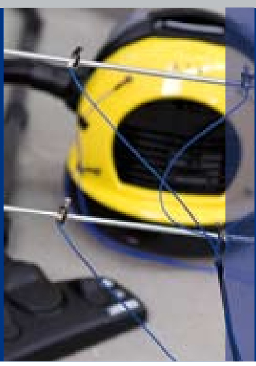
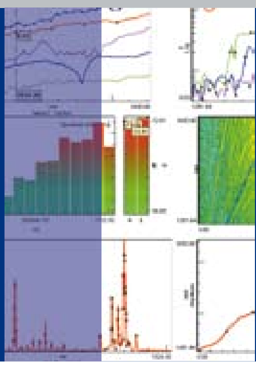
LMS Test.Lab Transfer Path Analysis

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ENGINEERING INNOVATION

LMS Test.Lab Transfer Path Analysis

Understanding the root causes of noise and vibration problems

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The LMS Test.Lab Transfer Path Analysis solution provides a systematic approach to test-based engineering processes and focuses engineering efforts on the components that matter the most.

As a method to fully understand vibro-acoustic behavior, TPA assists in troubleshooting vibro-acoustic issues and setting performance targets for each critical component.

In complicated structures with various sub-assemblies (such as cars, aircrafts or ships) vibro-acoustic phenomena at a certain location may have been caused by a remote vibration source. For example, the energy from a car engine is transmitted into the passenger cavity by a number of different routes: from the engine mounts, the exhaust system connection points and indirectly even via the drive shafts and the wheel suspension. Airborne contributions from the intake or exhaust system may also add to the vibro-acoustic issues.

These noise and vibration problems can be addressed by enhanced transfer path analysis techniques, which help engineers detect root causes of such issues early on in the design cycle. LMS Test.Lab provides a highly efficient solution to identify noise problems and their origins as well as quickly evaluate design improvements.

From troubleshooting to root cause analysis

Transfer Path Analysis or TPA is used to identify and assess structure-borne and airborne energy transfer routes – from the excitation source to a given receiver location. Once the sources and their paths have been quantified and modeled, it is a relatively straightforward design task to optimize the system. Transfer path analysis sets out to quantify the various sources and their paths and figure out which ones are important, which ones contribute to the noise issues and which ones cancel each other out.

The source-transmitter-receiver model: a systematic approach

The LMS Test.Lab Transfer Path Analysis solution is based on the source-transmitter-receiver methodology. All noise and vibration issues originate at a source and are transmitted through airborne or structure-borne transfer paths to a given receiver location where the vibro-acoustic disturbances are perceived. Solving vibro-acoustic issues can be done by acting on the source, the transmission path or the receiver, or by addressing several of these elements. The goal of transfer path analysis is to calculate the vector contribution of each energy path from the source to the receiver. Components along that path can be identified and thus modified to solve a specific problem. Alternatively, TPA helps optimize the product design by choosing effective and desirable characteristics for these components to avert noise and vibration problems.

