

Operational Modal Analysis Type 7760 Batch Processing Option BZ-8527

Operational Modal Analysis Type 7760 is the analysis tool for effective modal parameter estimation in cases where only the output is known. The software allows you to perform accurate modal analysis under operational conditions and in situations where the structure is impossible or difficult to excite using externally applied forces.

Using PULSE™ Modal Test Consultant™ Type 7753 for geometry-driven data acquisition, then seamlessly transferring data to Operational Modal Analysis Type 7760 for analysis and validation, comprises an integrated, easy-to-use modal test and analysis system.



Uses and Features

Uses

- Modal identification using only measured responses – no hammer or shaker excitation required
- Modal identification of structures under real operating conditions
- Estimation of modal parameters to be used for FE model correlation and updating, design verification, benchmarking, troubleshooting, quality control or structural health monitoring
- Integration of Modal Test Consultant Type 7753 and Operational Modal Analysis Type 7760 into a streamlined testing solution

Features

- Capacity to run several projects simultaneously for easy comparison of results
- Handles multiple data sets and multiple reference points, including automatic mode shape merging
- Effective and easy-to-use signal processing wizard
- Spectrogram of response signals
- Ability to use a reduced number of projection channels for analysis (manually or automatically)
- Time and frequency domain ODS in displacement, velocity and acceleration using SI or Imperial units

- Three patented frequency domain techniques: FDD, EFDD and CFDD
- Automatic identification and suppression of deterministic signals using the EFDD and CFDD techniques
- Three unbiased time domain stochastic subspace identification (SSI) techniques: principal components (PC), unweighted principal components (UPC) and canonical variate analysis (CVA)
- Crystal-clear stabilization diagrams to discriminate between physical and computational modes
- Automatic mode estimation in all techniques; FDD, EFDD, CFDD, SSI-PC, SSI-UPC, and SSI-CVA
- Synthesis of response spectra for validation
- Prediction error calculation between measured and synthesised response spectra and correlation functions
- Single, overlaid, difference, side-by-side, top-bottom or quad views of mode shape animation
- Definition of slave node equations and interpolation of non-measured nodes to nearest measured nodes
- Modal assurance criterion (MAC) plots and tables
- Transfer of all modal results in universal file format
- Export of all animations using AVI movie files
- Fast SSI analysis of large amounts of data files without user interaction (Batch Processing mode)

Experimental Modal Analysis

Experimental modal analysis is the process of determining the modal parameters (natural frequency, damping ratio, and mode shape) of a structure from measured data. Modal parameters are important because they describe the inherent dynamic properties of a structure. They are used for model correlation and updating, design verification, benchmarking, troubleshooting, quality control or structural health monitoring.

In classical modal analysis, the modal parameters are found by fitting a model to frequency response functions (or impulse response functions) relating excitation forces to vibration responses. In operational modal analysis (OMA), the modal identification is based on the vibration responses only, and different identification techniques are used.

The Concept Behind Operational Modal Analysis

Operational modal analysis is used instead of classical modal analysis for accurate modal identification under actual operating conditions and in situations where it is difficult or impossible to control an artificial excitation of the structure.

For many civil engineering and mechanical structures, it is difficult to apply the excitation by means of either hammer or shaker(s) due to their physical size, shape, fragility or location. Also civil engineering structures are loaded by ambient forces, for example, waves (offshore structures), wind (buildings) or traffic (bridges) and operating machinery exhibits self-generated vibrations. These natural input forces cannot easily be controlled or correctly measured. In operational modal analysis, the forces are used as unmeasured input, but if classical modal analysis was used, they would be superimposed as noise on the controlled artificial forces and would provide erroneous results.

For mechanical structures like aircraft, vehicles, ships and operating machinery there is a need to determine 'real-life' modal parameters using actual operating conditions, that is to say, actual boundary conditions, actual spatial and frequency distributions of forces and actual force and response levels.

Advantages of Using Operational Modal Analysis

The main advantages of OMA are:

- The measured responses are representative of the real operating conditions of the structure
- The setup is simple, straightforward and fast, because only accelerometers are used. No hammers or shakers are required. No elaborate setup of the structure, shakers or force transducers is required
- The measurement procedure is simple and quite similar to operating deflection shapes (ODS) analysis. Measurement data acquired for OMA can be reused for ODS analysis and vice versa
- Costly downtime can be reduced doing in situ testing during normal operation. No interruption or interference with the operation of the structure is required

Usually, OMA is used in cases where the excitation is relatively broadband and can be considered to be approximately Gaussian. However, it can also be used in cases involving rotating machinery exhibiting strong deterministic excitation due to rotating parts if broadband noise from bearings or other excitation forces is present. Similarly, it can be used for measurements on rotating machinery performing run-up/down tests.

When performing structural run-up/down tests, OMA is a powerful complement to run-up/down ODS. Together they provide in-operation determination of the modal parameters (the dynamic properties of the structure) and determination of the actual forced dynamic deflections of the structure. For more information on run-up/down ODS, see the "Structural Dynamic Test Consultants" product data ([BP 1850](#)).

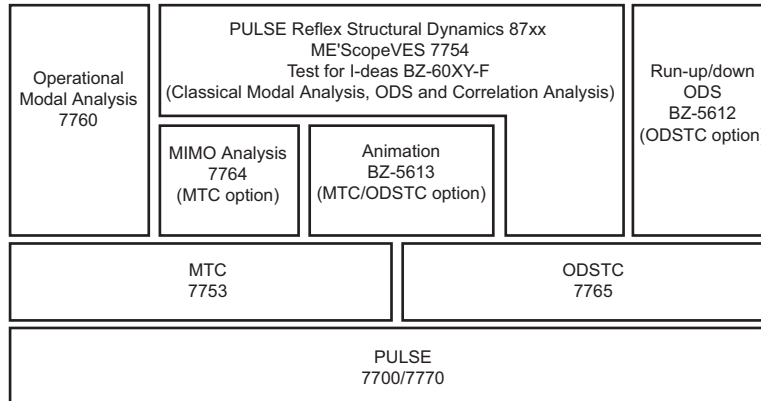
Accuracy of Operational Modal Analysis

Discarding the information about the input will add some uncertainty to the modal estimates. However, with the advanced techniques included in Operational Modal Analysis Type 7760, the added uncertainty is very small. In practice, the only major difference between modal parameters estimated from classical modal analysis and those from OMA is that OMA, by nature, produces unscaled mode shapes. Different techniques for scaling an OMA modal model are, however, available. Scaled mode shapes are needed when absolute simulations (such as forced responses and structural modifications) are applied to modal data.

Operational modal analysis can have a significant advantage over classical modal analysis when only a few artificial excitation forces can be applied. In this case, higher estimation accuracy can often be obtained by letting the better, spatially distributed, natural loading excite the structure. The OMA techniques are implemented as true multiple-input (multiple-reference) techniques.

