

WinPOS

Signal Processing Package

User's Guide

Revision 3.2.11

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About this Guide

This guide contains a complete description of WinPos Signal Processing Package features, as well as more effective ways of working with this software. The Manual is intended for Windows users, therefore, it does not describe standard Windows interface elements.

Structure of the Guide

Section 1 contains a description of the capabilities, applications, and information about the software design history. In *Section 2* we give the information necessary for software installation and upgrade, as well as PC requirements. *Section 3* contains a general overview of the WinPOS operation principles. It also provides links to all interface elements descriptions, so this Section can be used as a handbook. *Sections 4 through 8* describes in detail the interface and ways of working with software. *Parts 9 through 11* contains a description of the algorithms implemented in WinPOS and recommendations for their use. *Appendix A* describes the file formats. *Appendix B* lists the specific information that can help in case of failures and abnormal situations. At the end of Manual a small *Glossary* is provided.

Conventions

For ease of reading the text in the manual the following symbols are used.

- < > Angle brackets indicate function keys and their combinations, e.g., <Ctrl>.
- The → symbol is used for menu levels separation: e.g. the entry **File** → **Open...** means that the item **Open...** shall be selected in the **File** menu.
- File** Text in **bold** denotes the menu or dialog box items, which you can choose and activate using the mouse.
- Signal* Text in *Italic* denotes the titles of the Manual sections, WinPOS Windows and terms, first appearing in the text (the explanation which is given in the *Glossary*).
- signal Monospace font denotes text or characters to be entered from the keyboard and configuration files lines.
- ❗ Important information, caution or advice.

Section 1. Introduction

About WinPOS

WinPOS software is designed to process the measurement data using a standard mathematical and statistical *algorithms*. It also provides a graphical representation and documentation of data.

WinPOS main features:

- powerful graphic interface (2D & 3D),
- working with signals of unlimited length,
- more than 50 signals processing algorithms,
- batch data processing,
- supporting of scripts (VBScript) and plug-ins,
- tools for working with *charts*
- reporting,
- dynamic processes and vibrations analysis,
- integration with MR-300 and Recorder software packages,
- detailed User's Manual and Programmer's Manual,
- comprehensive help.

WinPOS delivery options

WinPOS is available in two delivery options: professional and expert.

WinPOS **professional** is ideal for processing any measuring data, viewing and documentation. Secondary processing is carried out using a large set of built-in digital signal analysis algorithms. Open software interface allows you to create your own processing algorithms, to automate the analysis and create reports.


WinPOS **expert** extends **professional** edition, allowing the analysis of nonstationary, dynamic processes, including vibrations (see Section 10 *Vibration analysis*).

WinPOS in measuring cycle

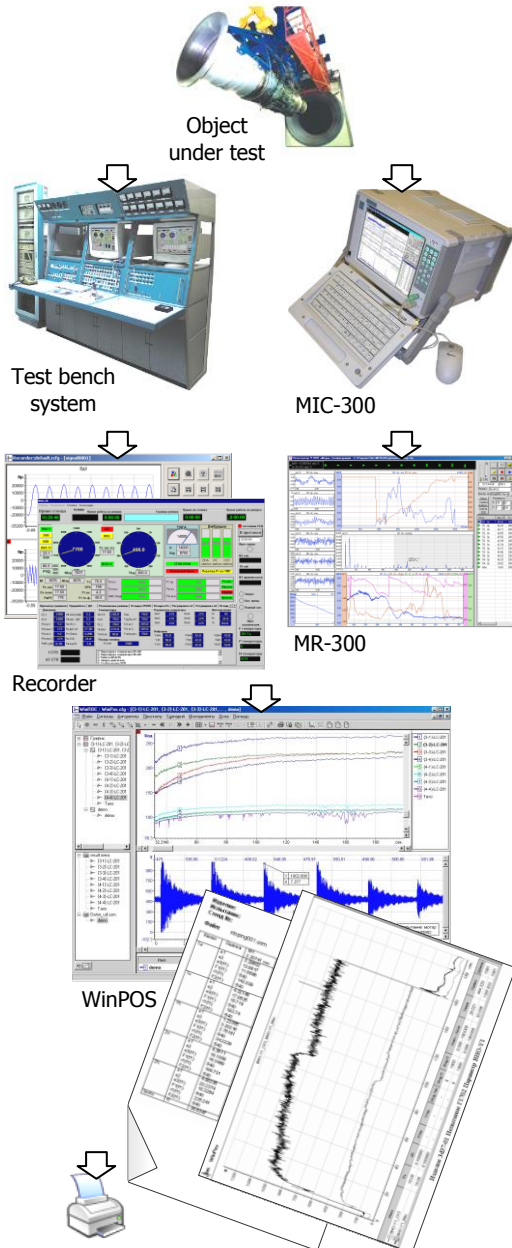
Mera Ltd manufactures and supplies hardware and software solutions for automation of the data collection and processing. WinPOS is used as one of the final parts of the measurement cycle.

Multi-channel portable systems, test benches and monitoring system are equipped with recording equipment (with Recorder and MR-300 software). Recorder performs the functions of a digital tape recorder and can perform specialized data processing and generate control actions.

Further processing of the recorded information produced in WinPOS software. In order to switch to

WinPOS click  button in Recorder. In conjunction with scripts and plugins WinPOS algorithms allow you to implement complex processing. To successfully complete processing you can use a professional set of reporting options.

WinPOS is perfectly complete data recording tools designed by Mera Ltd. Also it can be successfully used as a standalone tool or in combination with other research software.



WinPOS design history

The name **WinPOS** means the signal processing package (Пакет Обработки Сигналов (ПОС)) for Windows.

In the early 90s of the last century Mera Ltd has developed a **POS** signal processing package. For its time it was a software with revolutionary features. It applied practically in all industries and was used by many R&D companies.

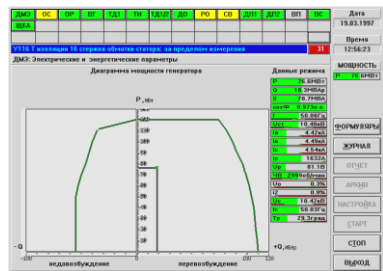
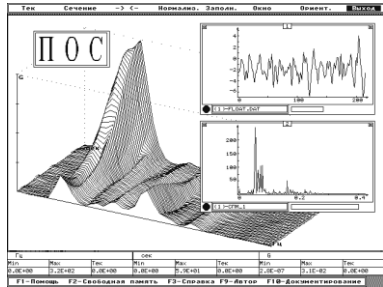
In the middle 90s, the POS-M has developed, which allowed to implement the successful solutions of POS in monitoring and test bench systems. The companies of energy and aircraft engines industries, as well as sea-based space launch facility «Sea Launch» still operate POS-M.

Limitations of MS-DOS operating system, and the growing demands for volumes of test data, ease of processing and representations did not allow to improve POS and POS-M in their original form. Therefore, MERA Ltd. has start to develop WinPOS.

WinPOS has inherited the best from POS (powerful mathematical tools, simplicity, usability and flexibility) and raised them to a new modern level.

WinPOS **expert** replaced the DAN and WDAN dynamic analyzers developed by MERA Ltd.

In 2004 the Official Registration Certificate of “WinPOS Signal Processing Package” was obtained.




PC requirements

WinPOS can be installed at any PC running Microsoft Windows 2000, XP, Vista, Windows 7, 8 and 10.

The PC one USB port must be free for the dongle installation. In network setup, the USB key connected to the server and the client workstations receive licenses across the network.

The software requires approximately 70 MB of disk space, but it is desirable to ensure sufficient disc space for storing temporary files, sessions and calculations results.

 In the lower right corner of the WinPOS window shows free hard disk space available for saving temporary files and session files. If there is insufficient free disk space, take measures on clearing of the disk or choose another disk (the disk partition) to accommodate WinPOS working directory (see Section 4 *Loading and saving signals, Sessions*, Fig. 4.7).

To ensure reasonable speed of calculations the CPU must be 1 GHz, and RAM at least 1 GB.

Comfortable working with 3D graphics is provided by graphics card with OpenGL hardware acceleration and a mouse with a scrolling wheel.

Section 2. WinPOS installation

Insert WinPOS installation CD in the PC CD-ROM drive. Installation will start automatically. If autorun is prohibited, run Setup.exe from the root directory of the CD. In the appeared window (Fig. 2.1) select «**Install WinPOS**».

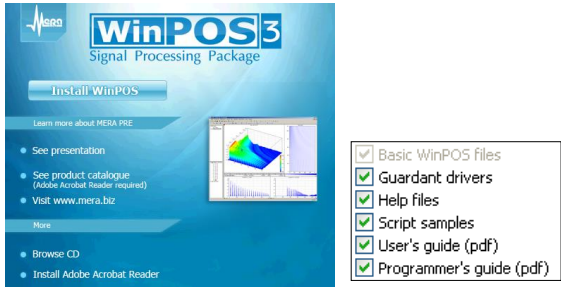


Fig. 2.1. WinPOS setup window and components for installation

Follow the instructions of the setup wizard. To navigate between the wizard pages, use <**Back** and **Next**> buttons. After setup is complete, click **Install**, click **Finish**.

During installation you will be prompted to read the *License agreement*. Accept it by selecting «**I accept the license agreement**».

The setup program allows:

- to change the default installation path (C:\Program Files\MERA\WinPOS),
- set the name of the folder in *Start* menu, select software content: select *full* or *compact installation*, or check the necessary items (see Fig. 2.1),
- place shortcuts on the desktop and on quick launch bar for quick WinPOS run.

After WinPOS installation You need to connect the USB dongle. The installation program displays detailed instructions for connection and operation of dongles. These instructions can also be found in the instruction file.pdf (Active subdirectory of the WinPOS installation directory).

1. USB dongle should not be connected to your computer before installing WinPOS, otherwise Windows will start searching drivers for it. If this happens, you should not search driver with Windows wizard, click **Cancel** and disconnect the USB dongle from PC.



2. You must have ADMINISTRATOR rights in the system. For users with the usual rights Windows prohibits of drivers installing, uninstalling, and configuring.

Starting WinPOS

WinPOS starts up from the desktop, the quick launch panel and from the Windows **Start**. To open recorded signals click the button in MR-300 or Recorder control panel or double click on the data file name (mera or, USML) in Windows *Explorer*.

How to upgrade

An updated WinPOS version can be downloaded from www.nppmera.ru (Technical support / Software Download / WinPOS). The name of the setup file depends on the delivery option and WinPOS version. For example, the name might look like this:

```
winpos-3.2.8.10-expert-eng-setup.exe
```

where *3.2.8.10* – version number, *expert* - delivery option (see *WinPOS delivery options* in Section 1), *eng* - language.

Your delivery option can be found on the dongle sticker. The dongle with the Expert designation also allows you to start WinPOS Professional.

List of changes and fixes can be found in the WhatsNew.txt file located in installation directory.

In order to reduce the size of the setup it does not contain electronic versions of the *User's Guide* (WPUUsersGuide.pdf) and *Programmer's Guide* (WPProgrammersGuide.pdf). The latest versions of these documents can be downloaded from the same webpage. If you save them in the same directory with the installer, they will installed the same way as from CD-ROM. You can also manually copy these files into the WinPOS installation directory.

Section 3. Getting started

WinPOS features

While developing WinPOS special attention was paid to user interface optimization with the aim to to simplify routine operations without losing flexibility and customizability.

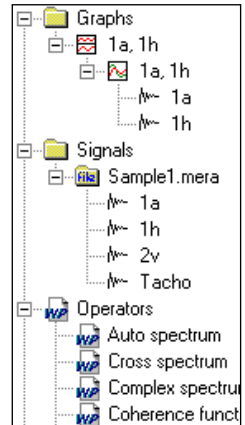
For example, to plot all the parameters of opened file you need only one mouse movement, the processing range can be set in one action. Simply select the algorithm in the drop down menu, configure if you want, click **Execute**, and you can view the results in graphs.

This model of user interface is based on few principles.

1. *What I See – Is What I Process*. By default, any action refers to the signal(s) currently displayed in the chart. If only a fragment of the signal displayed – the processing will be carried out within the selected interval.

2. All WinPOS objects stored in a hierarchical structure called *global tree*. This tree performs in WinPOS the same function as the Windows registry or file system. Any signal, graph, or algorithm has its own name and place in this tree. Therefore, even if the signal is not displayed in the chart, it can be accessed through the tree.

3. *Batch processing*. The operation with *folder* of the tree enables processing of all objects of this folder. Hence, all signals of the folder, graph or *page* can be processed as one signal.



Next a brief description of the WinPOS interface is given. This description (especially the Figs. 3.1-3.3) can be used as a reference when studying the rest of the Guide and in further work with WinPOS.

WinPOS interface. Main window

The program is controlled using the GUI familiar for Windows. WinPOS main window is shown in Figure 3.1.

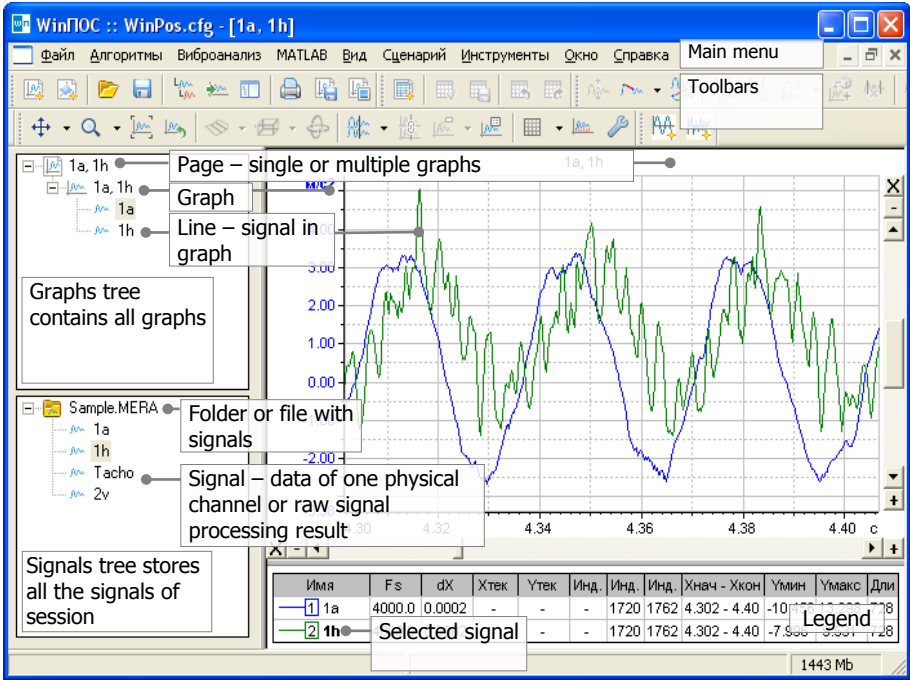


Fig. 3.1. WinPOS. General view

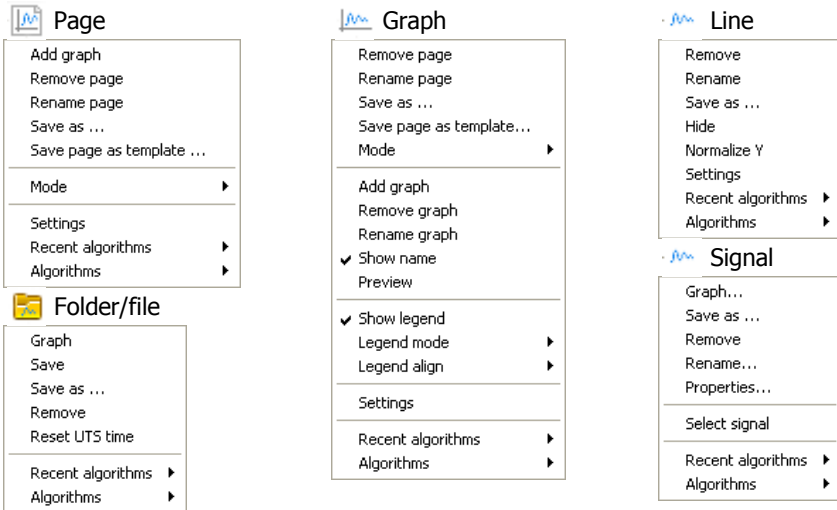


Fig. 3.2. Context menu of the main WinPOS objects

File

Open ...	
Save	
Save As...	
Open from MDB ...	
Save to MDB ...	
New session	
Restore last session	
Load session ...	
Save session as...	
Print ...	
Exit	

Vibroanalysis

Sequence processing (trends)	
Band RMS	
Amplitude-, phase-frequency response calculation	
Tacho	
Vibration survey	
Campbell diagram	
Order analysis	
Shock spectrum	
Tracking filter	
Save settings	
Load settings	

View

<input checked="" type="checkbox"/> Main toolbar	
<input checked="" type="checkbox"/> Graph bar	
<input checked="" type="checkbox"/> Table bar	
<input checked="" type="checkbox"/> Additional toolbar	
<input checked="" type="checkbox"/> Edit bar	
<input checked="" type="checkbox"/> Scroll bar	
Tree panel ▶	
Signal Manager	
Log	
Vibro calculator	
<input checked="" type="checkbox"/> Signal generator	
<input checked="" type="checkbox"/> MSOffice Tools	
<input checked="" type="checkbox"/> Extremum search	

Script

Script editor ...
Run script ...

Algorithms

Recent algorithms ▶	
Auto spectrum	
Octave spectrum	
Complex spectrum	
Cross spectrum	
Coherence function	
Transfer function	
Spectrum transformation	
IIR filtering	
FIR filtering	
Median filtration	
Integration (Antiderivative)	
Derivation	
Normalization	
Centering	
Arithmetic	
Taking the logarithm	
Resampling	
Hilbert transformation	
Envelope	
Probabilistic analysis	
Probability density	
Autocorrelation	
Cross-correlation function	
Parametric graph	
Wavelet analysis	
Save settings	
Load settings	

Window

New page	
New page from template	
Select template ...	
Instant Spectrum page	
Cascade	
Tile Horizontally	
Tile Vertically	

Tools

Normal mode	
XY-spin	
X-spin	
Y-spin	
XY-scale	
X-scale	
Y-scale	
Cursor ▶	
<input checked="" type="checkbox"/> XY-grid	
X-grid	
Y-grid	
Hide grid	
Vertical lines	
Normalize X	
Normalize Y	
Settings ...	
Default settings ...	
Load settings ...	
Save settings ...	
Wide graphs print ...	
Save image ...	
Copy image to clipboard	

Help

Contents ...	
Search ...	
Index ...	
User's Guide	
Programmer's Guide	
"Mera" Catalogue	
www.nppmera.ru	
About WinPOS ...	

Fig 3.3. Main menu

A major part of the window is the workspace, which contains pages with graphs. *Tree bar* is usually placed on the left to the workspace. *Signals tree* is placed in the lower part of the workspace, and *Graphs tree* in the upper part.

Signals tree



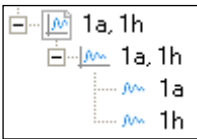
All signals opened in WinPOS are placed to the global tree to the Signals folder. The contents of this folder is displayed in the *Signal tree*.

Each signal corresponds to one element, ‘the leaf’ of the tree. The signals are grouped into folders. So all the calculation results are placed into the *Results* folder. Files in MERA and USML when the opening are placed in the tree as a folder with signals.

The "+" sign to the left of the folder name allows you to expand the content of the folder "-" sign – to collapse content. Double-clicking on a folder creates a page with graphs of the signals in this folder. Clicking on a signal opens the *Add lines* dialog window (Fig. 5.7).

Graph tree

The top level of the Signals tree consists of pages associated with the graphs, and the *lines* which plot a signal are associated with graphs.



Double-clicking on the page, graphics or line names make this item active. In the workspace on the right the selected page is displayed on top of other pages, the chart is marked with the icon "a" and the line is redrawn at the top of other curves and highlighted out in the legend in bold. See Section 6 *Signals Viewing*.

Main menu

The general view of the main menu is shown in Figure 3.3. A full description of commands is given in the relevant parts of this *Manual* (in parentheses).

File: open and save files, save and load settings, exit program. The lower part of the menu contains the list of recently open files. (see Section 4 *Signals loading and saving*).

Algorithms: a list of signals processing algorithms (see Section 9 *Signals processing*), saving and loading of algorithms settings. The checkbox to the left of the name shows that this algorithm is selected as the default algorithm. (see also *Quick call of algorithm*).

Vibration analysis (WinPOS **expert** only): list of vibration analysis algorithms (see Section 10 *Vibration analysis*), saving and loading of algorithms settings.

View – change WinPOS windows layout, enabling and disabling toolbars, and auxiliary windows (see below *WinPOS auxiliary windows*). Enabled element is marked with a check mark to the left.

Scripts (WinPOS **professional** and **expert**): built-in editor, running scripts (see Section 11 *WinPOS scripts*). The lower part of the menu contains the list of recently running scripts.

Tools: commands of the graph control panel, calling settings dialog of the active graph and default settings (see Section 6 *Signals Viewing*), reporting commands (duplicated on the main toolbar, see Section 8 *Reporting and printing*)

Window: commands for creating of new pages (See Section 5. *Graph creation*), the standard Windows MDI command for the pages layout in the workspace (usually all workspace is occupied by the current page). At the bottom of the menu there is a list of the created pages. The active page is marked with a tick.

Help - access the WinPOS help system (**Contents...**), package information, company, contact information.

Context menu

WinPOS objects can be managed through a context menu accessed with the right mouse button on the selected object (Fig. 3.2).

To open the context menu of page right click on the page name in the graphs tree.

Graph menu – on the graph name in the Graphs tree or in graph field. The graph menu includes the page menu items.











Line menu – on the line name in the Graphs tree or on the signal name in legend.

Folder and signal menu – on the signals tree.

Toolbars

The toolbar contain the most important WinPOS commands. Enabling and disabling the panels in the **Layout** menu, you can choose the best set of tools for every task. In parentheses are the number of parts of the manual that describe these tools. You can select the most convenient location of panels by moving them with the mouse ("catch" the strip on the left side panel with the mouse pointer).

Main toolbar

-  Create a new page (5)
-  Create a new 3D page (5)
-  Open... (4)
-  Save as... (4)
-  Group signals by origin
-  Add into the graph
-  Open Signal Manager (7)
-  Print graph/table
-  Save page screenshot in file
-  Copy screenshot in clipboard (8)

Graph toolbar



















-  Scrolling graph
-  Scaling graph
-  Show cursor
-  Normalize graph
-  Return to previous range
-  Grid
-  Vertical lines from signal points (8)
-  3D plotting style
-  Display mode
-  Move and rotate graph
-  Add a label
-  Add a comment
-  Synchronize cursors (6)
-  Settings (5)












Table toolbar

-  New table









Additional toolbar

-  Display labels, regimes, setpoints, breaks and statuses
-  Set, rename, delete label or regime
-  Select display mode with pauses
-  Synchronization of signals and additional date and time scale

Edit toolbar


-  Edit values
-  Change signal values
-  Signals concatenation
-  Shift the selected signal on the X-axis
-  Copy to a new signal
-  Copy a signal fragment
-  Paste into selected graph/page
-  Paste into new graph
-  Delete a signal fragment
-  Undo signal editing
-  Folder editing (7)


Scroll toolbar


-  Decrease
-  Scroll left
-  Stop
-  Scroll right
-  Increase
-  Playback of the current signal
-  Playback an audio track
-  Volume control (6)


MSooffice toolbar (plugin)

-  Report


 Save changes


 Save table as...


 Undo changes


 Redo last changes (6)


Signal generator (plug-in)

 Trigonometric functions generator


 White noise generator


 Table in Excel format


 Copy current value to Excel


 Copy legend to Excel

Min/max search (plug-in)

 Set the cursor on a maximum

 Set the cursor on a minimum

 Set the label on a maximum

 Set the label on a minimum

WinPOS auxiliary windows

Algorithm settings dialog window

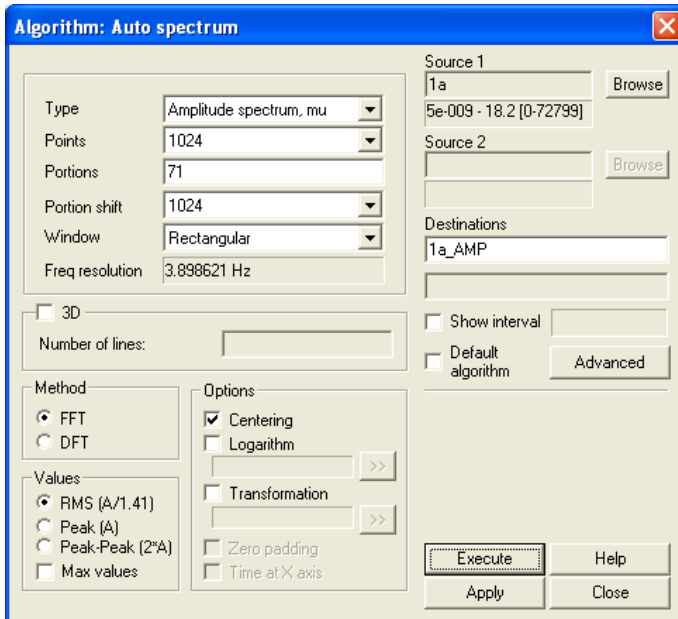


Fig. 3.4. Algorithm settings. Auto spectrum

Most signal processing algorithms require additional configuration. It is made after the choice of processing option in the *Algorithms* submenu of the main or context menu. The right part of the window settings is the same for all algorithms. It is

intended for specifying the data sources and the names of the results. The left part of the window contains the specific settings of the algorithm. For more detailed information - see - Section 9. *Signals processing*.

Signals selection

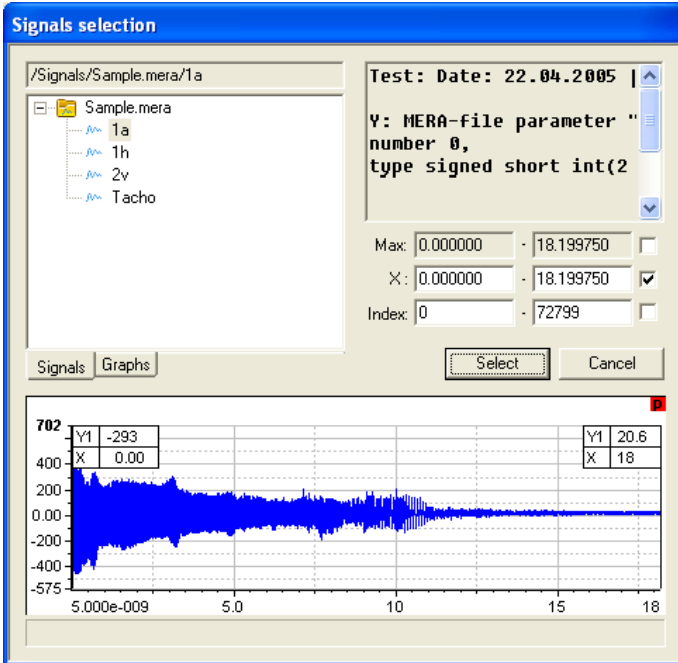


Fig. 3.5. Signals selection

The **Select** button in algorithm settings window and in saving signals window opens the Signal selection dialogue (Fig. 3.5). In the left part of the window you can select the signal from *Signals tree* or from *Graphs tree* (switch between tabs at the bottom of the tree window). On the right is a window with short information about the selected signals.

- ① When the signal selected from the *Graphs tree* the range of signals values displayed on the selected chart defined by default.

To select the processing interval move the left and right cursors in the preview window (when selecting the entire signal the cursors are coincide with the boundaries of the graph) or set the exact value in the **X** or **Index** fields. The checkboxes to the right of these fields sets the selection mode of the range for batch processing of signals from same folder (**Max** means the entire signal selection). See also Section 4 *Saving signals* and Section 9 *Signals processing*.

Signals manager

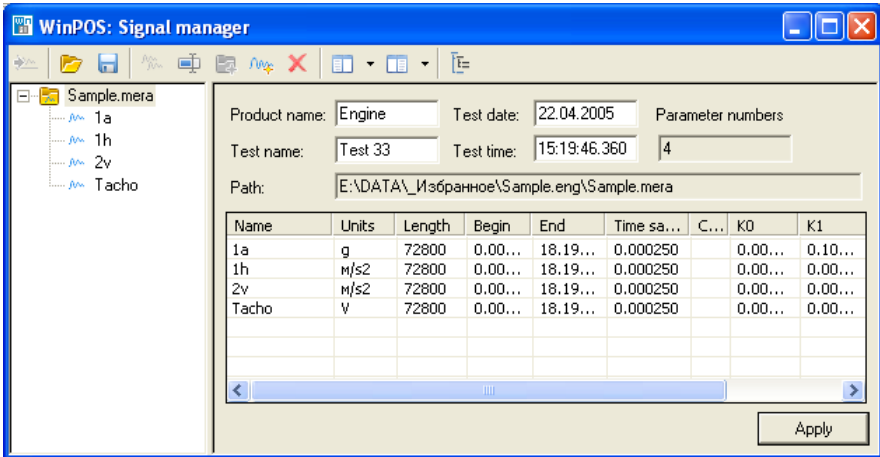
















Fig. 3.6. Signals manager

Signals manager is used to view and modify information about files, signals, calibration characteristics, as well as view the values of the signals in a tabular form. It gives the possibility of copying, renaming, cataloging, reading and writing of signals. To open the Signals manager click  button or select **Layout**→**Signals manager** command. See also Section 7. *Signals editing*.

Signals manager window (Fig. 3.6) is consist of two information panels and toolbar. Each of the information panels can be displayed as a "tree" or "list". In the right panel may displayed information about the selected object in the "properties pages". To switch between panel appearances use   buttons: a simple click of a button causes a change state of the panel, click the arrow to the right of the button to select the desired view.

The buttons of the Signals Manager toolbar.

-  F4 Show as graph
-  F3 Open file. Duplicates the **File**→**Open** `.
-  F2 Save as.... Duplicates the **File**→**Save as...** command
-  F5 Copy. Opens a dialog in which you can specify the new location of the signals and the range of values to copy. The originals delete option allows to replace the copying signals with a move operation.
-  F6 Rename selected option.
-  F7 Create new folder in Signals tree.
-  Create new signal.

-  F8 Delete selected object.
-  Alt+F1 Switch (set) the left panel layout
-  Alt+F2 Switch (set) the right panel layout
-  Show all WinPOS resources: displays the signals, charts and algorithms directories.

Scripts editor

WinPOS expert and professional delivery options allows you to create your own signal processing algorithms, and to automate the process of processing from the select input file to reporting. WinPOS includes a convenient environment for editing, executing and debugging scripts in VBScript (Fig. 11.1).

For more detailed information - see Section 11. *WinPOS scripts* and *Programmer's Guide*.

Log

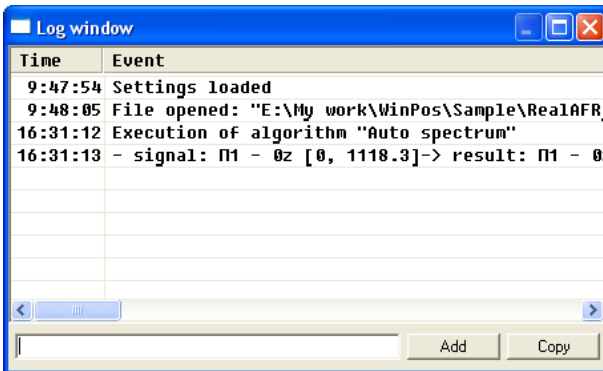


Fig. 3.7. Log window

The *Log* (Fig. 3.7) automatically records the operator actions (opening and saving files, execution of algorithms, etc.). The log can also be used as a notebook, making it a convenient tool to systematize the data processing. Each line of the log contains the time, event description, and the string of additional parameters (e.g., settings of the performed algorithm). The log window shows the history of the current session. The full history is stored in the winpos.log file in WinPOS working directory.

To work with the log select **Layout**→**Log** command. To add notes – enter text in the input field and click **Add**. For transferring text to the clipboard – select the rows and click **Copy**.

Graphs preferences window

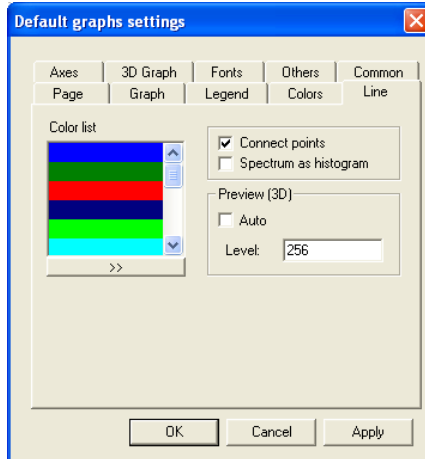


Fig. 3.8. Default settings

The arrangement of graphics on a page, diagram format, legend, format and color of signals can be selected using the tabs of the Graphs preferences window. *Graph default settings window* (Fig. 3.8) is intended to change of new graphs parameters. The format of already created graphs can be changed using the *Graph settings window* (Fig. 5.9-5.19). For more detailed information - see Section For more detailed information - see Section 5. *Graph creation, Graphs settings* chapter.

Vibration calculator

WinPOS allows to use the vibration parameters calculation window (Fig. 3.9). By setting the frequency and a single parameter (acceleration, velocity or displacement), you can calculate the other two parameters of vibration. To open the Vibration calculator select **Layuot**→ **Vibration calculator** command.

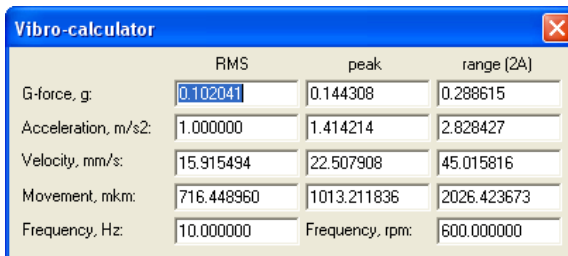


Fig. 3.9. Vibration calculator

Help window

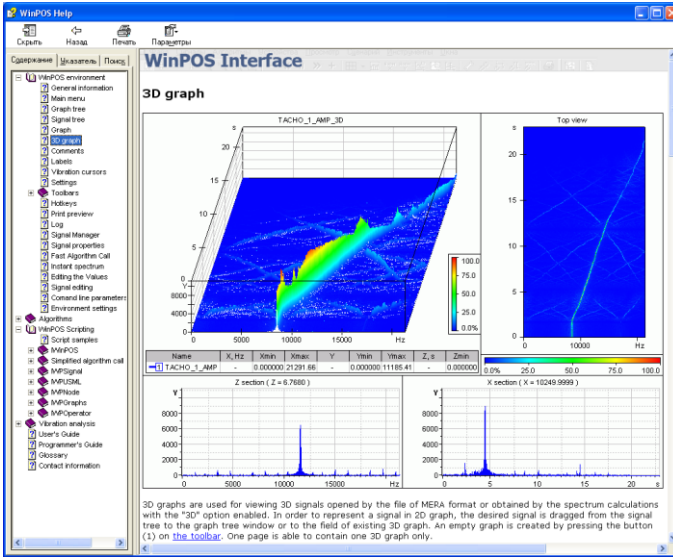


Fig. 3.10. Help window

WinPOS help system contains a description of the user interface, algorithms, methods of writing scripts, and links to electronic versions of the User's Guide and Programmer's Guide.

Access the help system is carried out by pressing <F1> key. You can also select **Help**→**Content...** command or click **Help** button in algorithms settings. WinPOS Help is designed as standard Windows help file and in addition to the list of articles contains an alphabetical index and keyword search (Fig. 3.10).

Section 4. Loading and saving signals

Files formats

MERA and USML files formats are designed for batch storage of signals. The binary data of each parameter are accompanied by a description of the signal, calibration characteristics, information about the test and the registration process.

MERA file format – a common format for storing the measuring data, is designed for use in recorders and in WinPOS.

The main characteristics of MERA file format:

- no restrictions on the number and length of signals,
- openness, ease of operations and flexibility,
- separate storage of each signal binary data and descriptions provides
 - increased reliability,
 - quick access to parameters options, including editing, adding and deleting signals.

UMSL file format created in the times of wide using tape recorders does not meet modern requirements due to the number of restrictions, and is implemented in WinPOS for compatibility reasons (including a compatibility with POS).

- ① You can easily convert file in USML format to the MERA format using **Save as...** menu item. It should be remembered that during the reverse conversion (from MERA to USML) there are a number of restrictions leading to loss of some recorded information (comments, labels, regimes, etc.).

MERA and USML files formats are described in Appendix A. *Files formats*.

In addition to working with specialized formats the import and export data in a variety of binary and text formats is also supported.

With the help of plug-ins you can work with DSPCon DATX (.datx, .datx_index), ETEP D.T.MUX (.eti), WAVE (.wav) and Universal File Format (.uff, .unv): 58 & 58b (binary). , This allows you to communicate with LabVIEW, LMS Test.Lab, etc.

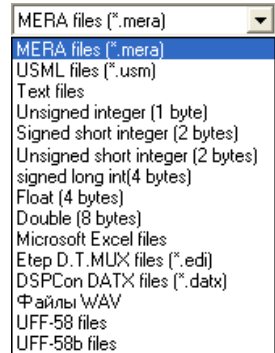


Fig 4.1. Types of files

Signals loading

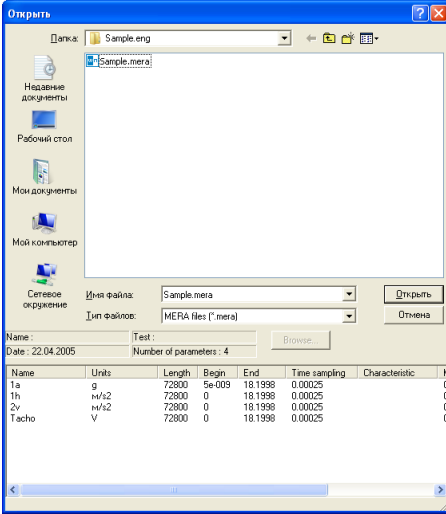


Fig. 4.2. File open

Select **File**→**Open...** menu item or click button of main toolbar. You can also press <F3> key.

File open window (Fig. 4.2) is a standard Windows dialog, in the lower part of which is the preview panel with the contents of the file.

Choose the data format from the list of **files types** (Fig. 4.1).

Locate the file and click **Open**. A new signal or signal folder appears in the Signals tree.

MERA and USML files can be opened from Windows Explorer by double-clicking on the file name.

The name of the signal is obtained from a MERA file, from the text file header or matches the name of the binary file. The name, units, and other signal characteristics can be modified on the signal properties pages or in *Signal manager* (See Section 7 *Signals editing*).

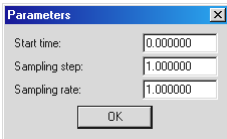


Fig. 4.3. Parameters

File in MERA format contains a complete description of the signals. For proper creation of signals from binary or text files you need to specify at least the sampling frequency. The opening and saving files wizards helps to work with text files (see below).

When you open a binary file you can specify the discretization of a signal (frequency or step) and time of recording in *Parameters* dialog window (Fig. 4.3).

Saving signals

To save the signals select **Save as...** command in the page, graph, line, signal or folder context menu. Data from Signals tree can also be saved using the **File** submenu of the main menu or by click button.

Save as window (Fig. 4.4) is a standard Windows dialog, in the lower part of which is the preview panel with the contents of the file.

Choose the data format from the list of **files types** (Fig. 4.1).

If you save data from the Signals then full ranges of signals values will be saved. When you call the dialog window from the context menu of a page, graph or line only visible range will be saved.

To change the range for saving and the list of signals, click **Select...** to open the *signals selection* window (Fig. 3.5).

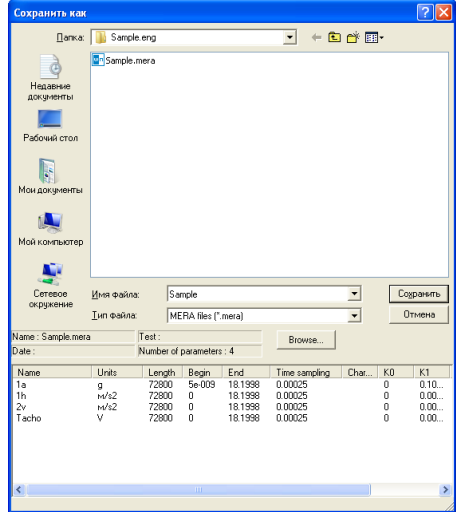


Fig. 4.4. Saving file

Text (ASCII) files

When you open the text file the *Text files opening wizard* appears (Fig. 4.5). A *Text files saving wizard* (Fig. 4.6) helps to create text files with columns of signal values.

To navigate between the wizard pages, use the **<Back** and **Next>** buttons, after the setup is complete, click **Finish** on the last page.

Opening wizard

On the first page, configure the general format of text file. The second page allows you to split data into columns. On the third page columns are associated with the signals. If the file contains columns of time, you must specify the order of columns. Otherwise, set the discretization (**x0** – initial value of time, **dx** - time step, **f** - frequency). In the list you can also change the signal names to default.

- ⓘ Opening a large text file and storing large signals in text files can take a long time. Press **<Esc>** to cancel the operation.

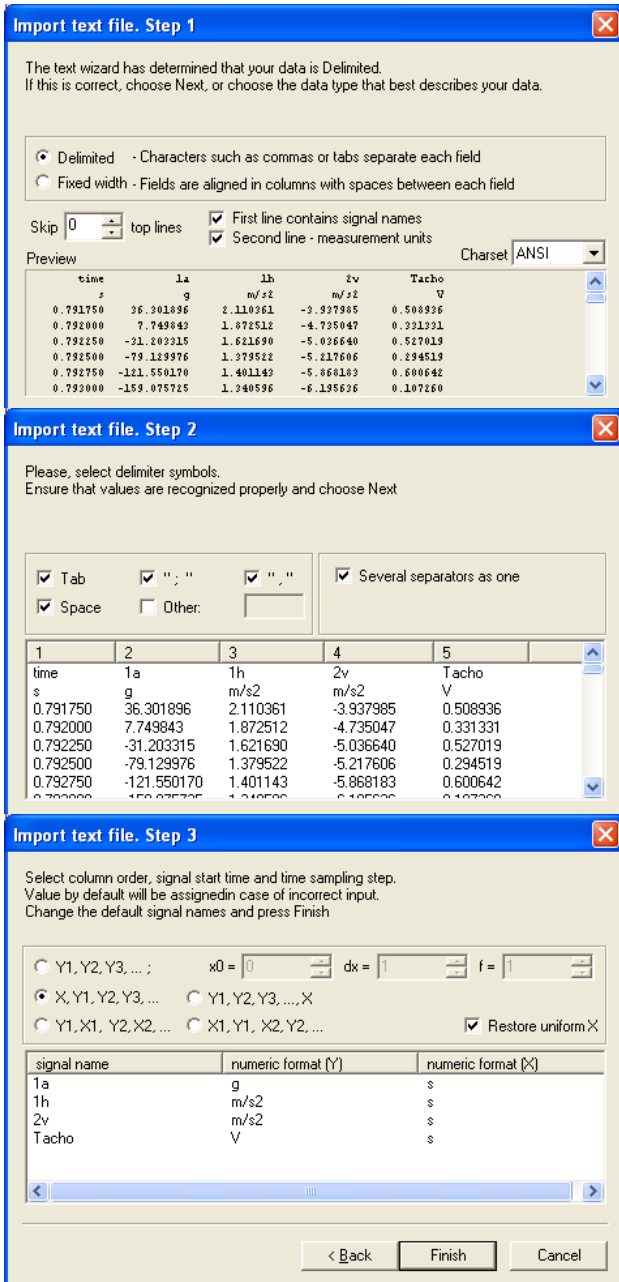


Fig. 4.5. ASCII files opening wizard

Saving wizard

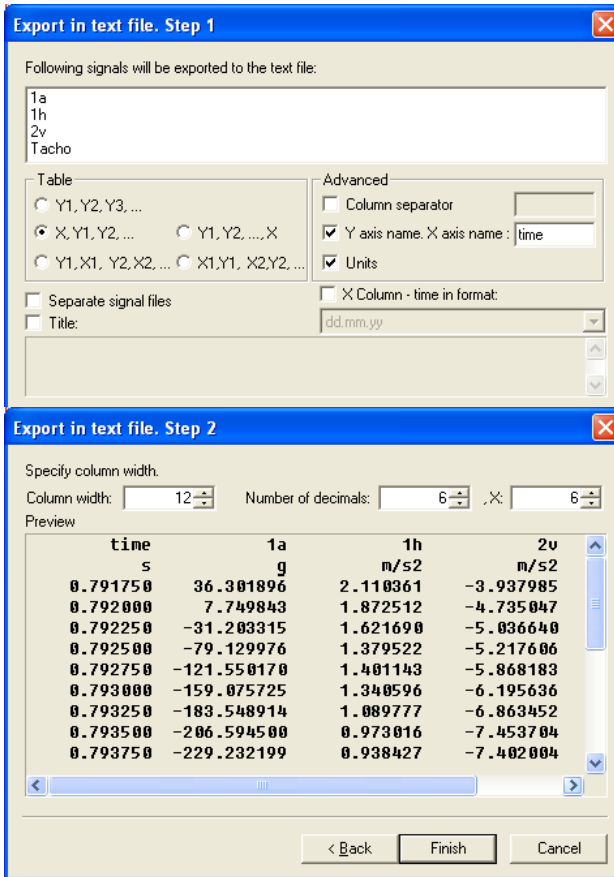


Fig. 4.6. ASCII files saving wizard. Step 2

On the first page displayed a list of selected signals and order of values columns and times. You can set the **columns delimiter**, enable automating creation of table header: enable **signals names** (the name of time column is given separate) and **units** In first and second lines of table. . If you choose the **Separate signal files** option, the folder will be created with the name which is displayed in the File name field in the Save as... window (Fig. 4.4). The separate files which contain measurements of only one signal will be put into this folder and the file name will matches the signal name. The text included into the **Title** field is placed over the table in the first lines of the file. On the second page you can adjust the column width and the number of significant digits after the decimal point separately for the signal values and the time columns, in accordance with the table preview.