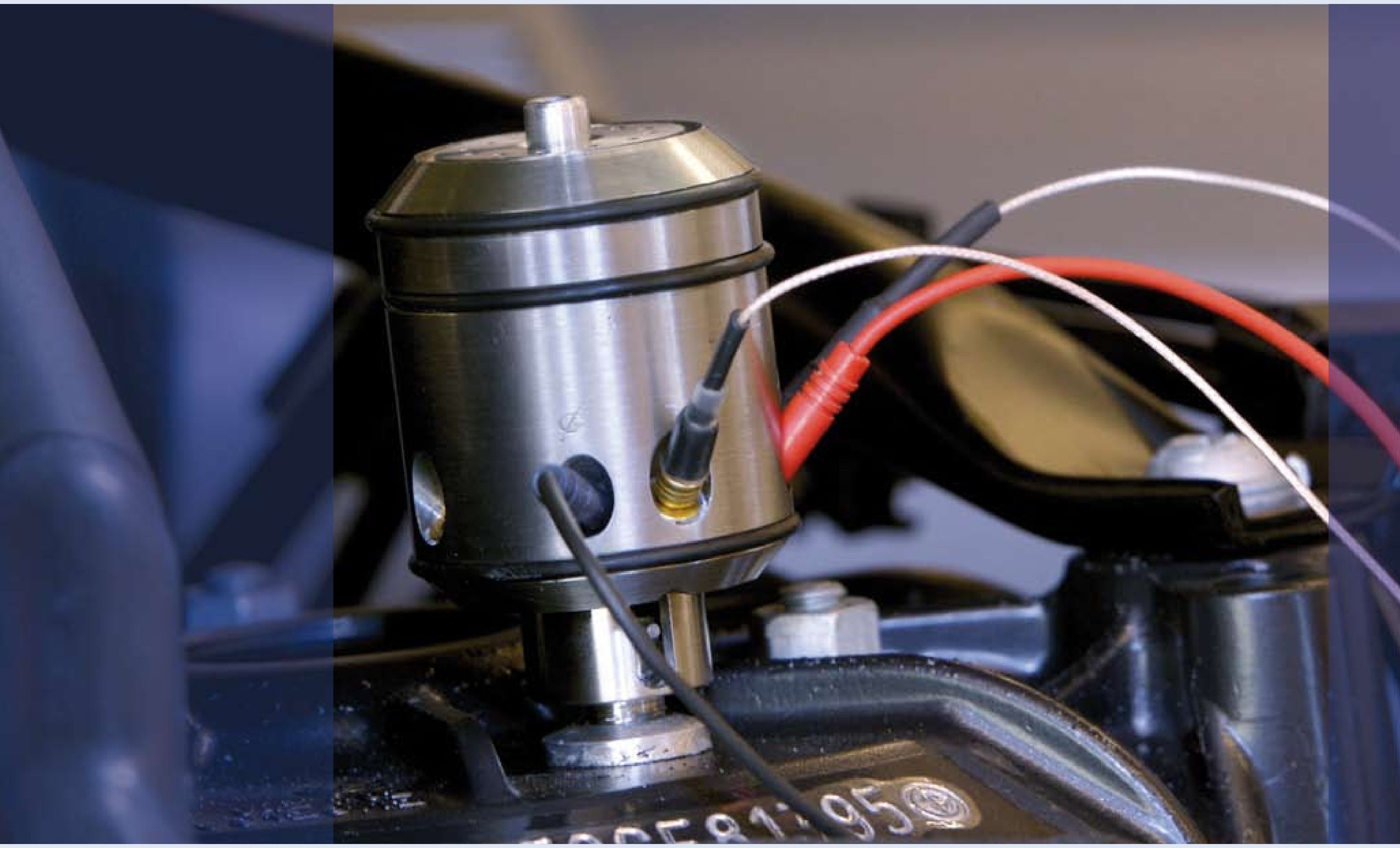
The most complete solution package on the market

LMS Test.Lab Transfer Path Analysis is packed with enhanced features that promise to help every test department save time and resources. With the broadest portfolio of TPA solutions on the market, LMS Test.Lab helps customers tackle issues from every possible angle – from simple systems to complex structures. LMS Test.Lab TPA features a wide range of TPA techniques, such as LMS Test.Lab Single Reference Transfer Path Analysis and Airborne Source Quantification, LMS Test.Lab Multi-reference Transfer Path Analysis, LMS Test.Lab OPAX Transfer Path Analysis solution and LMS Test.Lab Time Domain TPA.

Managing vast amounts of data

LMS Test.Lab Transfer Path Analysis is designed to manage data collected during measurement campaigns in a convenient and efficient way. Using embedded documentation, like function class or point IDs, transfer functions and operational data are automatically sorted through easy transfer path model definition. The automated procedures eliminate data handling errors and make the process as productive as possible.

Similar processing can be simultaneously applied to different operating conditions. For engine transfer path analysis, engineers will typically prefer to analyze the most important orders during run-up or run-down. Working on spectra in different formats (spectrum, autopower, 1/3 octave) is also completely supported by the solution.



