ASSYST

Offline Rodent EEG Analysis System for Epileptic and Oscillatory Activity Detection

v. 3.2

User's Manual

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Introduction

The *ASSYST* software is an interactive tool aimed to significantly automate the process of identification of seizures and/or other epileptiform events in rodent EEG recordings, in off-line operation mode.

The *ASSYST* is able to read, display, process the rodent EEG recordings, and save the processed results (the times of identified seizures and/or other events).

The *ASSYST* uses an advanced time-frequency analysis technique to reveal the EEG segments with excessive activity in a certain frequency band. The spectral content of the EEG within the frequency band is assessed by Spectral Band Index (SBI), which is derived from the power spectrum. The SBI is calculated over time using a pre-determined running time window. Based on the distribution histogram of SBI values, a threshold to discriminate between background and excessive activity is defined. This threshold then may be manually adjusted by the user to suit specific user needs (e.g., the threshold may be lowered to capture weaker or shorter events).

After the threshold is defined, all episodes of the EEG for which the SBI is above the threshold, are found and placed in a list of events with start and end times. The start and end times of the selected events are roughly determined as the points where the SBI curve crosses the threshold.

The final stage of processing requires input from the user to verify the selected events. The software advances from event to event and the user visually examines the selected events by advancing from event to event and reviewing the EEG raw data at the event time and classifies them as seizures, artefacts or other events. By default, there are two predefined categories in the program: "Seizures" and "Artefacts". The user can rename these categories and can also create arbitrary number of additional event categories. The user can reset the start and end times of the events manually when viewing the EEG, simply moving special cursors to desired positions on the EEG; and can also enter annotations or comments for each event.

For some types of events the user may apply an automatic procedure for event identification and classification. Currently, two such procedures are implemented in *ASSYST*: a procedure for automatic identification of spike-wave discharges (SWD), and a procedure for automatic identification of large instrumental artefacts.

After the processing, the identified EEG events in each category are saved in the output file(s).

What's New in ASSYST v. 3.0

ASSYST 3.0 has a key advantage compared to versions 2.0 and 2.1: it is powered with a new algorithm for automatic identification of events with regular repetitive structure,

such as spike-wave discharges. The algorithm, which is applied after the time-frequency analysis and the threshold-based event selection, can automatically distinguish spike-wave discharges from artefacts with a remarkable accuracy.

In contrast to rodent models that have few strong seizures during several weeks, the models with SWDs (e.g., GAERS or WAG/Rij) usually exhibit hundreds of SWDs in an hour. In such cases the number of events initially selected by *ASSYST*, based on SBI threshold, may be few thousands in just several hours-long recordings. Visual examination of such high number of selected events, to reveal artefacts or other irrelevant events, requires significant time from the user though still much less than visual examination of the entire EEG. With *ASSYST 3.0*, this will be much easier and faster.

What's New in ASSYST v. 3.1

In previous versions of the program it was possible to use a montage (i.e., linear combination of original EEG channel) by loading a special montage file created either manually or using other software. In version 3.1 it is possible to define and use a montage directly within the program.

Another addition is the possibility to measure intervals (and their reciprocal, i.e., the frequency) between specified points of the signal. This is very handy when defining the frequency range of SWDs.

Also, now it is possible to output some additional characteristics of the power spectrum of the selected events.

In addition, some changes are made in the SWD identification algorithm, which should improve performance especially for shorter events.

What's New in ASSYST v. 3.2

In the SWD identification algorithm, a new optional module is added aimed to eliminate too weak and too strong events (artifacts) that accidentally pass the running beat spectrum criteria. The algorithm is based on analysis of line length of the selected events.

1. The *ASSYST* Main Window

When the program is executed, the main window of the program shown in Fig. 1.1.1 appears. It contains a Menu bar, some controls on the upper panel (Fig.1.2.1), and a page control (or tab control). The page control has four tabs:

- SBI & Channels (see 1.3 The SBI & Channels tab)

- SBI Histogram (see 1.4 The SBI Histogram tab)

- Signal & Spectrum (see 1.5 The Signal & Spectrum tab)

- Parameters (see 1.6. The Parameters tab)

When the program opens, the active (visible) tab is "SBI & Channels". This is the main operational tab.
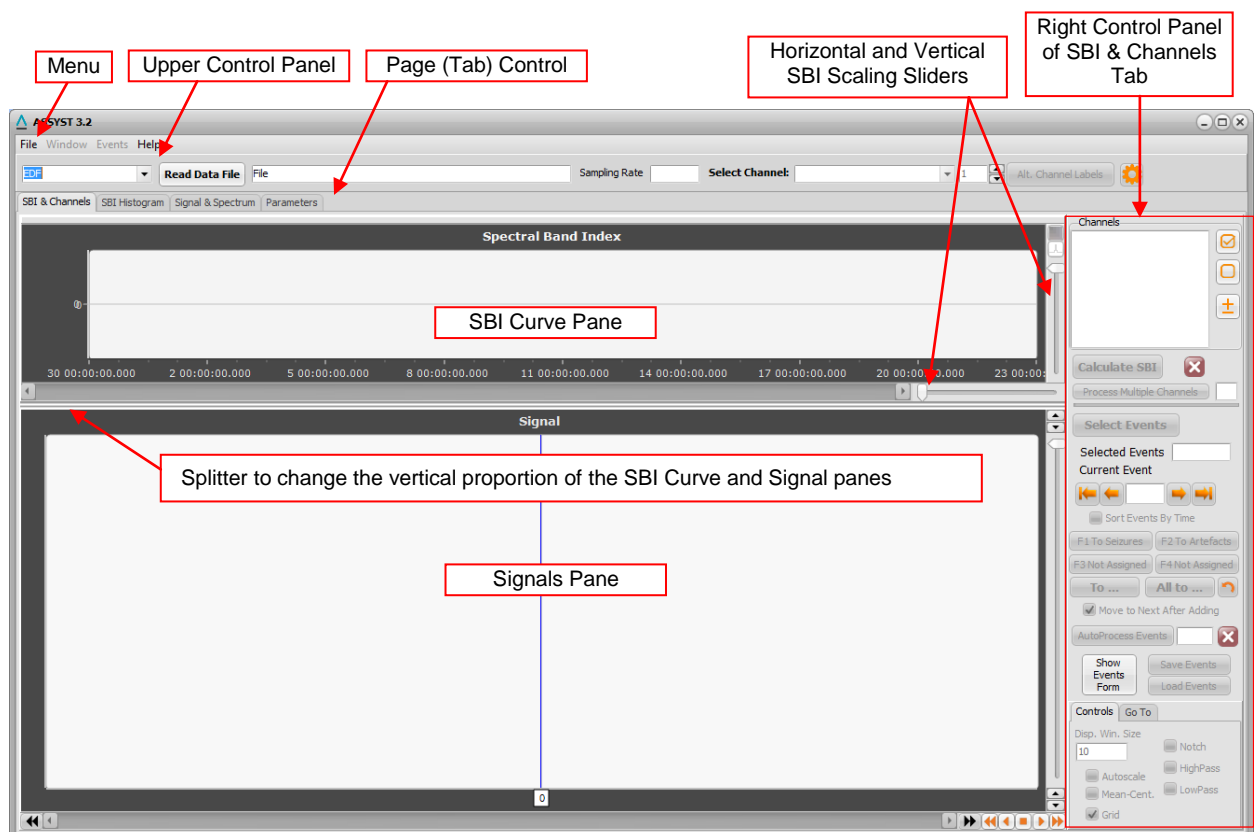
Fig. 1.1.1. The main window with the "SBI & Channels" tab open.

1.1 The Menu

The menu items and description of actions they perform are listed below:

File Menu (Fig. 1.1.2):
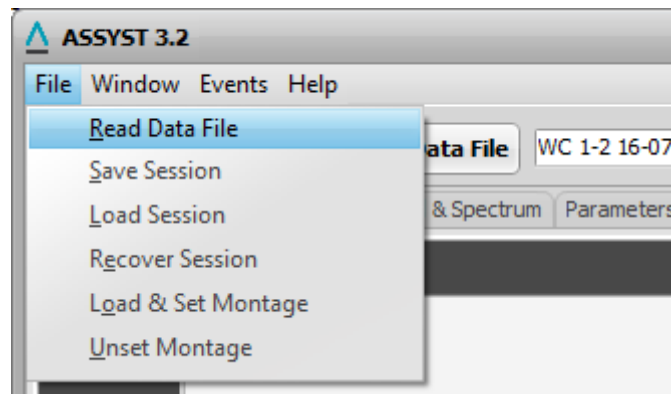
Fig. 1.1.2. File menu

Read Data File — Opens a standard "Open File" or "Select Directory" dialog (depending on the selected data file format, see 1.2 Upper Control Panel) where the user selects the EEG data to be loaded;

Save Session — Saves the current session, including all parameter settings, input data information, SBI curve, selected threshold and all selected and classified events, in a session file specified by the user (by means of a standard "Save file" dialog); this allows interrupting the work at any moment and continuing it later from the same point (by loading the previously saved session);

Load Session — Loads a previously saved session from a session file selected by the user (by means of a standard "Open file" dialog);

Recover Session — Recovers the last auto-saved session;

Load & Set Montage — Loads a standard montage file (must be an xml file with extension ".mtg"); the montage must be defined on the same channel set as the input EEG data, otherwise an error message will appear, and thus it must be loaded after the EEG data; the montage may contain any number of new channels, each one of which may be a linear combination (sum or difference) of several original channels; after loading a montage file the original channel list is replaced by the montage channels, and all subsequent processing is performed on these montage channels;

Unset Montage — Removes the montage and reverts to original channels.

Window Menu (Fig. 1.1.3):
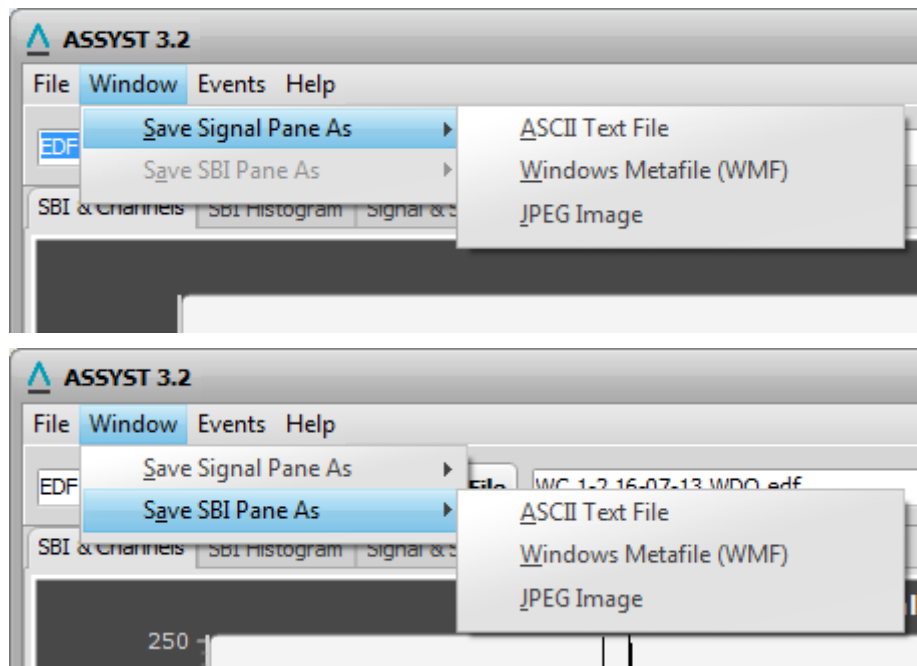
Fig. 1.1.3. Window menu and sub-menus

Save Signal Pane As ► - Saves the signal fragment visible in the current window shown in the Signal pane in one of the following formats (see 4.2. Additional output - current window's signal):

ASCII Text File   - Saves the signal values in a text file (each displayed channel as a column)

Windows Metafile (WMF) - Saves the image of the Signal pane as Windows Metafile (vector graphics format)

JPEG Image   - Saves the image of the Signal pane as JPEG Image

Save SBI Pane As ►   - Saves the SBI curve visible in the Signal pane in one of the following formats (see 4.3. Additional output - SBI curve):

ASCII Text File   - Saves the SBI values in a text file

Windows Metafile (WMF) - Saves the image of the SBI pane as Windows Metafile (vector graphics format)

JPEG Image   - Saves the image of the SBI pane as JPEG Image.

Events Menu (Fig. 1.1.4):

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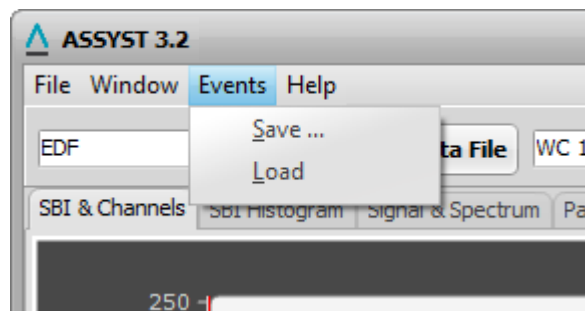
Fig. 1.1.4. Events menu

Save...   Opens the "Save Events" dialog to save the events that were added to the event categories to file(s) (see 4.1. The main output – selected events)

Load   Load events categories and events therein from a file that was saved earlier (by means of a standard "Open file" dialog)

Help Menu:

Contents   - Opens Help Window

1.2 Upper Control Panel

The Upper control panel (Fig. 1.2.1) contains the following controls (from left to right).
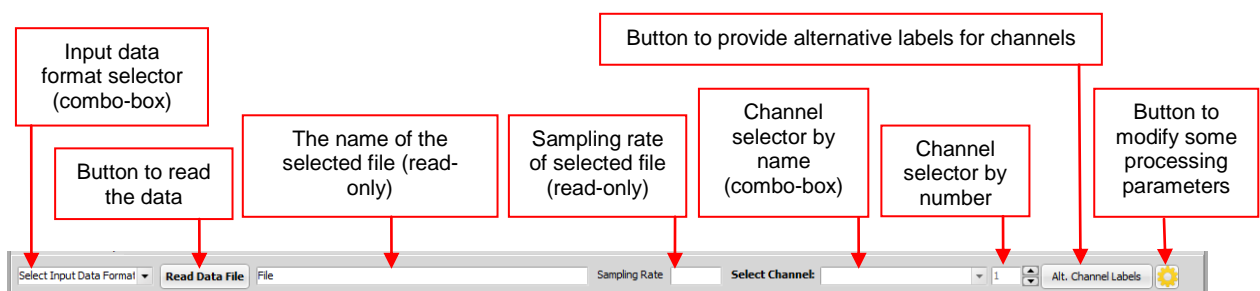
Fig. 1.2.1. Upper Control Panel.

Select Input Data Format combo box   - allows selecting the format of input data. ASSYST can read and process the EEG data of following formats:

European Data Format (EDF)

Compumedics Profusion4

Ripple NSx

Acknowledge ACQ

Accordingly, the Select Input Data combo box contains following items:

EDF

Profusion4

NEV-NSx

ACQ

Read Data File button – allows selecting and loading the data.

File   – a read-only field that displays the name of the loaded file (in case of EDF) or the name of the data directory (in case of Profusion4).

Sampling Rate – a read-only field that displays the sampling rate of the loaded data.

Select Channel – two interconnected controls: a combo box and a spin control, to select the channel either by its label (combo box) or by its serial number (spin control).

Alt. Channel Labels button – opens a dialog allowing to define different (alternative) labels for each channel (see 2.1. Alternative Channel Labels Dialog)

⚙ button – opens a dialog to modify some of the processing parameters (see 2.2. Processing Parameters Dialog).

1.3 The SBI & Channels tab

The "SBI & Channels" tab contains two horizontal panes designed to display the EEG (Signal pane, bottom, Fig. 1.1.1 and Fig. 1.3.4) and the Spectral Band Index curve (SBI Curve pane, top, Fig. 1.1.1 and Fig. 1.3.1), and a panel with several buttons and other controls on the right side (Control panel).

The SBI Curve and Signal panes are separated by a horizontal moveable splitter allowing to change the vertical space allocation between the SBI and Signal panes (this is useful, e.g. when displaying many channels when more vertical space is needed for the Signal pane).

1.3.1 The SBI Pane
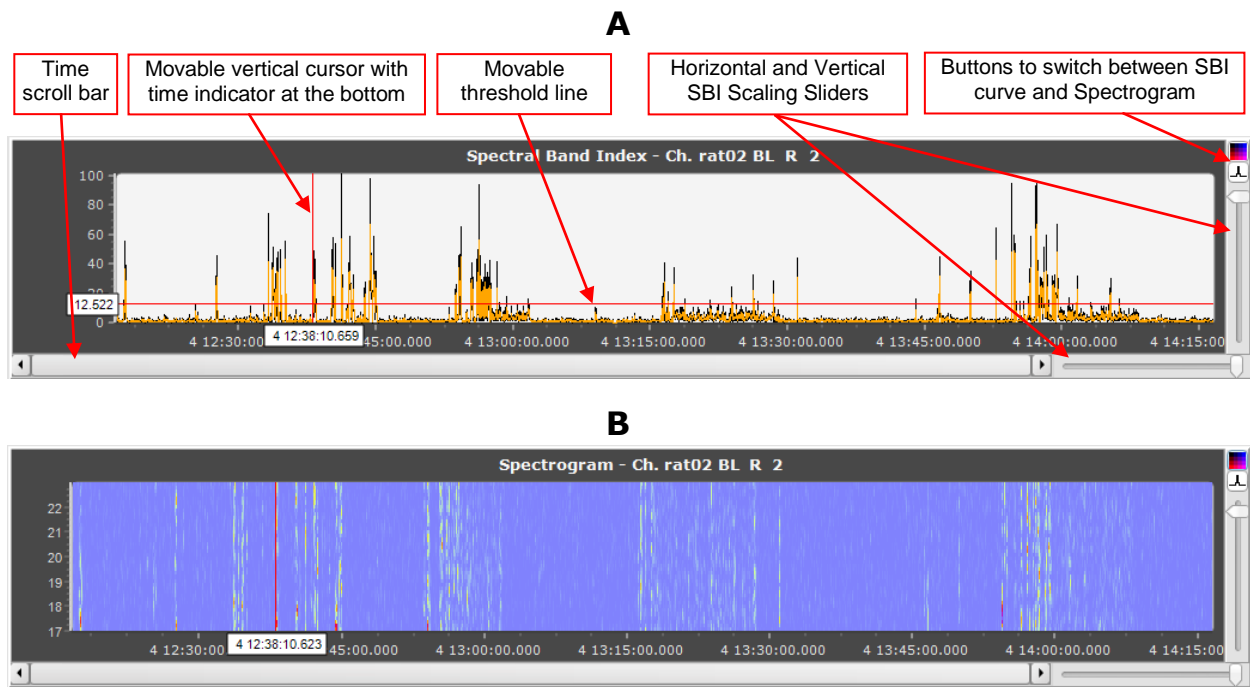
Fig. 1.3.1. A. The SBI pane showing the original (black line) and smoothed (orange line) SBI curves, in full vertical and horizontal scales (the sliders are in their extreme maximum positions). The time scroll bar in this case is not functional, since the entire curve is shown.
B. The SBI pane showing the Spectrogram.

The SBI pane (Fig. 1.3.1) is designed to show the spectral band index curve (Fig. 1.3.1 A), which is calculated when the user presses the "Calculate SBI" button on the right panel, or the spectrogram (Fig. 1.3.1 B), if the option to calculate spectrogram is selected on the "Advanced" sub-tab of "Parameters" tab (see 1.6.2 The Advanced tab). This pane has two sliders:

Vertical SBI Scaling slider - located on the right side of the pane and used to change the vertical scale of the SBI curve; the upper position of the slider corresponds to the full scale- i.e., in this case the plot shows the SBI curve from its minimum to maximum. As the slider is moved down the vertical scale "stretches up", so smaller SBI peaks become better visible (Fig. 1.3.1). When the spectrogram is displayed, the slider may be used to change to color scale of the spectrogram.

Horizontal SBI Scaling slider – located on the bottom-right side of the SBI pane and used to change the horizontal scale of the SBI curve; the rightmost position of the slider corresponds to the full horizontal (time) scale, i.e., the entire duration of the recording. When the slider is moved left, the time scale "stretches", or zooms in horizontally (Fig. 1.3.2). Note that if the user moves the slider when the spectrogram is displayed, the program automatically switches to displaying the SBI curve. This is done because scaling of the SBI curve is faster than scaling of the spectrogram. After zooming, the user may switch back to spectrogram by pressing the ■ (Show Spectrogram) button, and the spectrogram will be horizontally scaled according to the SBI curve.

Above the vertical scaling slider there are two buttons for switching between SBI curve plot and Spectrogram plot. These buttons are enabled only if the SBI is calculated with "Calculate Spectrogram" checkbox on the "Advanced" sub-tab of "Parameters" tab (see 1.6.2 The Advanced tab) is checked, and the SBI calculation is performed for single channel (see 5.1. Single channel processing; the Spectrogram currently is not calculated in multiple channels processing mode).

■(Show Spectrogram) button - shows the Spectrogram (if was calculated) in the SBI pane;

⊥(Show SBI) button - shows the SBI curve(s) in the SBI pane.

The SBI pane has also a scroll bar (at the bottom, Figs. 1.3.1, 1.3.2) that can be used to scroll the visible part of the SBI graph along the horizontal time axis. The width of the thumb tab (Fig. 1.3.2) of the scroll bar is proportional to the width of the visible part of SBI graph. When the entire time range of the SBI graph is visible (i.e., the horizontal slider is in the rightmost position) the thumb tab occupies the entire scroll bar (see Fig 1.3.1).

The scrolling can be done either by moving the thumb tab left or right, clicking the left or right arrow buttons of the scroll bar (to scroll in small steps), or clicking the scroll bar outside the thumb tab (to scroll in larger steps). Alternatively, the scrolling of the SBI graph can be done using the mouse wheel or the left and right arrow keys of the keyboard when the mouse pointer is placed inside the SBI pane.

There are two movable lines on the SBI pane: the vertical red cursor indicating the position in current time (*the time cursor*) and the horizontal red line indicating the threshold for separating significant and not significant SBI values (*the threshold*). The time cursor works for both SBI curve plot and Spectrogram, the threshold works only for SBI curve plot.

The *time cursor* can be moved horizontally by dragging it with mouse or by just clicking at the desired location in the SBI pane. When the time cursor is moved to a new position, the Signal pane (see 1.3.2 The Signal Pane) is updated accordingly to show the corresponding EEG fragment.

The *threshold* can be moved vertically by dragging it with mouse. When the threshold is moved to a new position, the coupled threshold line (vertical) on the histogram plot on the SBI Histogram tab (see 1.4 The SBI Histogram tab) automatically moves to the corresponding position.

A

| Click this button to scroll left with small step | Click in this area to scroll left with large step | Thumb tab, its size is proportional to the width of the visible part of the SBI graph | Click in this area to scroll right with large step | Click this button to scroll right with small step |

B
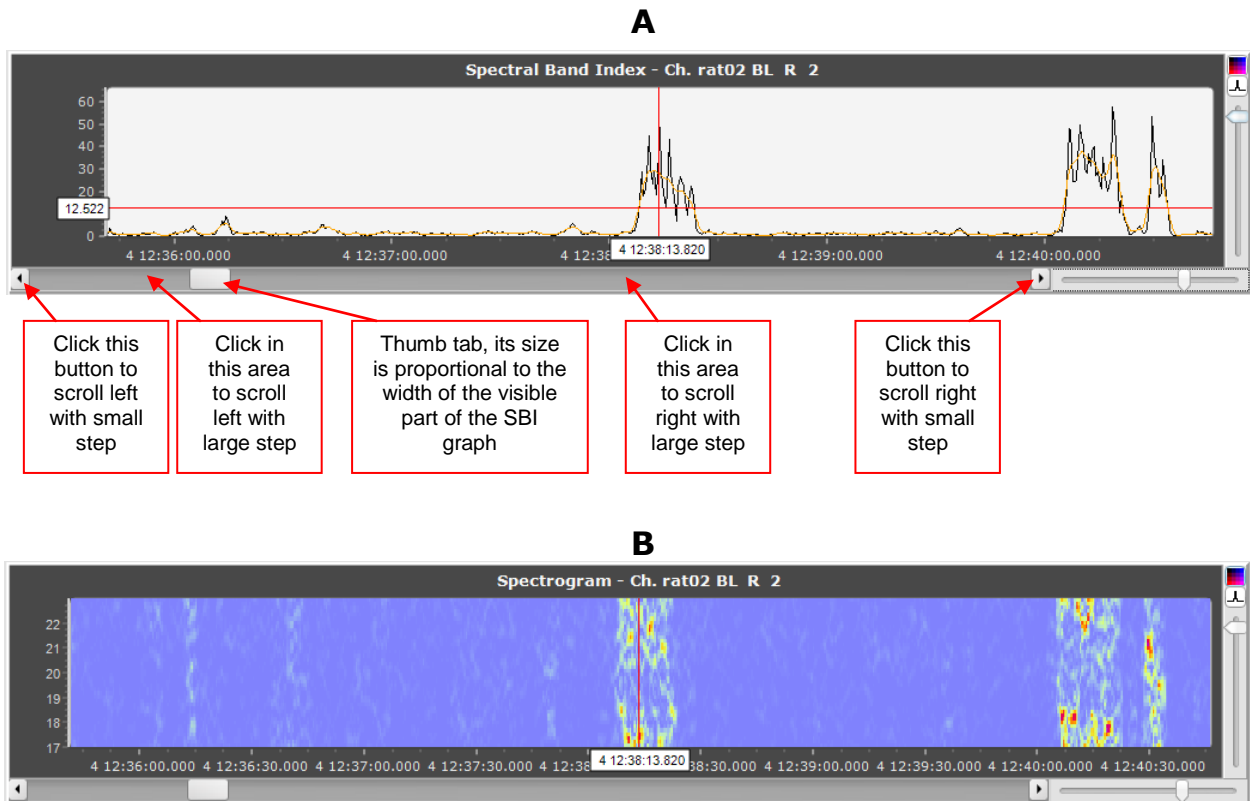
Fig. 1.3.2. A. The SBI pane showing original (black line) and smoothed (orange line) SBI curves, which are zoomed in using the vertical and horizontal sliders. The time scroll bar can be used to scroll the graph along the time (horizontal) axis.
B. The SBI pane showing the spectrogram after zooming.

The SBI pane has also a popup menu that appears when the user right-clicks in the pane (Fig. 1.3.3).
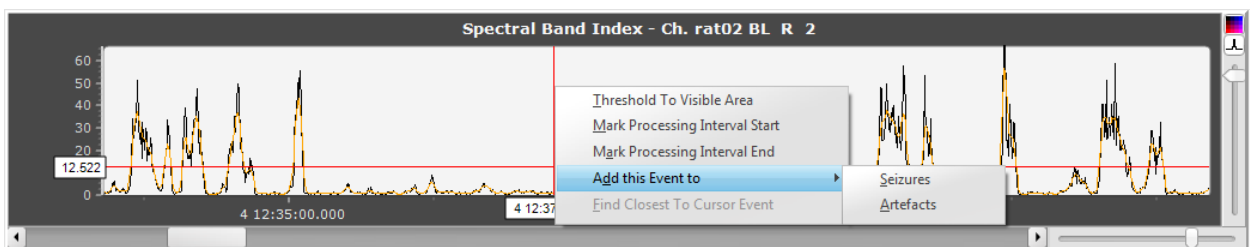
Fig. 1.3.3. The SBI pane with popup menus shown.

The popup menu items and description of actions they perform are listed below:

Threshold To Visible Area – Sets the threshold position to the center of the zoom (visible) area of the SBI plot; this option is useful when due to vertical

zooming in the current threshold position goes beyond the visible plot area, and the user wants to bring it in to manually set a new threshold position;

Mark Processing Interval Start – Sets the current time cursor position as the start of SBI processing time interval;

Mark Processing Interval End – Sets the current time cursor position as the end of SBI processing time interval;

Add this Event to – Adds the time window corresponding to the current position of the time cursor to an Event Category as an event. When this menu item is selected, a sub-menu appears that contains the list of existing event categories, from which the user selects the desired one (Fig. 1.3.3). The event of the size of one window will be added to the selected category, and the corresponding EEG fragment will be shown in the Signal pane, with the added window highlighted by a pink band. The user can then move the highlighting band edges to properly mark the event's start and end positions.

Find Closest To Cursor Event – finds in the preliminary event list (see 1.3.3 The Control Panel) the event which is closest, in terms of time, to the current vertical cursor position of the SBI pane, and sets this event as current event, updating accordingly the Signal pane and the SBI pane; this item will be enabled only if the preliminary event list is defined (i.e., after the "Select Events" button press).

The Mark Processing Interval Start and Mark Processing Interval End items of the popup menu allow to define a shorter time interval than the entire record duration for the analysis of the calculated SBI curve (including the histogram calculation and automatic threshold definition, see 5.1.6. Specifying the processing interval (if needed)) and selecting the episodes of signal with excessive SBI values (the action that is performed when the user presses the "Select Events" button, see 1.3.3 The Control Panel). This might be useful when, for example, part of the record is damaged or contaminated with strong artefacts, which would produce excessively high SBI values, which in turn would result in too high automatic threshold, so important events (e.g. seizures) will be missed. So in such cases the user might want to perform the analysis only in the "healthy" part of the record.

Note, that if the processing interval is redefined by the user who then wants the automatic threshold to be recalculated accordingly, the user has to press the "SBI Histogram & Auto Threshold" button in the *SBI Processing Parameters* group of the Advanced sub-tab of the Parameters tab (see 1.6.2 The Advanced tab) *before* pressing the "Select Events" button on the Control Panel of the SBI & Channels tab.

1.3.2 The Signal Pane

The Signal pane is designed to show the EEG signals of the user selected channels (Fig. 1.3.4).
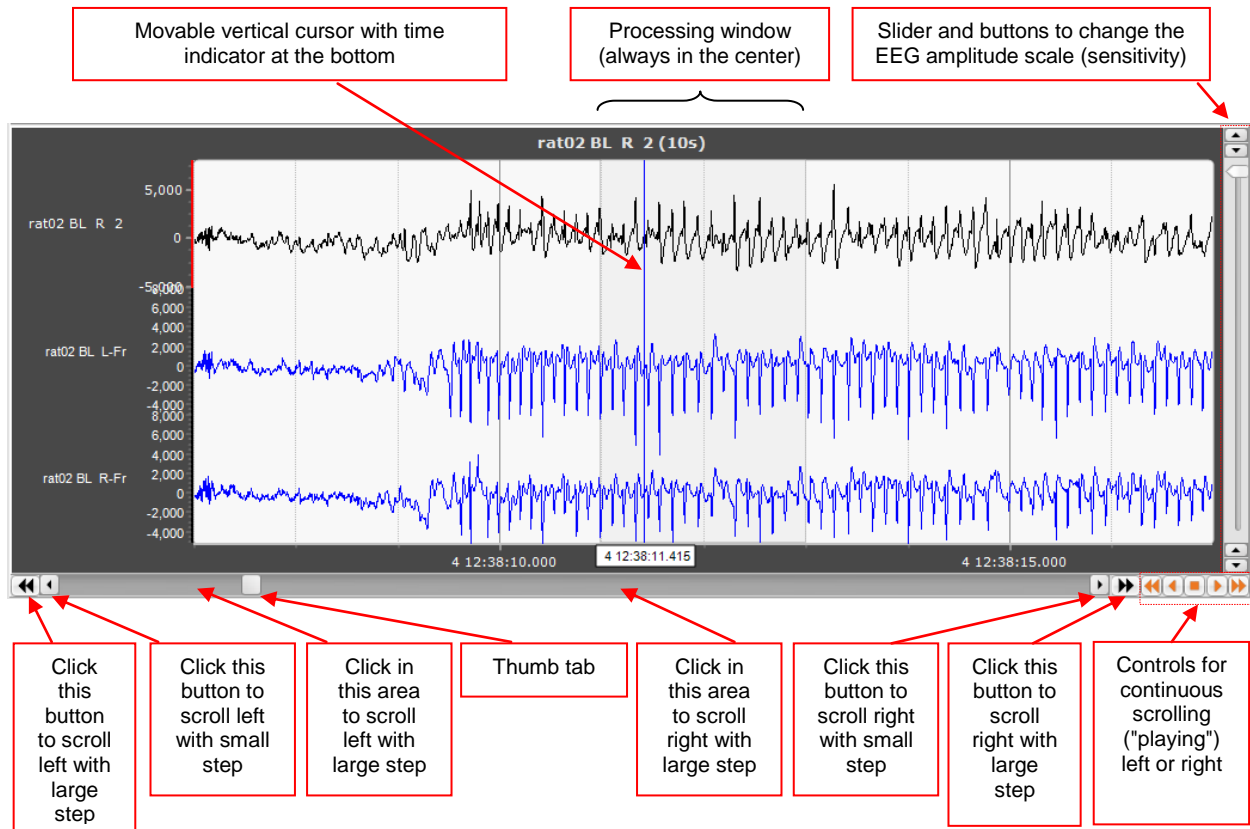
Fig. 1.3.4. The Signal pane showing three EEG channels. The active channel (the channel selected in the upper control panel) is black, others are blue.

The active channel, i.e., the channel that is selected for processing (in the upper panel of the main window) is always shown in black. In addition, other channels may be shown as well (in blue), according to the selection of checkboxes in the channels list on the Control panel (Fig. 1.3.5).

The duration of the displayed EEG fragment is defined by the "Disp. Win. Size" (Display Window Size) specified (in seconds) in the "Controls" tab on the Control panel (Fig. 1.3.10). Displayed signal window size may be different from the processing window size, which is defined in the parameters (see 1.6.2 The Advanced tab).

The processing window size is indicated on the Signal pane by the gray-shaded vertical band (Fig. 1.3.4).

The Signal pane has a scroll bar at the bottom allowing scrolling along the EEG (Fig 1.3.4)

The scrolling can be done either by moving the thumb tab of the scrollbar left or right, clicking the left (◀) or right (▶) arrow buttons of the scroll bar (to scroll in small steps), or clicking either the scroll bar outside the thumb tab or the ◀◀ or ▶▶ buttons (to scroll in larger steps). Alternatively, the scrolling of the EEG graph can be done using the mouse wheel or the left and right arrow keys of the keyboard when the mouse pointer is inside the Signal pane.

In addition to manual scrolling there is possibility for automatic continuous scrolling along the EEG to the right or to the left ("play" forward or backward) with two different steps: large and small. This is done using the following buttons on the right side of the scroll bar:

◀◀ Fast play backward button - scrolls automatically along EEG to the left with large step;

◀ Play backward button - scrolls automatically along EEG to the left with small step;

■ Stop button - stops automatic scrolling

▶ Play forward button - scrolls automatically along EEG to the right with small step;

▶▶ Fast play forward button - scrolls automatically along EEG to the right with large step.

The buttons ◀◀, ◀, ▶, ▶▶ work in "start/stop" mode: clicking the button first time starts automatic scrolling, clicking second time stops scrolling.

The vertical scale (sensitivity) of the EEG signals can be changed using the arrow buttons and the EEG amplitude scaling slider located at the right side of the Signal pane. The arrow buttons change the global limits (*min* and *max*) for the signal plots, and the slider changes the vertical scale of the signals within these margins. The slider's top position corresponds to showing the full range (from *min* to *max*), and the bottom position corresponds to showing 0.05^{th} of the full range. The vertical scale (and the slider position) can be changed also using the up and down arrow keys of the keyboard when the mouse pointer is inside the Signal pane.

The Signal pane and the SBI pane are dynamically coupled: the red vertical cursor line on the SBI pane is always at the position corresponding to the window (signal fragment) position being shown currently in the Signal pane, and vice versa – the Signal pane shows the signal window corresponding to the position of the cursor on the SBI pane. I.e. when the user scrolls along the EEG in the Signal pane, the cursor line on the SBI pane automatically moves accordingly. And vice versa: when the user moves the cursor on the SBI pane (by dragging it or just clicking on a new position in the SBI pane), the Signal pane is automatically updated to show the signal at this new position.

1.3.3 The Control Panel

The Control panel on the right side of the SBI & Channels tab contains the main controls for performing the EEG processing and event selection operations (Fig. 1.3.5).

List of channel labels with checkboxes. The checked channels will be displayed in the Signal pane and will be processed when the 'Process Multiple Channels' button is pressed. The active channel (the channel that is selected for processing in the upper panel of the main window) is always checked.

Button to calculate the Spectral Band Index (SBI)

Button to process (calculate the SBI and select events) several channels; the field on the right shows the number of processed channel

Read-only field showing the number of selected events in the preliminary list

Buttons and editable field to select the currently viewed event

Button to add the current event to an event category (the category is selected from the popup menu that appears when this button is pressed)

Checkbox to specify whether the next event should be selected as current after the current event is added to an event category, or not

Button to show the Event Categories form

Tab control with two tabs: 'Controls' and 'Go To'

Buttons to check and uncheck all channels (do not affect the active channel)

Button to define montage

Button to interrupt SBI calculation

Shows the index of currently processed channel

Progress bar showing the SBI calculation progress

Button to select the suprathreshold events

Checkbox to specify the sorting of events in the preliminary list

Shortcut buttons for quick adding of the current event to an event category. Each button can be individually (re)assigned to an event category

Button to "undo" last event addition to a category

Button to add all events to an event category (the category is selected from the popup menu that appears when this button is pressed)

Button for automatic event processing, processed event counter and button to interrupt processing

Buttons to save the filled event categories to file(s) or to load events categories (and events therein) from a file that was saved earlier

Fig. 1.3.5. The Control Panel.

These are:

Channels list - contains the list of channel labels with checkboxes. The checked channels will be displayed in the Signal pane and will be processed when the 'Process Multiple Channels' button is pressed. The active channel (the channel that is selected for processing in the upper panel of the main window) is always checked. To the right of the Channels list are two buttons to check (☑) and uncheck (☐) all channels. Checking or unchecking all channels does not affect the active channel. There is also the ± button, pressing which launches the 'Define Montage' dialog (see 2.6. Define Montage Dialog) that allows to define a montage, by defining new channels as linear combinations (sum or difference) of the original channels.

Calculate SBI button – starts calculation of the spectral band index of the active channel (the channel that is selected for processing in the upper panel of the main window) (see 5.1. Single channel processing) with the parameters specified or selected in the Parameters tab (see 1.6. The Parameters tab).

The calculation process is multi-threaded and uses all available processors. The calculation progress is reflected by the progress bar below the "Process Multiple Channels" button. After the calculation of SBI the program builds the distribution histogram of SBI values, and based on this histogram defines a threshold to discriminate between background interictal activity and ictal activity.

When the calculation is finished, the program "beeps" and plots the calculated SBI curve in the "SBI" pane, and the distribution histogram in the "SBI Histogram" pane on the "SBI Histogram" tab (Fig. 1.4.1). The defined threshold is shown as a red horizontal line on the "SBI" pane (Fig. 1.3.1) and as a red vertical line on "SBI Histogram" pane (Fig. 1.4.1). The calculation process may be interrupted by the user by clicking the ❌(Stop) button.

Process Multiple Channels button – starts SBI calculation and automatic event selection for several channels checked in the Channels tab of the Control panel (see 6.7. Multiple channels processing). The calculation progress for each channel is reflected by the progress bar below the "Process Multiple Channels" button. The field to the right of the button shows the index of the currently processed channel. When the calculation finishes, the program "beeps" and plots the SBI curve of the last checked channel in the SBI pane. The calculation process may be interrupted by the user by clicking the ❌(Stop) button.

❌(Stop) button – interrupts the calculation started by pressing the "Calculate SBI" or "Process Multiple Channels" buttons. The calculation will not stop immediately but after some time (few seconds). After the interruption, the fragments of the SBI calculated so far will be plotted in the "SBI" pane.

Select Events button – selects the episodes of signal with excessive values in the defined frequency band (the 'events'); the program finds the peaks of the SBI that are

above the threshold, and stores their times in a dedicated list – the preliminary event list.

Short events may be ignored, and close events may be merged, according to parameter settings in the *Event Processing* parameters group (Fig. 1.6.7) on the "Advanced" sub-tab of "Parameters" tab (see 1.6.2 The Advanced tab).

The number of selected events will be shown in the "Selected Events" field.

The events in the preliminary list may be sorted either according to their time of occurrence or their SBI peak value (in which case the sorting is in descending order - the first event has the highest value of SBI), depending on whether the "Sort Events by Time" checkbox is checked or not.

The first event becomes the current event, its index is displayed in the "Current Event" field and the corresponding EEG fragment is shown in the Signal pane.

Selected Events read-only field - shows the number of selected events in the preliminary list.

Current Event – a group of controls (⏮ ◀ 3 ▶ ⏭ left and right arrows and an editable field) to select the current event from the preliminary list of events for viewing or adding to an event category; the user can view the next and previous events using ▶ and ◀ buttons, or a particular event by entering its index directly in the editable field. The ⏮ and ⏭ buttons are used to jump to the first or last event, correspondingly. If current event was already added to an event category, a red text label "In Category" appears at the right side of "Current Event" text. When the user places the mouse cursor on this red text, the hint box appears indicating to which particular categories the current event was added (Fig. 1.3.6).

Fig. 1.3.6. "In Category" label indicating that the event is already in an event category.

Sort Events by Time checkbox – specifies, whether the selected events in the preliminary list will be sorted by their time of occurrence (if checked) or by their SBI peak value in descending order (if not checked).

Shortcut buttons – Four shortcut buttons for quick adding of the current event to an event category. Each button can be individually (re)assigned to an event category.

The first two buttons are by default assigned to the two default categories: "Seizures" and "Artefacts". The other two buttons are unassigned.

