

SEISMOWIN  
module  
SEISMOLOG-MT

USER'S MANUAL

(4 / 2012)

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*Note: Some features of the software may  
have been changed in the latest versions;  
the basic functions described in this manual are still valid.*

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**Warning!**

**This software is provided for business and research purposes. It must be used in a computer system in conjunction with suitable electronic devices, by qualified personnel in compliance with applicable laws regarding construction, civil engineering, mechanics and electronics.**

**The use of the software in order to determine structural parameters of buildings and/or evaluate risk levels and mechanical properties of the soils is reserved to qualified and specialized personnel such as doctors in engineering, architecture and physics who have attended specialization courses in geophysics and structural analysis.**

**The developer of SEISMOLOG-MT (SEISMOWIN package) assumes no responsibility for any loss, injury or damage of any kind when the software is used in a context of vital importance or without the technical expertise needed to validate the obtained data.**

## **Introduction**

The program SEISMOLOG-MT is a PC-based recording program (datalogger) dedicated to the microtremor recording. A microtremor recording session can be performed either on the ground or on structures. In order to provide the highest degree of reliability SEISMOLOG-MT allows to monitor in real-time the current measure. However SEISMOLOG-MT performs no processing on the recorded signal; this stage is left to another module of the SEISMOWIN series, SEISMOSURVEY, and/or to other software available on the market such as GEOPSY, created as a result of the work of the SESAME protocol.

SEISMOLOG-MT allows to view and deeply analyze in real time the acquired signal, allowing the user (geologist, engineer, etc..) to optimize the measure and giving him the awareness of its correctness.

SEISMOLOG-MT allows to evaluate the presence of polarized noise in HVSR surveys looking in real time at the *particle motion* of the horizontal sensors signal.

The real time FFT function with instrumental correction shows the spectrum of the signal both in acceleration and velocity with an estimate of the absolute signal amplitudes at different frequencies. When evaluating the seismic background noise of the site (feature required especially by seismologists) the program enables to return the signal in the frequency domain according to the evaluation model of Peterson.

The program allows to analyze the signal spectrum also in octave bands and one-third octave bands. Moreover, the values of each band can be weighted based on configurable filters, in order to obtain a single value comparable with the limit values indicated by the Italian code UNI 9614, regarding to the evaluation of the noise produced by vibrations.

The ability to examine the details of the waveform in real time in the time series also let the user immediately know whether the sensors working and their placement are good.

Above all, it is possible to calculate in real time the HV ratio, with the ability to dynamically change the windows selection parameters and to include or exclude each collected window from the calculation.

An easy manual and automated records management allows the user to record individual and/or multiple acquisitions synchronized with UTC time (through the use of devices equipped with a GPS receiver).

## **System requirements**

SEISMOLOG-MT must be used in combination with an A/D digitizer with at least 3 channels and compatible with the SADCxx protocol.

The SADC10, SADC20 and SADC30 boards, manufactured by *SARA electronic instruments srl* ([www.sara.pg.it](http://www.sara.pg.it)) allow the best performance, since SEISMOLOG-MT has been developed specifically to use such cards.

The program requires the use of a Pentium class processor. It does not need much ram memory and the hard disk memory footprint depends on how much data you want to record.

The program is compatible with all the most popular Windows systems (2000/XP/Vista/7).

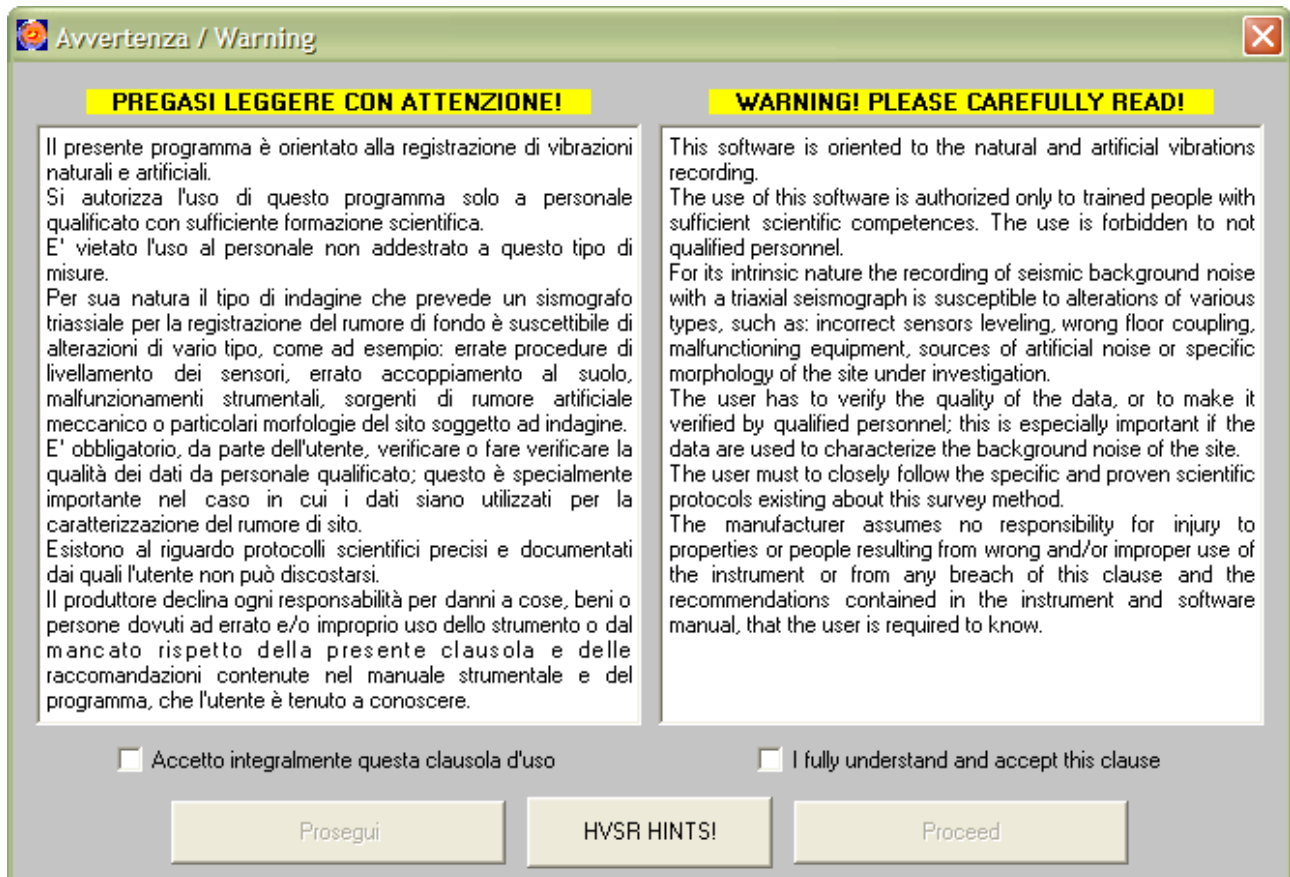
### **Installation and update**

SEISMOLOG-MT is automatically installed by the SEISMOWIN setup program, which is located inside the USB key supplied with the instrumentation and can also be downloaded from the site [www.sara.pg.it](http://www.sara.pg.it), at the section PRODUCTS → SOFTWARE → SEISMOWIN.

The update must be done through SEISMOWIN, the management program of our seismology software suite. To do this, your computer must be connected to the Internet; for more information please see the user's manual of SEISMOWIN.

## Program start

When the program starts is always shown a window like the one in the following picture.



The aim of this warning is to remind the user the responsibility to verify the accuracy of the recorded data.

