

# Product Data

## Non-stationary Signal Analysis Software — WT9362 & WT9364

Providing simultaneous time and frequency analysis

### USES:

- 0 Transient analysis
- 0 Noise source identification
- 0 Fault detection in machines
- 0 Structural analysis
- 0 Analysis of loudspeaker systems and headphones
- 0 Analysis of listening rooms
- 0 Speech analysis
- 0 Analysis of musical signals

### FEATURES:

- 0 3 advanced analysis methods:
  - Wavelet Transform\*
  - Short-time Fourier Transform
  - Wigner-Ville Distribution\*
- 0 Results displayed as a contour map in the time-frequency plane
- 0 Runs on an IBM® compatible PC, equipped with a co-processor and VGA monitor
- 0 Compatible with Brüel & Kjær Analyzers Types 2012, 2123/33, 2148\*\* and the 3550 System
- 0 Data input from above analyzers via IEEE interface or floppy disk

Non-stationary Signal Analysis Software WT9362 analyses signals with time-varying spectral properties using advanced analysis techniques, including the Wavelet Transform.

The program shows the signal's basic components at different time and frequency values. The result is displayed as a contour map in the time-frequency plane. The program has a wide range of applications in the fields of acoustics, electroacoustics and vibration where non-stationary signals are common.

Numerous display and post-processing features are available in the program. Data are transferred from Brüel & Kjær Analyzers (Types 2012, 2123/33 and 2148\*\*, and the 3550 System) via IEEE interface or by floppy disk to an IBM AT or PS/2 personal computer or compatible. The results are displayed on a VGA screen. Hard copies of the screen picture can be made on a colour printer.



\* WT 9362 only. WT 9364 is a limited functionality version with short-time Fourier transform only. Otherwise there are no differences

\*\* Or Type 2144 with Dual Channel FFT Option Type 7651

Fig.1 Set-up showing the Non-stationary Signal Analysis Software WT9362 running on an IBM PS/2 with Brüel & Kjær Analyzers 2012, 3550 and 2148\*\*

## Introduction

Non-stationary Signal Analysis Software WT9362 is the result of the latest developments in the field of signal analysis. The program's advanced analysis techniques allow more information to be extracted from the data than traditional analysis methods (i.e. FFT). This software helps solve analytical and diagnostic problems related to highly non-stationary acoustic and vibration signals. In addition, a great deal of attention has been paid to optimizing the speed of the calculations involved.

When the system has been set up, analyzer measurements are transferred to the personal computer using the software's import mode. Data are converted to a compatible format and then processed using one of the analysis techniques provided.

The calculation parameters are restricted to a single choice per method leading to a trade-off between time and frequency resolutions. The consequences of the choice made are clearly highlighted on the screen in order to avoid any confusion in a further interpretation of the analysis results.

When the calculation is finished, data are displayed in the time-frequency plane as a contour map. This representation can be compared to the way notes are shown on a music score. Such a display, for example, is commonly used in speech analysis (spectrograms) where a large amount of data can be represented in a clear way. This is usually a great improvement compared to waterfall displays.

A range of display features provides the user with an enhanced representation of the display. It is possible to save and recall each display. In addition, a dual display feature is particularly useful since the result of an analysis can be directly compared to a reference display. It is also possible to measure the level associated with a particular event in the time-frequency plane. Post-processing (backward integration and normalization) are provided for more specific applications (e.g. room acoustics).

