

BRÜEL & KJÆR® Acoustic Analysis Software

BK Connect Indoor Pass-by Pass-by SPC Type 8441-D

To avoid excessively high traffic noise in our urban environment, pass-by noise measurements are mandatory for vehicle noise certification. The standard pass-by test is normally performed outdoors on a dedicated pass-by test track, but the standard and regulations also allow for simulation using measurements indoors on a chassis dynamometer in a hemi-anechoic chamber.

The indoor pass-by noise test is a recognised alternative to the standard outdoor test for certifying road vehicles for exterior noise emission. The test is performed on a chassis dynamometer indoors enabling repeatable operating conditions all-year round without weather interruptions. The indoor test is also accepted under UN regulations for type approval and conformity of production.

BK Connect Pass-by SPC helps you investigate the contribution of noise sources such as, tyres, engine/motor, exhaust, to the overall pass-by noise.



210027

Uses and Features

Uses

- Perform source path contribution analysis (acoustic transfer functions and operating conditions) to evaluate source contributions to vehicle pass-by noise
- Ranking of contributions to pass-by noise
- Evaluation of design alternatives and their effects on pass-by noise emission
- Gain insights on root causes and potential solutions of pass-by noise problems
- SPC-based tyre noise correction of indoor pass-by simulations using outdoor track measurements
- Contribution analysis in conjunction with VI-Grade NVH Simulator or Insight Type 8601-S
- Management and sharing of large amounts of SPC data (measurement, calculation, and analysis) in an indexed, sharable, file-based database

Features

- Task-oriented, user-friendly software
- Offline setup in Microsoft® Excel® with one-step import to BK Connect for quick start-up
- Acoustic transfer function matrix validation tool to help optimise conditioning for SPC analysis
- User control of calculation frequency range
- Frequency-dependent control of condition number threshold to minimise inversion errors
- Component source grouping tool with the ability to control the order of analysis and minimize cross-talk errors
- Ability to import field pass-by data for results comparison or tyre noise calculation
- Network-based data file sharing in Team Server using a common file repository
- Results presented in Pass-by Viewer for comparison with regulation field (outdoor) and indoor pass-by noise tests
- Report to Excel for flexibility of downstream reporting
- Export time data for post-analysis, such as order extraction or narrow band spectral analysis with BK Connect
- Multiple file formats supported for acoustic transfer functions (ATFs) and operating data
- Results management using Team Server enabling comparison of pass-by results from any test source

Pass-by Source Path Contribution (SPC) Analysis

Source Path Contribution (SPC) analysis is a technique for evaluating noise contributions from suspected sound or vibration sources through various acoustic or vibro-acoustic paths to a desired receiver location. Dominant sources with respect to a given receiver can be highlighted to help focus engineering effort where it has the greatest effect.

