PRODUCT DATA

Non-stationary STSF — Type 7712

Non-stationary STSF Type 7712 is a Windows®-based software package for analysing non-stationary sound fields measured using PULSE™, the Multi-analyzer System Type 3560 E, and Acoustic Test Consultant™ Type 7761.

Effective use of non-stationary STSF measurements can help you:

- *Comply with noise standards*
- *Understand the noise radiation mechanism of your product*
- *Reduce design time by targeting engineering changes*
- *Save measurement time to free facilities for other purposes*
- *Optimise sound-related features of your product to an unprecedented degree*

From just one simple measurement, you can study any instant or averaged period of a radiated sound field in detail. You can also animate the data to show how the sound field changes over time.

USES AND FEATURES

USES

- Noise analysis of run-up/coast-down conditions of engines and vehicle components
- Analysis of transient micro-phenomena such as the effects of individual parts of a tyre tread pattern, the opening and closing of valves and other events during an engine combustion cycle
- Analysis of the transient noise

FEATURES

- One measurement gives a complete four-dimensional definition of the radiated sound field using the Time Domain Holography method
- Near-field Acoustical Holography with arrays smaller than sound source using SONAH – Statistically Optimal Near-field Acoustical Holography
- Calculation of any sound field descriptor (sound power, sound pressure, intensity, particle velocity, displacement) as a function of time and position on any plane parallel to the measurement plane
- Averaging as a function of time, RPM, shaft angle or engine cycle, or unaveraged
- Sound source modifications to simulate engineering changes

Brüel & Kjær

Non-stationary STSF

Applications for Non-stationary STSF (Spatial Transformation of Sound Fields) measurements are increasing. From noise-standard compliance to sound quality, governments and consumers are demanding that more and more attention be paid to the sound a product makes. And any time you need to locate and measure the source of a sound problem in a non-stationary sound field, non-stationary STSF could be the solution.

Traditional source location methods typically require stationary conditions for the test, and a time-averaged map of, for example, sound intensity is typically obtained. In many cases, however, this is insufficient for accurate identification of a noise problem. One example is noise problems that only occur, or are only important under transient conditions. For example, an engine may have a noise problem that occurs during fast acceleration, but is non-existent or far less dominant under stationary operating conditions. Another example is knocking types of engine noise, where it is just as important to localise the knocks in time (engine cycle) as in space. A third example is problems, where the average noise level is acceptable, but the sound is bad. Since non-stationary STSF is a time-domain measurement and data-processing tool, it provides basically time-domain output data, which can be input to a sound quality evaluation. You can even predict the sound after a simulated modification of the sound source.

Only non-stationary STSF measurements performed in free-field or semi-anechoic conditions can root out the source of the above-mentioned noise problems. They allow you not only to rank the sources, but also to locate the sound-generating mechanisms precisely in space and in time, RPM, crank angle, etc. As a result, attention can be quickly focused on the real causes of the noise problem, which can significantly save time and development costs.

Applications

The applicability of non-stationary STSF is vast, ranging from applications in the automotive industry, such as studying transient micro-phenomena in tyres and valves, to measuring of non-stationary sound fields created by components such as engines, gearboxes, brakes, etc.

The following examples show the applicability of Non-stationary STSF Type 7712 within some automotive applications such as brake-squeal testing, engine testing and estimation of surface vibration on tyres.

Brake Squeal

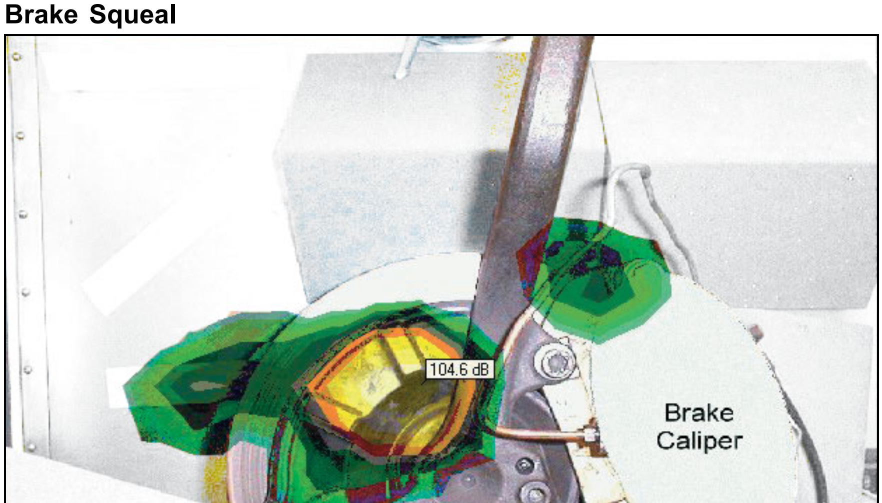


Fig. 1
Inside view of averaged narrow-band intensity of a squealing brake. The contour plot is overlaid on a digital photograph of the brake

Brake squeal is often hard to reproduce and maintain for a longer period of time since it depends heavily on operating conditions of the brake such as temperature and force. For this reason analysing squeal sources is difficult.

