WinPOS

Signal Processing Package

User's Guide

Edition 3.0

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About this Guide

The present Guide is a complete operation handbook of the signal processing package – WinPOS. This Guide is intended for Windows users and thus does not include any description of standard elements of the Windows graphic user interface (GUI).

Structure of the Guide

Part 1 tells about features, application areas, and design history of WinPOS.

Part 2 contains the information necessary for installation and updating of WinPOS, PC requirements.

Part 3 describes the interface and provides a general description of the WinPOS operation principles. This Part also covers references to description of all interface items and can be used as a handbook of the batch operation.

Parts 4 to 11 contain detailed descriptions of the operation methods and the WinPOS interface.

Appendix A contains mathematical descriptions of WinPOS algorithms.

Appendix B contains guidelines for the algorithm applications.

Appendix C contains WinPOS file formats.

Appendix D contains troubleshooting instructions.

Glossary is provided at the end of this Guide.

Conventions

The following conventions are used in the present Guide for the reader's convenience.

< >	Angle brackets indicate function keys and their combinations, e.g., <Ctrl>
→	The symbol → is used to divide the menu levels. E.g., **File→Open…** means that the item **Open…** shall be selected in the **File** menu.
File	**Bold** denotes the names of menu items or dialog box elements that can be selected and enabled by mouse button click.
Signal	*Italic* denotes the names of the Guide chapters, WinPOS windows explained in the *Glossary* at their first appearance in the text further.
`signal`	`Monospace` font denotes text or characters to be entered from the keyboard, lines of configuration files.
ⓘ	Important information, caution or recommendation.

Part 1. Introduction

What is WinPOS

The software product WinPOS is intended for processing of the measuring data by standard mathematical and statistical *algorithms*, graphic representation and documenting of the data.

WinPOS includes:

- Powerful graphic interface (2D & 3D),
- Batch data processing,
- More than 50 signal processing algorithms,
- Support of scripts (VBScript) and plug-ins,
- Graph plotting means,
- Report preparation,
- Vibration analysis,
- Signals with the length of up to $2 \cdot 10^9$ values,
- Integration with MR-300 and Recorder software packages,
- Detailed User's Guide and Programmer's Guide,
- Extended help.

WinPOS delivery versions

WinPOS is delivered in four main versions: View, Standard, Professional and Expert.

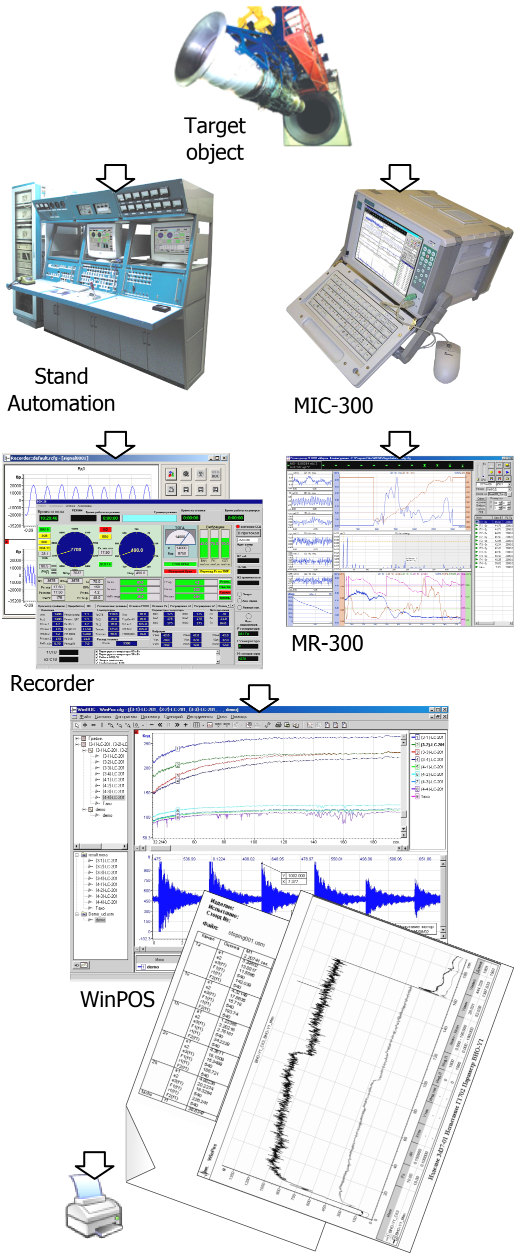
Unlike **Standard,** WinPOS **View** contains a demo algorithm set mainly intended for the measurement data viewing and documenting.

WinPOS editions **Professional** and **Expert** allow creation of own signal processing algorithms, automation of the input signal processing from the source file selection to the processing output documenting. 3D signals are also supported by two major versions only.

WinPOS **Expert** allows the analysis of stochastic, dynamic processes, including vibration ones (See Part 10 *Vibration analysis*).

	Algorithms	Scripts, plug-ins	3D signals	Vibration analysis
view	☐	☐	☐	☐
standard	☑	☐	☐	☐
professional	☑	☑	☑	☐
expert	☑	☑	☑	☑

WinPOS measurement cycle



RPE «MERA» manufactures and supplies hardware and software means intended for full automation of measurement data acquisition and processing. WinPOS represents one of the final stages of the measurement cycle.

Portable multi-channel equipment sets, testbeds and monitoring systems are equipped with recording software (Recorder and MR-300). The recording software operating as a digital tape recorder is able to perform specialized data processing and control.

Further the registered data are processed by WinPOS, the switching to WinPOS is performed by pressing the button on the recording program toolbars.

The WinPOS algorithms together with scripts and plug-ins make the implementation of complex processing procedures possible. The processing completion is assisted by a professional toolset for report drawing. WinPOS perfectly completes the development registration tools of RPE «MERA», and successfully applied both as a separate tool and in combination with other research packages.

WinPOS design history

The name **WinPOS** means the signal processing package (POS) for Windows.

In early 90s the signal processing package – **POS** developed by RPE «MERA» became a revolutionary by its options software. The program was applied to almost all industry branches and was successfully used by many R&D institutions.

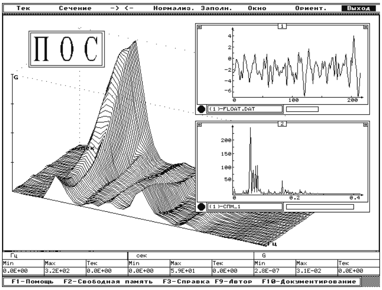
In mid 90s the package POS-M was developed, making application of advanced POS solutions to monitoring and to the testbeds possible. The energy production enterprises, aviation and machine building companies, sea-based space launch facility «Sea Launch» still operate POS-M.

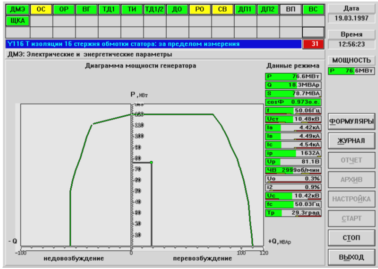
The limitations of MS-DOS and growing requirements to the measurement data volumes and convenience of the data processing and representation, constrained the improvement of POS and POS-M in their existing forms. Hence, WinPOS was elaborated.

WinPOS inherited the best features of POS (powerful mathematical toolset, simplicity and convenience of operation, extendibility), and pushed such features to a new modern level.

WinPOS **Expert** replaced the dynamic analyzers developed by RPE «MERA», i.e., DAN and WDAN software.

In 2004 the official registration certificate of the software "Signal Processing Package WinPOS" was obtained.





PC requirements

WinPOS is installed at any PC with Microsoft Windows 98 and higher (Windows 2000, XP, etc.).

On PC one USB or LPT port must be free (the parallel port key is transparent for communications between the PC and the external LPT-unit, e.g., printer).

The software requires no more than 20 Mbytes of the disc space (depend upon the delivery version). But it is desirable you have a reserve of the disc space for a storage of the calculation results. The PC processor clock rate must be not less than 1 GHz, and RAM - not less than 128 Mb to provide the appropriate calculation speed

ⓘ In the bottom right corner WinPos shows a free space on the chosen disk, suffice for a place of the temporary files and a saving the sessions. If it is not enough places on this disk either clear it or select the other partition of the hard disk as a work catalog of the WinPos. (See part 4, Fig. 4.7.)

You need a graphic adapter with OpenGL hardware accelerator and a mouse with a scrolling wheel for the operation with 3D graphics.

Part 2. WinPOS installation

Insert WinPOS CD to your PC CD-ROM drive. The WinPOS installation starts immediately. If autorun option is disabled, run the file Setup.exe from the CD root directory. Select «**Install WinPOS**» in the window.

Fig. 2.1. WinPOS setup window

Follow the setup program instructions. Use the buttons < **Back** and **Next** > to switch the pages (Fig. 2.1), and when the setup is finished, press **Install** and **Finish** on the last page.

In the course of installation you shall be offered to read the *License agreement.* Confirm your acceptance by clicking «**I accept the license agreement**».

The installation program let you:

- change the default installation path (C:\Program Files\MERA\WinPOS),
- rename the program group in the *Start* menu,
- select the installed software content: set *complete* or *compact installation*, or tick the necessary items (See Fig. 2.2),
- place the shortcuts on the desktop and quick start bar to make the WinPOS start easier.

Fig. 2.2. Software content

When the installation is complete, your PC should be restarted. When WinPOS is updated, you can select «**No, I will restart computer later**».

The WinPOS start requires a connection of an electronic USB-dongle or LPT-key. The installation program provides a detailed instruction on the connection and the operation of electronic keys in the file instruct.pdf (subdirectory \Active of the WinPOS installation folder).

USB-dongle should not be connected to the computer before WinPOS is installed, otherwise Windows starts its search for the driver. Cancel the driver searching by the Windows New Hardware Found Wizard by pressing the button **Cancel**, and disconnect the USB-dongle from the computer.

Windows NT/2000/XP requires the user to have the Administrator rights. In case the user has default rights, Windows NT disables the operations of installation, deletion and configuration of drivers.

The Add Hardware Wizard is started by Windows XP after the USB-dongle has been inserted into the port. Follow instructions of the Wizard. Ignore the warning that drivers were not tested for compatibility with XP, and proceed with the installation process.

WinPOS start

WinPOS could be started from the desktop, quick start menu, and Windows **Start** menu. The recorded signals could be opened in WinPOS by clicking the MR-300 and Recorder toolbar button or by double clicking the data file name (of MERA or USML format) in Windows Explorer.

Version upgrade

An upgraded WinPOS version can be downloaded from www.nppmera.ru (*Support/Download* section). The setup program filename depends upon the delivery version and version number of WinPOS. An example of the filename is given below:

```
winpos-3.0.0.0-pro-setup.exe
```

Where: *3.0.0.0* – version number, *pro* - delivery version (See Part 1, Section *WinPOS delivery versions*).

The list of updates and corrections is provided in the file WhatsNew.txt that can be found in the WinPOS setup directory.

To minimize download time, the setup program does not contain *User's Guide* (WPUsersGuide.pdf) and *Programmer's Guide* (WPProgrammersGuide.pdf) files. The latest versions of these documents could be downloaded from the same webpage. The downloaded versions saved in one catalog with the setup program will be installed in the same way as from CD. These files also can be copied to the WinPOS folder.

ⓘ The algorithms are delivered as a dynamic link library wpOperators.dll. At WinPos.exe start a menu item is added for each algorithm (**Algorithms** menu). The additional algorithm libraries are included by copying to the "DLL" subdirectory of the WinPOS folder.

Upgrade of delivery version

The WinPOS electronic key allows the start of its delivery version as well as lighter versions of the package. If WinPOS higher version has to be used. i.e., at the transition «View» → «Standard» → «Professional» → «Expert», the key can be remotely reprogrammed.

After the higher version of WinPOS is paid, run the program GSRemote.exe from the WinPOS setup directory, select **Update key memory**, and then **Create the question number**. The obtained question number shall be sent to winpos@nppmera.ru. When a response number is received, select **Process the response number** and **Update memory block** in the same program, then enter response number to the respective field. If the update is successful, the ordered WinPOS version can be downloaded and installed.

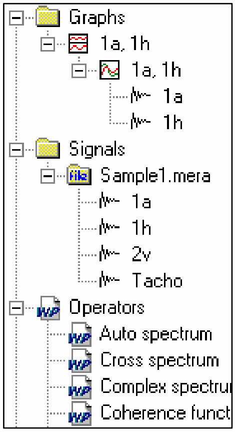
Part 3. Getting started

WinPOS features

While WinPOS development a special attention was paid to optimization of the user interface, simplification of repeated operations without loss of flexibility and customization options.

For example, to plot graphically all parameters in an open file, one movement of the mouse is necessary. The processing range can be set by one operation. Choose an algorithm in the context menu, customize it if necessary, press the button **Done,** and then you are able to view plotted results.

This user interface model is based upon several principles.



1. *WYSIWYG (the actual items are processed).* By default, any action is related to the signal(s) currently represented by the graph. If only a fragment of a signal is displayed - the processing will be performed within the selected range.

2. All WinPOS objects are stored in the hierarchy structure - *global tree*, which performs in WinPOS the same functions as a catalog or file system in Windows. Any signal, graphic or algorithm has its name and place in the tree. Hence, even if the signal is not plotted, this signal can be accessed via 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.

The present part also contains a brief description of the WinPOS interface which (especially the Figures 3.1-3.3) can be further used as a reference book to study other parts of the *Guide* and further operation in WinPOS.

WinPOS interface. Main window

The program is controlled by the graphic interface, usual for Windows users. The view of the WinPOS main window is shown in Figure 3.1.

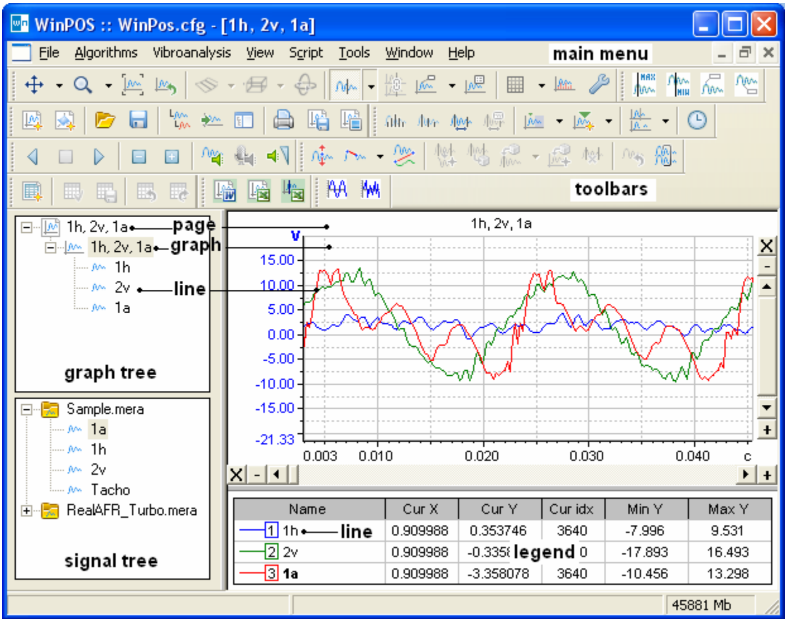


Fig. 3.1. WinPOS. General view

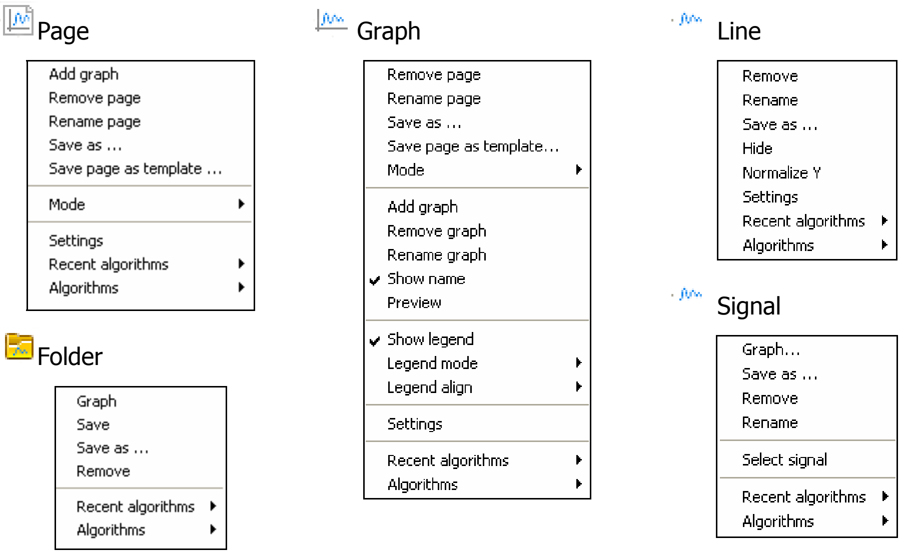


Fig. 3.2. Context menu of the main WinPOS objects

File

- Open ...
- Save
- Save As...

- Open from MDB ...
- Save to MDB ...

- New session
- Restore last session
- Load session ...
- Save session as...

- Exit

Vibroanalysis

- Sequence processing (trends)
- Band RMS
- Amplitude-, phase-frequency response calculation
- Vibropassport
- Campbell diagram
- Order analysis

- Save settings
- Load settings

View

- ✔ Main toolbar
- ✔ Graph bar
- ✔ Table bar
- ✔ Additional tollbar
- ✔ Edit bar
- ✔ Scroll bar
- Tree panel ▸
- Signal Manager
- Log
- Vibro calculator

- ✔ MSOffice Tools
- ✔ 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 analisys
- 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 Horisontally
- Tile Vertically

- ✔ 1 П1 - 0z

Tools

- Normal mode
- XY-spin
- X-spin
- Y-spin
- XY-scale
- X-scale
- Y-scale
- Cursor

- ✔ XY-grid
- X-grid
- Y-grid
- Hide grid

- Vertical lines
- Normalize X
- Normalize Y

- Settings ...
- Default settings ...

- Load settings ...
- Save settings ...

- Print ...
- Wide graphs print ...
- Save image ...
- Copy image to clipboard

Help

- Contents ...
- Search ...
- Index ...

- User's Guide
- Programmer's Guide

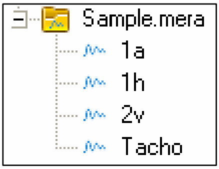
- "Mera" Presentation
- "Mera" Catalogue
- www.nppmera.ru

- About WinPOS ...

Fig. 3.3. Main menu

The major part of the window is occupied by the workspace containing pages with graphs. *Tree bar* is usually placed on the left to the workspace. *Signal tree* is placed in the lower part of the workspace, and *Graph tree* in the upper part.

Signal tree

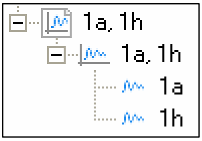


All signals opened in WinPOS are placed to the global tree to the Signals folder. The content of this folder is shown in the *Signal tree.*

The signals are grouped to folders. All calculation results get to the folder *Results*. The MERA and USML formats files are placed to the tree as signal folders when you open.

Click on the glyph «+» on the left of the folder name to open the folder content, click «-» to hide it. Double click at the folder to create the graph page of the folder signals. Double click at the signal to open *Add lines* dialog (Fig. 3.5).

Graph tree



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

Any of the above items can be activated by double click at the name of page, graph or line. The selected page is displayed above all other pages in the workspace, the graph is marked by a, and the line is displayed above all other plots of the graph and is shown by bold font in the legend. See part 6 *Viewing graphs*.

Main menu

The general view of the main menu is shown in Figure 3.3. The full description of the main menu is provided in the respective parts of the present *Guide* (named in brackets).

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

Algorithms: the list of signal processing algorithms (See Part 9. *Signal processing*), save and load the algorithm settings.

Vibroanalysis (WinPOS **Expert** only): the list of vibration analysis algorithms (See Part 10. *Vibration analysis*), save and load the algorithm settings.

View: change view of WinPOS, enable and disable toolbars and secondary windows (See *WinPOS secondary windows* below). The enabled item is marked by a tick on the left.

Script (WinPOS **Professional** and **Expert** only): embedded editor, script running (See part 11. *WinPOS scripts*). The lower part of the menu contains the list of recently executed scripts.

Tools: commands of the graph control panel, call settings dialog of the active graph and default settings (See Part 6 *Signal viewing*), documenting commands (duplicated on the main toolbar, See Part 8 *Report drawing and printing*).

Window: commands of new page creation (See part 5. *Graph creation*), standard MDI Windows commands arranging pages in the workspace (usually all workspace is occupied by the current page). The lower part of the menu contains the list of created pages. The active page is marked by a tick.

Help - access to the WinPOS help system (**Contents…**) and the information **About WinPOS…**: program version, technical support phone number, and other contact information.

Context menu

The WinPOS objects can be controlled by the context menu accessible by clicking the right mouse key over the selected item (Fig. 3.2).

For example, to open the page context menu click the right mouse key over the page name in the graph tree.

Graph context menu – click in the graph tree or over the graph field. The graph context menu also contains the page menu items.

Line context menu – click in the graph tree or over the signal name in the legend.

Folder and signal context menu – click in the signal tree.

Toolbars

The most important WinPOS control commands are included into the toolbar. By customizing toolbars in the **View** menu the optimum set of tools for any task is selected. The numbers of parts of the present Guide containing the descriptions of these tools are given in brackets. The most convenient arrangement of toolbars can be selected by moving the toolbars with the mouse (drag the left side of the toolbar with the mouse).

Main tool panel

- Create a new page (5)
- Create a new 3D page (5)
- Signal load
- Signal export (4)
- Group signals by origin
- Add into the graph
- Open Signal Manager (7)
- Print
- Save page screenshot in file
- Screenshot in clipboard (8)

Graph panel

- Spin of the graph
- Scaling of a graph
- Show cursor
- Normalize graph
- Return to previous range
- Grid
- Vertical lines from points of the signal (8)
- Plotting style
- View mode
- Move and turn of a graph

Additional tool panel

- Modulation vibrocursor
- Harmonic vibrocursor
- Differential cursor
- Extended information of a differential cursor
- Show marks, modes, breakpoints, settings and status
- Set, rename, remove a marker (mode)
- Selection of a displaying mode of the registration with pauses
- Normalization with UTS(6)

Edit panel

- Edit values
- Change signal values
- Signals concatenation
- Copy to a new signal
- Copy a signal fragment
- Past into selected graph/page
- Past into a new graph /page
- Delete a signal fragment
- Cancellation of a signal editing
- Folder editing (7)

The control panel of the table

- New table

Set label

Set comment

Synchronization of cursors (6)

Settings (5)

Scroll panel

Decrease speed

To the left

Stop

To the right

Increase speed

Play

Playback

Volume control(6)

Save changes

Save table as…

Undo last changes

Redo last changes (6)

Work with MSOffice

Send page to MSWord

Send page to MSExcel

Min/max search

Set the label on a minimum

Set the cursor on a maximum

Set the cursor on a minimum

Set the label on a maximum

WinPOS secondary windows

Algorithm customization dialog

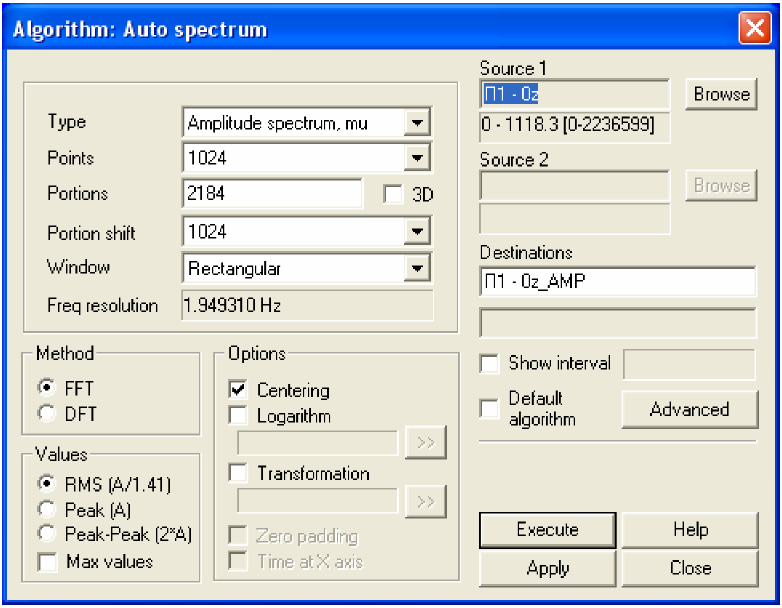


Fig. 3.4. Algorithm customization dialog

Most of the signal processing algorithms requires additional customization performed at selection of the processing option in the submenu *Algorithms* of the main menu or context menu. The right part of the customization window sets the data sources, and is similar for all algorithms. The left one contains the customization settings of the selected *operator*.

The detailed description is provided in the Part 9. *Signal processing*.

Signal selection

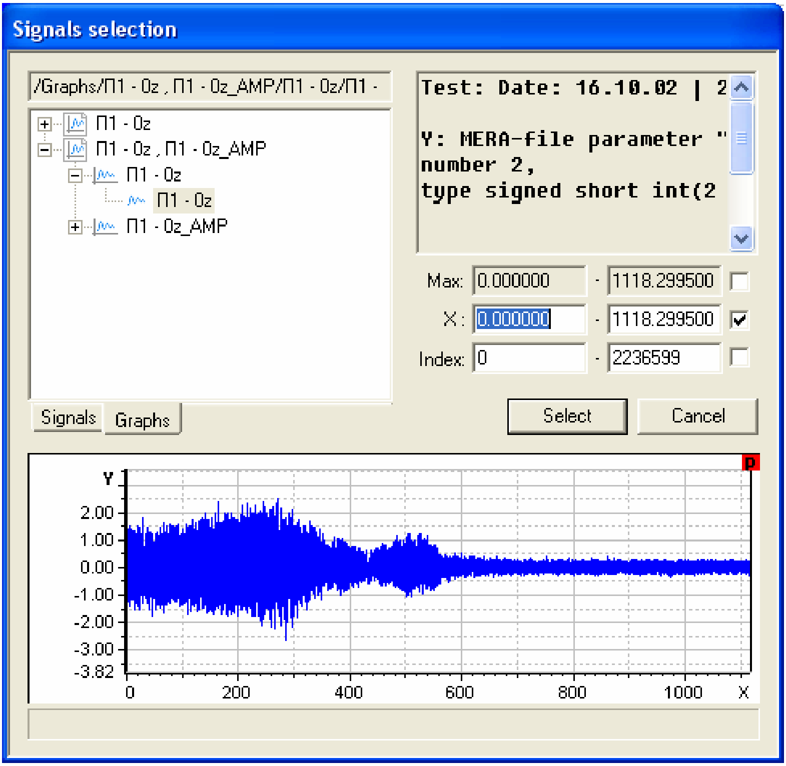


Fig 3.5. Signal selection

The *Select signal* dialog is opened by the **Browse** button of the algorithm customization window and the save signal window (Fig. 3.5).

In the left part of the window the signal is selected from the *Signal tree* or *Graph tree* (switched by tabs at the bottom of the tree window). The right part of the window contains brief information on the selected signals.

Preview window at the bottom on the right is used for selection of a signal part for further work, as well as the input textboxes.

In order to modify or select the range move the left and the right cursors in the preview window (at selection of the whole signal cursors are located at the graph margins), or type the exact values in the textboxes **X** or **Ind.** The checkboxes at the right of these fields are used for setting the range selection mode in case of batch processing of the signals from one folder (mark **Max** checkbox to select the whole signal).

ⓘ If user has selected the signal from the *Graph tree* on the *Graphs* tab then the signal range displayed in **X** textboxes automatically set equal to the range of selected signal.

See also Part 4, section *Signal saving* and Part 9 *Signal processing*.

Signal manager

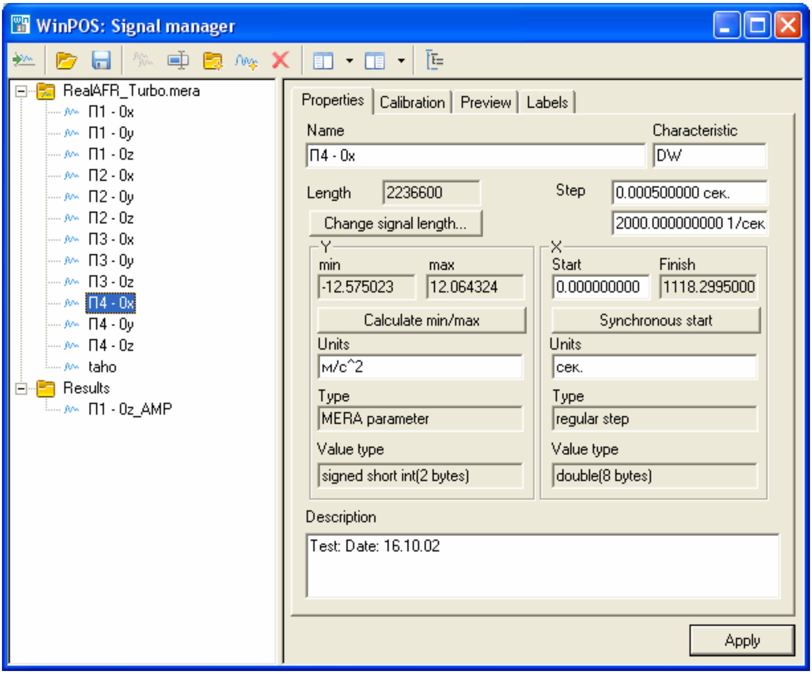


Fig. 3.6. Signal manager

The *Signal manager* is intended for a viewing and an editing of the data of files, signals, calibration characteristics, and a representing of the signal values in the table view. The Signal manager provides the options of copying, renaming, cataloging, reading and writing of the signals. This window is opened by the  button or **View→Signal manager.**

See also Part 7. *Signal editing.*

The *Signal manager* window (Fig. 3.6) comprises two data panels and the toolbar. Each data panel can be represented as "tree" or "list". The right panel can contain the information on the selected object as "property page".

The panel view mode is changed by pressing the buttons on the toolbar. Pressing the button causes cyclic changing of the panel view modes. The desired view mode can be selected by clicking the arrow on the right of the button and selecting the mode from the list.The purpose of buttons of the signal manager toolbar is described below.

F4	Create graph of the selected signal.
F3	Open file. Duplicates the command **File→Open**.
F2	Save as…. Duplicates the command **File→Save as…**
F5	Copy. A new layout of signals and a range of values for copying is set in the opening dialog window. The option of originals removal allows to substitute a copying of signals by operation of a moving.
F6	Rename signal.
F7	Create new folder in the signal tree.
	Create new signal.
F8	Delete selected signal.
Alt+F1	Switch (set) left panel view.
Alt+F2	Switch (set) right panel view.
	Show all WinPOS resources: the catalogs of signals, graphs and installed algorithms with the option to view the properties of all elements.

Script editor

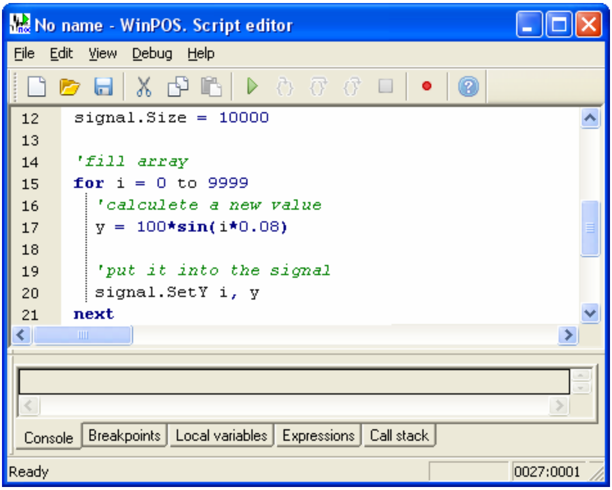


Fig. 3.7. Script editor

WinPOS (**Professional** and **Expert**) allows creation of user's signal processing algorithms, automation of the signal processing from the source file selection to the processing result documenting. WinPOS includes a convenient environment for editing, execution and debugging of scripts by VBScript (Fig. 3.7).

More details are provided in the Part 11. *WinPOS scripts* and *Programmer's Guide.*

Log

The *Log* (Fig. 3.8) automatically registers all actions of the user (open and save files, execute algorithms, load configuration, etc.).

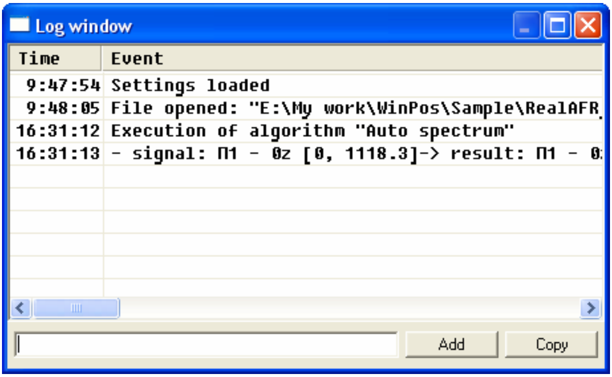


Fig. 3.8. Log window

The log can also be used as a notebook to include the remarks and comments of the user. This makes the log convenient tool for systematization of the data processing procedure. The log is opened by **View→Log**.

Each log line contains the time, description of the event and the additional parameter line, e.g., the executed algorithm parameters.

The log window shows the history of the current work session. The complete history is stored in the file winpos.log of the WinPOS folder.

Vibro-calculator

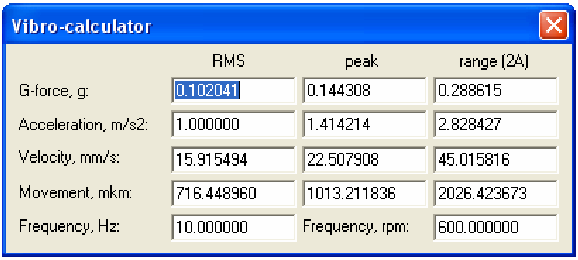


Fig. 3.9. Vibro-calculator

This is WinPOS vibration parameter calculation window (Fig. 3.9). Other two vibration parameters are calculated using the fixed frequency of vibration and sole parameter (acceleration, speed or displacement). This window is opened by **View→Vibro-calculator**.

Graph customization windows

The arrangement of graphs on a page, view of graph, legend, representation format and color of signal lines can be selected in the graph customization windows. The *Default graph customization* window (see Fig. 3.10) changes the properties of new graphs. The view of existing graphs can be modified by the *Graph customization* window (Fig. 5.9-5.19).

More details are provided in the Part 5. *Graph creation*, section *Graph customization*.

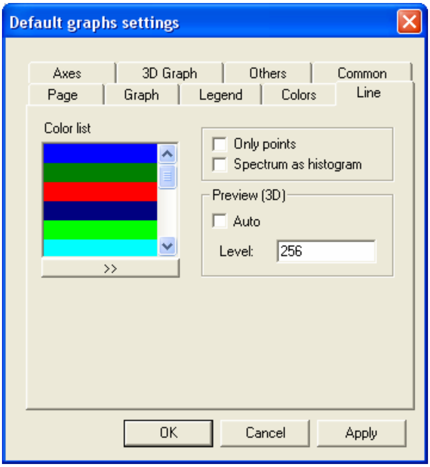


Fig. 3.10. Default graph set

Help window

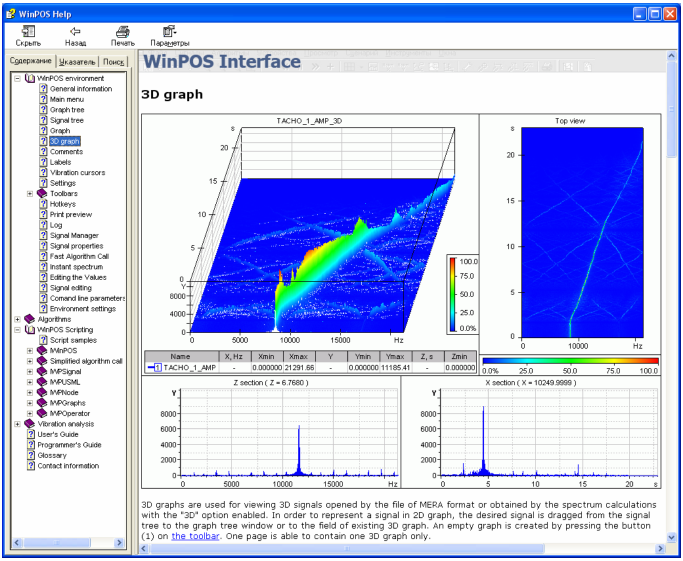


Fig. 3.11. Help system window

The WinPOS help system contains the description of user interface, algorithms, vibration analysis, script writing guidelines, contact information, and URLs of updated versions of the User's Guide and Programmer's Guide.

The help system is accessed by the key <F1>, via the menu **Help→Content…** or by the button **Help** in the algorithm settings. The WinPOS help is organized as a standard Windows help file (CHM), containing the index and the key word search system in addition to the list of help topics (Fig. 3.11).

Part 4. Signal loading and saving

File formats

WinPOS allows loading and saving of the data in the MERA and USML formats, as well as the operation with binary and text (ASCII) files, MS Excel tables (See Fig. 4.1).

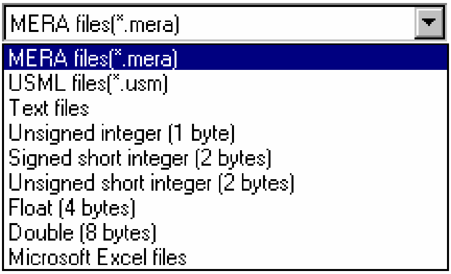


Fig.4.1 List of file formats

The MERA and USML formats are intended for structured signal storage. The binary data of each parameter are completed by the signal description with calibration characteristics, and signal source description.

MERA is a united storage format of the measurement information developed for application in the recording programs (MR-300 and Recorder) and WinPOS. The vibration analysis operates with the MERA files only.

The main features of the MERA format are:

- Practically unlimited number of signals,
- Signal length - up to $2 \cdot 10^9$ measurements (up to 16 Gbytes),
- The format is open,
- Simple operations and easy extendibility,
- Separated storage of binary data of each signal and description provides the following features:
  - Improved reliability,
  - Fast access to the parameters, including the options of editing, addition and deletion of signals.

The USML format, elaborated in the reel tape recorder age, does not meet modern requirements because of some constraints. This format is implemented in WinPOS for the sake of compatibility (including the POS package).

ⓘ The USML files can be easily converted to MERA by **Save as...** menu. Note, at the reverse conversion (from MERA to USML) some additional data are lost (comments, marks, modes, etc.).

The formats MERA and USML are described in the Appendix C. *File formats*.

Signal loading

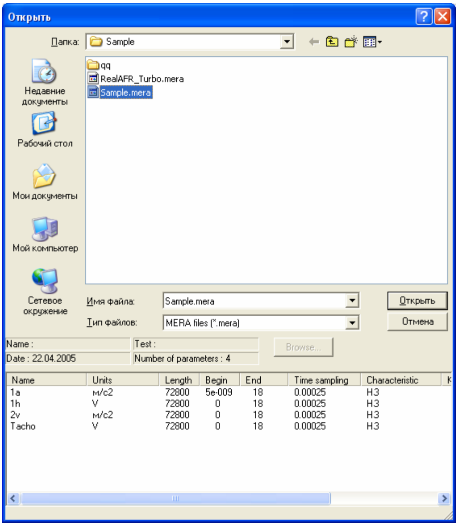


Fig. 4.2 File open dialog

Select **File→Open…**, or button of the main toolbar, or press the key <F3>.

The *Open file* dialog (Fig. 4.2) is a standard Windows dialog box, with the file preview window in the lower part.

