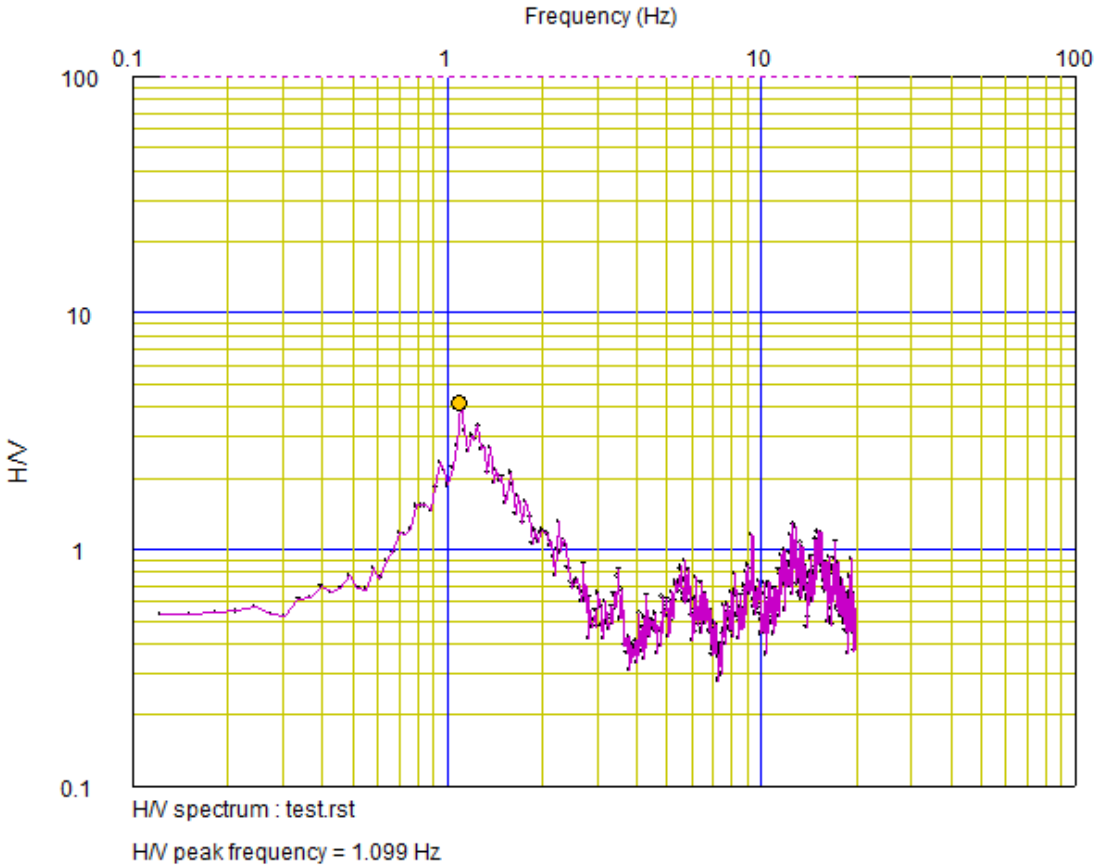
SeisImager/SW™ Manual Addendum (H/V)

Windows Software for Analysis of Surface Waves

Pickwin™ v. 5.1.0.5
WaveEq™ v.3.1.1.0
GeoPlot™ v. 10.0.0.7

Addendum v. 1.2

June 2013



kh

Table of Contents

1 - Introduction

The SeisImager/SW Manual Addendum provides description of the new H/V Spectrum Data Analysis Wizard and associated functions. The wizard automatically calls on specific functions from the Pickwin and WaveEq modules to walk you through the analysis process. The H/V Spectrum Data Analysis Wizard and associated functions are included in both the SeisImager/SW-1D and SeisImager/SW-2D packages.

SeisImager is also available for rent in run-time periods of 40, 75, and 250 hours. The rental package by default includes both SeisImager/2D and SeisImager/SW-2D.

In this manual addendum, only the wizard and explanation of the specific Pickwin and WaveEq functions called on by the wizard are briefly covered. Detailed explanation will be included in the next release of the SeisImager/SW Manual.

Some theory is touched on, but this manual is not meant to be a treatise on the H/V Spectrum (Nakamura) method. It is assumed that the user has a reasonable grasp of the main principals of seismology and mathematics in order to understand the principals behind the analysis techniques employed by the software. See Section 6 for a recommended reading list.

We are very interested in your constructive criticism of both this manual and the software itself. Please contact us at seismicsales@geometrics.com with any comments you might have.

Note: *All screens in this manual were captured in Windows XP Home or Professional Edition. If you are running a different version of Windows, some dialog boxes may look slightly different than they appear here.*

2 – Theory of H/V Spectrum

A three component micro-tremor measurement at single station has been widely used for estimating site characterization of earthquakes. The method has been called as Nakamura's method, HVSR (Horizontal Vertical Spectral Ratio) or H/V etc. In SeisImager/SW and this manual the word "H/V" is used for referring the three component micro-tremor measurement. Over the last few decades, theory of H/V has been the subject of controversy. Conventional theory of H/V was that microtremors mainly consisted of body waves and a peak frequency of H/V corresponded to resonance frequency of site. Based on this theory, a depth to bedrock (D_2) is calculated with peak frequency of H/V (f) as follows:

$$D_2 = \mathrm{Vs}_1 \div f \div 4. \quad (1)$$

Here, Vs_1 is an S-wave velocity of first layer.

Recently, it is generally agreed that the microtremors mainly consist of surface-waves and the H/V corresponds to ellipticity of Rayleigh waves. SeisImager/SW-Pro assumes the later theory and has introduced an inversion of H/V in which observed H/V data is compared with theoretical ellipticity of Rayleigh waves. In a calculation of theoretical H/V, higher modes of Rayleigh and Love waves can be considered. Conventional and latest theories of H/V are comparatively illustrated in Figure 2.1.

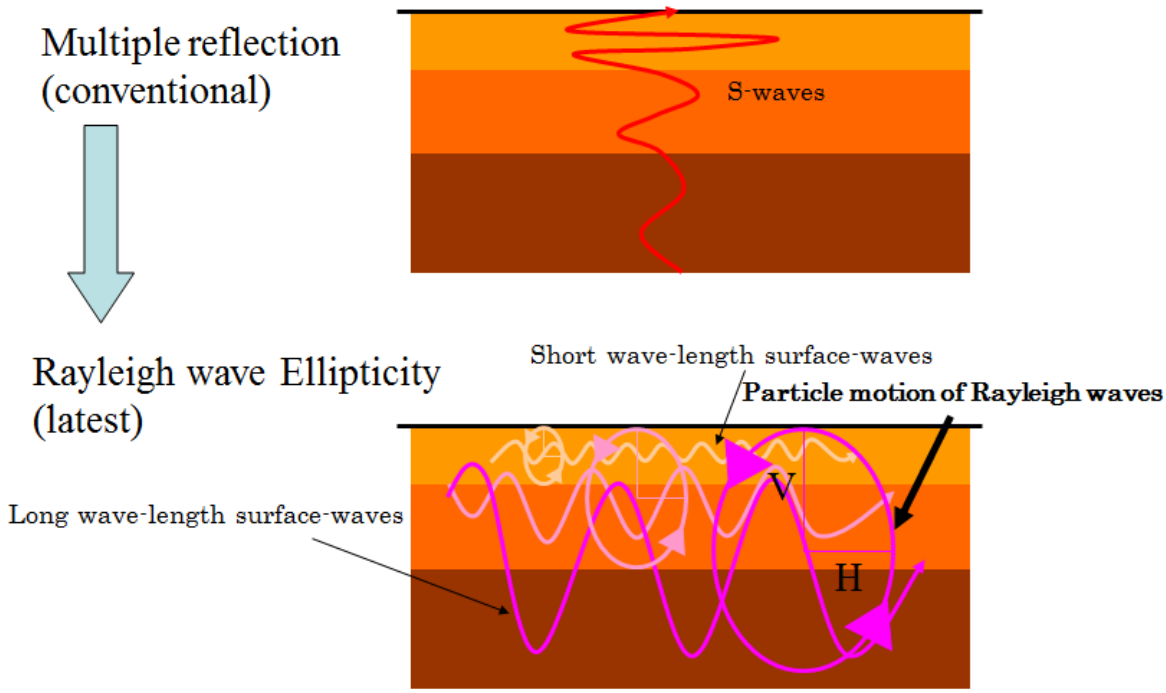
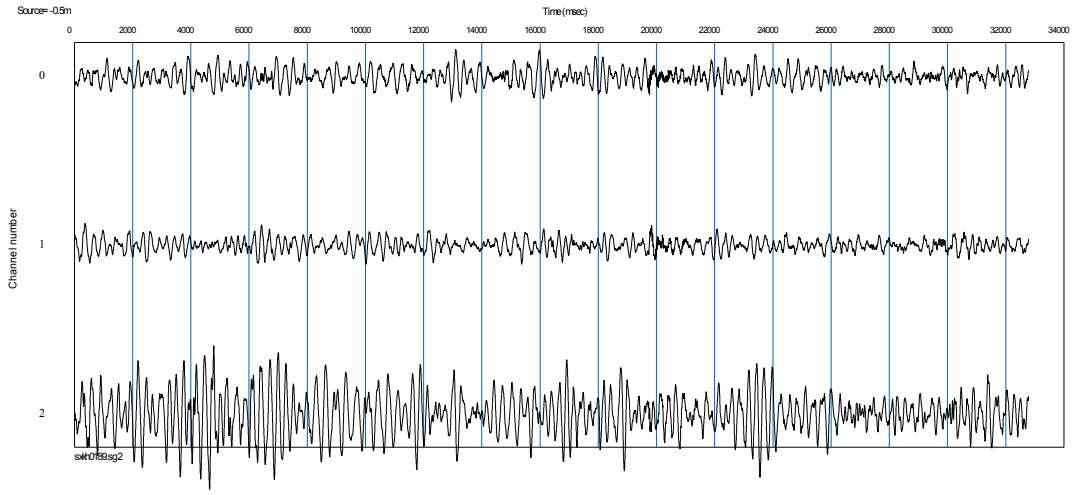


Figure 2.1. Conventional (top) and latest (bottom) theories of H/V

3 – Data Acquisition

A typical H/V Spectrum dataset is shown below.



An H/V analysis uses three component ambient vibrations generated by cultural noise, traffic, factories, wind, wave motions, etc. The ideal vibration sources are steady, at a constant level. The fundamental assumption of the H/V analysis is that sources are located infinite distance, waves are stable and isotropic (coming from all directions). In order to make up the assumption, the H/V analysis requires long record length. Required record length depends on a depth of investigation. Deep investigation requires longer record length. Table 3.1 shows typical required record length depending on the depth of investigation.

Table 3.1 Typical required record length depending on the depth of investigation

Depth of investigation (m)	Required total record length (min)	Sampling time (ms)	Number of samples	One file record length (sec)	Number of files
< 5	5	2	16384	32	10
2 to 30	10	4	16384	64	10
20 to 100	20	8	16384	128	10
100 <	30	8	16384	128	15

Depth of investigation relates to a frequency range of processing. Deeper investigation requires long period geophones or seismometers. Required frequency range and sensors depending on the depth of investigation is shown in Table 3.2.

