

**Data processing and interpretation program
of the HVSR method (Nakamura method)**

NAKAMURA

User manual

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Purpose and capabilities of the program

The "NAKAMURA" program is designed to process time series and interpret data using the Nakamura method. Convenient interface and wide possibilities of data representation allow to solve the set geological problem in the most effective way.

The NAKAMURA program is a convenient apparatus for processing HVSR method data and can be used on IBM PC-compatible personal computers with the Windows operating system.

System requirements

The NAKAMURA program can be installed on a computer with the Windows XP operating system or higher. Recommended system parameters: Processor P IV-2 GHz, 512 mb. memory, screen resolution 1024 X 768, color mode - True color.

Installing and uninstalling the program

NAKAMURA" program is delivered via Internet as an additional module of ZondST2D program. This manual is included in the delivery set. You can download the latest program updates at www.zond-geo.com.

To install the program, overwrite the program in the desired directory (e.g. "Zond"). To install an update, simply write the new version of the program over the old one.

If ZondST2D security key driver is not installed, you must install SenseLock security key driver before running the program. To do this open SenseLock folder (driver can be downloaded from the website) and run InstWiz3.exe file. Once the driver is installed, insert the key. If everything is OK, you will see a message in the lower system panel that the key is detected.

To remove the program, erase the program's working directory.

Symbols used in the program

X, Y, Z - measured components of the seismic signal.

H, V - horizontal average and vertical components.

t - time in seconds.

f is the frequency in hertz.

H - layer thickness in meters.

V_p - velocity of longitudinal waves, km/sec.

V_s - speed of transverse waves, km/sec.



ρ - density of rocks in the layer (g/cm³).

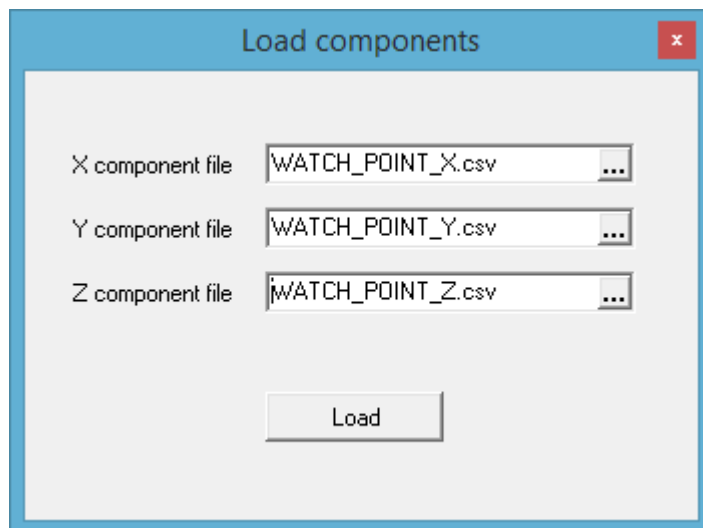
Q_p - attenuation parameter of longitudinal waves.

Q_s is the transverse wave attenuation parameter.

Opening data files

To start working with the Nakamura program, you need to import the time series from a file(s) of a certain format containing the seismic records of the three components. Usually one file containing all three components is used, or three files each containing only one component.

If the components are in different files, you can load them using the first toolbar  button. In the dialog box that appears next, select the files that correspond to each component. The button to  the right of the input field is used for selection.



The csv files loaded in this way have the following structure:

site1 ! first line, arbitrary text information


point1 ! second line, arbitrary text information

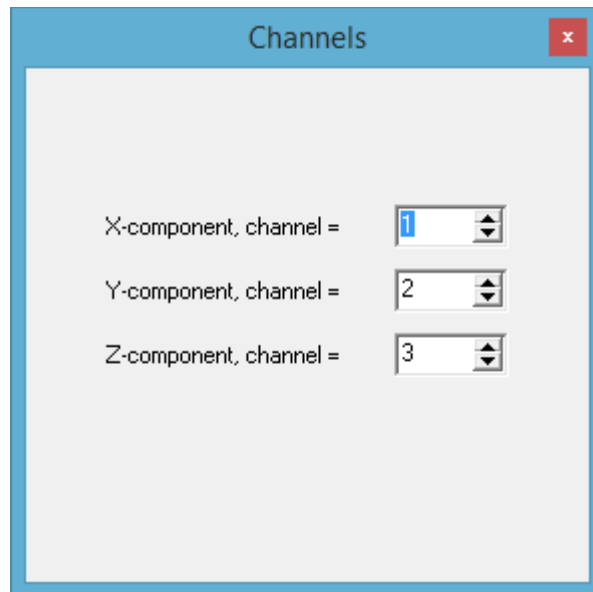
time,sec comp ! third line, arbitrary text information

0.0078125000 0 .07430157240699 ! All subsequent lines contain two entries

0.0156250000 0	.07419814081753 ! time (sec) and measured value of the field component
0.0234375000	0.07390537682702
0.0312500000	0.07349690970253

.....