Localisation and quantification of brake squeal
With Type 7712 you only need to capture a fraction of a second of the squeal to be able to accurately locate and quantify the sources.

Tyres

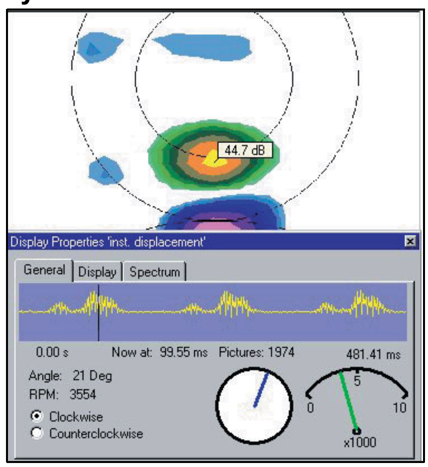


Fig. 2
Animated air particle displacement at the side wall of a tyre running at constant speed. The contour plot is overlaid on a simple drawing made using Microsoft® Paint

Measuring operational surface vibration on a rotating tyre is not possible using traditional techniques. Type 7712 provides a way of deriving this information from a non-contact acoustic measurement.

Estimation of surface vibration
Since the air particles just outside a rigid surface like the side wall of a tyre are bound to follow the movements of the surface itself, air particle velocity may be used to estimate vibrational behaviour of the surface itself. So using the inherent capability of Type 7712 to calculate any sound field property in any plane, the surface can actually be calculated from the same short measurement that can be used to determine the major sound sources of the tyre.

Engine Testing

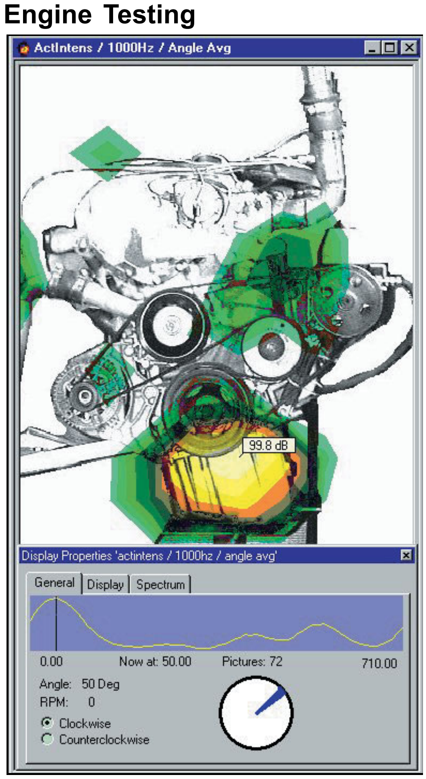


Fig. 3
Contour plot of a radiated sound field during engine run-up. The contour plot is overlaid on a digital photograph of the engine. Note the gauge for crank shaft angle. See also the front cover picture

Engine noise is transient by nature. Most combustion engines are not only subjected to transient operating conditions in terms of RPM, load and other parameters, but are also internally designed with a number of cylinders, each passing through a number of distinct stages in their operation (compression, ignition, etc.). As a consequence, any stationary approach will give only a limited description of the actual noise levels and source mechanisms involved.

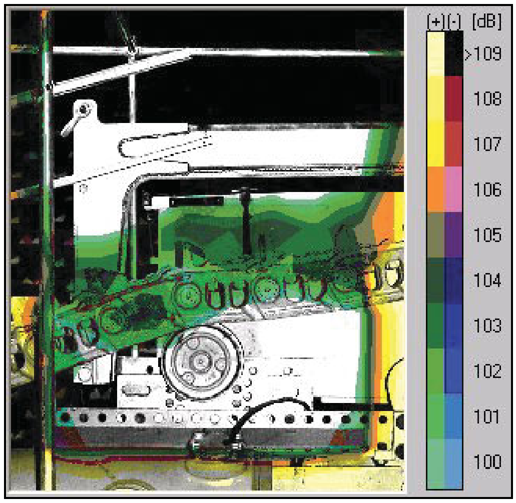
Localisation and quantification of noise sources also under transient conditions like fast run-ups
The transient capabilities of Type 7712 may be used to evaluate the noise radiation as a function of engine RPM. Filters may be used to focus the analysis to either specific frequencies or orders.