Sessions

The results and graphs obtained during data processing can be saved to disk as the *session*. After loading the session you can return to unfinished processing.

Automatic saving and restoring of the session

The session can be automatically saved on exit from program or periodically with the given intervals. A periodical saving of a session helps to restore the processing after a software or hardware failure.

To enable automatical saving of a session, choose this option on **General** tab (Fig. 4.7) of *Default settings window* (**Tools** menu, **Default settings...** command).

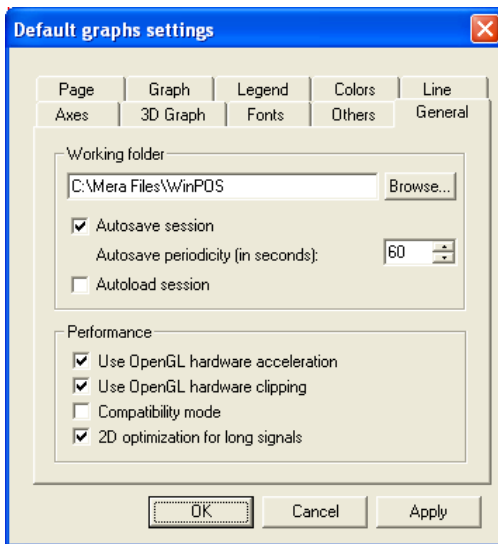


Fig. 4.7. WinPOS general settings

For periodical saving set the saving interval (in seconds) below on the same tab. You can load the last automatically saved session immediately after starting WinPOS. To obtain this capabilities check the *Session automatically loading*.

Additional, you can load the last automatically saved session using the command **File** → **Restore last session** (Fig. 3.3).

WinPOS working directory

The signals that you creating during data processing are temporary stored in the WinPOS working directory on the PC hard drive. The automatically saved session is placed in the same directory. You can change path to the working directory on the

General tab of *Default settings window* (Fig. 4.7). Click **Browse...** and select new location for works files. Be careful that the disk has free space.

Manual saving and restoring of sessions

If you want to interrupt working or choose another WinPos task, but then to return to the interrupted process, you can save and load the session manually.

Select **Save session as...** in **File** menu (Fig. 3.3) and choose a directory to save the session data. To clear the session select **File** → **New session** command. If you want return to saved session select **File** → **Resore session** command and choose a directory to save the session data.

The session can be copied to another PC or archived, and then you can restore it using the same commands. Note, that the sessions do not contain raw data files (Instead of them the links to files are saved).

Therefore when you transfer the session, you need also to copy the raw data files. The list of these “external” files is put into the log when they are copied (Fig. 3.7), and the proposal to open the log is displayed. If you want to transfer the session, copy the files from this list. Put these "external" files to the directories with the same names before restoring the session on other PC. Otherwise during loading the program will propose to locate the missing files manually, using the Open files dialog window.

Tests data base

Tests data bases (not included in WinPOS delivery) helps to organize measurement results and to automate of recorded data (using queries, sampling, etc.). Description of work with Tests data base is provided in *Tests data base User's manual*.

To open recorded data from Tests data base select **File** → **Open from MDB ...**, then choose required recording in MDB browser and click **Select**. Using MDB you can also open in WinPOS queries results, create samples, etc.

To save selected WinPOS folder in tests data base select **File** → **Save to MDB ...**, choose the test in database browser and click **Select**. It will create a new record with the current folder signals.

Section 5. Graph creation

At the WinPOS start a page with empty graph is created. New pages with graphs also created automatically for the signals processing results and after dragging-and-dropping the signal or folder to the *Graph tree*.

The most convenient and simple way of plot the signal graph in WinPOS is to drag the signal from the *Signals tree* to the graph area or to the *Graphs tree* using the mouse (Press the left mouse button at the signal name, move the cursor to the graph area, then release the button).

The commands for working with graphs are in Toolbars, **Tools** menu (Fig. 3.3) and context menu.

Graph types

WinPOS allows to create 2D graphs (Fig. 5.1) and 3D graphs (Fig. 5.2).

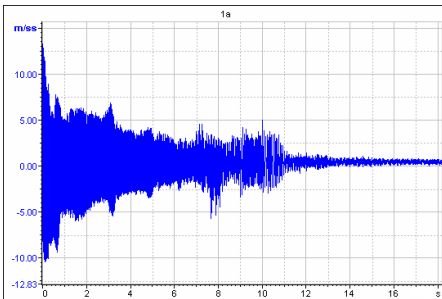


Fig. 5.1.

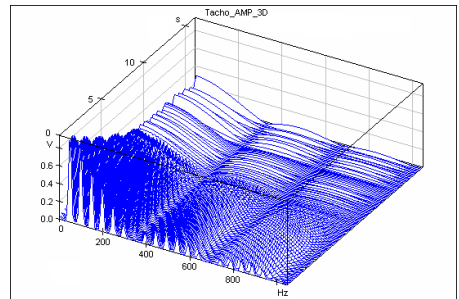


Fig. 5.2.

You can place several signals into one graph (Fig. 5.3) or create several graphs on one page (Fig. 5.4).

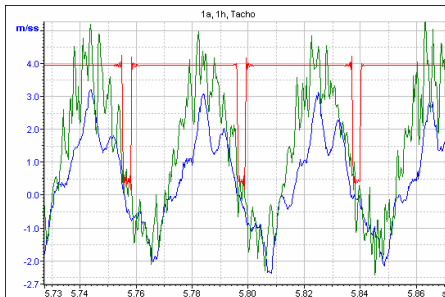


Fig. 5.3.

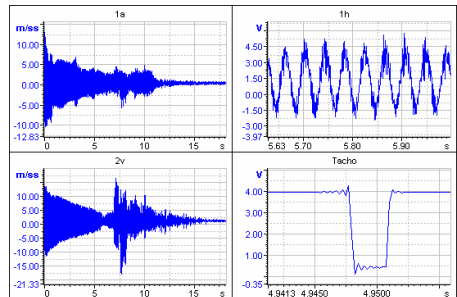


Fig. 5.4.

A separate Y axis can be created for each signal. The axis can be displayed separately (Fig. 5.5), or using several scales along common axis (Fig. 5.6).

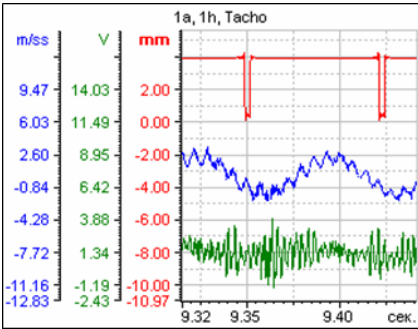


Fig. 5.4.

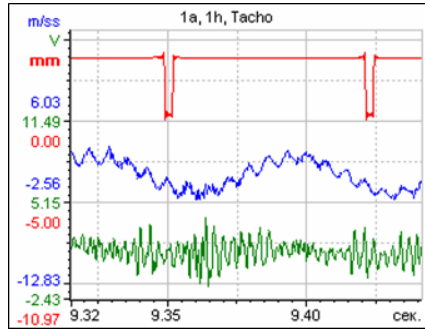




Fig. 5.5.

New page creation

Click the  button of the Main toolbar or select **Window** → **New page** command. It will create a new page with an empty page of 2D graph. The 3D graph page is created by clicking the  button of the 3D graph toolbar.

The page can be created using a template by clicking the **Window**→**New page by template** command, see *Page templates* below.

The **Window**→**Instant spectrum page** command creates a page with two graphs: the source signal and the spectrum calculated at the cursor position or for visible signal range - see Part 9 *Signals processing. Instant spectrum*.

Creating pages using template

The page templates allows to avoid repeated customization of the graphs, storing the signals view ranges, placement and format of the legend and comments. The templates are very useful tool for preparation of the reports with series of the graphs of pre-set format, for viewing the characteristic signal intervals.

To create a new template use **Save as template...** command from page context menu. The page layout will be saved as template file (.tpl), then this template will be set as current.

To change current template use **Window** → **Select template...** and choose new template file (.tpl) in standard window.

Window → **New page by template** command creates a new page using the current template. If the template is not selected, then tis command acts as **New window**.

Adding graph

Select the **Add graph** item of the context menu of graph or page.

Adding axis

Click **Add** in on *Y axis* tab of *Graph setting* (Fig. 5.14). Adjust the axis parameters and click **Apply**.

Adding signal (line)

with a a new graph or page creating

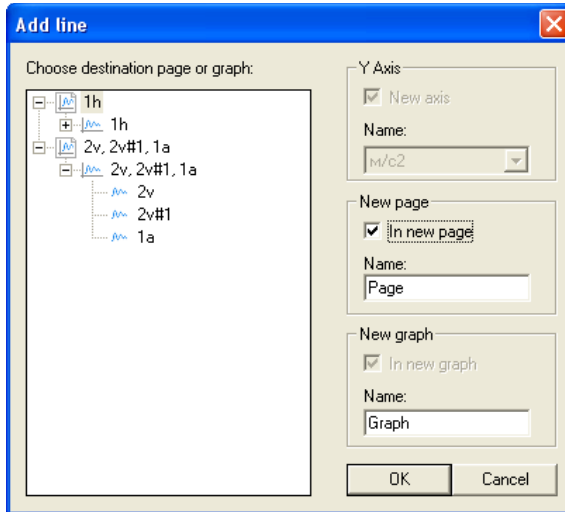



Fig. 5.6. Adding lines

Option 1. Using mouse drag signal from the Signals tree to the page (marked as ) in Graphs tree (press the left mouse button on the name of the signal, move the cursor to the Graphs tree field and release the button over the page name) – the new page will be created.

Option 2. Double click the selected signal and open the *Add lines* dialog window, then select the required page (Fig. 5.7), or choose **To new page**. Click **Ok**.

To selected graph

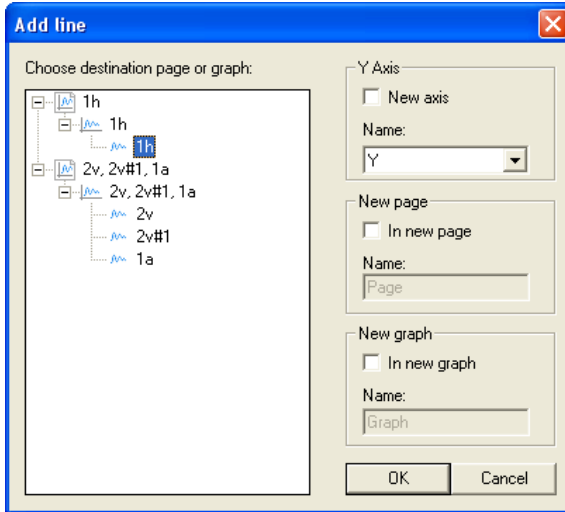



Fig. 5.7. Adding lines

Option 1. Using the mouse drag signal from the Signals tree to the Graphs tree, release the left mouse button over the name of the graph (graphs marked as ).


Option 2. Double click on the required graph in the Graphs tree to activate it. Drag the signal using mouse.

Option 3. Double click on the selected signal to open the *Add lines* dialog window and select required graph (Fig. 5.8) or select **To the new graph**. Click **Ok**.

To the selected coordinate axis

Option 1. Click the name of the axis or the maximum value of the graph scaling to make it the current (will be highlighted in bold). Drag the signal from the Signals tree to the graph.

Option 2. Double click on the selected signal to open the *Add lines* dialog window and select required graph. Select required axis in the **Y Axis** field or create new axis (**New axis** checkmark). Click **Ok**.

 The color of coordinate axis (scaling and names) is selected the same as the color of the first line of this axis.

Adding the several signals, folder

To the one page (Fig. 5.4). Using the mouse copy the folder from the Signals tree to the Graphs tree (click the left mouse button on the folder name, move the cursor to


the Signals tree field and release the button). You can simple double-click on the folder..

To the one graph (Fig. 5.3). Drag and drop the folder from the Signals tree to the Graphs tree, while hold down the <Ctrl> key (Press the <Ctrl> key on the keyboard, click left mouse button on the folder name, move the cursor to the box Graphs tree, release the button).


Deleting page, graph, line axis

You can delete graph and page using the context menu commands. The axis can be deleted from the graph settings window (*Y Axis* tab). The line can be deleted using the context menu that can be invoked with the right mouse button click in the Graphs tree charts or in the legend window.

Customizing graphs

The graphs can be changed using the *Graphs settings* window (Fig. 5.10). To open this window click , or press <Ctrl+O> keys or select **Settings...** in page, graph or line menu, as well as in **Tools** submenu of the main menu. In the left part of the settings window is a Graphs tree, to the right – tabs with parameters.

Using **Default settings...** (see below) of **Tools** menu you can set the parameters for all new graphs. The parameters of already created graphs will not affected.

 The settings are applied to the selected object and its child objects .

The tab *Page* (Fig. 5.10) allows to synchronize the axis: **Common X axis**, **Common Y axis** (the scaling of all graphs on the page will be made at the same time), and set arrangement of graphs (Fig. 5.9).

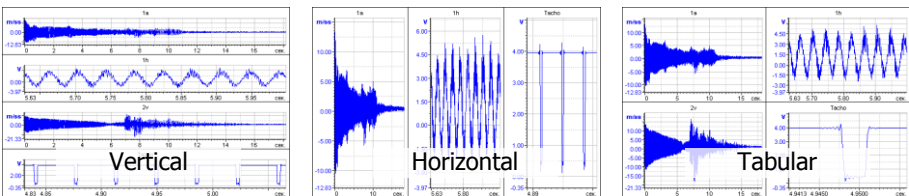


Fig. 5.8. Arrangement of graphs

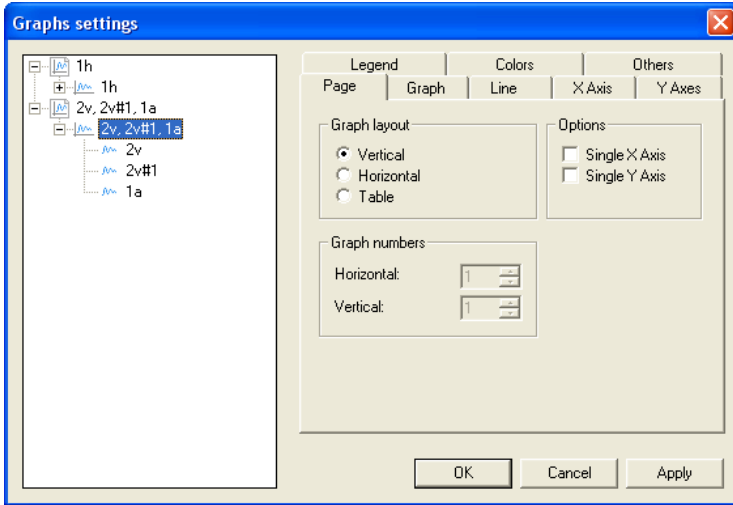


Fig. 5.9. Graph settings window. Page tab

If the tabular arrangement is selected you can specify the dimension of table (in the *Number of graphs* field). If the page has more graphs than you specify the the invisible graphs will be marked with shaded icon in the Graphs tree. To move to such graph, double-click on its name in the tree or use the scroll bar on the right.

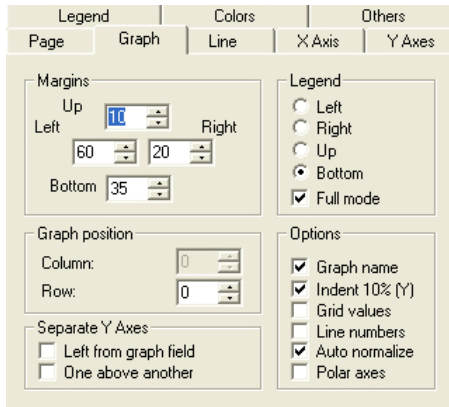


Fig. 5.10. Graph settings window. Graph tab

In the *Graph* tab (Fig. 5.11) you can set location and size of graph fields (*Borders size*, **Auto** – select borders automatically), alignment of the legend and additional settings:

Graph name – show graph name;

10% offset (Y) – the scale of Y axis is 10% more than signal magnitude;

Values on grid – place the signal values at the intersection points of lines with the grid on the graphs field;

Lines numbers – the numbers of lines in the graph field;

Autonormalize. – the scale of the Y-axis is automatically selected according to the maximum range of the signal;

Polar – polar graph.

Location of the graph axes can be set in the **Separate Y-axis: To the left of the graph** – each line of the graph with its own vertical axis; **One above the other** – vertical division of the graph by the number of axes.

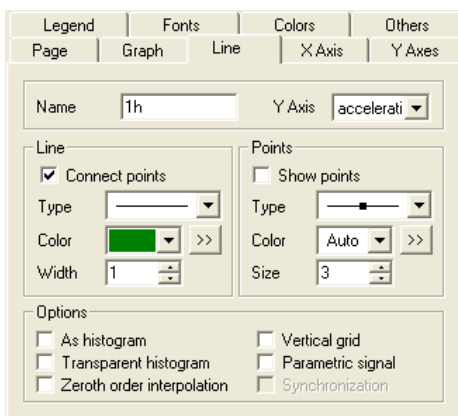



Fig. 5.11. Graph settings window. Line tab

Line tab (Fig. 5.12): **Name** – Line (signal) name;

Y Axis – the Y-axis, associated with the line. Select from the list, which contains all existing axis;

Connect points – the data points are connected by lines;

Type – the type of line that connects points on the graph. The line can be solid, dotted, dashed and dash-dotted;

Line color - can be selected from a list or from the standard *Color* dialog that appears when you clicks 

Line width – line width in pixels;

Draw points – each value on the graph is displayed using symbols that you can select from the *Type* drop down list.

Points color – specifies the color of the point. If you select *Auto*, the points will be displayed the same color as the line;

Points size – size of points (symbols);

Histogram style – the graph is displayed as a histogram. This style used e.g. to display octave spectra;

Transparent diagram – the histogram is displayed in contour. It is convenient when on the same graph the several histograms displayed simultaneously;

Zero order interpolation – values in points between measurement results are not interpolated;

Vertical lines – vertical lines from points of signal measured values respective to the X axis;

Parametric signal – the signal is considered as a dependence of Y from the index. X values are used only for X-axis scaling.

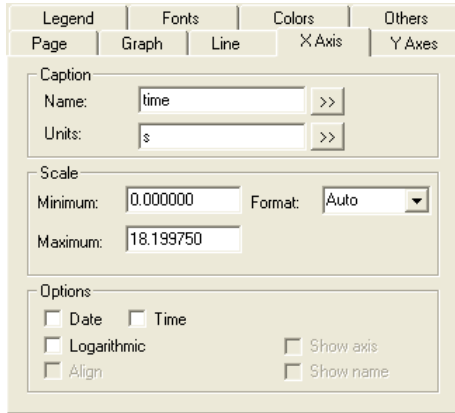


Fig. 5.12. Graph settings window. X-axis tab

On the Axis X tab (Fig. 5.13), you can rename the axis, set its boundaries, and set the following parameters:

Format - determines the scaling type. In the drop-down list you can select the appropriate format (**Auto** – automatic format selection) or set your own format. The # denotes a single digit (the number of # determines the accuracy), 0 – indicates a need to add the rows with zeros, e – engineering format, T=%H:%M:%S – displays astronomical time;

Date and **Time** - below the axis placed the second set of values indicating the date and(or) time;

Logarithm – logarithmic scaling.

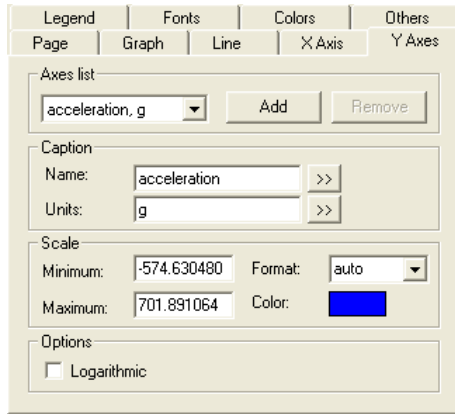


Fig. 5.13. Graph settings window. Y-axis tab

Y-axis tab (Fig. 5.14). In the drop-down **list of the axes** you can select one of the axes or **Add** a new one. The **Delete** button lets you delete all the axis except the last one. For the selected axis, you can set the scaling and color.

Format - determines the scaling type (see *X-axis*).

Name and **Units** – renaming of axes and units. Usually derived by a comma: "speed, m/s". Click ">>" to open the window with a list of previously entered names.

Logarithm – logarithmic scaling.

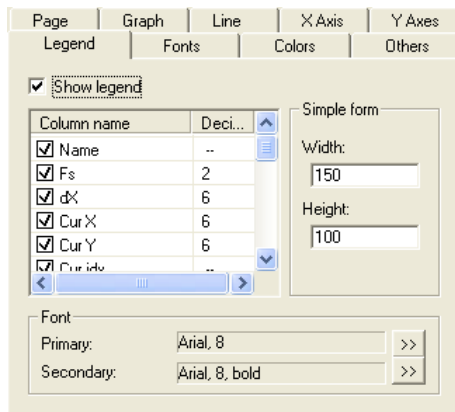


Fig. 5.14. Graph settings window. Legend

The *Legend* tab (Fig. 5.15) specifies the format and font of the legend. In the list of legend columns you can enable the characteristic display and set the number of decimal places (double-click left mouse button on the field) for each of the characteristics. Description of parameters is given in chapter *Legend* of Section 8

Formatting the graphs and reporting. In this page also defined the size of simple format legend.

The special set of fonts for specific page can be defined in *Fonts* tab (Fig. 3.8) ы.

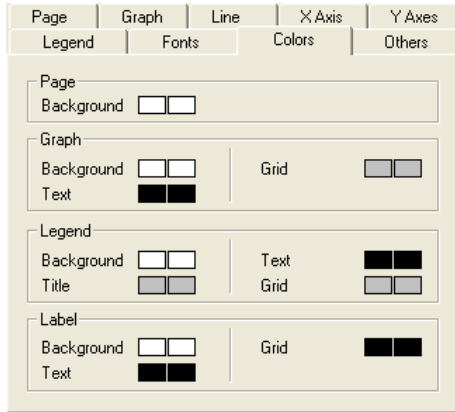


Fig. 5.15. Graph settings window. Color tab

The colors of selected page or graph can be defined in the *Colors* tab (Fig. 5.16). Click on the rectangle of current color to show the color selection dialog window. The left rectangle represents the color of the element on the screen, and the right one is color for print.

The *Other* tab contain some additional options as a grid values format, logarithmic axes scaling, etc.

The *Cursor* tab (Fig. 6.7) is shown in cursor mode (see Section 6).

3D graphs

To customize the 3D graphs use another set of tab in the right part of **Graph settings** window.

In the *Graph* tab (Fig. 5.17) you can set location and size of graph fields (*Borders size*), select *filling* mode (lines of X; Y; X and Y or plane (surface)), hide the invisible lines (**Hide invisible lines**).

The user can make the **graph name** visible, place the scaling on the right (**Labels on right**) and invert the Z axis direction (**Invert Z axis**). The data interpretation along Y axis can be changed (**Auto normalize** and **Color by max Y**). (see also *Default settings*). The context menu of **Color scale** field is allows to change, add, remove filling colors and and then save these settings.

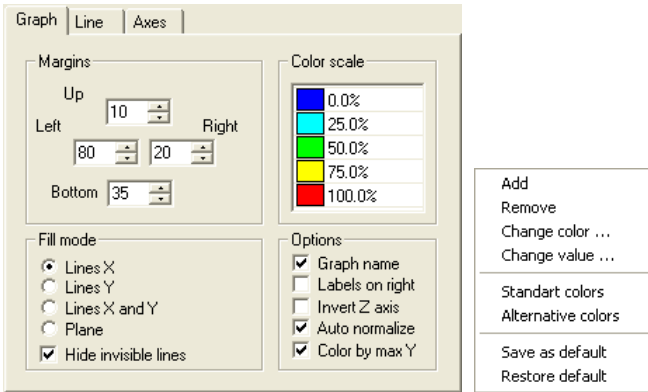


Fig. 5.16. 3D-graph settings window. Graph tab. Color scale context menu

The *Line* tab (Fig. 5.18) is used for renaming lines, adjusting of line width and color (similarly as for 2D-graph), and setting of two-colors painting brightness.

In order to accelerate the representation the user can **enable** preview mode by setting the resampling threshold **level**. The number of grid lines at each axis is then reduced in (Axis scale/threshold) times.

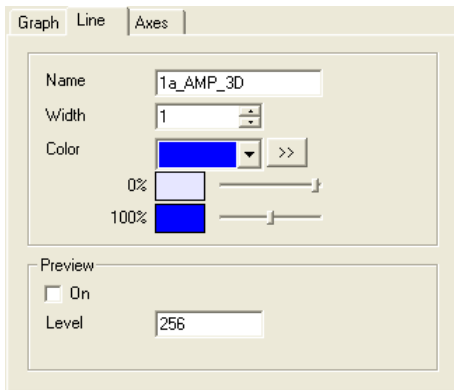



Fig. 5.17. 3D-graph settings window. Line tab

The *Axis* tab (Fig. 5.19) allows to change the name and scaling for each of three axis. Click  to open the window with a list of previously entered names.

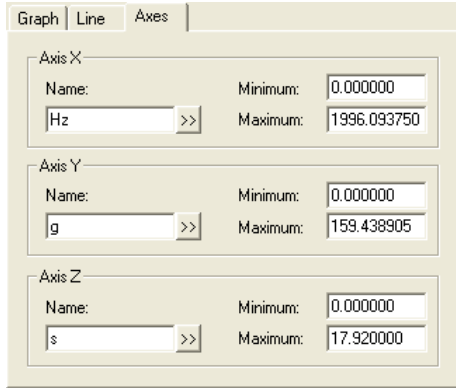


Fig. 5.18. 3D-graph settings window. Axis tab

Default settings

Graphs default settings are saved in configuration file and used for new pages. The *Page*, *Graph*, *Legend*, and *Color* pages are the same as in the **Graph settings** window (see above).

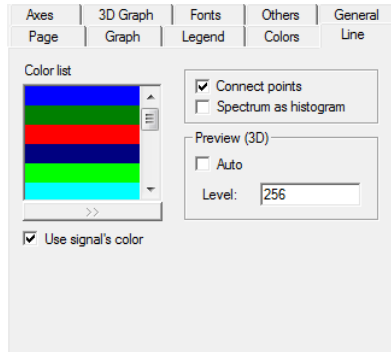



Fig. 5.19. 3D-graph settings window. Lines tab

Lines (Fig. 5.20): **Line colors list** – new line added to graph with the color from this list. To change the color click  under the list and select new color in the dialog window ;

Connect points – the data points are connected by lines;

Spectrum as histogram – graphs of any spectrum will be displayed as a histogram (otherwise – only octave spectra);

Preview (3D) – used for 3D-graphs: **On. Automatically** – graph will be displayed in preview mode (with resampling), if the number of points along one of the axes exceeds the number specified in the *Threshold* field.

Use signal's color – recording software can save signal's color properties in “*.mera” files. If this option was checked, signals will be drawn using saved colors instead of defaults ones (color still can be changed manually).

Axis tab (Fig. 5.21): **Name** – axis names by default. Click to select from set previously entered names; **Format** – axis scaling format;

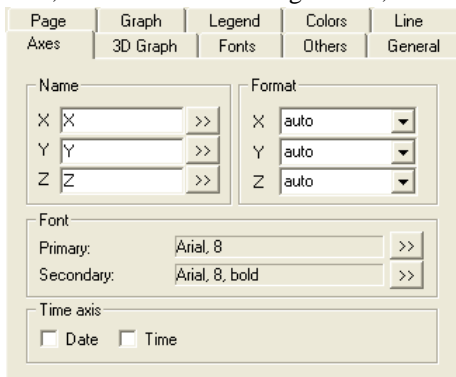


Fig. 5.20. Default settings. Axis tab

Font – fonts for scale labels and axis names. *Additional font* is used for selection of the active axis. Click to the right of the appropriate field to select the font. You can also change the font on the *Fonts* tab (Fig. 3.8). The format of the **time axis** determines the scaling of the secondary axis.

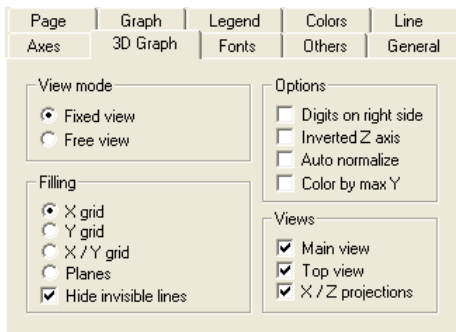


Fig. 5.21. Default settings. 3D-graph

3D-graph tab (Fig. 5.22):

View mode – the initial appearance of the main graph;

Filling – displaying of graph: lines along the X-axis, lines along the Y-axis, in both axes or as a surface (**Hide invisible lines** – removal of hidden lines mode);

Scale digits on right - Y and Z scales labels are in the right graph part.;

Invert Z axis – the Z axis is flipped so that the minimum value was at the far end of the axis and a maximum in the close end;

Auto normalize – the scale of the Y-axis is automatically selected;

Color by max Y – color: 100% corresponds to the maximum signal value, 0% to the minimum;

Views - specifies the types of data representation on the page (isometric, top view, cross section)

Section 6. Signals Viewing

During the signal viewing many actions are applied to the selected (current, active) graph, line or axis, rather than to the whole page. The current page is the page visible at the moment, or the top page if the pages are cascade arranged. The active graph is marked by the symbol **a** in the top left corner of the graph. The current line is marked by bold in the legend and is displayed above all other lines. The name of the current axis is also shown by bold. See Fig. 6.1.

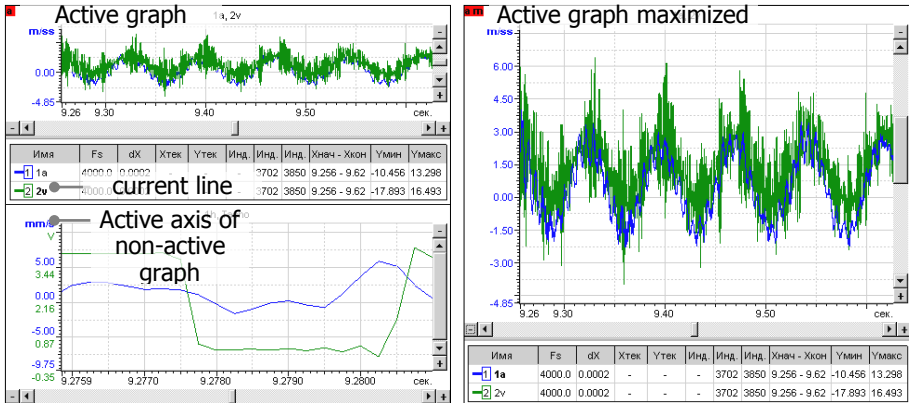



Fig. 6.1. Active graph and maximized active graph

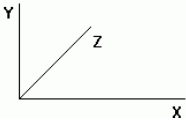
To make the graph active click in the graph field, to activate line click the signal name in the legend, to activate axis click the axis name.

Double click at the object in the *Graphs tree* makes this object current. If the selected object was hidden, the required page will be activated, the graph will be marked as active.

Double-click in the graph field allows you to expand the graph to the whole page. Such a graph is marked by the **am** symbol (active maximized). See the right graph of the Fig. 6.1. The previous graph size can be restored by another double click.

3D graph viewing features

The 3D graphs are used for viewing the 3D signals opened from the MERA format file or obtained by the spectrum calculation with the 3D option enabled. To display a signal in 3D graph drag it from the Signals tree to the Graphs tree window or to the already existing 3D graph field. Click  in the toolbar to create an empty graph. The page may contain only one 3D graph with one signal.



The figure on the left shows the axes directions. As applied to 3D spectrum, the frequency is put along the X axis, the portion start time along the Z axis, and spectrum amplitude values along the Y axis.

Usually 3D graph page is divided into four parts: 3D graph area and three projections of the graph into coordinate planes - see Fig. 6.2

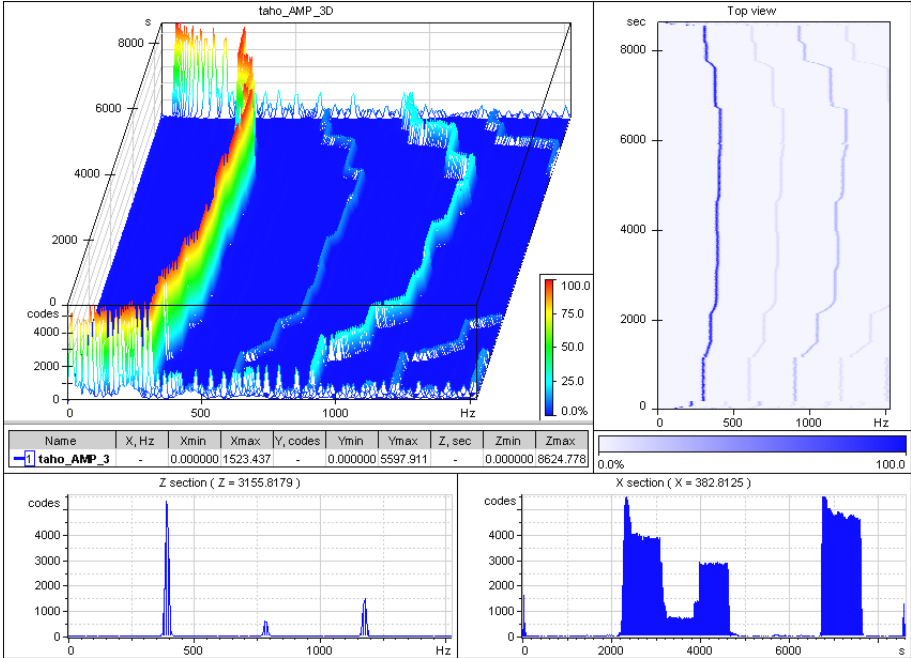
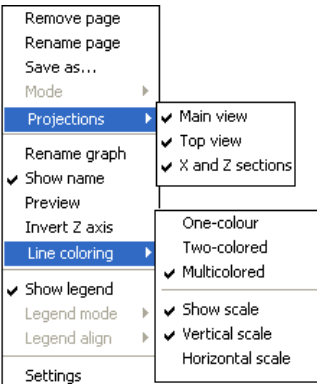


Fig. 6.2. 3D graph page

Unnecessary views can be disabled via **Projection** submenu of the page context menu. The main view and the top view cannot be disabled together, and the cross-sections of Z and X are disabled simultaneously. The views to be represented for a new page can be set in the default settings.

The main view and the top view can be filled by three ways using the **Line coloring** context menu. With two-color or multi-color filling the graph contains a color scale bar displaying the correspondence of colors and values by Y (Fig. 6.3).



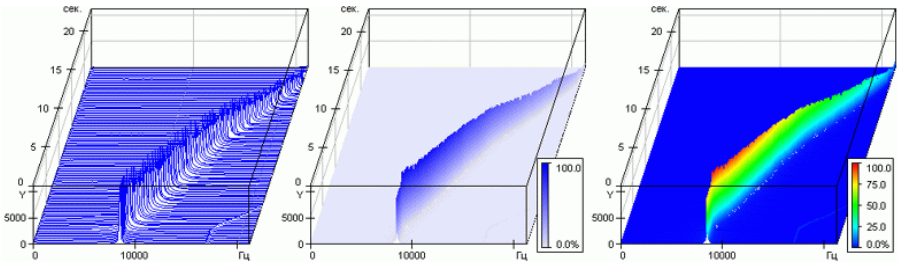



Fig. 6.3. Filling options: one-color two-color, multi-color

The color scale bar can be disabled and its orientation (vertical or horizontal) can be changed using the same menu or in the settings dialog window opened by the double mouse click.

Lines multi-color filling can be enabled only for the line graphs plotting by X or Y. For the top view, click  in the toolbar and the position of graph is automatically changed so that it does not overlap the scale. The scale must be placed quite near to the graph edge.

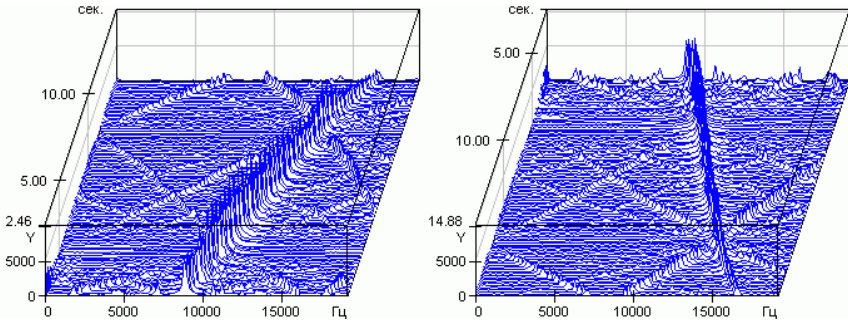



Fig. 6.4. 4 Graph with standard and inverted scale

If necessary, the axis Z can be inverted (**Invert Z axis** of the graph context menu). If this option is applied graph is visible from the opposite side, without turning the graph and without changing directions of other axis (see Fig. 6.4).`

The graph can be displayed in one of two modes - "fixed view" and "free view" (Fig. 6.5). In the first mode the X and Y axes directions are not changed, in the second mode the graph can be rotated arbitrary. Click  in the control toolbar to restore the graph to the initial view. Clicking the arrow on the right to the button displays the menu window which switches the graph viewing mode (fixed to free).

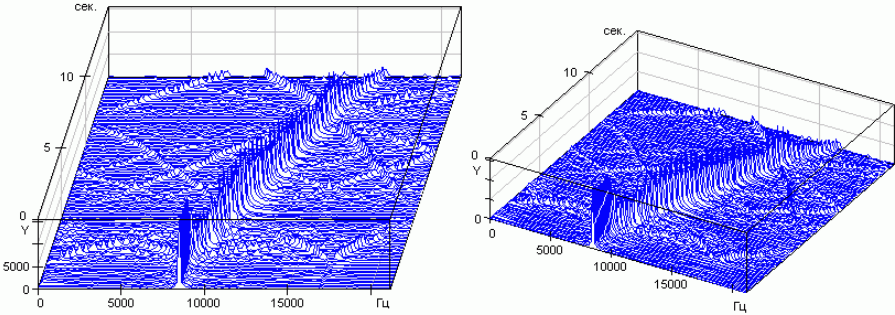





Fig. 6.5. Fixed and free view of 3D graph

The  button allows to rotate the graph, change the axis length and origin position. To move the graph press and hold the <Shift> key and drag the graph by the mouse left button; the graph size is changed using the mouse scrolling wheel (do not press the left mouse button for that).

To change of axes length press and hold the <Alt> key. Movement the mouse cursor horizontally (with the left button pressed) to changes the length of X, vertically - the length of Y; and the length of Z is changed by the mouse scrolling wheel.


To rotate the graph press and hold the button <Ctrl>, move the mouse cursor horizontally (with the left button pressed) to turns the graph around the imaginary vertical axis, vertically - around the imaginary axis perpendicular to the screen plane.

 Displaying of the huge signals may take tens of seconds . Such signals are more appropriately viewed in the decimated form which is enabled in the line context menu (**Preview**).

The  button changes the graph filling mode. Clicking the button change "invisible" lines to visible or hidden ones. Clicking the arrow on the right of the button displays the menu which allows to select the line plotting by X, Y, X and Y or by filled surface place.

Cursor. Viewing the current values

In the cursor mode the signal values can be viewed at the selected time point or, on the contrary, the time instance when the signal amplitude was, for example, maximal, can be identified.

The cursor mode is enabled by the  button of graph toolbar, as well as by **Tools**→**Cursor** menu item and by <Ctrl+3> shortcut.

2D graph

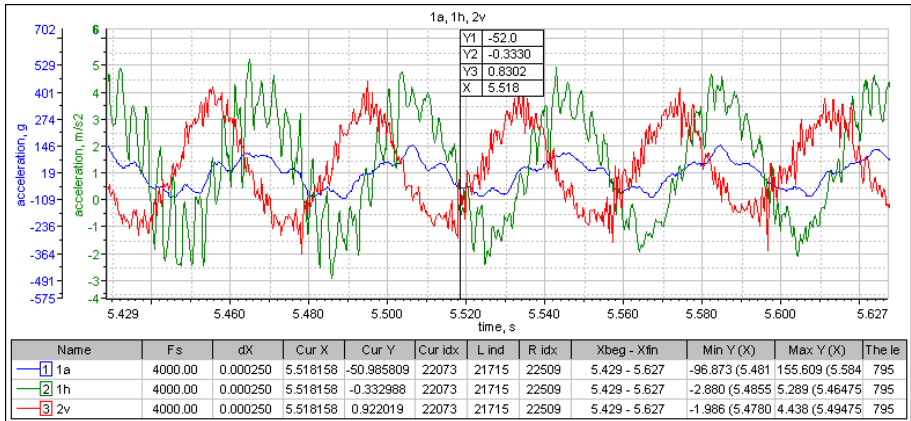




Fig. 6.6. Cursor mode for 2D graph

In the 2D graph the cursor is represented by black vertical line (see Fig. 6.6). The crossing point of the cursor with the signal line is marked by the horizontal line of the same color as the signal line. By clicking  arrow on the right of the  button, the horizontal line mode is set: **By all lines**, or **By one line** (the crossing with the active line only is marked).

The signal current values are displayed in the legend: X_{cur} , Y_{cur} , $IndCur$ (current index).

The cursor is moved by the mouse (hold the vertical line by pressing and holding the left mouse button and set the cursor to a new position). Press \leftarrow , \rightarrow keys or hold the $\langle Ctrl \rangle$ key while moving the cursor by mouse to move the cursor exactly by the signal discrete values (without interpolation). Press $\langle Tab \rangle$ key (or select Set cursor from the pull-down menu) to set the cursor position by entering the number from the keyboard.

In the cursor mode the tab *Cursor* is appears in the settings dialog window (see Fig. 6.7). This tab allows to change the cursor color and thickness, to turn on and configure cursor label in the *Cursor label* field.

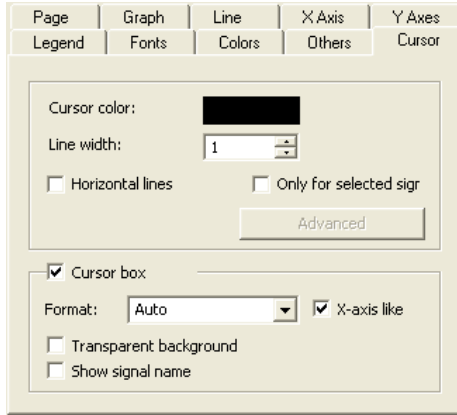


Fig. 6.7. 2D graph cursor settings

Cursors synchronization

If one page contains several graphs the cursors in each graph are moved independently. The *Cursor synchronization* (🔗) button combines the cursors of all page graphs and allows movement of all cursors as one.

3D-graph

In 3D graph the cursor is represented by two signal projections to the XY and YZ planes (see Fig. 6.7). In the projection windows the cursors of current values are also displayed: in the window *Top view* – as crossing, in the cross-section windows the cursors are shown as in 2D graphs, with the horizontal representation of the signal current level.

The current values are represented in the legend by the axes: *X, Y, and Z*.

The cursor is moved using the mouse (close to cursor lines when the mouse pointer has \updownarrow or $\leftarrow\rightarrow$ shape; press the left mouse button and move the cursor) or using keyboard (press $\leftarrow\rightarrow$ and $\rightarrow\leftarrow$ to move the cursor along X axis, press $\leftarrow\downarrow$ and $\leftarrow\uparrow$ to move the cursor along Z axis) in any window. The cursor movements are synchronized in 3D graph window and in the projection windows.