Select the data format from the **File type** drop-down list (Fig. 4.1).

Choose the file and press **Open** button. A new signal or signal folder appears in the tree.

ⓘ The files MERA and USML are also opened from the Windows Explorer by double clicking at the file name.

The signal name is derived from the MERA or USML format file, from the text file header, or from the binary file name. The name, measurement units and other signal properties can be modified in the *Signal manager* (See Part 7 *Signal editing*).

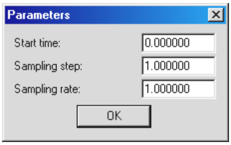


Fig. 4.3 Parameters

The files of MERA and USML format contain full description of the signals. At least the sampling rate has to be set for correct creation of signals from binary or text files. The operation with the text files is assisted by the opening and saving wizards (See below).

At opening of the binary file the *Parameters* dialog (Fig. 4.3) is shown. The signal sampling rate (frequency or step by X axis), and the record start time are set.

Signal saving

In order to save the signals using the context menu of the page, graph, line, signal or folder, select the **Save as…** menu item. The data from the *Signal tree* can also be saved by selecting **Save as…** item of the **File** menu or by clicking the button.

The *Save file* dialog (Fig. 4.4) is a standard Windows dialog box, with the file preview window in the lower part.

Select the data format from the **File type** drop-down list (Fig. 4.1).

In case of the data saving from the signal tree, full signal ranges are saved. If the dialog opened from the context menu of the page, graph or line, the visible signal range will be saved.

In order to modify the saved range and list of signals press the button **Select…** to open the *signal selection* window (Fig. 3.5).

The *File saving* dialog (Fig. 4.4) is a standard Windows dialog box with the file preview window in the lower part.

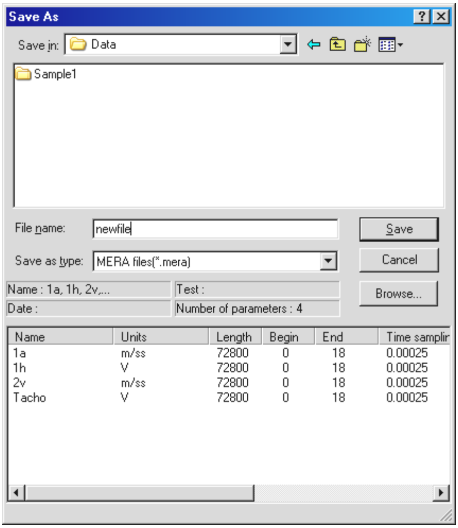


Fig. 4.4. File saving

Text (ASCII) files

At opening of a text file the *Text file opening wizard* runs (Fig. 4.5). The *Text file saving wizard* (Fig. 4.6) helps to create text files with the signal value columns.

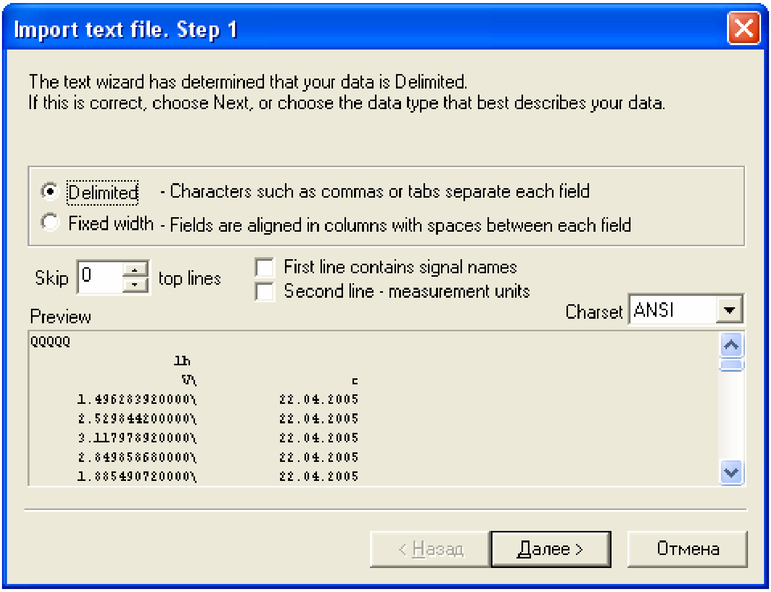
To switch between the wizard pages use the buttons **<Back** and **Next>**. When the customization is finished, press **Done** on the last page.

Opening wizard

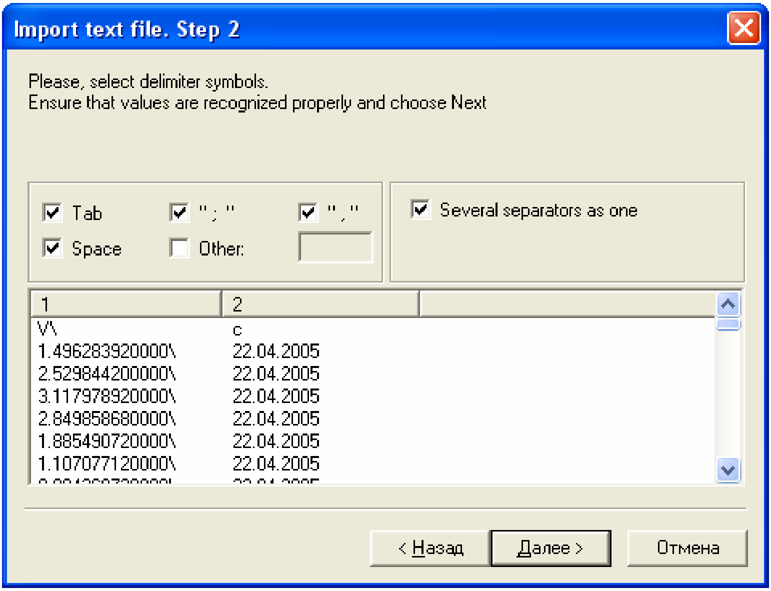
The text file general format is set on the first page.

The text is divided by columns on the second page.

On the third page the columns are associated with the signals. If the file contains the time columns, the order of columns has to be specified; otherwise the sampling has to be set (the fields **x0** contain the initial time values, **dx** – time step, **f** – frequency). The default signal names can also be modified in this list.


Import text file. Step 1
The text wizard has determined that your data is Delimited.
If this is correct, choose Next, or choose the data type that best describes your data.
Delimited - Characters such as commas or tabs separate each field
Fixed width - Fields are aligned in columns with spaces between each field
Skip 0 top lines
First line contains signal names
Second line - measurement units
Charset ANSI
Preview
< Назад
Далее >
Отмена

Step 1.


Import text file. Step 2
Please, select delimiter symbols.
Ensure that values are recognized properly and choose Next
Tab
Space
" ; "
Other:
" , "
Several separators as one
1
2
V\
c
1.496283920000\
22.04.2005
2.529844200000\
22.04.2005
3.117978920000\
22.04.2005
2.849858680000\
22.04.2005
1.885490720000\
22.04.2005
1.107077120000\
22.04.2005
< Назад
Далее >
Отмена

Step 2.

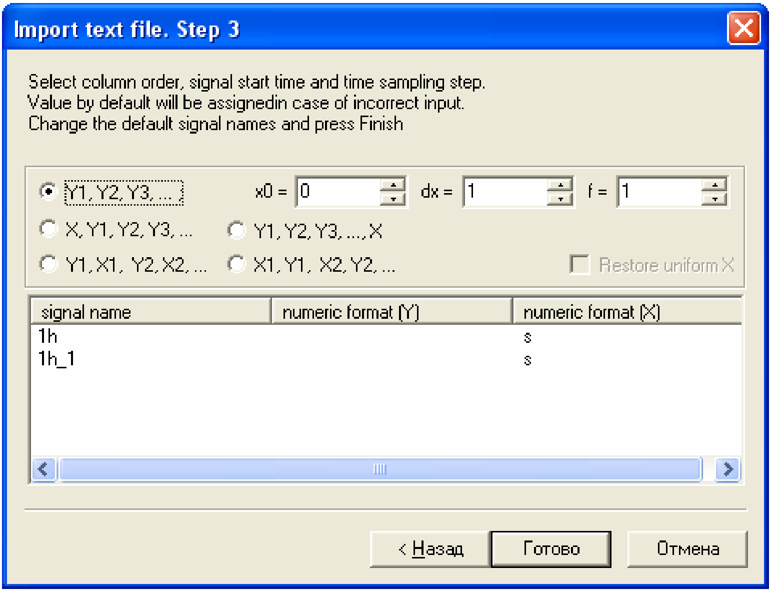
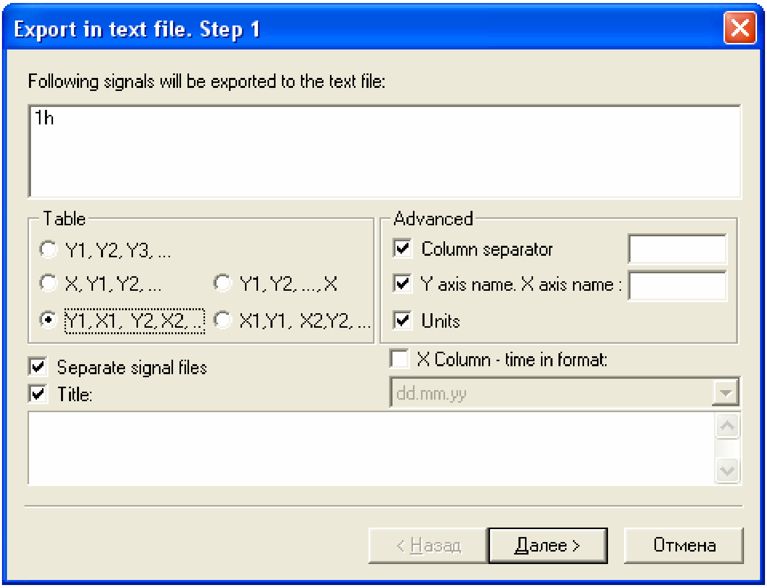


Fig. 4.5. Step 3. ASCII file opening wizard

Saving wizard

The first page contains the list of selected signals, and the order of columns of values and time is set. The **column delimiter symbols** can be set, the automated format of the table heading can be enabled: enable **signal names** (the time column name is set separately) and **measurement units** in the first two lines of the 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. 4.5). The separate files which contain calculations of only one signal will be put into this folder, and the file name will match the signal name. The text included into the field **Title** is placed over the table in the first lines of the file.

On the second page the column width can be changed and the number of significant digits after the decimal point can be set separately for the signal values and the time columns, in accordance with the table preview.



Step 1

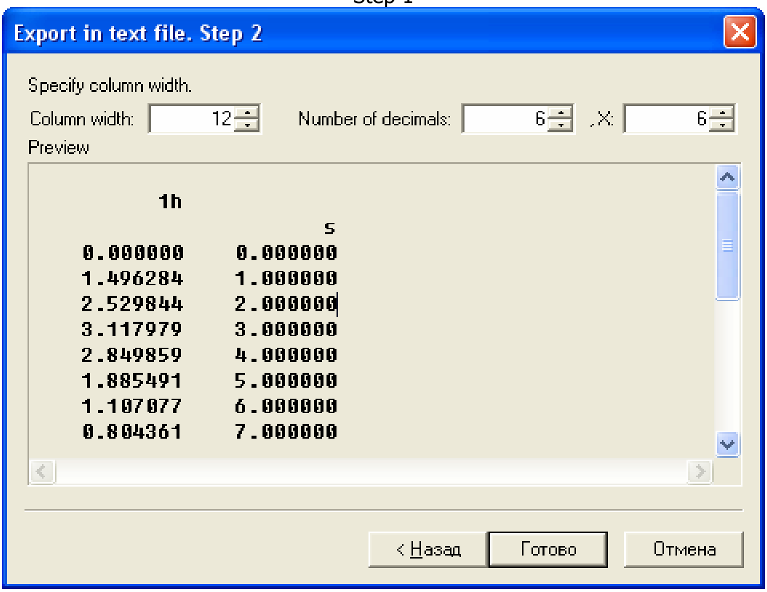


Fig. 4.6. Step 2. ASCII file saving wizard

ⓘ An opening of a big text file and a saving of big signals as text files can take much time. Use the <Esc> key for the breaking and the abolition of the operation

Work sessions

The results, received in the course of work, and graphs can be saved on a disk as a session. Having loaded a session, it is possible to return to the incomplete work..

Automatic saving and restoring of the session

The session can be automatically saved on an exit or periodically with the given interval. A periodical saving of a session will help to restore the work after a program or a machine failure.

To automatically save of a session, choose this option on a bookmark the Common (Fig. 4.7) on the Default setting window (the menu Tools, the Default setting item …). For periodical saving it you have to set a time interval in seconds on the same page.

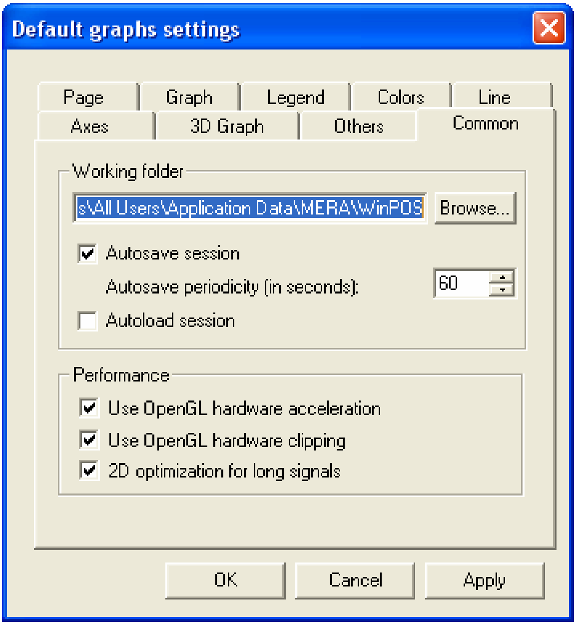


Fig. 4.7. Default graphs settings

When WinPos starts, the last automatically saved session can be loaded if ***the Automatic restoring of the session*** option was selected on the same page.

Besides, you can load the last automatically saved session using the menu **File ->Restore last session** (Fig. 3.3).

Working WinPOS directory

The signals which were created during the program working are temporarily saved on a hard disk in the working WinПОС directory. The automatically saved session is located there. To change this directory you have to open the Common page on the Default setting window (Fig. 4.7), press the Browse … button and select the necessary directory. When you select some directory, pay attention to the size of free space on the chosen disk (You can see it on a window of a directory choice).

A manual saving and restoring of sessions

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

Select Save a session as … in the File menu (Fig. 3.3) and choose a directory to save the session data. You can clear the session, having chosen **File -> New session** menu. To return to the some saved session choose File-> Restore a session… and then point the way to the saved session data.

You can transfer the session to other computer, place into the archive and then to restore it, using the same menu points. But you have to remember that the session data don't contain the files with basic data. (Instead of them the links to files are saved).

Therefore you have to transfer the files with basic data when you want to carry a session.

The list of such "external" files is put to the magazine during the saving (Fig. 3.8), and the proposal to open the magazine is displayed. And so if you want to transfer the session you have to copy the files from this list. Put these "external" files to the directories with the same name before the session restoring on other computer. If you don't do it, then at the time of a loading of the session the program will propose to find the missing files independently, using the dialogue of a choice of files.

Part 5. Graph creation

At the WinPOS start a page with empty graph is created. New graph pages are also created automatically for the signal processing results (refer to Part 9) and at the dragging-and-dropping the signal or folder to the *Graph tree*.

The most convenient and simple way of plotting the signal graph in WinPOS is to drag the signal from the *Signal tree* to the graph field or to the *Graph tree* by the mouse (Press the left mouse button at the signal name, move the cursor to the graph page, release the button).

The graphs are controlled by the toolbars, menu **Tools** (Fig. 3.2), and the context menus.

Graph types

WinPOS creates 2D graphs (Fig. 5.1) and 3D graphs (Fig. 5.2).

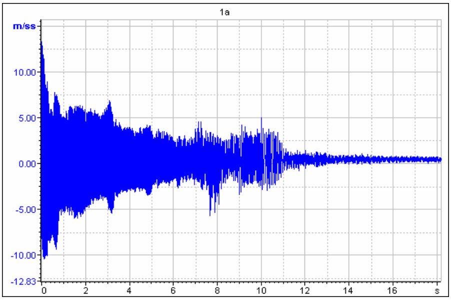


Fig. 5.1

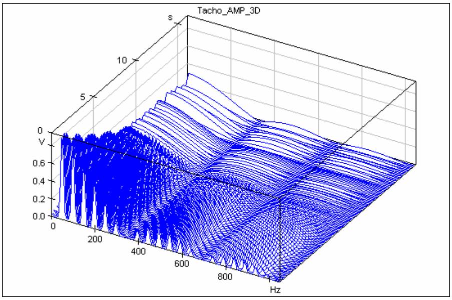


Fig. 5.2

Several signals can be placed into one graph (Fig. 5.3), or several graphs can be plotted on the one page (Fig. 5.4).

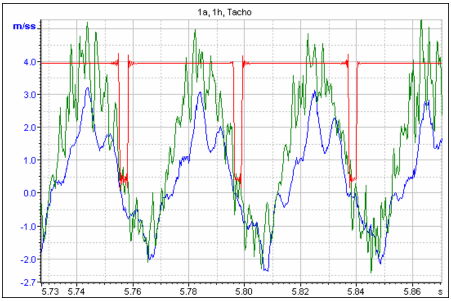


Fig. 5.3

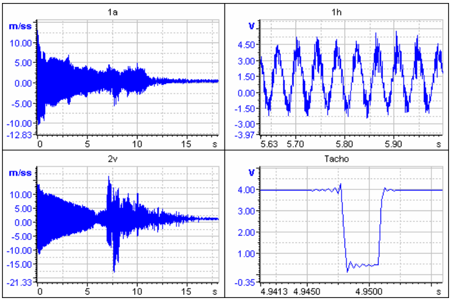


Fig. 5.4

A separate axis of ordinates can be created for each signal. The axis can be represented separately (Fig. 5.5) or by several scales along one axis (Fig. 5.6).

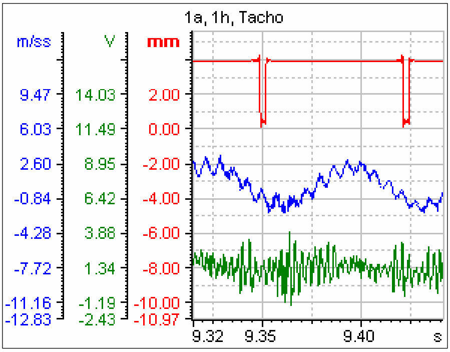


Fig. 5.5

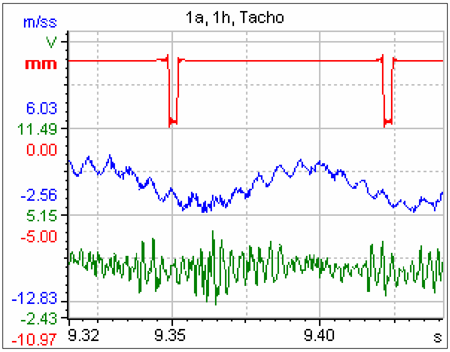


Fig. 5.6

New page creation

Press the button on the main toolbar or select the **Window→New page** menu item, and a new page with an empty 2D graph is created.

The 3D graph page is created by pressing the button of the 3D graph toolbar.

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

The **Window→Instant spectrum page** menu item creates a page with two graphs: the source signal and the spectrum calculated at the cursor position or by the visible signal range, - see Part 9 *Signal processing. Instant spectrum*.

Creating pages by template

The page templates allow avoiding the repeated customization of the graphs, storing the signal 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.

The item **Save as template…** of the context menu of page or graph saves the active page view as a template file (.tpl) and sets it as a current template.

Window→New page by template creates a new page by the current template. If the template is not selected (see below), the same actions as at **New window** of the same menu are made.

Window→Select template… sets the current template by the template file selection window (.tpl).

Adding the Graph

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

Adding the Grid

Press **Add** at the *Y axis* tab (Fig. 5.14) in the *Graph setting* dialog. Set the axis parameters and press **Apply**.

Adding the Signal (Line)

… with a new graph or page creation

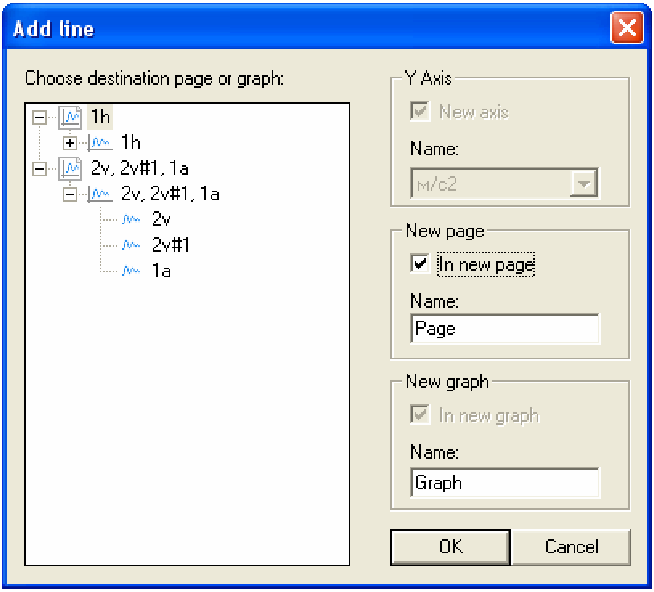


Fig. 5.7 Line addition

Variant 1. Drag the signal from the signal tree and drop it to the page (marked by  glyph) in the graph tree, or into the empty field of the graph tree. In the last case a new page is created.

Variant 2. Double click the selected signal and open the *Add lines* dialog, select the desired page (Fig. 5.7) or select the **New page option**. Press the **Ok** button.

... to the selected graph

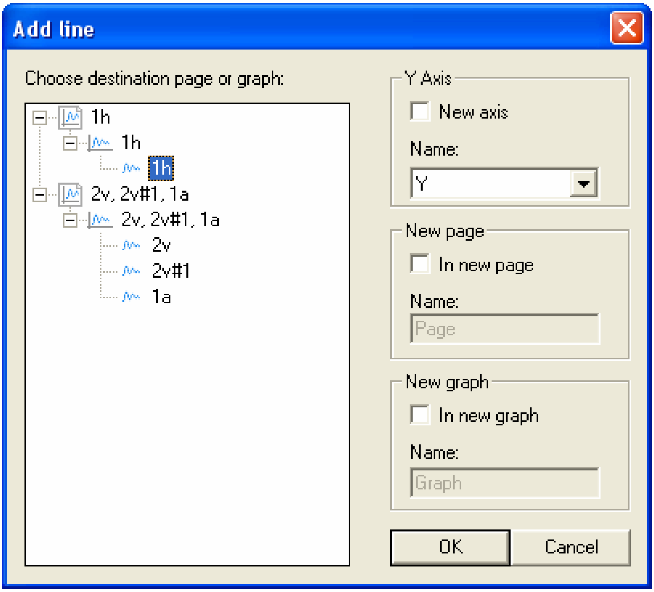


Fig. 5.8 Lines additions

Variant 1. Drag the signal from the signal tree to the graph tree, drop it at the graph name (marked by  glyph).

Variant 2. Double click the required graph in the graph tree and make it active. Copy the signal with the mouse to the selected graph.

Variant 3. Double click the required signal to open the *Add line* dialog, select the desired graph (Fig. 5.8) or select **New graph**. Press **Ok** button.

... to the selected coordinate axis

Variant 1. Click the graph axis name and make it active (marked by bold). Copy the signal with the mouse from the signal tree to the graph.

Variant 2. Double click the required signal to open the *Add line* dialog, select the desired graph. In the field **Y axis** select the desired axis or create a new one (**New axis** checkbox). Press **Ok** button.

ⓘ The color of coordinate axis is selected by the color of the first line associated with this axis.

Adding the several signals, folder

… to the one page (Fig. 5.4)

Drag and drop the folder from the signal tree to the graph tree, or choose the graph from the folder's contextual menu.

… to the one graph (Fig. 5.3)

Drag and drop the folder from the signal tree to the graph tree keeping the <Ctrl> key.

Deleting page, graph, line, axis

You can delete any page or a graph by the **Delete graph** and **Delete page** commands of the context menu of the page or the graph. The axis can be deleted from the Graph settings window (*Y axis* tab). To delete the line use the context menu of the graph tree or the legend window.

Graph settings

The graph view can be changed by the *Graph settings* window (Fig. 5.9). This window is opened by clicking the  toolbar button, or by pressing <Ctrl+O>, or by selecting the **Settings…** item from the menu of page, graph, line, as well as by selecting item of the **Tools** menu.

User can set the parameters of all new graphs by selecting the **Default settings…** item of the **Tools** menu. The settings of already created graphs remain the same.

The left part of the setting window contains the graph tree, the right part - the parameter tabs.

ⓘ The settings are applied to any selected object and its daughter objects.

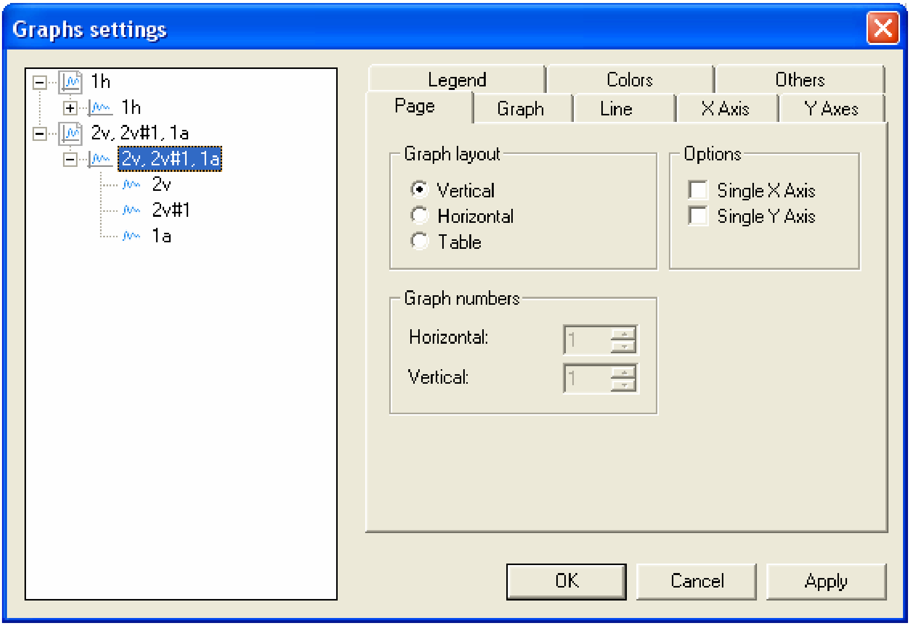


Fig. 5.9 Graph settings. Page

Fig. 5.9: The axis synchronization is set on the *Page* tab: **Single X axis**, **Single Y axis**. The scaling of all graphs on the page is simultaneous.

The mutual placement of graphs is shown in Fig. 5.10.

If table layout selected the table size can be set (the *Graphs number* fields). If one page contains more graphs than set, the hidden graphs are marked by dark glyph in the tree. Such graph can be accessed by double click at the name in the tree or by right scroll bar.

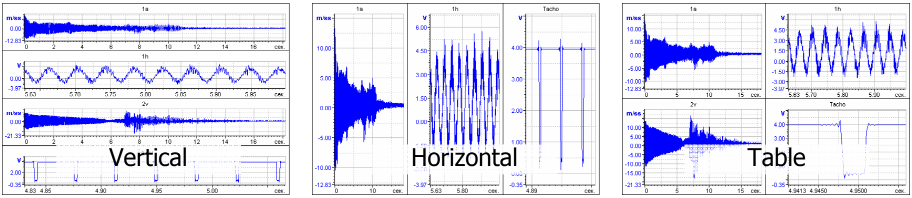


Fig. 5.10. Graph placement on a page

Fig. 5.11, ***Graph*** tab: change position and fields of the graph, alignment of the legend, and additional settings:

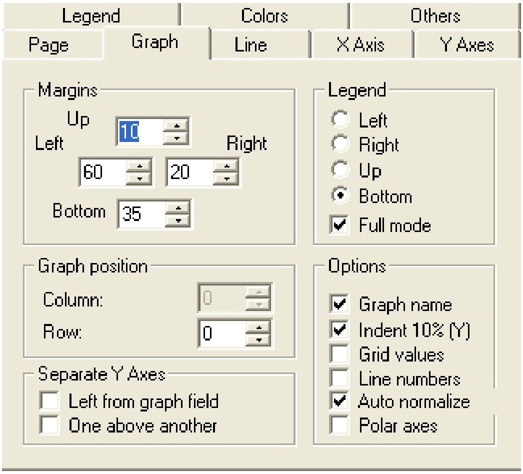


Fig. 5.11 Graph settings. Graph

Graph name - graph name is visible;
Indent 10% (Y) - Y axis range is 10% greater than the signal peak-to-peak range;
Grid values - signal values at the crossing points of the grid with the graph line is visible;
Line numbers - graph line numbers is visible;

Auto normalize - scale of Y axis is selected automatically by the maximum signal peak-to-peak range; **Polar axes** - plot/convert the graph in polar coordinates;
Separate Y axes - each graph line has its own vertical axis.
The axis position on the graph is set in the **Separate Y-axes** control group:
Left from graph field – a vertical axis is plotted individually for each graph line,
One above the other – an option of vertical division of the graph field according to the number of axes.

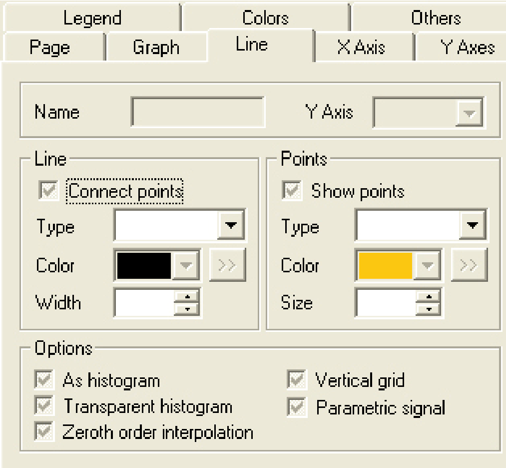


Fig. 5.12 Graph settings. Line

Fig. 5.12: ***Line*** tab*:*

Name – the name of the line. Usually, it is a name file or a parameter name in the file MERA or USML.

Y axis – Y axis, to which the line is attached. You can choose it from the list, in which all existing axes are displayed.

Connect points – The points on the graph are connected by lines.

Line type – a type of line, which connect points on the graph. A line can be solid, broken, dotted and stroke-dotted.

Line color can be selected from the list or from the standard Color dialog which is appeared after using the >> button.

Width – a line width is measured in points and can change from 1 to 5.

Show points – each value on the graph is displayed by the symbol, which you can choose from the drop down list, using **Type** option.

Point color – this option determines a point color. If you choose Auto option, the points will be painted the same color as the line.

Point size - determines a point size.

As histogram – a graph is presented as a histogram (For example, it is used for the displaying of octave spectrums).

Transparent histogram - a histogram is displayed by a contour. It is convenient when you wish to draw a few histogram on same graph concurrently.

Zeroth order interpolation - point values between dimensions aren't interpolated.

Vertical grid - on the graph vertical lines are drawn from signal points, corresponding measured values, to abscissa axis.

Parametric signal - The signal is viewed as a dependence Y from an index. Values on X are used for a numbering of X axis.

Fig. 5.13: ***X axis*** tab*:* rename the X axis, set margins, and select the following:

Logarithm - set logarithm scale;

Format - definition of the scale type. Select the suitable format from the drop-down list (**auto** – automated format selection) or set the customized format. The sign # - one digit, **0** – zeroes have to be added to the formatted value, **e** – engineering format enabled, T=%H:%M:%S – enables the display of astronomical time.

Date - adds date to the graph, it is displayed under astronomical time.

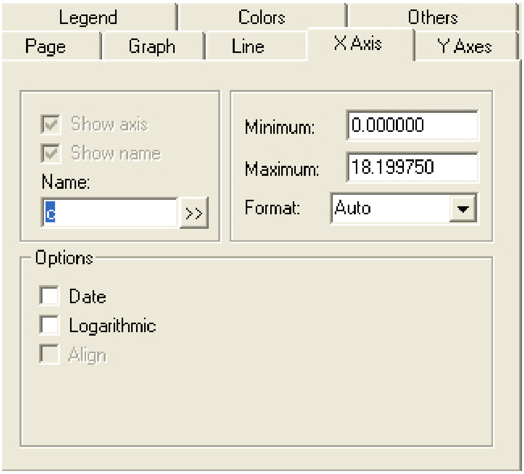


Fig. 5.13. Graph settings. X axis

Fig. 5.14, ***Y axis*** tab. Select one axis from the drop-down list or **Add** new one. The button **Delete** deletes all axes except the last one. Range and color can be set for the selected axis. **Logarithm** – enables logarithmic scaling, if the axis values are greater than 0. **Format -** definition of the custom scale format (see *X axis* above).

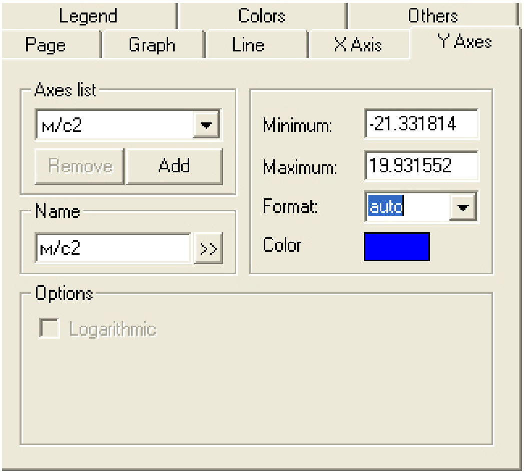


Fig. 5.14. Graph settings. Y axis

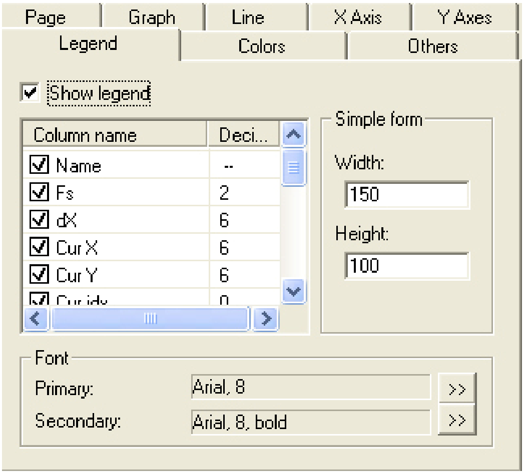


Fig. 5.15. Graph settings. Legend

User sets the format and font of the legend on the ***Legend*** tab (Fig. 5.15). User selects the list of legend columns and sets the number of digits after the decimal point (by double clicking the field) for each column. On the same page sizes of the simple form of the legend are set.

The names of columns (characteristics) are explained in the paragraph *Legend* of the section *Graph plotting* (Part 8).

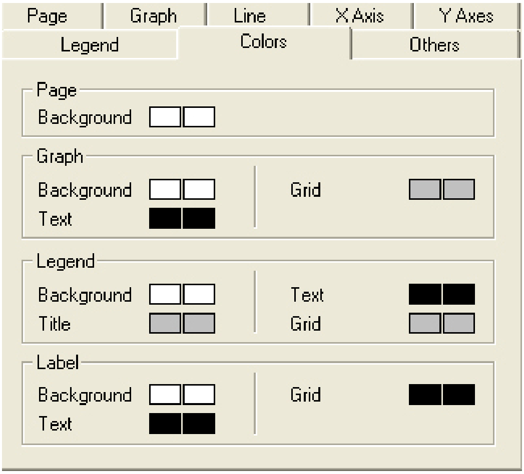


Fig. 5.16. Graph settings. Color

Color tab (Fig. 5.16) sets the colors of the selected page or graph. The color selection dialog is called by clicking the rectangle with current color of the element. The left rectangle represents the color of the element on the screen, and the right one is for print

3D graph

At selection of 3D graph in the graph tree the set of tabs is changed in the right part of the settings window.

By the *Graph* tab (Fig. 5.17) the graph margins can be set (*Margins*), the *Fill mode* can be selected (lines of X; Y; X and Y or plane (surface)), and the invisible lines can be hidden (**Hide invisible lines**).

The user can make the **graph name** visible, place the scale on the right (**Labels on right**) and invert the Z axis direction (**Invert Z axis**), change the data interpretation along Y axis (**Auto normalize** and **Color by max Y**).

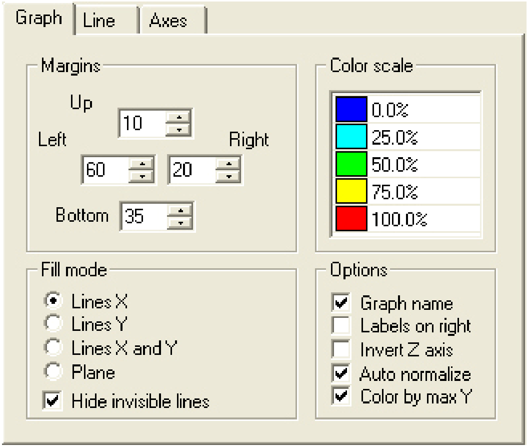


Fig. 5.17 3D graph settings. Graph

The context menu of the **Color scale** list allows changing, adding and removing colors and filling borders, and saving these settings.

Fig. 5.18: by the *Line* tab the line can be renamed, the line width and color can be changed (like for 2D graph), the brightness of foreground and background colors of the gradient fill can be set. In order to accelerate the representation the user can **enable** preview mode by setting the detail **level**. The number of grid lines at each axis is then reduced (or increased).

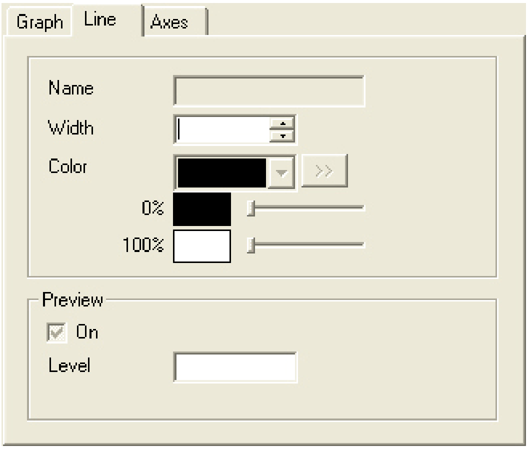


Fig. 5.18 3D graph settings. Line

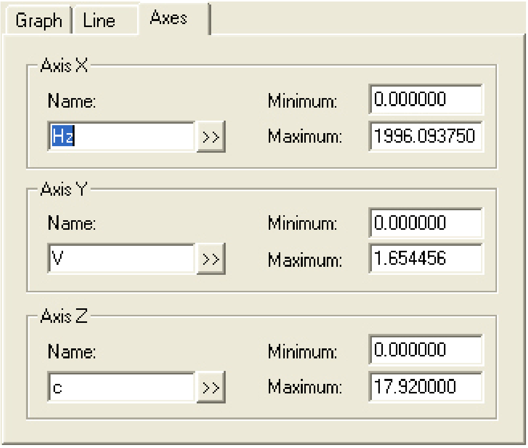


Fig. 5.19. 3D graph settings. Axis

The *Axis* tab (Fig. 5.19) allows editing of the name and changing the range of each of three axes. The >> button near the axis name field allows addressing the editing history and selection of previously entered name.

Default settings

Default graphic settings are stored in the configuration file and are used for new page creation. The *Page*, *Graph*, *Legend* and *Color* tabs are the same as the graph customization tabs (see Fig. 5.9-12, 17-18).

