

# Reflex Vibro

Version 1.4

Windows™ XP/7/8/10-program  
for the interpretation of  
seismic vibration data

Copyright 2016 by

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## ReflexVibro installation info

### Installing ReflexVibro under Windows™Vista and Windows™7/8/10:

There are 2 main differences between running under Vista and 7 and other former Windows systems:

1. the hlp-files are no longer supported. Therefore the new ReflexVibro from version 4.5 comes with a chm helpfile.

2. A new User Account Control:

When User Account Control (UAC) is enabled (the default), standard user permissions are used to run applications--even if the user is an administrator. According to Microsoft this "helps eliminate the ability for malware to invoke administrator privileges without a user's knowledge."

ReflexVibro won't normally crash when it tries to write to a protected resource, such as Program Files. Instead, those writes are virtualized. Trying to write to a file in C:\Program Files\Some Folder causes that file to be created or updated in C:\Users\username\AppData\Local\VirtualStore\Program Files (x86)\Some Folder, where username is the name of the logged-in user.

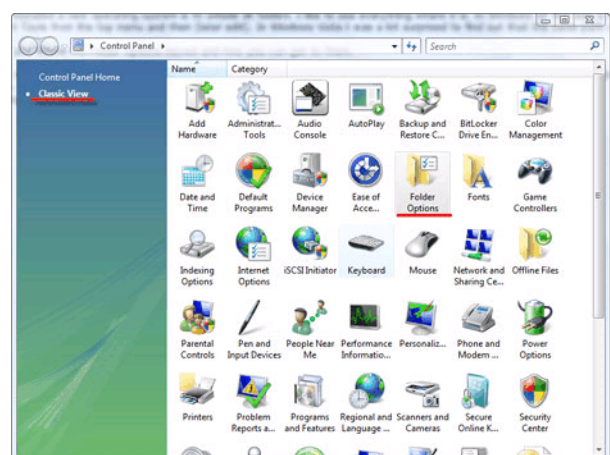
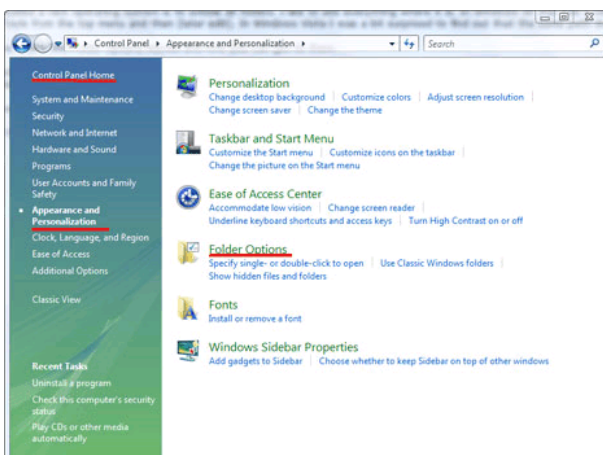
The folder AppData is **hidden** by default. Therefore the hidden attribute must be eliminated or the hidden files and folders are made visible. For that purpose you have several possibilities. The easiest way to make visible hidden folders is listed within the next two pages.

In order to eliminate the hidden attributes perform the following steps:

- go to computer and launch the folder C:\Users\username.
  - Use the right mouse button in order to show the attributes of the folder username.
  - Activate the option hidden and click on ok - all files and the subfolders will be hidden.
  - Use the right mouse button a second time and deactivate the option hidden and click again on ok.
- Now the folder AppData and all other subfolders and files will be visible.

In order to make visible hidden folders enter the Control Panel and choose Appearance and Personalization and then click on Folder Options.

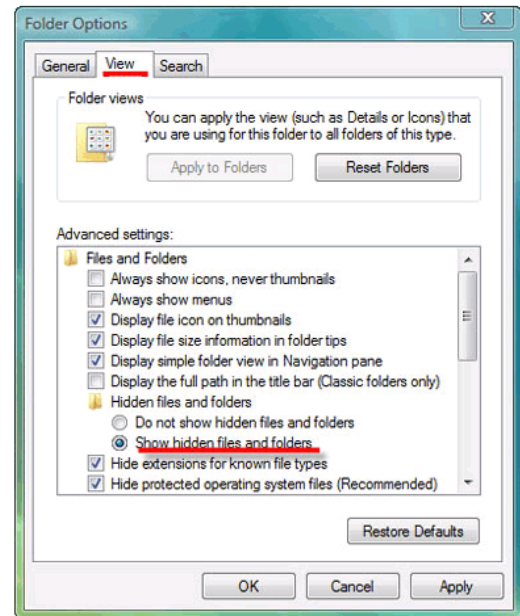
Alternatively you may use the classic view within the Control Panel and you may directly click on Folder Options.



With the Folder Options click von View:

- Select (dot) Show hidden files, folders, and drives.
- Click on the Apply button.

Now the hidden directories and files are visible.



