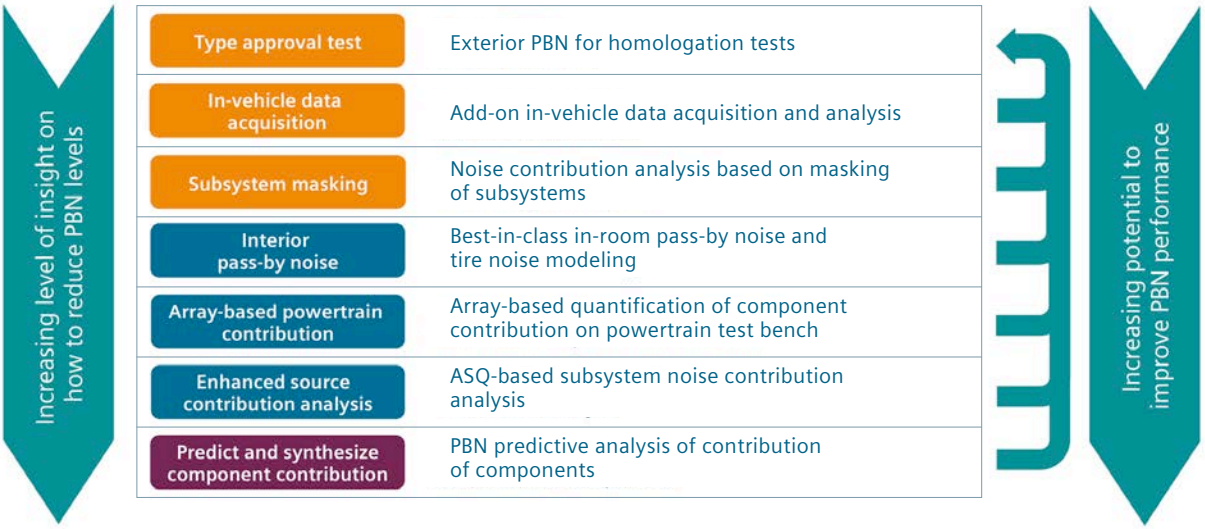
Developing techniques to identify the pass-by noise sources and set noise targets is critical for vehicle engineering teams. From type approval testing to source contribution analysis, Siemens Digital Industries Software offers a complete range of proven techniques for advanced PBN engineering. Siemens Digital Industries Software's pass-by noise solutions provide all the necessary hardware and software for exterior and interior pass-by noise testing and analysis, calibration and maintenance, and these solutions are backed by our experienced Simcenter™ Engineering and Consulting services teams.