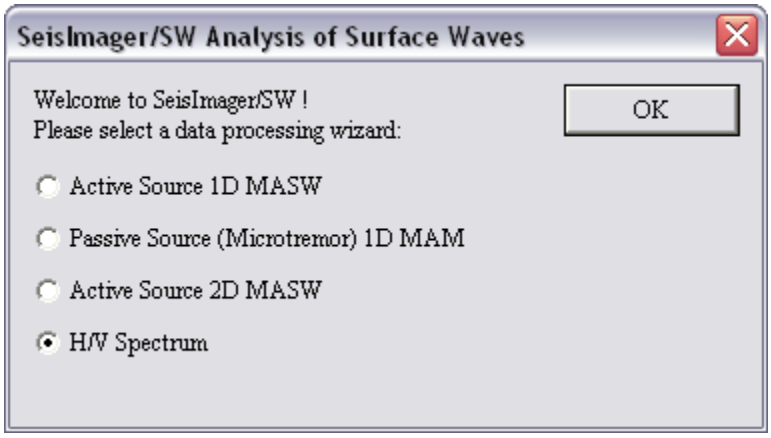
Table 3.2 Required frequency range and sensors depending on depth of investigation

Depth of investigation (m)	Frequency (Hz)	Sensor
> 5	10 <	4.5Hz
2 to 30	2 to 10	2Hz
20 to 100	0.5 to 2	2Hz, 1Hz or long period seismometer
100 <	0.1 to 0.5	Long period seismometer

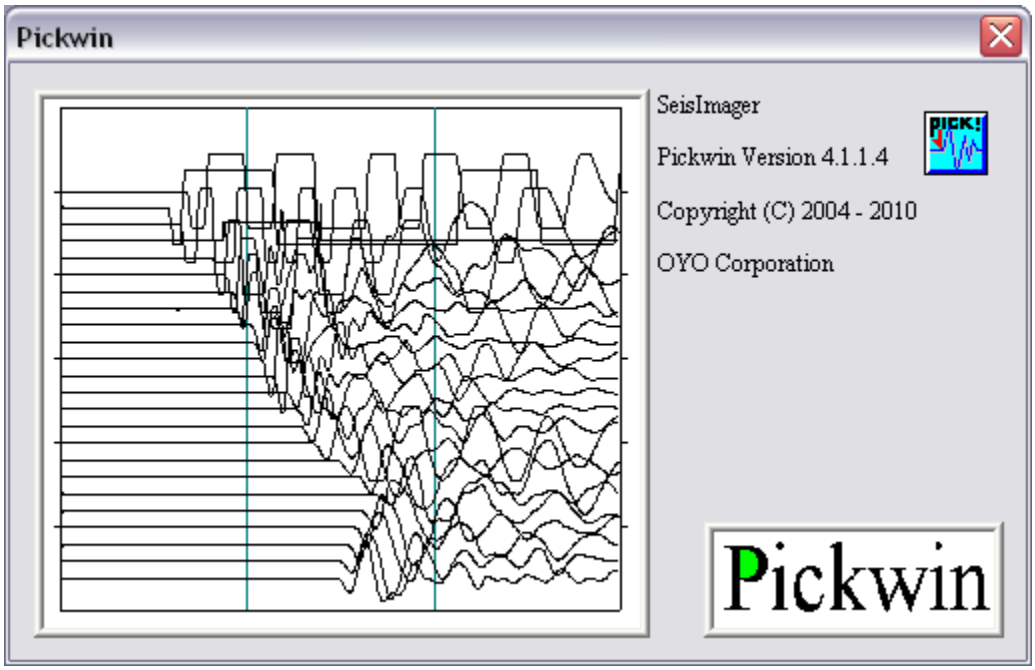
4 – H/V Spectrum Data Analysis Wizard

Double-click on the Surface Wave Analysis Wizard icon.

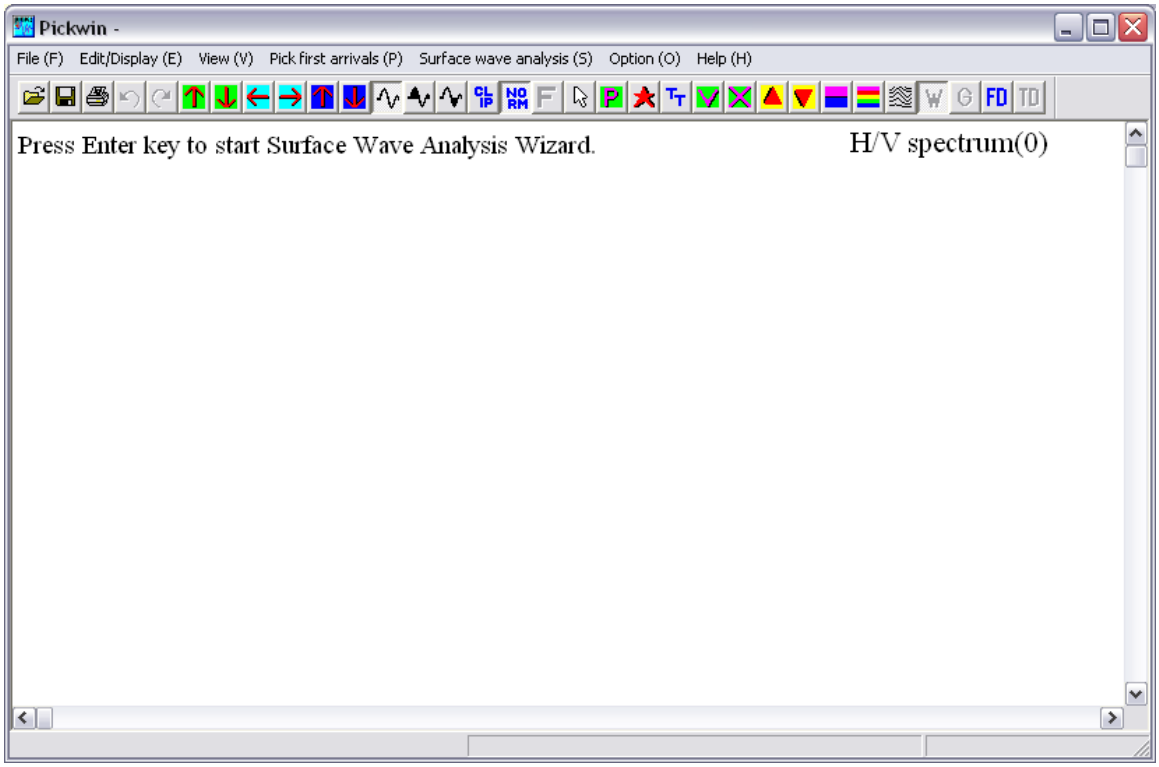
The *Welcome to SeisImager/SW* dialog box appears. Select *H/V Spectrum* and click *OK*.



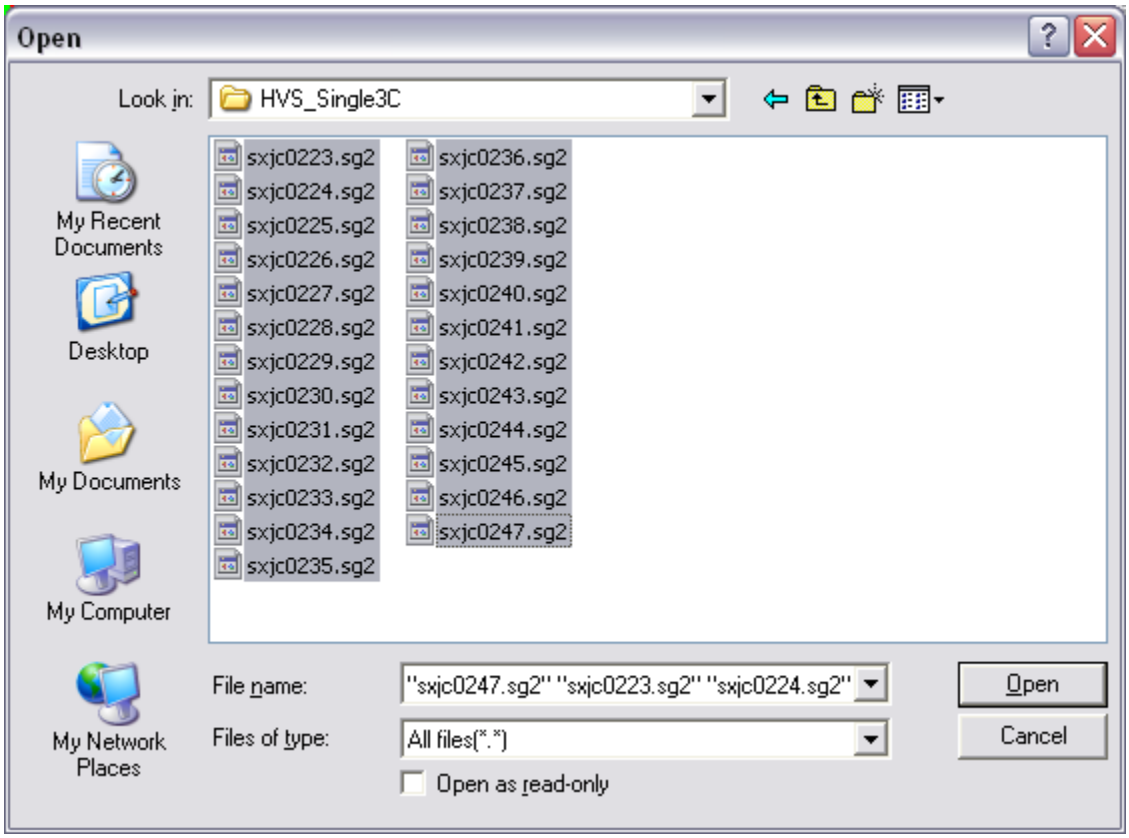
The Pickwin module is launched.



The main Pickwin window appears. The wizard calls functions from the *File* and *Surface Wave Analysis* menus. Press the *Enter* key as instructed in the upper left hand corner of the window to begin.

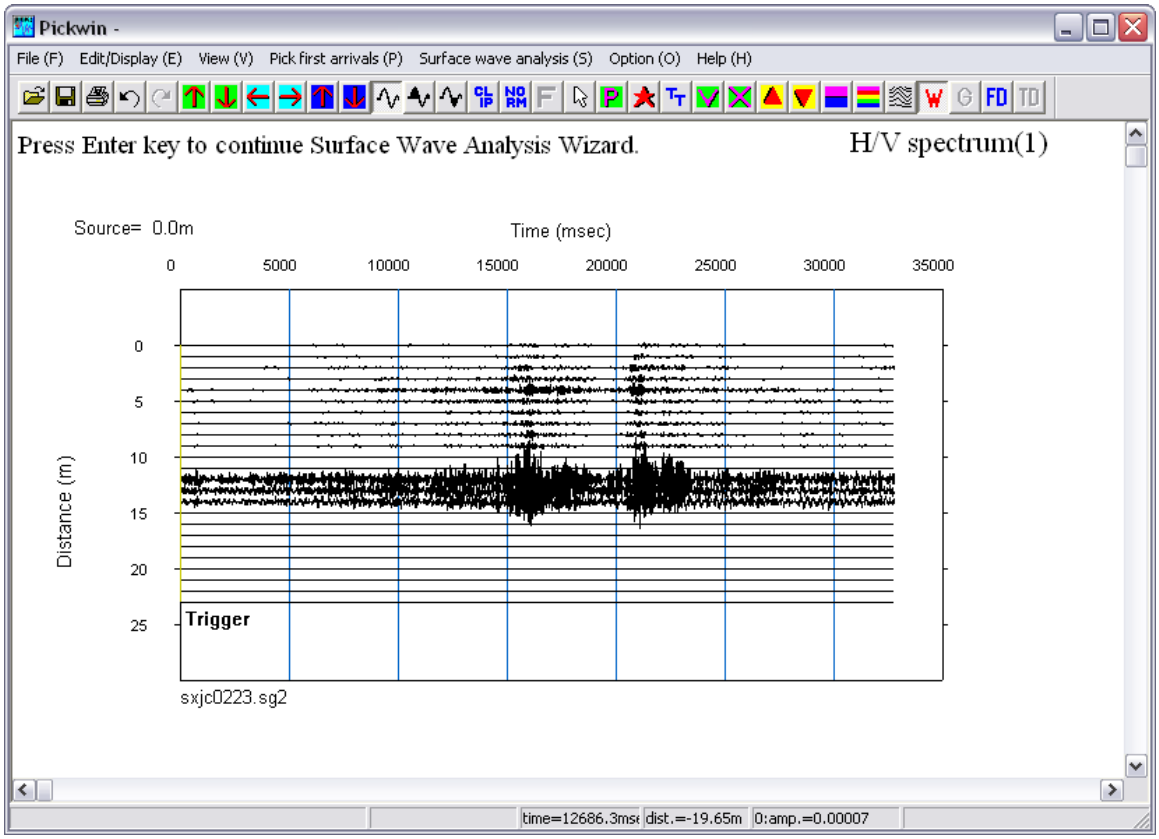


The first step is to input the dataset; all the dataset files are input at one time. Use the *Shift* key to highlight the first through last file in the dataset and click *Open*.

