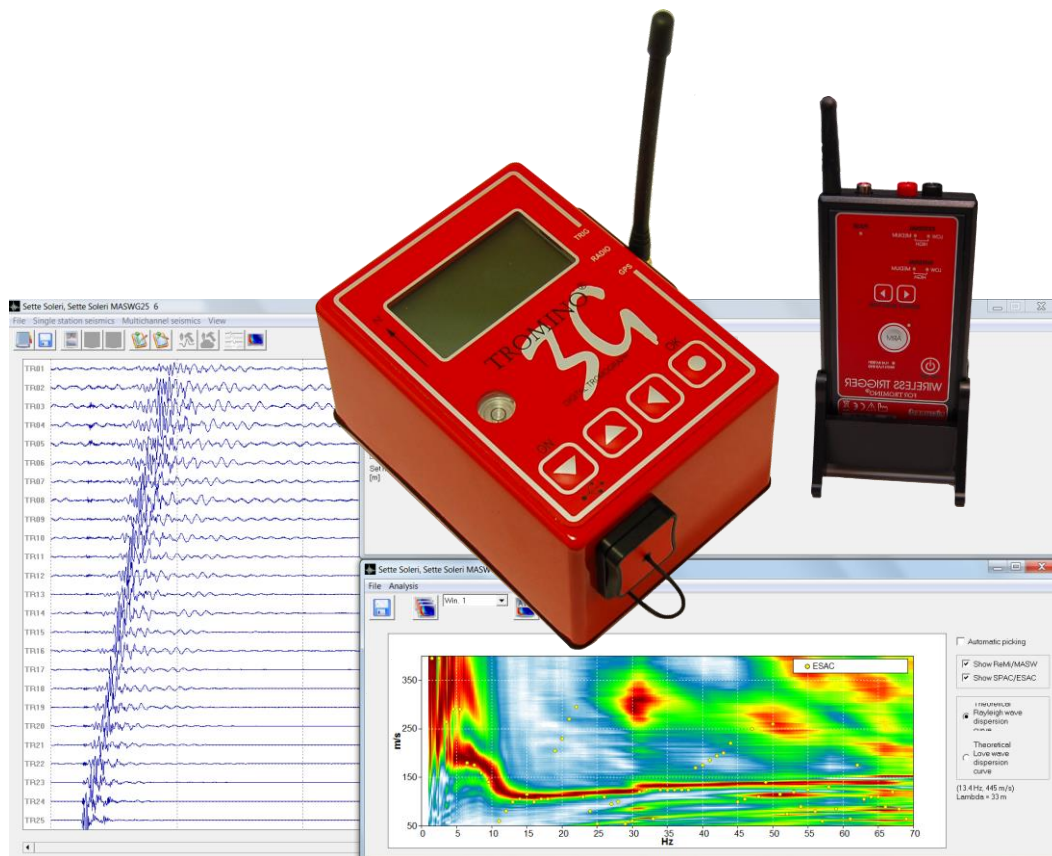


PSEUDO-MULTICHANNEL RECORDINGS WITH TROMINO[®]



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WARNING. The code described below is provided “as is” with the only aim of making a quick survey tool available to users with a solid experience in the analysis of seismic data. Its developers and distributors decline any responsibility for any improper use of this software.

Introduction

Multichannel recordings to be used for seismic refraction/reflection or dispersion curve surveys can be obtained from a single TROMINO® in two ways¹:

- 1) by using the external radio (cable-less) trigger,
- 2) by using a wired trigger.

Please consult p. 3 for instruction on the radio trigger set up or consult p. 10 for the wired-trigger set up and processing.

For Radio Triggered Devices

Field Survey Procedure



The radio trigger (WT) is a device that transmits an impulse to TROMINO® when a threshold level is passed in the built-in tri-axial accelerometer, in an external geophone or other device connected to the WT.

Two parameters need to be defined: 1) the threshold measurement device (internal accelerometer, external geophone/other), 2) the trigger level (low, medium, high).

The WT is used to mark the origin time in the multichannel seismic techniques based on both body and surface waves (e.g. seismic refraction, MASW with Rayleigh and Love waves). By keeping the receiver (TROMINO®) at a fixed position and by moving the source and the WT at different offsets from TROMINO®, the *Grilla* software will automatically merge the recordings in a 3-D multichannel recording.

Some settings are required on both the WT and TROMINO®.

Settings on the wireless trigger

- 1) Turn the WT on, by clicking ON-OFF (Figure 1),
- 2) Set the threshold measurement device:
 - a. INTERNAL: tri-axial accelerometer embedded in the WT,

¹ The same surveys can be achieved by using several TROMINO®s, synchronized through the radio or the GPS.

- b. EXTERNAL: geophone (or other passive transducer) linked to the WT through the bipolar connector located on the side panel of the WT,
- c. PULSE: (according to the firmware version) a) by clicking ARM, the WT transmits a TTL impulse to the RCA connector, b) the WT receives the 'passed threshold' signal from the TTL and transmits it to TROMINO®.

To surf among the options, click SOURCE (Figure 1) until the corresponding LED blinks.