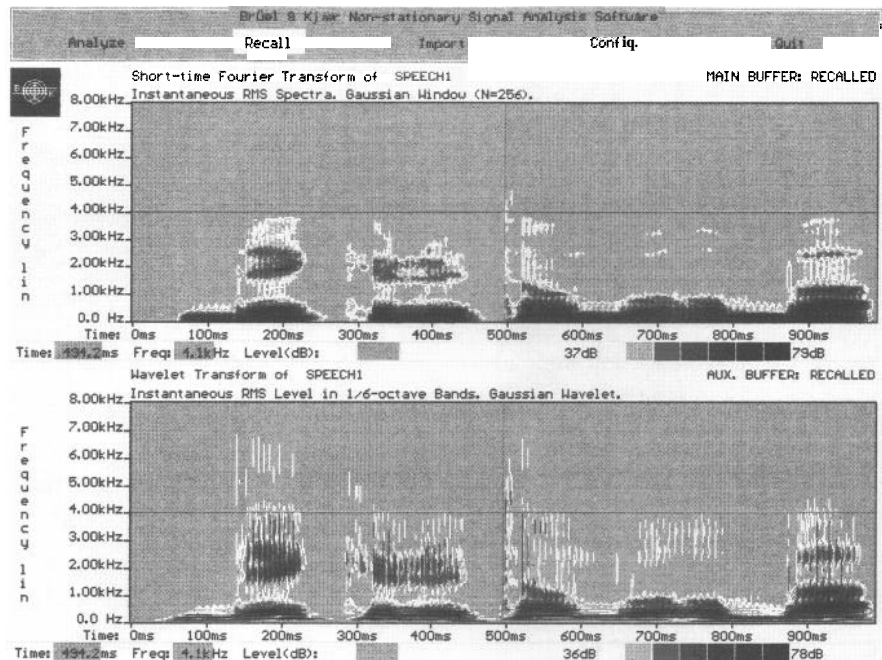


Fig.2 Dual display showing a STFT (upper display) and a WT (lower display) analysis of the same speech signal

## Three Advanced Analysis Techniques

The methods used in the program overcome the limitations of conventional spectrum analysis when examining signals with strong time varying properties. All of them have been optimized to provide the best possible resolution simultaneously in time and frequency. Such a feature is required when it is necessary to separate two components of a signal close to each other in time and/or frequency. In addition, the total energy of the signal is preserved in the time-frequency representation.

The Wavelet Transform\* (WT) is particularly relevant in acoustic applications since it provides constant percentage bandwidth analysis of non-stationary signals. Due to the similarities between this technique and the way our hearing system works, the WT is the only non-stationary analysis method that is well related to the perceptive domain. The Short-time Fourier Transform (STFT) can be preferred with vibration signals since it provides constant bandwidth analysis. The Wigner-Ville Distribution\* (WVD) is used to complement the other two methods in order to examine a particular event in greater detail.

\* WT9362 only

## Software Structure

Despite the complexity of the analytical tools used, a user-friendly interface makes the program very easy to use. The software is menu based, and each menu has a number of sub-menus. When results are displayed, the computer's function keys can be used to select the different display and post-processing features. In addition, there is a help function which can be accessed at any time to help guide you through the program.

### Config.

The Config. option is used to specify where to search for (or to store) the different files needed (or created) by the program. The software prevents specification of a path that does not exist.

### Import

The Brüel & Kjær analyzers interfaced with the program appear in list form. Data are transferred either from a floppy disk containing Brüel & Kjær analyzer files, or directly from the buffers of the analyzer via the IEEE interface. In the latter case, a General Purpose Interface Bus (GPIB) card must be installed in the computer.

### Analyze

This is the main mode of the program. A signal is chosen from a list of signals previously imported from

an analyzer, the analysis parameters are selected and the calculation made. The result is a display showing the signal's basic components at different time and frequency values.

### Recall

The recall option is used for recalling displays previously saved after an analysis. It is useful for comparisons and analysis of results.

### Quit

This option is for exiting the program and returning to DOS.

## Applications

### Speech analysis

The following example illustrates the differences in the resolution properties of the WT and the STFT for the analysis of a speech signal. The variety of information contained in speech: pseudo-stationary components (vowels) and transients (plosives) make such signals difficult to analyse. STFT, which is widely used in this field, produces spectrograms where the trade-off between the time resolution and the frequency resolution is determined by the length of the analysis window. STFT provides constant bandwidth analysis. WT, on the other hand, provides constant percentage bandwidth analysis, which results in an analysis where high frequency components are analysed with a sharper time resolution than low frequency components.

Fig.2 compares the STFT and WT analyses of the French sentence "Des que le tambour bat". The darkest areas on the contour map correspond to the highest dB levels.

The resolution properties of the WT (lower display) show good separation of the first harmonic components of the speech signal (the fundamental is around 150Hz), and the plosives are easily seen at higher frequencies. The STFT (upper display) cannot, however, show the same level of information on a single display. The Fourier window here is of intermediate length and favours neither the time resolution nor the frequency resolution.