To assign an event category to the button, the user has to right-click on the button, then select the desired event category from the popup menu (Fig. 1.3.7, the popup menu will contain the list of all available event categories, see 2.4. The Events Form).
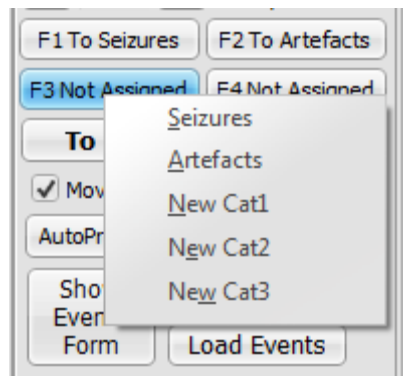
Fig. 1.3.7. The popup menu with available category names that appears when a shortcut button is right-clicked.

After the assignment, the text on the button will change and will show the name of the assigned category: "To <Category name>" (Fig. 1.3.8; note that long category names will be automatically truncated according to the button's size, so the user has to avoid long names or names with similar initial parts when creating new event categories, see 5.1.9.2.1. Creating additional Event Category, if necessary).
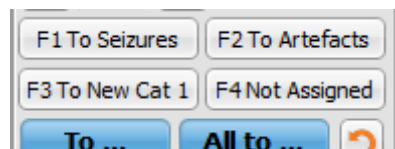
Fig. 1.3.8. Shortcut button after category assignment.

Left-clicking on the assigned button will add the current event to the corresponding category. After the addition, the current event index either will remain unchanged, or the next event will become current, according to the state of the checkbox "Move To Next After Adding". There are keyboard shortcuts for these buttons - the function keys F1, F2, F3, F4, correspondingly (this is also reflected on the text on the buttons).

To ... button – adds the current event to an event category. When this button is clicked, a popup menu appears with a list of available categories (Fig. 1.3.9), from which the user selects the category to which he wants to add the current event. As in case of shortcut buttons, after the addition, the current event index either will remain unchanged, or the next event will become current, according to the state of the checkbox "Move To Next After Adding".
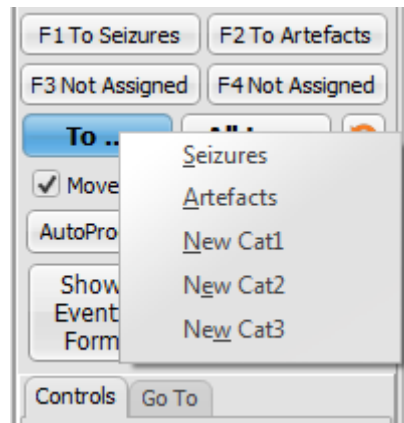
Fig. 1.3.9. The popup menu with available category names that appears when the "To…" button is clicked.

All to ... button – adds all events to an event category. When this button is clicked, a popup menu appears with a list of available categories, from which the user selects the category to which he wants to add the events.

(Undo) button – Removes the last added event from the category to which it was added (i.e., "undoes" the last add event to a category action). "Ctrl-Z" is the keyboard shortcut for this action.

Move To Next After Adding checkbox - specifies whether the next event should be selected as current after the current event is added to an event category (if checked), or the current event should remain current (if not checked).

Autoprocess Events button – starts the event automatic processing (see 6.8. Automatic Event Processing Methods) by opening the Autoprocess Events Dialog where the user selects the method and other options and starts processing. Automatic event processing processes all events from the preliminary list (see also 6.7.3. Behaviour of buttons and corresponding methods in multiple channels processing mode). The field next to this button shows the counter of already processed events. The processing might take long time and user might interrupt it by pressing the (Stop) button next to the event counter.

Show Events Form button – shows the Event categories Form (see 2.4. The Events Form), which is initially hidden when the program starts.

Save Events button - opens the "Save Events" dialog to save the events that were added to the event categories to file(s) (see 2.3. Save Events Dialog)

Load button - loads events categories and events therein from a file that was saved earlier (by means of a standard "Open file" dialog)

Tab control with two tabs:

Controls tab (Fig. 1.3.10) – contains controls for managing the EEG plot on the Signal pane:

Disp. Win. Size editable field – to specify the size, in seconds, of the EEG fragment displayed in the Signal pane (display window size).

Notch checkbox – specifies, whether a notch filter must be applied to the EEG, both when displaying in Signal pane *and when calculating the SBI* .

HighPass checkbox – specifies whether a high-pass filter must be applied to the EEG when displaying in Signal pane (*it is not applied when calculating the SBI*).

Editable field to specify the size, in seconds, of the EEG fragment displayed in the Signal pane (display window size)

Checkboxes to switch on or off filters when displaying the EEG. The parameters of filters must be set on 'Parameters' tab of the main window

Checkboxes to adjust the vertical scale of Signal plot

Checkbox to hide the raw (not filtered) EEG when filtering is applied (i.e., any of the 'Notch', 'HighPass' or 'LowPass' checkboxes is checked). If this checkbox is not checked, the raw signal is shown on the Signal pane as light gray line. This checkbox appears only if any filtering is applied.

Checkbox to show or hide the gridlines on the Signal plot

Fig. 1.3.10. The 'Controls' tab of the Control panel

LowPass checkbox – specifies whether a low-pass filter must be applied to the EEG when displaying in Signal pane (*it is not applied when calculating the SBI*).

Hide Orig. Signal checkbox – specifies whether the raw (not filtered) EEG must be shown on the Signal pane (when not checked) or not (when checked) when filtering is applied (i.e., when any of the 'Notch', 'HighPass' or 'LowPass' checkboxes is checked).

If this checkbox is not checked, the raw signal is shown on the Signal pane as light gray line, superimposed with the filtered signal (black or blue line). This checkbox appears only if any filtering is applied (i.e., any of the 'Notch', 'HighPass' or 'LowPass' checkboxes is checked).

Autoscale checkbox – turns on or off vertical auto-scaling of the plot. When checked (i.e. auto-scaling is on) the plot's maximum and minimum are set equal to the maximal and minimal signal values *within the currently displayed fragment* of the EEG (for each channel), thus, the vertical scale in this case will change during scrolling along the EEG.

Mean-Cent checkbox – specifies whether the vertical Y-axis limits of the EEG channels shown in the Signal pane must be adjusted so that the EEG curve will be centred (vertically) at the mean value of the signal calculated for the displayed fragment. This is useful when there is a

baseline drift so it is necessary to readjust the vertical axis limits while scrolling along the EEG.

Grid checkbox – shows or hides the gridlines on the Signal plot.

Go To tab (Fig. 1.3.11) – contains controls to jump to specific position along the EEG record:

Go To (time) button with an editable field next to it – to enable going go to a position in the EEG record specified by its absolute date and time. The format of the date and time entered in the editable field should be 'dd.mm.yy hh:mm:ss'.

Go To (sample) button with an editable field next to it – to enable going to a position in the EEG record specified by EEG sample number.
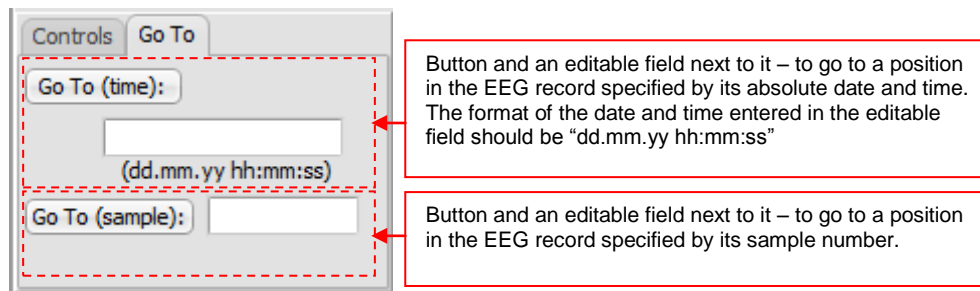
Fig. 1.3.11. The 'Go To' tab of the Control panel

1.4 The SBI Histogram tab
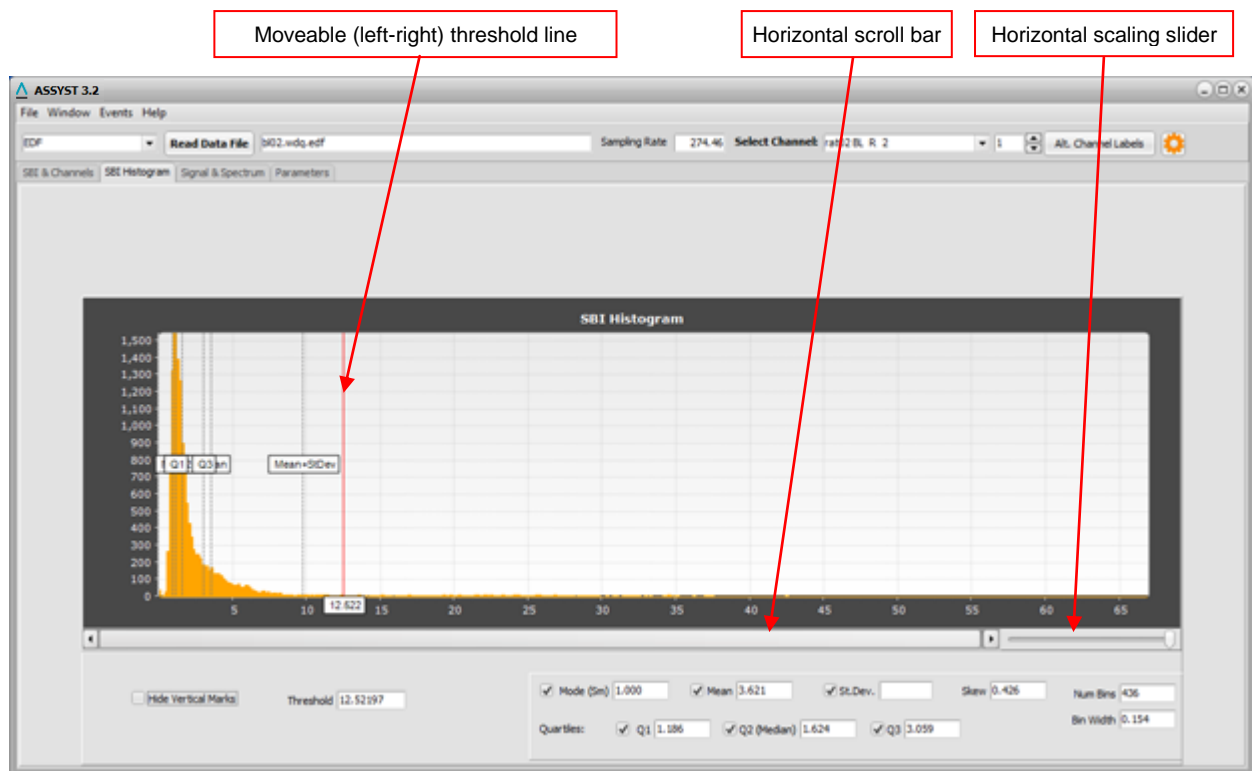
Fig. 1.4.1. The main window with the "SBI Histogram" tab open.

The **SBI Histogram** tab (Fig. 1.4.1) contains the "SBI Histogram" pane that shows the SBI histogram (or distribution) of SBI amplitudes. The SBI histogram is calculated automatically after the calculation of SBI curve. The bins of the histogram show how often particular SBI values (horizontal axis) are encountered during the entire record duration.

Some parameters of the SBI histogram are shown on the "SBI Histogram" tab. Some of these values (such as mode, mean, mean + st, dev., quartiles) are also marked on the histogram plot by vertical dashed lines. These marks may be hidden/shown using the checkboxes on the "SBI Histogram" tab.

The SBI histogram can be very handy for selecting a proper threshold. Along the x-axis of the histogram are the SBI values. The y-axis is the frequency of occurrence of the SBI values. The peak of the histogram shows the most frequently encountered values of the SBI. The histogram usually peaks at lower SBI values that are produced by the interictal EEG- the "usual", or background EEG. High SBI values are much more rare, as indicated by low values of the histogram at higher SBI values (right side of the histogram). These high SBI values are the ones that are of interest, because most probably they are produced by ictal EEG. The threshold should be set so that it "cuts off" the SBI values

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corresponding to the interictal EEG, i.e., the left part of the histogram containing the peak, as in the example shown in Fig. 1.4.1.

In this particular example, the vertical line corresponds to the automatically calculated threshold. However, for some records the histogram may be more wide and irregular, especially if the record duration is short and the signal is contaminated with artefacts. In such cases automatically calculated threshold may be not the best choice and manual editing may be required.

The vertical threshold line may be moved either by dragging it by mouse, or by pressing the left and right arrow keys on the keyboard. Besides, the threshold may be set by entering a numeric value in the "Threshold" field below the histogram.

Note that the vertical threshold line in the histogram plot on this tab is coupled with the horizontal threshold line on the SBI pane of the "SBI & Channels" tab (see 1.3.1 The SBI Pane), so when the user moves one of them, the other is moved as well to the corresponding position.

1.5 The Signal & Spectrum tab
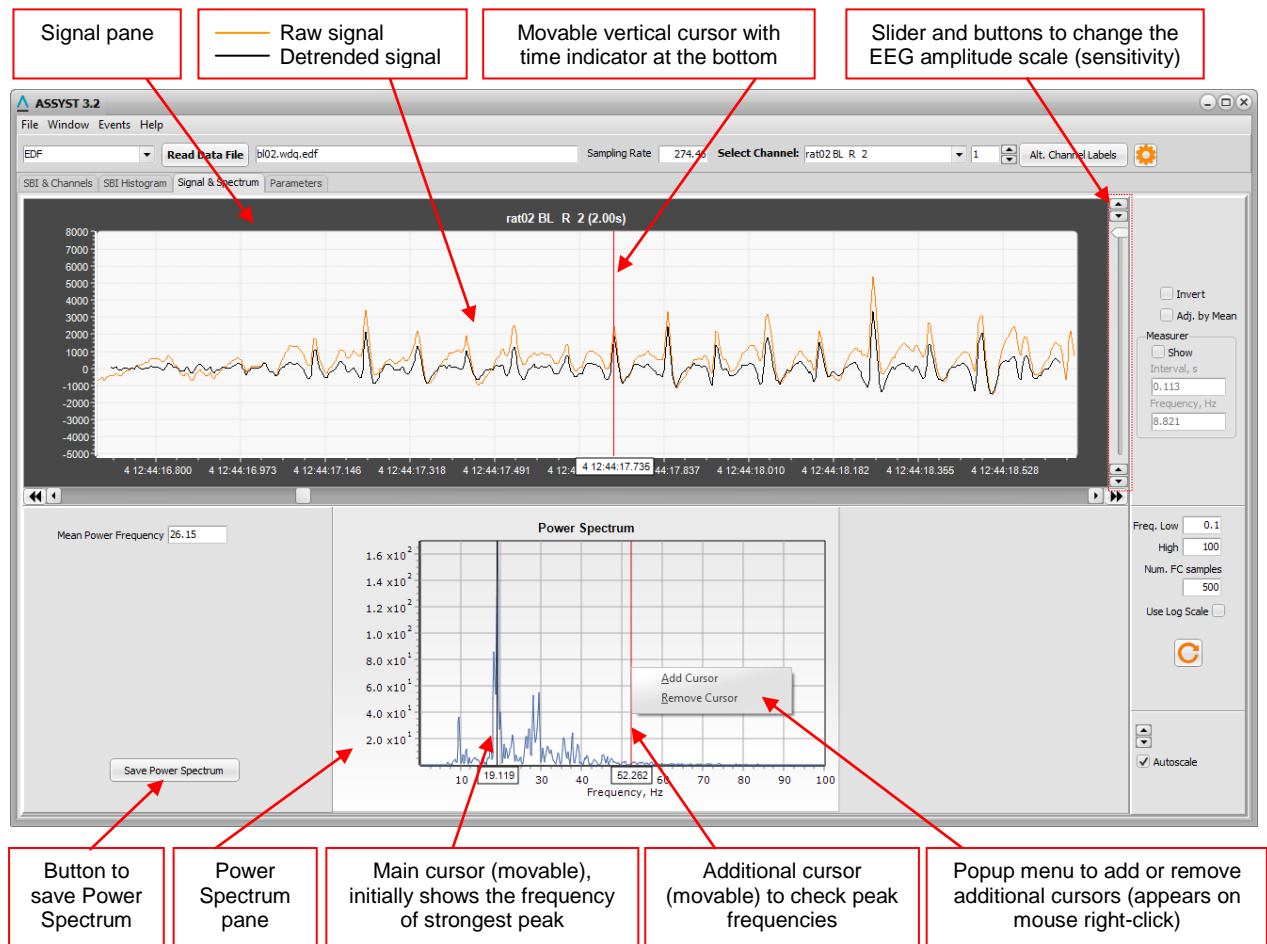
Fig. 1.5.1 The Signal & Spectrum tab of the main window.

The "Signal & Spectrum" tab (Fig. 1.5.1) is mostly for exploratory purposes. It gives the user a possibility to investigate the frequency contents of an EEG fragment (by viewing its power spectrum and measuring its peak frequencies), as well as to see the effect of baseline trend removal (de-trending).

The tab has two panes: Signal pane (showing a fragment of active channel's signal) and Power Spectrum pane (showing the power spectrum of the fragment shown in Signal pane); there are also some controls on the right side (Fig. 1.5.2).

1.5.1 The Signal pane of the Signal & Spectrum tab

The upper pane of the Signal & Spectrum tab shows the raw signal of the active channel (orange line) plus the signal after removing the baseline trend, or de-trending (black line,

Fig. 1.5.1). If any of the filtering checkboxes in the "SBI & Channels" or "Parameters" tab is checked, then the orange line shows the EEG *after* applying corresponding filters (but before de-trending).

The length of the displayed fragment of the signal is always equal to the processing window size set in the Parameters tab (see 1.6.2 The Advanced tab) or in the Processing Parameters dialog (see 2.2. Processing Parameters Dialog), which may be different from the "Display Window Size" specified on the "SBI & Channels" tab.

The title of the Signal pane shows the active channel's label and the length of the displayed fragment (processing window size) in parentheses.

Similarly to the Signal pane on the "SBI & Channels" tab, the Signal pane on this tab also has a scroll bar at the bottom allowing scrolling along the EEG and controls to change the vertical scale of EEG, which work in the same way as on the "SBI & Channels" tab (see 1.3.2 The Signal Pane).

The user can invert the polarity of the signal on the plot by checking the "Invert" checkbox on the right side of the Signal pane (Fig. 1.5.2).
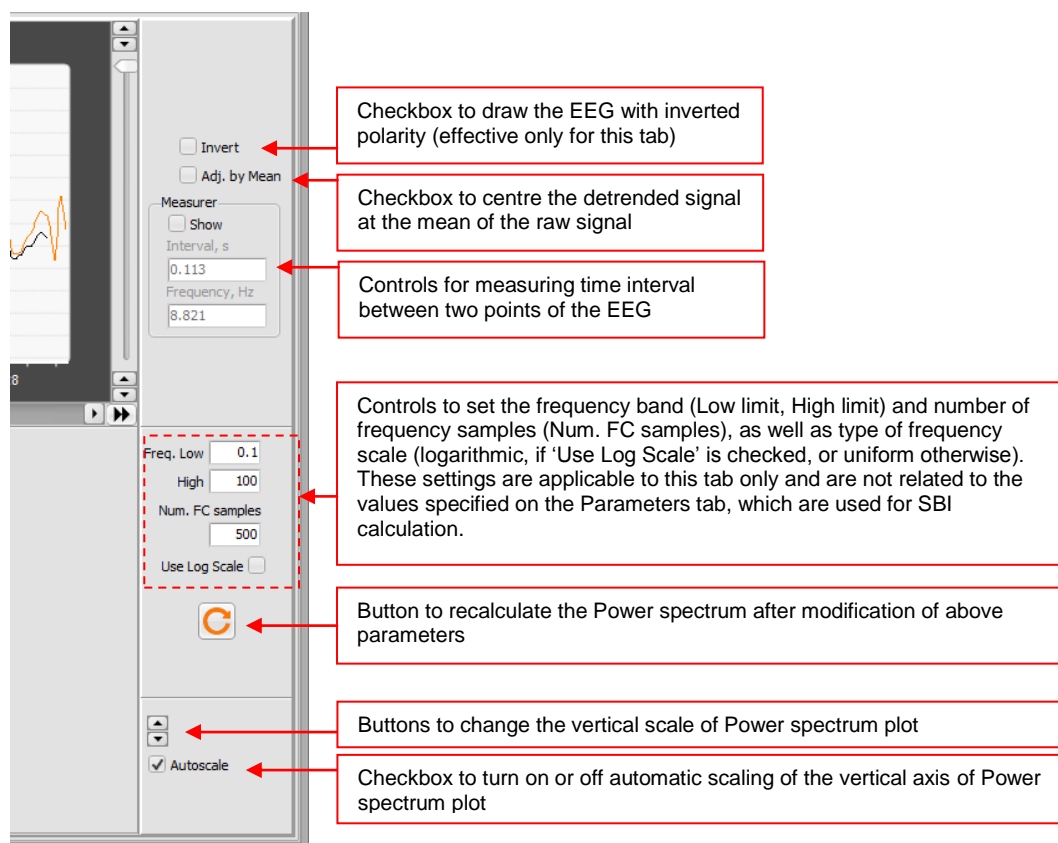
Fig. 1.5.2. Controls on the right panel of the Signal & Spectrum tab.

In some cases, when there is a large baseline shift in the raw signal (i.e. its mean is far from zero), the de-trended signal may be significantly shifted vertically compared to the

raw signal (because the de-trended signal's mean is close to zero). In such cases, to plot the signals overlapped, the user can check the "Adj. by Mean" checkbox (Fig. 1.5.2), in which case the raw signal's mean value will be added to the de-trended signal so the raw and resulting de-trended signals will have the same mean value.

With each scrolling step, as soon as the displayed signal fragment (window) changes, the power spectrum of the new fragment (window) is calculated and plotted in the Power Spectrum pane (see 1.5.2 The Power Spectrum pane of the Signal & Spectrum tab).

1.5.2 The Power Spectrum pane of the Signal & Spectrum tab

The lower pane of the "Signal & Spectrum" tab shows the power spectrum of the *de-trended* signal fragment that is currently shown in the Signal pane (Fig. 1.5.1).

The power spectrum is calculated using the parameters specified in the right-side panel of the window (Fig. 1.5.2), namely, the frequency range (Low and High), the number of frequency samples, and whether to use the uniform or logarithmic scale. The power spectrum is automatically recalculated for each signal window shown in the Signal pane when the user scrolls along the EEG signal. To recalculate the power spectrum without moving the window (e.g., after changing some frequency parameters), the user has to click the ⟳ button.

If the "Autoscale" checkbox (Fig. 1.5.2) is checked, the vertical axis of the power plot is rescaled automatically each time the power spectrum is recalculated, to fit into the plot window. Otherwise, the vertical axis scale of the power spectrum plot remains fixed.

It is possible to change the vertical scale of the power spectrum manually by clicking the ⬍ buttons on the right side of the power spectrum plot (Fig. 1.5.2) or using the up and down arrow keys of the keyboard when the focus is on the Power Spectrum pane.

The black vertical line (vertical cursor line) on the power spectrum plot shows the maximal peak of the power spectrum and its frequency (Fig. 1.5.1). It is possible to move this cursor line manually by mouse to see the frequencies of other peaks of the power spectrum. It is also possible to add arbitrary number of additional vertical cursor lines by right-clicking on the power spectrum plot and selecting the "Add Cursor" item from the popup menu. An added cursor can be removed by right-clicking on it and selecting the "Remove Cursor" item in the popup menu.

The power spectrum can be outputted in a ASCII text file by pressing the "Save Power Spectrum" button (Fig. 1.5.1, see 4.4. Additional output - power spectrum of the current window's signal).

1.5.3 Measuring interval between two points of EEG

The program has a possibility to measure the time interval between two points of the EEG and display it both as interval in seconds and frequency in Hz.
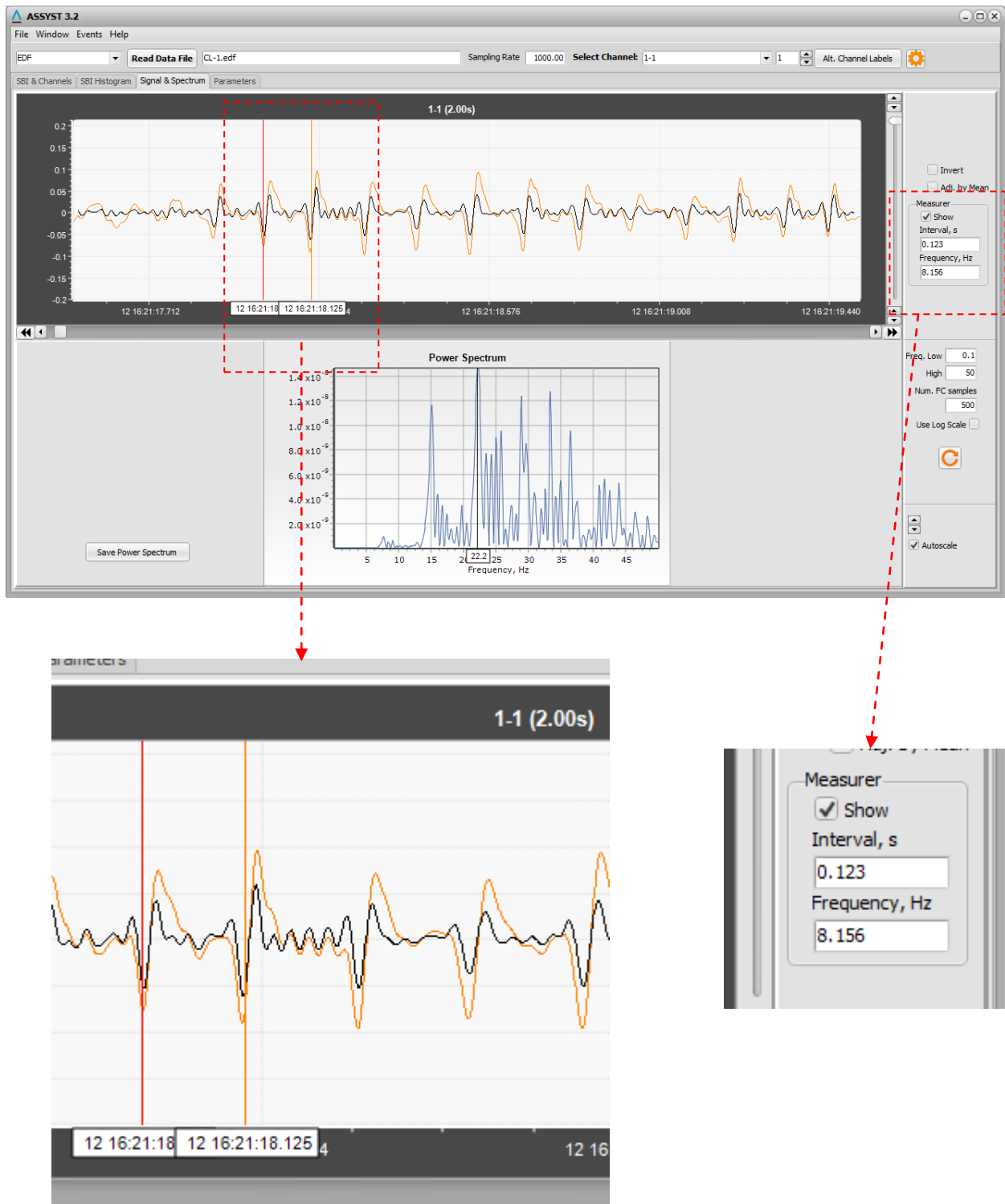
Fig. 1.5.3. Controls for measuring interval between EEG points.

The control group called "Measurer" contains a checkbox "Show" and two fields, "Interval, s" and "Frequency, Hz". If the "Show" checkbox is checked, a second vertical cursor appears on the "Signal" plot. This second cursor is orange (the first cursor - the red vertical line - is always there). Both cursors are moveable by mouse. When the position of any cursor is changed, the program automatically calculates the interval between the two cursors and displays it in the field "Interval, s". The reciprocal of the interval, i.e., the frequency, is simultaneously displayed in the field "Frequency, Hz".

For example, if one wants to measure the distance between two consecutive spikes, one cursor (it doesn't matter which one, red or orange) should be put on the first spike, and the second cursor - on the second spike. Doing this for a SWD, one can find out what is the shortest interval between spikes (i.e., the highest frequency within the SWD), and what is the longest interval (the lowest frequency within the SWD).

1.6. The Parameters tab

The "Parameters" tab is used to specify the parameters used in processing and event detection. These parameters can be specified either by selecting a parameter set from a list of pre-defined default parameter sets, or by setting or modifying the parameter values directly.

The "Parameters" tab contains a page control with two tabs:

Default (see 1.6.1 The Default tab)

Advanced (see 1.6.2 The Advanced tab)

1.6.1 The Default tab
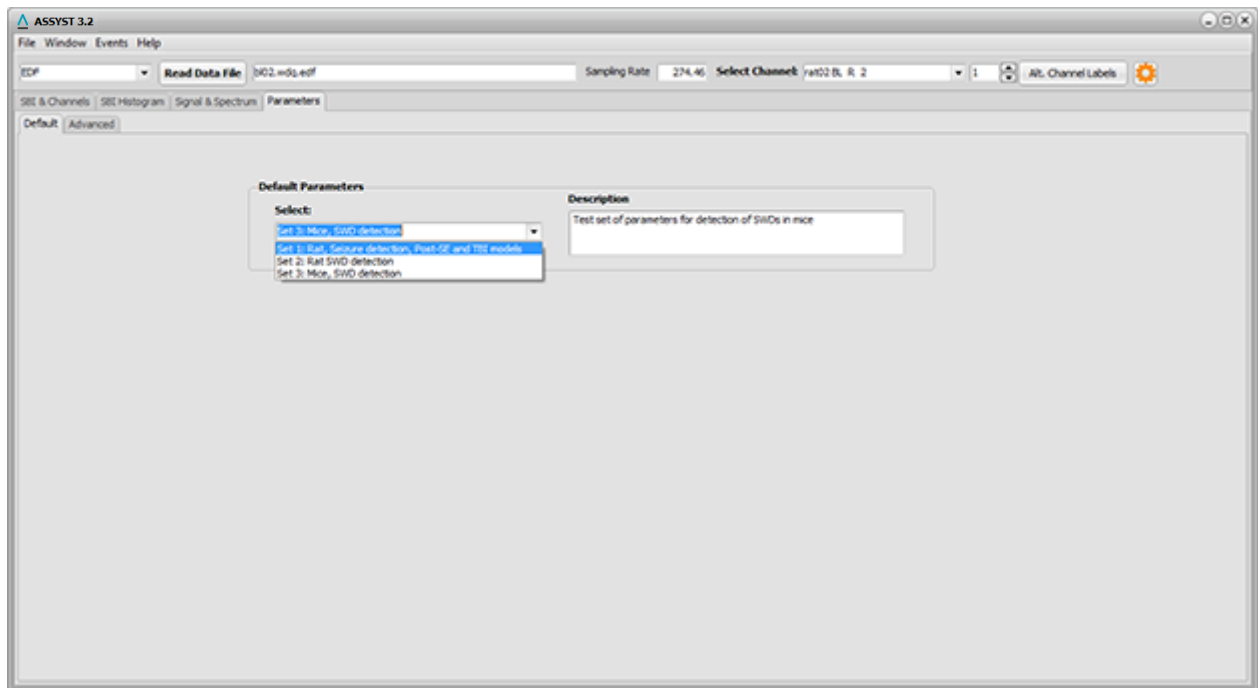
Fig. 1.6.1. The "Parameters" tab of the main window with "Default" sub-tab selected.

On this tab (Fig. 1.6.1) the user can select a named set of parameters from the list of default parameter sets. The sets should be created and saved in advance, using the controls on the "Advanced" tab (see 1.6.2 The Advanced tab). Initially, the program shipped to the client will contain one or more pre-defined default parameter sets.

The tab contains a "Select:" combo box filled with the names of existing default parameter sets, and a read-only text field "Description" that shows the description of the default parameter set selected in the "Select:" combo box.

The user can create arbitrary number of additional default parameter sets with arbitrary names (on the "Advanced" tab, 1.6.2 The Advanced tab); the only restriction is that there should be no duplicate names.

1.6.2 The Advanced tab
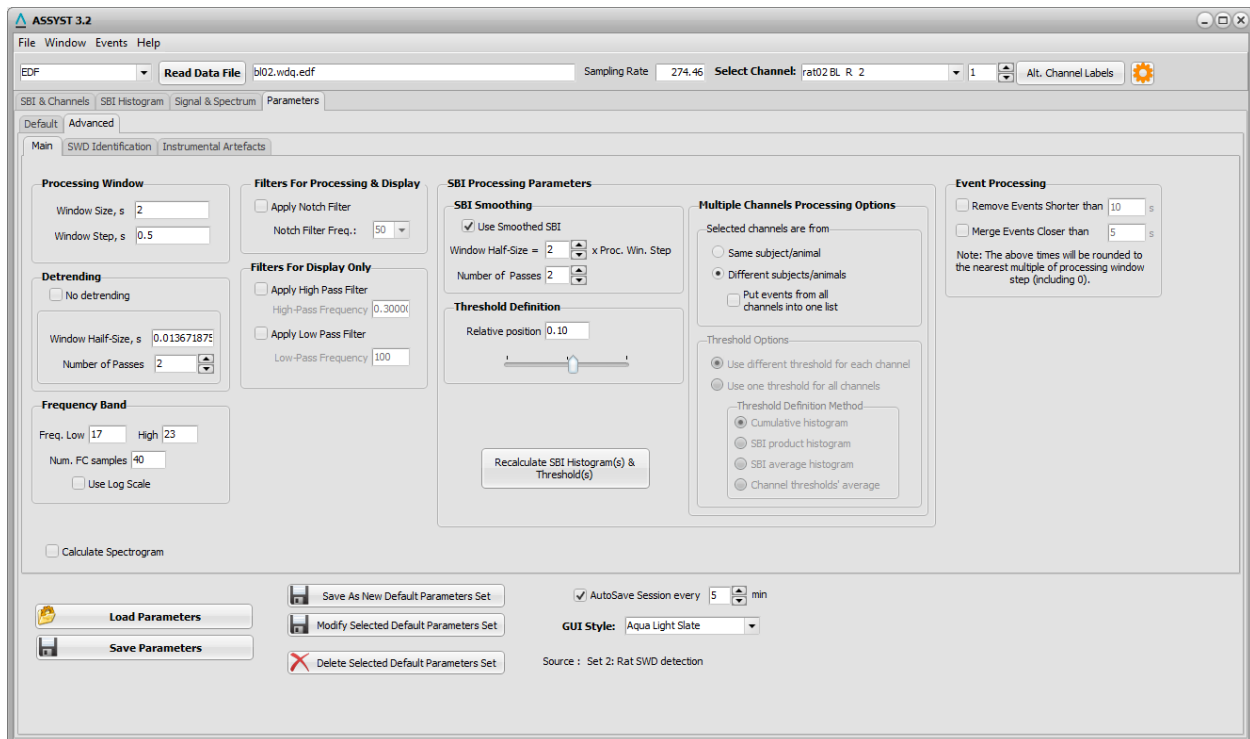
Fig. 1.6.2. The "Parameters" tab of the main window with "Advanced" sub-tab selected.

The "Advanced" tab (Fig. 1.6.2) contains a page control with tabs that contain controls to show and set the particular parameters' values, as well as some other controls (see 1.6.2.5. Other controls on the Advanced tab) including buttons to save or load parameter values to or from a file and to create new default parameter sets or modify the existing ones. This tab also contains a combo box allowing to select a style for the graphical user interface (i.e. the "look" of the program windows).

The page control has the following tabs:

Main (see 1.6.2.1. The Main parameters tab)

SWD Identification (see 1.6.2.2. The SWD Identification parameters tab)

Instrumental Artefacts (see 1.6.2.3. The Instrumental Artefacts tab)

LineLength Definitions (see 1.6.2.4. The LineLength Definitions tab)

1.6.2.1. The Main parameters tab

The "Main" sub-tab of the "Advanced" tab (Fig. 1.6.2) contains controls to show and set the parameters used in the main processing algorithm described in 6. Processing method.

The parameters are grouped according to their meaning into the following groups:

> Processing Window
>
> De-trending
>
> Frequency Band
>
> Filters For Processing & Display
>
> Filters For Display Only
>
> SBI Processing Parameters
>
>> SBI Smoothing
>>
>> Threshold Definition
>>
>> Multiple Channels Processing Options
>
> Event Processing

The **Processing Window parameters** (Fig. 1.6.3) specify the processing window that is used to calculate the SBI curve; they include the processing window size and step which should be provided in seconds.
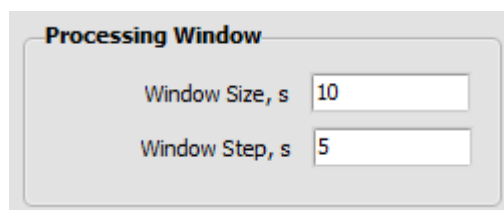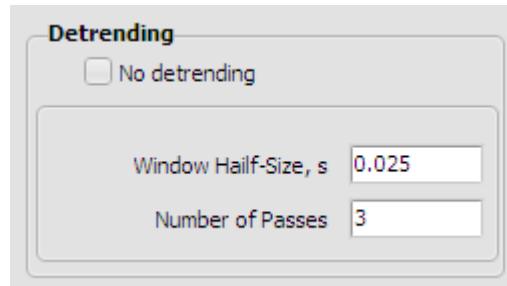
Fig. 1.6.3. The Processing Window parameters group.

The **De-trending parameters** group (Fig. 1.6.4) contains the parameters that are used for baseline trend removal.

The de-trending procedure consists of two steps: definition of baseline trend and subtracting of this trend from the original signal.

The baseline trend is defined using multiple pass moving averaging. This method requires a moving window which is defined by its half-size, in seconds (provided in the "Window Half Size, s" field). The window is moving along the signal, with step equal to signal's sampling step, and for each position the signal at the sample corresponding to the window centre is replaced by the average of all samples in the window. This

procedure may be repeated multiple times (multiple passes, provided in the "Number of Passes" field). The wider the window or the bigger the number of passes, the more smoothed the baseline trend will be, and vice versa.
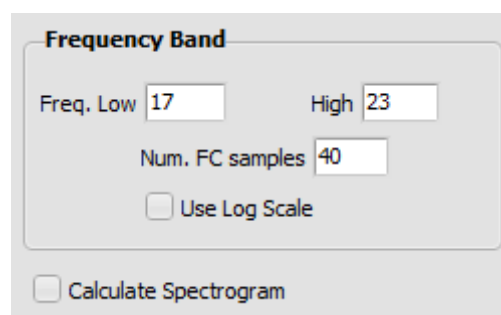
Fig. 1.6.4. The De-trending parameters group.

The de-trending may be considered as a kind of high-pass filtering. De-trending is an important step of the algorithm, so these parameters must be set carefully. The effect of de-trending and how it depends on these parameters may be verified on the Signal & Spectrum tab (see 1.5.1 The Signal pane of the Signal & Spectrum tab) where both original and de-trended signals are shown.

The De-trending parameter group contains also a checkbox "No detrending". If this checkbox is checked, then the baseline trend will not be removed.

The *Frequency Band* **parameters** group (Fig. 1.6.5) specifies the frequency band and the number of frequency samples within the band, as well as the type of sampling – equidistant or logarithmic) for SBI calculation.

Fig. 1.6.5. The Frequency Band parameters group.

These include: "Freq. Low" – band's left edge frequency, "High" – band's right edge frequency, "Num FC samples" (number of frequency characteristic's samples) – number of samples within the frequency band, "Use Log Scale" checkbox – specifies whether a uniform (or equidistant) sampling should be used for frequency scale (if not checked) or logarithmic (if checked).

The "Calculate Spectrogram" checkbox specifies whether the spectrogram (2-dimensional time-frequency plot) must be calculated in addition to the SBI. **Note:** The spectrogram may be calculated only in single channel processing mode (i.e. when the user presses the "Calculate SBI" button on the right panel of the "SBI & Channels" tab. In multiple channels processing mode ("Process Multiple Channels" button on the right panel of the "SBI & Channels" tab) this checkbox is ignored and the spectrogram is not calculated.

The **Signal Filtering parameters** are separated into two groups: *Filters For Processing & Display* and *Filters For Display Only* (Fig. 1.6.6).

This is done to emphasize that the notch filter, if applied, is applied to the signal both during the SBI calculation and when displaying the signal. In contrast, the high pass and low pass filters are applied only when displaying the signals and not during the calculation of SBI (because the SBI calculation actually does its own band-pass filtering).
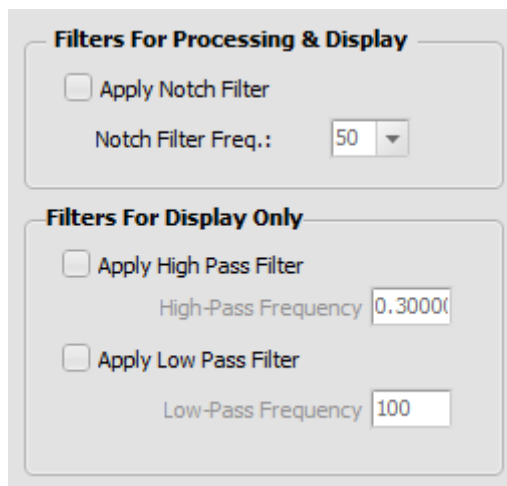
Fig. 1.6.6. The Filters parameters.

In the current version of the program the filters are RBJ Biquad (biquadratic) filters. All the parameters of the filters are fixed according to the filter type (notch, low pass or high pass), except the main frequency, which may be set/modified by the user in this parameters group.

The **SBI Processing Parameters** group unites parameters that are used for SBI post-processing and threshold definition (Fig. 1.6.7).