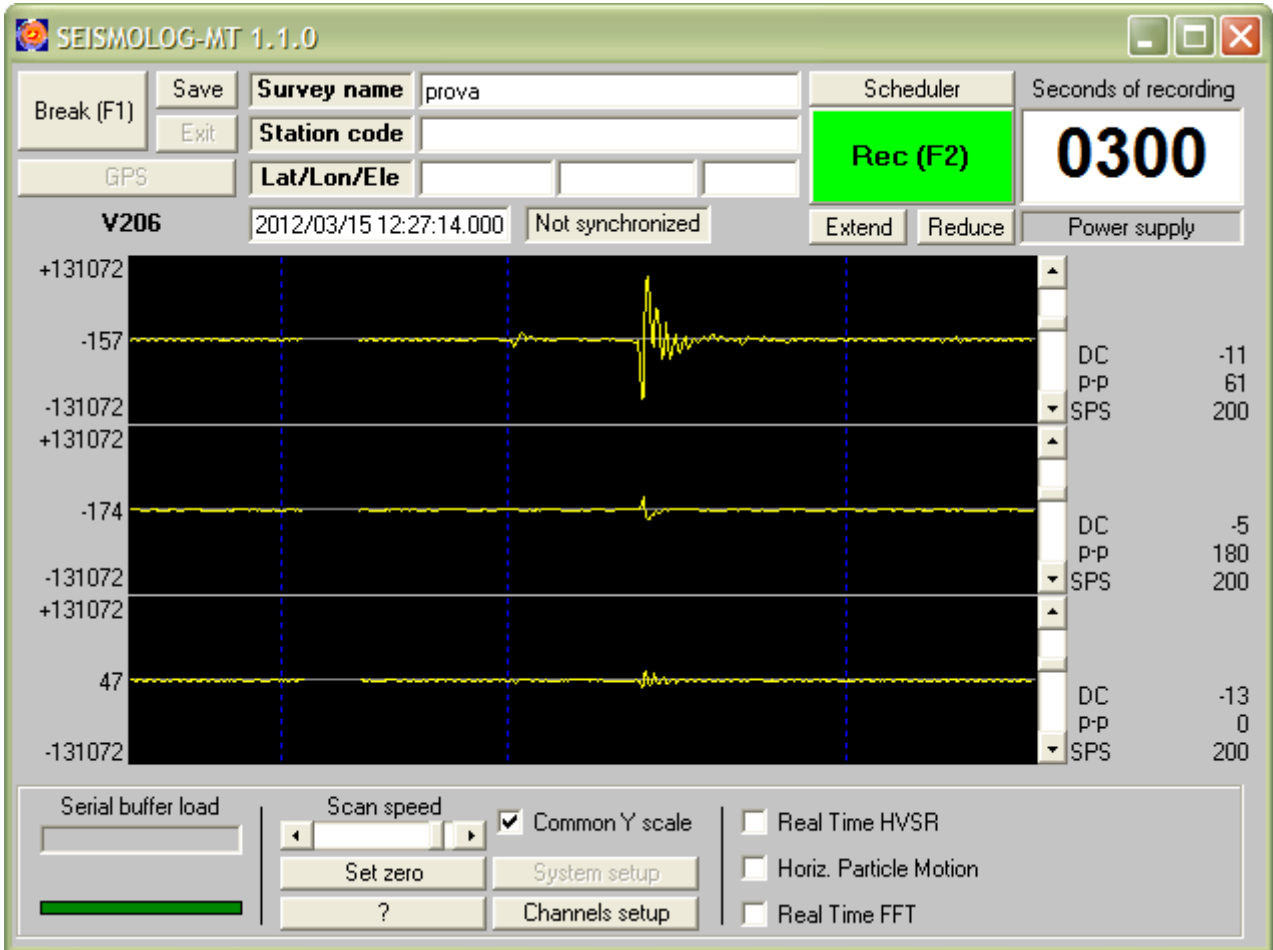
It is required to tick the accepting check box and click on the PROCEED button to continue loading the program.

The HVSr HINTS! button shows an additional window that groups the actions to be done and those to be avoided to perform a good record.

This window is also available at a later time using the WARNINGS button in the *Credits* window, which will be mentioned in the following section.

**Main window**

This section explains the main control panel of the program, which is shown in the following picture. The screenshot is related to a 24-bit digitizer, with the 2.0.6 firmware version.



### RUN/BREAK

This button starts and stops the acquisition of the seismic signals.

Acting on RUN the communicating process with the instrument begins and the program starts displaying the signal in the time series, but no signal is currently recorded.

Acting on BREAK the acquisition is stopped; it is not allowed to use this button when there is a recording in progress.

The keyboard shortcut for this button is *F1*.

### SAVE

Saves the current system configuration. Any change to the program settings will be lost at the exit if not saved through this button.

This button DOES NOT save the data currently being recorded, which are automatically saved in the way later described in this manual.

### GPS

This button allows to obtain the current position from the GPS board. To do this, the PC must be connected through the serial port specified in the configuration to a device that outputs GPS data in the standard NMEA format. In the instruments of the SRxx series equipped with a GPS you can usually get this information connecting to the instrument lower serial port. When the device is synchronized with the GPS network, a few seconds after pressing the button the geographical coordinates will be displayed in the LAT and LON fields, next to the button. To stop this phase and bring back the program in standby state, use the BREAK button.

### SURVEY NAME

This field should be filled at every acquisition. It will allow to distinguish the various working sessions, saving the recorded files in a new folder named with the indicated name. If this field contains characters not allowed for file names by the Windows operating system (e.g. “:” or “?”) it will be shown an error message when you attempt to start a recording.

The main folder where files are saved is [program installation folder]\files, usually “C:\SEISMOWIN\SEISMOLOG-MT\files”, and it cannot be changed. If the SURVEY NAME field is left blank, the files are saved in the main folder; if it contains a valid name, a subfolder with that name is created inside the main folder and files are saved in that subfolder. The produced files are automatically saved at the end of the recording without taking any action.

### STATION CODE

This field is used to indicate the code of the seismic station, assigned either arbitrarily or by a standardization authority (e.g. FDSN). The indicated value is stored in the recorded files in the appropriate field, depending on the file format chosen in the setup window (e.g. in the STA\_CODE field in SAF format files).

A useful value to put in this field could be the serial number of the instrument, in the format "0000" (e.g. “0400” for the instrument with serial number 400). In this way, when the recorded file will be opened with the program SEISMOSURVEY, the response file corresponding to each channel will be automatically loaded, if it is in the global folder which is supposed to contain the response files (that is [SEISMOWIN root folder]\NETWORK\RESPFILES, usually “C:\SEISMOWIN\NETWORK\RESPFILES”) and its name meets a specific format (the names of the response files supplied with our instruments are already in the proper format).



#### LAT/LON/ELE

These data, related to the geographic coordinates, are used to mark the location of the survey within the parameters of the recorded files. The values can be entered in any format; if the data were obtained from the instrument embedded GPS board, through the GPS button, they are given in decimal degrees format.

#### DATE, TIME and SYNCHRONISM LABEL

The field that contains the indication of the date and time is self-explanatory. However note that these date and time are related to the time stamping of the data coming from the digitizer and they may therefore be different than the PC time.

The synchronism label shows instead whether the displayed time and date are synchronized or not to the UTC time. When it says “*Not synchronized*” the time may not be reliable.

#### SCHEDULER

This button shows the window to schedule automatic recordings.

#### REC/STOP

This button allows to manually start and stop the recording. The recording stops either automatically, after the number of seconds set in the SECONDS OF RECORDING field, or manually, using the STOP button.

The recorded files are automatically saved right after the recording stops, in the way specified in the paragraph on the SURVEY NAME field. During the recording the data coming from the instrument are added to the file every second, so that even in case of malfunctions the recorded signal up to that moment is usable.

When the recording stops it may happen that some warning or error messages are shown.

A message like: “*Warning: record length (x seconds) different from the set one (y seconds)*” means that the recorded file is x seconds long, while the recording time, set in the SECONDS OF RECORDING field, is y seconds. This is normal when the recording is interrupted by hand and in this case the length x of the recorded file will be an integer number. But when the recording is automatically completed at the end of the seconds countdown, the number shown is usually a decimal number: this indicates that there has been a loss of data during the recording. The file produced in this last case should not be used.

A message like “*Recording error: different lengths*” means instead that the three channel recordings inside the file have a different length. Also this message is symptomatic of a data loss and the recorded file should then be discarded.

The data loss problems that can generate these errors do not occur frequently: a common cause is the instrument connection to a native serial port of an older PC, not fast enough. In this case, connecting the instrument to an USB port via an USB-serial converter should solve the problem.

The keyboard shortcut for this button is *F2*.

#### EXIT

Closes the program. You can not exit the program when it is in acquisition mode, not even using the keyboard shortcut ALT+F4 or the standard X box at the top right corner of the window.

#### EXTEND

This button allows to extend the recording of 10 seconds, when it is already active.

## REDUCE

This button allows to manually reduce the recording length of 10 seconds; this happens only when the left time is more than 20 seconds. When the left time is between 10 and 20 seconds it is shortened by only 5 seconds, otherwise (the left time is less than 10 seconds) the button does no action.

## SECONDS OF RECORDING

This field is both an indicator and a setting field of the recording length, in seconds.

Before the recording starts it has to be used to set the recording length; during the recording it shows the time left, using a countdown.

## POWER SUPPLY

This field shows the current status of the internal battery of the instrument.