Many non-stationary acoustic and vibration signals have similar properties to speech signals: they contain stationary components at low frequencies and transients at higher frequencies. The WT is, therefore, an

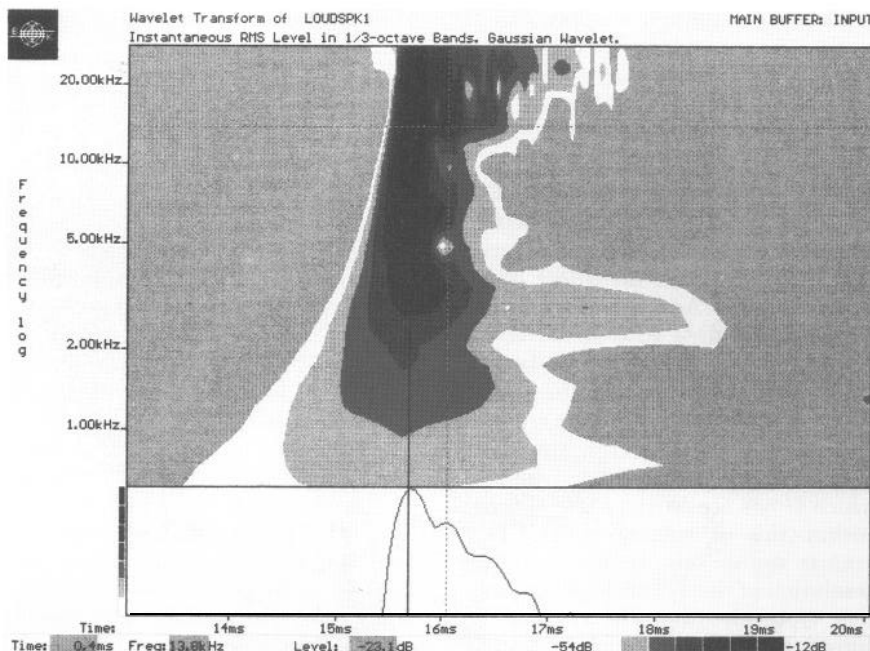


Fig.3 1/3-octave WT analysis of a two-way loudspeaker system. The lower curve shows a time slice of a 1/3-octave filter centred around a frequency of 13.8kHz. The double time cursor indicates the delay between the excitation and the reflection on the front panel (0.4 ms)

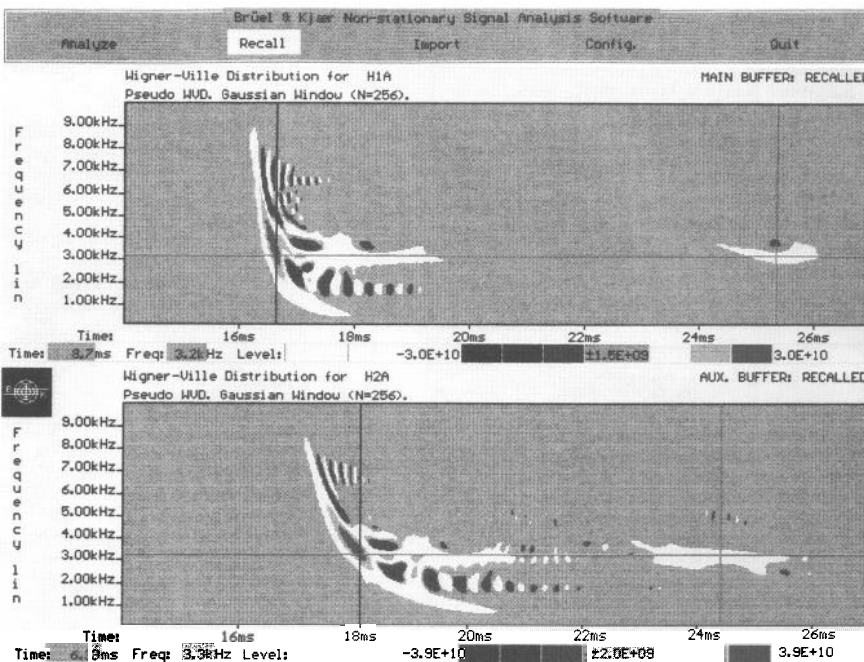


Fig.4 Wigner-Ville analysis of the impulse response of a brass beam at two positions along its length

outstanding tool for analysing these signals in greater detail.