LMS Test.Lab Transfer Path Analysis focuses on ease-of-use and productivity. Engineers appreciate the workflow-oriented GUI, the powerful data management that continuously checks data and minimizes translation issues and operator errors. The productivity enhancing features like active displays make it possible for any person in the organization to dive into the data and investigate it from all possible angles to achieve the best understanding of the TPA results.

Easy results interpretation

LMS Test.Lab Transfer Path Analysis helps users perform data processing and results interpretation fast and efficiently. The enormous amount of TPA results is easily accessibly and clearly organized. For each operational condition and transfer path, the operational forces can be retrieved and accessed. To quickly visualize the relative importance of the different paths, a color display shows the amplitude of the partial contributions for all selected paths as a function of rpm or frequency.

The LMS solution helps users analyze the interior acoustic response both objectively and subjectively and identify the disturbing spectral components or even the lack of masking constituents. For those frequencies, the operating and laboratory data are combined to quantify the contributions of the various sources and their paths. Once the sources and their paths have been quantified and modeled, it is a relatively straightforward design task to optimize the system.

The various TPA techniques can be expanded to support “what-if” scenarios, whereby loads and/or transfer paths can be interactively modified and visually evaluated in real-time. Multiple modifications can be compared against each other, by a single mouse-click, which greatly enhances the target setting process.

Backed by years of experience

The solution incorporates years of market leadership, assuring maximum data quality and avoiding operator errors. It also provides enough engineering freedom to tune the process to the specific needs of each problem. With the final contribution analysis, the system can be examined in multiple dimensions, using comprehensive 4D displays.

LMS Test.Lab Transfer Path Analysis is based on extensive consolidated hands-on experience, which has been translated into innovative extensions that help engineers solve mission-critical noise and vibration issues.

LMS Test.Lab Single Reference Transfer Path Analysis and Airborne Source Quantification

LMS Test.Lab Single Reference Transfer Path Analysis helps engineers trace the flow of vibro-acoustic energy from a source, through a set of known airborne and structure-borne pathways, to a given receiver location. The solution supports contribution analysis for single source noise or vibration issues, during stationary or run-up and run-down operating conditions. Airborne and structure-borne paths can be analyzed together or separately, using frequency response functions and operational data.

The LMS Test.Lab Single Reference Transfer Path Analysis solution includes LMS Test.Lab's very convenient workflow. At each stage of the process, clear user-feedback is given. The source-transfer-receiver model is deployed in a very flexible way, with different data sets that can be easily compared against each other for the different operating cases under investigation. Operational forces can be accurately defined using the complex stiffness and matrix inversion methods.

The complex stiffness method is used to identify transfer paths in cases where the source side is connected to the receiver via mounts. The operational forces can be determined from knowledge of the complex dynamic mount stiffness and the differential displacement over the mount during operation. The matrix inversion method is used to identify operational loads when the stiffness curve is unknown or for rigid connections. The technique is based on inversion of a measured accelerance matrix between structural responses on the receiver side due to force excitation.

LMS Test.Lab Airborne Source Quantification (ASQ) quantifies acoustic source strengths and their airborne transmission paths under stationary or run-up and run-down operating conditions. The method helps quantify operational acoustical loads from single point sources, multi-point sources, or even multiple partially correlated acoustical sources. Multiple techniques are supported: point-to-point surface sampling, sound intensity measurements and matrix inversion. The solution supports also the quantification of vibration loads, separately or at the same time. Acoustical Transfer Functions are measured using volume velocity source excitation techniques.

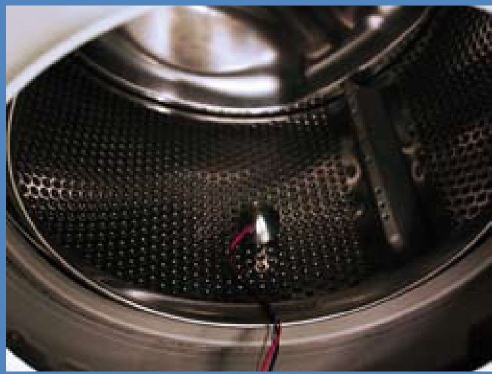
Throughout the entire application, display layouts will automatically switch to layouts specific for the data evaluation at hand. The solution helps engineers easily manage vast amounts of analysis data.