These parameters are separated into three sub-groups:

    SBI Smoothing - This sub-group contains the following controls:

Use Smoothed SBI checkbox – is used to specify whether after the calculation of SBI the SBI must be smoothed; the smoothing is done by means of multiple pass moving averaging;

Window Half-Size editable field – is used to specify the half size of the window used for smoothing; here it is defined relatively to the processing window step (which is the SBI curve's sampling interval), as a given number times processing window step;

Number of Passes editable field – is used to specify the number of passes in multiple pass moving averaging.
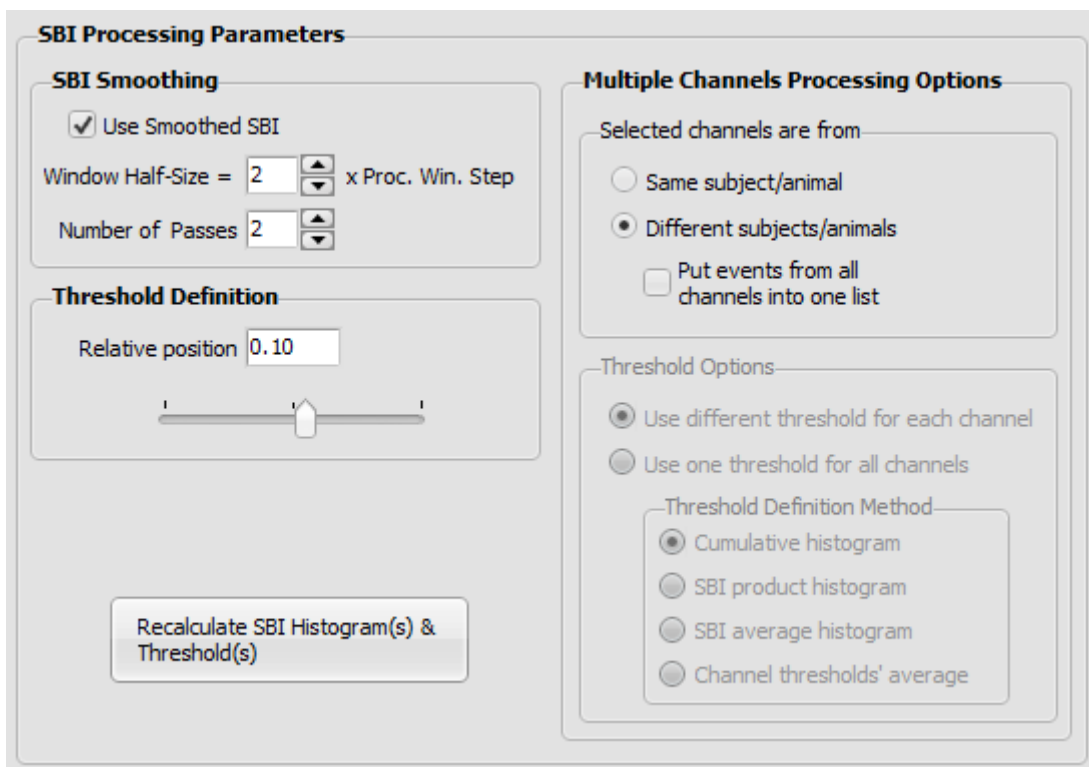
Fig. 1.6.7. The SBI processing parameters.

Threshold Definition – This sub-group contains parameter for *automatic* threshold definition based on the SBI histogram. For detailed description see 6.3 Automatic Threshold definition.

Multiple Channels Processing Options – This sub-group contains controls to specify the options for multiple channel processing. For the meaning of the options see 6.7. Multiple channels processing. The "Threshold Options" group is relevant only for the case when the selected channels are from the same subject/animal, so otherwise this group is disabled (as in Fig. 1.6.7).

The SBI post-processing parameters do not affect the calculation of SBI itself. They are used only for automatic threshold definition, which in turn requires building the SBI histogram. Thus, if the SBI curve is already calculated, there is *no* need to recalculate it (by pressing the "Calculate SBI' button on the "SBI & Channels" tab (1.3.3 The Control Panel) if any parameter in this group is changed. But the SBI histogram and the automatic threshold can be recalculated by pressing the "Recalculate SBI Histogram(s) & Threshold(s)" button at the bottom-left of this parameters group.

The ***Event Processing* parameters** group (Fig. 1.6.8) contains parameters related to the selection of suprathreshold events when the user presses the <u>Select Events </u>button on the "SBI & Channels" tab (see 1.3.3 The Control Panel):
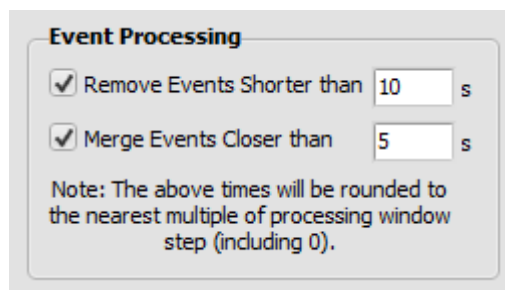
Fig. 1.6.8. The Event Processing parameters.

<u>Remove Events Shorter than</u> checkbox and editable field – if this checkbox is checked, the events that are shorter than the number of seconds specified in the editable field are ignored. It should be noted, that the event duration is defined from the time when the SBI curve crosses the threshold in the up direction to the time when it crosses the threshold in the down direction, thus, the duration is dependent on threshold; it should be taken into account, also, that the precision of event duration calculation is one window step (which is the sampling interval of the SBI curve);

<u>Merge Events Closer than</u> checkbox and editable field – if this checkbox is checked, the consecutive events with interval in between (the time from the end of first event to the start of the second) less than the number of seconds specified in the editable field are merged into one event.

1.6.2.2. The SWD Identification parameters tab

The "SWD Identification" sub-tab of the "Advanced" tab (Fig. 1.6.9) contains controls to show and set the parameters used in the automatic identification of spike-wave discharges algorithm described in 6.8.1. Automatic Identification of Spike-Wave Discharges (SWD).
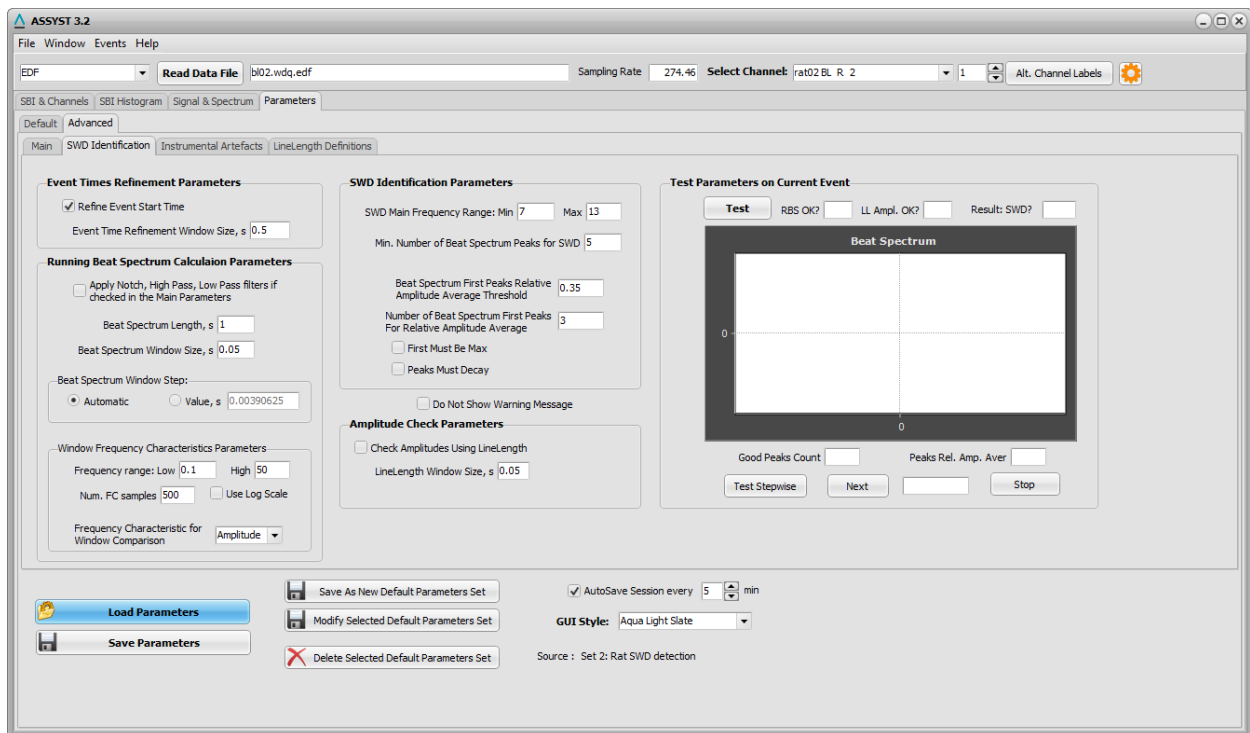
Fig. 1.6.9. The "SWD Identification" sub-tab of the "Advanced" sub-tab of the "Parameters" tab of the main window.

The parameters are grouped according to their meaning into the following groups:

       Event Time Refinement Parameters

       Running Beat Spectrum Calculation Parameters
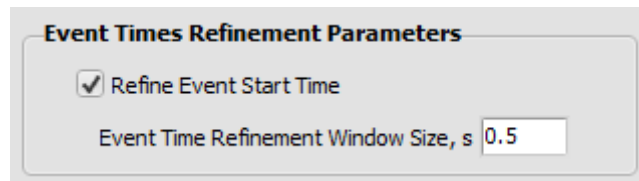
       SWD Identification Parameters

       Amplitude Check Parameters

The tab contains also the "Test Parameters on Current Event" widget allowing to test the parameter set on the current event (i.e., the event from the preliminary event list that is selected for viewing in the "SBI & Channels" tab, see 1.3.3 The Control Panel).
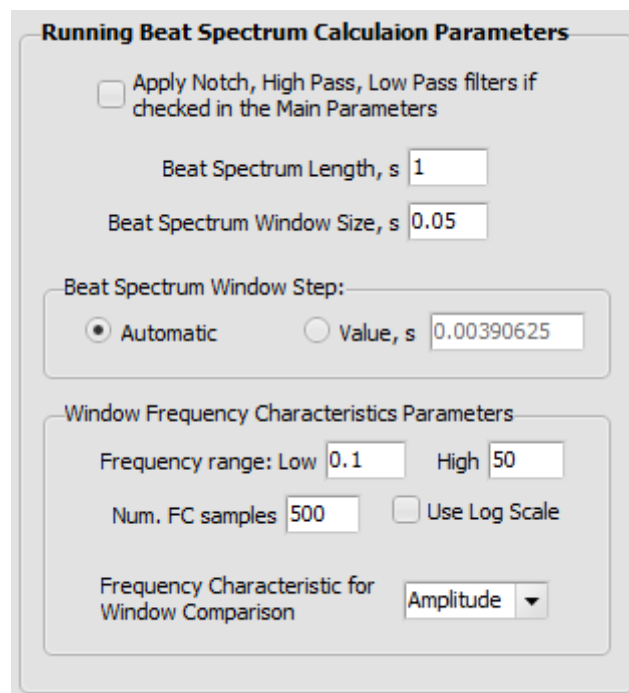
The ***Event Times Refinement Parameters*** (Fig. 1.6.10) specify whether the refining of the event's start time must be performed (as described in 6.8.1.1. Pre-processing) - if the checkbox "Refine Event Start Time" is checked, and if yes, the size of the window, in seconds, that is used to refine the event start time. This window must be smaller than the processing window used for SBI calculation (see 1.6.2.1. The Main parameters tab).

Fig. 1.6.10. The Event Times Refinement Parameters.

The ***Running Beat Spectrum Calculation Parameters*** group (Fig. 1.6.11) unites parameters and options that are used in calculation of running beat spectrum (see 6.8.1.2. Checking the event for rhythmic parts with given frequency using running beat spectrum).

Fig. 1.6.11. The Running Beat Spectrum Calculation Parameters.

The group contains the following controls:

> Apply Notch, High Pass, Low Pass filters if checked in the Main Parameters checkbox - if this checkbox is checked, the EEG within the event interval will be filtered before running beat spectrum calculation. Which filters will be applied

(notch, high-pass or low-pass) and their parameters depends on the settings of the corresponding controls on the "Main" sub-tab of the "Advanced" sub-tab of the "Parameters" tab (Signal Filtering parameters, 1.6.2.1. The Main parameters tab, see also 6.8.1.1. Pre-processing.)

Beat Spectrum Length, s editable field – is used to specify the running beat spectrum length, in seconds. This value also defines the size of the running rhythmogram window for which the rhythmogram and then the beat spectrum are calculated; this size is twice the length of the beat spectrum (see 6.8.1.2.2. Calculation of rhythmogram and beat spectrum for the current rhythmogram window.).

Beat Spectrum Window Size, s editable field - is used to specify the size of the window, in seconds, that is used for rhythmogram and beat spectrum calculation (parameter W, see 6.8.1.2.2. Calculation of rhythmogram and beat spectrum for the current rhythmogram window.).

Beat Spectrum Window Step radio button group - is used to specify how the window step for beat spectrum calculation is defined. It contains the following controls:

Automatic radio button – if this radio button is checked, the beat spectrum window step will be defined automatically as 1/256 s;

Value, s radio button and editable field next to it – if this radio button is checked, the value specified in the editable field next to it will be used as the beat spectrum window step;

Window Frequency Characteristics Parameters group of controls - contains controls to set the parameters and options for the calculation of frequency characteristics (feature vectors) of beat spectrum windows (see 6.8.1.2.2. Calculation of rhythmogram and beat spectrum for the current rhythmogram window.). These include:

Frequency range: Low, High editable fields – specify the frequency range for which the frequency characteristic will be calculated;

Num FC samples (number of frequency characteristic's samples) editable field – specifies the number of samples within the frequency range;

Use Log Scale checkbox – specifies whether a uniform (or equidistant) sampling should be used for frequency scale (if not checked) or logarithmic (if checked).

Frequency Characteristic for Window Comparison combo box - is used to select which frequency characteristic will be used as a feature vector in beat spectrum calculation; it contains the following items:

Amplitude - use amplitude frequency characteristic (option 1);
Imaginary - use imaginary frequency characteristic (option 2);

<u>Real</u> - use real frequency characteristic (option 3);

<u>Power</u> - use power spectrum (option 4)

Note: The recommended options for SWD identification are Power or Amplitude.

The **SWD Identification Parameters** group (Fig. 1.6.12) contains parameters used in the beat spectrum analysis for periodicity, see <u>6.8.1.2.3. Analysing the beat spectrum of the current rhythmogram window to reveal periodicity.</u>

The group contains the following controls:

<u>SWD Main Frequency Range: Min, Max</u> editable fields – specify the acceptable range for the SWD main frequency (parameters $\left[f_{\min} ; f_{\max} \right]$ in <u>6.8.1.2.3. Analysing the beat spectrum of the current rhythmogram window to reveal periodicity.</u>);

<u>Min. Number of Beat Spectrum Peaks for SWD</u> editable field - is used to specify the minimal number of consecutive beat spectrum peaks (that satisfy the SWD main frequency condition) to classify the event as SWD (parameter $M_{\min}$ in <u>6.8.1.2.3. Analysing the beat spectrum of the current rhythmogram window to reveal periodicity.</u>);
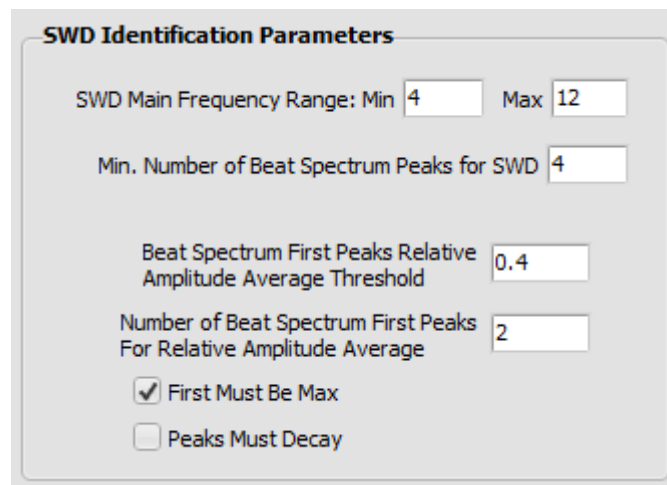
Fig. 1.6.12. The SWD Identification Parameters.

<u>Beat Spectrum First Peaks Relative Amplitude Average Threshold</u> editable field - is used to specify the threshold (minimal value) for the averaged relative amplitude of first K peaks of the beat spectrum (parameter $H_{\min}$ in <u>6.8.1.2.3. Analysing the beat spectrum of the current rhythmogram window to reveal periodicity.</u>);

<u>Number of Beat Spectrum First Peaks For Relative Amplitude Average</u> editable field - is used to specify the number of peaks of the beat spectrum for calculation of

the average relative peak amplitude (parameter K in [6.8.1.2.3. Analysing the beat spectrum of the current rhythmogram window to reveal periodicity.](#)).

First Must Be Max checkbox - if this checkbox is checked, then an additional condition that the very first peak of the beat spectrum (the first value of the beat spectrum) is the beat spectrum's maximum must be satisfied to classify the event as SWD.

Peaks Must Decay checkbox - if this checkbox is checked, then an additional condition that the amplitudes of the first M_{min} peaks successively decrease.

Note: The parameters "SWD Main Frequency Range", "Min. Number of Beat Spectrum Peaks for SWD" and "Beat Spectrum Length" are related: the beat spectrum length must be such that it contains required number of peaks, distanced from each other by intervals defined by the frequency range limits.

There are three possible cases.

1. For both low and high frequencies of the frequency range (i.e., for the entire frequency range) the given min. number of beat spectrum peaks fits into the given beat spectrum length. This is fully acceptable case, and the program will perform calculations without giving any warning or error messages.

2. For high frequency of the frequency range the given min. number of beat spectrum peaks fits into the given beat spectrum length, but for the low frequency it does not. For example, if the given beat spectrum length is 1 s, the lower frequency of the frequency range is 5 Hz, the higher is 10 Hz, and the given min. number of beat spectrum peaks is 6, then for 10 Hz (interval between peaks = 1/10 = 0.1s) for 6 peaks we will have 6x0.1=0.6s, which fits into 1s, but for 5 Hz (interval between peaks = 1/5 = 0.2s) for 6 peaks we will have 6x0.2=1.2s, which is greater than given 1s (so 6 peaks with 5 Hz do not fit into 1s interval). The calculations still may be performed in this case, taking into account the fact that the parameter space is restricted. Before accepting the parameters and performing calculations, the program will give the following warning message and ask the whether the calculations should be performed or not:
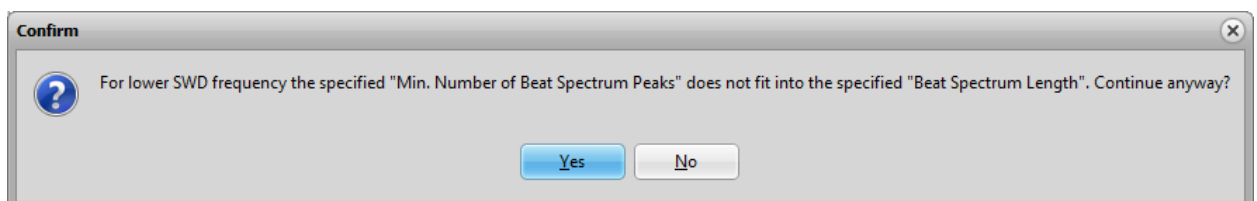
This message will be shown every time the program checks the correctness of the parameters, which is performed before every calculation (e.g., before every press of the "Test" button in the "Test Parameters on Current Event" group of controls, see

below), or when the user moves away from the Parameters tab. However, the user may choose not to show this message (i.e., ignore the situation and perform the calculations, as if he would press "Yes" on this message box every time), by checking the checkbox "Do Not Show Warning Message", which is located below the "SWD Identification Parameters" group.

3. For the entire frequency range the given min. number of beat spectrum peaks does not fits into the given beat spectrum length. This is not acceptable case, and the program will give the following error message:
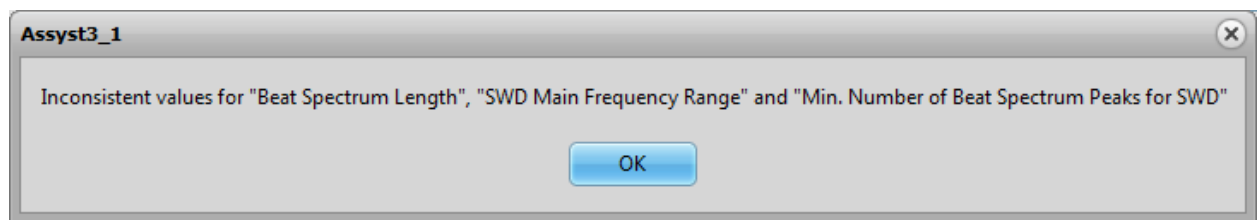
The **Amplitude Check Parameters** group (Fig. 1.6.13) specifies whether the amplitude checking based on line length method will be performed for the events that pass the periodicity criteria (as described in 6.8.1.3. Checking the SWD amplitudes based on Line length.) - if the checkbox "Check Amplitudes Using LineLength" is checked, and if yes, the size of the window, in seconds, that is used for line length calculation.
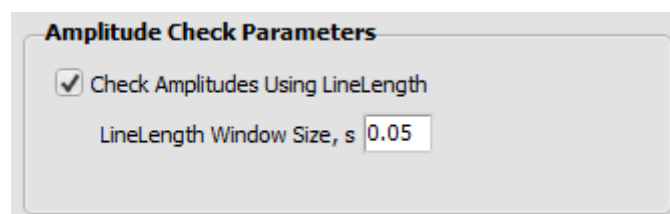
Fig. 1.6.13. The Amplitude Check Parameters.

The **Test Parameters on Current Event** group of controls (Fig. 1.6.14) allows to apply the running beat spectrum method, with the current parameter set, to a single event from the preliminary event list to check whether the event satisfies the conditions to be classified as an SWD or not. The event to which the method will be applied is the current event, i.e., the event from the preliminary event list that is currently selected for viewing in the "SBI & Channels" tab (see 1.3.3 The Control Panel).

The group contains the following controls:
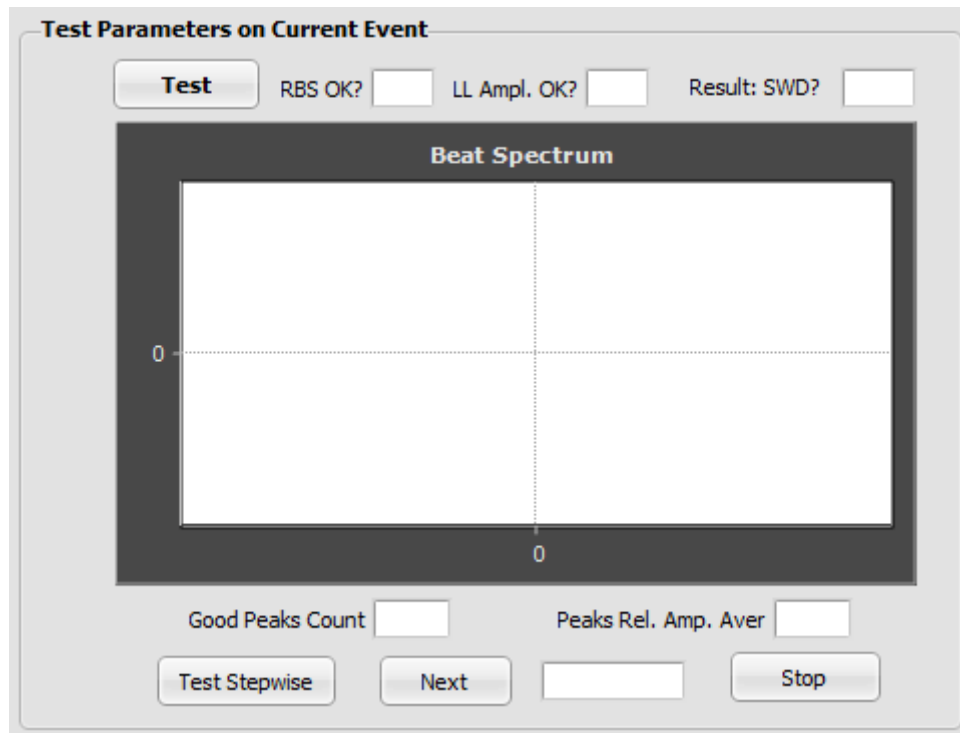
Fig. 1.6.14. Test Parameters on Current Event widget.

Test button - when pressed, the running beat spectrum algorithm is applied to the current event.

Result: SWD? read-only field - when the checking of the current event finishes, this field shoes either "YES" if the current event is classified as an SWD (or a rhythmic event with given frequency), or "NO" otherwise.

Beat Spectrum plot - shows the last calculated running beat spectrum. If the event is classified as SWD, then this will be the beat spectrum of the first rhythmogram window for which the conditions were satisfied (note that the running beat spectrum calculation is terminated as soon as the conditions for SWD are satisfied). If the event is not classified as SWD then this will be the beat spectrum of the last running rhythmogram window.

Good Peaks Count read-only field - shows the number of consecutive peaks of the beat spectrum shown in the plot that satisfied the frequency condition.

Peaks Rel. Amp. Aver. read-only field - shows the average of the relative amplitudes of the first K ("Number of Beat Spectrum First Peaks For Relative Amplitude Average" parameter) peaks of the beat spectrum that satisfied the frequency condition.

Test Stepwise button - when pressed, the program starts stepwise calculation of running rhythmogram and beat spectrum for the current event; it calculates the running beat spectrum for the first running rhythmogram window position, and then waits until either the "Next" button is pressed (to calculate the beat

spectrum at next position of running rhythmogram window) or the "Stop" button is pressed (to exit the stepwise running beat spectrum calculation mode). The calculated beat spectrum is plotted in the Beat Spectrum plot. When the "Test Stepwise" button is pressed, the "Next" and "Stop" buttons become enabled (otherwise they are disabled), and the "Test Stepwise" button becomes disabled (to prevent multiple presses) until the "Stop" button is pressed or the running rhythmogram window reaches the last position.

Next button and a read-only field next to it- this button is enabled after pressing the "Test Stepwise" button. When pressed, it moves the running rhythmogram window to the next position and calculates the beat spectrum for that position. The new window position - offset, in seconds, from the event's start time - is displayed in the read-only field on the right side of the "Next" button. The beat spectrum is plotted in the Beat Spectrum plot.

Stop button - this button is enabled after pressing the "Test Stepwise" button. When pressed, the program exits the stepwise running beat spectrum calculation mode, the "Next" and "Stop" buttons become disabled, and the "Test Stepwise" button becomes enabled again.

Fig. 1.6.15 shows examples of the "Test Parameters on Current Event" widget look in case of processing an event that is a SWD (left) and of an event that is not (right).
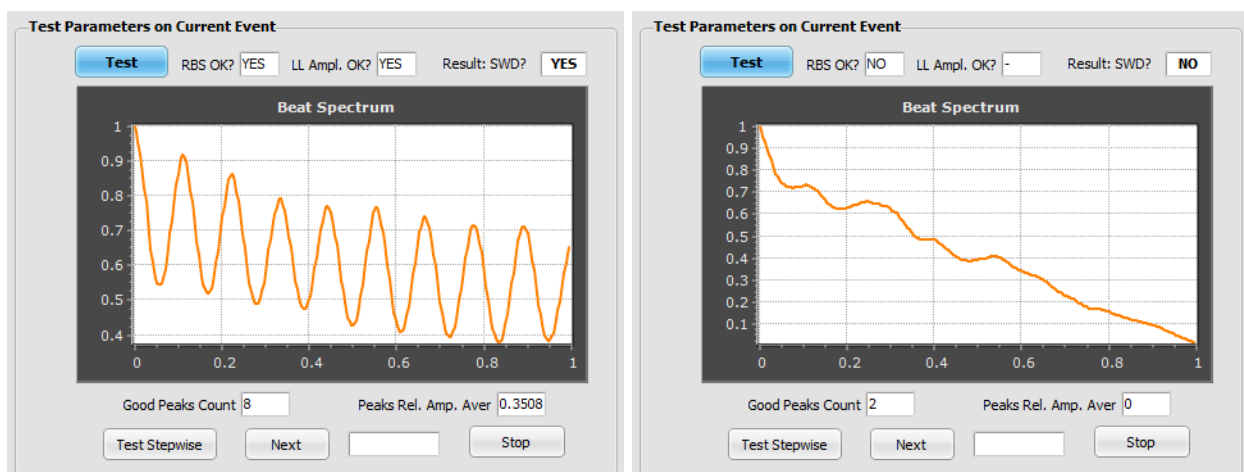
Fig. 1.6.15. Examples of the "Test Parameters on Current Event" widget look in case of processing an event that is a SWD (left) and of an event that is not (right).

1.6.2.3. The Instrumental Artefacts tab

The "Instrumental Artefacts" sub-tab of the "Advanced" tab (Fig. 1.6.16) contains controls to show and set the parameters used in the algorithm of automatic identification of strong instrumental artefacts described in 6.8.2. Automatic identification of large instrumental artefacts.

This tab currently contains a single control:

> Derivative Cut-off level editable field - is used to specify the value of the parameter p ($0<p<1$).
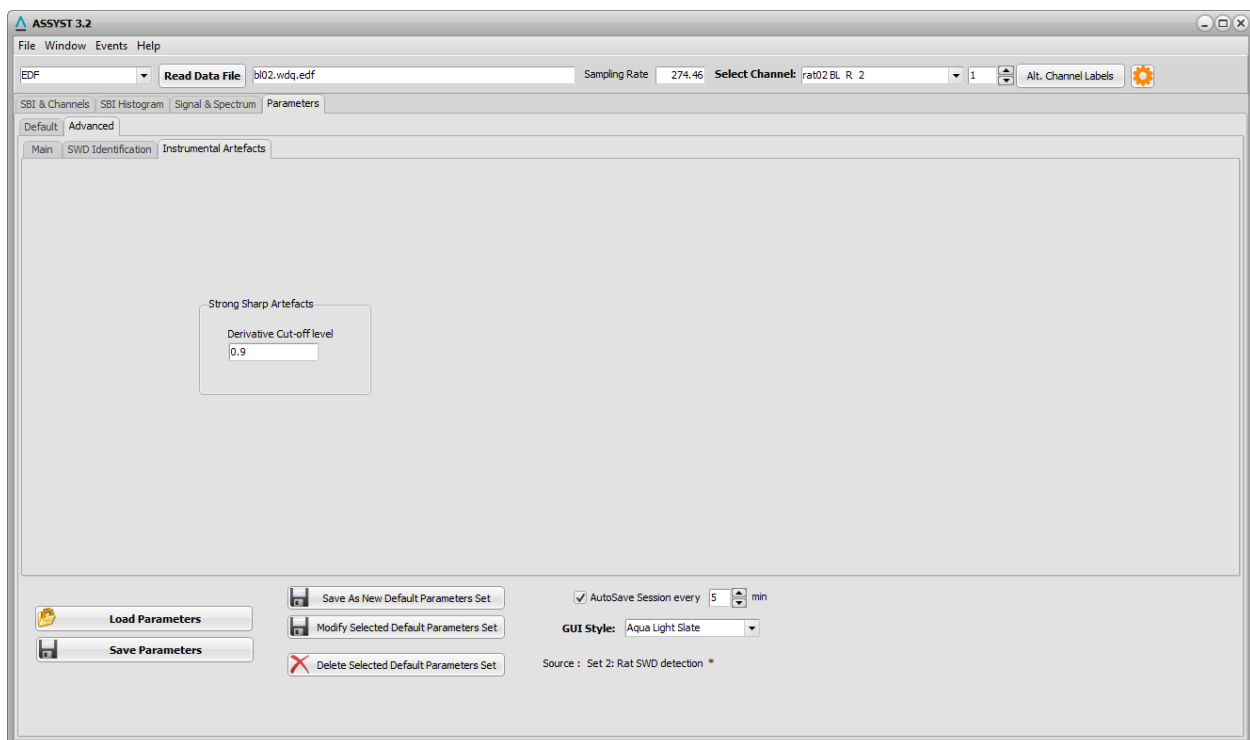
Fig. 1.6.16. The "Instrumental Artefacts" sub-tab of the "Advanced" sub-tab of the "Parameters" tab of the main window.

1.6.2.4. The LineLength Definitions tab

The "LineLength Definitions" sub-tab of the "Advanced" tab (Fig. 1.6.17) contains plots and controls for defining the line length thresholds (low and high) that are used for additional amplitude check during SWD identification, described in 6.8.1.3. Checking the SWD amplitudes based on Line length.

The tab contains two horizontal panes designed to display the line length (LL) peaks histogram ("LL Peaks Histogram" pane, top, Fig. 1.6.17) and the selected event's pre-processed (filtered and/or detrended) EEG and its line length curve ("Line Length" pane, bottom, Fig. 1.6.17), and a panel with several controls on the right side.

The "LL Peaks Histogram" and "Line Length" panes are separated by a horizontal moveable splitter allowing to change the vertical space allocation between the "LL Peaks Histogram" and "Line Length" panes.
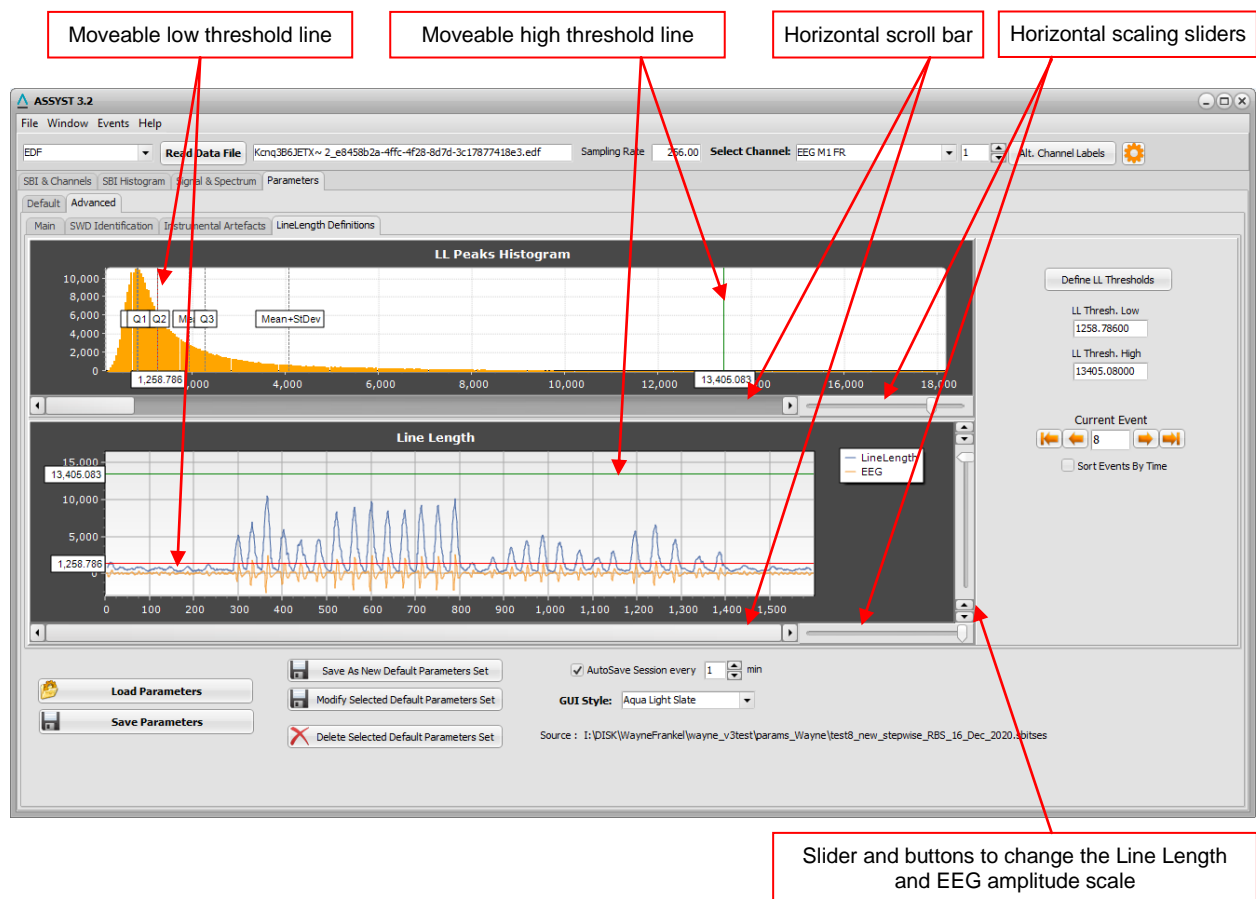
Fig. 1.6.17. The "LineLength Definitions " sub-tab of the "Advanced" sub-tab of the "Parameters" tab of the main window.

The panel on the right side contains the following controls (Fig. 1.6.18):
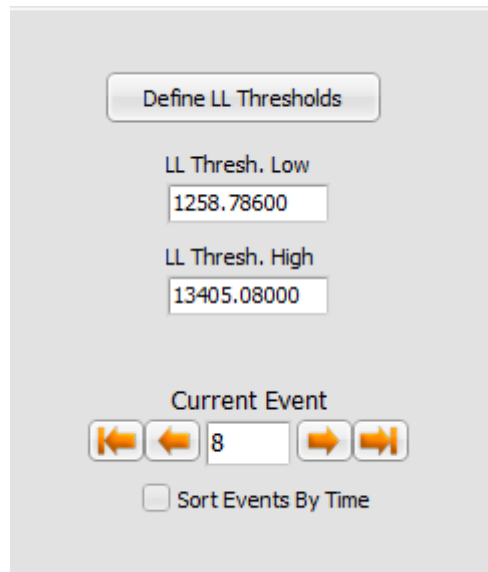
Fig. 1.6.18. The controls on the right panel of the "LineLength Definitions " sub-tab of the "Advanced" sub-tab of the "Parameters" tab of the main window.

Define LL Thresholds button - when pressed, the LL peaks histogram is calculated and the low and high LL threshold values are defined as described in 6.8.1.4. Automatic definition of Line length (LL) thresholds. The LL peaks histogram is calculated for the events that are in the preliminary event list, thus, this button must be pressed only after the events are selected into the preliminary list (otherwise this button is disabled). The defined threshold values are displayed in the "LL Thresh. Low" and "LL Thresh. High" editable fields.

LL Thresh. Low and LL Thresh. High editable fields - display the low and high LL threshold values defined either automatically (after pressing the "Define LL Thresholds" button) or manually by moving the corresponding threshold lines on "LL Peaks Histogram" and "Line Length" panes. The values of thresholds may also be directly entered manually in these fields.

Current Event group of controls and Sort Events By Time checkbox are identical to (and coupled with) the similar controls on the "SBI & Channels" tab (see 1.3.3 The Control Panel).

1.6.2.5. Other controls on the Advanced tab

Autosave Set Up - The "Advanced" tab contains also a checkbox (Fig. 1.6.19) to switch on or off the automatic saving of the current state of the program (session), including all parameter settings, input data information, SBI curve, selected threshold and all selected and classified events, in a special file '~autosave.sbitses' (this file will be located in the home path of the application's writable scratch directory or storage; on Windows this will be "***X***:*Documents and Settings****your_user****Application Data*").

The periodicity of auto-saving is specified in minutes in the spin control next to the checkbox. Auto-saving allows to restore the session after an unexpected interruption of the program, using the File → Recover Session menu item in the program's main menu (see 1.1 The Menu).
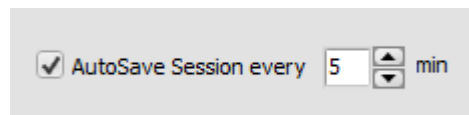
Fig. 1.6.19. Controls for automatic saving of the current state of the program.

The "Advanced" tab contains the following buttons (Fig. 1.6.20):
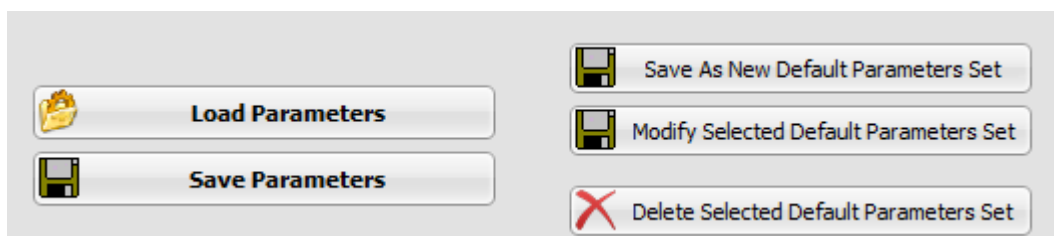
Fig. 1.6.20. Buttons to save or load parameter values to or from a file and to create new default parameter sets or modify the existing ones.

Load Parameters – Loads the parameter values from a parameter file (these files have extension '.sbitpar') selected by the user by means of a standard "Open file" dialog;

Save Parameters – Saves the parameter values to a parameters file (these files have extension '.sbitpar') by means of a standard "Save file" dialog; the user can create arbitrary number of such parameter files and place them in arbitrary locations;

Save As New Default Parameters Set – Allows the user to create and save a new named set of default parameters which is then added to the list of default parameter sets and, accordingly, to the "Select" combo box on the "Default" tab.

When this button is pressed, a small dialog appears asking the user to enter a name and a description for the new default set (Fig. 1.6.21). The user has to provide a unique name for the set, not repeating the names of existing sets, because the file name in which the default set is stored is generated automatically based on the set's name given by the user. The "Description" is optional. The user can create arbitrary number of additional default parameter sets with arbitrary (but non-duplicate) names. The default parameter sets files are stored in the program's data directory: "*X*:\ProgramData\Kaoskey\ASSYST*".
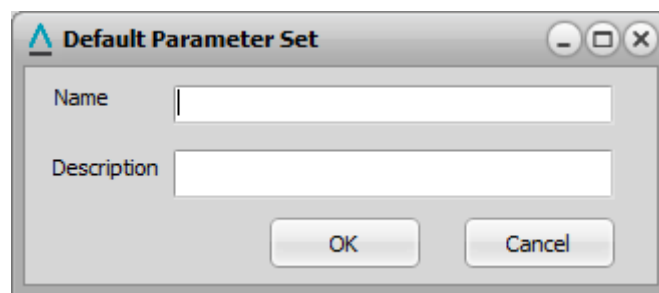
Fig. 1.6.21. Dialog to provide a name and description for a new default parameter set.