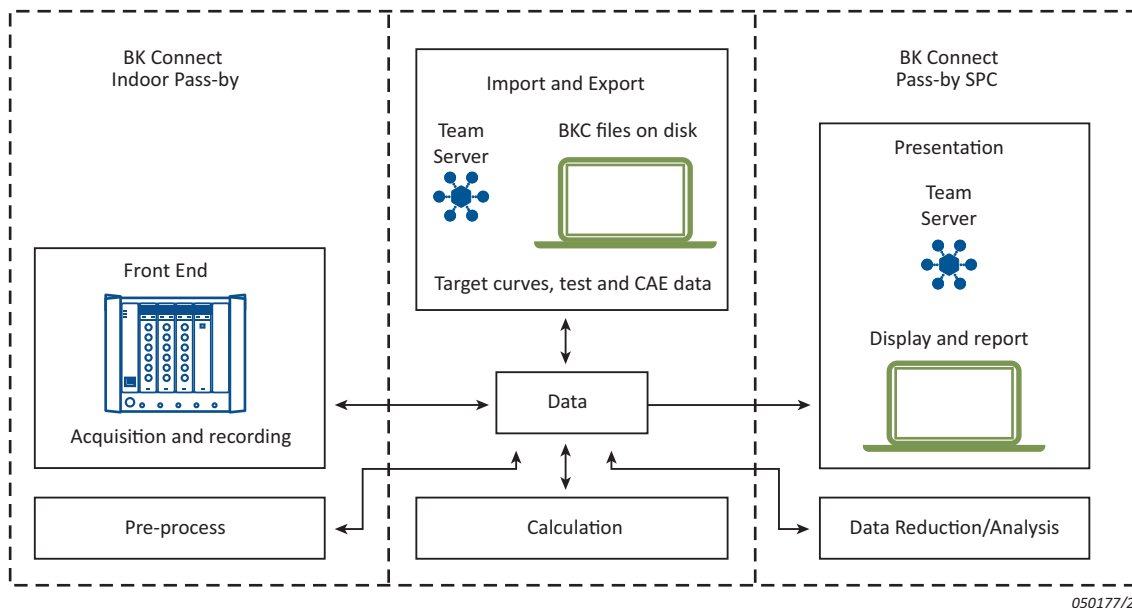
While SPC methods are often used for interior cabin noise analysis with sources and paths being both acoustic and vibratory, BK Connect Pass-by SPC is specially designed for pure acoustic analysis using measurements from an indoor pass-by setup. Pass-by operating measurements include indicator microphones around each source so that, combined with ATFs measured using a volume velocity source (VVS), the operating source strengths are determined for each source. The source contributions are then evaluated at each pass-by array microphone in the same way as in a standard indoor pass-by

test, then processed to produce a pass-by noise simulation with contributions from each source. The overall result can be validated using the standard pass-by result.

BK Connect Pass-by SPC answers questions like:

- Which noise sources are important?
- Which noise paths are most critical over which frequency ranges?
- How do the paths interact?
- How does the noise get to the pass-by microphone?
- Is the source too loud, or does the path transmit noise too easily?
- Will my vehicle meet pass-by noise emission targets with these new components?
- What will happen to the pass-by noise when I make a design change?

Fig. 1 Diagram showing pass-by SPC



The BK Connect Pass-by SPC Solution

Unlike solutions from some other suppliers, BK Connect's SPC methods calculate source contributions explicitly, rather than breaking down the measured total sound into contributions which must always equal the original measured sound. The explicit method enables greater confidence as comparing the sum of contributions with the original overall measured data is a true validation of the model with results that are obtained independently of each other. A close match gives confidence in the modelling assumptions, which is important when using SPC

for making real engineering decisions such as in design optimisation or problem resolution.

The BK Connect method enables component source modelling where the noise components represent the true physical noise sources to be modelled by a set of assumed point source locations. For example, each engine face, the intake orifice and the exhaust orifice, can be taken as one source each. Each source then has an associated source strength explaining how powerful the given source is.

The Pass-by SPC Workflow

The first step in 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 vehicle with an array 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 powerful volume velocity source when the vehicle is not operating. 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, this first step will be the source separation step, which is necessary for obtaining the correct contributions of individual noise components at a later stage.

The second step uses another set of transfer functions, from all source positions to one, or several, receiver positions. Using the obtained vehicle model from the first step (above) in combination with the second set of transfer functions, provides estimates of the sound field at all the receivers. In Indoor Pass-by, the receivers are the micro-phones of the pass-by array. For each receiver we calculate the contribution from one source

position, or make a simple time series summation, 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, that is, the sum over all source positions.