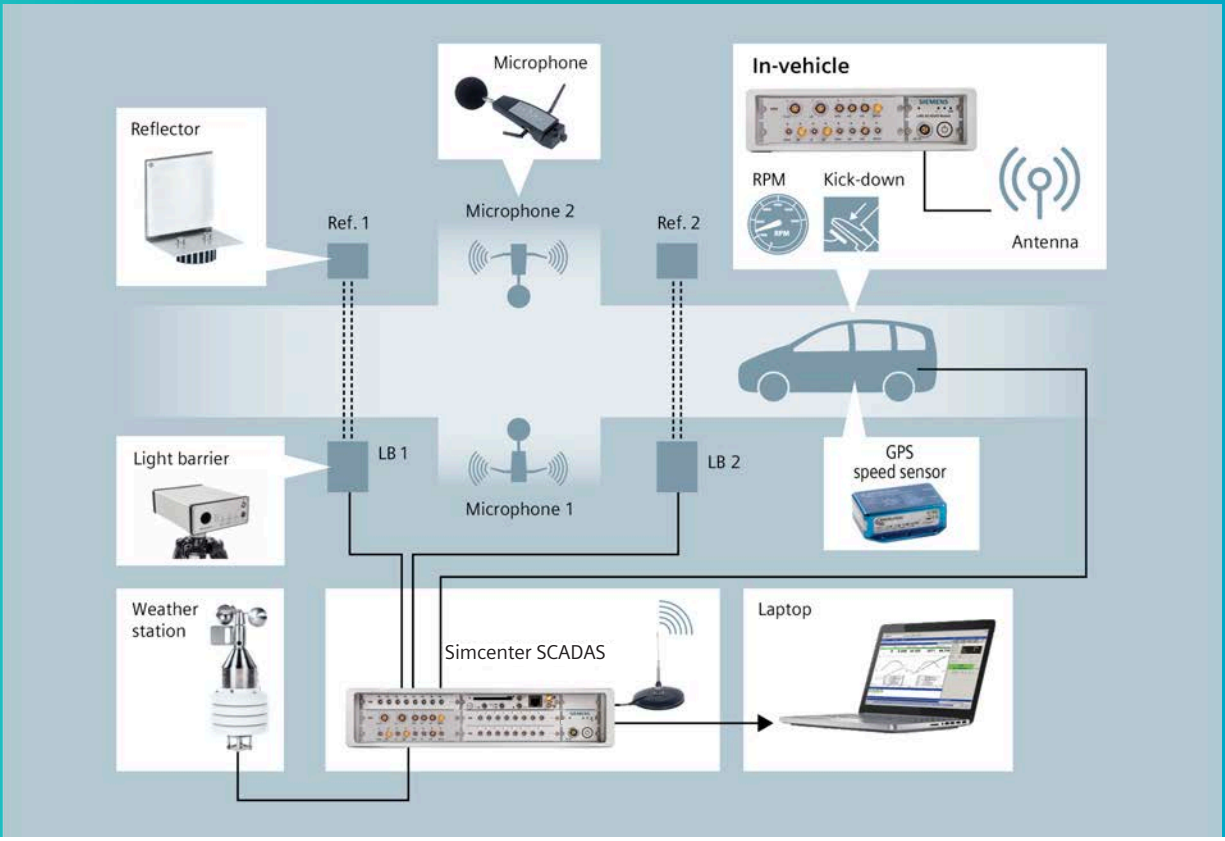
Simcenter pass-by noise testing solutions that are integrated in the Simcenter portfolio provide:

- A fully integrated hardware solution on the Simcenter SCADAS™ hardware acquisition platform
- Software on the Simcenter Testlab™ software platform, with built-in processing, analysis and reporting functionality
- Driver guidance to guarantee maximum efficiency and effectiveness to conduct the test correctly from the beginning
- Coverage for most existing standards and the possibility to extend it
- A broad range of scalable pass-by noise engineering techniques for advanced source contribution analysis such as acoustic source quantification (ASQ) and component-based ASQ
- The ability to perform simulation early in the development process

Pass-by noise engineering

From homologation to advanced PBN engineering





Comprehensive solutions for pass-by noise engineering

Flexible testing platform

Pass-by noise engineering includes the automotive original equipment manufacturer (OEM) strategy of having a final vehicle prototype successfully pass the test: setting PBN targets, predicting PBN levels in the early design phase, assessing the contribution of individual noise contributors and conducting the final approval test.

Simcenter Testlab for exterior pass-by noise from Siemens Digital Industries Software can be configured for dedicated user-defined procedures and specific requirements.

Two typical configurations for standard PBN testing are available:

- Track-based exterior pass-by noise in which Simcenter SCADAS for data acquisition is placed near the test track
- In-vehicle exterior PBN in which Simcenter SCADAS is placed in the vehicle to acquire additional measurement channels for more in-depth analysis

A complete set of sensors

A single pass-by noise system can be used in both configurations. Testing teams can easily swap or combine configurations for advanced tests. The demands of updated testing standards (ISO 362-1:2015, UN/ECE R51.03, R138, FMVSS141) place greater data management demands on pass-by noise testing setups, linking them with advanced engineering tasks. This is especially true for the R51.03 testing method for the Additional Sound Emission Provisions (ASEP).

For techniques such as ASQ or subsystem masking, large amounts of data must be captured near the track and on the vehicle.

The exterior pass-by noise solution has a complete set of sensors, including speed radar or Global Positioning System (GPS) speed sensors, track-based light barriers, optical engine speed and kick-down sensors, a weather station and wired or wireless microphones.

All sensors are conditioned with dedicated pass-by noise modules in Simcenter SCADAS Mobile hardware. The sensors are powered directly by Simcenter SCADAS Mobile without requiring any additional external power supply.