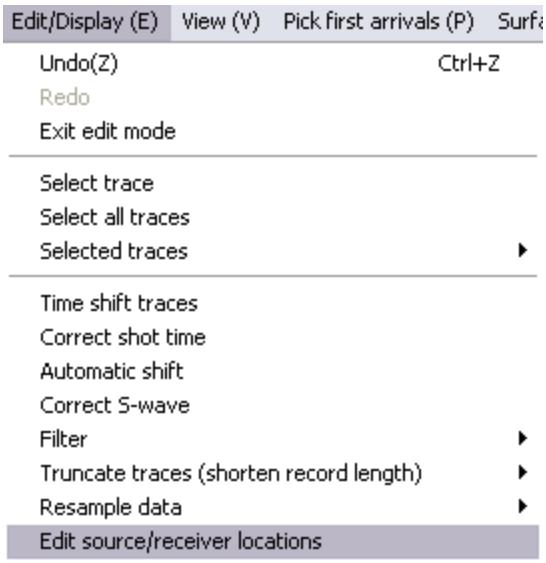


Once the selected files are open, click *OK*.

The first in the group of waveform files is displayed. In this example, a 24-channel seismograph was used and the files contain 21 traces of system noise in addition to the traces from the two horizontal and one vertical geophone components. The noise traces will be deleted at a later stage of the wizard.

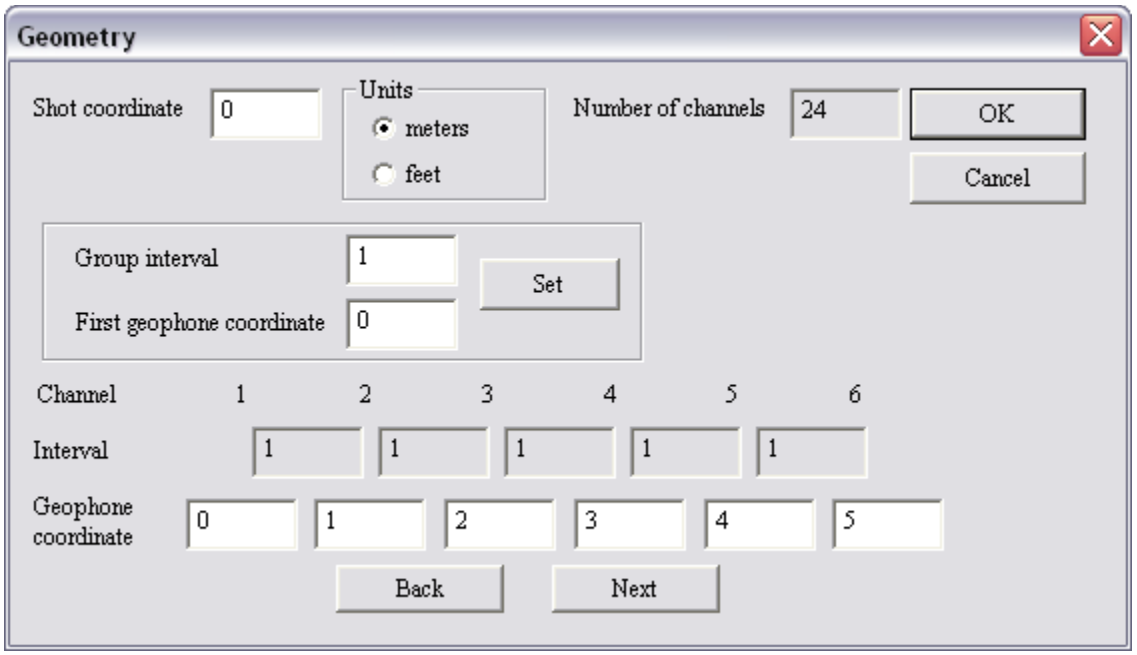


If the unit labels displayed are incorrect, select the *Edit/Display* menu, *Edit source/receiver locations*.

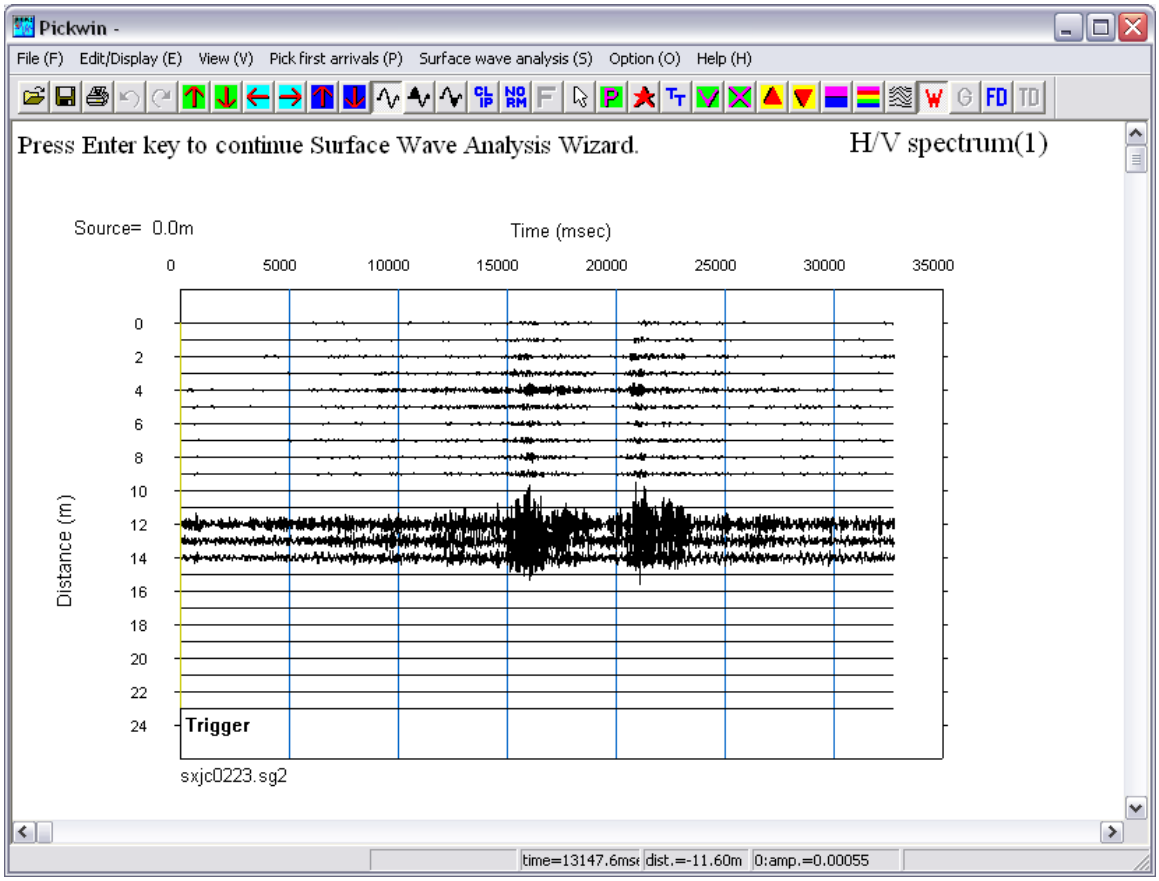

Edit/Display (E)
View (V)
Pick first arrivals (P)
Surfa
Undo(Z)
Ctrl+Z
Redo
Exit edit mode
Select trace
Select all traces
Selected traces
Time shift traces
Correct shot time
Automatic shift
Correct S-wave
Filter
Truncate traces (shorten record length)
Resample data
Edit source/receiver locations

The *Geometry* dialog box appears and the *Units* setting allows selection between *meters* and *feet*. The *Units* setting will affect the unit labels shown in the dialog boxes. Once set (and Pickwin is closed), the assigned units will be recalled for subsequent uses of the wizard. (It is necessary to close Pickwin to register the new *Units* setting. At the end of the wizard, simply close Pickwin to register the new *Units* setting.)

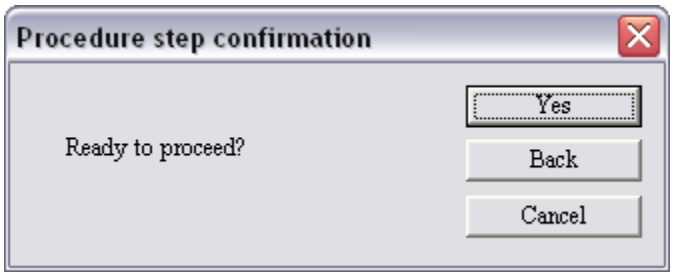
The *Geometry* dialog box also reports the source and receiver coordinates saved in the file header at the time of acquisition. This is non-applicable for H/V spectrum datasets. Click *OK* when done.



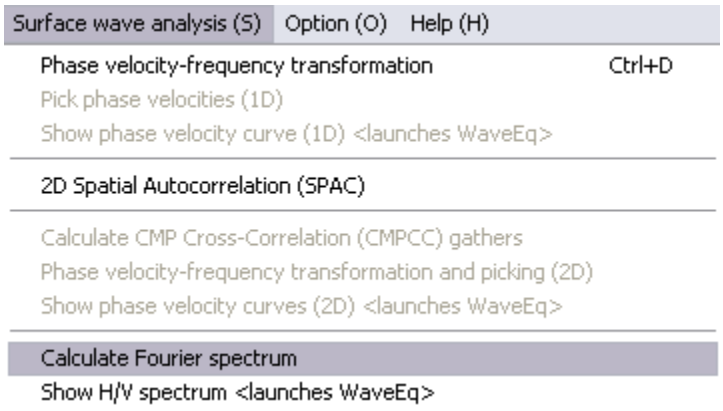
In the waveform view, the settings can be modified to optimize the display. All of these settings are common with SeisImager/2D for refraction data processing; refer to the SeisImager/2D manual included on the SeisImager CD for complete explanation. The main functions needed are the *Waveform amplitude*  buttons, the *Horizontal scale*  buttons, and the *Vertical scale*  buttons. When done, press the *Enter* key to continue.