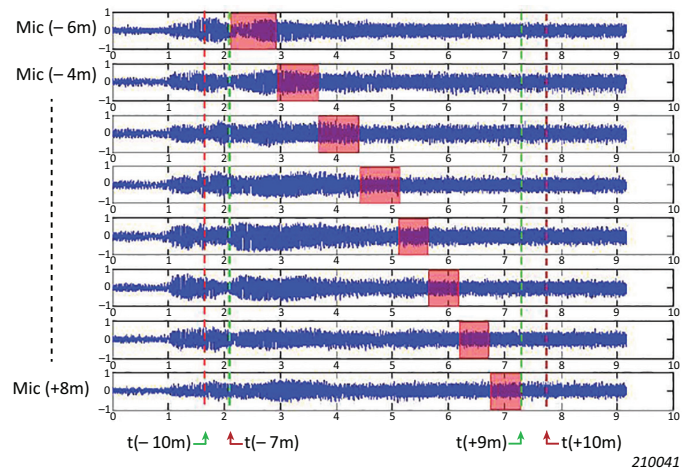
The final simulated pass-by results are obtained using standard indoor pass-by synthesis approach, which needs to know which part of the time recordings to use (measured or predicted at the pass-by array) and when to switch between pass-by array microphones. This information is derived from the drum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

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.

Fig. 2 Example of time signal synthesis



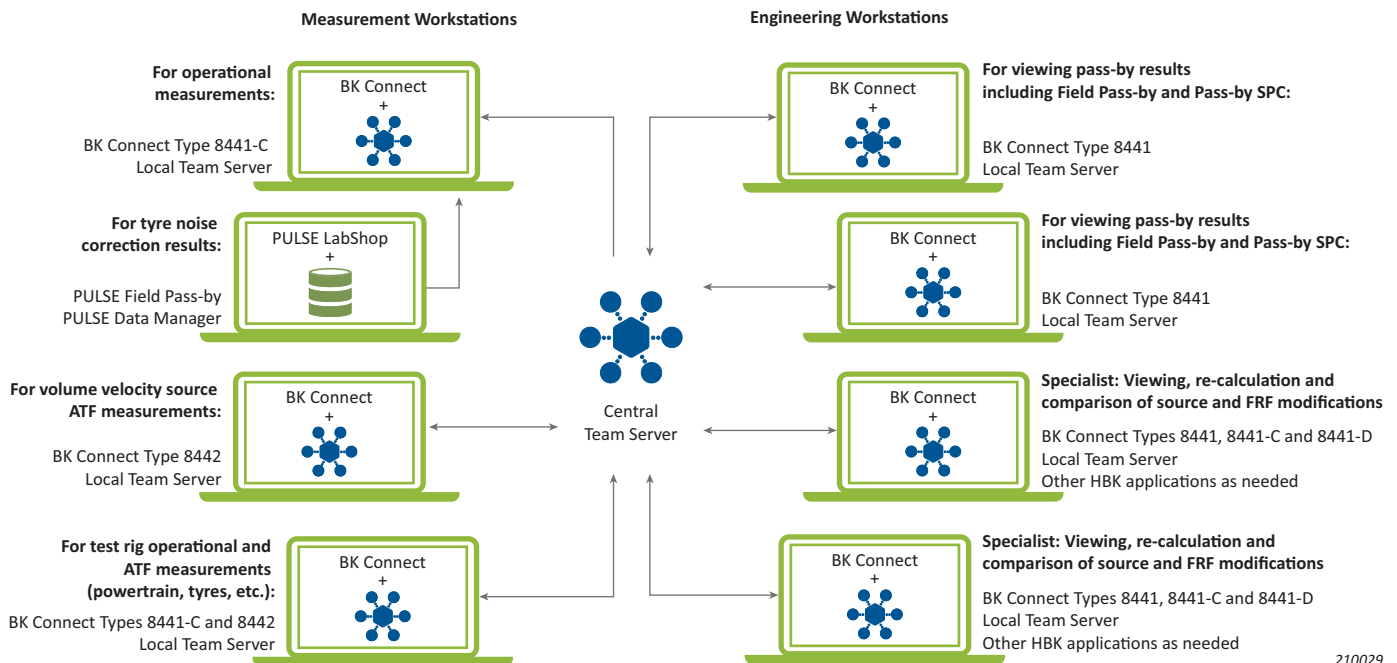
Team Server Concept

The Team Server concept enables data to be shared easily across organisations by storing data files in a central shared file repository that is accessible using standard Windows profiles. With Team Server automatically integrated in the Pass-by Viewer interface, results can be effortlessly inspected by any tester or engineer with access to the shared file repository – including those working remotely. The file repository is, by default, local on

the measurement PC, but it can also be in a shared folder on the network which enables collaborative working across the organisation. Access can be extended to engineers from partner companies if access privileges have been granted.