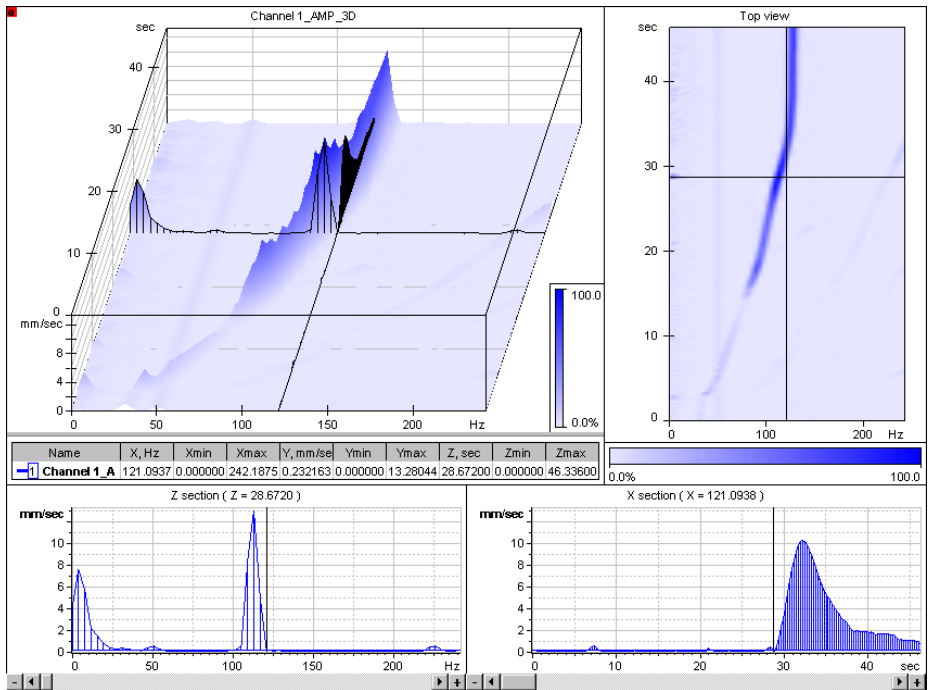




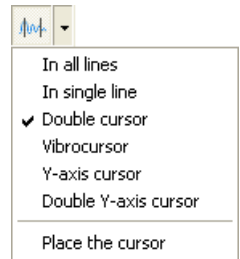
Fig. 6.8. Cursor mode for 3D graph

Special cursors

To switch between cursors types for 2D graphs click  to the right of  button.

Double cursor used to select processing range and for signals editing. It can be used to calculate some additional parameters: the difference (Δ) in X and Y between selected points, definite integral (area under curve), RMS. These parameters are displayed in the comment window in the graph field.

To display the calculated parameters, click **Advanced** button on the cursor settings tab (Fig. 6.7). Mark **Additional information** and select what information should be displayed (Fig. 6.9).



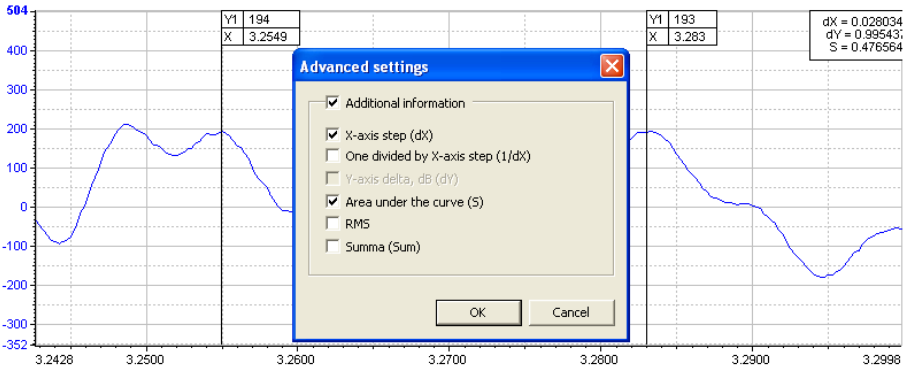


Fig. 6.9. Delta cursor. Additional settings

Vibration cursor (Fig. 6.10) is designed to identify harmonically related components of the calculated spectral characteristics of the signal. On the *Cursor* tab of settings window you can specify the number of additional cursors, the thickness and color of cursor lines and the label appearance. Symmetrical vibration cursor (**Symmetr.** field) helps in identifying the groups of side bands in the frequency domain.

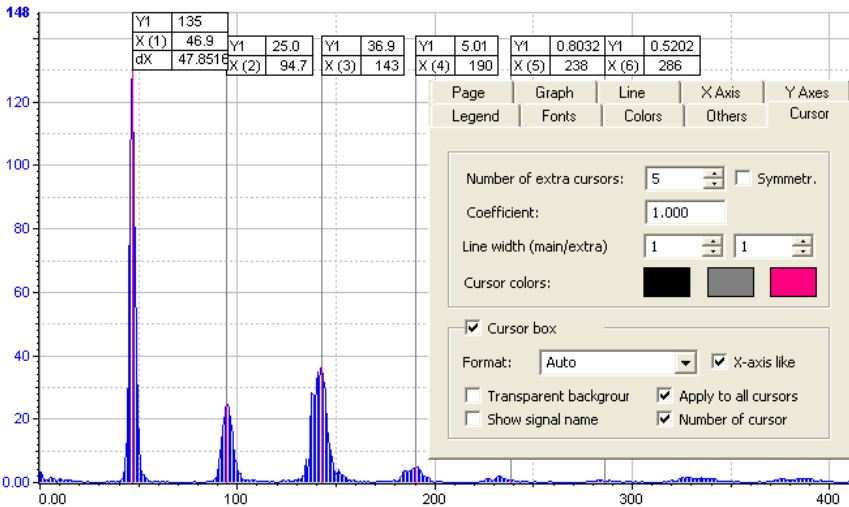




Fig.6.10. Vibration cursor and its settings

Select the component with the main frequency by moving the main cursor. Move additional cursors by mouse to superimpose their lines with the corresponding harmonics. For more contrast you can change the color of cursor line, superimposed on the spectrum (*Cursors color* of the cursor settings tab).

Graphs zooming and scrolling

Usually when you create a graph signal the entire range of the signal values is displayed. (this behavior is configured by setting **Autonorm.** checkmark on the *Graph* tab of the graphs settings dialog window, see Fig. 5.11). In order to study in detail the signals on the short time interval use instruments of the group of zooming and scrolling.

Zooming and scrolling is switched on using  and  buttons of toolbar, via the **Tools** menu, the context menu (**Mode** command) or using the mouse in combination with keyboard controls..

2D graph

• Zooming

Press and hold the <Ctrl> key. Set the mouse cursor in the graph field on the beginning of the signal interval to zoom. Press the left mouse button and without releasing the button, select on the graph zoom area (marked with a rectangle), release the button and <Ctrl> key. The selected area is the entire field of graph. Select the area within the graph to zoom in both axes or over an axis to scale only along that axis.




You can also switch to zoom mode using  button of toolbar, <Ctrl+2> keys or using Tools menu:

	Graph zooming	Tools → Zooming by X and Y , <Ctrl>+ mouse
	Graph zooming by X	Tools → Zooming by X , <Ctrl>+ mouse at X
	Graph zooming by Y	Tools → Zooming by Y , <Ctrl>+mouse at Y

• Scrolling

The viewing area can be scrolled in respect to the initial graph. Select scrolling mode:


	Scroll graph	Tools → Scrolling by X and Y , <Shift>+ mouse
	Scroll graph by X	Tools → Scrolling by X , <Shift>+ mouse at X
	Scroll graph by Y	Tools → Scrolling by Y , <Shift>+ mouse at Y








Scrolling can also be enabled by pressing <Ctrl+1>.

- ① Scrolling mode is enabled automatically by pressing and holding down the <Shift> key in the process of shifting the graph in both axes (in the graph area), and on a separate axis - on the given axis field.


Click left mouse button in the graph field and move the graph using the mouse without releasing the button, then release the mouse button.



- **Scroll bars**

 Scroll bars located at the right and bottom borders of the graph, are also used to zoom and pan signal graph. The relative size and position of the slider corresponds to the size and position of the displayed fragment.







The  button increases scale,  – reduce scale,  – normalization of given axis. , , ,  buttons shifts the viewport. Holding slider by mouse you can also scroll the graph.

- **Restore the initial zooming**

The  button restores previous zooming or viewing area. Each click of this button cancels the last operation of change the viewing range.

The second way. When you move the mouse with pressed left button the cursor takes the form . After releasing the button the graph is returns to the previous scale. If the displacement is large enough, the cursor changes () , and the graph it will return to the original zoom.

- **Automated scrolling**

The buttons for automatic scrolling along the X axis control the chart, are grouped with signal playback buttons  (see below *Signal playback*):  - scroll left,  - scroll right,  – decrease,  - increase the scrolling speed,  - stop scrolling.

3D graph

- **Zooming**

Press and hold <Ctrl> key, select an area for zooming: press the left button and release after the area selection. In the selection process on the graph the red frame is displayed, outlining the zoom area.

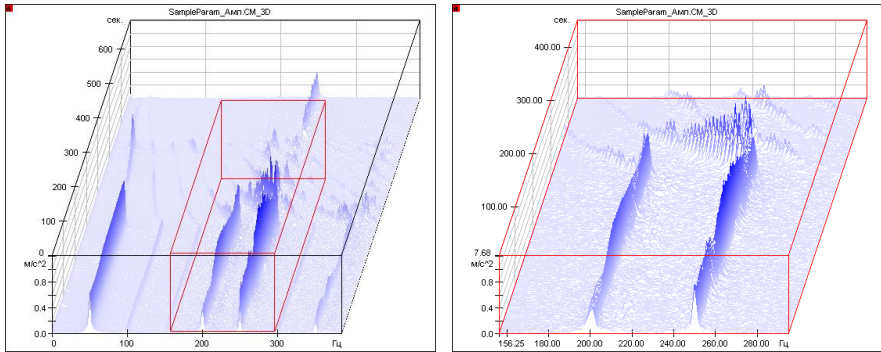






Fig. 6.11. Zooming of 3D graph (before and after pressing <Enter> key)


The zooming is also enabled using  of toolbar. In this case, the frame borders are moved using mouse (over the lines of the frame, the mouse pointer takes the form of ,  or ), press the left mouse button and change the frame size, press <Enter>. Figure 6.11 shows the graph before and after pressing <Enter>.

The frame can be moved using <←>/<→> and <↑>/<↓> keys. To move right or upper bound hold down <Shift> key. The change of scale happens when you press <Enter>. The scale on the Y-axis changes automatically. In zoom mode the legend fields Xmin, Xmax, Zmin, Zmax shows the current border.


To zoom and scroll you can also use the projections of the signal.

- **Scrolling**


Scrolling is performed in the cursor mode. With the <←>/<→> keys, move the cursor outside of the visible part of the graph.

 Scrolling mode is automatically enabled when you move the mouse in the graph and press <Shift> and then press the left mouse button.

- **Restoring of the initial zoom**

The graph is normalized by clicking the  button. The normalization sets the maximum ranges for the axis to make the whole graph visible.

Signal playback

MR-300 allows you to supplement the data frame (.MERA file) with audio track (for recording to MIC-300 the microphone is connected). When you view these frames in the graph you can click  («Play audio track»). For the displayed interval of the record the audio will be replayed ("audio" parameter). In this case the cursor of the current values will shift synchronously on all graphs of this frame (from left to right from the current position or the beginning of the displayed section of the signal).



The ("Play current signal") button allows you to play the current (not necessarily audible) signal, the signal frequency will be converted to 22050 Hz, and the amplitude normalized.

The button allows you to change the playback volume or mute it entirely (extreme bottom position of the slider). To close the window of volume adjustment click the same button.

The additional signal information and parameter status

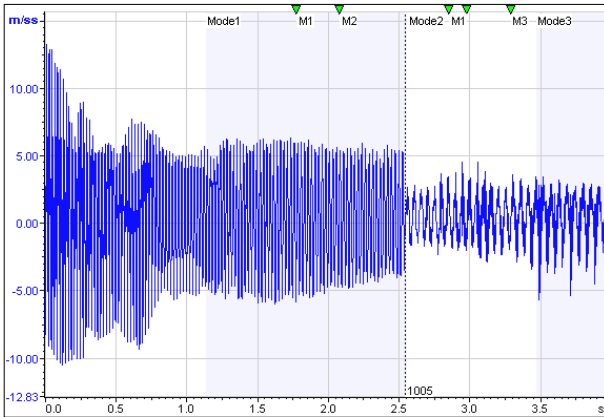
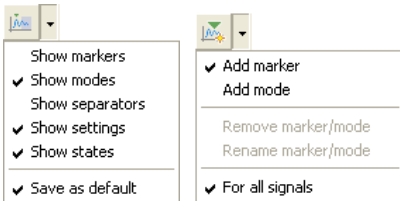


Fig.6.12. Regimes, marker, breaks

WinPOS allows you to view information about the signal recording process. *Modes* ("Start", "Run up", etc.) of tests are displayed by named shaded areas, and value labels – by green triangles. See Fig. 6.12.



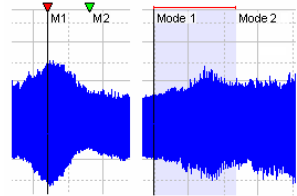
To turn on and off displaying the labels, regimes, pauses, setpoints and statuses, you can click the button on the secondary toolbar. Pressing the button toggles the display of all items, clicking the arrow to the right of the button displays a menu with which you can toggle the display for

individual items. If you select **Save as default**, a switch will be saved in the default settings.

The information on markers and signal recording modes can be modified in the cursor mode.

The label is set using the secondary toolbar button the or by selection **Add marker** menu item to (on the arrow to the right of this button). The regime is set using the **Add mode** button. If you select the **For all signals** option the mode or a label will be set on all the lines to the active graph. Otherwise it would be set only in the active line.

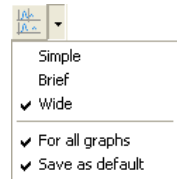
To delete or rename a label or regime select it by moving the cursor to the label or the beginning of the regime. In this case the label will change color to red and the mode is highlighted by a horizontal line above the box graphics. Then select the action in the same menu. You can select a desired marker or mode in the marker list as well (one of the legend view modes).



If in the recording process were the blanks (caused by hardware failures or pressed "Pause"), the place of "gluing" in WinPOS is marked by a dotted line with the signed real timeline.

The signal with blanks can be represented in three ways:

- **simple** – the time scale is depicted as if the signal was without breaks, the signal is displayed together (Fig.6.14);
- **reduced** – the time scale is uneven, the signal is displayed together (Fig.6.13);
- **detailed** – the time scale is uniform, the signal is displayed fragmented with gaps (Fig.6.13).



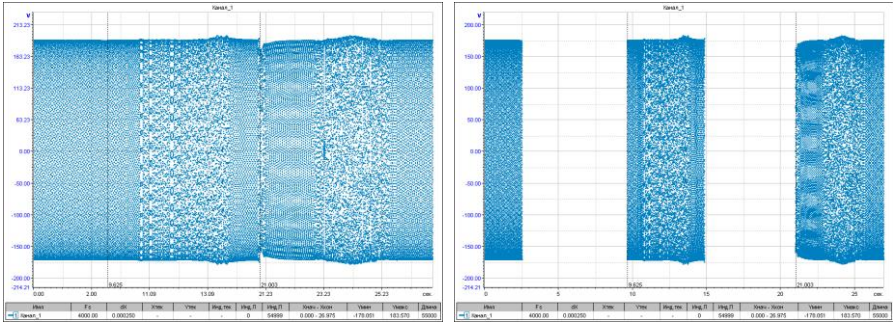


Fig. 6.13. Reduced and detailed presentation of signal with blanks

On the graph WinPOS can show the *setpoint* regions above or below the setpoint value with defined color.

Changes of signal status (excesses, failures, etc.) are marked by vertical labels on the upper border of the graph. When you move the cursor, information about the current signal status appears in the status bar.

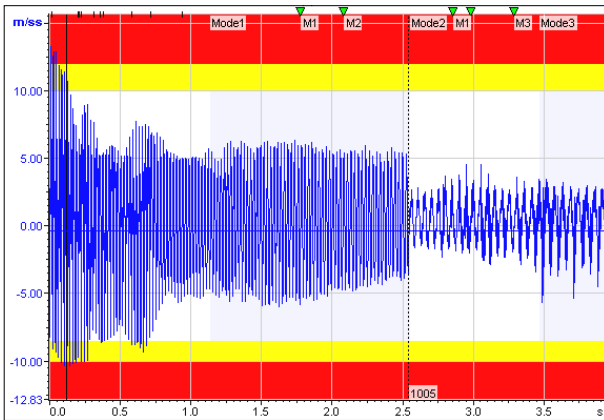



Fig. 6.14. Setpoints, change status labels with description

Figure 6.14 shows a graph of the signal with applied supporting information. Enabled the displaying the labels, modes, gaps, settings and labels3 of change the signal status.

Unified Time Scale

If the data contain UTS (Unified Time System) information, it will be automatically used and signals from different recorders displaying synchronous. The time on the x-axis is displayed in seconds from the start of recording (first measured values) (when IRIG-B format of UTS used), or as the time from switching on the UTS system. In

the second case, it may take a lot of time prior to registration, and large values of the seconds will be hard to recognise. In this case, select all the files relating to the same recording session in the tree and click **Reset UTS** in the context menu of a MERA file. Information about UTS data channel is available in the signal properties page (Fig. 7.1). To decouple the signal from the UTS scale set an empty string instead of the channel name in the *Correction using UTS* (not recommended).

If signals do not contain UTF data and was recorded at different times, they will be automatically shifted relative to each other by time difference. This function can be turned off by unchecking option “Time synchronization” in menu which appearing by pressing down arrow to the right of  button in toolbar. “For all graphs” option applies changes to all graphs in active page, “Save as default” set new values as default.

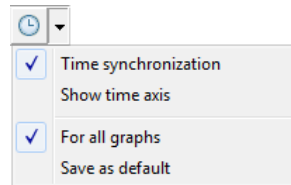





Fig. 6.15. Synchronization menu

The data can be also combined in manual mode. For this you need to find a couple of characteristic signals, which have features corresponding to the same physical process (ideally, this command parameters). Put them in one graph, click  in the edit panel. Click the left mouse button over the field of the graph and, while holding down button move the mouse to left and right to combine the signals so that the characteristic points coincided. Release the mouse button. If necessary, repeat these steps. Click the  button to exit the alignment mode. Please note that the amendment refers to the active line. To adjust the time of the entire measurement (MERA file), click the "Edit directory" before correction.

In order to see the date and time in the days, hours and minutes format, select “Show time axis” from synchronization menu (additional axis will appear) or check the boxes "Date" and "Time" on the Axis X tab (Fig. 5.13) or adjust the format.




Tabular representation of signals


The table allows you to view the signals as columns of values tied to a common time scale (Fig. 6.15).


Click  (New table) on the table control panel. Adding a signal in the table is the same as in fraph – drag and drop signal (or folder) to the page of table.

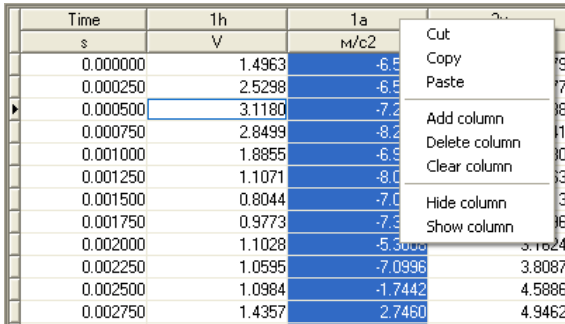
To remove a signal from a table use the column context menu (Fig. 6.15, **Delete column**), which is invoked by pressing the right mouse button on the header of the column.

Also from the context menu of column and row the standard editing functions (copy, paste, etc.) as well as adding a blank row or column are available.

Signal values in the table cells can be changed. The active cell is marked with a frame. Changed values appear in red. Use the  and  buttons to cancel changes or to re-enter. Save changes using the  button.

To print the selected fragment of the table click .

The button  (Save table as...) allows you to export the table data into a CSV file (Common Separated Values). After saving the file the system trying to open it in MS Excel. Note that the dimension of the CSV file (number of columns and rows) can exceed the maximum value of the table size of MS Excel.



Time	1h	1a	2a
s	V	m/c2	
0.000000	1.4963	-6.5	3.8087
0.000250	2.5298	-6.5	3.8087
0.000500	3.1180	-7.2	3.8087
0.000750	2.8499	-8.2	3.8087
0.001000	1.8855	-6.5	3.8087
0.001250	1.1071	-8.0	3.8087
0.001500	0.8044	-7.0	3.8087
0.001750	0.9773	-7.3	3.8087
0.002000	1.1028	-5.3000	3.8087
0.002250	1.0595	-7.0996	3.8087
0.002500	1.0984	-1.7442	4.5886
0.002750	1.4357	2.7460	4.9462

Fig. 6.16. Tabular representation of signals

Keyboard shortcuts for viewing

<F5>	Switching between the windows of the graph tree /signal tree /workspace (page)
<Ctrl+Tab>	Switching between the pages
<Ctrl+1>	Switch on and switch off the graph scrolling mode (both axis)
<Ctrl+2>	Switch on and switch off the graph zoom mode
<Ctrl+3>	Switch on and switch off the graph cursor mode
<Ctrl+[~]>	Back to the previous scale, position
<Ctrl+G>	Switching the graph grid mode
<Ctrl+L>	Display/hide vertical lines from signal values
<Ctrl+F>	Set label at the cursor position
<Ctrl+O>	Open the settings window
<Ctrl+P>	Print the active page

The following keys are valid only if the page is active. If when you press the keys nothing happens, probably the Signals tree or graph selected, press <F5> one or two times or click the mouse on the page.

<G>	Activate the next graph
<Y>	Activate the next Y axis
<L>	Activate the next line
<+>, <->	Zoom out/in by X axis of the active graph
<Shift+"+", "-">	Zoom out/in by Y axis of the active graph
<<->, <->>	Graph scrolling by X axis
	In the cursor mode - movement of the cursor by X axis
<Shift+←, →>	In the cursor mode - movement of the cursor by X axis
<Tab>	Set cursor to the preset position.
<↑>, <↓>	Graph scrolling by active Y axis

Other hotkeys (use not only when viewing a graph):

<Esc>	Interruption of a current operation (calculation, displaying, etc.)
<F1>	Open help system
<F3>	Open file dialog window
<Spacebar>	In the Signals tree : excludes a signal from processing

Section 7. Editing of signals and files

This part of the User's Guide describes how to use WinPOS program for:

- correcting signals and measurement files,
- deleting signals or signal fragments containing no meaningful data,
- creating new signals and measurement files.

WinPOS creates new signals automatically after executing of algorithms (see Section 9 "Signals Processing"). Besides that you can:

- create a new signal by copying the source signal or its fragment,
- combine several signals or fragments to a new signal,
- create a signal presenting one parameter as a function of another,
- generate an artificial signal using program.

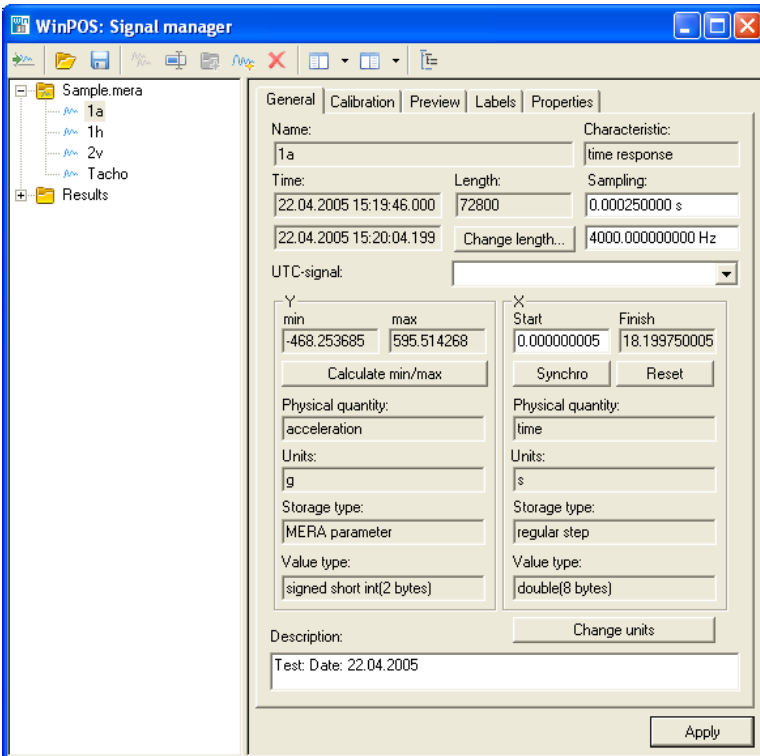



Fig. 7.1. Signals manager. Properties widow

You can activate editing functions in the main window using Edit toolbar and arrange files with measurement results in the Signals tree.


The *Signal Manager* (see Fig.7.1) helps to modify signal properties and work with the tabular presentation of signal. The Signal Manager control elements are described in Part 3 of the *WinPOS Secondary Windows* (Part 3). Select **Properties...** item in context menu to change signal characteristics.

Files editing

The measurement file information fields can be modified on the *Signal Manager* pages (see Fig.3.6). The procedure of adding signals to a file is described in the *Signal Copying* section below. To delete a signal from file select **Delete** menu item in the signal context menu in the Signals tree, or click  in the *Signal Manager*.

Actually the file will be modified on the disk only after the *Save* or *Save as* operation (for a new file) is executed. See Section 4 “*Signal Loading and Saving*” for details.

Modifying Signal’s X Axis

To modify properties of signal’s X axis open signal in graph and press  button on toolbar.

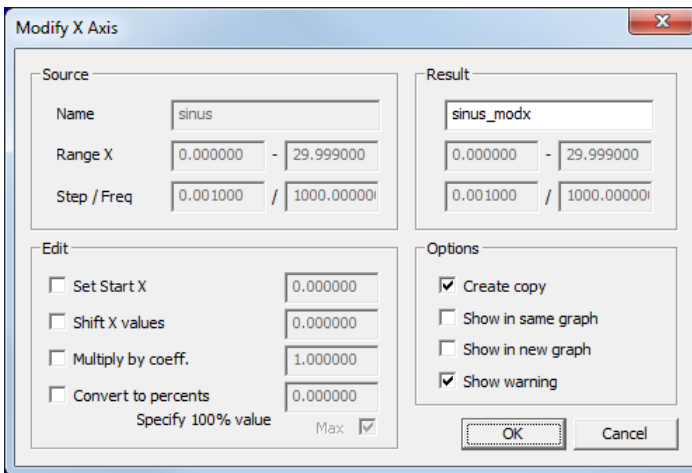


Fig. 7.2. Modify X Axis

Top half of dialog shows properties of source and result signals. Use controls in “Edit” section to change signal as required.

Set Start X – changes start value of X.

Shift X values – shifts X values by specified value. If initial start X equals zero result is a same as changing start X.

Multiply by coeff. – multiplies steps between individual X values by specified value, leaves start X unchanged.



Convert to percents – recalculates X values in procents relative to specified value. If “Max” option selected, maximum value is taken as 100%.

Signal Copying

Using the Signals tree

To copy a signal using the Signals tree is as simple as to put a signal in a graph. Press left mouse button on the signal name in the Signals tree and holding down the button move the mouse cursor to the destination folder. Release the mouse button when mouse cursor is above the folder name. The signal is copied.

Using the Signal Manager

- Click  buttons in Signal manager window to display the Signals tree in in the left and right panels.
- Select a destination folder in one of these panels and select a signal to be copied in the other panel.
- Click .

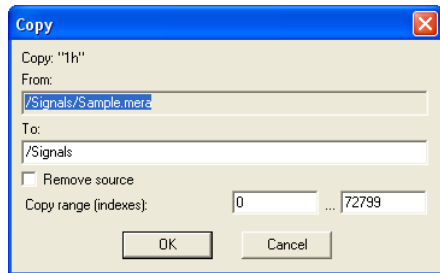




Fig. 7.3. Signal manager. Signal copying

In the *Copy* dialog window (Fig.7.3) check the paths in the “*From*” and “*To*” fields click **OK**. The signal will be copied to the destination folder. If *Remove Source* is checked the signal will be moved to the chosen folder.

Signal Fragment Copying

Using the graph editing panel

- Enable the double cursor (see Fig. 7.4, 1).
- Select required fragment of signal and click *Copy*  in the *Edit* toolbar (Fig.7.4, 2). The information about selected fragment will be saved in the clipboard.
- Click  in the *Edit* toolbar (Fig. 7.4, 3). A new signal will be created and shown in the graph (Fig. 7.4, 4).

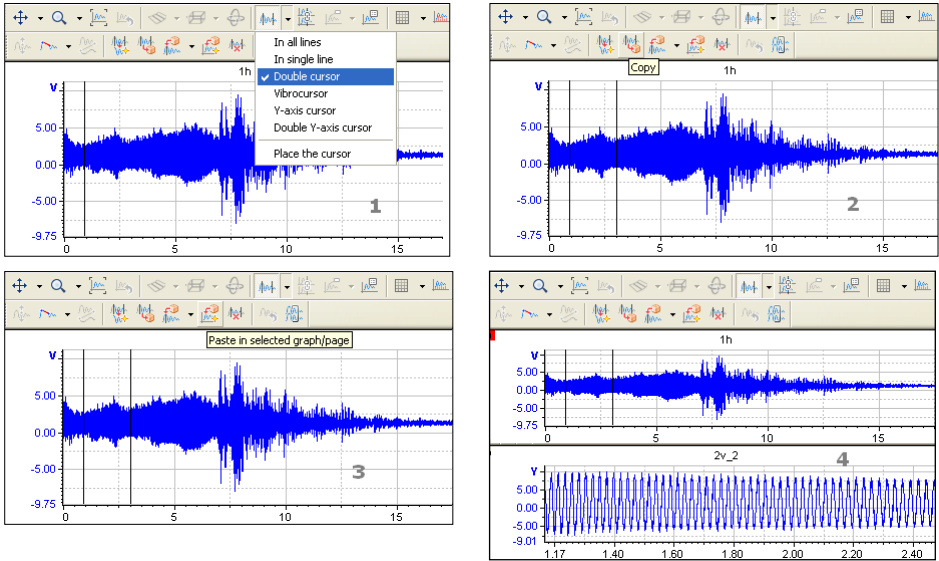


Fig.7.4. Signal Fragment Copying

The copied data are not physically doubled until the signal not saved to disk. Instead the resulting signal is supplemented with a reference to the source. That is, the signals from which the data was copied cannot be deleted till the resulting signals are removed. The source signal modification may bring resulting signal changes as well.

Using the Signal Manager

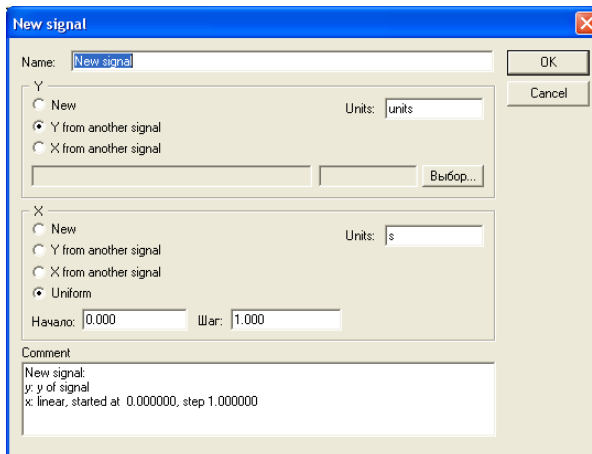



Fig. 7.5. Creation of a new signal

Perform the operations you executed for copying an entire signal but set a new index range in the *Copy range* fields of the *Copy* dialog window (Fig.7.3), .


Or create a new signal having set the old one as a source..


- Click  in the *Signal Manager* toolbar.
- Mark *Y from other signal* in the *Y* frame of the window shown in Fig.7.5, click **Browse...** and select the source signal or its fragment in the signal selection window (Fig. 3.5).
- Mark *X from other signal* in the *X* frame, click **Browse...** and select the same signal as for *Y* axis.
- Type the new signal name and click **OK**. The new signal will be placed in the *New Signals* folder of the *Signals* tree.


Concatenation of the signals

Using the graph editing panel

You can add copied signal or fragment to another signal.

- Copy a signal in the way described above.
- Select a graph with a signal to be concatenated with a fragment, then click .


If the current values cursor is enabled the source fragment will be inserted at the cursor position. Otherwise, it will be inserted at the signal end. The arrow on the right of  button enables to forced set the insertion mode: at the cursor position (prohibited when the cursor is disabled), at the signal start or at end.

 When a fragment of one signal is copied in the start of another signal the latter signal start time (the initial value along the X-axis) is made equal to the start time of the copied fragment.

It is necessary to have the same data type and calibration characteristics of the two signals.

Automatic concatenation of the signals

This function may be useful when splicing the fragments of a signal data distributed among different measurement frames.

- Put the signals to be concatenated in a single graph.
- Click  in the editing toolbar.

The active graph signals will be combined in a single signal according to the sequence of the graph legend. The resulting signal gets all properties (frequency, start time, calibration curve, etc) of the first signal. The connection points are marked with names of concatenated signals. The result signal is put in the *New Signals* folder of the WinPOS *Signals* tree.

Parametric and Polar Signals


Using the Parametric Graph algorithm

In Section 9 described the settings for Parametric Graph algorithm, designed to create parametric or polar signals. If you want to build parametric graphs often, you can speed up the calling of the algorithm:

- Set the “Parametric Graph” as default algorithm (in the algorithm setting window).
- Choose **Select signal** in the context menu of the signal to be used as a function parameter.
- Holding down <Alt> key drag and drop the signal to the graph by the mouse in the way you create an ordinary graph.


The default algorithm will be performed and the result (the parametric graph) will be created instead of simple graph.

Using the Create New Signal dialog window in the Signal Manager

- Click  on the toolbar of *Signal manager* window.
- Mark *Y of the other signal* in the Y frame (see Fig.7.5), click **Browse...** and select the source signal or its fragment in the signal selection window (Fig.3.5).
- Mark *Y of the other signal* in the X frame, click **Browse...** and select the signal with the values corresponding to the new X-axis.
- Type the new signal name and click **OK**. The new signal will be put in the *New Signals* folder of the Signals tree.

① When a new signal is created using other two signals the new signal length will be equal to the length of the shortest of the source signals.

Signals from software generator


You can call the signal generation plugin ( panel), to use one of the examples supplied, or to write your own script, program, or plug-in almost any programming language that supports OLE technology. See Section 11 and *Programmer's Manual*.

Signal Fragment Deletion

Removing parts of the signal containing no useful information, significantly reduces the amount of data and processing time. However, it should be remembered that this may distort the data reference to the timeline.

Using the graph editing panel

- Enable the double cursor and select a fragment to be removed (Fig.7.6, 1).

- Click  button on the *Edit* toolbar (Fig.7.6, 2). Confirm the operation. The selected fragment of the signal is removed, and in its place a break mark will be set (Fig.7.6, 3).

When you remove a portion of the signal the data is not physically deleted as long as the signal is not saved to disk (Fig.7.6, 4).

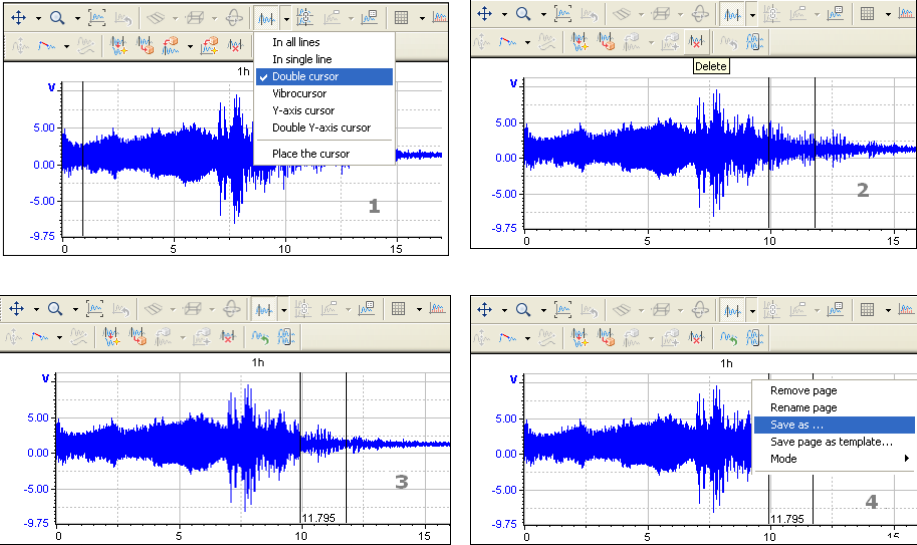


Fig. 7.6. Signal fragment deletion steps

Using the Signal Manager

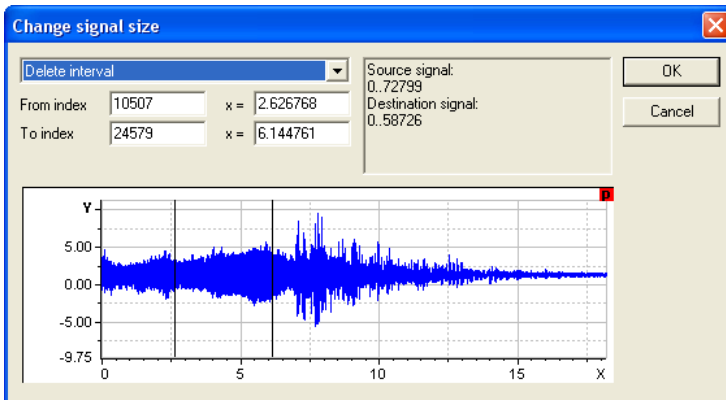



Fig. 7.7. Changing the signal length

- Choose the signal in the *Signal manager* window.
- In the *Prorties* tab (Fig. 7.1) click **Change signal length...** next to *Length, values* field.
- In the *Change Signal Length* (Fig. 7.7) select the fragment of signal using cursors (on window opening the cursors are set at the signal start) or type exact values in the corresponding fields.
- Select an operation in the drop-down list:
 - cut (leave the selected interval),
 - delete selected interval,
 - Insert the given number of values.
- Click OK.

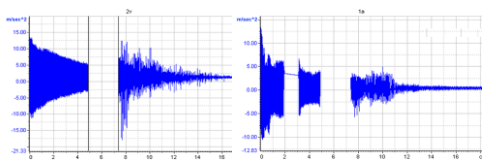
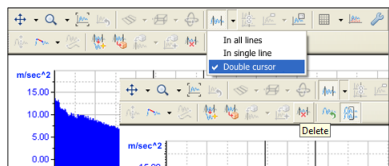
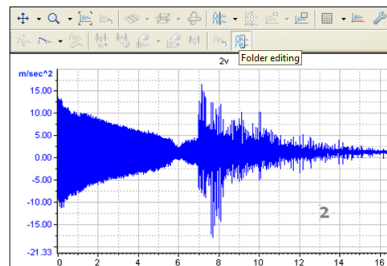
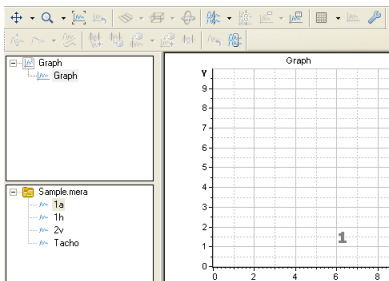
Changing the length of the signal occurs immediately after confirmation and cannot be undone.

Cancel edit

Pended edit operations (copy, paste, and delete using the edit panel) can be cancelled.

Select the graph with the changed signal and click  in the edit panel. Confirm the action. From the signal will be removed all information about editing and it will be restored to original appearance. If the signal is entirely composed of copied segments of other signals, then when canceling editing it will be removed.

Folder (file) handling



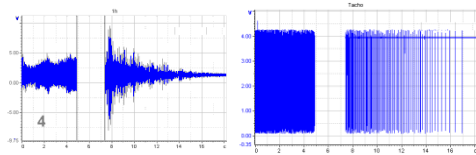





Fig. 7.8. Folder editing


Editing operations (copy, paste, and delete using the edit panel) can be performed, on one signal or on all signals in folder (file) simultaneously.

- Open one of signals in the graph and click  (Fig. 7.8, 1-2).
- Perform all necessary operations on the selected signal. Similar operations will be automatically performed on the other signals in a folder (Fig. 7.8, 3-4).
- Click  again to exit the working with folder mode.

 The choice of a particular signal does not affect the result. In the process of editing the folder for the next operation you can select a signal other than the first one.

Signal Characteristics Modification

Main Properties of Signal

Choose **Properties...** in the signal context menu or open the *Signal manager* window (**Layout**→**Signal manager** or click ) and select the signal. On the *General* tab (Fig. 7.1) you can change the unit of measure, type of characteristics, add description, change the sample rate, set start time.

To set the start time for all signals of the folder, use a **Synchronous start** button.

The minimum and maximum values are calculated automatically when plotting. The "unknown" in the appropriate fields shows that the values are not calculated. Run the calculation using **Calculate the min/max** button.

The signal characteristics are changed after you click **Apply**.

Modification of Measurement Units

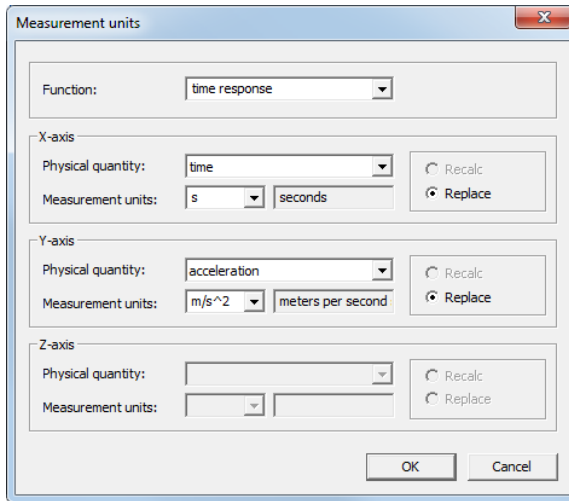


Fig. 7.9. Signal manager. Measurement units

In measurement units dialog (Fig. 7.9) you can change signal's function and units for X/Y/Z axes. Function indicates type of signal, for example, direct record from sensor (time response), or output of algorithm (spectrum, frequency response). Depending on selected function, units set can be limited, for example, units on X axis for time response function can only be time, and for spectrum – frequency. Physical quantity (time, frequency, velocity etc) and units are specified for each axis, list of units depends on selected physical quantity.

If only units are changed while physical quantity stays the same (e.g. “Hz” changed to “kHz”), you can select “Recalc” option to recalculate values accordingly (for previous example, range 10-100 Hz will be changed to 0.01-0.1 kHz). If “Replace” option was selected, only units will be changed.

Modification of Calibration Curve

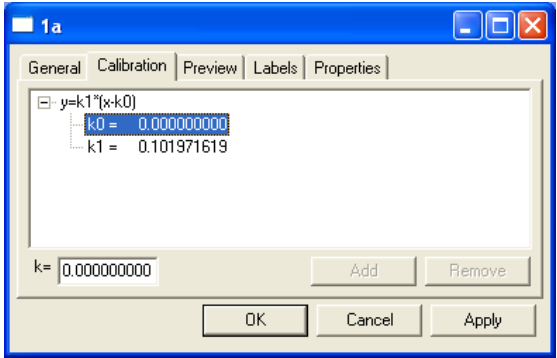


Fig. 7.10. Signal manager. Calibration characteristic

Select the signal in the *Signal manager* window. The *Calibration* tab (Fig. 7.10) displays the calibration characteristics of the signal as a tree with the coefficients. At the bottom of the tab you can add, remove and edit the coefficients. When you add a new scale, you can specify its type in the *Add the Scale* dialog window (Fig. 7.11).

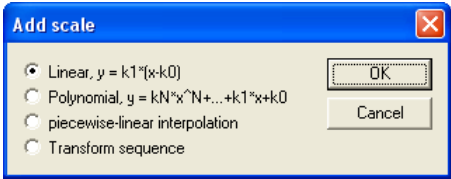


Fig. 7.11. Add the scale

If required, for example, to convert values from codes to volts, and volts to kg/cm^2 , select a **Transformations Sequence** and add two scales.

On the *View* tab in the column y (file) the signal values in the codes (before use CC) are shown, and the fourth column - in the units of the signal (after the CC application). See Fig. 7.12.

Signal Value Editing

Tabular Values Editing

Signal values in a tabular form are displayed on the *View* page of the signal properties window (Fig. 7.12). In *y(file)* column shown the values before applying the calibration characteristics (values of the data file). For three-dimensional signal *z* and *z-index* columns are added.

For convenience, a table has three additional work modes. Click the desired mode, enter the new data in a table cell, hit the Enter key. To return to the view mode click the same button.

Jump. To navigate to the desired value along the X-axis, enter a value in any cell of column *x*. To jump to the index enter a value in the cell of *index* column.

