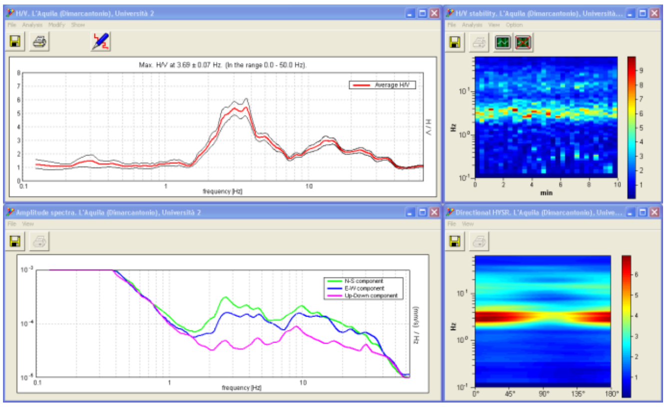
THE SHORT TROMINO® HOW TO



What should I do now?

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SUMMARY

Introduction

This document has the scope of guiding your first steps with TROMINO® and *Grilla* software. TROMINO® has been designed to be carried along anywhere like a camera. It's a peculiar camera, though, since it can take pictures inside the earth and the buildings.

This document is meant to provide just the basic information to get you started on data acquisition and interpretation using as an example a few common cases For specialized applications please refer to the appropriate TROMINO® manual. The manuals for all the available applications are accessible by clicking *?* on the *Grilla* menu, as shown in Figure 1.

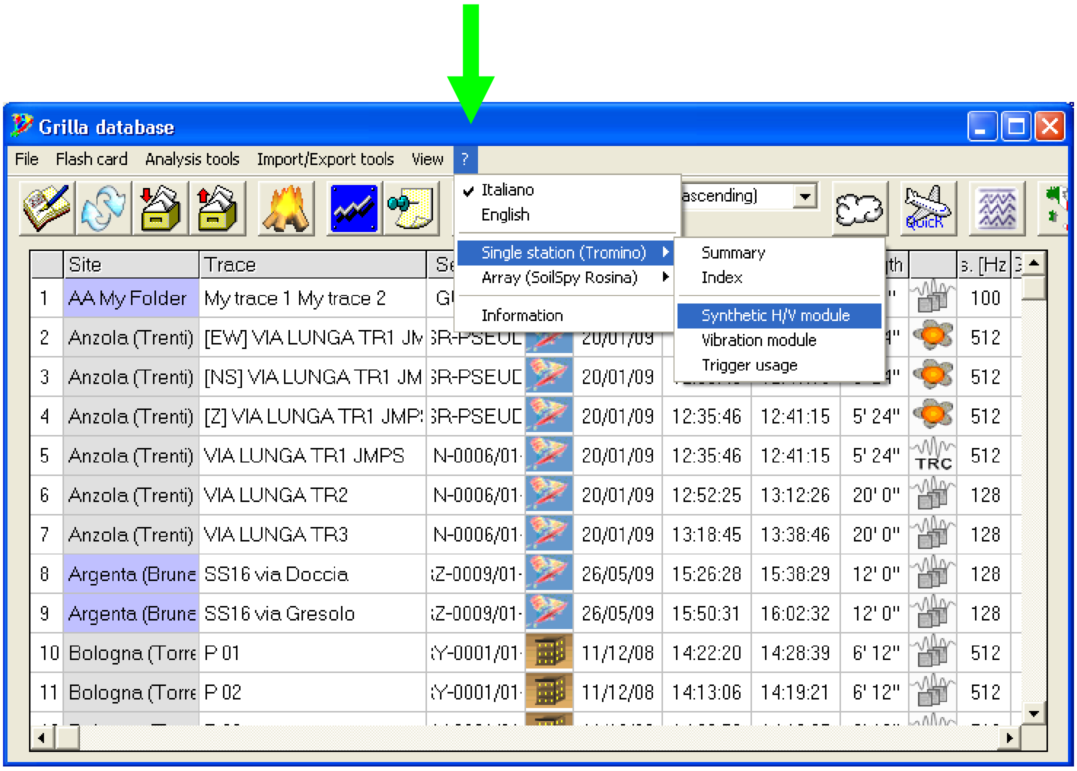

Figure 1.

TAKING MEASUREMENTS WITH TROMINO®

CHOOSING THE APPROPRIATE SAMPLING FREQUENCY

1. STRATIGRAPHIC APPLICATIONS

TROMINO® has been designed to measure *seismic noise* and extract information from it through different time domain and spectral techniques. Traditionally regarded as a nuisance by seismologists, seismic noise has been shown from physical Acoustics to be rich in information on the local structure of the subsoil. Since noise is present always and everywhere, it appears a convenient exploration tool. For what concerns soil stratigraphy, you may think of TROMINO® as a device that measures – first of all – the resonance frequencies of soil by using the spectral ratio of the horizontal and vertical components H/V. The reason is that seismic noise varies largely in amplitude as a function of the noise "strength" but the spectral ratio remains essentially unaffected and is tied to local subsoil structure.

In simple double layer stratigraphy sedimentary cover + bedrock, there is a simple equation[1] relating the resonance frequency f to the thickness h of the layer and Vs (the shear wave velocity in the same layer):

$$f = Vs / (4\ h) \qquad [1]$$

In Appendix 1 (page 24) this relation is illustrated graphically.

Recalling that:

1. clay has Vs typically equal to 100-180 m/s,
2. sand has Vs typically equal to 180-250 m/s,
3. gravel has Vs typically equal to 250-500 m/s

equation [1] yields that 1 m of clay above a bedrock has a resonance frequency f = 100-180 m/s / (4 x 1 m) = 25-45 Hz. Since layers thinner than 1 m are seldom of practical interest, frequencies larger than 30-40 Hz can be disregarded.

Hence, a sampling frequency of 128 Hz is adequate[2].

2. ENGINEERING APPLICATIONS

The vibration frequencies of buildings are, to first order approximation, a function of the stiffness of the construction material and an inverse function of their height. For standard r.c. buildings typical

[1] Warning! This simple formula applies just to a single stratum over an infinite half-space.

[2] Recall that according to Nyquist theorem, the highest frequency that can be recovered from a digitized signal is always lower than *half* the sampling frequency. Hence, sampling at 128 Hz one can resolve signals at frequencies at most 64 Hz high.

relations can be derived. Figure 2 shows this relative to the first vibration mode. It is easy to note that one storey buildings have frequencies around 10-12 Hz while multi-storey buildings have always lower frequencies. Even considering that higher modes may be important, a 128 Hz sampling frequency appears adequate[2].

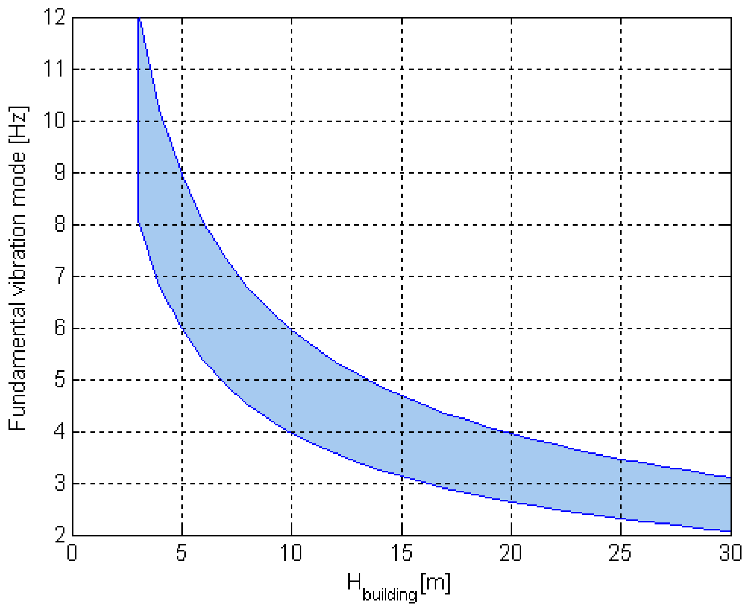

Figure 2.