The repository, whether local or shared, is automatically indexed by the Team Server to enable powerful data searches in BK Connect.

Fig. 3 The Team Server integration in the BK Connect Indoor Pass-by suite



Model Task

The Pass-by SPC model defines the relationships between operating data for indicators and pass-by microphones, and the ATFs which are used to perform calculations to:

- Estimate the individual operating source strengths
- Derive the source contributions at each of the pass-by array microphones
- Calculate the contributions, including underlying 3rd octave spectral data, to a simulated pass-by measurement at the PP line

The model is loaded from the same Excel file as originally used for the Indoor Pass-by operating measurements. If needed, metadata may be edited beforehand in the Excel file or in BK Connect. Once the model has been defined in BK Connect, the ATFs are loaded and validated against the SPC model. The user

interface indicates green for OK and red when data is missing. An example is shown in Fig * after all ATFs have been loaded.

Validation Tasks

The Time Editor task is included to enable the SPC analyst to inspect the operating data before proceeding to SPC processing. Here the analyst can view the time data, gain insights on frequency content, and listen to it. Listening, in particular, helps with data validation of times series data.

In an SPC analysis, the source-to-indicator ATFs are combined with the indicator operating sound pressures to generate operating source strengths for each assumed source. With the FRF Validation task the analyst has a tool to view the full matrix of ATFs, investigate the details of any one individual ATF, nullify individual ATFs or groups of ATFs, and make an early estimate of the optimum threshold below which the inversion is zeroed to avoid artifacts caused by low-level noise.

Fig. 4 The full matrix shown for a given frequency which is selected in the FRF graph

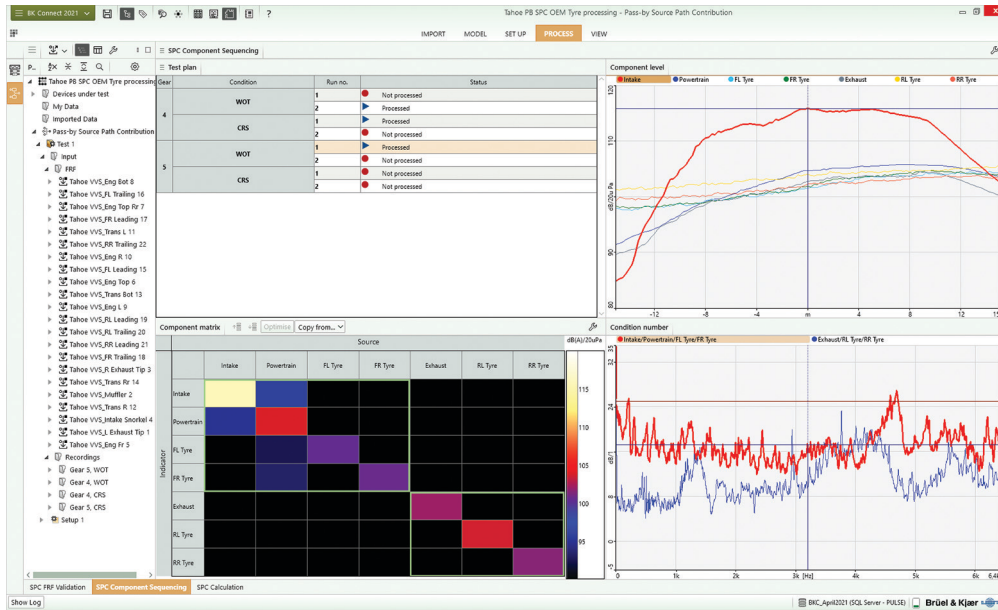


Component Sequencing

Component sequencing is performed before the final SPC calculation. It is a pre-analysis of the effects of different choices in sequencing the analysis of source groups, the so-called Component Matrix method. When selected, the analyst can choose the order in which the components are processed, which often produces better results. If the Component Matrix method is not selected, all source grouping is ignored and the full matrix of sources and receivers is used for the analysis.