Change. Enter a new value in *y*, *y (file)* or *x* cell. Editing the values in the column *x* is not available for signals with a constant step. Changed values are highlighted in red. The data will change only after you click **Apply**.

Precision. Enter the desired number of decimal places in fields *x*, *y*. Changing the precision affect the entire table column.

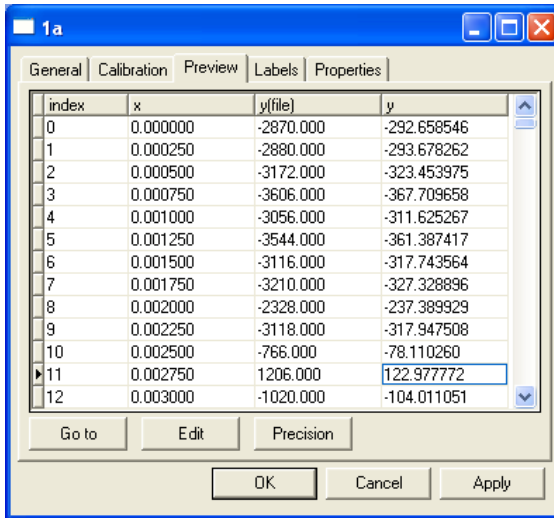



Fig. 7.12. Signal manager. Preview

Single Value Modification

To change the value at the selected point, switch to cursor mode, position the cursor on the desired point and click **Values edit** ().

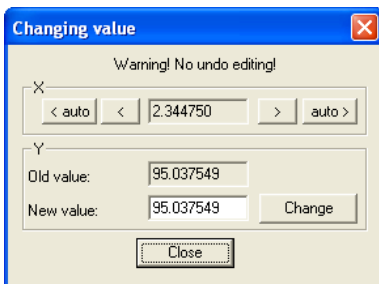




Fig. 7.13. Edit data

Enter the new signal value at a given point in the *Edit data* dialog window (Fig. 7.13). Click **Change**. Use “<” and “>” buttons to select previous or next value for editing.

Graph Interval Editing

ⓘ Changing the values of the signal cannot be canceled. At the entrance to the values replacement modes a warning issued.

To change signal values at several points click the  icon to the right of the **Replacing signal the values** () button.

In the submenu, select the mode of signal values replacement. Draw the region for the values cutoff (Click the left mouse button and without releasing the button, move the mouse pointer, release the button). The values of the signal which fall under the replacement will appear lighter.

The cutoff line (drawn in red) means the following:

in the **Draw lines** mode - replace the values of the signal to values of this line (Fig.7.14),

in the **Erase higher** mode - values above the line will be replaced with points of a line, below the line –not change (Fig.7.15), in the **Erase below** mode - delete values below the cutoff, replacing them with the values of the line (Fig.7.16).

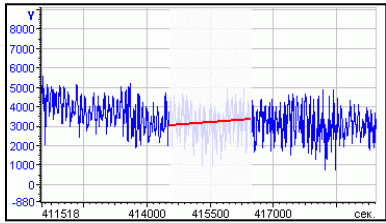


Fig. 7.14. Draw lines

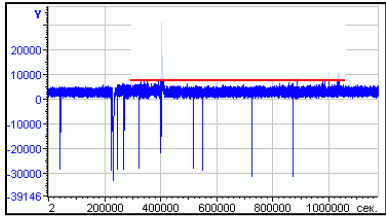


Fig. 7.15. Erase higher

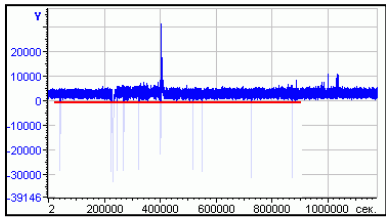


Fig. 7.16. Erase below

Section 8. Formatting the graphs and reporting

Formatting the graphs

To enhance the information content and clarity of results presentation WinPOS contains the elements of graphs formatting. These include a multifunctional legend, lines numbering, printing values on the grid, captions, labels, regimes and comments (See Fig. 8.1).

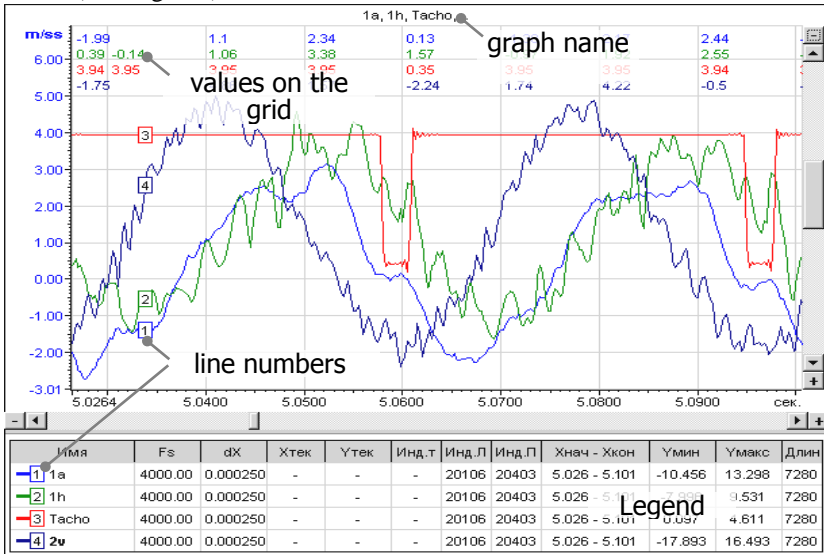


Fig. 8.1. Enhancing the information content of graph

In the graph settings dialog window on the *Graph* tab (Fig. 5.11) you can turned on and off the display of the graph name (**Graph name**), line numbers (**Lines numbering**), the values on the grid (**Val. on the grid**), select the location of the legend, and change other settings.

Legend

One of the main elements of the chart is the legend. The legend may be presented in one of three ways - simple, complete, and as the list of labels.

The simplest form of the legend displays only the names of the lines. If the cursor mode is enabled, the current cursor position and values of each line at this point are also shown.

1	K_1-53A	Y = -58.9178
2	K_2-53B	Y = -20.7214
3	K_3-53Д	Y = -12.5634
		X = 72.7220

The complete form of the legend is a table in which for each signal displayed the several parameters: the sampling rate, the values of X and Y at the point of the cursor, etc. A

full list of available parameters is given in Table 8.1. In the Legend tab *Graph settings* window (Fig. 5.15) you can specify which of these columns will be shown in the legend. You can show or hide the legend on the same tab page or using the graph context menu (**Show legend**). The size of the legend fields can be changed by capturing the field with the mouse cursor and sliding it in the desired direction.

Имя	Fs	dx	Xтек	Yтек	Инд.тек	Инд.П	Инд.П	Хнач - Хкон	Размах Y	МО	СКЗ	Длина
1 K_1-53A	5333.33	0.000188	72.721986	-58.917813	387851	383626	468115	71.930 - 87.772	329.095	18.296	46.941	875719
2 K_2-53B	5333.33	0.000188	72.721986	-20.721377	387851	383626	468115	71.930 - 87.772	166.327	0.237	22.028	875719
3 K_3-53Д	5333.33	0.000188	72.721986	-12.563433	387851	383626	468115	71.930 - 87.772	172.566	15.474	30.302	875719

<i>Name</i>	Name of the line(signal), the color and number of the line is displayed near
<i>Fs</i>	Sampling rate of the signal
<i>dx</i>	Step on the X axis, dx = 1/Fs
<i>Cur X</i>	Current lines cursor
<i>Cur Y</i>	Signal value in the cursor point
<i>Cur idx</i>	Index of the value in the cursor point
<i>L ind</i>	Index of the first value on the graph
<i>R idx</i>	Index of the last value on the graph
<i>Xbeg-Xfin</i>	Current range on X
<i>Ymin-Ymax</i>	minimum and maximum values of the signal on a current range on X
<i>Y range</i>	Difference of the maximal and minimal values on a current range
<i>Ymin (X)</i>	The minimum value of the signal over the entire range, in brackets shown the value of X at which it is achieved
<i>Ymax (X)</i>	The maximum value of the signal over the entire range, in brackets shown the value of X at which it is achieved
<i>Min Y</i>	Minimum signal value over the entire range
<i>Max Y</i>	Maximum signal value over the entire range
<i>Mean</i>	Mathematical expectation of the signal on a current range on X
<i>RMS</i>	RMS of the signal on a current range on X
<i>SD</i>	Standard deviation of the signal on a current range on X
<i>Segm. length</i>	The number of values in the displayed section of the signal
<i>Length</i>	Number of the signal values

Table 8.1 The list of available columns in the complete legend

In the legend you can display a list of all the labels, labels, and modes presented on the graph.



— K_1-53A X = 93.9517 Y = 37.6206	— K_1-53A X = 75.5692 Режим 1	— K_3-53Д X = 93.4049 M1
— K_1-53A X = 95.1875 Y = -24.9363	— K_2-53B X = 93.4049 M1	— K_3-53Д X = 93.1350 M2
— K_1-53A X = 93.4049 M1	— K_2-53B X = 93.1350 M2	— K_3-53Д X = 75.5692 Режим 1
— K_1-53A X = 93.1350 M2	— K_2-53B X = 75.5692 Режим 1	

Line numbers


The change in each parameter on the graph containing multiple lines can be tracked using color highlighting of each signal. However, when a large number of lines and when printing graphics on a black and white printer the color highlight is not enough. The numbers of lines are put down in the rectangle on the corresponding

line and in the legend next to the name of the signal. To activate the numbers of lines use *Graph* tab of settings window.

Hidden lines

If the graph has many lines, and they're blocking each other, some lines can be temporarily hidden without removing them from the graph. To do this, in the context menu of the line (called from the legend and tree graphs) you can choose to **Hide the line** or press <space> on the selected line in the Graphs tree. The hidden line is marked in the legend as  1h, and in the Graphs tree of is a special sign  1h on the icon.

The active line is always drawn on top of other lines.

 Hidden line and hidden signal (see Section 9 *Signals Processing*), are excluded from processing when you call the algorithms.

Coordinate grid

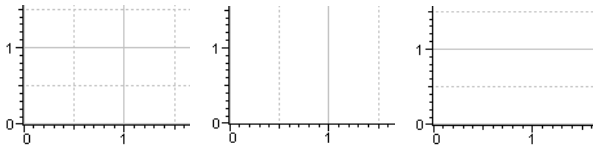



Fig. 8.2. Coordinate grid types

The type of a grid changes using the  button (sequential clicks or selecting from the menu on the arrow next to it) or via the **Tools** menu. The following settings can be made: **Grid by X and Y**, **Grid by X**, **Grid by Y** (see Fig. 8.2) and **Hide grid**.


Grid values

The values of the signals on the grid make it easy to see changes of signals on paper, replacing partly the cursor on the printed graph. The numbers in the column follows in the same order as the signals in the legend and displays the same color of the line. The values of the hidden line (see above) are displayed, in order not to violate the order of the numbers. To activate mode use *Graph* tab of settings window.

Line style

Typically, the signal looks on the graph as a solid line, the signal lines are connected (first order interpolation). This mode allows you to evaluate the form and change the of the signal, but you can't see the individual measurements (dots).

Vertical lines from points of the signal displaying mode (See The second graph in Fig. 8.3) not only solves this problem. It can be useful for a more precise reference to the time axis and when comparing signals with different sampling. To activate

this mode check **Vertical lines** in the *Line* tab of *Graphs settings* window (Fig. 5.12) or click  button on the graph toolbar.

In some cases (for example, when you view the telemetry data) may be a useful mode, in which the signal is depicted as individual points (measurements) (third graph in Fig. 8.3). Such mode is enabled by ticking **No point connection** on the *Line* tab in the graph settings window (Fig. 5.12).

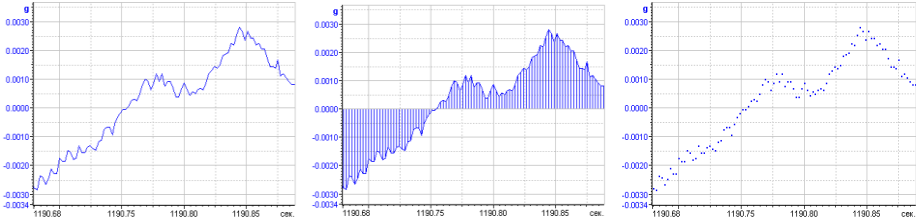


Fig. 8.3. Lines displaying options

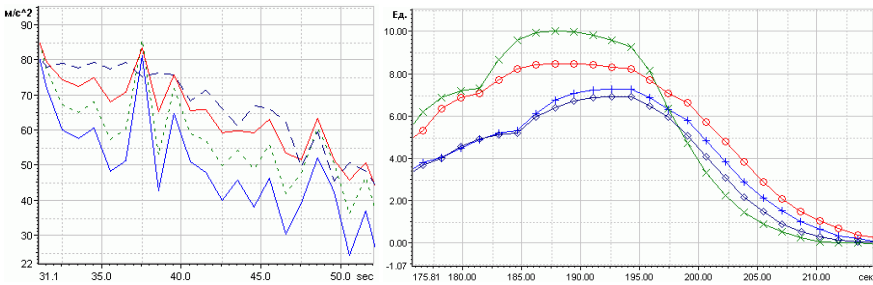


Fig. 8.4. Line selection

If several slowly varying parameters in the same graph are hardly distinguishable by color (for example, when monochrome printing) you can change the shading of a line or mark the value of the signal by markers as shown in Fig. 8.4. To do this use options **Line type** and **Point type** on the *Line* tab in the graph settings window (Fig. 5.12).

Display spectrum as histogram

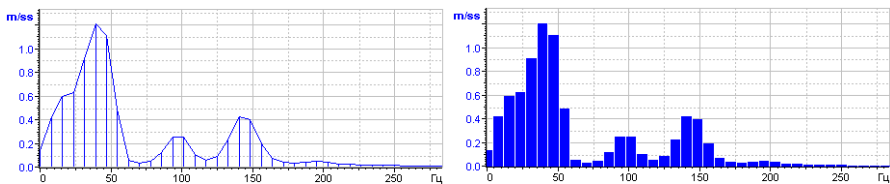


Fig. 8.5. Histograms

Typically, the spectra are represented using curves with vertical lines (See. Fig.8.5), but you can set the spectrum display in the form of histogram on the *Lines* tab in the **Tools**→**Default Settings...** (*Spectrum as histogram* option). This mode is automatically set to octave spectra.

Labels

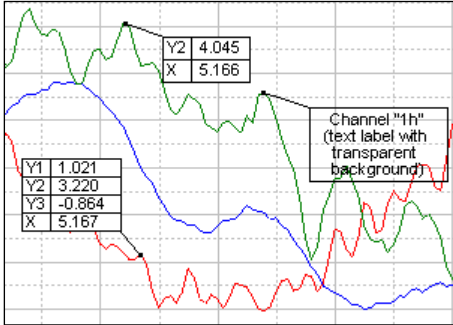




Fig. 8.6. The labels

The labels allows you to add the exact values of the signals at selected points or to comment fragments of the signals (Fig. 8.6).

Switch to cursor mode clicking  in the toolbar. Set the cursor at the desired value. Click to **Add a label (flag)** (or press <Ctrl+F>).

Click the left mouse button to specify the position of the label. The label is set to nearest to the cursor point of the signal. The icon  to the right of the button allows you to select the type of label: **On one line**, **On all lines** or **Text**.

To edit or delete the label, double click in its field.

To move the label, click and hold the left mouse button in label field and drag the rectangle to a new position, then release the button. The size of the rectangle is automatically selected and cannot be changed.

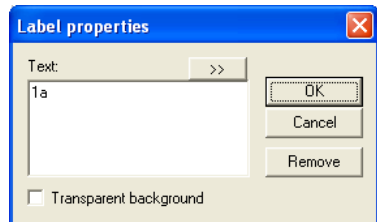
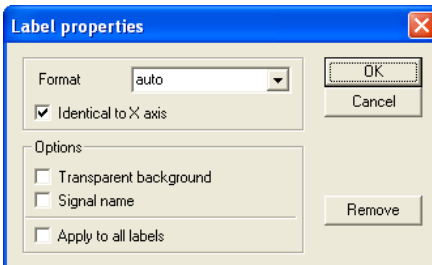




Fig. 8.7. Labels settings

In the configuration dialog windows of the label (Fig. 8.7) you can enable a **transparent background**. For labels with values – replace abbreviations lines (Y1,Y2,Y3,...) with **signals names** and set the **Format** for output values: use the dropdown list to choose the appropriate format (**auto** – automatic choice of format)

or set your own in the edit field. The # sign denotes a single digit, 0 – indicates a need to add the rows with zeros, e – enables the engineering format for numbers.

The text of label can be edited in the **Text** field (Fig. 8.7). The  button opens the "history" with previously entered text strings.

Comments

Click  (**Add comment**). Using the mouse draw a rectangle for the text comment (Click the left mouse button in graph, then, without releasing the mouse button, move the cursor, outlining the rectangle of the future comment). To change the size of the region grasp the frame (the mouse pointer over the frame is replaced with arrows indicating the direction of movement: press the left mouse button and move the frame). To edit or delete the comment, double click in the comment box, this will open the edit dialog window (Fig. 8.8).

You can change the text in the *Text* field of the comment. The **History** button opens the history window. To delete comment click **Delete comment**.

In the same dialog window you can change the alignment and text display style. The *Move comment* field allows to align the comment along one of the sides of the graph. To move the comment, click and hold the left mouse button in the text box, move the rectangle to a new position, release the button.

The **Advanced**>> button expands the comment window. In the right part of the window displays a list of the signal properties (if signals in the chart a few – select from the drop down list Signal). To copy the property strings in the comment field, click the arrow ←.

You can copy as the value of the property, and template. In this case, instead of the expression in brackets the comment will be filled with the corresponding value properties of the selected line or the signal number specified in the template after the # sign. In Fig. 8.8 shows an example of a template and its application for naming of the signal.

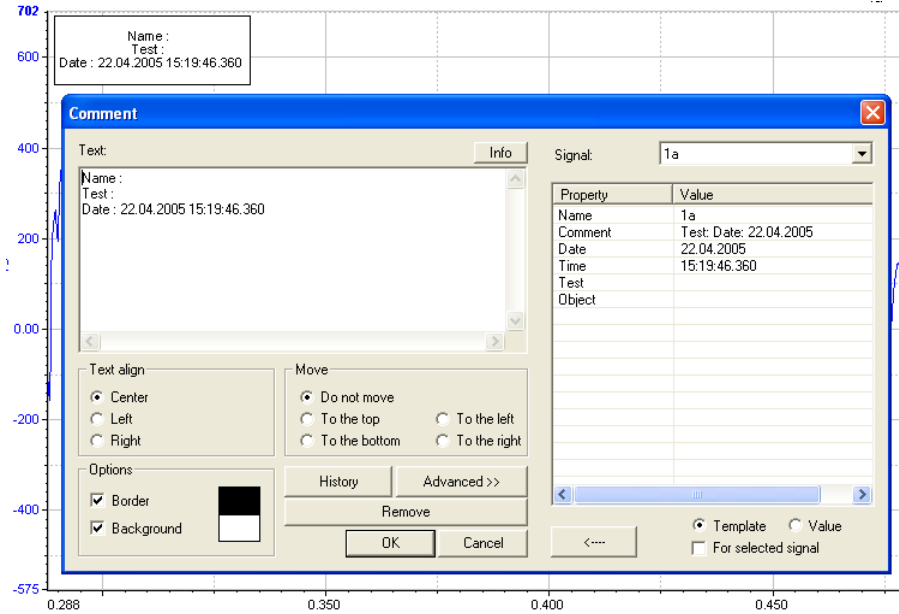



Fig. 8.8. Customizing comment

Graph printing and saving

Page printing

Printing of the active page is performed from a preview window (Fig. 8.9), which is opened by clicking  on the main toolbar or via **Tools**→**Print...** menu

The **Page...** button in the preview window allows you to set margins, and select the size and orientation of paper in the standard Windows dialog. The **Save** button creates a graphic file (in BMP format) with the page image. The **Load** button allows you to find and print a previously saved page.

The **Print** button opens the standard dialog of the printer setup and printing.

The **Comment...** button of preview window (See. Fig. 8.9) allows you to the accompanying text at the bottom of the page.

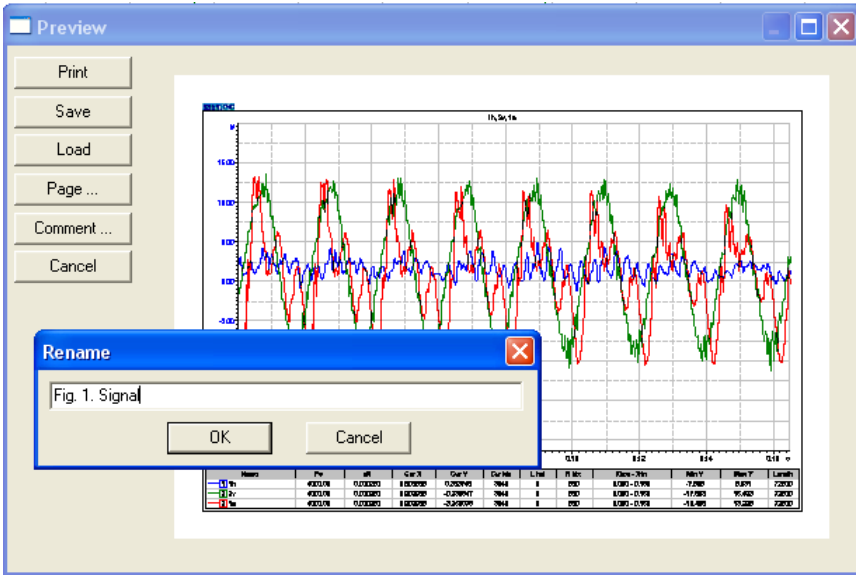


Fig. 8.9. Preview. Comment

Roll printing, emulation

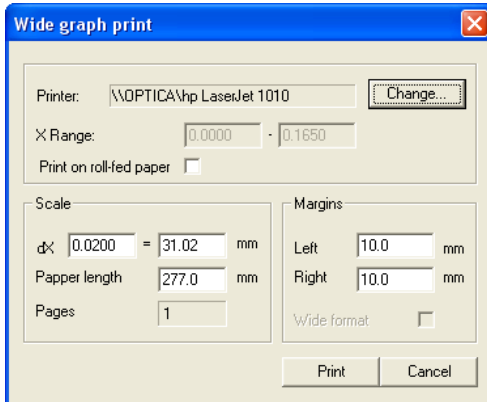



Fig. 8.10. Roll printing setup

Roll printing window is opened through the **Tools** → **Roll printing...** menu. Printing on the scroll printer (see Fig. 8.10) allows you to get more convenient for further study graphs in more detail on the time axis. If the printer does not support roll paper, the emulation of roll printing on separate sheets of paper is performed, so the graph with a high time resolution can be obtained by bonding of such sheets. In the roll printing settings window you can select the printer (**Change** button...), set the **Scale** (resolution fields **dX...=...mm** are associated with a **Length of paper** field)

and set the *Boundaries*. The **Range for X** is customized according to on the current graph.

Saving images

The current graph page can be saved in a graphic file (BMP format) by clicking  in the main toolbar or via the **Tools** → **Save image** menu (opens a standard file selection dialog window).

Graph copying via the clipboard

You can insert WinPOS graphs directly in the text of the document (see Fig. 8.11).

Click  or select **Tools**→ **Save image in the clipboard**.

Move the cursor to the desired location in the document and click **Paste** in your text processor or press <Ctrl+V>.

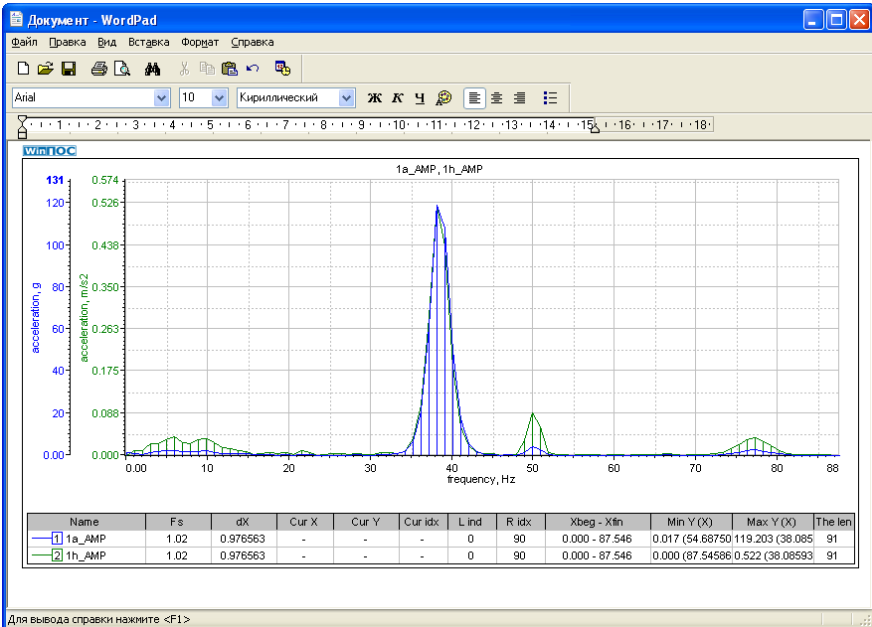



Fig. 8.11. Paste graph in the document

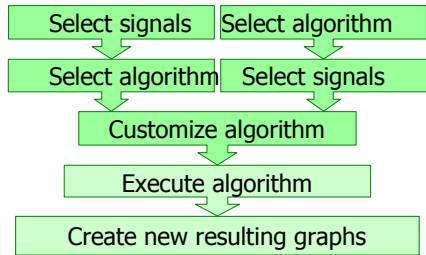
Section 9. Signals processing. Standard algorithms

WinPOS allows to perform digital processing of the recorded data using a large number of built-in standard algorithms. Expert edition contains additional tools for working with dynamic processes and vibration analysis. This will be discussed in the next section. WinPOS scripts (see Section 11) allows to create unique integrated processing programs with the use of WinPOS algorithms.

The correct application of processing algorithms assumes familiarity with the basics of higher mathematics, knowledge of the physical processes occurring during testing, and measurement procedures. In the description of algorithms presents the basic formulas and comments on their implementation in WinPOS. Provided recommendations that will help to set algorithms in the best way to produce results that best meets the set objectives. More detailed information on the methods of digital signal analysis can be obtained in the sources listed at the end of the section.

Operations Sequence

The sequence of signal processing can be represented by a diagram of the five steps. The algorithm can be applied to the signal, to the folder with multiple signals, to all signals, or graphs or to the one line. When you select a page, graph or line, the algorithm will be applied to the displayed range of values according to the principle: what you see is what you process. If processing selected the folder with the signals or graph with multiple lines, pressing <space> on the signal, lines in the Graphs tree or hide the line (See *Formatting the graphs* in Section 8) Excluded signal is marked in the Graphs tree with a special icon before the name:  1h.



Step 1-2 Select signals – Select algorithm

1. Select the object (signal, folder, page, graph, line) to which the algorithm be applied.
2. Open the context menu of the object to be processed (See *Context menu* in Section 3 and Fig. 3.2), select **Algorithm** submenu and choose algorithm.

Step 1-2 Select algorithm – Select signals

1. Choose the algorithm in the **Algorithms** submenu of the main (see Fig. 3.3).

2. In the algorithm settings dialog window (Fig. 9.1) click **Select** next to the *Sources* field, select the object and set the processing range using the *Signals selection* dialog window (Fig. 3.5).

By default the algorithm is applied to the current line of the active graph.

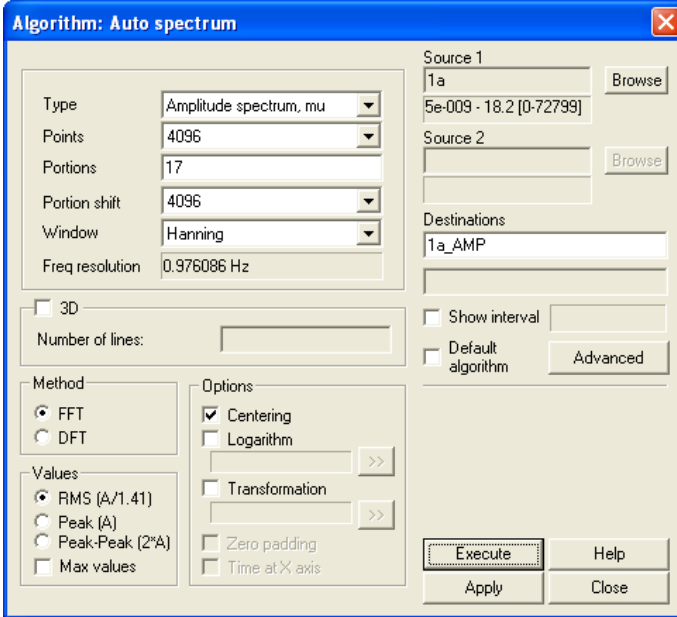


Fig. 9.1. Customization of algorithms. Auto spectrum

Step 3 Customize algorithm

The choice of any algorithm (except the **Probabilistic characteristics**) leads to opening the algorithm settings dialog window (Fig. 9.1).

The settings window consists of the right part which is the same for all algorithms where you set the data sources and the names of the results, and the left part in which you can set parameters for a specific algorithm.

Most of the algorithms takes as input one source signal, and produces a single result signal, but, for example, for *Cross-spectrum*, you need to specify two sources, the calculation of the *Real* and *Imag* characteristics of the autospectra produces two result signals.

Selected to processing signal range of values and indexes is displayed under *Sources* field. To change the processed range of values or a repeated signal selection use the **Select** button and the *Signals selection* dialog window (Fig. 3.5). The **Apply** button allows to save the settings without executing the algorithm. The **Help** button displays help about the algorithm.

Step 4 Execute algorithm

The button **Execute** starts the calculation process, the progress of which can be monitored by the indicators at the bottom of the main WinPOS window. To the right shows the general state of the computation, to the left - the name of the processed signal and the calculations. To interrupt the calculation press <Esc>.

The calculated signals are placed in the *Results* folder, to the signal names added the suffix which is an abbreviation of the algorithm. Processed folder has a corresponding folder in the *Results*.

Step 5 Create graphs of the results

At the end of the computation the page with graph of the results is automatically created and becomes the current. see fig. 9.2.

Processing of one signal creates a page with two graphs: the source (on the selected range) and resultant signals. If the algorithm includes two sources or two results, then one graph shall be created for each signal (up to four graphs). At the batch signal processing the result page is created and the source signals are not included into this page.

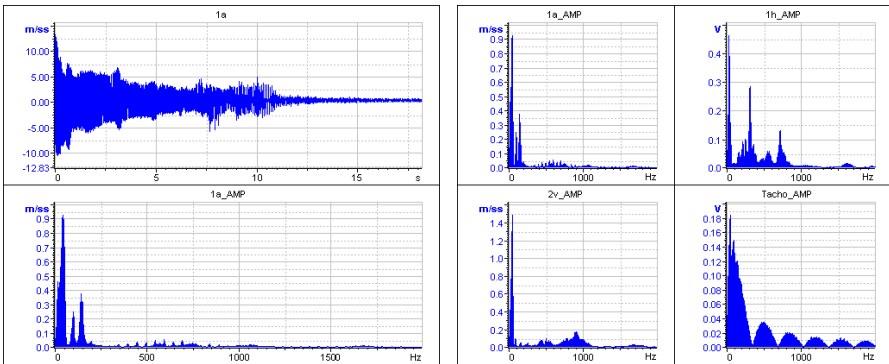
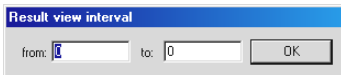


Fig. 9.2. Results of Spectrum calculation of the single signal and of all the signals in the folder



To set the preferred viewing range of the resulting signals set the **Display the interval** and define the x-axis values range for the result graph.


Algorithms settings are automatically saved when you close WinPOS and when you save the session (see Section 4). To save several sets of settings, for example, for various processing programs, you can use **Algorithms**→**Save settings** and **Algorithms**→**Load settings** commands.

To facilitate access to the most relevant tasks the submenu **Recent algorithms** (**Algorithms** menu) maintains a list of previously executed operations ordered by the time of their call.

A quick call of the algorithm

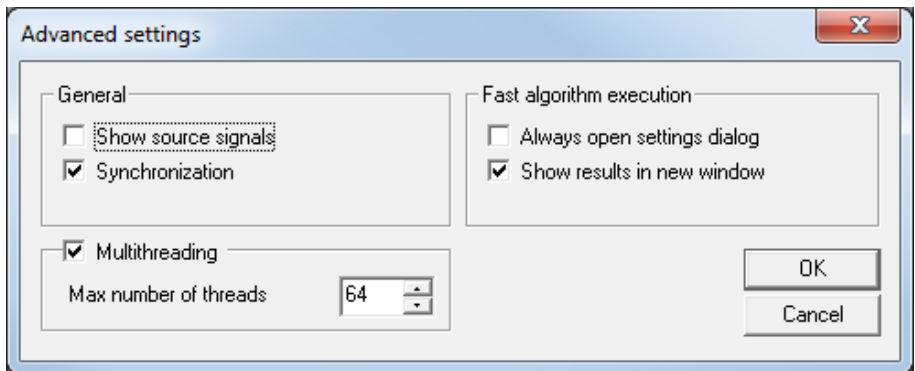
1. If you frequently calls the same algorithm you can significantly accelerate the work:
 - check the **Default algorithm** mark (see Fig. 9.1),
 - hold down <Alt>, drag signal with the mouse from the Signals tree to the graph, as when creating graph (Section 5. Creation of graphs).

The default algorithm will be performed and the graph of the original signal and instead of graph of the original signal you will see on the graph with result.

2. If you use algorithms working with two sources, you can specify a second source. Click **Highlight signal** in the context menu of the signal. The signal is marked in the tree, with the  icon.

To make a quick call to the algorithm the most convenient for you, click **Advanced settings** (Fig. 9.1).

In the *Advanced settings* window check:



Always open the settings dialog - to configure the default algorithm with a quick call (otherwise the algorithm invoked with the current settings),

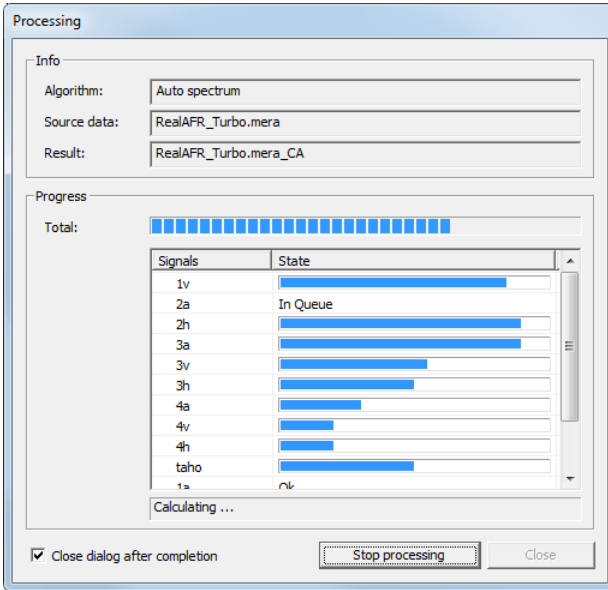
Open result in new window – to put the results in a new page (otherwise the result will fall where it moved with the mouse),

Show source signals - to create pages with the original signals (otherwise, only the graphs of the resulting signals will be displayed).

Multithreading

If whole folder was selected, algorithm can be executed in multithreading mode, with every signal processed its own thread simultaneously (“Multithreading” option

in advanced settings must be checked, see above). Progress is shown in separate dialog.



Introduction. Analysis of signals using FFT algorithm

One of the most important methods in the analysis of signals is the algorithm of fast Fourier transform (FFT), which is the fastest method of computing the discrete Fourier transform (DFT). FFT gives the possibility of determining the number of variables and functions related to signal analysis, multichannel measurements and characterization systems, e.g., correlation functions, coherence functions, frequency characteristics, etc. One of the main advantages of FFT analysis is to preserve the phase information and, consequently, the possibility of simple direct and inverse transformations from time domain into frequency and vice versa.

The defining expressions for the Fourier transform of the input sequence $\{x(n), n=0, \dots, N-1\}$ are:

$$G(k) = \frac{1}{N} \cdot \sum_{n=0}^{N-1} x(n) \cdot \exp\left\{-j \cdot \frac{2\pi kn}{N}\right\}, \text{ direct transform,}$$

$$x(n) = \sum_{k=0}^{N-1} G(k) \cdot \exp\left\{j \cdot \frac{2\pi kn}{N}\right\}, \text{ inverse transform.}$$

The computational procedure for the discrete Fourier transform (DFT) is the algorithm of fast Fourier transform (FFT). Below we consider a specific algorithm that is incorporated in the WinPOS package.

In most cases in practice, the value of $x(n)$ are real and the FFT algorithm is designed for complex values. To resolve this redundancy and load imaginary part of the input data, the input stream is divided into two sequences as follows: one samples with odd sequence numbers, other sequence - even-numbered. Accordingly, one of these sequences will be real, and the other the imaginary part of the input array for the FFT algorithm.

Thus, if $\{x(n)\}$, $n=0, \dots, N-1$ - the input sequence, and $W = \exp\left\{-j \frac{2\pi}{N}\right\}$, $f(l) = x(2l)$, $h(l) = x(2l+1)$, in result we have :

$$G(k) = \frac{1}{N} \cdot \sum_{n=0}^{N-1} x(n) \cdot W^{k \cdot n} = \frac{1}{N} \cdot \sum_{l=0}^{N/2-1} (f(l) \cdot W^{2lk} + h(l) \cdot W^{(2l+1)k}) =$$

$$= \frac{1}{N} \cdot \sum_{l=0}^{N/2-1} f(l) \cdot (W)^{2lk} + \frac{1}{N} \cdot \sum_{l=0}^{N/2-1} h(l) \cdot (W)^{(2l+1)k} = F(k) + W^k \cdot H(k)$$

finally:

$$G(k) = \begin{cases} F(k) + W^k \cdot H(k), \text{ для } : 0 \leq k \leq \frac{N}{2} - 1 \\ F(k - \frac{N}{2}) + W^k \cdot H(k - \frac{N}{2}), \text{ для } : \frac{N}{2} \leq k \leq N - 1 \end{cases}$$

Further formed input array: $Z(k) = f(k) + ih(k)$, where $k=0, 1, \dots, N/2-1$, to which applied the FFT decimation algorithm in time with the replacement of the base 2 with binary-inverse order at the input.

Using partitioning formulas to the Fourier transformation $\{Z(k)\}$, we obtain two transformations $\{F(k)\}$ and $\{H(k)\}$

$$Re(F(k)) = 0.5 \cdot (ReZ(k) + ReZ(N/2-k))$$

$$Im(F(k)) = 0.5 \cdot (ImZ(k) - ImZ(N/2-k))$$

$$Re(H(k)) = 0.5 \cdot (ImZ(k) + ImZ(N/2-k))$$

$$Im(H(k)) = 0.5 \cdot (ReZ(k) - ReZ(N/2-k)), \text{ where } k=1, \dots, N/2-1.$$

The transformation $\{G(N/2-k)\}$ calculated according to the formulas:

$$ReG(0) = ReZ(0) + ImZ(0)$$

$$ImG(0) = 0$$

$$ReG(N/2) = ReZ(0) - ImZ(0)$$

$$ImF(N/2) = 0$$

The limitations of the method

Limitations are mostly determined by the finite and discrete nature of the DFT algorithm. The nature of these restrictions will become clearer if we consider the

DFT as a result of passing the signal through a set of matching bandpass filters with central frequencies:

$$f_i = i \cdot (f_s / N), \text{ where } f_s - \text{ sampling rate, } N - \text{ number of FFT points.}$$

Component of the analyzed signal, with the frequency f_a which does not coincide with the frequency of a spectral line (bin) of DFT, will appear on neighboring spectral lines and the amplitude values are determined with some errors (See. Fig. 9.3).

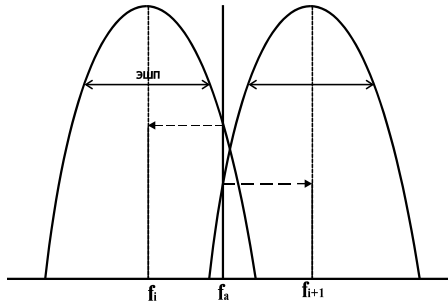


Fig. 9.3. DFT as a set of matching bandpass filters

The effect of aliasing

The first operation of the digital analysis is the discretization of the time signal. Formulated by the Shannon theorem on discrete representation establishes that the time function in the discrete representation should not contain components with frequencies above half the sampling frequency (the Nyquist frequency). Otherwise, the components of the original signal $g(t)$ spectrum $G(f)$, frequencies which exceed the Nyquist frequency, misinterpreted as the components with lower frequencies ("aliasing").

- ① Recommendations. In the analysis of stationary and other signals in the frequency range with precisely defined limits the problem of the overlapping are usually resolved by the use of analog low pass filters

Note: In "Bruel&Kjaer" equipment the problem is solved by the use of low-pass filters with sharp cutoff at a frequency equal to $\approx 80\%$ of the Nyquist frequency. For the effective exclusion of FRF components in excess of the limit of the working frequency range the slope of the low pass filter is taken equal to 120dB/Oct. The display unit and the external equipment displays only the results that are generally not affected by the presence of the filter. For example, in the conversion process with account of 1024 discrete values in the time domain, in the frequency domain are calculated values of 512 components, but the display unit and the external equipment displays the values of only 400 frequency components.

The effect of weighting

The next step in analysis is the limitation of the signal in the time domain (finite realization). This operation is equivalent to multiplying by a rectangular weighting

function (time window). The result of applying the weight function is only relatively little noticeable in the case of spectra without obvious peaks. However, if the spectra contain discrete components, application of weight function is accompanied by the replacement of these components with spectrum of used weight function. The weight window acts as a filter (with the corresponding characteristics of the ENB and K_{KG} see table. 9.1), the power of the signal at the output of which is proportional to the power of the harmonics of the input signal in the band of his bandwidth. This effect is known as "weighting effect", "the effect of framing", "formation of side bands" and "leakage" (inherent in discrete component power by leakage appears in the adjacent bands).

① Recommendations. A rectangular weighting function (or lack of weight function) is not optimal in the analysis of stationary signals, in particular of signals containing discrete components, due to the potential discontinuity at the connected ends of the processed implementation.

The weight function optimal for analysis of stationary signals, must have zero values at both ends, and smoothly changing values within a given length analyzed signal realization. On the selection of weighting functions, see the relevant Section.

Fence effect

The fence effect is associated with the discrete representation of the continuous frequency spectra (see explanation to Fig. 9.3). This effect is found not only in the analysis based on the FFT, but in those situations where the discrete (not tunable) bandpass filters are used, for example, in octave or third octave analysis. In practice this effect is the following: while the frequency of a certain component of the analyzed signal do not coincide with the frequency corresponding to the spectral lines inherent in this component the values of amplitude and frequency will be determined with some systematic errors (the frequency value will correspond to the frequency nearby in the direction to higher frequencies of the spectral lines). Compensation of these errors is possible if the considered component is isolated, stable frequency component.

The use of weighting windows in harmonic analysis

The finiteness of the observed time interval and the choice of the orthogonal trigonometric basis (continuous or discrete) in this interval leads to the adverse effects of erosion or leakage of the spectral components. To reduce the erosion of spectral components the window (weight function) are used. Impact of windows to the data array is in decreasing order of gap on border of the periodic extension due to the smoothing effect. The window acts as a filter, the signal level at the output of which is proportional to the power of the harmonics of the input signal in-band its bandwidth (see Fig. 9.4). Windows affect to many of harmonic analysis indicators, including detectability, resolution, dynamic range, reliability and ease of

computational operations implementation. To be able to make the right choice of weight function, consider the most significant parameters.

Equivalent noise bandwidth (ENB)

Due to the presence of broadband noise falling within the bandwidth of the window, the estimation of the amplitude spectrum at a given frequency is shifted. To minimize the accumulated noise use the narrowband windows. A convenient measure of the window bandwidth is the equivalent noise bandwidth (ENB - bandwidth of a rectangular filter with the same maximum power gain that accumulates the same power as this window - see Fig. 9.4).

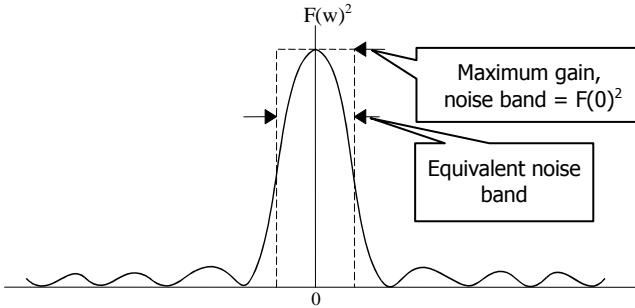


Fig. 9.4. Window equivalent noise bandwidth

The values of ENB for implemented windows in WinPOS are given in table. 9.1. The formula for calculating ENB has the form:

$$ENB = \frac{\sum_n w^2(nT)}{[\sum_n w(nT)]^2}, \text{ where } w(nT) \text{ - discrete values of the weighting function.}$$

Note: ENB is normalized by the N_0/T value, where N_0 is the noise power in unit bandwidth, T is the time interval of observation.