3) Set the trigger threshold:

- a. LOW (maximum sensitivity, a low energy source suffices to trigger the system),
- b. INTERMEDIATE
- c. HIGH (active when both LEDs are on, implies the lowest sensitivity and requires a high energy source to trigger the system. This settings is recommended to avoid accidental triggerings).

4) Couple the WT to the ground - by using the provided spike - at the desired offset from TROMINO®.

5) Press ARM. The blue LED on the top-left starts blinking. When it stops blinking, the WT is ready. Energize the ground (with a heavy jump, with a sledgehammer or other conventional sources).

6) When the threshold is passed, the WT beeps and is ready to be armed again for a new shot. At the same time a black rectangle appears on the TROMINO® display, which indicates the correct reception of the trigger time (see the next paragraph about TROMINO® settings).

7) Move the WT to the next shot position (see also Figure 8 and read p. 11 for additional information) and repeat the process from item 5) above.

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Emergency options (beginners please skip this step). Should a shot need to be repeated and overwritten, move the counter back to the desired shot (see Figure 6 to be sure that you understand how the triggers are numbered):

- 1) click ARM,
- 2) while the blue LED blinks, click ARM again,
- 3) the blue LED blinks a number of times corresponding to the current trigger number (one time for trigger 1, two times for trigger 2, etc.). Click SOURCE (▶ or ◀) to increase or decrease the number of the trigger to be overwritten,

- 4) click ARM to repeat the shot and overwrite the information. Note: the trigger counter is now set back to an older position. Unless you move the counter forward with the (▶) key, you could overwrite some information.

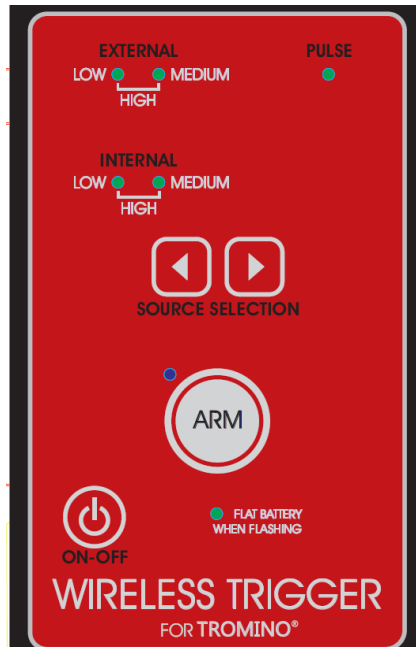


Figure 1. Control panel of the TROMINO® Wireless Trigger.

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Settings on TROMINO®

In order to work with the Wireless Trigger (WT), TROMINO® has to be set as it follows:

- 1) Connect the radio antenna to the side panel of TROMINO® marked with R). Note that the radio and the GPS antennas are not meant to be used at the same time,
- 2) Enter the RADIO SET, GPS SHOW menu,
- 3) Use the (LE ▼) and (CL ▲) keys to move among the display items and the (CR ◀) and (RI ●) keys to modify the values.

Set RADIO ACTIVE (NO) as shown in the panel below.



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INITIAL MENU			
RADIO ACTIVE	NO		
MODULE NUMBER	1		
DEVICES ON CHAIN	my number		
CLOCK TIME	UTC 00:00		
GPS SHOW			
GPS ANTENNA	EXT/INT		
▼	▲	◀	●

Figure 2. The RADIO SET, GPS SHOW panel of TROMINO®.

- 4) Go back to INITIAL MENU,
- 5) Enter the ACQUISITION >> MODE menu. Use the (LE ▼) and (CL ▲) keys to move among the display items and the (CR ◀) and (RI ●) keys to modify the values.

INITIAL MENU			
HIGH GAIN CH.	YES		
LOW GAIN CH.	NO		
ACCELEROMETER	NO		
AUX CHANNEL	NO		
WIRELESS TRIGGER	YES		
GPS ANTENNA	EXT/INT		
ALLARM SETUP			
			

Figure 3. The ACQUISITION >> MODE panel of TROMINO®.

- 6) Set WIRELESS TRIGGER >> YES.
- 7) Go back to the ACQUISITION menu,
- 8) Set SELECT PROGRAM >> PROGRAM 1,
- 9) Go back to the ACQUISITION menu,
- 10) Click ACQUIRE. The traces are now visible on the TROMINO® display,
- 11) Click any keys. The display illustrated in Figure 4 appears,

12) Move the cursor to SAVE and click (●). Data will be saved on TROMINO® after 10-15 seconds, in order to let the operator move away from the instrument.