Modular hardware for reliable data acquisition

The centerpiece of the solution is the Simcenter SCADAS Mobile Pass-by Noise Conditioner module, a dedicated two-slot module that features high-quality integrated signal conditioning. This module conditions sensor inputs and delivers outputs for all sensors. By using telemetry, all sensors are synchronized with track and vehicle sides. Standalone wireless microphone conditioner units provide a high-speed data link for the moving vehicle and are used for in-vehicle configuration.

This expanded portfolio provides maximum efficiency and is easy to deploy and use. The Simcenter SCADAS Mobile Pass-by Noise Conditioner module is suitable for testing on standard configuration types such as track-only, track-based and in-vehicle.

The postprocessing software reflects the same user-centric approach. Increased testing and shorter development timeframes can make documenting and reporting results a burden. Thanks to the PBN application, data and reports can be easily archived, retrieved and compared.

To support permanent outdoor installations, standard hubs are installed at trackside. These provide local connection points for track sensors, such as light barriers and support transport, over long cables to a measurement cabin outside the mandatory obstacle-free area. In the cabin, the lightning-strike-protected unit connects the sensor input to Simcenter SCADAS.

Maximizing valid PBN runs

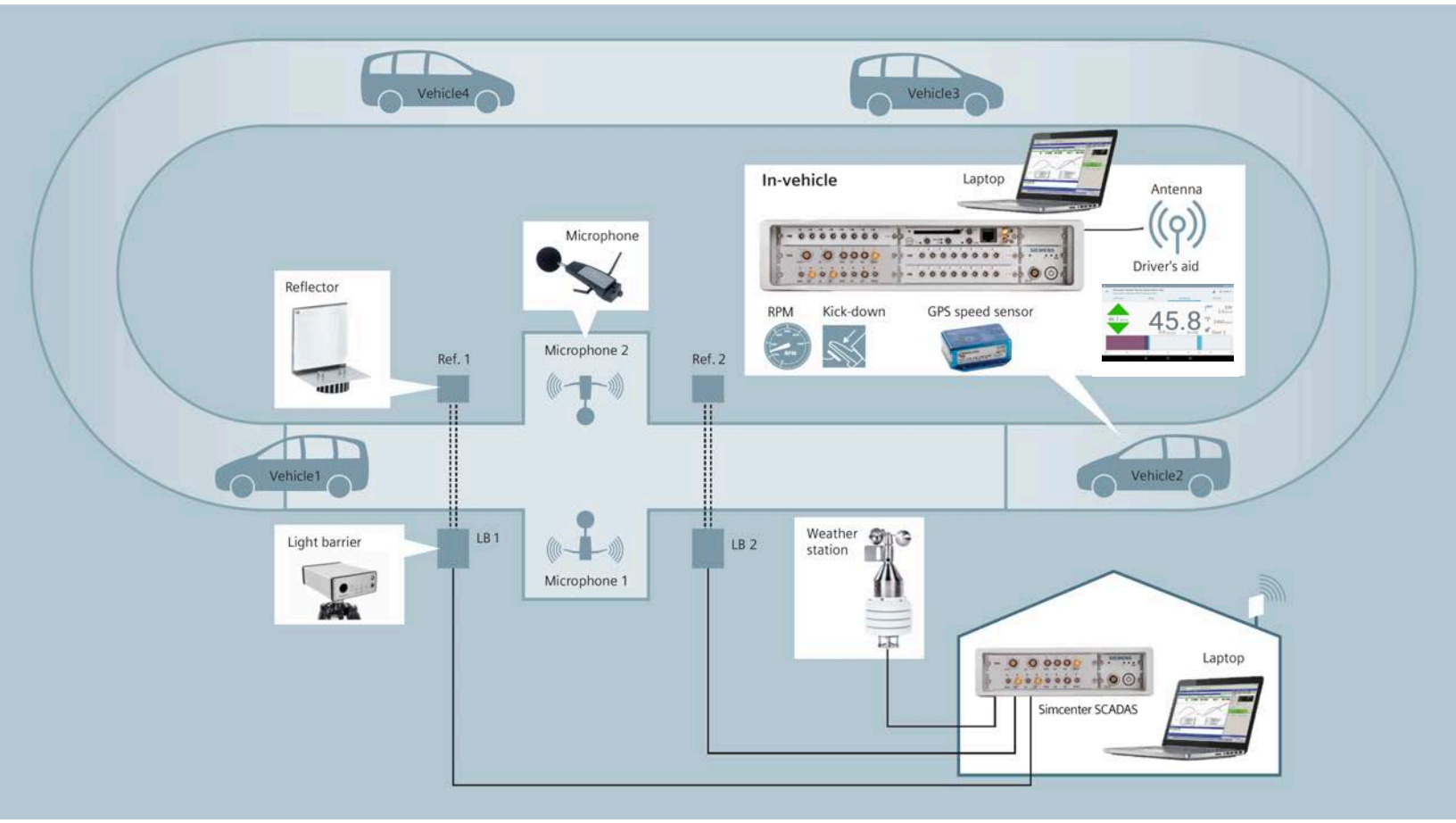
With changing testing standards, the number of PBN runs per vehicle has increased from two to 30. These involve acceleration, constant speed and ASEP: all in multiple gears. Moreover, the operational testing condition differs from one vehicle to another when it comes to reaching the target speed of 50 kilometers per hour (km/h) at the center of the track during wide-open throttle acceleration.