When it contains the words “*Power supply*” on a gray background it means that no information is available. This may happen when the program is in idle state and the acquisition is not active or because the instrument does not provide information about the status of the battery because it has no internal power supply.

If it contains the words “*Power OK*” on a green background it means that the battery is charged, even if you can not know the exact charge level.

When it contains the words “*POWER LOW*” on a red background it means that the battery is running low, but usually you can always successfully end the current recording.

## TIME SERIES CHARTS and SCROLL BARS

The three charts shown in the previous picture (with a signal example) show in real time the signal flow. Through these diagrams, the user can evaluate the correctness of the communication with the instrument and the signal quality.

By convention, the upper diagram shows the vertical component of the signal, the middle one the North-South component, and the lower one the East-West component.

The vertical scroll bars on the right of the charts amplify or reduce the graphical scale of the view.

## SCAN SPEED

This horizontal scroll bar controls the scanning speed of the signal in the time series.

## COMMON Y SCALE

This control, when selected, allows you to simultaneously change the graphical vertical scale of the charts in all the three channels, keeping them directly comparable.

## SET ZERO

This button attempts to automatically correct the channels offset, according to the current average of the sampled values. Further details are available under the A/D COUNT OFFSET item in the *Channels Setup* section.

?

Shows the credits and program authors window.

## SYSTEM SETUP

Shows the system setup window.

#### CHANNEL SETUP

Shows the channel setup window.

#### REAL TIME HVSR

This box shows the window of the real time calculation and display of the HV ratio of the acquired signal.

#### HORIZONTAL PARTICLE MOTION

This box shows the particle motion window, that displays the horizontal sensors movement on a 2D plane in order to detect the presence of polarized signals sources.

#### REAL TIME FFT

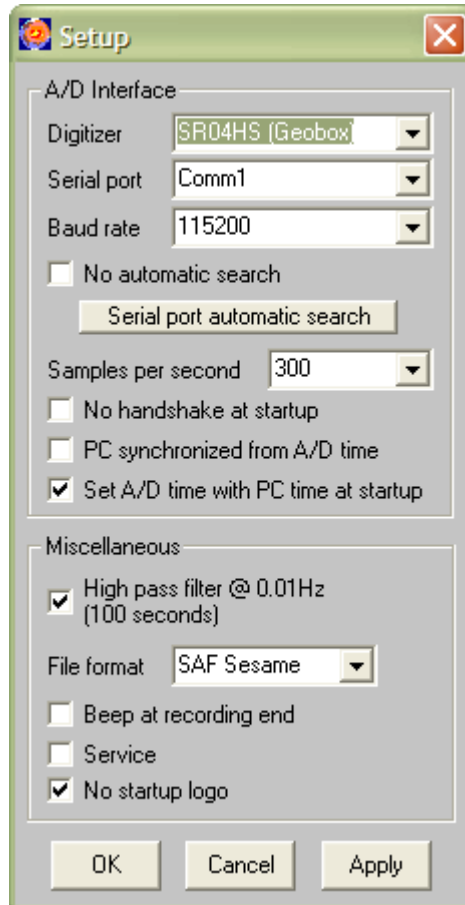
This box shows the real time display window of the acquired signal in the frequency domain, with many different display options.

### System setup window

This window shows some hardware and recording options.

The A/D INTERFACE section contains some controls that allow you to control different versions of the SADCxx series cards and to set the sampling frequency of the instrument.

The MISCELLANEOUS sections provides other settings that may be changed according to the user's preference.



## DIGITIZER

Select from this list the type of instrument that is currently connected to your PC, among SR04, SR04HS, SL06 and SL07; the program will use the proper communication protocol.

## SERIAL PORT

Allows you to select the number of the serial port which the instrument is connected to, from 1 to 16.

Modern laptops and netbooks almost never have a serial port, replaced by the de facto standard USB ports. There are in the market USB-RS232 converters that work very well. We recommend buying only good quality converters and of the USB 2.0 type, which ensures a more reliable data flow.

The operating system arbitrarily assigns a port number to the converter simulated serial port. When the number is within the range from 1 to 16, the program can automatically detect the port where the instrument is connected to, via its automatic search function. However, it could happen that the given number is greater than 16; in this case the number should be manually changed, using the converter device properties window accessible from the *Device Manager* (the standard Windows operating system panel used to manage external devices), setting it within the range 1-16. A standard way to access the *Device Manager* is to use the keyboard shortcut *WIN+R*, type *devmgmt.msc* in the window which opens and press the *Enter* key. When the number is greater than 16 not only the automatic search function will fail, but the entire program will not work.

### **Note: converters latency time**

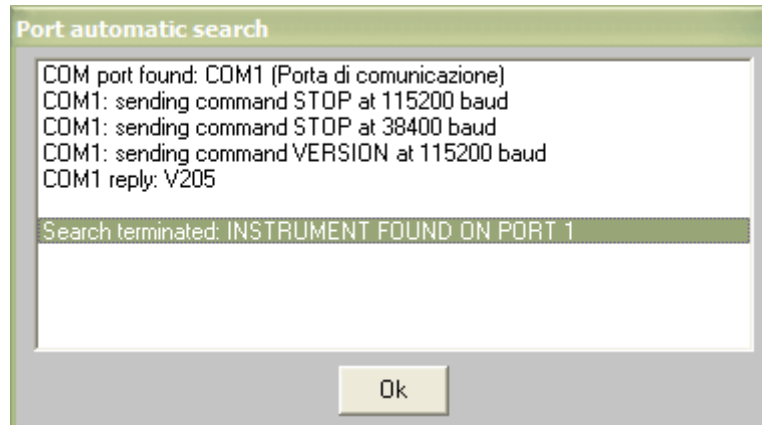
*When using SEISMOLOG-MT on a netbook (mini-laptop) with an high sampling frequency (SAMPLES PER SECOND parameter over 300), it may happen that the visualization of the acquired signal is not smoothly but jerky. This problem, which however does not affect the correctness of the recording, may depend on the settings of the USB-RS232 converter, especially on the latency time parameter. When using the converters usually supplied with our instruments, this parameter can be changed using the Device Manger, accessing the driver properties. Its default value is 16 msec; to avoid the jerky display it must be set to a value less than 10 msec.*

## BAUD RATE

Allows to change the digitizer baud rate. The SR04HS instrument (GeoBox) usually work at 115200 baud. This field allows to adjust the baud rate when using other equipments or communication systems.

## NO AUTOMATIC SEARCH

When you start the acquisition, using the RUN button in the main window, the program automatically looks for the serial port where the instrument is connected to. During the search a window like the following is shown; it closes by itself within a few seconds from the end of the search.



The automatic search procedure can be successful only if the instrument is properly connected to your PC. When the instrument is found, the number of the serial port where it is connected to is stored in the program settings. Because the port number assigned by the operating system to the USB-RS232 converter usually does not change, even if the PC is rebooted or the device is plugged into a different USB port, the subsequent searches after that one done at the first program start are needless. This option allows to disable the automatic search feature; you can always perform it manually using the SERIAL PORT AUTOMATIC SEARCH button.

## SAMPLES PER SECOND

Indicates the sampling rate, i.e. the frequency of the data acquisition. If the real time FFT is active, changing this parameter restarts the samples collection and deletes the last calculated FFT, if any.

**Important warning!** *It is very important to know some basic laws of signal processing in order to avoid recording anomalous signals. To sample a digital signal without affecting the waveform, the sampling frequency must be at least twice the frequency of the signal to be analyzed (Nyquist theorem). For example, if the sensor or the electronic board has a 5 Hz bandwidth, the sampling frequency must be at least 10 Hz (or SPS). In a practical way, it is recommended to sample at a frequency that is 5 times the concerned frequency (25 Hz in the example). Obviously it has to be also applied an electronic filter that prevents frequencies above half the sampling rate to reach the board. If this happens, the record would be affected by the so called ALIAS effect (i.e. aliasing) and the filter used to avoid it is called anti-aliasing filter. You can test the aliasing presence trying to increase the sampling rate and check whether the waveform changes: if this happens the displayed waveform is an "alias" and does not represent the real signal. To correct the problem it should be applied a better anti-aliasing filter or used an higher sampling frequency.*

#### NO HANDSHAKE AT STARTUP

Selecting this box tells SEISMOLOG-MT to not check the digitizer firmware and speed. It should usually NOT be used.

#### PC SYNCRONIZED FROM A/D TIME

This box indicates that the PC time has to be synchronized with the digitizer time, when the instrument locks on GPS.

#### SET A/D TIME WITH PC TIME AT STARTUP

This option indicates that the program must set the digitizer time according with the PC time when the acquisition starts. This feature is very useful when you do not use the GPS (e.g. in spot acquisitions without the need for synchronization with other instruments) and allows you to record reasonably accurately timestamped seismograms based on the PC clock.