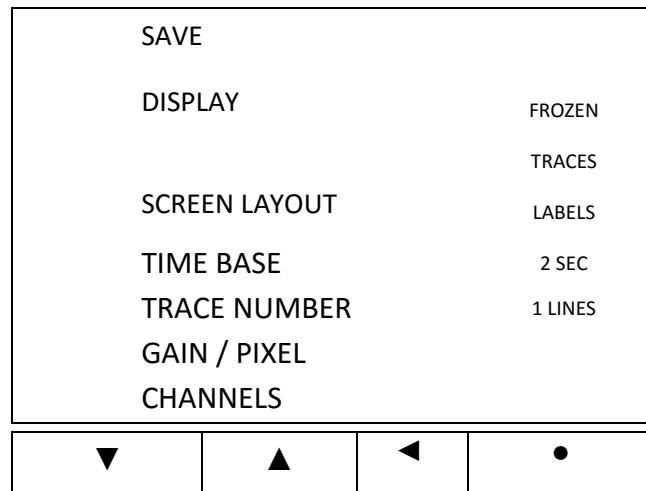


Figure 4. The SAVE-DISPLAY panel of TROMINO®.

The TROMINO® screen now appears as in Figure 5.

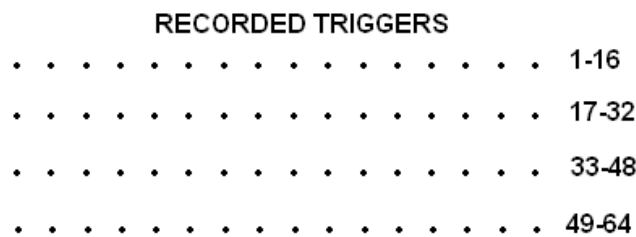


Figure 5. TROMINO® display ready to receive the triggers from the WT.

It is now possible to arm the wireless trigger and shoot the ground. When the threshold is passed, the WT transmits a signal to TROMINO® and a black rectangle appears on its screen (Figure 6).

If no transmission errors occur, the TROMINO® display show a number of consecutive rectangles ranging from 1 to the number of performed shots (Figure 6).

Empty rectangles indicate attempts of the WT to transmit threshold times that were not received from TROMINO®. In the example of Figure 6, TROMINO® received 12 triggers (black rectangles) from the WT. However, the first 3 transmission attempts from WT to TROMINO® were not successful and a fourth energization in position 1 was required (shot position 1, received as trigger no. 4). The shot performed in position 2 was also repeated 2 times, since the first attempt to transmit the data from the WT to TROMINO® was unsuccessful. Shots in positions 3 to 5 were immediately successfully transmitted. The shot in position 6 was repeated 2 times before the data transmission to TROMINO® was successful and so on.

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In practice the user has just to be sure that a black rectangle is present on TROMINO® for any desired source position, no matter whether empty rectangles (i.e. unsuccessful attempts to transmit data from the WT to TROMINO®) are also present.

Should the user want to repeat a shot, move the WT back to the corresponding trigger number (referring to Figure 6 the trigger number is 1 for the shot position 1, it is 2 for the shot position 2 and so forth. However, referring to the different case of Figure 7, the trigger number is 4 for the shot position 1, it is 11 for the shot position 6, it is 17 for the shot position 10 and so on).

Note: data are saved in the internal memory of TROMINO® every 12 seconds. Wait 12 seconds before stopping the acquisition after the last shot.

Note: during the recordings with the WT, in order to get good quality curves, it is important that the lowest random noise as possible is produced close to the receiver (i.e. TROMINO®). People close to TROMINO® should be asked not to move, while the operator moves away from it with the WT.

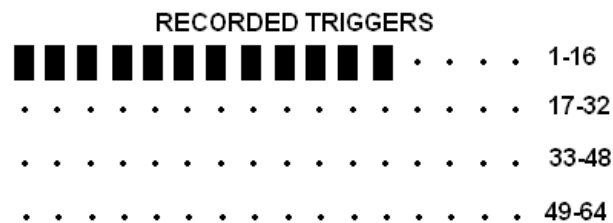


Figure 6. TROMINO® panel showing a standard receipt of 12 triggers (black boxes) from the WT.

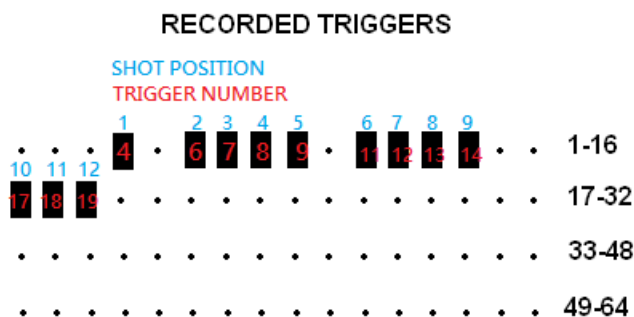


Figure 7. TROMINO® panel showing the receipt of 12 triggers from the WT. The first 3 transmission attempts from WT to TROMINO® were not successful and a fourth energization in position 1 was required (shot position 1, received as trigger no. 4). The shot performed in position 2 was also repeated 2 times, since the first attempt to transmit the data from the WT to TROMINO® was unsuccessful. Shots in positions 3 to 5 were immediately successfully transmitted. Shot in position 6 was repeated 2 times before the data transmission to TROMINO® was successful and so on. In practice the user has just to be sure that a black rectangle is present on TROMINO® for any desired source position, no matter whether empty rectangles (i.e. unsuccessful attempts to transmit data from the WT to TROMINO®) are also present.