The Simcenter Testlab Pass-by Noise Driver's Aid app allows drivers to maximize the number of successful PBN runs and minimize the number of invalid runs. This tool increases productivity for drivers by showing only relevant information before, during and after the run.

Enhancing the level of accuracy

The Simcenter Testlab Pass-by Noise Driver's Aid runs on a tablet and gives real-time feedback on ideal target vehicle and engine speeds, guides the driver to reach these targets by both visual and auditory means, and updates the approach speed target after each correctly executed run.

It also provides real-time weather information and a report after each run showing only information that is relevant to the driver: Was the run successful, was the speed correct, was the kick-down correct, was the wind speed okay? Failed tests are shown at the top.



Maximizing efficiency on the track

Multi-vehicle driving is a common request from large PBN teams that have lots of vehicle types and configurations to test. This allows multiple vehicles to be driven simultaneously while additional vehicles are being instrumented.

Siemens offers a dedicated, scalable multi-vehicle system in which data is measured both on the track and in the vehicle. Such a system manages which vehicle can use the measurement zone and connect to the track hardware. It can be controlled manually by the driver using the Simcenter Testlab Pass-by Noise Driver's Aid, or it can be a customized, fully automatic monitoring system.

Productivity can be further increased by using multiple sets of microphones, a few pairs before the center line and a few after. A dedicated algorithm can then be used to select the microphone pair that is closest to the target engine speed. This increases repeatability and facilitates a more accurate comparison of PBN runs.