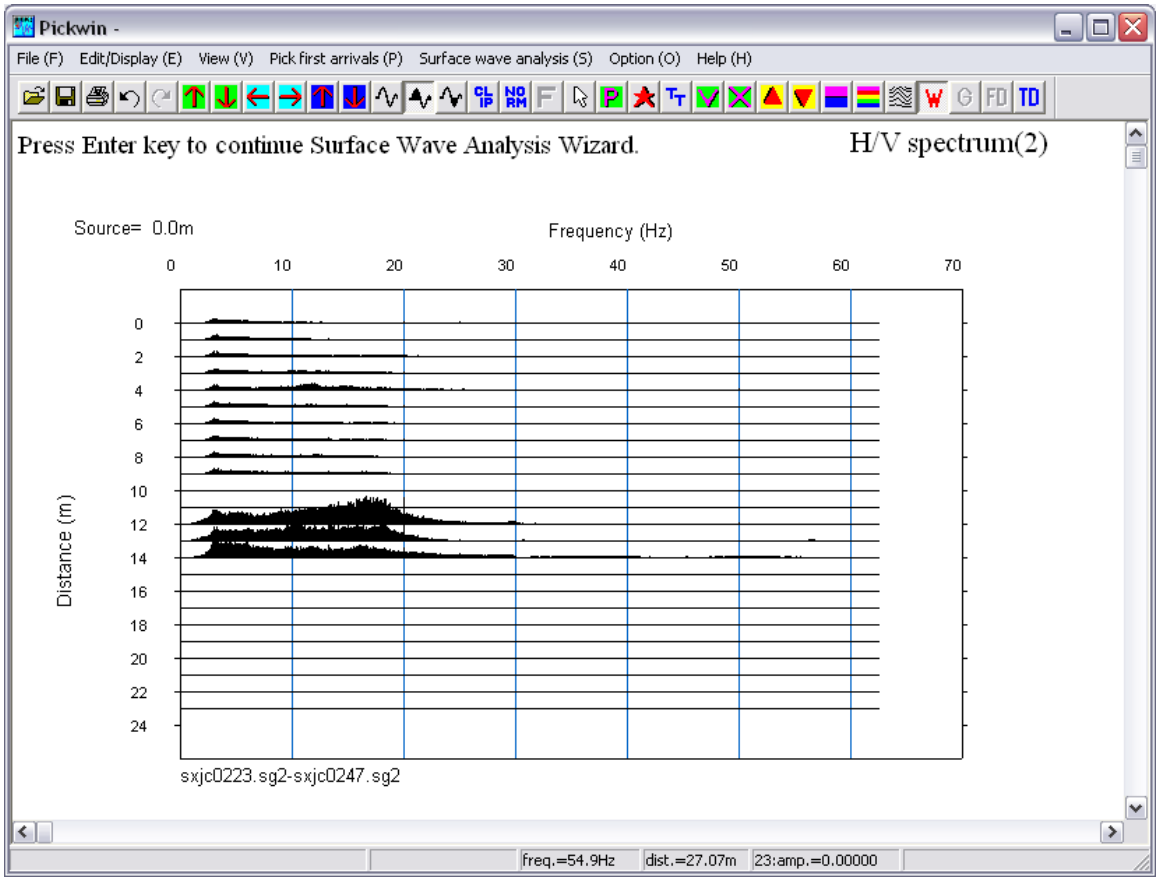
Click *Yes* when ready to proceed.



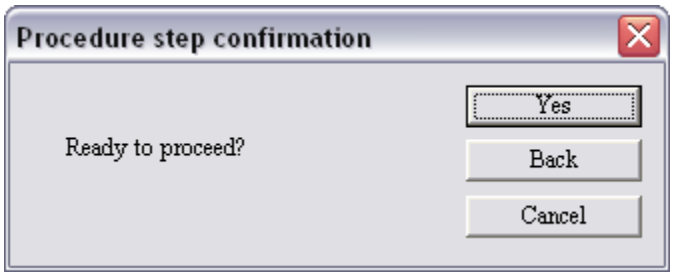
Next, the Fourier spectrum is calculated. To run this function outside of the wizard, select the *Surface wave analysis* menu, *Calculate Fourier spectrum*.



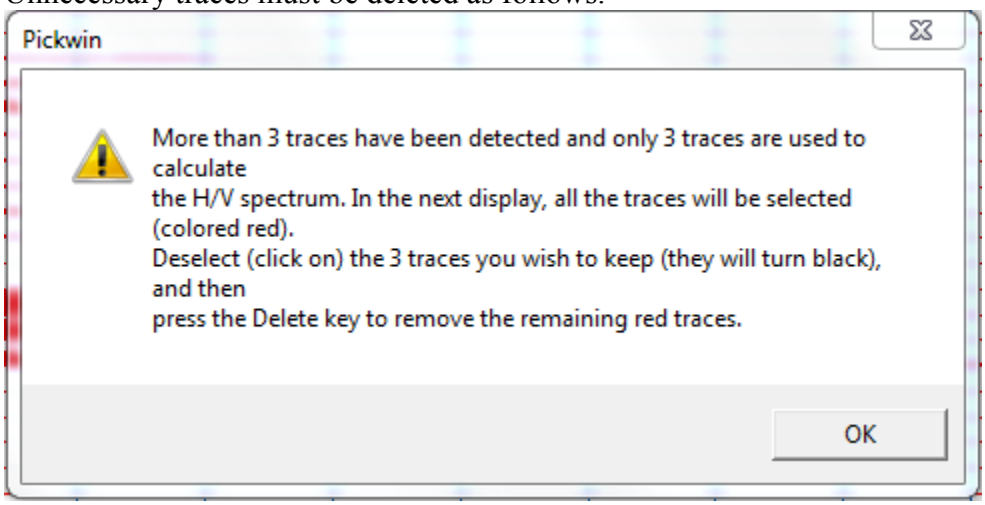
Once the calculation is complete, the spectrum is displayed. Press the *Enter* key to continue.



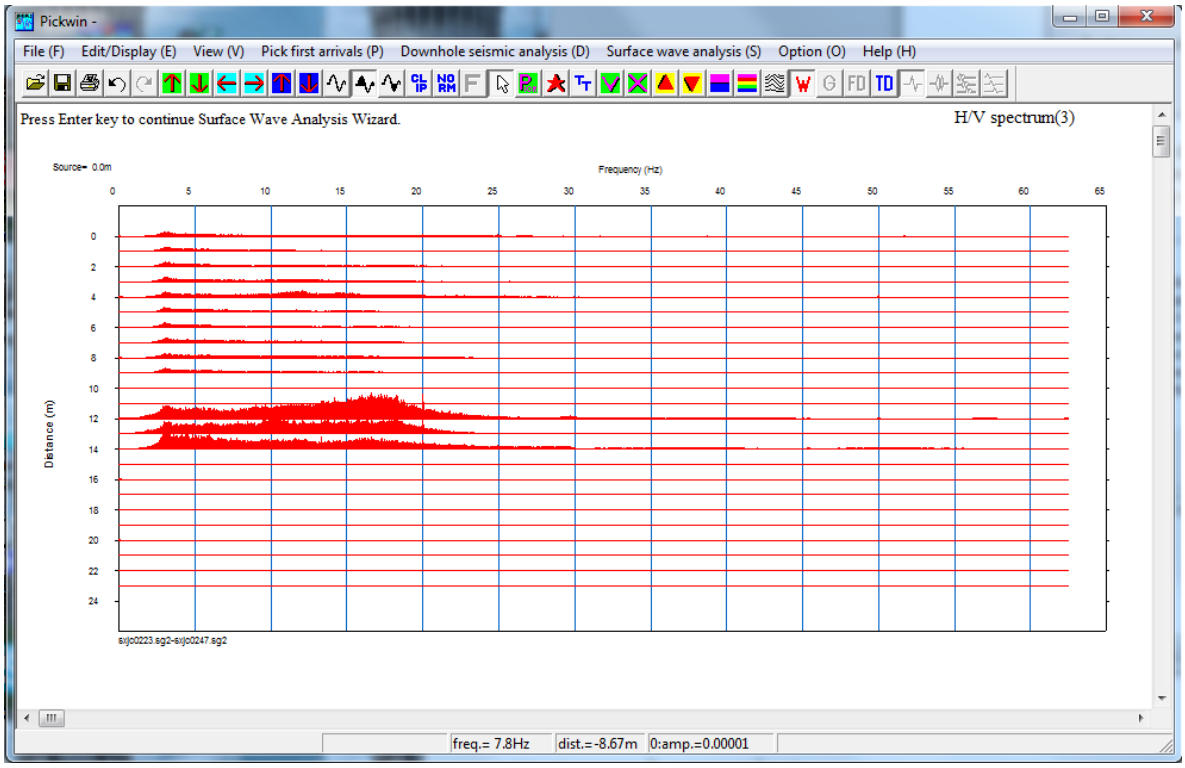
Click *Yes* when ready to proceed.



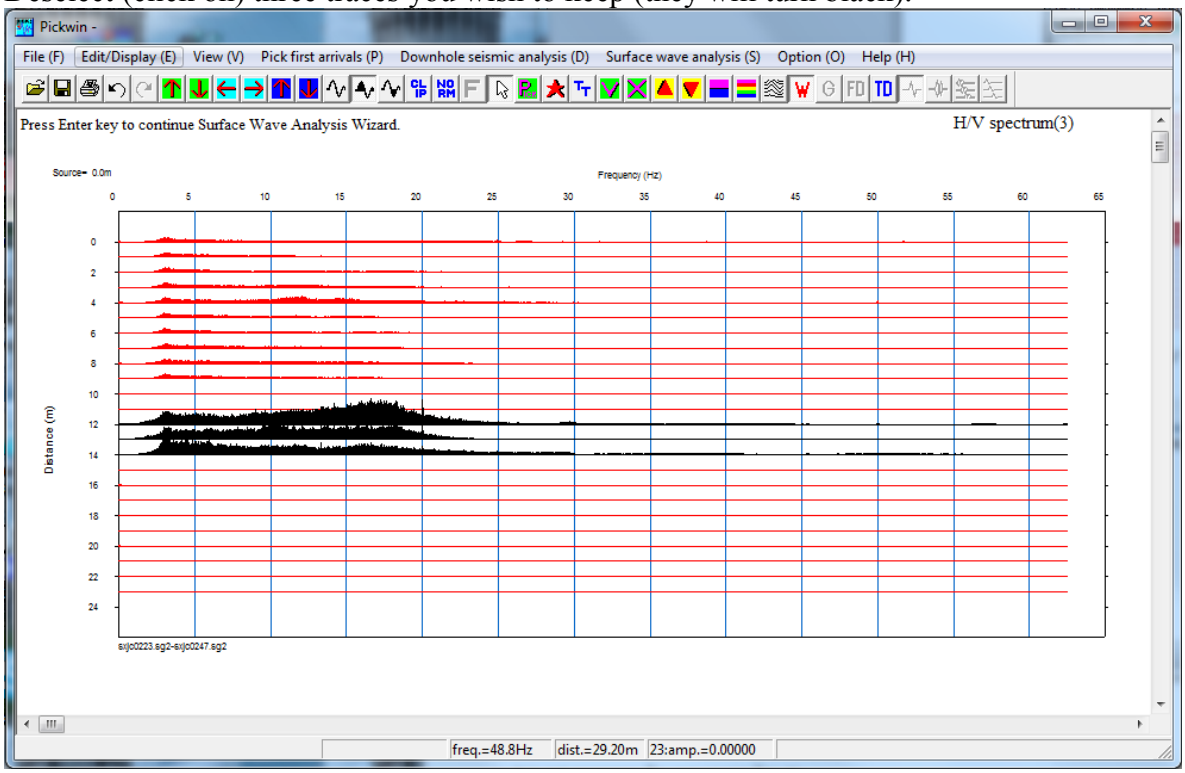
If there are more than 3traces, following message appears. In H/V analysis, only three traces (two horizontal components and one vertical component) are going to be used. Unnecessary traces must be deleted as follows.