Modify Selected Default Parameters Set – Allows the user to change the parameter values in the currently selected (in the "Select" combo box on the "Default" tab) default parameter set, by modifying the desired parameter values on the "Advanced" tab and then pressing this button to replace the old values in the corresponding default parameter sets file with the new ones (the file is actually rewritten and old values are lost and cannot be restored). When this button is pressed, a warning message appears (Fig. 1.6.22) asking to confirm the action.
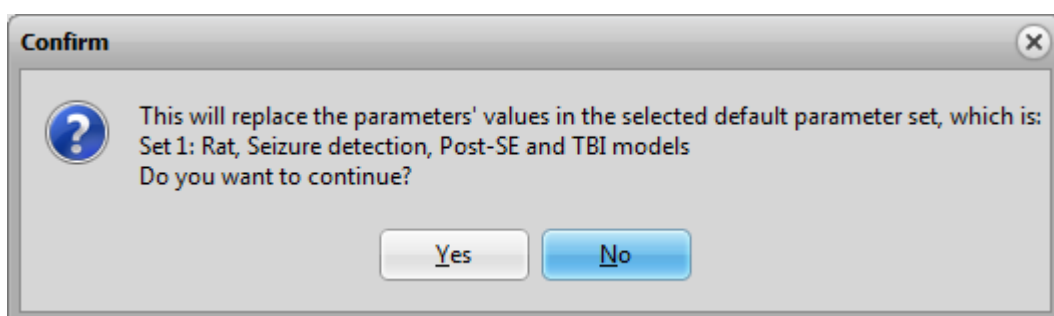
Fig. 1.6.22. Warning message that appears when the user presses the "Modify Selected Default Parameters Set" button.

Delete Selected Default Parameters Set – Allows the user to delete the currently selected (in the "Select" combo box on the "Default" tab) default parameter set. When this button is pressed, a warning message appears (Fig. 1.6.23) asking to confirm the action.
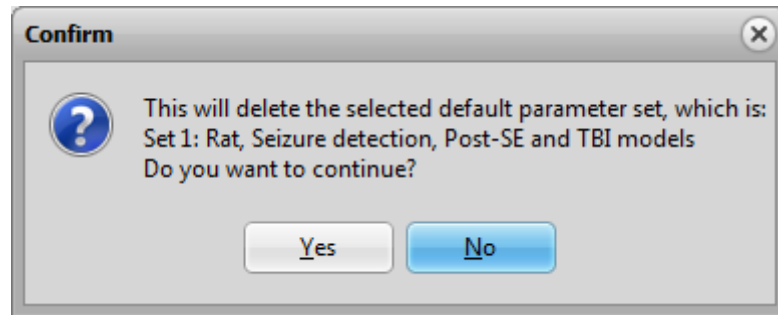
Fig. 1.6.23. Warning message that appears when the user presses the "Delete Default Parameters Set" button.

Combo box for Selecting the GUI style - The "Advanced" tab also contains a combo box (Fig. 1.6.24) allowing to select a style for the graphical user interface (i.e. the "look" of the program windows). The combo box contains a list of available GUI styles.
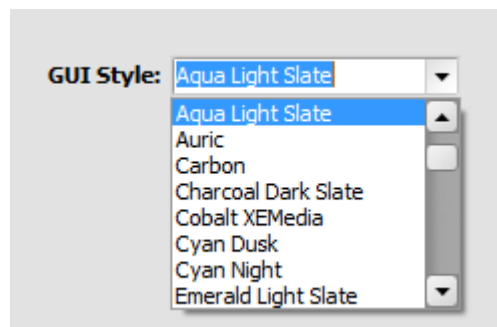
Fig. 1.6.24. Combo box for selecting the GUI style.

When a style is selected in the combo box, the change to the program look occurs immediately; the selected style is remembered so the next time the user starts the program it will have the selected style.

An example of the program's main window with different GUI style is shown in Fig. 1.6.25.
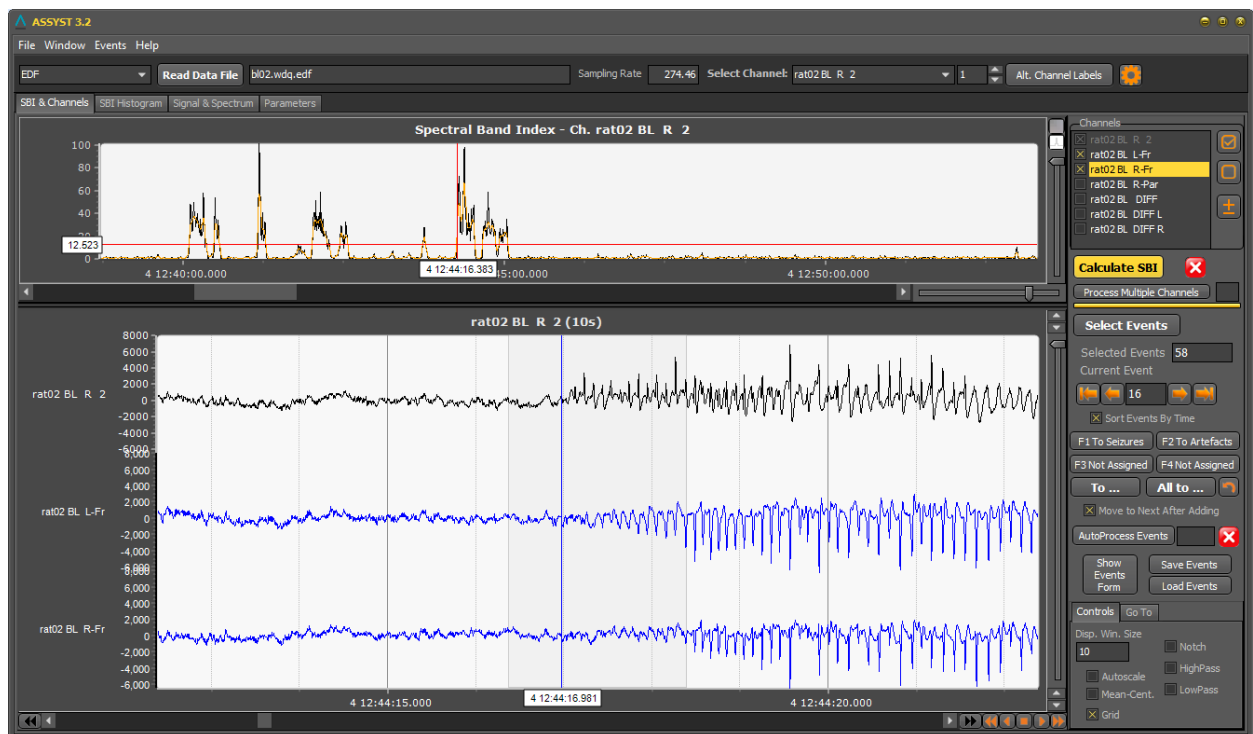
Fig. 1.6.25. An example of program's main window with different GUI style.

2. Other Windows and Dialogs

2.1. Alternative Channel Labels Dialog

This dialog (Fig. 2.1.1) appears when the user presses the "Alt. Channel Labels" button on the upper control panel (see 1.2 Upper Control Panel) of the program's main window.

It allows defining (and then using) alternative labels (names) for channels. The dialog contains a table with three columns. The first column ('#') is the channel's index, the second column ('Orig. Label') is the original label of the channel as read from the data file, and the third column ('Alt. Label') is the alternative label. The first two columns are read-only, while the third column can be edited by the user. Initially the 'Alt. Label' column contains the same labels as the 'Orig. Label' column. The user can edit the values in the third column, replacing the original labels with desired ones.

These changed alternative labels will be remembered by the program after the dialog is closed with the "OK" button (and will be shown the next time the user opens this dialog), but they will not be applied unless the "Use Alternative Labels" checkbox is checked. If the dialog is closed with "Cancel" button, all the new changes are discarded.
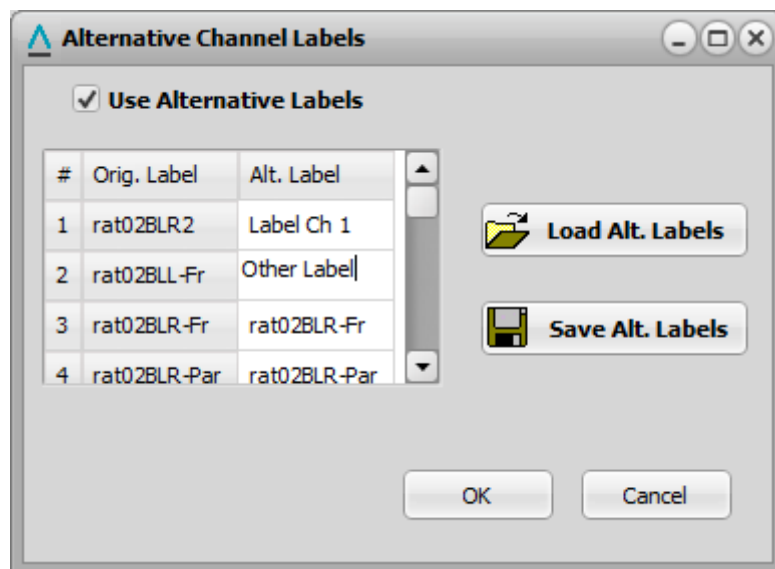
Fig. 2.1.1. Alternative Channel Labels dialog.

It is possible to save the defined labels for subsequent use, by pressing the "Save Alt. Labels" button. This will open a standard save file dialog where the user selects the location and provides the file name. The saved file is a text file, with extension ".altlab.txt", which contains two columns (for original and alternative labels), separated by a colon. So it can be opened and edited (with care, preserving the structure) by any

text editor. The previously saved alternative label definitions may be loaded into the program by pressing the "Load Alt. Labels" button, which will open a standard file open dialog, where the user selects the desired ".altlab.txt" file to load. When loading labels from a file, the program compares the number of channels and the original channel labels from the file with the number of channels and channel labels of the loaded EEG data (which must coincide), and if there is a mismatch, the program gives an error message shown in Fig. 2.1.2.
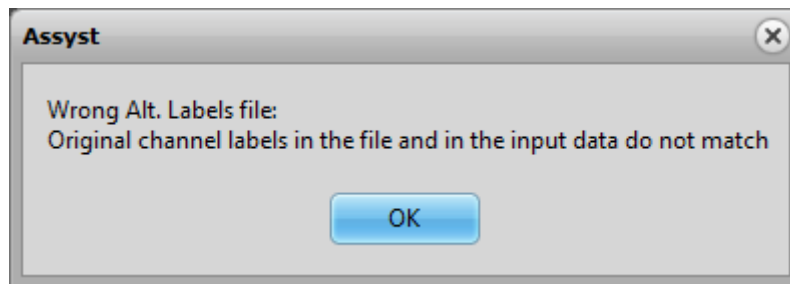
Fig. 2.1.2. Error message shown when trying to load a wrong label definitions file (e.g., a file defined for a different EEG data set).

2.2. Processing Parameters Dialog

This dialog (Fig. 2.2.1) appears when the user presses the 🔧 button on the upper control panel (see 1.2 Upper Control Panel) of the program's main window.
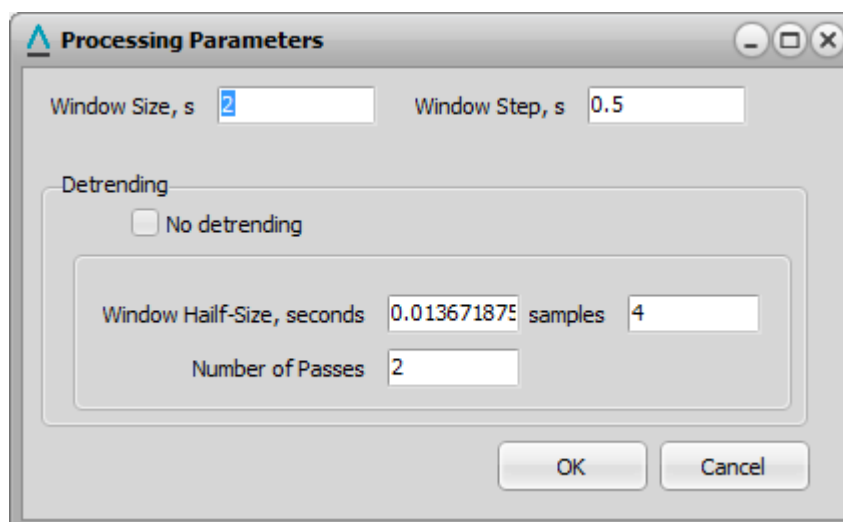
Fig. 2.2.1. Processing Parameters dialog.

The dialog contains a subset of processing parameters, including processing window and de-trending parameters. These parameters can be set also on

"Parameters"→"Advanced" tab of the program's main window (see 1.6.2 The Advanced tab), but sometimes using this dialog may be more convenient, especially when experimenting with baseline trend removal and window size and their effect on EEG's power spectrum on the "Signal & Spectrum" tab (1.5 The Signal & Spectrum tab).

2.3. Save Events Dialog

The "Save Events" dialog (Fig. 2.3.1) appears when the user presses the "Save Events" button on the Control panel of the "SBI & Channels" tab of the program's main window (see 1.3.3 The Control Panel).
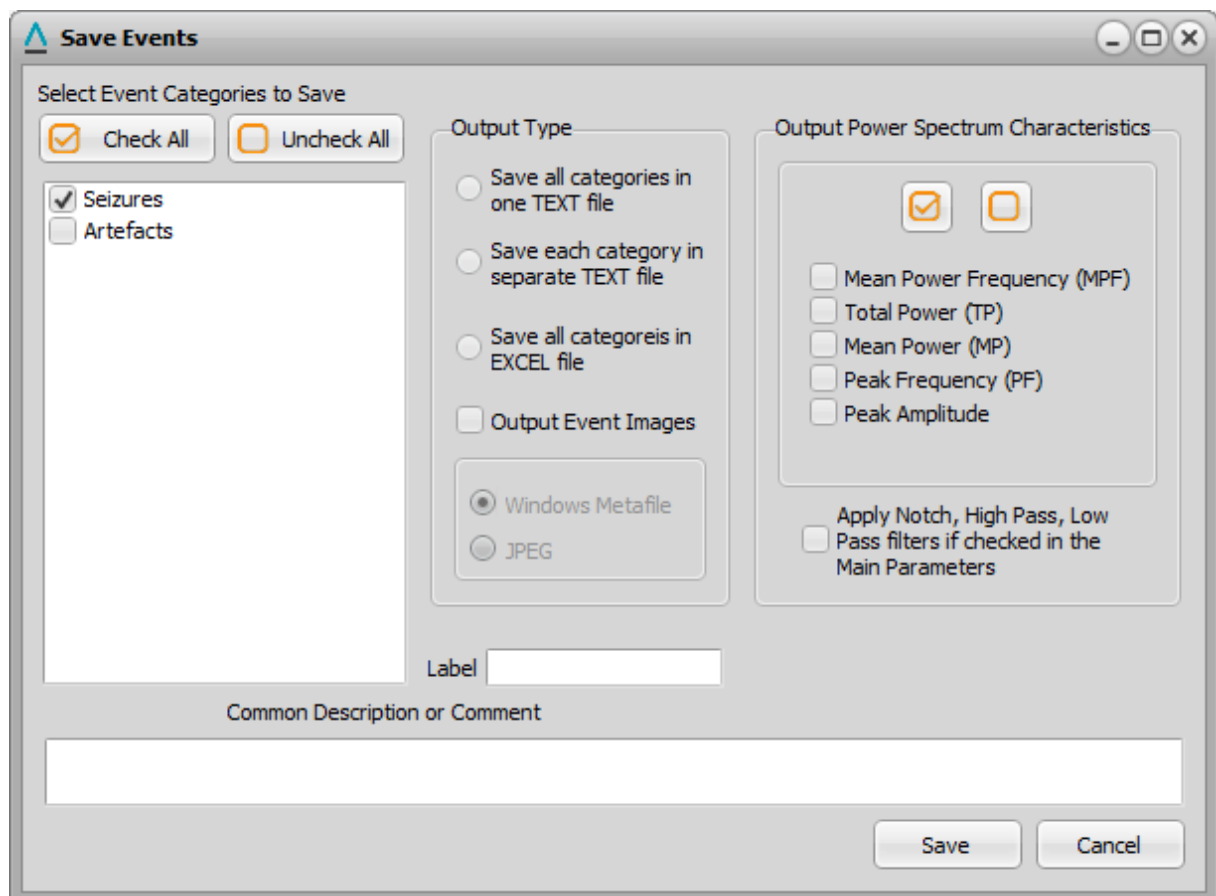
Fig. 2.3.1. Save Events dialog.

The dialog allows to select the event categories that need to be saved and the type of the output file(s), as well as to provide a text string (label) that will be added to the output file name, and a description or comment that will be inserted into the output file.

The dialog contains the following controls:

<u>Select Event Categories to Save</u> list - contains the list of Event Categories with checkboxes. Only the contents of the checked categories will be included in the output file(s); pressing the "Check All" or "Uncheck All" buttons above the list will check or uncheck all event categories;

<u>Output type</u> - a group of radio buttons to select how the contents of event categories will be saved. It contains the following options (see <u>4.1. The main output – selected events</u> for file formats and name):

    <u>Save all categories in one TEXT file</u> – if this radio button is selected, then all the checked event categories (and events therein) are saved into a single ASCII file;

    <u>Save each category in separate file</u> – if this radio button is selected, then each checked category contents will be output in a separate ASCII file;

    <u>Save all categories in EXCEL file</u> - if this radio button is selected, then all the checked event categories (and events therein) are saved into a single Excel file;

    <u>Output Event Images</u> checkbox - if this checkbox is checked, the program will automatically generate and save image files for all events in the checked categories (see <u>4.1.1. Saving images of the events</u>). Below this checkbox there is a group of radio buttons for selecting the image file type; it contains the following options:

        <u>Windows Metafile</u> - save the event images in Windows Metafile (WMF) format (WMF is a vector graphics format which is portable between Microsoft Office applications (such as Word, PowerPoint, and Publisher). Some non-Microsoft applications also can deal with WMF files).

        <u>JPEG</u> - save the event images in JPEG format.

<u>Output Power Spectrum Characteristics</u> - a group of checkboxes to select which of the additional power spectrum characteristics will be saved in the output file(s). It contains the following options and controls:

    <u>Mean Power Frequency (MPF)</u> – if this checkbox is checked, the mean power frequency of each event will be outputted, for original ('MPF Or') and detrended ('MPF Det') EEG;

    <u>Total Power (TP)</u> – if this checkbox is checked, the total power of each event will be outputted, for original ('TP Or') and detrended ('TP Det') EEG;

    <u>Mean Power (MP)</u> - if this checkbox is checked, the mean power of each event will be outputted, for original ('MP Or') and detrended ('MP Det') EEG;

Peak Frequency (PF) - if this checkbox is checked, the frequency at which the power spectrum of an event has maximum will be outputted, for original ('PF Or') and detrended ('PF Det') EEG;

Peak Amplitude (PA) - if this checkbox is checked, the maximum value of the power spectrum of each event will be outputted, for original ('PA Or') and detrended ('PA Det') EEG;

Check all ☑ and Uncheck all ☐ buttons - allow to check or uncheck all above options at once;

Apply Notch, High Pass, Low Pass filters if checked in the Main Parameters checkbox - if this checkbox is checked, the EEG within the event interval will be filtered before calculating the power spectrum characteristics. Which filters will be applied (notch, high-pass or low-pass) and their parameters depends on the settings of the corresponding controls on the "Main" sub-tab of the "Advanced" sub-tab of the "Parameters" tab (Signal Filtering parameters, 1.6.2.1. The Main parameters tab, see also 6.8.1.1. Pre-processing.);

Label editable field – allows to enter a text string that will be added to output file(s) name;
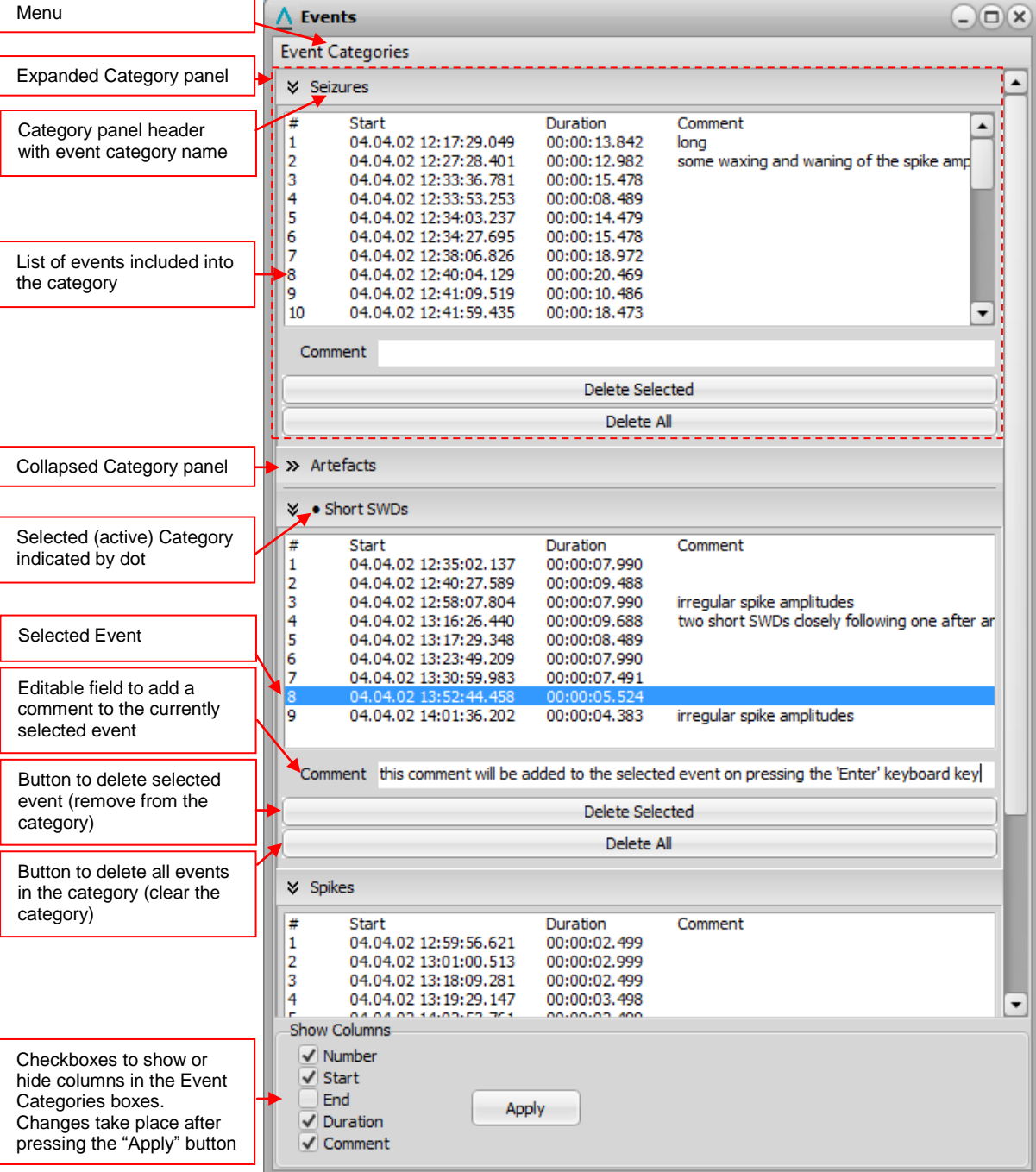
Common Description or Comment editable field – allows to enter a text that will be included into the output file(s);

Save button – pressing this button will open a standard file save dialog to select the location of the output file. The file name field of the file save dialog will show the proposed automatically generated name for the output file (see 4.1. The main output – selected events), which can be further modified by the user;

Cancel button – closes the dialog without saving the events.

2.4. The Events Form

The Events form (Fig. 2.4.1) shows the lists of events included by the user into corresponding event categories.

Fig. 2.4.1. The Events form.

The Events form contains vertically arranged collapsible/ expandable panels (*Event Category panels*), each one of which contains the events from one category (there are as many panels as the event categories). The panel has a caption, which shows the name of the corresponding event category. The panel can be collapsed or expanded by clicking on the panel's header.

The Event form has a *Menu* and some checkboxes (*Show Columns*) to select which information about the event is shown in the event lists.

2.4.1. Menu

The menu items and description of actions they perform are listed below:

Event Categories Menu (Fig. 2.4.2):
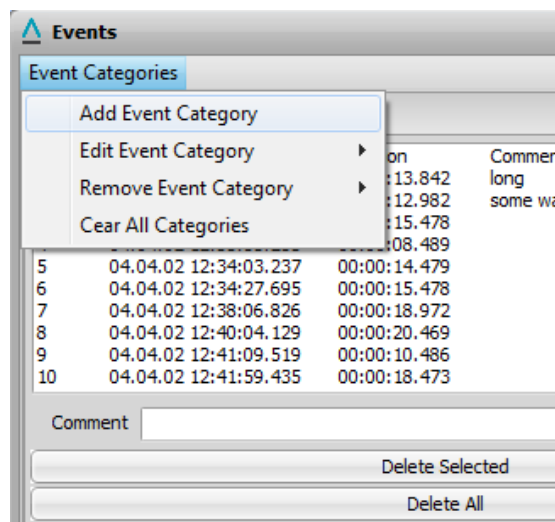
Fig. 2.4.2. The Event Categories menu.

Add Event Category - Adds a new event category; when this item is selected, the "Event Category" (Fig. 2.4.3) modal dialog appears where the user provides a name (obligatory) and description (optional) for the new category; pressing the "OK" button on this dialog will add the new category (corresponding category panel will appear on the "Events" form); pressing the "Cancel" button will cancel this action;
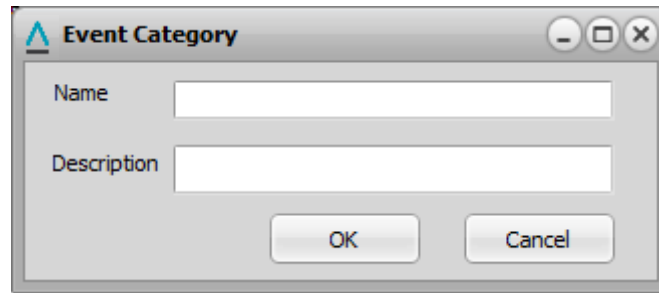
Fig. 2.4.3. The New Event Category dialog allowing to provide a name (obligatory) and description (optional) for a new Event Category

Edit Event Category - Allows to edit the name and description of an existing event category; when this menu item is selected, a sub-menu appears that contains the list of existing event categories, from which the user selects the desired one (Fig. 2.4.4).
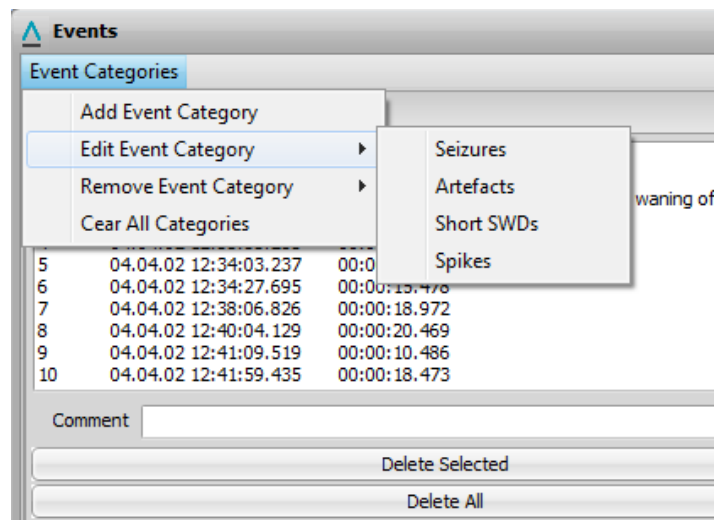
Fig. 2.4.4. The submenu of the "Edit Event Category" menu item listing the names of defined Event Categories.

When the desired category is selected in this sub-menu, the "Edit Event Category" dialog appears (Fig. 2.4.5) with the "Name" and "Description" fields filled with the current name and description of the selected Event Category, and the user can change them; pressing the "OK" button on this dialog will apply the changes; pressing the "Cancel" button will cancel this action;
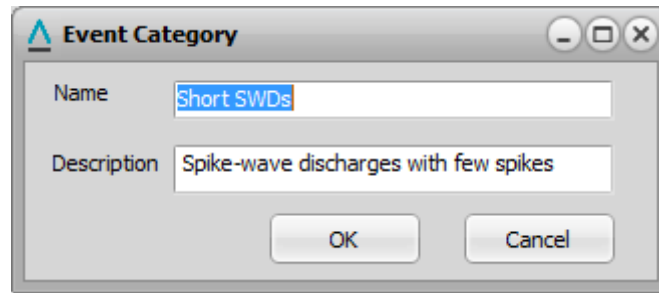
Fig. 2.4.5. The Edit Event Category dialog allowing to change the name and description of an existing Event Category.

Remove Event Category - Removes an existing event category (and its contents, if any); when this menu item is selected, a sub-menu appears that contains the list of existing event categories, from which the user selects the category he wants to delete (Fig. 2.4.6); the first two categories cannot be removed, since there must be at least two categories for classification (but they can be edited and provided with desired name and description using the Edit Event Category action above);
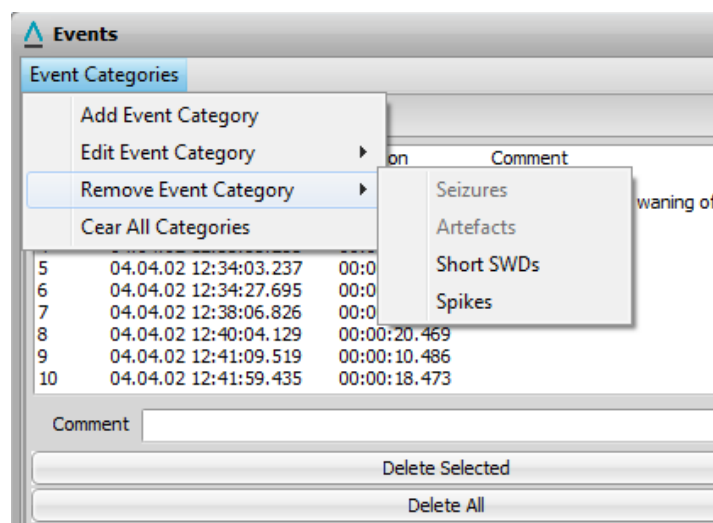
Fig. 2.4.6. The submenu of the "Remove Event Category" menu item listing the names of defined Event Categories. Note that the first two categories are disabled, i.e., they cannot be deleted – there must be at least two categories in the program.

Clear All Categories - empties the contents of all categories, i.e. removes all events that were included into the categories; it does not remove the event categories themselves; this is equivalent to pressing the "Delete All" buttons on all category panels.

2.4.2. Event Category panel

Each Event Category panel has the following fields and controls (Fig. 2.4.1):

Header – The upper part of the panel that contains the category name. Clicking the header will collapse or expand the panel. The panel that is currently active is indicated by a '●' symbol in front of the category's name.

Events list – The list of events included into the event category. The list may have up to five columns (the user may select which columns are shown using the checkboxes at the bottom of the Events form):

'#' (Number) – The number of the event. The events in the list are sorted according to occurrence time ('Start'), in ascending order.

'Start' – The start date and time of the event. The format of the date and time is 'dd.mm.yy hh:mm:ss.000' ('000' for milliseconds).

'End' – The end date and time of the event.
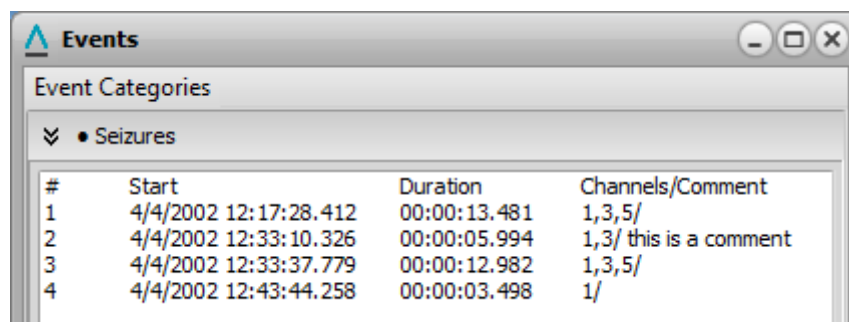
'Duration' – The duration of the event. The format is 'hh:mm:ss.000'.

'Comment' (in single channel processing mode) or 'Channels/Comment' (in multiple channels processing mode) – The comment or brief description entered by the user for the event. The comments are entered by selecting an event in the Events list and then typing the comment's text in the "Comment" field below the Events list and hitting the keyboard's "Enter" key. If multiple channels processing was performed (see 6.7. Multiple channels processing) then this column is titled 'Channels/Comment' and shows, in front of the comment text, the indices of the channels in which the event was detected (Fig. 2.4.7).

Comment - editable field where the user can enter a comment or description for the event currently selected in the Events list. The comment will appear in the 'Comment' column of the selected event after the user presses the "Enter" key on the keyboard.

Delete Selected button – Deletes the selected event from the Event Category.

Delete All button – Deletes all events from the Event Category.

Fig. 2.4.7. The Events Category panel after multiple channels processing.

The Event Category panel has also a popup menu that appears when the user right-clicks in the Events list area (Fig. 2.4.8).
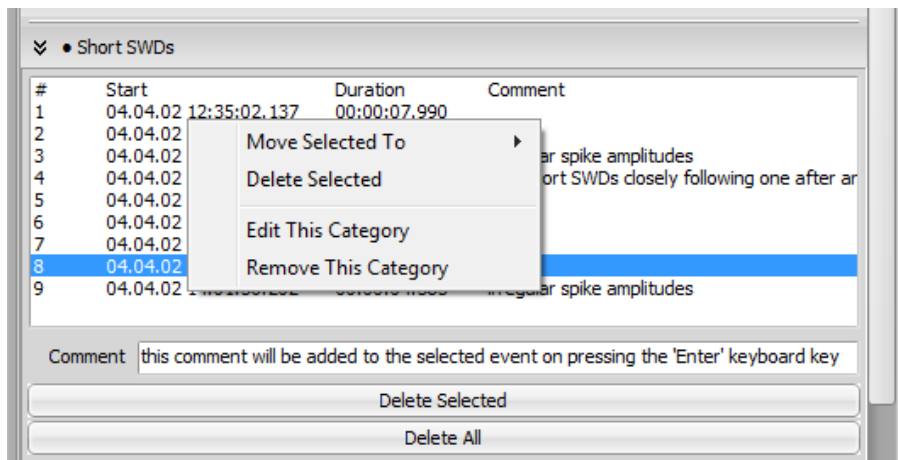
Fig. 2.4.8. The popup menu of the Event Category panel.

The popup menu items and description of actions they perform are listed below:

Move Selected To – Moves the selected event from this category to another category. When this menu item is selected, a submenu appears that contains the list of existing event categories, from which the user selects the one to which the event must be moved (Fig. 2.4.9; logically, the current category is disabled in the submenu);
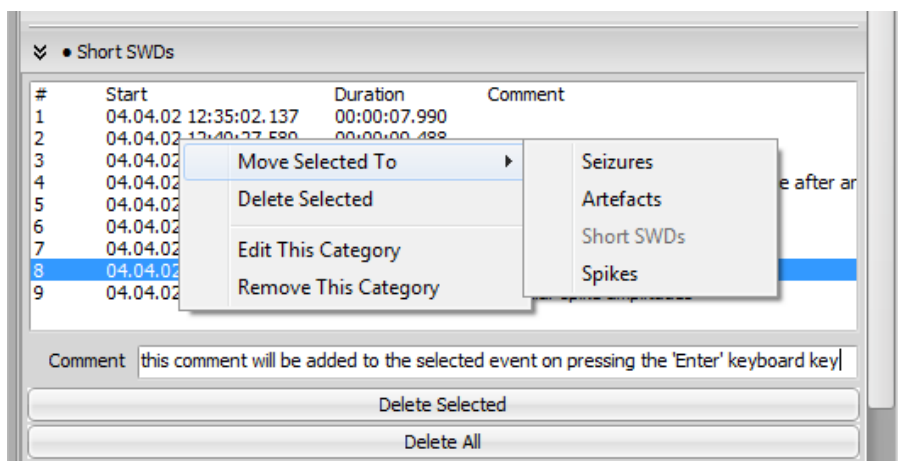
Fig. 2.4.9. The submenu of the "Move Selected To" popup menu item listing the names of defined Event Categories. Note that in the submenu the current category name is disabled.

Delete Selected - Deletes the selected event from the Event Category (identical to the "Delete Selected" button).

Edit This Category – Allows to edit the name and description of this event category. When this menu item is selected, the "Edit Event Category" dialog appears (Fig. 2.4.5) with the "Name" and "Description" fields filled with the current name and description of the Event Category, and the user can change them; pressing the "OK" button on this dialog

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will apply the changes; pressing the "Cancel" button will cancel this action. This action is identical to the "Edit Event Category" action of the Events form's menu.

Remove This Category - Removes this event category (and its contents, if any). This action is identical to the "Remove Event Category" action of the Events form's menu.

2.4.3. Selecting an Event

The user can select an event by clicking on the corresponding row of the Events list of an Event Category panel; or can also use the up or down arrow keys of the keyboard to select the previous or next event in the list, correspondingly.

When the user selects an event in the Events list of an Event Category panel, the corresponding EEG fragment is automatically shown in the Signal pane of the SBI & Signal tab of the program's main window (Fig. 2.4.10). The event is highlighted by a pink band, the left and right edges of which correspond to the event's start and end times. These edges are movable (by mouse), so the user can adjust the start and end time of the event. When the position of left or right edge is changed, the start or end time (correspondingly) of the event in the Events list of the Event Category panel on the Event form is immediately updated.
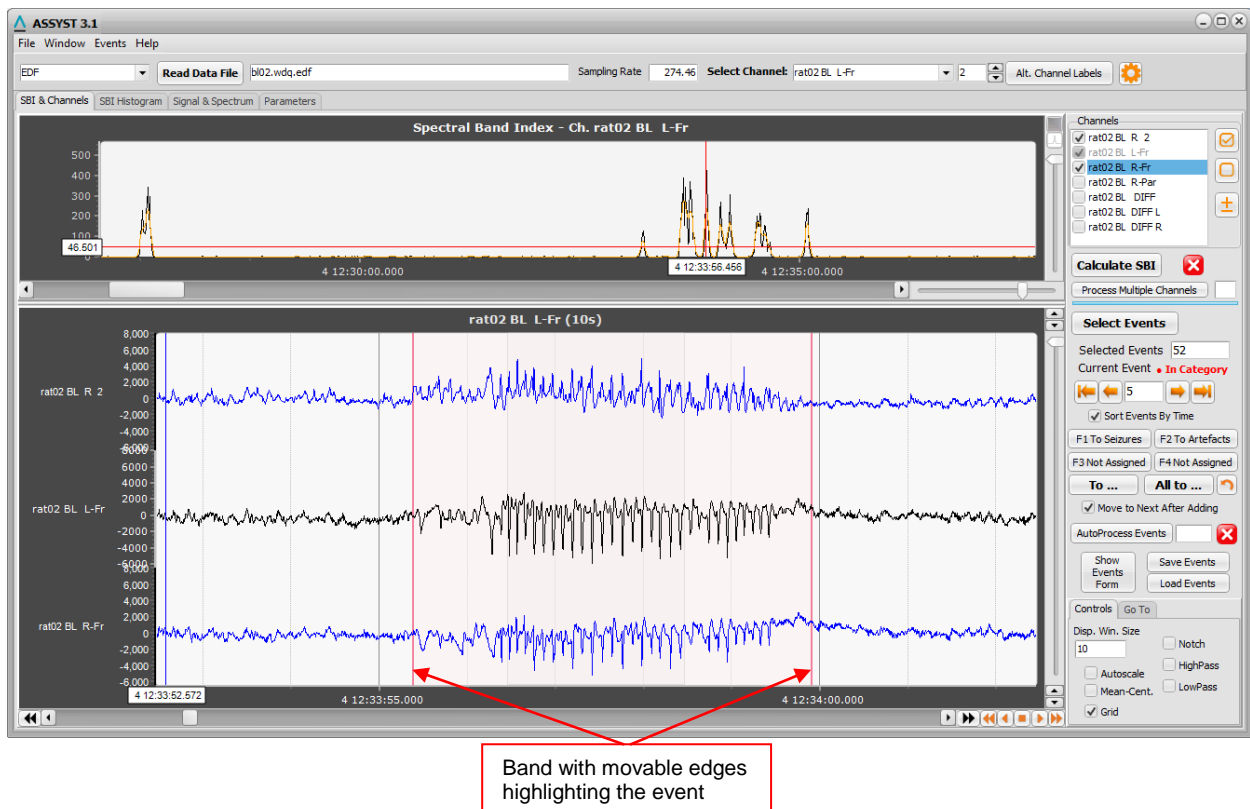
Fig. 2.4.10. The main window showing the selected event in the current event category panel on the Events form.