3. APPLICATION TO VIBRATION PROBLEMS

The norms UNI 9916 and DIN 4150 concern the study of vibrations up to at least 100 Hz. For such applications a 512 Hz[2] sampling is therefore appropriate.

At present, the *Grilla* vibration analysis module accepts only the 128 and 512 Hz sampling frequencies. If a different sampling frequency has been already used for a recording, you can analyse it by decreasing this to 128 or 512 Hz through the function *File > Desampling* of the *Grilla* database.

SUMMARY

	SAMPLING FREQUENCY
For stratigraphic applications	128 Hz
For modal analysis of buildings	128 Hz
For vibration analysis (UNI 9916, DIN 4150 etc.)	512 Hz

DURATION OF THE RECORDING

1. STRATIGRAPHIC APPLICATIONS

The duration of the recording must be tied to the lowest frequency of interest. For example, if we wish to observe the resonance of a 300 m thick sedimentary cover, then, according to equation [1], we may expect frequencies around f = 0.5 Hz. Such a frequency means a period T = 2 s, that is a signal which repeats itself after 2 seconds. It is then obvious that we must record for at least 2 seconds.

In practice, spectral estimates are statistical in nature and, to have stable results, the observation time should be long enough to comprise at least 10 repetitions of the longest period of interest. In the above example this means 10 x 2 s = 20 s.

Furthermore, since we are going to extract information from seismic noise, we expect fluctuations with time, which can be appropriately controlled by sampling a number N of 20 s windows sufficient to compute an average which is statistically significant. Common practice shows this number N to be 30-50, which means in the above example a total recording time of 10-15 minutes.

2. ENGINEERING APPLICATIONS

Since soil responds differently to the different types of waves which compose seismic noise, its vibration pattern is comparatively complex and unstable. Conversely, recordings in buildings are more stable and can have a shorter duration. In addition to this, large buildings respond with lower frequency but larger amplitude, which automatically improves the resolution. Common practice shows that 5-6 min are sufficient to take a stable vibration picture of buildings of any size.

3. VIBRATION PROBLEMS

The duration of the recording depends on the specific vibratory phenomenon of interest and on its nature, continuous or transient.

SUMMARY

	RECORDING TIME
For stratigraphic applications	
- very superficial (5 m)	5 min
- within the first 30-50 m	> 10 min
- very deep	>15 min
For modal analysis of buildings	5-6 min
For vibration analysis (UNI 9916, DIN 4150 etc.)	variable, depends on vibration type

USING GPS

TROMINO® instruments equipped with GPS (series TRS, TEN and TEP) can use it for different purposes. The first one is simple **geographic location.** To this extent, acquire data using program 2 (outdoor) or program 3 (indoor).

The second one is to provide a **common time basis.** To this extent acquire data using program 4 (outdoor) or 5 (indoor).

The third use of GPS is to **synchronize** several TROMINO® to make a synthetic array. To this goal also acquire data using program 4 (outdoor) or 5 (indoor).

TROMINO® instruments of the TEP series can use both an internal and an external GPS antenna. Select the appropriate one in the MODE menu.

SETTING TROMINO® ON THE GROUND

1. STRATIGRAPHIC APPLICATIONS

TROMINO® should always be set on ***natural ground***[3], never on asphalt, pavement, cement, etc. Should this not be possible, data interpretation must be performed according to the footnote 3. The main effect of taking measurements on artificial ground, which is usually more rigid than the underlying natural ground, is to deamplify the entire H/V curve from high frequency down to 1-2 Hz. It is essential that this deamplification is properly identified, which is relatively easy because it is accompanied by an evident depression of the H/V below 1 in a large frequency interval. For the appropriate treatment of this effect refer to the footnote 3.

Look for true natural ground and avoid also natural ground patches *inside* large asphalted or artificially paved areas, e.g. flowerbeds in squares. Always look for natural ground *outside* artificially paved areas, or *at their border*.

Orienting the instrument with the geographic North is not necessary, unless you a performing a large scale study, for example a seismic microzonation, which requires a common orientation.
In presence of particular morphologic structures (ridges, scarps, lineaments) it is preferable to align the instruments parallel or orthogonal to such structures, since they may potentially induce directional effects.

2. ENGINEERING APPLICATIONS

Set the instrument parallel to the axes of the structure to be studied.
If you are taking measurements at different levels, instruments must be positioned *following a close vertical alignment* and with the same orientation at each level.
Complex buildings have generally a complex dynamic response and it may be necessary to take measurements along several vertical alignments.

[3] This point is discussed in detail in Castellaro and Mulargia, *Pure and Applied Geophysics*, 2009. Reprints can be requested at support@tromino.it

The minimum number of measurements to characterize a structure and the underlying subsoil relative to the coincidence of their resonance frequencies, which would result in potentially destructive amplification is:

3

- one measurement at or near the top level
- one measurement at the basement level
- one measurement on natural soil external to structure. This is to characterize the free-field subsoil response, which results unaffected by the structure itself already at a distance of 5-10 m from the basement.

Note the unmistakable difference in the shape (see Figure 3) of the H/V peaks of stratigraphic origin and the H_i/H_0 peaks of buildings. After a little practice it is simple to discriminate them.

(A) (B)