Data Acquisition and Pre-analysis

Fig. 1
Schematic overview of the PULSE-based system for operational modal analysis, classical modal analysis, operating deflection shapes analysis and correlation analysis

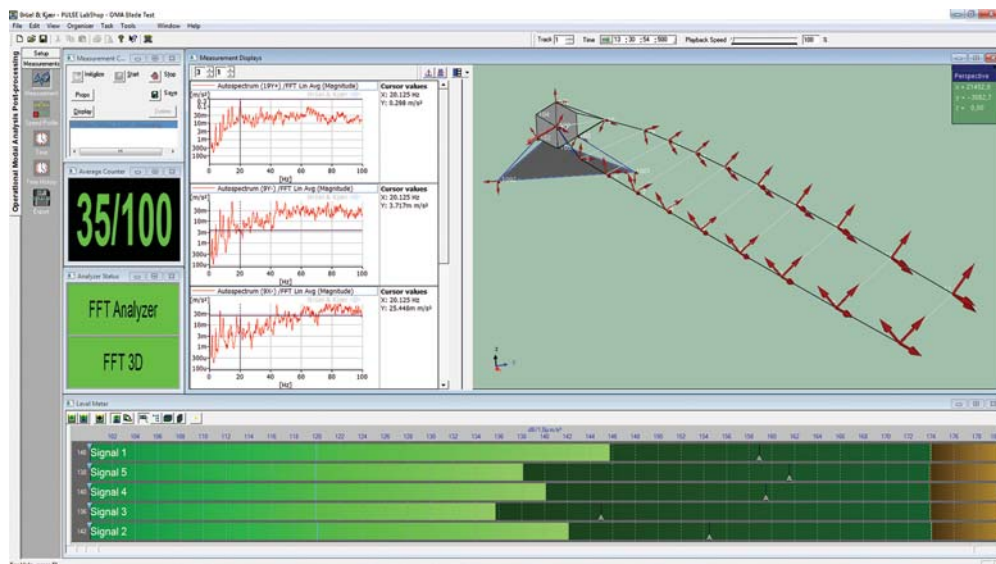


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PULSE Modal Test Consultant

PULSE Modal Test Consultant (MTC) Type 7753 is developed to simplify and dramatically reduce the time required to perform modal analysis measurements. Type 7753 supports both classical modal analysis using hammer and shaker excitation, and operational modal analysis based on output-only measurements. Type 7753 utilizes the PULSE multi-analysis platform and guides you through the measurement process in simple intuitive steps tailored to perform fixed or roving hammer testing; fixed or roving shaker testing; or OMA testing. Type 7753 is graphically driven and easily controlled, linking the measurement directly to the on-screen test object geometry. These features, together with highly effective tools for set up, measurement and measurement validation, make testing fast and reliable.

Fig. 2
OMA measurements on a wind turbine blade using PULSE MTC

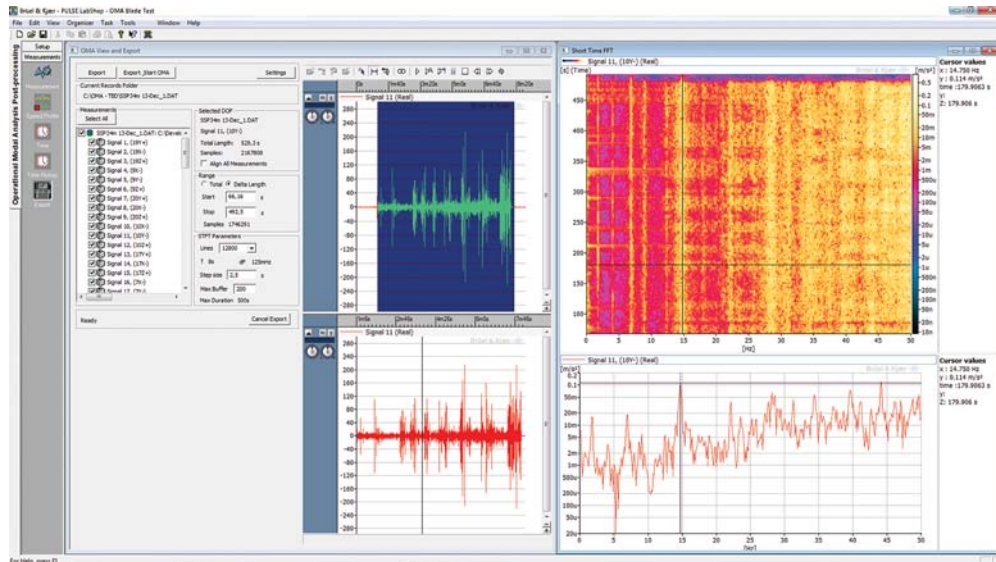


MTC fully integrates with Operational Modal Analysis Type 7760 turning them into a streamlined testing solution for operational modal analysis. Before transferring the geometry and DOF-labelled time data from MTC to OMA, a short-time Fourier transform (STFT) analysis can be performed to give an overview of the acquired time data for validation and selection.

Templates for real-time OMA measurements and OMA post-processing using recorded time data are available (see Fig. 3). Data can also be recorded to disk using the stand-alone PULSE Time Data Recorder Type 7708 and exported in UFF format. Geometry information can be imported using UFF.

For more information on MTC, see the product data for PULSE's Structural Dynamics Test Consultants, [BP 1850](#).

Fig. 3
Using the OMA templates in MTC, part of the time signals for the various channels can be selected and a short-time Fourier transform (STFT) contour plot can be displayed. An STFT plot can reveal potential structural modes and harmonic components before transferring the data to Type 7760



Import from Universal File Format

Geometry and measurement data can be imported using the universal file format (UFF), making it easy to import data from any standard measurement system. Both ASCII and binary UFF are supported for the measurement data.

Import from ASCII Files Using the Configuration File

All geometric data can be specified in the Operational Modal Analysis configuration file, which can be generated using any ASCII file editor. In some cases, this format is more useful than the UFF format. Response data can be read from ASCII or binary files where the data is stored in a time series matrix organized column by column.

Project Documentation and Data Processing

Project Documentation

When data has been transferred to OMA, you can document your project in the Notes task either by writing text, including pictures, or inserting OLE objects such as Excel® worksheets. The software's Data Organizer task allows you to view your geometry, including the DOF information, change directions and disconnect data sets and individual transducers in case of bad measurements or incorrect DOF directions. Projection channels (see description below) can be set manually as a supplement to the automatic selection in the Signal Processing Control tab. Projection channels are shown on the geometry. The acquired time data is documented in terms of source, number of data sets, sampling interval and sampling frequency, number of data points and measurement duration. Also the number of modes calculated by the various techniques is listed as well as signal processing status.

Signal Processing

In the Signal Processing Control task, different kinds of signal processing can be applied to the imported time data. It is possible to decimate to reduce the sampling frequency and to apply low-pass, high-pass, band-pass and band-stop filters. Filtering can be useful in removing high-frequency modes (low-pass), DC components (high-pass) or harmonics (band-stop); or concentrating on a narrow frequency range (band-pass).

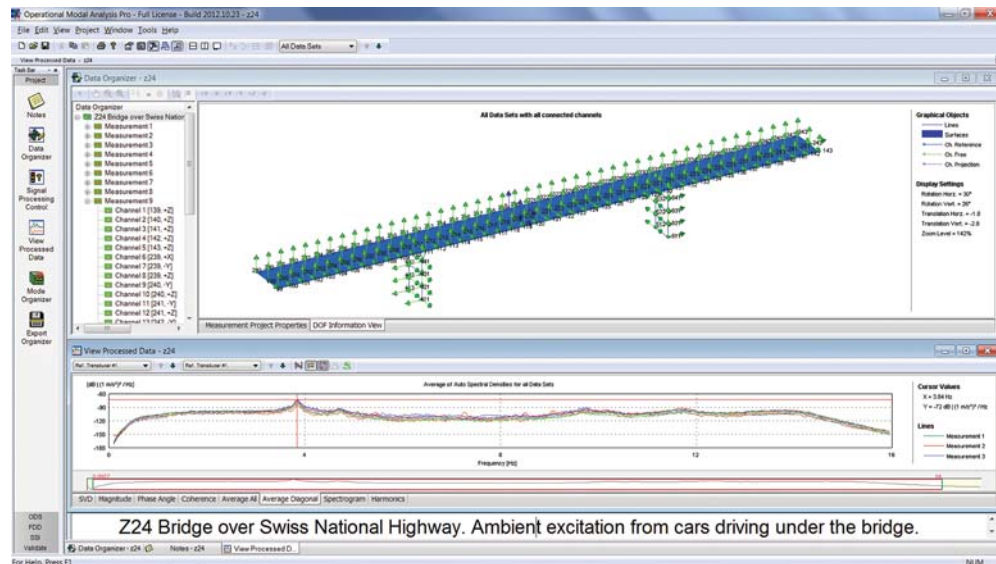
It is possible to set a reduced number of projection channels for the analysis, thereby reducing the amount of cross information calculated between the response channels when estimating spectral density matrices and the common SSI input matrix. This is done to maximize the amount of independent information. The

benefits of using a reduced number of projection channels are: faster algorithms, smaller project size, improved accuracy of results due to cancellation of noise channels, and improved easiness to fit state space models of smaller dimensions due to less redundant information. The actual channels are automatically selected by the software.