#### HIGH PASS FILTER

This feature enables the application of an high-pass 1 pole Bessel filter with a corner frequency of 0.01 Hz on the acquired data. The data are processed by the filter before their display and recording. This type of filter is effective in the automatic removal of the signal offset without the need for additional settings. For more information about the signal offset and its removal please see the item A/D COUNT OFFSET in the *Channels Setup* section.

#### FILE FORMAT

You can choose among four different output formats for the recorded files:

PSN TEXT	ASCII standard format, supported by WinQuake
GSE2 CM6	CM6 compressed data in the common GSE 2.0 format
SAF SESAME	Widely used ASCII format supported by Geopsy
RAW ASCII	Simple ASCII format, with a short header and then the list of samples

#### **Note: What is CM6?**

*CM6 is a compression scheme which uses ASCII symbols to encode binary data. Although it may seem illogical, the algorithm can remove all the redundant data generated by environmental noise, especially for 24-bit samples. In 70-80% of cases, in fact, the seismic noise falls within a very narrow amplitude band, and not all available bits are used. The CM6 format is able to reduce the files size of about 2-4 times, deleting all the useless leading zeros present in the samples. The ASCII encoding allows to transfer the file through any media/modem/standard.*

#### BEEP AT RECORDING END

Enabling this option, the computer will beep to signal the end of the recording.

#### SERVICE

Service option that should be left disabled. The authors of the program may ask you to turn it on.

#### NO STARTUP LOGO

SEISMOLOG-MT displays the credits window as splash screen. Acting on this box you can disable its display for the subsequent starts.

**Channels Setup window**

This window contains the calibration parameters of the system.

**TRANSDUCER TYPE**

Type of the used transducer. There are three options:

- 1) Unknown.
- 2) Velocity (velocimeter); this transducer is generally of electrodynamic type and measures the instantaneous velocity where the sensor itself is put in place.
- 3) Acceleration, (accelerometer); this transducer measures in acceleration the shaking, or vibrations, of the place where it is installed.

The value specified here is basically used only to choose the measurement unit of some parameters in this and other program windows and it does not affect at all the signal recording.

**A/D COUNT OFFSET**

Digitizers (especially the high resolution ones) are very often affected by a small measurement error (which usually does not change the absolute measurement of the signal) called *offset*.

For example, a channel could have an offset of 10 or 100 counts. Assuming giving a sinusoidal periodic signal of 1000 counts of peak amplitude, we would expect to see a sinusoid which goes from +1000 to -1000; but with a positive offset of, for example, +132 counts, the signal will be between +1132 and -868 counts. The signal absolute amplitude is always +/-1000 but it is shifted of +132 counts. This error could be easily corrected applying the proper offset value. The offset is usually temperature sensitive, so it is better to set the offset after 10–15 minutes after the instrument switch on.



Some devices are affected by this error, some are not. It is not something to worry about because all the analysis software can easily remove this problem without affecting in any way the signal quality. However, if your instrument constantly returns values very far from zero, for example +45000 or -28000, you should have it checked by the manufacturer or its authorized service center, because it could also be a symptom of a more serious system fault.

The SET ZERO button, in the main window, set a proper offset on all channels based on the current signal measurement. Usually there is no need to apply any offset correction when the high pass filter is enabled. For more details, see the Setup section at the HIGH PASS FILTER item.

#### RESOLUTION

Use this field to indicate the transduction factor of the channel. When this factor is not known in advance, it can be calculated through the *Resolution calculator* window, which can be opened by the CALC button. The program uses this value in the *FFT* window, to perform the real time correction of the frequency domain visualization of the signal, only whether the correction by the transduction factor is enabled. There is no need to set this parameter to correctly record the signal. Please see the section about the *Resolution calculator* window for more details.

#### RESPONSE FILE

This field allows to specify the name of the file that contains the system frequency and phase response, in the SRE format (SEISMORESP system response file). This file describes the system response with its poles and zeros and a normalization factor. The file (or at least the poles and zeros) is usually supplied with the instrumentation. If you do not know these parameters ask for them to your dealer or send your unit to a calibration specialized center (the SARA electronic instruments srl can provide this service).

To compute the response of any system (different combinations of sensors/filters/digitizer or other manufacturers equipment) when the system parameters are known, you can use the software SEISMORESP, part of the SEISMOWIN package. The BROWSE button allows you to choose the response file using a standard “Open file” dialog box.

The response file is used in the *FFT* window to correct in real time the frequency domain visualization of the signal, when the velocity, acceleration or displacement correction is enabled. The *HV* window too uses the response files to correct the signal in real time, before the HV ratio calculation, when the correction option is enabled. There is no need to set this parameter to correctly record the signal.

#### OK, CANCEL, APPLY

OK saves the changes and closes the window, APPLY saves the changes without closing the window, CANCEL closes the window without saving the changes, if any.

### Resolution calculator window

In this window you can calculate the system transduction factor, from counts to the proper measurement unit, based on the characteristics of the used transducer and digitizer (m/s for a velocimeter,  $m/s^2$  for an accelerometer).

The A/D BIT RESOLUTION must be filled with the digitizer resolution, in bits. The A/D RANGE (P–P) field is instead the digitizer gain, in Volts. It can clarify saying that the A/D BIT RESOLUTION parameter tells how many elements are making up the signal range, while the A/D RANGE (P–P) parameter indicates how large is the “cake” to split. For example, an SR04 standard digitizer has a peak to peak range of 2V, and because it can split these 2V on  $2^{24}$  elements (having a resolution of 24 bits) each bit represents 0.000000119209 Volts (about 119 nV).

Finally, the TRANSDUCER SENSITIVITY field is usually provided by the manufacturer of the sensor and/or by the vendor. There are known sensor brands which have a standard sensitivity value (for example *Sercel L4C 5500 ohm coil*: 180V/m/s; *GS11D 380 ohm coil*: 27V/m/s; *L15B 320 ohm coil*: 25V/m/s) but every single sensor has its own exact value (below or above the standard value within a certain tolerance threshold) that should be accurately estimated through the calibration of the sensor itself.

The sensitivity of the sensors purchased from our company is shown in the certificate of calibration supplied with the instrument, in the *Generator Constant* field of each sensor.

In any case, the sensitivity should be given in the unit indicated on the side of the field (V/m/s for a velocimeter,  $V/m/s^2$  for an accelerometer).

Once entered these input values, click on the CALCULATE button to display the following output values:

- V/COUNTS: the Volts value of each digitizer count; the smaller the value the higher the resolution.
- COUNTS/V: is the inverse of V/COUNTS, the greater the value the greater the digitizer gain.
- DATA OUT: indicates how many m/s (or  $m/s^2$  in the case of an accelerometer) for Volts the system outputs. The higher this value the lower the global sensitivity of the system.
- FULL RANGE: is the saturation or clipping value of the system, that is the largest signal the system is able to deal with. The shown value is the peak value; the peak-to-peak value is obviously twice.
- RESOLUTION: is the transduction factor, the calculation end result. A usage example could

be as follows: assuming that the digitized value is 865 count, simply multiply this number by the transduction factor to know the value in the original measure unit (m/s or m/s<sup>2</sup>); given a RESOLUTION of 0.000000001987 m/s/count (1.987 nm/s/count) multiplying by 865 we have 1640.905 nm/s.