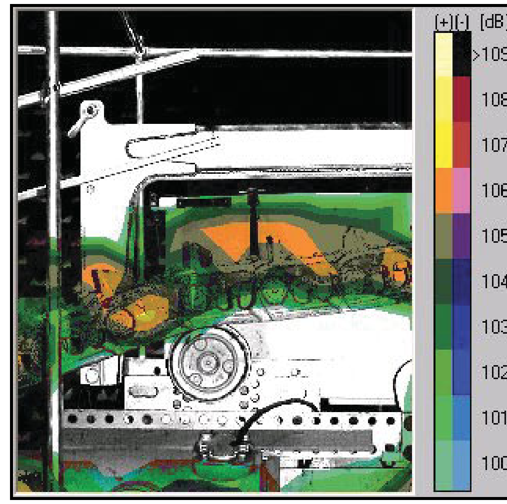
Evaluation of micro-phenomena during engine cycle
Micro-phenomena can be studied by time domain animation of any sound-field descriptor. One function, Instantaneous Active Intensity, is particularly useful for tracking moving or time-varying sources. Engine-cycle averaging makes it possible to relate the observed sound sources to specific events during the engine cycle such as the firing of individual cylinders. Engine-cycle averaging intervals can be expressed in either 360° or 720° of crankshaft angle depending on engine type.

Component Testing

In a measurement on the side of the steel track of a large Caterpillar track-type tractor, the main sources of sound radiation were around the areas where the track passes over the sprocket and around the rear and front idlers. Measurements were made with a 10 cm spaced 10 × 12 element array positioned over a small Carrier Roller with a relatively low level of noise radiation compared to the rest of the track. Fig. 4 shows plots of the A-weighted, time-averaged (RMS) particle velocity maps for the frequency band 205 – 1454 Hz (1/12-octave bands). This example illustrates SONAH's unique ability to suppress the windowing effects that are inherent when applying classical NAH on a part of the larger source.

Fig. 4
Averaged particle velocity maps for the 1/12-octave bands 205 – 1454 Hz, A-weighted. Left: NAH, Right: SONAH

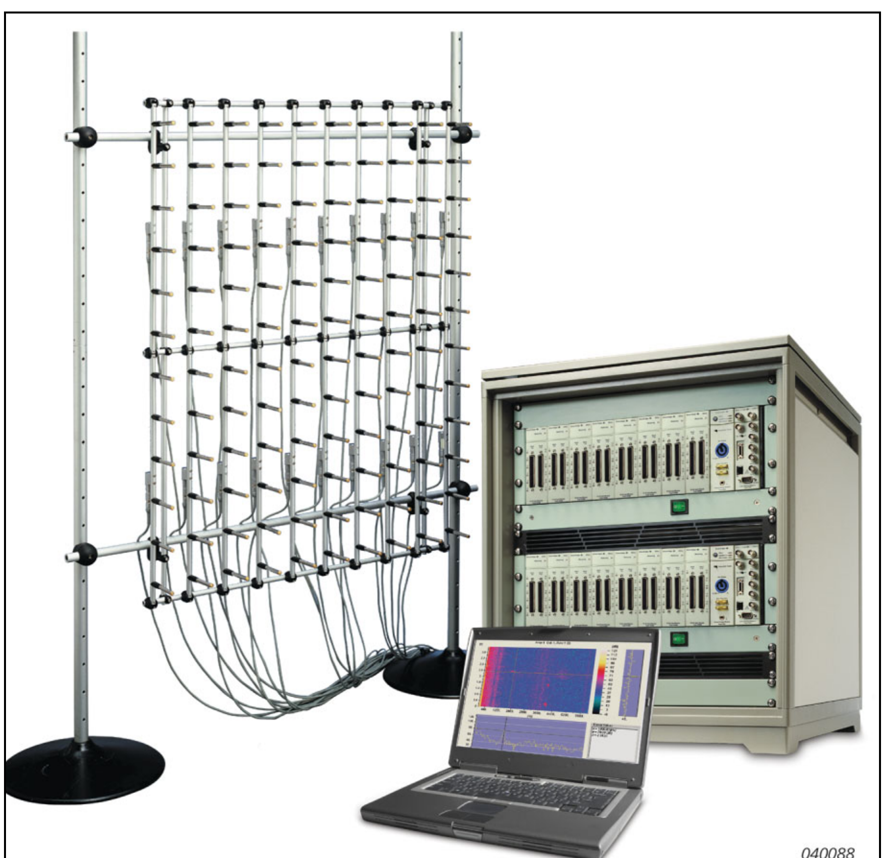




Measurement Made Easy

Measurements for non-stationary STSF analysis are made with a fixed microphone array (see Arrays and Hardware on page 9). Since you only need to acquire time data corresponding to one transient or a few seconds of a stationary signal, measurement is very fast. In addition to the microphone array, you can configure a number of additional channels to perform simultaneous measurements of auxiliary signals, for example, RPM tachometers or vibration signals from accelerometers.

Fig. 5
Integrated 120-channel non-stationary STSF system including:
- *Microphone grid with integrated cabling*
- *Multichannel data acquisition system*
- *PC for control of data acquisition and analysis*



System Configuration

Keeping track of the cables involved in a multichannel measurement can be a nightmare. To minimise the potential for cabling problems and save setup time, the software includes a **Detect** function. All you need to do is apply a calibrator signal to each channel. The system then automatically assigns the physical address of the microphone on the array to the detected channel location on the front-end so you don't have to worry about where each microphone is physically plugged into the front-end. The microphone array is easy to set up as the microphones snap easily into and out of place on the scalable microphone grid. And with one microphone cable connecting to six microphones, the number of cables is minimised.