If the field components are contained in one file, e.g. sg2 (or saf) format, they can be loaded using the button . In the following dialog box, select which channel the component corresponds to.

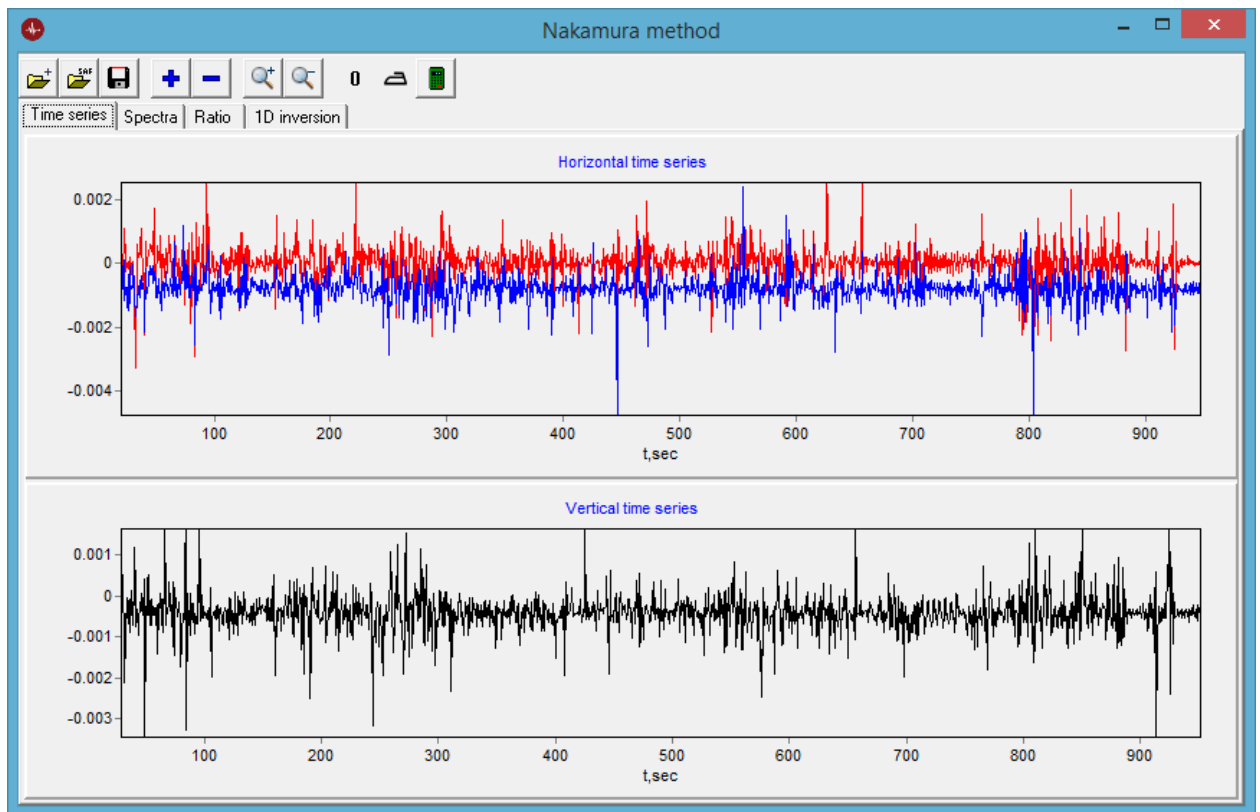


A dialog box titled "Channels" with a blue border and a red close button in the top right corner. Inside the dialog, there are three rows of labels and spinners:

X-component, channel =	<input type="text" value="1"/>
Y-component, channel =	<input type="text" value="2"/>
Z-component, channel =	<input type="text" value="3"/>









Main program window



The main program window consists of a toolbar and a multi-layered section implementing the different stages of processing and interpreting the HVSR method data.