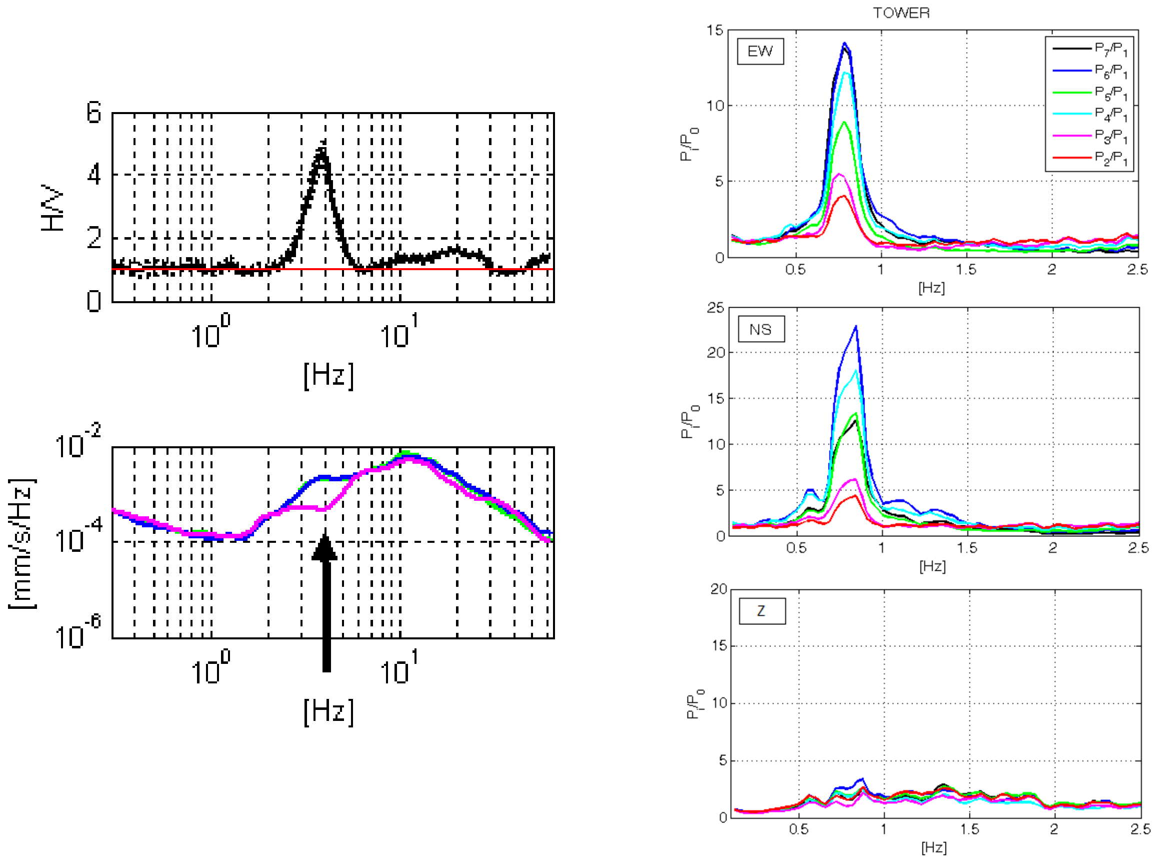

Figure 3. (A) H/V peaks of stratigraphic origin are characterized by local minima in the Z-component, absent on the horizontal components, leading to eye-shaped spectral structures. (B) The P_i/P_0 (spectral ratios among different levels) curves on modern r.c. buildings are characterized by narrow peaks in the horizontal H_i/H_0 components and flat curves in the vertical Z_i/Z_0 components.

3. APPLICATIONS TO VIBRATION PROBLEMS

Proceed as described at point 2 above. See also the UNI 9916, DIN 4150 etc. protocols.

HOW TO POSITION TROMINO®

1. STRATIGRAPHIC APPLICATIONS

The key is to couple the instrument to the ground as rigidly as possible. In case of soft soil, plant it as much as possible. It is OK if the bottom touches the ground. There is no need to dig a hole. Don't be fussy with levelling: a 2° misalignment (the bubble at the border of the spirit level centre) is fine. Just press on one spike at a time applying a firm vertical pressure. Do *not* try to improve levelling by working the nails back and forth out of the ground: that might improve levelling but will spoil coupling rigidity and the measurements. Recall that spikes are nails and work in shear: would you hang a picture to the wall by making the nails loose to achieve sub-millimetre precision in absolute height? If you happen to end up severely off level, move the instrument laterally a few centimetres and start the whole operation from the beginning.

Sometimes coupling to the ground can be difficult, like for example in presence of large cobble stones. You may then use sand or soft ground as a coupling means. Avoid to spoil the instrument coupling to the ground with an additional base of any material. Never use bases of metal.

2. ENGINEERING APPLICATIONS

On levelled artificial surfaces (e.g. pavements) put the instrument on the ground with *no* spikes. TROMINO®'s base is expressly designed to provide the best possible coupling in this case. On uneven artificial surfaces (e.g. pavements) use the short spikes, and level.

3. APPLICATIONS TO VIBRATION PROBLEMS

Proceed as described at point 2 above. Do *not* use any spikes on levelled surfaces.

ANALYSING TROMINO® RECORDINGS

PARAMETER SETTING

1. STRATIGRAPHIC APPLICATIONS

WINDOW SIZE. The length of the window to be analysed (WINDOW SIZE in Figure 4) should be chosen according to the lowest frequency of interest and to the duration of the recording.
Typically, it is 20-30 s for recordings longer than 10 min, and 15 s for recordings shorter than 10 min.
Do not use window sizes shorter than 15 s if the lowest frequency of interest is lower than 0.1 Hz.

SMOOTHING. A 10% triangular smoothing is a good compromise for most stratigraphic applications.
If in doubt about the stratigraphic origin of an H/V peak, drop the smoothing to 1-5%. In this way, the peaks of anthropic origin become thin spikes (Dirac δ like) on all 3 spectral components and appear completely different from the stratigraphic peaks, which, on smoothed spectra, occur at a local minimum on the vertical component which is absent in the horizontal spectral components. This originates a typical "eye shaped" pattern when the three components are plotted together (Figure 6).

ANALYZE BETWEEN. The significance analysis of the largest H/V peak is performed by default according to the SESAME (2005) criteria, which consider the largest peak.
However, for what concerns seismic vulnerability, the most important soil resonance, and the related H/V peak, is not the one with the largest amplitude, but the one which has a frequency comprised between that of the building and its half. The reason is that a coincidence of the resonance frequencies induces a strong amplification which may damage an integer building. This is only the first part of the story: damage decreases the building resonance frequencies, so that a resonant coincidence at a lower frequency will continue the job and destroy it.
Therefore, in presence of multiple H/V peaks, the significance analysis should be forced on the peaks of interest by modifying the frequency range through the ANALYZE BETWEEN function, as in Figure 4.

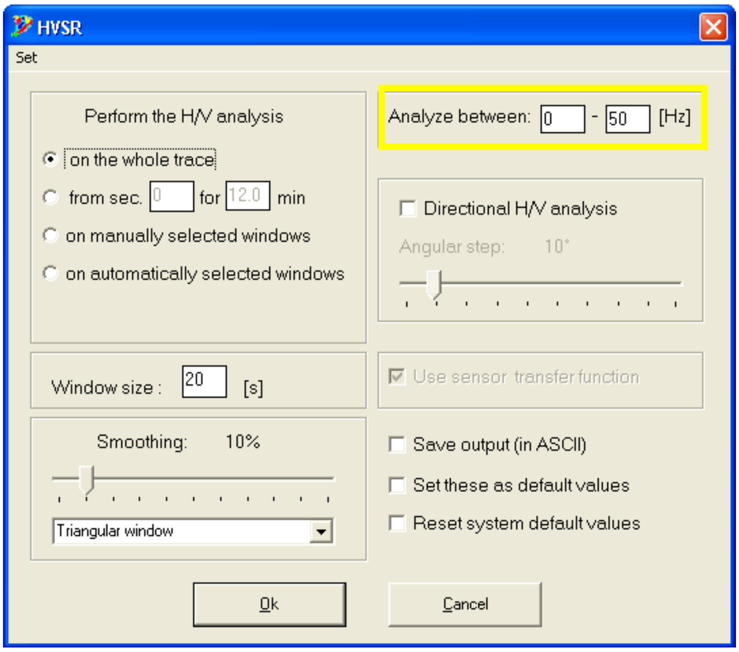

Figure 4.

TRACE CLEANING. Taking 'noise' out of a noise recording may sound as a contradiction. Quite on the contrary, since we are interested in the coherent part of noise, trace cleaning is a step of crucial importance to obtain the best results. Trace cleaning must be carefully performed before any interpretation attempt, bearing in mind what are the characteristic features of coherent and coherent noise.

The first of these features is that incoherent noise in the time domain is essentially due to 1) transients and 2) stationary near-white noise. While these two are totally different in the time domain, they are very similar in the frequency domain, in which they are both characterized by a flat spectrum. Note that also from the point of view of information theory a flat spectrum lacks information. In summary, trace cleaning is more effectively performed in the frequency domain, by simply excluding from the analysis the time intervals sections with a near flat spectrum. The basic practical rules to achieve an effective cleaning are reported in *? > Single Station (Tromino) > Index > HVSR on selected windows* (Figure 1).