If deterministic signals (harmonic components) are likely to be found in the responses, an automated method for identification and suppression of the deterministic signals can be applied based on the enhanced frequency domain decomposition (EFDD) and curve-fit frequency domain decomposition (CFDD) techniques. For time ODS, SI, imperial or user-defined units can be selected and a high-pass integration filter can be applied to suppress DC errors during integration and differentiation.

For the FDD, EFDD, and CFDD techniques, spectral density matrices are calculated; for the stochastic subspace identification (SSI) techniques, a Hankel matrix is estimated – which constitutes the basis for calculation of the stabilization diagram. It is also possible to do an automatic model estimation simultaneously using one or more SSI techniques.

Fig. 4
In the Project pane you can view your geometry and DOF information and properties about the recorded time data and the analysis done. This is also the place where you can write notes, execute the various signal processing tasks, view the processed data, organise the calculated modes and export processed data



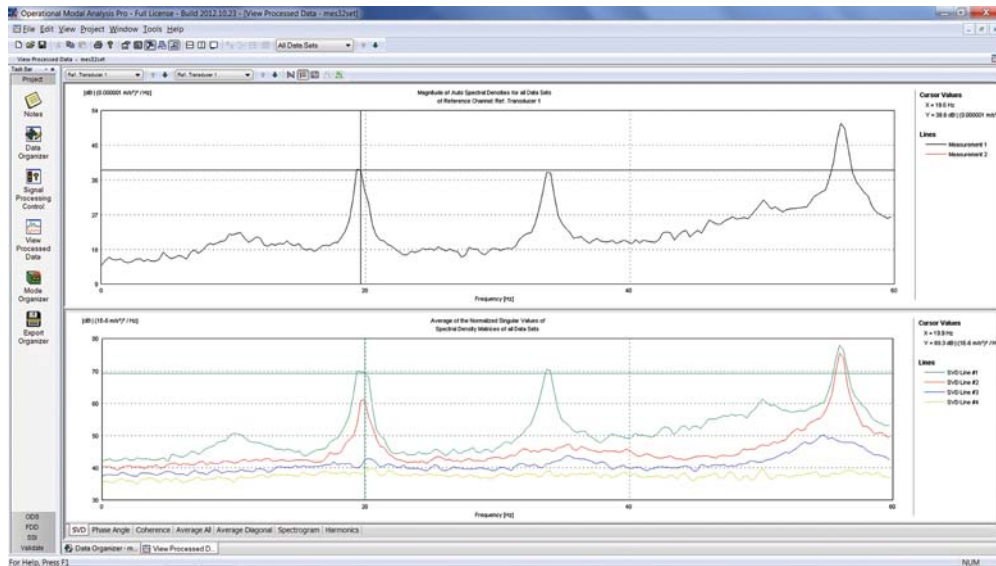
Signal processing in OMA comes with logical default values, but configuration files can also be saved and reloaded making signal processing extremely efficient.

View Processed Data

The View Processed Data task allows you to inspect the results of the signal processing of a selected data set or all data sets together. This includes the display of functions like autospectra, cross-spectra and coherence as well as condensed plots of the spectral matrix like singular value decomposition (SVD), average all elements and average diagonal elements. Time versus frequency contour plot and a plot showing identified harmonic components are also available.

Selecting all data sets is very useful in comparing data across data sets to ensure they all contain the same physical information (for example, comparing the autospectra of the references across the data sets to investigate amplitude and frequency stability).

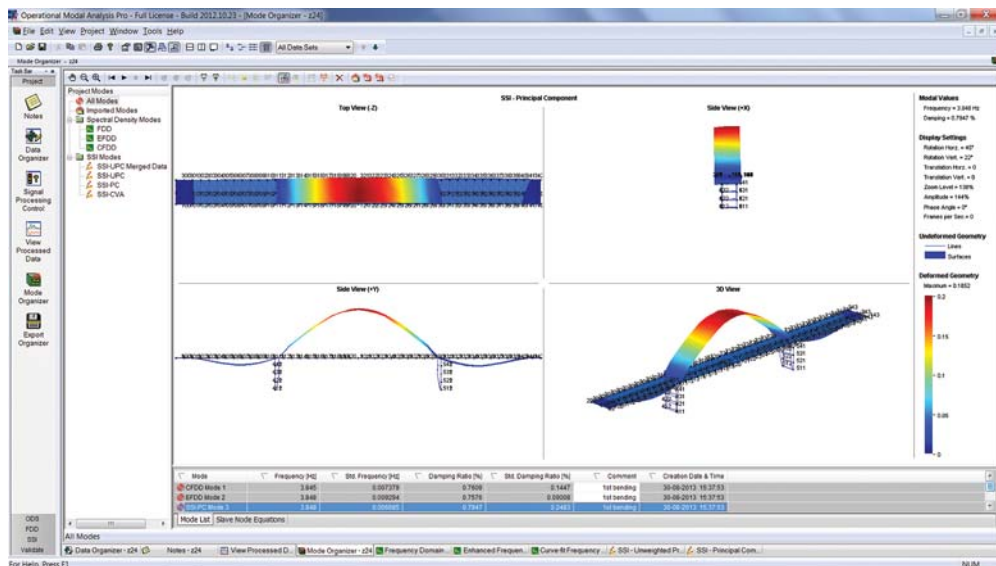
Fig. 5
The View Processed Data task showing an autospectrum in the upper plot and a singular value decomposition (SVD) in the lower plot. The lower plot clearly reveals two close mode cases



Mode Organizer

The Mode Organizer task lists all estimated modes and allows you to compare modes from the different identification techniques as well as to compare them with imported modes. The natural frequencies and damping ratios can be compared and the standard deviation of these modal parameters is listed when multiple data sets are being used. Slave node equations can be generated and the mode shapes can be animated.

Fig. 6
Fast overview of imported and estimated modes using the Mode Organizer



Export Organizer

In the Export Organizer task, you can export geometry, DOF information and signal processed measurement data in .cfg or .uff format, and with ASCII or binary measurement files.

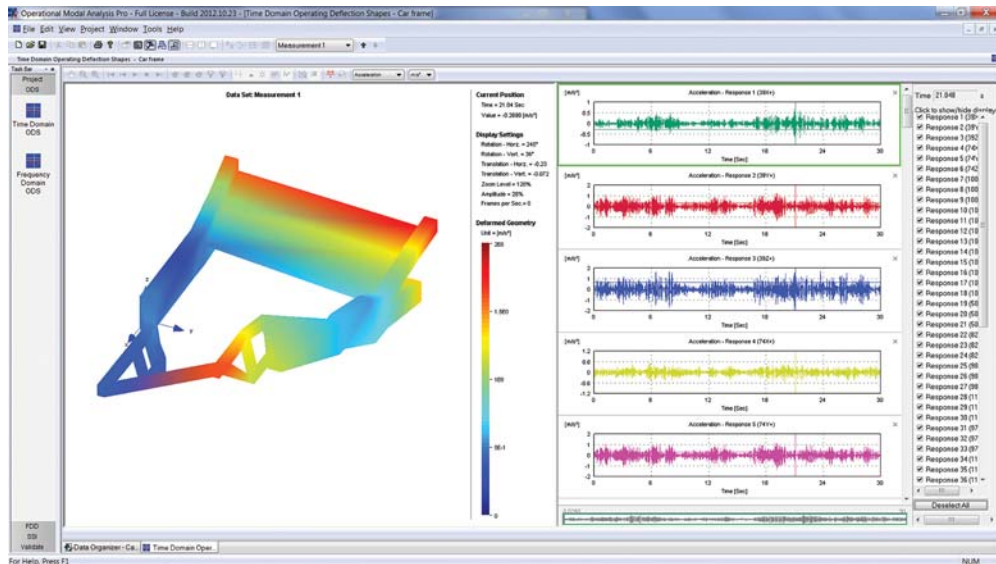
Forced Dynamic Deflections Analysis

Where OMA is the process of creating a mathematical model of the dynamic properties and behaviour of a structure, operating deflection shapes (ODS) analysis is the process of determining the forced dynamic deflections of a structure. As a model is not created in ODS analysis, no assumptions are made about linearity, characteristics of input forces or boundary conditions. In both cases, the measurements are done under operating conditions by response testing only.

