APPLICATION NOTE

PULSE™ Indoor Pass-by and Exterior Noise Contribution Analysis System

A pass-by noise measurement is defined as the method of measuring the noise emission of a road vehicle under acceleration conditions, with various gear positions in a certain measurement range. These measurements are mandatory for automotive manufacturers in terms of product certification. For this reason, ISO (International Organization for Standardization) regulates the measurement and analysis procedures, as well as the reporting format.

Pass-by noise measurements are the most important part of trouble-shooting in the mass production of cars, for example in the analysis of engine, intake and exhaust, and tyre noise. The pass-by noise measurement method is designed to meet the requirements of simplicity, as far as it is consistent with the reproducibility of the results.

The pass-by noise measurement should be performed in a large open space, for type approval of commercial vehicles, or measured during the official test station's manufacturing stage. Therefore, it is very important that the certification of emission noise measurements is performed before mass production starts.

In some cases, however, pass-by noise measurements cannot be taken out in 'the field' because of bad weather or poor test-track conditions. In such cases, the indoor simulated pass-by noise measurement is often used. The indoor simulated pass-by noise measurement does offer a number of advantages such as good repeatability, flexibility, ease of use, etc., and is being considered as the conformance test, together with the field pass-by test, by ISO standard.

Introduction

The specifications for the Indoor Pass-by and Exterior Noise Contribution Analysis System are intended to recreate the noise levels produced during the use of intermediate gears, with full utilisation of the available engine power, as may occur in urban traffic. It should be noted that spot-checking of random vehicles can rarely be made in an ideal acoustical environment, and that the obtained results might deviate appreciably from the results obtained using the specified conditions. As a general requirement, the test should be done with the vehicle moving on a road surface; also, the vehicle should be in motion under the operating conditions that yield the highest noise level. The noise measurement should be performed on the test track under acceleration conditions with full throttle.

The Indoor Pass-by and Exterior Noise Contribution Analysis System is a tool to make measurement and analysis simple and reliable not only for trouble-shooting, but also for development procedures.

Instead of making the test vehicle pass two stationary microphones as is standard in a field pass-by measurement, indoor pass-by setups use two rows of microphones placed alongside the vehicle. The vehicle runs on a chassis dynamometer (dyno) and is accelerated in the same way it would be for a field pass-by measurement. Time histories are measured by the microphones in conjunction with vehicle parameters and dyno drum speed. A sophisticated algorithm uses information from the dyno to calculate a vehicle's position relative to the microphones as a function of time. This is then used to extract the contributing portions of the time histories that correspond to when the vehicle would have passed the standard microphone positions had it been moving. A synchronised single time history is created by stitching all of these time history sections together and interpolating across the segments' boundaries. This synchronised single time record combined with the dyno drum speed profile represents the vehicle noise emitted during a pass-by measurement.

This new time history is then played back through the analysis section of the system, offering the option of applying various types of frequency analysis to the time history. It can also be previewed and listened to in order to determine whether it sounds right by using PULSE Time Type 7789 and Pulse Reflex™.

The system implementation is very flexible. Normally it is assumed that noise comes from one point (an acoustic centre), independent of frequency; with indoor pass-by, however, acoustic centres for both the left and right side of the vehicle can be freely chosen.

This system has been developed to allow microphone positions closer than 7.5m from the vehicle centre, while still providing correct results. This is extremely useful for situations where space is limited.

Understanding Exterior Noise Contribution Analysis

The Exterior Noise Contribution Analysis begins with Source Path Contribution (SPC), a technique designed to evaluate contributions from different sources through various paths to a desired receiver location. As such, the dominating source, with respect to a given receiver, can be identified.

The SPC technique can be exploited in order to model the exterior sound field of a vehicle. The exterior noise can be seen as a sum of the contributions from a set of noise components. These components represent the true physical noise sources to be modelled by a set of assumed point source positions. For example, each engine face as well as the intake and exhaust orifice can be taken as once source each. Each source then has an associated strength.