If the event selected by the user in the Events list of an Event Category panel is a result of multiple channel processing (see 5.2. Multiple channels processing and 6.7. Multiple channels processing), then in the Signal pane of the SBI & Signal tab of the program's main window the channels in which this event was detected (i.e., the SBI was suprathreshold) are drawn in red (Fig. 2.4.11).
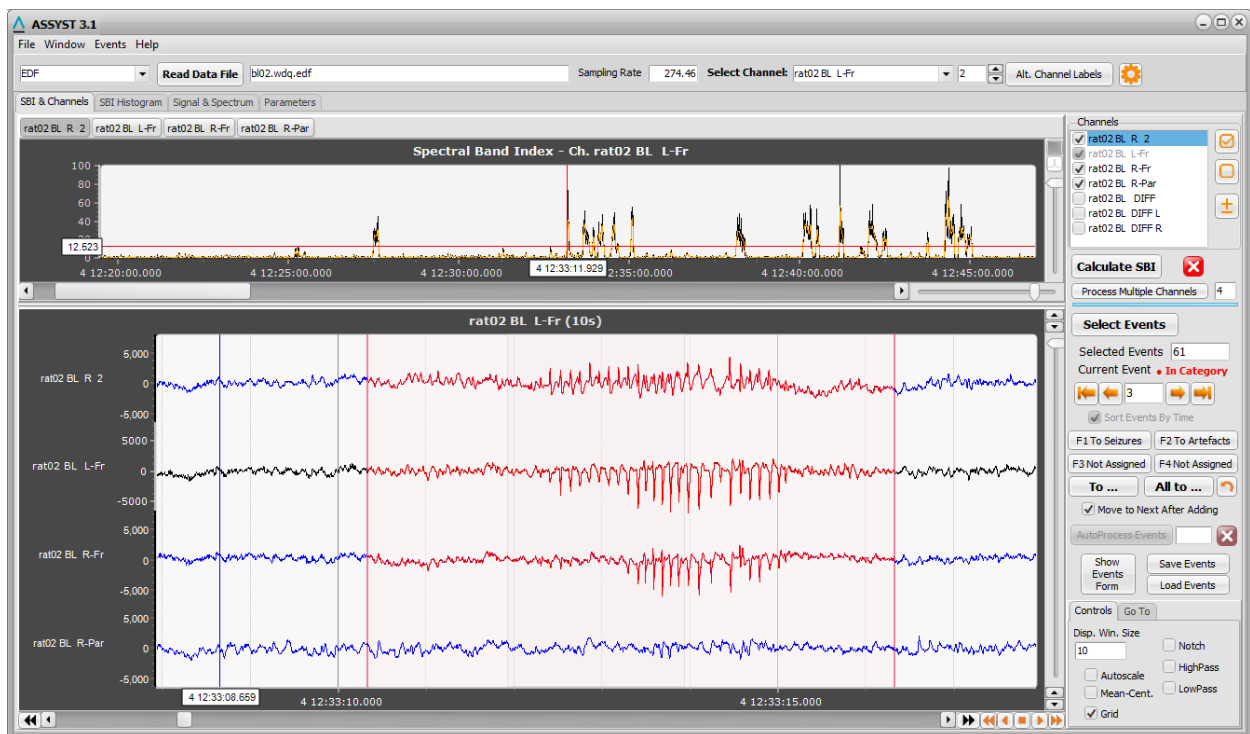
Fig. 2.4.11. The main window showing the selected event in the current event category panel on the Events form in case of the Multiple channels processing. The channels with red signal are the channels in which this event was detected.

2.4.4. Show Columns group of controls

The Show Columns group of controls at the bottom of the Events form contains checkboxes to show/hide corresponding columns in the events lists, and the "Apply" button to apply the changes made to the checkboxes (Fig. 2.4.1).

2.5. Autoprocess Events Dialog

The "Autoprocess Events" dialog (Fig. 2.5.1) appears when the user presses the "AutoProcess Events" button on the Control panel of the "SBI & Channels" tab of the program's main window (see 1.3.3 The Control Panel).
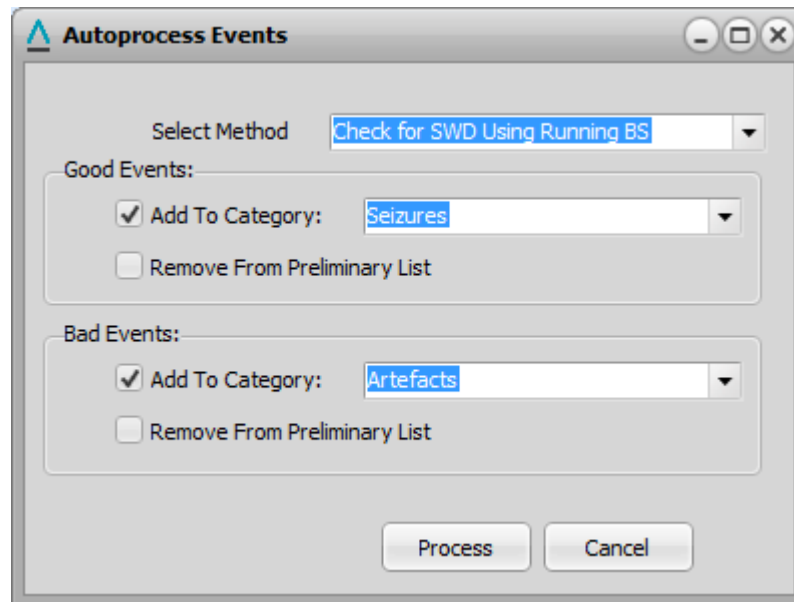
Fig. 2.5.1. Autoprocess Events Dialog.

The dialog allows to select the method for automatic processing of the events in the preliminary events list and specify what should be done with the resulting events.

Currently, there are two methods for automatic processing of events:

1. Automatic Identification of Spike-Wave Discharges Using Running Beat Spectrum (see 6.8.1. Automatic Identification of Spike-Wave Discharges (SWD))

2. Automatic Identification of Strong Instrumental Artefacts (see 6.8.2. Automatic identification of large instrumental artefacts)

All methods of automatic event processing separate the events from the preliminary event list into two groups: "Good Events" - the events that satisfy certain criteria and thus must be accepted, and "Bad Events" - the events that must be rejected. The "good" or "bad" events may be added to a selected event category and/or removed from the preliminary list of events.

The dialog contains the following controls:

Select Method combo box - allows to select the processing method. It contains the following items:

Check for SWD Using Running BS - for method 1 (Automatic Identification of Spike-Wave Discharges Using Running Beat Spectrum);

Check for Instrumental Artefacts - for method 2 (Automatic Identification of Strong Instrumental Artefacts).

Good Events group box - contains controls to specify what should be done with the events that are identified as "good". The group has following controls:

Add to Category checkbox with associated combo box next to it – if this checkbox is checked, then the events identified as "good" will be added to the event category selected in the combo box next to it. The combo box contains list of all currently available event categories (see 2.4. The Events Form). The user may create dedicated categories for "good" and "bad" events before the automatic event processing, on the Events form (see 2.4.1. Menu, "Add Event Category").

Remove From Preliminary List checkbox - if this checkbox is checked, the events identified as "good" will be removed from the preliminary list of events; accordingly, the number of the events in the preliminary list shown in the "Selected Events" field on the right control panel of the "SBI & Channels" tab of the main window will decrease by the number of removed events.

Bad Events group box - contains controls to specify what should be done with the events that are identified as "bad". The group has following controls:

Add to Category checkbox with associated combo box next to it – if this checkbox is checked, then the events identified as "bad" will be added to the event category selected in the combo box next to it. The combo box contains list of all currently available event categories (see 2.4. The Events Form). The user may create dedicated categories for "good" and "bad" events before the automatic event processing, on the Events form (see 2.4.1. Menu, "Add Event Category").

Remove From Preliminary List checkbox - if this checkbox is checked, the events identified as "bad" will be removed from the preliminary list of events; accordingly, the number of the events in the preliminary list shown in the "Selected Events" field on the right control panel of the "SBI & Channels" tab of the main window will decrease by the number of removed events.

2.6. Define Montage Dialog

The "Define Montage" dialog (Fig. 2.6.1) appears when the user presses the ⊞ button in the "Channels" list control on the Control panel of the "SBI & Channels" tab of the program's main window (see 1.3.3 The Control Panel).
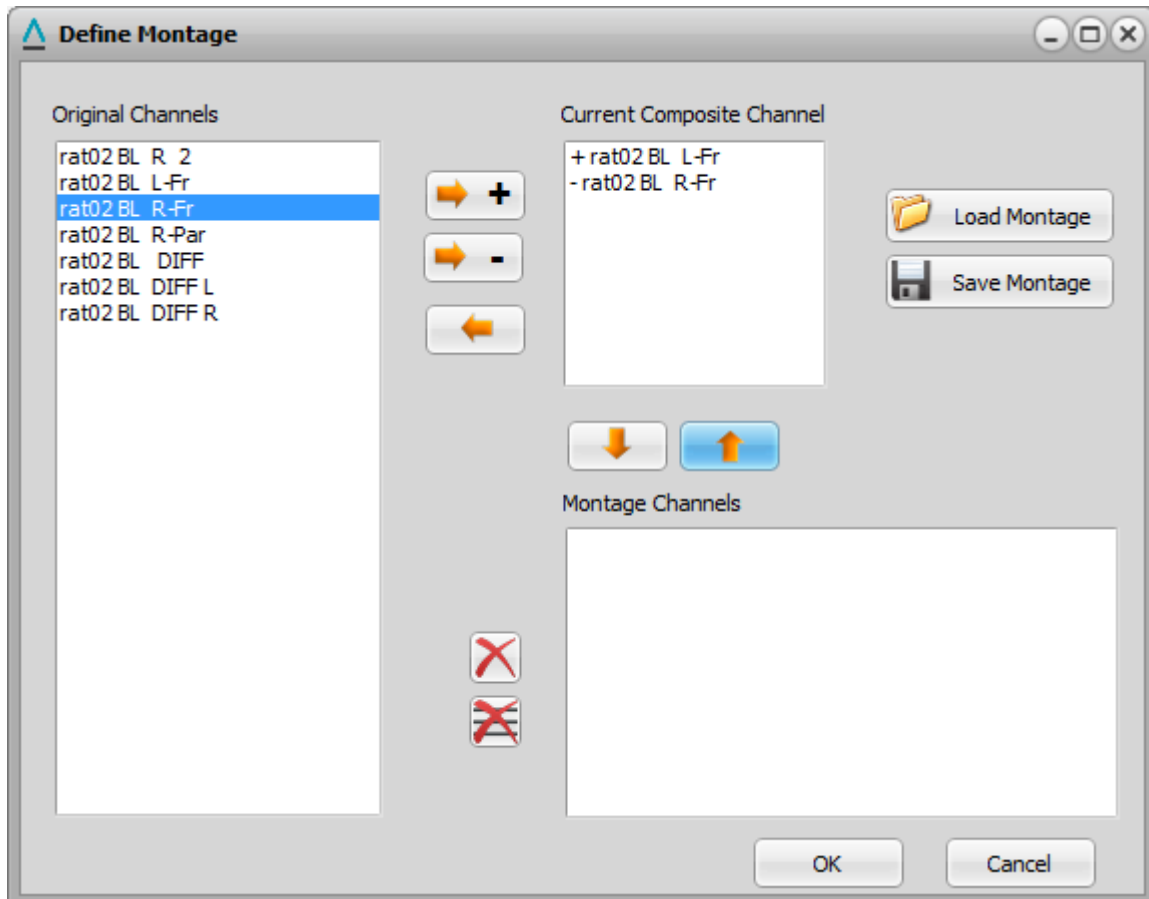
Fig. 2.6.1. Define Montage dialog.

The dialog allows to define a montage by defining new channels as linear combinations (sum or difference) of the original channels.

The "Original Channels" list on the left of the dialog contains the list of original channels. The montage channel, or the composite channel, is an algebraic sum of two or more original channels taken with "+" or "-" sign. The montage channels are created one by one, by adding original channels to the "Current Composite Channel" list using the ➡ + and ➡ - buttons, with a "+" and "-" sign, correspondingly. The ⬅ button may be used to remove the selected original channel from the "Current Composite Channel" list.

After the current composite channel is defined in this way, it is added to the list of montage channels ("Montage Channels") using the ⬇ button. When the composite channel is added to the "Montage Channels" list, the "Current Composite Channel" list is emptied and prepared for the next composite channel definition. A composite channel which is already added to the "Montage Channels" list can be moved back to the

"Current Composite Channel" list for editing by pressing the ⬆ button. The ✕ button allows to delete the selected composite channel from the "Montage Channels" list. The ✖ button deletes all composite channels from the "Montage Channels" list.

The "Save Montage" button allows to save the defined montage in a xml file, with extension ".mtg". This is a common file format that. The montage may be loaded later using the "Load Montage" button on this dialog, or by selecting the "Load & Set Montage" item in the "File" menu of the program's main window (see 1.1 The Menu).

After all the montage channels are defined, the OK button should be pressed to close the dialog. Note that after this only the defined montage channels will be in the "Channels" list on the main form. If the user wants some original channels also to be present, then these channels should be included into the "Montage channels" during defining the montage channels (the composite channel may consist of a single original channel, either with "+" or "-" - in the latter case the channel will be inverted).

If the user wants to revert to the original channels, he needs to open the "Define Montage" dialog again, clear the montage channels by pressing the ✖ button and then pressing the "OK" button. The "Channels" list on the main form will show the original channels.

3. Program Input

ASSYST can read and process the EEG data of following formats:

1. *European Data Format (EDF)*
2. *Ripple NSx*
3. *Acknowledge ACQ*

   In these three cases a single continuous record is stored in a single file with extension ".edf", ".ns*<a number>*" or ".acq".

   To load the data from an EDF, NSx or ACQ file, the user has to select "EDF", "NEV-NSx" or "ACQ", correspondingly, in the "Select Input Data Format" combo box on the upper control panel of the program's main window (see 1.2 Upper Control Panel) and then either press the "Read Data File" button on the upper control panel or select File → Read Data File menu item from the program's main menu (see 1.1 The Menu).

   A standard "Open File" dialog will appear where the user selects an EDF, NSx or ACQ file.

4. *Compumedics Profusion4*

   In this case a single continuous record is stored in several files, residing in the "EEGData" subdirectory of the Compumedics study directory. The study directory contains other necessary files as well, particularly, the file with extension ".sdy". For this reason the user has to select the study directory (and not a particular file). To load the Compumedics Profusion4 data, the user has to select "Profusion4" in the "Select Input Data Format" combo box on the upper control panel of the program's main window (see 1.2 Upper Control Panel) and then either press the "Read Data File" button on the upper control panel or select File → Read Data File menu item from the program's main menu (see 1.1 The Menu).

   A standard Select Directory dialog will appear where the user selects the Compumedics study directory (that contains the ".sdy" file and the "EEGData" subdirectory).

4. Program output

4.1. The main output – Selected Events

The result of the EEG processing by the program, and the user classification of these events, are the lists of events, classified into event categories. These event lists can be saved by means of 2.3. Save Events Dialog which appears when the user presses the "Save Events" button on the Control panel of the "SBI & Channels" tab of the program's main window (see 1.3.3 The Control Panel).

The events included into each of the event categories can be saved into output files of the following types:

ASCII Text file

Excel file

In case of ASCII text output, there are two possible options:

1. A single text file is generated, which contains events from all event categories (grouped according to the categories); the file header contains

2. As many text files are generated as the number of event categories marked for output, in which case each file contains events from one category only.

In case of Excel file output, a single excel file is generated with events from each event category listed on a separate worksheet.

In all cases, the program automatically generates the name of the output file(s), which may be modified by the user during saving (in the standard file save dialog, where the automatically generated file name is prompted). The automatically generated file name has the following format:

Single file:

<Label>_<Parameters string>_EventPositions.<Extension>

Multiple files, for each event category:

 <Label>_<Parameters string>_EventPositions_<Category name>.<Extension>

Where

<Label> is the text label provided by the user in the Save Events dialog (see 2.3. Save Events Dialog);

<Parameters string> is a string containing information about input data file and main parameters used during processing (see below);

<Category name> is the name of corresponding event category;

<Extension> is:

       'txt'   in case of ASCII text file(s) output

       'xls'   in case of Excel file output

The format of the *<Parameters string>* is:

*<Parameters string> = <Data file name>*_ch_*<Channel label>*_ws_*<Proc. Window size in sec>*s_dtr_*<Detrending window half size in samples>*_*<Detrending Num. passes>*_fr_*<Freq. low>*-*<Freq. high>*Hz_Nfs_*<Num. freq. samples>*_*<Optional string for SBI smoothing>*_thr_*<Threshold value>*

Where

<Data file name> is the name of input data file if it is an EDF file, or the name of data files directory in case of Profusion4 data processing;

<Channel label> is the label of the processed channel; if the selected events are the result of multiple channels processing (i.e., when "Process Multiple Channels" button was pressed), then *<Channel label>* is 'mult';

<Proc. Window size in sec> is the size of processing time window in seconds (see 1.6.2 The Advanced tab, Fig. 1.6.3);

<Detrending window half size in samples> is the half-size of the window in multiple pass moving averaging for detrending, in samples (not in seconds) (see 1.6.2 The Advanced tab, Fig. 1.6.4);

<Detrending Num. passes> is the number of passes in multiple pass moving averaging for detrending (see 1.6.2 The Advanced tab, Fig. 1.6.4);

<Freq. low> is the left edge frequency of the frequency band (see 1.6.2 The Advanced tab, Fig. 1.6.5);

<Freq. high> is the right edge frequency of the frequency band (see 1.6.2 The Advanced tab, Fig. 1.6.5);

<Num. freq. samples> is the number of frequency samples within the band (see 1.6.2 The Advanced tab, Fig. 1.6.5);

<Optional string for SBI smoothing> is an optional sub-string which is added if smoothing of SBI curve was applied, and contains the parameters for SBI smoothing (see 1.6.2 The Advanced tab, Fig. 1.6.7):

<Optional string for SBI smoothing> = use_smoothed_*<SBI smoothing win. half- size>*-*<SBI smoothing num. passes>*

where

<SBI smoothing win. half- size> is the half size of the window used for SBI smoothing, in samples;

<SBI smoothing num. passes> is the number of pusses in multiple pass moving averaging for SBI smoothing;

<Threshold value> is the value of threshold used for event selection.

Example of an output ASCII text file name in case of single file for all event categories:

Experiment_1_bl02.wdq.edf_ch_rat02BLL-Fr_ws_2.00s_dtr_4_2_fr_17-23Hz_Nfs_40_use_smoothed_2-2_thr_18.91_EventPositions.txt

In this example, 'Experiment_1' is the user-provided label; 'bl02.wdq.edf' is the input data file name (EDF file); 'rat02BLL-Fr' is the label of the processed channel, the processing window size was 2.00s; baseline removal (de-trending) parameters were: window half-size = 4 samples and number of passes = 2; frequency band was 17 to 23 Hz, number of frequency samples was 40; smoothed SBI was used with parameters: window half-size = 2 samples and number of passes = 2; the threshold for event selection was 18.91.

Example of output ASCII text file names in case of separate file for each event category (3 categories):

Experiment_2_bl02.wdq.edf_ch_rat02BLL-Fr_ws_2.00s_dtr_4_2_fr_17-23Hz_Nfs_40_use_smoothed_2-2_thr_18.91_EventPositions_Seizures.txt
Experiment_2_bl02.wdq.edf_ch_rat02BLL-Fr_ws_2.00s_dtr_4_2_fr_17-23Hz_Nfs_40_use_smoothed_2-2_thr_18.91_EventPositions_Short SWDs.txt
Experiment_2_bl02.wdq.edf_ch_rat02BLL-Fr_ws_2.00s_dtr_4_2_fr_17-23Hz_Nfs_40_use_smoothed_2-2_thr_18.91_EventPositions_Spikes.txt

In this case the output file names are identical except the last part, which is corresponding event category name ('Seizures', 'Short SWDs', 'Spikes').

The ASCII text file contains a header part, which includes the user's common description and some information about the recording, including record start time, sampling rate and time step (which is the reciprocal of sampling rate).

The header is followed by the events, grouped according to categories. For each category, there is a header part which includes the category name and description and

the number of events in this category, and the events list. The events list has at least five columns: number of event (column '#'), event's absolute start date and time ('Start'), event's absolute end date and time ('End'), duration of the event ('Duration') and user's comment, if any ('Comment').

If multiple channels processing was performed (see 6.7. Multiple channels processing) then the last column is titled 'Channels/Comment' and shows, in front of the comment text, the labels of the channels in which the event was detected, depending on the multiple channel processing options as listed in the table below.

Processing Options	Are the channel labels outputted?	Comment
1. Selected Channels are from same subject/animal 1) Use different threshold for each channel	yes	
2) Use one threshold for each channel a) Cumulative histogram	yes	
b) SBI Product histogram	no	Information about channels is not available in this method
c) SBI Average histogram	no	Information about channels is not available in this method
d) Channel threshold's average	yes	
2. Selected Channels are from different subjects/animals 1) "Put events from all channels into one list" checkbox is not checked	no	In this case for each channel the Event Lists and the output files must be made separately; so each Events list and output file correspond to one channel only
2) "Put events from all channels into one list" checkbox is checked	yes	

If the user selected to output also one or more power spectrum characteristics (see 2.3. Save Events Dialog), then, according to user's selection, there might be the following additional columns in the events list:

'MPF Or' - Mean power frequency of the power spectrum of the event calculated using the original EEG;

'MPF Det' - Mean power frequency of the power spectrum of the event calculated using the detrended EEG;

'TP Or' - Total power of the power spectrum of the event calculated using the original EEG;

'TP Det' - Total power of the power spectrum of the event calculated using the detrended EEG;

'MP Or' - Mean power of the power spectrum of the event calculated using the original EEG;

'MP Det' - Mean power of the power spectrum of the event calculated using the detrended EEG;

'PF Or' - Peak frequency of the power spectrum of the event calculated using the original EEG;

'PF Det' - Peak frequency of the power spectrum of the event calculated using the detrended EEG;

'PA Or' - Peak amplitude the power spectrum of the event calculated using the original EEG;

'PA Det' - Peak amplitude of the power spectrum of the event calculated using the detrended EEG;

The content of the Excel file is similar to the contents of text file, except that the common description and each category occupy separate worksheets, and every category's worksheet contains the common information on data: record start time, sampling rate and time step.

Example of output ASCII text file contents containing events from all event categories:

```
Description:
This is an output file generated for illustration purpose.

Record Start time = 04.04.02 12:16:36.000
Sampling rate = 274.46
Time step =  3.64350000000000E-0003

Event Category: Seizures
Description: Seizures
Number of events: 33

#        Start                End                  Duration          Comment
1        04.04.02 12:17:27.913   04.04.02 12:17:42.891   00:00:14.978     long
2        04.04.02 12:27:28.401   04.04.02 12:27:41.383   00:00:12.982     some waxing and waning of the spike amplitudes is observed
3        04.04.02 12:33:36.781   04.04.02 12:33:52.259   00:00:15.478
4        04.04.02 12:33:53.253   04.04.02 12:34:01.743   00:00:08.489
5        04.04.02 12:34:03.237   04.04.02 12:34:17.716   00:00:14.479
6        04.04.02 12:34:27.695   04.04.02 12:34:43.173   00:00:15.478
7        04.04.02 12:38:06.826   04.04.02 12:38:25.798   00:00:18.972
8        04.04.02 12:40:04.129   04.04.02 12:40:24.598   00:00:20.469
9        04.04.02 12:41:09.519   04.04.02 12:41:20.005   00:00:10.486
10       04.04.02 12:41:59.435   04.04.02 12:42:17.907   00:00:18.473
11       04.04.02 12:42:24.892   04.04.02 12:42:36.875   00:00:11.983
12       04.04.02 12:44:15.705   04.04.02 12:44:34.677   00:00:18.972
13       04.04.02 12:44:38.667   04.04.02 12:45:05.126   00:00:26.459
14       04.04.02 12:53:36.261   04.04.02 12:53:48.245   00:00:11.983
```

15	04.04.02 12:53:58.224	04.04.02 12:54:22.188	00:00:23.963
16	04.04.02 12:55:17.092	04.04.02 12:55:40.556	00:00:23.464
17	04.04.02 12:55:55.028	04.04.02 12:56:11.504	00:00:16.476
18	04.04.02 12:56:12.998	04.04.02 12:56:43.949	00:00:30.952
19	04.04.02 12:56:44.944	04.04.02 12:56:56.927	00:00:11.983
20	04.04.02 12:56:58.421	04.04.02 12:57:25.878	00:00:27.457
21	04.04.02 12:57:27.871	04.04.02 12:57:37.359	00:00:09.488
22	04.04.02 13:26:07.975	04.04.02 13:26:19.459	00:00:11.484
23	04.04.02 13:28:22.249	04.04.02 13:28:30.738	00:00:08.489
24	04.04.02 13:54:41.590	04.04.02 13:54:52.575	00:00:10.985
25	04.04.02 13:56:21.422	04.04.02 13:56:38.397	00:00:16.975
26	04.04.02 13:57:03.850	04.04.02 13:57:15.334	00:00:11.484
27	04.04.02 13:57:16.828	04.04.02 13:57:25.318	00:00:08.489
28	04.04.02 13:57:36.795	04.04.02 13:57:52.771	00:00:15.977
29	04.04.02 13:57:54.265	04.04.02 13:58:06.249	00:00:11.983
30	04.04.02 13:58:12.235	04.04.02 13:58:30.708	00:00:18.473
31	04.04.02 13:58:54.164	04.04.02 13:59:03.153	00:00:08.989
32	04.04.02 13:59:03.648	04.04.02 13:59:12.637	00:00:08.989
33	04.04.02 13:59:19.622	04.04.02 13:59:36.097	00:00:16.476

Event Category: Short SWDs
Description: Spike-wave discharges with few spikes
Number of events: 9

#	Start	End	Duration	Comment
1	04.04.02 12:35:02.137	04.04.02 12:35:10.128	00:00:07.990	
2	04.04.02 12:40:27.589	04.04.02 12:40:37.077	00:00:09.488	
3	04.04.02 12:58:07.804	04.04.02 12:58:15.794	00:00:07.990	irregular spike amplitudes
4	04.04.02 13:16:26.440	04.04.02 13:16:36.128	00:00:09.688	two short SWDs closely following one after another
5	04.04.02 13:17:29.348	04.04.02 13:17:37.838	00:00:08.489	
6	04.04.02 13:23:49.209	04.04.02 13:23:57.199	00:00:07.990	
7	04.04.02 13:30:59.983	04.04.02 13:31:07.474	00:00:07.491	
8	04.04.02 13:52:42.790	04.04.02 13:52:50.780	00:00:07.990	
9	04.04.02 14:01:35.859	04.04.02 14:01:40.752	00:00:04.893	irregular spike amplitudes

Event Category: Spikes
Description: Single or double spikes
Number of events: 6

#	Start	End	Duration	Comment
1	04.04.02 12:59:56.621	04.04.02 12:59:59.120	00:00:02.499	
2	04.04.02 13:01:00.513	04.04.02 13:01:03.512	00:00:02.999	
3	04.04.02 13:18:09.281	04.04.02 13:18:11.781	00:00:02.499	
4	04.04.02 13:19:29.147	04.04.02 13:19:32.644	00:00:03.498	
5	04.04.02 14:02:53.761	04.04.02 14:02:56.260	00:00:02.499	
6	04.04.02 14:04:30.598	04.04.02 14:04:32.598	00:00:02.000	

Example of output ASCII text file contents containing events from one event category:

Description:
This is an output file generated for illustration.

Record Start time = 04.04.02 12:16:36.000
Sampling rate = 274.46
Time step = 3.64350000000000E-0003

Event Category: Short SWDs
Description: Spike-wave discharges with few spikes
Number of events: 9

#	Start	End	Duration	Comment
1	04.04.02 12:35:02.137	04.04.02 12:35:10.128	00:00:07.990	
2	04.04.02 12:40:27.589	04.04.02 12:40:37.077	00:00:09.488	
3	04.04.02 12:58:07.804	04.04.02 12:58:15.794	00:00:07.990	irregular spike amplitudes
4	04.04.02 13:16:26.440	04.04.02 13:16:36.128	00:00:09.688	two short SWDs closely following one after another
5	04.04.02 13:17:29.348	04.04.02 13:17:37.838	00:00:08.489	
6	04.04.02 13:23:49.209	04.04.02 13:23:57.199	00:00:07.990	
7	04.04.02 13:30:59.983	04.04.02 13:31:07.474	00:00:07.491	

```
8          04.04.02 13:52:42.790   04.04.02 13:52:50.780   00:00:07.990
9          04.04.02 14:01:35.859   04.04.02 14:01:40.752   00:00:04.893          irregular spike amplitudes
```

Example of output ASCII text file contents resulting from multiple channels processing. The channel labels in which the event was detected are shown in 'Channels/Comments' column.

```
Event Category: Seizures
Description: Seizuress
Number of events: 5

# Start              End                  Duration      Channels/Comment
1 4/4/2002 12:17:27.913  4/4/2002 12:17:42.392  00:00:14.479   rat02 BL R 2, rat02 BL R-Fr, rat02 BL R-Par, rat02 BL DIFF /
2 4/4/2002 12:27:28.401  4/4/2002 12:27:40.884  00:00:12.483   rat02 BL R 2, rat02 BL R-Fr, rat02 BL R-Par, rat02 BL DIFF /
3 4/4/2002 12:33:09.827  4/4/2002 12:33:17.318  00:00:07.491   rat02 BL  R  2, rat02 BL  R-Fr, rat02 BL   DIFF /
4 4/4/2002 12:33:36.781  4/4/2002 12:33:52.259  00:00:15.478   rat02 BL  R  2, rat02 BL  R-Fr, rat02 BL  R-Par, rat02 BL   DIFF /
5 4/4/2002 12:41:47.455  4/4/2002 12:41:50.454  00:00:02.999   rat02 BL  R  2 /
```

4.1.1. Saving images of the events

Together with saving event times the program may automatically generate and save also an image file for every event. The image file of the event contains the image of the Signal pane when the event is selected in the Events form (see 2.4.3. Selecting an Event). Before saving the events with images the user has to select the desired channels to be displayed in the Signal pane and the desired Display window size (Fig. 1.3.10).

The image files can be in two formats:

1. Windows Metafile (WMF)

2. JPEG

The files will be placed in a sub-directory of the directory where the output event file is saved. The name of the directory will be generated automatically and will be identical to the name of the output event file, except the extension (there will be no extension in the sub-directory name) and the last sub-string "_EventPositions", which will be replaced by "_IMAGES":

<Label>_<Parameters string>_IMAGES

were the *<Label>* and *<Parameters string>* are the same as described above.

The names of the image files inside the sub-directory will have the following format:

<Category name>_<Event number>.<Extension>

where

<Category name> is the name of corresponding event category;

<Event number> is the number of the event in the events list;

<Extension> is:

    'wmf' in case of Windows Metafile output

'jpg'   in case of JPEG file output.

In the events output file, either text or Excel, an additional column titled "Image file" will be added after the "Channels/Comments" column that will contain the full path to the corresponding image file. In case of Excel file output these image file paths will be hyperlinks, so the user will be able to click on them within the Excel file and directly open the image (in the image viewer program assigned by the operating system).

To save the image files together with the events the user has to check the "Output Event Images" checkbox and select the image file format in the Save Events Dialog.

4.2. Additional output - current window's signal

The fragment of the EEG shown in the Signal pane (the displayed window) on the "SBI & Channels" tab of the main window may be saved for subsequent use in other applications (e.g., for preparing figures or presentations). Currently, it is possible to save the displayed window in the following formats:

1. ASCII Text File
2. Windows Metafile (WMF)
3. JPEG Image

To save the displayed window the user has to select Window → Save Signal Pane As ► menu item and then choose from the above options (Fig. 1.1.3). A standard File Save dialog will appear with automatically generated file name prompted. The user can modify this name before saving.

The automatically generated file name has the following format:

<Parameters string>.<Extension>

Where

<Parameters string> is a string containing information about input data file and the display window (see below);

<Extension> is:

'txt'   in case of ASCII text file output

'wmf'   in case of Windows Metafile output

'jpg'   in case of JPEG file output.

The format of the *<Parameters string>* is:

*\<Parameters string\> = \<Data file name\>*_ch_*\<Channel label\>*_ws_*\<Disp. Window size in sec\>*s_pos_*\<Position of left edge of disp window\>*

Where

\<Data file name\> is the name of input data file if it is an EDF file, or the name of data files directory in case of Profusion4 data processing;

\<Channel label\> is the label of the processed channel; if the selected events are the result of multiple channels processing (i.e., when "Process Multiple Channels" button was pressed), then *\<Channel label\>* is 'mult';

\< Disp. Window size in sec\> is the size of display time window in seconds (which is specified in the "Disp. Win. Size" field on the Control panel on the "SBI & Channels" tab, see 1.3.3 The Control Panel, Fig. 1.3.10);

\<Position of left edge of disp window \> is the position, in samples, of the left edge of the display window (i.e., the number of the first sample in the window counting from the record start).

The ASCII Text File option

When this option is selected, a plain text file is generated that contains the EEG values for all channels currently displayed in the Signal pane (i.e. the channels checked in the "Channels" list on the Control Panel on the "SBI & Channels" tab, see 1.3.3 The Control Panel, Fig. 1.3.5). If filters are applied (see Signal Filtering parameters in 1.6.2 The Advanced tab), then filtered EEG signals are outputted in the file. Otherwise the raw EEG is outputted. The file will have two or more columns. The first column is time, in seconds, relatively to the start of the record. The subsequent columns are the corresponding channel's values. The columns are comma-separated. The first row contains the channels' labels ('time(s)' for the first column).

The Windows Metafile option

When this option is selected, a Windows Metafile (WMF) is generated that contains the image of the Signal pane. WMF is a vector graphics format which is portable between Microsoft Office applications (such as Word, PowerPoint, and Publisher). Some non-Microsoft applications also can deal with WMF files.

The JPEG Image option

When this option is selected, a JPEG image file is generated that contains the image of the Signal pane.

4.3. Additional output - SBI curve

The fragment of the SBI curve shown in the SBI pane on the "SBI & Channels" tab of the main window may be saved for subsequent use in other applications (e.g., for preparing figures or presentations). Note that only the fragment of the SBI curve visible in the SBI pane will be saved. I.e., to save the entire SBI curve the horizontal SBI zoom slider must be in the rightmost position.

Currently, it is possible to save the SBI curve in the following formats:

1. ASCII Text File

2. Windows Metafile (WMF)

3. JPEG Image

To save the SBI curve the user has to select Window → Save SBI Pane As ► menu item and then choose from the above options (Fig. 1.1.3). A standard File Save dialog will appear with automatically generated file name prompted. The user can modify this name before saving.

The automatically generated file name has the following format:

<Parameters string>.<Extension>

Where

<Parameters string> is a string containing information about input data file and the display window (see below);

<Extension> is:

      'txt'   in case of ASCII text file output

      'wmf' in case of Windows Metafile output

      'jpg'   in case of JPEG file output.

The format of the *<Parameters string>* is:

<Parameters string> = <Data file name> _SBI_Chan_<Channel label> _start_<Date and time of the first sample of the saved fragment of the SBI curve>_end_<Date and time of the last sample of the saved fragment of the SBI curve>_ws_<Processing Window size in sec>s_pos_<Position of the first sample of the SBI curve, in samples>

Where

<Data file name> is the name of input data file if it is an EDF file, or the name of data files directory in case of Profusion4 data processing;

<Channel label> is the label of the channel for which the SBI curve is calculated;

<Date and time of the first sample of the saved fragment of the SBI curve>

<Date and time of the last sample of the saved fragment of the SBI curve> are the times of the first and last sample of the saved fragment of the SBI curve, in the following format: dd-mm-yyy_hh-mm-ss ;

<Processing Window size in sec> is the size of time window used for SBI calculation, in seconds (which is specified in the Processing Window parameters group of the [Advanced sub-tab of Parameters tab](#), Fig. 1.6.3);

<Position of the first sample of the SBI curve, in sample > is the position, in samples, of the left edge (first sample) of the saved fragment of the SBI curve (i.e., the number of the first saved sample counting from the record start).

The ASCII Text File option

When this option is selected, a plain text file is generated that contains the SBI curve values. If SBI smoothing was applied, then smoothed SBI values will be outputted, otherwise the original SBI values will be outputted in the file. The file will have two columns. The first column is date and time. The second column is SBI values. The columns are comma-separated. The first row contains the columns' headers: "date/time" and "SBI Chan. *<Channel label>*", correspondingly.

The Windows Metafile option

When this option is selected, a Windows Metafile (WMF) is generated that contains the image of the SBI pane. WMF is a vector graphics format which is portable between Microsoft Office applications (such as Word, PowerPoint, and Publisher). Some non-Microsoft applications also can deal with WMF files.

The JPEG Image option

When this option is selected, a JPEG image file is generated that contains the image of the SBI pane.

4.4. Additional output - power spectrum of the current window's signal

The power spectrum (see 1.5.2 The Power Spectrum pane of the Signal & Spectrum tab) of the current EEG shown in the Signal pane of the Signal & Spectrum tab may be saved in an ASCII text file for subsequent use in other applications (e.g., for preparing figures or presentations).

To save the power spectrum the user has to press the "Save Power Spectrum" button on the Signal & Spectrum tab. A standard File Save dialog will appear with automatically generated file name prompted. The user can modify this name before saving.

The automatically generated file name has the following format:

*<Parameters string>*_PowerSpectrum.txt

The format of the *<Parameters string>* is:

<Parameters string> = <Data file name> _ch_*<Channel label>* _start_*<Date and time of the first sample of the EEG window>*_ws_*<Window size in sec>*s_pos_*<Position of the first sample of the EEG window, in samples >*

Where

<Data file name> is the name of input data file if it is an EDF file, or the name of data files directory in case of Profusion4 data processing;

<Channel label> is the label of the active channel;

<Date and time of the first sample of the EEG window> is the time of the first sample of the current EEG window for which the power spectrum was calculated, in the following format: dd-mm-yyy_hh-mm-ss ;

<Window size in sec> is the size of processing time window (which is specified in the Processing Window parameters group of the Advanced sub-tab of Parameters tab, Fig. 1.6.3);

<Position of the first sample of the EEG window, in samples > is the position, in samples, of the left edge (first sample) of the EEG window (i.e., the number of the first sample in the window counting from the record start).

The generated ASCII file will contain three columns with titles. The first column is index (titled "N"), the second is frequency, in Hz (titled "Freq(Hz)"), and the third is power spectrum value (titled "Power").

5. Processing Procedure

5.1. Single channel processing

Steps for single channel processing:

1. Load EEG data

2. Select the channel for processing

3. Set parameters (Default or Custom) (this step does not depend on steps 1 and 2, so it can be done before 1 or 2)

4. Calculate SBI

5. Readjust SBI threshold (if needed)

6. Specify the processing interval (if needed)

7. Select Events

8. Apply an automatic event processing (optional)

9. Inspect and classify the remaining events into Categories

10. Save the classified events

5.1.1. Loading EEG data

ASSYST can read and process the EEG data of following formats:

European Data Format (EDF)

Compumedics Profusion4

Ripple NSx

Acknowledge ACQ

Specify the format by selecting corresponding item in the "Select Input Data Format" combo box (in the upper left corner of the Main Window). This should be done before loading the data.
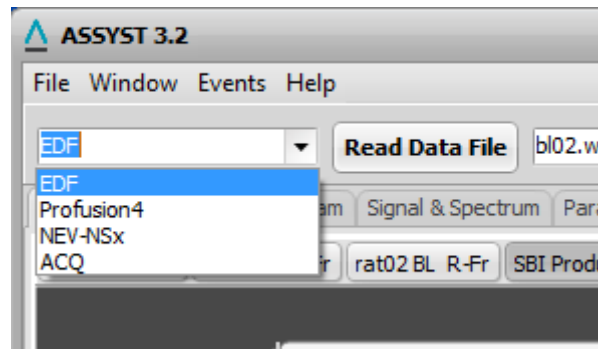
To load the data, select File → Read Data File from the main menu, or click the "Read Data File" button next to the "Select Input Data Format" combo box. If the data format is "EDF", "NEV-NSx" or "ACQ", this will open a standard "Open File" dialog, allowing browsing and selecting an EDF file. If the selected file format is "Profusion4", a standard "Select Directory" dialog will appear, allowing selecting a folder containing the Profusion4 data (this is because Profusion4 data are stored in several files).
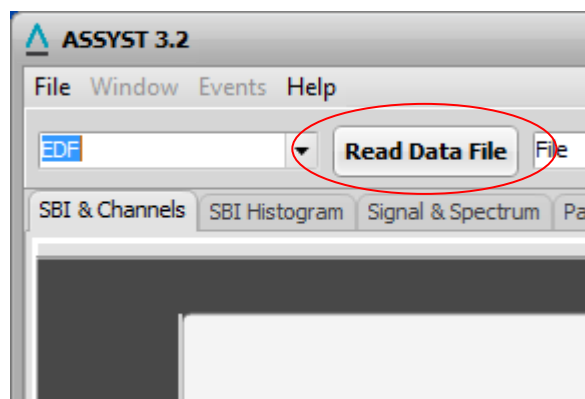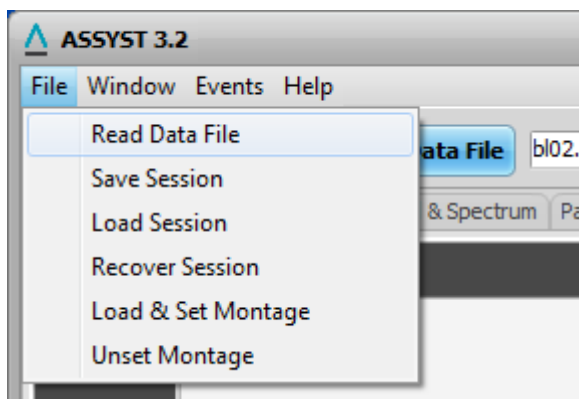
Note: The program remembers the last opened folder and sets this as initial folder in the "Open File" or "Select Directory" dialogs.

The program then loads the data, fills the "Select channels" combo box on the upper control panel and the "Channels" list on the right control panel of the "SBI & Channels" tab with the channels' labels, selects the first channel, and displays the first fragment of the first channel in the Signal pane of the "SBI & Channels" tab.