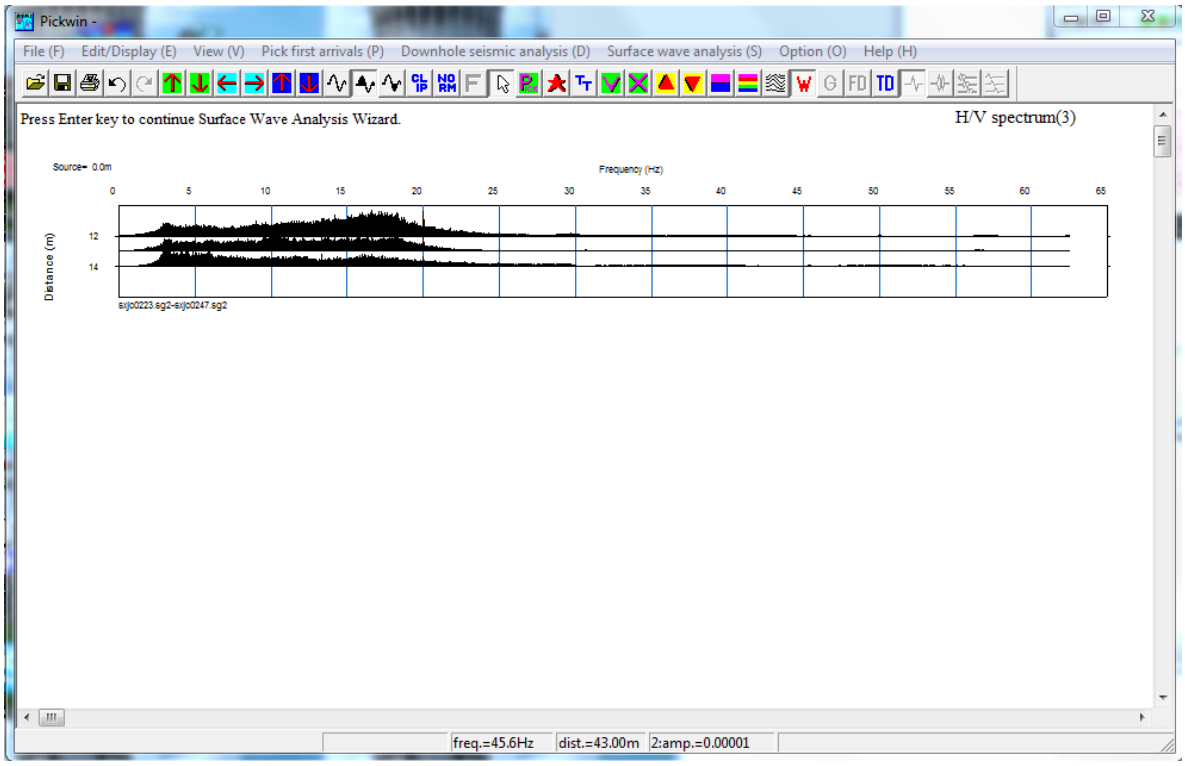
Click *OK* and all traces will be selected (colord red).



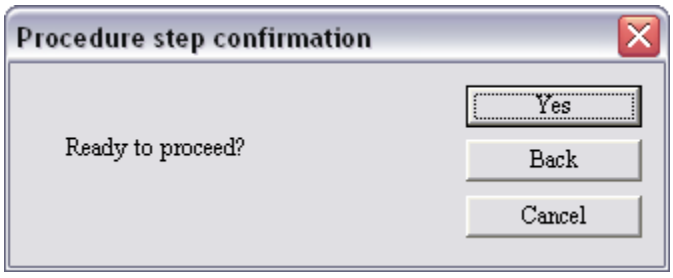
Deselect (click on) three traces you wish to keep (they will turn black).



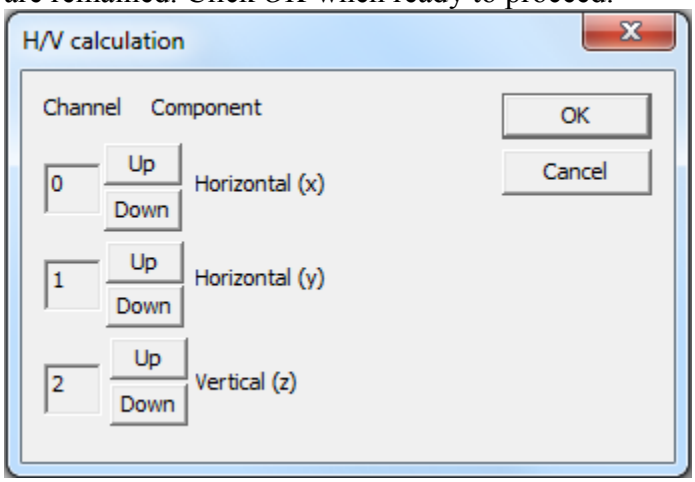
Then press the *Delete* key to delete remaing red traces. Theree traces will be remained.



Press the *Enter* key to continue. Click *Yes* when ready to proceed.

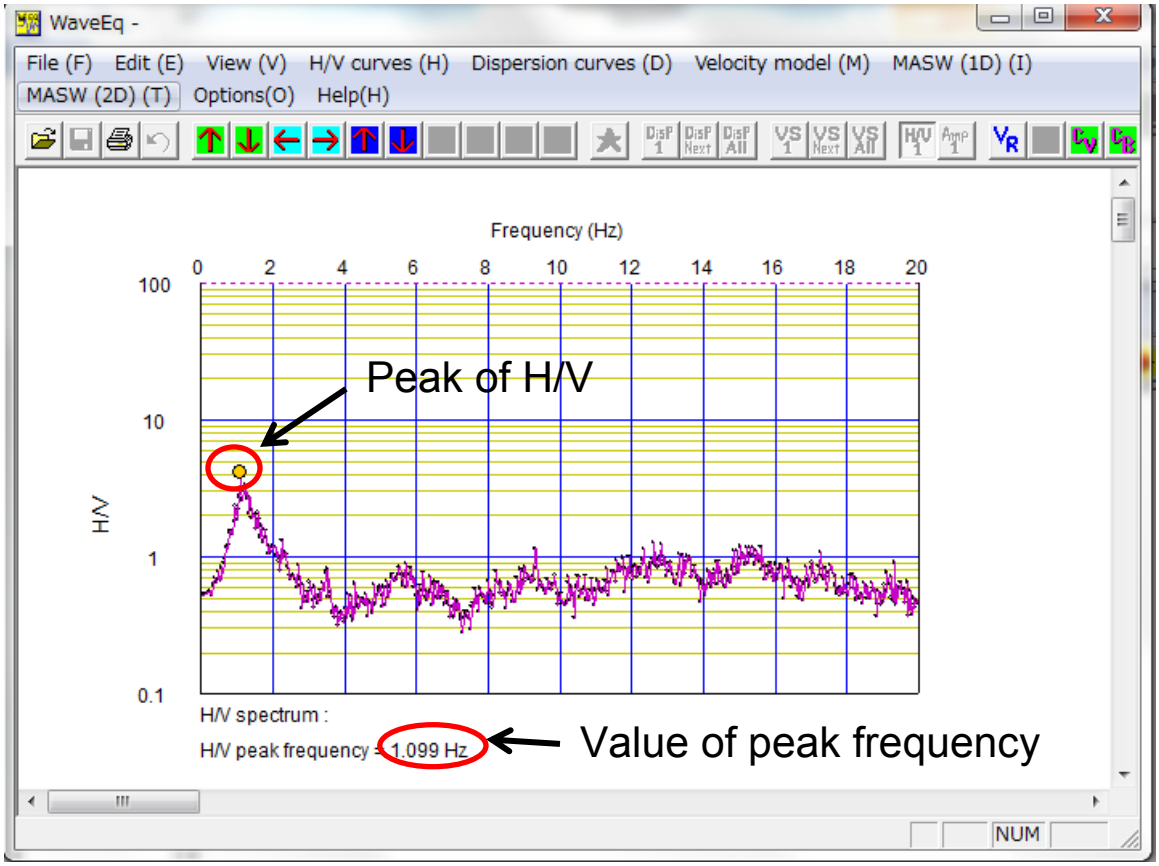


Channel selection dialog box appears and set each component using the *Up* and *Down* buttons. Index of channel number must start 0 and it must be 0, 1 or 2 when three traces are remained. Click *OK* when ready to proceed.

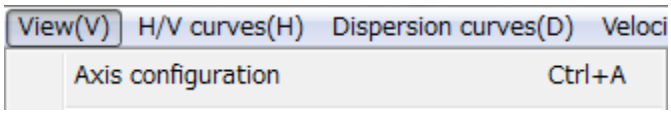


Once the Fourier spectrum is calculated in Pickwin, the spectrum is held in memory for import to WaveEq. WaveEq is used for detailed editing, analysis and making figures for final report. WaveEq can be opened separately and can read in text file that contains 3 components spectrum data. But this single step is the easiest way to automatically launch WaveEq and import a spectrum just calculated in Pickwin. In this step, H/V is automatically calculated and shown in a display of WaveEq.

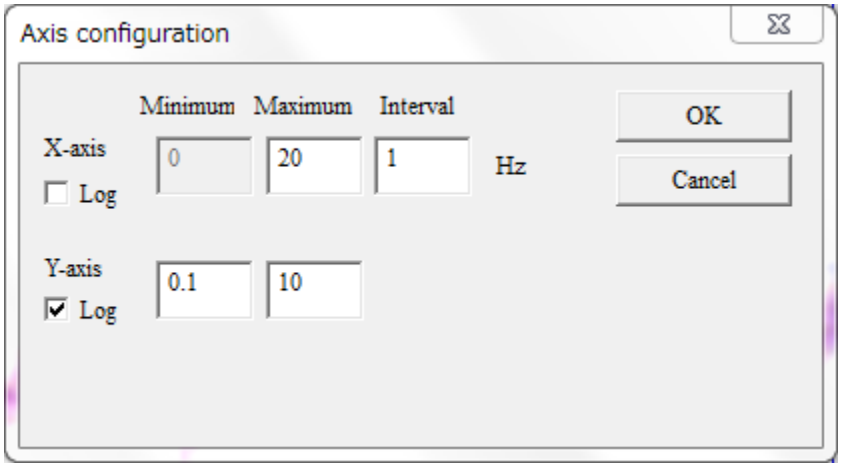
Here is an example of H/V curve shown in WaveEq. Peak frequency of H/V is marked as an orange circle and a value of the peak frequency is shown at the bottom left corner of window.



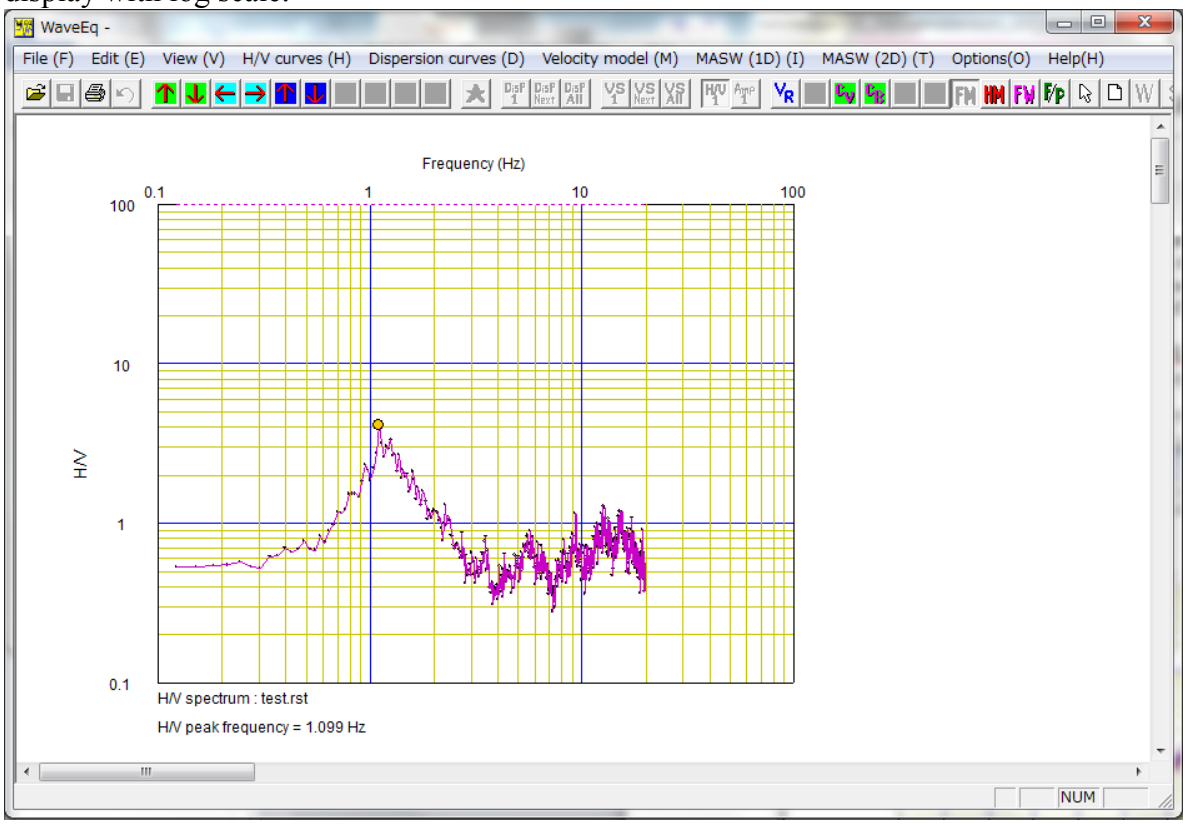
If the plotting scales need adjusment, select the *View* menu, *Axix configuration* or press Ctrl+A.