The following files will be stored under this “virtual” folder:

- password.txt
- palette.fil
- dummy\*.bmp
- dummy\*.sta

The file ReflexVibro.ini will be stored under  
C:\Users\username\AppData\Local\VirtualStore\Windows

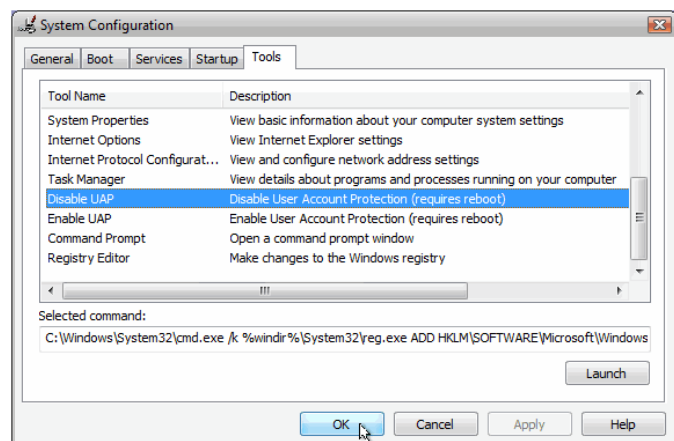
The processed files of the folder demodata will also be written to the virtual folder. This is not visible when running the program ReflexVibro.

It is strongly recommended not to use any protected folder for the data projects.

If you disable the user account control no difference exists to the former Windows version. Two different method of disabling the user account control are listed below:

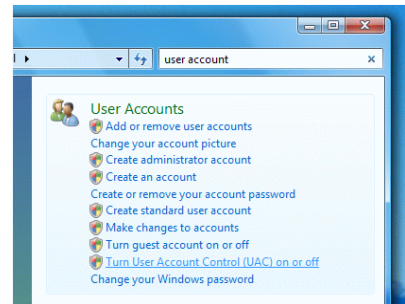
#### Method 1 - Using MSCONFIG

1. Launch MSCONFIG by from the Run menu.
2. Click on the Tools tab. Scroll down till you find "Disable UAP" (this should probably change to UAC in next Vista beta builds and in the RTM version). Click on that line.
3. Press the Launch button.
4. A CMD window will open. When the command is done, you can close the window.
5. Close MSCONFIG. You need to reboot the computer for changes to apply.



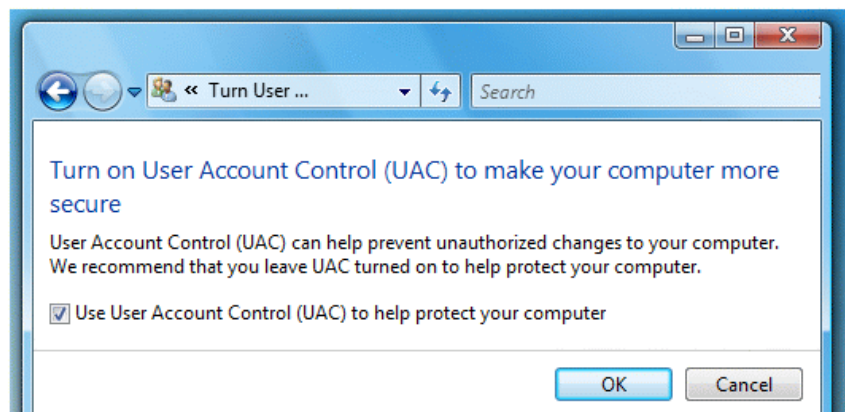
Method 2 - using the user control panel

1. Open Control Panel.
2. Under User Account and Family settings click on "user account" the "Add or remove user account".
3. Click on "Turn User Account Control (UAC) on or off" link.



4. In the "Turn on User Account Control (UAC) to make your computer more secure" click to unselect the "Use User Account Control (UAC) to help protect your computer". Click on the Ok button.

5. You will be prompted to reboot your computer. Do so when ready. In order to re-enable UAC just select the above checkbox and reboot.



## ReflexVibro guide

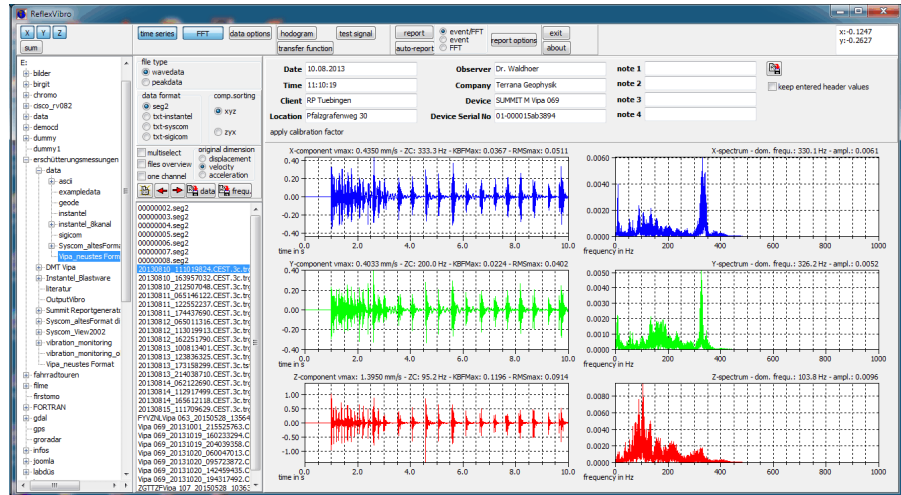
The program REFELXVibro allows the presentation of vibration data (velocity as a function of time  $v(t)$ ) and the generation of reports.