Data processing

Download the acquired recording in the *Grilla* database. Double click the downloaded record: this

will open the trace window (Figure 9). Click the *Dromochrone module*  button from the *Grilla* toolbar. The multichannel analysis will be reconstructed automatically. If you wish to proceed manually, follow the instruction on p. 11.

The length of the multichannel file to be exported can be set from the *Multichannel seismics > Tromino trigger > Post-trigger length (1, 2, 3 s)* menu of *Grilla* (Figure 11).

For instruction on the refraction/reflection/surface wave processing, read the steps from *P3. Single channel and synthetic multichannel phase picking* (p. 14) onwards.

For Wired Trigger Devices

Field Survey Procedure

The TROMINO® instruments of the series ENGy, SEISMO and ENGy PLUS (serial number starting with TEN, TRY, TEP) are equipped with a lateral connector (small or large BNC plug, according to model), to be connected to an external triggering system. In its easiest form, available as a TROMINO accessory, this trigger consists of a cable and a geophone.

The user should:

- 1) firmly set TROMINO® on the ground as usual,
- 2) set acquisition to the highest sampling frequency (1024 Hz or 512 Hz),
- 3) set FREE LENGTH as recording length,
- 4) set acquisition (select MODE in the TROMINO® menu) from channels HIGH GAIN or FULL SCALE >> 51 mV and TRIGGER ACTIVE → YES **[do not forget to set TRIGGER ACTIVE → YES],**
- 5) unwind a meter cord starting from TROMINO® in G1, G2, G3, ... direction, as shown in also Figure 8,
- 6) start TROMINO® acquisition and data saving,
- 7) position the trigger geophone in G1 at N meters from TROMINO®. We advise to unwind the trigger cable along the EW TROMINO® direction to avoid any cable clogging around the instrument and to make all acquisitions homogeneous, which will make all interpretations coherent.

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Please note that the distance of the different “shot” points (G1, G2, ecc.) should be chosen considering the seismic wave velocities of the subsoil. On fine grained alluvial soils, 2-3 m is usually a good compromise. On coarse grained alluvial soils this distance can be increased to 4-5 m.

- 8) energize near G1 (use an appropriate source: for example, use a vertical point source for P wave refraction and SASW/MASW, and a NS horizontal line source in both directions together with a polarity check for S wave refraction),
- 9) move the trigger geophone to point G2, $2 \times N$ meters from TROMINO®. Energize near G2,
- 10) move the trigger geophone to point G3, $3 \times N$ meters from TROMINO®. Energize near G3,
- 11) repeat up to the desired distance,
- 12) stop TROMINO® data acquisition *[note that since the instrument saves the data each 12 seconds, one must wait at least 12 seconds after the last shot before stopping the acquisition].*

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IMPORTANT NOTICE

To achieve the best record quality be sure to:

- a) make identical shots,
- b) stay away from the trigger cable and TROMINO® during energization.

In particular, TROMINO® and the trigger cable **should never move** and the shots should be **never made too close to the trigger cable**, since mechanical disturbs on the cable are easily transmitted to TROMINO®.

Please note that the above procedure **SSOR**– **S**everal **S**hot points and **O**ne **R**ecording position - is opposite to the standard **OSSR** - **O**ne **S**hot point and **S**everal **R**ecording positions. The two approaches are symmetric only on simple 1D subsoil stratigraphy. This should not be regarded as a major limitation since the same is implicitly assumed by most survey techniques such as MASW, ReMi™, FTAN, etc. In any case, the presence of a 1D subsoil geometry can be checked with TROMINO® by taking short (7-10') recordings at beginning, at the centre and at the end of the synthetic array. Nearly identical H/V curves stand for a 1D subsoil stratigraphy.

Remember that in the standard seismic prospection resolving 2D subsoil geometries requires large amount of data and, e.g., the use of tomographic inversion techniques. Attempts to map 2D subsoil geometries with a single ReMi, SASW and MASW is not realistic irrespective of the instrumentation used.

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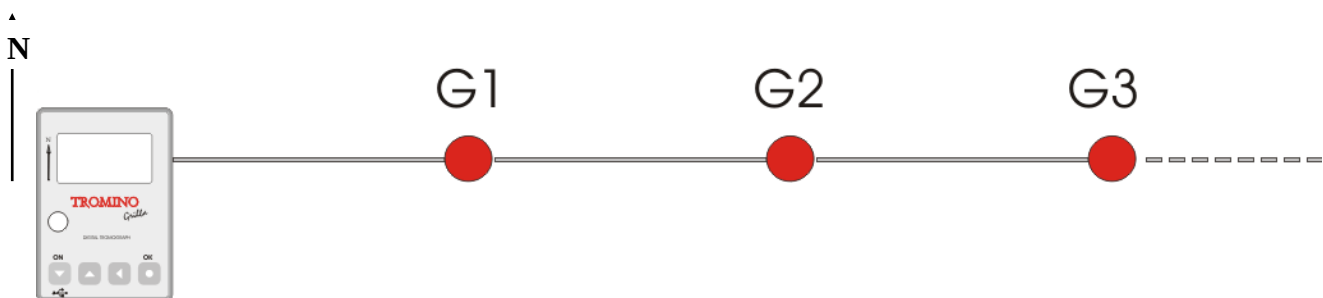


Figure 8. Example of how to deploy a TROMINO® -trigger cable system. The shot points are G1, G2, G3... The same geometry however applies to the TROMINO® radio trigger.