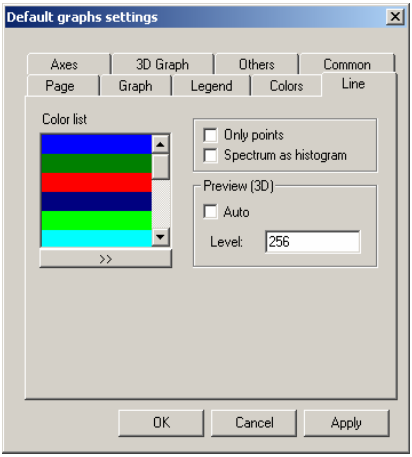


Fig. 5.20. Default settings. Lines

Line tab (Fig. 5.20):

Color list - when added to the graph the color of new line is selected from the list. To make the change, select the color pressing the >> button under the list and select a new color from the standard dialog box;

Only points – Represent the signal values by separate points without connecting them;

Spectrum as histogram - spectrum graphs are represented as histograms;

Preview (3D) - used for 3D graph. **Auto -** 3D graph is created in the preview mode, if the number of points by one axis is less than the value specified in the *Level* textbox.

Axes Tab (Fig. 5.21):

Name - axis names by default. Select the one of the previously entered names by pressing >> button.

Format - axis scale format.

Font - fonts of scale labels and axis names. *Additional font* is used for selection of the active axis. The font is selected from the dialog by pressing the >> button on the right of the respective field. The font change imparts all graphs (already opened and new).

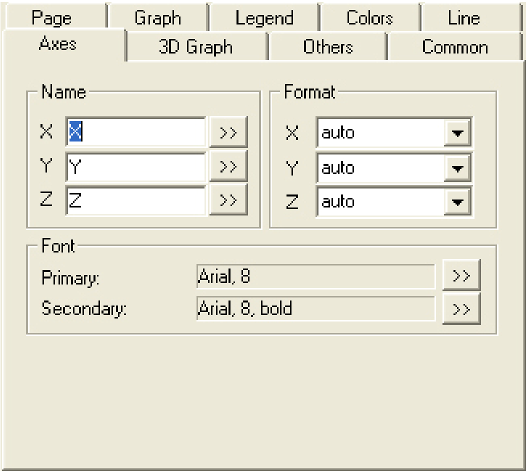


Fig. 5.21. Default settings. Axes

3D Graph Tab (Fig. 5.22):

View mode – view of the main graph.

Filling - the graph drawing technique as the lines by X axis, lines by Y axis, lines by both axes or like a surface.

Hide invisible lines – invisible line deletion mode.

Digits on right side – scale labels by axis Y and Z are in the right graph part.

Invert Z axis - inversion of the axis Z to put the minimum value at the far end of the axis, and the maximum value - at the near end of the axis.

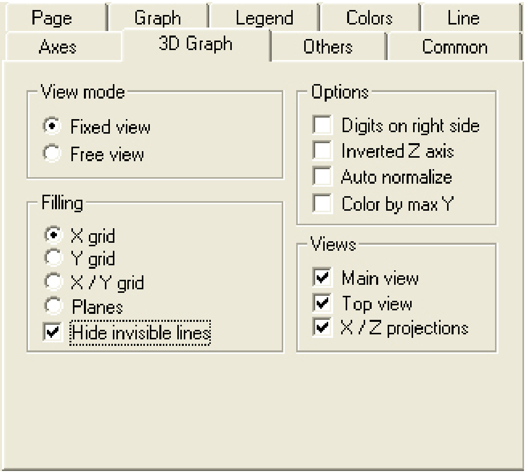


Fig. 5.22. Default settings. 3D

Auto normalize – Y-axis auto scaling.

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

Views - selection of the views to be represented on the page.

Part 6. Viewing the Signals

At the signal viewing many actions are applied to the selected (current, active) graph, line, axis, rather than to the whole page. The current page is the page visible at the present moment or the top page if the pages are arrange by cascade. 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.

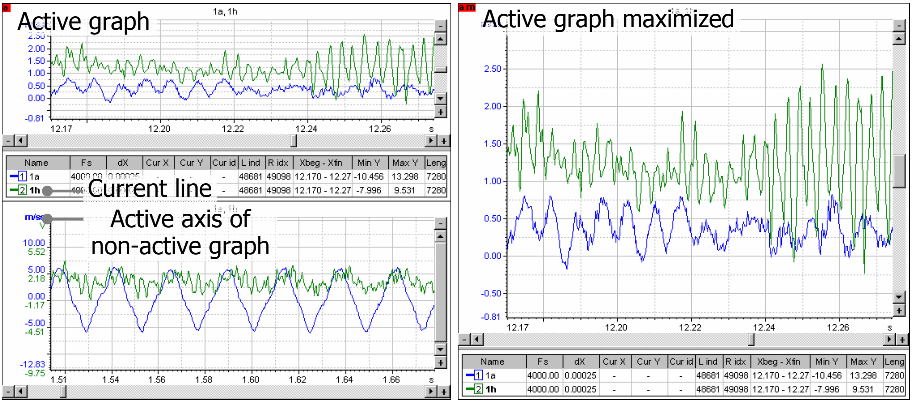


Fig. 6.1 Active graph and maximized active graph

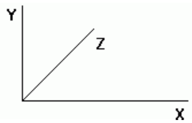
The graph can be made current by clicking the mouse button in the graph filed, the line - by clicking at the signal name in the legend, the axis - by clicking at the axis name.

Double click at the object in the *Graph tree* makes this object current. If the selected object was hidden, the activation of the necessary page is made; the graph is marked as active.

Double click in the graph field allows the graph scaling up to the whole page. Such graph is marked by the symbol a m (active maximized). See the right graph of the Fig. 6.1. The previous graph sizes can be restored by another double click.

Features of 3D graph viewing

3D graphs are used for 3D signals viewing opened from the MERA format file or obtained by the spectrum calculation with the **3D** option enabled. To represent a signal in 3D graph it must be dragged from the signal tree to the graph tree window or to the already existing 3D graph. The empty graph can be created by pressing the  button on the toolbar. The page may contain only one 3D graph of 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.

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

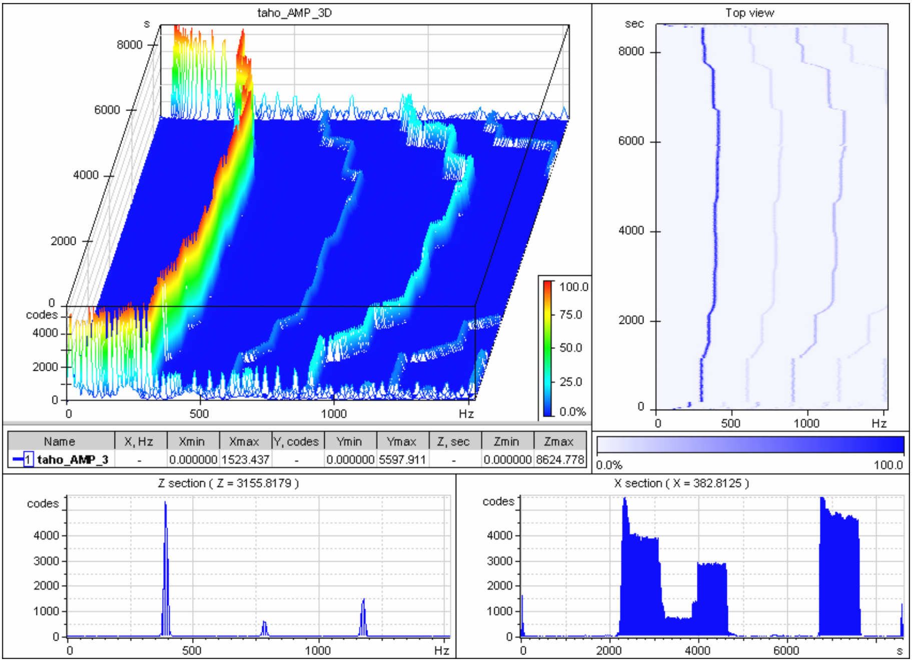
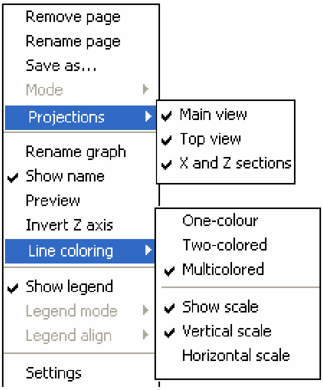


Fig. 6.2 3D graph page



The views can be disabled by the **Projections** 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).

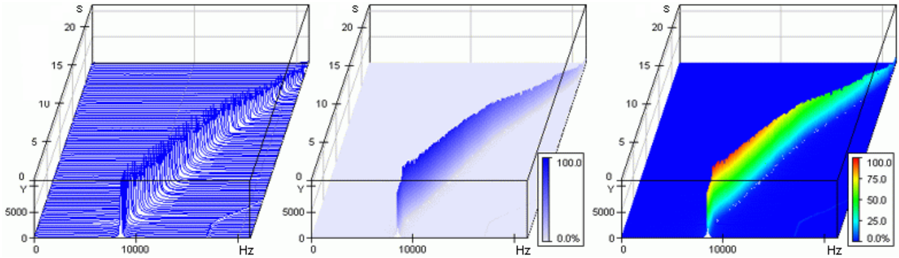


Fig. 6.3 Versions of filling: one-color two-color, multi-color

The color scale bar can be disabled and its orientation (vertical or horizontal) can be changed by the same menu or in the settings dialog which is open by the double mouse click. The position and size of the color scale bar can be changed by the mouse.

Multi-color filling is enabled only for the line graph plotting by X or Y. For the top view, by pressing the  button on the toolbar the size and position are changed automatically in order not to enclose the graph by the scale. The scale must be placed quite near to the graph edge.

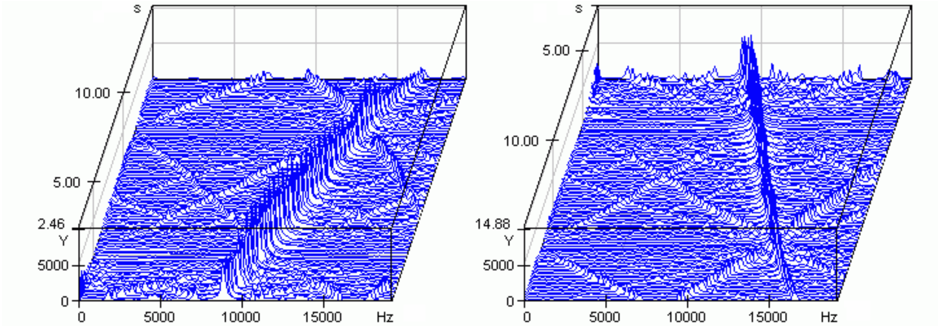


Fig. 6.4 Graph with regular and inverted scale

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 may be represented in one of two viewing modes - "fixed view" and "free view" (Fig. 6.5). In the first mode the X and Y axes of the graph are not changed, in the second mode the graph can be rotated arbitrary. The toolbar  button restores the graph to the initial view. At pressing the arrow on the right to the button, the menu which switches the graph viewing mode (fixed to free) appears.

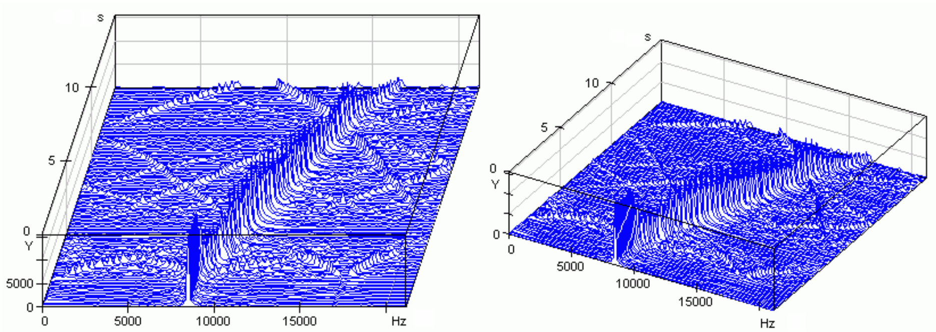


Fig. 6.5 Fixed and free view of 3D graph

The  button (*Graph view customization*) allows rotating 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 by the mouse scrolling wheel (do not press the left mouse button for that).

To change the length of axes press and hold the <Alt> key, movement of the mouse cursor horizontally (with the left button pressed) 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>, movement of the mouse cursor horizontally (with the left button pressed) turns the graph around the imaginary vertical axis, vertically - around the imaginary axis perpendicular to the screen plane. The fixed view graph allows control of the Z axis direction only.

ⓘ The signal representation with a lot of values (300000 and more) may take tens of seconds. Such signal should be viewed in the decimated form which is enabled by the line context menu (**Preview**).

The  button changes the graph filling mode. The "invisible" lines became visible or hidden by pressing the button. At pressing the arrow on the right of the button the menu allowing selection of the line plotting by X, Y, X and Y or by filled surface place appears.

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 toolbars of 2D and 3D graphs, as well as by **Tools→Cursor** menu item.

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 pressing 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).

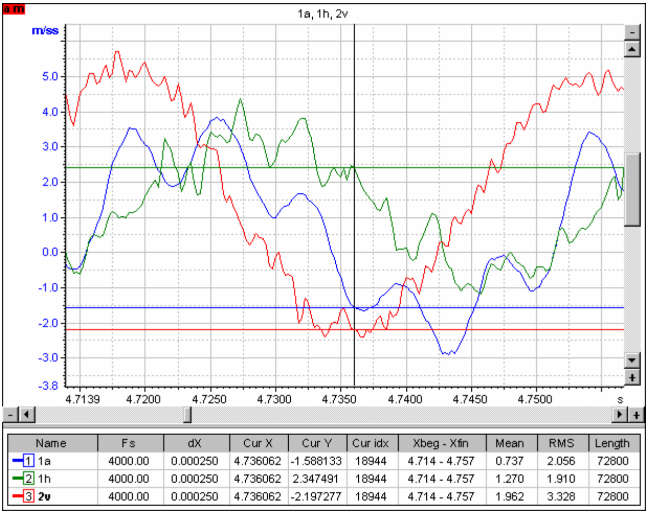


Fig. 6.6 Cursor mode for 2D graph

The signal current values are represented in the legend: *Xcur*, *Ycur.*, *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 <←>, <→> keys or hold the <Ctrl> key while moving the cursor by mouse to move the cursor exactly by the signal discrete values (without interpolation). Press <Tab> key to set the cursor position by entering the number from the keyboard.

Cursor 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.

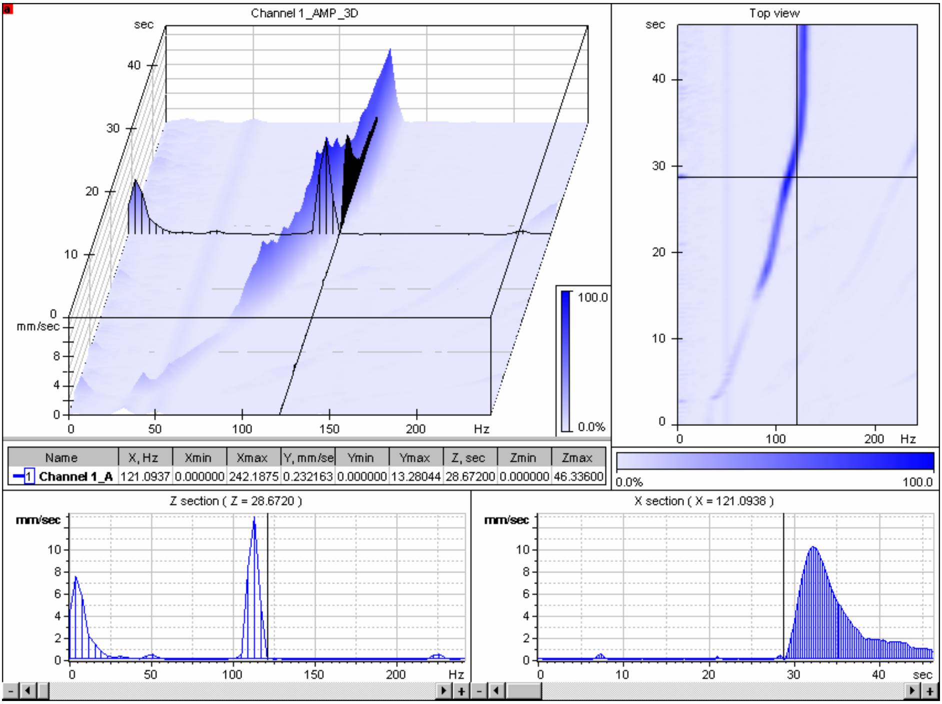


Fig. 6.7 Cursor mode for 3D graph

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

The cursor is moved by the mouse (the mouse cursor has  or  shape; press the left mouse button and move the cursor) or by the keys (press <←> and <→> to move the cursor along X axis, press <↓> and <↑> to move the cursor along Z axis) in any window. The cursor movements are synchronized in 3D graph window and in the projection windows.

Graph zooming and scrolling

Usually the whole signal value range is shown at creation of the graph. (This is set by marking **Auto-normalizing** checkbox of the *Graph* tab of the graph setting dialog. See Fig. 5.11). To study the details of the signal behavior within a short time interval the tools of zooming and scrolling are used.

You can switch on a zooming and a shifting by the  and  toolbar buttons or using context menu (**Mode**) and the **Tools** menu or by mouse in combination with control keys.

2D graph

- **Zooming**

Select zooming mode:

 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

The zooming buttons of the toolbar are switched by <Ctrl+2>.

ⓘ The graph zooming mode is enabled automatically by pressing and holding <Ctrl> when selecting the area of the graph (zooming by both axis), and the area of one axis (zooming by one axis).

Move the mouse cursor in the graph to begin of signal segment to be zoomed. Press and hold the left mouse button and mark the area to be zoomed on the graph (rectangle), release the button. The selected area takes the whole graph box.

- **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

The scrolling buttons of the toolbar are switched by <Ctrl+1>.

ⓘ The graph scrolling mode is enabled automatically by pressing and holding <Ctrl> when selecting the area of the graph (scrolling by both axis), and the area of one axis (zooming by one axis).

Press and hold the left mouse button in the graph area and move the graph by the mouse cursor, release the button.

- **Restore the initial zooming**

The  button restores previous zooming or viewing area. Each click of the button undoes the last zooming operation.

- **Scroll bars**

The scroll bars located on the right and bottom borders of the graph change scale of the signal graph and shift it. The relative size and position of a scroll box indicates size and an arrangement of a displayed fragment.

The button increases scale, - reduces. The , , , and buttons are responsible for shift of the viewing area. Also it is possible to scroll the graph, having dragged a scroll box by the mouse.

Automated scrolling

The control buttons of the graph automated scrolling by X axis are grouped with the signal playback buttons (See *Signal playback* below): - to the left, - to the right, – decrease scrolling rate, - increase scrolling rate, - stop scrolling.

3D graph

- **Zooming**

You can switch on a zooming by toolbar button only. In the 3D graph mode zooming the axes X and Z only is possible. The frame by which the zoomed area is selected is shown by red on the graph. The frame margins are moved by the mouse (over the frame lines the mouse cursor takes the shape of , or , press the left mouse button and change the frame size, then press <Enter>). Figure 6.8 shows the graph view before and after pressing <Enter>.

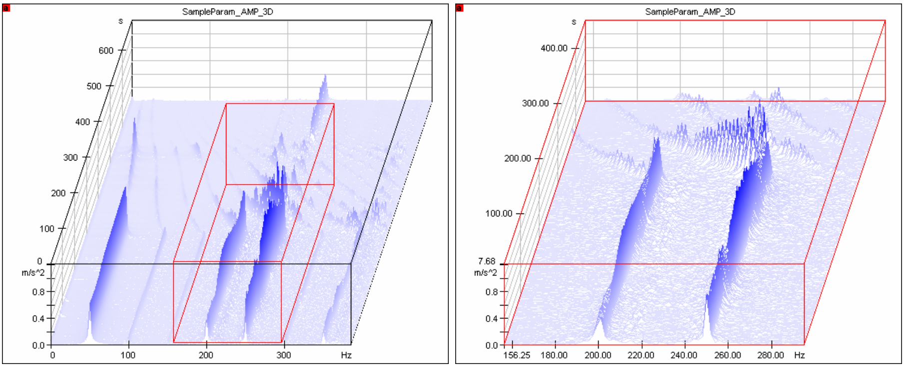


Fig. 6.8 Zooming of 3D graph (before and after pressing <Enter>)

The frame can be also moved by the <←>/<→> and <↑>/<↓> keys. To move the right or top margin press and hold the <Shift> key. The zoom is changed at pressing the <Enter> button. The zoom of the Y axis is changed automatically. In the zooming mode the current margins are represented in the Xmin, Xmax, Zmin, and Zmax fields of the legend.

- **Scrolling**

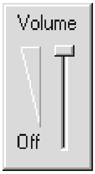
The scrolling is made in the cursor mode by moving the cursor by keys out of the displayed area of the graph.

- **Restoring of the initial zoom**

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

Signal playback

The **MR-300** recording program allows to attach a soundtrack (microphone is connected to MIC-300) to the measurement data (.MERA file). When viewing such file in the graph press the  button («Soundtrack playback»), and the soundtrack is played ("audio" parameter of the .MERA file). Simultaneously with playback the current cursor is moved in all graphs on the display (from left to right from the current position or from the start of the signal fragment).



The  button ("Current signal playback") allows playback of the current (not necessary sound) signal, and the signal frequency in this case is set to 22050 Hz, and the amplitude is normalized.

The  button allows changing or muting (the lowest position) the playback volume. Press this button again to close the Volume window.

Auxiliary signal information and parameter status

WinPOS allows viewing the information on the signal recording session. *The signal modes* ("Start", "Idling", etc) of the test are displayed by named highlighted areas, the value *markers* – by green triangles (see Fig. 6.9).

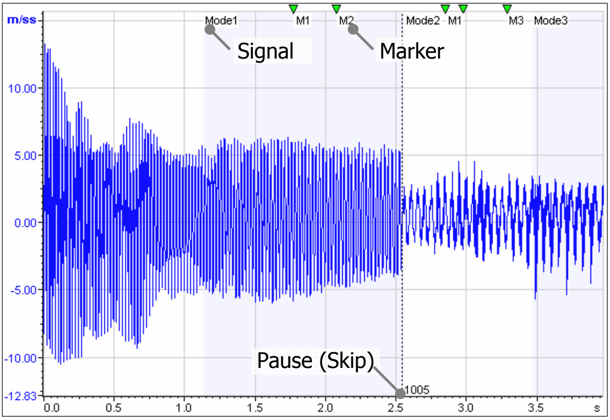
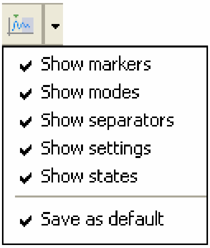


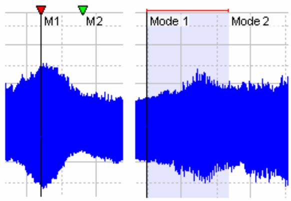
Fig. 6.9 The signal modes, marks, pauses



The user enables and disables the display of markers, modes, pauses, set values and statuses by the button on the auxiliary toolbar. By pressing the button the user toggles the display of all elements. By clicking the arrow at right side of the button the user shows the menu for displaying the elements individually. If the **Save as default** menu item is selected, then the settings will be saved as default.

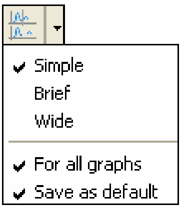
The information on markers and signal recording modes can be modified in the cursor mode.

The marker is set by the button on the auxiliary toolbar or by selecting the **Add marker** menu item in the pop-up menu (appearing when user clicks the arrow on the right of this button). The mode is set by selecting the **Add mode** menu item. If you selected the **For all lines** option then the marker/mode would be set in all active graph lines. Otherwise it would be set only in the active line.



The user selects a marker/mode to remove or rename it by moving the cursor to the marker or the mode start (in this case the marker color becomes red, while the mode is highlighted by a horizontal line above the graph field) and selects an operation in this same menu. You can select a desired marker or mode in the marker list as well(one of the legend view modes).

If there appeared *gaps* in the course of recording (due to hardware failures or if the **Pause** button was pressed) then gap place is marked by a dashed line with the signed time of the real time scale.



The signal with gaps can be presented in three ways:

- **Simple** – The time scale is depicted as if the signal was recorded without gaps and it is plotted continuously (Fig.6.11).
- **Brief** – The time scale is non-uniform and the signal is plotted continuously (Fig.6.10).
- **Wide** – The time scale is uniform, the signal is plotted as fragments with gaps (Fig.6.10).

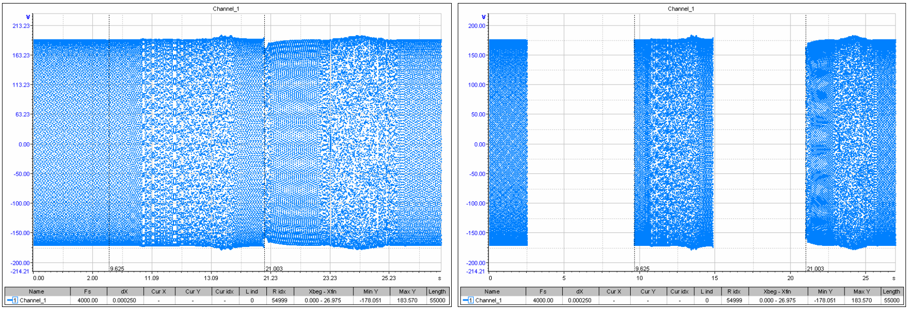


Fig. 6.10 Brief and wide signal with gaps views

The WinPOS program enables to show the *signal set values* on the graph: the regions above or below the set value will change to the set value color.

The signal status changes (excess, uncertainty, etc) are marked by vertical hairlines on the graph upper boundary. When the cursor is moved the current signal status information is displayed in the status bar.

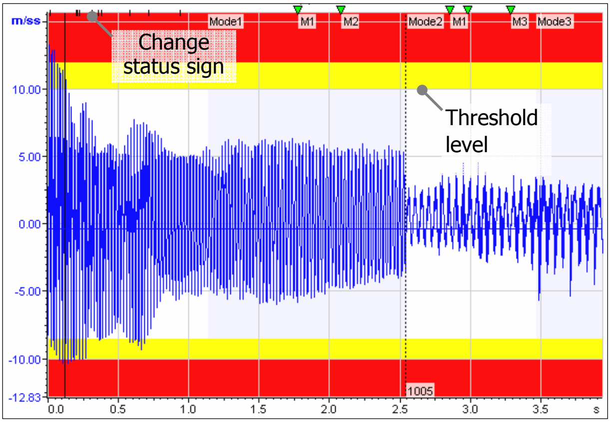


Fig. 6.11 Markers, gaps, set values, status change notches

Figure 6.11 shows the signal graph with plotted ancillary information. The display of markers, gaps, set values and signal status change marks is enabled.

If the signals were recorded with TRS (Time Reference System) data WinPOS will show them in the Common Time Scale. Press the button for signal viewing in the CTS, and press the button once again for returning to the recording time scale.

Specialized cursors

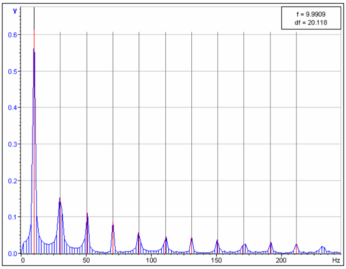


Fig. 6.12. Harmonic cursor

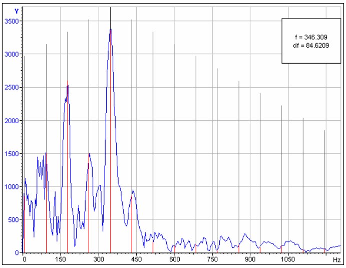


Fig. 6.13. Modulation cursor

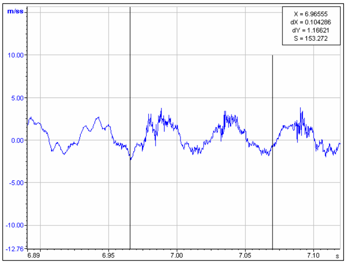


Fig. 6.14. Differential cursor

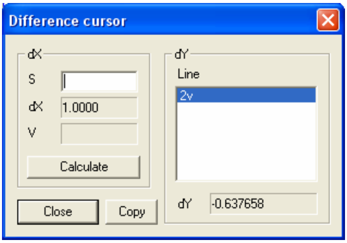


Fig. 6.15. Differential cursor

Harmonic cursor is intended for identification of harmonics of the calculated spectrum of the signal. At pressing the  button the cursor setting dialog is open.

Set the necessary number of additional cursors (harmonic grid lines) and press **Ok**. Select the main harmonic by moving the main cursor. Move the additional cursors by the mouse to match their lines to the respective harmonics. For better visibility the color of the cursor lines imposed to the spectrum are changed to red (by default). See Fig. 6.12. The frequency values - position of the main cursor and interval between secondary cursors are displayed in the right top corner of the graph. The cursor setting window is opened by double mouse click in this window (Fig. 6.16).

Modulation cursor () assists searching the groups of sidebands in the frequency band. Cursor control is similar to the harmonic cursor control (Fig. 6.13).

Differential cursor (, Fig. 6.14) calculates the difference between two signal values by X and Y axes, as well as calculates the definite integral (the area under the signal line).

In differential cursor mode the  button calls the speed calculation window (V) by the preset distance (S) and measured movement dX (Fig. 6.15).

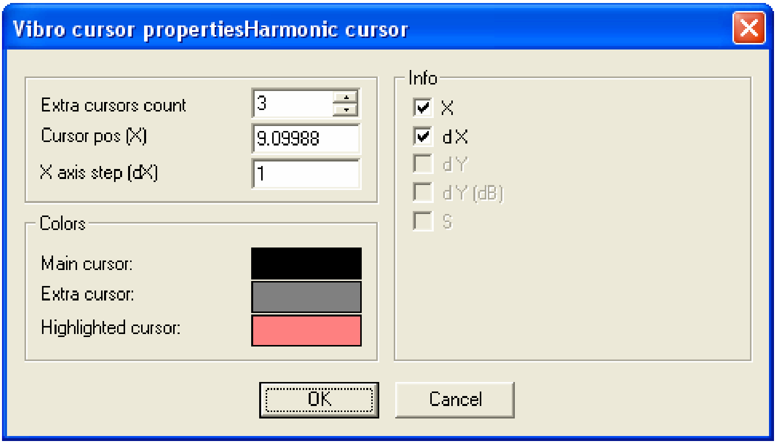


Fig. 6.16. Cursor properties

Tabular representation of signals

The table allows to through signals in the form of columns of the values attached to the common time scale.

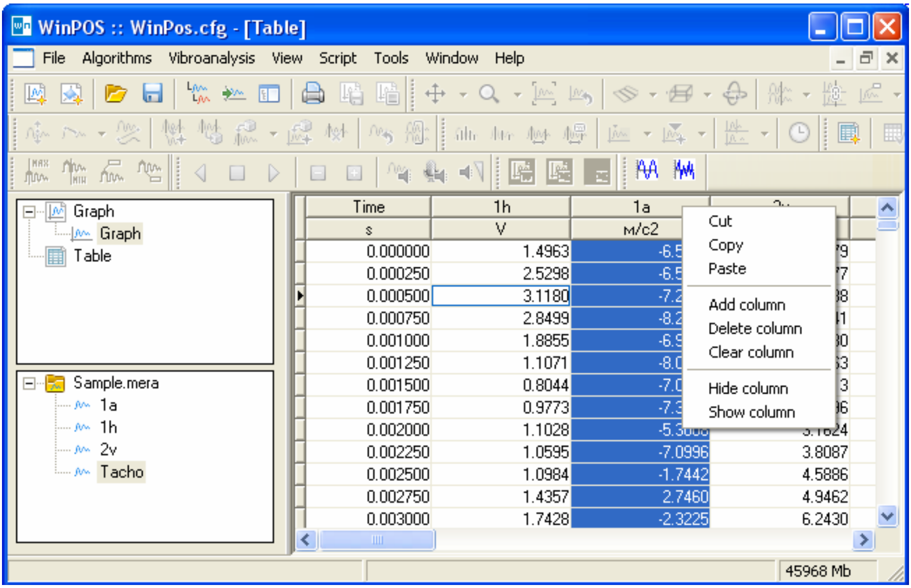


Fig. 6.17. Tabular representation of signals

Press the button on the management panel of the table. To add a signal into the table it is necessary to drag a signal (or a folder) by mouse to the page of the table. Use the contextual menu of a column to remove a signal from the table (a Fig. 6.17, item Delete a column). This menu is appeared by pressing by the right button of a mouse on a cap of the column. Also standard functions of editing (to copy, insert, etc.), addition of an empty line or a column are accessible, using the contextual menu of a column and a line.

You can change the values of signal in the table cells. The active cell is marked by a frame. The changed values are displayed by red color.

You can use and buttons for a cancellation of the changes or for the repeated input. Save the changes using button.

Press the button to print a selected fragment of the table.

The button (Save as …) allows exporting the table data to a file of CSV format (Common Separated Values).

Hot keys for viewing

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

The following keys operate only on the active page. If nothing happens after pressing the buttons, probably the signal tree or the graph tree is selected. Then press once or twice <F5> or click the mouse button over the page.

<G>	To make the next graph active
<Y>	To make the next Y axis active
<L>	To make the next line active
<+>, <->	To zoom out/in by X axis of the active graph
<Shift+"+","-">	To 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 - graph scrolling by X axis
<Tab>	Set cursor to the preset position
<↑>, <↓>	Graph scrolling by active Y axis

Other hot keys (work not only at viewing the graph):

<Esc>	Interruption of a current operation (calculation, drawing, etc.)
<F1>	Call of a help window
<F3>	Call of the Open window
<Space>	In the signals tree : excludes a signal from processing

Part 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.

The WinPOS program creates new signals automatically by executing algorithms (see Part 9 "Signal 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 programmatically.

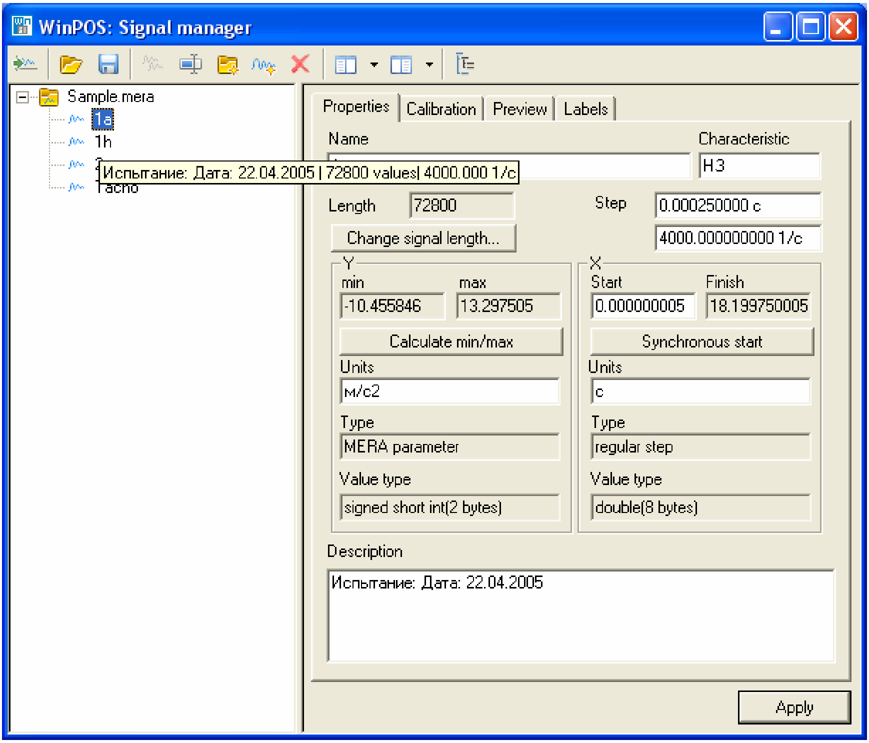


Fig. 7.1. Signal manager. Properties

You can activate editing functions in the main window by the *Edit* toolbar and compose measurement files in the signal tree window.

The *Signal Manager* (see Fig.7.1) helps to modify signal properties and handle the signal tabular presentation. The Signal Manager control elements are described in Part 3 of the *WinPOS Secondary Windows* (Part 3).

File 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 a file select **Delete** menu item in the signal context menu in the signal tree window, or click the toolbar button 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 Part 4 *"Signal Loading and Saving"* for details.

Signal Copying

Using the signal window

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

Using the Signal Manager window

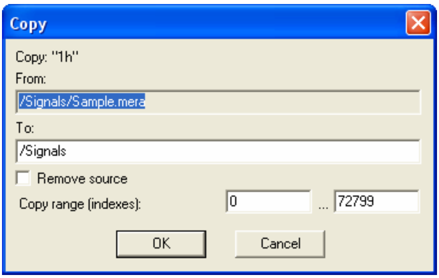


Fig. 7.2. Signal manager. Signal copying

- Enable the signal tree view in the left and right panels by pressing the Signal Manager buttons.
- Select a destination folder in one of these panels and select a signal to be copied in the other panel.
- Press the button.

Check the paths in the *"From" and "To"* fields in the *Copy* dialog (Fig.7.2) and press **OK**. The signal will be copied to the destination folder. The signal will be not copied, and only moved to the chosen folder, when the *Remove Source* checkbox is checked..

Signal Fragment Copying

Using the graph editing panel

- Enable the double cursor (see Fig.7.3.1).
- Select a signal fragment of interest and press button on the *Edit* toolbar (Fig.7.3.2). The selected fragment information will be saved in the internal exchange buffer.
- Press button on the *Edit* toolbar (Fig.7.3, 3). A new signal will be created and shown in the graph (Fig.7.3.4).

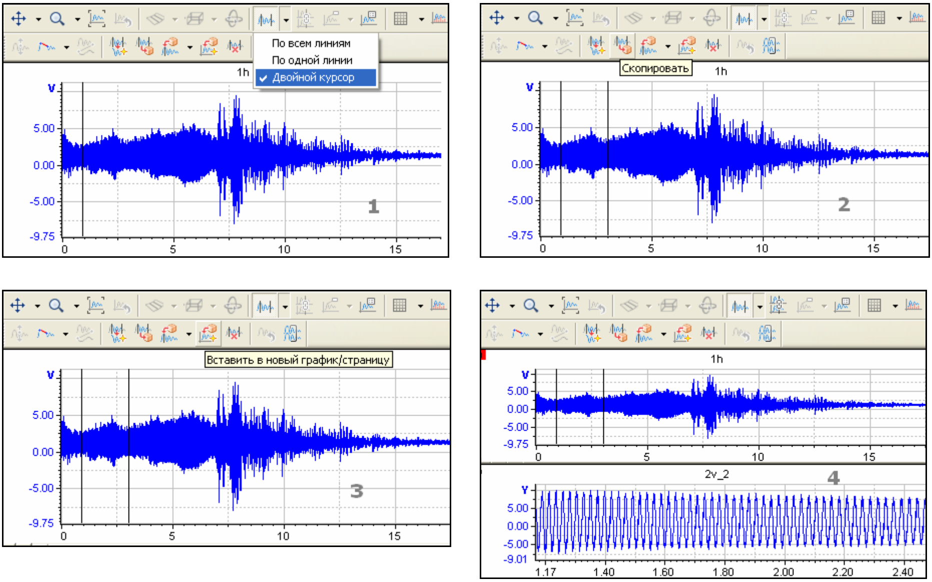


Fig. 7.3. Copy operation steps

When copying the data they are not physically doubled. Instead the resulting signal is supplemented with a reference to the initial data for handling the given signal. It follows from the above-said that you must not remove the signals whose data were copied till the moment the resulting signals are removed. Besides that the source signal modification may bring about resulting signal changes as well.