Enter the desired values for the *X-axis* and *Y-axis Minimum, Maximum* scale and *Interval*. Bothe axes can be plotted linear or log scale. Click *OK* when done.



Horizontal (Frequency) and vertical (H/V) axes can be shown with linear or log scale. Check *Log* to on to show the axes with log scale. Here is an example of H/V curve display with log scale.



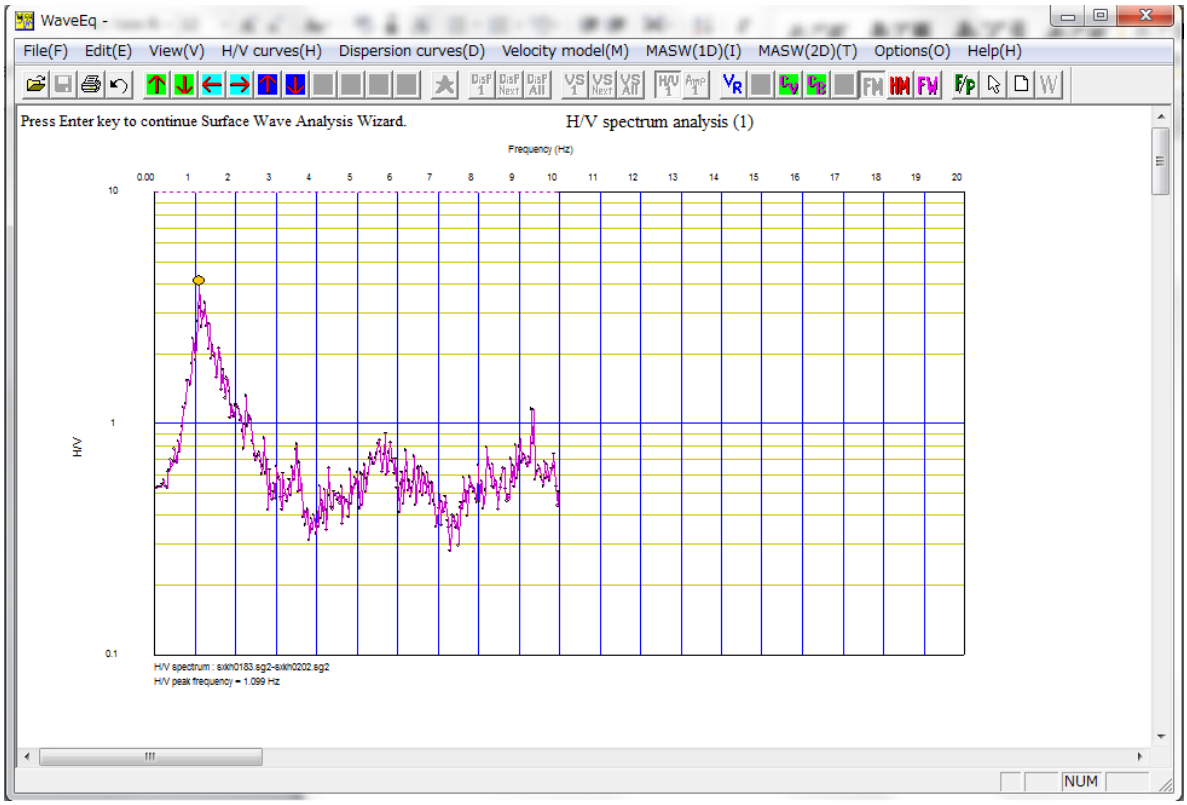
Next, edit the H/V curve as needed. In the H/V curve, lower frequency data contains information of deeper structure and higher frequency data contains information of shallower structure. Table 4.1 summarizes general guideline of frequency and depth of interest.

Table 4.1 Frequency and depth of interest

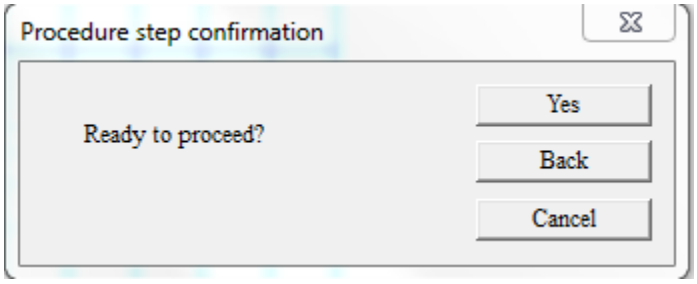
Frequency (Hz)	Depth of interest
0.1 to 0.5	100 <
0.5 to 2	20 to 100
2 to 10	2 to 30
10 <	5 >

H/V data outside of frequency of interest has meaningless and it is better to remove them. Here, H/V data can be easily removed by a gate.

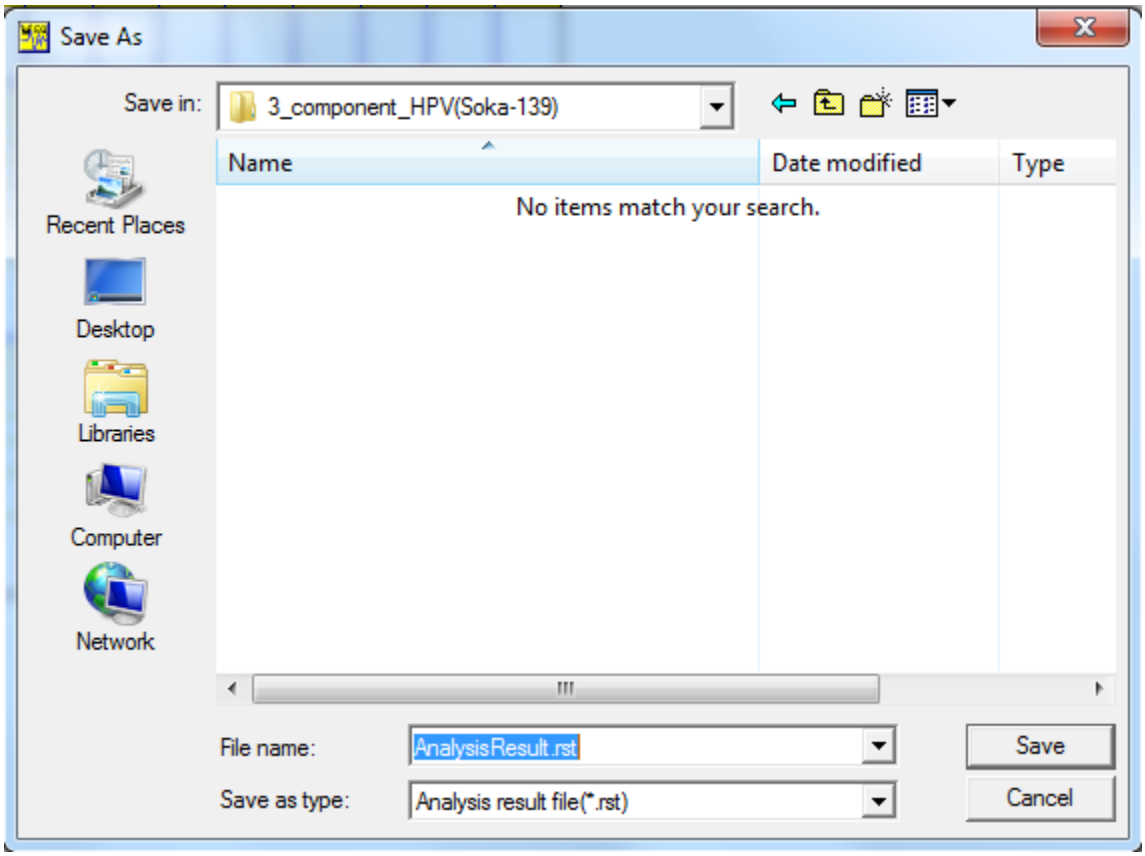
Follow the instruction in the upper left-hand corner of the window. The red gate is the active gate. Use the *right arrow* key to position the gate at the frequency, H/V point up to which you want to delete. Press the *enter* key to activate the right-hand gate and position it the same way using the *left arrow* key. Press the *enter* key when done,



Click *Yes* when reday to proceed.

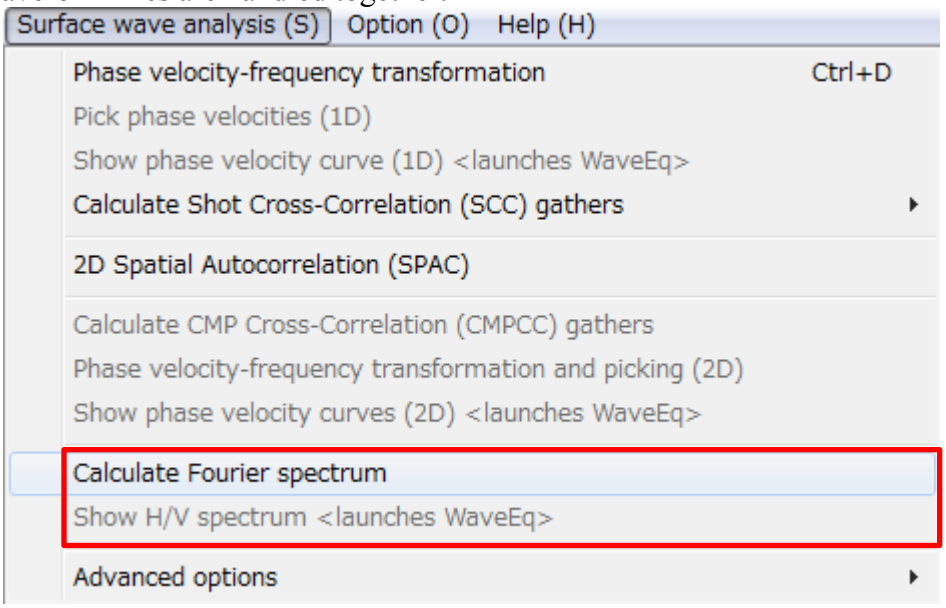


Lastly, save the result. Assign a file name with the extension .rst and click *Save*.