Features

- Convenient data management
- Assisted selection of FRF and operational data
- Workflow-oriented solution with user guidance
- Context sensitive display layouts and contribution analysis (4D displays)
- Convenient comparison of multiple data sets

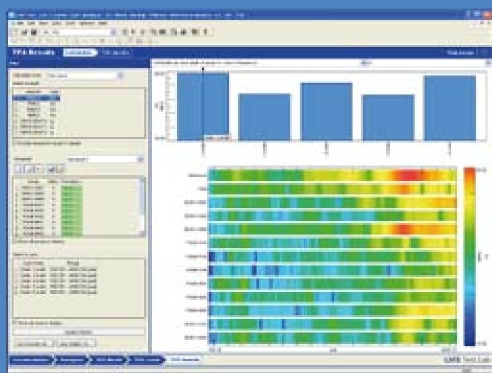
Benefits

- Systematic approach to vibro-acoustic refinement
- Common solution for structural and acoustic source quantification
- Ease-of-use for optimal productivity
- Supports multiple vibration or acoustical load quantification techniques
- 20-year experience of enhanced engineering insights

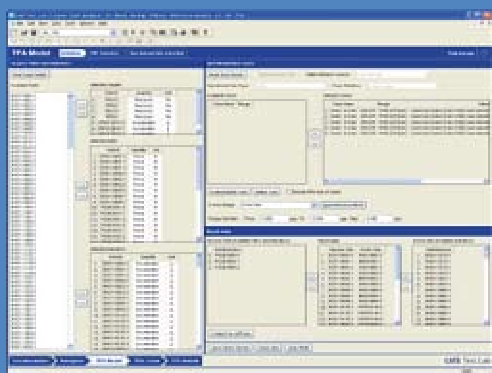


ASQ on a washing machine helps identify the panel contribution to the overall noise level.

Engine TPA identifies structural contribution of the engine mount.



LMS Test.Lab TPA includes an advanced 4D display that helps analyze results from every angle.



The analysis yields efficient and structured TPA model definition.

LMS Test.Lab Multi-reference Transfer Path Analysis

LMS Test.Lab Multi-reference Transfer Path Analysis supports contribution analysis for multi-source noise and vibration issues. The complex analysis of multiple partially-correlated sources is reduced to multiple analyses of independent, uncorrelated sources by using singular value decomposition. Each individual uncorrelated source can be investigated using the LMS Test.Lab Transfer Path Analysis solution. Structure-borne and airborne paths can be analyzed together or separately, using frequency response functions and operational data. The final analysis will recombine the results of the individual sources to investigate their combined effect on the target location.

LMS Test.Lab Multi-reference Transfer Path Analysis is particularly adapted to road noise analysis. It helps engineers understand the noise source when the car is on the road, independently from the engine noise. In the first step, Principle Component Analysis (PCA) decomposes the road noise into principle components. Transfer path analysis will then be applied on single decorrelated components in a second step.

The convenient workflow of LMS Test.Lab Multi-reference Transfer Path Analysis even helps users perform principle component analysis and transfer path analysis sequentially. Operational forces can be accurately defined using the complex stiffness and the matrix inversion methods.

The solution offers easy management and analysis of large databases. It greatly simplifies analysis of the structure in different operating conditions and provides easy data comparison.

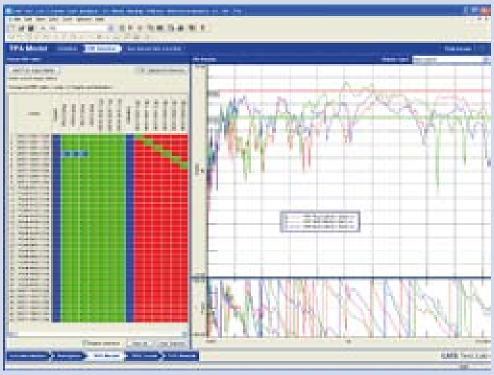
Features

- Workflow-oriented solution
- Solution for single and multi-source issues
- Convenient source-transfer-receiver model and data management
- Wide range of load identification techniques
- Context sensitive display layouts and contribution analysis

Benefits

- Ease-of-use for optimal productivity
- Supporting multiple vibration or acoustical load quantification techniques
- Convenient comparison of multiple data sets
- Support for stationary operating conditions

TPA techniques are applicable for single coherent sources and for multiple partially-correlated sources.