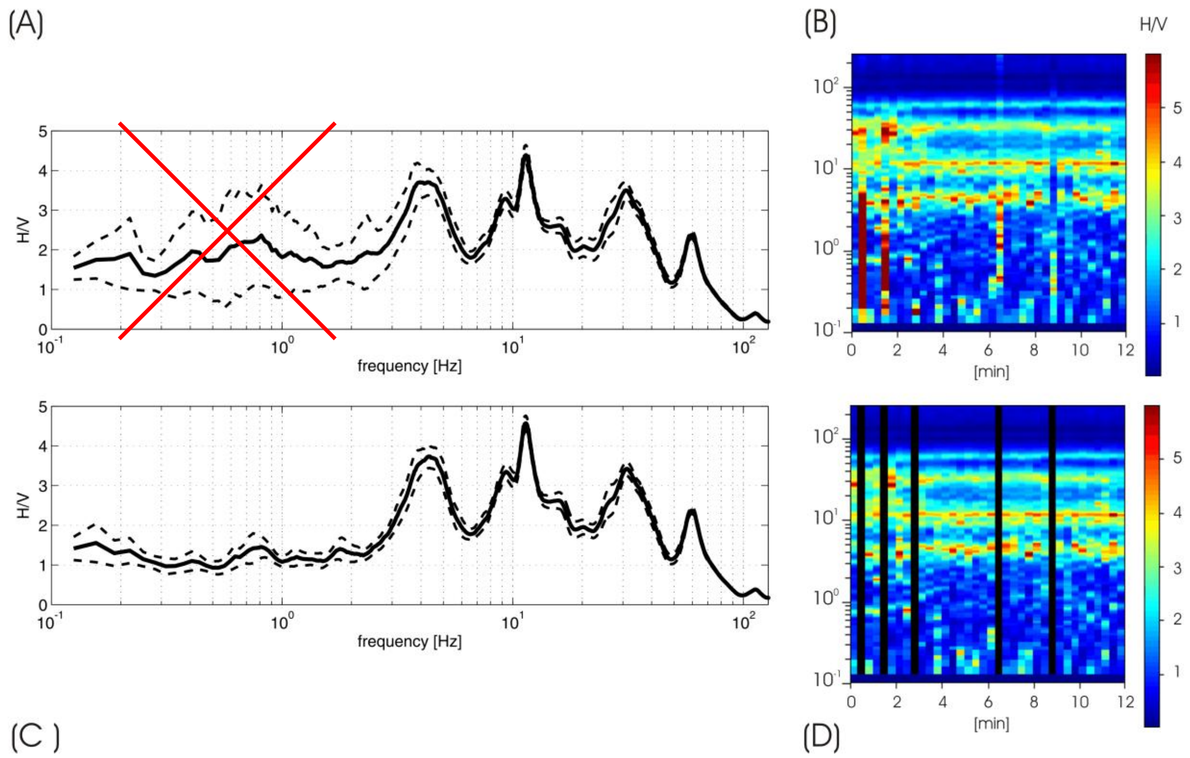

Figure 5. Average (solid lines) and σ intervals (dashed lines) recorded at the same site before (A) and after (C) the removal of noisy transients. (B) time stability of the H/V curve during the measurement (H/V amplitude in color, rime on the x-axis, frequency on the y-axis). (D) time windows remaining after the transient removal.

The basic steps to select the trace sections *to be retained* in the analysis are the following. In the window *HVSR stability* (to the right of Figure 5):

1) position the mouse on the H/V stability window (expand it to full screen to see it better),
2) left click on the starting point of the first trace section that you want *to keep*,
3) move the mouse to the right while still left clicking,
4) release the left click where you want the first trace section to end,
5) use the arrow keys (up, down, left, right) for fine corrections,
6) repeat for all the trace sections you want to keep,
7) press the green button on the toolbar to perform the analysis on the selected windows.

2. ENGINEERING APPLICATIONS

SMOOTHING. The vibration modes of structures occur at very well defined frequencies. Smoothing is nevertheless necessary due to the definition itself of spectral analysis, the statistical nature of which is not compatible with a zero smoothing. Nevertheless, due to the fact that structural modes are independently known to be tightly defined, smoothing can be kept low not to loose resolving power, with values ~5% representing an overall acceptable option.

3. APPLICATIONS TO VIBRATION PROBLEMS

Proceed according to the manual ? > *Single Station (Tromino)* > *Vibration module* (Figure 1).

DATA INTERPRETATION

GETTING SOMETHING OUT OF THE RECORDINGS

1. STRATIGRAPHIC APPLICATIONS

DISCRIMINATING NATURAL AND ANTHROPIC H/V PEAKS. H/V peaks of anthropic origin are not uncommon but discriminating these from stratigraphic H/V peaks is relatively easy. Proceed as we mentioned in the above: drop the smoothing to 1% so that the peaks of anthropic origin will appear as narrow spikes (Dirac δ like) at the same frequency on all 3 spectral components. This makes completely different from the stratigraphic peaks, which, on smoothed spectra, occur in correspondence of a local minimum on the vertical component absent in the horizontal spectral components. This originates a typical "eye shaped" pattern when the three components are plotted together (Figure 6).

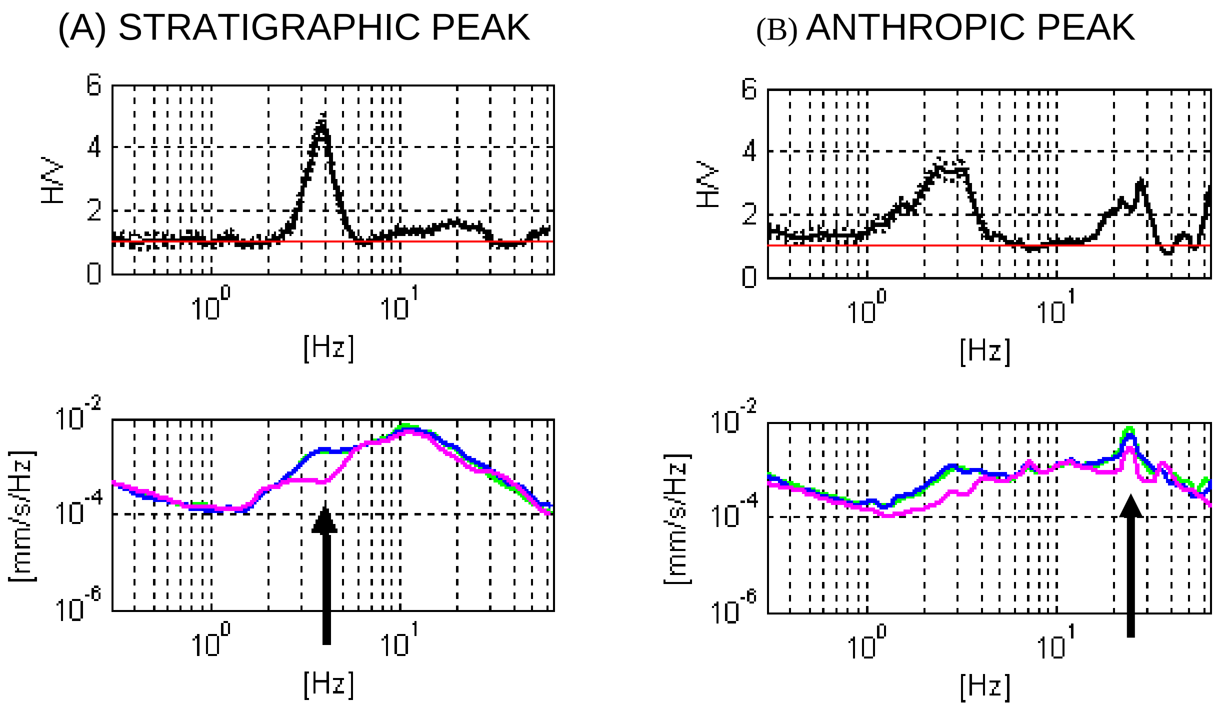

Figure 6. A) The H/V peaks of stratigraphic origin are characterized by a local minimum in the Z-component, leading to eye-shaped spectral structures. B) the H/V peaks of anthropic origin are characterized by narrow peaks of different amplitude on all spectral components. In the case illustrated the artefactual peak at 25 Hz is superimposed to a natural H/V peak.