Toolbar of the main program window

The toolbar is used to quickly call the most frequently used functions in the program. It contains the following function buttons (from left to right):



	Load time series from three csv text files.
	Load the time series from the seg2 or saf file. You must select which channel each of the three components corresponds to.
	Save the spectral ratio or interpretation result either to a text file or an excel spreadsheet.
	Set a new window for calculating the spectrum. The window is set with the mouse on the graphs of the first tab of the Time series.
	Delete the selected (with the mouse) spectrum calculation window.
	Increase the horizontal scale of the time series display. At that, scroll bars will appear in the lower areas of the sections.
	Decreasing the horizontal scale of time series display.
	Bring the time series to the zero mean. This operation can distort information about low frequencies.

	Mode of additional smoothing of the resulting spectral ratio (if the curve shows very many features).
	Depending on the active tab, this button is used to calculate the spectral ratio (first three tabs) or to calculate the model response (1D inversion tab). When calculating the spectral ratio, it is necessary to set at least one spectrum calculation window.

How to work with the program

After the time series have been successfully loaded, they will be displayed in the two sections of the first tab of the Time series window. This tab is intended for the analysis of the time series and the selection of the spectrum calculation windows. The tab is divided into two sections: the upper one contains the horizontal components and the lower one contains the vertical components.

To zoom or move an individual section of the graph, use the mouse. To select the area to be zoomed in, the mouse pointer moves down and to the right, with the left button pressed. To return to the original scale, the same actions are performed, but the mouse moves up and to the left.

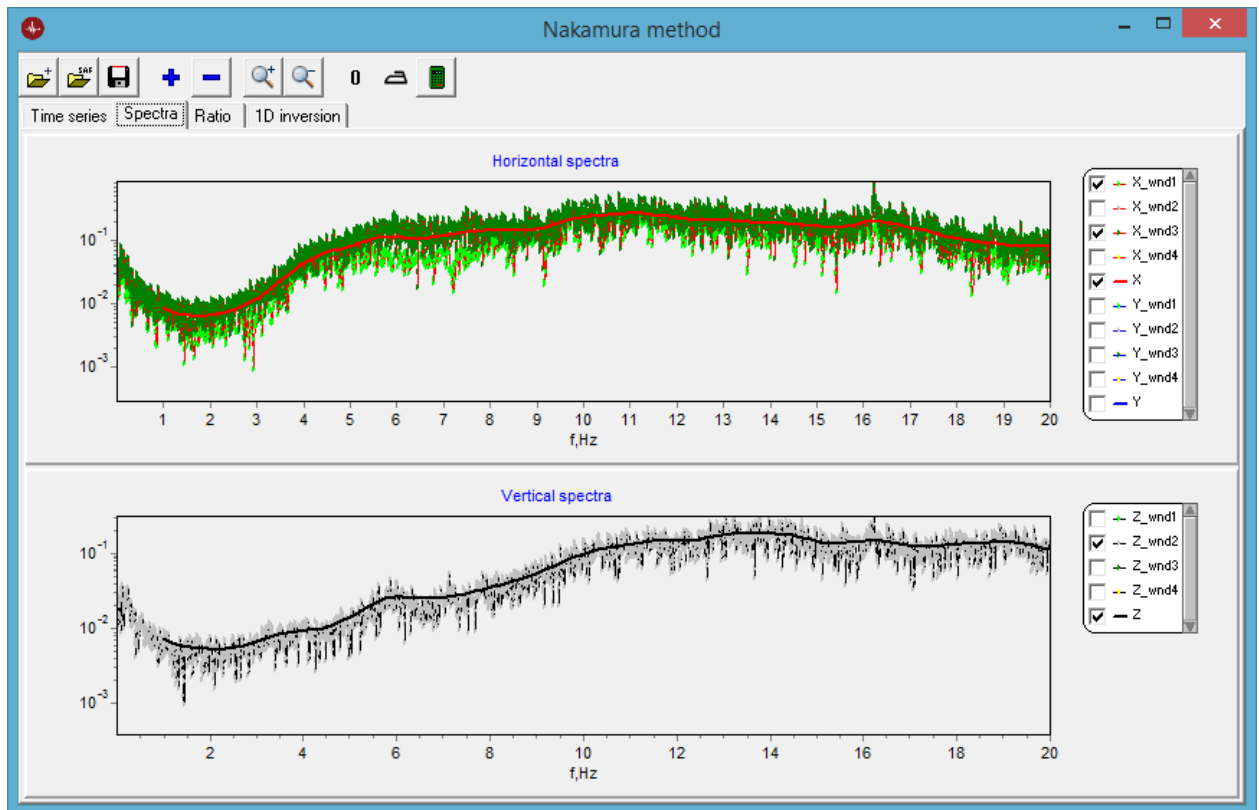
Creation of a new window starts by clicking the button , after that you can start selecting the size of the window directly on the graphs with time series. To set the window, click the left mouse button at the point corresponding to the beginning of the time range (directly on the graph). The cursor moves to the end of the supposed time range of the window and the button is released. It is necessary to avoid windows in which there are local strong jumps. It is desirable that the data within the window be sufficiently homogeneous. To delete a window, first press the button  and then the window to be deleted.