5.1.2. Selecting the Channel for Processing

In the "Select channels" combo box, select the name (label) of the desired channel to be processed. Alternatively, use the spin control next to the combo box to select the channel by its number (use the ⬍ buttons or type in the desired number directly). The

"Select channels" combo box and the spin control are interconnected: changing the value in one automatically updates the value in the other.
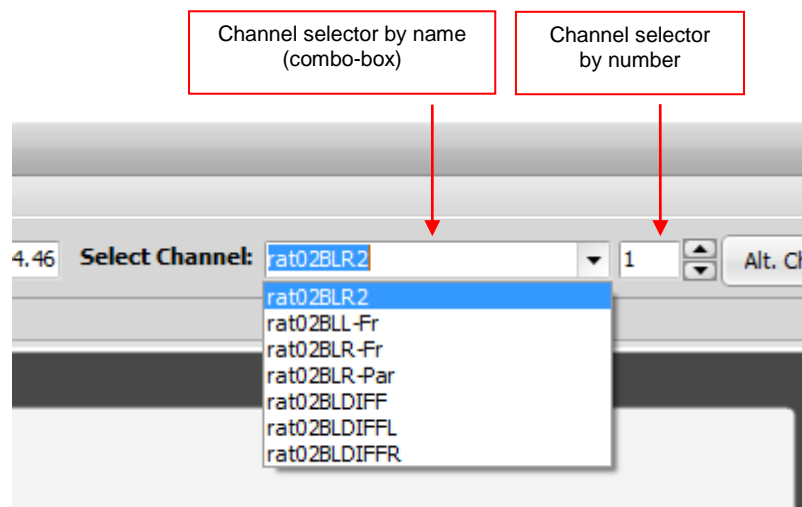
The selected channel will be automatically checked in the "Channels" list on the right control panel and its EEG will be displayed in the Signal pane. The channel that was selected previously will remain checked in the "Channels" list and its EEG will still be displayed in the Signal pane. To hide the previously selected channel, uncheck the corresponding checkbox in the "Channels" list on the right control panel. Note that the checkbox of the currently selected (active) channel in the "Channels" list is disabled and cannot be unchecked.

5.1.2.1. Using alternative Channel Labels

You can define alternative labels for channels that then might be used instead of the labels provided in the input data files.

To define alternative labels:

Press the "Alt. Channel Labels" button on the upper control panel (see 1.2 Upper Control Panel) of the program's main window. The Alternative Channel Labels dialog will appear.
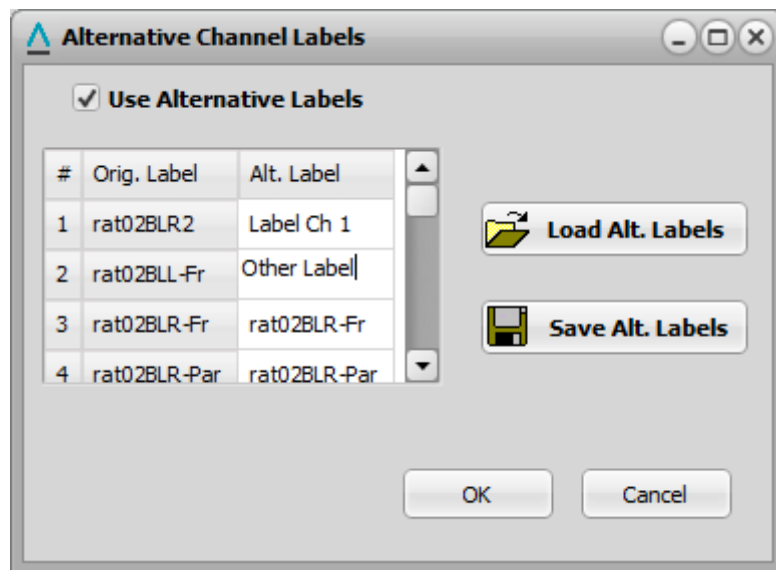
In the 'Alt. Label' column, enter the new labels for the channels (initially the "Alt. Label" column contains the original labels - same as in the "Orig. Label").

Check the "Use Alternative Labels" checkbox.

Press the "OK" button. The alternative channel labels will replace the original ones wherever the channel labels are indicated.

If you do not want to use the alternative labels right away, leave the "Use Alternative Labels" checkbox unchecked. The changed alternative labels will be remembered by the program after the dialog is closed with the 'OK' button (and will be shown next time you open this dialog), but they will not be applied.

If you close the dialog with "Cancel" button, all the new changes will be discarded.

You can save the defined labels for subsequent use, by pressing the "Save Alt. Labels" button. This will open a standard save file dialog where you select the location and provide the file name for the alternative labels file. The saved file is a text file, with extension '.altlab.txt', which contains two columns (for original and alternative labels), separated by a colon. So it can be opened and edited (with care, preserving the structure) by any text editor.

You can load the previously saved alternative label definitions into the program by pressing the "Load Alt. Labels' button, which will open a standard file open dialog, where you select the '.altlab.txt' file to load. When loading labels from a file, the program compares the number of channels and the original channel labels from the file with the number of channels and channel labels of the loaded EEG data (which must coincide), and if there is a mismatch, the program gives an error message:
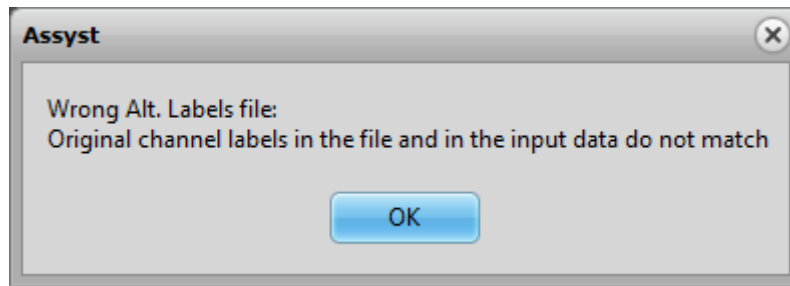
5.1.3. Setting the Processing Parameters

Before processing, set the desired processing parameters on the "Parameters" tab.

Go to the "Parameters" tab of the main window (Fig. 1.6.1). If you wish to use default parameters, select the appropriate set of default parameters using the "Select" combo box on the "Default" sub-tab. You can examine the values of particular parameters of the selected default set by switching to "Advanced/Main" sub-tab (Fig. 1.6.2).

If you wish to use custom parameters, then switch directly to the "Advanced/Main" sub-tab (or you can first select the closest default parameter set on the "Default" sub-tab and then switch to "Advanced/Main" sub-tab to modify the values) and enter the desired parameter values, or load previously saved values from a parameters file using the "Load parameters" button.

The program checks the parameter values at the moment of switching from the "parameters" tab to a different tab of the main window. If the new parameter values are not within the allowed limits or syntactically incorrect (e.g., a non-numeric value where a numeric value is expected), then the program gives a corresponding error message, stating which parameter is incorrect, and stays on the "Parameters" tab. Moving away from the "Parameters" tab will be possible when all parameters have correct values.

Saving Custom Parameters

The modified parameter values can be saved into special parameters file(s) for further use.

To save the parameters, press the "Save Parameters' button on the "Advanced" sub-tab. The program will check the values. If any of the parameter values is not within the allowed limits or syntactically incorrect (e.g., a non-numeric value where a numeric value is expected), then the program will give a corresponding error message, stating which parameter is incorrect. If all parameter values are correct, a standard "Save file" dialog will appear allowing to select a location and a name for the parameter file. The

parameter file will have extension ".sbitpar". You can create arbitrary number of such parameter files and place them in arbitrary locations.

Loading Custom Parameters

Press the "Load Parameters" button on the "Advanced" sub-tab. A standard Open file dialog will appear. Choose the desired parameter file (these files have extension ".sbitpar") and press "Open". The values of he parameters on the "Advanced" sub-tab will be replaced by the values read from the selected parameter file.

Creating new Default Parameter set

You can create and save a new named set of default parameters which is then added to the list of default parameter sets and, accordingly, to the "Select" combo box on the "Default" tab. For this:

- Enter the desired parameter values in the corresponding fields on the "Advanced" sub-tab.

- Press the "Save As New Default Parameters Set" button on the "Advanced" sub-tab. The program will check the values. If any of the parameter values is not within the allowed limits or syntactically incorrect (e.g., a non-numeric value where a numeric value is expected), then the program will give a corresponding error message, stating which parameter is incorrect. If all parameter values are correct, a small dialog appears asking to enter a name and a description for the new default set (Fig. 1.6.21). Provide a unique name for the set in the "Name" field of this dialog. The name should not repeat the names of existing sets, because the file name in which the default set is stored is generated automatically based on the set's name given by the user. Provide a description in the "Description" field (the description is optional). Then press the "OK" button on the dialog. The program will generate a new default parameter set file and store it in the directory where the program's executable is. The program's list of default parameter sets and the "Select" combo box on the "Default" tab will be updated accordingly. You can create arbitrary number of additional default parameter sets with arbitrary (but non-duplicate) names.

Modifying existing Default Parameter set

You can change the parameter values in a default parameter set. For this:

- On the "Default" sub-tab select (in the "Select" combo box) the default parameter set you want to modify.

- Go to the "Advanced" tab and modify the desired parameter values.

- Press the "Modify Selected Default Parameters Set" button. A warning message will appear (Fig. 1.6.22) asking to confirm the action (the default parameter file will actually be rewritten and the old values will be lost). After confirmation (pressing the "Yes" button) a small dialog will appear showing the current name and description of the selected default set (Fig. 1.6.21). Modify the name and description, if necessary (remember that the name should be unique), and then press the "OK" button on the dialog. The program will replace the existing default parameter set file. The program's list of default parameter sets and the "Select" combo box on the "Default" tab will be updated accordingly (with the new name and description).

5.1.4. Calculating the SBI Curve

Switch to the "SBI & Channels" tab of the main window.

Press the "Calculate SBI" button on the right control panel (Fig. 1.3.5).

The calculation will start, and its progress will be reflected by the Progress bar on the control panel (Fig. 1.3.5). The calculation process may be interrupted by clicking the ❌(Stop) button.

When the calculation finishes, the program will beep and will plot the SBI curve in the SBI pane on the "SBI & Channels" tab (Fig. 1.3.1), and the SBI distribution histogram in the "SBI Histogram" pane on the "SBI Histogram" tab (Fig. 1.4.1). Based on the histogram, the program will also define the threshold that will be shown as a red horizontal line on the "SBI" pane (Fig. 1.3.1) and as a red vertical line on "SBI Histogram" pane (Fig. 1.4.1).

5.1.5. Readjusting the SBI Threshold (if needed)

If you wish to change the automatically defined threshold before the event selection, simply drag (with mouse) up or down the horizontal threshold line on the "SBI" pane on the "SBI & Channels" tab (Fig. 1.3.1) or drag left or right the vertical threshold line on the "SBI Histogram" tab (Fig. 1.4.1) of the main window.

Recommendation: Change the horizontal and vertical scales of the SBI curve so that you can see smaller peaks. Examine several small peaks by clicking on them - the Signal pane will show the corresponding fragment of the EEG. If the small peaks are caused by events of interest (e.g., seizures or SWDs), and they are subthreshold, then lower the

threshold so that these peaks become suprathreshold to be selected by the automatic event selection procedure (step 7).

5.1.6. Specifying the Processing Interval (if needed)

It is possible to define a shorter time interval than the entire record duration for the analysis of the calculated SBI curve (including the histogram calculation and automatic threshold definition) and selecting the episodes of signal with excessive SBI values (the action that is performed when the "Select Events" button is pressed). This might be useful when, for example, part of the record is damaged or contaminated with strong artefacts, which would produce excessively high SBI values, which in turn would result in too high automatic threshold, so important events (e.g. seizures) will be missed. So in such cases one might want to perform the analysis only in the "healthy" part of the record.

To specify a shorter processing interval:

- Right-click on the SBI pane at the position which you want to mark as the interval start. In the appearing popup menu, select the first item, "Mark Processing Interval Start".

- Right-click on the SBI pane at the position which you want to mark as the interval end. In the appearing popup menu, select the second item, "Mark Processing Interval End".

If you wish to recalculate the automatic threshold based on the selected interval only, go to the "Advanced" sub-tab of the "Parameters" tab and press the "SBI Histogram & Auto Threshold" button in the *SBI Processing Parameters* group.

5.1.7. Selecting the Events

Press the "Select Events" button on the right control panel (Fig. 1.3.5) of the "SBI & Channels" tab.

The program will find the peaks of the SBI curve that are above the threshold, and store their times in a dedicated list – the preliminary event list. According to parameter settings in the *Event Processing* parameters group (Fig. 1.6.7) on the *Advanced* sub-tab of *Parameters* tab (see 1.6.2 The Advanced tab), during the selection process the short events may be ignored, and close events may be merged.

The number of selected events will be shown in the "Selected Events" field on the right control panel. The events in the preliminary list may be sorted either according to their time of occurrence or their SBI peak value (in which case the sorting is in descending order - the first event has the highest value of SBI), depending on whether the "Sort Events by Time" checkbox is checked or not. The first event becomes the current event, its index is displayed in the "Current Event" field and the corresponding EEG fragment is shown in the Signal pane. You can change the sorting any time after the event selection by checking/unchecking the "Sort Events by Time" checkbox.

5.1.8. Applying an automatic event processing method (optional)

For some types of events the user may apply an automatic procedure for event identification and classification. Currently, two such procedures are implemented in *ASSYST*: a procedure for automatic identification of spike-wave discharges (SWD), and a procedure for automatic identification of large instrumental artefacts.

To apply an automatic event processing, press the "Autoprocess Events" button the right control panel of the "SBI & Channels" tab. The Autoprocess Events Dialog will appear:
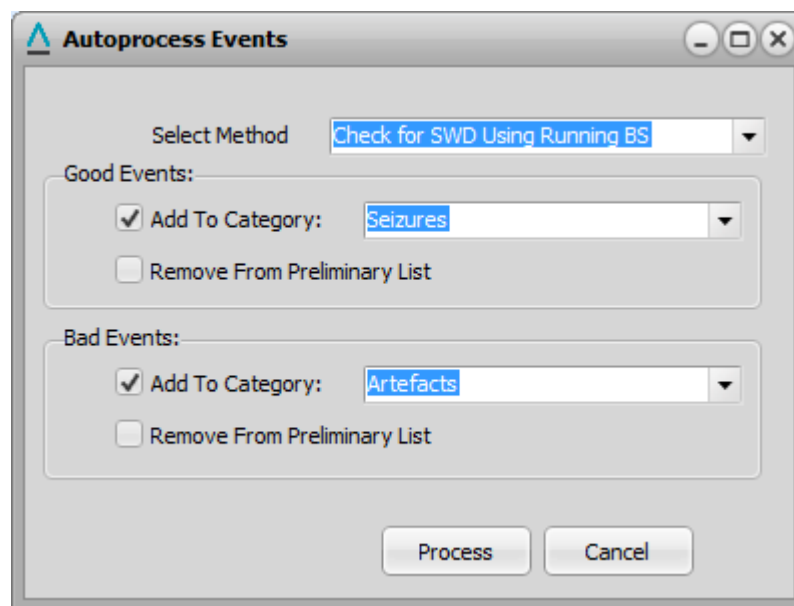
In the "Select Method" combo box select the method you wish to apply:

Check for SWD Using Running BS - for Automatic Identification of Spike-Wave Discharges (SWD), or

Check for Instrumental Artefacts - for Automatic identification of large instrumental artefacts

In the "Good Events" group of controls, check the "Add To Category:" checkbox if you wish to add the events that are classified as "good" by the selected method (i.e., as SWD if the method is Automatic Identification of Spike-Wave Discharges) to an event category. Select the event category to which the "good" events should be added in the combo box next to the checkbox (you may create new event categories before starting the automatic event processing).

If you wish to remove the "good" events from the preliminary list, check the "Remove From Preliminary List" checkbox in the "Good Events" group. If you check this check box and uncheck the "Add To Category:" checkbox, the "good" events will be removed from the preliminary list without adding them to any event category.

Similarly, in the "Good Events" group of controls, check the "Add To Category:" checkbox if you wish to add the events that are classified as "bad" by the selected method to an event category. Select the event category to which the "bad" events should be added in the combo box next to the checkbox.

If you wish to remove the "bad" events from the preliminary list, check the "Remove From Preliminary List" checkbox in the "Bad Events" group. If you check this check box and uncheck the "Add To Category:" checkbox, the "bad" events will be removed from the preliminary list without adding them to any event category.

Press the "Process" button to start the processing. The dialog will close and the processing will start. The progress of the processing will be reflected in the field next to the "Autoprocess Events" button that will show the counter of already processed events. You may interrupt the processing by pressing the ❌(Stop) button next to the event counter.
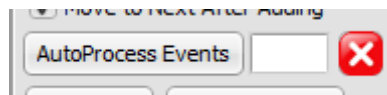
5.1.9. Inspecting and Classifying the Events from the Preliminary List into Categories

5.1.9.1. Inspecting the events in the preliminary list

After the step 7 the events in the preliminary list will be sorted either according to their time of occurrence or their SBI peak magnitude (in which case the sorting is in descending order - the first event has the highest value of SBI), depending on the current state of the "Sort Events by Time" checkbox. You can change the sorting any time after the event selection by checking/unchecking the "Sort Events by Time" checkbox.

View the events in the Preliminary List using the Current Event group of controls on the right control panel: . You can view the next and previous events using and buttons, or a particular event by entering its index number directly in the editable field.

The corresponding EEG fragment will be shown in the Signal pane. Use the "Disp. Win. Size" field to specify the desired timescale of the Signal pane.

If current event was already added to an event category (see 5.1.9.2. Adding events to Event Categories), a red text label "In Category" appears at the right side of "Current Event" text. When the user places the mouse cursor on this red text, the hint box appears indicating to which particular categories the current event was added.
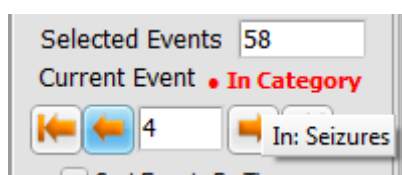
5.1.9.2. Adding events to Event Categories

5.1.9.2.1. Creating additional Event Category, if necessary

If the Events form is not already showing, press the "Show Events Form" button on the right control panel. The Events Form will show.

In the Event Form's menu, select "Event Categories → Add Event Category".
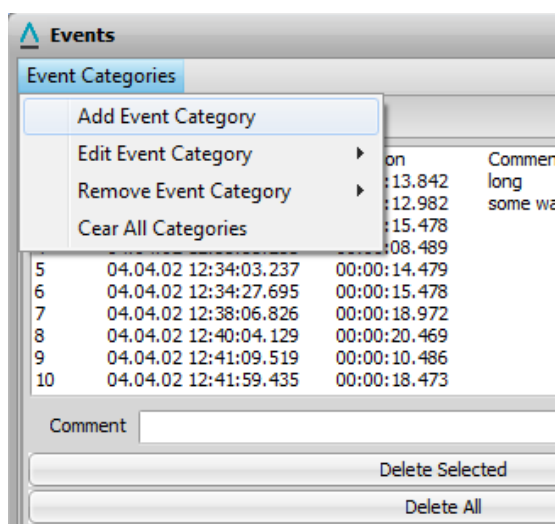
The "Event Category" modal dialog will appear. Provide a name (obligatory) and description (optional) for the new category in the "Name" and "Description" fields, correspondingly. Press the "OK" button. The new category will be created and the corresponding category panel will appear on the "Events" form.
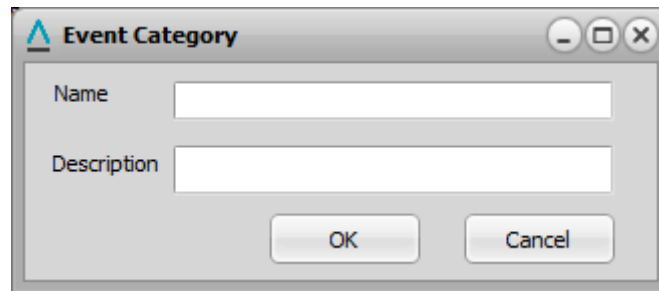
5.1.9.2.2. Modifying an existing Event Category

If the Events form is not already showing, press the "Show Events Form" button on the right control panel. The Events Form will show.

Method 1

In the Event Form's menu, select "Event Categories → Edit Event Category". A sub-menu will appear containing the list of existing event categories. Select the category you want to modify. The "Event Category" dialog will appear with the "Name" and "Description" fields filled with the current name and description of the selected Event Category. Edit the name and/or description as desired. Press the "OK" button - the changes will be applied.
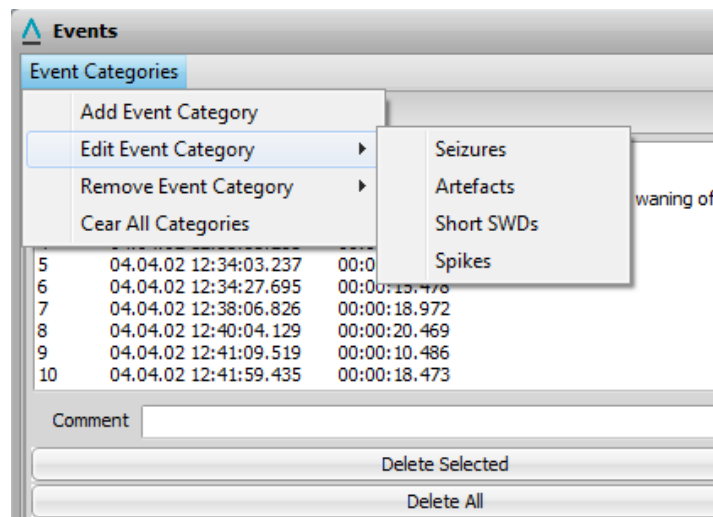
Method 2

Right click in the Events list area of the Category panel you want to modify. In the appearing popup menu select "Edit This Category". The "Event Category" dialog will appear with the "Name" and "Description" fields filled with the current name and

description of the selected Event Category. Edit the name and/or description as desired. Press the "OK" button - the changes will be applied.
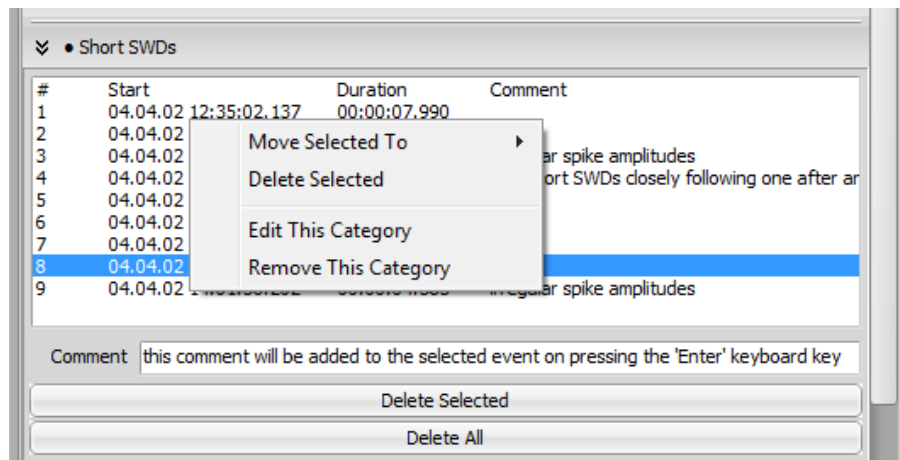
5.1.9.2.3. Removing an Event Category

If the Events form is not already showing, press the "Show Events Form" button on the right control panel. The Events Form will show.

Method 1

In the Event Form's menu, select "Event Categories → Remove Event Category". A sub-menu will appear containing the list of existing event categories (the first two categories cannot be removed). Select the category you want to remove.
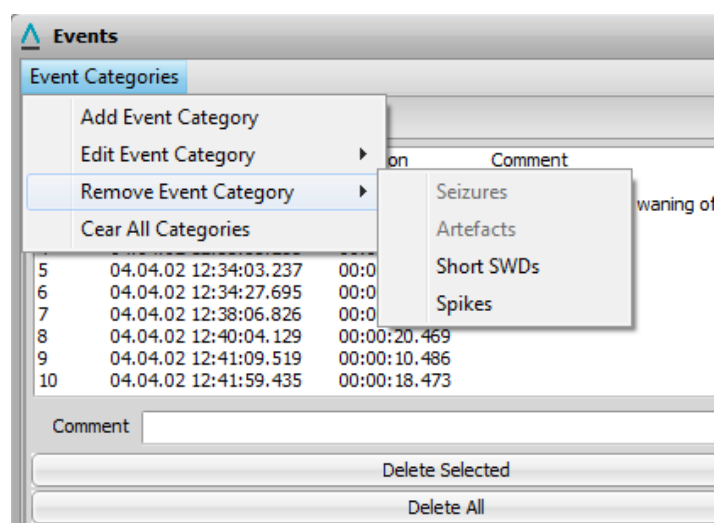
Method 2

Right click in the Events list area of the Category panel you want to remove. In the appearing popup menu select "Remove This Category".

5.1.9.2.4. Adding the Current Event to an Event Category

Method 1 - using the "To ..." button

Press the "To..." button on the right control panel. A popup menu will appear next to the button with the list of existing event categories. Select the category to which you want to add the current event.
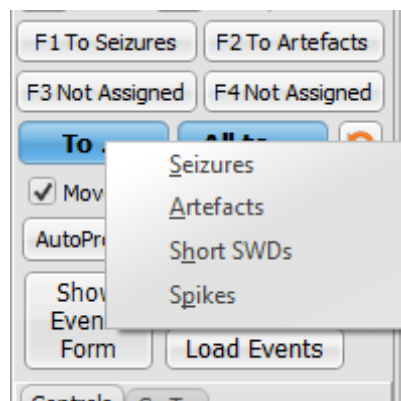
Method 2 – using the shortcut buttons

There are four shortcut buttons on the right control panel of the "SBI & Channels" tab of the main window for quick adding the current event to an event category.
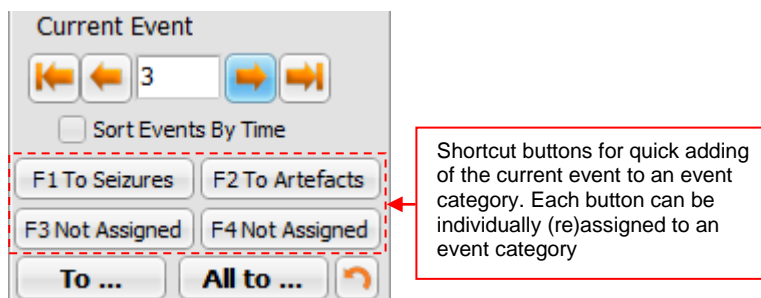
Shortcut buttons for quick adding of the current event to an event category. Each button can be individually (re)assigned to an event category

Each button can be individually (re)assigned to an event category. The first two buttons are by default assigned to the two default categories: Seizures and Artefacts. The other two buttons are initially unassigned. To assign an event category to the button, right-click on the button, then select the desired event category from the popup menu (the popup menu will contain the list of all available event categories). After the assignment, the text on the button will change and will show the name of the assigned category: "To *<Category name>*" (note that long category names will be automatically truncated according to the button's size, so avoid long names or names with similar initial parts when creating new event categories).

Left-click on the assigned shortcut button – this will add the current event to the corresponding category.
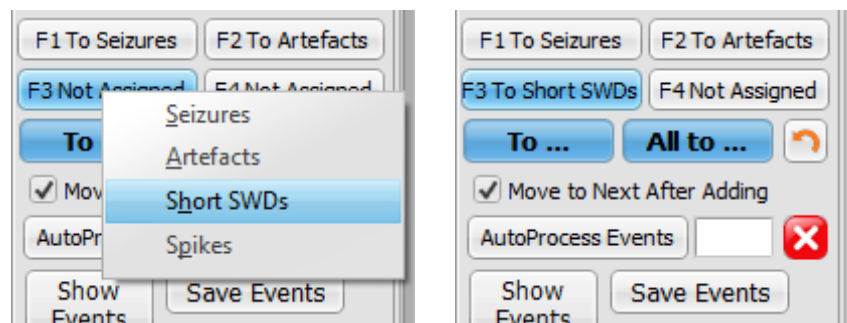
Method 3 – using the shortcut keys

There are keyboard shortcuts for the four shortcut buttons - the function keys F1, F2, F3, F4, correspondingly (this is also reflected on the text on the buttons).

Press the corresponding keyboard key (F1, F2, F3 or F4) to add the current event to the corresponding category (the keys will work only if a category was assigned to the corresponding shortcut button on the right control panel of the "SBI & Channels" tab of the main window).

All the above methods are equivalent. As a result, the current event will be added to the list of events in the selected category and will appear in the Events list of the corresponding event category panel on the Events form. The events in the Events list of the event category panel are sorted chronologically; the newly added event will be inserted in the proper position in the list, and will be highlighted. Simultaneously, on the Signal pane of the "SBI & Channels" tab of the main window the event will be highlighted by a pink band, the left and right edges of which correspond to the event's start and end times. These edges are movable (by mouse), so you can immediately

adjust the start and end time of the event, if desired (this can be done later as well, see 5.1.9.2.6. Viewing the events in the Event categories). When the position of left or right edge of the highlighting band is changed, the start or end time (correspondingly) of the event in the Events list of the Event Category panel on the Event form is immediately updated.

After the addition, the current event index in the "Current Event" control on the right control panel of the "SBI & Channels" tab of the main window will either remain unchanged, or the next event will become current, according to the state of the checkbox "Move To Next After Adding".

5.1.9.2.5. Adding arbitrary window as an event to an event category

It is possible to directly add any window as an event to an event category, irrespectively of whether it was selected into the preliminary list at step 7 or not (i.e., irrespectively of whether the SBI of this window is suprathreshold or subthreshold). For this:

1. Right-click on the SBI pane at the desired position (e.g. a subthreshold peak)

2. From the popup menu, select the "Add this Event to" item. A second popup menu will appear with the list of existing Event Categories.

3. In the second popup menu, select the desired event category. The event of the size of one window will be added to the selected category, and the corresponding EEG fragment will be shown in the Signal pane, with the added window highlighted by a pink band.

4. Move the highlighting band edges to properly mark the event's start and end positions.

5.1.9.2.6. Viewing the Events in the Event Categories

You can select an event by clicking on the corresponding row of the Events list of an Event Category panel. You can also use the up or down arrow keys of the keyboard to select the previous or next event in the list, correspondingly.

When you select an event in the Events list of an Event Category panel, the corresponding EEG fragment is automatically shown in the Signal pane of the SBI & Signal tab of the program's main window. The event is highlighted by a pink band, the left and right edges of which correspond to the event's start and end times.

The edges of the pink band are movable (by mouse), so you can properly adjust the start and end time of the event. When the position of left or right edge is changed, the start or end time (correspondingly) of the event in the Events list of the Event Category panel on the Event form is immediately updated.

Band with movable edges highlighting the event
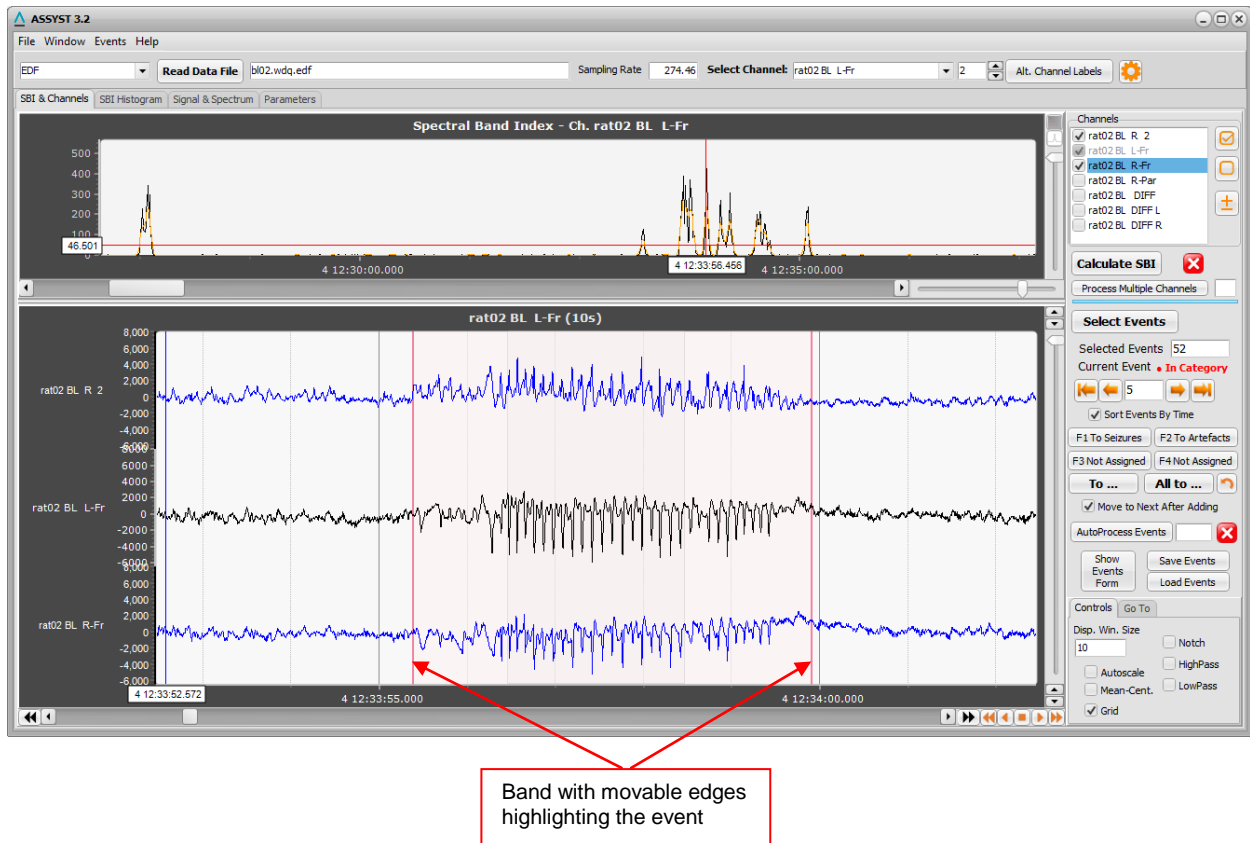
5.1.10. Saving the Classified Events

Press the "Save Events" button on the Control panel of the "SBI & Channels" tab of the program's main window. The Save Events dialog will appear.

In the "Select Event Categories to Save" list check the Event categories the events from which must be saved in the output file(s). You can use "Check All" or "Uncheck All" buttons to check/uncheck all event categories.

Select the desired output type in the "Output type" radio buttons group.
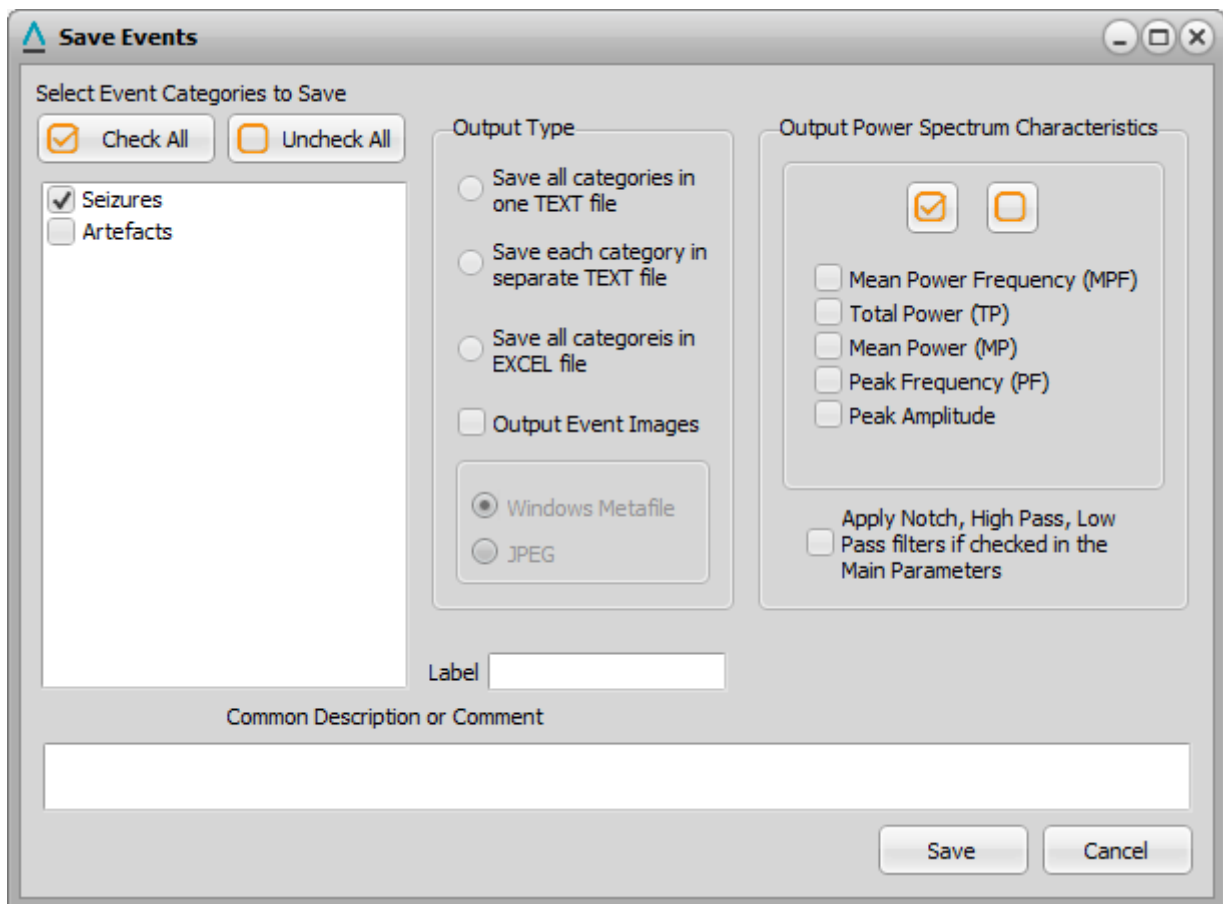
If you wish to output also the screenshots of the events (event images), check the "Output Event Images" checkbox and select the image file format (Windows Metafile or JPEG).

If you wish to output also some power spectrum characteristics, check the corresponding checkboxes in the "Output Power Spectrum Characteristics" group. If you wish to filter the signal according to filter settings on the "Parameters/Advanced/Main" sub-tab before calculating these characteristics, check the "Apply Notch, High Pass, Low Pass filters if checked in the Main Parameters" checkbox.

Provide a text string that will be added in front of the name(s) of output file(s) in the "Label" field (optional).

In the "Common Description or Comment" field enter a comment or description that will be included into the output file(s).

Press the "Save" button. A standard file save dialog will open to select the location of the output file. The file name field of the file save dialog will show the proposed automatically generated name for the output file (see 4.1. The main output – selected events), which you can modify before saving (before pressing the "Save" button on the file save dialog).

5.2. Multiple Channels Processing

Multiple channels processing allows to process several EEG channels, selected by the user, according to specified processing options (see 6.7. Multiple channels processing).

Steps for multiple channels processing:

1. Load EEG data
2. Select the channels for processing
3. Set parameters (Default or Custom) (this step does not depend on steps 1 and 2, so it can be done before 1 or 2)
4. Specify the processing options
5. Process Multiple channels
6. Readjust the SBI Threshold(s) (if needed)
7. Apply an automatic event processing (optional)
8. Inspect and classify the events into Categories
9. Save the classified events

5.2.1. Loading the EEG data

This step is identical to Step 1 in 5.1. Single channel processing.

5.2.2. Selecting the Channels for processing

In Multiple channels processing, the program consecutively processes all the channels that are checked in the "Channels" list on the right control panel of the "SBI & Channels" tab of the main window.

Since the channel that is selected in the "Select channels" combo box on the upper control panel is always checked in the "Channels" list on the right control panel, it will be processed as well.

In the "Select channels" combo box on the upper control panel, select one of the channels that must be processed. This channel will become checked in the "Channels" list on the right control panel.

In the "Channels" list, check the rest of the channels that must be processed.

5.2.3. Setting Processing Parameters

This step is identical to Step 3 in 5.1. Single channel processing.

5.2.4. Specifying the processing options

In the "Multiple Channels Processing Options" group box of the "SBI Processing Parameters" group on the "Advanced" sub-tab of "Parameters" tab select whether the channels to be processed are from the same animal or from different animals (see 6.7. Multiple channels processing for details).

If the channels are from the same animal, in the "Threshold Options" group box select whether you want to apply its own threshold for each channel ("Use different threshold for each channel" option) or to define one common threshold that will be applied to all channels ("Use one threshold for all channels" option). In the latter case you have to specify the method for common threshold definition in the "Threshold Definition Method" options group (see 6.7.1. Channels are from the same animal for description of different methods).

If the channels are from different animals (see 6.7.2. Channels are from different animals), the threshold will always be defined for each channel separately, so the "Threshold Options" group will be disabled. If, for some reason, you want to put the events detected in different channels/animals into one common list, check the "Put events from all channels into one list" checkbox.

5.2.5. Processing Multiple Channels

Switch to the "SBI & Channels" tab of the main window.

Press the "Process Multiple Channels" button on the right control panel (Fig. 1.3.5). The program will present a dialog with Multiple Channels Processing Options (same as "Multiple Channels Processing Options" group box of the "SBI Processing Parameters" group on the "Advanced" sub-tab of "Parameters" tab) – to ensure that the options are selected correctly. Edit the options if necessary and press the "OK" button. The program will start processing the checked channels one by one. The progress bar on the control panel (Fig. 1.3.5) will indicate the progress for each channel. The field to the right of the button will show the index number of the currently processed channel.

The calculation process may be interrupted by pressing the ❌(Stop) button.

When the calculation finishes, the program "beeps" and plots the SBI curves of the channels in the SBI pane. If Threshold Definition Method was "SBI product histogram" or "SBI average histogram", in addition to channel's SBI curves, the SBI plot will contain also the product SBI or the average SBI, correspondingly.

To switch from one channel's SBI curve to another, use the buttons on the top of the SBI plot.

The program also defines the threshold(s) according to selected processing options and makes event selection based on these thresholds. As a result, there will be either one events list or several (as many as the number of channels), according to the processing options (see the table in 5.2.8). In case of multiple events lists, you can switch from one to another by pressing the corresponding channel's button above the SBI plot.