CONSTRAIN AN H/V CURVE AND FIT A SYNTHETIC MODEL. Please refer to:

1) *? > Single Station (Tromino) > Synthetic H/V module* (Figure 1),

2) Vs30 estimates using constrained H/V measurements, Castellaro and Mulargia, *Bull. Seism. Soc. Am.* (2009),

In a nutshell, the steps towards a data fit are:

1. recognize on the H/V curve a peak which can be clearly ascribed to a stratigraphic discontinuity of independently known depth,
2. fix this depth as the thickness of the first layer. Give a first order approximate estimate of Vs in the first layers by using the equation f = Vs / (4h),
3. add a second layer roughly estimating its Vs from the H/V amplitude and proceed by trial and error (increase the Vs of the second layer if the synthetic peak is too low, decrease it if it is too high),
4. proceed similarly for all the other H/V peaks and the related layers.

A few "golden rules":

a) **To reproduce one H/V peak 2 layers are sufficient. To reproduce a number N of H/V peaks N+1 layers are sufficient.** Recall that the addition of any other layer is against Occam's razor, the basic principle of physical modelling, which prescribes that the lowest number of parameters must always be used[4],
b) The presence of true velocity inversions requires the addition of one layer in the model. Make sure that the velocity inversion is 1) large enough to be practically meaningful, 2) supported by solid evidence and 3) geologically justifiable.
c) Model the curve only for frequencies below 30 Hz. Higher frequencies are relative to the first meter of subsoil, which has generally large local variations of modest stratigraphic and engineering interest.

RECALL THAT THE H/V CURVES CAN BE CONVERTED TO Vs CURVES ONLY IF AN INDEPENDENT CONSTRAINT, i.e. the depth of a discontinuity or the Vs of the first layer, IS AVAILABLE.

[4] "With four parameters I can fit an elephant, with a fifth I can make his trunk move" (Enrico Fermi).

Example. Consider the example of Figure 7. There is a clear peak at 17 Hz which can be associated to a *known* seismic discontinuity at 3 m depth. We can then fix the thickness of the first layer (3 m) and proceed with a first order estimate of its Vs (17 Hz x 4 x 3 m = 204 m/s).

For the second layer we have to reproduce an H/V peak with amplitude 4. After a few trials we find that a Vs = 480 m/s in the second layer produces a very good fit of this peak.

Let us now move to the peak at 3 Hz, which requires the presence of a third layer. According to the velocity in the two first layers, we may roughly estimate the weighted average of Vs from the surface down to this second discontinuity around 450 m/s. This yields a depth h = Vs / (4f) = 450 / (4 x 3) = 37 m. We use 34 m as a starting value for the thickness of the second layer and set the bedrock Vs at 800 m/s. After a few trials we obtain that a thickness of 37 m and a Vs bedrock of 950 m/s provide an acceptable fit and a simple model that satisfies Occam's razor.

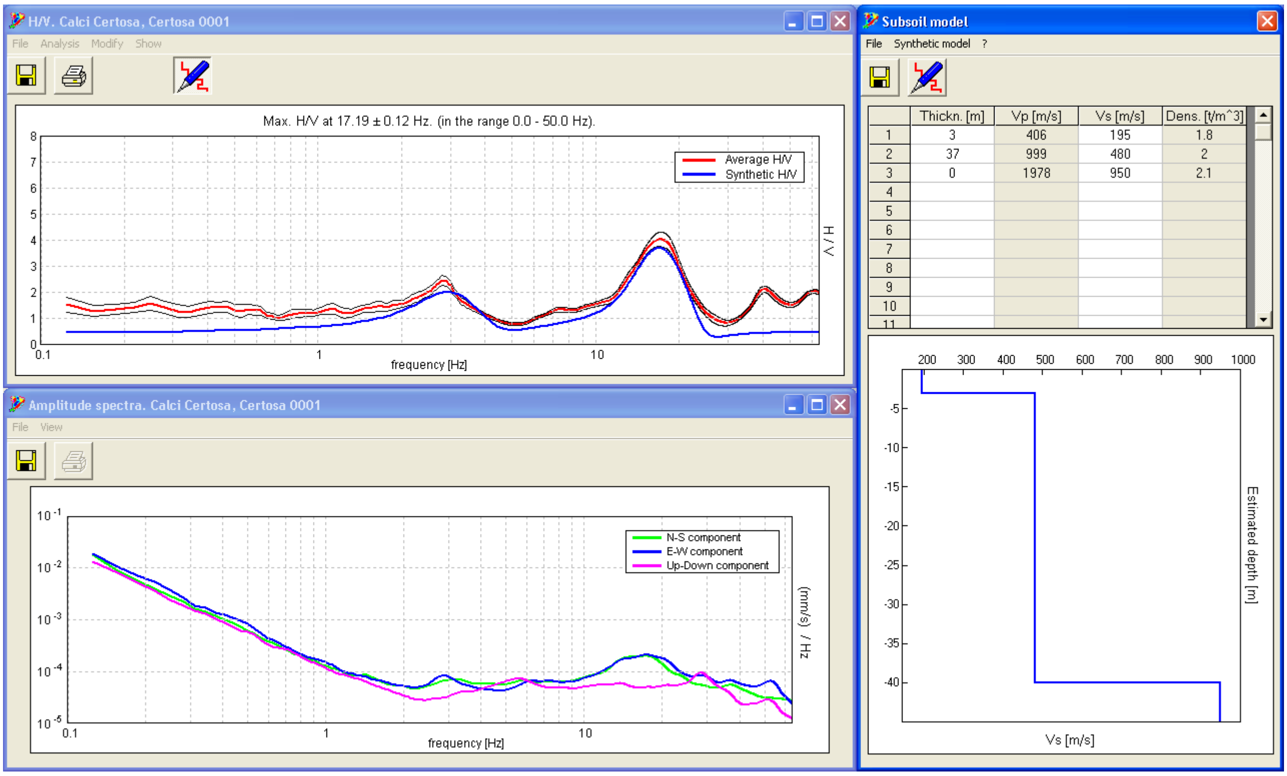

Figure 7.

FRAMING THE H/V PEAKS WITHIN THE SESAME (2005) SIGNIFICANCE TABLES. After analyzing a file, select it as shown in Figure 8 step (1), then press the key (2). A window will open, summarizing all the analyses which have been performed on that specific file. Double clicking on the row of which you want to create a report, the Word™ document of which will automatically open.