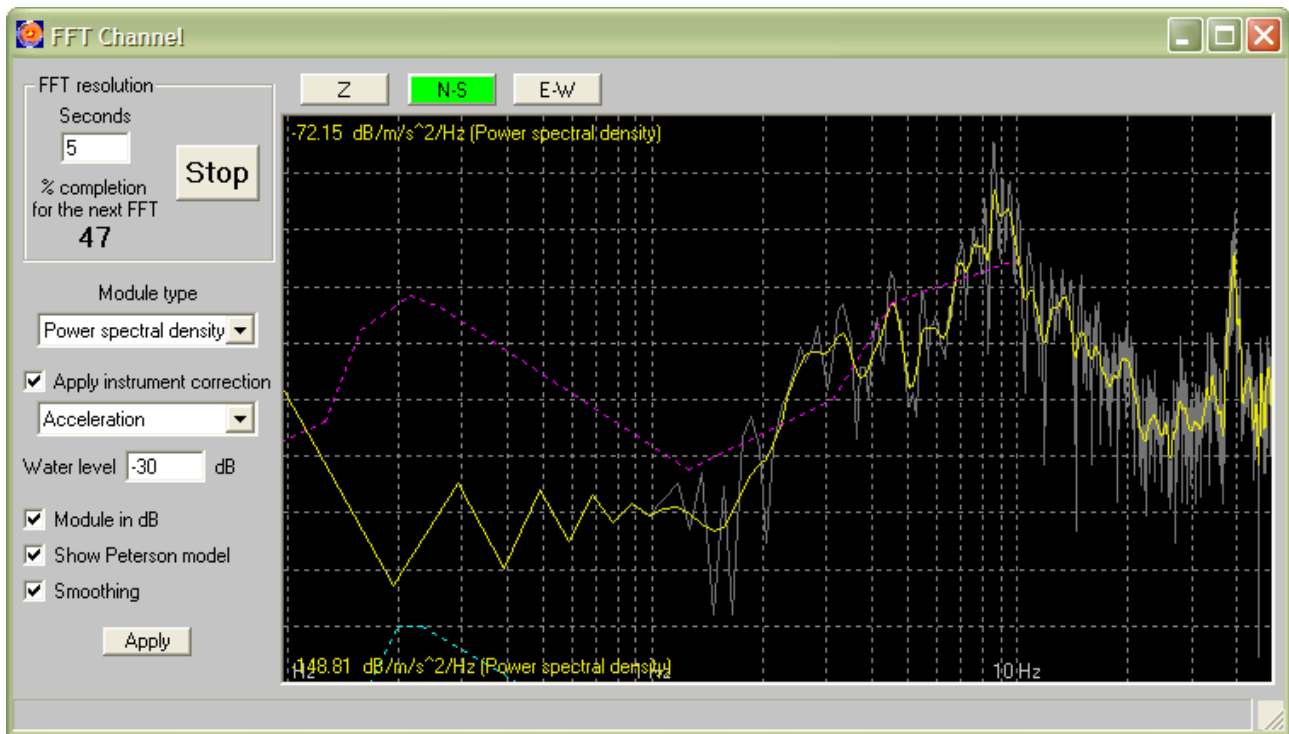
*Warning! The transduction factor is valid only within the frequencies region where the system has a "flat" response, the use of this value ignores the other areas of the response curve, which are instead taken into account when using the transfer function contained in the response files.*

The OK button fills the RESOLUTION field related to the channel from which the *Resolution calculator* window has been called, in the *Channel Setup* window, with the calculated RESOLUTION value.

## FFT window

The real time frequency analysis window can be opened clicking on the REAL TIME FFT box in the main window; it appears as shown below (some options related to the octave band analysis are missing; they are shown in the following section).

The shown FFT is relative to the channel whose button color is green, among the three buttons at the top of the window.



The picture shows the window in the PSD NOISE EVALUATION mode. In this mode the background noise is evaluated to determine whether a site is suitable to host a permanent seismographic station for earthquakes recording. The site is generally considered good when the noise curve falls within the two purple and blue curves. These curves, known as Peterson's curves, represent the model of the global noise level, indicating its upper and lower bounds (L and H or, according to Peterson, NLML and NLMH). This model is regularly updated by the USGS (U.S. Geological Survey) and is a standard reference to evaluate the background noise of a site.

It is also important to say that this type of measurement needs the power spectral density spectrum in acceleration, expressed in dB referred to 1 m/s<sup>2</sup>/Hz. When any of these visualization options is disabled, for example the acceleration correction is not enabled, the Peterson's curves will not be shown.

## FFT RESOLUTION

In this panel you can set the length, in second, of the window of samples on which the FFT is made. During the collection of the samples for the current window, the completion percentage is shown in real time. When it ends, the FFT is performed on the collected samples and is immediately shown, based on the current display settings. Any previous FFT is not stored and is no longer recoverable. Use the START/STOP button, which stops the next FFT samples collection, to preserve the last

calculated FFT. To store the FFT in an image file you can click with the right mouse button over the FFT display area.

#### MODULE TYPE

This field allows to choose the FFT spectrum display mode: amplitude, RMS amplitude, magnitude, power density SSA (sum squared amplitude) or power spectral density.

#### APPLY INSTRUMENT CORRECTION

This box enables the real time instrumental correction of the spectrum. You can choose to correct either by the transduction factor calculated in the *Channels Setup* window or the instrumental response, associated to the different channels through the same window, in an optional domain (velocity, acceleration, displacement). When the box is not selected, no correction is done.

Enabling the correction, the measure unit changes properly (for example, m/s when using the transduction factor and the sensor is a velocimeter or m when correcting in the displacement domain through the instrumental response). It should be noted that in the REPRESENTATION phase the measurement unit is adjusted to make the data more readable as possible: for example, for a maximum value of 0.000000054 m/s, the maximum value label in the upper left corner will give 54 nm/s.

#### WATER LEVEL

This value is only used when the instrumental response correction is enabled; it indicates the minimum threshold value beyond which the attenuation produced by the system (indicated by the instrumental response) is not taken in account. The purpose of the water level is to stabilize the correction at low frequencies.

For example, a seismograph with 4.5 Hz sensors softens the input signals at the frequencies below 4.5 Hz, up to over -100 dB for frequencies below 1 Hz. If the water level is set to -30 dB, it is assumed that at each frequency the system maximum attenuation is -30 dB, even for the lower frequencies where it is actually higher.

#### MODULE IN DB

This box enables the dB representation, relative to the current measure unit (m for the displacement correction, m/s for the velocity correction,  $m/s^2$  for the acceleration correction, Count when no correction is active).

#### SHOW PETERSON MODEL

This box enables the display of the Peterson's model, which was discussed in the introductory part of the paragraph. To be able to check this box, all the other parameters must be set as shown in the previous picture.

#### SMOOTHING

This option allows to “filter” the FFT curve to make it more readable. When the option is enabled the original spectrum curve will be gray and the smoothed curve yellow.

#### APPLY

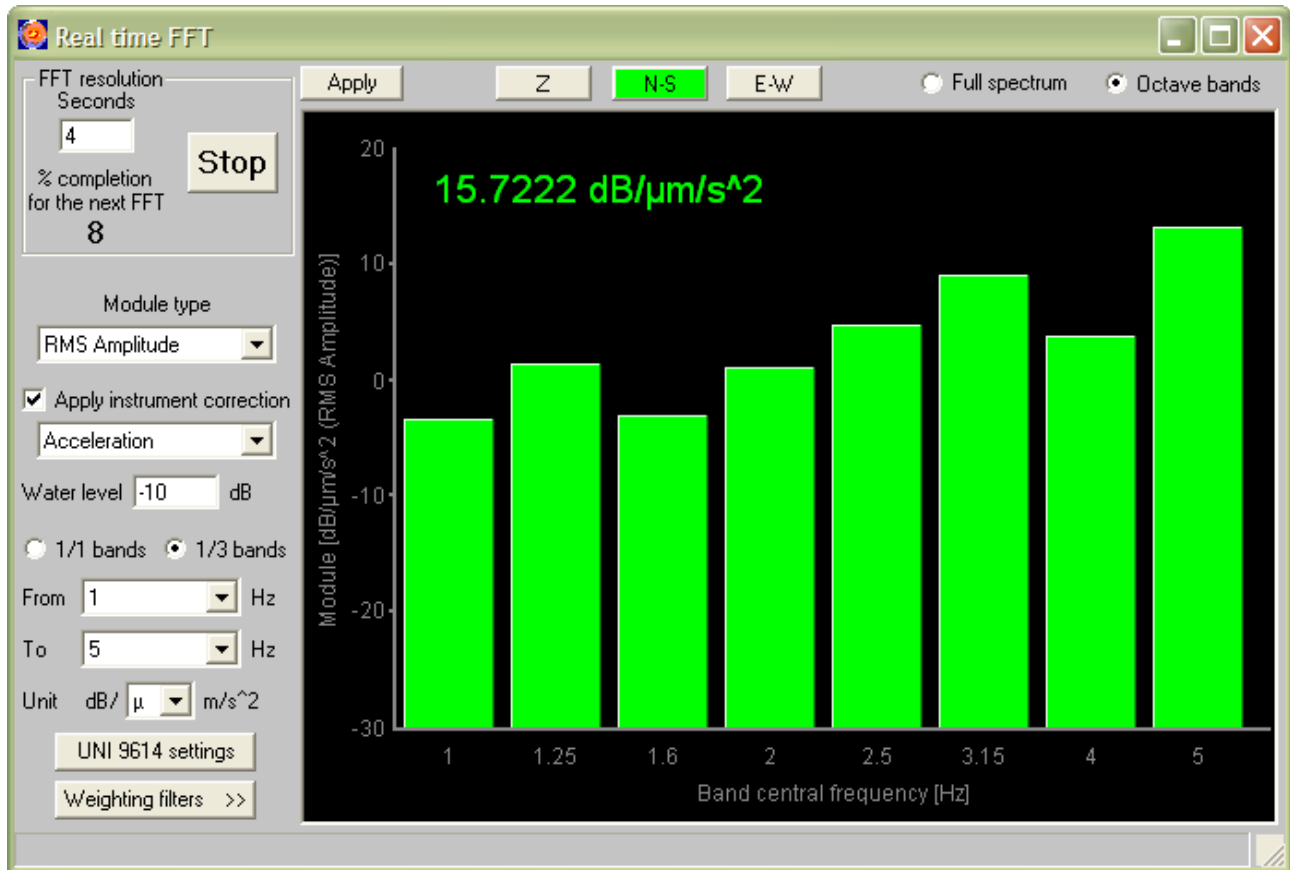
This button activates the current settings after checking their validity. It is always needed to use this button after any change in order to apply it, on the displayed FFT and all of the following. Changing the FFT length restarts the samples collection and delete the last shown FFT, if any.