In Operational Modal Analysis Type 7760, both time domain ODS and frequency domain ODS are included allowing the determination and visualization of deflection shapes as a function of time or for specific frequencies. Results can be shown as displacement, velocity or acceleration in SI or imperial units. Decimation and various filters (low-pass, band-pass, band-stop and high-pass) can be applied, in time domain ODS, to frequency limit the analysis.

ODS analysis is very beneficial in combination with operational modal analysis as it determines and visualizes the combination of the actual forcing functions acting on the structure and the dynamic behaviour of the structure.

Fig. 7
Time domain ODS animation of a sports car frame in a selected time interval



Frequency Domain Decomposition

Quick and Easy Identification

The concept behind the frequency domain decomposition (FDD) technique is to perform a decomposition of the system response into a set of independent single degree of freedom (SDOF) systems, one for each mode. The decomposition is based directly on singular value decomposition (SVD) of the spectral density matrix, where the singular values are estimates of the auto-spectral density of the SDOF systems, and the singular vectors are estimates of the mode shapes.

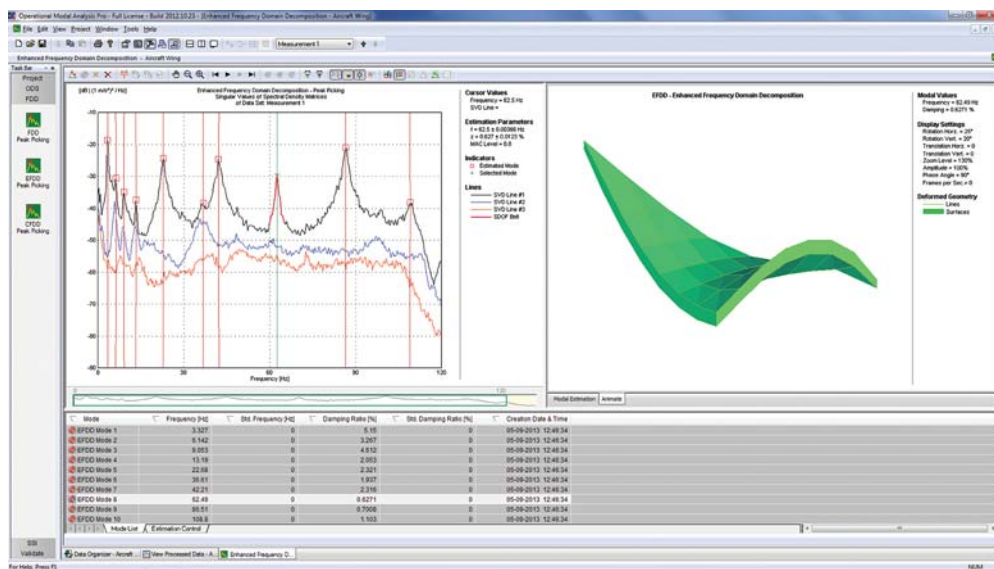
FDD is an extremely quick and easy-to-use technique. You identify the physics by looking at the plot, identifying the SDOF functions, and simply picking the peak of each function by using the snap-to-peak facility. The animated mode shape can then be displayed immediately. The technique deals effectively with close modes and noise, and you can define, delete or edit modes with user-friendly modal editing facilities. Since information from just a single frequency line is used in this technique, damping estimates are not provided.

Improved Modal Identification

The enhanced frequency domain decomposition (EFDD) technique is an extension of the FDD technique. In EFDD, the SDOF function, identified around a resonance peak, is taken back to the time domain using the inverse discrete Fourier transform (IDFT). The natural frequency is obtained by determining the number of zero-crossings as a function of time, and the damping by the logarithmic decrement of the corresponding SDOF normalized auto-correlation function. The SDOF function is estimated using the shape determined by the previous FDD peak-picking technique as a reference vector in a correlation analysis based on the modal assurance criterion (MAC). A MAC value is computed between the reference FDD vector and the singular vector for each frequency line around the resonance peak. If the MAC value is above a user-specified MAC rejection level, the corresponding singular value is included in the description of the SDOF function.

Compared to the FDD technique, the EFDD technique includes damping estimation and gives an improved natural frequency and mode shape estimation.

Fig. 8
 Modal identification of an aircraft wing by peak-picking using the enhanced frequency domain decomposition technique. Mode shapes are immediately animated



Curve-fit Frequency Domain Decomposition

The curve-fit frequency domain decomposition (CFDD) technique is an extension of the EFDD technique. Like the EFDD technique, the CFDD technique includes damping estimation, improved natural frequency estimation, and improved mode shape estimation. SDOF functions are estimated, but where the EFDD technique uses time domain methods to find the natural frequencies and damping estimates, the CFDD technique finds them by curve-fitting the SDOF functions in the frequency domain. Both the EFDD and CFDD techniques find modes shapes in the same way.

The CFDD technique is superior to the EFDD technique when the SVD plot is noisy, caused by things like short time recording lengths or when deterministic signals are present. The FDD, EFDD and CFDD techniques are all protected by patents.

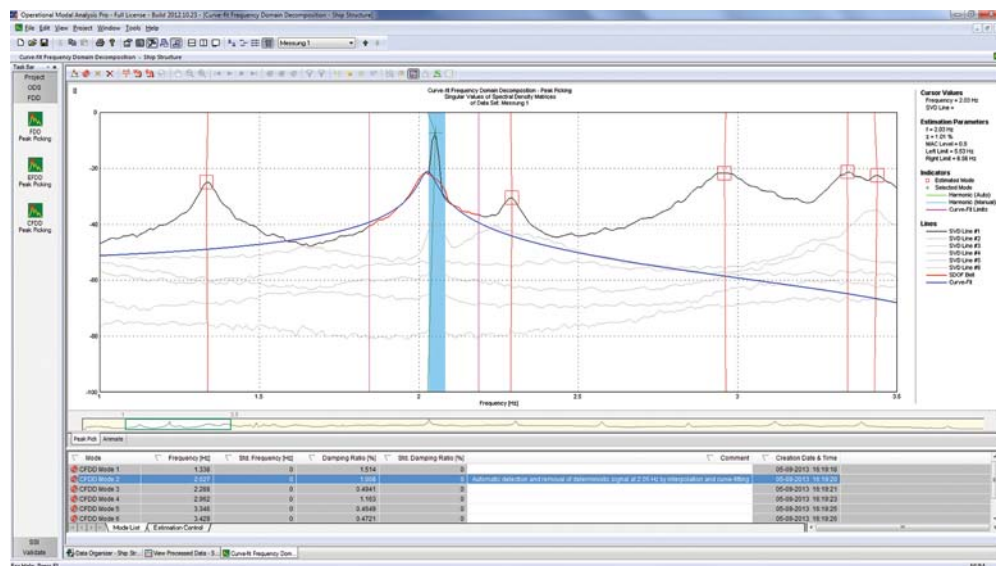
The techniques used in operational modal analysis assume that the input forces are stochastic in nature. This is often the case for civil engineering structures like buildings, towers, bridges and offshore structures, which are mainly loaded by ambient forces like wind, waves, traffic or seismic micro-tremors. The loading forces of many mechanical structures are, however, often more complex. They are typically a combination of deterministic signals originating from the rotating and reciprocating parts and broadband excitation originating from either self-generated vibrations from, for example, bearings and combustions or from ambient excitations like air turbulence and road vibrations. However, civil engineering structures can also have broadband responses superimposed by deterministic signals from, for example, ventilation systems, turbines and generators. The deterministic forces are seen as harmonic components in the responses, and their influence should be significantly reduced before extracting the modes in their vicinity.