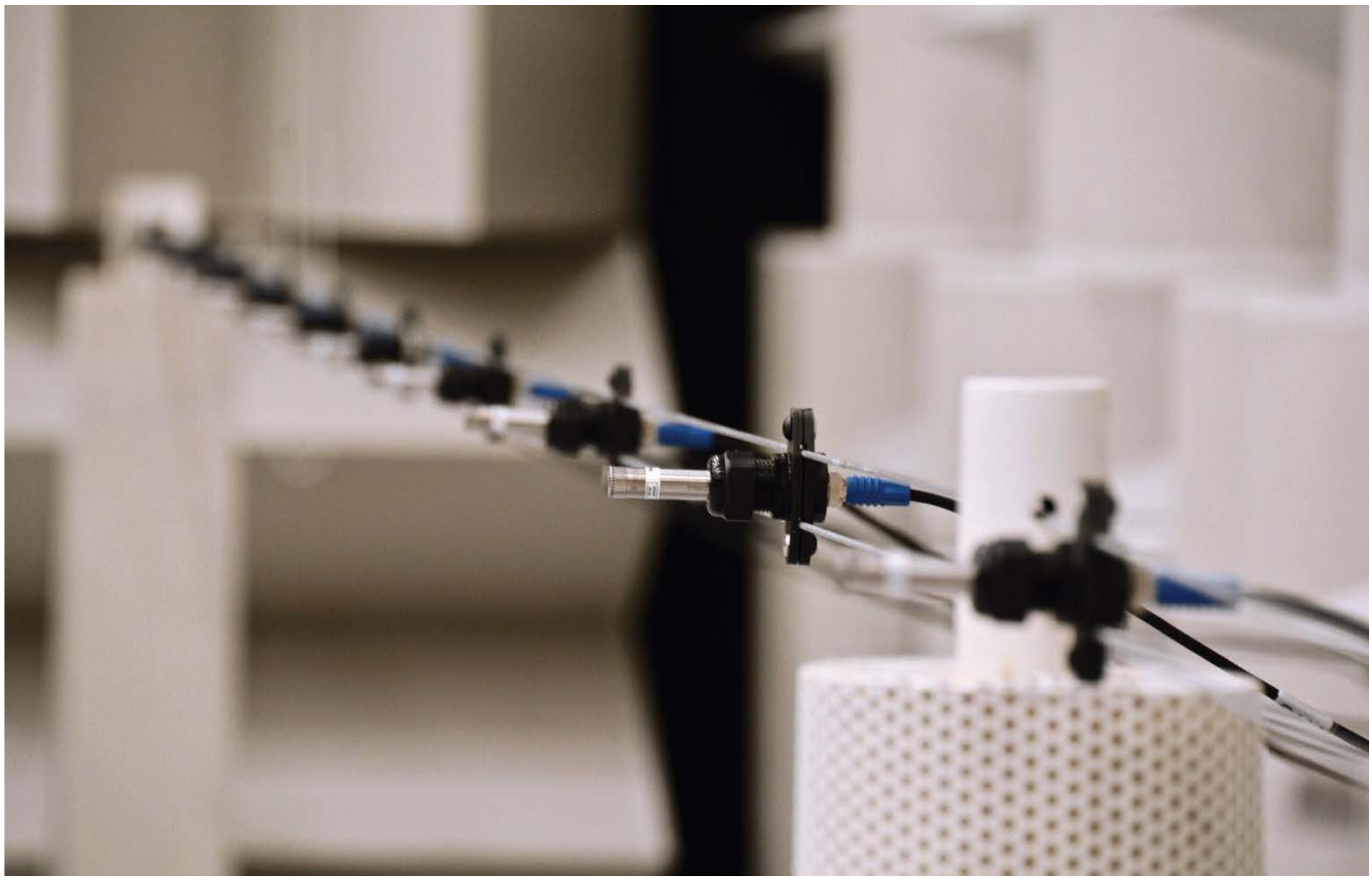
Gaining increased engineering insight

Conducting interior pass-by noise testing in a controlled laboratory environment simulates PBN while eliminating work delays due to weather conditions. This increases productivity and keeps the testing process on schedule. Additionally, it facilitates vehicle development programs, making the run and re-run test requirements associated with vehicle modifications reliable and easy to reproduce. Interior pass-by noise tests in combination with tire noise correction can be used for certification purposes (ISO 362-3).

The in-room PBN solution is like exterior pass-by noise measurements. It measures an array of microphones on each side of the vehicle and recreates the noise level results as a function of vehicle position, as if a single pair of microphones were being measured.

Additionally, the time-based method enables the user to listen to the synthesized time signal and use it for the overall sound pressure (level calculation and throughput postprocessing). This provides better correlation analysis, enabling engineers to glean insight into which components contribute the most.

The in-room pass-by noise solution provides the ability to combine interior PBN with engineering solutions for sound source localization and source ranking, reducing development time while increasing productivity and accuracy.



Detecting dominant pass-by noise sources

Source identification is a major impediment to conducting enhanced pass-by engineering. Different techniques can be used to localize the most dominant sources during a PBN test.

The masking technique provides insight into the contribution of subsystems to the overall PBN level. This technique consists of testing a vehicle indoors or outdoors when noise sources, such as the powertrain, exhaust, tailpipe and tires, are modified or insulated to eliminate their contribution to the overall noise level. A dedicated module in Simcenter Testlab allows you to derive the contribution from masked components by analyzing the difference between the original vehicle and the vehicle with masked components.

To improve identification and ranking of the noise contribution from different subsystems, such as intake, powertrain, exhaust, tailpipe and tires, a dedicated technique is applied based on ASQ, a transfer path analysis (TPA) derivative. It facilitates troubleshooting for reducing pass-by noise and is increasingly used for target setting, thus frontloading PBN engineering in the design process.