Using the Signal Manager

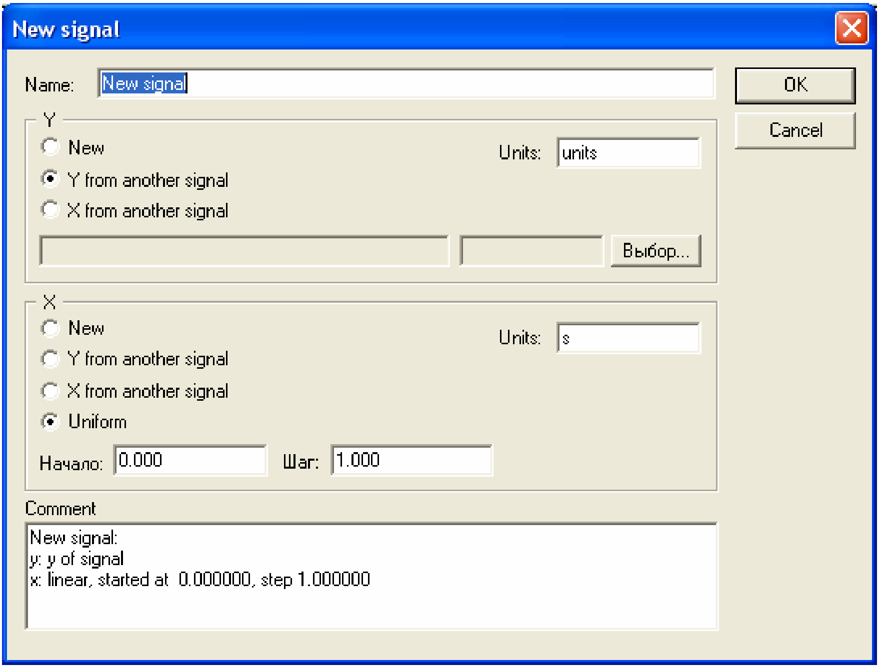


Fig. 7.4 Creation of a new signal

Execute the operations you executed for copying an entire signal but set a new index range in the *Copy range* fields in the *Copy* dialog (Fig.7.2), .

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

- Press  button on the *Signal Manager* toolbar.
- Mark *Y from another signal* in the Y frame in the window of Fig.7.4, press **Browse…** button and select the source signal or its fragment in the signal selection window (Fig. 3.5).
- Mark *X from another* signal in the X frame, press **Browse…** button and select the same signal as for Y axis.
- Type the new signal name and press **OK**. The new signal will be placed in the *New Signals* folder of the signal tree.

Signal Splicing

Using the graph editing panel

You can add copied signal or fragment to another signal.

- Copy a signal in the way described in the paragraph "Signal Fragment Copying using the graph editing panel". See Figures 7.3.
- Select a graph with a signal to be complemented with a fragment, then press toolbar button. If the current value cursor is enabled the source fragment will be inserted in the cursor position. Otherwise, it will be inserted in the signal end. The arrow on the right of button enables to forcedly set the insertion mode: in the cursor position (prohibited when the cursor is disabled), in the signal start or 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.

If a fragment is copied in an existing signal it would be necessary to have the same data type and calibration curve of the two signals.

Automated Signal Splicing

The automated signal splicing function may be useful when splicing the fragments of a signal data distributed among different measurement files.

- Put the signals to be spliced in a single graph.
- Press button on the *Edit* toolbar.

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

Parametric and Polar Signals

Using the Parametric Graph algorithm

Part 9 describes the procedure of constructing the Parametric Graph algorithm for producing parametric or polar signals. If you need to plot parametric graphs often you should expedite the algorithm activation.

- Set the "Parametric Graph" as default algorithm (in the algorithm setting window).

- Press **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 executed and a parametric graph instead of an ordinary one will be plotted as a result.

Using the Create New Signal dialog in the Signal Manager

- Press button on the *Signal Manager* toolbar.
- Mark *Y of the other signal* in the Y frame (see Fig.7.4), press **Browse…** button 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, press **Browse…** and select the signal with the value corresponding to the new X-axis.
- Type the new signal name and press **OK**. The new signal will be put in the *New Signals* folder of the WinPOS signal tree.

ⓘ 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.

Program Signal Generator

An artificial signal can be generated by the WinPOS Professional and Expert versions. You can activate supplied plug-in for signal generation by the toolbar, or load a sample script from the WinPOS installation, or you can write on your own a script, program or plug-in (an attachable module) basically in any programming language supporting the OLE technology. See Part 11 "*WinPOS Automation*" and "*Programmer's Guide*".

Signal Fragment Deletion

Deletion of signal fragments free of useful information significantly reduces the measurement data size and processing time. However one should remember that in this case the data-to-time scale timing may be distorted.

Using the graph editing panel

- Enable the double cursor and select a fragment to be removed (Fig.7.5.1).
- Press button on the *Edit* toolbar (Fig.7.5.2). Confirm the operation. The selected signal fragment will be removed and a break mark will be set in its place (Fig.7.5.4).

When a signal fragment is removed the data are not removed physically till the time the signal is saved on a disk (Fig.7.5.4).

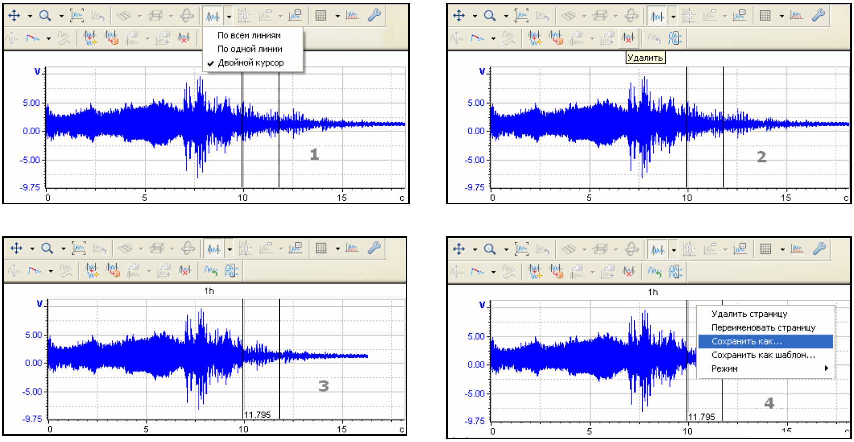


Fig. 7.5 Signal fragment deletion steps

Using the Signal Manager

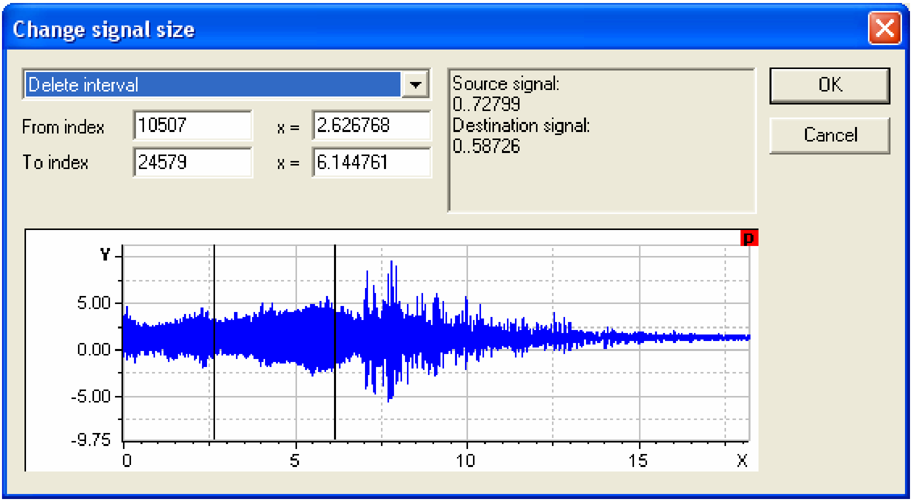


Fig. 7.6 Changing the signal length

- Select a signal in the *Signal Manager*.
- Press the **Change signal length…** button next to the *Length* field on the *Properties* tab (Fig.7.1).
- Select a signal fragment in the *Change Signal Length* dialog window (Fig.7.6) by the cursors (on window opening the cursors are set at the signal start) or type precise values in the corresponding fields.

- Select an operation in the drop-down list:
  - Crop (leave) the given interval,
  - Delete the given interval,
  - Insert the given number of values.
- Press **OK**.

The signal length will be changed right after confirmation and can't be cancelled.

Editing Cancellation

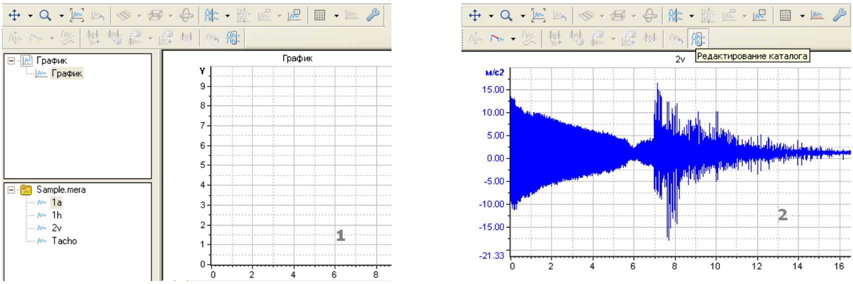
Postponed editing operations (such as copying, insertion, and deletion by the editing panel) may be cancelled.

Select a modified signal graph and press  panel on the *Edit* toolbar. Confirm the operation. The signal will be freed of all editing data and it will be restored in its initial form. If a signal completely consists of copied fragments of other signals it will be removed at editing cancellation.

Folder (file) handling

Editing operations (such as copying, insertion, and deletion made using *Edit* toolbar) can be executed on all folder (or file) signals simultaneously in the same way, as described below for a single signal.

- Open a signal in the graph and press  toolbar toggle (Fig. 7.7, 1-2).
- Execute all necessary operations with the selected signal. Similar operations will be simultaneously executed with all other signals in the folder (Fig.7.7, 3-4).
- Press  toolbar toggle again for exit from the folder handling mode.



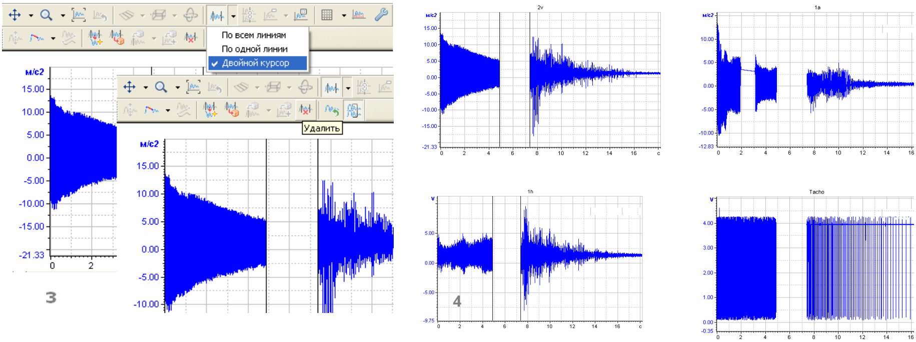


Fig. 7.7. Folder editing

ⓘ Selection of a specific signal makes no effect on the results. When editing a folder you can select a signal for the next operation differing from the initially selected signal.

Signal Characteristics Modification

Main Signal Properties

Open the *Signal manager* (select **View→Signal manager** menu item or press toolbar button). Select the signal in the left window. The *Properties* tab of the signal (Fig. 7.1) allows changing of the signal name, measurement unit, type of characteristic; addition of description, changing the sampling rate; setting the start time.

In order to set the start time for all signals of the folder at once, the button **Synchronous start** is provided.

The minimum and maximum values are calculated automatically at plotting the graph. The sign "unknown" in the respective fields means that the values are not yet calculated. The calculation can be manually started by pressing the **Calculate min/max** button.

The signal characteristics are changed after pressing the **Apply** button.

Calibration Curve (Scale) Modification

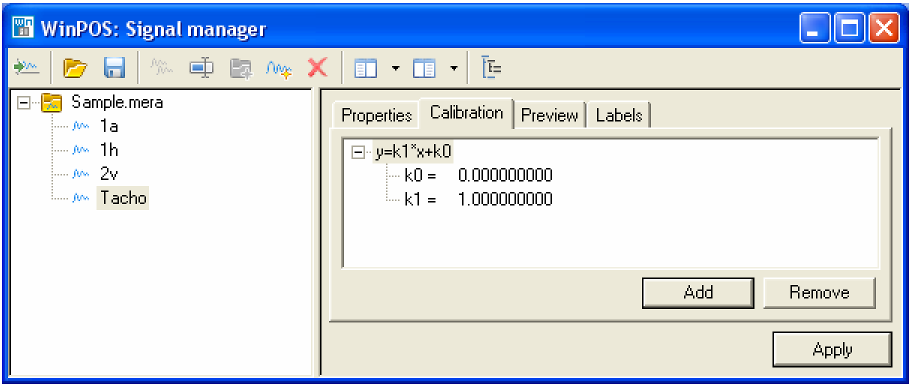


Fig. 7.8. Signal manager. Calibration

Select a signal from the *Signal manager*. At the *Calibration* tab (Fig. 7.6) the calibration curve (CC) of the signal is displayed as a tree with coefficients. In the bottom part of tab the coefficient values can be added, deleted or edited. At addition of a new calibration the calibration type shall be set in the *Add calibration curve* dialog box (Fig. 7.9).

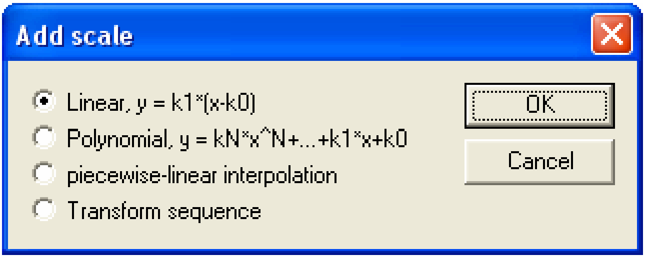


Fig. 7.9. Add calibration curve

For example, if it is necessary to recalculate the ADC codes to Volts, and the values in Volts to kg/cm^2, select **Transformation sequence** option in the dialog box and add two CCs.

The signal values in codes (before CC application) are placed in the *Preview* tab in the column *y (codes)*. The fourth column contains the signal measurement units after the transformation. (See Fig. 7.10.)

Signal Value Editing

Tabular Values Editing

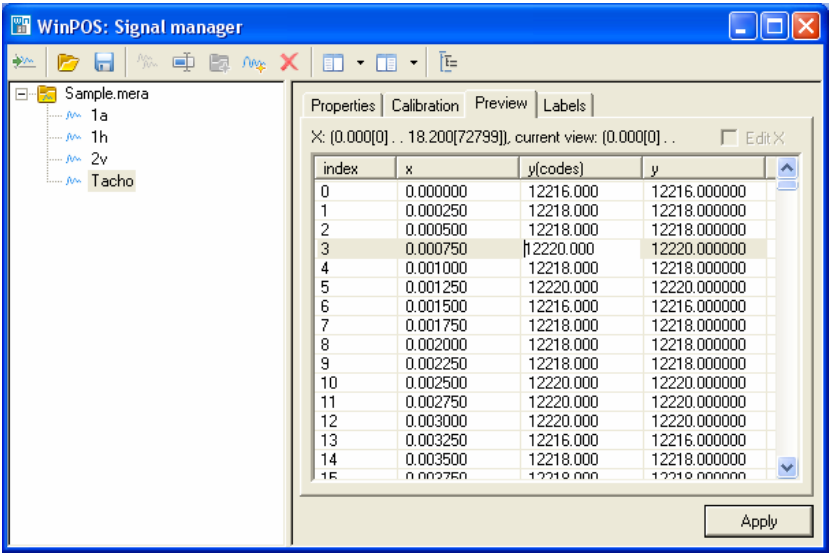


Fig. 7.10. Signal manager. Preview

Select the signal from the *Signal manager*. The *Preview* tab (Fig. 7.10) contains the signal values in the table.

If the required value isn't displayed on the screen within the limits of 1000 values it is necessary to switch on an editing mode of a table cell by double click of a mouse on any cell in the index column or the x column and then enter the required value of a displacement or time. The jump to the required value occurs after the mouse click outside of a field of an edited cell

The signal value can also be changed by double click at the cell of the *y* column. The table value is changed by the mouse click outside the edited cell, and the signal data is changed after pressing the **Apply** button only.

Values by the axis *x* of the signals with non-uniform step can be changed too, by checking of **Edit X** checkbox. However, the abscissa scrolling mode in this case is disabled.

The number of digits after decimal point can be changed by the right mouse click at the cell. The control element appears in the cell filed, and the accuracy of digit representation is either increased by the right button of this element or reduced by the left button. The accuracy change impacts the whole table column.

Graph Interval Editing

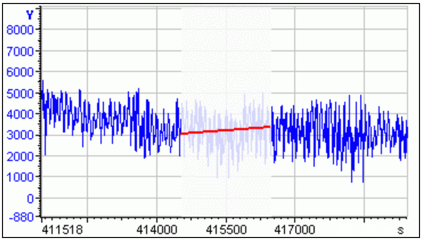


Fig. 7.11. Signal editing. Draw lines

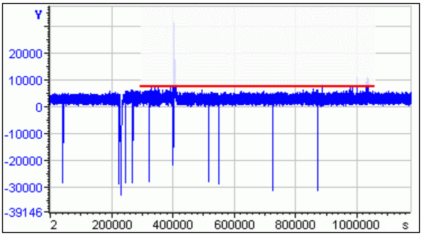


Fig. 7.12. Signal editing. Erase above

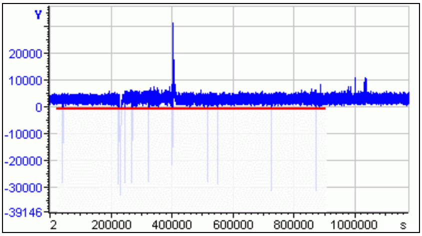


Fig. 7.13. Signal editing. Erase below

In order to change the signal values at several points press the ▾ button on the right to the **Replace signal value** ( ) button.

Select the signal value change mode in the submenu. Mark the value selection area by the mouse (holding the left mouse button move the mouse cursor, release the button). The signal values to be changed will be shown by a lighter color.

The cut line (red) means the following:

In the **Draw lines** mode - replace the signal values with the values of this line (Fig. 7.11),

In the **Erase above** mode - the values above the line are replaced with the line points, and the values below remain the same (Fig. 7.12),

In the **Erase below** mode - the values below the cut line are erased and replaced with the line values (Fig. 7.13).

ⓘ The replacement of signal values cannot be undone. When entering the value replacement mode a respective warning is displayed.

Single Value Modification

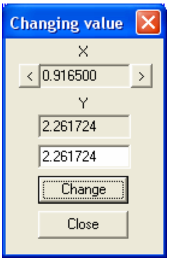


Fig. 7.14. Data editing

In order to change the signal(y) value of the selected point switch to the cursor mode, place the cursor to the desired point and press the **Data editing** ( ) button on the editing toolbar.

Enter new signal value at this point in the *Data editing* dialog box (Fig. 7.14). Press **Change.**

Part 8. Graph plotting and report drawing

Graph plotting

For better information and representation of the results, WinPOS includes such elements of graph plotting as the legend, line numbers, grid values, marks, notes and comments (See Fig. 8.1).

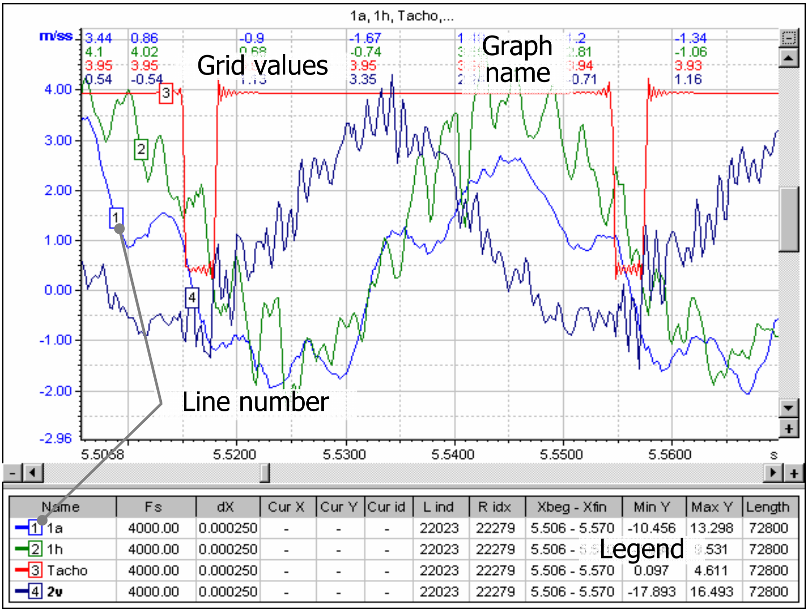


Fig. 8.1. Improvement of the graph self-descriptiveness

On the *Graph* tab (Fig. 5.11) of the graph customization dialog the representation of the **Graph name**, **Line numbers**, **Grid values** can be enabled or disabled, and the placement of the legend can be selected.

Legend

The legend is one of basic elements of the graph. The legend can be presented in one of three types - simple, full and as the list of labels. In the simple legend form only the names of lines are displayed. If the cursor mode is switched on, the current cursor position and values of each line in this point is displayed.

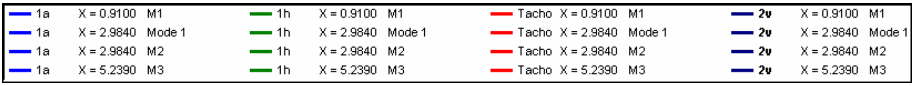
A full form of the legend is a table in which for each signal a few parameters are displayed: a rate of digitization, the value of X and Y at the point of the cursor, etc.

The full list of accessible parameters is shown in the table 8.1. On the Legend tab in the Graph settings window (Fig. 5.15) you can choose columns which will be shown in the legend. There is an option to display or hide the legend on the same tab. As well as you can choose this option using the graph context menu. (**Show legend**). It is possible to change the size of the legend field: grasp the border of the field by the cursor of a mouse and move it to the required side

Table 8.1. The list of accessible columns in the full form of a legend:

Name	Name of the line(signal), the color and number of the line is displayed near
Fs	Sampling rate of the signal
dX	Step on the X axis, dx = 1/Fs
Cur X	Current lines cursor
Cur Y	Signal value in the cursor point
Cur idx	Index of the value in the cursor point
L ind	Index of the first value on the graph
R idx	Index of the last value on the graph
Xbeg-Xfin	Current range on X
Ymin-Ymax	minimum and maximum values of the signal on a current range on X
Y range	Difference of the maximal and minimal values on a current range
Min Y	Minimum signal value on a whole range
Max Y	Maximum signal value on a whole range
Mean	Mathematical expectation of the signal on a current range on X
RMS	RMS of the signal on a current range on X
Length	Number of the signal values

The list of all tags, markers and the modes, which are present on the graph, can be displayed in a legend.



Line numbers

At simultaneous representation of several signal lines at a graph the change of each parameter can be tracked by color highlighting of each signal. However, if the lines are too numerous, or the graph is printed in black-and-white copy, the color representation is not enough. The lines are numbered in the rectangle at the respective line in the graph window and in the legend near the signal name. The line numbering is enabled by the *Graph* tab of the settings window (see above).

Hidden lines

If a graph has too many lines, and they enclose each other, some lines can be temporary hidden but they will still be present in the graph. In order to hide the graph lines select the **Hide line** item of the line context menu (called from the legend and from the graph tree) or press the <Space> key at the selected line in the graph tree. The hidden line is marked in the legend by a crossed number sign (1h), and in the tree - by a special glyph standing before the name: 1h.

The active line is always plotted above other lines.

ⓘ Hidden lines as well as hidden signals (see Part 9 *Signal processing*) are elapsed from the processing by the algorithms.

Grid values

The grid signal values facilitate viewing of the signal changes on the hard copy, replacing the cursors in some respect. The numbers in the column placed in the same order as the signals in the legend, and have the some color. The values of the hidden line (see above) are represented to preserve the order of values. This mode is enabled by the *Graph* tab in the settings (see above).

Coordinate grid

The coordinate grid view is changed by sequential clicks on the button or by drop-down menu (click arrow near the button), or by **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**.

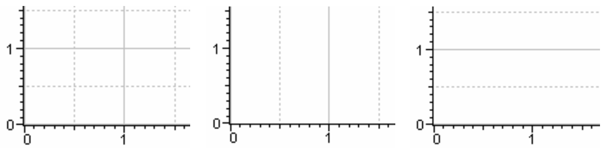


Fig. 8.2. Kinds of the coordinate grid

Line view

The signal is usually represented on the graph by a solid line, the signal points are connected with segments (1st order interpolation). Such mode allows the estimation of the signal form and changes. However, such mode does not provide viewing o separate measurements (points).

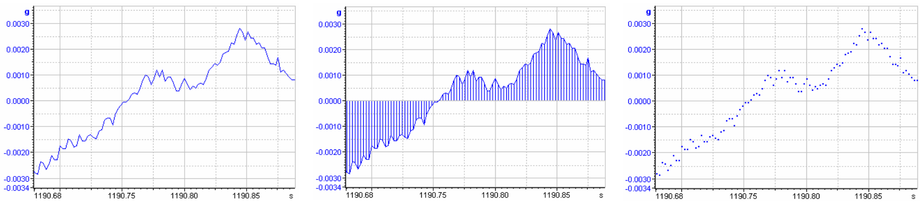


Fig. 8.3a. Kinds of graph line representation

The vertical line plotting mode from the signal points (see the 2nd graph in the Fig. 8.3) helps to resolve the above problem. This mode is helpful for more accurate association with the time axis and for comparison of the signals with different sampling rates. The mode is enabled by ticking **Vertical lines** on the *Line* tab in the graph settings (Fig. 5.12) or by the button on the graph toolbar.

In some cases, e.g., while viewing telemetric signals, the mode of signal representation by separate measurement points (3rd graph in the Fig. 8.3) can be helpful. Such mode is enabled by ticking **No point connection** on the *Line* tab in the graph settings (Fig. 5.12).

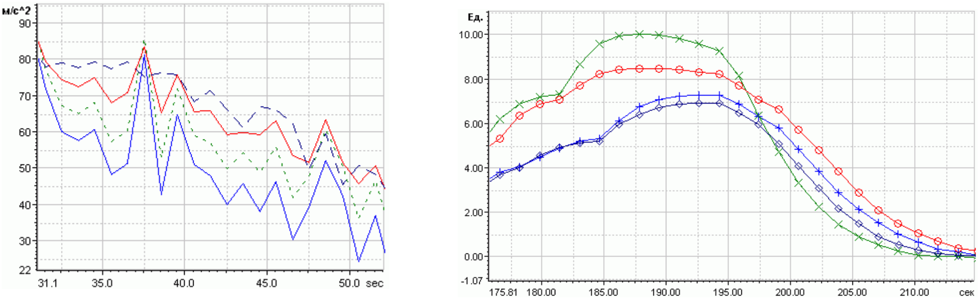


Fig. 8.4. Line selection

If lines of several slowly varying parameters in one graph is badly discernible by colors (for example, at a monochrome printing), it is possible to change the shading of a line or to mark values of a signal by badges as it is shown on fig. 8.4. For this you need to open the *Line* tab in the Graph settings window and then the *Type of a point* option. (Fig. 5.12).

Spectrum representation by histograms

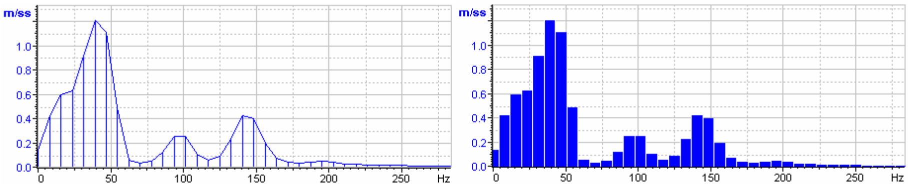


Fig. 8.5. Different ways of line representation

Usually spectrums are represented by curves with vertical lines (see Fig. 8.5), but in the Lines tab in the Default settings … window you can set the spectrum a representation in the form of histograms if to select the Spectrum histogram checkbox.

Labels

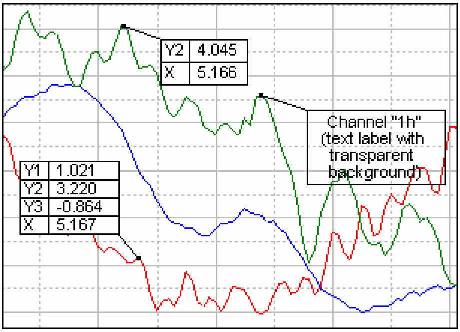


Fig. 8.6. Types of labels

The labels allow addition of precise signal values to the graph at the selected points and commenting the signal segments (Fig. 8.6).

Switch to the cursor mode by clicking the toolbar button. Set the cursor at the desired value. Press the button - **Add label (flag)** (or <Ctrl+F>). Point the label position by clicking the left mouse button.

Click the sign on the left of the button to select label type: **In one line**, **In all lines** or **Text**.

Editing or deletion is performed by double click in the label field.

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

In the label customization dialogs (Fig. 8.7) **Transparent background** option can be enabled. For the label values the format precision can be set (**number of digits after the point**), and the short graph line names (Y1, Y2, Y3, and further in accordance with signal ordering in the legend) can be replaced with the corresponding **signal names**.

The label text is edited in the **Text** field (Fig. 8.7). The >> button opens the window of history with the lines of previously entered text.

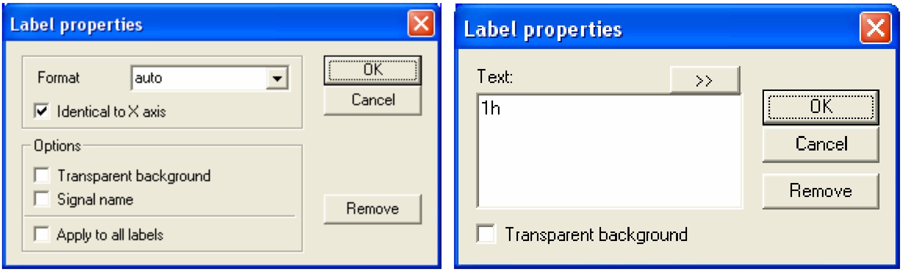


Fig. 8.7. Customization of labels

Comments

Press the button (**Add comment**). «Draw» a rectangle for the comment text by the mouse (press and hold the mouse button in the graph plotting field and then move the cursor, drawing the future comment area with the rectangle). For editing (Fig. 8.9, the *Comment* textbox) or deletion double click the comment field.

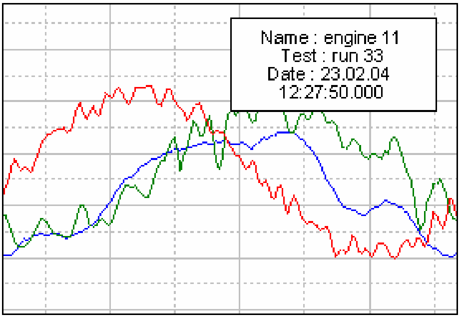


Fig. 8.8. Comment

The >> button opens the input window history.

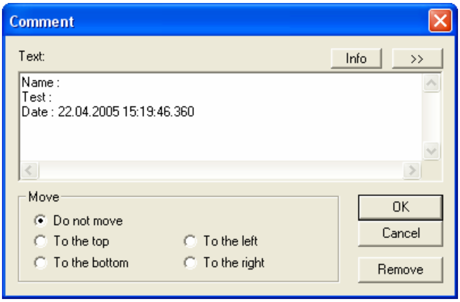


Fig. 8.9. Commentary settings

The **Info** button adds comment from the MERA or USML format file.

The **Move comment** field allows alignment of the comment along one of the graph sides.

To move the comment press and hold the mouse left button in the text field, then move the rectangle to a new position, and release the button.

The comment size can be changed by moving its frame (the mouse cursor over the frame is replaced with arrows pointing the movement direction: press the left mouse button and move the frame).

Graph printing and saving

Page printing

The active page is printed from the preview window (Fig. 8.10) which is opened by the button of the main toolbar or by the menu **Tools→print…**

The **Page…**button of this window allows setting the borders sizes and selecting the paper source and orientation by a standard Windows dialog box.

The **Save** button creates a graphic file (in BMP format) with the page view. The **Load** button allows finding and printing a previously saved page.

The **Print** button opens a standard dialog of selection and setting the printer and printing.

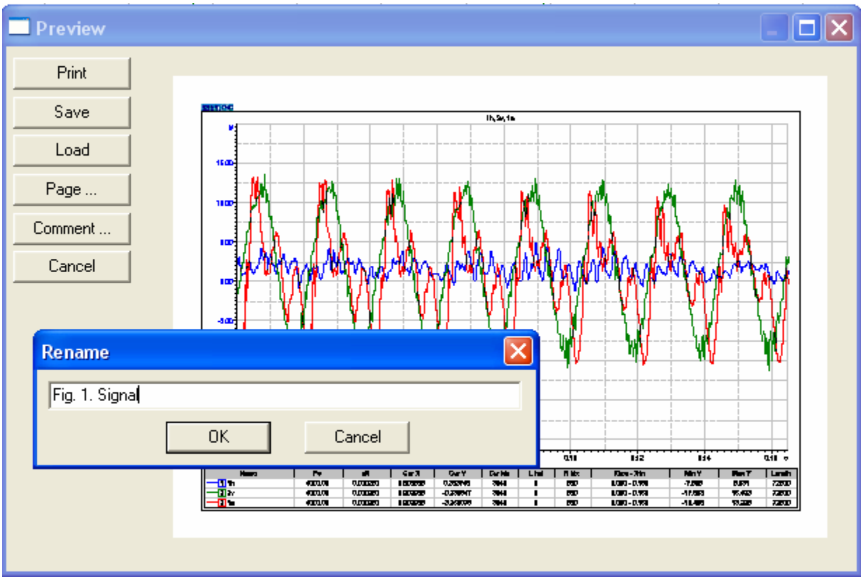


Fig. 8.10. Preview. Comment

Comment

Wide-graph print, emulation

The **Comment…** button of the preview window (see Fig. 8.10) allows addition of a comment at the bottom of the page when printing. Printing by the roll-fed printer (see Fig. 8.11) produces more convenient for further study graphs with better detalization by the time axis. If reel feeding is not supported by the printer, the wide-graph print is emulated by separate sheet. In that case high resolution by the time axis can be obtained by gluing these sheets into one.

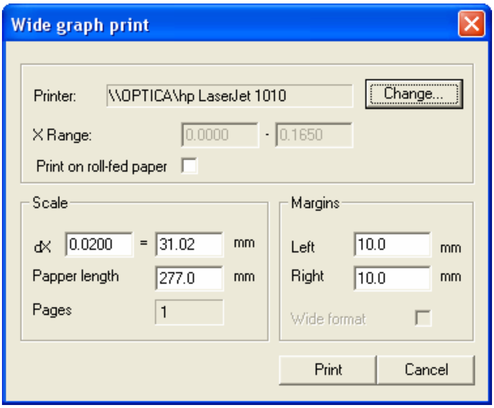


Fig. 8.11. Wide graph print setup

In the **Wide graph print** setting window the printer can be selected by the **Change…**button), also set *Scale* (resolution margins, **dX**…=…**mm**, related to the **Paper length** field) and set the *Margins*. The **X range** is set by the current graph.

The **Wide graph print** window can be opened by the **Tools→Reel printing…** menu.

Image saving

The current graph page can be saved in a graphic file (BMP format) by pressing the button of the main toolbar or by the **Tools→Save image in file…** menu (a standard file selection dialog box is opened).

Graph copying via the clipboard

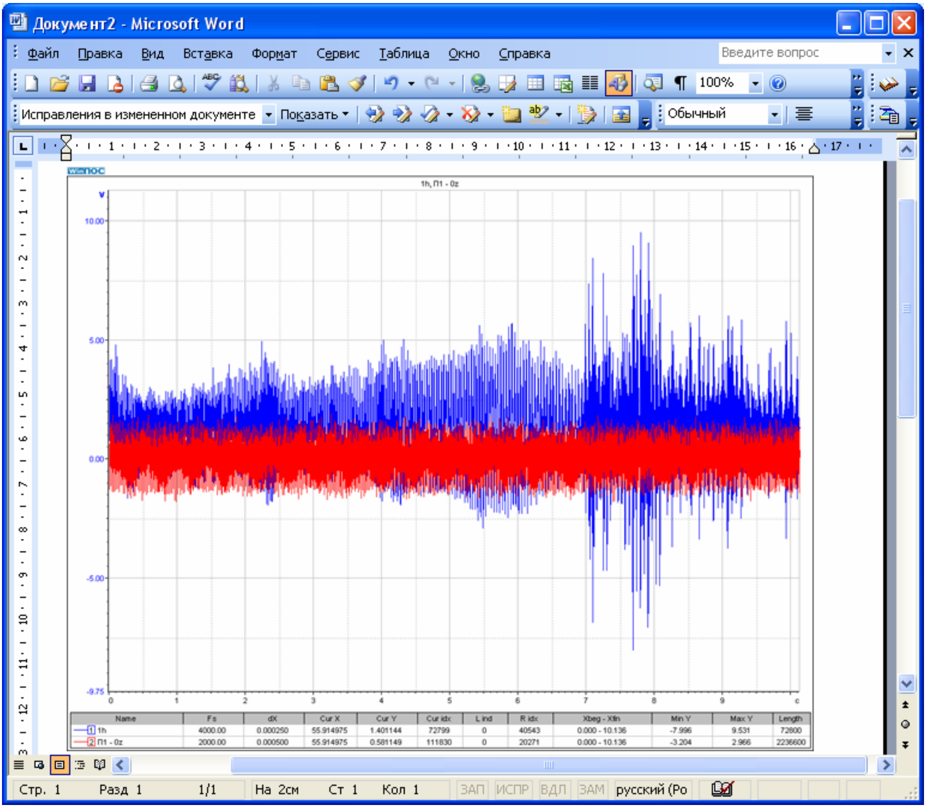


Fig. 8.12. Graph in the WordPad document

This tool allows insertion of WinPOS graphs directly into the text document to illustrate your reports (see Fig. 8.12).

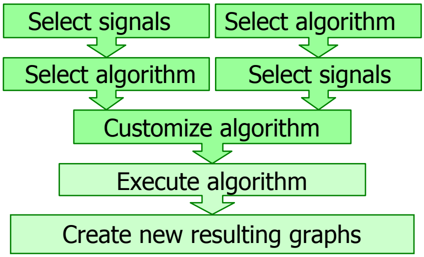
The  button and the menu item **Tools→ Copy image to clipboard** create a copy of the current page in the clipboard. In order to include the WinPOS graph into the text document, move the cursor to the desired place of the document and select the **Insert** command in the context menu of your text processor or press <Shift+Ins> on the keyboard.

Part 9. Signal processing

WinPOS allows digital processing of the stored data by using a large number of embedded standard algorithms. The WinPOS scripts (see Part11) allow creation of customized processing programs with application of standard algorithms.

Operations Sequence

The sequence of signal processing can be divided into five steps.



This algorithm can be applied to a signal, or to a folder with several signals, or to all signals on the page or graph, or to one signal line.