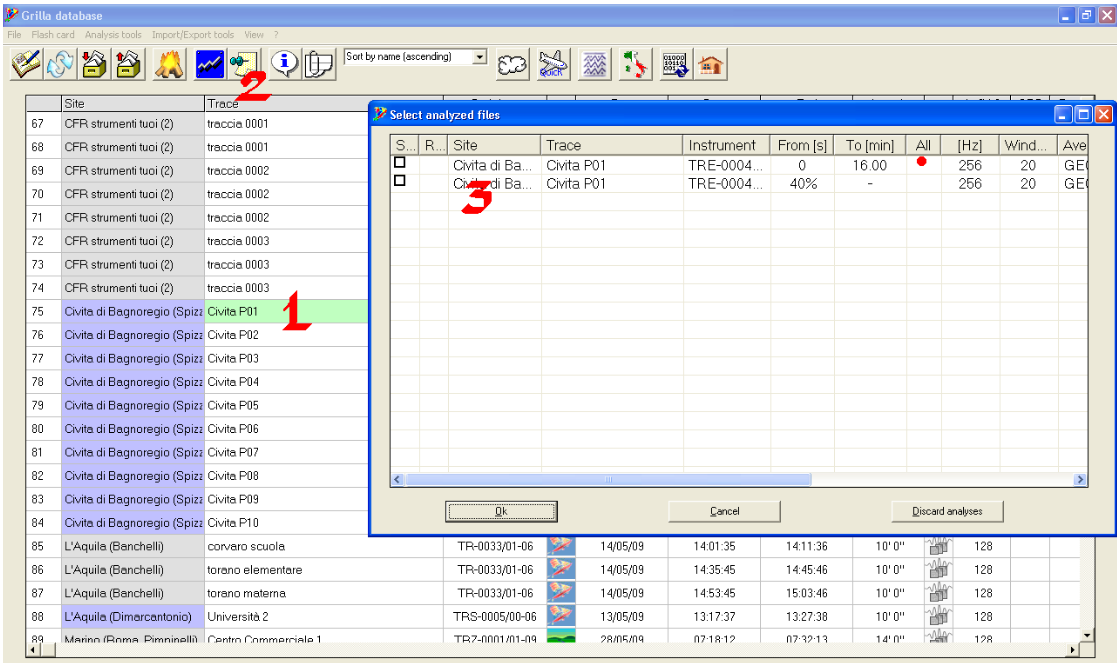

Figure 8.

The last page of this document compiles a table with SESAME (2005) criteria relative to the statistical significance of the considered peak (Table 1). Recall that the subsoil at a given site can have more than one resonance frequency and that none of these is *the* fundamental. The importance of each resonance, and its destructive potential, depends in fact on the resonance frequencies of what will erected above it. From an engineering point of view, the main H/V peak(s) (cfr. Figure 2) is therefore a concept that does not exist per se, but only relative to such building resonance frequencies.

Analysing a specific peak:

1) the first 3 criteria of the SESAME (2005) table concern the relative length of the time partition as a function of the frequency of the peak. All the 3 criteria should be satisfied. If not, the data should be typically reanalyzed after modifying the WINDOW SIZE in Figure 4.

2) the second 6 criteria of the SESAME (2005) table concern the statistical significance of the peak. It is important that as many criteria as possible are satisfied but the fact that some

criteria are not satisfied does NOT imply that the H/V curve is faulty. In fact, a perfect recording on rock would give NO to all these criteria.

Max. H/V at 55.94 ± 2.76 Hz (in the range 0.0 - 64.0 Hz).

Criteria for a reliable HVSR curve [All 3 should be fulfilled]			
$F_0 > 10 / L_w$	55.94 > 0.50	**OK**	
$n_c(f_0) > 200$	46987.5 > 200	**OK**	
$\sigma_A(f) < 2$ for $0.5f_0 < f < 2f_0$ if $f_0 > 0.5Hz$ **$\sigma_A(f) < 3$ for $0.5f_0 < f < 2f_0$ if $f_0 < 0.5Hz$**	Exceeded 0 out of 1154 times	**OK**	
Criteria for a clear HVSR peak [At least 5 out of 6 should be fulfilled]			
Exists f^- in $[f_0/4, f_0]$ | $A_{H/V}(f^-) < A_0 / 2$	47.656 Hz	**OK**	
Exists f^+ in $[f_0, 4f_0]$ | $A_{H/V}(f^+) < A_0 / 2$			**NO**
$A_0 > 2$	3.83 > 2	**OK**	
$f_{peak}[A_{H/V}(f) \pm \sigma_A(f)] = f_0 \pm 5\%$	|0.0241| < 0.05	**OK**	
$\sigma_f < \varepsilon(f_0)$	1.34815 < 2.79688	**OK**	
$\sigma_A(f_0) < \theta(f_0)$	0.1644 < 1.58	**OK**	

Table 1.

2. ENGINEERING APPLICATIONS

To measure the vibration modes of a construction, it is necessary to sort out the vibration modes of the of subsoil. The classical technique to do this is called Standard Spectral Ratio (SSR). In *Grilla* you perform this through the following steps:

1) select the traces acquired at different floors of the structure as shown in Figure 9. A successful selection is indicated by green highlighting of the line. Selection is operated by clicking on the database (DB) line while pressing the SHIFT or CONTROL keys, like when you are using Explorer in Windows,

2) click on the button indicated by the red arrow in Figure 9 and the window of Figure 10 will open. As a reference site (that is the site with respect to which you refer the other traces through an operation called *deconvolution*) choose the measurement performed at the ground level. This site must be indicated as REF. (reference site) by clicking on the column Ref. of the window shown in Figure 10 and selecting the appropriate row (red arrow in Figure 10),

3) last, choose the traces to plot against the reference trace by clicking on the first column (green arrow in Figure 10).

WARNING!

Consider the H/V curve to analyse measurements performed **on soil** only.
Always use the reference site deconvolution H_i/H_0 (and never the H/V) to analyse **structures**!

H/V → soil
H_i/H_0 → structures

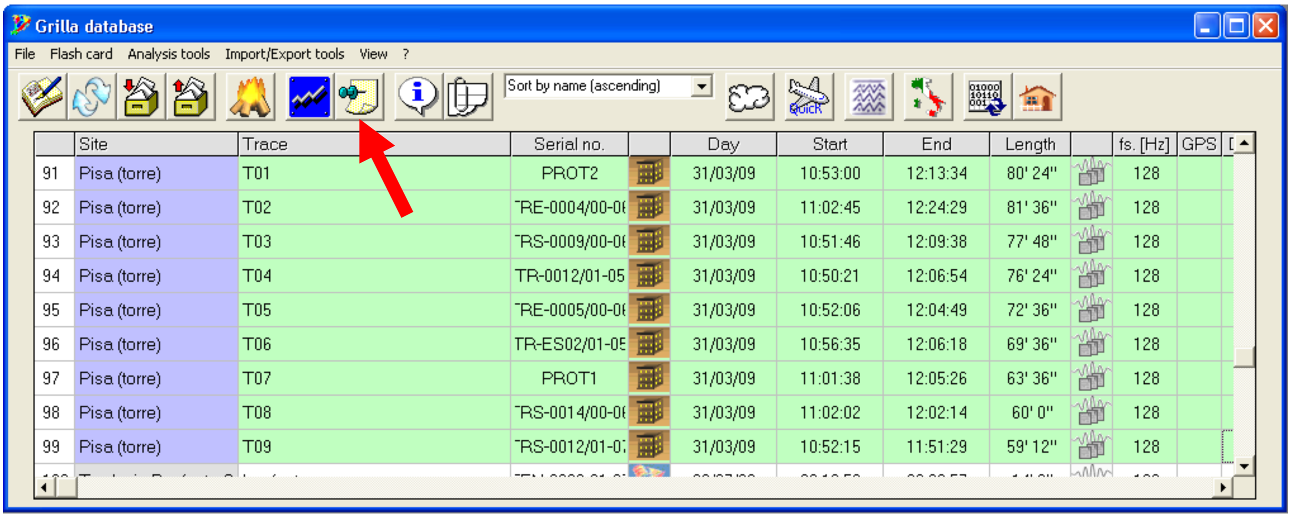

Figure 9.