Fig. 5 below shows a full test plan of multiple runs with four different driving conditions. The analyst selects a run and performs the calculation. The upper right graph shows the contribution level as a function of position of each source group to its own indicator group. The cursor controls what is seen on the lower left Component Matrix which is visual feedback on the amount of direct and crosstalk contributions between source groups and indicator groups. The ideal is a perfect diagonal of dominant contributions, but the reality is often a degree of crosstalk between groups. The objective is to sequence the sources with the least crosstalk to be at the beginning so that any cross contamination is left until the final step in the sequence.

Fig. 5 A full test plan of multiple runs with four different driving conditions



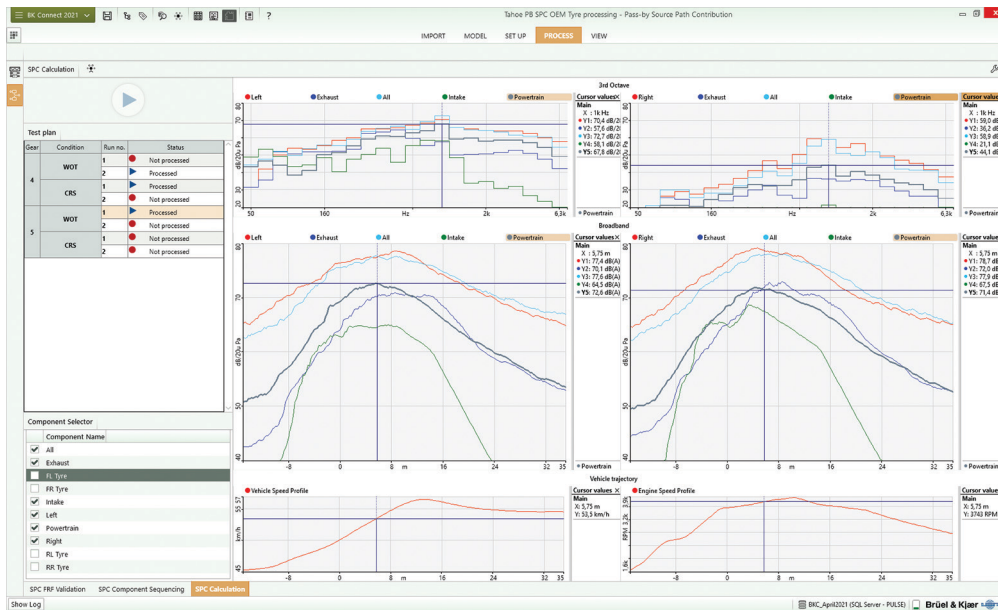
Calculation

The Calculation task is where the final SPC calculation is performed and the results are viewed. As in the Component Sequencing task, the full test plan is shown. Each run can be processed independently to produce the overall pass-by result with contributions and underlying third-octave spectra.

Cursors in the displays are linked so that a particular feature in the overall result can be traced to the contributing frequencies and the source(s) which most dominate at those frequencies.

The results are easily shared to Team Server.

Fig. 6 The Calculation task



Data Management Using Team Server

The BK Connect Pass-by SPC software is seamlessly integrated with the Indoor Pass-by (Type 8441-C) and VVS Measurement (Type 8442) software with a shared data model enabling them to work together as an integrated whole. If all three applications are present on one computer, data integration can be handled, either directly in a BK Connect project or by means of a local file repository and Team Server. The advantage of the Team Server approach is it enables much more freedom to build and work with projects using a variety of different data sources.