When selecting windows, the following rules should be followed:

- The more windows, the more reliable the spectrum can be obtained. But if the windows are too small, you can "lose" the low frequencies.
- You should choose windows of approximately equal length.
- Too many windows makes it difficult to see and cull.

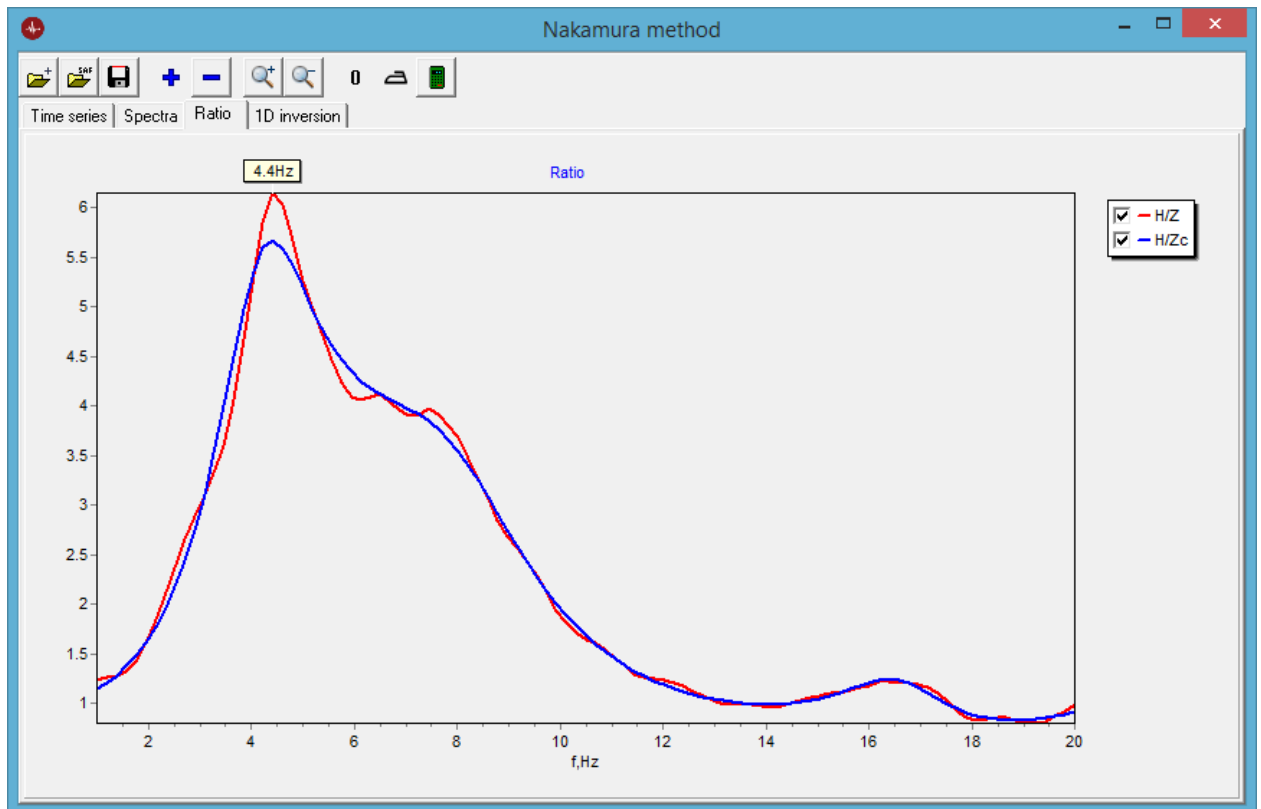
We recommend using 4-6 windows when constructing the spectral ratio. On the one hand, this will not complicate the rejection of spectra, on the other hand, it will allow to obtain a reliable resulting spectrum in a sufficiently wide frequency range.