As the input forces to the structure are not measured in operational modal analysis, special attention must be paid to identify and separate deterministic signals from the response of true structural modes and reduce the influence of the deterministic signals in the modal parameter extraction process. In the EFDD technique, an automatic two-stage method is used, where first the deterministic signals are identified using various kurtosis calculations and subsequently suppressed using interpolation across the deterministic signals in the SDOF functions. The CFDD technique goes one step further by curve-fitting the interpolated SDOF functions. This is particularly useful when deterministic signals are located at or very near resonance frequencies.

It should be noted that the techniques do not involve any time or frequency domain filtering as this would bias and potentially destroy the estimation of the structural modes. In addition, prior knowledge of the number of deterministic signals, their frequencies and their stability is not required.

If significant deterministic signals are present in the responses, high dynamic range measurements might be required to extract 'weak' modes.

Fig. 9
Ship structure example showing an identified deterministic signal (light blue vertical line), a restored SDOF function for the selected mode (red curve), and a curve-fitted SDOF function (blue curve)



Stochastic Subspace Identification

Time Domain Techniques

In the time domain, you can perform modal identification using three different kinds of data-driven, stochastic subspace identification (SSI) techniques: unweighted principal components (UPC), principal components (PC) and canonical variate analysis (CVA). These techniques fit a full modal model in discrete time to the data in the time domain. The theoretical assumption for these advanced time domain methods is that the input to the modal model is a stationary force signal that can be approximated by filtered, zero-mean, Gaussian white-noise. In practice, the methods work with any broadband excitation, including run-up/down excitation.

The SSI techniques are the most powerful and accurate techniques available on the market for operational modal analysis. Because the techniques work entirely with time domain data, the benefits are unmatched. These benefits include:

Unbiased Estimation

- No leakage – The SSI techniques are data-driven methods working in the time domain. Since the model estimation is not relying on any Fourier transformations to the frequency domain, no leakage is introduced and hence there is no unpredictable overestimation of the damping
- No problems with deterministic signals – Since the modal parameters are extracted directly by fitting parameters to the raw measured time histories, the presence of deterministic signals does not create problems. Deterministic signals are just estimated as very lightly damped modes and can consequently be excluded. In contrast, methods relying on the estimation of half power spectral densities all assume that the excitation is broadband (white noise) and thus the presence of deterministic signals introduce bias in the modal parameter estimation

Less Random Errors

- Low-order model estimator used – The SSI techniques are born as linear least-squares fitting techniques fitting state space systems with correct noise modelling. The benefit is that low-order model estimators can be used. High-order model estimators are, however, often used to approximate a non-linear least squares fitting problem with a linear least-squares fitting problem. This is an often seen approximation when fitting, for example, polynomial matrix fractions, where a high polynomial order is required. As a result more parameters have to be estimated compared to using a low-order technique and with the same amount of data available, less independent information per estimated parameter is obtained. Consequently the uncertainties of the high-order parameter estimates become significantly larger
- All modal parameters are fitted in one operation – All parameters fitted are taking advantage of the noise cancellation techniques of the orthogonal projection used in SSI. Other available techniques often fit the poles (frequency and damping) first, and then use the noisy spectral data and the estimated poles to fit the mode shapes resulting in poorer mode shape estimates

The use of different SSI techniques is important in order to validate extracted modal parameters by comparison.

Crystal-clear Stabilization Diagrams

A stabilization diagram is used to display the natural frequencies of all the estimated eigenvalues (modes) as a function of state-space dimension (model order). For an enhanced overview, the stabilization diagram is shown on top of a wallpaper of the singular value decomposition of the spectral density matrix of the currently selected data set. Modes are classified as either stable, unstable or noisy (that is, computational non-structural modes used by the algorithms to account for non-fulfilled assumptions). Using modal indicators, you can set up a series of requirements that modes must repeatedly fulfil, from one model order to another, in order to be classified as stable.

Crystal-clear SSI (CC-SSI) is an improvement to the well-known SSI techniques resulting in even cleaner stabilization diagrams. By specifying the maximum number of poles (eigenvalues) to be estimated any less significant poles will not be shown in the stability diagram. Operational Modal Analysis Type 7760 automatically sets the maximum number of poles using a special data-dependent technique, but it can also be specified by the user.

Crystal-clear SSI is also significantly faster than the traditional SSI techniques by using a special algorithm for creating the stabilization diagrams.

The CC-SSI technique is extremely robust in many difficult cases such as:

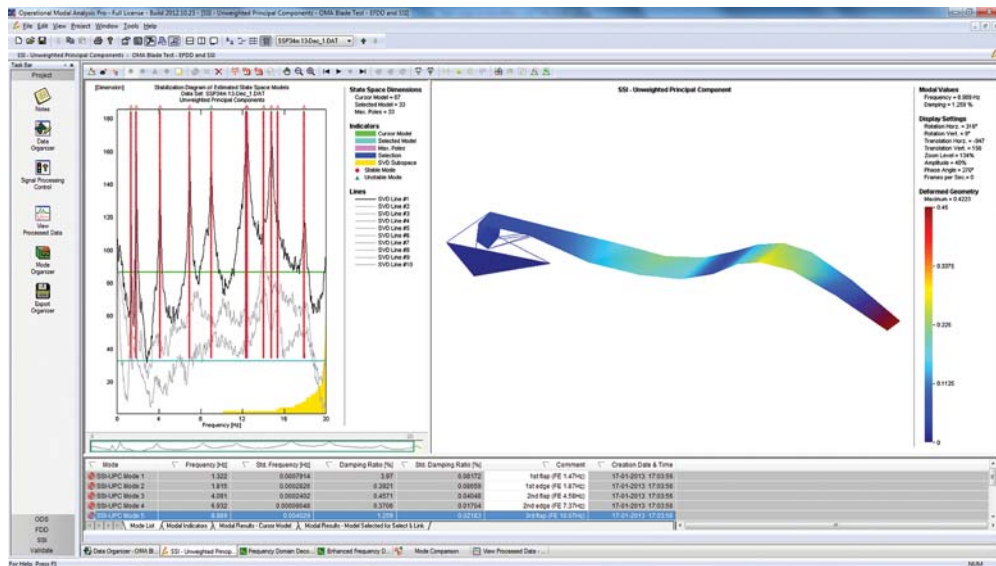
- Heavily damped modes
- Weak modes mixed with dominant deterministic signals
- High mode density

Due to the highly consistent estimation of the poles across model orders, the search for the optimal model order is less critical when using CC-SSI.

Using SSI techniques, both structural modes and deterministic signals are estimated. The deterministic signals are estimated as modes with very low damping, and can consequently be excluded.

Fig. 10

Crystal-clear stabilization diagram showing stable modes in red and unstable modes in green. All modes for each model can be inspected in the Mode List. The SVD diagram to the right, indicates a reasonable range of models to estimate. A selected model order should be high enough to include all singular values significantly different from zero in the SVD diagram



Model Validation

You can validate the quality of a cursor model and a selected model for each of the three SSI techniques by comparing the synthesized modal model results to the directly measured and processed data. You can synthesize the magnitude and phase of the response autospectra and cross-spectra and the magnitude and correlation of the prediction errors. This assists in the selection of an adequate model order.