At the selection of the page, graph, or signal line the algorithm is applied to the viewed range of values, by the WYSIWYG principle.

If a folder with signals or a graph is selected for processing, then the signal can be elapsed from the processing by pressing the <space> key on signal name in the signal tree, or on the graph line name in the graph tree, or by hiding the graph line (see Part 8. *Graph plotting*). The elapsed signal is marked in the tree by a special glyph before the name: 1h.

Step 1-2. Select signals – Select algorithm

1. Choose an object, to which the algorithm will be applied.

2. Open the context menu of the object to be processed (see Part 3, section *Context menu* and Fig. 3.2) and select the **Algorithms** submenu, then select the algorithm.

Step 1-2. Select algorithm - Select signals

1. Choose the algorithm from the **Algorithms** submenu of the main menu (see Fig. 3.3). In the algorithm customization dialog box (Fig. 9.1) press the **Select** button near the *Sources* field.

2. Press the Browse button, which is near the Source field in the Algorithm settings window, and choose the object and set the range of the processing by the *Select signals* dialog (Fig. 3.5). By default chosen algorithm is applied to a current line of the active chart.

Step 3. Customize algorithm

A selection of any algorithm, except **Probabilistic Analysis**, opens the Algorithm settings window (Fig. 9.1).

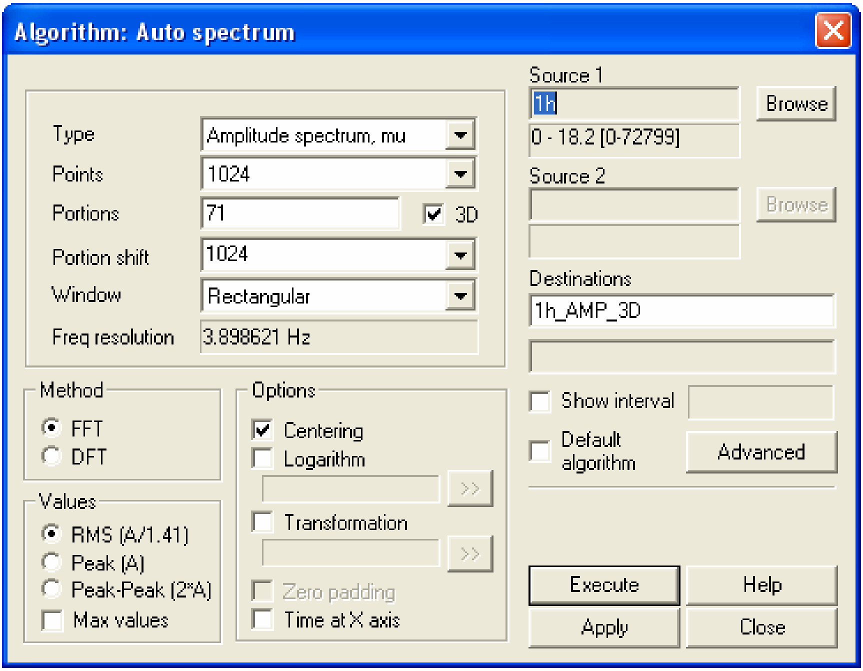


Fig. 9.1. Customization of algorithms. Auto spectrum

The right part of the customization window is similar for all algorithms, containing the settings of data sources, and result names. The left part is related to customization of the selected algorithm (operator). The algorithm customization is described below.

The main part of algorithms receives one source signal only at the input, and produces one resulting signal. However, for example, for *Cross spectrum* algorithm two sources must be specified, and the *Auto spectrum* algorithm calculates the *Real* and *Imag* resulting signals.

The range of the signal values and indices selected for processing is displayed under the *Source* field. In order to change the processed value range or to select signals use the **Select** key and the *Signal selection* dialog box (Fig. 3.5). The **Apply** button allows storing of the settings without algorithm execution. Brief information on the algorithm is obtained by the **Help** button.

Step 4. Execute algorithm

The calculations are started by pressing the **Execute** button and can be monitored by the indicators placed at the bottom of the WinPOS main window. The right indicator shows a general status of calculations, the name of the processed signal; the calculation progress is shown on the left. The calculations can be interrupted by the <Esc> key.

The calculated signals are placed to the *Results* folder. The processed signal names are completed with shortened algorithm name as a suffix. In case of the signal folder processing resulting folder name is completed with such suffix but not the signal names inside.

Step 5. Plot the result graphs

After the calculations are completed the page with calculation results is automatically created and made as current (see figure below).

If only one signal is processed, a page with two graphs is created: the source signal (within the selected range) and the resulting one. 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.

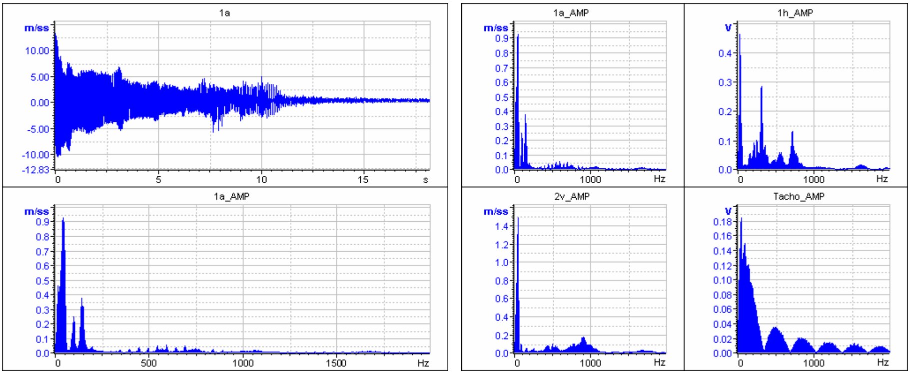
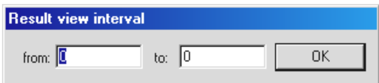


Fig. 9.2. Results of Spectrum calculation of the single signal and of all the signals in the folder

In order to set the preferable viewing range of the resulting signal, the **Show interval** option must be checked, and the value range by the abscissa of the resulting graph must be set in the dialog box.



Proper application of processing algorithms assumes basic knowledge of higher mathematics, and physical processes occurring during testing, as well as measurement methods. Though descriptions of all algorithms can be found in the higher mathematics reference books, The Appendix A. *Processing algorithms* contains the main formulae and comments of the algorithm implementation in

WinPOS. The Appendix B. *Recommendations to the Processing algorithm application* helps to make a correct choice of algorithms in order to achieve the necessary results.

The settings of the algorithms are automatically stored at the closing WinPOS, at the saving the séance (see p. 4). In order to save several settings, e.g., for different processing scenarios, use the **Algorithms→Save settings** and **Algorithms→Load settings** items.

Fast Algorithm Activation

1. If you often use some algorithm during processing you can expedite noticeably the process in the following way:

   - Mark the **Default algorithm** checkbox (see Fig.9.1);
   - Drag the signal holding down the <Alt> key from the signal tree to the graph as you do when creating a graph (see Part.5. *Graph Creation*).

   The default algorithm will be executed and you will see at once the result on the graph instead of the source signal graph.

2. If you use the algorithms processing two sources then you can set in advance the second source. Press **Select signal** in the signal context menu**.** The signal is marked with the sign in the signal tree.

Press **Advanced** button (see Fig.9.1) for making the fast activation function more convenient for you.

Mark the following in the *Advanced settings* dialog:

Always open settings dialog – for changing settings of the default algorithm at fast activation (otherwise the algorithm will be activated with current settings),

Show results in new window – for putting the results on a new page (otherwise the result will be where it was dragged to by the mouse),

Show source signals – for creating pages with source signals (otherwise only resulting signal graphs will be plotted).

Customization of standard WinPOS algorithms

Auto spectrum

Spectrum **Type**:

PSD - power spectrum density (result dimension: $units^2/Hz$),
PS - power spectrum ($units^2$),
ESD - energy spectrum density ($units^2 \cdot s/Hz$),
AmpSp - amplitude spectrum (*units*),
Real&Imag - real and imaginary spectrum parts,
Amp&Phase - amplitude and phase.

Number of FFT 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.

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.

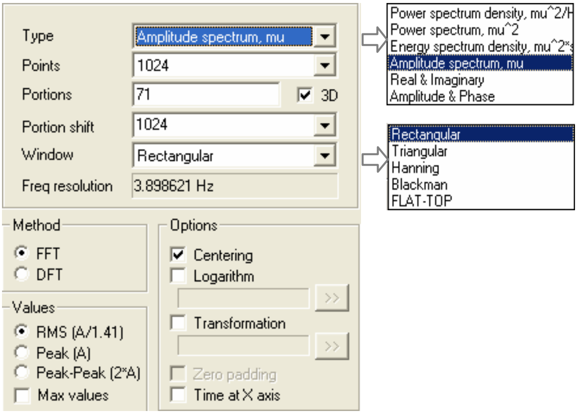


Fig. 9.3. Auto spectrum

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.

Portion shift - shift of the next portion start after calculation by the previous portion: 1, ¼*N*, ½*N*, ¾*N*, *N*, where *N* - number of FFT points.

Window type**:** rectangular, triangular, Hanning, Blackman, FLAT-TOP

Values: effective (RMS), amplitude: Peak, Max Peak, Peak-Peak.

Centering – removing the constant component of the signal.

Logarithm – The “Taking the logarithm” algorithm will be applied to the result (see below Fig. 9.9). Press the >> 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. 9.10). Press the >> button on the right of the transformation parameter field to modify the parameters.

Zero padding – 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.

Octave spectrum

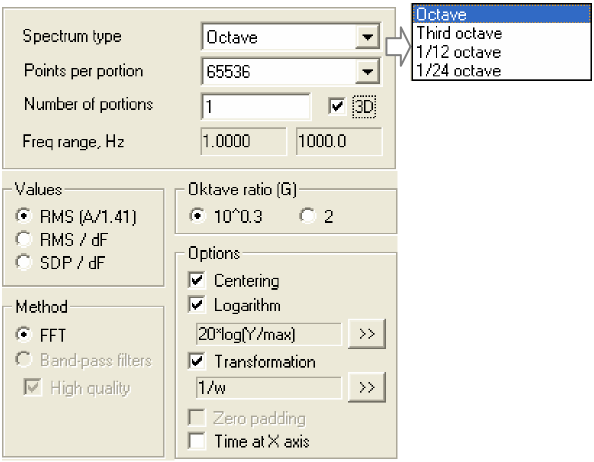


Fig. 9.4. Octave spectrum

Spectrum type – the calculated spectrum type: octave, third-octave, 1/12-octave.

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

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

Spectrum Calculation **Method**: FFT, Band-pass filters.

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.

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.

Centering – elimination of the signal constant component.

Logarithm – the "Taking the logarithm" algorithm will be applied to the result. The >> button opens the logarithm settings window.

Transformation – the “Spectrum Transformation” algorithm will be applied to the result. The >> button opens the algorithm settings window.

Cross spectrum

Spectrum **Type**:

PSD - power spectrum density,

Real & Imaginary - real and imaginary parts of the spectrum,

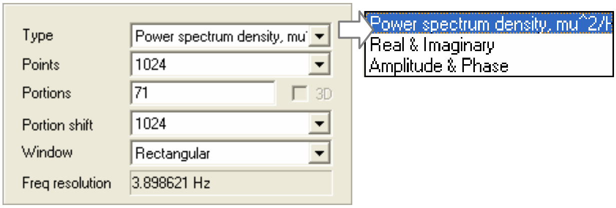


Fig. 9.5. Cross spectrum

Amplitude & Phase - amplitude and phase. Other settings - see Auto spectrum

Complex spectrum

Spectrum **Type** – Real & Imaginary - the real and imaginary parts of the spectrum only.

Other settings - see Auto spectrum

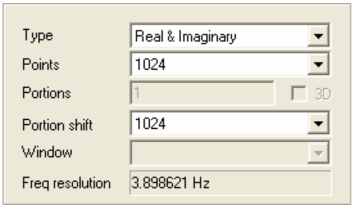


Fig. 9.6. Complex spectrum

Coherence function

Function **Type**:

COHERENCE – coherence function;

INCOHER – non-coherence function;
COP – coherent output power,
INCOP – non-coherent output power,
S/N - signal-to-noise ratio.
Other settings - see Auto spectrum

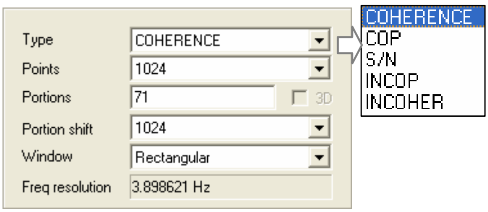


Fig. 9.7. Coherence spectrum

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Transfer function

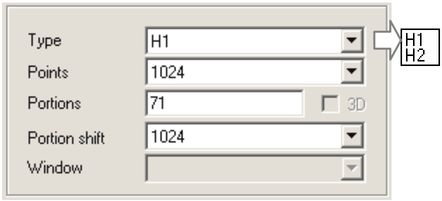


Fig. 9.8. Transfer function

Spectrum **Type**: the function H_1 or the function H_2.

Other settings - see Auto spectrum

Taking the Logarithm

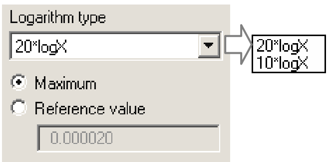


Fig. 9.9. Taking the logarithm

Logarithm: 10*logX or 20*logX coefficient is set.

Maximum/reference value. Selection of reference value (U_{ref}, see Appendix A): the maximum value of the source signal or the value specified in the input field.

Spectrum transformation

Transformation:

1 - none, $\frac{1}{\omega}$ - once, $\frac{1}{\omega^2}$ - double, $\frac{2\sqrt{2}}{\omega^2}$ - switch from the acceleration spectrum to the movement spectrum, $1 \cdot \omega$ - single differentiation, $1 \cdot \omega^2$ - double differentiation.

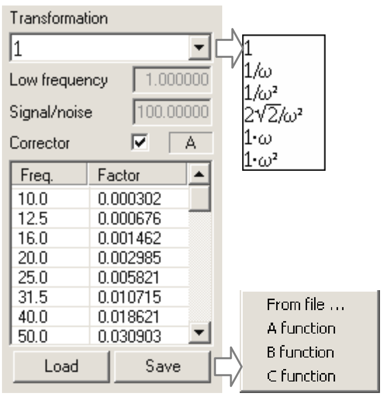


Fig. 9.10. Spectrum transformation

Low frequency and **SNR** – HPF settings.

The spectrum values can be multiplied by the correction function values. The function is set by pairs of figures: a frequency and relevant amplitude multiplication factor.

Mark the **Corrector** checkbox for attaching the correction function.
To put in the frequency and factor values activate the table cell by double click, enter the figure and press the <Enter> key. Use the <Ins> and <Del> keys for inserting and deleting strings.

Press **Save** and select a file in the standard save dialog for saving the entered characteristic to a file.

To load a function from a disk press **Load** button, select the **From file…** menu item and select the file. Press **Load** and select **A, B** or **C function** (see [7] and [8] in the *Appendix B*) for loading frequency (acoustic) characteristics of the third-octave spectrum.

Characteristics are stored in the CSV (Comma-Separated Value) format files. You can open a characteristic file in MS Excel or as a text file.

Hilbert transformation

The operation is executed applying the fast Fourier transform (FFT).

Set the block size (**FFT points**) and the number of blocks (**FFT portions**).

Centering – suppression of source signal constant component.

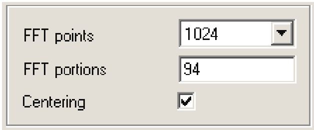


Fig. 9.11. Hilbert transformation

IIR filtering

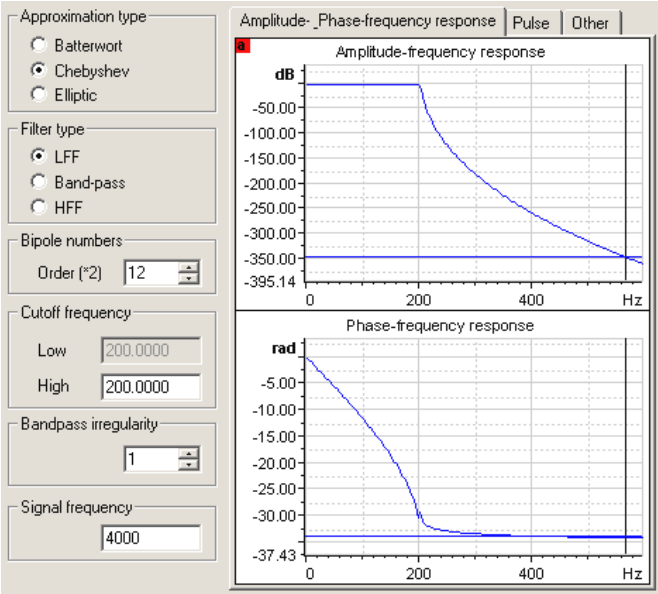


Fig. 9.12. IIR filtering

Approximation type: Butterworth, Chebyshev or elliptic.

Filter type: HPF – high pass filter, Bandpass filter, LPF – low pass filter.

The **bipole numbers** defines the filter order (see *FIR filtering* below).

Cut-off frequency - the filter cut-off frequency by the level of –3 dB. The higher frequency is intended for LPF, the lower - for HPF. Both frequencies are set for the bandpass filter.

Bandpass irregularity - the variation of attenuation in the passband of the filter.

Signal frequency - the input signal sampling rate is set by default.

In the central part of the filter parameter settings window the graphs of amplitude-frequency, phase and impulse (on the *Pulse* tab) filter responses are plotted in respect to the set parameters. The change of the filter or approximation type is immediately represented by the response graphs; after changing the numeric parameters press the **Apply** button for the graph updating.

The following condition should be observed when the parameter setting:

$$2 < \frac{F_s}{F_{co}} < 100$$

, where F_{co} – filter cut-off frequency, F_s - sampling rate.

FIR filtering

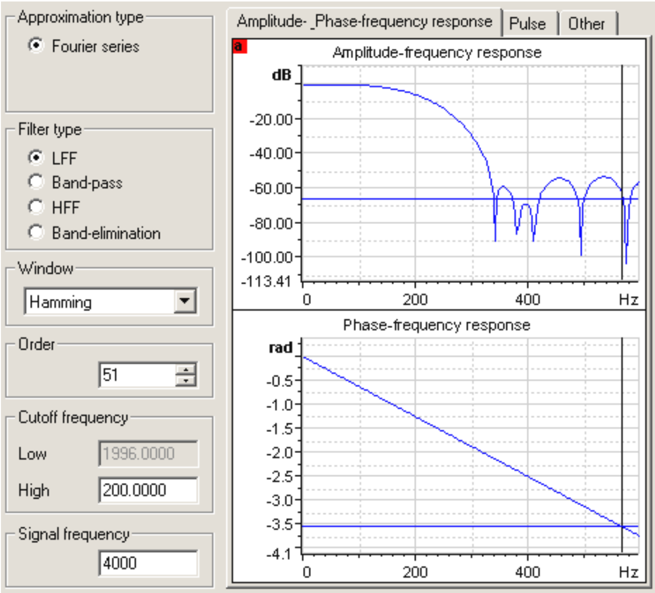


Fig. 9.13. FIR filtering

Approximation type: Fourier series.

Filter type: HPF – high pass filter, bandpass filter, LPF – low pass filter; bandstop filter.

Type of **Window** - to perform Fourier transformations: Hamming or Hann.

The filter **Order** defines the curvature, i.e., the amplitude-frequency response decrease rate at transfer from the passband to the stopband. The higher is the filter order, the more accurate its passband is generated, and, consequently, the less is the number of unwanted components of the input signal is applied to the output.

Cut-off frequency - the filter cut-off frequency by the level of –3 dB. Both frequencies are set for the bandpass and bandstop filters. The high frequency is set for LPF, the low - for HPF.

Signal frequency - the input signal sampling rate is set by default.

In the central part of the filter parameter settings window the graphs of amplitude-frequency, phase and impulse (on the *Pulse* tab) filter responses are plotted in respect to the set parameters. The change of the filter or approximation type is immediately represented by the response graphs; after changing the numeric parameters press the **Apply** button for the graph updating.

Median filtering

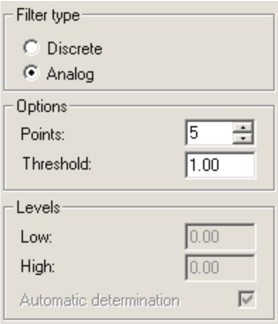


Fig. 9.14. Median filtration

Filter type: discrete or analog.

Number of **Points** - width of filter aperture can be only odd.

Threshold - used for the discrete filter at automated definition of levels, defines the possible value variations within one level; used for analog filter to define the tolerated variation of the signal value from the median, when the current value of signal is not replaced with median value.

High and **Low levels** - the respective signal levels used by discrete filter only.

Auto level definition - automated determination of the top and bottom signal levels in respect to the pre-set threshold.

Envelope

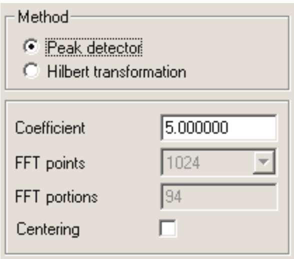


Fig. 9.15. Envelope

Select a method for calculating the envelope in the **Method** frame: either the peak-detector or Hilbert transformation

If the peak-detector method is to be applied select the **Coefficient** (C) determining the "time constant".

If the Hilbert transformation method is to be applied set the block size (**FFT points**) and the number of blocks (**FFT portions**).

Centering – centering of the source signal, removing its constant component.

Derivation

Fig. 9.16 Derivation

Method: 3 and 5 points.

Integration (antiderivative)

Method: Euler, Hanning, RC-chain or as application to the vibration analysis.

Centering – removing source signal constant component**.**

Averaging points number – see *Appendix A*. (for RC series only).

Only for vibration integration:
Transient process – the transient process suppression mode,

Points and **Cut-off frequency** - FFT settings

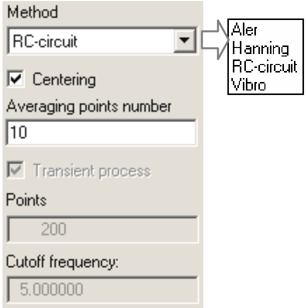


Fig. 9.17. Integration

Normalization

Minimum, maximum – extreme values of the result,

Enable shift – the signal is shifted to fill the pre-set range (the min and max fields set the minimum and maximum values of the new signal).

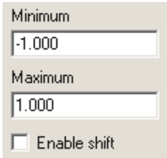


Fig. 9.18

Auto correlation, Cross-correlation

Number of **Points** – sample length

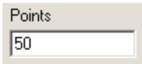


Fig. 9.19

Arithmetic operations

For performance of the elementary arithmetic actions:

- Choose the **Function** field,
- Select the operation from the drop down list,
- enter the number into a **Constant** field at a choice of actions with values of one signal

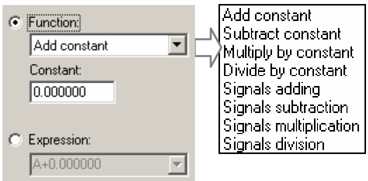


Fig. 9.20. Arithmetic operations

The operations with buffers are performed with pairs of values of the chosen signals.

If the time scales of signals do not coincide, then for each measurement of the first signal the value of the second signal, interpolated at the same time, is taken (linear interpolation).

It is possible to perform the more hard operations with the signal values if to write a expression or formula (it is accessible for the professional and expert versions only)

- Choose the **Function** field,
- Type the arithmetic expression using the VBS syntax (Visual Basic Script) or select the earlier typed expression from the drop down list

An expression can contain numbers, designations of signals, the characters of arithmetic operations (,-, *,/,), parentheses and calls of mathematical functions. For a designation of entrance signals latin letters A (the first signal) and B (the second signal) are used. Besides it is possible to use value of variable I - an index of the next value (0 corresponds to the beginning of the chosen range of an entrance signal).

The formula will be serially applied to all values of the first entrance signal (A). If there is a second signal in the expression (B), then for the each value of the first signal the value of the second signal, corresponding the same time (at absence - it is interpolated) will be taken.