The second tab Spectra is intended for analysis and rejection of spectra. In the two sections of the tab, the spectra for each window and the resulting smoothed spectrum are plotted (the upper section contains the horizontal spectra, the lower section the vertical spectra). In the legend on the right, you can select which of the spectra should be shown and which should not. This makes it possible to compare the spectra of different windows. The wndN caption means the number of the window for which the spectrum is calculated.



If the spectrum for a window is very different from the rest or the average, its window can be deleted in the first tab, using the button . After that, it is necessary to perform the calculation again . The range of spectrum calculation is set in the 1D inversion tab by options Min freq, Max freq.

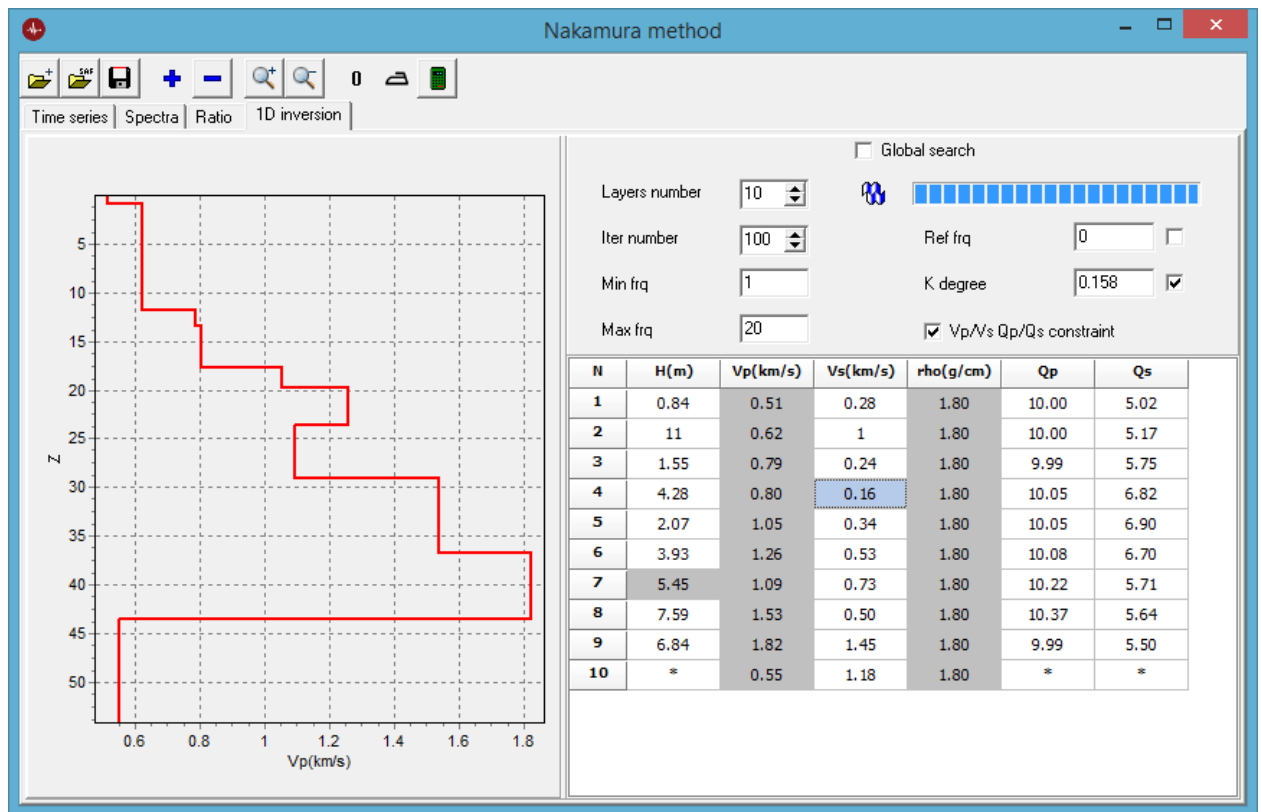
The next tab Ratio shows the calculated spectral ratio (red curve), for the average spectra.



The peak frequency value of primary interest for the HVSR method is shown as a label on the curve.

If an inversion has already been performed, the blue curve shows the theoretical relationship for the resulting model.

The next tab 1D inversion is for inverting the field data of the spectral ratio. Since the results of such inversion should not be trusted too much, the set of options for setting the inversion is very limited.