Data processing

P1. Phase picking

Import the recording in *Grilla*, visualize the trace and press the *Dromochrone module* button identified by the yellow hammer blow icon (yellow box in Figure 9).

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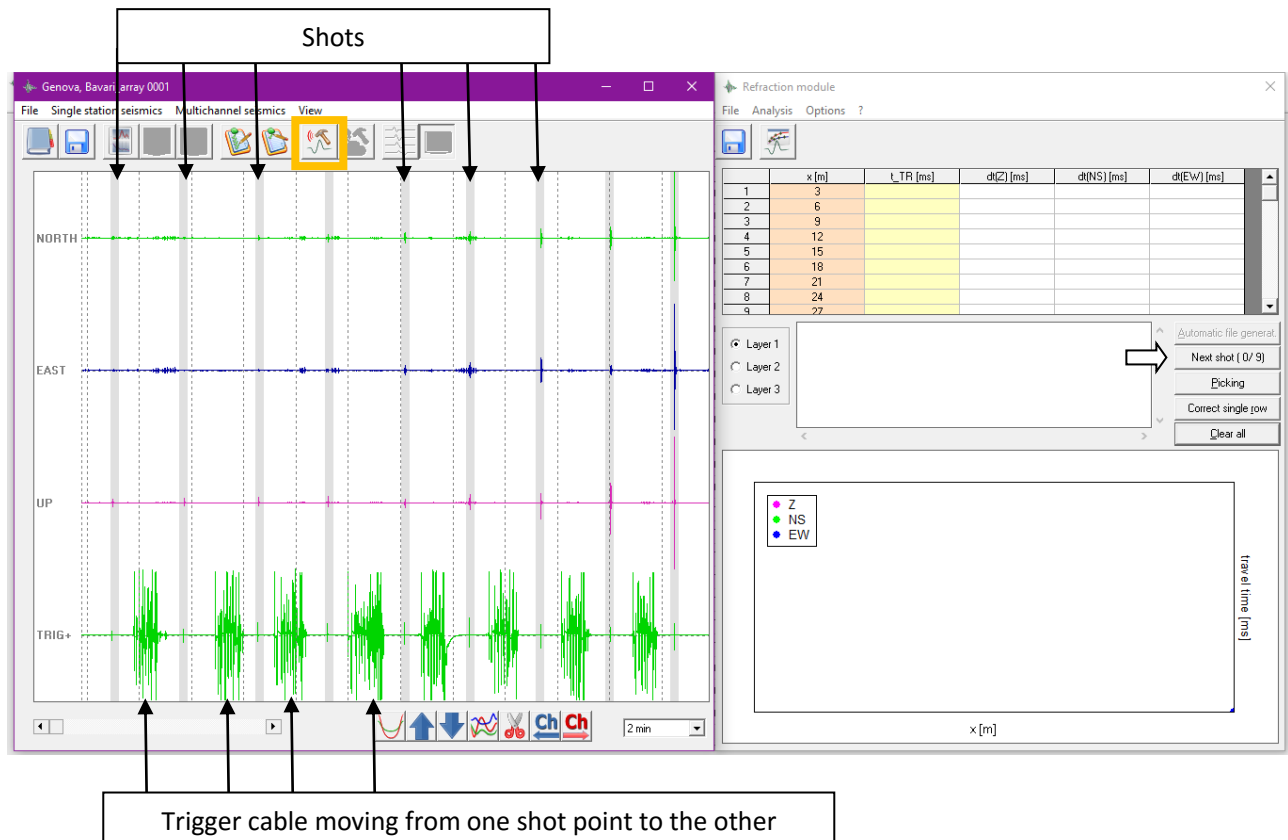
As a first step, select the *shot times*.

To this extent, move the cursor (left panel in Figure 9) on the first shot time, left-click the mouse and press “S” (which stands for “Select”) on the keyboard.

The shot times are easy to identify since they appear as isolated pulses clearly visible on all channels. They should not be confused with the broad and repeated pulses corresponding to the trigger moving from one shot point to the other, during which signal clipping is also frequently apparent.

Proceed from the first to the last shot, moving along the record with the moving bar at the bottom left.

The selected shot times will appear in black. In case of wrong selection press *Clear all* in the window at the right of Figure 9 and redo from the beginning.



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Figure 9. Selection of the shot times (black vertical bars).

P2. Picking the shot times

To precisely identify the beginning of each shot time, proceed as follows. Press *Next shot* (t_i / t_{tot}) in the right panel in (Figure 9, white arrow).

t_{tot} is the total number of pre-selected shots,
 t_i is the number of the present shot.