Conversion gain (CG)

In the case of using weighting windows for a constant signal in the absence of the noise the spectral component will be proportional to the input amplitude. A similar statement holds for the mathematical expectation of this component in the presence of noise. For a rectangular window this coefficient is maximum. Reducing the coefficient of proportionality for one or the other window relative to a rectangular window characterizes the error (bias) of the spectral components amplitudes estimation. Table. 9.1 shows the values of coherent gain (the proportionality factor), normalized relative to the maximum possible value of N (the number of samples in the window). Conversion gain is defined as the quotient of the relationship *signal/noise* at the output and at the input and is the reciprocal of the normalized

ENB window. And thus, the increase in *ENB* of the window leads to a reduction of CG.

Correlation of overlapping intervals

Consider the case of dividing the input sequence into multiple sequences of shorter length. The number of counts N of the sequence is chosen to provide the required spectral resolution, which is determined by the formula

$$\Delta f = \beta \cdot \frac{f_s}{N} \quad , \text{ where } f_s - \text{ sampling rate;}$$

β - the coefficient characterizing the increase in bandwidth for the selected window (usually set equal to the *ENB* of the window in the bins table. 9.1).

To avoid data loss near the borders of the interval (in the case when the FFT operates on the weighted data), the transformation is usually subjected to overlapping sections of the sequence. In most cases the degree of overlap selected 50 or 75%. This raises questions about the correlation degree of the random components of the signal in the transformation of two neighboring sequence and, as a consequence, about the reduction of variance when averaging correlated measurements. The values of correlation coefficient (with a relatively flat noise spectrum within the bandwidth of the window) for each of the windows implemented in WinPOS with 50 - 75% overlap are shown in table. 9.1.

Now, with regard to dispersion. When averaging of K independent measurements of ergodic random variables the variance of averaged value associated with the average of individual measurements by the following relationship:

$$\frac{\sigma_{\text{ср.оц.}}^2}{\sigma_{\text{измер.}}^2} = \frac{1}{K}$$

For averaging of correlated measurements:

- 50%-overlap:

$$\frac{\sigma_{\text{ср.оц.}}^2}{\sigma_{\text{измер.}}^2} = \frac{1}{K} \cdot [1 + 2c^2(0,5)] - \frac{2}{K^2} \cdot [c^2(0,5)]$$

- 75%-overlap:

$$\frac{\sigma_{\text{ср.оц.}}^2}{\sigma_{\text{измер.}}^2} = \frac{1}{K} \cdot [1 + 2c^2(0,75) + 2c^2(0,5) + 2c^2(0,25)] - \frac{2}{K^2} \cdot [c^2(0,75) + 2c^2(0,5) + 3c^2(0,25)]$$

where $c^2(0.75)$, $c^2(0.5)$ and $c^2(0.25)$ – correlation coefficients for 75%-, 50%- and 25%-overlap. The negative components are describes the edge effects of averaging

and when $K > 10$ they may not be taken into account. For good windows $c^2(0.25) \ll 1$, it can also be omitted.

Maximum conversion loss

Maximum conversion loss consists of maximum losses due to spurious amplitude modulation of the spectrum (fence effect) for given window (in dB) and conversion losses due to the shape of the window. The maximum loss is always between 3.0 and 4.3 dB (the window with the index > 3.8 dB are unsatisfactory).

Detection of two close tones

The leakage of the spectral components leads to biased estimation of the amplitudes and locations of the harmonic components of signal. This effect is most unpleasant for detection of weak signals in the presence of strong interference of close frequencies. To reduce the undesirable effects the amplitude of the side bands away from the main of window should be small, and the transition from the central to the low-amplitude side bands very fast. The maximum level of the side bands (relative to the main band) and the asymptotic decreasing rate of the lateral bands are shown in table. 9.1.

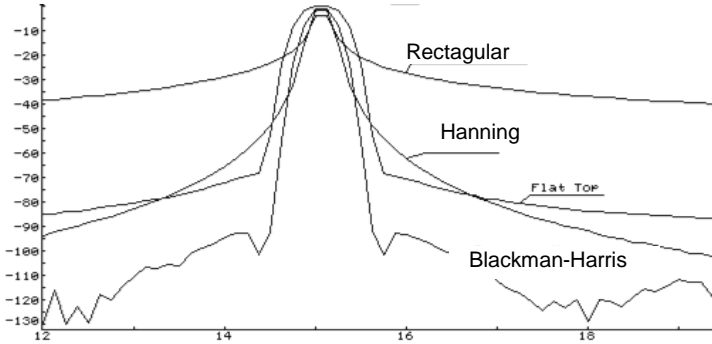
Weighting windows

The windows (functions) can be used to reduce unwanted effects due to the finite length of observation intervals:

- rectangular weighting function (no weighting function);
- Hanning window :
 $W(n) = 0.5 \cdot (1 - \cos(2\pi n/N))$, $n = 0, \dots, N-1$;
- Blackmann-Harris window:
 $W(n) = A_0 - A_1 \cos(2\pi n/N) + A_2 \cos(2 \cdot 2\pi n/N) - A_3 \cos(3 \cdot 2\pi n/N)$, $n = 0, \dots, N-1$,
 where N is the number of discrete samples of the weighed process,
 $A_0 = 0.35873$; $A_1 = 0.48829$; $A_2 = 0.14128$; $A_3 = 0.01168$;
- triangular window:
 $W(n) = \begin{cases} 2 \cdot \frac{n}{N}, & \text{for } n = 0, 1, \dots, N/2; \\ W(N-n), & \text{for } n = N/2 + 1, \dots, N-1 \end{cases}$
- Flat Top:
 $W(n) = 1 - A_0 \cos(2\pi n/N) + A_1 \cos(2 \cdot 2\pi n/N) - A_2 \cos(3 \cdot 2\pi n/N) + A_3 \cos(4 \cdot 2\pi n/N)$,
 $n = 0, \dots, N-1$, $A_0 = 1.93$; $A_1 = 1.29$; $A_2 = 0.388$; $A_3 = 0.0322$;

The type of used window is critical for detection of tones in the presence of other closely located tones. In order to have maximal dynamic range for detectable signals the window conversion should have a narrow main band and a very low level of side bands.

Fig. 9.5. illustrates the spectra of cos-function, weighted in the time domain, using respectively, the rectangular function, Hanning function, Blackman-Harris and Flat Top function. The frequency of the cos-function is in the interval between two adjacent spectral lines ($\Delta X=0.125$, $f=15.0625$).



	Flat Top	Hanning	Blackman-Harris	Rectang.
Y (dB)	-0.016	-1.424	-0.856	-3.937
X	15.000	15.000	15.000	15.000

Fig. 9.5. cos-function spectra

From Fig. 9.5. it is clearly seen that the narrowest main band (bandwidth) has a rectangular window. At the same time, this window has the highest level of the side bands, which leads to additional conversion losses - increases power spurious (outside the passband) signals, the impact of "leakage" of the spectral components is stronger. Blackman-Harris window has the lowest level of the side bands, but a wide bandwidth. Among the above windows, the Hanning window is optimal and has the minimum conversion loss, which allows to recommend it for use in virtual devices. Flat Top function, which has most wide bandwidth, contributes to a significant reduction of the fence effect and applied for calibrating the analyzing instrument using the reference tone signal with a frequency in the interval between adjacent spectral lines.

Weighting window	ENB (bins)	ratio of coherent gain	maximum level of sideband (dB)	maximum amplitude error (dB)	speed of decay of the side lobes (dB/oct)	correlation of overlapping intervals (%)	
						75	50
Rectangular	1.0	1	-13	3.92	-6	75.0	50.0
Blackman-Harris	2.0	0.36	-92	0.83	-6	46.0	3.8
Hanning flat top	1.5	0.5	-32	1.42	-18	65.9	16.7
Triangle	3.77	1.33	-93	0.01	0		
			-27	1.82	-12	71.9	25.0

Table 9.1 Main parameters of winwow functions

Normalization of the weighting window described above, maintains the amplitude of the signal:

$$\frac{1}{N} \sum_{n=0}^{N-1} W_{norm}(n) = 1$$

To preserve signal energy (in accordance with Parseval theorem), used the windows normalized in accordance with the condition:

$$\sqrt{\frac{1}{N} \sum_{n=0}^{N-1} W_{norm}(n)^2} = 1$$

In the setting dialog windows these windows provided with "(RMS)" mark. Example: "Hanning (RMS)".

Spectral analysis

Spectral analysis is used to assess the following characteristics:

- amplitude spectrum, power spectrum, power spectral density, spectral energy density, complex spectrum;
- cross-spectrum;
- coherence function, coherent output power, non-coherent output power, the signal-to-noise ratio;
- transfer functions.

The **main frequency range** of analysis extends from 0 Hz to the Nyquist frequency and does not depend on the number of discrete values in analyzed signal realization. The Nyquist frequency f_N is related with a sampling frequency f_s as $f_N = f_s / 2$.

The actual **frequency range** is bounded from above by the cutoff frequency of used low pass filter.

The number of spectral lines of analysis in the main frequency range is related to the number of discrete values of N and is usually equal to $N/2$ in the range with the upper limit established by the Nyquist frequency.

Frequency corresponding to the **i -th spectral component** (harmonic):

$$f_i = i \cdot (f_s / N), \text{ where } f_s - \text{ sampling frequency}$$

The frequency resolution (Δf) or the interval between adjacent spectral lines for analysis is determined by the following equations:

$\Delta f = 1/T = 1/(N \cdot \Delta t) = f_s / N$, where T – length of converted realization of the analyzed signal;

N – number of input discrete values (conversion size);

Δt – time sampling;

f_s – sampling frequency.

The width of the frequency band (B) for analysis usually is more than frequency resolution and depends on the time-domain weighting function:

$B = \Delta f \cdot K_{ENB}$, where K_{ENB} – coefficient associated with the selected weighting function.

Auto spectrum

Based on the discrete Fourier transform $F(k)$ the 6 characteristics are defined.

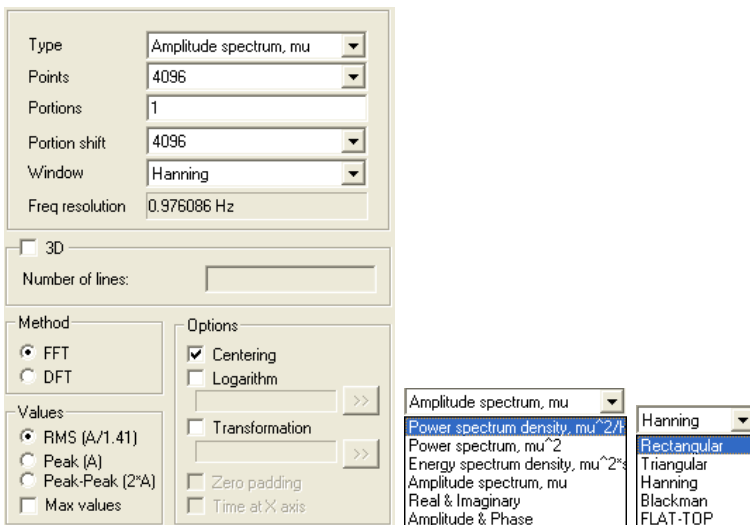


Fig. 9.6. Auto spectrum

Amplitude spectrum

Ampl. Is determined through the power spectrum and has a dimension of (*units*): $G_A(k) = \sqrt{G_{PS}(k)}$. For single-sided amplitude spectrum and in the case of the application of weighting windows: $G'_A(k) = \sqrt{G'_{PS}(k)}$.

Power spectrum

PS. Characteristic is determined by averaging over M realizations and has a dimension of (*units*²):

$$G_{PS}(k) = \frac{1}{M} \cdot \sum_{j=0}^M G_{PSj}(k) = \frac{1}{M} \cdot \sum_{j=0}^M |F_j(k)|^2 = \frac{1}{M} \cdot \frac{1}{N^2} \cdot \sum_{j=0}^M |F'_j(k)|^2, \text{ where: } F_j(k) = \frac{1}{N} \cdot F'_j(k)$$

In the case of calculation of single-sided power spectrum (it is calculated in the WinPOS) and using the weighting windows it is necessary to introduce correction factors:

$G'_{PS}(k) = 2 \cdot K_n \cdot G_{PS}(k) / K_{cpgf}$, where 2 - indicates that we calculate single-sided power spectrum,

$K_n = 1$ for effective values, $K_n = 2$ for peak values,

K_{cpgf} - the coefficient of coherent gain of power (equal to the square of the coefficient of coherent gain), depends on the choice of weighting function (see table above).

Power spectrum density

PSD. Characteristic is determined by averaging over M realizations and has a dimension of (*units*²/Hz): $G_{PSD}(k) = \frac{1}{\Delta f} \cdot G_{PS}(k)$

For single-sided amplitude spectrum and in the case of the application of weighting windows:

$$G'_{PSD}(k) = \frac{G'_{PS}(k)}{\Delta f \cdot \beta} \text{ where } \beta - \text{ENB: correction factor associated with the use}$$

of weight functions is taken into account automatically, Δf - sampling frequency.

Energy spectrum density

ESD. Characteristic is determined by averaging over M realizations and has a dimension of (*units*² s/Hz):

$$G_{ESD}(k) = \frac{1}{M} \cdot \sum_{j=0}^M G_{ESDj}(k) = \frac{1}{M} \cdot \sum_{j=0}^M G_{PSDj}(k) \cdot T = G_{PSD}(k) \cdot T$$

For single-sided amplitude spectrum and in the case of the application of weighting windows:

$G'_{ESD}(k) = G'_{PSD}(k) \cdot T$. Herein and after T - observation interval.

Complex spectrum, the module and phase

Spectrum, calculated as the complex value can be represented in one of two forms:

- of real and imaginary parts (**Real and Imag**):

$$\operatorname{Re} F(k) = \frac{1}{M} \cdot \sum_{j=0}^M \operatorname{Re} F_j(k) = \frac{1}{M} \cdot \frac{1}{N} \cdot \sum_{j=0}^M \operatorname{Re} F'_j(k)$$

$$\operatorname{Im} F(k) = \frac{1}{M} \cdot \sum_{j=0}^M \operatorname{Im} F_j(k) = \frac{1}{M} \cdot \frac{1}{N} \cdot \sum_{j=0}^M \operatorname{Im} F'_j(k)$$

- module (amplitude) and phase (**Mod. and Phase**):

$$\operatorname{Mod} F(k) = |F(k)| = \sqrt{(\operatorname{Re} F(k))^2 + (\operatorname{Im} F(k))^2}$$

$$\operatorname{Fas} F(k) = \operatorname{arctg}\left(\frac{\operatorname{Im} F(k)}{\operatorname{Re} F(k)}\right)$$

Here, the phase – phase difference with the cosine function.

Method: Fast (FFT) or Discrete Fourier Transform (DFT).

Points – number of points (size of portion) by which the spectrum is calculated: 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384, 32768, 65536, 131072, 262144. Arbitrary for DFT.


Number of FFT portions - the number of portions for averaging. The maximum possible number of portions is set by default, depending on the selected number of FFT points, portions shifts and the data file size.


Portion shift - shift of the next portion start after calculation by the previous portion: $1, \frac{1}{4}N, \frac{1}{2}N, \frac{3}{4}N, N$, where N - number of FFT points.

Weighting window: rectangular, triangular, Hanning, Hanning (RMS), Blackman, Blackman (RMS), FLAT-TOP, FLAT-TOP (RMS).

Values: effective (*RMS*), amplitude: (*Peak, Peak-Peak*). The values are averaged, unless *Max.values* option is used.

Centering – removing the constant component of the signal.

Logarithm – The “Taking the logarithm” algorithm will be applied to the result (see below Fig. 9.16). Click  button on the right of the logarithm parameter field to modify the factor (10 or 20) and to enter a reference value.

Transformation – The “Spectrum Transformation” algorithm will be applied to the result (see below Fig. 9.17). Click the  button on the right of the transformation parameter field to modify the parameters.

Zero filling – Allowance for calculation of the signals with the length smaller than the number of FFT points. It can help to eliminate the uncertainties conditioned by the presence of signal narrow band components.

Time on X axis - is accessible, if a three-dimensional spectrum is calculated (the option 3D is chosen). If this option is switched, then time will be put along the X axis of the resultant three-dimensional spectrum, and on Z axis – a frequency.

3D – the spectrums calculated by portions are not averaged but put along the Z axis. The number of FFT portions is the resulting ‘depth’ by Z axis. See the 3D spectrum section below. The Z axis is digitized in seconds, showing the start time of another portion. Here the number of FFT portions determines the dimension of the result along the Z. For a number of signals the three-dimensional spectrum gives a more complete and clear pattern of the processes.

In the cursor mode (see Section 6. *Signals viewing*) the projection of the three-dimensional spectrum allows to analyze in detail the parts of the spectrum. *Section Z* is a conventional two-dimensional spectrum for the portions with an offset equal to Z (listed at the top of the graph). *Section X* shows the amplitude dependence on time for a fixed frequency (see line “X=...” at the top of the graph).

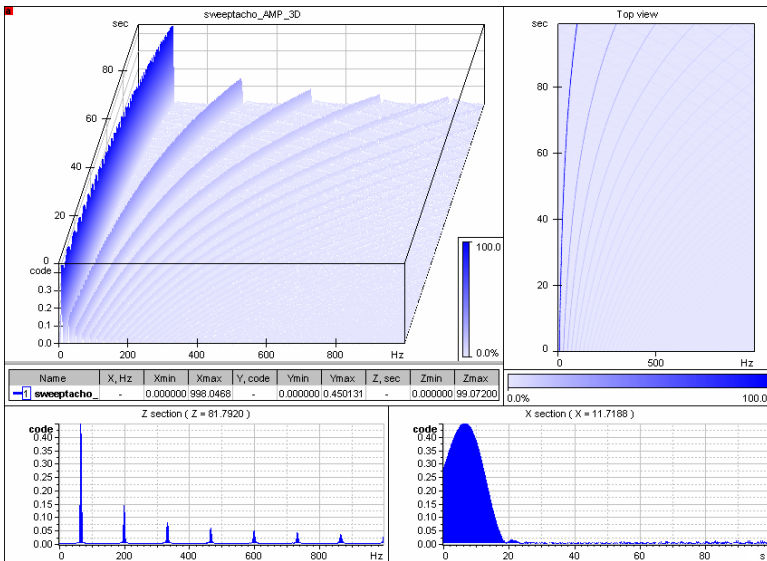


Fig. 9.7. The three-dimensional amplitude spectrum calculation result

Octave spectrum

For calculation of the octave, third-octave, 1/12 - and 1/24-octave spectrum, select the **characteristics**, as well as one of the two **methods** of calculation.

Band-pass filters. The method is based on the use of recursive filtering, and is implemented by the classical scheme: bandpass filter - quadratic detector – integrator. The basis of the scheme is the mathematical definition of the power

spectrum. In this scheme, a bandpass filter selects the spectral components lying in the required band, then the filtered signal is squared and averaged. To obtain a normalized spectrum, the result is divided by the bandwidth of the current octaves or fractions of octaves.

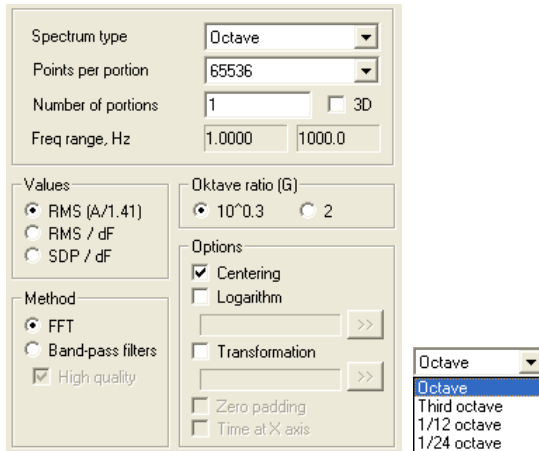


Fig. 9.8. Octave spectrum

Thus, for example, the third-octave power spectrum is calculated according to the formula:

$$A_{1/3}(f_0) = \frac{1}{T} \cdot \int_{\pi} L(X(t))^2 dt = \frac{1}{T} \cdot \int_{f_0 - (1/6)_{oct}}^{f_0 + (1/6)_{oct}} A^2(f) df$$

where: T - period of analysis;

$X(t)$ – input signal;

$L(X(t))$ - band-pass recursive filter operator.

The recursive filtering algorithms are applied here due to the fact that they are the most adequate procedures of the analysis with the same relative width of the elementary band. For the third-octave analysis the ratio of the left and right elementary band boundaries is $2^{1/3}$.

The frequency response of the filter and the deviation of effective bandwidth from the nominal should correspond to GOST 17186-82. Filters used in WinPOS meet the first class of accuracy according to GOST 17186-82 (filters for accurate laboratory or field measurements).

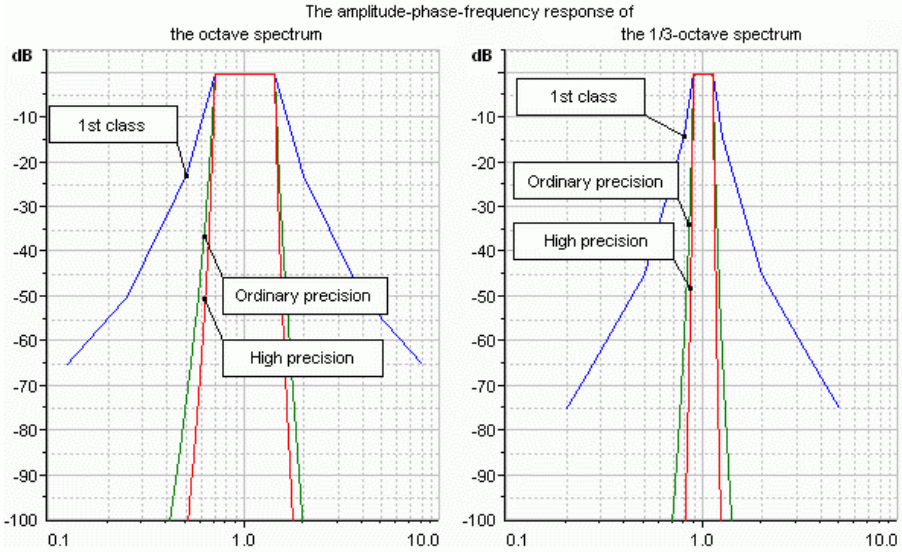


Fig. 9.9. Frequency responses for octave and third octave filters in WinPOS and for first class filters

Figure 9.9 shows the frequency response for octave and third octave filters in WinPOS and first class filters according to GOST 17168-82 (see table 9.2).

Octave filter, 1 st accuracy class		Third octave filter, 1 st accuracy class	
Relative frequency, f / f_m	Decay, dB	Relative frequency, f / f_m	Decay, dB
0.125	< -65	0.2	< -75.0
0.25	< -50	0.25	< -68.0
0.5	< -23	0.5	< -45.0
0.7071	-6.0 .. 0.5	0.7937	< -14.0
0.8409	-1.0 .. 0.5	0.8909	-6.0 .. 0.5
1.0000	-1.0 .. 0.5	0.9439	-1.0 .. 0.5
1.1892	-1.0 .. 0.5	1.0000	-0.5 .. 0.5
1.4142	-6.0 .. 0.5	1.0595	-1.0 .. 0.5
2	< -23	1.1225	-6.0 .. 0.5
4	< -50	1.2599	< -14.0
8	< -65	2	< -45.0
		4	< -68.0
		5	< -75.0

Table 9.2 First accuracy class filters parameters according to GOST 17168-82

Filter	Nominal value	Deviation of effective bandwidth, %			
		GOST 17168-82		Normal accuracy	High accuracy
		1 st class	2 nd class		
Octave	0.7071	8	10	18.3	5.1

third octave	0.2316	8	10	20.1	4.0
1/12-octave	0.0576	8	10	7.4	4.9

Table 9.3 Deviation of effective bandwidth

Table 9.3 shows the deviation of the effective bandwidth from the nominal bandwidth. The values given for filters with maximum errors.

The fast Fourier transform. The method is implemented based on the FFT, described above. In this case, the requirements of GOST are not fully met, due to the smaller steepness of the filters. 1/24-octave spectrum is calculated through FFT only.

Figure 9.10 shows the dependence of the results from the selected method.

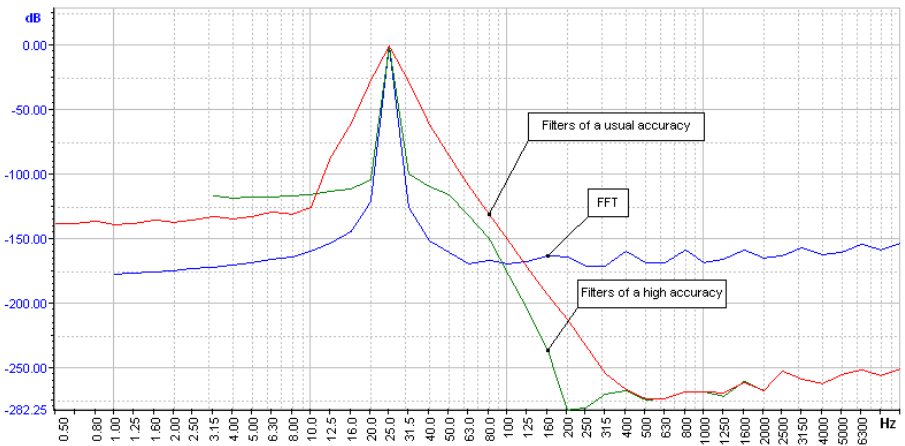


Fig. 9.10. Third-octave logarithmic spectra of the sine with a frequency of 25 Hz, calculated by different methods

In most cases it is recommended to use the FFT method in the calculation of the octave spectra. Calculation using FFT runs much faster than filtering and does not require a large amount of raw data and provides high accuracy (of the order of -160 dB) in entire frequency range. Filtration method with high precision filters is useful if you need to obtain maximum precision in the high frequencies and the original signal has a greater length. The longer the original signal is, the wider the frequency range, which ensures high accuracy (of the order of -250 dB). Filters with normal accuracy allows to calculate the spectrum of the signal with shorter length, provide the same precision as the high-precision filters in high frequencies, and they have a flatter frequency response. Filters of usual accuracy allow to obtain the values of the spectrum in the low frequency region, the greater the length of the original signal, the further in the low frequency area expands the frequency range of the spectrum.

Central and boundary frequencies

The center frequencies are calculated by the following formulas:

for octave and third octave spectra: $f_m = G^{xb} * f_r$,

for 1/12- and 1/24-octave spectra: $f_m = G^{(2x+1)/2b} * f_r$, where

G - octave coefficient (equal to 2 or 1.995, depending on settings),

f_r - reference frequency, 1000 Hz, b – fraction of octave filter (1, 3, 12 or 24, respectively), x - number of octaves or fractions of octaves

The boundary frequencies are calculated by the formulas:

$$f_1 = G^{-1/2b} * f_m, f_2 = G^{+1/2b} * f_m$$

It should be remembered that the range of the analyzed frequencies limited by the Nyquist frequency (Fs/2). So for Fs = 1 kHz, we gain range up to 450 Hz (see table 9.4).

Octave	1/3-octave	Octave	1/3-octave	Octave	1/3-octave
125000	160000	500	630	2	2.5
	125000		500		2
	100000		400		1.6
63000	80000	250	315	1	1.25
	63000		250		1
	50000		200		0.8
31500	40000	125	160	0.5	0.63
	31500		125		0.5
	25000		100		0.4
16000	20000	63	80	0.25	0.315
	16000		63		0.25
	12500		50		0.2
8000	10000	31.5	40	0.125	0.16
	8000		31.5		0.125
	6300		50		0.1
4000	5000	16	20	0.063	0.08
	4000		16		0.063
	3150		12.5		0.05
2000	2500	8	10	0.0315	0.04
	2000		8		0.0315
	1600		6.3		0.025
1000	1250	4	5		
	1000		4		
	800		3.15		

Table 9.4 Center frequencies of octave and third octave spectra

Other settings:

FFT portions – the number of portions the spectrum will be averaged by. A maximum practicable value is set by default.

3D – the spectrums calculated by portions are not averaged but put along the Z axis. The number of FFT portions is the resulting ‘depth’ by Z axis. See the 3D spectrum section below.

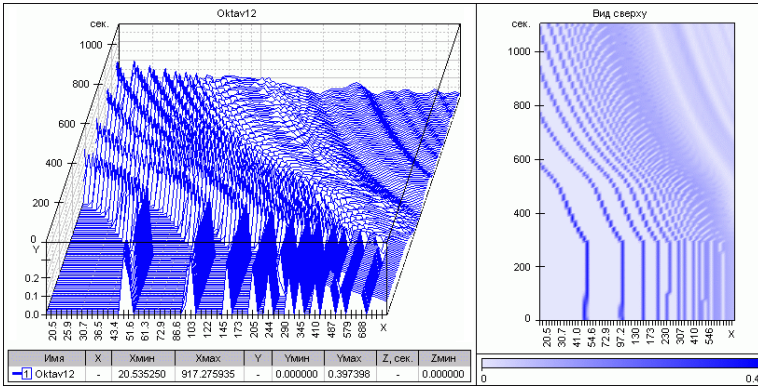


Fig.9.11. 3D 1/12-octave spectrum calculation result

Values – A result type is set: RMS, RMS-to-bandwidth ratio, power-to-bandwidth ratio.

High quality – available only for calculation applying the filtration method; in this case the band-pass filters of a higher order are used.

Octave ratio (G) – a coefficient used for calculating octave boundaries or an octave portion.

Other settings are the same as for Auto-spectrum

Cross spectrum

The cross-spectral characteristics of the input processes $a(t)$ and $b(t)$ are determined from the complex instantaneous spectra $A(f)$ and $B(f)$ and cross-spectrum $G_{AB}(f)$.

$$A(f) = \int_0^T a(t) \cdot \exp\{-j2\pi f t\} dt; \quad B(f) = \int_0^T b(t) \cdot \exp\{-j2\pi f t\} dt$$

In discrete form :

$$A(k) = \left(\sum_{n=0}^{N-1} a_n \cdot \exp\left\{-j \cdot \frac{2\pi kn}{N}\right\} \right) \cdot \Delta t = \frac{1}{F_{omp}} \cdot A_{omp}(k); \quad B(k) = \frac{1}{F_{omp}} \cdot B_{omp}(k)$$

Cross-spectrum is determined on the basis of the instantaneous spectra $A(f)$ and $B(f)$ and is given by the expression:

$$S_{AB}(k) = A^*(k) \cdot B(k), \text{ where “}^* \text{” is the sign of complex conjugation.}$$

The relationship between single-sided and double-sided characteristics is set by the ratio:

$$G_{AB}(f) = \begin{cases} 2 \cdot S_{AB}(f), \text{ для } f > 0 \\ S_{AB}(f), \text{ для } f = 0 \\ 0, \text{ для } f < 0 \end{cases}$$

Similarly, for autospectra $G_{AA}(f)$ and $G_{BB}(f)$, where $S_{AA}(k) = A^*(k) \cdot A(k)$ and $S_{BB}(k) = B^*(k) \cdot B(k)$.

Select the **characteristic** and set the other parameters, referring Autospectrum.

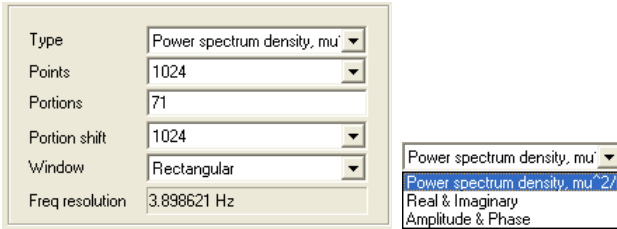


Fig. 9.12. Cross spectrum

Cross power spectrum density

PSD. The dimension of the result: $unit^2/Hz$.

$$G_{psdAB}(k) = \frac{1}{T} \cdot |G_{AB}(k)|$$

In the case of use of weighting windows it is necessary to introduce correction factors, and the formula would be:

$$G'_{psdAB}(k) = G_{psdAB}(k) / (K_{cpgf} \cdot \beta)$$

where: K_{cpgf} - the ratio of the coherent signal gain by power;

β - ENB.

Complex spectrum, the module and phase

Spectrum, calculated as the complex value can be represented in one of two forms:

- of real and imaginary parts (**Real and Imag**):

$$Re G_{AB}(k) = \frac{2}{M} \cdot \sum_{j=0}^M Re(S_{ABj}(k))$$

$$Im G_{AB}(k) = \frac{2}{M} \cdot \sum_{j=0}^M Im(S_{ABj}(k))$$

- module (amplitude) and phase (**Mod. and Phase**):

$$Mod G_{AB}(k) = |2 \cdot S_{AB}(k)|,$$

$$Fas G_{AB}(k) = arctg \left(\frac{Im S_{AB}(k)}{Re S_{AB}(k)} \right)$$

Complex spectrum

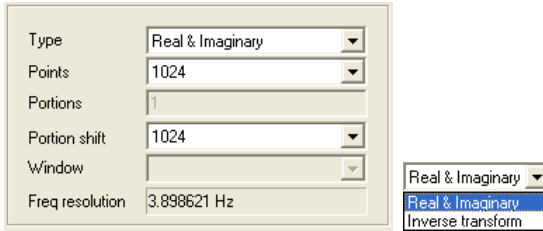


Fig. 9.13. Cross complex spectrum

Select characteristics: **Real** and **Imag**, or the inverse transformation. Set the remaining options, referring Autospectrum.

Coherence function

The coherence function is used to determine the degree of linear relationship between signals at input and output. Select the **characteristics** and set the other parameters, referring Auto-spectrum.

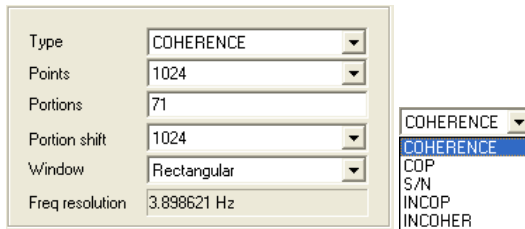


Fig. 9.14. Coherence function

Coherence

COHERENCE. The coherence function $v^2(k)$ shows in the frequency domain on a scale from 0 to 1 a quantitative measure of linear dependence inherent to individual values at the frequency f of two processes (signals) $a(t)$ and $b(t)$. The coherence function is determined on the basis of eigen spectra and cross-spectrum of the considered signals according to the formula:

$$v^2(k) = \frac{|G_{AB}(k)|^2}{G_{AA}(k) \cdot G_{BB}(k)},$$

Inherent to separate frequency values $f(k)$ values of the coherence function $v^2(k)$ are correspond to the squared values of the correlation coefficient.

Note: the coherence function is based on the undergone the averaging functions, in the case of a single isolated assessment is equal to the unit value.

The coherence function $v^2(k)$ values can be negative for the following reasons:

- 1) presence of uncorrelated noise in the signal $a(t)$ and/or $b(t)$;
- 2) nonlinear coupling between the signals $a(t)$ and $b(t)$;
- 3) leakage due to insufficient resolution and/or using of non-optimal weighing functions (a special kind of nonlinearity caused by the analysis procedure);
- 4) the time delay between the signals $a(t)$ and $b(t)$, commensurate with the duration of these signals.

Applications of the coherence function

The coherence function is used when checking the validity of other functions and in determining influence of noise and/or nonlinearities of these functions.

Note: small values of the coherence function does not always indicate the invalidity of the functions being defined, and in some cases they are a sign of the need to increase the number of cycles of averaging to ensure valid results.

Incoherence

NOTCOHER. Defined by: $1 - \nu^2(k)$.

Coherent output power

COP. Determined on the basis of the coherence function and displays the part of measured spectrum of (output) signal $G_{BB}(k)$ which is completely coherent with a certain (input) signal represented by the function $a(t)$ and a spectrum $G_{AA}(k)$. The mathematical expression of the characteristics has the form: $COP(k) = \nu^2(k) \cdot G_{BB}(k)$.

Note: at small values of the coherence function COP is valid only in the case when the decrease of coherence is due only to superimposed on the output signal noise.

Incoherent output power

NOTCOP. Defined by: $NCOP(k) = (1 - \nu^2(k)) \cdot G_{BB}(k)$

If the only factor affecting the degree of coherence is the noise imposed on the output then the coherent output power (proportional to $\nu^2(k)$) displays "signal at output", while the non-coherent output power (proportional to $1 - \nu^2(k)$) displays the "noise at output".

Signal-to-noise ratio

S/N. Determined on the basis of the coherence function according to the formula:

$$\frac{S}{N}(k) = \frac{\nu^2(k)}{1 - \nu^2(k)}$$

Transfer function

The transfer function shows in the frequency domain the ratio of the magnitudes of the output values to the values at the input of the different systems and, therefore, completely characterizes the stable, linear, time-invariant physical systems (mechanical, acoustic, and electric).

Based on the results of simultaneous measurements and based on FFT signals analysis at the input and output of the physical system it is possible to identify two differ from each other complex frequency characteristics of the system, i.e.

$$H_1(k) = \frac{S_{AB}(k)}{S_{AA}(k)} \quad \text{and} \quad H_2(k) = \frac{S_{BB}(k)}{S_{BA}(k)}$$

where $a(t)$ – input signal, $b(t)$ – output signal.

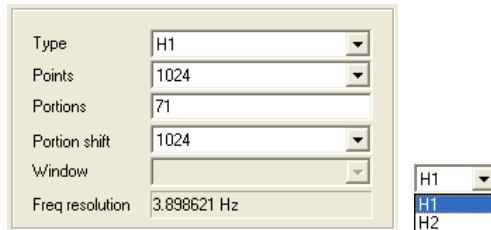


Fig. 9.15. Transfer function

Choose characteristic (H_1 or H_2). Set the other parameters, referring Auto-spectrum.

Recommendations for use

1. In the presence of parasitic (non-correlated) noise at the output or several independent from each other signals at the input, it is advisable to use the estimate $H_1(k)$ as the optimal approximations of the frequency characteristics of the corresponding system.
2. In the presence of parasitic (non-correlated) noise at the input use $H_2(k)$ as the optimal approximations of the frequency characteristics of the corresponding system.
3. In cases of difficulties associated with leakage (due to insufficient resolution frequency) in the areas of the resonances preference is given to the evaluation of $H_2(k)$, approximating the frequency response of the system more accurately than the estimate $H_1(k)$.

In the areas of antiresonances of the system under study, which does not exclude the presence of noise on the output, normally it is advisable to use the $H_1(k)$ estimation

while the application of evaluation $H_2(k)$ is generally useful in the areas of the resonances, where not excluded difficulties due to input noise and/or leak .

In situations where spurious (uncorrelated) noise is present on the input and output of the system under study, and the leak is not the cause of large systematic errors, estimates of $|H_1(k)|$ and $|H_2(k)|$ can be used respectively for lower and upper limits of the interval which contains the true values of the modulus of the frequency characteristic $|H(k)|$.

Taking the logarithm

Taking the logarithm is performed by the formula:

$$U_{lg} = k \cdot \log_{10}\left(\frac{U}{U_{ref}}\right)$$

Here k is the factor taking one of two values (10 or 20) depending on characteristics (e.g.,for amplitude spectrum, this ratio is equal to 20, for the power spectrum to 10). Set in the "logarithm" field . U_{ref} is a **reference value** that can be set manually or using the **maximum** value logarithmorum signal.

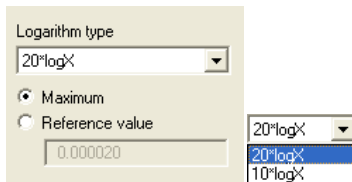


Fig. 9.16. Taking the logarithm

Spectrum transformation

Select conversion type: 1 – no transformation, $\frac{1}{\omega}$ – integration, $\frac{1}{\omega^2}$ – double integration, $\frac{2\sqrt{2}}{\omega^2}$ – the transition from acceleration spectrum to displacement spectrum, $1 \cdot \omega$ - single differentiation, $1 \cdot \omega^2$ - double differentiation.

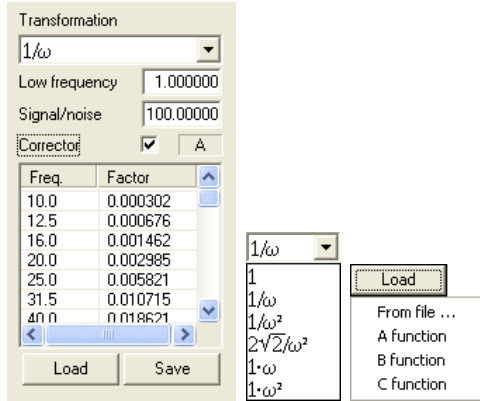


Fig. 9.17. Spectrum transformation

Lower frequency and Signal/noise - HPF settings.

The spectrum values can be multiplied by a correction function. Function is specified by pairs of numbers: frequency and the corresponding amplitude multiplication factor. To use correction function select **Corrector** field.

For enter frequencies and coefficients from the keyboard activate the table cell by double-clicking, enter the number and press <Enter>. To insert and delete rows, use <Ins> and keys. In order to save specified characteristics in the file, click **Save** and select the file in the standard save dialog.

To load functions from disk, click **Load**, select the menu item **From file...** and specify the file. To load frequency (acoustic) characteristics for the third-octave spectrum click the **Load** and choose the option A, B or C (see [4] and [6]).

Characteristics are stored in CSV (Common Separated Values) files. You can open the file in MS Excel or as a text file.

Recursive filtering

Recursive filtering is based on the sequential use of canonical units of the second order.

$$Y_n = B_0 \cdot Y_{n-2} + B_1 \cdot Y_{n-1} + A_0 \cdot X_{n-2} + A_1 \cdot X_{n-1} + A_2 \cdot X_n$$
, where: Y_n - the filtered array, X_n - the input array, B_0 , B_1 , A_0 , A_1 , A_2 - coefficients of the filter, calculated in accordance with the specified characteristics.

The transfer function for a recursive link has the form

:

$$H(Z) = \frac{A_0 \cdot Z^{-2} + A_1 \cdot Z^{-1} + A_2}{B_0 \cdot Z^{-2} + B_1 \cdot Z^{-1} + 1}$$

To avoid transients of long duration processes you are advised to fulfill the condition:

$$2 < \frac{F_s}{F_{cp}} < 100 \quad , \text{ where } F_{cp} - \text{filters cutting frequency, } F_s - \text{ sampling rate.}$$

Thus, for example, the filter of the 12th order will have no more than 700 counts of the transition process.

If, for example $2 < \frac{F_s}{F_{cp}} < 50$, it is possible to ensure that the maximum duration of the transitional process not more than 350 counts.

Type of approximation: Butterworth, Chebyshev or elliptic characteristics.

Filter type: high-pass filter, band-pass or low-pass filter.

Filter order defines the slope – the rate of decline in frequency response during the transition from the passband to the band suppression. The higher the filter order, the better formed his bandwidth and therefore the lower the amount of unwanted components of the input signal at its output.

To ensure the best ratio quality-performance, it is recommended to apply the following filters:

- elliptic filter of the sixth order (provides attenuation at twice the cutoff frequency of no less than 65 dB);
- Chebyshev sixth order (provides attenuation at twice the cutoff frequency of no less than 60 dB);
- Butterworths filter of eight order (provides attenuation at twice the cutoff frequency of no less than 55 dB).

All of these filters satisfy to requirements for class 1 filters (filters for accurate laboratory and field measurements) in accordance with GOST 17168-82.

To check the quality of the required characteristics you can obtain amplitude-frequency and phase-frequency characteristics of synthesized filter in the frequency range:

$$0 < F < 2 \cdot F_c \quad \text{for LP filter;}$$

$$F_n/2 < F < 2 \cdot F_v \quad \text{for bandpass filter;}$$

$$F_c/2 < F < 2 \cdot F_c \quad \text{for HP filter,}$$

where F_c - cutoff frequency for the LF, RF filters, F_n , F_v - upper and lower cutoff frequencies for a bandpass filter.

Cutoff frequency - the cutoff frequency of the filter by -3 dB level. The top - to the low-pass filter, the lower one for the HPF. For a bandpass filter set both frequencies.

Flatness in the passband - maximum amplitude of the unevenness of the filter.