A more common scenario is where the SPC analysis is performed away from the engineering lab in an office setting. In this case, the data files can either be transferred across the

network to the analysis computer's own local file repository, or they can be shared to a common file repository accessible across the network. In each case, the Team Server enables powerful data searches using any available metadata.

Results Storage and Viewing

Once the Pass-by SPC results are stored or shared to Team Server, they can be viewed in the Pass-by Viewer alongside any other type of pass-by result; including other SPC results, field pass-by and indoor pass-by.

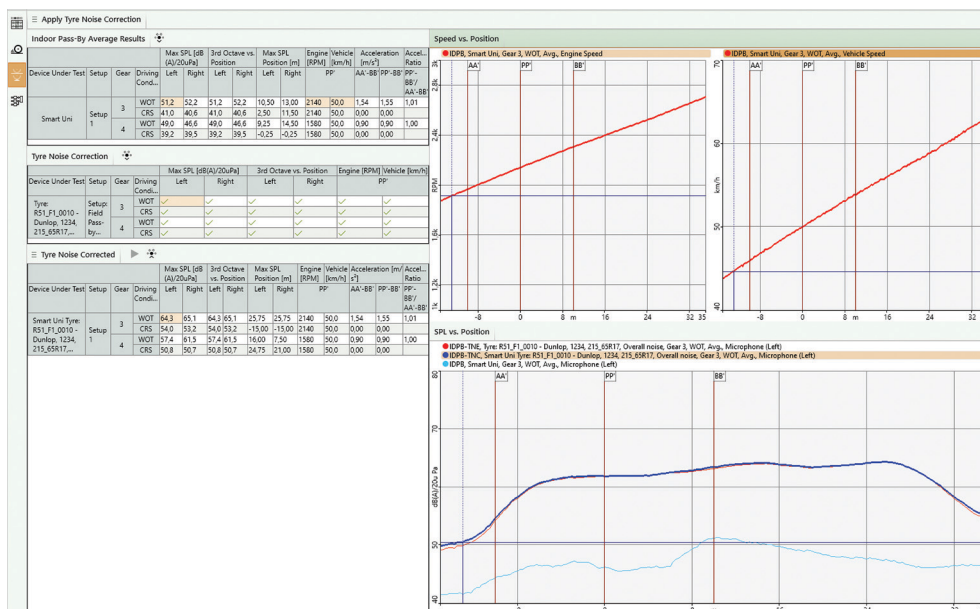
Pass-by Viewer functionality is described in the [Indoor Pass-by PD](#).

Tyre Noise Correction

The SPC, source-indicator, method for extracting tyre noise correction involves using the full SPC model to determine an indoor pass-by result with no tyre contribution, then subtracting that from the same model including tyre noise contribution from

an outdoor measurement on a test track. Identical tyre noise indicators are used in both sets of operating measurements, and the performance curve must be the same or similar between matching conditions.

Fig. 7 Tyre Noise Correction sub-task. The highlighted section comprise: (from the top): the original indoor pass-by results; the tyre noise correction data; the corrected indoor pass-by results



Specifications – BK Connect Pass-by Software

This Windows®-based analysis software is delivered via download option or USB installation media. The licence is either: node-locked to a PC host ID or dongle; or floating, locked to a network server

Supported Standards

Pass-by noise testing of accelerating road vehicles according to ISO 362-3 for M and N category vehicles (light vehicles, buses, and trucks) plus L category vehicles (two and three wheelers).

Conformance to UN regulation R51.03, noise emission of M1, M2 (below 3500 kg) and N1 category vehicles

System

PC SYSTEM REQUIREMENTS

- Microsoft® Windows® 10 Pro or Enterprise (x64) with either Current Branch (CB) or Current Branch for Business (CBB) servicing model
- Microsoft® Office 2016 (x32 or x64) or Office 2019 (x32 or x64)
- Microsoft® SQL Server® 2019