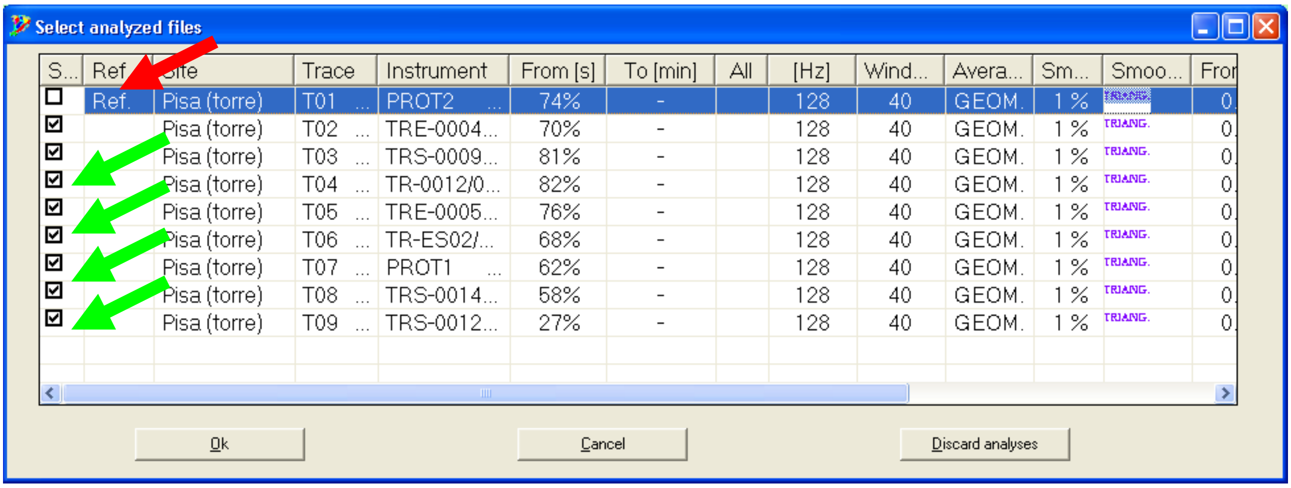

Figure 10.

3. VIBRATION PROBLEMS

Please proceed following manual ? > *Single Station (Tromino)* > *Vibration module* (Figure 1).

I CAN'T DO IT. PLEASE, HELP ME!

If you really get stuck on a particular problem that you don't find in these pages, you may contact support@tromino.it. **Please use only e-mail and *not* the phone.**

FACING A REALLY TOUGH CASE? SEND US THE TRACE

In some cases seismic noise analysis can be really challenging. Compatibly with their other commitments, our analysts will be happy to help you.

To send a record to support@tromino.it, enter the *Grilla* window which shows the recorded traces and press the button FILE INFO (the first one to the left of the toolbar, as shown by the yellow arrow in Figure 11). The path to the trace is reported at the bottom of the window that will open up (yellow box in Figure 11).

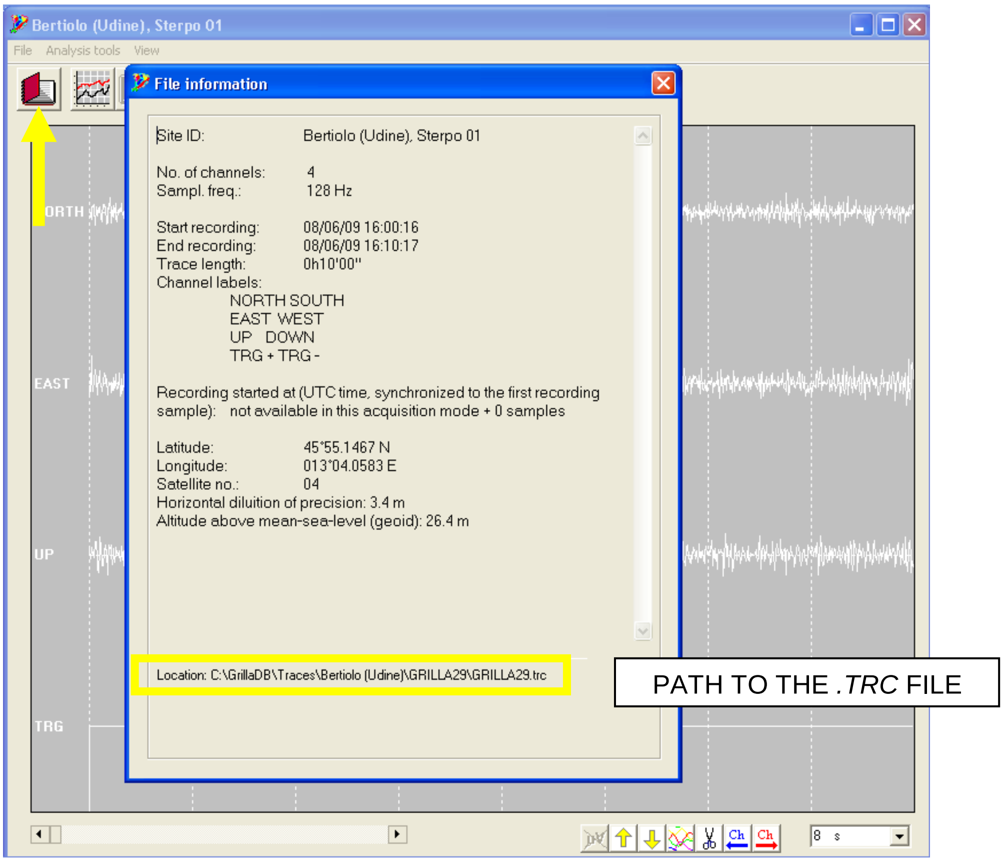

Figure 11.

APPENDIX

TYPICAL V-f-z RELATIONS IN 1-DIMENSIONAL SYSTEMS WITH 2 LAYERS

Since the most simple system, represented by a 1D layer (i.e. a half-space) is of little practical interest, we must regard the two layers (soft + bedrock-like[5]) system as the basic systems. Figure 12 to Figure 14 illustrate the relation between the velocity in the first (soft) layer, its thickness (i.e. the depth of the bedrock-like layer) and the resonance frequency of the system.

Remember that this relation is valid only for the basic 2 layer system. If this proves to be incompatible with the data, i.e. if more than one H/V peak is present, there is no such a simple relation. The reason is that the Physics of surface waves, which dominate the coherent noise wavefield, is nonlinear and the modelling of multilayer systems requires specific algorithms, like those present in the specific *Grilla*. module. In the multilayer systems you can use the figures below only to select the starting values, if independent data are unavailable.

For a better readability, the graphs have been separated into 3 frequency classes, corresponding to 3 depth classes of the bedrock-like layer (5-50 Hz, 1-10 Hz, 0.1-1 Hz).

The shear velocity in the soft layer has the typical following values:

- Vs = 100 m/s → typical of low quality clays, turfs…
- Vs = 200 m/s → typical of medium-good quality clays and sandy silts
- Vs = 300 m/s → typical of sand and gravel
- Vs = 400 m/s → typical of gravel and alterated/soft rocks
- Vs = 500 m/s → typical of soft /layered sedimentary rocks

[5] With bedrock-like we indicate any layer with a Vs velocity markedly larger than that of the above layer. In the H/V curve, this shows up as a clear peak. Note how a bedrock-like layer is not necessarily a rock. In alluvial planes it is most often cemented sand or gravel.