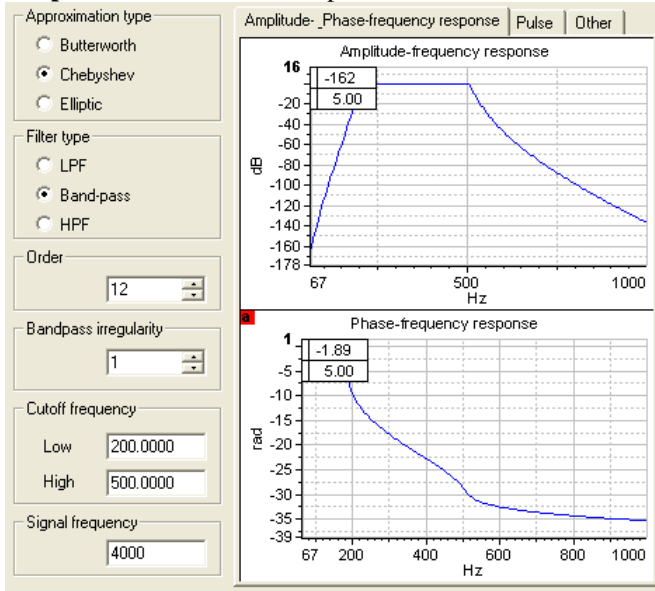


Fig. 9.18. Recursive filtering

Sampling frequency. By default the sampling frequency of the input signal is used.

In the central part of the filter parameters settings window displayed the graphs of amplitude-frequency, phase and pulse (*Pulse* tab) characteristics based on the parameters set. Changing the type of filter or approximation is immediately reflected in the graphs of characteristics. For updating graphs after changing the numerical characteristics click the **Apply** button.

Non-recursive filtering

Type of approximation - Fourier series.

Filter type: ФВЧ – high-pass filter, low-pass filter or nothing.

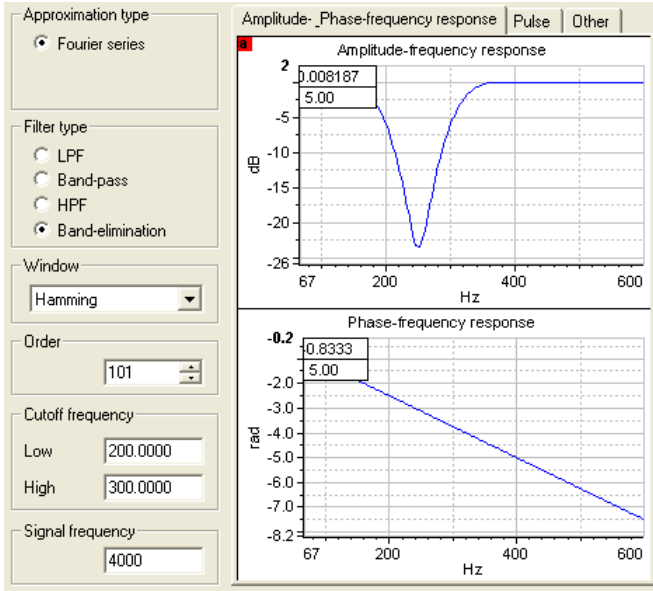


Fig. 9.19. Non-recursive filtering

Weighting window for Fourier transform: Hamming or Hann.

Filter order defines the slope – the rate of decline in frequency response during the transition from the passband to the band suppression. The higher the filter order, the better formed his bandwidth and therefore the lower the amount of unwanted components of the input signal at its output.

Cutoff frequency - the cutoff frequency of the filter by -3 dB level. The top - to the low-pass filter, the lower one for the HPF. For a bandpass and notch filter set both frequencies.

Sampling frequency. By default the sampling frequency of the input signal is used.

In the central part of the filter parameters settings window displayed the graphs of amplitude-frequency, phase and pulse (*Pulse* tab) characteristics based on the parameters set. Changing the type of filter or approximation is immediately reflected in the graphs of characteristics. For updating fraphs after changing the numerical characteristics click the **Apply** button.

Median filtering

The median filter suppresses the pulse noise, the duration of which is less than half the width of the aperture.

Filter type

Discrete
 Analog

Options

Points: 5
Threshold: 1.00

Levels

Low: 0.00
High: 0.00

Automatic determination

Fig. 9.20.

Specify the **number of points** – width of the filter aperture (can only take odd values), select a filter type.

Discrete filter

This filter can work only with signals that have two distinct states, e.g., "0" and "1" such as control signals. Designed for cleaning command signals from random noise and the characteristic features, such as "contact bounce". Set the **upper** and **lower levels** manually or select the checkbox "**define automatically**". The **threshold** determines the range of possible variations within the same level.

Analog filter

Used mostly to keep out of the points of impulse noise. Often used for primary filtration of strain gauges channels signals. A specified number of consecutive signal points is sorted, then selected the mean by ordinal number value (the value of $N/2+1$, where N is the width of the aperture), called the median. If the median differs from the original signal value at a given point by more than the threshold value, the corresponding point of the resulting signal will be recorded with the median value, otherwise the value of the original signal. The filter window is shifted by one position towards the end of the signal and the process repeats. For the analog filter the **threshold** specifies the allowable deviation of the signal values from its median, (does not replace the values with the median).

Hilbert Transform

FFT points: 1024
FFT portions: 94
Centering:

Fig. 9.21. Hilbert Transform

To obtain the Hilbert transformant direct and inverse fast Fourier transform (FFT) are used. For the input array the direct Fourier transform is used:

$$F(k) = \frac{1}{N} \cdot \sum_{n=0}^{N-1} f(n) \cdot \exp\left\{-j \cdot \frac{2 \cdot \pi \cdot k \cdot n}{N}\right\}$$

The resulting spectrum is transformed to the:

$$Z(k) = \begin{cases} 2 \cdot F(k), & \text{для } k=1, \dots, N/2-1; \\ F(k), & \text{для } k=0; \\ 0, & \text{для } k=N/2, \dots, N-1 \end{cases}$$

By inverse Fourier transform of the spectrum $Z(k)$ get the analytical signal: $z(n) = f(n) + j \cdot \tilde{f}(n)$, where $\tilde{f}(n)$ is the Hilbert transformant of input signal $f(n)$.

Set N - the **number of FFT points**. If the **number of FFT portions** is greater than 1, the original signal is divided into consecutive blocks of length N and the calculation is repeated specified number of times. For eliminating the constant component, check the box **Centering**.

Envelope

Select one of the two methods of the envelope calculating.

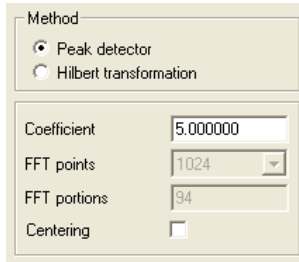


Fig. 9.22. Envelope

The peak detector

To obtain reliable results, the original signal must be narrowband and **centered**. The algorithm for computing the envelope in digital form:

$$y'_n = y_{n-1} + \frac{|x_n| - y_{n-1}}{K}$$

where $K=RC/\Delta t$ – "RC" is the averaging **coefficient** that defines the "time constant",

$$y_n = \begin{cases} y'_n, & \text{npu } y'_n > x_n \\ x_n, & \text{npu } y'_n \leq x_n \end{cases}$$

Δt - sampling time

Hilbert Transform

The formula for calculating the envelope:

$|z(n)| = \sqrt{f^2 + \tilde{f}^2(n)}$, where $\tilde{f}(n)$ is the Hilbert transform of input signal $f(n)$.

Envelope calculation settings are similar to the Hilbert transform settings.

Differentiation

Select one of the two methods of numerical differentiation.

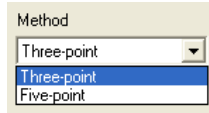


Fig. 9.23. Differentiation

Three-point

The first derivative is calculated by the formula:

$$Y'_n = \frac{1}{2 \cdot \Delta x} \cdot (Y_{n+1} - Y_{n-1})$$

Five-point

The formula for the first derivative:

$$Y'_n = \frac{1}{12 \cdot \Delta x} \cdot [(Y_{n-2} - Y_{n+2}) - 8 \cdot (Y_{n-1} - Y_{n+1})]$$

Integration

Select one of four methods of Cauchy problem numerical solution, i.e., integrating the differential equation of the first order: $y' = f(x, y)$

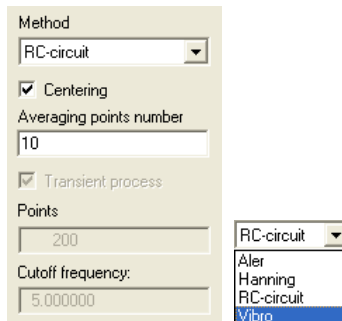


Fig. 9.24. Integration

Euler's Method

Is step-by-step application of the formula of the third order:

$$y_{n+1} = y_n + 0.5 \cdot (3 \cdot f_n - f_{n-1}) \cdot \Delta x$$

Hamming method

Without modification (formula of the fourth order) with the calculation of the first three points on the Euler formulas:

$$y_{n+1}^{pred} = y_{n-3} + \frac{4}{3} \cdot (2 \cdot f_n - f_{n-1} + 2 \cdot f_{n-2}) \cdot \Delta x$$

$$y_{n+1}^{corr} = \frac{1}{8} \cdot (9 \cdot y_n - y_{n-2}) + \frac{3}{8} \cdot (f_{n+1} + 2 \cdot f_n - 2 \cdot f_{n-1}) \cdot \Delta x$$

$$y_{n+1} = y_{n+1}^{corr} - \frac{9}{121} \cdot (y_{n+1}^{corr} - y_{n+1}^{pred})$$

The first two methods, being the best approximation of the ideal integrator that significantly raise (amplify) the signal at low frequencies, and therefore the solution of practical problems is hardly applicable. Greatest practical importance are the following two methods.

RC-chain

The numerical analogue of the RC circuit (low pass filter of the 1st order). Given by the formula: $y_{n+1} = y_n - y_n/M + f_{n+1} \cdot \Delta x$, where M is the **number of averaging points** for the RC-chain. To determine the number of averaging points you can use the following formulas: $M = F_s / (2\pi F_b)$ or $M = RC / \Delta t$, where: F_s - sampling frequency, F_b is the cutoff frequency of the equivalent low-pass filter, the RC - constant of the RC-chain, Δt is the sampling period.

Since the bass effect, although much weaker, is in this case, it is necessary to use an HF filter.

Vibro

This method uses the RC-chain, but first performs high-frequency filtering in a given band of frequencies, which allows to adapt the algorithm to the conditions of vibrations measurement. Select the HPF _____ **cutoff frequency**. To suppress the **transition process**, specify the **number of points**.

Another problem is minimizing the error of the method. The greatest contribution make the low and high frequencies (see Fig. 9.25).

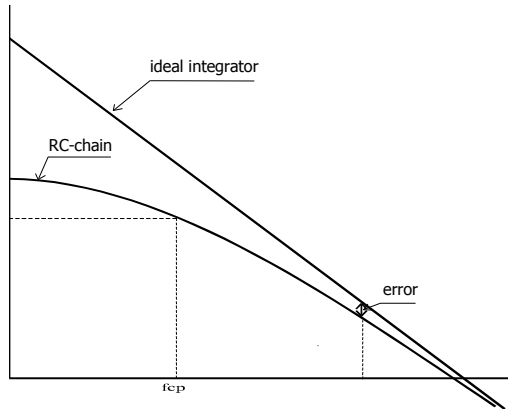


Fig. 9.25. The frequency response of an ideal integrator and an RC circuit

The problem is solved by excluding from the analysis those areas which have the greatest errors

- for low frequencies: if $F_{cp} = F_n/6$, (where F_{cp} - cut-off frequency; F_n is the lower frequency of the analyzed frequency range), the error will be $<1,5\%$;
- at high frequencies, it makes sense to use the results of integration up to a frequency of $F = F_s/6$ where F_s is the sampling frequency.

The third problem is related to the phase characteristics of the RC circuit that has a nonlinear dependence on frequency. In this case, it is necessary to introduce corrective phase-frequency function, which is experimentally determined.

For example, $F_s = 2000$ Hz and $F_n = 10$ Hz – $F_{cp} \approx 1.7$ Hz; $F \approx 333.3$ Hz; number of averaging points $M \approx 180$

For eliminating the constant component, check the box **Centering**.

Calculation of the definite integral

Calculation of the definite integral is produced in the double-cursor. Include area calculation in the advanced settings of the cursor (see Fig. 6.9).

To calculate the definite integral within the specified limits the trapezium method is used:

$$S = 0.5 \cdot Y_0 + \sum_{n=1}^{N-2} Y_n + 0.5 \cdot Y_{N-1}$$

Normalization

The signal normalization is performed in cases where it is necessary that the resultant values of the signal has changed within the specified limits.

Set the **minimum** and **maximum** - limit values of the result

Fig. 9.26. Normalization

Usually the normalization is a multiplication of each value of the signal at a certain coefficient so that signal values do not exceed given values:

$$Y_i^{nor} = \frac{Y_0}{Y_{max}} \cdot Y_i, \text{ where: } Y_0 \text{ is the given (required) the maximum value; } Y_{max} -$$

the maximum measured value; Y_i – the current value of the signal. However, if you **allow the shift** then the signal will be shifted to fill entire range.

Cross-correlation

The cross-correlation function expresses the degree of statistical relationship between two signals based on their mutual displacement (delay parameter) in the time domain. Evaluation of cross-correlation function is calculated by the formula:

$$K_{xy}(k) = \frac{1}{N-k} \cdot \sum_{j=1}^{N-k} x^o(j) \cdot y^o(j+k), k=0,1,2,\dots,m$$

where: $\{x^o(j)\}, \{y^o(j)\}$ – centered realization;

m – the maximum number of steps (**Number of points**).

In practice it is more convenient to use a normalized cross-correlation:

$$\rho_{xy}(k) = K_{xy}(k) / (\sigma_x \cdot \sigma_y),$$

where σ_x, σ_y - average quadratic deviation of the relevant processes.

Based on the Fourier transform and the convolution theorem we prove a relationship between a cross-correlation function $K_{xy}(k)$ and the cross-spectrum $S_{xy}(k)$: $K_{xy}(k) = F^{-1}\{S_{xy}(k)\}$.

Fig. 9.27. Cross-correlation

The practical application

a) Define the time delays

The cross correlation function $R_{ab}(\tau)$ of signals $a(t)$ and $b(t)$, recorded in the spread of the points A and B , has a peak whose position corresponds to the time delay τ , i.e. the time occupied by the propagation on the distance between the points A and B .

Note: it is assumed that the signals are broadband, and the propagation is not dispersive in nature (the speed of propagation is not frequency dependent). When the dispersive nature of the propagation of the signal you need to either limit the portion of the frequency range, assuming it constant velocity or use the cross-spectrum phase to determine the time delay $\tau_0(f)$:

$$\phi_{AB}(f) = 2\pi f \tau_0(f)$$

b) Identification of transfer paths

In the presence of multipath signal propagation between points A and B the cross correlation function $R_{ab}(\tau)$ of signals $a(t)$ and $b(t)$ recorded at these points is contains the corresponding number of peaks. The peaks associated with individual pathways are in the positions the delay values τ_n of which are correspond to the values held by transfer into separate tracks in n time. The amplitude of the mentioned peaks represent the relative quality of the respective paths.

Note: it is assumed that the signals are broadband, and the propagation is not dispersive in nature (the speed of propagation is not frequency dependent).

Often it is more appropriate instead of the real-type normalized autocorrelation function $\rho_{aa}(\tau)$ and normalized cross-correlation functions $\rho_{ab}(\tau)$ use envelopes (modules) of the corresponding analytical signals. The curve reflecting the module is smooth (maximums and minimums, often available in the initial characteristics, do not exist), so that is possible identification of peaks (due, for instance, reflections) and the correct definition of their amplitudes.

c) Detection of noise masked signals

In the case that the signals $a(t)$ and $b(t)$ contains a common signal $s(t)$, masked with noise, i.e. if $a(t)=s(t)+n(t)$ and $b(t)=s(t)+m(t)$ and the components $n(t)$ and $m(t)$ are uncorrelated with each other, then the cross correlation function $R_{ab}(t)$ only contains information about the correlated component $s(t)$ of signals $a(t)$ and $b(t)$ and has the form which is inherent to the autocorrelation function $R_{ss}(t)$ of signal $s(t)$, which do not contain uncorrelated noise components $n(t)$ and $m(t)$.

Autocorrelation

The autocorrelation function is a special case of cross-correlation function. To compute the correlation function of the random sequence having the properties of stationarity and ergodicity, the following formula is used:

$$K_x(k) = \frac{1}{N-k} \cdot \sum_{j=1}^{N-k} x^0(j) \cdot x^0(j+k), k= 0,1,2,\dots,m$$

where: $\{x^0(j)\}$ – centered realization;
 m – the maximum number of steps (**Number of points**).

In practice it is more convenient to use a normalized autocorrelation:

$$\rho_x(k) = K_x(k)/D_x \quad \text{where } D_x \text{ – is the variance.}$$

Based on the Fourier transform and the convolution theorem we prove a relationship between a cross-correlation function $K_x(k)$ and the spectrum $S_x(k)$: $K_x(k) = F^{-1}\{ S_x(k)\}$.

The practical application

a) Detection of echoes (reflections) in the signals

In the case that the signal $a(t)$ contains the echo with τ_0 time delay, then the autocorrelation function $R_{aa}(t)$ of this signal has a peak $\tau = \tau_0$ near the peak for $\tau = \tau_0$.

In addition, the value $\rho_{aa}(\tau_0)$ displays the intensity of the echo. This applies to broadband signals with the width of the frequency band sufficient to ensure a narrow and separated from each other peaks of the autocorrelation function.

b) Detection of periodic signals in the noise

The autocorrelation function of a periodic signal is always a periodic function. Masking noise (noise background) is usually a random signal with the amplitude of the autocorrelation function decreases with increasing of time delay and after a certain time takes zero value. Therefore, the autocorrelation function can be using to detect a periodic signal after a time necessary for the noise disappearance.

Note:

1. The amplitude of the normalized autocorrelation function of the broadband random signal (noise) decreases rapidly to zero in accordance with the so-called law of uncertainty functions related via the Fourier transform. This law establishes a relationship between the bandwidth Δf of eigen spectrum $G_{AA}(f)$ and duration Δt of corresponding autocorrelation function $R_{aa}(t)$ in the form: $\Delta f \cdot \Delta t \geq 1$.

2. To detect the periodic signal containing several frequency components, it is often more advisable to use the eigen spectrum instead the autocorrelation function. On the basis of eigen spectrum can be defined as the frequencies as the amplitudes of the individual components which were masked by noise of periodic signal. However, if the amplitudes of these components are small in comparison with the level of the masking signal (noise background), it is necessary to perform analysis with increased frequency.

Arithmetic operations

To perform the simplest arithmetic operations:

- check th **Operation type**,
- select an operation from the drop-down list,

when choosing the operations on values of one signal enter the number in the **Constant** field

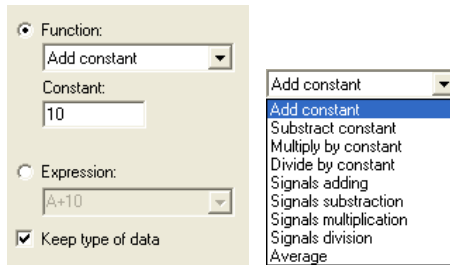


Fig. 9.28. Arithmetic operations

Operations with buffers are performed over the pairs of selected signals values o . If the time scales of the signals does not coincides, then for each value of the first signal the interpolated at the same time value of the second signal is taken (linear interpolation).

More complex operation on the values of signals can be performed by writing the expression.

- check **Expression**,
- enter arithmetic expression in the VBS (Visual Basic Script) syntax or select from the drop down list of previously typed expression.

The expression can contain numbers, symbols, signals, signs of arithmetic operations (+,-,*,/,^), parentheses and calls of mathematical functions. To denote the input signals are used Latin letters A (the first signal) and B (second signal). In addition, you can use the value of the variable I is the index of the next value (0 corresponds to the beginning of the selected input range).

The formula will be applied alternately to the values of the first input signal (A). If the second signal (B) is involved in expression, then for each first signal value will be taking the value of second signal corresponding to the same time.

Examples of correct expressions:

```

ATN (A)
10*SIN (A) + 3.33*COS (B)
(0.1*B*B - 0.7*A + 17) / (A+12.345)
(A-20)^3+(A-7)^2+A-0.15

```

List of mathematical functions:

ABS - norm of number,	LOG - natural logarithm,
ATN - arc tan,	SIN - sine,
COS - cosine,	SQR - square root,
EXP - exponent,	TAN – tangent

Probability density function

Select the type of assessment: frequency distribution, probability distribution or expectancy of hitting.

Select evaluation method and specify the number of points.

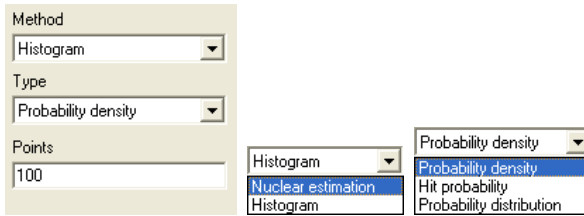


Fig. 9.29. Probability density function

Kernel density estimate

Assessment of PDF by the method of Kernel density estimate using the quadratic kernel function is given by the formula

$$P(x_m) = \frac{1}{N \cdot h} \cdot \sum \exp \left\{ -\frac{(x_m - x_k)^2}{2 \cdot h^2} \right\}$$

where: $\{X_k\}$ - source signal;

N - length of source signal;

$h = \sigma N^{-1/5}$;

σ - the standard deviation of the process;

M - the number of assessment points.

Histogram

The basis for building the histograms is the so-called "statistical series": the entire range of values of the random variable X is divided into intervals or "ranks" (the number of intervals is specified in **number of points** field); counts the number of values of m_i attributable to each i -th rank (if the value is exactly on the border of two ranks, then 0.5 is added to the numbers m_i of the category), the resulting number is divided by the total number of observations n , and thus find the frequency corresponding to the i -th rank: $p^*_{i=m_i/n}$.

The histogram is constructed as follows. On the x-axis is laid the ranks, on each rank is constructed a rectangle whose area is equal to the frequency of this rank. To construct the histogram we need the frequency of each category divide by its length and take the resulting number as the height of the rectangle. With the increase of the source data and, accordingly, the number of digits, the histogram will approximate to the graph of the density function of the variable X .

Note: In practice, it is recommended to have in each rank not less than 5-10 observations. If the number of observations in the individual rank is small (1-2), these ranks are combined.

Centering

Centering is performed with the purpose of the cutoff constant component of the signal: $Y_i^{uemp} = Y_i - \bar{Y}$, where \bar{Y} is the mathematical expectation.

Probability characteristics

For a sequence of samples $\{x_n, n=0, \dots, N-1\}$ the characteristics are calculated according to the formulas given below.

The mathematical expectation

$$m_x = \frac{1}{N} \cdot \sum_{n=0}^{N-1} x_n$$

Dispersion

Characterizes the scattering of the random value around its mathematical expectation value.

$$D_x = \frac{1}{N-1} \cdot \sum_{n=0}^{N-1} (x_n - m_x)^2$$

Standard deviation

Characterized dispersion, but is measured in the same units as the random value:

$$\sigma_x = \sqrt{D_x}$$

Root-mean-square value

Characterizes the dispersion, but has the dimension of a random variable:

$$x_{RMS} = \sqrt{\frac{1}{N} \sum_{n=0}^{N-1} x_n^2}$$

Skewness

Is used to measure the asymmetry of the distribution. If the distribution is symmetrical around its mathematical expectation value, then the skewness is equal to 0.

$$Sk = \frac{1}{N \cdot \sigma_x^3} \cdot \sum_{n=0}^{N-1} (x_n - m_x)^3$$

Amplitude

Maximum (by module) deviation from the mathematical expectation.

$$A_x = \max |x_n - m_x|$$

Double amplitude

The difference between the maximum and minimum values.

$$P_x = |\max(x_n) - \min(x_n)|$$

Kurtosis

Characterizes the steepness (peakedness or flattoppedness) of the distribution..

$$E_x = \frac{1}{N \cdot \sigma_x^4} \cdot \sum_{n=0}^{N-1} (x_n - m_x)^4 - 3$$

Note: The kurtosis value for normal distribution is equal to 0. Curves that are more peaked as compared to the normal distribution curve, have positive kurtosis values. Curves that have more flat tops than the normal distribution curve, have negative kurtosis values.

Estimations of mathematical expectation, dispersion, RMS, skewness, and kurtosis are logged.

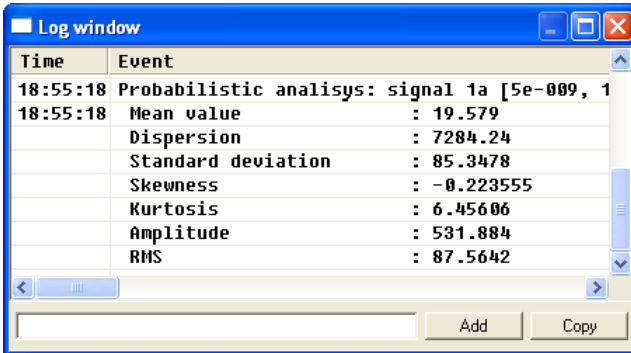


Fig. 9.30. Probability characteristics

For graph the estimation of mathematical expectation (MO), standard deviation (SD) and root mean square values (RMS) for the visible range of the signal are calculated. Turn on the display of ratings on the settings page of the legend. see Fig. 5.15.

Resampling

Frequency	Step	Begin
4000.000000	0.000250	0.000000
New freq	New step	New begin
4000.000000	0.000250	0.000000

Approximation type

w/o filtering
 Recursive filtration
 Non-recursive filtration

Keep type of data

Fig. 9.31. Resampling

Source Frequency, Source Step, Source begin – sampling parameters of the source signal.

New frequency, new step – sampling parameters of a new signal.

Approximation type: linear interpolation, 2nd order polynomial, cubic local splines or approximation by LPF.

Keep type of data – the resulting signal has the same format (e.g., two-byte signed integer) of the data as the source signal. In such cases at the frequency increase some "shelves" can be observed due to limited resolution of the source data format.

Changing the sampling rate of the signal, we must not forget the theorem Kotelnikov – Nyquist – Whittaker – Shannon from which it follows that the signal with a sampling frequency F_s cannot have harmonics equal to or above $F_s/2$, i.e., $F_{max} < F_s/2$

Therefore, when resampling to a lower frequency, you need to perform low-pass filtering of the original signal. If this is not done, the higher harmonics of the original signal will be in the new signal in the form of noise, distorting all subsequent processing. In practice, the value of the cutoff frequency reduces to approximately 75-85% of F_{max} .

Parametric graph

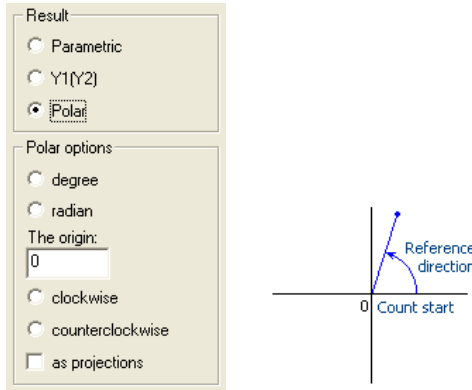


Fig.9.32. Parametric and polar graph

The algorithm allows creating graphs of dependency of a parameter from another one and graphs in polar coordinates.

Select **Parametric** result if the signals along X and Y axes bound to the same time scale. In this case, the signal along the X axis is taken as the base for the new signal. Result signal values along Y axis will have matching time with values of signal along Y axis. The sampling rate of source signals may be of different.

Select **Y1(Y2)** if the signals bound by value indices (usually these are the signals of equal sampling rate).

To plot a graph in polar coordinates select **Polar** result and select as sources module (amplitude) signal and phase (in **degrees** or **radians**) signal. Start counting direction and the reference direction is shown on the graph 9.32. Change them if required. Select "as projections," to get the two signals of the polar graph projections to axis X and Y.

Instant spectrum

Using the menu item **Windows→Instant spectrum** a specialized page for the spectrum calculation "on the fly" can be created (Fig. 9.33). This page contains two graphs: the source signal is to be added to the first graph, and the signal spectrum is shown by the lower graph. The signals can be added to (deleted from) the top graph only.

The spectrum is calculated in the current range and recalculated when the range is changed. If this range is less than the portion length specified in the algorithm settings, the calculation is not performed and spectrum is not represented. If the cursor mode is enabled, the spectrum is calculated by one portion selected by the

cursor position (the cursor pointing at the portion center) irrespective of the current range.

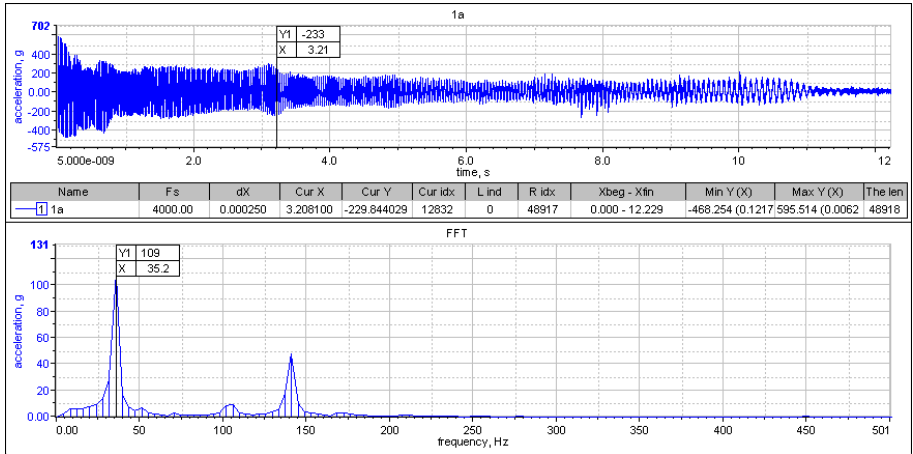


Fig.9.33. Instant spectrum page

In order to change the spectrum settings open the page context menu of the instant spectrum (click the right mouse button) and select the **Algorithm settings** item (see Fig. 9. 6).

In the same way it is possible to investigate a probability of the hit, the density of probability and DDP for a visible part of a signal (Fig. 9.34). Choose the **Autospectrum** for switching back.

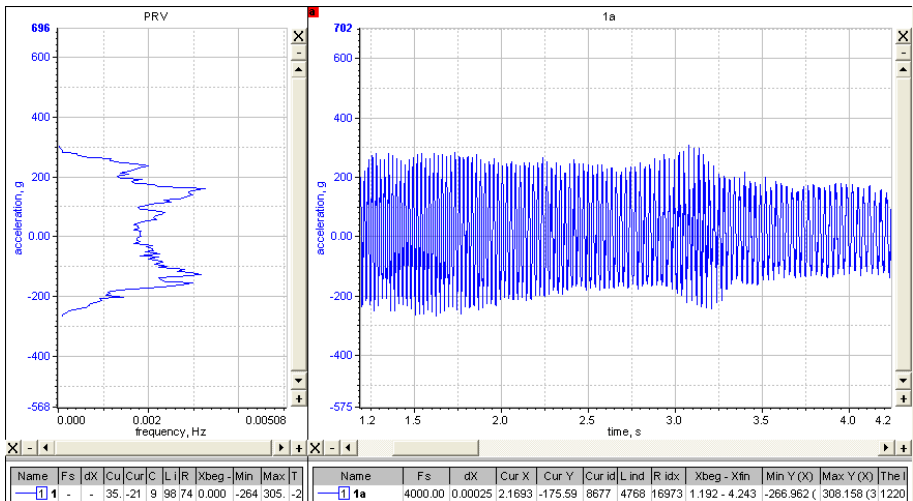


Fig.9.34. The page of a quick calculation DDP

Wavelet analysis

Wavelet - transformation of signals is one of sorts of spectral analysis, such as classical Fourier transform. The feature of a wavelet t-transformation is a possibility of the analysis of a signal with localization simultaneously on time and on a frequency.

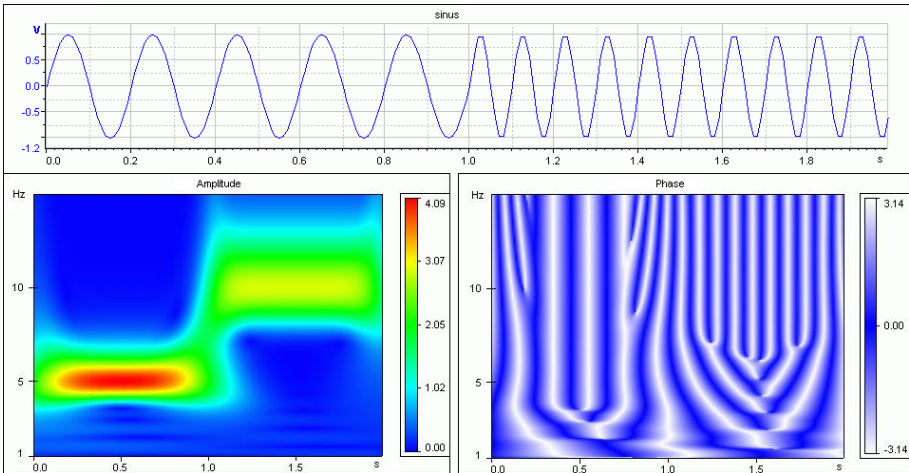
Wavelets are the generalized name of mathematical functions sets of a definite form which are local in time and on a frequency and in which all functions are result from one base (generating) by means of its shifts and expansions on time axis..

Wavelet transform is a method convolution of the original signal and wavelet functions. Wavelet function is calculated by the formula:

$$\psi(t) = \sqrt{1/f_s S} \pi^{-1/4} e^{jmt/s} e^{-(\nu s)^2/2}$$

where f_s is the sampling frequency of the original signal, m is the parameter of the wavelet, S is the wavelet scale (inversely proportional to frequency):

$$S = 1 / (f * L), \text{ где } L = 4\pi / (m + \sqrt{2 + m^2})$$



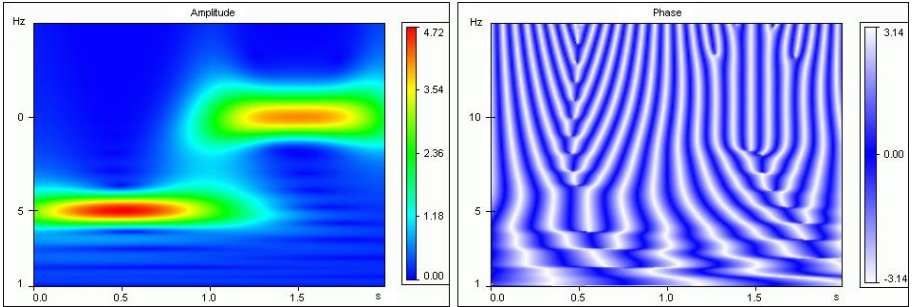


Fig.9.35. Source signal and wavelet transform for $m = 6$ and $m = 12$

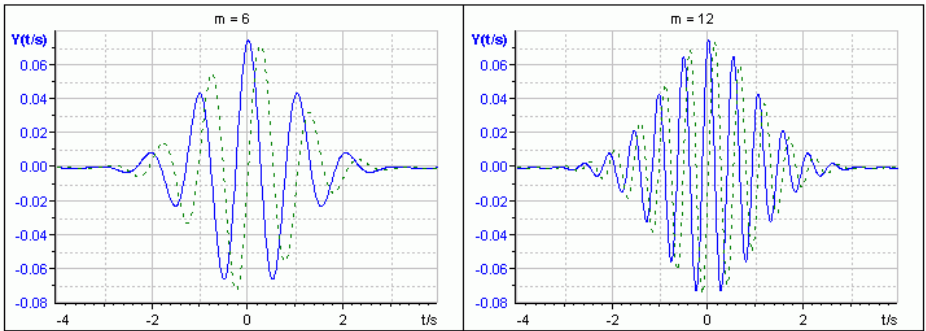


Fig.9.36. "Morlet" wavelet, $m = 6$ and $m = 12$

The size of the wavelet window values is calculated as: $N = 8 * S * fs$

The factor 8 is selected from the condition that the value of $t/s = (i - N/2)/(S fs)$ varied from -4 to 4.

To determine the value of $W(n,s)$, the values of the original signal in the range of indices $(n-N/2, n+N/2)$ are multiplied to the corresponding values wavetoy function of scale S and summed (values outside the range of the signal is zero). For the calculation the following values of $W(n+1,s)$ the window is shifted by a predetermined number of values (set in settings of the algorithm, the default value is 1). After passing along the signal the calculation is repeated for the next value of S .

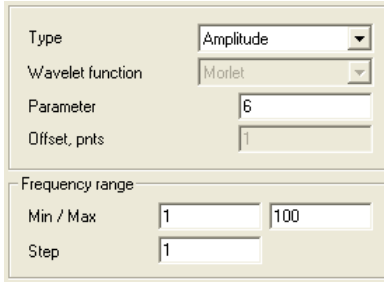


Fig.9.37. Wavelet settings

Type – type of a calculated characteristic (amplitude, amplitude & phase, real & imaginary).

Wavelet function – type of a wavelet function, only the wavelet of the type "Morlet" is available in the current version.

Wavelet parameter - a quantity defining a type of a wavelet function. larger values correspond to a larger localization on a frequency, smaller – on time.

Window offset - offset of a window during the calculation of the next portion. A value larger than one allows diminishing a volume of calculations at the expense of a smaller resolution on time of the resulting signal.

Frequency range – a range of frequencies in which wavelet is carried out, and a step of a change of frequencies. The smaller step the resolution on time is better but the volume of calculations is greater.

Recommended reading

1. Bendat, J., Pearsall, A. Measurement and analysis of random processes. - Moscow: Mir, 1974.
2. Randall, R. B. Frequency analysis. Printed by: K. Larsen and Son, A/O, DK-2600 Glostrup, Denmark, August 1989.
3. Herlufsen, H. Two-channel FFT-based analysis, Part 1 and Part 2. Bruel&Kjaer. Technical Review, 1984.
4. Antonew, A. Digital filters: analysis and design, Moscow: Radio i svyaz, 1983.
5. Randall, R.B. & Hee, J.: "Cepstrum Analysis", B&K Technical Review, No.3, 1981.
6. Bradshaw, P. & Randall, R.B. Early Detection and Diagnosis of Machine Faults on the Trans Alaska Pipeline, MSA-Session, ASME Conf., Dearborn MI, Sept. 1983, pp.7-17

Section 10. Analysis of dynamic processes and vibrations

WinPOS allows to perform the analysis of non-stationary dynamic processes, including the vibrations. The tools from the **Vibration analysis** menu are used in such applications as:

- Multi-channel processing of dynamic processes,
- Rotating machines vibration analysis (on stationary regimes),
- Calculations of parameter in the start/run-down modes,
- Processing of strain measurement data,
- Processing of audio signals,
- Processing of transient pressure and noise.
- Shock analysis, shock spectra calculation

The input data file obtained by the measurements contains the signals from different sensors (accelerometers, linear variable differential transformers, proximity probes, microphones, strain sensors, resistance temperature detectors, thermocouples, etc.). The vibration analysis algorithms allow to plot selected characteristics of these signals as a function of time or study the signals characteristics in association with the tachosignals. Such analysis is applied in the vibration inspections of the equipment with rotating parts, e.g., turbines. The same characteristics can be documented as a vibration report of a product, i.e., as files or special tables (See the section *Vibration survey* below).

To access the vibration analysis algorithms select the **Vibration analysis** item of the main menu (See Fig. 3.3).

Calculated characteristics

- Tacho,
- Amplitude/RMS/peak-to-peak value and phase of harmonics,
- Amplitude/RMS/amplitude-phase response,
- Amplitude/RMS/peak-to-peak value,
- Mathematical expectation,
- Low frequency vibration,
- RMS value in the band,
- Spectrum characteristics,
- Shock, shock spectrum,
- Tracking filter.

Calculations

All the settings window are divided into two parts (Fig. 10.1). The top part contains three functional areas – the group of processing options, the window containing the selected signals list, and the control group to select a file for processing and specify the file to save the results. The lower part of the window contain a graph for the results preview.

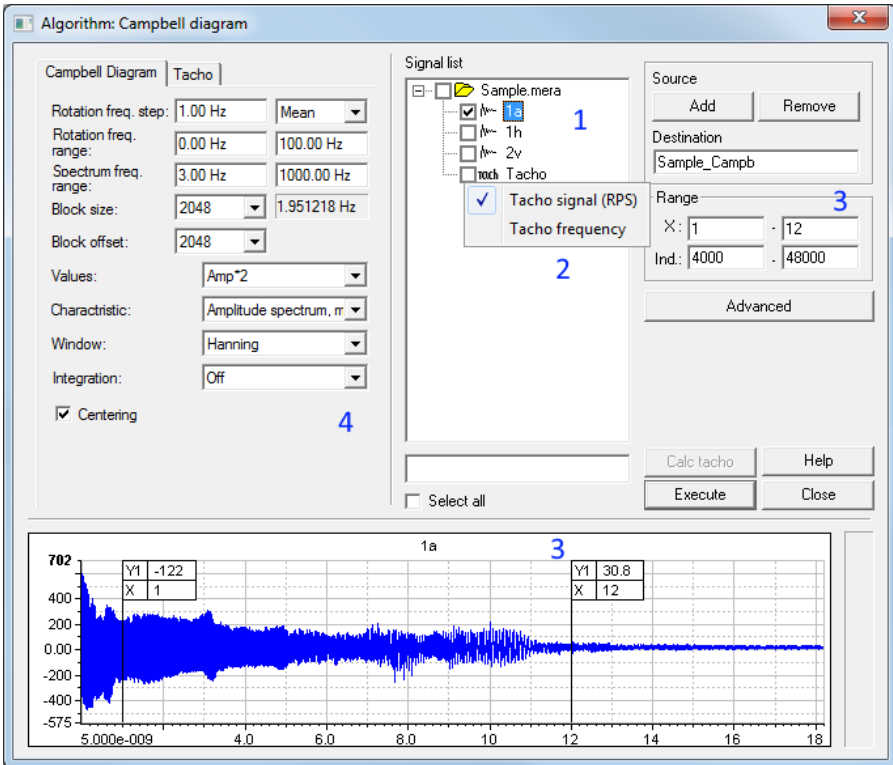


Fig. 10.1. Settings window on the example of the Campbell diagram

Calculation.

1. Select the source signals in the "List of signals"

Check the signals involved in the calculation.

The folder selected in the Signals tree already been added to the list. To add other folders, click "Add" and "Delete" in the right part of the window.

2. Specify the tacho

The rpm signal (or tacho) shows the change of the rotational speed during the test and is required for most algorithms.

- If you have signal from tachometer, click the right mouse button on its name in the list of signals. Select the item "Tacho signal".
- If you have previously calculated tacho, select the "RPM Signal".

3. If required, select the time interval

Move the cursor in the preview window or specify the exact values in the field "**Range**".

4. Tune the settings and click «Execute»

For most algorithms, the calculation process of each signal is displayed on the chart at the bottom of the window. The General course of the calculation displays a progress indicator at the bottom right. To abort the calculation at any time, press <Esc>.

The processing result can be found in the "Results" folder of the Signals tree under the name specified in the *Result* field. Change the folder name if required. Also the calculation result for the first signal is automatically added to graph.

Calculation details

The selected time range of the signal is divided into an integer number of intervals with equal length, defined either by the user or by the tachosignal. Then the user desired characteristic is calculated by the array of points corresponding to the specified length, and the time function with a resolution given by $T_d = \frac{N}{F_s}$ is produced, where: F_s – the source signal sampling rate; N – number of points in the array. The first calculated point is associated with the start of the range (T_n), the next one is associated with $T = T_n + T_d$, etc. The general formula is: $T_i = T_n + T_d \cdot i$. Note, after such conversion the resulting signal has the sampling rate of $F_d = \frac{F_s}{N}$.

The calculated characteristic can be represented as $Y(T_i) = F([X]_i)$, where: i - the number of interval starting from zero, T_i - the time matching i interval, Y - calculated signal characteristic, $[X]_i$ - array of points of i interval.

At change of time resolution of the signal characteristic the proportional decrease of length of the processed intervals should be considered. This effect causes the change of the processed signal bandwidth.

Amplitude and phase frequency characteristics. The power (amplitude, root-mean square value, or peak-to-peak value) of the selected harmonic element is defined in the array of points by the cosine-sine conversion, which corresponds to

passing of the resulting signal through narrow-band LPF with automatically adjustable central frequency. The bandwidth of the analyzing filter is represented as $\Delta f = \frac{F_s}{N}$, where: F_s – the source signal sampling rate; N – number of points in the array (to be set at the algorithm customization).

The phase is defined as a difference of arguments of the selected harmonic component and imaginary cosine function, the peak of positive semi period of which corresponds to the tachosignal mark. Hence, the tachosignal passing over a certain threshold is associated with the cosine wave with a zero phase offset.