The possibilities:

- easy import of wave and peak data in different formats (seg2, csv-DMT, txt-instantel and txt-syscom). The integration of other nonstandard formats is possible.
- amplitude spectrum, power spectrum, octave spectrum max., octave spectrum aver., 1/3 octave spectrum max. and 1/3 octave spectrum aver..
- filtering (DC-correction, 50 Hz Notchfilter, integration, differentiation and bandpass).
- many different display possibilities (discretely adjustable axis-lengths for time-series and spectra, grid, color, fonts).
- KB-calculation (arbitrary high pass and high cut).
- generation of event and FFT reports, including compliance graphs (DIN 4150 and other).
- printing of reports in different languages.
- auto report option for an automatic generation of reports for incoming data
- hodogram calculation for an interactive display of the movement direction.
- generation of a transfer function
- generation of test signals.

The files:

- ReflexVibro.exe: The program file itself.
- report\_language.fil: Language file, which is delivered with the program file. Allows to print a report in German language instead of English language, but can be customized for any other language, too (see chapter 4).
- logo.jpg: a jpg containing a logo which will be displayed within the report if desired
- vibration\_monitoring.fil: This file is generated every time the program is closed and contains different settings, which are used when the program is opened again.
- compliance\_curves.fil: Self-defined compliance curves will be stored in this file (see chapter 4).
- Parameter files of the form <name of the datafile>.par: If information belonging to individual datafiles shall be stored, this is done in such par-files (see chapter 2).
- Export of the data in ANSI-files: Every data set displayed can be stored as ANSI-file (see chapter 1).
- Summary text report files: A report can not only be printed but also stored as an ANSI-file (see chapter 4).





## 1. Loading the data

ReflexVibro is able to handle both, wave data and peak data in the following formats: SEG2, csv-DMT, txt-instantel, txt-syscom and txt-sigicom. The peak data need not to be equidistant. The standard channel number is 3 but the program also allows to import multichannel (up to 8) txt-instantel data.


Pecularity for txt-sigicom: One data file only contains one channel. Therefore the option multiselect must be used in order to load all 3 channels together. The parameter Node Number is used for the definition of the component: 1 stands for z-component, 2 for x-component and 3 for y-component. Peculiarities for SEG2:



- it is possible to choose between two sortings of the original data: xyz means that the 1. channel contains the x-data, the 2. the y-data and the 3. one the z-data. If zyx is chosen the 1. channel contains the z-data and the 3. one the x-data.
- ignore BlockSize: if activated the datablocksize within the SEG2-traceheader will not be used for discriminating the individual traces
- ignore StrLength: if activated the trace strings will be interpreted even if the stringlengths are set to 0

The program does not effect the original data but the original data are always the base for all processing steps.

Below the panel with the speed buttons the working area of the program is divided in three columns.


In the left column the working directory can be selected, so that the data of the working directory is listed according to the preset data format and file type in the mid column. The right column is used for the display of the data.

The listed data (middle column) can be displayed in the right column (display area) by a simple double click on the chosen file or by using the button  above the list.

Using the left and right arrows   it is possible to scroll through the individual files of the current working directory.

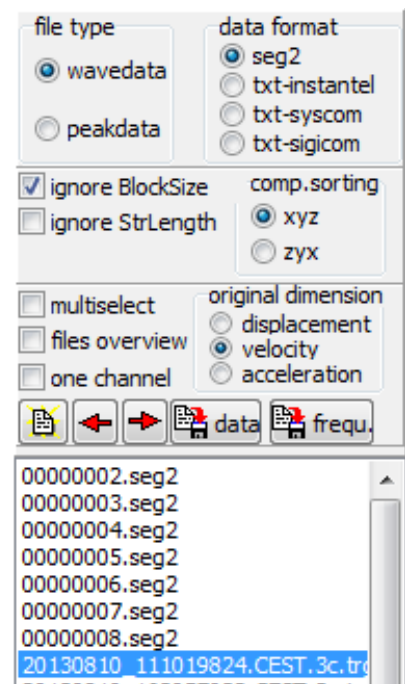
You must choose the *original data dimension* displacement, velocity or acceleration. The data may be converted into another data dimension within the data options menu.

Multi selection and display is possible, if the option *MultiSelect* is activated:

Just select the files, push the button  and the time series will be shown consecutively in chronological order (except txt-sigicom data).

If the option *files overview* is activated, the files are listed (and can be sorted) at the top of the display area by filename, date/time, date, time, duration, x-max, y-max, z-max and samples (see below).

filename	date/time	date	time	duration ...	x-max	y-max	z-max	samples
20120824_140529599.3c.t...	2012_08_24/14:05:29	24.08.2012	14:05:29	26.00	11.5270	4.1069	8.4793	26000
20120824_140541002.3c.t...	2012_08_24/14:05:29	24.08.2012	14:05:29	26.00	11.5270	4.1069	8.4793	26000
20120824_140630732.3c.t...	2012_08_24/14:05:29	24.08.2012	14:05:29	26.00	11.5270	4.1069	8.4793	26000





It is possible to copy the table to the clipboard using the speed button at the right.