RECOMMENDED PC SYSTEM

- Intel® Core™ i9, 3 GHz processor or better
- 32 GB RAM
- 1 TB Solid State Drive (SSD) with 100 GB free space, or better
- 1 Gbit Ethernet network
- Microsoft® Windows® 10 Pro or Enterprise (x64) with CB
- Microsoft® Office 2019 (x32)
- Microsoft® SQL Server® 2019
- Screen resolution of 1920 × 1080 pixels (full HD)

Specifications – BK Connect Pass-by SPC Type 8441-D

Software Prerequisites

- BK Connect Pass-by Viewer Type 8441
- BK Connect Native File Importers Type 8400-B – for access to PULSE Data Manager

Team Server

EXPORT	<ul style="list-style-type: none"> • Measurement and analysis files saved and exported to folder via the Project Browser • Does not require Microsoft® SQL® database
IMPORT	<ul style="list-style-type: none"> • Import data directly in BK Connect project
FILE FORMAT	<ul style="list-style-type: none"> • Works for all of file types supported by BK Connect, however the .bkc file has more attributes available to be indexed
SEARCH DATA	<ul style="list-style-type: none"> • Search using multiple attributes (metadata) • Two search methods: <ul style="list-style-type: none"> – Basic: Select search criteria from dropdown menu – Advanced: Build search string using standard query syntax • Search strings can be stored as favourites for future reuse • Get overview of query results in Results Matrix • Select one or more results in matrix and view and inspects data in Results Display

Import/Export

IMPORT/EXPORT	<ul style="list-style-type: none"> • Import model from Microsoft® Excel® • Import time and function data via Team Server (.bkc format) • Export model to Microsoft Excel for off-line editing • Export recording and processed data (.bkc format)
IMPORT FROM PULSE DATA MANAGER (PDM)	<ul style="list-style-type: none"> • Data in PDM database must include PULSE pass-by data

Modelling

ARRAY GEOMETRY	<ul style="list-style-type: none"> • Load model from Excel – model previously created in Indoor Pass-by or by editing existing Microsoft Excel file • Review model geometry • Edit the acoustic centre as needed
SPC	<ul style="list-style-type: none"> • Check whether FRFs are missing – red or green status • Operating data (multiple runs on a specific vehicle), full test plan if required

SPC Processing

FRF VALIDATION	<ul style="list-style-type: none"> • View the complete matrix of ATFs • Interactive displays showing FRF level for each indicator and source, individual FRF selected in matrix, condition number at a selected frequency • Indicates where the most error could come from the matrix inversion which is at the heart of the source strength calculation and gives instant feedback on the effect of potential changes • Matrix refinement by excluding data below or above specified frequencies, or excluding individual FRFs, sources or indicators • Define preliminary (starting) condition number threshold value for matrix inversion
-----------------------	---

SPC COMPONENT SEQUENCING	<ul style="list-style-type: none"> Interactive displays show source group ranking and contribution to pass-by noise level Enables both the order of component sequencing to be switched and combining of source groups if the amount of crosstalk is considered too high Includes an automatic optimisation feature to select sequencing and grouping Condition number give feedback on its effect The condition number threshold can be set as constant across all frequencies, or as a frequency-dependent curve
SPC CALCULATION	<ul style="list-style-type: none"> Test plan overview of available conditions and runs with controls for calculating contributions Calculate button - uses source grouping from previous step Comprehensive result displays including: <ul style="list-style-type: none"> 3rd-octave colour maps Pass-by noise levels Speed profiles

Tyre Noise Correction

Method	Source-indicator method
Extraction	Result stored and used for tyre noise correction of Indoor Pass-by measurements

Data Viewing

Data Selection	<ul style="list-style-type: none"> Uses Team Server to query data in files stored in the Team Server file repository
Data Viewing	<ul style="list-style-type: none"> Queried data automatically sorted into a test plan view that shows the numerical results and status icons associated with each run and run group average in a table Can view and compare multiple data sets from different tests on different vehicles or different vehicle variants Display panel can be undocked and moved to another computer screen Displays: <ul style="list-style-type: none"> Speed curves 1/3-octave spectra at max SPL position A-weighted SPL vs position 1/3-octave waterfall spectra vs positions
Data Comparison	<ul style="list-style-type: none"> Select cells in the table to view underlying data Select a row to view all the data for the selected run Cursors between the SPL vs position curves and 1/3-octave plots are linked Selecting from multiple rows compares (overlays) data for those runs
Data Reporting	<ul style="list-style-type: none"> Results can be exported to CSV files for reporting