Calibration

Calibration is easy too. Brüel & Kjær has designed an adaptor for Pistonphone Type 4228 that allows you to calibrate six microphones simultaneously. The software automatically senses which channels you are calibrating.

On-line Channel Monitoring

To ensure the integrity of the measurement chain and save time, on-line monitoring using PULSE's Level meter detects such problems as cable breaks, overloads and CCLD faults even during measurement.

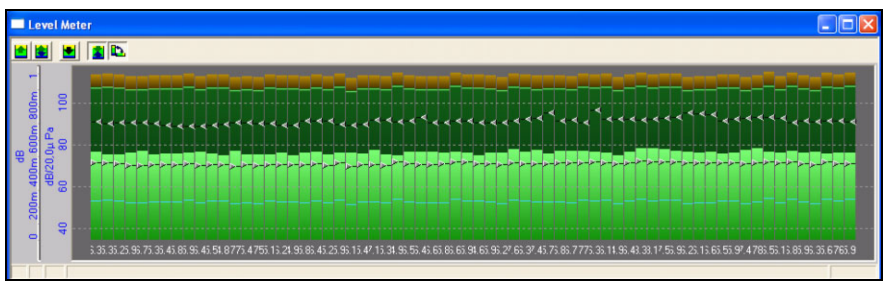
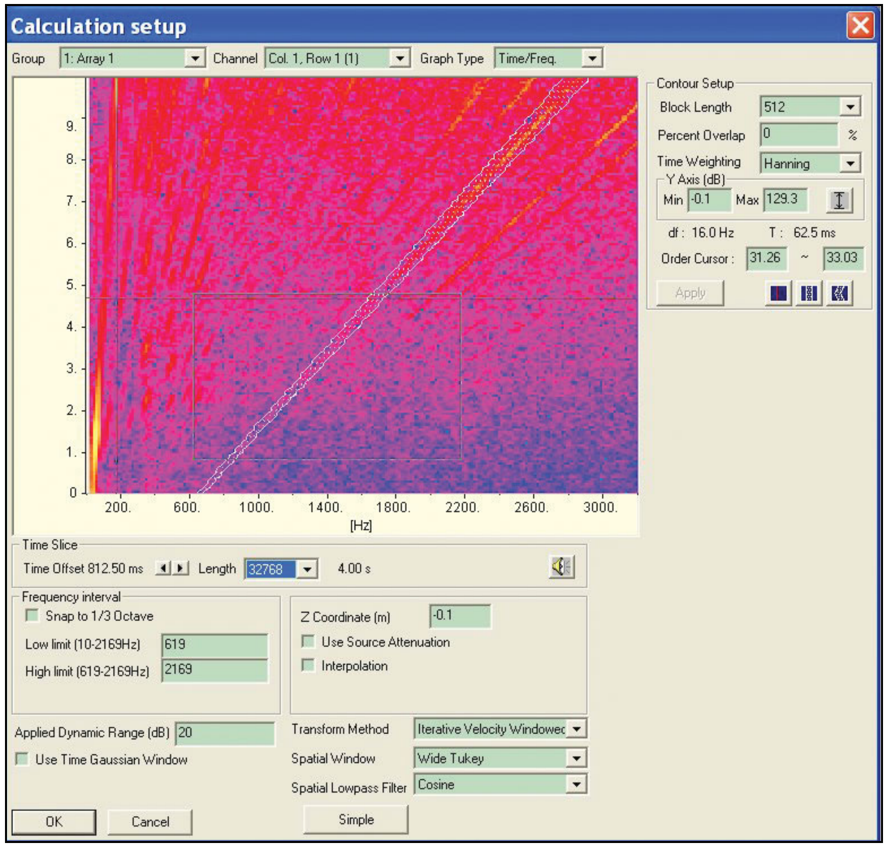


Fig. 6
PULSE's Level Meter

Fig. 7
Type 7712's calculation setup showing orders in a time/frequency contour plot. This provides guidance for the selection of the time and frequency ranges for the calculation



Calculation

The basic calculation methods used by Type 7712 are Time Domain Holography (TDH), which can be performed either by traditional NAH (Near-field Acoustical Holography) or by the new SONAH (Statistically Optimal Near-field Acoustical Holography) algorithm. From the measured pressure time signals, TDH calculates the pressure and the particle velocity time signals in any plane parallel to the measurement plane but not intersecting the measurement object. The main parameter sets defining this holography calculation are:

- The position of the calculation plane
- The time and frequency interval to be processed

The new SONAH calculation method avoids the use of spatial FFT processing and therefore avoids the major part of the spatial windowing effects produced by traditional NAH. This allows measurement by an array which does not completely cover the source and which can be significantly smaller than the wavelength. Such conditions would produce serious errors with NAH.