5.2.6. Readjusting the SBI Threshold(s) (if needed)

At this stage it is possible to manually change the threshold (or thresholds – depending on processing options) and repeat event-selection based on new threshold(s) value(s), by pressing the "Select Events" button. The event re-selection will be applied to all channels that were selected for multiple channels processing and in accordance with the multiple channels processing options (Fig.6.8) that were set before multiple channels processing.

5.2.7. Applying an automatic event processing (optional)

This step is identical to 5.1.8. Applying an automatic event processing method (optional), except the following.

When the "AutoProcess Events" button is pressed after multiple channels processing, the automatic event processing methods (see 6.8. Automatic Event Processing Methods) are applied to the current event list. Depending on the multiple channels processing options the current event list is either (see also the table in 5.2.8. Inspecting and Classifying the Events into Categories):

- The event list defined for the channel the SBI of which is displayed in the SBI pane (Fig. 6.7); this will be in the case when the processed channels are from different animals and the checkbox "Put events from all channels into one list" was not checked. In this case, when the "AutoProcess Events" button is pressed the automatic event processing is applied only to the current channel's event list. Thus, to apply automatic event processing to all channels, the user has to do it one by one: select a channel by pressing corresponding button above the SBI plot (Fig. 6.7) and then press the "AutoProcess Events" button.

- The cumulative events list, irrespective of which channel's SBI is displayed; this will be in the case when the processed channels are from the same animal, or when the channels are from different animals but the checkbox "Put events from all channels into one list" was checked. In this case, since the cumulative events

list is common for all processed channels, the "AutoProcess Events" button shall be pressed only once.

5.2.8. Inspecting and Classifying the Events into Categories

Depending on the selected processing options, the output of the multiple channels processing is either a single event list or as many event lists as the number of processed channels (see the table below). Accordingly, the visual event inspection and classification (and saving to output file(s)) should be done either once or as many times as the number of processed channels.

In the latter case, use the buttons at the top of the SBI plot (Fig. 6.7) to select a channel's SBI plot and the corresponding event list, and perform the event inspection and classification in a similar way as for single channel processing (see Step 9 in 5.1. Single channel processing), then save the final selected events (5.1.10. Saving the Classified Events), then repeat the same procedure for the next channel, etc.

In the former case (a single events list for all channels), the event inspection and classification is done once, again similarly to Step 9 in 5.1. Single channel processing. The only difference is that when viewing the events in the preliminary list (5.1.9.1. Inspecting the events in the preliminary list) or in the event categories (5.1.9.2.6. Viewing the events in the Event categories), the Signal pane of the "SBI & Signal" tab of the program's main window highlights those channels in red in which the selected event was detected (by drawing the signal trace in red rather than blue).

Processing Options	One (cumulative) events list for all channels	Different event list for each channel	Are the channel indices outputted?	Comment
1. Selected Channels are from same subject/animal 1) Use different threshold for each channel	∨		yes	
2) Use one threshold for each channel a) Cumulative histogram	∨		yes	
b) SBI Product histogram	∨		no	Information about channels is not available in this method
c) SBI Average histogram	∨		no	Information about channels is not available in this method
d) Channel threshold's average	∨		yes	

2. Selected Channels are from different subjects/animals		v		
1) "Put events from all channels into one list" checkbox is not checked				
2) "Put events from all channels into one list" checkbox is checked	v		yes	

In the example shown below this particular event was detected in first three channels (upper red traces) and was not detected in the last one (bottom blue trace).
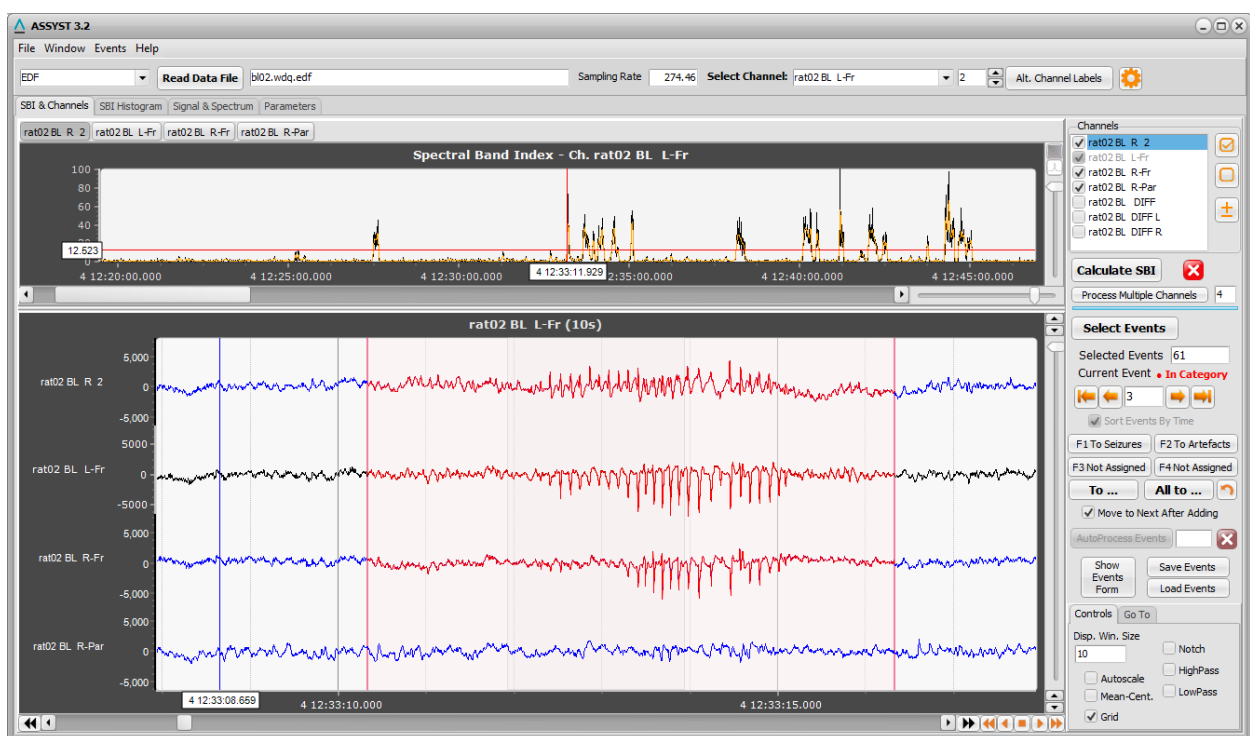
5.2.9. Saving the Classified Events

This step is identical to Step 10 in 5.1. Single channel processing (but note that if there are different event list for each channel (see the table in 5.2.8) the event inspection and classification, as well as saving the classified events must be done for each channel).

6. Processing method

The seizure/SWD detection method implemented in the program utilizes an advanced time-frequency analysis to reveal the EEG segments with excessive activity in certain frequency band. The spectral content of the EEG within a given frequency band is assessed using a measure referred to as Spectral band index (SBI), which is calculated over time using a pre-determined running time window.

The main steps of the algorithm are presented in Fig 6.1. The algorithm consists of main (shaded blocks) and optional (white blocks) steps. The algorithm is interactive: some operations are performed by the computer (right column in Fig 6.1), others require user influence (left column in Fig 6.1).

6.1. Pre-processing

The pre-processing of the input EEG is performed in order to remove the low frequency components, and to make the components in the seizure frequency range more pronounced. During this step the low-frequency baseline trend is subtracted from the EEG signal (de-trending). The low-frequency baseline trend is obtained by smoothing the input signal using multiple pass moving averaging. In this method a moving window of a given size is moving along the signal, with step equal to signal's sampling step, and for each position i of the window the signal at the sample corresponding to the window centre $s_i = s(t_i)$ is replaced by the average of all samples in the window:

$$\bar{s}_i = \frac{\sum_{k=1}^{M} s_{i-l} + s_s + \sum_{k=1}^{M} s_{i+k}}{2M+1},$$

where M is the smoothing window half size in terms of the number of samples.

This procedure may be repeated multiple times. The wider the window or the higher the number of repetitions (passes), the more smoothed the baseline trend will be, and vice versa.

The smoothing window half size and the number of repetitions of moving averaging are parameters provided by the user, in the "Detrending" parameters group of the Advanced sub-tab of Parameters tab (see Fig. 1.6.4 in 1.6.2 The Advanced tab). For convenience and independence of the window size on sampling rate of particular data, the window half size is specified in seconds.

De-trending procedure may be omitted, for which the checkbox "No detrending" in the De-trending parameter group must be checked.
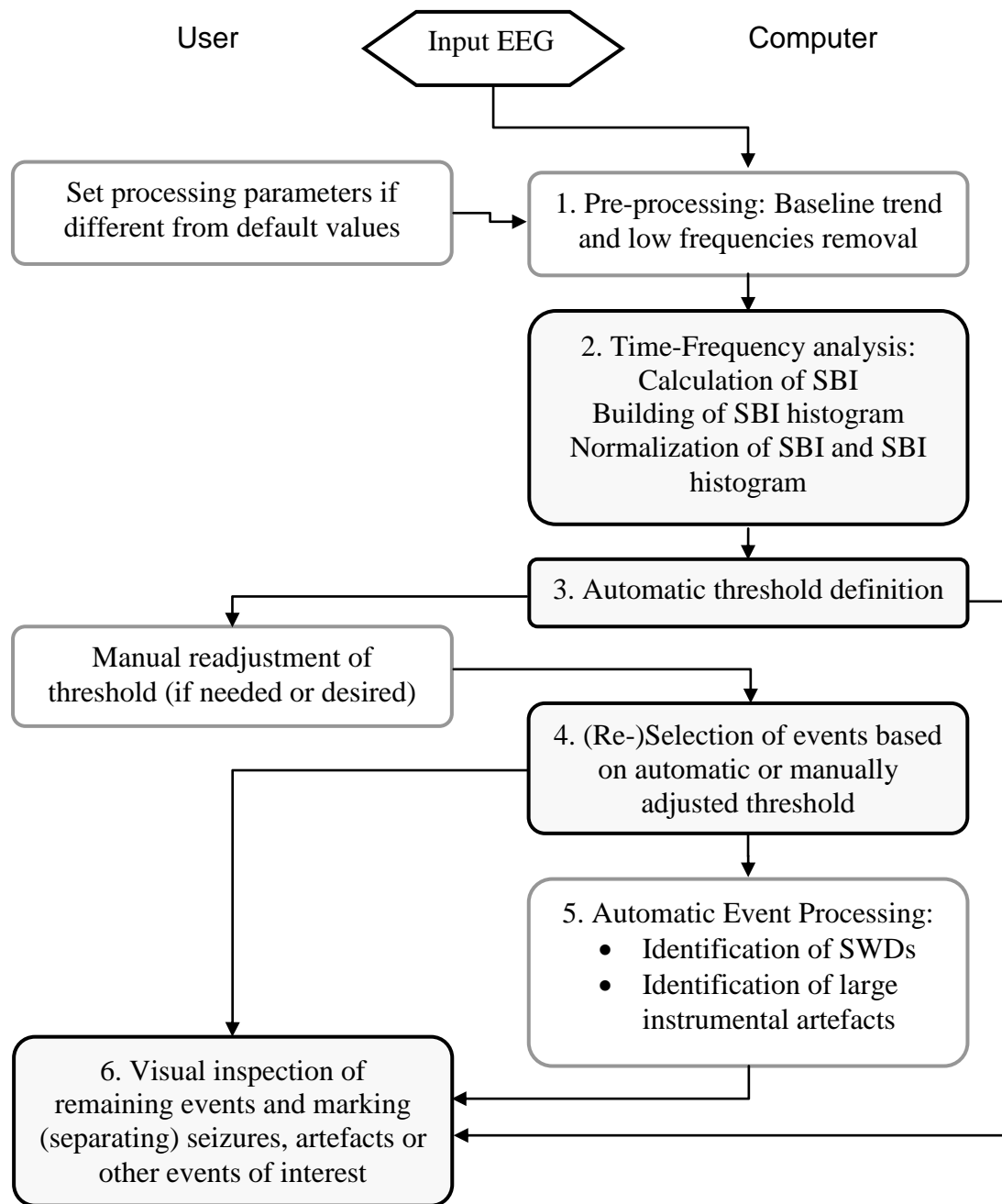
Fig. 6.1 Block diagram of the algorithm. Shaded blocks indicate main steps; white blocks indicate optional steps. The blocks on the left side indicate operations performed by the user, and blocks on the right side those performed by the computer.

6.2. Time-Frequency analysis

Calculation of spectral band index

This step is intended to reveal the temporal dynamics of a particular frequency component of the EEG. The frequency range of interest is defined by the user, by providing the lowest (parameter "Freq. Low" in the Frequency Band parameters group of the Advanced sub-tab of Parameters tab, Fig. 1.6.5) and highest (parameter (parameter "Freq. High") frequency of the range. The frequency resolution is also specified by the user, by providing the number of frequency samples in the range (parameter "Num. FC samples").

The user also specifies the length of EEG segments (time window size, parameter "Window Size" in the Processing Window parameters group of the Advanced sub-tab of Parameters tab, Fig. 1.6.3) that will be used to calculate the power spectrum of the EEG. This window then is moved along the EEG signal, with user-defined step (parameter "Window Step"), which is usually (but not necessarily) less than the length of the window to allow for window overlap. For each window position (Fig 6.2, A):

- the power spectrum of the EEG segment from this window is calculated within the defined frequency range (Fig. 6.2, B);

- the maximum of the power spectrum in this frequency range is found, and this value, which we call "Spectral band index" (SBI, Fig 6.2, B) is used as an estimate for spectral intensity of the EEG within this frequency band at the time moment corresponding to the centre of the current time window;

- the SBI values plotted against time (at centres of consecutive windows) form the SBI curve – the dependence of SBI on time (Fig. 6.2, C).

Smoothing the SBI curve

Due to possible fluctuations of the SBI values the SBI curve may have several peaks during a single seizure and may cross the threshold several times (Fig. 6.3). In such cases the event selector will produce several detections. To avoid or minimize this effect, a smoothing of the SBI may be performed (again, using multiple-pass moving average) to unite nearby sharp peaks above threshold into one and thus to reduce the number of selected events.

The effect of smoothing of the SBI curve is demonstrated in Fig. 6.3. In the example shown in the figure the original not smoothed SBI curve has three sharp peaks during this single seizure which all go above the threshold. This will cause three detections for this seizure. The smoothed SBI has only one peak and will produce a single detection.
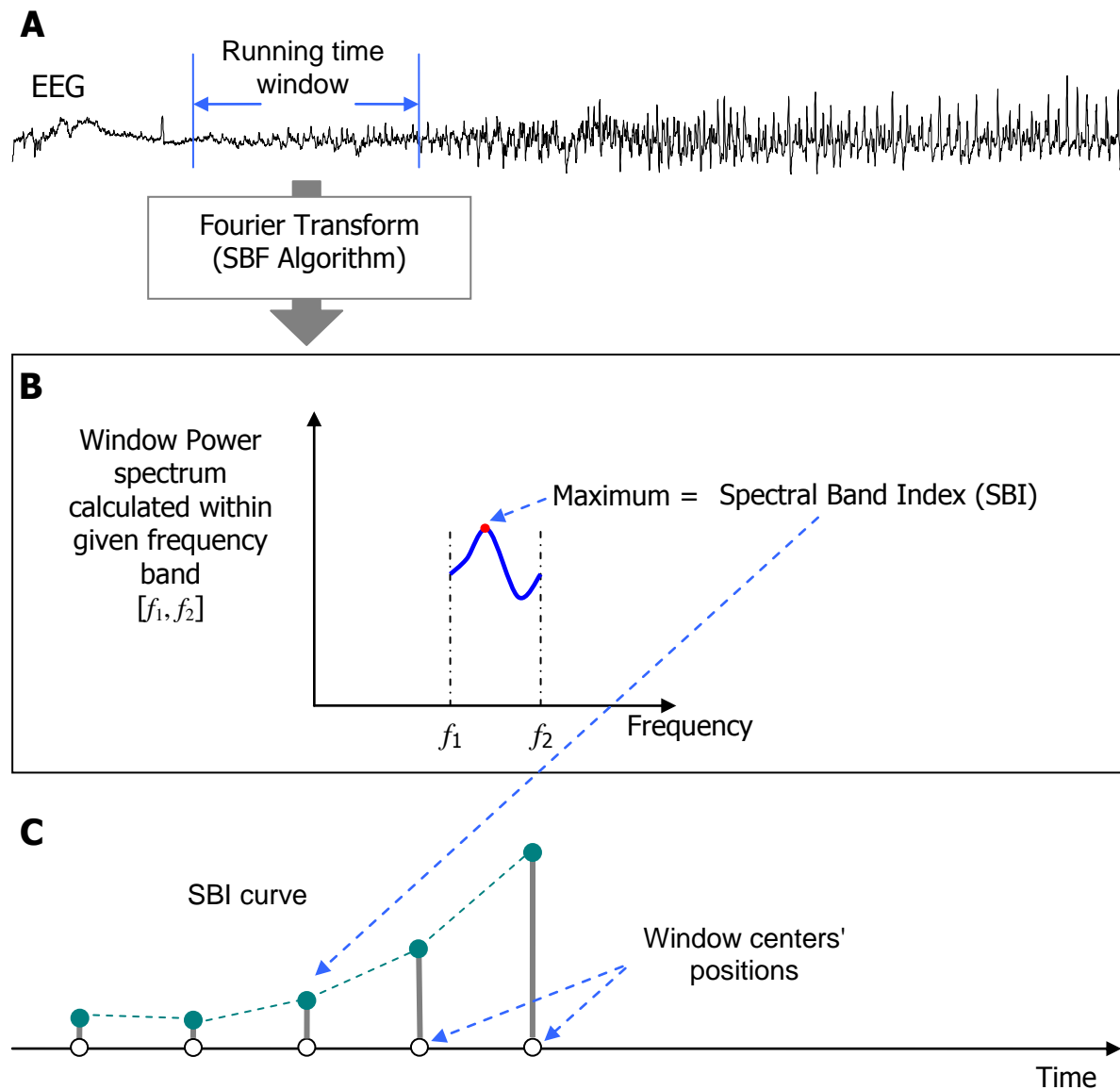
Fig. 6.2. Diagram showing calculation of SBI curve. A. An example fragment of EEG and the current position of running time window. B. The Fourier transform and the power spectrum of EEG segment from this window is calculated using the SBF algorithm, for the frequency range [f1, f2]. The maximum of power spectrum in this range is the SBI of current window. C. The SBIs of consecutive time windows are then plotted against time and form the SBI curve (upper graph).
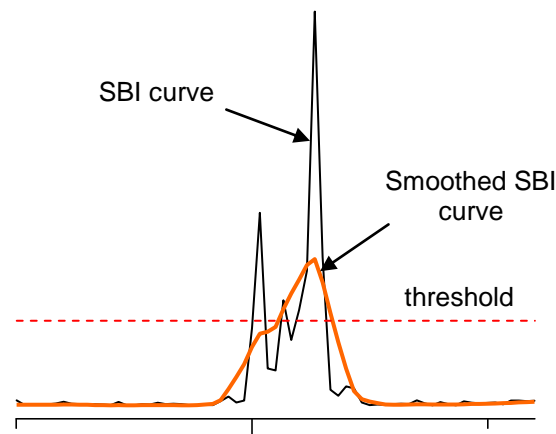
Fig. 6.3. A fragment with a seizure of an SBI curve and smoothed SBI curve. Original (not smoothed) SBI curve has three sharp peaks during this single seizure which all go above the threshold, which means that there will be three detections for this seizure, while smoothed SBI has only one peak and will produce a single detection.

Building the SBI distribution histogram

After calculation of the SBI curve, the histogram of distribution of SBI values is built. The bins of the histogram show how often particular SBI values (horizontal axis) are encountered during the entire record duration. The bin width and number of bins of the histogram are defined automatically based on the inter-quartile range.

This histogram is used then for two purposes:

1) To normalize the SBI curve and the histogram itself

2) To define the threshold for cutting off the background EEG signal leaving only the events that possibly are epileptiform activity.

Normalization of SBI curve and SBI histogram

Due to possible differences in signal strength (which may be caused by differences in electrode impedance, amplification factors, etc.) in different channels of the same recording, and especially in different recordings, the SBI values and the thresholds defined on their basis may significantly differ and thus be not comparable.

To make the SBI curves and the defined thresholds comparable across channels in one recording, as well as across different recordings and animals, the SBI curves and SBI histograms are normalized in the program. The principle underlying the normalization is that the average baseline values (i.e., the SBI values corresponding to the baseline, or

inetrictal, EEG) of SBIs of different channels/animals/recordings must be identical after normalization. So for every SBI curve, the normalization factor (the value by which the SBI is multiplied during the normalization) is defined so that after the normalization the SBI's baseline value is equal to 1. Thus, to define the normalization factor we first must define the baseline value of the original (not normalized) SBI. We define the baseline SBI value as the most frequently occurring SBI value. If we build the SBI distribution histogram, the mode of the histogram will correspond to the most frequently occurring SBI value, i.e., the baseline (Fig. 6.4).
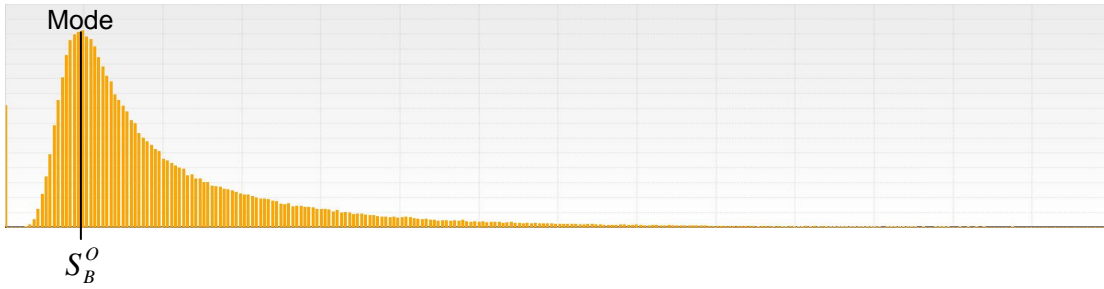
Fig. 6.4. The SBI values distribution histogram (in short, the SBI histogram).

The normalized SBI is then calculated according to

$S_i^N = cS_i^O$, $i = 1,...N$, where

S^O is the original SBI, S^N is the normalized SBI,

$c = 1/S_B^O$ is the normalization factor, S_B^O is the baseline (mode) value of the original SBI obtained from the SBI histogram.

The SBI histogram's X axis is then normalized in the same way.

6.3 Automatic Threshold definition

To find the times of high electrical EEG activity within the frequency band of interest, suggestive of seizures or other epileptiform activity, a threshold value of the SBI is defined. This threshold allows to filter background EEG signal and non-epileptiform interictal activity, from the seizures or other epileptiform activity. The automatic threshold definition is based on distribution histogram of SBI values over entire recording time. Assuming that the total duration of ictal and other epileptiform events is only a small fraction of overall duration of the record, the region of the histogram with highest density of distribution will indicate the interictal, or baseline, SBI value range. By setting the threshold somewhere above this range we will cut off the "ordinary" values of the SBI and leave only the seizure events.

The threshold is calculated based on the SBI values distribution histogram and the "Threshold relative position" parameter specified by the user.
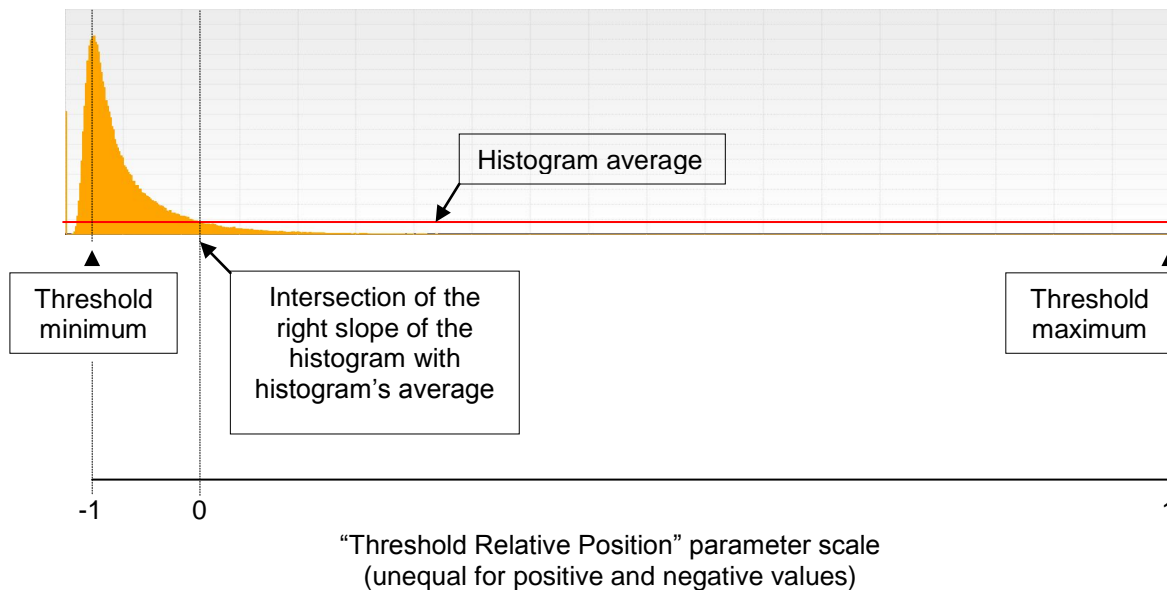
Fig. 6.5. Characteristic points of the SBI histogram used for threshold definition.

The following three points are determined using the SBI histogram (Fig. 6.5):

1. The minimal value for the threshold (threshold minimum). We define this value as the value corresponding to the SBI baseline, i.e., the most frequent SBI value, which is determined from the SBI histogram as the mode of the SBI distribution (the SBI value at which the histogram has its peak). Putting the threshold below this value is meaningless – in this case the majority of SBI values will be higher than the threshold.

2. A cutting point, that separates the SBI values close to the baseline from the ones that are significantly different (higher) from the baseline. We take as such point the position on the right slope of the histogram peak where the histogram values become less than the histogram values' average.

3. The maximal value for the threshold (threshold maximum), which is equal to the maximal SBI value (the rightmost edge of the SBI histogram). There is no sense in putting the threshold higher than this point, as no SBI values are higher than that.

After these three points are defined, the actual threshold position is determined from the user-specified parameter "Threshold relative position". This parameter may have values from -1 to +1, with -1 corresponding to the threshold minimum, 0 corresponding to the "cutting point", and 1 corresponding to the threshold maximum (note that the negative and positive scales are different). So if, for example, the "Threshold relative position" = 0, then the actual threshold will be equal to the cutting point SBI value. If,

e.g., the "Threshold relative position" = -0.5, then the threshold will be in between the threshold minimum and the cutting point.

Note that due to SBI and histogram normalization, the threshold minimum, which is the histogram's mode, is equal to 1 (see Normalization of SBI curve and SBI histogram).

Manual readjustment of threshold

The automatically defined threshold will be indicated by red horizontal line on the SBI plot on the SBI pane of the SBI&Channels tab and by red vertical line on the histogram plot on the Histogram tab. In some cases the automatically calculated threshold may be not the best choice and manual editing may be required. This might be the case when, e.g., the record duration is short and the signal is contaminated with artefacts. Or the user may wish to lower the threshold to capture weaker or shorter events.

The threshold can be changed simply by dragging the threshold line with mouse vertically on the SBI pane of the SBI&Channels tab or horizontally on the SBI Histogram tab. Alternatively, the threshold can be set by entering its numeric value in the "Threshold" field below the histogram on the SBI Histogram tab.

Recommendation: Change the horizontal and vertical scales of the SBI curve so that you can see smaller peaks. Examine several small peaks by clicking on them - the Signal pane will show the corresponding fragment of the EEG. If the small peaks are caused by events of interest (e.g., seizures or SWDs), and they are subthreshold then lower the threshold so that these peaks become suprathreshold to be selected by the automatic event selection procedure.

The SBI histogram also can be very handy for selecting a proper threshold. Along the x-axis of the histogram are the SBI values. The y-axis is the frequency of occurrence of the SBI values. The peak of the histogram shows the most frequently encountered values of the SBI. The histogram usually peaks at lower SBI values that are produced by the interictal EEG- the "usual", or background EEG. High SBI values are much rarer, as indicated by low values of the histogram at higher SBI values (right side of the histogram). These high SBI values are the ones that are of interest, because most probably they are produced by ictal EEG. The threshold should be set so that it "cuts off" the SBI values corresponding to the interictal EEG, i.e., the left part of the histogram containing the peak, as in the example shown in Fig. 1.4.1.

6.4. Selection of events

After the threshold is defined, the program finds the peaks of the SBI that are above the threshold, and stores their times in a dedicated list – the preliminary event list each element of which contains the event's start and end times.

According to parameter settings in the *Event Processing* parameters group (Fig. 1.6.7) on the *Advanced* sub-tab of *Parameters* tab (see 1.6.2 The Advanced tab), during the selection process the short events may be ignored, and close events may be merged.

The start and end times of the selected events are roughly determined as the points where the SBI curve crosses the threshold. The precision of defining the starts and ends in this way is equal to the size of processing time window. However, the user has possibility to redefine the start and end times of selected events manually, simply moving special cursors to desired positions on the EEG.

The number of events in the preliminary event list will be shown in the "Selected Events" field on the right control panel of the SBI&Channels tab. The events in the preliminary list may be sorted either according to their time of occurrence or their SBI peak value (in which case the sorting is in descending order - the first event has the highest value of SBI), depending on whether the "Sort Events by Time" checkbox is checked or not. The first event becomes the current event, its index is displayed in the "Current Event" field on the right control panel of the SBI&Channels tab and the corresponding EEG fragment is shown in the Signal pane.

6.5. Automatic Event Processing

The events in the preliminary event list may be either visually inspected and classified into different event categories by the user, as described in 5.1.9. Inspecting and Classifying the Events from the Preliminary List into Categories, or, in some cases, automatic event identification and classification may be applied.

The following optional automatic event processing procedures are implemented in *ASSYST*:

- Automatic identification of spike-wave discharges (SWDs)
- Automatic identification of large instrumental artefacts

These procedures and underlying algorithms are described in 6.8. Automatic Event Processing Methods.

6.6. Visual inspection of remaining events

This step is performed by the user, as described in 5.1.9. Inspecting and Classifying the Events from the Preliminary List into Categories.

6.7. Multiple channels processing

Multiple channel processing is performed by the program when the user presses the "Process Multiple Channels" button on the right control panel of the SBI & Channels tab.
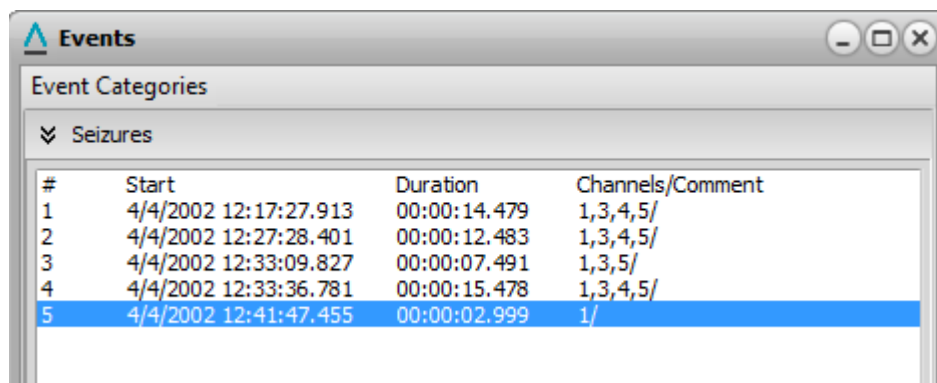
In Multiple channels processing, the program consecutively processes all the channels that are checked in the "Channels" list on the right control panel of the "SBI & Channels" tab of the main window.

Processing of several channels in one go is performed differently depending on the two following cases:

1. Channels to be processed are different leads of the same recording from the same animal. I.e., epileptiform events occurring in different channels may be (and mostly are) correlated.

2. Channels to be processed are recordings from different animals. I.e., epileptiform events occurring in different channels are unrelated.

6.7.1. Channels are from the same animal

In the first case, the output is always a single list of events – so-called cumulative list, composed from events detected in all channels. Each event of the cumulative list contains information on in which channel it was detected (i.e., was suprathreshold). This information will be indicated in the Events lists of the Events form and in the output file(s). In the Events list of the Events form the indices of the channels in which the event was detected will be displayed in the "Channels/Comments" column (Fig. 6.6).

Fig. 6.6. The Events form showing the channels in which the event was detected

In the output files, instead of channel indices, the channels' labels will be stored, again under the "Channels/Comments" column, as shown in the example below.

```
Event Category: Seizures
Description: Seizuress
Number of events: 5

# Start                End                  Duration      Channels/Comment
1 4/4/2002 12:17:27.913 4/4/2002 12:17:42.392 00:00:14.479  rat02 BL R 2, rat02 BL R-Fr, rat02 BL R-Par, rat02 BL DIFF /
2 4/4/2002 12:27:28.401 4/4/2002 12:27:40.884 00:00:12.483  rat02 BL R 2, rat02 BL R-Fr, rat02 BL R-Par, rat02 BL DIFF /
3 4/4/2002 12:33:09.827 4/4/2002 12:33:17.318 00:00:07.491  rat02 BL  R  2, rat02 BL  R-Fr, rat02 BL   DIFF /
4 4/4/2002 12:33:36.781 4/4/2002 12:33:52.259 00:00:15.478  rat02 BL  R  2, rat02 BL  R-Fr, rat02 BL  R-Par, rat02 BL   DIFF /
5 4/4/2002 12:41:47.455 4/4/2002 12:41:50.454 00:00:02.999  rat02 BL  R  2 /
```

In this processing mode, the following ways of threshold definition and event selection are possible:

1) Different threshold for each channel

2) One threshold for all channels

1) Different threshold for each channel.
In this case, for each channel, its own threshold is defined based on SBI curve of that channel, as described in 6.3. Automatic Threshold definition, and then event selection is performed separately for each channel based on the channel's own threshold. Then the events from each channel are grouped into one common event list (cumulative list), in which the overlapping events from different channels are merged and the information about the channel the event comes from is preserved.

2) One threshold for all channels.
In this case, one common threshold is defined for all channels. The following methods for defining the common threshold are implemented in the program:
   a) Cumulative histogram

b) SBI product histogram
c) SBI average histogram
d) Channel thresholds' average

The event selection procedure may be different depending on which of the common threshold definition method is selected.

a) Common threshold definition using Cumulative histogram.

The SBI curves for each channel are normalized as described in Normalization of SBI curve and SBI histogram, and then a general (cumulative) histogram of SBI values distribution is built from all values of all SBI curves. From this cumulative histogram, the threshold value is defined as described in 6.3. Automatic Threshold definition.

In this case of common threshold definition the event selection is performed for each channel separately, but using the same common threshold. Then events from each channel are grouped into one common event list (cumulative list), in which the overlapping events from different channels are merged and the information about the channel the event comes from is preserved.

b) Common threshold definition using SBI product histogram.

The SBI curves for each channel are normalized as described in Normalization of SBI curve and SBI histogram, and then the product of these SBIs is calculated:

$\dot{S}_i = \prod_{j=1}^{M} S_i^j$, $i = 1,...N$, where M is the number of channels, N is the number of samples of

the SBI curves, S_i^j is the ith value of the SBI of channel j.

Then the histogram of distribution of values of product SBI $\dot{S}$ is built and the common threshold is defined from this histogram as described in 6.3. Automatic Threshold definition.

In this case of threshold definition the event selection is made using the product SBI $\dot{S}$ (and not the channels' SBIs), by finding the times when $\dot{S}$ is above the defined threshold (so the events in the event list may not contain information about the channels).

c) Common threshold definition using SBI average histogram.

The SBI curves for each channel are normalized as described in Normalization of SBI curve and SBI histogram, and then the average of these SBIs is calculated:

$\bar{S}_i = \frac{1}{M} \sum_{j=1}^{M} S_i^j$, $i = 1,...N$, where M is the number of channels, N is the number of samples

of the SBI curves, S_i^j is the ith value of the SBI of channel j.

Then the histogram of distribution of values of average SBI $\bar{S}$ is built and the common threshold is defined from this histogram as described in 6.3. Automatic Threshold definition.

In this case of threshold definition the event selection is made using the average SBI $\bar{S}$ (and not the channels' SBIs), by finding the times when $\bar{S}$ is above the defined

threshold (so the events in the event list may not contain information about the channels).

d) Common threshold definition as channels' thresholds average.
The SBI curves for each channel are normalized as described in Normalization of SBI curve and SBI histogram, and then for each channel its own threshold T_j is defined based on the SBI curve of that channel. The common threshold is then calculated as the average of channels' thresholds:

$$\bar{T} = \frac{1}{M}\sum_{j=1}^{M}T_j \ .$$

In this case of common threshold definition the event selection is performed for each channel separately, but using the same common threshold $\bar{T}$. Then events from each channel are grouped into one common event list (cumulative list), in which the overlapping events from different channels are merged and the information about the channel the event comes from is preserved.

In all cases of multiple channels processing of channels from the same animal the result with which the user deals is a single event list – the cumulative event list.

6.7.2. Channels are from different animals

In this case each channel is processed separately, as in case of single channel processing. For each channel, its own threshold is defined as described in 6.3. Automatic Threshold definition, and then event selection is performed based on the channel's threshold. As a result, for each channel there will be a separate events list. The user switches from one channel's SBI plot and events list to another channel's ones by clicking the corresponding button on the top of the SBI pane (Fig. 6.7). The captions of these buttons show the corresponding channel's label. There will be as many buttons as the number of channels processed in multiple channels mode. When a channel is selected (by pressing the corresponding button), its SBI curve is plotted in the SBI pane, with the automatically calculated threshold for that channel indicated by horizontal red line, and event list selected for this channel becomes active in the right control panel.
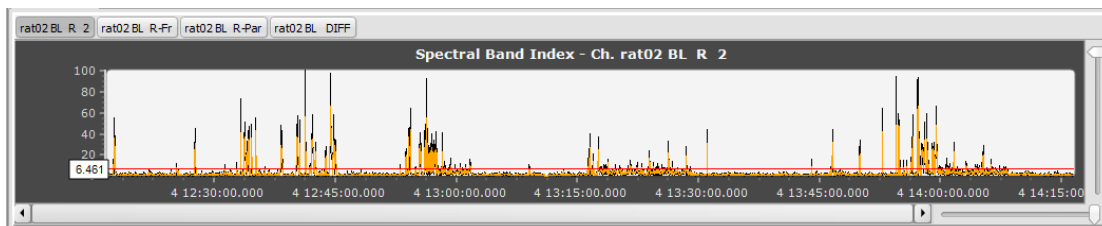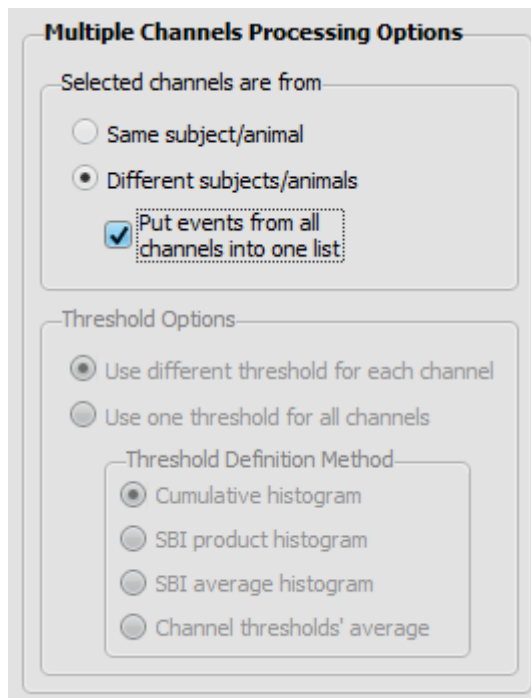
Fig. 6.7. The SBI pane after multiple channels processing for channels from different animals.

In some cases the user may want to put the events selected for different channels (animals) into one common list. For this, the check box "Put events from all channels into one list" in the "Multiple Channels Processing Options" parameters group on the Advanced sub tab of the Parameters tab must be checked (Fig. 6.8). In this case, after the events are selected for each channel based on that channel's threshold, they are sorted by time of occurrence and then put into one common list, preserving the information about the channel where from the event comes. In this case, the right control panel always operates on this common list, irrespective of which channel's SBI curve is shown in the SBI pane. Note that in this case the overlapping events from different channels will not (and must not) be merged, since they are from different animals.

Fig. 6.8. The "Multiple Channels Processing Options" parameters group on the Advanced sub tab of the Parameters tab.

6.7.3. Behaviour of buttons and corresponding methods in multiple channels processing mode

Automatic Event Processing (button "AutoProcess Events")

When the "AutoProcess Events" button is pressed after multiple channels processing, the automatic event processing methods (see 6.8. Automatic Event Processing Methods) are applied to the current event list. Depending on the multiple channels processing options the current event list is either:

- The event list defined for the channel the SBI of which is displayed in the SBI pane (Fig. 6.7); this will be in the case when the processed channels are from different animals and the checkbox "Put events from all channels into one list" was not checked. In this case, when the "AutoProcess Events" button is pressed the automatic event processing is applied only to the current channel's event list. Thus, to apply automatic event processing to all channels, the user has to do it one by one: select a channel by pressing corresponding button above the SBI plot (Fig. 6.7) and then press the "AutoProcess Events" button.

- The cumulative events list, irrespective of which channel's SBI is displayed; this will be in the case when the processed channels are from the same animal, or when the channels are from different animals but the checkbox "Put events from all channels into one list" was checked. In this case, since the cumulative events list is common for all processed channels, the "AutoProcess Events" button shall be pressed only once.