- 1) Press *Next shot* ($1 / t_{tot}$) and a zoom of the first selection will appear,
- 2) the selection of the first shot time must be made on the Trigger channel, which is identified by the TRIG+ tag (see Figure 10). Use the buttons (amplification, number of channels displayed, channel shift) at the bottom of the window to achieve the best readability,
- 3) accurately pick the trigger time by moving the cursor, left-clicking the mouse and pressing "T" (as "Time") on the keyboard,
- 4) a picking is properly completed when row t_i and t_{TR} (Trigger time) are filled (yellow box in Figure 10).

In case of error the picking can be redone by repeating step 3) above. The shot time will be automatically updated also in the table.

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- 5) Proceed to the second shot by pressing *Next shot* ($2 / t_{tot}$). Operate just as for the first shot.
- 6) Proceed for all the shots t_{tot} . Move to the next shot by pressing *Next shot* (t_i / t_{tot}).

Should you realize that a previous shot time has been mispicked, left-click the mouse on the related row in the shot time table (see Figure 10) and press the button *Correct single row*. The row content will be cancelled and you will be able to redo the picking as described in step 3) above.

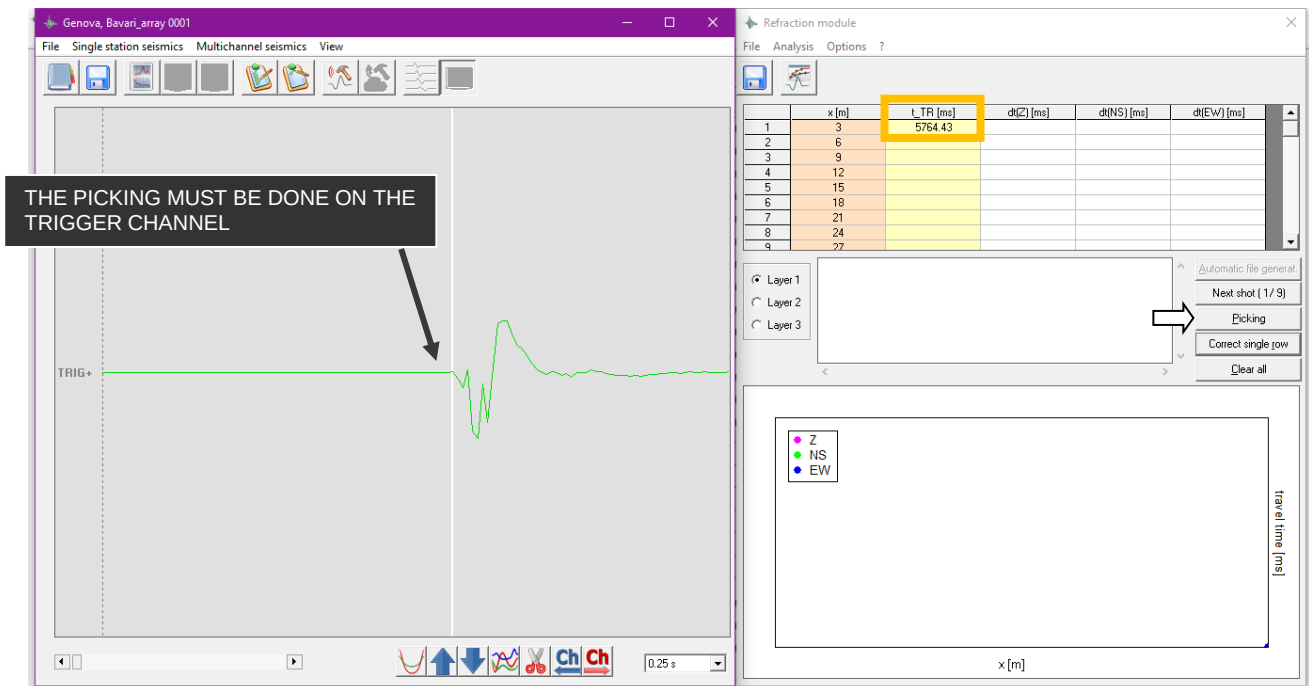


Figure 10. Selection of the shot time (vertical white rose line).

P3. Single channel and synthetic multichannel phase picking

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When the picking of the shot times is completed, *Grilla* will merge each shot in 3 multichannel recordings (one for each component, Z, NS and EW).

The length of the multichannel file to be exported can be set from the *Multichannel seismics* > *Tromino trigger* > *Post-trigger length (1, 2, 3 s)* menu of *Grilla* (Figure 11).

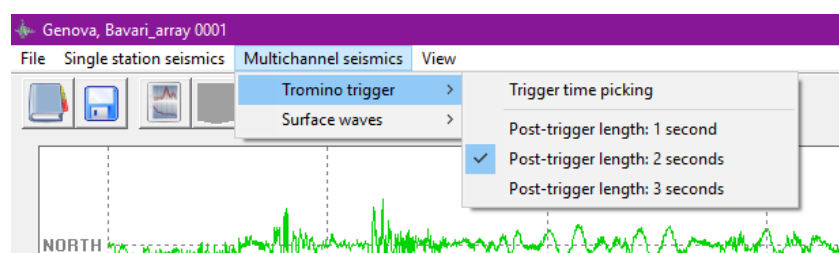


Figure 11. Selection of the length in seconds of the multichannel file to be reconstructed.