The right side displays the model of one of the parameters, the right side displays the parameter table and the inversion settings. In order to display one or another parameter in the right section or to set this parameter for inversion, you must click on the column header of this parameter with the mouse.

Settings

Values ☐

Start value: 0.50
 Inc factor: 1.10


Limits ☐

Minimum: ×
 Maximum: ×

☒ Invert ☒

Apply

In the window that appears, you can set the initial model for this type of parameters or set parameter limits for inversion. In the Values area (if the option to the right of Values is selected) the value of the parameter in the first layer and the coefficient of increase of this parameter in each subsequent layer are set. In the Limits area (if the option to the right of Limits is selected) sets the limits of change for the given parameter during inversion. The option to the right of Invert determines whether this type of parameter should be adjusted if Invert itself is on. After exiting the dialog box, the parameter being adjusted becomes active and is displayed in the graphical section on the right.


Parameters not participating in the inversion are displayed in dark gray in the table. To exclude a certain parameter of one of the layers from the inversion, right-click on it in the table. Parameters can be edited in the table using the keyboard. After editing you can calculate the response with the button  and see the result in the previous tab.

Setting up the simulation parameters, inversion and others, is done in the area above the table.

Layers number option - sets the number of model layers for modeling and inversion. The partitioning algorithm can be set by left-clicking the power column header in the table.

The *Iter number* option sets the number of inversion iterations.

The options *min freq*, *max freq* set the frequency range for which all spectra will be calculated and the inverse problem will be solved.

The button  Ratio tab.


Global search option - enables the global model search algorithm within a given range of parameter changes. This option should be enabled if it is not possible to find a satisfactory model using standard inversion. Global search does not require a good initial approximation, but the parameter variation ranges should be narrow enough.

The *Ref freq* option sets the reference frequency to calculate the response from the model. If it is unknown, it should be set to zero. The reference frequency can be picked up during inversion, if the option to the right of the input field is selected.

The *K - degree* option sets the model attenuation coefficient. It is usually selected in the inversion process (the option to the right of the input field is selected).

Vp/Vs Qp/Qs constraint option - limits Vp/Vs and Qp/Qs parameter ratios in the inversion to a reasonable range.

Saving results

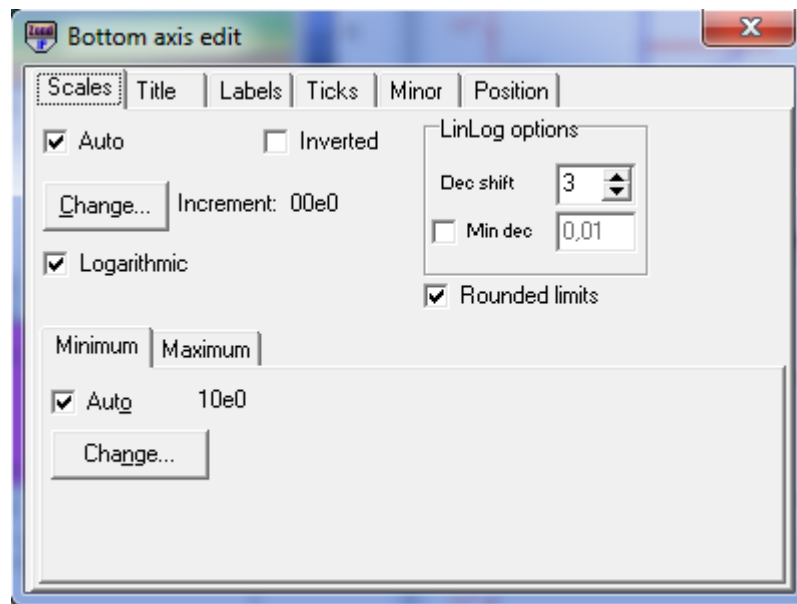
The result of the processing or interpretation of the data interpretation result, you can click the button on the toolbar  In the dialog box that appears, you can select one of the following options:

Spectrum to text file - save the spectral ratio to a text file.

Spectrum to Excel file - save the spectrum ratio to an Excel table.

Model to text file - save the result of the inversion to a text file.

Axis editor



The editor is intended for adjusting the graphical and scale parameters of the axes. It can be called by right-clicking with the SHIFT key on the axis of interest. A pop-up menu with three items appears: **Options**, **Default** and **Fix range**. The first calls the Axis Editor dialog box, the second sets the values equal to the default ones, and the third fixes the axis within the current limits.