### Wavelet analysis of a loudspeaker system

Analysis of the response of auditoria (concert halls or listening rooms) and acoustic devices (loudspeakers, headphones, etc.) are fundamental applications of the WT. Optimal time-frequency resolution and constant

percentage bandwidth analysis are provided by the linear-phase wavelet filters. Therefore, this tool is ideal for examining such systems.

Manufacturers usually examine the frequency response of loudspeaker systems to detect various frequency domain anomalies. The time or impulse response reveals information about delays and reflections. With WT analysis, this information is

available on a single display and it is, therefore, easy to relate the irregularities in the frequency response to the reflections that appear in the time response.

Fig.3 shows a WT analysis of a two-way loudspeaker system. The crossover frequency between the two transducers is 2.5kHz. The loudspeaker system was measured using a Brüel & Kjær Audio Analyzer Type 2012 and the data transferred to the software using the Import option.

The dark area, lying on the dotted time cursor above 12kHz, corresponds to a reflection on the front panel of the loudspeaker cabinet, which is not acoustically transparent within this frequency range. This area is visible due to the high time resolution of the WT at high frequencies. Note also that the response is spread out in time around 2.5kHz.

This resonance is caused by a malfunction of the crossover filter.

Such an analysis technique can be used to optimize loudspeaker system design as well as for detecting problems in the manufacturing process.

#### Structural analysis

The response of mechanical structures is another application. Fig.4 shows an analysis of a brass beam fixed at one end and excited at the free end. Two accelerometers placed at different positions along the length of the beam were used for the measurement. The upper display shows the impulse response of the accelerometer nearest to the point of excitation. The lower display shows the response of the accelerometer furthest from the point of excitation. The WVD has been used for this specific application, and clearly shows the

frequency dependent delay along the length of the structure. The resonance at 3.3 kHz is also easily seen.

#### Reciprocating machinery analysis

The program has many applications in connection with reciprocating machinery. The software helps detect malfunctions and helps locate their origins within one period of rotation. All three analysis techniques are applicable here.

In addition, using the WT's "perceptive" property it is possible to determine the different noise sources of an engine. For example, within one single cycle of rotation of a diesel engine: the opening and closing of the valves; the combustion in cylinders; the fuel injection; etc., produce various excitations that this analysis technique is able to separate and distinguish between.

## Specifications WT9362, WT9364

<p><b>HARDWARE:</b> Supported Analyzer Types: 2012, 3550, 2123, 2133, 2148, and 2144 with option 7651.</p> <p><b>SOFTWARE:</b> The Non-stationary Signal Analysis Software is supplied on a 3.5" 1.4 Mbyte floppy disk for use with the personal computers specified below. A software protection key is supplied by Brüel &amp; Kjær and must be attached to the IEEE or Centronics printer interface. WT9364 is a limited functionality version of WT9362. It is only possible to calculate short-</p>	<p>time Fourier transforms, but otherwise there are no differences</p> <p><b>DATA STORAGE:</b> All measurements may be stored on the hard disk (disk drive and directory determined by the computer configuration) and recalled. File names (max. 8 characters) are user definable.</p> <p><b>COMPUTER REQUIREMENTS:</b> IBM Personal computer PS/2 series or AT with a hard disk drive. An AT must include: min. 640 kbyte RAM, VGA colour monitor, co-processor, DOS version 3.0</p>	<p>or later and an optional National Instruments GPIB-PC2A card. A PS/2 must include: min. 840 kbyte RAM, 80286 processor or higher, VGA colour monitor co-processor, DOS 3.3 or later and an optional National Instruments MC-GPIB card.</p> <p><b>HARD COPY:</b> Hard copies (screen pictures) available using the HP Paint Jet Colour Printer.</p>
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## Ordering Information

<p><b>TYPICAL NON-STATIONARY SIGNAL ANALYSIS SOFTWARE SYSTEM:</b> WT 9362 or WT 9364: Non-stationary Signal Analysis Software Type 2012: Audio Analyzer</p>	<p>Type 3550: Multichannel Analysis System Type 2123 or 2133: Single or Dual Channel Real-time Frequency Analyzer Type 2148: Dual Channel Portable Signal Analyzer</p>	<p>or Type 2144: Dual Channel Real-time Frequency Analyzer with Type 7651: Dual Channel FFT Option</p>
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Brüel & Kjær reserves the right to change specifications and accessories without notice

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