Managing large databases of TPA models.

With PCA, engineers decompose the excitation in orthogonal components and select relevant ones.

Result worksheets provide fast and easy comparison between operational conditions or configurations.

LMS Test.Lab OPAX

The unique LMS Test.Lab OPAX solution is a fast, test-based procedure which supports troubleshooting of vibro-acoustic problems in a very efficient and reliable way. LMS' breakthrough approach is nearly as accurate as conventional TPA and almost as fast as traditional operational path methods that often fail to identify the root cause of vibrations and find remedies to NVH problems. The LMS Test.Lab OPAX solution separates loads and transfer paths so that vibro-acoustic energy can easily be traced right from the source, through a set of known structure-borne and airborne pathways directly to a given receiver location. This helps engineers accurately identify the root cause of the problem quicker than ever before with the minimum of time-consuming measurements. The solution supports contribution analysis for stationary or run-up and run-down operating conditions. Structure-borne and airborne loads can be estimated together or separately, using a minimum set of additional indicators to increase the reliability of the estimated loads.

The LMS Test.Lab OPAX solution follows the same convenient workflow as other LMS Test.Lab Transfer Path Analysis-based solutions. At each instance of the process, clear user-feedback is given. The TPA source-transfer-receiver model can be filled up in a very flexible way, with different data sets that can be easily compared against each other for different operating cases under investigation. Operational loads can be defined accurately using the SDOF-estimator or band-estimator methods. Users can further increase the data reliability by adding information about the actual physics of the investigated system to the estimation process.

Throughout the application, display layouts will automatically switch to layouts specific for the data evaluation at hand.

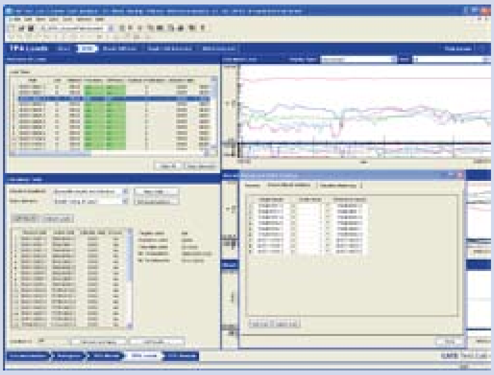
Features

- Convenient source-transfer-receiver model and data management
- SDOF and band parametric models for loads estimation
- Possibility to include indicators for higher accuracy and missing path compensation
- Context-sensitive display layouts and contribution analysis (4D displays)

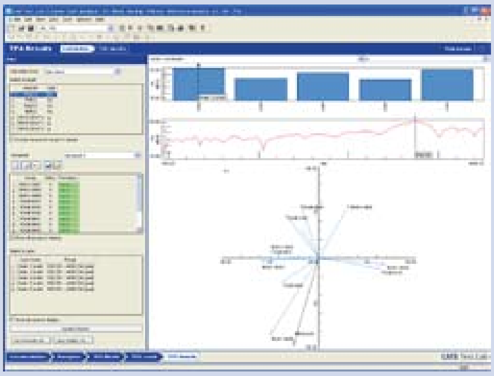
Benefits

- Maximum accuracy with a minimal set of measurements
- Ease-of-use for optimal productivity
- Models that correspond to mount physics
- Enhanced engineering insights

The use of parametric models helps reduce the number of required measurements.



LMS Test.Lab OPAX simultaneously analyzes acoustic and structural contributions.



With vector contribution, users can compare the relative contribution of the different paths.

Immediate and complete visualization of results per contribution.