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
```

The list of the mathematical functions:

ABS - the module of number,
ATN - arctangent,
COS - cosine,
EXP - an exhibitor,
LOG - the natural logarithm,
SIN - a sine,
SQR - a square root of number,
TAN – a tangent

Probability density

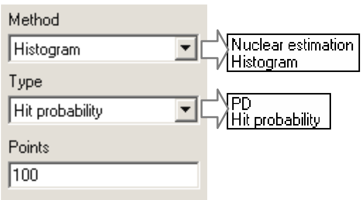


Fig. 9.21. Probability density

Method: histogram or kernel estimation,

Type: hit probability or distribution density.

Number of Points - number of points of the output signal length.

Centering

A suppression of a constant component. No additional settings.

Probabilistic analysis

Estimations of mathematical expectation, dispersion, RMS, skewness, and kurtosis (“peakedness”) are logged.

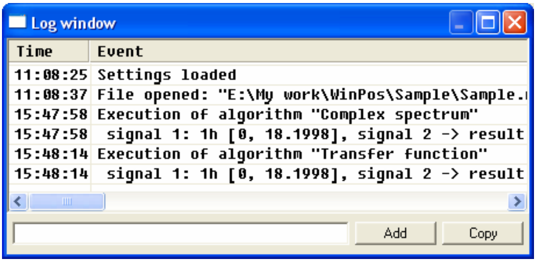


Fig. 9.22. Probabilistic analysis

Resampling

Source signal **Frequency** and **Step** – 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 the 1st-6th order polynomial applying the least-squares method.

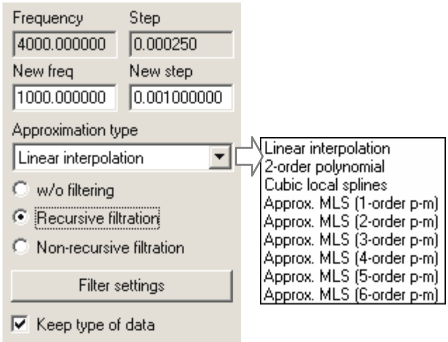


Fig. 9.23. Resampling

The button Filter settings allows assigning of the IIR and FIR parameters, if w/o filtering option is not selected.

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

Parametric graph

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

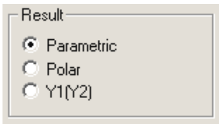


Fig. 9.24

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. Source signals may be of different sampling rate.

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.

Instant spectrum

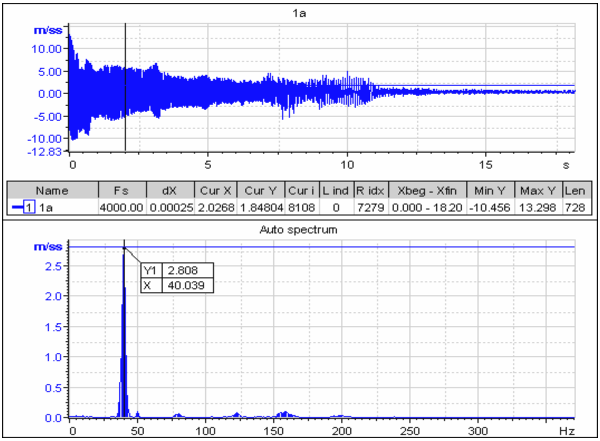


Fig. 9.25. Instant spectrum page

By the menu item **Windows→Instant spectrum** a specialized page for the spectrum calculation "on the fly" can be created (Fig. 9.25).

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 it 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.

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. 9.26).

The following spectrum types: "Real & Imag", "Amp & Phase" are not calculated.

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. 9.27). Open the contextual menu of the Spectrum analysis window. Select the **Algorithm** selection point (Fig. 9.26) and than choose **Density of probability.** Choose the Autospectrum for the return of switching.

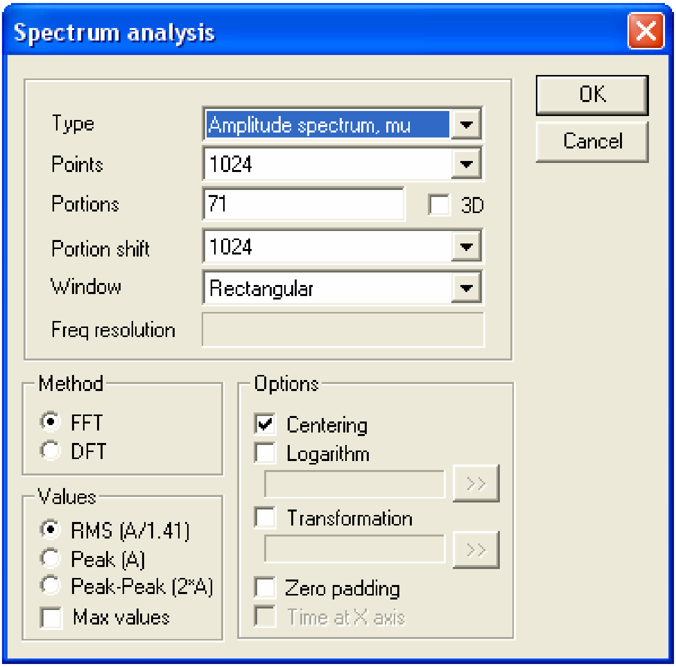


Fig. 9.26. Customization of instant spectrum

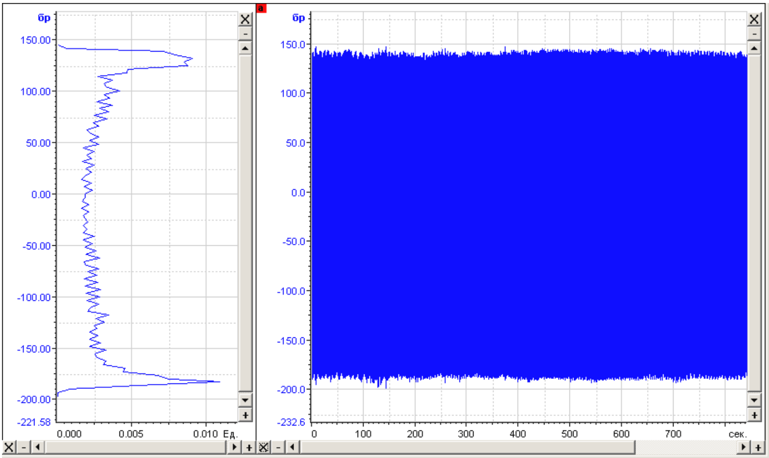


Fig. 9.27 The page of a quick calculation DDP

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. wavelet s 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.

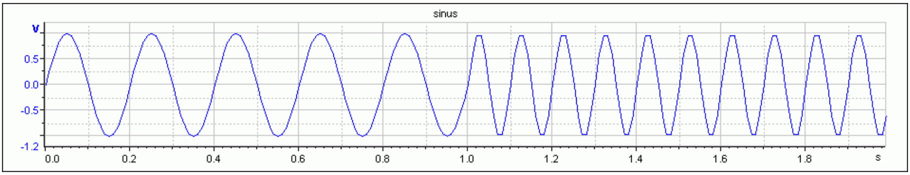


Fig. 9.28 Initial signal

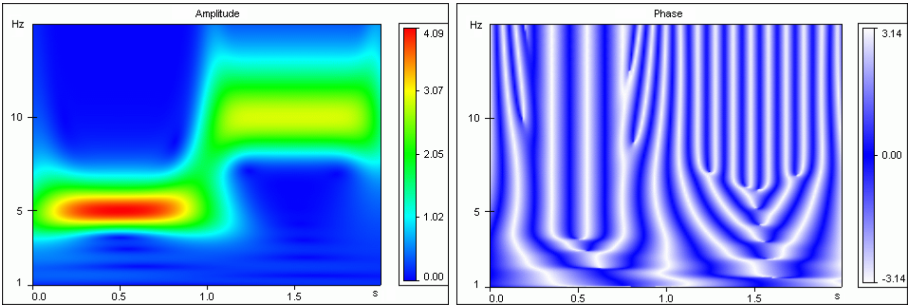


Fig. 9.29 Wavelet - transformation (morlet – wavelet, m = 6)

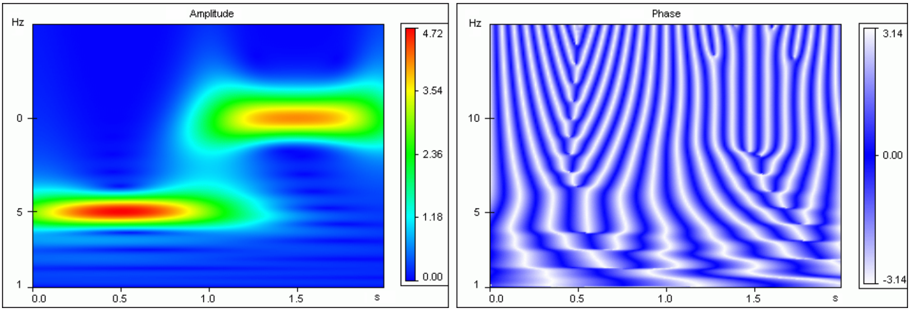


Fig. 9.30 Wavelet- transformation (morlet – wavelet, m = 12)

In the current implementation the algorithm is limited by the wavelet of the type "Morlet".

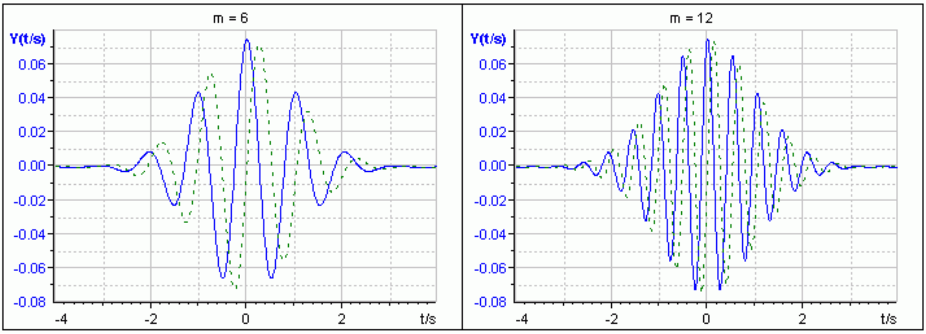


Fig. 9.31 "Morlet" wavelet

Settings

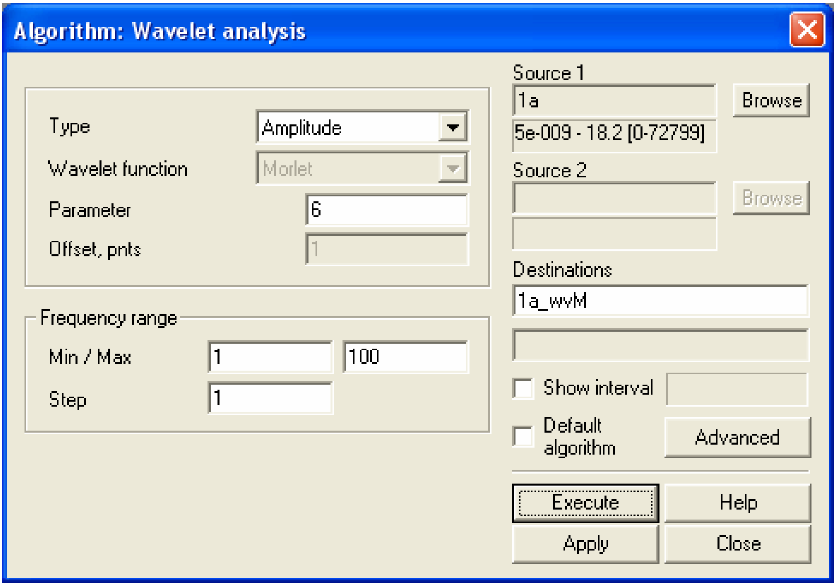


Fig. 9.32 Wavelet settings

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.

Offset of a window - 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.

3D spectrum

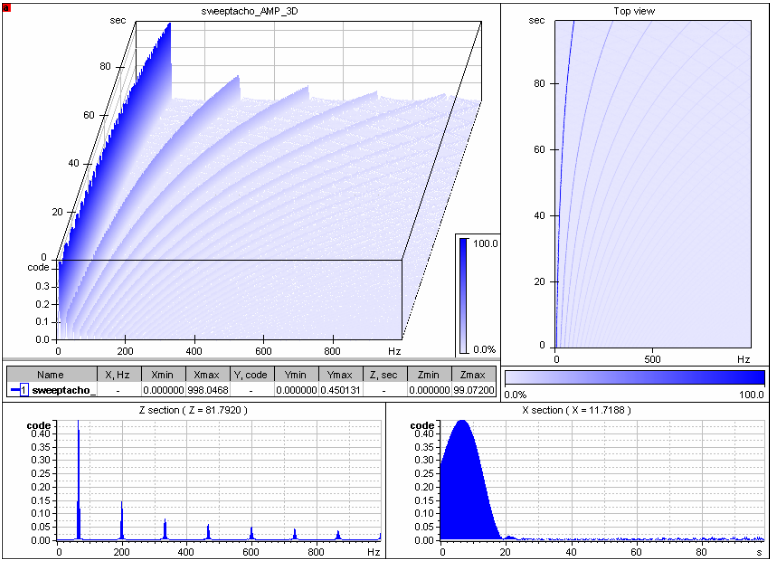


Fig. 9.28 Calculated result of 3D amplitude spectrum

For some signals 3D spectrum provides more informative representation of the measured processes. The spectrums calculated by portions are not averaged in such case but put along the Z axis.

By setting the **3D** flag in the auto spectrum settings (see Fig. 9.1),
3D amplitude spectrum, power spectrum, power density spectrum, and energy density spectrum can be calculated. The *Number of FFT portions* field defines the result size (‘depth’) by Z. The axis Z is digitized in seconds, showing the time of start of the next portion. Similarly the 3D-octave spectrum (see fig. 9.4 and 9.29) is plotted.
In the cursor mode (see Part 6. *Viewing the signals*) the 3D signal projection allows detailed inspection of the spectrum parts. *Z cross-section* is a conventional 2D spectrum calculated by portions with an offset equal to Z (specified above the

graph). *X cross-section* shows the amplitudes as functions of time at a fixed frequency (see X value in the label above the graph).

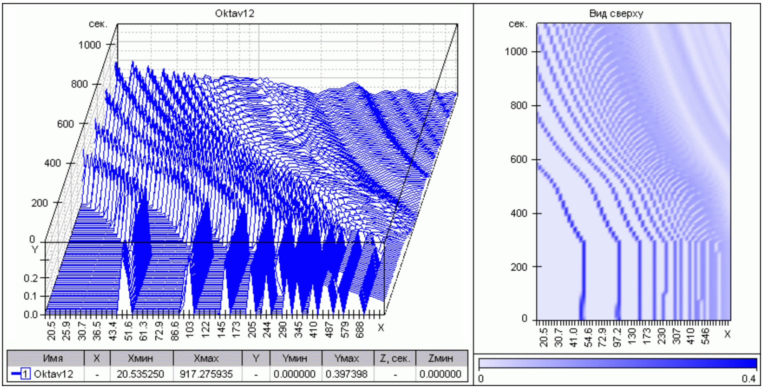


Fig. 9.29 Calculated result of 3D 1/12 -Octave spectrum

Part 10. Analysis of dynamic processes and vibrations

WinPOS allows the analysis of stochastic, dynamic processes, including the vibration ones. The tools from the **Vibration analysis** menu are used in such applications as:

- Multi-channel processing of dynamic processes,
- Estimation of rotor vibration status (on stationary modes),
- Parameter calculations in the start/stopway modes,
- Processing of strain measurement data,
- Processing of audio signals,
- Processing of transient pressure and noises.

The input data file obtained by the measurements contains the signals of different sensors (accelerometers, linear variable differential transformers, proximity probes, microphones, strain sensors, resistance temperature detectors, thermocouples, etc.). The vibration analysis algorithms allow plotting of selected characteristics of these signals as a function of time or study the signal characteristics in association with the tachosignals. Such analysis is applied to 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 report* below).

To access the vibration analysis algorithms select the **Vibration analysis** item of the program main menu (See Fig. 3.3).

The order of processing, obtaining and storing the results is the same as described above for the standard algorithms. Note, the amplitude-phase-frequency response is calculated for the MERA and USML format (*.usm, *.mera) file only.

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.

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 $Y(T_i) = \mathrm{F}([\mathrm{X}]_i)$, 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.

Mathematical expectation (*MV - Mean Value*) is defined by the formula estimating the average of the discrete data set.

$MV_k = \frac{Sum[X]_k}{N}$, where: N – number of points in the selection $[X]_k$

Amplitude. The mean value is found. Then the maximum and the minimum values in respect to the mean value are found, and the greatest absolute value is derived from the obtained maximum and minimum values.

$$A_k = \mathrm{Max}(\mathrm{Abs}(\mathrm{Min}([X]_k - MV), \mathrm{Abs}(\mathrm{Max}([X]_k - MV))$$

Peak-to-Peak value. The minimum and maximum values are found, the peak-to-peak value is calculated by subtraction of the minimum value from the maximum one.

$$P_k = \mathrm{Max}([X]_k) - \mathrm{Min}([X]_k)$$

Root Mean Square value is the signal power characteristic. Calculated according to formula:

$$RMS = \frac{\sqrt{\sum([X]_k - MV)^2}}{N}$$

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 point array by the cosine-sine conversion, corresponding to the resulting signal passing 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-set 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:

$f_i = i \cdot f_T$, where: i - harmonic number (may be fractional);
f_T – tachofrequency;
f_i - central frequency of the filter pass band;

$\Delta f = (F_S \cdot k_{\%})/100 \cdot k_{ENB}$, where: F_S - sampling frequency;
k_{ENB} - 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 formulae of 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.

Sequence processing (trends)

This algorithm allows time representation of the signal instantaneous characteristics. The *Sequence processing* window (Fig. 10.1) is opened by the **Vibration analysis→sequential processing (trends)** menu item.

The window is divided into two parts. 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 has a graph for the results preview. Preview allows interruption of the processing by the <Esc> key in case of evident failure, and taking of the appropriate measures. (This option is important while processing big files, when the calculation time may be of great importance).

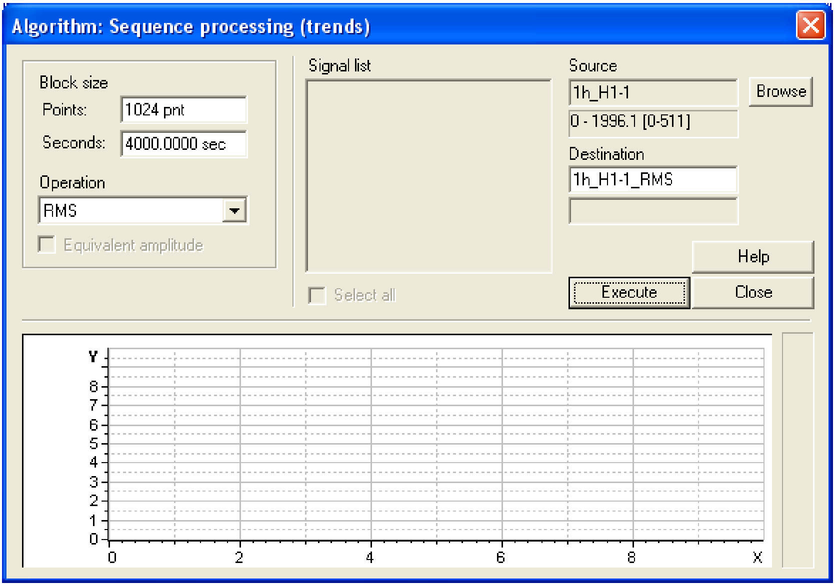


Fig. 10.1. Sequence processing (trends)

The customization of this algorithm includes setting of the calculation parameters, the averaging time and selection of the file/signals for the analysis.

The calculation parameter is entered into the *Operation type* field by selection of the average (mathematical expectation), root mean square (RMS) value, amplitude, peak-to-peak value (double amplitude) from drop-down list of the possible operations.

The averaging time is set in the *Portion size* fields in samples (points) either in second.

Select by the **Browse** button a signal or a folder in the *Select signal* dialog (Fig. 3.5). The signal names and frequencies are shown in the *Signal list*; the signals to be processed are marked by a tick near the signal name. In order to process all signals check the **Select all** checkbox. The resulting file name is shown in the *Destination* field.

Press the **Execute** button to start the processing. The progress can be monitored in the preview window. The resulting signals are displayed as separate graphs for each signal.

Calculation of band RMS value

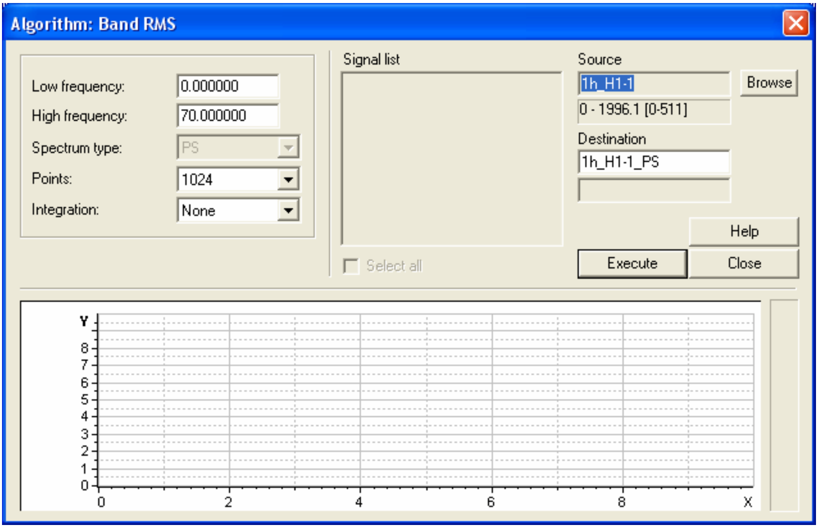


Fig. 10.2. Calculation of band RMS

To perform the time research of the signal power estimation per a pre-set frequency range, select **Vibration analysis→Band RMS** menu item. The *Calculation of band RMS* window (Fig. 10.2) is differentiated from the S*equence processing* window (Fig. 10.1) by the processing options, where the frequency range and FFT parameters are set. In the Top frequency field any negative number can be specified, and the maximal value of frequency will be accepted. as the top border of a frequency range. The *Integration* field allows calculation of vibration acceleration, vibration speed and vibration displacement.

Calculation of amplitude-phase-frequency response

This group of algorithms allows representation of the signal harmonics in time or as a function of frequency. Select the **Vibration analysis→Calculation of amplitude-phase-frequency - response** menu item. The *Calculation of amplitude-phase-frequency response* window (Fig. 10.3) is differentiated from the *Sequence processing* window (Fig. 10.1) by the processing options.

The amplitude-phase-frequency response is calculated for the MERA and USML format files (*.usm, *.mera) only.

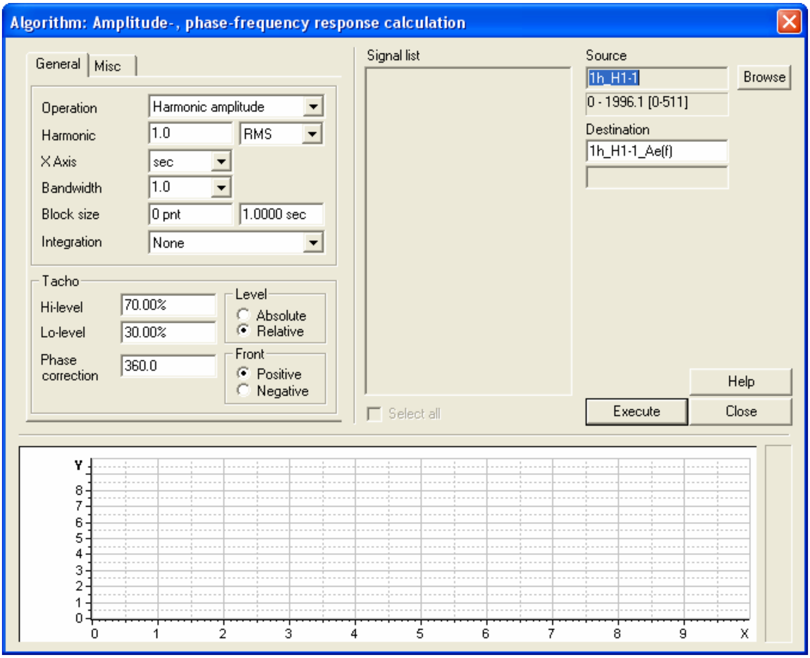


Fig. 10.3. Calculation of amplitude-phase-frequency response

In order to calculate an amplitude-phase-frequency response choose initial signals, having marked them by a tick, set the tachosignal, having pressed the right button of the mouse on the tachosignal's name in the list of signals and having chosen the Tachosignal point from the contextual menu. It is not necessary to mark by the tick itself tachosignal.

ⓘ If frequencies of digitization of the initial signals are differ, then an over-digitization them is carried out to a greater frequency before the calculation. At the same time the additional error is set, depending on a difference between frequencies. On the average, the size of an error is within the limits of 1 %.

Similarly a tachosignal it is possible to set a basic signal. In this case AFC of the initial signals is divided on AFC of the basic signal.

A phase is calculated as the difference of the basis signal and the initial one. The same signal can be simultaneously by the basis signal and by the tachosignal. The influence of the basis signal on the result of the algorithm is shown on the figure 10.4.

The settings are separated into two groups: basic settings and additional, which are on the individual tabs. The settings of the characteristic and the processing of the tachosignal are on the same tab.

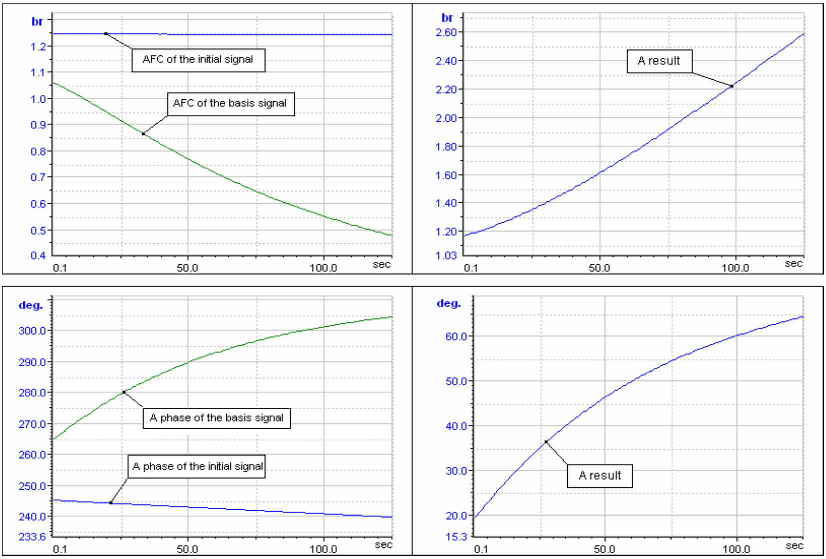
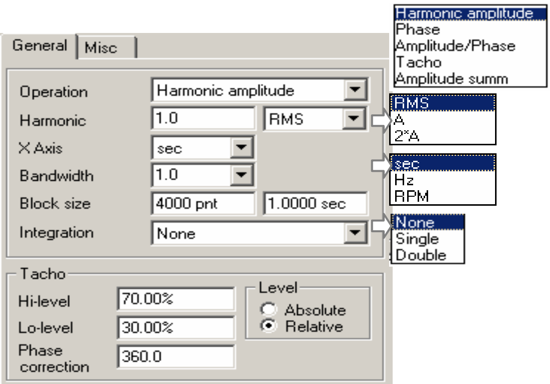


Fig. 10.4. An Influence of a basis signal on a result of a calculation of amplitude-phase-frequency response

The basic settings of the characteristic



Operetion - defines the counted characteristic:

- Amplitude (*Harmonic amplitude*), phase (*Phase*), amplitude and phase (*Amplitude/Phase*) of the selected harmonics;
- Frequency as function of time – tachocharacteristic (*Tacho*);
- Amplitude sum – effective value (RMS), the amplitude or peak-to-peak value of the signal general level (by all harmonics), see below.

Harmonic- 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;

X axis - defines a dimension of the calculated characteristic on axis X (*Hz* - frequency, *sec.* – time, or *RPM* - revolutions) is set.

Bandwidth - the bandwidth of the analyzing filer in Hz. At a change of the bandwidth the values in the *Block size* field are also changed.

Block size - definition of the size of the portion by which the calculation is performed. The size can be set in samples or seconds.

Integration - defines a kind of a transformation with the calculated characteristic in the frequency area:: *none*, *single* and *double* integration.

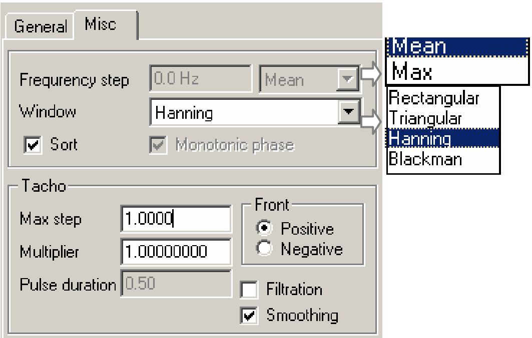
The basic settings Tacho

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.

Level - defines units in which absolute or relative levels (in percentage of the maximal – the peak-to-peak value) are set.

Phase correction - the value from which the phase starts to change.

The additional settings of the characteristic



Frequency step - the step of the frequency change. If some values get in the same range, the resulting value will be taken as either average or maximum (depending upon the mode is chosen in the field on the right). That makes sense only if Hz or RPM are selected in the X axis field.

Window - defines a type of a weight window:: *Rectangular*, *Triangular*, *Hanning*, *Blackman*. The choice of a window influences an effective bandwidth of the analyzing filter.

Sort - the obtained data are sorted by increase of the calculated frequency. The sorting can be demanded in the event that the frequency of the tachosignal changed not monotonously.

Monotonous phase - allows to the phase to change out of the range of 0-360 degrees.

The additional settings Tacho

Front (*Positive* or *Negative*) - defines the tachosignal front, from which the phase will be calculated.

Max. step - The maximum permissible difference between two successive reading. If this value is exceeded, a random peak has occurred. This option is used if *Smoothing* is enabled.

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. Then the rotation frequency of the inspected equipment equals the product of the reduction coefficient and the measured rotation frequency of the secondary shaft.

Pulse duration - the minimum allowable "regular" duration of the tachosignal (in shares from the calculated maximal duration of an impulse of the gauge of turns) for the performance of a time filtration. In some cases the presence of rotor defects leads to that besides a " regular "signal of the gauge of turns the handicaps are imposed on the tachosignal, which deteriorate a normal work of the program processing. The essential difference of these handicaps is them considerably smaller duration. The time filtration removes such signals from the record of the tachosignal, the duration of which less of the value set in the **Pulse duration** field. The time filtering is enabled if only the *Filtering* checkbox is checked. The source signal is filtered, and the result of the filtration is used in calculations.

Filtering - enables a filtering of the source signal throughout width of impulses (see *Pulse duration* above).

Smoothing - an additional amplitude filtering of the tachosignal. 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.

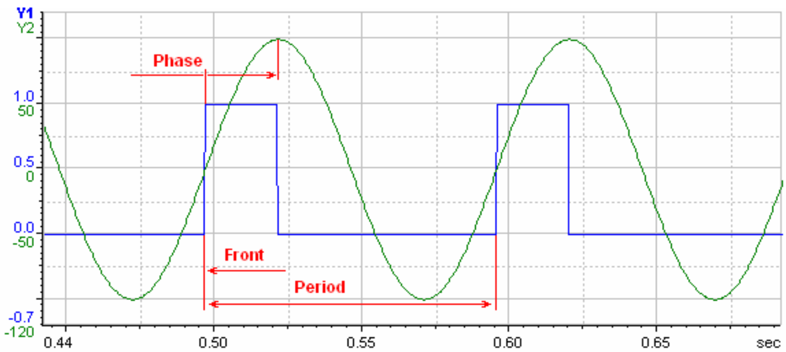


Fig. 10.5. A graphic presentation of peculiarities of the PFC calculation

The calculation is performed by the **Execute** button. At the time of calculations the characteristics are displayed on the preview panel (bottom).

ⓘ Note, if the calculated graph contains negative frequency (time) values that means a failure of the tachosignal. There was no a crossing through a certain threshold or the tachosignal dropped to zero. In this case the settings of the tachosignal analysis should be verified.

Recommendations for an algorithm setting

AFC is calculated by different ways, depending on what is chosen in the Operation field - Amplitude or Amplitude/phase, results can differ a little. Generally, the preference should be given to operations Amplitude/phase even if a calculation of a phase is not required, however sometimes the Amplitude operation can give more correct results.

The size of the block should be chosen such that at the minimum a few full periods are placed into this block on all range of a frequency change. If too small block is chosen, on some areas the algorithm cannot calculate a frequency over the tachosignal. However, it is not necessary to choose too big size of the block, because there will be a loss of the information owing to the averaging a plenty of values.

The levels for calculation tacho are recommended to set in relative units (percent), especially, if the amplitude of the tachosignal essentially changes with time. In this case, absolute values will be calculated separately on each block.

Vibration Report

The algorithm is intended for batch calculation of vibration characteristics and generation of the report by the industrial standards. The list of characteristics calculated by the present algorithm 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 Report* mode the above estimations are calculated separately for each revolution of the rotating equipment parts with the signal interpolation between the samples. The tachosignal is used to divide the whole signal implementation into revolutions.

In the energy industry the table representation (Microsoft Excel, XLS format) of vibration characteristics is used for the static analysis. See Fig. 10.4.

In the aviation industry, as a rule, the processing results have to be represented in text format, e.g., RTF. See Fig. 10.5.

Consequently, two operation modes of the vibration report algorithms are provided:

- Placement of results into the signal tree (*WinPOS mode*);
- Placement of results into the Excel tables (*Excel mode*).

Both modes have the means of switching to another mode with preservation of the calculated parameter settings.

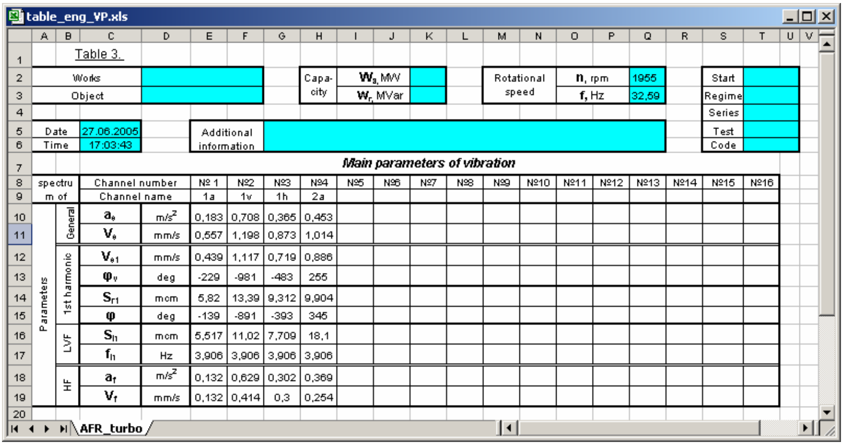

table_eng_VP.xls

Table 3.

Works		Capa-city	W_a, MW		Rotational speed	n, rpm	1955	Start	
Object			W_r, MVar			f, Hz	32,59	Regime	
								Series	
Date	27.06.2005	Additional information						Test	
Time	17:03:43							Code	

Main parameters of vibration

spectrum of		Channel number		№ 1	№2	№3	№4	№5	№6	№7	№8	№9	№10	№11	№12	№13	№14	№15	№16
		Channel name		1a	1v	1h	2a												
Parameters	General	a_e	m/s^2	0,183	0,708	0,365	0,453												
		V_e	mm/s	0,557	1,198	0,873	1,014												
	1st harmonic	V_{e1}	mm/s	0,439	1,117	0,719	0,886												
		φ_v	deg	-229	-981	-483	255												
		S_{r1}	mcm	5,82	13,39	9,312	9,904												
		φ	deg	-139	-891	-393	345												
	LVF	S_{l1}	mcm	5,517	11,02	7,709	18,1												
		f_{l1}	Hz	3,906	3,906	3,906	3,906												
	HF	a_f	m/s^2	0,132	0,629	0,302	0,369												
		V_f	mm/s	0,132	0,414	0,3	0,254												

AFR_turbo

Fig. 10.6. Excel table with the vibration parameters

Object:
Test:
Testbed №:

File: stoping001.usm **Date:** 08.12.2003

Channel	Charact	M1 2.20741 s	M2 5.01022 s	M3 7.55963 s	M4 9.99148 s	M5 13.4378 s
1a	e1	3.29602	1.66669	1.53153	1.69005	0.158795
	e2	13.8817	9.75624	11.3436	20.433	2.00621
	e3(f1)	11.5586	8.20884	9.80571	20.5317	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	3.36018	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	45.0174
	F2(f1)	540	540	540	540	540
1h	e1	1.23365	1.73131	1.87921	0.735065	0.255682
	e2	3.20216	9.92384	4.75192	2.47321	2.67217
	e3(f1)	2.75161	10.306	3.65622	2.46789	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	2.6857
	e3(f1)	15.3499	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	36.6347	25.4769	17.4234	11.3542	7.48363

Fig. 10.7. RTF table with the vibration parameters

WinPOS Mode

When the **Vibration Report** menu item is selected, the settings window is created for the WinPOS mode (Fig. 10.8).

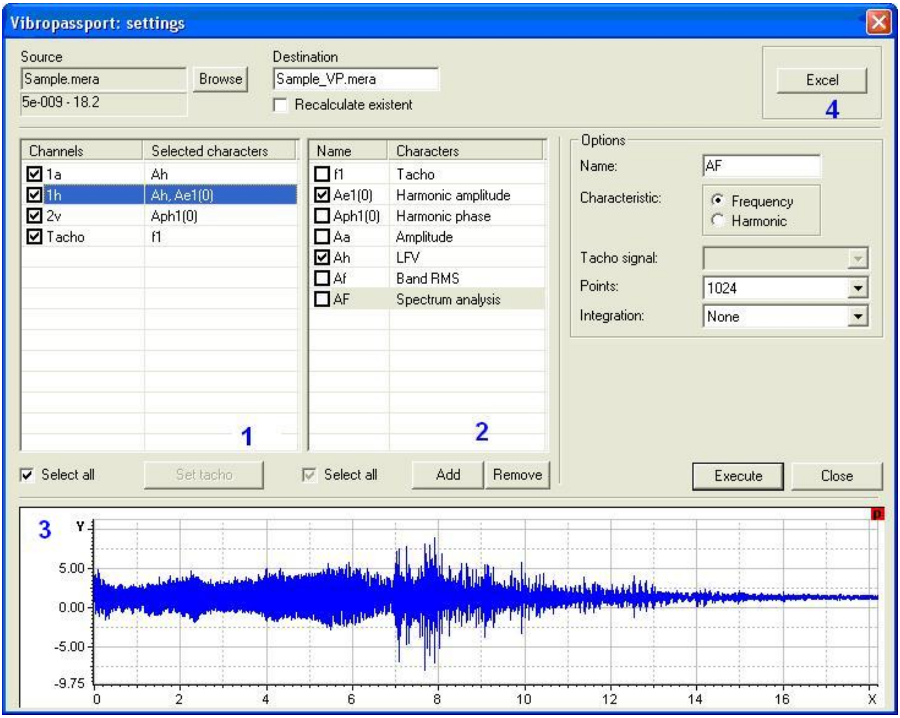
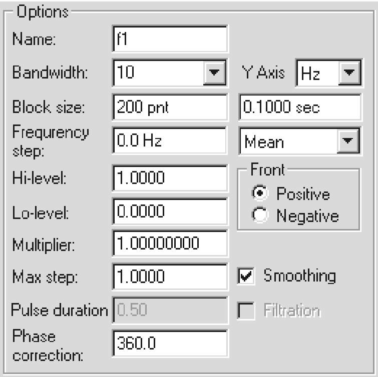


Fig. 10.8 Vibration Report settings window
Where: 1 – list of channels; 2 – list of characteristics (estimations); 3 – calculation progress preview window; 4 – Excel table selection button (switching to the Excel mode); 5 – selected characteristic options.

On the panel (1) all signals (channels) of the selected file are shown. The channels to be processed by the present algorithm must be ticked. 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 (2) 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.

In course of the algorithm execution the panel (3) shows the calculation process of the current characteristic. The calculation can be interrupted at any time by pressing the <ESC> key. Switching to the Excel mode is made by pressing the button (4) selecting an Excel file and a worksheet in it.

Characteristic calculation settings



Tacho

Name - name of characteristic.

Y axis - units of the calculated tachocharacteristic by Y axis: *Hz* or *rev*.

Passband width - the passband width of the analyzing filter in Hz. At a change of the passband width the values in the **Block size** field are changed too.

Block size - the block size (in samples or seconds) by which the calculation is performed.

Frequency step - frequency range step. 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 drop-down list on the right).

Hi level, **Lo level** - positive and negative signal levels used for the signal front detection.

Front - the tachosignal front from which the phase is calculated.

Multiplier - coefficient by which the calculated tachosignal value is multiplied.

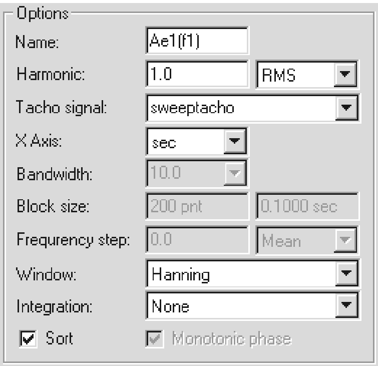
Max.step - maximum tolerable difference of two successive samples. If **Smoothing** is enabled, and the value is exceeded, the random peak is occurred.

Smoothing - peak smoothing enabled.

Pulse duration - maximum tolerable pulse duration (as multiplier of the calculated maximum pulse duration of revolution sensor). Used only if **filtering** is enabled.

Filtering - enables the source signal filtering by the pulse duration.

Phase correction - starting value of the phase



Amplitude and phase of harmonic

Name - name of characteristic.

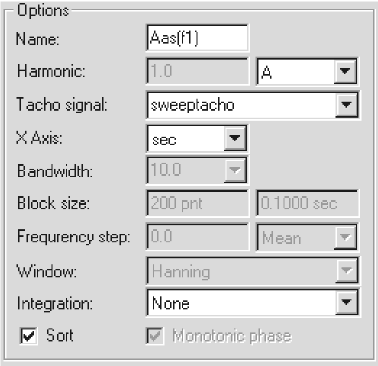
Harmonic - harmonic order (it is required only for amplitude and a phase of a harmonic).

Tachosignal - name of the tachosignal.

X axis - units of the calculated tachocharacteristic by X axis: *Hz* or *rev*.

Passband width - the passband width of the analyzing filter in Hz. This value is set by the tacho settings.

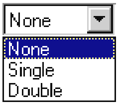
Block size - the block size (in samples or seconds) by which the calculation is performed. This value is set by the tacho settings.



Frequency step - frequency range step. 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 weight window.

Integration - the characteristic conversion type in the frequency domain: *none*, *single* and *double* integration.



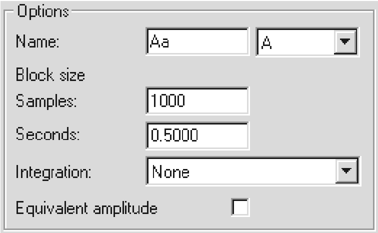
Sort - data sorting by the X axis.

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-peek 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

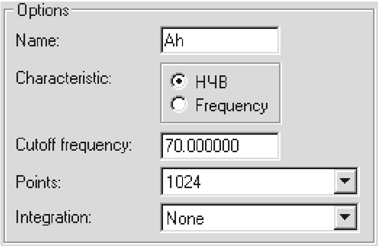


Name - name of characteristic.

Block size - the block size (in samples or seconds) by which the calculation is performed.

Integration - the characteristic conversion type in the frequency domain: *none*, *single* and *double* integration.

LFV



Name - name of characteristic.

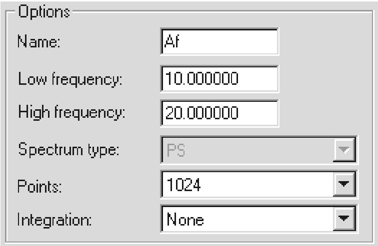
Characteristic type - the calculated characteristic type.

Cutoff frequency - the frequency dividing high and low frequency ranges.

Number of FFT points - the number of points by which the spectrum is calculated.

Integration - the characteristic conversion type in the frequency domain: *none*, *single* and *double* integration.

Band RMS value



Name - name of characteristic.

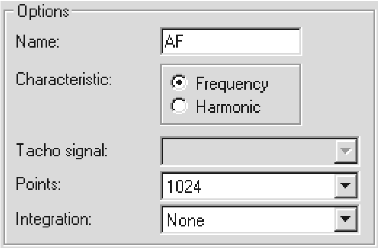
Low frequency – lower limit of the frequency range.

High frequency – higher limit of the frequency range.

Spectrum type – control is disabled. The power spectrum is always calculated.

Number of FFT points – the number of points by which the spectrum is calculated.

Integration – the characteristic conversion type in the frequency domain: *none*, *single* and *double* integration.



Spectrum analysis

Name - name of characteristic.

Characteristic - type of the calculated characteristic.

Tachosignal - name of the source tachosignal.

Number of FFT points - the number of points by which the spectrum is calculated.

Integration – the characteristic conversion type in the frequency domain: *none*, *single* and *double* integration.

After finishing calculations the result window (Fig. 10.9) is opened automatically. Besides, all calculation results are placed as signals into the signal tree to the branch called by the processed file name with addition of the suffix «_VR».

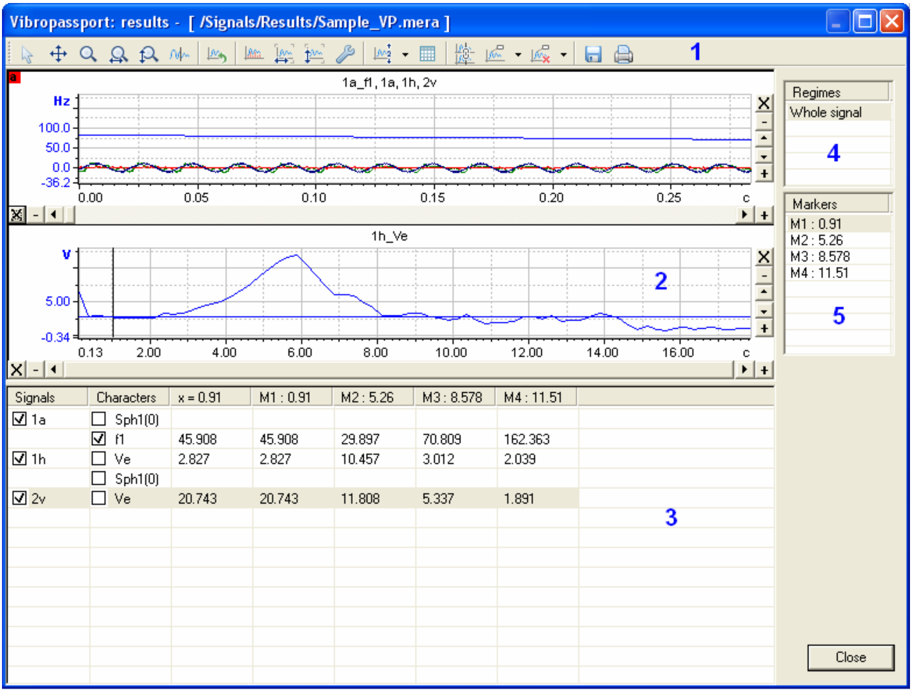


Fig. 10.9. Results of vibration report calculations
Where: 1 – toolbar; 2 – characteristic graphs; 3 – characteristic table; 4 – list of modes; 5 – list of marks.

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. The first view is shown in Fig. 10.7. 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 (see *Auxiliary signal information and parameter status* section of *Part 6. Signal viewing*), the modes will be listed in the window (4), otherwise, the list has one line only: "Whole signal". 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 marks outside this range are not shown. At the selection of the mark the cursor of all graphs shall be moved to the mark, and the X axis range of the graph is changed when necessary to display the selected mark. The marks are added or removed by the toolbar 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	Ae1(f1)	Aph1(f1)	Aa	Af	AF
ph=00sweep-sinus		70.693	449.591	144.034		
sweeptacho	12.932					
ph=60sweep-sinus		70.733	389.376		67.120	13.672

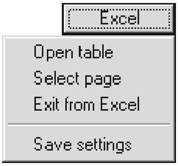
In this view the source channels are shown in columns, and the characteristics set in the Vibration Report settings window are shown in rows. The table cells contain the characteristic values calculated by the respective channels, at the position of selected mark or cursor in the active graph (if this 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.

If the source signals contain signal modes, the modes will be listed in the window (4), otherwise, the list has one line only: "Whole signal". 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 marks outside this range are not shown. At the selection of the mark the cursor of all graphs shall be moved to the mark, and the X axis range of the graph is changed when necessary to display the selected mark. The marks are added and removed by the  and  buttons on the toolbar.

In order to obtain the final report in RTF format file (an example is shown in Fig. 10.5), the markers should be set while viewing of the calculation results (see Fig. 10.7).

After the table formatting is completed, the report can be saved in an RTF format file. Press 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 Report allows calculation of vibration parameters by the pre-set templates and storing the results to the Excel file.

This option is accessible by the **Excel** button at the right top corner of the Vibration Report settings window. When this button is pressed, the drop-down menu is shown. 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. 10.10). Select the page containing the required template and press **OK**.

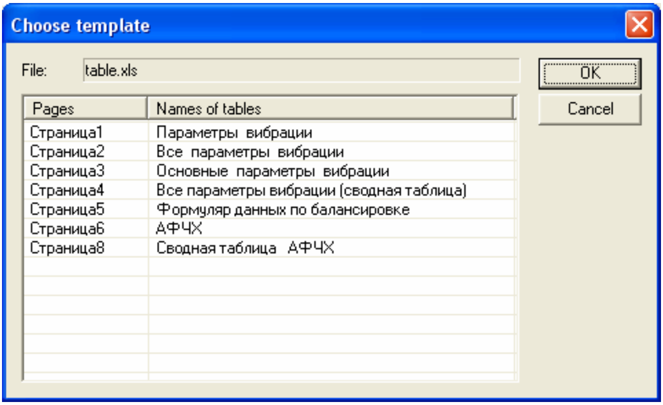


Fig. 10.10. Page selection window

Attention! The selected table is only a template to generate the report. 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 found 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 by 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.

The calculation progress is displayed on the graph in the lower part of the Vibration Report settings window (see Fig 10.8). After the calculation is completed, the generated table is automatically opened by Microsoft Excel (if installed).

Sample templates (Excel tables):

1.

Table 1.

Works		Capacity	W_a, MW		Rotational speed	n, rpm	
Object			W_r, MVar			f, Hz	

Start	
Regime	
Series	
Test	
Code	

Date		Additional information	
Time			

Parameters of vibration

Channel number		№1	№2	№3	№4	№5	№6	№7	№8	№9	№10	№11	№12	№13	№14	№15	№16
Channel name																	
V_e	mm/s																
S_{r1}	mcm																
φ	deg																

2.

Table 8+.

AFC (summary table)

Works		***Regime***	
Object		***№***	
Date			

Main parameters of vibration

№	***Time***	**Section number**		**№ 1**						**№ 2**						**№ 3**					
		Channel name		**1v**		**1h**		**1a**		**2v**		**2h**		**2a**		**3v**		**3h**		**3a**	
		n	**f**	**S**	**φ**	**S**	**φ**	**S**	**φ**	**S**	**φ**	**S**	**φ**	**S**	**φ**	**S**	**φ**	**S**	**φ**	**S**	**φ**
		rpm	Hz	mcm	deg	mcm	deg	mcm	deg	mcm	deg	mcm	deg	mcm	deg	mcm	deg	mcm	deg	mcm	deg

3.

Table 3.

Works		Capa-city	W_a, MW	Rotational speed	n, rpm
Object			W_r, MVar		f, Hz
Date		Additional information			
Time					

Start	
Regime	
Series	
Test	
Code	

Main parameters of vibration

spectrum of		Channel number		№ 1	№2	№3	№4	№5	№6	№7	№8	№9	№10	№11	№12	№13	№14	№15	№16
		Channel name																	
Parameters	General	a_e	m/s²																
		V_e	mm/s																
	1st harmonic	V_{e1}	mm/s																
		φ_V	deg																
		S_{r1}	mcm																
		φ	deg																
	LVF	S_h	mcm																
		f_h	Hz																
	HF	a_f	m/s²																
		V_f	mm/s																

4.

Table 5.

Form B2

Balancing logbook

Power station					
Turbounit					
Date					
Time					
Start, №					
Regime					
Correction weight	removed/installed				
	№ plane				
	Marking				
	Weight, gram				
	Angle, deg				
Additional information					

№ bearing	Channel number	Parameters of vibration			
bearing № 1	1v	S_{r1}, mcm			
		φ, deg			
	1h	S_{r1}, mcm			
		φ, deg			
	1a	S_{r1}, mcm			
		φ, deg			
bearing № 2	2v	S_{r1}, mcm			
		φ, deg			
	2h	S_{r1}, mcm			
		φ, deg			
	2a	S_{r1}, mcm			
		φ, deg			
bearing № 3	3v	S_{r1}, mcm			
		φ, deg			
	3h	S_{r1}, mcm			
		φ, deg			
	3a	S_{r1}, mcm			
		φ, deg			

Campbell diagram

Campbell diagram is applied to the analysis of dynamic processes, mainly, in the transient modes.

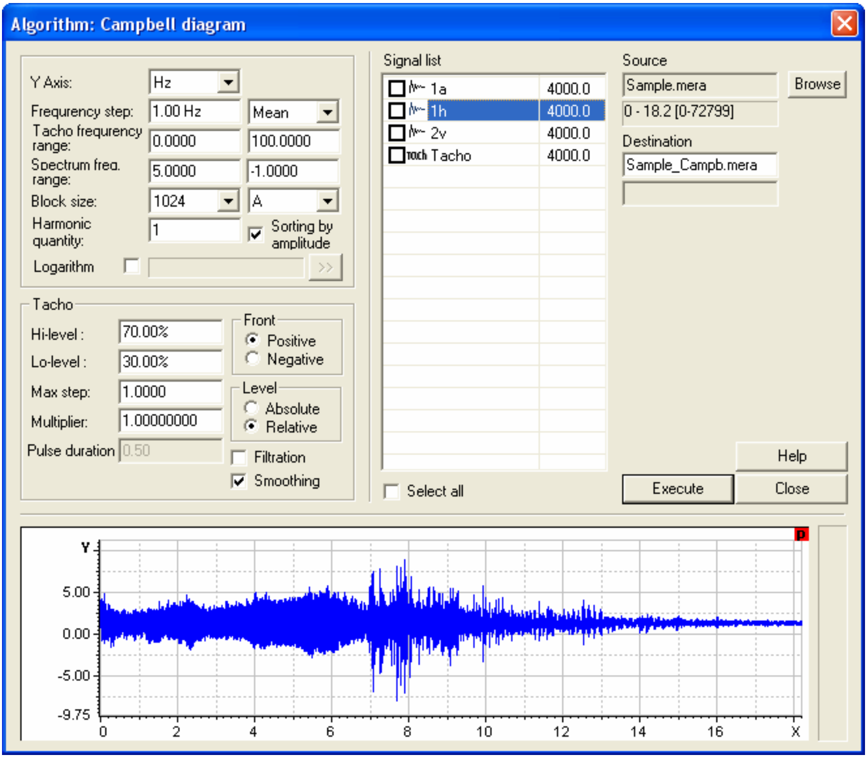


Fig. 10.11. Settings window of Campbell diagram calculations

In order to perform the calculations the tachosignal must be set by pressing the signal name in the list of signals with the right mouse button, and by selection of the **Tachosignal** item in the context menu. The tachocharacteristic describing the change of the rotation rate as a function of the test time is calculated by this signal. For each value of the obtained characteristic being within the specified *tachofrequency range* the amplitude spectrum is plotted by the respective data block of selected signals. More details on the intermediate spectrum calculation method are provided in the section *Order analysis*.

The peaks (maxima) are searched in the frequency spectrum specified in the settings. Such peaks are sorted by the amplitude or frequency, accordingly to the settings. The Figure shows the maximum values to be selected from the one spectrum when being sorted by the frequency (upper graph) and by the amplitude (lower graph).

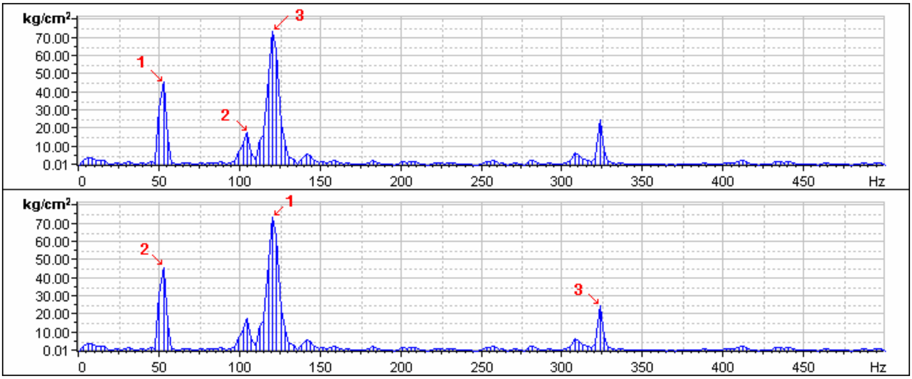


Fig. 10.12. Options of the spectrum peaks selection

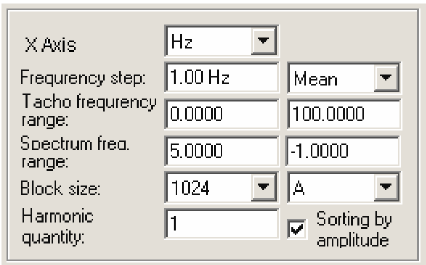
If several values of tachocharacteristic are found in the same range (defined by the pre-set frequency step), either average or maximum peak values are selected, depending upon the method specified in the settings (to the right from the “Frequency step” field). This may happen if a large frequency step is selected, or at this interval the frequency was changed slowly, or the frequency change was not monotonous.

Tachofrequency, spectrum peak frequency, amplitude (RMS or peak-to-peak value) and the order (the spectrum peak frequency to the tachofrequency ratio) for each peak are stored in a separate signal (in *Results* folder). After calculation is completed the window containing the results represented by a table or a diagram is displayed.

ⓘ Only the signals with the sampling rate matching the sampling rate of tacho signal are included into the calculations.

Settings

The settings are divided into two groups: the algorithm settings and tachocharacteristic settings. The tachocharacteristic settings are described above, in the *Vibration Report* section.



X Axis - the size by X axis (tachofrequency range): in *Hz* or *rev*.

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 .

Spectrum frequency range - the minimum and the maximum values of the frequencies where the spectrum maximum values are searched. If a negative value is specified as the maximum value, (e.g., "-1"), the maximum frequency value is set automatically.

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.

Harmonic quantity - the number of peaks in the spectrum for plotting the diagram.

Sorting by amplitude - if this option is selected, the peaks found in the spectrum are sorted by the amplitude, otherwise - be frequency.

Result window

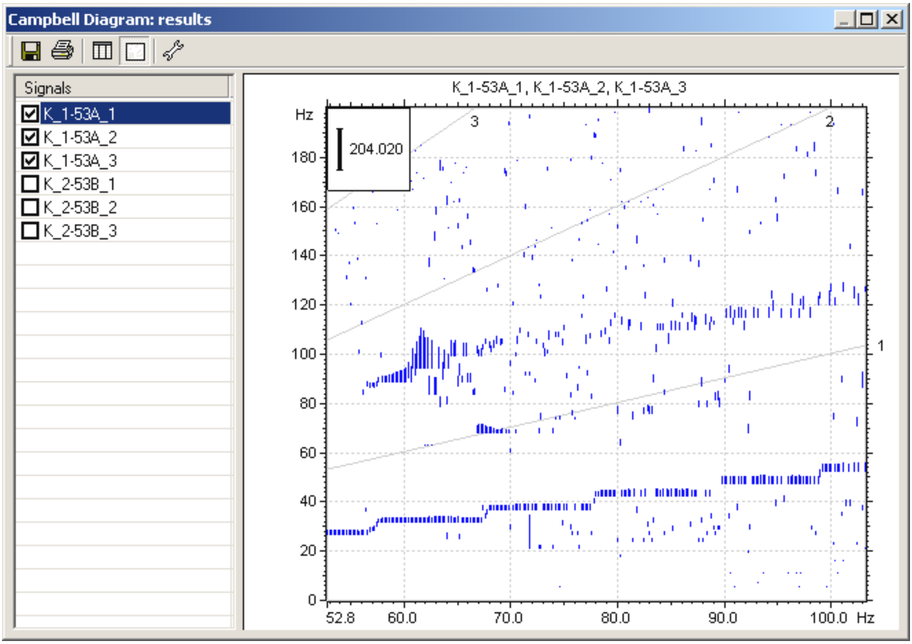


Fig. 10.13. Campbell diagram window

All calculated signals are contained in the list in the left part of the window. Their names consist of the source signal name and the number of maximum, e.g. "Test_2". The calculation results can be viewed as table or diagram. The views are switched by the  and  toolbar buttons.

The table represents only one signal which is selected from the list. The first column of the table contains the tachofrequency values,

Tacho frequency (f), Hz	Frequency (f), Hz	Order (K)	Amplitude (A)
100.6	10.4167	0.1035	4.2026
100.2	22.5694	0.2252	16.5146
100.4	15.6250	0.1556	5.1209
100.0	52.0833	0.5208	39.7405
99.8	52.0833	0.5219	41.2057
99.6	5.2083	0.0523	5.4201
99.4	52.0833	0.5240	37.9457
99.2	52.0833	0.5250	37.9738

Fig. 10.14. Calculated results in table

the second - the spectrum peak frequency, the third – the order of harmonics (the maximum frequency divided by the tachofrequency), the fourth - the spectrum value at a given point. For all columns except the first one, the rounding can be tuned in the settings window opened by the toolbar button. The toolbar button saves the selected signals in a text file or a Microsoft Excel file.

The diagram shows the spectrum peak frequencies as a function of the tachofrequency. The signals with the selected names in the list are displayed in the diagram. All signals obtained in one channel are represented by the same color in the diagram.

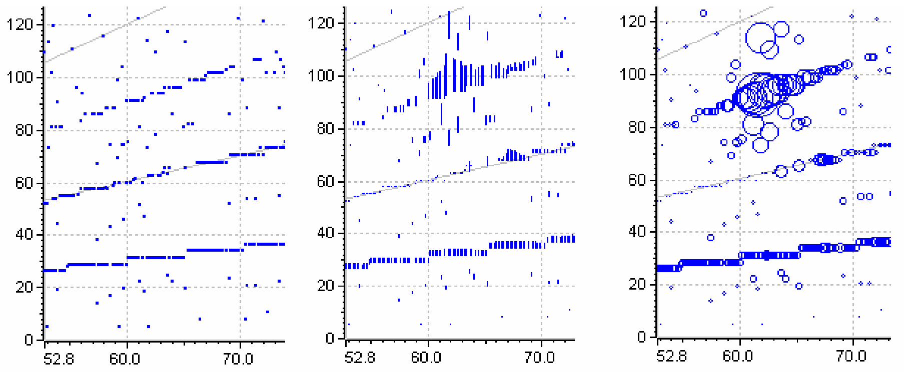
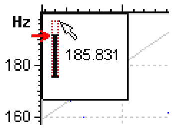


Fig. 10.15. Views of Campbell diagram

The points on the diagram are shown by the markers. The marker has shape of either dot, or vertical line, or circle. The line heights and circle diameters depend upon the signal values (RMS, amplitude or peak-to-peak value) at a given point. This dependence is set by the "Zoom" control group (see Fig. 10.16). If the option "value in %" is selected, then the maximum value among all signals is equal to 100%.



The zoom can be changed by dragging the zoom scale box top with the mouse.

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.

By pressing the  toolbar button the diagram is printed out.

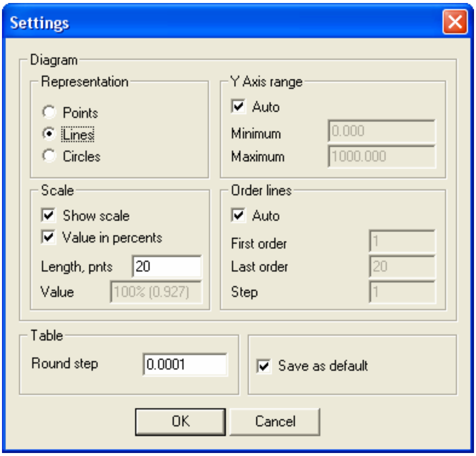


Fig. 10.16. Campbell diagram settings

Representation - the shape of the markers to be displayed - dots, vertical lines, or circles.

Scale - dependence of the signal value and the size of its marker on the diagram. The size is set in pixels, the signal value - in the absolute units or in percents. If the markers are displayed by dots, this control group is disabled and the size of the marker is 2 × 2 pixels.

Y Axis range - enable or disable automatic Y range detection; if detection is disabled, the range is set manually.

Order lines – this control group sets the step of the order line representation and their first and last number. If automatic setting is enabled then first order is assigned to 1, the last order is detected automatically, and the step (order increment) is 1. Otherwise the settings are assigned manually.

Rounding - setting of the rounding precision for values in all table columns, except the first column.

Save as default settings - if this option is checked, all changes of settings are saved in the file WinPOS.cfg and will be used at next session.

Order analysis

The order analysis is applied to the dynamic processes, mainly in transient modes, such as run up and run down. A 3D signal is the result of calculations, where the spectrum frequency or the harmonic order is put by the X axis, the tachofrequency or time - by the Z axis, and amplitude, peak-to-peak value or RMS - by the Y axis. For calculations the source tachosignal must be set, by clicking the tachosignal name in the list of signals with the right mouse button and selecting the **Tachosignal** context menu item. Tachocharacteristic is calculated by this signal. If frequency (in Hz or RPM) is specified in the settings of Z axis, the frequency range specified in the settings (the **Tachofrequency range** field) is selected for the characteristic. If seconds are selected at the Z axis, further calculations is performed over the whole frequency range, i.e., with the whole signal.

ⓘ Only the signals with the sampling rate matching the sampling rate of tachosignal are included in the calculations.

For each tachocharacteristic value within the above range a respective data block is selected from the source signal.

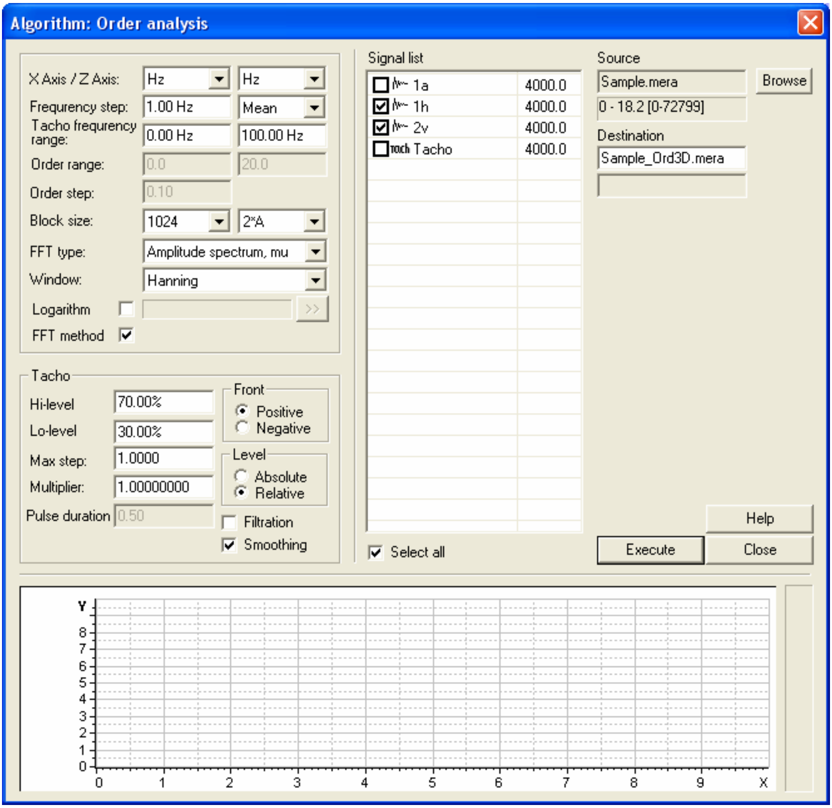


Fig. 10.17. Order analysis settings window

For example: the value of tachocharacteristic is calculated by the block with the size of 1024 samples, starting at the 10th second. Then, the block of 1024 samples starting from the 10th second of recording session is taken from the source signal from the sensor. The spectrum with the selected settings is calculated by this block and then stored in the resulting signal as a current cross-section by the Z axis. If the orders are selected in the settings of the X axis, the frequencies of the spectrum are divided by the frequency of the tachocharacteristic, at which the spectrum is obtained.

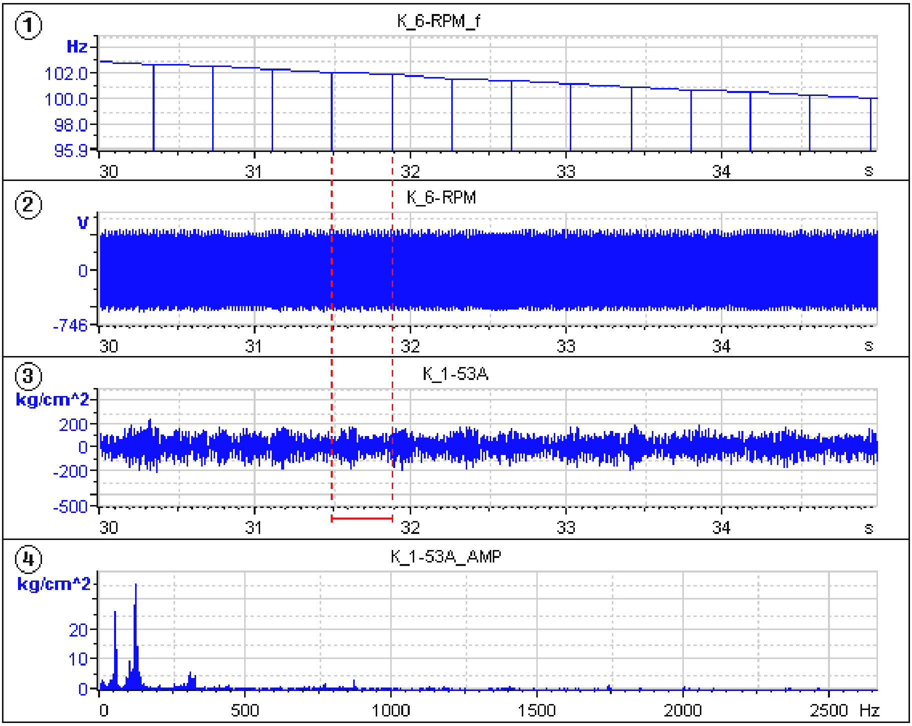


Fig. 10.18. Range selection for spectrum calculation

1 - Tachocharacteristic;
2 - Source signal from the tachometer (tachosignal);
3 - Source signal from the sensor;
4 - Spectrum of the selected block of sensor signal.

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.

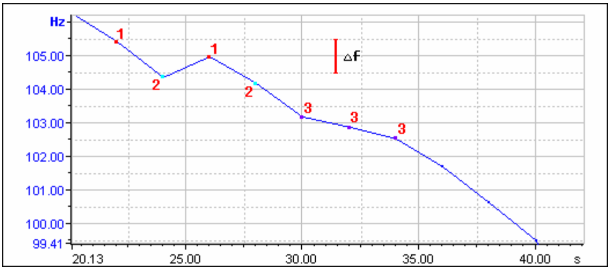


Fig. 10.19

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. 10.20 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.

After calculations the result is represented by a 3D graph.

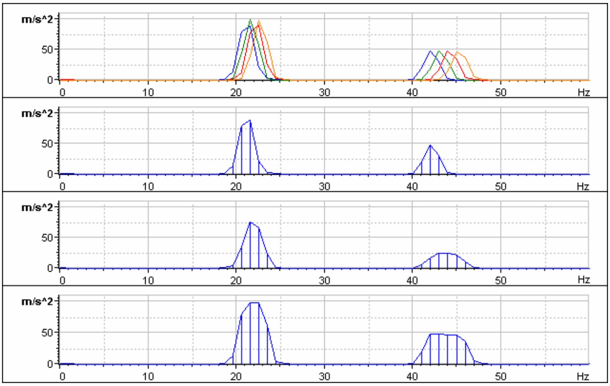


Fig. 10.20

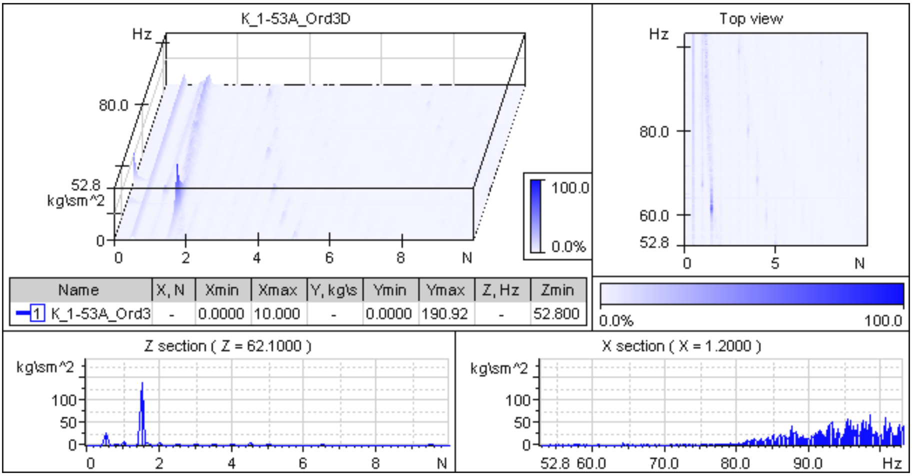
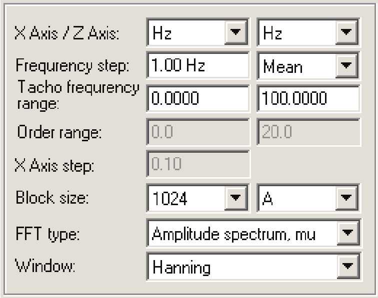


Fig. 10.21. Viewing the order analysis results as 3D graph

Settings

The settings are divided into two groups: the algorithm settings and the tachocharacteristic settings. The tachocharacteristic settings are described in the *Vibration Report* section.



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 - the step of the tachofrequency increment. The kinds of method of spectrum calculation are selected from the drop-down list to the right of the **Frequency step** field. The methods are described above. **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.

FFT type - the spectrum type.

Window type – the type of the weight window used for the spectrum calculations.

Part 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.

The script editor (Fig. 11.1) is opened by the **Script→Script editor…** menu item.

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.

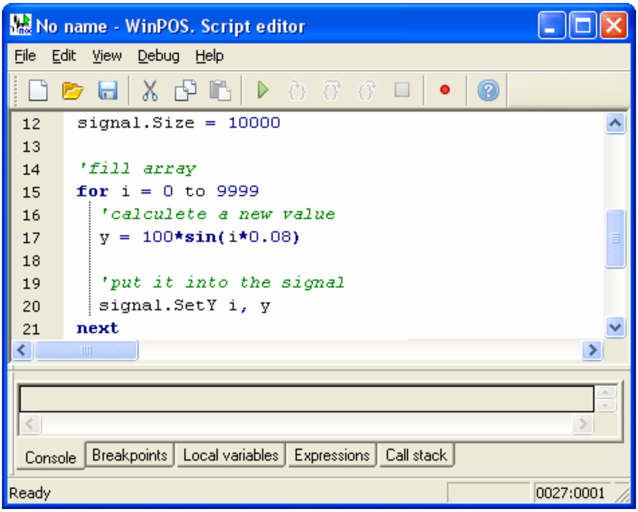


Fig. 11.1. Script editor

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. Processing algorithms

Introduction

In order to avoid any possible methodological discrepancies, this section contains the formulas and short explanations, in accordance with which the data processing algorithms are executed.

The WinPOS package allows you to perform data processing of the following types: spectrum analysis, correlation analysis, filtering, envelope calculation, integration, differentiation, and to calculate estimates of the following characteristics: probability frequency distribution, mathematical expectation (mean value), dispersion (variance), root mean square error, skewness and kurtosis.

The frequency analysis is based on the Fourier transformation. The determining expressions for the Fourier transformation of the input sequence *{x(n)} n=0,..,N-1* are:

$$G(k)=\frac{1}{N}\cdot\sum_{n=0}^{N-1}x(n)\cdot\exp\left\{-j\cdot\frac{2\pi kn}{N}\right\}$$, for the forward transformation,

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

The calculation procedure for the discrete Fourier transformation (DFT) is the fast Fourier transformation (FFT) algorithm. The discussion of the specific algorithm, which is built into the WinPOS package, is given below.

In most practical cases the *x(n)* values are real, and the FFT algorithm is designed for complex numbers. In order to eliminate this redundancy and load the imaginary part of the input data, the input stream is divided into two sequences, in the following way: the odd numbered points represent one sequence, while the even numbered points represent the other sequence. Then, one of these sequences will represent the real part, and the other will represent the imaginary part of the input array for the FFT algorithm.

Thus, given the *{x(n)}, n=0,..,N-1* input sequence and denoting $W=\exp\left\{-j\frac{2\pi}{N}\right\}, f(l)=x(2l), h(l)=x(2l+1)$, we have the following separation result :

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

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

Which gives us:

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

Then we form the input array: *Z(k) =f(k) + ih(k)*, where *k=0,1,..., N/2-1*, and apply the FFT time thinning algorithm, with the substitution of the base equal to 2, with the binary-inverse input data order.

Applying the separation formulas to the Fourier transformation *{Z(k)}*, we obtain the following two transformations: *{Fk }* and *{Hk },*

Re(F(k))=0.5·(ReZ(k) + ReZ(N/2-k))
Im(F(k))=0.5·(ImZ(k) - ImZ(N/2-k))
Re(H(k))=0.5·(ImZ(k) + ImZ(N/2-k))
Im(H(k))=0.5·(ReZ(k) - ReZ(N/2-k)), where *k=1,..., N/2-1.*

The *{G(N/2-k)}* transformation is calculated according to the following formulas:

ReG(0)=ReZ(0)+ImZ(0)
ImG(0)=0
ReG(N/2)=ReZ(0)-ImZ(0)
ImF(N/2)=0

Some specific comments regarding the use of the FFT algorithm will be presented in the description of the characteristics calculation algorithms description, and in Appendix B *Recommendations to the processing algorithm application.*

Spectrum analysis

Within the scope of the spectrum analysis the following characteristics estimates are calculated:

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

In order to decrease the undesired effects caused by the finiteness of observation intervals, you may use weighting functions. The WinPOS package contains the following weighting functions:

- the rectangular function (no weighting function);
- the Henning function:
  W(n)=0.5·(1-cos(2πn/N)), n=0,...,N-1;
- the Blackman-Harris function:

$W(n)=A_0-A_1cos(2\pi n/N)+A_2cos(2\cdot 2\pi n/N)-A_3cos(3\cdot 2\pi n/N),\ n=0,...,N-1,$

where N is the number of discrete points within the process being weighted, $A_0=0.35873;\ A_1=0.48829;\ A_2=0.14128;\ A_3=0.01168$;

- the triangular function:

$$W(n)=\begin{cases}2\cdot n/N,\ for: n=0,1,...,N/2; \\ W(N-n),\ for: n=N/2+1,...,N-1\end{cases}$$

- the Flat Top function:

$W(n)=1-A_0\cdot cos(2\pi n/N)+A_1\cdot cos(2\cdot 2\pi n/N)-A_2\cdot cos(3\cdot 2\pi n/N)+A_3\cdot cos(4\cdot 2\pi n/N),$
$n=0,...,N-1,\ A_0=1.93;\ A_1=1.29;\ A_2=0.388;\ A_3=0.0322;$

More details about the choice of the weighting function for use are presented in Appendix B *Recommendations to the processing algorithm application.*

The spectrum

The discrete Fourier transformation for the $\{x(n),n=0,...N-1\}$ process sample is given by the following formula $\{x(n),n=0,...N-1\}$:

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

Based on the discrete Fourier transformation $F(k)$, a set of characteristics is determined. The type of a characteristic and a set of parameters for its determination are specified from the left part of the algorithm configuration window of the ***WinPOS*** program, while some of the parameters are set automatically. The "realization" term corresponds to the "portions" term in the WinPOS package.

The power spectrum

This characteristic is determined by averaging over M realizations and is measured in *squared units*:

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

When calculating the one-sided power spectrum (the one implemented in the WinPOS package), with the use if weighting windows, we have to introduce the following correcting factors:

$G'_{PS}(k)=2\cdot K_n\cdot G_{PS}(k)/K_{cpgf}$, where 2 shows that we are calculating the one-sided power spectrum,

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

K_{cpgf} is the coherent power gain factor (equal to the coherent gain factor squared) depending on the weighting function chosen, which is determined from the table (see Appendix B *Recommendations to the processing algorithm application*), and is automatically accounted for in the WinPOS package.

The power spectral density

This characteristic is determined as the average over *M* realizations and is measured in *squared units/Hz*:

$$G_{PSD}(k) = \frac{1}{\Delta f} \cdot G_{PS}(k)$$

For the one-sided power spectral density, when the weighting functions are used, the formula looks as follows:

$$G'_{PSD}(k) = \frac{G'_{PS}(k)}{\Delta f \cdot \beta},$$

where β is the equivalent noise band, the correction factor associated with the use of weighting functions, which is automatically accounted for in the package; Δf is the sampling frequency.

The energy spectral density

The averaging is performed over *M* realizations and the characteristic is measured in *squared units*seconds/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 the one-sided energy spectral density, taking into account the weighting windows:

$G'_{ESD}(k) = G'_{PSD}(k) \cdot T$. Here and above *T* is the observation interval.

The amplitude spectrum (the RMS value)

This characteristic is determined through the power spectrum and is measured in *units*: $G_A(k) = \sqrt{G_{PS}(k)}$

For the one-sided amplitude spectrum, when the weighting windows are used, the formula becomes: $G'_A(k) = \sqrt{G'_{PS}(k)}$

The complex spectrum

The spectrum calculated as a complex measure, may be presented in one of the following two forms:

- as the real and the imaginary part:

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

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

- as the module and the phase:

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

$$\text{Fas}F(k) = arctg(\frac{\text{Im}\,F(k)}{\text{Re}\,F(k)})$$

Cross spectral characteristics

The cross spectral characteristics for the *a(t)* and *b(t)* input processes are determined based on the momentary spectra *A(f)* and *B(f)*, and the cross spectrum $G_{AB}(f)$.

$$A(f) = \int_0^T a(t) \cdot \exp\{-j2\pi f\, t\}\, \mathrm{d}\,t\,; \qquad B(f) = \int_0^T b(t) \cdot \exp\{-j2\pi f\, t\}\, \mathrm{d}\,t$$

In discrete form :

$$A(k) = (\sum_{n=0}^{N-1} a_n \cdot \exp\left\{-j \cdot \frac{2\pi kn}{N}\right\}) \cdot \Delta t = \frac{1}{F_{ref}} \cdot \grave{A}_{dft}(k)\,; \qquad B(k) = \frac{1}{F_{ref}} \cdot B_{dft}(k)$$

The cross spectrum is determined by the momentary spectra *A(f)* and *B(f)*, and is given by the following expression:

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

The relationships between one-sided and two-sided characteristics are established by the following expression:

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

Similarly for the $G_{AA}(f)$ and $G_{BB}(f)$ auto spectra, where

$S_{AA}(k) = A^*(k) \cdot A(k)$ and $S_{BB}(k) = B^*(k) \cdot B(k)$.

Everywhere below it is assumed, that the cross spectrum estimates, and the auto spectra estimates are those averaged over *M* realizations.

The cross spectrum

This characteristic is a complex value that may be represented in one of the following two ways:

- as the real and the imaginary part (the co-spectrum, and the quad-spectrum):

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

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

- as the module and the phase:

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

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

The cross power spectral density

The characteristic is measured in *squared units /Hz*:

$$G_{psdA\hat{A}}(k) = \frac{1}{T} \cdot \left| G_{AB}(k) \right|$$

When the weighting windows are used, we have to introduce the correction factors, and the formula becomes:

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

where: K_{cpgf} - is the coherent signal power gain factor;

β - is the equivalent noise band width.

The coherence function, and the incoherence function

The coherence function is determined on the basis of the intrinsic spectra and the cross spectrum of the signals und investigation, according to the following formula:

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

Note: the coherence function is determined on the basis of the averaged functions, and is the case of a single isolated estimate has unit values.

The incoherence function is determined as $1 - \nu^2(k)$.

The coherent output power. The incoherent output power

The coherent output power is determined on the basis of the coherence function, and shows the measured (output) signal $G_{BB}(f)$ intrinsic spectrum share, which is perfectly coherent with a certain (input) signal represented by the function *a(t)* and the intrinsic spectrum $G_{AA}(f)$.

The mathematical expression of this characteristic is as follows:

$$\text{COP}(k) = \nu^2(k) \cdot G_{BB}(k) \cdot$$

The incoherent output power expression becomes: $\text{NCOP}(k) = (1 - \nu^2(k)) \cdot G_{BB}(k)$

The signal to noise ratio

The signal to noise ratio is determined on the basis of the coherence function using the following formula: $S/N(k) = \dfrac{\nu^2(k)}{1 - \nu^2(k)}$

The Transfer function

Two complex frequency response characteristics of the system are determined, which are principally different from each other:

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

Filtering

The filtering subsystem implements digital recursive filtering, and is based on the consecutive connection of second order canonical links.

$Y_n = B_0 \cdot Y_{n-2} + B_1 \cdot Y_{n-1} + A_0 \cdot X_{n-2} + A_1 \cdot X_{n-1} + A_2 \cdot X_n$, where: Y_n - is the filtered array, X_n - is the source array, B_0, B_1, A_0, A_1, A_2 - are filtering factors calculated according to the specified characteristics.

The transfer function for the recursive set is:

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

The following notes should be treated as recommended suggestions. In order to avoid obtaining periodic processes of great length you should take care that the following condition is met:

$$2 < \frac{F_s}{F_{co}} < 100$$

, where F_{co} - is the filters cutoff frequency, F_s - is the sampling frequency.

Thus, for example, the 12-th order filter will have no more that 700 periodic process points.

If, for example, $2 < \frac{F_S}{F_{co}} < 50$, then we may guarantee that the maximum length of the periodic process will not exceed 350 points.

Median filtering

The median filter cancels impulse noise with duration less than ½ of the aperture width.

A certain number of sequential points, equal to the filter aperture width, is selected from the signal Further this sequence is sorted to select the average value (the value number N/2+1, where N - the aperture width) called a median. If the median at this point is different from the source signal value greater than at the threshold value, the median value is written to the respective point of the resulting signal; otherwise the source signal value is written. The filter window is offset at one value towards the signal end, and the process is repeated.

The probabilistic characteristics

For the sequence of points $\{x_{n,}\ n=0,...N-1\}$ evaluations of the abovementioned characteristics are performed according to the formulas given below.

The mathematical expectation (the mean value)

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

Dispersion (Variance)

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

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

Root mean square error

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

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

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.

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

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.

Probability density

The probability density estimate is constructed either by using nuclear estimations with the square nuclear function, or as a histogram.

The nuclear estimations method

The PFD estimation using the nuclear estimations method with the square nuclear function is given be the following 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: $\{X_k\}$ - is the process for which the PFD is constructed;

N is the number of points in the source process, for which the PFD is estimated;

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

σ is the root mean square of the process;

M is the number of points in the estimated PFD function (selected by the user).

The histogram method

The basis for the construction of the histogram is the so-called "statistical array": the whole range of the values of a random variable *X* is divided into intervals or "stages" (the number of these intervals is specified by the user); then the number of points m_i falling within each *i*-th stage is calculated (if a point falls exactly between two stages, then 0.5 is added to the m_i numbers of both stages), the resulting value is divided by the number of observations *n*, and so the frequency corresponding to the *i*-th stage is determined: $p^*_i = m_i / n$.

The histogram itself is plotted in the following way. The stages are plotted along the X axis, and a rectangle with an area equal to the frequency of the stage is drawn with the stage as the basis. In order to plot the histogram we divide the frequency of each stage by its length, and the resulting value is taken as the height of the rectangle. If we increase the amount of source data, and the number of stages, then the histogram will approach the frequency distribution graph for *X*.

Note: It is recommended to have at least 5-10 observations within each stage. If the number of observations in some stages is small (1-2), then these stages should be merged.

Taking the logarithm

Taking the logarithm of the data is done according to the following formula:

$$U_{\lg} = k \cdot \log_{10}\left(\frac{U}{U_{ref}}\right), \text{ [dB]},$$

where *k* is a factor, which takes one of the two values (10 or 20) depending on the characteristic (for example, the value of this factor for the amplitude spectrum is equal to 20, and for the power the value of this factor is equal to 10);

U_{ref} - is a reference value. In the WinPOS package this parameter s specified by the user, either as a specific number, or by selecting the maximum value form the array, of which we are taking the logarithm.

Autocorrelation

To calculate the estimate of the random sequence normalized correlation function, which has the properties of stationarity and ergodicity, we use the following formulas:

a) the correlation function estimate:

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

where: $\{x°(j)\}$ is the centered realization;

m is the maximum number of step (this parameter is specified by the use in the WinPOS package);

N is the number elements is the sequence.

b) the normalized correlation function estimate:

$\rho_x(k) = K_x(k)/D_x$, where D_x is the dispersion (variance).

Cross-correlation

The cross correlation function estimate is calculated on the basis of the following formulas:

a) the cross correlation function:

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

where $\{x°(j)\}$, $\{y°(j)\}$ are the centered realizations,

b) the normalized cross correlation function:

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

where σ_x, σ_y are root mean squares of the corresponding processes.

Derivation

The WinPOS implements the following three numeric differentiation algorithms:

- "the three-point algorithm", which uses the following formula to calculate the first derivative:

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

- "the five-point algorithm":

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

Integration

Calculating the definite integral

We used the trapezoid method to calculate a definite integral within a given range of values:

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

The numeric solution of the Cauchy problem

The ***WinPOS*** package offers you three methods of the numerical integration of the first order differential equation

$y' = f(x,y)$

The starting condition y(x0)=y0 may be either specified by the user, or is automatically set equal to 0. To exclude the zero-frequency component from the results, we have to center the process.

The Eiler method consists of step-by step application of the third order formulas:

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

The Hamming method without modification (the fourth order formula), when the first three points are calculated using the Eiler method:

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

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

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

The RC-circuit method:

the numeric analog of the RC-circuit (the first order low-pass filter) is given by the following 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-circuit (specified by the user).

The following formulas may be used to determine the number of averaging points

$M=F_s/(2\pi F_b)$ or $M=RC/\Delta t$

where: F_s is the sampling frequency,
F_b is the cutoff frequency of the equivalent low-pass filter;
RC is the RC-circuit constant value,
Δt is the sampling period.

Vibro.

This method uses a method of a RC-chain, but preliminary carries out a high-frequency filtering in the set strip of frequencies that allows to adapt algorithm for conditions of measurement of vibrations.

Normalization

Normalization of a signal is made when it is necessary that resulting values of a signal changed in strictly certain limits. Procedure of normalization is reduced to multiplication of each value of a signal to some factor so, values of a signal do not exceed preset values.

$$Y_i^{nor} = \frac{Y_0}{Y_{\max}}\cdot Y_i$$

, where: Y_0 is the set (demanded) maximal value; Y_{max} is the maximal measured value; Y_i is current value of a signal.

Centering

The centering is carried out with the purpose cut-off a constant component of a signal: $Y_i^{centr} = Y_i - \overline{Y}$, where $\overline{Y}$ is the mathematical expectation (the mean value).

Hilbert transformation. Envelope calculation

To obtain a Hilbert transformation of the input signal it is necessary to execute the direct Fourier transformation:

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

The obtained spectrum is transformed to the genus:

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

The analytical signal is obtain by the Z(k) spectrum inverse Fourier transformation:

$z(n) = f(n) + j \cdot \tilde{f}(n)$, where $\tilde{f}(n)$ - Hilbert transformation of the input signal $f(n)$.

The signal envelope is determined by the expression:

$$|z(n)| = \sqrt{f^2 + \tilde{f}^2(n)}$$

Envelope calculation using the peak detector method

The input process must conform to the following conditions: the process must be centered, and must have a sufficiently narrow band to obtain reliable results. The algorithm for the calculation of the envelope in discrete form:

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

$$y_n = \begin{cases} y'_n, \textit{when}\ y'_n > x_n \\ x_n, \textit{when}\ y'_n \le x_n \end{cases}$$

where $K=RC/\Delta t$ is the RC-averaging factor, Δt is the sampling period.

The calculation of the octave spectrum

The WinPOS program calculates octave, third- and 1/12-octave spectra by the two methods.

The first method is based on recursive filtering, and is implemented according to the classical scheme: band-pass filter – quadratic detector – integrator, this scheme is based on the mathematical definitions of the power spectrum. The band-pass filter in this scheme extracts the spectral components, which lie within the required band, and then the filtered signal is squared and averaged. To obtain a conditioned spectrum the result is divided by the current octave band width or octave portion.

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

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

where: T is the analysis period;
X(t) is the input signal;
L(X(t)) is the recursive band-pass filtering operator.

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

There are two main filter precision requirements – the filter FRF (frequency-response function) and deviation of the effective bandwidth from the nominal which should meet GOST 17168. The filters used in the WinPOS program meet the first class precision under GOST 17168-82. (These are filters for precise laboratory and full-scale test application).

Figure A.1 gives the frequency-response functions of the WinPOS octave and third-octave filters and first class precision filters under GOST 17168-82 (see Table A.1).

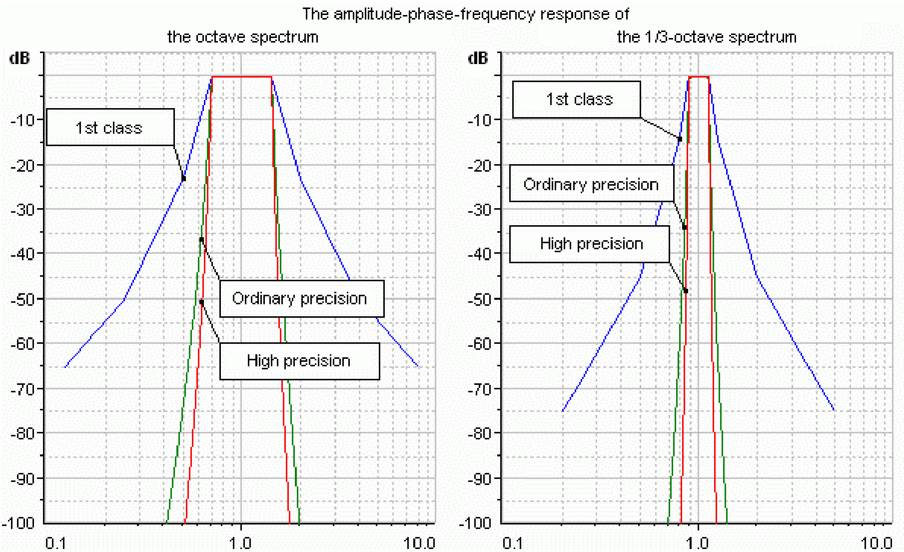


Fig. A.1 FRF of Octave and third-octave WinPOS Filters and First Class Filters

Table A.1 Parameters of First Class Precision Filters under GOST 17168-82

Octave filter, 1st class precision		Third-octave filter, 1st class precision	
Rel. freq, f / fm	Attenuation, dB	Rel. freq, f / fm	Attenuation, dB
0.125	< -65	0.2	< -75.0
0.25	< -50	0.25	< -68.0
0.5	< -23	0.5	< -45.0
0.7071	От -6.0 до 0.5	0.7937	< -14.0
0.8409	От -1.0 до 0.5	0.8909	От -6.0 до 0.5
1.0000	От -1.0 до 0.5	0.9439	От -1.0 до 0.5
1.1892	От -1.0 до 0.5	1.0000	От -0.5 до 0.5
1.4142	От -6.0 до 0.5	1.0595	От -1.0 до 0.5
2	< -23	1.1225	От -6.0 до 0.5
4	< -50	1.2599	< -14.0
8	< -65	2	< -45.0
		4	< -68.0
		5	< -75.0

Table A.2 shows the deviation of the effective bandwidth from the nominal value of the bandwidth. The filter values with minimum errors are presented.

Table A.2. Deviation of Effective Bandwidth

Filter type	Nominal value	Efficient bandwidth deviation, %			
		GOST 17168-82		Ordinary precision	High precision
		1 class	2 class		
Octave	0.7071	8	10	6.4	4.0
Third-octave	0.2316	8	10	10.3	3.8
1/12-octave	0.0576	8	10	7.7	4.9

The second method is implemented applying the fast Fourier transformation; its description is given above. In the given case the GOST requirements are met not fully - the fact justified by the lower steepness of the frequency response curve. The 1/24 -octave spectrum is calculated by FFT method only.

Figure A.2 shows the dependence of the results from the chosen method.

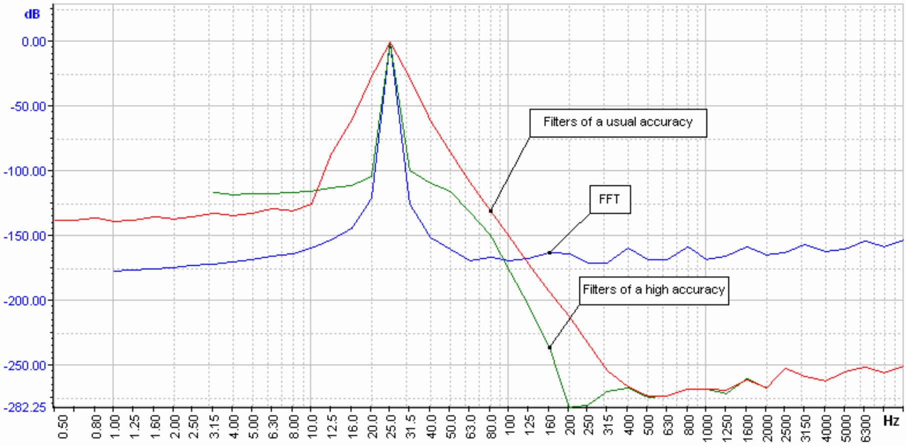


Fig. A.2. A third-octave logarithmic spectrum of the is a sine with the frequency of 25 Hz calculated by different methods

In most cases, it is recommended to use the FFT method at a calculation of an octave spectrum. Using FFT a calculation is carried out more rapidly than a filtration, does not require a plenty of initial data and provides a high accuracy (-160 dB) on all interval of frequencies. It is expedient to use a method of a filtration with filters of a high accuracy, if it is necessary to receive the maximal accuracy in the field of high frequencies and the initial signal has the greater length. The more long an initial signal, the more widely a range of frequencies on which a high accuracy (250 dB) is reached. Filters of usual accuracy allow to calculate a spectrum on a signal of a smaller length, provide an accuracy similar to the high -precision filters in the field of high frequencies, but for all that these filters have a more gentle AFC. Filters of usual accuracy allow receiving the values of a spectrum in low-frequency area. The more the length of an initial signal, the further to the low-frequency area the range of frequencies of a spectrum amplifies.

The central and boundary frequencies

The central frequencies are calculated by the following formulas:

For octave and third-octave spectrums: $f_m = G^{x/b} * f_r$,

For1/12-octave and 1/24-octave spectrums: $f_m = G^{(2x+1)/2b} * f_r$, where

G – an octave coefficient (equals 2 or 1.995, depending on the settings),

f_r - a basic frequency, 1000kHz, b - a part of the filter octave (1, 3, 12 or 24 accordingly), x – a number of the octave or an octave part.

Boundary frequencies are calculated by the formulas:

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

One should bear in mind that the analyzed frequency band is limited by the Nyquist frequency (Fs/2). For example for Fs = 1 kHz we get a band of up to 450Hz (see Table A3).

Table A. 3.

The values of the central frequencies of the octave and third-octave spectrums.

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

Appendix B. Processing algorithm application guidelines

(Methodical instructions)

This chapter contains information concerning the practical application of characteristics in the analysis of signals. The information presented here is for reference purposes only, more detailed information may be obtained from the sources listed in the end of this Appendix.

Practical signal analysis using the FFT algorithm

One of the most important methods in the signal analysis field is the Fast Fourier Transformation (FFT) algorithm. The Fast Fourier Transformation algorithm allows you to determine a set of values and functions related to signal analysis, multi-channel measurements, and the determination of such system characteristics as correlation functions, coherence, frequency responses, etc. One of the main advantages of the Fast Fourier Transformation-based analysis is the ability to preserve the phase information, and, consequently, the capability to perform simple forward and inverse transformations from the time domain to the frequency domain, and backwards.

The limitations of the FFT method

The inherent limitations of the FFT process arise essentially from the Discrete Fourier Transformation (DFT). These limitations are mainly based on the finite and discrete nature of the Discrete Fourier Transformation algorithm. The nature of these limitations will be made clearer if we look at the DFT as the result of the passing of the signal through a set of matched band-pass filters with the central frequencies equal to:

$f_i=i\cdot(f_s/N)$, where f_S is the sampling frequency, and N is the number of FFT points.

The analyzed signal component with a frequency f_a, which is not equal the DFT spectral line (bin) frequency will appear at the neighboring spectral line, and the amplitude values will be measured with some inaccuracies (see Figure B.1).

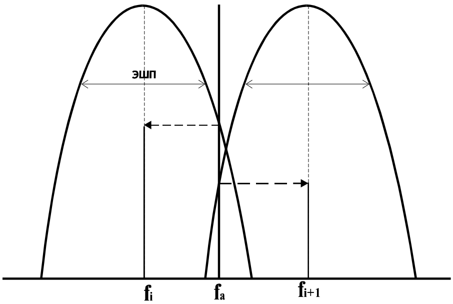


Figure B.1. The DFT as a set of matched and-pass filters

The hashing effect

The first operation in digital analysis is the sampling of time analysis data. The discrete presentation theorem formulated by Shannon states than the time function in its discrete representation must not contain any component with the frequencies higher than one-half of the sampling frequency (the Nyquist frequency). Otherwise the components of the spectrum *G(f)* of the source signal *g(t)* having the frequencies exceeding the Nyquist frequency, are incorrectly interpreted and represented as components with lower frequencies (the "hashing" effect).

ⓘ Recommendations: when analyzing stationary ad other signals with exactly determined frequency ranges, the problems arising from the hashing effect are usually eradicated by applying analog low-pass filters.

Note: In the Bruel&Kjaer equipment this problem is solved by using low-pass filters with a sharp cut-off frequency equal to ≈80% of the Nyquist frequency. In order to effectively block the components with frequencies exceeding the working range, the slope of the amplitude-frequency response of the low-pass filter is set to about 120dB/octave. The indicator and the external equipment receive only those results, which are not affected by the presence of the filter in any way. For example, when performing a transformation using 1024 discrete samples in the time domain, 512 frequency-domain components are calculated, but the indicator and the external equipment receive only 400 frequency components.

The weighting effect

The next operation in our analysis is the limiting of the signal within the time domain (the final realization). This operation is equivalent to multiplication by the rectangular weighting function (the time window). The result of the application of the weighting function is relatively trivial, when working with spectra containing no marked peaks. But if the spectra contain discrete components, then, after the weighting function is applied, those components are replaced by the spectrum of the weighting function. The weighting window behaves as a filter (with the corresponding *equivalent noise band* and K_{KG} characteristics, see Table B.1), and the signal power output by this filter is proportional to the power of the input signal harmonics within the bandwidth of the filter. This effect is known as "the weighting effect", "the framing effect", "the sideband formation effect", or "the leakage effect" (the power inherent to the discrete component appears within the sidebands as a result if the leakage).

ⓘ Recommendations: The rectangular weighting function (or no weighting function) is not an optimal option when analyzing stationary signals, particularly when analyzing signals containing discrete components, because of the potential discontinuity at the connected ends of the realization being processed.

The function that is optimal for stationary signal analysis must have zero values at both ends, and smoothly changing values within the specified length of the realization of the signal being analyzed. See the corresponding section on the selection of the weighting function.

The fence effect

The fence effect is associated with the discrete representation of continuous frequency spectra (see comments to Figure B.1). This effect can occur not only when using the FFT-based analysis, but also in situations where discrete (non-adjusting) band-pass filters are used, e.g. in octave or 1/3 octave analysis. This effect, practically, consist of the following: while the frequency of a certain component of the signal being analyzed is not equal to the frequency of the corresponding spectral line, the amplitude and frequency values inherent to this component will be measured with some systematic inaccuracies (the frequency value will correspond to the value of the frequency nearest to the higher frequencies of the spectral line). It is possible to compensate for these inaccuracies when the accounted component is an isolated and stable frequency component.

The FFT with increasing frequency scale

The Fast Fourier Transformation with increasing frequency scale is used when it is required to improve the frequency resolution within a certain spectrum band of the signal being analyzed. You may use two methods, which differ from each other:

- "the real-time frequency scale increase", employing the lowering of the sampling frequency f_s;
- "the lossless frequency scale increase", employing the increasing of the length of the realization N.

The real-time frequency scale increase

The basic principles of this method are as follows:

- multiply the time signal $g(t)$ by the unit vector rotating with the frequency -f_k , the zero frequency value is placed at the f_k frequency;

- the modified complex number signal is filtered by a digital low-pass filter to eliminate all components, whose inherent frequencies do not lie within the narrow band around the f_k frequency. When performing the filtering, the part of the signal where hashing may have occurred as a result of the shift, is also eliminated.
- the discrete value sampling process is repeated, with the new sampling frequency (for the ten times frequency scale increase, the sampling frequency must be increased as 20:1);
- based on the complex discrete values obtained in this way, and using the Fast Fourier Transformation, we determine the spectrum with the increased frequency scale.

The lossless frequency scale increase

Using this method, we may account for a bigger number of discrete values during the sampling process, by repeating the transformation process that used a lower number of discrete values. The idea behind this method is as follows:

- the source realization, consisting of a big number of discrete values, is subdivided into *n* realizations;
- the shortened realizations are cyclically subjected to the Fast Fourier Transformation;
- since the Discrete Fourier Transformation is linear, the sum of the transformations of the shortened realizations id equal to the transformation of the sum of these realizations.

The sum of the shortened realizations is identical to the source realizations after compensation for slight shifts of some of the shortened realizations within the time domain. Within the frequency domain, this compensation consists of a linear change of the phase angle.

Note: This method has high requirements to the memory storing the discrete values of the time signal. The maximum possible value of the frequency scale increase factor is often limited by the amount of this memory.

Examples of the analysis based on the FFT

This section is presented as a reference.

The **main frequency range** during the analysis spans from 0 Hz to the Nyquist frequency, and does not depend upon the number of discrete values constituting the realization of the signal being analyzed. The Nyquist frequency f_N is related to the sampling frequency f_S as follows: $f_N = f_S/2$

The real **working frequency range** is limited from above by the cutoff frequency value of the low-pass filter used.

The **number of the spectral lines** when performing the analysis within the main frequency range depends upon the number of the discrete values *N* and is usually equal to *N*/2 within the range having the upper frequency boundary set by the Nyquist frequency.

The **frequency** corresponding to the **i-the spectral component** (harmonic), is:

$f_i = i \cdot (f_S/N)$, where f_S is the sampling frequency.

The **frequency resolution (*Δf*)** or the interval between the neighboring spectral lines while performing the analysis is determined by the following relationship:

$\Delta f = 1/T = 1/(N \cdot \Delta t) = f_S/N$,

where *T* is the length of the transformed realization of the signal being analyzed;

N is the input number of discrete values (the size of the transformation);

Δt is the sampling step;

f_S is the sampling frequency.

The **frequency band width (*B*)** in this analysis is usually bigger than the frequency resolution, and depends upon the weighting function used in within the time domain:

$B = \Delta f \cdot K_{ENB}$, where K_{ENB} is the equivalent noise band factor corresponding to the selected weighting.

Using weighting windows in harmonic analysis

The finiteness of the observed time interval and the selection of the orthogonal trigonometric basis (either continuous or discrete) within this interval lead to the appearance of undesired dithering or leakage of spectral components.

The windows (weighting functions) are used to decrease the dithering of spectral components. The impact of a weighting window upon the data array consists of the decrease of the order of the break at the periodic continuation boundary by using the smoothing effect. The window behaves as a filter, the output signal power of which is proportional to the power of the input signal harmonics within the filter bandwidth (see *Figure B.2*). The weighting windows affect many harmonic analysis factors, such as the detectability, the resolution, the dynamic range, the degree of reliability, and the ease of implementation if calculation operations. In order to be able to make the correct selection of a weighting function, lets look at the most significant weighting function parameters.

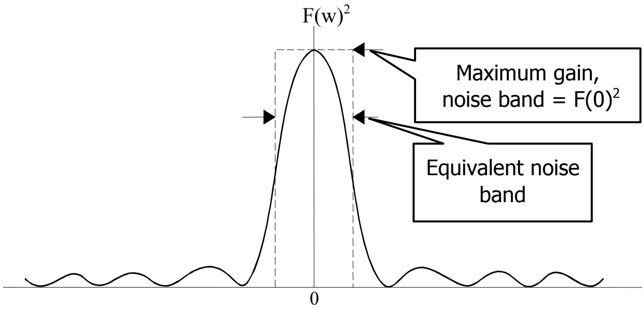


Figure B.2. The equivalent noise band of a window

The equivalent noise band (ENB)

Because of the presence of wide-band noise falling into the window bandwidth, the amplitude estimate for a specified frequency becomes shifted. We may minimize the cumulative noise using a narrow-band window. A convenient measure of the bandwidth is its equivalent noise band (*ENB)*, which represents the bandwidth of a rectangular filter with the same maximum gain, which accumulates the same power as the window, see Figure B.2).

The ENB values for the windows employed within the WinPOS package are given in Table B.1. The ENB calculation formula is as follows:

$$ENB = \frac{\sum_n w^2(nT)}{[\sum_n w(nT)]^2}$$

, where *w(nT)* are the discrete values of the weighting function.

Note: The *ENB* is normalized to N_0/T, where: N_0 is the power of the noise within a unit bandwidth; *T* is the observation time interval.

The transformation gain (TG)

If we use weighting windows for a constant signal in the absence of any noise, the spectral component will be proportional to the input amplitude. The same is true for the mathematical expectation of this component when noise is present. This effect is maximal for a rectangular window. The decrease of the proportionality factor for one or another window in relation to the rectangular window characterizes the spectral component amplitude estimate error (shift). Table B.1 shows the values of coherent gain for windows (the proportionality factor), normalized with relation to the maximum possible value of *N* (where *N* is the number of points within the window). The transformation grain is determined as the quotient of the output and input signal to noise ratios, and is the reciprocal of the normalized *ENB* of the window. So, increasing the *ENB* leads to the decrease of the *TG*.

The correlation of overlapping areas

Let us consider the case of the division of the input sequence into several sequences of smaller length. The number of point N of the sequence is selected in such a way, as to provide the required spectral resolution, which is defined by the following formula:

$$\Delta f = \beta \cdot \frac{f_S}{N}$$

, where fs is the sampling frequency;
β - is the ratio characterizing the increase of the bandwidth of the selected window (is usually selected equal to the *ENB* of the window measured in bins, see Table B.1).

In order to avoid losing the data lying close to interval boundaries (when the FFT affects the weighted data), we usually apply this transformation to the overlapping areas of the sequence. The overlapping degree is selected, in most cases, to be equal to 50 % or 75 %. In this case some questions arise concerning the degree of the correlation of random signal components in the transformations of two neighboring parts of the sequence, and, as a question, concerning the decrease of the dispersion (variance) after averaging the correlated measurements. The correlation factor values (when the noise spectrum is relatively flat within the bandwidth of the window) for each window used in the WinPOS package with 50 % and 75% overlaps are given in Table B.1.

Now let us discuss the dispersion. If we average *K* independent values of an ergodic random variable, then the dispersion of the average is related to the dispersion of individual measurements by the following formula:

$$\frac{\sigma^2_{average}}{\sigma^2_{measured}} = \frac{1}{K}$$

When averaging correlated measurements:

- for the 50 % overlap:

$$\frac{\sigma^2_{average}}{\sigma^2_{measured}} = \frac{1}{K} \cdot [1 + 2c^2(0,5)] - \frac{2}{K^2} \cdot [c^2(0,5)]$$

- for the 75 % overlap:

$$\frac{\sigma^2_{average}}{\sigma^2_{measured}} = \frac{1}{K} \cdot [1 + 2c^2(0,75) + 2c^2(0,5) + 2c^2(0,25)] - \frac{2}{K^2} \cdot [c^2(0,75) + 2c^2(0,5) + 3c^2(0,25)]$$

where $c^2(0.75)$, $c^2(0.5)$ and $c^2(0.25)$ are the correlation factors for the 75 %, 50 %, and 25 % overlaps. The negative terms describe the border effects of the averaging, when $K > 10$ we may omit them. For good window c^2 (0.25)<<1, and may also be omitted.

Maximum transformation losses

Maximum transformation losses arise from the maximum losses related to the parasite amplitude modulation of the spectrum (the fence effect) for the given window (in dB), and the transformation losses related to the shape of the window. The level of maximum losses always lies between 3.0 and 4.3 dB (windows having this value >3.8 dB are inadequate).

Detection of two near tones

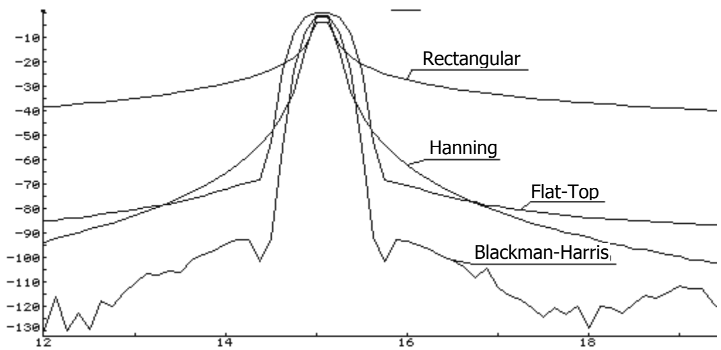
The leakage of spectral components leads to the shift of amplitude estimates, and the positions of the harmonic components of the signal. This effect is the most troublesome when detecting weak signals in the presence of strong noises having a near frequency. To decrease the undesired consequences, the side-band amplitude far enough from the main band of the frequency range of the window must be small, and the transition from the central band to the low-amplitude side-bands must be very fast. The maximum side-band values (relative to the main band), and the values of the asymptotical decrease speed of the side-bands are given in Table B.1.

Conclusions

The applied window type is critically important when detecting a tone in the presence of other nearby tones. In order to maximize the dynamic range of detectable signals, the transformation of the window must have a narrow main band, and very low levels of side-bands.

The Bruel&Kjaer equipment gives preference to the Henning function.

The WinPOS package implements the following weighting windows: triangular, Henning, Blackman-Harris, and Flat-Top Figure B.3 shows the spectra (the results of the Discrete Fourier Transformation) of the **cos**-function weighted within the time domain by the rectangular, Henning, Blackman-Harris, and Flat Top functions respectively. The frequency of this **cos**-function lies within the interval of two neighboring spectral lines (ΔX=0.125, f=15.0625).



	Flat Top	Henning	Blackman-Harris	Rectangular
Y (dB) X	-0.016 15.000	-1.424 15.000	-0.856 15.000	-3.937 15.000

Figure B.3. The spectra of the weighted cos-function

It is evident from Figure B.3. that the rectangular window has the narrowest main band (bandwidth), but at the same time this window has the highest side-band level, which leads to additional transformation losses (the parasite signal power increases, and the leakages of spectral components increase). The Blackman-Harris window has the lowest level of side-bands, but a wide bandwidth. Among the window shown, the Henning window has optimal characteristics, and the lowest transformation losses, which allows us to recommend it for use in virtual devices. The Flat Top function, having the widest bandwidth, leads to a significant decrease of the fence effect, and is used for the calibration of analyzing equipment with the help of a tonal signal with a frequency lying within the interval between two neighboring spectral lines.

Table B.1 Main parameters of the windows

Window	ENB (bin)	K_{CG}	MSL (dB)	MAI (dB)	SBDS dB/octave	OAC (%)	
						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
Henning	1.5	0.5	-32	1.42	-18	65.9	16.7
Flat Top	3.77		-93	0.01	0		
Triangular	1.33	0.5	-27	1.82	-12	71.9	25.0

Here: ENB is the equivalent noise band (bin);
K_{CG} is the coherent gain factor;
MSL is the maximum sideband level (dB);
MAI is the maximum amplitude inaccuracy (dB);
SBDS is the sideband decrease speed (dB/octave);
OAC is the overlapping area correlation.

The correlation analysis

The autocorrelation function and the cross-correlation function

The cross-correlation function $R_{ab}(\tau)$ expresses the degree of statistical connection between two signals *a(t)* and *b(t)* depending on their mutual shift (the delay parameter) τ within the time domain

The cross-correlation function for short duration signals is given by the following expression:

$$R_{ab}(\tau) = \int_{-\infty}^{\infty} a(t) \cdot b(t+\tau) \mathrm{d}t$$

In case of stationary signals this function has to be slightly modified (a move from "energy" to "power"):

$$R_{ab}(\tau) = \lim_{T\to\infty} \frac{1}{T} \int_{-T/2}^{T/2} a(t) \cdot b(t+\tau) \mathrm{d}t$$

A special case of the cross-correlation function (when *a(t)=b(t)*) is the autocorrelation function $R_{aa}(\tau)$.

Practically, it is more convenient to use the normalized autocorrelation function:

$$\rho_{aa}(\tau) = \frac{R_{aa}(\tau)}{R_{aa}(0)}$$

and the normalized cross-correlation function:

$$\rho_{ab}(\tau) = \frac{R_{ab}(\tau)}{\sqrt{R_{ab}(0) \cdot R_{aa}(0)}}$$

Based on the Fourier transformation and the convolution theorem, we may prove the relationships between the autocorrelation function $R_{aa}(\tau)$ and the intrinsic spectrum $S_{aa}(f)$, and between the cross-correlation function $R_{ab}(\tau)$ and the cross-spectrum $S_{ab}(f)$:

$$R_{aa}(\tau) = \mathbb{F}^{-1}\{S_{aa}(f)\} \quad \text{and} \quad R_{ab}(\tau) = \mathbb{F}^{-1}\{S_{ab}(f)\}$$

Main areas of practical application

The cross correlation function

a) Determining time delays

The cross-correlation function $R_{ab}(\tau)$ of the *a(t)* and *b(t)* signals, recorded at points *A* and *B* lying on the propagation path, has a peak value, the position of which corresponds to the delay time τ, that is the time of the propagation between the *A* and *B* points.

Note: it is assumed that the signals are wide-banded, and their propagation is non-dispersive (the propagation speed is independent of the frequency). When the propagation of a signal is dispersive, the we may either limit the frequency range band, assuming that the propagation speed within this band is constant, 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 propagation paths

When there are several propagation paths between the A and B points, the cross-correlation function $R_{ab}(\tau)$ for the signals *a(t)* and *b(t)* recorded at these points, has the corresponding number of peaks. The peaks corresponding to separate propagation paths are located at positions with inherent delay time values τ_n corresponding to propagation times along different paths *n*. The amplitudes of these peaks show the relative quality of those propagation paths.

Note: it is assumed that the signals are wide-banded, and their propagation is non-dispersive (the propagation speed is independent of the frequency).

It is often more appropriate to use envelopes (amplitudes) of the respective analytical signals, instead of using the real-valued normalized autocorrelation function $\rho_{aa}(\tau)$ and the normalized cross-correlation function $\rho_{ab}(\tau)$. The amplitude curve is smooth (due to the absence of maximum and minimum values, which are often present in the source characteristic), so it is possible to identify peaks (caused by reflections, for example), and to correctly determine their inherent amplitudes. With the amplitude representation we may use logarithmic scale, and, therefore, enjoy the benefits of the expanded dynamic range and the enhanced resolution of presented results.

c) Detecting signals masked by noise

If the *a(t)* and *b(t)* signals contain a common signal *s(t)* masked by noise, that is, if $a(t)=s(t)+n(t)$ and $b(t)=s(t)+m(t)$, and the *n(t)* and *m(t)* components do not correlate with each other, then the cross-correlation *Rab(t)* contains only information only about the correlated component *s(t)* of the *a(t)* and *b(t)* signals, and the shape of this function corresponds to the autocorrelation function *Rss(t)* inherent to the *s(t)* signal, which has absolutely no *n(t)* and *m(t)* noise components.

The autocorrelation function

a) Detecting echoes (reflections) in signals

If a signal, *a(t)* contains an echo with time delay τ_0 , then the autocorrelation function $R_{aa}(t)$ of this signal, beside the peak at $\tau=0$ has a peak at $\tau=\tau_0$. Moreover, the value of $\rho_{aa}(\tau_0)$ shows the relative intensity of the echo present. This is true for wide-band signals, the frequency bandwidths of which are enough to provide narrow and separated peaks for the autocorrelation function.

b) Detecting periodic signals in noise signals

An autocorrelation function of a periodic signal is always a periodic function. The masking noise (the background noise) is usually a random signal, and the amplitude of its autocorrelation function decreases with the increase of time delay, and after some the amplitude takes on a zero value. Therefore, the autocorrelation function may help to detect a periodic signal after the time required for the noise component to disappear.

Note:

1. The amplitude of the normalized autocorrelation function of the wide-band random signal (noise) decreases rapidly in conformance with the so-called law of the uncertainty of the functions related through the Fourier transformation. This law sets the relationships between the bandwidth, Δf of the intrinsic spectrum $G_{AA}(f)$, and the length, Δt, of the corresponding autocorrelation function, $R_{aa}(t)$, in the form of $\Delta f \cdot \Delta t \geq 1$

2. In order to detect a periodic signal containing several frequency components, it is often more appropriate to use the intrinsic spectrum, instead of the autocorrelation function. Based on the intrinsic spectrum, we may determine not only the frequencies, but also the amplitudes of separate components of the periodic signal masked by noise. However, if the amplitudes of these components are small compared to the level of the masking signal (the background noise), then it is required to perform the analysis with the increase of the frequency scale.

The correlation factor and the coherence function

When performing systems analysis involving the processing of input and output signals, it is required to determine or estimate the degree of linear interdependence of the signals being processed.

The correlation factor

The quantitative measure of the degree of statistical interdependence of two random variables, x and y, which may represent input and output signals of the system under investigation, is the correlation factor ρ_{xy}, the formula for which is as follows.

$\rho_{xy} = \dfrac{\sigma_{xy}}{\sigma_x \cdot \sigma_y}$, where the covariance: $\sigma_{xy} = E[(x-\mu_x)\cdot(y-\mu_y)]$, and the standard deviations, σ_x and σ_y, of the x and y variables are determined by the following two expressions:

$$\sigma_x = \sqrt{E[(x-\mu_x)^2]} \qquad \text{and} \qquad \sigma_y = \sqrt{E[(y-\mu_y)^2]}$$

The amplitude of the correlation factor, $|\rho_{xy}|$ lies between 0 and 1, and

1. $|\rho_{xy}| = 1$ in the case of perfect linear interdependence between x and y;

2. $|\rho_{xy}| = 0$ in the case of absence of any dependence between the x and y variables (the case of random distribution of the corresponding values);

3. $|\rho_{xy}| < 1$ in all other cases, and, in particular:

a) when there is come amount of random noise, that is, then the x and y values are somewhat dispersed, despite their linear interdependence x and y. This situation may be encountered in linear systems analysis, where there is random noise present in input and/our output signals.

b) when there is a clearly defined, but non-linear interdependence between the noise- and dispersion-free variables, x and y.

The coherence function

Similarly to the correlation factor, the coherence function, $\gamma^2(f)$, shows within the frequency domain, and on the scale from 0 to 1 the quantitative measure of the linear interdependence between two processes, *a(t)* and *b(t)*, inherent to separate frequency values, *f*.

The coherence function is defined by the following expression:

$$\gamma^2(f) = \frac{|G_{AB}(f)|^2}{G_{AA}(f) \cdot G_{BB}(f)}$$

The coherence function values, $\gamma^2(f)$, inherent to separate frequency values, *f,* correspond to the squared values of the correlation factor ρ_{xy} .

Note: In the case of a uniform isolated evaluation (with no averaging), the coherence function has values equal to 1.

The coherence function, $\gamma^2(f)$, may have values below 1 for the following reasons:

1) the presence of uncorrelated noise in *a(t)* and/or *b(t)* signals;

2) non-linear interdependence between the *a(t)* and *b(t)* signals;

3) the presence of leakage due to and inadequate resolution and/or the application of a non-optimal weighting function (a special no-linearity type, conditional upon the analysis procedure);

4) the presence of time delay between the *a(t)* and *b(t),* which is comparable to the lengths of their respective realizations.

Applications of the coherence function

The coherence function is used to check the validity of other function, and to determine the degree of noise influence upon the linearity and/or non-linearity of these functions.

Note: Small values of the coherence function do not always indicate the invalidity of the determinate functions, and in some cases, indicate the need to increase the number of averaging cycles to guarantee valid results.

On the basis of the coherence function, you may define a number of other functions, having various practical applications.

The coherent output power

$COP = \gamma^2(f) \cdot G_{BB}(f)$ indicates the share of the measured intrinsic spectrum of the (output) signal $G_{BB}(f)$, which is perfectly coherent with a certain (input) signal *a(t)*.

Note: In the case of small coherence function values, the COP is valid only when the decrease of coherence is due only to noise superimposed upon the output signal.

In the case when the only factor affecting the degree of coherence is the noise superimposed upon the output signal, the coherent output power (proportional to $\gamma^2(f)$) represents the "output signal", while the **non-coherent output power** (proportional to 1- $\gamma^2(f)$) represents the "output noise".

Frequency responses

Frequency responses (transfer functions) show the ratio of the output values to the input values of various systems in the frequency domain, and, therefore, perfectly characterize stable, linear, time-invariant physical systems (such as mechanical, acoustic and electric systems).

Based on the results of simultaneous measurements, and the FFT-based input and output signal analysis of the physical system, we may determine two different estimates of the complex frequency response of this system, i.e.

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

where *a(t)* is the input signal, and *b(t)* is the output signal of the system.

Recommendations for the application of frequency responses

1. In the presence of parasitic (non-correlated) noise at the output, or in the presence of several independent signals at the input, it is appropriate to use the $H_1(f)$ estimate as an optimal approximation of the frequency response of the corresponding system.

2. In the presence of parasitic (non-correlated) noise at the output of the system, the optimal approximation for the frequency response of the system is the $H_2(f)$ estimate.

3. In cases of leakage (caused by inadequate frequency resolution) in resonance areas, the $H_2(f)$ estimate is preferred, since it approximates the frequency response of the system more precisely , as compared to the $H_1(f)$ estimate.

In the anti-resonance areas of the system under investigation, where the presence of noise at the output is possible, it is usually appropriate to use the $H_1(f)$ estimate, while the $H_2(f)$ estimate is usually appropriate in resonance areas, where troubles may be caused by the noise at the input and/or the leakage..

In situations where parasitic (non-correlated) noises are present at both the input and the output of the system under investigation, and the leakage does not cause large systematic inaccuracies, the $|H_1(f)|$ and $|H_2(f)|$ estimates may be used as, respectively, the lower and the higher limits of the interval containing the true values of the frequency response amplitude, $|H(f)|$

Recommendations for the application of analog filters

The filtering subsystem built into the ***WinPOS*** package, implements recursive digital filtering when virtually any characteristics of frequency selection may be applied to the filter, but in order to obtain an optimal quality/speed ratio it is recommended to use the following filters:

- the sixth-order elliptical filter (providing the attenuation at of at least 65 dB at double cut-off frequency);
- the sixth-order Chebyshev filter (providing the attenuation at of at least 60 dB at double cut-off frequency);
- the eighth-order Butterworth filter (providing the attenuation at of at least 55 dB at double cut-off frequency);

All these filters comply on the safe side to Class 1 filter requirements (filters for precise measurements at laboratory and in the field) according to the Russian standards GOST 17168-82.

To check the quality of the required characteristics you may obtain amplitude-frequency and phase-frequency responses of the synthesized filter in the following frequency ranges:

a) $0 < F < 2 \cdot F_{co}$ for the low-pass filter;
b) $F_l/2 < F < 2 \cdot F_u$ for the band-pass filter;
c) $F_{co}/2 < F < 2 \cdot F_{co}$ for the high-pass filter, where F_{co} if the cut-off frequency for low-pass and high-pass filters, F_l, F_u are the lower and upper cut-off frequencies for the band-pass filter.

The comparative characteristic of methods of numerical integration of the differential equation

WinPOS offers three methods of numerical integration of the differential equation of the first order:

- Eiler's method;
- Hamming's mathod;
- RC-chain method.

First two methods, being the best approach of the ideal integrator, more considerably, than last, lift (amplify) a signal on low frequencies that is why at the decision of practical problems it is not enough applicable. The greatest practical value has a method of a RC-chain. As low-frequency effect though also much weaker, takes place and in this case, application of the high-pass filter is necessary.

The second problem – a minimization of an error of a method. The greatest contribution is given with low and high frequencies (See figure B.4).

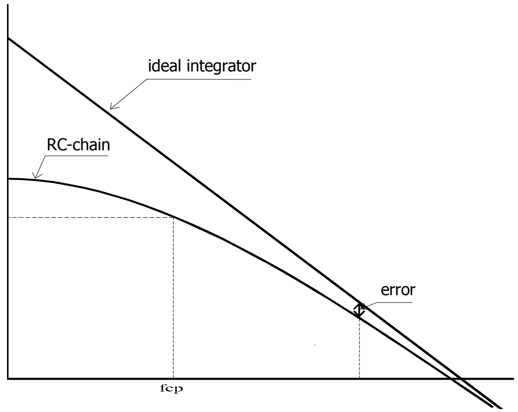


Fig. B.4. Amplitude-frequency response of the ideal integrator and a RC-circuit

The problem is solved exception of the analysis of those sites which have the greatest error

- for area of low frequencies:

  if $F_{co}=F_n/6$, (where F_{co} – cut-off frequency; F_n - the bottom frequency of an analyzed frequency range), error less than 1,5%;

- in the field of high frequencies it is meaningful to use results of integration up to frequency $F=F_S/6$, where F_S is a sampling rate.

The third problem is connected with phase characteristic RC of a circuit which has nonlinear dependence on frequency. In this case introduction correcting phase-frequency is necessary for function which is defined experimental by.

Example: F_S=2000 Hz; F_n=10 Hz;

For the given case F_{co}≈1.7 Hz; F≈333.3 Hz;
number of points of averaging (refer Appendix A. *Processing algorithms*) - M≈180.

Recommended reading

1. Bendat, J., Pearsall, A. Measurement and analysis of random processes. - Moscow: Mir, 1974.

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3. Herlufsen, H. Two-channel FFT-based analysis, Part 1 and Part 2. Bruel&Kjaer. Technical Review, 1984.

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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

Appendix C. File formats

1. USML file structure

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 1st parameter	Massive end attribute (FFFF)	Value massive of the 2nd 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 te 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. Sapling 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".

2. MERA file structure

The present format is distinguished from USML primarily by another data representation: instead of one USML file (.usm) the MERA format data are distributed in several files (data type extensions).

The list of files according to the data type is given below:

Test name**.mera**	- text data an 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 paramneters (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. Version 1	Values. Version 2	Description
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 **.lbl** (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 **.lvl** (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.

3. File structure of Vibration Report 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».
charact[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
charact1_options=type=6,name=e1,username=0,srcTaho=-1,tRez=0,tAxesX=0,tRezMag=0,tTransf=1,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
charact1_cell=4,10
… [ some settings skipped ] …
charact4_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
charact4_cell=
------------------- end of file ------------------------
```