The first tab of the **Scales** dialog box contains options related to adjusting the scale parameters of the axis.

The **Auto** option tells the program how to determine the minimum and maximum of the axis. If the option is enabled, the axis limits are found automatically, otherwise they are set by the user in the Minimum and Maximum areas.

The **Inverted** option determines the orientation of the axis.

The **Increment change** button brings up a dialog box for setting the axis label step.

The **Logarithmic** option sets the axis scale - logarithmic or linear. In the case of an alternating axis you should additionally use the options of the **LinLog options** area.

The **LinLog options** area contains options designed to adjust the linear-logarithmic axis. The linear-logarithmic scale allows you to represent alternating or zero containing data on a logarithmic scale.

The **Dec Shift** option sets the offset (in logarithmic decades) relative to the maximum modulo limit of the axis to zero. The minimum (pre-zero) decade has a linear scale, the rest have a logarithmic scale.

The **Min dec** option sets and fixes the value of the minimum (pre-zero) decade, if the option is enabled.

The **Rounded limits** option tells the program whether or not to round the axis minimum and maximum values.

The **Minimum** and **Maximum** areas contain a set of options for setting the axis limits.

The **Auto** option determines how the axis limit is determined - automatically or set with the **Change** button.

The **Title** tab contains options related to setting the title of the axis.

The **Style** tab:

The **Title** option defines the title text of the axis.

The **Angle** option determines the angle of the axis header text.

The **Size** option defines the indent of the axis header text. When set to 0, the indentation is set automatically.

The **Visible** option allows you to show/hide the axis header.

Text tab:

The **Font** button brings up a dialog box for setting the font for the axis header.

The **Outline** button brings up a dialog box for setting the outline lines of the axis header letters.

The **Labels** tab contains options related to configuring the axis labels.

The **Style** tab:

The **Visible** option allows you to show/hide axis signatures.

The **Offset** option sets the percentage shift of the axis limit relative to its actual value.

The **Angle** option defines the angle of the axis caption text.

The **Min separation %** option sets the minimum percentage distance between signatures.

Text tab:

The **Font** button brings up a dialog box for setting the font for the axis captions.

The **Outline** button brings up a dialog box for setting the outline lines of the axis captions.

The **Ticks** tab contains options related to setting the main axis labels.

The **Axis** button brings up the Axis line setup dialog box.

The **Grid** button brings up a dialog box for setting the grid lines of the main axis labels.

The **Ticks** button brings up a dialog box for setting the lines of the main external axis labels. The **Len** option sets their length.

The **Inner** button brings up a dialog box for setting the lines of the main internal axis labels. The **Len** option sets their length.

The **At labels only** option tells the program to draw the main labels only when there is a signature on the axis.

The **Axis behind** option sets the order in which the axes and graphs are drawn.

The **Minor** tab contains options related to the setting of intermediate axis labels.

The **Ticks** button brings up a dialog box for setting the lines of intermediate external axis labels.

The **Grid** button brings up a dialog box for configuring the grid lines of intermediate axis labels.

The **Length** option sets their length.

The **Count** option sets the number of secondary labels between the main labels.

The **Position** tab contains options that define the dimensions and position of the axis.

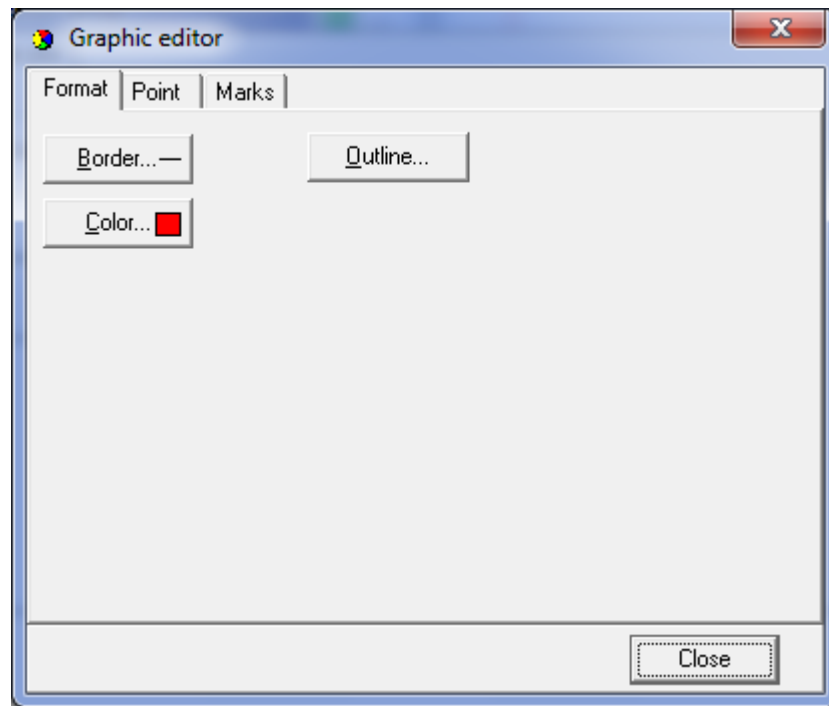
The **Position %** option sets the offset of the axis on the graph relative to the standard position (as a percentage of the graph size or screen units, depending on the value selected by the Units option).