LMS Test.Lab Time Domain Transfer Path Analysis

LMS Test.Lab Time Domain Transfer Path Analysis is a solution to identify transfer paths in the time domain. This solution provides accurate identification of transfer paths related to a specific event in the time domain. Compared to frequency domain TPA, the LMS Test.Lab Time Domain TPA lets engineers analyze transient phenomena. Users can listen to the partial path contribution and compare it to the target sound. The path contributions are not reflected as spectra but as time-domain contributions. These contributions can then be used for further analysis, such as signature throughput processing. Any processing can be applied to the partial path contribution, such as acoustic metrics.

Time domain TPA analyses can be applied to various phenomena. It is particularly useful to understand phenomena of transient excitations (engine start-up), semi-stationary excitations (idle noise) as well as analyze any other signal for which it is crucial to listen to the produced sounds. The solution can further be used to make a detailed modulation study.

Time domain TPA complements frequency domain TPA. While frequency domain TPA gives a better overview on vibro-acoustics issues, time domain TPA provides users with more detailed information about transitory occurrences and offers time domain pre- and post-processing.

LMS Test.Lab Time Domain Transfer Path Analysis is a fast and easy-to-use solution for analyses on transient events and offers users a wide range of load identification techniques.

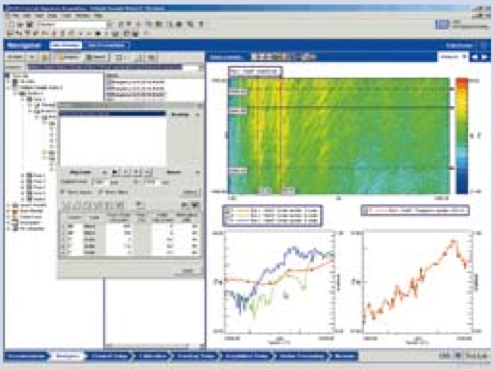
Features

- Workflow-oriented solution
- Joint model definition with frequency domain TPA
- Wide range of load identification tools

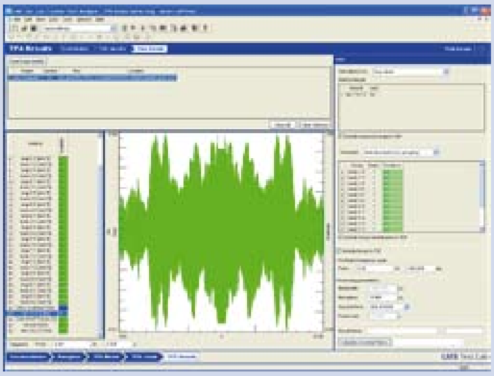
Benefits

- Ease-of-use
- Possibility to listen to partial path contributions

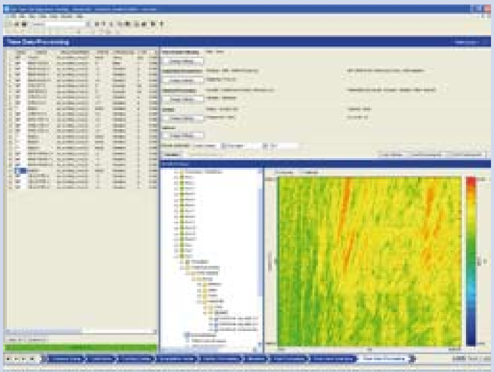
Time domain TPA is used to analyze transient phenomena.



With LMS Test.Lab Time Domain TPA, users can listen to partial contributions without sound distortion.

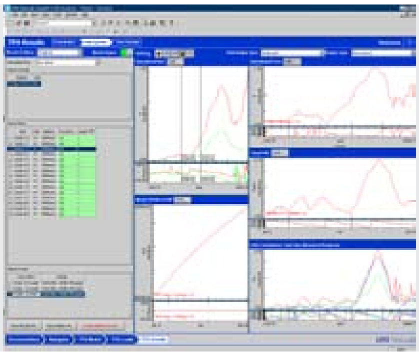


Fast FFT convolution helps compute the partial contribution in time domain.