To display the multichannel records, click the *Picking* button (white arrow in Figure 10). A new window will open as in Figure 12.

The number of tracks shown corresponds to the number of shots selected at the step P1 above.

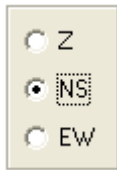
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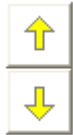
DISPLAY OPTIONS:



Display the Z, NS or EW component of the synthetic multichannel recording.



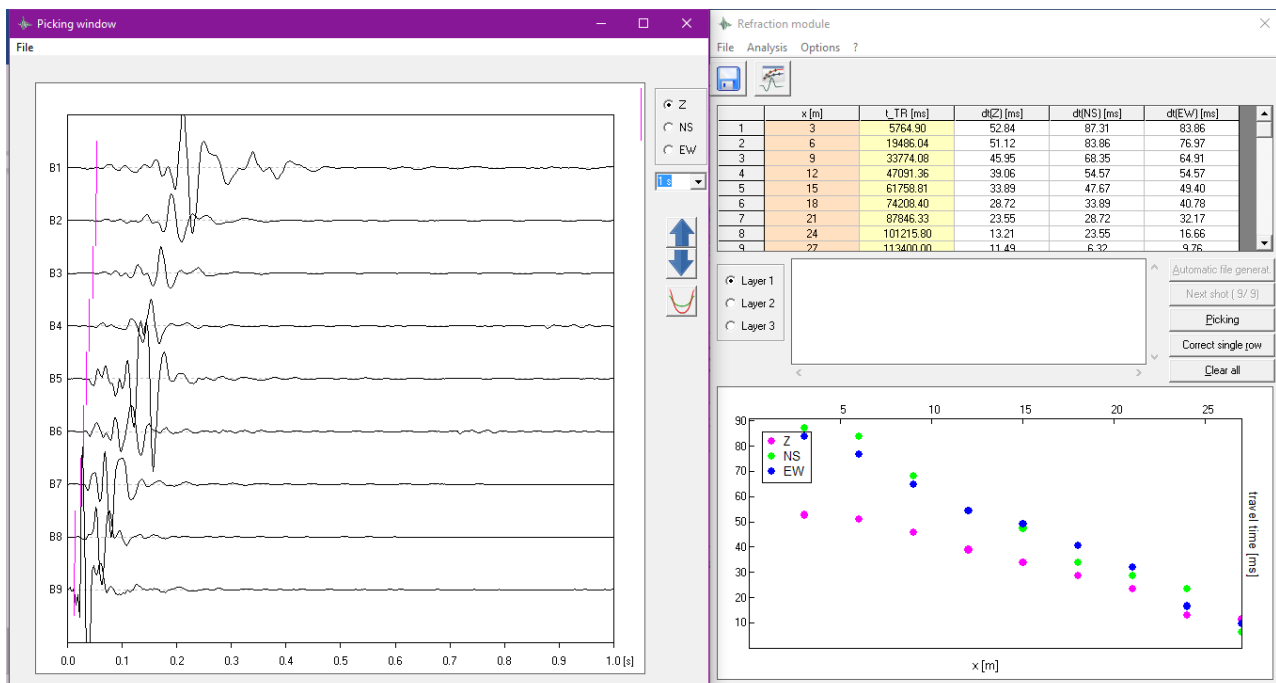
Modify the time base.



Modify the amplification of each trace.



Normalize the trace amplitude to achieve the best readability of traces with different maximum amplitudes. This option is convenient in most cases.



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Figure 12. Example of a synthetic multichannel recording (left panel) and of the related dromochrones for the 3 components (lower right).

You can pick the time of each phase for the three components Z, NS e EW by left-clicking the mouse and pressing "T" (as "Time") on the keyboard. **Note: picking the first break times is not necessary for surface wave dispersion analysis.**

This will progressively fill the phase picking table (see the right of Figure 12)

Note that picking the various phases at each pseudo-geophone G1, G2... is made easier by the software capability to increase/decrease amplification but requires nevertheless a good expertise in field seismology.

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P4. Refraction analysis

The *dromochrones* are plotted in different colours (Figure 13) for the different components and can be inverted for both stratigraphy and seismic velocities using the standard seismic methods. Recall that, especially for S waves, but both the generation and the picking remain a not trivial task.

A refracted dromochrone appears as a piecewise linear curve with different segments corresponding to different strata (Figure 13). The key goal of the analyst is to identify the points of change in slope of the dromochrone.

To this extent:

- 1) select the layer the properties of which are going to be identified on the dromochrone (Layer 1, Layer 2 or Layer 3 in the options menu, see Figure 13),
- 2) left-click the mouse on the change-point of the dromochrone,
- 3) proceed in the same way for all the strata. A vertical dashed bar will appear to separate the different dromochrone segments,
- 4) an automatic fit will be performed and the velocity and thickness of each stratum will be displayed. The table can be “refreshed” by pressing *Dromochrone analysis* on the toolbar.