Automatic Mode Estimation

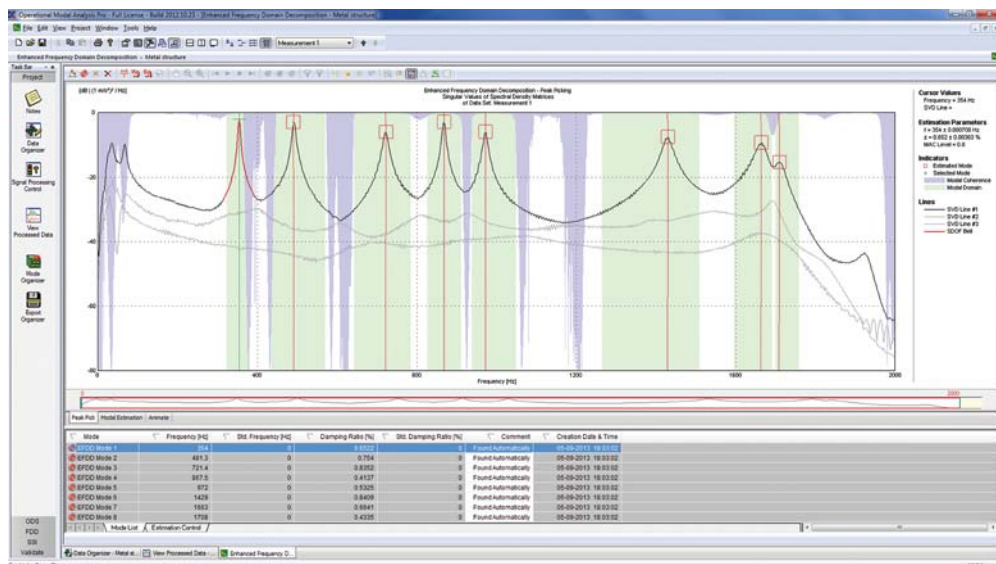
Automatic mode estimation is possible for all available identification techniques. For the FDD, EFDD, and CFDD techniques, an automatic mode estimation can find the most well-excited modes in a specified frequency band. Deterministic signals are automatically excluded in the estimation process. Apart from presenting the modes, two indicators are displayed for assessing the quality of the estimates: modal coherence and modal domain.

Automatic mode estimation is supported for all SSI techniques. In the stabilization diagram all stable modes of all estimated models across all data sets are included in a search and the result is very accurate modal estimates of natural frequencies, damping ratios and mode shapes. The estimates are presented in terms of both mean values and standard deviations.

For all techniques, automatic mode estimation can even be performed immediately after transferring data to Type 7760, thereby facilitating preliminary modal analysis with very little user interaction.

Fig. 11

Automatic mode estimation in EFDD. The modal coherence indicator (purple area) defines the extent to which a frequency region is primarily dominated by modal information or noise. For frequency regions dominated by modal information, the modal domain indicator (green area) defines for each mode the frequency region dominated by that particular mode



Validation of Modal Results

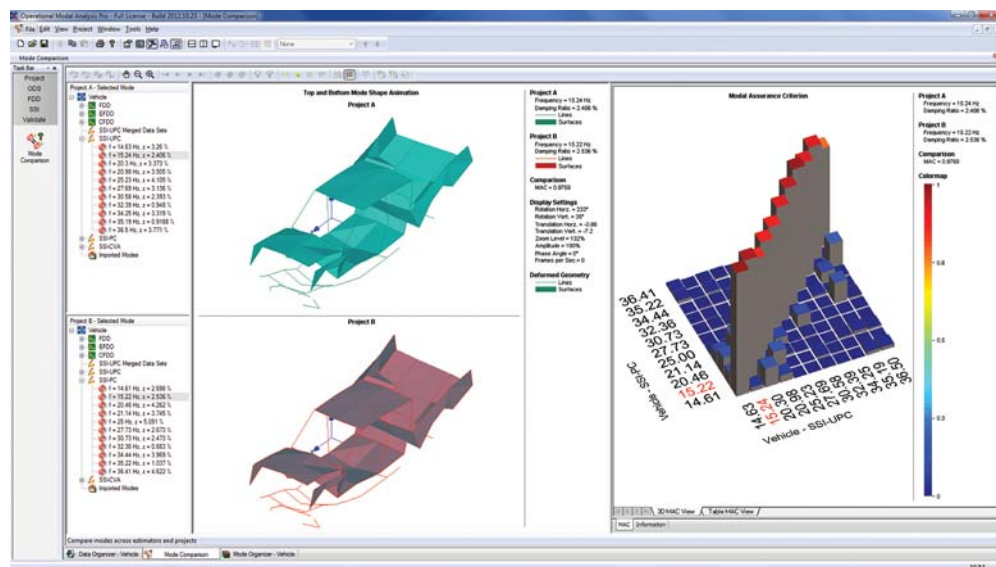
Modal results can be compared between different projects and identification techniques. It is also possible to import modes from other programs, such as classical modal analysis programs, and compare them with modes estimated in the Operational Modal Analysis software.

Visual inspection of two mode shapes can be done by animation. The mode shapes can be compared in a single- or quad-view as overlaid or difference animation. Alternatively, two modes can be compared using a top-bottom view or a side-by-side view. Animations can be shown as wire frames with or without coloured surfaces. Slave node equations and interpolation of non-measured DOFs are also supported.

In order to examine how well different mode shapes compare, a 3D MAC plot or a Table MAC view can be shown. The MAC values are easily exported to Microsoft® Office applications like Excel®.

A Mode Shapes Information Table can be used to compare, at each of the DOF coordinates, the difference in magnitude, phase, real and imaginary parts between two selected mode shapes.

Fig. 12
Analysis validation by comparing the results from different modal identification techniques. In this case, comparing the SSI-UPC with the SSI-PC techniques for a trimmed vehicle



Reporting

Results are presented in flexible tables, 2D plots and 3D plots. Tables and plots can be immediately printed or transferred as pictures using standard copy/paste procedures and plots can be saved as bitmaps or JPEG files.

Geometry data (nodes, trace lines and surfaces) and modal results (natural frequency, damping and mode shapes) can be exported in UFF to be used for FE model updating, for example. The user can also export the estimated parametric models from the stochastic subspace identifications in state-space format to an ASCII file.

Animations can easily be saved as AVI movie files. Various compression modes are available for selectable quality. AVI movie files can be shown in Windows Media® player or included in a Microsoft® Office file such as Word, Excel® or PowerPoint® for creation of live reports.

Operational Modal Analysis Type 7760 is available in three different versions: Pro, Standard and Light. The versions differ mainly in the number of techniques available.

Operational Modal Analysis Pro

This version offers the best techniques available, the highest accuracy, and the best validation of results. With this, you can perform accurate identifications in the time domain as well as in the frequency domain using the most powerful identification tools available today. The best validation you can perform is to compare frequency and time domain results with each other. This version also includes the Export Organizer task.

Operational Modal Analysis Standard

This version includes efficient frequency domain identification tools for optimum user-friendliness and computational efficiency. Complete and accurate analysis of natural frequencies, damping ratios and mode shapes are provided.

Operational Modal Analysis Light

This version offers identification of natural frequencies and mode shapes with just a few simple clicks of the mouse. The FDD technique is often used as a first technique to get an overview of the natural frequencies and mode shapes before continuing with the more advanced enhanced FDD, curve-fit FDD, and stochastic subspace identification (SSI) techniques.

Table 1
Techniques available in the different versions of Operational Modal Analysis Type 7760

Technique	Pro	Standard	Light
Time ODS*	✓	✓	✓
Frequency ODS*	✓	✓	✓
FDD [†]	✓	✓	✓
Enhanced FDD [†]	✓	✓	
Curve-fit FDD [†]	✓	✓	
SSI [‡] UPC**	✓		
SSI [‡] PC ^{††}	✓		
SSI [‡] CVA ^{‡‡}	✓		

- * Operating deflection shapes
- † Frequency domain decomposition
- ‡ Stochastic subspace identification
- ** Unweighted principal components
- †† Principal components
- ‡‡ Canonical variate analysis

Batch Processing Option for OMA Pro BZ-8527

The Batch Processing Option for OMA Pro makes it possible to do SSI analysis on a large amount of acquired time data without user interaction.