Harmonic analysis is performed by the discrete Fourier transform to calculate the amplitude and phase at the pre-defined frequency. This method is equal to application of the bandpass non-recursive filter with the central frequency being multiple of the tachofrequency f_i and the filter frequency bandwidth Δf :

$$f_i = i \cdot f_T, \quad \text{where: } i - \text{harmonic number (may be fractional);}$$
$$f_T - \text{tacho-frequency;}$$
$$f_i - \text{central frequency of the pass band filter;}$$

pass band filter width:

$$\Delta f = (F_s \cdot k_{\%}) / 100 \cdot k_{\text{ЭНБ}}, \quad \text{where: } F_s - \text{sampling frequency;}$$

$k_{\text{ЭНБ}}$ - equivalent noise band (see the Appendix B. *Processing algorithm application guidelines* for details);

$k_{\%}$ - adjustment coefficient of the filter pass band (% of the pass band filter in respect to the signal sampling frequency).

Note: The Fourier discrete transform serve as a basis only. In order to make the algorithm closer to the calculated one, the additional research works have been carried out. By the results of such works some fine issues about the algorithm (when the standard technique provided an instable practical implementation) were considered and improved.

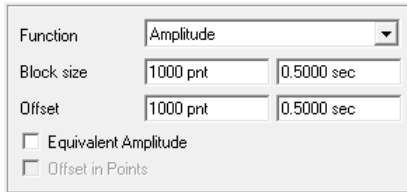
In order to verify the calculated results in respect to the harmonic analysis algorithms contained in the WinPOS package, special Bruel&Kjaer equipment was used. The identity of results was proved by the conducted tests.

- ❶ If sampling frequencies of the source signals are differ, then the resampling to a greater frequency is carried out before the calculation. This leads to the additional error, depending on a difference between frequencies. On the average, the size of an error is within the limits of 1 %.

Sequence processing (trends)

This group of algorithms allows the time representation of the signal instantaneous

characteristics (Fig. 10.2).



The image shows a dialog box titled "Sequence processing (trends)". It contains the following controls:

- Function:** A dropdown menu currently showing "Amplitude".
- Block size:** Two input fields, the first containing "1000 pnt" and the second containing "0.5000 sec".
- Offset:** Two input fields, the first containing "1000 pnt" and the second containing "0.5000 sec".
- Equivalent Amplitude:** An unchecked checkbox.
- Offset in Points:** An unchecked checkbox.

Fig. 10.2. Sequence processing (trends)

Set the *Block size* (counts or seconds) and choose *Operation type*:

- the mean (expectation),
- RMS or standard deviation (standard deviation or value),
- amplitude,
- magnitude (double amplitude),
- peak factor.

If the “*Equivalent amplitude*” option is selected then RMS calculated first, and then the result is transformed to amplitude or peak-peak value. The “*Offset in Points*” option used with nonuniform X axis for specifying offset in number of samples, instead of time in seconds.

Band RMS

The calculation of the RMS in the band shows the time behavior of the signal power per a predetermined frequency range. The settings are divided into two pages - the settings of the algorithm (Fig. 10.3) and calculation settings Tahoe-features (Fig. 10.4).

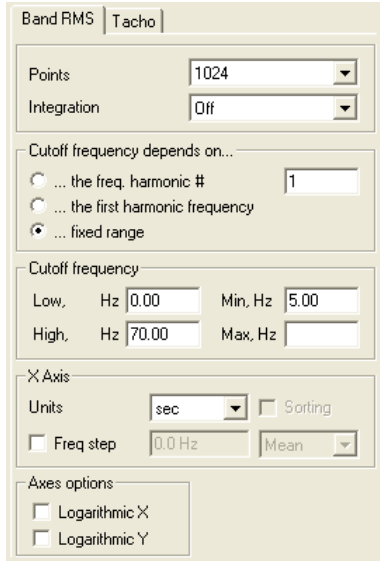


Fig. 10.3. Band RMS settings

Number of FFT points – the number of points on which the spectrum calculated

Integration – result as vibration acceleration, velocity or displacement.

Band calculating – boundaries of the band are set or percentage of selected harmonics or in Hertz.

Setting bands – from the bottom up to the top, but not *Min* and not wider *Max* if specified. In the *Upper* field may be set to "-1", as an upper bound. In this case the range will be made of the maximum frequency value.

Setting the x-axis Units. – choose the units for the x-axis: seconds, Hertz or rpm.

Min. step – enable decimation with a given minimal step and the choice of method of approximation results: the average or maximum value.

Configure axes – turning on logarithmic scales.

Tacho

Function for calculation of the rpm signal (revs) signal t (Fig. 10.4).

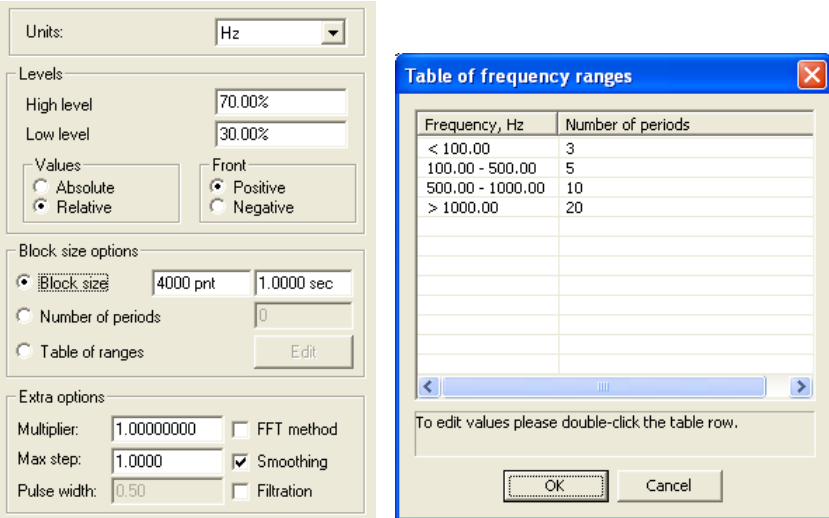


Fig. 10.4. RPM calculation (tacho) and frequencies table

Units of measurement – the dimension count features: Hz frequency, rpm./min – rpm.

Hi-Level and Lo- Level - accordingly positive and negative levels. The consecutive transition of a signal through these levels is considered as a front of a signal. Such algorithm of the definition of the signal front considerably raises a noise stability of the algorithm.

Values –the units in which are set a levels - absolute or relative (percent of maximum amplitude). It is recommended to set the levels in relative units (percentage), especially if the amplitude of tacho significantly change with time. In this case, absolute values will be calculated for each block separately.

Edge (*Positive* or *Negative*) - defines the tachosignal front, by from which the phase is will be calculated.

Multiplier – the coefficient by which the calculated value of the frequency of the tachosignal is multiplied. It is necessary to perform such operation in the cases, when the rotation frequency has been measured via some reducer but not on the inspected shaft directly. Such operation must be performed in the cases, when the rotation frequency has been measured via some reducer but not on the inspected shaft directly. Then the rotation frequency of the inspected equipment is equals to the product of the reduction coefficient and the measured rotation frequencyspeed of the secondary shaft.

Block size - calculation may be specified in the counts or in seconds. The block size should be chosen so that it have at least several full periods on the entire range of frequencies. If you selected too small block, then in some areas, the algorithm will

not be able to calculate the frequency tacho. However, you should not choose too large a block size as this will be a loss of information due to averaging of a large number of values. In other words, a large portion of data provides a more accurate frequency measurement by averaging, but lost the ability to track fast frequency changes.

To combat this phenomenon, you can set the number of revolutions, which will determine the size of the portions. This can be a single value – the number of periods, or table, which gives the possibility to set the portion size as a function of frequency. For table settings, click "Change". In the table columns by double-clicking the mouse to determine the frequency bands and the number of turns on the portion of data in each range.

Max. step - The maximum permissible difference between two successive readings the maximum tolerable difference of two successive samples. If this value is exceeded, a random peak has occurred. This option is used if *Smoothing* is enabled.

Filtering - enables a filtering of the source signal throughout width of impulses. In some cases, the presence of defects in the rotor leads to the fact that in addition to "regular" signal of the rpm sensor on tachosignal is jammed preventing normal operation of the processing program. The essential difference of these interferences is their much smaller duration. Temporal filtering removes from tachosignal signals, the duration of which is less than the established in the Width of the pulse. values (in percentage of the calculated maximum pulse speed sensor).

Smoothing - an additional amplitude filtering of the tachosignal is performed. The purpose of such filtering is to exclude random amplitude peaks of the tachosignal. Several successive values (frame) are analyzed, and if within such frame the signal amplitude is above the pre-set value (tolerable increase rate, or peak – set in the *Max.step* field), the linear interpolation of the frame values is performed.

Calculation of amplitude-phase-frequency response

This group of algorithms allows representation of the signal harmonics as a function of time of frequency. The settings are divided into two pages – the settings of the algorithm (Fig. 10.5) and tacho calculation settings (Fig. 10.4).

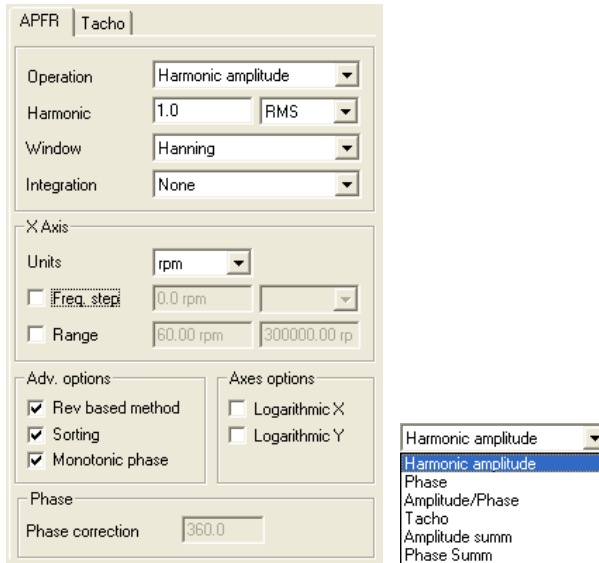


Fig. 10.5. Calculation of amplitude-phase-frequency response

Operation – calculated characteristic:

- amplitude (Amplitude of harmonics), the phase (Phase), amplitude and phase (Amplitude/Phase) of the selected harmonics;
- frequency change – tacho;
- amplitude from frequency - the effective value (RMS), amplitude, or magnitude of the common signal level (for all harmonics), the phase of the frequency;

Harmonics - an ordinal number of the harmonic. To the right of this field it is possible to specify the type of the result: RMS, A – the amplitude, 2*A – the peak-to-peak value;

Integration – result as vibration acceleration, velocity or displacement.

Window - type of a weighting window: *Rectangular*, *Triangular*, *Hanning*, *Blackman*.

Setting the X-axis: Units of measurement. – the dimension of the calculated characteristics on the X-axis: Hz is the frequency, in seconds. – time, rpm - the revs. Min. step (only for Hz or rpm.) - defines the step which will change the frequency. If multiple values falling in one range, the resulting value will be taken or the average or maximum (depending on the mode chosen in the box to the right). Frequency range - if selected, the minimum and maximum frequencies of tacho within which will be calculated, otherwise full range.


Calculation by rpm - allows you to select variations of the algorithm that is used to calculate the frequency response. In the general case, it is recommended to set this option in the calculations according to the data taken with the rotating units; the analysis of vibration processes, the best result can be obtained by removing the option.

Sort – if checkbox is checked, the obtained data are sorted by increase of the calculated frequency. The sorting can be required when the frequency of the tachosignal changed not monotonously.

Monotonous phase - allows to the phase to change beyond out of the range of 0-360 degrees.

Configure axes - displays the axes X and Y in the resulting graphs in logarithmic scale.

Phase correction - the value from which the phase starts to change.

 Note, if the calculated graph contains negative frequency (time) values than it means a failure of the tachosignal, i.e.,. there was no a crossing through a certain threshold or no crossing of a certain threshold took place or the tachosignal dropped to zero. In this case the settings of the tachosignal analysis should be verified.

Define the reference signal if required: click with the right mouse button on its name in the list of signals, select the "reference signal". The frequency response of the source signal is divided into frequency response of the reference signal, and the phase is considered as the phase difference between the reference signal and the source. The same signal may be simultaneously reference and tacho. The influence of the reference signal to the result of the algorithm is shown in figure 10.6.

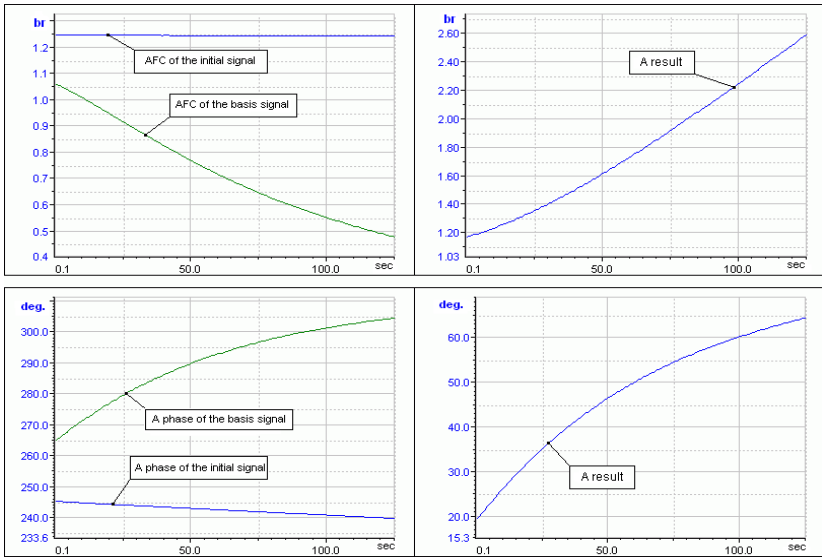


Fig. 10.6. Reference signal and calculation of amplitude-phase-frequency response

If the reference signal is not set when calculating the phase response the phase is measured from the **edge** of tachosignal (*Positive* or *Negative*) (Fig. 10.7).

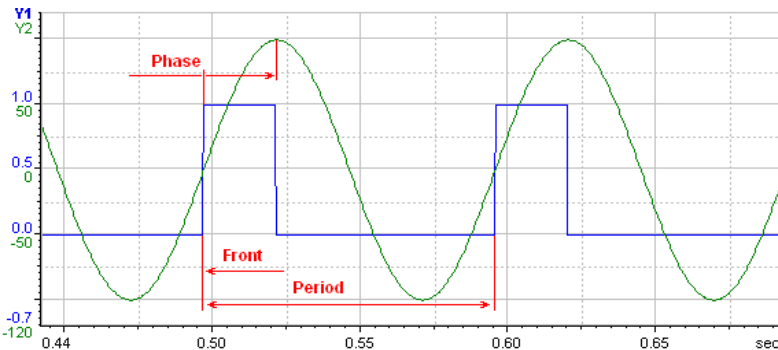


Fig. 10.7. Graphical view of features of calculation of the phase response

Vibration survey

This set of algorithms is intended for batch calculation of vibration characteristics and generation of the reports according to industrial standards. Select menu command **Vibration analysis**→**Vibration survey**. A window will open, shown in Fig. 10.10.

The list of calculated characteristics and their symbols are provided in the table below:

Characteristic	Symbol
Tacho	n / f
Harmonic RMS value	$e(f)$
Harmonic amplitude	$a(f)$
Harmonic peak-to-peak value	$r(f)$
Harmonic phase	$F(f)$
Harmonic RMS value vs. frequency	$es(f)$
Amplitude vs. frequency	$as(f)$
Peak-to-peak value (Amplitude*2) vs. frequency	$rs(f)$
RMS value	e
Amplitude	a
Peak-to-peak value	r
Mathematical Expectation (Mean Value)	m
LFV (Low frequency vibration)	h / fh
Band RMS value	f suffix
Spectrum analysis	$F / K(f)$

In the *Vibration survey* mode the above estimations are calculated separately for each revolution of the rotating parts with the signal interpolation between the samples. The tachosignal is used to divide the whole signal realization into revolutions.

In the energy industry the table representation (Microsoft Excel, XLS format) of vibration characteristics is used for the statistic analysis. See Fig. 10.8. In the aviation industry, as a rule, the processing results have to be represented in text format, e.g., RTF. See Fig. 10.9.

Consequently, two operation modes of the vibration survey algorithms are provided:

- Placement of results into the Signals tree (*WinPOS mode*);
- Placement of results into the Excel tables (*Excel mode*).

To switch in Excel mode click **Excel** and select table and page of xls file. When switching to another mode the calculation parameters settings.

Section 10. Vibration analysis

The screenshot shows an Excel spreadsheet with the following data:

- Table 3:** Works, Object, Date: 27.06.2006, Time: 17:03:43, Capacity: W_0 MW, W_r MVar, Rotational speed: n , rpm: 1956, f , Hz: 32.59, Start, Regime, Series, Test, Code.
- Main parameters of vibration:**

spectru m of	Channel number	N#1	N#2	N#3	N#4	N#5	N#6	N#7	N#8	N#9	N#10	N#11	N#12	N#13	N#14	N#15	N#16
	Channel name	1a	1v	1h	2a												
LF	a_0	m/s ²	0,183	0,708	0,365	0,453											
	V_0	mm/s	0,557	1,198	0,873	1,014											
	V_{e1}	mm/s	0,439	1,117	0,719	0,886											
	Φ_0	deg	-229	-981	-483	255											
	S_{r1}	mm	5,82	13,39	9,312	9,904											
MF	Φ	deg	-139	-891	-393	345											
	S_n	mm	5,517	11,02	7,709	18,1											
HF	f_n	Hz	3,906	3,906	3,906	3,906											
	a_r	m/s ²	0,132	0,629	0,302	0,369											
	V_r	mm/s	0,132	0,414	0,3	0,254											

Fig. 10.8. Excel table with the vibration parameters

Object:
Test:
Testbed №:

File: stoping001.usm

Date: 08.12.2003

Channel	Charact	M1	M2	M3	M4	M5
		2.20741 s	5.01022 s	7.59963 s	9.99148 s	13.4378 s
1a	e1	3.29602	1.66899	1.53183	1.69005	0.158795
	e2	13.8817	9.75624	11.3436	20.433	2.00621
	e3(f1)	11.5586	8.20894	9.80571	20.6317	0.312789
	F1(f1)	540	540	540	540	540
	r1(f1)	142.039	145.069	255.006	814.528	18.815
	F2(f1)	540	540	540	540	540
1v	e1	4.32148	3.47219	3.35018	1.55396	0.267673
	e2	17.8635	20.8942	16.0408	14.9193	1.75021
	e3(f1)	15.718	17.7165	13.4423	14.962	0.748389
	F1(f1)	540	540	540	540	540
	r1(f1)	193.74	312.98	343.991	593.542	46.0174
	F2(f1)	540	540	540	540	540
1h	e1	1.23365	1.73131	1.87921	0.735065	0.255682
	e2	3.20216	9.92394	4.75192	2.47321	2.67217
	e3(f1)	2.75161	10.306	3.65622	2.48789	0.137348
	F1(f1)	540	540	540	540	540
	r1(f1)	34.2229	182.057	92.8304	97.8809	8.26182
	F2(f1)	540	540	540	540	540
2v	e1	4.3611	2.21766	2.9113	1.66933	0.347251
	e2	18.1009	12.8183	14.7606	15.705	2.6657
	e3(f1)	15.3489	8.16912	9.05638	15.7689	0.22606
	F1(f1)	540	540	540	540	540
	r1(f1)	188.721	144.364	227.006	625.607	13.598
	F2(f1)	540	540	540	540	540
2h	e1	4.88236	5.92361	4.15628	1.73109	0.198203
	e2	20.2374	35.2655	34.6068	21.3111	2.3253
	e3(f1)	18.3264	33.3259	24.13	23.3674	0.733191
	F1(f1)	540	540	540	540	540
	r1(f1)	226.241	588.857	610.707	927.129	44.1032
	F2(f1)	540	540	540	540	540
tacho	f1	36.8347	25.4769	17.4234	11.3542	7.48363

Fig. 10.9. RTF table with the vibration parameters

WinPOS Mode

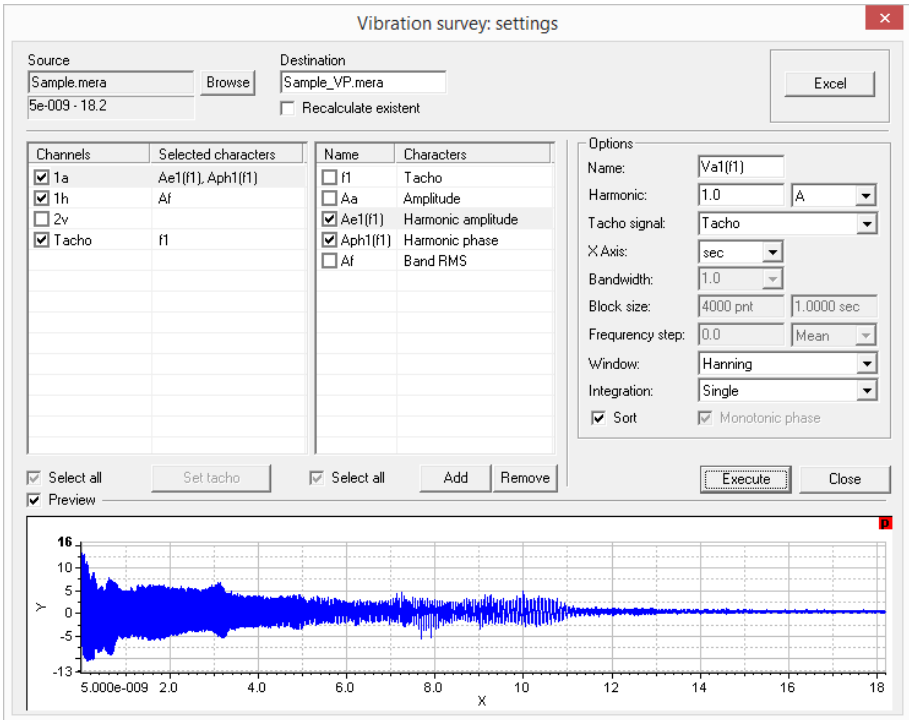


Fig.10.10. Vibration survey settings window

In the list on the left all signals of the selected file are shown. Mark channels to be processed. To mark all channels use the **Select all** option. The second column of the list contains symbolic names of characteristics calculated for the respective channels. The window at the center shows the characteristics prepared for use in the calculations. New characteristics are added and the exiting characteristics are removed by the **Add** and **Remove** buttons located below this list. The characteristics calculated for the selected channel are marked by ticks. When the characteristic is selected in the list, the options of this characteristic are shown on the right.

Calculation settings

Common for all pages (Fig. 10.11) **Name** field allows you to change the default name of assessments. **Characteristic** - defines calculated characteristic. Number of **FFT Points** - the number of points on which the calculated spectrum. **Integration** - the result: acceleration, velocity or displacement. **Tacho signal** - the name of the rotation signal.

The image shows a screenshot of a software interface with seven panels for configuring vibration analysis settings:

- Tacho:** Name: f1, Y Axis: Hz, Block size: 4000 pnt, 1.0000 sec, Periods num.: 0, Frequency step: 0.0 Hz, Mean, HI-level: 70.00%, Lo-level: 30.00%, Multiplier: 1.00000000, Max step: 1.0000, Pulse duration: 0.50, Phase correction: 360.0, Front (Positive/Negative), Level (Absolute/Relative), Smoothing, Filtration.
- Amplitude and phase of harmonic:** Name: Ae1(f1), Harmonic: 1.0, RMS, Tacho signal: Tacho, X Axis: sec, Bandwidth: 1.0, Block size: 4000 pnt, 1.0000 sec, Frequency step: 0.0, Mean, Window: Hanning, Integration: None, Sort, Monotonous phase.
- RMS, Amplitude, peak-peak, ME:** Name: Aa, A, Block size, Samples: 1000, Seconds: 0.2500, Integration: None, Equivalent amplitude.
- LFF:** Name: Ah, Characteristic: LFF, Cutoff frequency: 70.000000, Points: 1024, Integration: None.
- Band RMS:** Name: Af, Low frequency: 10.000000, High frequency: 20.000000, Spectrum type: PS, Points: 1024, Integration: None.
- Spectral analysis:** Name: AF, Characteristic: Frequency, Tacho signal, Points: 1024, Integration: None.

Fig.10.11. Calculation settings

Tacho

Tacho treatment settings described above in paragraph “Tacho”.

Amplitude and phase of harmonic

Harmonic - harmonic order (required only for amplitude and a phase of a harmonic). **X axis** - units of the characteristic calculated for X axis (sec/Hz/RPM). **Passband width** - the passband width of the analyzing filter in Hz. This value is set by the tacho settings. **Block size** - the block size for the calculation. This value is set by the tacho settings. **Frequency step** – step of frequency change. If several values are found in one range, the average or the maximum resulting value shall be used (depending upon the mode selected in the menu on the right). This value is set by the tacho settings. **Window** - type of the weighting window. **Sort** - data sorting by the X axis. **Monotonous phase** - allows the phase changing beyond the range of 0-360 degrees. Used for the phase calculations only.

RMS value, amplitude and peak-to-peak value of source signal as function of tachofrequency

The settings are similar to the harmonic amplitude settings. Only the fields **Name**, **Tachosignal**, **X axis**, **Integration** and **Sorting** are enabled.

RMS value, amplitude, peak-to-peak value and Mathematical Expectation

In the drop-down list next to the **Name**, select the desired type of assessment. **Block size** - the block size for the calculation (in samples or seconds). If the **Equivalent amplitude** option is selected then RMS calculated first, and then the result is transformed to amplitude or peak-peak value.

LFV

Cutoff frequency - the frequency dividing high and low frequency ranges.

Band RMS

Low frequency and **High frequency** – frequency range limits.

After calculations complete the result window (Fig. 10.12) is automatically opened. Besides, all calculation results are placed as signals into the Signals tree to the folder called by the processed file name with addition of the suffix «_VS»

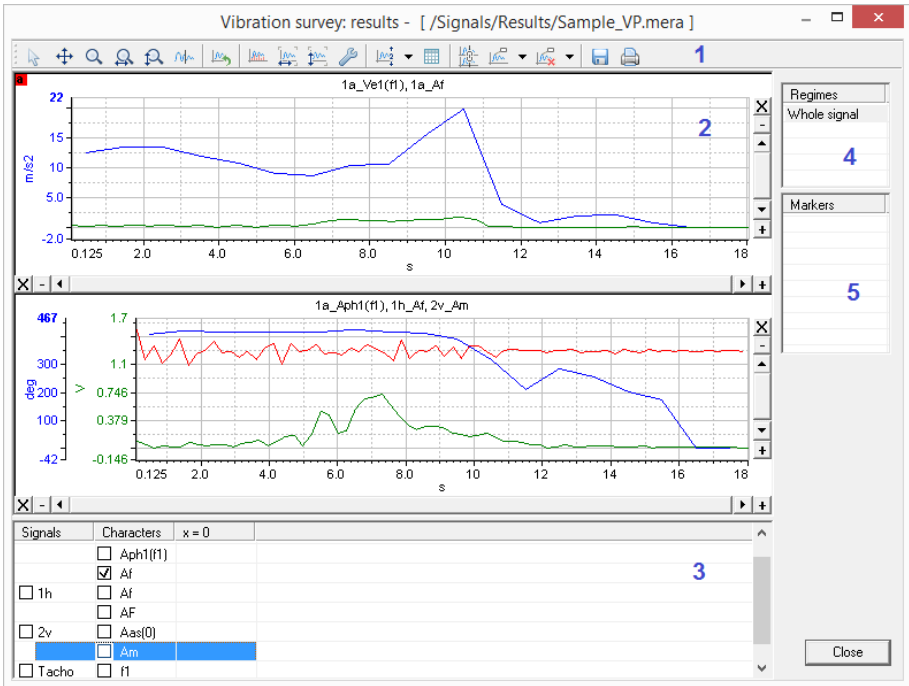






Fig. 10.12. Results of vibration survey calculations

Where: 1 – toolbar; 2 – characteristic graphs; 3 – characteristic table (two modes); 4 – list of regimes; 5 – list of labels.

After finishing calculations and opening the result window the first two characteristics are displayed in the graphs (2) by default. Further the number of








graphs and the represented signals can be modified (by the  button on the toolbar) by selection of the active graph and marking the desired signals or characteristics with a tick in the characteristic table (3).












In turn, the characteristic table has two views switching by the  button on the toolbar (1). The first view is shown in Fig. 10.11. The first column contains the names of the source signals, the second - the calculated characteristics, and the third - the characteristic values at the point defined by the cursor position in the active graph. In the next columns the characteristic values at the mark points are represented. The table contains the markers within the selected signal mode range only.

If the source signals contain signal modes they will be listed in the window (4), otherwise, the list has only "Entire signal" line. Under the list of signal modes the list of marks (5) is provided. The list contains all marks set in the selected signal mode range; the labels outside this range are not shown. At the selection of the label the cursor of all graphs shall be moved to the label, and the X axis range of the graph is changed when necessary to display the selected label. The labels are added or removed by the toolbar  and  buttons.

The generated report can be saved as a table in an RTF format file.

The purpose of the result window toolbar buttons is described below.

-  General view - viewing only the signal graph and processing results. Operations with the input data are possible. The graph view cannot be modified.
-  Scrolling, the graph shifting by both axis (X and Y) simultaneously. To make the shift press and hold the left mouse button in the graph window, and then move the mouse cursor to the desired direction. The signal graph is shifted with the cursor.
-  Zooming by both axis (X and Y) simultaneously. To zoom in the graph move the cursor to the start/end of the area to be zoomed. Press and hold the left mouse button and move the cursor to the desired direction, to the start/end of the area to be zoomed. The rectangular frame of the zoomed area will be shown by dotted line in the graph window. At release of the left mouse button the interval will be zoomed in the whole viewing window.
-  Zooming by X axis.
-  Zooming by Y axis.
-  Cursor mode (vertical and horizontal lines in the graph window).
-  Return to the previous axis range of the graph axis.

-  Vertical lines from the signal values to X axis.
-  Set the scale by the X axis to display all measured points from the maximum to the minimum value in the viewing window (normalization by X).
-  Set the scale by the Y axis to display all measured points from the maximum to the minimum value in the viewing window (normalization by Y).
-  Customization. Allows setting the graph representation parameters.
-  Set the number of graphs in the window.
-  Switch the characteristic table views.
-  Synchronization of cursors. The button is active when the cursor mode is enabled and the number of graphs on the page more than one.
-  Set the mark at one or all signals at the cursor position.
-  Remove the mark selected from the list of marks.
-  Save the characteristic table to an RTF format file.
-  Print graphs.


The second view of characteristic table is shown below.

Signals	f1	Vel1(f1)	Aph1(f1)	Af	Am	AF
1a		12.425	409.475	0.298		
1h				0.098		0.098
2v					1.574	
Tacho	47.066					

Fig. 10.13. Characteristic table

In this view the source channels are shown in columns, and the characteristics set in the Vibration Report settings window are shown in rows. The table cells contain the characteristic values calculated by the respective channels, at the position of selected label or cursor in the active graph (if this position does not match the selected mark). If the particular characteristic has not been calculated by all channels, the respective table cells are left empty.

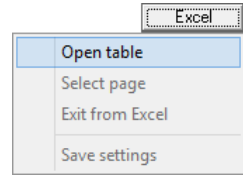
In order to obtain the final report in RTF format file (an example is shown in Fig. 10.9), the labels should be set while viewing of the calculation results (see Fig. 10.12).

After the table formatting is completed, the report can be saved in an RTF format file. Click the  button on the toolbar and specify the filename. Further the report file can be processed by Microsoft Word or WordPad, or imported to the user's applications.

Excel Mode

Vibration survey allows to calculate the vibration parameters using the pre-set templates and to store the results to the Excel file.

To access this option click **Excel** button at the right top corner of the Vibration Report settings window. Select **Open table** menu item to open an XLS format file. A standard open file dialog appears.



After the table is selected, the window in which all pages of the given file are enumerated opens (Fig. 10.14).

Select the page containing the required template and click **OK**.

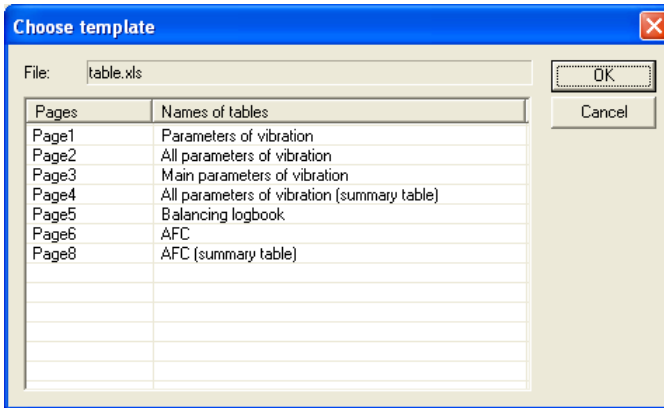


Fig. 10.14. Page selection window

Attention! The selected table is only a template for report generation. All settings required for calculations are taken from the .INI file (the name of this file matches with the name of selected XLS format file), that must be saved in the same folder with the XLS format file.

After that the settings are read and the characteristic list is populated. If the processed file is already opened, the characteristics are automatically linked to the channels using the following criterion: if the channel with this name has the characteristics list in the settings file, then only the specified characteristics are set to this channel. Otherwise, all the characteristics except tacho are linked to the channel. In the “Result” field the file name and the page for the calculation results are specified.

If necessary, the user can change any settings before calculations. The list of characteristics and their options can be saved in the settings file by selection of the «Save settings» items from the above menu.

WinPOS. User's Guide

The calculation progress is displayed on the graph in the lower part of the Vibration Report settings window. After the calculation is completed, the generated table is automatically opened by Microsoft Excel (if installed).

Sample templates (Excel tables):

Description of the structure and an example of a Vibration survey settings file is given in Appendix A *File Formats*.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V						
1	Table 1.																										
2	Works					Capacity	W_a , MW					Rotational speed	Π , rpm					Start									
3	Object						W , MVar						f , Hz					Regime									
4																											
5	Date					Additional information																Series					
6	Time																					Test					
7	Parameters of vibration																										
8	Channel number	N81	N82	N83	N84	N85	N86	N87	N88	N89	N810	N811	N812	N813	N814	N815	N816										
9	Channel name																										
10	V_g	mm/s																									
11	S_{r1}	mcm																									
12	Φ	deg																									
13																											

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W				
1	Table 8+.																									
2	AFC (summary table)																									
3	Works					Main parameters of vibration										Regime										
4	Object															N_c										
5	Date																									
6																										
7	№	Time	Section number	№ 1				№ 2				№ 3														
8			Channel name	1v		1h		1a		2v		2h		2a		3v		3h		3a						
9			n	f	S	φ	S	φ	S	φ	S	φ	S	φ	S	φ	S	φ	S	φ	S	φ				
10			rpm	Hz	mcm	deg	mcm	deg	mcm	deg	mcm	deg	mcm	deg	mcm	deg	mcm	deg	mcm	deg	mcm	deg				
11																										
12																										
13																										

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V						
1	Table 3.																										
2	Works					Capacity	W_a , MW					Rotational speed	Π , rpm					Start									
3	Object						W , MVar						f , Hz					Regime									
4																											
5	Date					Additional information																Series					
6	Time																					Test					
7	Main parameters of vibration																										
8	spectru	Channel number	N8 1	N82	N83	N84	N85	N86	N87	N88	N89	N810	N811	N812	N813	N814	N815	N816									
9	m of	Channel name																									
10	Parameters	General	a_b	m/s^2																							
11			V_o	mm/s																							
12		1st harmonic	V_{of}	mm/s																							
13			Φ_v	deg																							
14			S_{r1}	mcm																							
15			Φ	deg																							
16		LUF	S_h	mcm																							
17			f_h	Hz																							
18		HF	a_f	m/s^2																							
19			V_f	mm/s																							
20																											

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P						
		Table 5.					Form B2															
1		Balancing logbook																				
2	Power station																					
3	Turbount																					
4		Date																				
5		Time																				
6		Start, №																				
7		Regime																				
8		Correction weight	removed/installed																			
9			N2 plane																			
10			Marking																			
11			Weight, gram																			
12		Angle, deg																				
13		Additional information																				
14		N2 bearing	Channel number	Parameters of vibration																		
15		bearing № 1	1v	S ₁₁ , mom																		
16				φ, deg																		
17			1h	S ₁₁ , mom																		
18			φ, deg																			
19		1a	S ₁₁ , mom																			
20			φ, deg																			
21		bearing № 2	2v	S ₁₁ , mom																		
22				φ, deg																		
23			2h	S ₁₁ , mom																		
24			φ, deg																			
25		2a	S ₁₁ , mom																			
26			φ, deg																			
27		bearing № 3	3v	S ₁₁ , mom																		
28				φ, deg																		
29			3h	S ₁₁ , mom																		
30			φ, deg																			
31		3a	S ₁₁ , mom																			
32			φ, deg																			

Campbell diagram

The Campbell diagram shows how the change of the characteristic frequency components with the change of the rotational speed. The amplitude is displayed by color or height of the associated bar or the diameter of the circle. Campbell diagram applied to the analysis of dynamic processes, mainly on non-stationary modes. It the most useful for the detection of self-excitation oscillation.

The settings are divided into two pages – the settings of the algorithm (Fig. 10.15) and tacho calculation settings (Fig. 10.4).

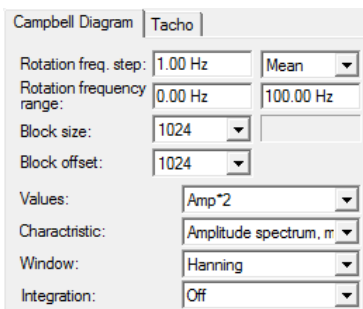


Fig. 10.15. Campbell diagram calculation window

Frequency step - the step of the tachofrequency changing. If several values are found in the one range, then the averaged or maximum value is taken as a resulting one (depending upon the mode selected in the drop-down list to the right of the field).

Tachofrequency range - the minimum and maximum values of the tachofrequency.

Block size - the block size (in samples) to perform the calculations. To the right of this field displayed the resolution of the spectrum.

Block offset – specifies the offset of the next block in the counts.

Values – The type of calculated values - RMS/Amplitude/Peak-to-peak.

Characteristic – defines the type of the spectrum. Possible values: Amplitude spectrum, power spectrum, power density spectrum and the energy density spectrum

Window – weighting window function for spectrum calculation.

Integration – vibration acceleration, velocity or displacement as result.

For each specified signal is the following sequence of actions performed:

- 1) The signal is divided into blocks, the size and offset of which was specified in settings.
- 2) For the next block determined the tacho frequency corresponding to the center of the block. If the value is out of specified RPM range, the block is discarded and not included in calculations.
- 3) The amplitude spectrum is calculated for data block and stored with the respective tacho frequency value. Steps 2 and 3 are repeated for all blocks
- 4) From the obtained spectra the 3D signal is created, where the spectra are located along the Z-axis and the tacho (RPM) – along the X-axis. If several spectra falls into one frequency range of tacho, they are averaged; the frequency step and the way of averaging are configurable.

Displaying of results

When the calculation is finished a dialog box (Fig. 10.16) is opened, where you can specify the desired type of graph: three-dimensional graph, the graph top-down or classic Campbell diagram.

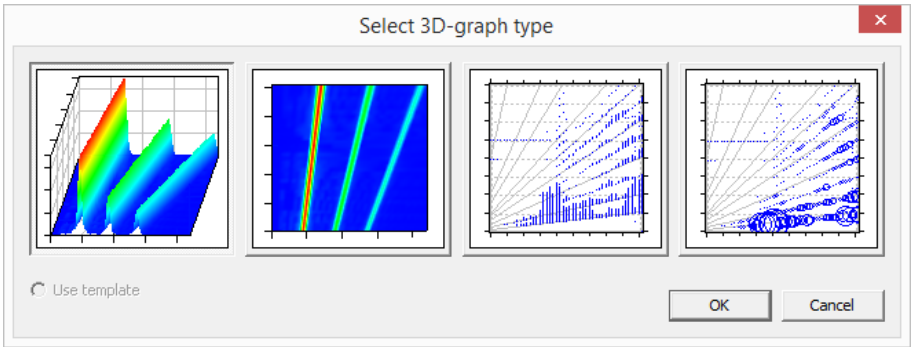


Fig. 10.16. Graph type selection

Fig. 10.17 shows the different types of the same graph.

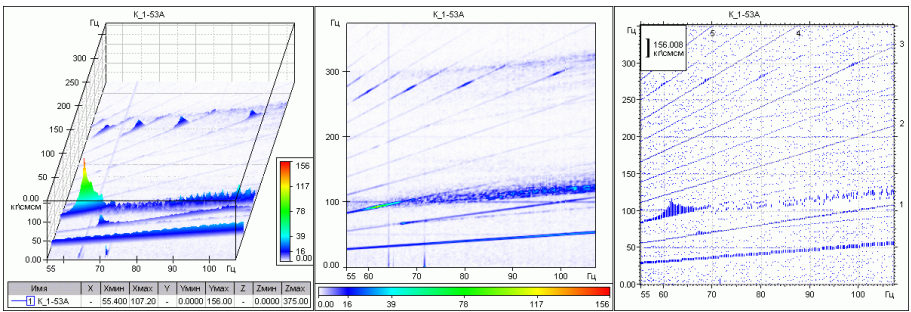


Fig. 10.17. Campbell diagram types

Fig. 10.18 depicts the graph window of the Campbell diagram, top view. The upper graph displays a chart directly in the form that was specified in the previous step. If necessary, you can change it by right-click on the chart and selecting "Main view" from the context menu.

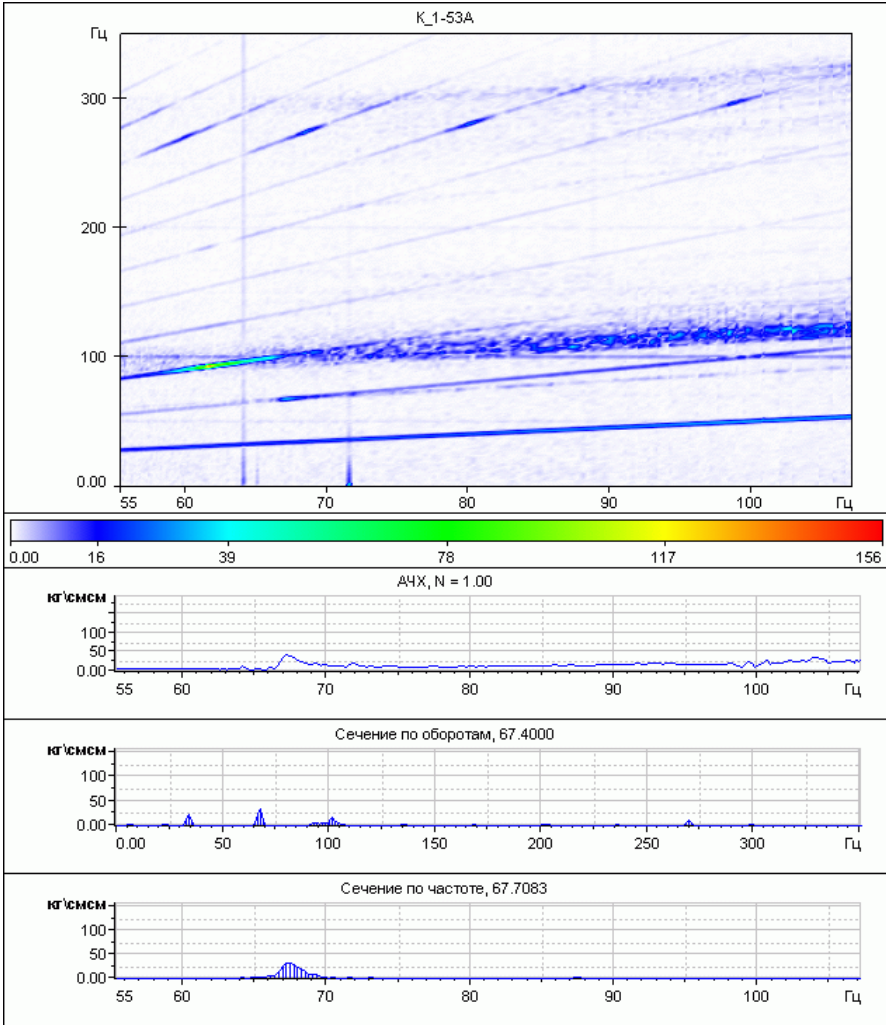



Fig. 10.18. Campbell diagram window

On the second chart shown the frequency response for the selected harmonic (harmonic number displayed in the header). To select the harmonic activate the order cursor (the button  on the control panel, select the appropriate item from the drop-down menu). Move the cursor using the mouse or the buttons <Up> and <Down> on the keyboard. The number of the selected harmonic is also shown slightly to the right of the cursor.

The following two graphs shows the cross section for RPM (X-axis) and frequency (Z-axis), respectively. Display of each section can be switched using the "Projection" in the context menu.

Main view settings

Settings for 3D-graphics and the top view are described in the *3D-graph* chapter. The following describes the settings related to classic Cambell diagram.

Scale - allows you to configure the correspondence between the signal value and size of its marker on the graph. The size is specified in screen pixels, the value of the signal in absolute values or in percent. When displayed in the form of points these fields are not available and do not affect the size of the points.