The displayed file(s) can be saved as ANSI-File using the speed button

```
original filename: A Testfile.txt
date: 25092013
time: 0,44748842593
client: XYZ
location: Karlsruhe
company: Sandmeier Geophysik
observer: Mayer
device_name: XYZ-Device
device_serial_no: 123456789
note: This
note: is
note: a
note: testfile!
note: Bearbeiter: mw
timeincrement: 97656
timedelay: -25000
number of samples: 5376
```

```
::
data:
channels 1-3 (up to 8):
  X      Y      Z
-552    -867    236
-552    -946    315
-552    -946    394
.....
.....
.....
4100    -1340   -1810
4260    -1500   -1500
4340    -1730   -1340
```



The spectral data can be saved as ANSI-File using the speed button


```
original filename: A Testfile.txt
date: 25092013
time: 0,44748842593
client: XYZ
location: Karlsruhe
company: Sandmeier Geophysik
observer: Mayer
device_name: XYZ-Device
device_serial_no: 123456789
note: This
note: is
note: a
note: testfile!
note: Bearbeiter: mw
```

```
Frequency increment:97656
0.06104
number of points: 16384
```

```
::
X-spectrum - dom. frequ.: 336.2 Hz - ampl.: 0.0071
Y-spectrum - dom. frequ.: 328.2 Hz - ampl.: 0.0052
Z-spectrum - dom. frequ.: 107.7 Hz - ampl.: 0.0094
channels 1-3:
  X      Y      Z      frequency
0.000000000 0.000000000 0.000000000 0.000000000
0.0000372668 0.0001202864 0.0001372332 0.0610351563
0.0000296370 0.0000675570 0.0000672601 0.1220703125
0.0000391569 0.0000684945 0.0000578179 0.1831054688
0.0000362542 0.0001219367 0.0001583492 0.2441406250
.....
```




## 2. Display of the data


In the display area – below the file list if *files overview* is checked – several information like date and time, resp., which are stored to the data file during the recording, is shown above the data. This information can be modified or complemented, resp.. Additional notes can be added, too.


Using the speed button  besides on the right handside of the panel, this information can be stored in a parameter-file named *<name of the datafile>.par* in the actual working directory (E.g., datafile: data.sg2 => parameter-file data.par). From then on this information will be automatically shown every time the related data file is loaded. If this is not wanted the corresponding par file must be manually deleted.



With the option *keep entered header values* activated the entered header values will be kept if a new file will be loaded except for those values which are defined within the original data.

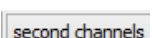
Which part of the data is displayed depends on the speed buttons in the upper panel:

   : Selection of the data components.

 : Selection of an aux channel, which is provided by some multichannel (more than 3 channels) instruments. (Only activated, if the selected data set contains aux channel data.)

 : The vector-sum of the measured data is displayed.


  : The data themselves and/or their FFT spectra are displayed.

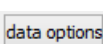
 : Display of the second channels  $x_2$ ,  $y_2$ ,  $z_2$  and  $aux_2$  of a multichannel instrument (6 or 8 channels). (Only activated, if the selected data set contains multi channel data.)

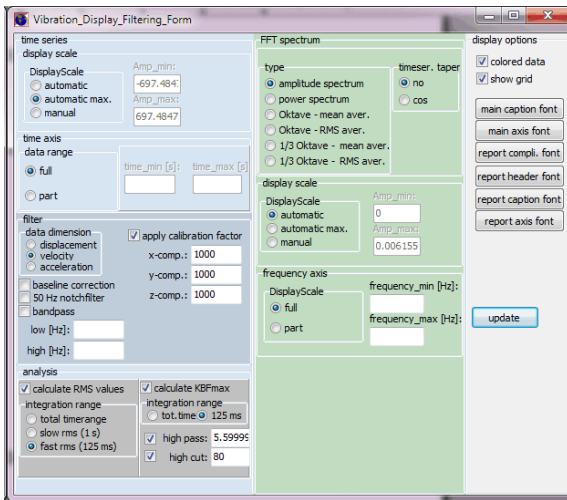
If all components are selected, there are up to eight graphs displayed:

Up to four time series (x, y, z, aux or the second channels) and their corresponding spectra.

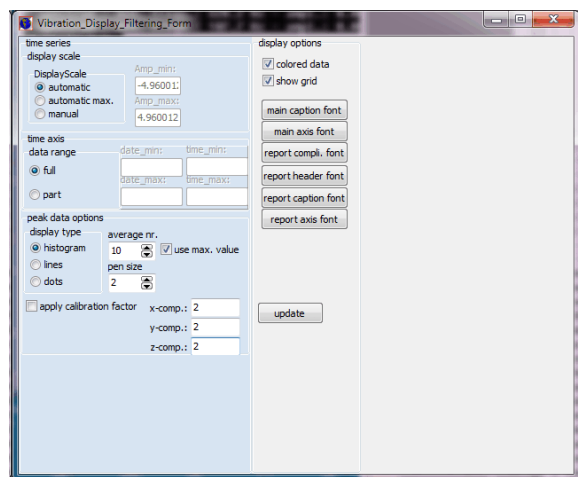
If the vector sum of the time series (for further information please refer to appendix) is active the aux-channel will be automatically disabled and vice versa.

If the time series is peak data, the calculation of a spectrum makes no sense and  is disabled for this reason.

Entering the data display and filtering options menu using the speed button , the display of the data can be adjusted, see figures below.



Wave data



Peak data

The graphs of the time series and the spectra can be configured separately. Display options like colors, grid and fonts can be set in addition.

Please note: The options, e.g the restriction to a special time range, affect the display of the data in all subsequent processing steps like calculating the spectra, KB-calculation, generating reports and displaying the data as hodogram, e.g..