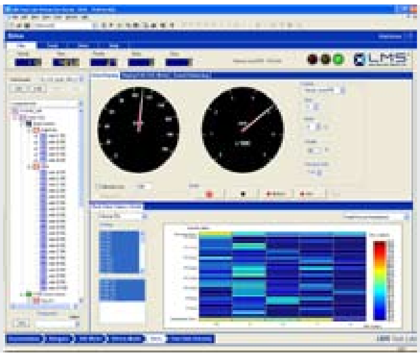
The time domain contributions can be processed with other LMS Test.Lab applications for further analysis.

LMS Test.Lab Transfer Path Analysis – Options



LMS Test.Lab Component Editing

With the LMS Test.Lab Component Editing add-in, users can edit different components of the TPA model (force, FRF), and immediately evaluate the effect of these changes on the path contribution. Graphical editing of the FRF and/or forces is supported; individual path or case contributions can be enabled or disabled. The changes can be saved as a new model, and the different models can be compared against each other.

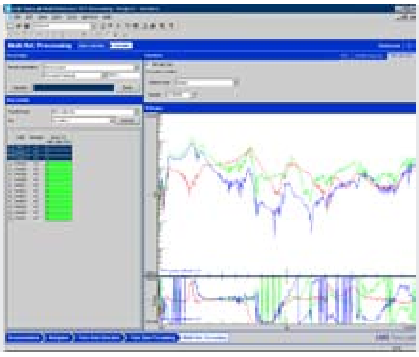


LMS Test.Lab Virtual Car Sound

LMS Test.Lab Virtual Car Sound can be used for general sound design and target setting as well as advanced vibro-acoustic troubleshooting in the vehicle refinement stage. Starting from experimental or CAE data, a sound quality equivalent model (SQE) is generated that decomposes the interior car noise into powertrain, road/tire, and wind noise. The SQE model is equivalent in quality and features to the original sound. For troubleshooting and target setting applications, the model can be refined with a TPA model to study the different structure-borne and airborne path contributions. The LMS Test.Lab Virtual Car Sound solution is mainly applied to vehicles, but can be helpful when analyzing issues found in other rotating machinery products and components.

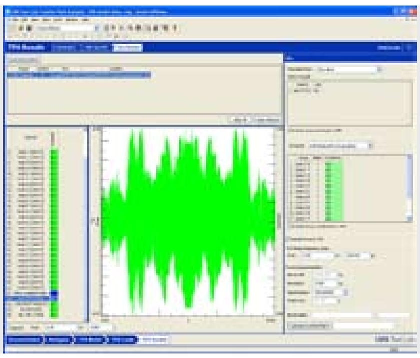
LMS Test.Lab Principal Component Analysis

LMS Test.Lab Principal Component Analysis helps users reduce complex noise and vibration problems to more manageable, independent, and uncorrelated problems with multiple, partially correlated references. These problems range from structure-borne road-noise to the combined effects of air-conditioning compressor and engine noise. By applying singular value decomposition techniques on a multi-reference crosspower matrix, this matrix is decomposed into its principal components, yielding as many single reference sets of crosspowers as there are references. The solution also features other functions such as virtual coherence and virtual spectra. Principle component analysis results can be used for further transfer path analysis.



LMS Test.Lab Multi-reference Post-processing

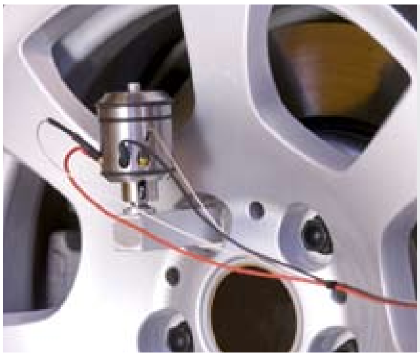
This add-in provides off-line multi-reference spectral processing on crosspower, FRF, partial coherence and transmissibility. It can be used separately and will then only support stationary averaging. It can also be used together with signature throughput processing to include tracked processing. The calculated transmissibilities can be used in LMS Test.Lab Transfer Path Analysis to perform a response-only operational path analysis. Autopower and crosspower spectra can be used as input for a principal component analysis.