The **Start %** option sets the offset of the axis start on the graph relative to the standard position (as a percentage of the graph size).

The **End %** option sets the offset of the axis end on the graph relative to the standard position (as a percentage of the graph size).

The **Other side** option allows you to draw the axis from the back side. If the option applies to the bottom axis, the axis will be drawn from the top.

Graphics Editor



The editor is intended for adjusting the appearance of the graph. It can be called by right-clicking with the SHIFT key on the graph.

The **Format** tab contains settings for the connecting lines of the graph.

The **Border** button opens a dialog box for setting the parameters of the connection lines of the graph.

The **Color** button brings up a dialog box for selecting the color of the graph.

The **Outline** button brings up a dialog box for setting the parameters for outlining the connecting lines of the graph.

The **Point** tab contains the settings for the graph pointers.

The **Visible** option allows you to show/hide the graph pointers.

The **Style** option sets the shape of the pointer.

The **Error gates** option allows you to display the confidence limits of the measurement point, if any.

The **Width** option sets the width of the pointer in screen units.

The **Height** option sets the height of the pointer in screen units.

The **Pattern** button opens a dialog box for selecting the pointer fill options.

The **Border** button opens a dialog box for configuring the pointer outline settings.

The **Marks** tab contains the settings for the labels of the graph indicators.

The **Style** tab.

The **Visible** option allows you to show/hide the captions to the graph pointers.

The **Draw every** option allows you to draw every second, third, etc. signature, depending on the value selected.

The **Angle** option determines the angle of the caption text to the pointers.

The **Clipped** option specifies whether a caption should be drawn to a pointer if it extends beyond the graph area.

The **Arrows** tab is used to customize the appearance of the arrow going from the caption to the pointer.

The **Border** button brings up a dialog box for setting the arrow line parameters.

The **Length** option sets the length of the arrow.

The **Distance** option sets the distance between the arrow head and the chart pointer.

The **Format** tab contains the graphical settings for the frame around the pointer caption.

The **Color** button opens a dialog box for selecting the background color of the frame.

The **Frame** button brings up the Frame Line Settings dialog box.

The **Round frame** option allows you to display a frame with rounded corners.

The **Transparent** option sets a transparent background for the caption.

Text tab:

The **Font** button brings up a dialog box to set the font for the signatures of the pointers.

The **Outline** button opens a dialog box for setting the outline of the caption lines pointers.

Additional materials:

Video tutorials on youtube channel:

https://www.youtube.com/channel/UCGtprIIZkc9CsLfiuz4VvmQ?view_as=subscriber

Support group in linkedin:

<https://www.linkedin.com/groups/6667336/>.

Zond demonstration projects:

<ftp://zond-geo.com/>.

Username: download@zond-geo.com

Password: 12345

The program does not work with the USB dongle

1) The dongle driver is not installed or is not installed correctly. On some systems the dongle is detected as a HID device correctly and there is no need to install the driver, but on some systems it is not and must be installed. The link to download the driver: http://senselock.ru/files/senselock_windows_3.1.0.0.zip. In the Device Manager the dongle should appear as "Senselock Elite".

2) The free update period has expired. In this case, you need to use the latest working version or buy an additional 2 years of updates.

3) Sometimes when you switch the dongle to HID mode, the system may not recognize it as a HID device. In this case you need to switch it back to USB mode with a small application which can be downloaded from the following link: <http://www.zond-geo.com/zfiles/raznoe/SenseSwitch.zip> "senseswitch.exe" is started from the cmd command: senseswitch.exe usb