## **Time series:**

### Display scale:

The scaling of the amplitudes can be set to

- automatic: The amplitude axis of each graph is adjusted in dependency of the absolute max. amplitude of each component.
- automatic max.: The amplitude axis of all graphs is adjusted in dependency of the absolute max. amplitude of all components.
- manual: The amplitude axis of all graphs is adjusted in dependency of arbitrary set min. and max. amplitudes.

### Time axis:

Wave data: The data range of the time series to be displayed can set to *full* or *part*, at which the part is defined by *time\_min* [s] and *time\_max* [s].

Peak data: The data range of the time series to be displayed can set to *full* or *part*, at which the part is defined by *date\_min/time\_min* and *date\_max/time\_max*, which have to be entered always in the following format: date: DD.MM.YYYY, time: hh:mm:ss

### Analysis (wave data):

If the time series is wave data, RMS values can be calculated over three different integration ranges: *Total timerange*, *slow rms (1s)* and *fast rms (125 ms)*.

Furthermore,  $KB_{F_{max}}$  can be calculated over the *tot. timerange* or over a time range of 125 ms with  $f_0 = 5,6$  Hz (*high pass*) and  $f_{cut\ off} = 80$  Hz (*high cut*) set as default values, which both can be adjusted or even deactivated, if desired.

### Filter (wave data):

The following filters can be applied to wave data:

- *change the dimension to displacement, velocity or acceleration, if the dimension differs from the entered original dimension an integration (or double) or differentiation (or double) will be performed*
- *apply calibration factor*
- *baseline-correction*
- *50 Hz notchfilter*
- *bandpass* with arbitrary *low* and *high* cut frequencies. A butterworth taper of order 3 will be applied on both sides of the entered cut frequencies.
- *apply calibration factor - a factor may be entered for each component. The data will be multiplied with this factor.*

### Peak data options:

If the time series is peak data, it can be displayed as histogram, lines or dots whereby the pen size can be adjusted.

To control its display furthermore, the peak data can be averaged over an arbitrary number of data points by using an *average nr.*  $> 1$ : By default, the option *use max. value* is selected, so that the maximum value of that data points, over which is averaged, is taken. If the option *use max. value* is deselected, the arithmetic mean of the data points within the average range is determined.

With the option *apply calibration factor* activated a factor may be entered for each component. The peak data will be multiplied with this factor.

For further information about the filters and the calculation of RMS values and  $KB_{F_{max}}$ , resp., please refer to the appendix.

**Spectrum:**

Note: If only a part of the time series is considered (option *Time axis* is set to *part*), the belonging spectrum is only calculated for this part of the data!

Type:

The following spectrum types are available

- *amplitude spectrum* (default),
- *power spectrum*,
- *Octave - mean aver.*,
- *Octave - RMS aver.*,
- *1/3 octave - mean aver.* and
- *1/3 octave - RMS aver.*

(For further information about the different types please refer to the appendix.)

If desired a *cos* taper within the time range can be applied in addition. For this purpose the cosine taper will be applied on the timeseries data over a fixed timerange at the start and the end of the relevant timerange before the spectrum calculation. *No* taper is set as default.

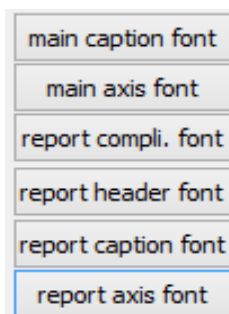
Display scale:

The scaling of the amplitudes of the spectra can be set – as described for the time series (see above) – to automatic, automatic max. and manual.

Frequency axis:

The data range of the spectrum to be displayed can set to *full* or *part*, at which the part is defined by *frequency\_min* and *frequency\_max*.

**Display options:**

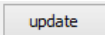


To display the data in color (blue, green, red for x, y, z) please activate the option *colored data*.

If a grid shall be shown in addition, please activate *show grid*.

To adjust the fonts, indicated in the left figure, please click on one of the buttons.

An additional window will open, in which the font, its style, its size, its color, etc. can be chosen.

To apply the settings to the data, please click the button  .

For each of the shown components of the time series the max. value of the velocity *vmax*, the max. displacement *smax* (option *integrate* is activated) or the max. acceleration *amax* (option *differentiate* is activated), resp., together with its corresponding zero-crossing-frequency (*ZC*) is specified above the data.

For the corresponding spectra the dom. frequencies and their amplitudes are stated.

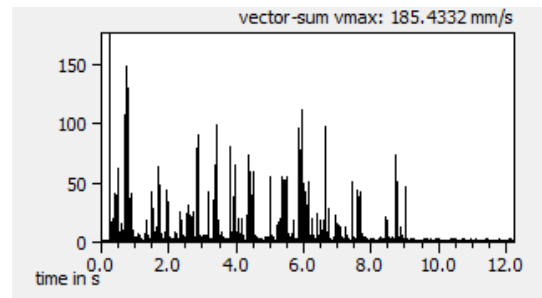
If the vector sum is displayed, its max. value is also indicated.

The exact x-y-coordinates of the mouse cursor (time versus amplitude or frequency versus amplitude) are indicated rightmost in the upper panel.




8-channel wave data set displayed with the indicated display and filtering options.