Z, N-S, E-W

These buttons allow to display the FFT curve of the corresponding channel.

### Octave bands window

The octave bands analysis window is as shown below. It is actually the same window as described in the previous section, using the *Octave bands* display option instead of the *Full spectrum* option. The data collection and spectrum calculation modes are as described above, so only the fields and buttons not shown in the window when the *Full spectrum* option is enabled will be described.



### 1/1 and 1/3 OCTAVE BANDS

This option allows to choose how to split the octave bands, whole bands or 1/3 bands.

### FROM and TO

These fields allow to choose the first and the last band to display. The shown values are the nominal center frequencies of the bands from 0.75 to 315 Hz. Obviously the bands actually viewable also depend on the size of the FFT window (specified in the FFT RESOLUTION box), which constrains the minimum band, and on the sampling frequency, which constrains the maximum band.

### UNIT

The amplitude of each band is always calculated and shown in dB. The reference value is relative to the current measure unit, as for the spectrum display, but this field allows to choose the order of magnitude, from Mega ( $10^6$ ) to nano ( $10^{-9}$ ).

#### CHECKING OF COMPLIANCE WITH THE UNI 9614 CODE

The program is designed to calculate values directly comparable with the reference values expressed in the UNI 9614 Italian code.

The UNI 9614 SETTINGS button sets the calculation parameters in accordance with that regulation, that is:

- RMS amplitude
- Acceleration correction
- $\text{dB}/\mu\text{m}/\text{s}^2$  ( $\text{dB}/1 \text{ m}/\text{s}^2 * 10^{-6}$ )

You always need to press the APPLY button to apply the changes.

The WEIGHTING FILTERS button shows or hides a grid in which, for each band, you can insert a weighting filter, i.e. a dB value which will be subtracted from the actual value of the band in order to calculate the band weighted value; in this grid are usually inserted the filters specified in the UNI 9614.

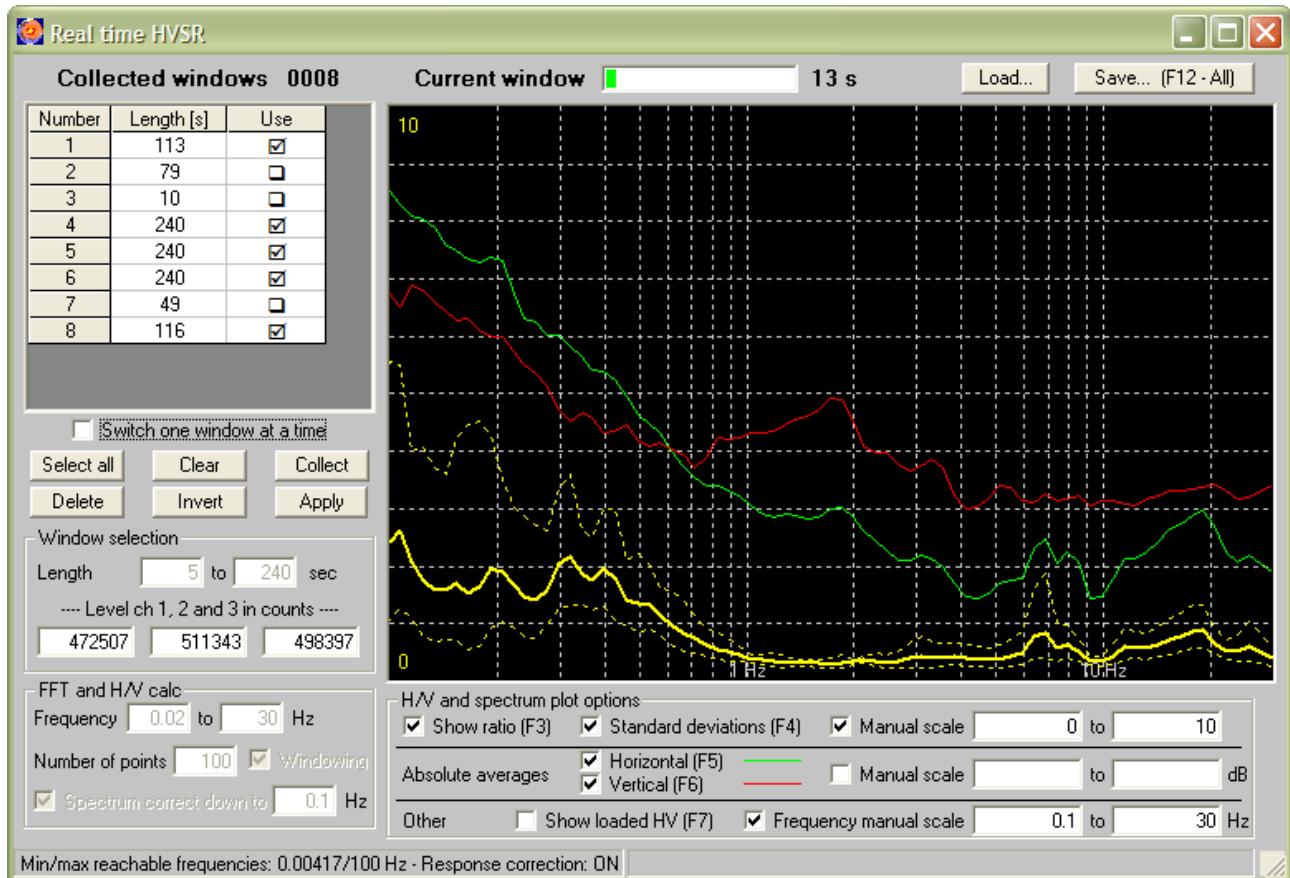
Finally, in the upper left corner of the graph is shown the final value resulting from the application of the weighting filters and the combination of all the weighted values, calculated as indicated by the regulation, and therefore directly comparable with the reference values that it specifies. It should be noted that this final value is always shown, even though the calculation parameters are not in accordance with the UNI 9614.



## HV window

The real time HV ratio window can be opened clicking on the REAL TIME HVSR box in the main window; it appears as shown below.

The software continuously collects data windows, calculates the HV ratio of each one of them, and shows the average of the calculated ratios. The calculation parameters can be changed only while the program is in idle state, that is the acquisition is not active. The real time HVSR feature can be used at any time during the acquisition and is completely disconnected from the data recording.



## COLLECTED WINDOWS GRID

This grid shows the list of the collected HV windows; for each window it shows the length (LENGTH column) in seconds and whether it is used in the calculation of the HV ratio (column USE) currently shown. Clicking on a grid row at the USE column, you can activate or deactivate the usage of the related window.

## CURRENT WINDOW BAR

This bar shows the length, in seconds, of the current data window. The red color means that the window is shorter than the minimum length set, the green color indicates that, on the contrary, the minimum length has been exceeded.

#### SWITCH ONE WINDOW AT A TIME

This box forces the selection of only one window at a time in the windows grid. This option allows to quickly understand how each window contributes to the overall HV ratio.

#### SELECT ALL

This button selects all the windows listed in the windows grid.

#### CLEAR

This button deselects all the windows listed in the windows grid.

#### COLLECT

This button forces the closing of the data collection for the current window. More details are contained in the section about the WINDOW SELECTION box.

#### DELETE

This button PERMANENTLY deletes all the selected windows. Use with caution.

#### INVERT

This button inverts the windows selection state in the windows grid.

#### APPLY

This button activates the changes made to the calculation and selection of the windows parameters contained in the FFT WINDOW SELECTION and FFT AND H/V CALC boxes.