An executable can be run from a command prompt, from a batch (.bat) file or from a Visual Basic® script file. The results are automatically saved in result files.

The option allows for:

- Increased productivity: Process data automatically, freeing up the test operator’s time to do other tasks
- Ease of use: Even less experienced operators can use the option
- User-independent results: Analysis based on predefined configurations

Typical applications include repetitive testing and structural health monitoring.

From PULSE v21 (OMA v5.4):

PC System

MINIMUM SYSTEM REQUIREMENTS

- Windows® 7 Pro, Enterprise or Ultimate (SP1) (x32) and (x64) or later
- Microsoft® Office 2007 (SP2) (x32)
- Microsoft® SQL Server® 2008, 2008 R2, 2012, 2012 R2 or 2014 (SQL Server 2014 Express (SP1) is included in PULSE installation)

RECOMMENDED PC

- Intel® Core™ i7 3 GHz processor, or better
- 32 GB RAM
- 480 GB Solid State Drive (SSD) with 20 GB free space, or better
- DVD-RW drive
- 1 Gbit Ethernet connection
- Microsoft® Windows® 10 (x64)
- Microsoft® Office 2016 (x32)
- Adobe® Reader® XI
- Microsoft® SQL Server® 2014 Express (SP1)

Data Input

- Import of measurement data in a single data set or using multiple data sets (roving transducers)
- Time data and geometry input from PULSE system using Modal Test Consultant™
- Universal file format (ASCII or binary) from UNIX and PC
- Operational modal analysis configuration file and data file (ASCII or binary)
- Maximum number of channels: Not limited by the software
- Maximum amount of data: Not limited by the software

Project Documentation

- Formatted text note including pictures and OLE objects
- Tree structure showing projects, data sets and DOFs
- Possibility to connect/disconnect data sets and transducers and change direction of transducers
- Documentation of project including source, number of data sets, sampling interval, sampling frequency, number of data points per channel and measurement duration, number of modes estimated by the various methods, and signal processing status
- Geometry with DOFs for complete project or for individual data sets and transducers

Signal Processing

Decimation: 1, 2, 3, 4, 5, 10, 20, 30, 40, 50 and 100 times, including digital, anti-aliasing filter, cut-off at 0.8 times Nyquist frequency

Filtering: Low-pass, high-pass, band-pass, band-stop, Butterworth filter, filter order 1 – 50 poles, selectable 3 dB cut-off frequencies, test for filter stability

Projection Channel: All channels or a selectable number. Recommended minimum stated. Best projections channels automatically selected

Harmonic Detection: Automated method for identification and suppression of the deterministic signals using the EFDD and CFDD techniques, extended kurtosis check and fast kurtosis check methods

Time ODS:

- High-pass Integration filter

Spectral Estimation Using FFT: Includes processing of auto- and cross-spectra:

- Number of frequency lines: 2 – 65536 (radix-2) only limited by the amount of data
- Overlap – 66.7%
- Window – Hanning

SSI: Data Hankel matrix estimation to be used in all stochastic subspace identification algorithms

- Maximum state space dimension – arbitrary, but limited by the amount of data
- Automatic model estimation for one or more of the SSI methods (PC, UPC, CVA)

Configuration: Reload original (raw) data or keep processing current data:

- Reset configuration
- Load configuration from file
- Save configuration to file

View Processed Data

Display of signal processing results of a selected data set or across all data sets:

- Function plots – Autospectra, cross-spectra and coherence
- Condensed plots – Singular value decomposition (SVD) of spectral matrix, average of spectral matrix, average of main diagonal of spectral matrix
- Spectrogram of selected responses
- Harmonics plot – Identified harmonic components
- Plots of raw time data and advanced Time-Frequency plots (STFT) are done using PULSE MTC

Mode Organizer

Comparison of estimated modes from FDD, EFDD, CFDD, SSI-PC, SSI-UPC and SSI-CVA techniques or from imported modes (UFF):

- Mode list – Source, frequency, standard deviation frequency, damping ratio, standard deviation damping ratio, comment field, creation date and time
- Animation including slave node equations

Export Organizer

Export of geometry, DOF information and measurement data. Formats:

- CFG - ASCII measurement files
- CFG - Binary measurement files
- UFF - ASCII measurement files
- UFF - Binary measurement files

Time and Frequency Domain ODS

Operating deflection shapes animation as a function of time, or at a specific frequency:

- Selectable time range using graphical zoom bar
- Display results as displacement, velocity or acceleration
- Display results in SI or Imperial units

Frequency Domain Decomposition – Patented

Frequency domain peak-picking technique based on singular value decomposition (SVD) of the system response into a set of independent single degree of freedom (SDOF) systems, one for each mode:

- Frequency resolution – As the frequency resolution in the spectral-density function. Set by frequency range and number of frequency lines
- Damping – No damping estimated
- Mode shape estimation – From the singular vector at the identified natural frequency
- Uncertainty estimation – In case of several data sets, the standard deviation is calculated for natural frequencies
- Automatic mode estimation – Identification of most well-excited modes based on peak identifications, modal coherence and modal domain indicators, and mode shape correlation analysis

Enhanced Frequency Domain Decomposition – Patented

Frequency domain peak-picking technique based on singular value decomposition (SVD) of the system response into a set of independent single degree of freedom (SDOF) systems, one for each mode:

- SDOF estimation – MAC Rejection Level

- Auto-correlation function – From inverse discrete Fourier transform (IDFT) of SDOF. Limited by Max/Min settings
- Frequency estimation – Determined by the number of zero-crossing as a function of time in auto-correlation function
- Damping estimation – Determined by the logarithmic decrement of the corresponding SDOF normalized auto correlation function
- Mode shape estimation – Based on using a weighted sum of the singular vectors and singular values around each natural frequency
- Uncertainty estimation – In case of several data sets, the standard deviation is calculated for natural frequencies and damping ratios
- Deterministic signals – Automatic two-stage method (identification and suppression) requiring no prior knowledge of the deterministic signals or, use of tacho signals. Identification using kurtosis calculations (extended kurtosis check and fast kurtosis check methods). Suppression using interpolation across the deterministic signals in the SDOF functions
- Automatic mode estimation – Identification of most well-excited modes based on peak identifications, modal coherence and modal domain indicators, and mode shape correlation analysis

Curve-fit Frequency Domain Decomposition – Patented

Frequency domain peak-picking technique based on singular value decomposition (SVD) of the system response into a set of independent single degree of freedom (SDOF) systems, one for each mode:

- SDOF estimation – MAC rejection level
- Natural frequency and damping estimation – From frequency domain curve-fitting of SDOF functions
- Mode shape estimation – Based on using a weighted sum of the singular vectors and singular values around each natural frequency
- Uncertainty estimation – In case of several data sets, the standard deviation is calculated for natural frequencies and damping ratios
- Deterministic signals – Automatic two-stage method (identification and suppression) requiring no prior knowledge of the deterministic signals or use of tacho signals. Identification using kurtosis calculations (extended kurtosis check and fast kurtosis check methods). Suppression using interpolation across the deterministic signals in the SDOF functions followed by curve-fitting
- Automatic mode estimation – Identification of most well-excited modes based on peak identifications, modal coherence and modal domain indicators, and mode shape correlation analysis