Display

Various displays can be defined to view the calculated time data. For each display, you typically have to input the following parameter sets:

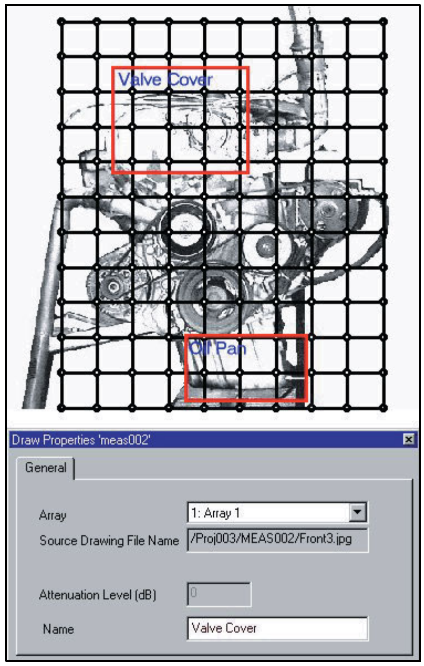
- The frequency filters – 1/3-, 1/12-octave, Constant Bandwidth, Order Band
- The display function – Pressure, Particle Velocity, Intensity, etc.
- The averaging – None, Time, RPM, Engine Cycle Interval, Shaft Angle

Contour plots of any quantity can be easily aligned and superimposed on a digital photograph of the test object.

Background Processing

Since the holography calculations and some of the post-processing types needed for the displays are rather time consuming, these calculation jobs are performed as background processes. This allows you to continue working as the calculations are being made.

Fig. 8
Determining the sound power of user-defined sub-areas



Sound Power Calculation

Sub-areas for sound power calculation (see Fig. 8) can be freely positioned over the measurement grid. Each sound power area can be named and the overall spectrum or the spectrum for each area viewed. This lets you see which areas contribute most to the total sound power and where it may be most beneficial to make modifications.

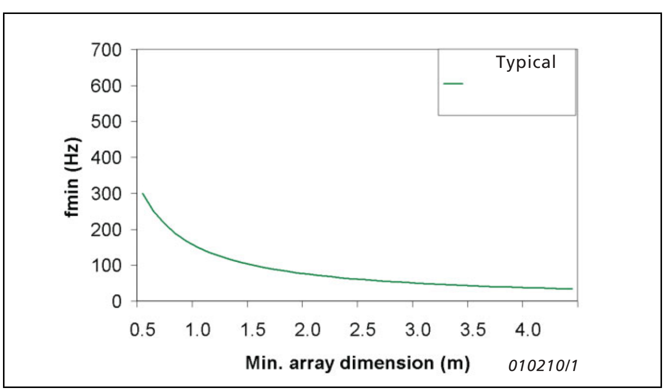
Source Modification Simulation

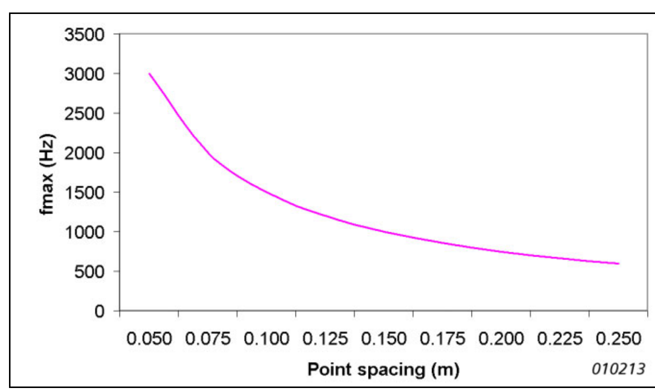
To simulate the result of design changes, you can define a number of sub-areas on the measurement grid and apply an attenuation to each. The attenuation simulation is performed on the particle velocity in the source plane. Exporting the display data in WAV format, with and without attenuation, will then allow, for example, subjective studies using sound quality.

Frequency Range

The frequency range, resolution and measurement time depend on dimensions of the measurement array, object and surface. Fig. 9 illustrates on the left how the minimum analysis frequency depends on the array dimensions. On the right, the figure shows how the maximum analysis frequency depends on microphone measuring point spacing.

Fig. 9 *Typical f_{min} as a function of array dimension (left) and f_{max} as a function of point spacing (right)*





Viewing and Documenting Your Results

Once Type 7712 has calculated the results, a number of options are available for displaying them.

- *Animated Contour Plots* – Any sound field descriptor you wish to investigate can be displayed in a contour plot, both instantaneous or averaged. These plots can be shown as a sequence creating, in effect, an animation of the sound field parameter. Several plot animations can also be displayed in parallel for comparison.
- *Spectra* – The software can display a spectrum plot for any position in a contour plot. If sound power areas are defined, you can also display the sound power spectra.