Analyzing pass-by noise source contributions

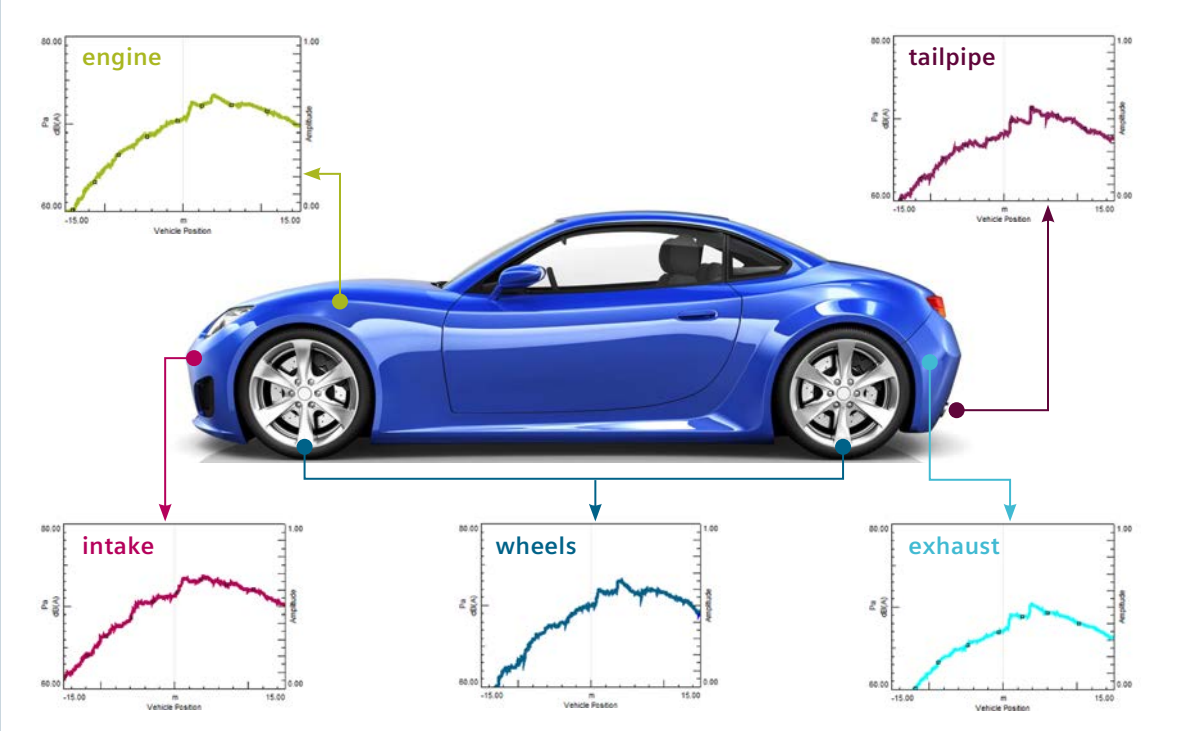
ASQ makes it possible to use the operational signals of microphones placed near noise sources to quantify their contribution. It uses a robust matrix inversion calculation method based on local noise transfer functions. Target noise transfer functions (NTFs) between the sources and exterior target microphones are used to calculate the propagation of these identified sources toward the pass-by noise microphones. The combination of source strength and target noise transfer results in the individual source contributions.

To acquire all the noise transfer functions and optimize the directionality and noise output level, a dedicated Simcenter Qsources™ hardware monopole sound source has been developed. It covers a frequency range from 150 hertz (Hz) to 10 kilohertz (kHz).