Ordering Information

Type 8441-D BK Connect Pass-by SPC

REQUIRED SOFTWARE

Type 8400-X BK Connect Data Viewer
Type 8400-B-X BK Connect Native File Importers – for access to PULSE Data Manager
Type 8441 BK Connect Pass-by Viewer

OTHER PASS-BY SOFTWARE

Type 8441-C BK Connect Indoor Pass-by
Type 8442 BK Connect VVS Measurement

Other Available BK Connect Software

Type 8400-NT BK Connect Data Viewer (free viewer)
Type 8400-A-X BK Connect Data Viewer (advanced)
Type 8400-C-X BK Connect External File Importers
Type 8400-D-X BK Connect Nastran Interface
Type 8400-E-X BK Connect Ansys Interface
Type 8400-F-X BK Connect Abaqus Interface

DATA ACQUISITION APPLICATION MODULES

Type 8401-X BK Connect Hardware Setup
Type 8401-A-X BK Connect Hardware Setup (advanced)
Type 8401-V-X BK Connect Virtual Hardware Setup

DATA RECORDING APPLICATION MODULES

Type 8402-X BK Connect Time Data Recorder

DATA PROCESSING APPLICATION AND OPTION MODULES

Type 8403-X BK Connect Data Processing
Type 8403-A-X BK Connect Data Processing (advanced)
Type 8405-B-X BK Connect Advanced Frequency Analysis Option
Type 8405-C-X BK Connect CPB Option

Type 8405-E-X BK Connect Order Analysis Option
Type 8405-F-X BK Connect Order Tracking Option
Type 8405-G-X BK Connect Sound Quality Metrics Option

Software Maintenance and Support Agreements*

M1-8400-X Agreement for Type 8400
M1-8400-A-X Agreement for Type 8400-A
M1-8400-B-X Agreement for Type 8400-B
M1-8400-C-X Agreement for Type 8400-C
M1-8400-D-X Agreement for Type 8400-D
M1-8400-E-X Agreement for Type 8400-E
M1-8400-F-X Agreement for Type 8400-F
M1-8401-X Agreement for Type 8401
M1-8401-A-X Agreement for Type 8401-A
M1-8401-V-X Agreement for Type 8401-V
M1-8402-X Agreement for Type 8402
M1-8403-X Agreement for Type 8403
M1-8403-A-X Agreement for Type 8403-A
M1-8405-B-X Agreement for Type 8405-B
M1-8405-C-X Agreement for Type 8405-C
M1-8405-E-X Agreement for Type 8405-E
M1-8405-F-X Agreement for Type 8405-F
M1-8405-G-X Agreement for Type 8405-G
M1-8441 Agreement for Type 8441
M1-8441-C Agreement for Type 8441-C
M1-8441-D Agreement for Type 8441-D
M1-8442 Agreement for Type 8442

* Agreement expiration date to be agreed at time of contract

Teknikerbyen 28 · DK-2830 Virum · Denmark
Telephone: +45 77 41 20 00 · Fax: +45 45 80 14 05
www.bksv.com · info@hbkworl.com
Local representatives and service organizations worldwide

To learn more about all HBK offerings, please visit hbkworl.com

Although reasonable care has been taken to ensure the information in this document is accurate, nothing herein can be construed to imply representation or warranty as to its accuracy, currency or completeness, nor is it intended to form the basis of any contract. Content is subject to change without notice – contact HBK for the latest version of this document.

Brüel & Kjær and all other trademarks, service marks, trade names, logos and product names are the property of Hottinger Brüel & Kjær A/S or a third-party company.