- *Source Drawings* – To further aid visual interpretation of the event you have measured, you can import source drawings or digital photographs (bitmap or jpeg). These pictures can be scaled and aligned to fit the measurement grid as an overlay.
- *Documentation* – For documentation of your results, you can copy either the graphical content or the data from the currently active window to, for example, a Word document. You can print directly from the software or save animations in AVI format.

Comparison of STSF and Non-stationary STSF

Both STSF and Non-stationary STSF techniques use acoustical holography calculations, but the measurement method and the types of data being processed are very different.

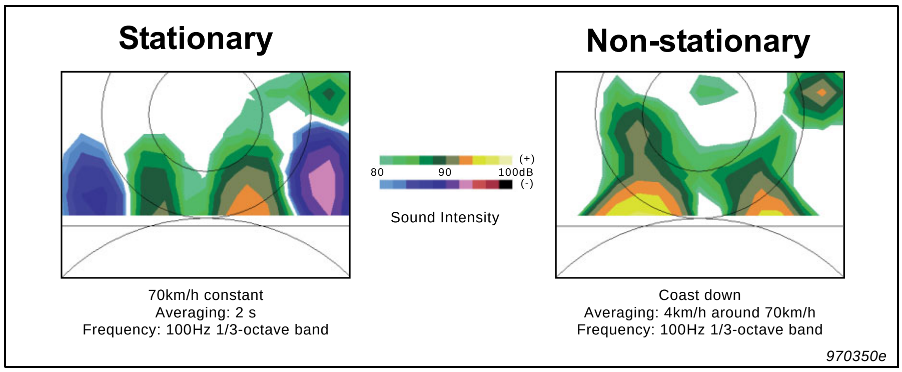


Fig. 10
Identical instantaneous conditions can show very different results when comparing stationary sound fields (a tyre at constant speed) with non-stationary sound fields (a tyre during coast-down). Note the difference in the radiated sound intensity pattern

STSF measures only *coherent* sound field descriptors of a stationary stochastic sound field, that is to say, the part of a sound field coherent with a selected set of reference signals. Data reduction occurs during acquisition because autospectra and cross-spectra are averaged. Scanning is possible because the sound field is stationary. This method has advantages and disadvantages. On the one hand, it excludes incoherent sound field components (uncorrelated background noise, for example) and allows a principal component representation of the sound field. On the other hand, it can be a problem when dealing with a sound field with many independent partial sources, to provide a proper set of reference signals. The use of an incomplete set of references means that any sound field components that are not coherent with any one of the references will not be included.

Table 1
The differences between the two techniques. Stationary and non-stationary STSF complement each other very well because they use the same or similar equipment to accomplish different tasks

	STSF	Non-stationary STSF
Scanning (large area and high frequency)	♦	
Background noise suppression before holography calculations	♦	
Data reduction before holography	♦	
Non-stationary (transient) sources		♦
Animated contour plots		♦
Gated averaging at various intervals		♦
Order filtering		♦
Output to sound evaluation (sound quality)		♦
Mapping over 3D region	♦	♦
Correlation with references	♦	

A non-stationary STSF measurement gathers time history data and performs no data reduction before holography calculations are made. This means that non-stationary measurements don’t lose detailed time information by averaging during measurement, though you can average as a post-processing function. Maintaining full sampling rate time resolution allows you to find the precise moment and location of sound generating mechanisms.

Arrays and Hardware

Two microphone arrays are available: Integral Connection Array WA 0806 and Flexible Configuration Array WA 0807.

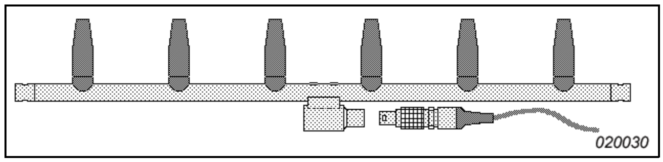


Fig. 11
Integral Connection Array WA 0806

The Integral Connection Array comprises six microphone holders for Brüel & Kjær prepolarized Array Microphone Type 4935. These are permanently mounted on a 10 mm diameter tube with integral wiring and common output connector (LEMO 7-pole).