The image shows two panels from a software interface. The left panel is titled "Scale" and contains the following controls: a checkbox for "Show scale" (unchecked), a checked checkbox for "Percents", a text input for "Length, points" with the value "10", a text input for "Value" with the value "100% (10.290)", and a text input for "Dead band" with the value "0.00%". The right panel is titled "Diagram mode" and contains three radio button options: "Points" (unchecked), "Lines" (checked), and "Circles" (unchecked).

Show scale - shows or hides the scale of the graph.

Dead band - sets the lower display limit values

Graph view - the way of rendering the values as dots, vertical lines, or circles..

Y-range - allows you to enable or disable the auto-detection and set the Y range manually.

The image shows two panels from a software interface. The top panel is titled "Y axis range" and contains a checked checkbox for "Auto", a text input for "Minimum" with the value "0.000", and a text input for "Maximum" with the value "1000.000". The bottom panel is titled "Orders" and contains a checked checkbox for "Auto", a text input for "First order" with the value "1", a text input for "Last order" with the value "20", and a text input for "Step" with the value "1".

Order lines - sets the frequency of the display order lines and their range

Classical Campbell diagram can be displayed in three ways - in the form of dots, vertical lines, or circles. The height of the lines and the diameter of the circles depends on the value of the signal (RMS amplitude or magnitude) at a given point. This dependence is set by the *Zoom* group in the settings. If you select the **Value in percent**, 100% is taken as the maximum value in the signal.

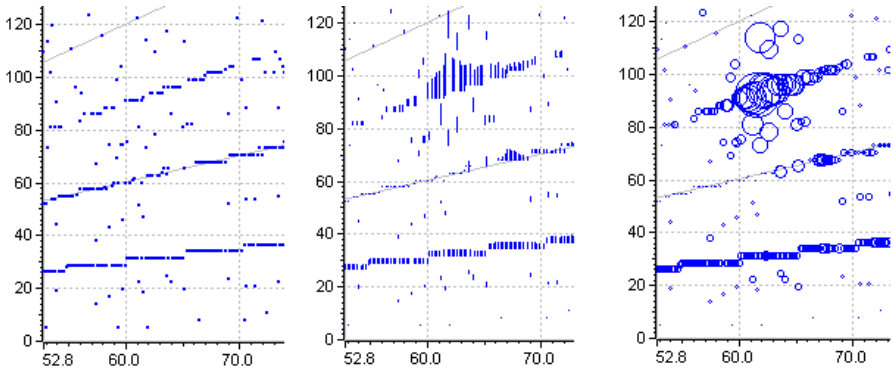
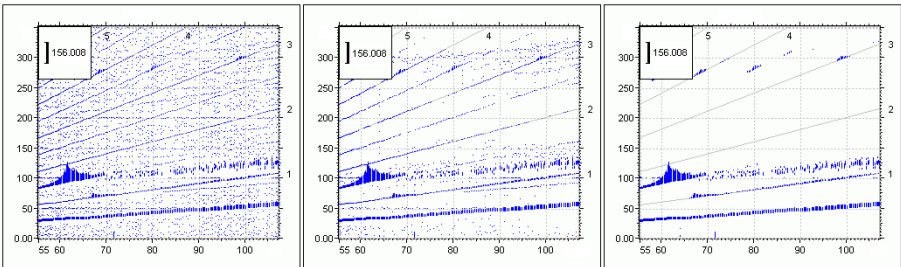
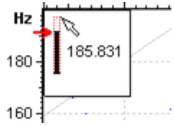


Fig. 10.19. Views of Campbell diagram

The zoom can be changed by dragging the zoom scale box top with the mouse.

Using **the Dead zone** parameter you can filter data, the value of which in relative units is less than a specified threshold. The following picture shows the graphs with different values of dead zone.



1) Dead zone = 0% 2) Dead zone = 1% 3) Dead zone = 5%

Fig. 10.20. The influence of the "dead zone" on the representation of the result

The range of the X axis matches that of tachocharacteristic. If the automatic Y range detection is enabled, the range is set from zero to the maximum value of the spectrum frequency of all signals represented by the diagram. The automatic detection of the range by Y can be disabled, and the required values can be set manually. Except for the grid by the axes X and Y, the diagram contains an additional grid showing the multiple harmonics (orders). The order of the first and the last lines as well as the step between the lines can be set.

Amplitude-Frequency Response calculation ✕

Range depends on the frequency...

... of the selected harmonic
 ... of the first harmonic

Scope

Lower limit, %	<input type="text" value="-10.0"/>	Min value, Hz	<input type="text" value="0.00"/>
Upper limit, %	<input type="text" value="10.0"/>	Max value, Hz	<input type="text" value="0.00"/>

Export

Harmonic range: ..

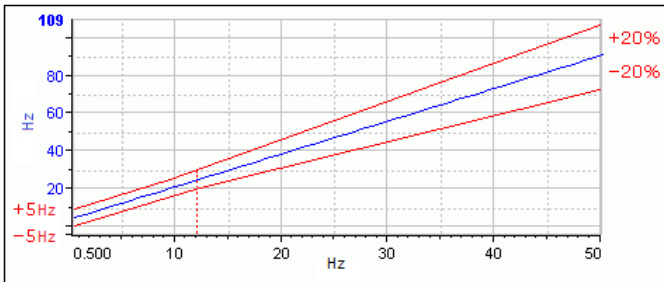


Fig. 10.21. Example of amplitude-frequency characteristic calculation

The frequency response is calculated using the RMS strip, the width of which is specified in the block *Boundaries*. Depending on the method of calculation of the boundaries, the range is calculated or the percentage frequencies of the selected harmonics, or the frequency of the first harmonic (tacho frequencies). Fields **Min./Max value** specifies the minimum bandwidth in Hz, if the field contains zero, this value is ignored. The graph shows how it will look in the band at the specified bounds +/-20% and min/max values of +/-5 Hz.

The frequency response of one or more harmonics can be saved as signals in the tree. Select a range of harmonics and click **Save**.

Order analysis

The order analysis is used to analyze dynamic processes, mainly on non-stationary modes such as run-down or run-up. The end result is a three-dimensional signal, where on X-axis is frequency spectrum or a multiplicity of harmonics, Z- axis is RPM or time, and Y-axis - amplitude, peak-peak, or RMS.

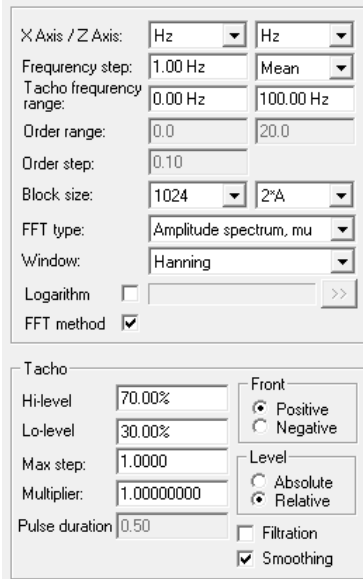


Fig. 10.22. Order analysis settings

The settings are divided into two groups: the algorithm settings and the tachocharacteristic settings.

Axis X / Axis Z - the size by the axes X and Z. The values in Hertz or the orders can be set by the axis X, and the values in seconds, Hertz or rpm can be set by the axis Z

Frequency step - determines the step to change the frequency of the tacho. If multiple values falls into a single range (for example, with non-monotonic tacho frequency in the selected time range), then the result will be taken from the first resulting spectrum, the average or maximum range (depending on the mode selected in the box to the right of this).

Tachofrequency range - the minimum and maximum values of the tachocharacteristic for the calculations.

Order range - the minimum and the maximum values to be set for the X axis in the resulting signal, if the orders are selected by the X axis.


Step by X axis - the step at which resampling is made while recalculating the spectrum frequencies into orders. The less is this value the more precisely the form of the resulting spectrum matches that of the source spectrum (the size of the resulting signal is increased in this case).

Block size - the block size (in samples) to perform the calculations. The type of values - RMS/Amplitude/Peak-to-Peak Value is selected on the right from this field.

Characteristic type – defines the type of the spectrum. Possible values: Amplitude spectrum, power spectrum, power density spectrum and the energy density spectrum

Weighting window – window function for spectrum calculation.

Logarithm - the logarithm of the result (algorithm of "taking the logarithm"). The

 button opens the logarithm settings window.

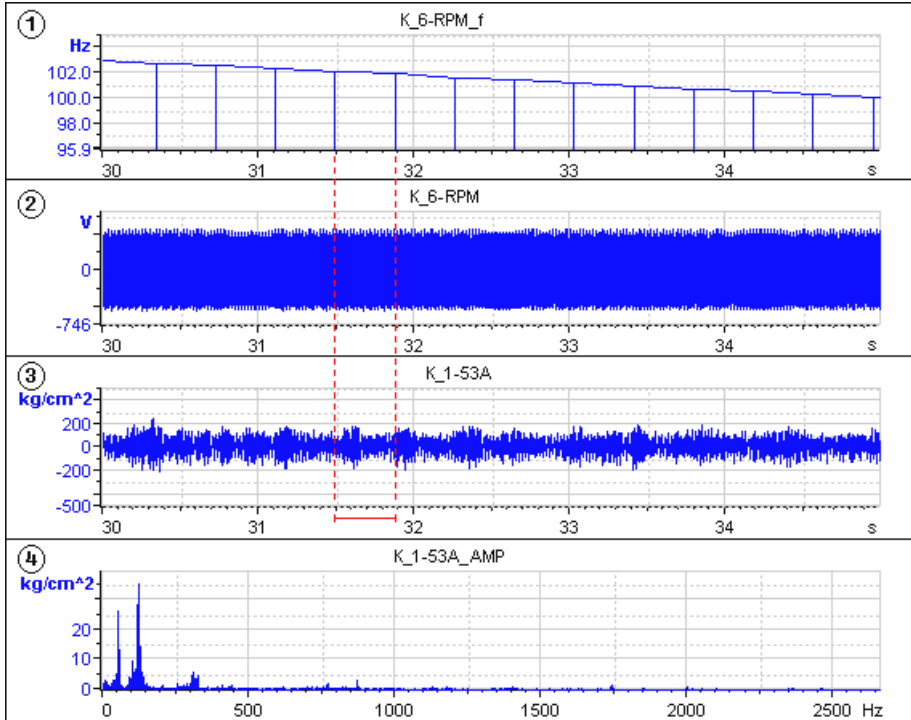



Fig. 10.23. Range selection for spectrum calculation

where:

- 1 - Tachocharacteristic;
- 2 - Source signal from the tachometer (tachosignal);
- 3 - Source signal from the sensor;
- 4 - Spectrum of the selected block of sensor signal (3).

If the settings for the Z-axis indicated the frequency (in Hz or rpm) then on the characteristics selected the range according to the frequency specified in the settings (*Tacho frequency range* field); if for Z axis the seconds selected, then the subsequent calculation is for the entire frequency range (i.e. entire signal).

 The calculation can only be made between the signals, the sampling frequency of which is coincides with the sampling frequency of tachometer.

For each value of the tacho that falls within this range, it is determined the corresponding data block in the source signal. For example, the next value for tacho was calculated for block size of 1024 counts, beginning in the 10th second, then from the raw signal from the acceleration sensor taking block with 1024 counts, starting from the tenth second of record. For this block calculated the spectrum with parameters specified in the settings, and stored in the resulting signal, as the next section of the Z axis. If in the settings for X-axis selected orders then, frequencies of spectrum are divided into tacho frequency, for which this spectrum was obtained.

If frequency is selected by the axis Z, and several values of tachocharacteristic are found in the same range defined by the set frequency step, only one spectrum is written to the resulting signal in the given range. This effect occurs if a large frequency step is selected, or frequency is changed slowly or monotonously at the given range.

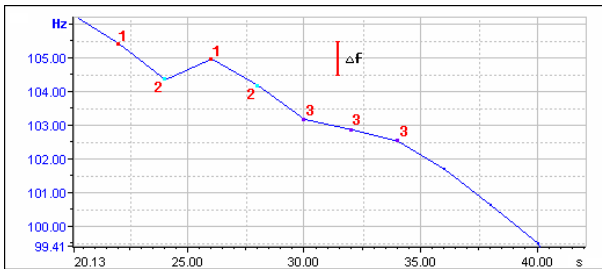


Fig. 10.24.

Fig. 10.24 shows the points of the same range by similar color. The frequency step is 1 Hz (shown by red vertical line). In the ranges 104.5 - 105.5 Hz (1) and 103.5 - 104.5 Hz (2) the tachocharacteristic is not monotonous, hence, two values are found in these spectrums. Three values are found in the range 102.5 - 103.5 Hz (3) due to slow tachocharacteristic changes.

Fig. 10.19 shows the points of the same range by similar color. The frequency step is 1 Hz (shown by red vertical line). In the ranges 104.5 - 105.5 Hz (1) and 103.5 - 104.5 Hz (2) the tachocharacteristic is not monotonous, hence, two values are found in these spectrums. Three values are found in the range 102.5 - 103.5 Hz (3) due to slow tachocharacteristic changes.

The method of obtaining the resulting spectrum is specified by the settings (on the right to the **Frequency step** field). The first spectrum calculated for the given range, or the spectrum obtained by averaging of several spectrums, or the spectrum obtained by selection of maximal values of several spectrums can be taken as a resulting one.

Fig. 10.25 demonstrates the results of application of different methods to four source spectrums shown by the top graph. The second graph shows the first spectrum, the third - averaged spectrum, the fourth - the maximum spectrum.

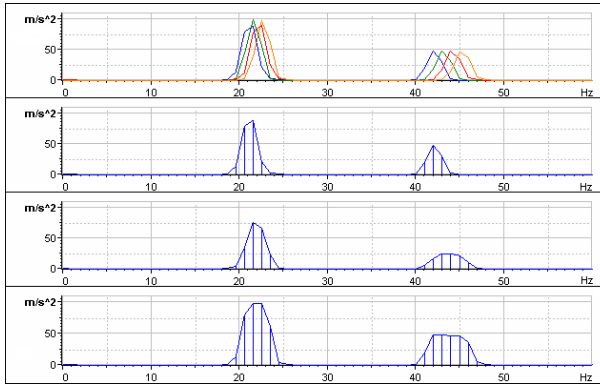


Fig. 10.25.

After calculation, the result is displayed in the form of three-dimensional graph (Fig. 10.26).

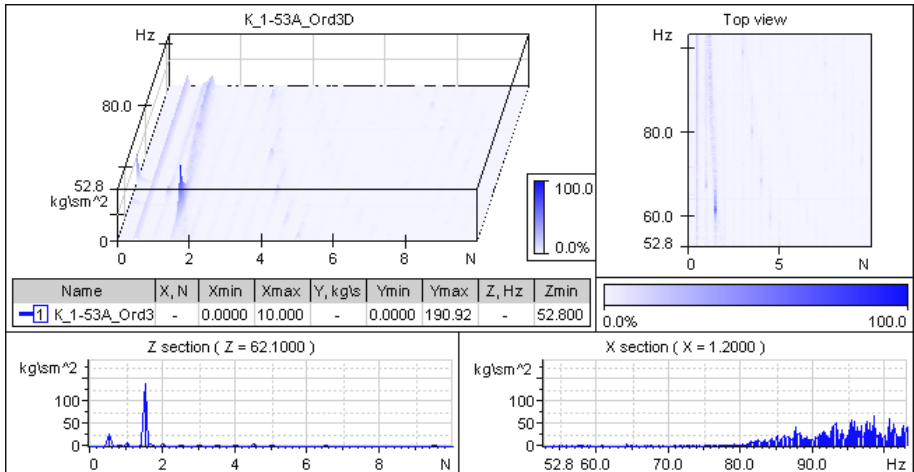


Fig. 10.26. Viewing the order analysis results as 3D graph

Shock spectrum

The aim of the tests for resistance to impact is analysis of the measurements results obtained during recording of signals from vibration sensors located on the test object. The shock spectrum is calculated to determine the number of responses of the investigated components and subassemblies, which in the mathematical model

are presented in the form of oscillatory systems (oscillators), each of which has a natural frequency f_n determined by the characteristics of the M_n and C_n (Fig. 10.27). Shock spectrum allows to determine the frequency of the oscillators (nodes and elements) that will experience the greatest load when installed on the test unit.

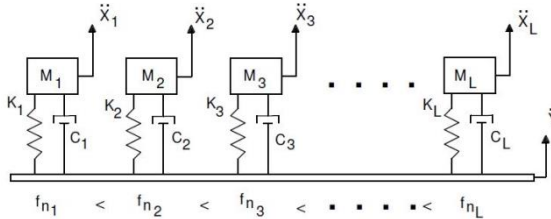


Fig. 10.27. Model of the oscillating system

Calculation of the shock spectrum based on the analysis of the time realization of the signal coming from accelerometer. When calculating, the force acting upon a number of oscillators with natural frequency f_n can be expressed using the acceleration signal. The response of each oscillator (with frequency ω_n) is independent of the other oscillators. According to Newton's second law, the motion of each oscillator can be represented in the form of the differential equation:

$m\ddot{x} + c\dot{x} + kx = c\dot{y} + ky$, where x – the movement of the oscillator (the desired value).

The maximum value is shown as the point on the graph of the shock spectrum (X_{max}, ω_n), y – moving of support on which is fixed the oscillating system (the signal from accelerometer). The equation can be rewritten in the form:

$\ddot{z} + 2\xi\omega_n\dot{z} + \omega_n^2z = -\ddot{y}(t)$, where $z = x - y$; $\omega_n^2 = k/m$ – oscillator natural frequency rad/s); $2\xi\omega_n = c/m$, where ξ – the damping ratio, which is also often presented as $Q = 1/2\xi$.

The last equation has no analytical solution for random effects $Y(t)$.

Below is the formula that allows to solve the equations numerically, presenting the input stimulus in the form of finite differences. Here Δt is the time interval with which it is registered, the sequence $Y(t)$, defined by the sampling frequency of the ADC.

$$\ddot{x}_i = +2 \exp[-\xi\omega_n\Delta t] \cos[\omega_d\Delta t] \ddot{x}_{i-1} - \exp[-2\xi\omega_n\Delta t] \ddot{x}_{i-2} + 2\xi\omega_n\Delta t \ddot{y}_i + \omega_n\Delta t \exp[-\xi\omega_n\Delta t] \left[\left[\frac{\omega_n}{\omega_d} (1 - 2\xi^2) \right] \sin[\omega_d\Delta t] - 2\xi \cos[\omega_d\Delta t] \right] \ddot{y}_{i-1}$$

where $\omega_d = \omega_n \sqrt{1 - \xi^2}$

For this equation it is possible to build the response of an oscillator with a specified damping ratio and natural frequency $X(t)$ on the input stimulus, $Y(t)$.

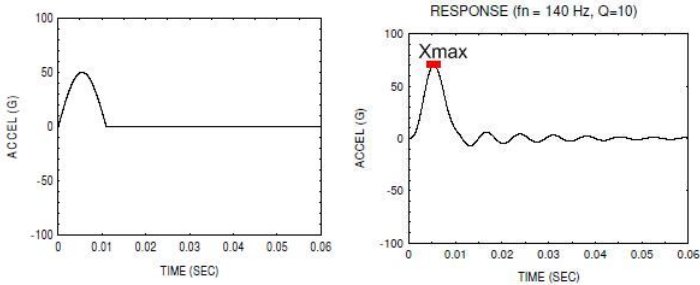


Fig. 10.28. Source influence and example of the reaction to it

The shock spectrum algorithm performs the following calculation:

- 1) The user defines the damping ratio ξ .
- 2) The range of analyzed frequencies and the step frequency (determines the amount of calculation algorithm and, accordingly, the time of his execution). The number of points of the shock spectrum is the frequency range divided by the step frequency.
- 3) or each oscillator with frequency ω_n calculated response $X(t)$.
- 4) The maximum value X_{max} (see Fig. 10.28) shown as a point on the y-axis of the shock spectrum, on x-axis assumes a value of f_n (natural frequency of the oscillator).

<input checked="" type="checkbox"/> Search shock	
Signal/noise ratio	20.0 <input checked="" type="checkbox"/>
Excess of level, %	70.0 <input type="checkbox"/>
Duration, sec	0.3000
Gap before, sec	0.0500 <input checked="" type="checkbox"/> Auto
FFT options	
Begin frequency, Hz:	0.0
End frequency, Hz:	0.0
Frequency step, Hz:	10.0000
Damping coefficient	0.050
<input type="checkbox"/> Logarithmic step	<input type="checkbox"/> Quality factor
Other options	
<input type="checkbox"/> Filtration	Low freq, Hz: 0.0
	High freq, Hz: 0.0
<input type="checkbox"/> Resampling	New sampling rate, Hz: 0.0

Fig. 10.29. Settings of shocks search and shock spectra calculation

Group of *Impact search* settings allows you to automatically determine the portions of the signals to be processed. Search impact is as follows: the signal is divided into portions, equal to 1% of the signal. At each portion is calculated the RMS signal. The RMS signal calculated by the first portion is assumed as a threshold value. When this value is exceeded in the number of times equal to the ratio of **signal /noise**, the detector of the presence of the shock is triggered. To the left of the trigger point is shown a time specified in the **Left space** line (if the mode is set to **Auto**, then the left will displayed time equal to 2% duration of the shock pulse). The duration of a shock pulse specified in the **Duration** line. If you select Auto mode, and the signal contains multiple shocks, the algorithm will identify them all and calculate the spectrum for each pulse (Fig. 10.30).

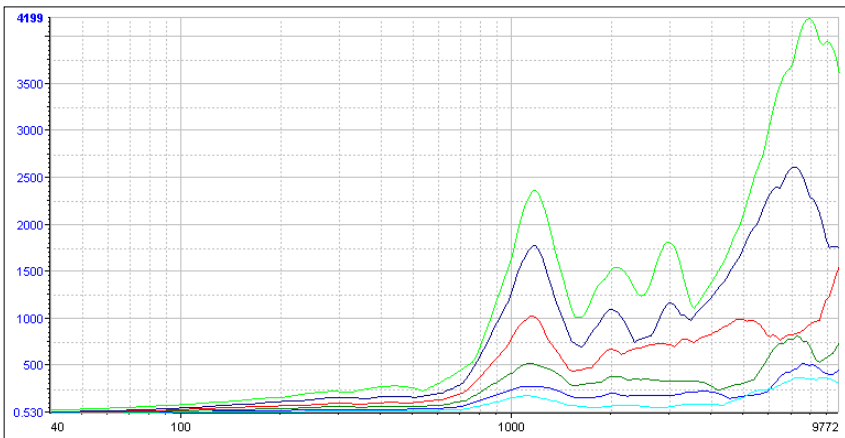


Fig. 10.30. Result of processing of signal contains multiple shock pulses.

The *Setting of the spectrum* group determines the processed amount of data. The number of shock points equal to the difference between the spectrum start frequency and end frequency divided by the step frequency, with a uniform step.

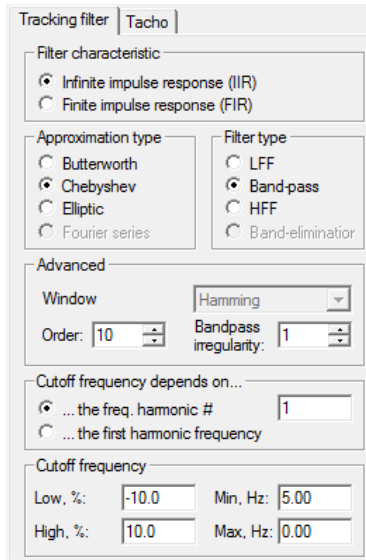
For logarithmic step instead of step frequency the number of points per decade is specified. The damping ratio ξ is set as a percentage. The default value is 0.05, which corresponds to 5%. If you have selected the "Q" option, instead of damping then the quality factor ($Q=1/2 \xi$) will be specified.

The *Options* group allows you to **filter** the original signal with a bandpass filter. **Oversampling** mode enables the use of the calculation of the shock spectrum with increased sampling frequency of the original signal. Since the algorithm uses the method of finite differences, the accuracy of the calculation depends on the sampling rate. According to the experimentally derived ratio the sampling frequency of the signal should be 20 times greater than the frequency of the source exposure. With further increase of the sampling frequency calculation results do not change.

Tracking filter

Used to filter signal with cutoff frequencies specified as function of tacho frequency.

The settings are divided into two groups: the algorithm settings (Fig. 10.31) and settings of the tacho (Fig. 10.4).



Tracking filter | Tacho

Filter characteristic

Infinite impulse response (IIR)
 Finite impulse response (FIR)

Approximation type

Butterworth
 Chebyshev
 Elliptic
 Fourier series

Filter type

LFF
 Band-pass
 HFF
 Band-eliminator

Advanced

Window: Hamming

Order: 10

Bandpass irregularity: 1

Cutoff frequency depends on...

... the freq. harmonic # 1
 ... the first harmonic frequency

Cutoff frequency

Low, %: -10.0

High, %: 10.0

Min, Hz: 5.00

Max, Hz: 0.00

Fig. 10.31. Settings of tracking filter.

Section 11. WinPOS scripting features

WinPOS scripts

WinPOS provides the user with the interfaces for creation of own scripts, plug-ins or applications, operating with the data and algorithms of WinPOS almost in any modern programming environment.

Borland Delphi is the best solution for writing own effective processing algorithms, processing of large amount of data, creation of applications based upon WinPOS but requiring additional customization or being able to generate specialized reports. Borland C++ Builder, Microsoft Visual C++, Visual Basic or FoxPro can also be used.

However, Visual Basic Script is more suitable for writing small WinPOS scripts or simple algorithms. VBScript is included into the Microsoft Windows delivery package, requires no separate compiler, and a convenient environment for editing and debugging of scripts is included into WinPOS.

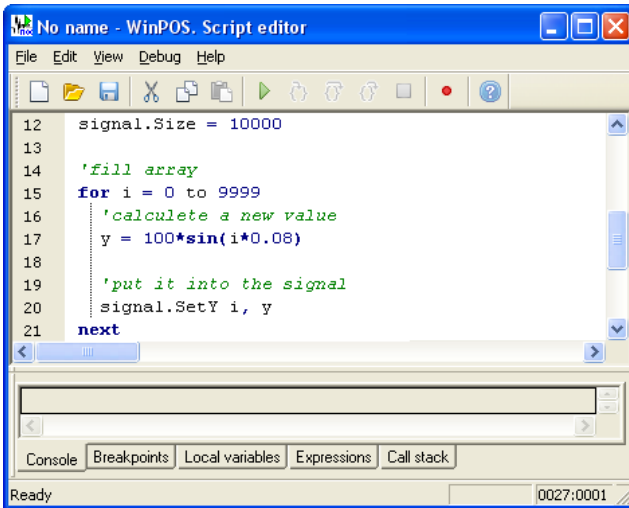


Fig. 11.1. Script editor

The script editor is a text editor with syntax highlighting and a standard toolset that can be accessed by menu, toolbar and hot keys/

The script editor provides the user with all necessary tools for the script execution while debugging: breakpoints and step by step execution, viewing of local variables and the call stack, calculation of expressions.

A detailed description of the script editor, interfaces, methods of program documenting and samples are provided in the *Programmer's Guide*.

The script execution could be started in several ways:

- From the script editor - **Debug**→**Run/Break** (<Ctrl+F10>),

- Select **Script**→**Run script...** in the WinPOS main window or select one of previously executed scripts from the same menu.
- From the command line (“winpos.exe myscript.wps”).

A typical example of the first program by VBScript is given below:

```
sub main
  DebugPrint "Hello, world!"
end sub
```

The line «Hello, world!» will be printed in the *Script editor* panel.

Start from the command line

The file names - USML(.usm), MERA(.mera) or script files(.wps) can be specified (separated by a space) as the WinPOS command line parameters. In this case the data files are placed to the signal tree, and the script is executed. The data file (USML or MERA) can be placed to the graph page by the -s key.

```
WinPos.exe [-h] [[-s] [usmlfile1.usm]..[-s]
  [-q]..[usmlfileN.usm]] [[wpsfile1.wps]..[wpsfileM.wps]]
```

List of command line keys

- s Open all files after the ”-s” key in graphs
- q Cancel the ”-s” key effect
- h Information on the command line keys and parameters

Examples

```
WinPos.exe -h
- WinPOS Help is opened

WinPos.exe test.mera u123_45.usm start.mera
- 3 files are added to the signal tree

WinPos.exe test.usm u123 45.usm -s start.mera error.usm -q finish.usm
- 5 files are added to the signal tree, start.usm and error.usm files are opened in the graphs

WinPos.exe myscript.wps
- the myscript.wps script is executed

WinPos.exe test.mera myscript.wps
- the test.mera file is opened and the script myscript.wps is executed
```

Appendix A. File formats

1. MERA file structure

The data in the MERA format stored in the same directory and distributed across multiple files (with extensions that define type of data).

The list of files according to the data type is given below:

- Test name.**mera** - text data a parameter list
- Parameter name1.**dat** - parameter binary data
- Parameter name1.**x** - binary data on x axis (at unequal step)
- Parameter name1.**prt** - shift and time of portion start without registry interrupt
- Parameter name1.**lbl** - marks, modes, in association with time
- Parameter name1.**stat** - information on the signal status
- Name of settings.**lvl** - file containing settings list
- Name calibration.**tx** - linked calibration files

1. File **.mera** (text)

Standard ini-file syntax: [section], field=field value, ";" – comment. Any field can be skipped, and then the default value is used. The fields of **[MERA]** are the file heading (example of field listing):

- [MERA]** - *file signature*
- Test**=TestName - *test name*
- Prod**=ObjectName - *product name*
- Date**=03.02.01 - *test date*
- Time**=12:34:45.789 - *test time*
- LinkAll**=FALSE - *the flag considering all files *.dat of this catalog as parameters (at LinkAll=TRUE). All parameter data fields are filled by default values. If this flag is missing, commented or LinkAll=FALSE, the parameters of the file .mera only are used.*

Each parameter has a section **[parameter name]** in the file **.mera** (example of field listing):

- [{16-1}-M2408]** - *parameter name*
- Char**=DR - *performance name («DR», «AFR», «spectrum»,...)*
- Comment**=Test1 - *comment*
- StartTime**=01:02:03.045 - *start time of parameter writing, by default: Time(from heading) + Start(seconds)*
- XUnits**=s - *X axis units, by default: "s"*
- YUnits**=V - *Y axis units*
- Start**=0.0 - *start time (initial value of X) , by default: 0*
- Step**=3.125e-005 - *sampling, by default: 1*
- Freq**=32000 - *frequency, by default: 1*
- k0**=0 - *linear conversion coefficients, if not specified: k0=0, k1=1*
- k1**=0.038
- PolyTX**=0 - *$y=k1*(x-k0)$ if PolyTX=0, $y=k1*x+k0$ if PolyTX=1*

XFormat=R4 - data format by X, by default: I2 (see below)
YFormat=R8 - data format by Y, by default: I2 (see below)
maxY=11172 - maximum value of Y
minY=-14358 - minimum value of Y
TX0=calibration.tx - calibration files (must be found in the same catalog)
 ⓘ If k1 and k0 are set, the linear conversion is made first.
 If Calibration1=, Calibration2=,..., CalibrationN=, use sequence calibration
Lvl=settings.lvl - settings file (must be in the same catalog).
For 3D signals only:
ZSize=0 - Z axis size: number of sections (for 3D parameters)
ZStart=0 - Z start value (for 3D parameters)
ZStep=1 - step by Z axis (for 3D parameters)
ZUnits=s - Z axis units (for 3D parameters)
ZFormat=I2 - data format by Z, by default: I2 (see below)

Possible field values **YFormat**, **XFormat** and **ZFormat**. The line constants analog to VARTYPE should be used (*Version 1*). Example: **YFormat**=R8

Values.	Values.	Description
Version 1	Version 2	
I1	byte	- one byte integer with sign
UI1	-	- one byte integer without sign
I2	int	- two byte integer with sign
UI2	-	- two byte integer without sign
I4	int32	- four byte integer with sign
I8	-	- eight byte integer with sign
R4	single	- four byte integer with floating point (single precision)
R8	double	- eight byte integer with floating point (double precision)

2. File **.dat** (binary)

It contains the parameter binary data. Data format is defined by the field **XFormat** (see above) of the file **.mera**

3. File **.x** (binary)

It contains the X axis parameter binary data. Data format is defined by the field **XFormat** (see above) of the file **.mera**

At equal signal X scale this file is absent!

4. File **.prt** (text)

It contains the information on shifting and the time of portion start when writing and 3D processing.

Each line contains the information on one interval in the following formats:

Field number	Format	Description
1	number	Initial time value of the next interval.
2	number	Shift in the file.dat, in indexes.

The fields are separated by spaces, the line is finished by the enter line and line return symbols.

This mode cannot be used with unequal X axis!

5. File **.Jbl** (text)

It contains the information on modes and marks with association to the signal time scale.

Each line contains the information on one mark in the following formats:

Field number	Format	Description
1	number	Shift by the abscissa, in XUnits.
2	key word, symbol line	Key word «MODE» – attribute of new mode start. If skipped, a simple mark is set by the line.
3	symbol line	Name or mode or mark

The fields are separated by space symbols, the line is finished by the line feed and return symbols.

Example:

```
105.533 MODE Mode1
112.178 M1
145.300 M2
```

6. File **.Jvl** (text)

Contains the information on settings. As well as a calibration file, can be connected (in a file .mera) to several parameters simultaneously.

Each line contains the information on one setting in the following formats:

Field number	Format	Description
1	symbol "L" or "H"	Attribute of high ("H") or low ("L") setting. The signal values above the high or below the low setting are considered beyond the setting.
2	number	setting level in YUnits.
3	hexadecimal constant	RGB color of setting
4	symbol line	text message of setting (if any)

The fields are separated by space symbols, the line is finished by the line feed and return symbols.

Example:

```
H 5.500 0xFF0000 emergency temperature raise
H 4.500 0xFFFF00 temperature above normal value
L -6.500 0xFFFF00 temperature below normal value
L -7.500 0xFF0000 emergency temperature fall
```

7. File **.stat** (binary)

Contains the information on changing the signal status in association with the shift. Contains the pair sequence of binary words:

Field number	Format	Description
1	binary word, 32 bits	Shift in file .dat, in bytes.
2	binary word, 32 bits	Signal status code

The values of separate status code bits are explained in the file .mera (section [MERA]) in format:

st1=beyond the scale

st2=unreliable

The digit here corresponds the bit number of the double status word (1..32).

8. File **.tx** (text)

Contains polynomial coefficients or interpolation nodes (line written numbers). Has two formats:

x0 y0
x1 y1
...

Each line of file contains a pair of numbers separated by space symbol, to set the portion linear conversion.

k0
k1
k2
...

Each line of file contains one number, definition of polynomial coefficients. Number of coefficients matches the polynomial degree, i.e. k0, k1 – linear conversion, k0,...k7 – 7th degree polynomial, etc.

The fields are separated by space symbols; the line is finished by the line feed and return symbols.

1. The data file of USML type is characterized by the following structure:

Data file heading	Table of parameter passport	Information
32 bytes	58 • <number of parameters>	Size not limited

2. The file heading is characterized by the following structure:

USML	Product name	Test name	Test date ss/mm/yy	Number of parameters (performances)	Reserve field
4b	8 bytes	8 bytes	8 bytes	2 bytes	2 bytes

3. The structure of the parameter passport in the table of passport:

Parameter	Performance	Size	Discrete	K0	K1	Massive size	Format	Tb	Te	RESERVE
12b	12 bytes	8b	4b	4b	4b	4b	1b	4b	4b	1b

4. The information is structured as follows:

Value massive of the 1 st parameter	Massive end attribute (FFFF)	Value massive of the 2 nd parameter	Massive end attribute (FFFF)	...	Value massive of the last parameter	Massive end attribute (FFFF)
--	------------------------------	--	------------------------------	-----	-------------------------------------	------------------------------

5. General notes

5.1. Each separate file may contain either direct parameter data entry, or the parameter characteristics. Direct records and characteristic should not be stored in one file.

5.2. One file may contain performance of different parameters.

5.3. The number of parameters (performances) in one file should not be more than 65536.

6. USML file heading

6.1. "USML" letters must be found in the first 4-byte field.

6.2. The fields "product name", "test name", and "test date" contain ten symbol lines 8 byte each.

7. Parameter passport table

7.1. The field "characteristic name" contains a symbolic name of performance or the line "DR", in case the file contains direct entry of the parameter data.

7.2. Sampling step, scaling coefficients K0 and K1, and the time of start and end of the data in the massive are set by the floating point format.

7.3. The scaling coefficients are considered as follows:

$y = K1 \cdot (x - K0)$, where x - value of parameter or characteristic in the massive, y - transformed value of x. If K1=0.0, the scaling is not used.

7.4. Massive length is an integer without sign.

7.5. The value format field takes 1 byte and may contain the following data:

Format	Length	Format	C type	Pascal type
1	1 byte	integer	unsigned char	byte
2	2 bytes	integer	short	integer
3	4 bytes	integer	long	longint

4	4 bytes	with floating point	float	single
8	8 bytes	with floating point	double	double

7.6. The value of reserve byte equal to three means the signal writing with unequal step, i.e., by Y,X pairs, and the format of each value of the pair is defined by the format field. The first half of value massive is taken by the values of Y, the second – by the values of X.

8. Arrays of the parameter (performance) values are arranged in the order of their passports in the passport table. The number of bytes of each value is defined by the passport field "value format".

3. File structure of Vibration survey calculation settings

The settings file has INI format and can contain several sections, one for each Excel page. The section name is written in square brackets and this name must match the name of respective page. After the section name the parameters are listed as follows:

<name_parameter>=<value>

Tolerable parameters:

- num_chars Number of estimations
- channel_cell Table cell coordinates corresponding the name of the 1st channel.
Values: number_column, number_line
- channel_orient List of channels in the table.
Values: HORZ – horizontal; VERT – vertical.
- num_named_channels Number of pre-set channels
- channel1_name Name of the 1st preset channel;
- channel1_chars List of estimation numbers calculated by the present channel
- ...
- channel[n]_name Name of preset channel
- channel[n]_chars List of estimation numbers calculated by the present channel
- charact1_options Options of the 1st estimation. Note! This parameter should not be used manually. To change this parameter use the vibration report settings window and save the result by the menu item «Save settings».
- charact1_cell Table cell coordinates the corresponding name of the 1st channel. if this field is empty the estimation is not put into the report.
Values: number_column, number_line
- ...
- charact[n]_options Options of the estimation. Note! This parameter should not be used manually. To change this parameter use the vibration report settings window and save the result by the menu item «Save settings».

character[n]_cell Table cell coordinates the corresponding name of the 1st channel. If this field is empty the estimation is not put into the report.
Values: number_column, number_line

Sample settings file (parameter names are shown by bold font):

```
----- start of file -----  
[Template1]  
num_chars=4  
channel_cell=4,9  
channel_orient=horz  
num_named_channels=1  
channel1_name=TAXO_1  
channel1_chars=4  
  
character1_options=type=6,name=e1,username=0,srcTaho=-  
1,tRez=0,tAxesX=0,tRezMag=0,tTransf=1,tWin=3,rGarm=1.000,deltaF=1.0  
00000,nPointsSM=1000,fSortRez=1,fMonFase=1,LevelLo=0.000000,LevelHi  
=1.000000,level_dF=1.000000,dPNTwide=0.500000,coefTaho=1.000000,fFr  
ont=0,fAbsOtn=0,fFiltrTaho=1,fFiltrTahoSrc=0,nPNTAvr=5  
character1_cell=4,10  
  
... [ some settings skipped ] ...  
  
character4_options=type=0,name=f1,username=0,srcTaho=,tRez=24,tAxesX=  
1,tRezMag=0,tTransf=0,tWin=3,rGarm=1.000,deltaF=1.000000,nPointsSM=  
1000,fSortRez=1,fMonFase=1,LevelLo=0.000000,LevelHi=1.000000,level_  
dF=1.000000,dPNTwide=0.500000,coefTaho=1.000000,fFront=0,fAbsOtn=0,  
fFiltrTaho=1,fFiltrTahoSrc=0,nPNTAvr=5  
character4_cell=  
----- end of file -----
```

Appendix D. Troubleshooting

Problem	Cause	Solution
<p>WinPOS gives a message that the electronic key is not installed. WinPOS cannot be started.</p>	<p>Mismatching of the key and installed WinPOS copy. E.g., the key «Professional» allows starting of professional and lower versions of WinPOS. <i>WinPOS Expert</i> does not operate with this key.</p>	<p>Install WinPOS, matching the key marking. If marking is damaged run the program <code>chknsw.exe</code> from the subdirectory <code>Active</code> of the WinPOS installation folder. Usually this folder is found «<code>c:\Program Files\MERA\WinPOS</code>».</p> <p>The number in the field Mask means: 001Fh – Expert, 000Fh – Professional, 0003h – Standard, 0001h – View.</p>
	<p>Incorrect installation of WinPOS or the system configuration disables USB driver installation (LPT).</p>	<p>Check the following.</p> <ol style="list-style-type: none"> 1. In CMOS Setup: USB (or LPT) ports enabled. 2. In NT/2000/XP the installation is made with Administrator rights. 3. USB-key is connected after installation of the program and drivers (If Windows founds an unknown USB-unit – remove this unit). <p>Try to reinstall WinPOS considering the above recommendations and following the prompts of the installation program.</p> <p>If the problem remains unresolved, run the program <code>instdrv.exe</code> from the folder <code>Active</code>. Press Configure driver and check setting of Yes in the field Use this port? Press the button Reinstall driver.</p>
<p>Noticeable defects of the graph printout: wide black “frame” on the right and below, chaotic color strips or points, wrong printing of text, etc.</p>	<p>Found at some types of Windows 2000 graphic adapters. This is caused by incorrect operation of OpenGL drivers from the standard Windows package.</p>	<p>1. Preferable. Update drivers from the manufacturer's webpage or install a universal package for your adapter (Detonator for NVIDIA, Catalyst for ATI Radeon, etc)*</p> <p>2. Universal. If the video adapter drivers cannot be updated for some reason, disable graphic acceleration in WinPOS settings. Set <code>EnableHAL=false</code> in the file <code>winpos.ini</code>.</p>
<p>The line extends beyond the graph field.</p>	<p>Incorrect operation of OpenGL drivers of the Windows standard package.</p>	<p>If the problems remains after updating the video adapter* drivers set in the <code>winpos.ini</code> file: <code>SafeClip=true</code></p>
<p>Empty page instead of graph printout.</p>	<p>Insufficient memory for the printer to print the graph (half-tone).</p>	<p>Try to reduce resolution in the printer settings from 1200dpi to 600dpi or from 600dpi to 300dpi.</p>

Problem	Cause	Solution
In Windows XP if WinPOS is started the tooltips of the taskbar buttons contains incorrect text.	According to the Microsoft Support Service the given problem emerges in Windows XP when any application with the OpenGL hardware acceleration is used.	The error is corrected in the Windows XP Service Pack 2. You can find the instructions as to updating and auxiliary information at the address: http://support.microsoft.com/kb/814135

* - You can find a universal drivers package for NVIDIA in the Drivers folder of the WinPOS installation disk.

In case you have questions and find no answer in the present *User's Guide*, or detected errors of WinPOS operation, we recommend you to address the technical support service.

WinPOS technical support contacts

E-mail: winpos@nppmera.ru

Phone: +7 (495) 783-71-59

Upgrade software

www.winpos.ru or

www.nppmera.ru

Menu **Supporting**, command **Download**, **WinPOS** section.

Glossary

Algorithm

A mathematical description of the sequence of operations to convert one signal into another.

Folder

The software object created for convenience of storage and searching of the signals of similar type. The file of MERA and USML format can be regarded as a folder containing signals registered in the course of one test.

Graph

The domain limited by the coordinate axis, containing the plotted signal lines. One graph can contain several lines.

Index

The number of value, offset in the signal value massive. The first signal change is associated with zero index.

Line

A flat curve graphically representing changing of one signal parameter in respect to another one. As a rule, the line shows a change of registered or calculated parameter as a function of time.

Operator

The algorithm with the customization set.

Page

The software object uniting several graphs.

Signal

The information (data massive containing service information) registered in the course of test in one physical channel or obtained by the source signal processing.

Tachosignal

Tachosignal is the signal from the RPM sensor mounted on a rotating part of machine.

Tachocharacteristic

The tachocharacteristic is the frequency characteristic of the tachosignal. It shows the rotation frequency expressed in Hertz (Hz) or RPM change over the time. The reduced designation of the tachocharacteristic – "tacho" – is also used in the WinPOS.

Tachofrequency

The tachofrequency is the calculated value of the tachocharacteristic in a given moment.

Tree

A hierarchy data storage structure used by WinPOS for systematization of access to the source data and results, algorithms, graphs, etc. In Windows the tree is displayed by a standard element.

Work session

The WinPOS state: the signals loaded and received during processing, the plotted graphs. The session can be saved on a disk and later is restored.