Stochastic Subspace Identification

Time domain data-driven stochastic subspace identification technique

- Methods – unweighted principal components (UPC), principal components (PC), canonical variate analysis (CVA) and UPC merged data sets
- Fast techniques compared to traditional SSI techniques by using a special algorithm for creating the stabilization diagrams
- Unbiased estimation – No leakage
- Less random errors – Low-order modal estimators, all modal parameters fitted in one operation
- Crystal-clear stabilization diagram shown on wallpaper of the SVD of the spectral density matrix of the currently selected data set
- Stability indicators – Stable modes, unstable modes and noise modes
- Stabilization criteria – Natural frequency, damping ratio, mode shape MAC, modal amplitude MAC
- Physical mode separation – Damping ratio range
- SVD diagram for subspace selection
- Select and link – Selected models from each data set are linked with snap functions and editing facilities (Using the UPC merged data sets method no select and link is required. The individual data sets are automatically merged before UPC is performed.)
- Uncertainty estimation – In case of several data sets, the standard deviation is calculated for natural frequencies and damping ratios
- Model validation – Comparison of synthesized results for cursor model and selected model vs measured results. Magnitude and

- phase of autospectra and cross-spectra. Magnitude and correlation of prediction errors
- Deterministic signals – Deterministic signals are estimated as modes with very low damping and can consequently be excluded
- Automatic mode estimation – Identification of stable modes of all estimated models across all data sets, modal parameters presented in terms of mean value and standard deviation.
- Export of the complete estimated model (state-space system) in ASCII format

Mode Comparison

Comparison of modes between different projects and/or identification techniques including imported modes (UFF):

- Animation – Overlaid and difference animation of two mode shapes using single or quad view. Comparison of two mode shapes using top-bottom or side-by-side view
- Modal assurance criterion – MAC plots and tables. MAC values are easily exported to Microsoft® Office applications like Excel®
- Mode shapes information table – Difference in mode shape coordinates for magnitude, phase, real and imaginary parts between two selected modes

Graphics and Tables

GENERAL

Tabbed View (single view), Split Views Horizontal, Split Views Vertical

2D PLOTS

- Cursor readings and legends
- Selectable line style and colour-coding for individual graphs
- Numerical format (engineering, fixed or scientific) and number of significant digits (1 to 6) can be set for horizontal and vertical axes
- Scaling (dB or linear) can be set for the vertical axis
- Zoom on the horizontal axis using graphical zoom bar
- Annotation of specific data points on a graph
- Mode marker lines across data sets

3D PLOTS

- Cursor readings and legends
- Selectable colour-coding
- Zoom, pan and arbitrarily rotation including continuous rotation
- Reset of viewpoint

TABLES

- Mode lists with selectable layouts, sorting and show/hide of columns and comment fields
- Colour-coded MAC table

Geometry and Animation

GEOMETRY

- Single or quad view (free 3D view and fixed XY-, XZ- and YZ- 2D views)
- Wireframe geometry with optional coloured surfaces
- Optional node numbers and lighting

ANIMATION

- Single, overlaid, difference, side-by-side, top-bottom or quad view mode or deflection shape animation
- Animation of non-measured nodes using slave node equations (fixed or linear combination of measured nodes)
- Animation of non-measured nodes using interpolation (user-defined number of nearest measured/slave nodes in the X-, Y- and/or Z- directions)
- Animation with/without undeformed geometry
- Wireframe animation with optional surfaces. Surfaces can be either a constant colour, or be coloured according to their deflection
- Animation control – Amplitude, speed, start/stop, step backward/forward

Data Output

- Geometry data (nodes, trace lines and surfaces) and modal results (mode shapes) can be exported in UFF (ASCII) to UNIX or PC or in internal ASCII format
- Export of the estimated parametric models from the stochastic subspace identification techniques in state-space format (ASCII)
- Copy/paste and print of tables and 2D and 3D plots
- Export of 2D and 3D plots as bitmaps and JPEG files
- Export of animations using AVI movie files in various compression modes

On-line Help

- Tool-tips on all buttons

- Context-sensitive help on controls and plots
- Description of all menus and control bars
- Introduction to the idea of operational modal analysis
- Detailed description on the whole modal identification process
- Demo projects included

Software Rights

- The Operational Modal Analysis software is developed by Structural Vibration Solutions A/S in close cooperation with Brüel & Kjær
- Brüel & Kjær Sound & Vibration Measurement A/S has the exclusive worldwide rights to market and sell Operational Modal Analysis Type 7760 software

Specifications – Batch Processing Option for OMA Pro BZ-8527

From PULSE v21 (OMA v5.4)

Fast SSI analysis of acquired time data without user interaction.

Requires Type 7760-A/B to be installed

- Run executable file from a command prompt, a.bat file or a Visual Basic script
- Results saved in .uff or .svs result file

The executable:

- Uses the fast crystal-clear SSI techniques
- Supports multiple measurements and multiple SSI techniques at a time
- Supports measurements done in a single or multiple data sets
- Supports automatic selection of projection channels

Ordering Information

Type 7760-A-X*	Operational Modal Analysis, Pro
Type 7760-B-X*	Operational Modal Analysis, Pro (Academic Version)
Type 7760-C-X*	Operational Modal Analysis, Standard
Type 7760-D-X*	Operational Modal Analysis, Standard (Academic Version)
Type 7760-E-X*	Operational Modal Analysis, Light
Type 7760-F-X*	Operational Modal Analysis, Light (Academic Version)
BZ-8527-A-X*	Batch Processing Option for OMA Pro
BZ-8527-B-X*	Batch Processing Option for OMA Pro (Academic Version)

Type 4524-B	Miniature Piezoelectric Triaxial IEPE Accelerometer
Type 8340	Seismic Piezoelectric IEPE Accelerometer
Type 8344	Seismic Piezoelectric IEPE Accelerometer
Type 4575	DC Response Variable Capacitance Accelerometer
Type 2981	CCLD Laser Tacho Probe
UA-1473	Set of 100 Big Swivel Bases
UA-1478	Set of 100 Small Swivel Bases
UA-1480	Spirit Level for Swivel Bases
Type 2647	Charge to DeltaTron Converter
Type 4294	Calibration Exciter
DV-0459	Small Calibration Clip
DV-0460	Big Calibration Clip

Note: If using Type 7760 and PULSE FFT Analysis Type 7700/7770, the application is included on the PULSE software DVD. Type 7700/7770 must be installed as the PULSE protection key is used

If using Type 7760 as a stand-alone product, order Micro USB Security Key Type 7450-D and a Type 7760 license

Accessories

A wide range of Brüel & Kjær transducers and accessories are available for operational modal analysis. Different sensitivities, for accelerometers with or without TEDS fitted, are available. Please contact Brüel & Kjær for details

Type 4326-A	Miniature Triaxial Piezoelectric Charge Accelerometer
Type 4393	Piezoelectric Charge Accelerometer
Type 4394	Miniature Piezoelectric IEPE Accelerometer
Type 4397	Miniature Piezoelectric IEPE Accelerometer
Type 4506-B	Miniature Triaxial Piezoelectric IEPE Accelerometer
Type 4507-B	Miniature Piezoelectric IEPE Accelerometer
Type 4508-B	Miniature Piezoelectric IEPE Accelerometer

* X = license model either N for node-locked or F for floating

Maintenance and Support Agreements

M1-7760-A-X*	Operational Modal Analysis Pro Software Maintenance & Support Agreement
M1-7760-B-X*	Operational Modal Analysis Pro (Academic Version) Software Maintenance & Support Agreement
M1-7760-C-X*	Operational Modal Analysis Standard Software Maintenance & Support Agreement
M1-7760-D-X*	Operational Modal Analysis Standard (Academic Version) Software Maintenance & Support Agreement
M1-7760-E-X*	Operational Modal Analysis Light Software Maintenance & Support Agreement
M1-7760-F-X*	Operational Modal Analysis Light (Academic Version) Software Maintenance & Support Agreement
M1-8527-A-X*	Batch Processing Option for OMA Pro Software Maintenance & Support Agreement
M1-8527-B-X*	Batch Processing Option for OMA Pro Software (Academic Version) Maintenance & Support Agreement

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