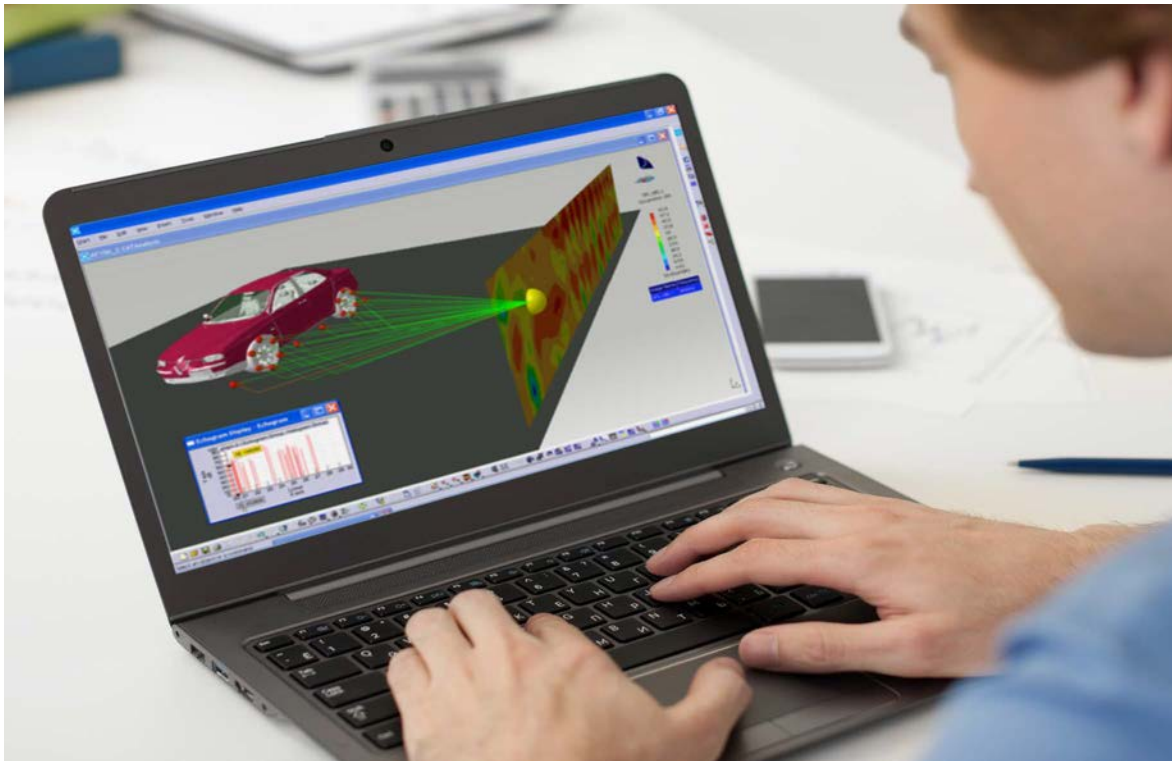
Enabling PBN predictions early in the development cycle

An innovative technique called component-based TPA can be applied in the context of PBN early in the development cycle. This technique consists of defining invariant loads in each of the subsystems, measuring a new component on a component test bench and recombining these components in variants of vehicles and predicting its NVH performance, including PBN levels.

This technique is an important move toward predicting PBN and setting targets for subcomponents.



Creating the ideal virtual test environment



NTFs are most often physically measured. Alternatively, they can be simulated with Simcenter 3D software. The added value of using simulation models is they make it possible to easily create an ideal virtual test environment and obtain results for many designs early in the test and prototype phases. For an effective simulation model, the results should typically range from 20 Hz up to 4 or 5 kHz. Since the model represents the geometry of the full vehicle, the required computer-aided engineering (CAE) models can become large, and, as a result, many frequencies must be computed, resulting in time-consuming tasks.

Simcenter 3D provides state-of-the-art powerful acoustic simulation methods, such as the fast multipole boundary element method (FM BEM) and the adaptive order finite element method (FEM AO), to obtain the acoustic NTFs for all sources contributing to the overall pass-by noise level.

Supported standards

Light vehicles
- ISO 362:1998, implementing UN/ECE Regulation 51.02
- ISO 362-1:2007, ISO362-1:2015 for type M (light vehicles) UN/ECE Regulation 51.03 Annex 3 and Regulation (EU) 540/2014
- ASEP according to R51.03 Annex 7
- ISO 362-3-2016 for indoor testing, including tire-noise modeling
- Test Requirements and Instructions for Automobile Standards (TRIAS) 20 (with tire coasting noise test)
- SAE J1470
- SAE J986