LMS Test.Lab Time Domain TPA

The LMS Test.Lab Time Domain TPA add-in is the ideal solution to decompose transient and semi-stationary responses into path contributions. Starting from a TPA model (direct, mount stiffness, LMS OPAX, single path inversion or matrix inversion), it provides the analysis and auralization of the time domain contributions. The contribution time traces are available for further analysis with for example signature throughput processing or sound diagnosis.

LMS Qsources - Structural and acoustic exciters



Integral Shaker

The integral shaker is a unique inertial shaker especially designed for FRF measurements. It contains both force and local acceleration sensors, yet it is very compact and able to generate a high force. Thanks to its patented suspension, the mass loading is kept to a minimum and its self-aligning behavior makes it perfect for excitation in all direction of various systems. The integral shaker is able to generate a force of 6N rms with a flat spectrum over a frequency range from 22 up to 2200Hz. The integrated transducers are ICP-type sensors, fully compatible with the LMS SCADAS III input modules. The shaker is ideal for use in difficult-to-reach excitation locations where high input force is required.

Low-frequency volume sources

Volume acceleration sound sources are acoustic excitation devices. The source is capable of producing very high noise levels, sufficient for the excitation of complete systems. The integrated volume acceleration sensor gives a real-time feedback of the source strength and can directly be used as a reference for FRF-measurements, without any post-processing. The low-mid frequency source is designed to be used in the 10 to 800 Hz frequency band which covers the most important frequency band for noise source analysis during system development. The low-frequency volume source was deliberately made to simulate the acoustic properties of a person at low frequencies. The device is optimized for quick positioning on a seat with the acoustic center at ear location.

Mid-frequency volume sources

This acoustic exciter covers the 200 to 8000 Hz frequency band and provides an accurate real-time reference signal of the acoustic source strength, essential for accurate transfer function measurements. The sound is generated in a high pressure driver and transferred to the nozzle by a flexible tube. The nozzle will distribute the noise as a monopole source. The nozzle is so small that the omni-directionality of this source becomes comparable to that of a ½ inch microphone. The mid to high frequency volume acceleration sound source offers numerous advantages: positioning flexibility, high impedance, compact size, omni-directionality, time stable sensitivity, high noise levels, and real-time volume acceleration signal.

Miniature shaker

This miniature shaker provides excitation with very low mass and stiffness loading of the test object. The system includes integrated force and acceleration transducers with constant sensitivity between 50-5000Hz. Engineers can thus obtain driving point FRFs in a fast way. The shaker is designed to introduce forces in places that are inaccessible for conventional shakers and unpractical for impact hammers. The excitation device, including sensors, is designed within a sphere of 41 mm providing a perfect solution for all those hard-to-reach excitation locations. This self-supporting device improves testing efficiency by eliminating all of the support and alignment work associated with conventional shaker testing. To increase measurement speed, the shaker can be easily glued to the test object.

Miniature volume sources

This miniature acoustic exciter can be used as a compact low-level volume displacement source. The sound source is suitable for lower frequency reciprocal acoustic transfer function measurements in special situations. Local FRFs between nozzle acoustic centers and local indicator microphones can be captured efficiently and accurately. The same acoustic exciter can also be used as a low-frequency microphone. With only 74mm in length, this sound source-receiver can be used in minimal space with minimal diffraction disturbance, and at a lower excitation level. As a microphone, the device is suited for locations with high levels of low frequency noise and/or high airflow conditions. Typical applications are airborne source quantification (ASQ) of intake and exhaust systems and vibro-acoustic modal analysis. It covers a frequency range from 100-1000Hz in which the reference sensor exhibits a constant sensitivity behavior.

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LMS is an engineering innovation partner for companies in the automotive, aerospace and other advanced manufacturing industries. With 30 years of experience, LMS helps customers get better products to market faster and turn superior process efficiency into key competitive advantages.

With a unique combination of 1D and 3D simulation software, testing systems and engineering services, LMS tunes into mission critical engineering attributes, ranging from system dynamics, structural integrity and sound quality to durability, safety and power consumption. With multi-domain solutions for thermal, fluid dynamics, electrical and mechanical system behavior, LMS can address the complex engineering challenges associated with intelligent system design.

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