**WINDOW SELECTION BOX**

This box contains the parameters for the selection of the data windows.

The LENGTH fields indicate the minimum and maximum allowed windows lengths.

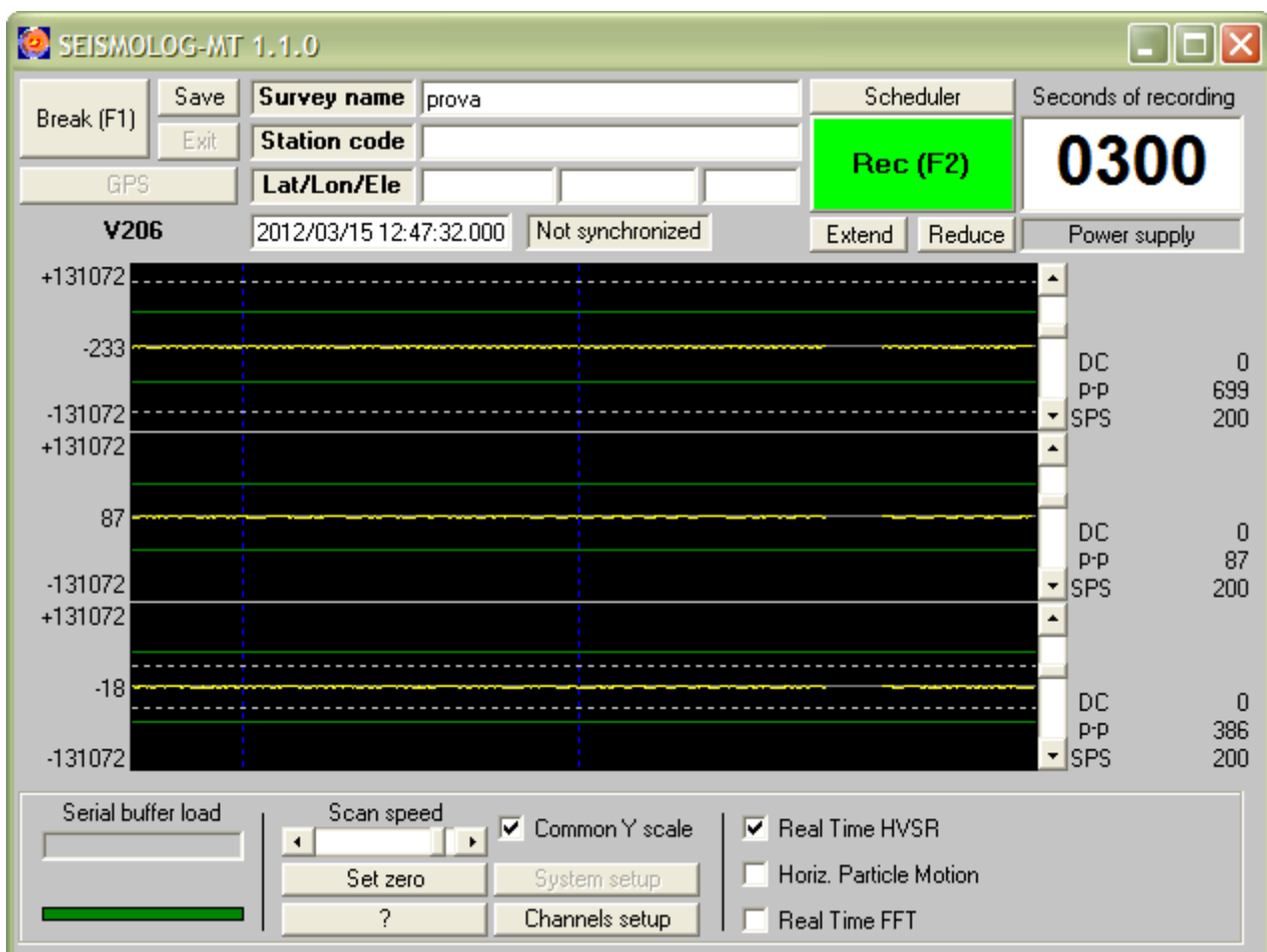
The LEVEL fields indicate the minimum width, in count and different for each channel, which is considered evidence of a transient that can significantly affect the HV ratio calculation and should therefore be discarded.

The data collection for a single window can be interrupted for several reasons, related to the just mentioned parameters:

- Data loss: the received seconds are incomplete. In this case, if the minimum length has been reached the window is closed and used in the calculation, otherwise it is entirely discarded.
- Overcoming the threshold levels set in the LEVEL fields. Also in this case the window is not used if shorter than the minimum length set.
- Maximum length set reached.
- COLLECT button press.

When a window is closed, the data collection for the next window begins on the first full second whose samples are all below the threshold levels.

If the HV window is opened, the values in the LEVEL fields are also highlighted in the waveforms charts on the main window, by a solid green line, as shown in the picture.



You can use these graphs to change the threshold levels: just click the mouse over the graph of the waveform of the desired channel. You will see a dotted white line and the value in the matching LEVEL field will be properly changed. The following clicks will move the white line, in order to make easier the visual selection of the optimal threshold level. Clicking on the APPLY button in the HV window, the changes will be applied, the dashed white lines hidden and the green rows shifted on the new threshold levels.

These threshold levels are the only HV ratio calculation parameters editable during the acquisition, either manually or by the just described method.

#### FFT AND H/V CALC BOX

This box contains the parameters that control the HV ratio calculation.

The FREQUENCY fields contain the minimum and maximum frequencies to be used in the calculation, while the NUMBER OF POINTS field should be filled with the number of points on which the HV ratio will be calculated. These points are frequencies between the minimum and the maximum, taken with a logarithmic step.

The WINDOWING box indicates whether to perform the windowing operation on the horizontal and vertical spectra before calculating their ratio. It is used the *Tukey* window with the  $\alpha$  parameter = 0.5.

When the SPECTRUM CORRECTED DOWN TO box is checked, the horizontal and vertical spectra are corrected before the HV ratio calculation. The instrumental correction is actually performed only when the response files has been specified in the proper fields of the *Channels Setup* window. The Hz value to be inserted is similar to the WATER LEVEL parameter in the *FFT* window: the spectrum components with a lower frequency are amplified with the same factor used for this frequency, even though, according to the instrumental response, should be further amplified.

#### H/V AND SPECTRUM PLOT OPTIONS BOX

This box allows you to change the HV spectrum display options.

The SHOW RATIO box (*F3* keyboard shortcut) shows and hides the main HV ratio.

The STANDARD DEVIATIONS box (keyboard shortcut *F4*) shows and hides the curves representing the result of the multiplication and division of the HV ratio by its standard deviation. These curves are always hidden when the HV ratio is not shown.

The HORIZONTAL (keyboard shortcut *F5*) and VERTICAL (keyboard shortcut *F6*) boxes show and hide the horizontal and vertical spectrum averages, calculated on the same windows used to calculate the ratio.

The SHOW LOADED HV box (keyboard shortcut *F7*) shows and hides the reference HV ratio, only if it has been successfully loaded via the LOAD button, as described in the following paragraph.

You can also manually set the vertical graphic scale, separately for the HV ratios and the horizontal and vertical spectra, and the horizontal (frequency) graphic scale. To apply the graphic scale changes, simply press the ENTER keyboard button right after the change, when the focus is still on the field. There is no need to press the APPLY button: the changes are immediately applied.

You can save the current view in an image file clicking the right mouse button over the display area.

## LOAD BUTTON

This button shows a submenu to load different file types.

- **WINDOWS:** loads a file that contains data windows previously saved through the SAVE button (*hvw* file format). If the calculation parameters match the current ones, loaded windows are added to the existing ones, otherwise they are removed, after showing a warning message.
- **HV AVERAGE:** loads a file that contains an HV ratio (*hv* file format) previously saved through the SAVE button or created by the *Geopsy* software. The loaded ratio can be hidden or displayed through the SHOW LOADED HV box in the H/V SPECTRUM AND PLOT OPTIONS box.

## PULSANTE SAVE

This button shows a submenu to save different file types. The files are always saved in the same folder where the recording files are saved: this means that the save folder depends on the content of the SURVEY NAME field in the main window.