The first step with the SPC technique is to determine the strength of all the vehicle model sources. This is done indirectly, by measuring the sound field at points close to the sources and vehicle with a variety of indicator microphones during vehicle operation. The link between strengths at source positions and sound pressure at indicator positions is made by a set of acoustic transfer functions, measured with a volume velocity source when the vehicle is not in operation. Combining the indicator operating measurements (pass-by run-up data) with the set of transfer functions provides an estimate of the individual source strengths. Additionally, the first step will be the source separation step, which is necessary for obtaining the correct contributions of individual noise components later.

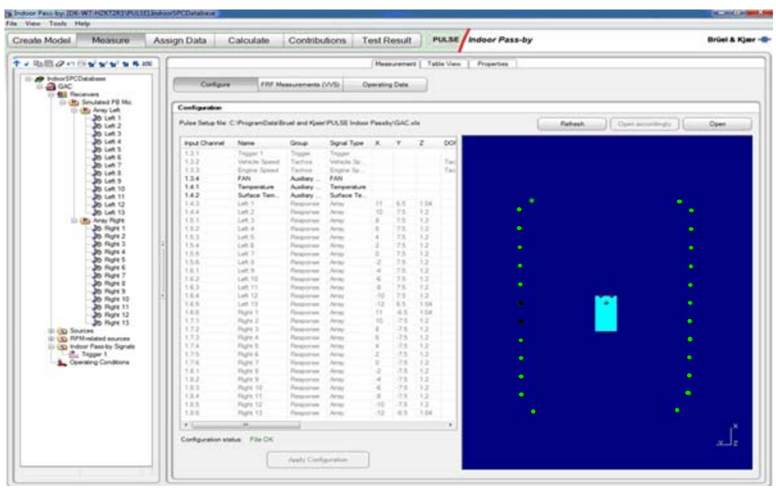
The second step makes use of another set of transfer functions from all source positions to all receiver positions. Using the obtained vehicle model from the first step in combination with the second set of transfer functions provides estimates of the sound field at all the receivers. Here, the receivers will be the microphones of the pass-by position. For each receiver the contribution from one source position can be calculated, a simple time series summation can be made in order to express the predicted contribution from a group of sources. This is necessary to get the contribution from a noise component modelled by several point sources, or to get the overall vehicle contribution, i.e., sum over all source positions.

The final simulated pass-by results are obtained using standard synthesis approach (see standard indoor pass-by calculation procedure), which needs to identify the correct part of the time recordings to use (measured or predicted at the pass-by array microphones) and when to switch between pass-by array microphones. This information is derived from the drum tacho and a fixed factor, like vehicle speed at a certain position relative to the pass-by array.

Phase 1 – Microphone and Measurement Setup

The microphones should be positioned to cover the whole measurement range in an anechoic chamber. The typical type of microphone is line-array, which covers both sides of the vehicle from –10 to +10 metres (Fig. 1). The selection of the number of microphones is a very important factor to be considered for the precise result. As a typical consideration, the span of microphones is generally 1–2 metres. So, the number of microphones would typically be between13 and 24 on a single side; additionally, the vehicle speed signal, trigger and engine RPM signals are required.The microphone position is shown in the measurement setup, together with the coordinates, degree of freedom (DOF), signal name, and the hardware's input channel information. Operating measurement conditions such as trigger type, driving type and gear positions can also be determined at this stage. For the small size room, the microphone positions can be modified to cover the of measurement area. This technology is available for the smaller room with optimized microphone array profile.