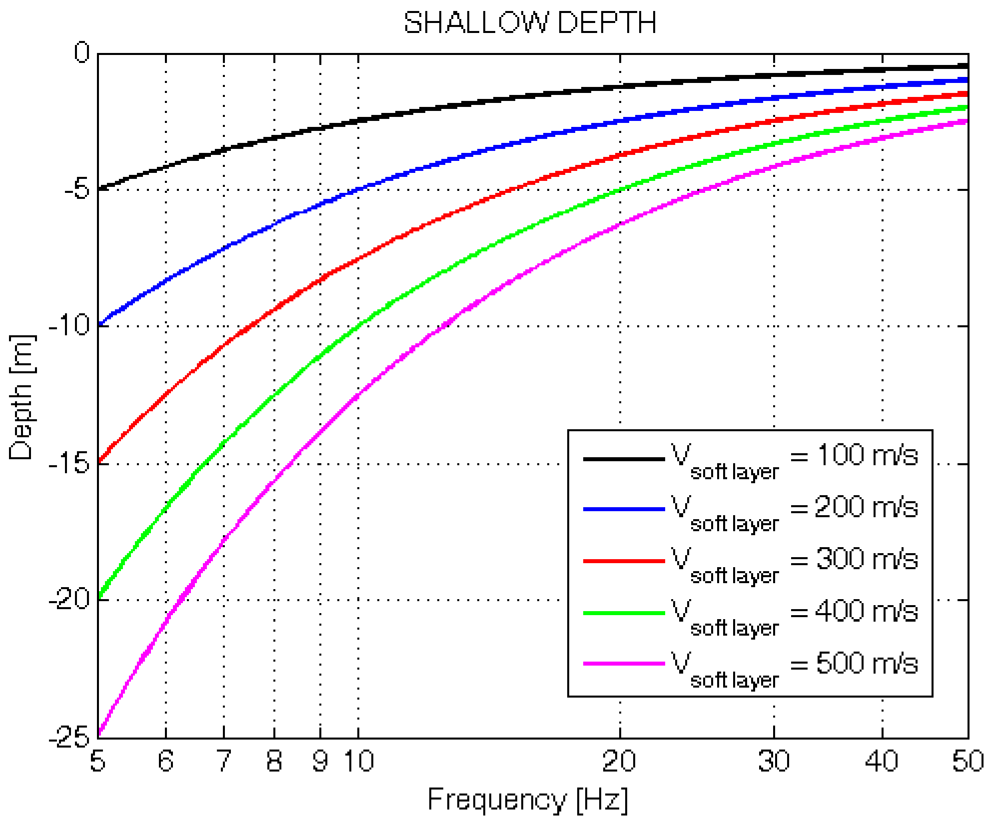

Figure 12. Typical frequency – shear wave velocity – bedrock depth relation for a 1-D 2 layer basic system (high frequency detail).

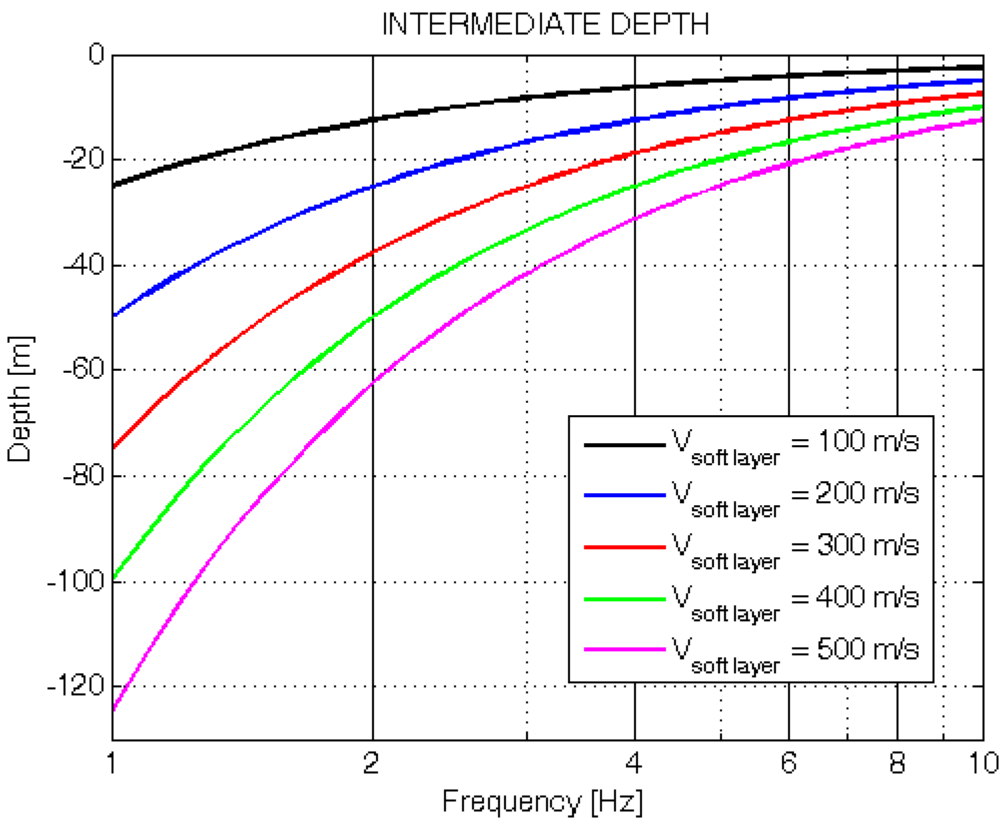

Figure 13. Typical frequency – shear wave velocity – bedrock depth relation for a 1-D 2 layer basic system (mid frequency detail).

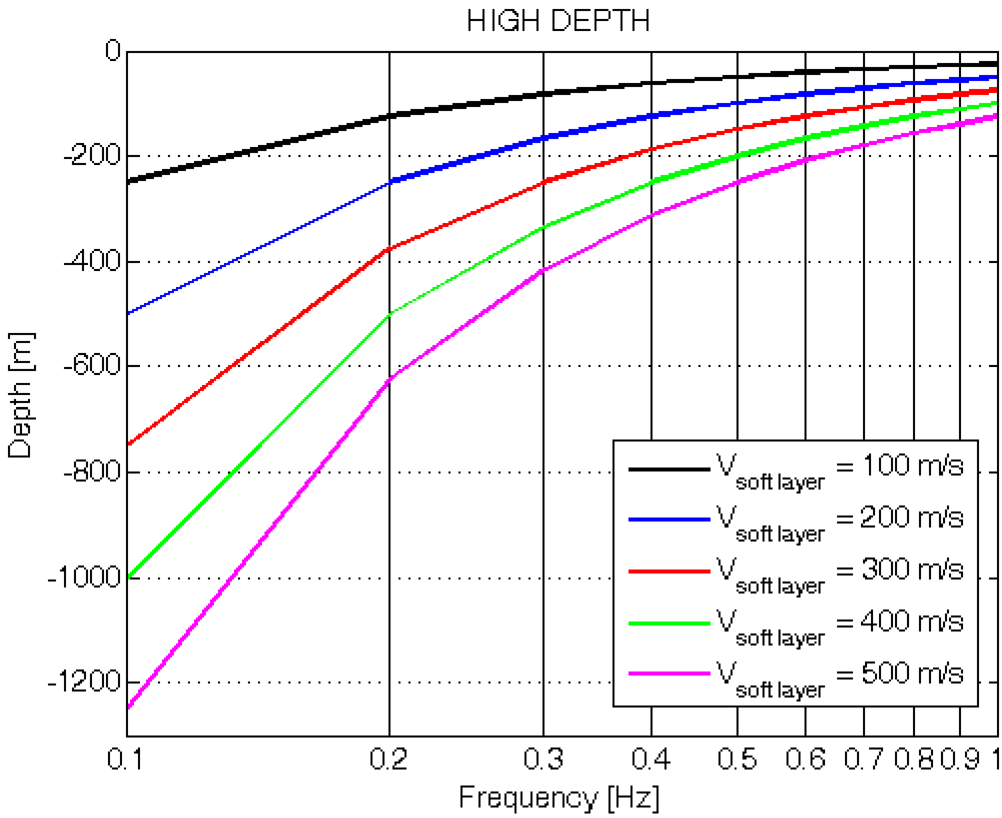

Figure 14. Typical frequency – shear wave velocity – bedrock depth relation for a 1-D 2 layer basic system (low frequency detail).