A right mouse click in one of the figures (vector sum in the figure above) enables you to copy this figure to clipboard:



### 3. Additional Functions

#### Hodogram:

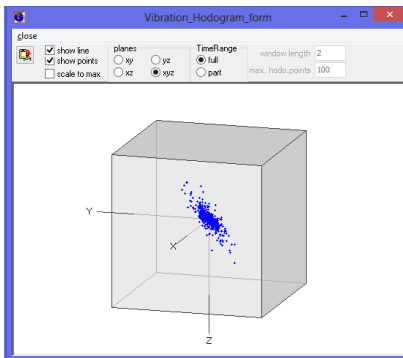
In addition to the display of the time series component-by-component, the data can also be displayed as a hodogram to get an overview about the spatial distribution of the data. The hodogram window is opened using the button .

If the option *integrate* is selected in the data options, e.g., the tips of the three-dimensional vectors  $s(t)$  are shown, so that the spatial distribution of the displacement can be seen. Of course a hodogram can be generated for  $v(t)$  and  $a(t)$ , too.

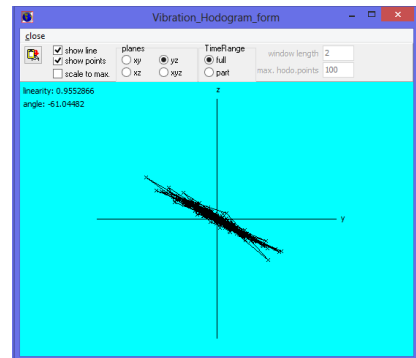
The data can be displayed as line and/or points, arbitrarily arranged in space (three-dimensional or coordinate planes) and copied to the clipboard. In addition, the display can be scaled to the maximum of the currently shown data (default) or the maximum of the whole data set (option *scale to max.* is activated).

If the option *xyz* is chosen, the data cube can freely be rotated by selecting the cube with the left mouse button and moving the mouse with pressed button. (In this case, the data is only shown as points.)

If the data is displayed in one of the coordinate planes, the linearity and the angle of the main vibration direction are shown in addition: The more the value of the linearity equals to 1 the more the data is aligned along a line, which is positioned in the shown plane with the indicated angle.




Hodogram: Data shown as cube.



Hodogram: Same Data shown in y-z-plane with options show line and show points activated.

The number of shown data points (option *max. hodo points* is set to 1000 by default) can be customized as well as the time range of the data to be represented.

If the option *TimeRange* is switched from *full* (default) to *part*, a time range can be defined by the option *window length*: If the *window length* is set to  $T$ , the data is shown in a (moving) time interval  $[-T/2 \text{ s}; T/2 \text{ s}]$ , whereby the zero point of this interval is defined by the actual position in time of the mouse cursor in one of the time series component graphs in the program's main window:  $T = 10$  given and the mouse cursor is positioned at  $t = 7 \text{ s}$ , e.g., leads to the interval  $[2 \text{ s}; 12 \text{ s}]$ . Thus, the data can be displayed as hodogram in defined time ranges by simply moving the cursor along the time axis in one of the time series graphs.

At least, the hodogram can be copied to clipboard by .

To close the hodogram window please click on *close*.



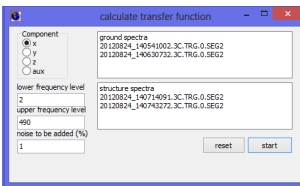
**Transfer function:**

If data outside the structure are recorded (named ground measurements in the following) in addition to the actual vibration measurements (named structure data in the following), the structure's transfer function  $T_s(\omega)$  can be calculated:

The spectrum of the ground data  $D_g(\omega)$  includes information about the ground's transfer function  $T_g(\omega)$ , the spectrum of the structure data  $D_s(\omega)$  both, the transfer function of the ground  $T_g(\omega)$  and of the structure  $T_s(\omega)$ .

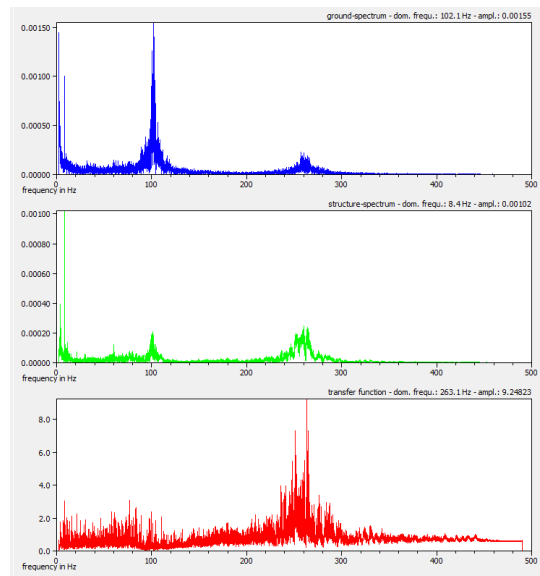
By a simple division of the structure spectrum  $D_s(\omega)$  by the ground spectrum  $D_g(\omega)$ , the transfer function of the structure  $T_s(\omega)$  can be calculated. (For further information see appendix.)

By clicking on **transfer function** the following window opens, in which the component, which shall be used to calculate the transfer function, can be selected: x, y, z or aux.



A lower and an upper frequency level can be adjusted and noise can be added, before the ground data (first files) and the structure data (second files) are chosen by clicking on **start**.