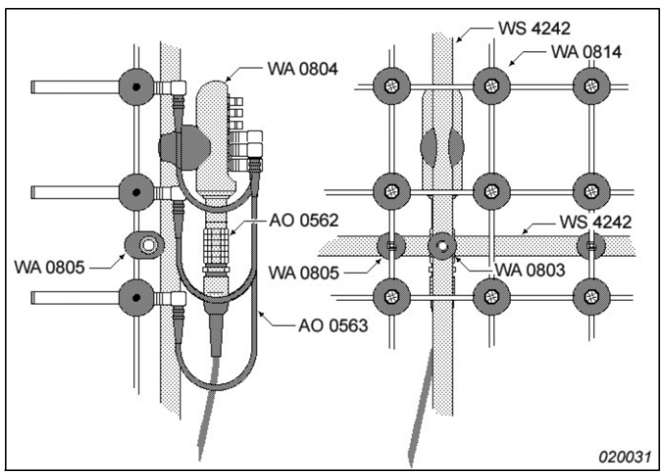
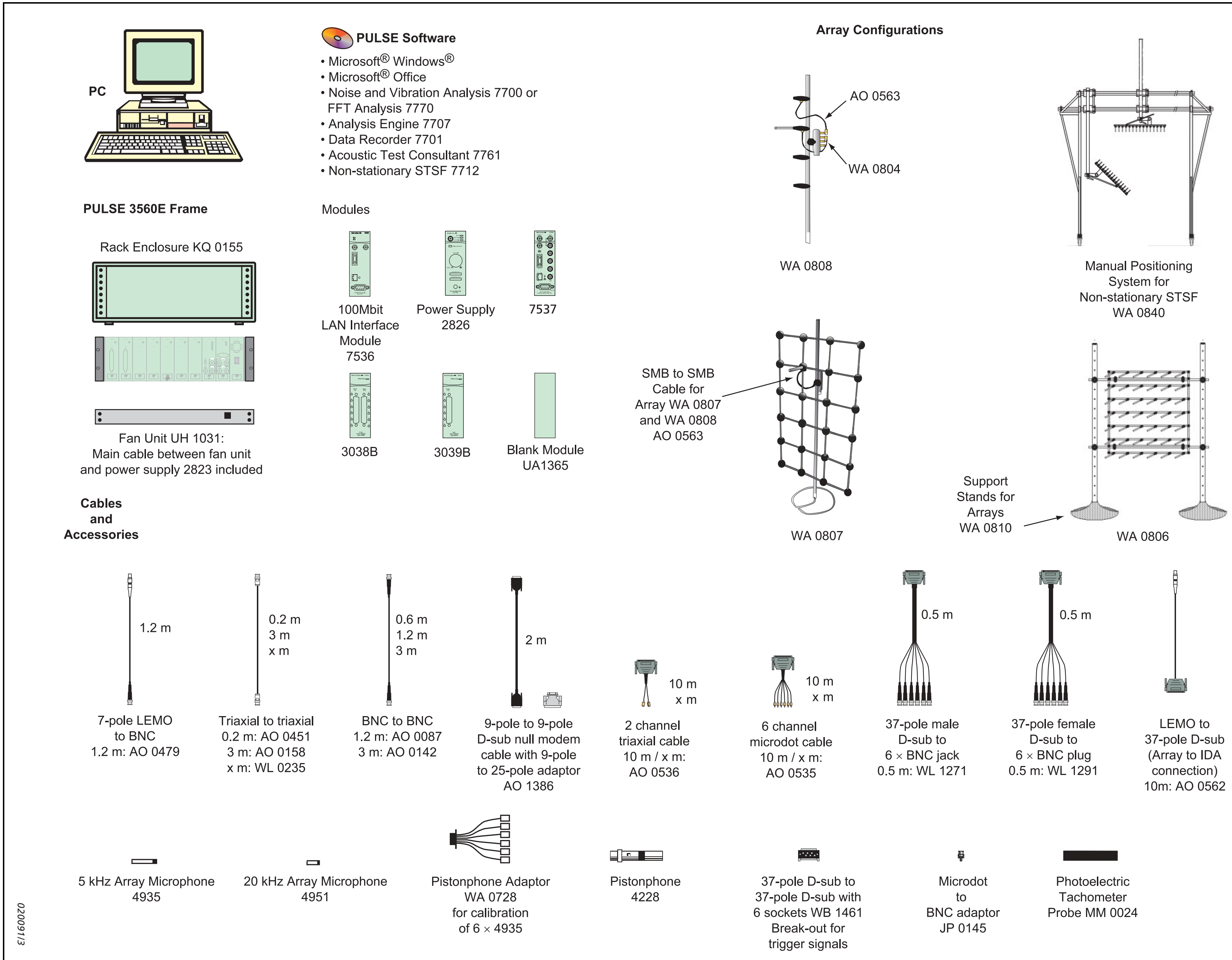


Fig. 12
Flexible Configuration Array WA 0807 allows you to change the microphone spacing

In the Flexible Configuration Array microphones are inserted into balls and each of the six microphones are connected to a patch connector using short and flexible SMB cables of appropriate lengths.