The inferred velocity values in the 3 components and the related stratigraphy will be displayed in the box at the center (see Figure 13).

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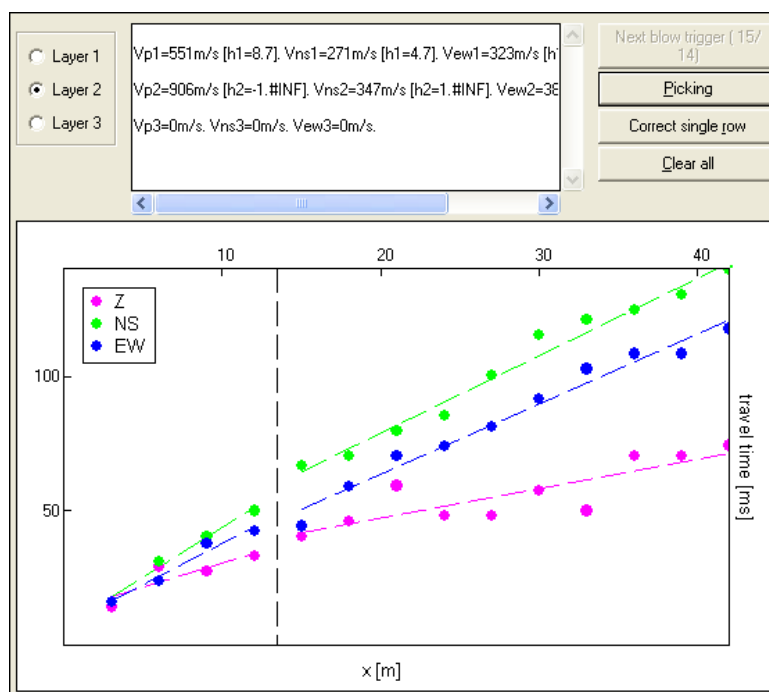


Figure 13. Detail of the dromochrone module.

P5. SASW / MASW analyses

SASW / MASW analyses aim at computing the phase velocity dispersion curves of surface wave trains artificially generated by a vertical impulse. Only Rayleigh waves packets appear on the vertical component (Z), while both Rayleigh and Love waves appear on the horizontal components. When the prospection is conducted with the same instrumental orientation shown in Figure 8, and a shear source is used in the NS direction, Love waves only will appear on the NS component.

Choose *File >> Convert traces for Grilla database* in the menu of the left window (Figure 12). This will produce 3 pseudo-array files (one for each component) in the *Grilla* database.

SASW / MASW processing can be performed in the *Dispersion curve module* of *Grilla* (manual accessible from the *Grilla* menu ? >> Array (SoilSpy Rosina) >> Dispersion curve).

Note that the real duration of the reconstructed multichannel file will be the one selected by the user as in Figure 11, while the duration that appears in the database is equal to the whole original trace length.

An example of a dispersion curve that can be obtained from the procedure described above is given in Figure 14.

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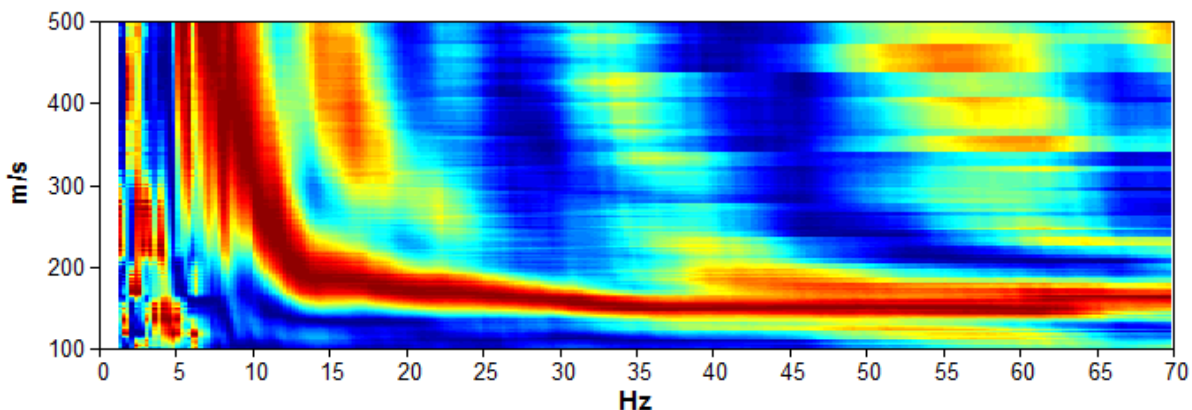


Figure 14. Example of phase velocity spectra obtained with TROMINO® + trigger cable.

Last, but not least

TROMINO® trigger channel has a variety of potential applications, of which we gave just a few examples related to its use with the trigger+geophone cable. However, the user must be aware all times that seismic surveying can be difficult even for the most experienced people. Please make sure that you thoroughly understand the theory of a survey technique before committing to use it. Keep always in mind that obtaining “some” result is easy, but trustworthy results require careful measurements, much knowledge and a solid experience.