Appendix D. Troubleshooting

Problem	Cause	Solution
WinPOS gives a message that the electronic key is not installed. WinPOS cannot be started.	Mismatching of the key and installed WinPOS copy. E.g., the key «Professional» allows starting of professional and lower versions of WinPOS. *WinPOS Expert* does not operate with this key.	Install WinPOS, matching the key marking. If marking is damaged run the program chknskw.exe from the subdirectory Active of the WinPOS installation folder. Usually this folder is found «c:\Program Files\MERA\WinPOS». The number in the field **Mask** means: 001Fh – Expert, 000Fh – Professional, 0003h – Standard, 0001h – View.
	Incorrect installation of WinPOS or the system configuration disables USB driver installation (LPT).	Check the following. 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). Try to reinstall WinPOS considering the above recommendations and following the prompts of the installation program. If the problem remains unresolved, run the program instdrv.exe from the folder Active. Press **Configure driver** and check setting of **Yes** in the field **Use this port?** Press the button **Reinstall driver**.
Noticeable defects of the graph printout: wide black "frame" on the right and below, chaotic color strips or points, wrong printing of text, etc.	Found at some types of Windows 2000 graphic adapters. This is caused by incorrect operation of OpenGL drivers from the standard Windows package.	**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) * **2. Universal**. If the video adapter drivers cannot be updated for some reason, disable graphic acceleration in WinPOS settings. Set `EnableHAL=false` in the file winpos.ini.
The line extends beyond the graph field.	Incorrect operation of OpenGL drivers of the Windows standard package.	If the problems remains after updating the video adapter* drivers set in the winpos.ini file: `SafeClip=true`
Empty page instead of graph printout.	Insufficient memory for the printer to print the graph (half-tone).	Try to reduce resolution in the printer settings from 1200dpi to 600dpi or from 600dpi to 300dpi.

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 videocards (Windows 2000 and XP) 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)783-42-49

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.