- **WINDOWS SAMPLES:** save the samples of all the currently selected windows in a *saf* format file. This file is different from the standard recording files because the automatically assigned name begins with “*MTHV*” instead of “*MT*”.
- **WINDOWS SPECTRUM AND RATIOS:** saves all the data of the currently selected windows (samples, spectra, and HV ratios) in a single file, so you can save the window state and restore it later, using the LOAD button. The file format is *hvw* and the assigned name begins with “*HVWD*”.
- **HV AVERAGE:** saves the current HV ratio in an *hv* format file directly compatible with the *Geopsy* software. The assigned name begins with “*HV*”. The file can be used in the *dinver* module of *Geopsy* or reloaded via the LOAD button, in order to be used as a reference in future surveys.
- **ALL DATA:** performs all the actions of the three menu just described, hence producing three files. The keyboard shortcut for this item is *F12*.

### **Keyboard shortcuts**

Some of the main program features are available via the keyboard.

Some actions are associated with the function keys (F1, F2, etc..), other with combinations of keys like CTRL+[key].

Below is a list of all the functions available from the keyboard.

#### **MAIN WINDOW**

*F1* – Starts/stops the signal acquisition.

*F2* – Starts/stops the signal recording.

#### **FFT WINDOW**

*CTRL+A* – Acts on the APPLY button (when the *HV* window is open, it also acts on its APPLY button).

*CTRL+E* – Shows the E–W channel spectrum.

*CTRL+N* – Shows the N–S channel spectrum.

*CTRL+U* – Shows the vertical channel spectrum.

*CTRL+F* – Acts on the FULL SPECTRUM option.

*CTRL+O* – Acts on the OCTAVE BANDS option.

#### **HV WINDOW**

*F3* – Acts on the SHOW RATIO box.

*F4* – Acts on the STANDARD DEVIATIONS box.

*F5* – Acts on the HORIZONTAL box.

*F6* – Acts on the VERTICAL box.

*F7* – Acts on the SHOW LOADED HV box.

*F12* – Acts on the ALL DATA item of the menu showed clicking on the SAVE button.

*CTRL+A* – Acts on the APPLY button (when the *FFT* window is open, it also acts on its APPLY button).

*CTRL+R* – Acts on the CLEAR button.

*CTRL+D* – Acts on the DELETE button.

*CTRL+I* – Acts on the INVERT button.

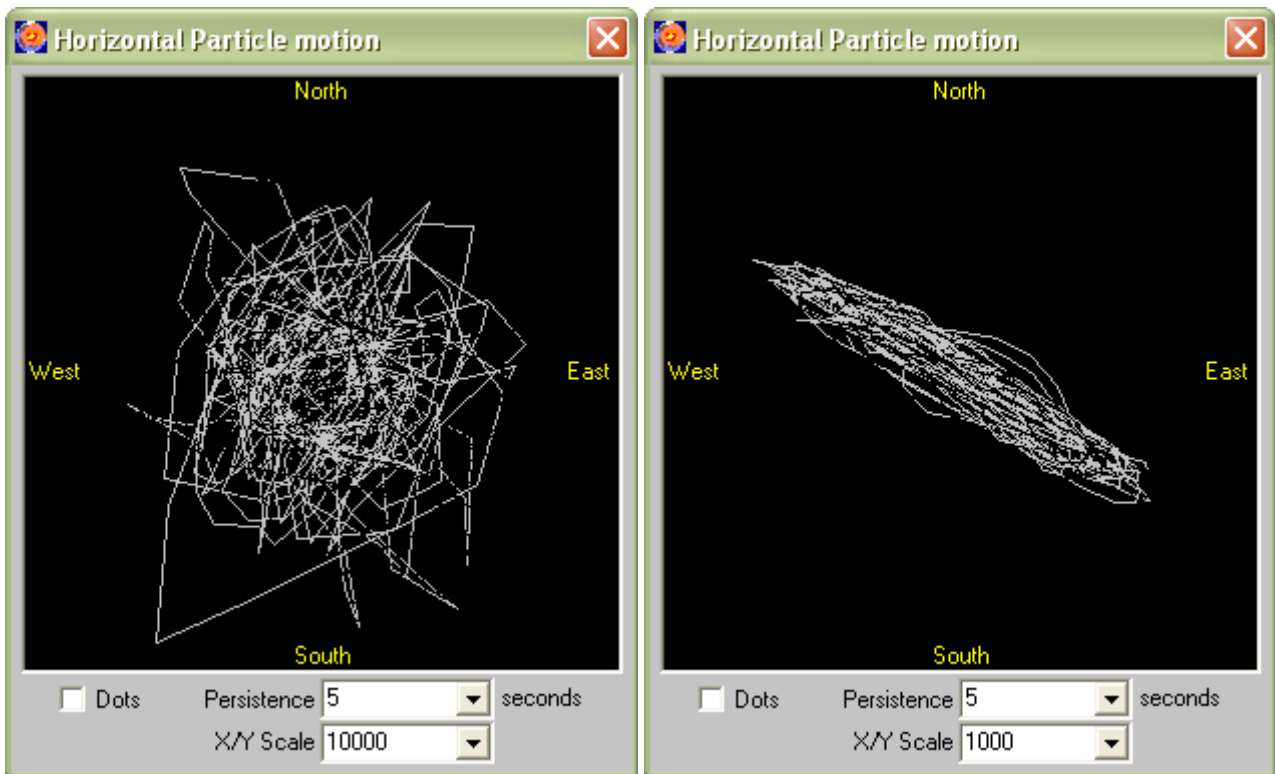
*CTRL+L* – Acts on the COLLECT button.

*CTRL+S* – Acts on the SELECT ALL button.

**Particle Motion window**

This window allows the user to detect signal sources that can significantly harm the measure. The graphic representation is made drawing on a 2D plane the motion detected on the horizontal channels. The user can change the graphic scale to correctly view the particle motion in all the signal conditions and display the data as lines or as points. It is also possible to have the chart displayed either permanently or limited to few seconds.

The user can check in real time whether the background noise is affected by a signal coming from a fixed source. In the example picture on the left, the signal is quite random and has no relevant source of noise. The right picture, however, shows a motion affected by a clear dominant artificial signal that can be related to a source placed diagonally between the two horizontal channels.



**DOTS**

Represents the graph in points rather than in lines.

**PERSISTENCE**

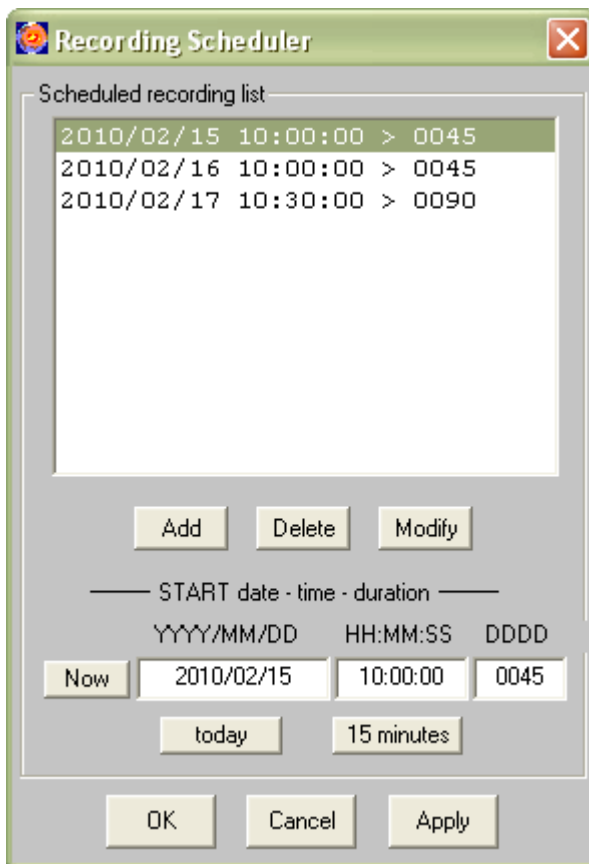
Sets the persistence of the graph from 1 to 5 seconds, or infinite. When the persistence is set to infinity, you can still clean the screen clicking on it with the mouse.

**X/Y SCALE**

Sets the graphic scale.

**Scheduler window**

The *Scheduler* window allows the user to schedule up to 100 events, to record the signal at a preset time. This function is useful in seismic refraction or reflection surveys that use artificial explosions, or simply to check the environmental noise level at certain times of the day. The window allows to set, edit or delete events from the list.



**ADD**  
Adds a scheduled event.

**DELETE**  
Deletes the selected event from the list

**MODIFY**  
Applies the changes to the selected event.

YYYY/MM/DD            year month day  
HH:MM:SS            hour minute second  
DDDD                 recording length, in seconds

**NOW**  
Fills the proper fields with the current date and time (one minute after the current).



**TODAY**

Fills the date field with the current date.

**15 MINUTES**

Fills the time field with the time corresponding to 15 minutes after the current time.

The changes should always be validated clicking on the APPLY button.