PC
PULSE Software
• Microsoft® Windows®
• Microsoft® Office
• Noise and Vibration Analysis 7700 or FFT Analysis 7770
• Analysis Engine 7707
• Data Recorder 7701
• Acoustic Test Consultant 7761
• Non-stationary STSF 7712
Array Configurations
AO 0563
WA 0804
WA 0808
Manual Positioning System for Non-stationary STSF WA 0840
PULSE 3560E Frame
Rack Enclosure KQ 0155
Fan Unit UH 1031: Main cable between fan unit and power supply 2823 included
Modules
100Mbit LAN Interface Module 7536
Power Supply 2826
7537
3038B
3039B
Blank Module UA1365
SMB to SMB Cable for Array WA 0807 and WA 0808 AO 0563
WA 0807
Support Stands for Arrays WA 0810
WA 0806
Cables and Accessories
1.2 m
7-pole LEMO to BNC 1.2 m: AO 0479
0.2 m 3 m x m
Triaxial to triaxial 0.2 m: AO 0451 3 m: AO 0158 x m: WL 0235
0.6 m 1.2 m 3 m
BNC to BNC 1.2 m: AO 0087 3 m: AO 0142
2 m
9-pole to 9-pole D-sub null modem cable with 9-pole to 25-pole adaptor AO 1386
10 m x m
2 channel triaxial cable 10 m / x m: AO 0536
10 m x m
6 channel microdot cable 10 m / x m: AO 0535
0.5 m
37-pole male D-sub to 6 × BNC jack 0.5 m: WL 1271
0.5 m
37-pole female D-sub to 6 × BNC plug 0.5 m: WL 1291
LEMO to 37-pole D-sub (Array to IDA connection) 10m: AO 0562
5 kHz Array Microphone 4935
20 kHz Array Microphone 4951
Pistonphone Adaptor WA 0728 for calibration of 6 × 4935
Pistonphone 4228
37-pole D-sub to 37-pole D-sub with 6 sockets WB 1461 Break-out for trigger signals
Microdot to BNC adaptor JP 0145
Photoelectric Tachometer Probe MM 0024
020091/3

Specifications – Non-stationary STSF Software Type 7712

Non-stationary STSF Software Type 7712 is application software for use with PULSE Systems

Accessories Required

PC
Please refer to the PC specifications in the System Data for PULSE software (BU 0229)

ARRAY TRANSDUCERS
Microphones (free-field or pressure) or hydrophones with ±3° phase match.

- Array Microphone Type 4935 is recommended

AUXILIARY TRANSDUCERS
Microphones, hydrophones, accelerometers, laser velocity transducers, tacho-probes, etc.

Features

LICENSE	Analysis 7712 D	Viewer 7712 E
Calculations/Analysis		
Time domain holography (NAH and SONAH)	♦	
Sound pressure, intensity, active intensity, reactive intensity, velocity, displacement	♦	
Spectra in any user-defined position	♦	
Averaging in time, RPM, shaft angle or engine cycle intervals	♦	
Filtering in 1/3-, 1/12-octave bands, order bands or constant bandwidth frequency bands	♦	
Sound power in user-defined areas	♦	
Source attenuation simulation	♦	
Display		
Time signals	♦	♦*
Spectra	♦	♦*
Time frequency contour plot	♦	♦*
Mapping contour plot	♦	♦*
RPM graph	♦	♦*
Shaft angle graph	♦	♦*
Animation		
Mapping contour plots	♦	♦*
Documentation		
Copy/Paste	♦	♦
Print	♦	♦
AVI animation	♦	♦
Data Storage		
Split and join projects using export and import of projects and measurements	♦	♦
Compare with other results: multiple projects and measurements for comparison between results	♦	♦
Other Features		
On-line context sensitive help	♦	♦
Exports data in UFF (Universal File Format), BUFF (Binary Universal File Format) and WAV	♦	♦
Imports drawings/photographs in BMP and JPEG formats	♦	

* Only for inspection of existing displays

MAX. LENGTH OF TIME SLICE
The maximum length of time slice (that is, segment of the time record) that you can select for calculation depends on the sampling frequency:

Sampling Frequency (kHz)	Max. Length of Time Slice (s)
6.4	64
3.2	128
1.6	256

Note, however, that for high channel counts and large frequency ranges, this figure may be reduced.

Ordering Information

Type 7712 Non-stationary STSF Software is available with different licenses. Please order:
Type 7712 D Analysis License
Type 7712 E Viewer License
Note: The Analysis license includes the Viewer

Typical Configurations

PULSE Analyzer Type		Entry Level 36-ch 3.2 kHz	Typical 95-ch 6.4 kHz	Analysis only
Type	**Description**	**Quantity**		
Type 3560 D		1	0	0
Type 3560 E		0	1	0
Type 7536	Controller Module	1	0	0
Type 7537	5/1-ch. Input/Output Controller Module	0	1	0
Type 3039 B	6-channel Input Module	0	1	0
Type 3038 B	12-channel Input Module	3	7	0
Type 7770-N16	FFT Analysis	1	1	0
Type 7701-N	Data Recorder	1	1	0
Type 7707	Analysis Engine	0	1	0
Application Software				
Type 7761	PULSE Acoustic Test Consultant	1	1	0
Type 7712 D	PULSE Non-Stationary STSF	1	1	1
Microphones and Array				
	Array and Cables	36	90	0
Type 4935	Array Microphones	36	90	0

Training

A training course is recommended in connection with the installation of this system. Order:
WW 5750 Installation and training on site

Software Maintenance and Support

M1-7712 x Non-stationary STSF Software Maintenance and Upgrade (x =D, E)

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Local representatives and service organisations worldwide

Brüel & Kjær