Fig. 1
Indoor pass-by microphone configuration and measurement tree

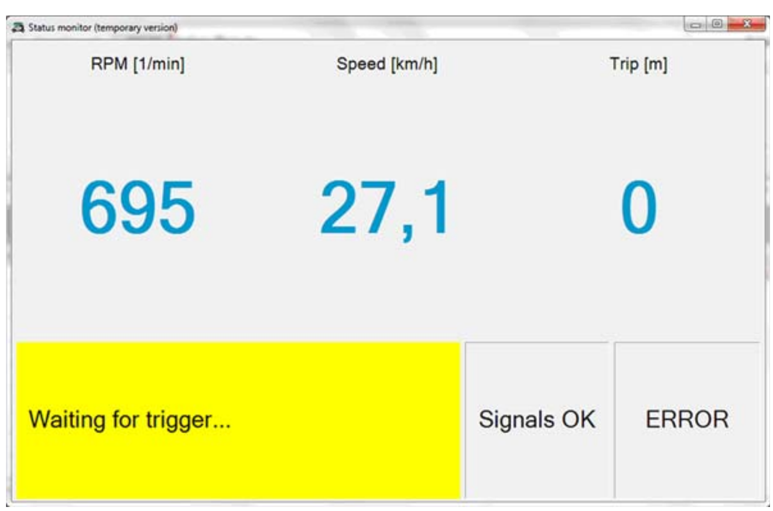


The analysis properties can also be configured: cut-off frequency, engine rpm properties, vehicle speed calculation properties, and the effective measurement range according to the microphone position (Fig. 1).

Phase 2 – Measurement

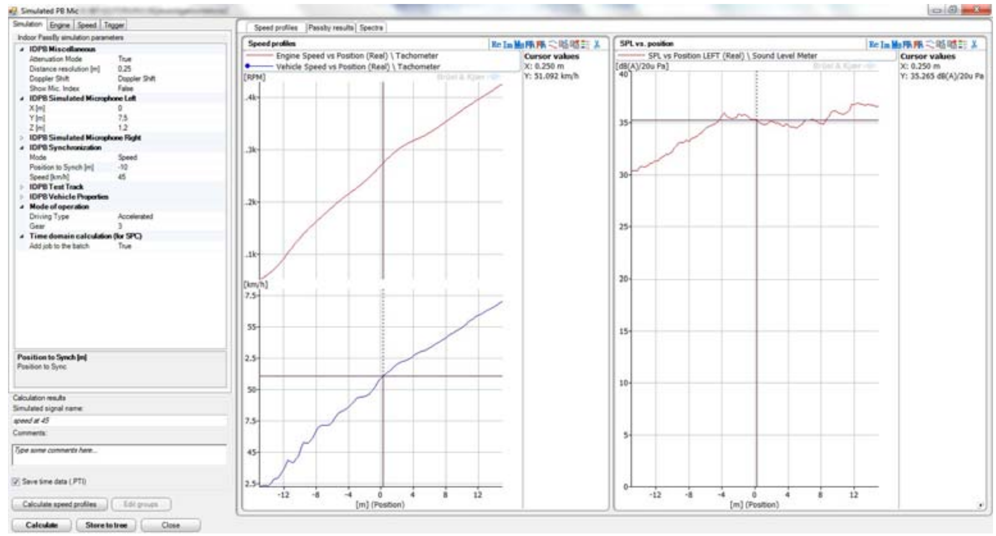
After setup, the measurement records the pass-by data – speed, engine RPM, trigger and noise level of pass-by microphones in time-history status. During the recording, the pass-by is monitored as shown in Fig. 2.

Fig. 2
Monitoring the measurement status



Once the measurement has been done, the results can be seen immediately in terms of vehicle speed profile, engine RPM, noise level at the pass-by position, together with the information that is required for ISO 362 (see Fig. 3)

Fig. 3
Measurement evaluation result under operating conditions, showing Distance vs. Speed, Distance vs. Engine RPM and Distance vs. Pass-by Noise Level



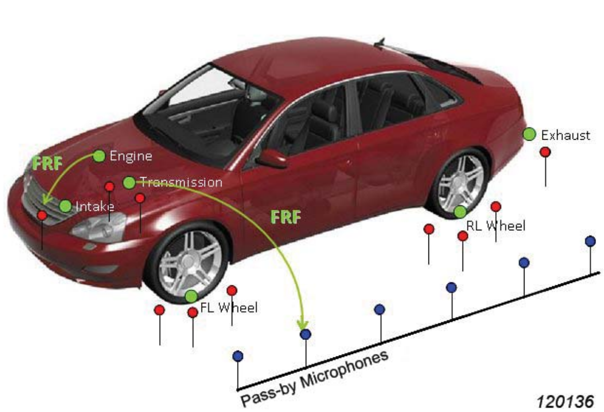
Phase 3 – Tyre-noise Correction

The essential idea of tyre-noise correction is to replace the indoor tyre noise with field tyre noise in the same vehicle. For this, you can choose the tyre noise on the chassis dynamometer; and at the same time, the coast-down tyre noise from the field test should be chosen to replace and correct the tyre noise. This option is giving the equivalency of field pass-by. (Fig. 4).