Thereafter the ground spectrum, the structure spectrum and the transfer function are displayed.



*Note: File types and data formats of all files have to be of the same type as preselected in the ReflexVibro main window. If the data is 6- and 8-channel data, resp., the ground spectrum has to be recorded on channel 1 to 3 and 1 to 4, resp., and the structure spectrum on channel 4 to 6 and 5 to 8, resp.. If the data is 3-channel data, several ground spectrum files can be loaded as well as several structure spectrum files to ensure statistical independency by averaging the data (see upper left figure).*

### Test signal:

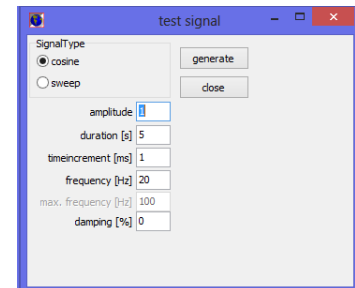
Two different test signals (*cosine* and *sweep*) are implemented in ReflexVibro. They can be used to make oneself familiar with the different features of the program, if no measured data is existent.

Tapping on  the test signal window opens and the signals can be defined:

For both *SignalTypes* the amplitude, the duration [s], the timeincrement [ms] and the frequency [Hz] have to be defined.


For the *sweep* the max. frequency [Hz] has to be chosen also.

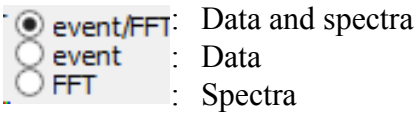
Furthermore a damping can be defined. By setting the damping to 25 %, e.g., the initial signal amplitude (100 %) is damped over the specified time interval up to 75% at the end of this interval.



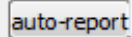
Please keep in mind that the duration of the time series defines the frequency resolution of the spectrum and that the timeincrement has to be chosen in a way that the Nyquist-theorem is satisfied (For further information see appendix.).

## 4. Generating a report

If the actual time series is wave data, one of the following three reports can be generated using the speed button  :



As mentioned before, the calculation of a spectrum makes no sense if the time series is peak data. Therefore the upper three speed buttons are deactivated in this case and only the generation of an event report is possible.

The speed button  allows to automatically generate and print a report for a newly incoming dataset. The actual report settings are used. The program controls if a new dataset will be present within the actual project directory. As soon as this dataset will be available a report is generated and printed using the default printer type. A delay in secs may be entered within the report options (option autoreport delay (s)).

The generated reports differ only in the presented data. Apart from that the reports have the same structure, which is effected by the data and filter options, the specifications and the notes, given in the report options and in the upper part of the display area of the program's main window, see below.



As can be seen in the following figures, the information about date, time, location, client, company, observer, notes, file name, device and device serial\_no, is presented in the upper part of the report followed by the results for the individual components:

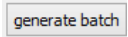

Depending on the chosen data display and filtering options and the report options v<sub>max</sub>, s<sub>mx</sub> and a<sub>max</sub>, resp., is shown together with its corresponding time and peak vector sum.

Dom.frequency, ZC-frequency, max. displacement and max. acceleration can be shown in addition if activated in the report options.

Beside the results a compliance graph can be shown, which makes only sense for velocity wave data.

Subsequently the data are depicted corresponding to the chosen type of report.

The actually displayed report (default: portrait format, for landscape format please activate *landscape*) can be copied to clipboard  or printed .

If reports of several time series of the same working directory shall be printed in the actual visible design, please use . A file table opens and the files can be selected. Using the button , one report is generated for each selected file.

The display of these reports can easily be controlled by clicking the left and right arrow, resp.,

  or by entering the relevant number of the report.

To print these reports altogether please use: 

Whatever report is printed, a summary text report can be generated and stored in the program's directory, if the option *summary text report* is selected. The summary text report for our example contains the following information:

Report for file A Testfile.txt

Device: XYZ-Device  
Device serial\_no: 0123456789  
Date: 25.09.2013  
Time: 10:44:23  
Location: Karlsruhe  
Client: XYZ  
Company: Sandmeier Geophysik  
Observer: Mayer

Notes:  
This  
is  
a  
testfile!

Results:

	X	Y	Z
vmax [mm/s]:	0.7330	0.4570	1.2100
Dom.frequency [Hz]:	11.000	11.000	11.000
ZC-frequency [Hz]:	11.907	10.449	10.343
Time (rel.trig) [s]:	4.0010	4.3535	4.0693
KBFmax:	0.3667	0.2114	0.6254
max. displacement [mm]:	0.024932	0.008027	0.020525
max. acceleration [g]:	0.031748	0.012950	0.010954

Peak vector sum: 1.2665 [mm/s] at 4,0713 [s]

If several reports are printed altogether, the information of all files are stored in one summary text report file.

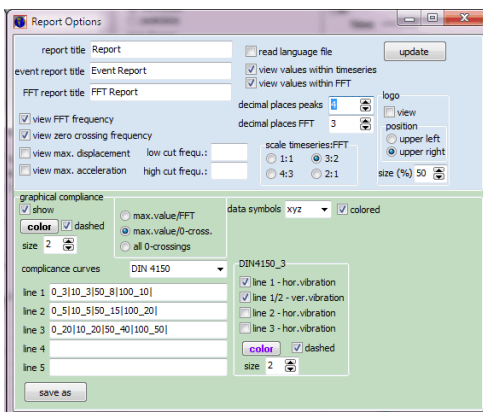
## Report options/General:

Entering the report options menu using `report options`, the titles of the different reports can be changed as well as the decimal places for the numbers shown in the report (separately for peaks and FFT).