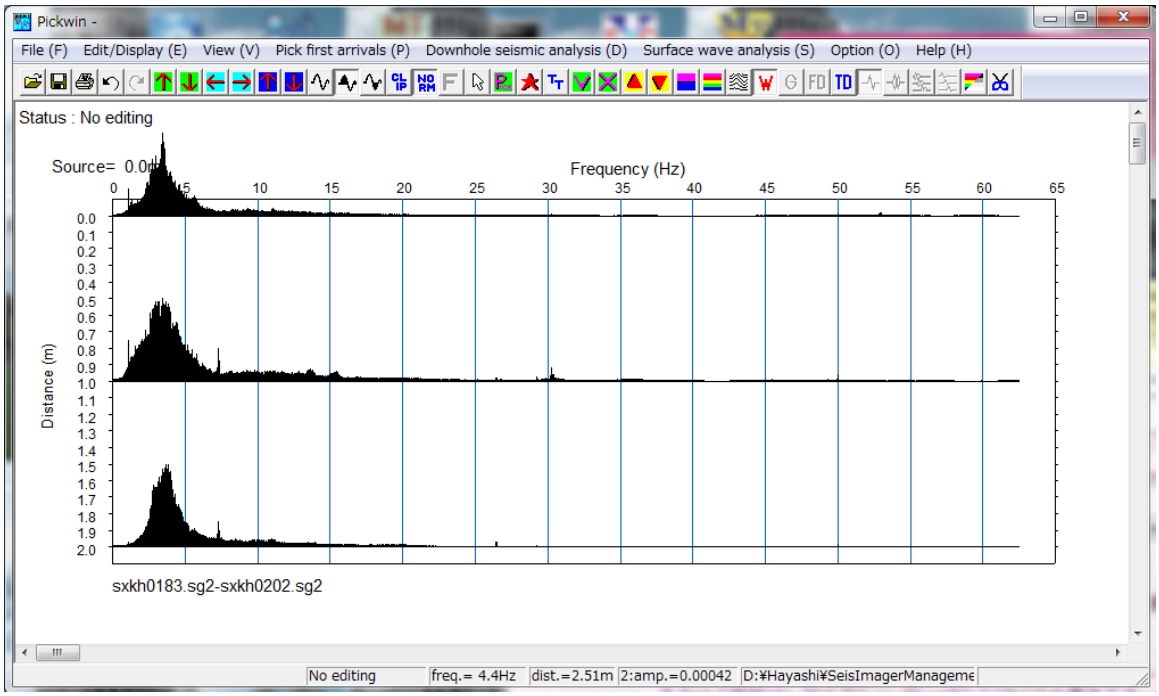
5 – Surface wave analysis Menu in Pickwin Module

In this section, functions for H/V Spectrum data analysis in a Pickwin module will be described. *Surface wave analysis* menu includes the functions. Functions framed with red are used for H/V analysis. Note that H/V analysis generally needs long time waveform data and SeisImager processes H/V data with *Group (File list)* functions in which several waveform files are handled together.



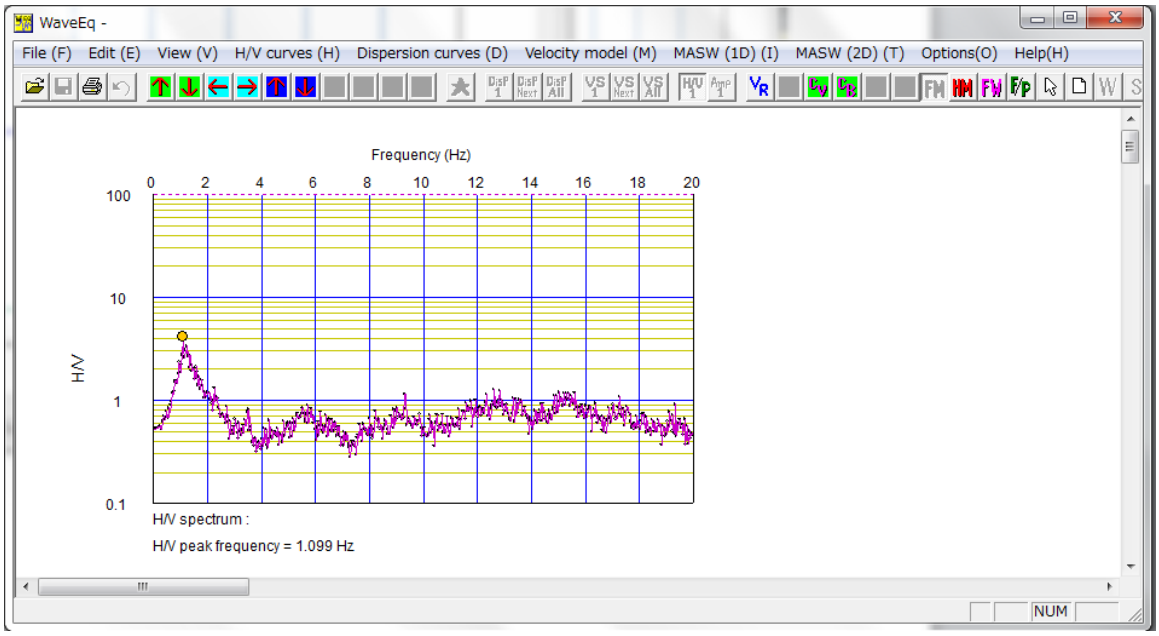
5.1 Surface wave analysis Menu: Calculate Fourier spectrum

The function is only available when a group (file list) was made. Make the file list by selecting *File, Group (File list), Make file list* before calculating Fourier spectrum. To calculate average Fourier spectrum to all files belonging to a group (file list), select *Calculate Fourier spectrum*. It may take several seconds depending on number of files. After the calculation, averaged Fourier spectra are shown as below.



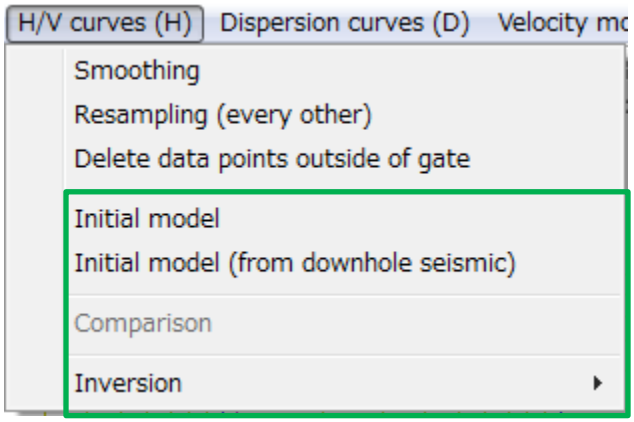
5.2 Surface wave analysis Menu: Show H/V spectrum <launches WaveEq>

To show an H/V spectrum by WaveEq, select *Show H/V spectrum <launches WaveEq>*. Select three components and nominate them to two horizontal components and one vertical component. WaveEq is automatically launched and an H/V spectrum is shown.

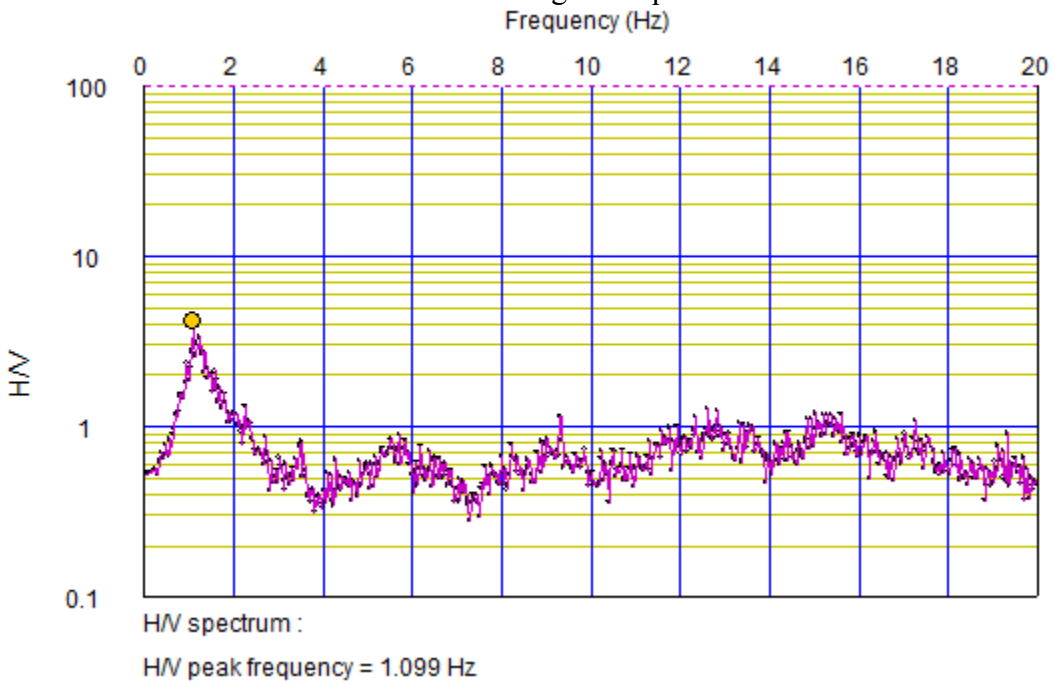


6 – H/V Spectrum Data Analysis Menu in WaveEq Module

In this section, functions for H/V Spectrum data analysis in a WaveEq module will be described. *H/V curves* menu includes the functions. Functions framed with green are only available to SeisImager/SW-Pro. See the *SeisImager/SW-Pro™ Manual* for these functions.

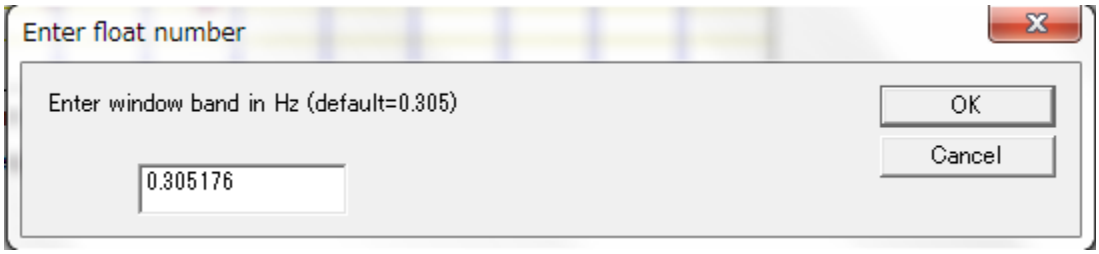


Data shown below will be used for following description.

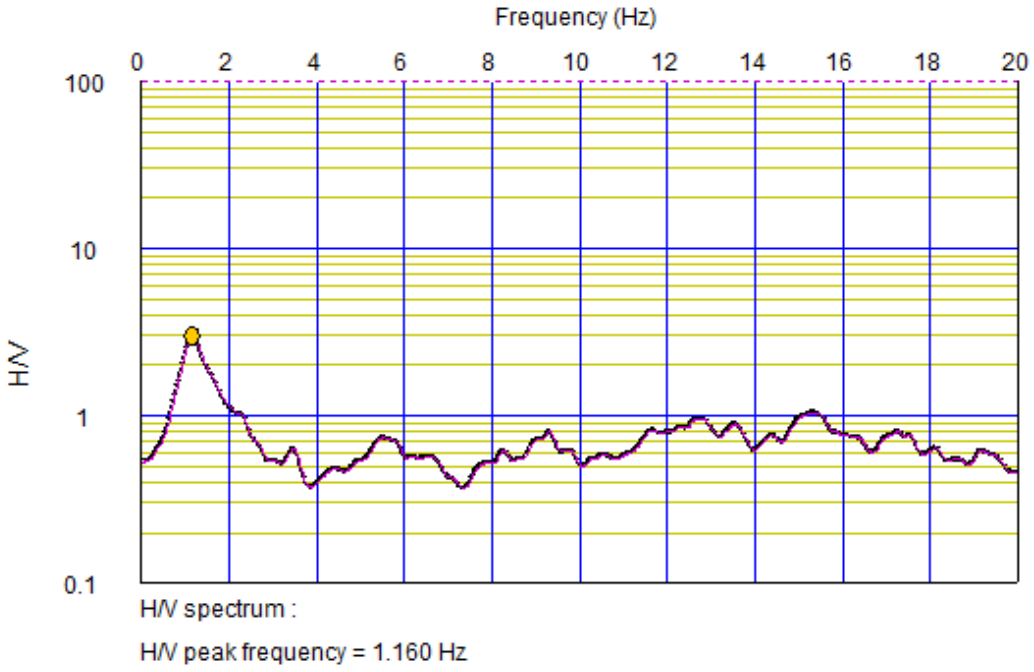


6.1 H/V curves Menu: Smoothing

Theoretical H/V curve is generally smooth. Observed data is, however, noisy and it is difficult to define a peak frequency of H/V. To define stable peak frequency, smoothing is effective. WaveEq can apply a Parzen window to smooth the observed H/V curve. Select *Smoothing* to apply the Parzen window. Set window band for the Parzen window. Larger window band yields smoother H/V curve. The default value is suitable for most cases.