Fig. 4
Tyre-noise correction option

Phase 4 – Exterior Noise Contribution Analysis

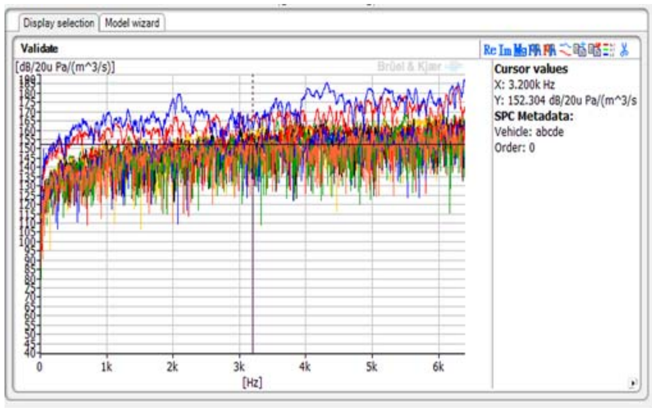
Fig. 5
Set-up of pass-by and indicator microphones for FRF measurement



Measure FRF between Source Positions and Microphones

Some indicator microphones are used for determining the source strength, in a similar way to an SPC analysis. Essentially, the indicator microphones are placed around the sources, which can represent the source characteristics as shown in Fig. 5. The first step with an Exterior Noise Contribution Analysis is to measure the FRFs (Frequency Response Functions) between source positions and both sets of microphones.

Fig. 6
FRF Source to Pass-by and Source to indicator microphones



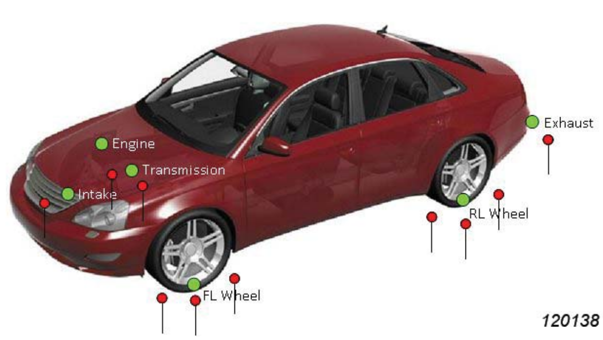
This FRF measurement uses a VVS (Volume Velocity Sound Source, Fig. 7) as a known source that moves around the source positions. These positions should be decided in order to reflect the sound-source characteristics – in terms of power as well as propagation.

Fig. 7
Volume Velocity Sound Source for FRF measurement

Measure Source Strength under Operation

The indicator microphones are also used for the calculation of the source strength under operating conditions.

Fig. 8
Operating source strength measurement



During operation, the indicator microphones use the source sound characteristics to calculate the source strength. They should, therefore, be positioned in locations that do not interfere with the vehicle's operation (Fig. 8).

Fig. 9
Typical exterior noise contribution results (in terms of engine, exhaust and tyres) for, in this case, Smart cars

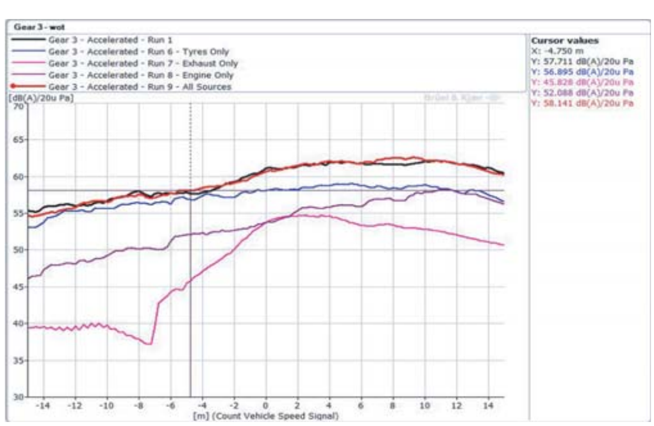


Fig. 9 shows a typical result of an Exterior Noise Contribution Analysis, with a breakdown of individual sound sources: engine, exhaust and tyres. In this result, the summation of all contributions is understood as the total level of Pass-by noise, and each sound source contributes under certain operational conditions.