Event (Re-)Selection (button "Select Events")

After multiple channels processing, which includes event selection based on automatically defined threshold(s), the user may manually change the threshold(s) and repeat event-selection based on new threshold(s) value(s), by pressing the "Select Events" button. The event re-selection will be applied to all channels that were selected for multiple channels processing and in accordance with the multiple channels processing options (Fig.6.8) that were set before multiple channels processing.

Repeating multiple channels processing for the same set of channels but with different parameters or options ("Recalculate SBI Histogram(s) & Threshold(s)" button on the "Advanced" sub-tab of the "Parameters" tab)

The user may repeat all steps of multiple channels processing except the time consuming SBI curves calculation, for the same set of channels but with different options or parameters, by changing the parameters in the "SBI Processing Parameters" group on the "Advanced" sub-tab of the "Parameters" tab (Fig. 6.9) and pressing the "Recalculate SBI Histogram(s) & Threshold(s)" button. The channel selection, however, cannot be changed since the recalculation is based on already calculated SBI curves for the selected channels.

Fig. 6.9. The "SBI Processing Parameters" group on the "Advanced" sub-tab of the "Parameters"

6.8. Automatic Event Processing Methods

6.8.1. Automatic Identification of Spike-Wave Discharges (SWD)

Starting from version 3.0, ASSYST is empowered with an algorithm for automatic identification of SWDs. The algorithm exploits the fact that SWDs consist of spike-wave complexes repeating at certain almost constant rate. This rate is specific for the particular animal model.

The algorithm passes through the fragments of EEG initially selected using the SBI threshold (as described above in 6.1 - 6.4) and reveals whether the fragment contains rhythmic patterns consisting of similar elements repeating with given frequency. The evaluation of the rhythmicity is performed by calculating and analysing the beat spectrum of the EEG fragment.

The beat spectrum quantifies the signal self-similarity as a function of time lag. Peaks of the beat spectrum correspond to major rhythmic components of the signal, revealing key periodicities across different timescales. The beat spectrum is a robust measure of rhythmic signal constituents with weak, well-characterized dependence on the level of signal noise.

Sometimes the pieces of the EEG containing clear repetitive patterns are shorter than the EEG interval selected for the event by the SBI threshold method. In these cases, if the beat spectrum is calculated for the entire interval, its peaks may be blurred or less pronounced, such that it is difficult to decide whether the event is rhythmic (or contains rhythmic parts) or not. To tackle this issue, we introduce "running" beat spectrum, which is calculated for short fragments of EEG (presumably shorter than the event interval) starting from the event interval's start and moving towards the interval's end with time step equal to the EEG's time step. For each such short fragment the beat spectrum is calculated as described below and its peaks are analysed to find out if the fragment contains periodic signal with given frequency.

For each event from the preliminary event list, the processing algorithm consists of the following steps (Fig. 6.10):

> 1. Pre-processing.
>
> 2. Checking wether the event has rhythmic parts with given frequency using running beat spectrum.
>
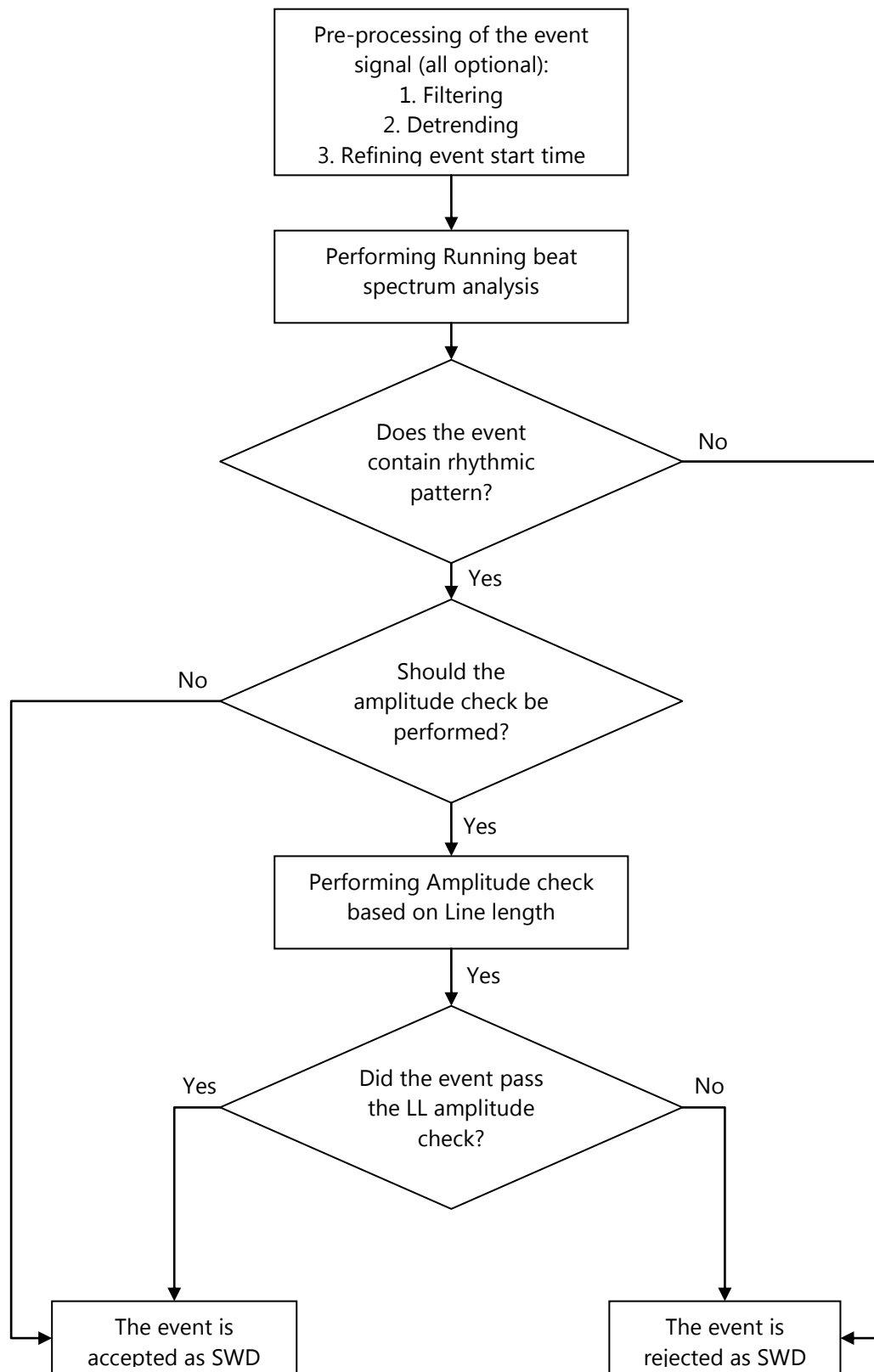> 3. Checking the amplitude based on line length (optional).

Fig. 6.10. Flow chart showing the main steps of identifying of an event as SWD.

6.8.1.1. Pre-processing.

The pre-processing of each event selected by the SBI threshold method consists of the following steps (Fig. 6.11, 1):

> 1. Notch, low-pass or high-pass filtering (optional)
>
> 2. De-trending
>
> 3. Refining event start time

1. Notch, low-pass or high-pass filtering (optional). If the "Apply Notch, High Pass, Low Pass filters if checked in the Main Parameters" checkbox in the "Running Beat Spectrum Calculation Parameters" group of controls on the Advanced/SWD Identification sub-tab of the Parameters tab (see The Running Beat Spectrum Calculation Parameters) is checked, the original signal in the event interval will be notch-, high-pass or low-pass-filtered according to the states of the checkboxes in the "Filters For Processing & Display" and "Filters For Display Only" groups of controls on the Advanced/Main sub-tab of the Parameters tab (see The Signal Filtering parameters).

2. De-trending. This step is similar to the de-trending step in the SBI calculation described in 6.1. Pre-processing and uses exactly the same parameters (see The De-trending parameters).

3. Refining event start time. The event start time is defined in the SBI threshold method as the left edge of the processing window for which the SBI value becomes larger than the threshold (6.4. Selection of events). The precision of such definition is comparable with the size of the processing time window used for SBI calculation. To refine the event start time before the running beat spectrum calculation (to avoid excessive computations), the following procedure is performed.

A window of smaller size than the processing window used for SBI calculation is moved along the event interval with smallest possible step - the EEG time step, - and for each position of this window the SBI is calculated again as is compared with the SBI threshold. As soon as this newly calculated SBI value exceeds the threshold, the left edge of the small window for which this occurs becomes the new event interval start.

> This small window size is specified by the user as the "Event Time Refinement Window Size" parameter (see The Event Times Refinement Parameters). Note that the program does not check whether this parameter is smaller than the processing window (Processing Window Size parameter, see The Processing Window parameters).

6.8.1.2. Checking the event for rhythmic parts with given frequency using running beat spectrum.

6.8.1.2.1. Running rhythmogram and beat spectrum.

It is possible that only some part(s) of the initially selected event interval contain clear rhythmically repeating pattern. This may be the case, e.g., when the selected event interval is longer than the clear part of the SWD, or the SWD itself is not regular. To not miss these shorter events, we introduce the following rule: if the event in its initial interval contains at least one fragment of duration not less than D that has regular periodic structure with given frequency, then the event is considered as "good" (SWD). This minimal duration D is specified by the user by specifying the value of parameter "Beat Spectrum Length".

This rule is implemented as follows. A window of size 2xD (rhythmogram window) is moved along the event interval with step equal to time step of the signal. For each rhythmogram window position, the rhythmogram and then the beat spectrum of the signal from the window is calculated as described below. Note that to calculate a beat spectrum of length D the rhythmogram must be calculated for signal of length 2D (see below). Then the peaks (if any) of the beat spectrum are analysed to reveal whether the beat spectrum shows presence of desired rhythmicity in this signal fragment or not. If the conditions of rhythmicity are satisfied, the rest of the event interval is not analysed and the event is marked as 'good', i.e., containing SWD. If the running rhythmogram window reaches the end of the event interval and rhythmicity conditions are not satisfied, the event is marked as 'bad' (not containing rhythmic part with desired properties).

The steps of processing of one rhythmogram window are described below.

6.8.1.2.2. Calculation of rhythmogram and beat spectrum for the current rhythmogram window.

The main processing steps for the computation of the rhythmogram

and beat spectrum are shown in Fig. 6.11, 2.

Let $s(t)$ be the signal for which the beat spectrum must be computed, defined by discrete samples at times t_k: $s_k = s(t_k)$, $k = 1,...,N$ $k = 1,...,N$. Let $s_w^i(t)$ be the subset of $s(t)$ between $t_i - W/2$ and $t_i + W/2$, i.e. with t_i the center time, and W the size of the window.

> The size of time window W is specified by the user in "Beat Spectrum Window Size" field in the "Running Beat Spectrum Calculation Parameters" group of controls on the Advanced/SWD Identification sub-tab of the Parameters tab (see The Running Beat Spectrum Calculation Parameters). For identification of SWDs W must be comparable to duration of a single spike-wave complex, better results are obtained if W is smaller than the SW duration, but greater than its half. Recommended setting for rodent SWDs is 0.05 s.

Computing the beat spectrum of $s(t)$ involves the following three basic steps:

Step 1) Parameterization of the signal. The Fourier transform (FT) $F_i(j2\pi f)$ of $s_w^i(t)$, $i = 1,..., N_W$, where N_W is the number of time windows, $j = \sqrt{-1}$, is calculated for all time windows. The feature vectors are defined as either

option 1: $\mathbf{V}_i = |F_i(j2\pi f)| = \sqrt{\text{Re}(2\pi f)^2 + \text{Im}(2\pi f)^2}$ - the amplitude frequency characteristic

option 2: $\mathbf{V}_i = \text{Im}(2\pi f)$ - the imaginary frequency characteristic

option 3 : $\mathbf{V}_i = \text{Re}(2\pi f)$ - the real frequency characteristic

option 4: $\mathbf{V}_i = |F_i(j2\pi f)|^2 = \text{Re}(2\pi f)^2 + \text{Im}(2\pi f)^2$ the power spectrum

where $\text{Re}(2\pi f)$ and $\text{Im}(2\pi f)$ are the real and imaginary frequency characteristics (the cosine and sine Fourier transforms).

The Fourier transform is calculated using the same SBF algorithm that is used for SBI calculation. The SBF algorithm allows to calculate the real and imaginary frequency characteristics for arbitrarily chosen frequencies, i.e., in any frequency range and for any frequency sampling rate.

> The frequency range in which the frequency characteristics are calculated, as well number of frequency samples and the frequency scale (uniform or logarithmic) are specified by the user in the "Window Frequency Characteristics Parameters" group of controls on the SWD Identification sub-tab of the Advanced sub-tab of the Parameters tab (see The Running Beat Spectrum Calculation Parameters). The user also specifies which of the above 4 options (frequency characteristics) must be used as the feature vector, by selecting the corresponding item in "Frequency Characteristic for Window Comparison" combo box in the same group of controls.

The result of this step is the spectrogram, i.e. a two-dimensional time-frequency distribution representing frequency specific changes over time.

Step 2) Computation of similarity measures between feature vectors (matrices) for successive temporal windows of the spectrograms. The distance measures D_{ij}, $i = 1,..., N_W$, $j = 1,..., N_W$ between all feature vectors $\mathbf{V}_i$ and $\mathbf{V}_j$ are calculated as a scalar product in the M-dimensional parameter space (where M, the size of $\mathbf{V}_i$, is the number of frequency samples):

$D_{ij} = \mathbf{V}_i \cdot \mathbf{V}_j$,

where $\mathbf{V}_i$ and $\mathbf{V}_j$ are the feature vectors of i-th and j-th temporal windows.

The matrix $\mathbf{D} = (D_{i,j})_{N_W \times N_W}$ is the rhythmogram, from which the beat spectrum is calculated.

Step 3) The periodicity and relative strength of the transient responses are straightforwardly derived from the rhythmogram matrix using the estimate of the "beat

spectrum", computed from the autocorrelation of the rhythmogram matrix, as a function of time lag τ:

$$B(\tau_k) = B_k = \sum_{i=1}^{N_B} D_{i,i+k} \, , \ k = 1,...,N_B, \ N_B = N_W / 2 \, .$$

1. Pre-processing

Event start

Event end

Event

Filtering & De-trending

Refining event start time

Refined event start

2. Running Beat Spectrum calculation

Running rhythmogram window

For each rhythmogram window:

Windowing input signal

$s(t)$

window i

window j

Parameterization of the signal (Fourier transform of time windows)

Feature vectors (power spectrum)

V_i

V_j
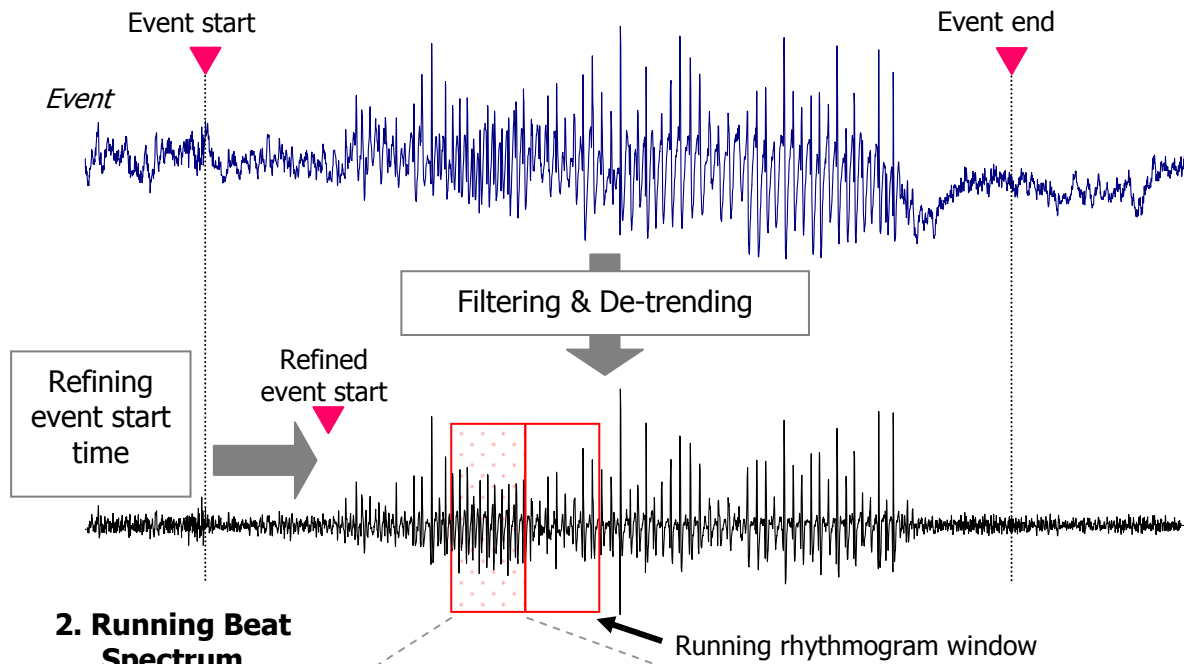
Continued on next page

Fig. 6.11. Illustration of running beat spectrum method (continued on next page).

Computation of similarity measures between feature vectors and forming the rhythmogram matrix

Computation of beat spectrum from the rhythmogram.

Each value of the beat spectrum is the sum of the diagonal elements of the rhythmogram for the given time lag τ
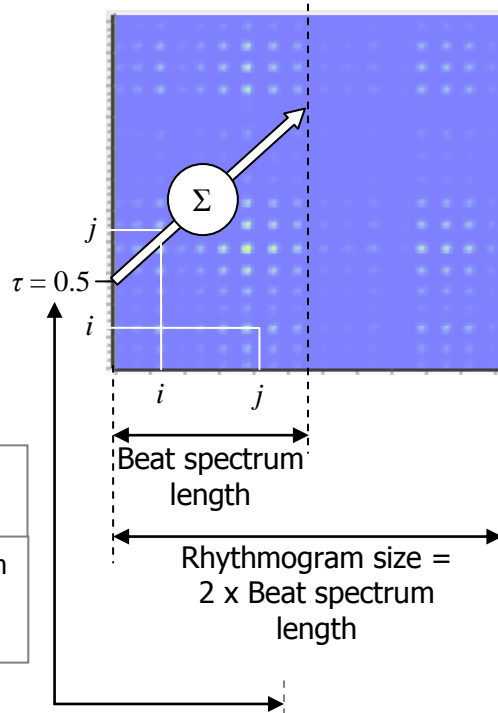
Analysis of beat spectrum peaks and checking the conditions

Conditions to be satisfied to classify the event as having periodic structure with desired frequency (SWD):

$$M \geq M_{\min}$$

$$\bar{h} \geq H_{\min}$$

where

M is the number of consecutive peaks, starting from the first peak, for which the following condition is satisfied:

$$T_{\min} \leq T_i \leq T_{\max} , \; i=1,2,...,M$$

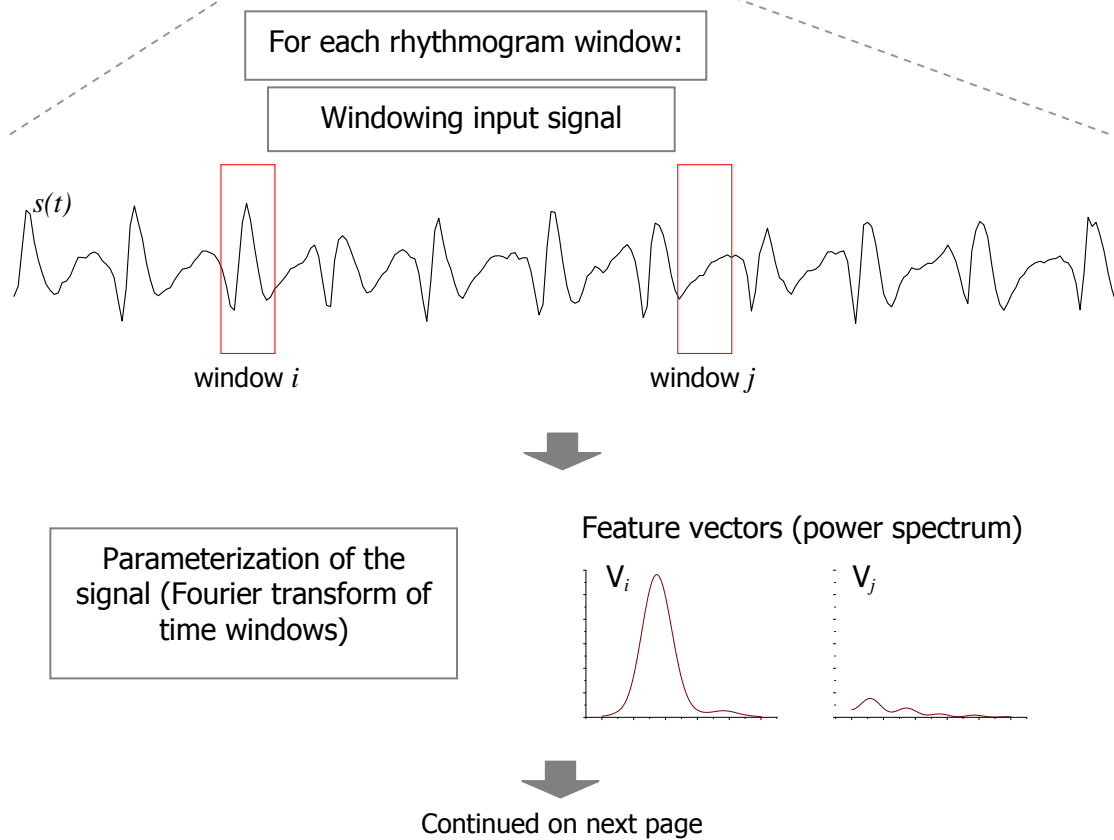where T_i is the distance between peaks, $T_{\min}=1/f_{\max}$, $T_{\max} = 1/f_{\min}$

$\left[f_{\min} ; f_{\max} \right]$ is user-defined SWD main frequency range;

$M_{\min}$ is user-defined parameter (Min. Number of Beat Spectrum Peaks for SWD);

$$\bar{h} = \frac{1}{K} \sum_{k=1,K} h_k$$, where h_k is the relative amplitude of k-th peak;

K is user-defined parameter (Number of Beat Spectrum First Peaks for Relative Amplitude Average);

$H_{\min}$ is user-defined parameter (Beat Spectrum First Peaks for Relative Amplitude Average Threshold).
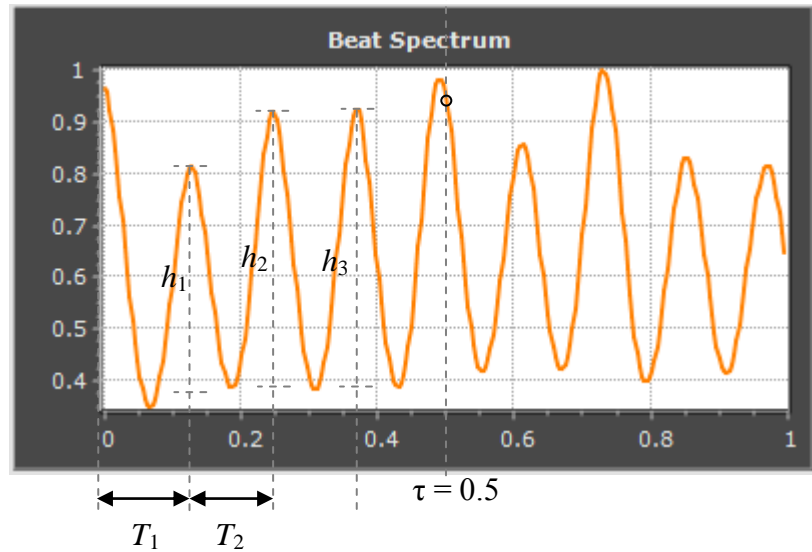
The beat spectrum is then normalized so that the maximum is always one:

$$B_k^N = B_k / B_{\max} ,$$

where $B_{\max} = \max(|B_k|)$, $k = 1,...,N_B$.

6.8.1.2.3. Analysing the beat spectrum of the current rhythmogram window to reveal periodicity.

The x-axis of the beat spectrum is time lag. If the beat spectrum has a peak at a time lag τ, this means that there is a repetitive pattern in the signal that repeats every τ sec. Accordingly, there will be also 'harmonics' - peaks at 2τ, 3τ, etc. For example, the beat spectrum shown in Fig. 6.11, 2 has 8 peaks at ~0.125, 0.25, 0.375, 0.495, 0.61, 0.725, 0.85, 0.975 s, which means that the signal has clear repetitive pattern repeating every ~0.125 s, i.e., with frequency ~8 Hz, which corresponds to main frequency of SWD in WAG/Rij rats (the example is taken from a WAG/Rij rat).

To decide whether the signal contains SWD (or other periodic event of interest) we have to find out

   a) whether the beat spectrum has sufficient number of consecutive peaks at time lags corresponding to SWD main frequency and its multiples, and

   b) whether these peaks are well expressed.

The SWD main frequency is provided by the user, in the form of acceptable frequency range $[f_{\min}; f_{\max}]$ ("SWD Main Frequency Range" fields in the "SWD Identification Parameters" group of controls on the Advanced/SWD Identification sub-tab of the Parameters tab, see The SWD Identification Parameters). This range usually is determined by and depends on the animal model. The minimal number of beat spectrum peaks to classify as SWD is also provided by the user ("Min. Number of Beat Spectrum Peaks for SWD" field in the "SWD Identification Parameters" group of controls on the Advanced/SWD Identification sub-tab of the Parameters tab, see The SWD Identification Parameters).

Thus, the first condition to be satisfied to count the event as SWD is:

$$M \geq M_{\min} ,$$

where M is the number of consecutive peaks, starting from the first peak, for which the following condition is satisfied:

$$T_{\min} \leq T_i \leq T_{\max} , \quad i=1,2,...,M,$$

where T_i is the distance between peaks, $T_{\min}=1/f_{\max}$, $T_{\max} = 1/f_{\min}$,

$[f_{\min}; f_{\max}]$ is user-defined SWD main frequency range;

$M_{\min}$ is user-defined minimal number of beat spectrum peaks to classify as SWD.

Whether the peaks of the beat spectrum are well expressed or not is judged by the average relative amplitude of the first few peaks of the normalized beat spectrum. The condition is:

$$\bar{h} \geq H_{\min} ,$$

where $\bar{h}$ is the average relative amplitude of the first K peaks:

$$\bar{h} = \frac{1}{K} \sum_{k=1,K} h_k ,$$ where h_k is the relative amplitude of k-th peak;

$H_{\min}$ is user-defined threshold - a value between 0 and 1.

Parameters K and $H_{\min}$ are provided by the user ("Number of Beat Spectrum First Peaks for Relative Amplitude Average" and " Beat Spectrum First Peaks for Relative Amplitude Average Threshold" fields in the "SWD Identification Parameters" group of controls on the Advanced/SWD Identification sub-tab of the Parameters tab, see The SWD Identification Parameters).

There may be two additional optional conditions for the beat spectrum to be satisfied to count the event as SWD:

1) the very first peak of the beat spectrum (the first value of the beat spectrum) is the beat spectrum's maximum; this condition is checked if the "First Must Be Max" checkbox in the "SWD Identification Parameters" group of controls on the Advanced/SWD Identification sub-tab of the Parameters tab is checked;

2) the amplitudes of the first $M_{\min}$ peaks of the beat spectrum decrease (i.e., the second peak is smaller than the first, the third is smaller than second, etc.); this condition is checked if the "Peaks Must Decay" checkbox in the "SWD Identification Parameters" group of controls on the Advanced/SWD Identification sub-tab of the Parameters tab is checked.

6.8.1.3. Checking the SWD amplitudes based on Line length.

The SWD Identification is based on calculation of the beat spectrum, which reveals the presence of repetitive patterns in the signal. However, due to the necessary normalization of the beat spectrum, it will highlight also those repetitive fragments of the signal that have low magnitude, if they satisfy other criteria (particularly, the frequency of the repetition). Similarly, it will give positive result also for very large magnitude events caused mostly by artifacts, if they accidentally satisfy the repetition frequency criteria.

To eliminate such low and high magnitude events, an additional check may be performed in the program, that estimates the magnitudes of the repeating fragments in the signal and compares them to predefined thresholds.

This procedure is performed if the 'Check Amplitudes Using Linelength' checkbox in the 'Amplitude Check Parameters' group on the "Parameters/Advanced/SWD Identification" sub-tab is checked. It is applied only to those events that pass other SWD identification criteria (based on running beat spectrum).

The procedure consists of the following steps (the 'event signal' is the fragment of the EEG of the current channel from event's start time to event's end time).

1. Calculation of the Line length (LL) curve of the event signal (Fig. 6.12).

   A window of size M samples (defined by the parameter "LineLength Window Size" in the "Amplitude Check Parameters" group on the "Parameters/Advanced/SWD Identification" sub-tab) is moving along the event signal with step equal to one sample, and for each window position i the line length is calculated as

   $$LL_i = \sum_{j=0}^{M-2} \left| s_{i+j+1} - s_{i+j} \right|,$$ where s_j is the jth signal value, $j=0..N-1$, N is the number of windows.

Fig. 6.12. Event signal (filtered and detrended, orange curve) and its line length (blue curve).

2. Finding all local maxima of the LL curve (i.e., the peaks of the LL curve and their amplitudes, Fig. 6.12).

3. From these, selecting those peaks that satisfy the following conditions:

   1) The LL peak amplitude must be greater than the low LL threshold and less than the high LL threshold. The low and high LL threshold values must be defined before the SWD Identification procedure either automatically or manually (see 6.8.1.4. Automatic definition of Line length (LL) thresholds and 6.8.1.5 Manual definition or adjustment of Line length thresholds).

2) The distances between adjacent LL peaks must be within the limits defined by the "SWD Main Frequency Range" ("Min" and "Max") in the "SWD Identification Parameters" group on the "Parameters/Advanced/SWD Identification" sub-tab. For example, if *SWD Main Frequency Range Min* = 5Hz and *SWD Main Frequency Range Max* = 10Hz then the distance between adjacent peaks must be within 0.1 s (1/10) and 0.2 s (1/5).

4. If the number of LL peaks that passed the conditions 1) and 2) is greater than or equal to the "Min. Number of Beat Spectrum Peaks for SWD" parameter specified in the "SWD Identification Parameters" group on the "Parameters/Advanced/SWD Identification" sub-tab, then the event passes the amplitude check.

6.8.1.4. Automatic definition of Line length (LL) thresholds

The automatic definition of line length thresholds (low and high thresholds) is performed when the user presses the "Define LL Thresholds" button on the on the "Parameters/Advanced/Linelength Definitions" sub-tab. Note that this procedure must be performed *after* the selection of events into the Preliminary event list (this list is formed when pressing the "Select Events" button on the "SBI & Channels" tab).

Automatic definition of LL thresholds is based on the histogram of distribution of amplitudes of all local maxima, or peaks, of LL curves of all events selected into the preliminary event list.

The LL peak amplitudes distribution histogram is built as follows.

For each event from the Preliminary event list, the following steps are performed.

1. Pre-processing of the event signal.

    - If the "Apply Notch, High Pass, Low Pass filters if checked in the Main Parameters" checkbox in the "Amplitude Check Parameters" group on the "Parameters/ Advanced/SWD Identification" sub-tab is checked, then the event signal is filtered according to the filters selection and parameters on the "Parameters/Advanced/Main" sub-tab.

    - The event signal is detrended according to the detrending parameters on the "Parameters/Advanced/Main" sub-tab.

2. Calculation of the Line length curve of the event signal.

    A window of size M samples (defined by the parameter "LineLength Window Size" in the "Amplitude Check Parameters" group on the "Parameters/Advanced/SWD Identification" sub-tab) is moving along the event signal with step equal to one sample, and for each window position i the line length is calculated as

$$LL_i = \sum_{j=0}^{M-2} \left| s_{i+j+1} - s_{i+j} \right|,$$ where s_j is the jth signal value, $j=0..N-1$, N is the number of windows.
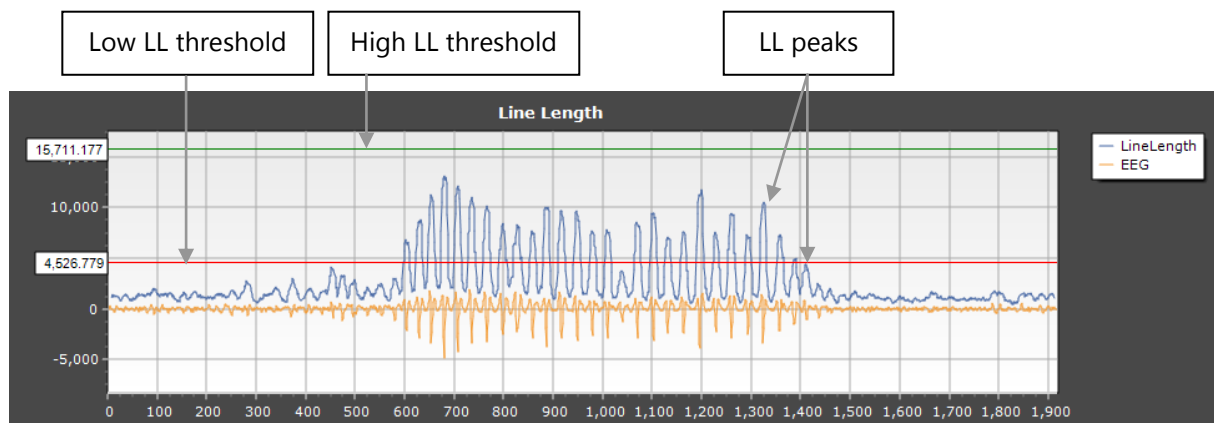
3. Finding all local maxima of the LL curve (i.e., the peaks of the LL curve and their amplitudes). From these, selecting sequences of consecutive peaks such that the distances between adjacent peaks in the sequence are within the limits defined by the "SWD Main Frequency Range" ("Min" and "Max") in the "SWD Identification Parameters" group on the "Parameters/Advanced/SWD Identification" sub-tab. For example, if *SWD Main Frequency Range Min* = 5Hz and *SWD Main Frequency Range Max* = 10Hz then the distance between adjacent peaks must be within 0.1 s (1/10) and 0.2 s (1/5).

The amplitudes of LL peaks from these sequences are stored to be used later to build the LL peak amplitudes distribution histogram.

After finding the LL peaks (satisfying the peak distances condition) for all events in the Preliminary event list, the distribution histogram of amplitudes of these peaks is built. The histogram parameters (range and bin width) are defined automatically based on the inter-quartile range.

The histogram is plotted on the "LL Peaks Histogram" plot on the "Parameters/ Advanced/Linelength Definitions" sub-tab (Fig. 6.13).
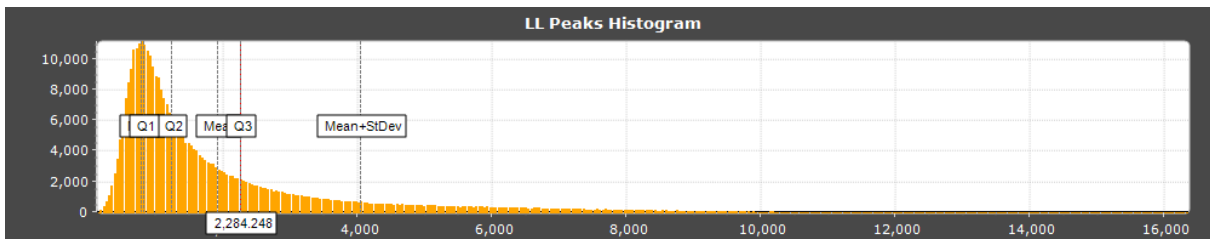

Fig. 6.13. Distribution histogram of amplitudes of all LL peaks.

The LL peak amplitudes distribution histogram helps to define the thresholds that will be used to discard the peaks with too high amplitudes (mostly caused by strong artifacts) - the 'High' LL threshold, and the peaks with too low amplitudes (caused by weak or irrelevant events) - the 'Low' LL threshold.

The definition of the High LL threshold is based on the assumption that there is an "amplitude gap" between the LL peaks corresponding to SWDs and LL peaks corresponding to strong artifacts. The amplitudes of LL peaks corresponding to SWDs must be relatively close, and fall into close histogram bins, thus they will form the dense part of the histogram. The amplitudes of LL peaks caused by strong artifacts are much larger than those of the SWDs, and more dispersed, so they will form the scarce 'tail' of the histogram. The algorithm defines and finds the right edge of the dense part of the

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histogram such that all the peak amplitudes corresponding to the SWDs are most likely to the left of this edge. This is done in the following way (Fig. 6.14).

Let N be the number of bins of the histogram, h_i be the value of the i-th bin. We find the maximum of the histogram and corresponding bin i_{max}. Then, starting from the maximal bin, we move to the right and try to find where the histogram goes down to almost zero. For this, starting from i_{max} we calculate the sum of K consecutive bins:

$$S_j = \sum_{k=i_{max}+j}^{i_{max}+j+K} h_k , \quad j = 0,1,2,...$$

and check condition $S_j < A$, where A is a parameter. As soon as this condition is satisfied, the corresponding $j + K$ bin's x-value is taken as the threshold (the x-values of the histogram are the LL peak amplitudes).

The values for parameters used are $K = N/20, A = K/2$. This means that the sum of bins must be not greater than the half of the number of bins, i.e., at least half of the bins must be empty.

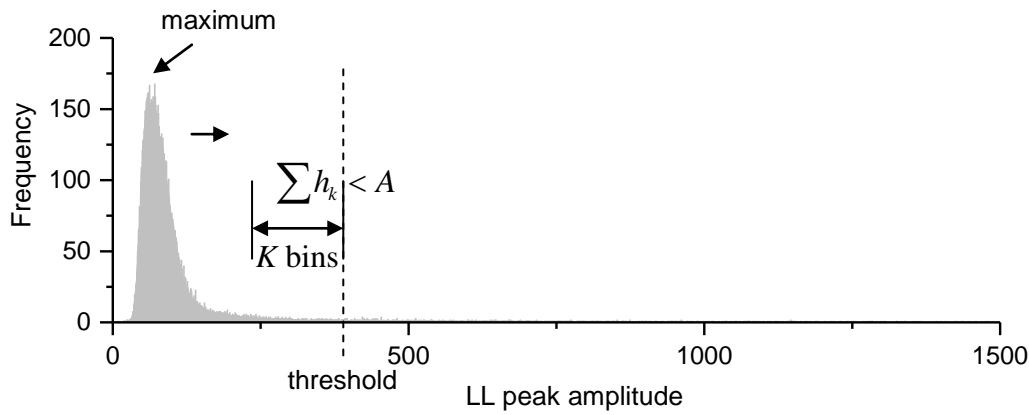Fig. 6.13. An example of LL peak amplitudes histogram and automatically defined High LL threshold. A, K – parameters, h_k – value of kth bin.

The Low LL threshold is taken as the second quartile (Q2) of the LL peak amplitudes. This is not always the best choice though (depends on the particular data), so it is recommended to check and adjust the Low LL Threshold manually.

The values of high and low LL thresholds are displayed in the "LL Thresh. Low" and "LL Thresh. High" fields, correspondingly, on the "Parameters/Advanced/Linelength Definitions" sub-tab.

6.8.1.5 Manual definition or adjustment of Line length thresholds

The Low and High LL thresholds may be defined or adjusted (after the automatic definition) manually by

1) directly entering their values into the "LL Thresh. Low" and "LL Thresh. High" editable fields on the "Parameters/Advanced/Linelength Definitions" sub-tab;

2) by dragging the vertical threshold lines by mouse on the "LL Peaks Histogram" plot on the "Parameters/Advanced/Linelength Definitions" sub-tab; the red vertical line is the Low LL threshold, the green vertical line is the High LL threshold;

3) by dragging the horizontal threshold lines by mouse on the "Line Length" plot on the "Parameters/Advanced/Linelength Definitions" sub-tab; the red horizontal line is the Low LL threshold, the green horizontal line is the High LL threshold.

The vertical thresholds on the "LL Peaks Histogram" plot and the horizontal thresholds on the "Line Length" plot are coupled: when the user moves one of them, the other is moved as well to the corresponding position. When the user moves the low or high threshold line on either plot, the corresponding threshold value is immediately updated in the "LL Thresh. Low" and "LL Thresh. High" fields.

6.8.2. Automatic identification of large instrumental artefacts

Note: This step is optional and should be used with care as still there is a little risk that some seizures may be removed as well, especially if they are contaminated with artefact.

In the current version of the program a relatively simple algorithm is implemented that identifies and removes a limited subclass of instrumental artefacts, such as those caused by disconnected cable, which are reflected on the EEG in the form of abrupt up and down deflections spanning almost the entire amplitude range.

The artefact removal procedure works as follows.

For each selected event e_i ($i = 1, \ldots, N$, where N is the number of events selected by the threshold-based event selector), with start time t_i^s and end time t_i^e, a small time window (250 ms) runs from t_i^s to t_i^e with step equal to the half of the window (125 ms), and for each window the derivative of the signal is calculated as absolute differences between consecutive signal values: $d_j = \left| s_j - s_{j-1} \right|$ (j=2, ..., M, M is the number of signal samples in

the window, s_j is the signal value at j). If any of d_j is greater than $p(A_{max} - A_{min})$, where A_{max} and A_{min} are the maximal and minimal possible values of the signal, correspondingly, and p is a parameter ($0<p<1$) provided by the user ("Derivative Cut-off level" on the Advanced/Instrumental Artefacts sub-tab of the Parameters tab, see 1.6.2.3. The Instrumental Artefacts tab), the window is marked as possibly containing an artefact. In all windows for the event e_i that were marked as containing artefact the signal is then replaced by a straight line connecting the first and the last samples of the window. Then, for the entire event e_i with replaced "artefactual" fragments, the SBI curve is calculated again. If the new SBI curve does not exceed the threshold anymore (i.e., there is no epileptiform activity and the high SBI values were produced by an artefact), the entire event e_i is considered as an artefact and removed from the list of selected events. If, however, the new SBI curve still has some suprathreshold values, this means that the signal possibly contains epileptiform activity and the event e_i is not removed from the list (to ensure that we do not accidentally remove a seizure).