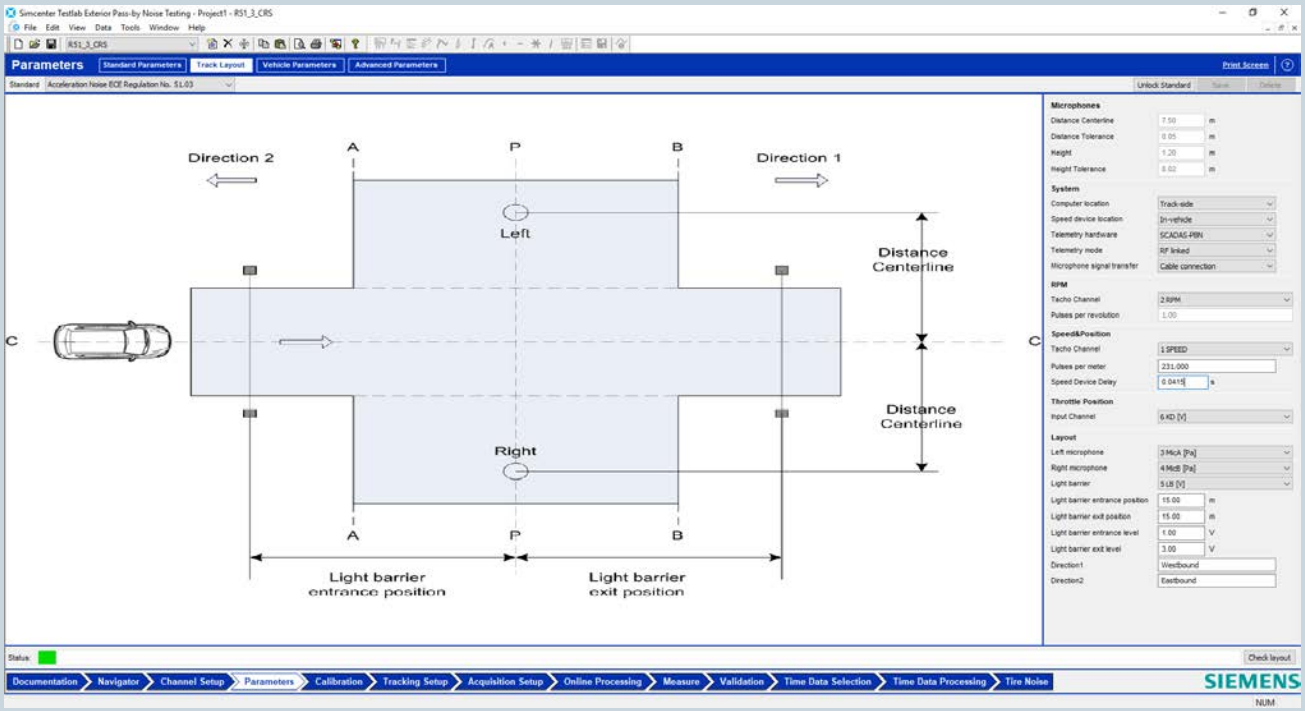
Heavy vehicles
- ISO 362-1:2007, ISO362-1:2015 for type M3 and type N (trucks)
- UN/ECE Regulation 51.03 and Regulation (EU) 540/2014
- SAE J366

Minimum noise
- UN/ECE Regulation 138
- FMVSS 141
- ISO 16254 for minimum noise

Motorcycles
- ISO 362-2:2009 for L category motor cycles (L1, L2, L3)
- UN/ECE Regulation No 41.02 for L3 category motorcycles
- UN/ECE Regulation No 63.01 for L1 category motorcycles
- UN/ECE Regulation No 9.03 for L2, L4, L5 category motorcycles
- ASEP Regulation 41: extension for motorbikes
- F76A US
- NOM-082-ECOL-1994

Exhaust noise
- Exhaust noise: ECE 93/ 97, ISO 5130, TRIAS 20
- SAE J1169 exhaust noise

Tire noise
- UN/ECE Regulation 117 for tire noise
- General tire noise test for generic coast-down testing and regression analysis (no checks defined)
- Tire-noise modeling according to ISO 362-3:2015 for in-room pass-by noise certification
- TRIAS 20 (tire coasting noise test)



About Siemens Digital Industries Software
Siemens Digital Industries Software is driving transformation to enable a digital enterprise where engineering, manufacturing and electronics design meet tomorrow. Our solutions help companies of all sizes create and leverage digital twins that provide organizations with new insights, opportunities and levels of automation to drive innovation. For more information on Siemens Digital Industries Software products and services, visit www.sw.siemens.com or follow us on LinkedIn, Twitter, Facebook and Instagram. Siemens Digital Industries Software – Where today meets tomorrow.

Headquarters:	+1 972 987 3000
Americas:	+1 314 264 8499
Europe:	+44 (0) 1276 413200
Asia-Pacific:	+852 2230 3333

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