Summary and Remarks

This system is a combination of PULSE Indoor Pass-by and PULSE Time Domain SPC Analysis, which will analyze the exterior noise as well as indoor pass-by noise with tyre noise correction, as shown in Fig. 10

The system consists of indoor pass-by microphones that cover either one, or both sides of the vehicle in the anechoic chamber, and indicator microphones which surround the sound source. A VVS is also used for the measurement of FRFs.

Flexibility

The system fits in a normal room and is able to measure the full range of pass-by measurements regulated by ISO, as well as in a smaller room with microphone array modifications.

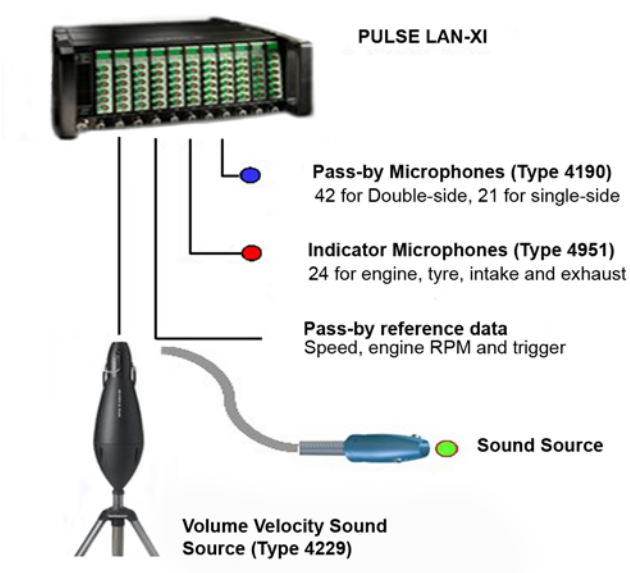
Efficient Operation

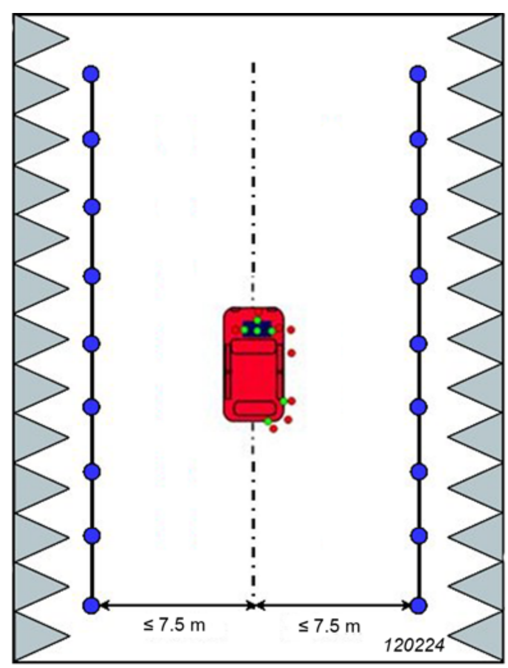
This system utilizes a SPC user interface based on a SQL server database. Operation is therefore simple and visible afterwards in the tree architecture. From setup to results only a few mouse clicks are required, and the results can be viewed almost immediately after the measurement.

Reliability

Results are easily understandable, with the sound pressure level from the sources presented in a straightforward and clear way. The Indoor Pass-by result can be shared with the Field Pass-by; the Exterior Noise Contribution can also be shared with the SPC result, both under an evaluation procedure.

Fig. 10 *System configuration of PULSE Indoor Pass-by*





BO 0519 – 11 2012-03

HEADQUARTERS: Brüel & Kjær Sound & Vibration Measurement A/S · DK-2850 Nærum · Denmark
Telephone: +45 7741 2000 · Fax: +45 4580 1405 · www.bksv.com · info@bksv.com

Local representatives and service organisations worldwide

Brüel & Kjær