Here is an example of H/V curve that Parzen window with a band width of 0.305Hz.



6.2 H/V curves Menu: Resampling (every other)

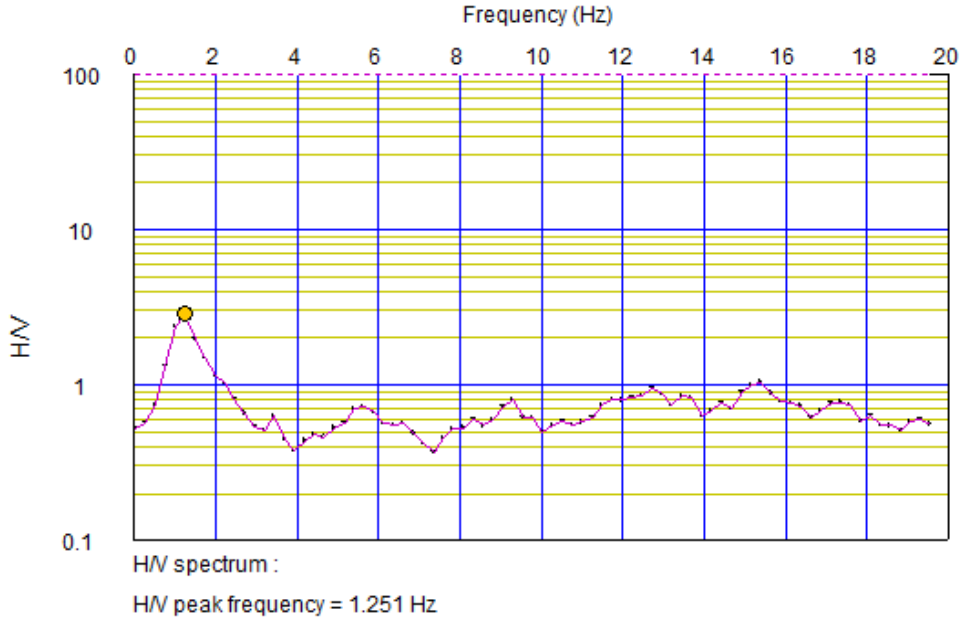
Use this function when inversion of H/V will be applied. Frequency interval (Δf) of H/V data is defined by defined by length of time domain waveform data used for a calculation of FFT.

$$\Delta f = \frac{1}{T} \quad \text{Hz} \quad (2)$$

Where T (sec) is the length of the FFT calculation and the same as data length of one file (discontinuously recorded data as SEG2 file) or one block (continuously recorded data). H/V is calculated less than 20Hz and number of observed data N is:

$$N = \frac{20}{\Delta f} \quad (3)$$

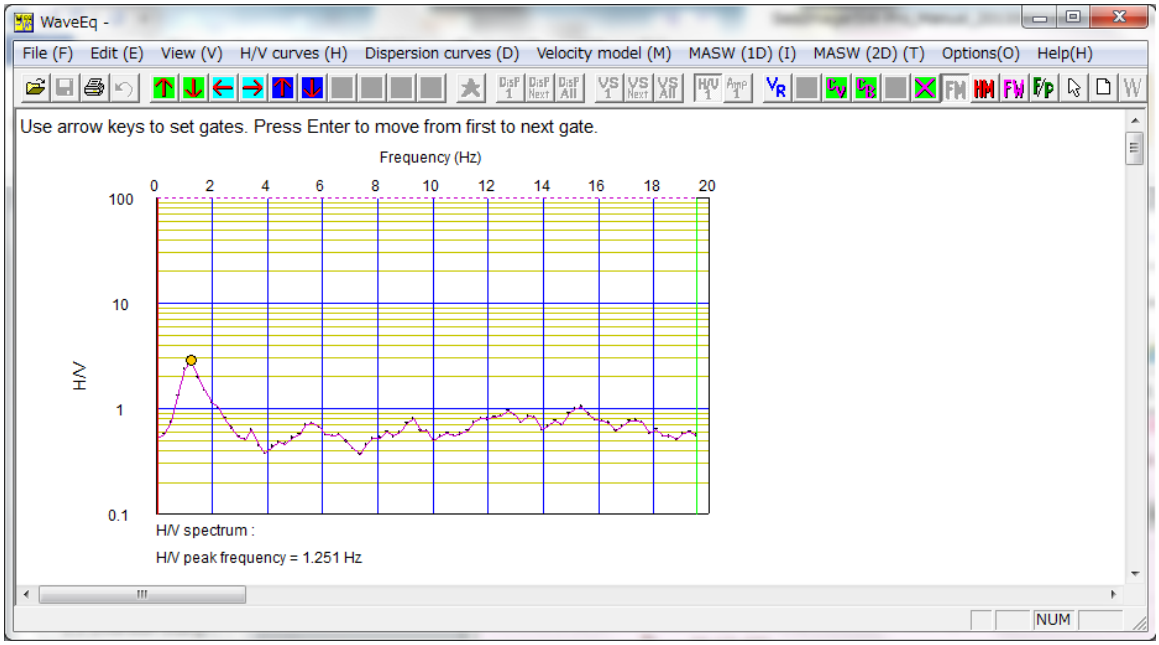
Number of observed data is generally more than several hundreds and too large to apply inversion. Resample data before applying the inversion. Keep number of data less than 100 if inversion will be applied.
To resample the H/V data, select *Resampling (every other)*. Here is an example of resample data after resampled several times.



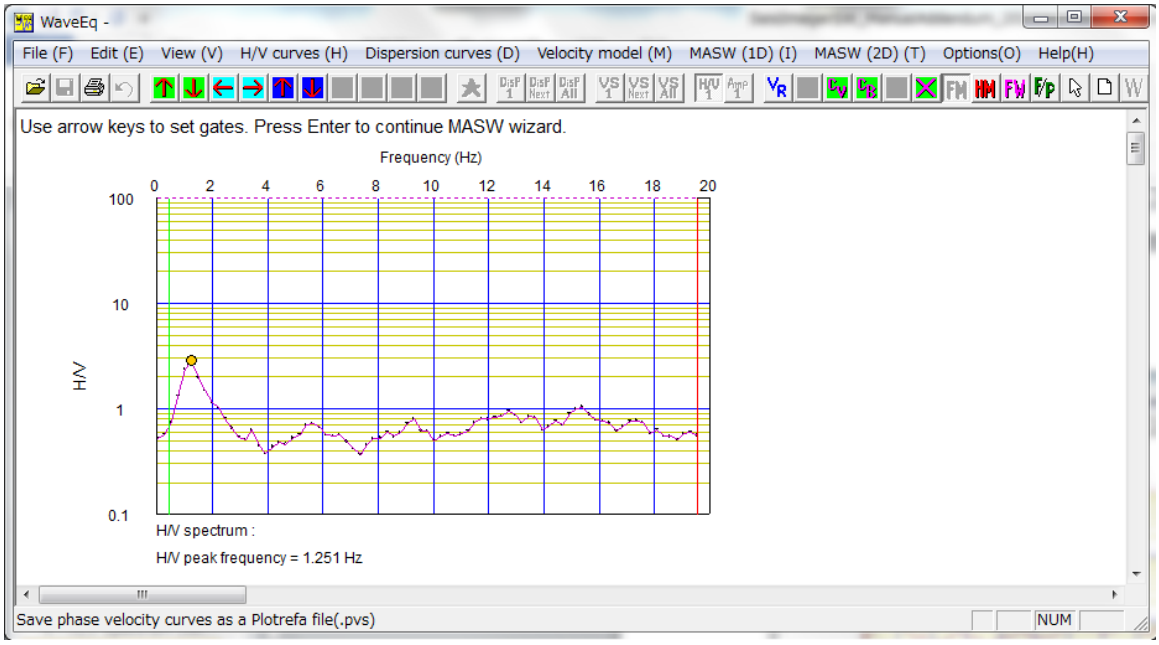
6.3 H/V curves Menu: Delete data points outside of gates

H/V data outside of frequency of interest has meaningless and it is better to remove them. To remove the H/V data by a gate, select *Delete data points outside of gates* or press Ctrl +x.

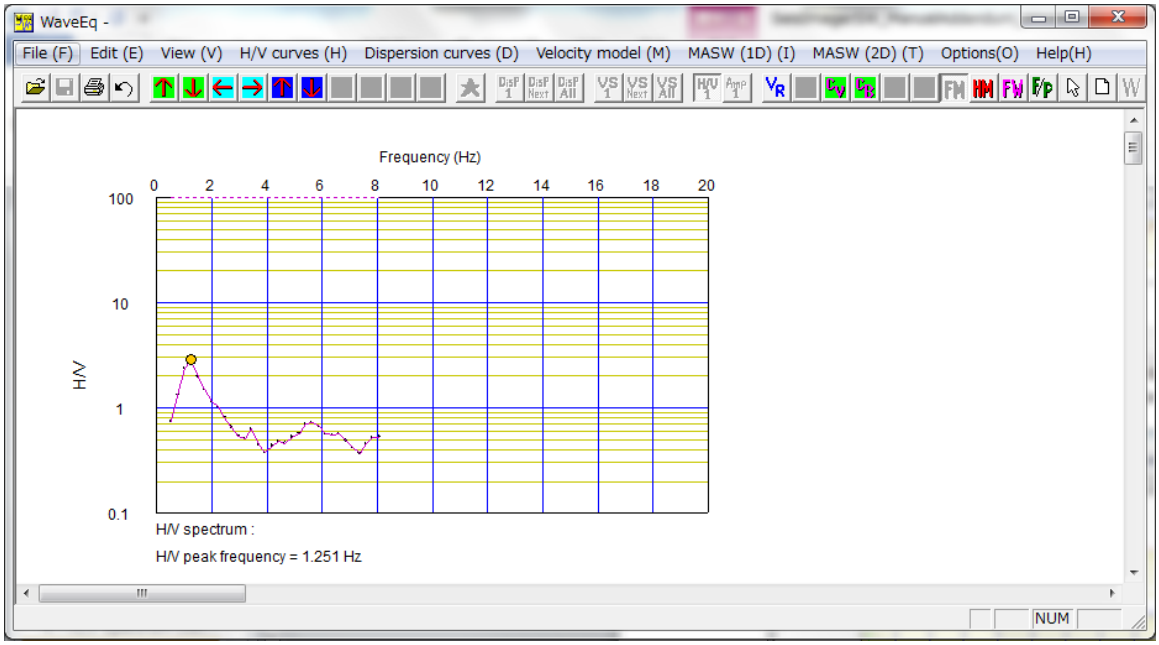
Follow the instruction in the upper left-hand corner of the window. The red gate is the active gate.



Use the *right arrow* key to position the gate at the frequency, H/V point up to which you want to delete. Press the *enter* key to activate the right-hand gate and position it the same way using the *left arrow* key.



Press the *enter* key when done.



6.4 Button Bar Functions

The WaveEq button bar functions for H/V spectrum analysis are explained in this section.

6.4.1 Button Bar : Show H/V spectrum 

To show H/V spectrum, click the *Show H/V spectrum* button.

7 – References