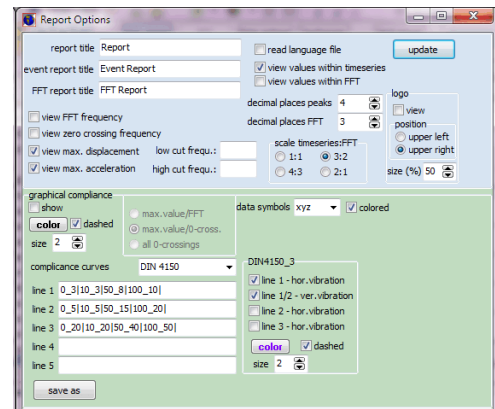
If the option *view* is activated a logo from file `logo.jpg` stored under the program path will be displayed either at the upper left or right. The option *size* controls the logo size in percent of the original size.

If the option *read language file* is activated, the ASCII-file `report_language.fil`, which is delivered with the program file `ReflexVibro.exe`, is read.

As default, the language file allows generating a report in German language substituting the necessary English terms by their German counterparts. To generate reports in other languages, please edit `report_language.fil` and make the relevant modifications.



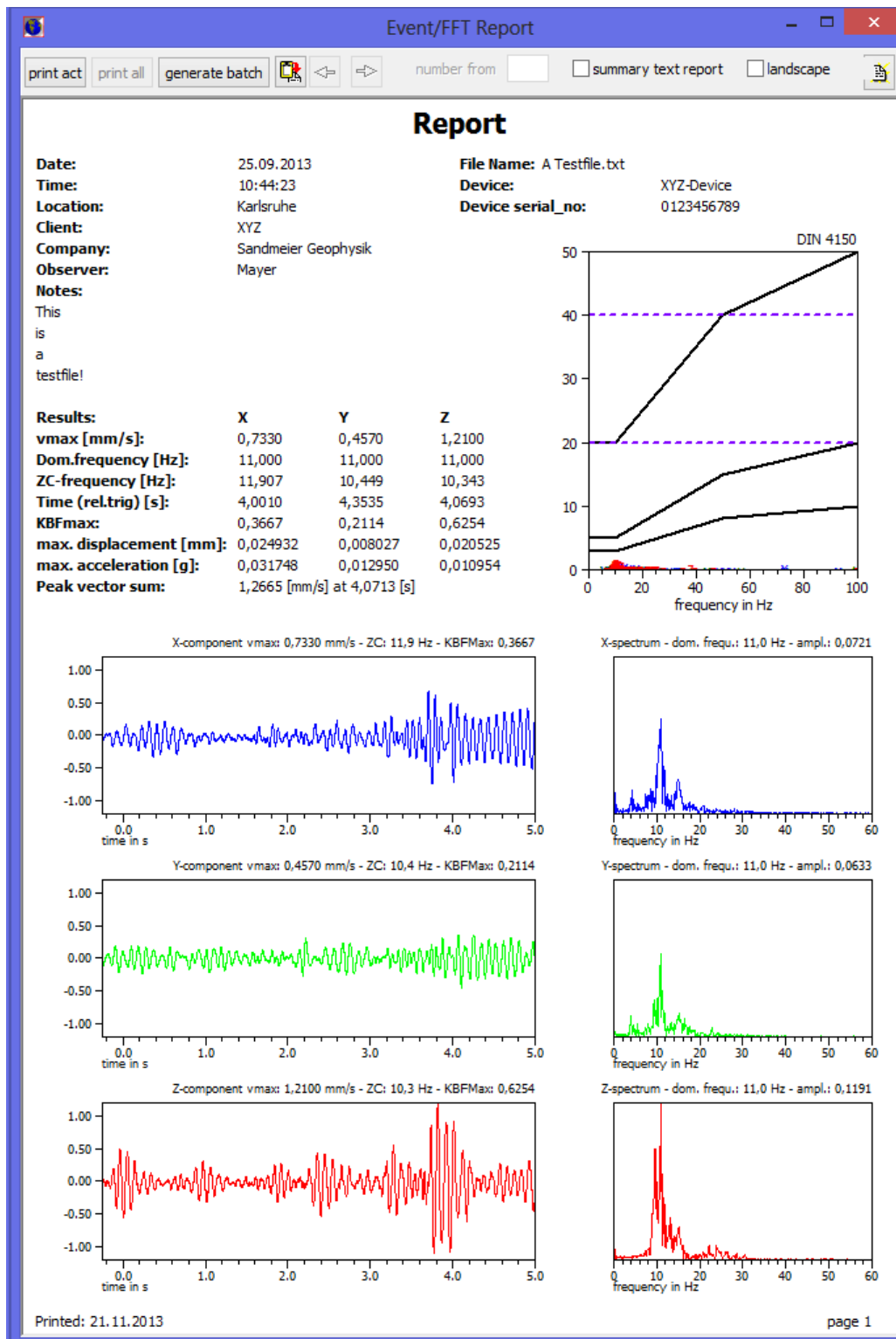
Report options for wavedata Event/FFT report shown below



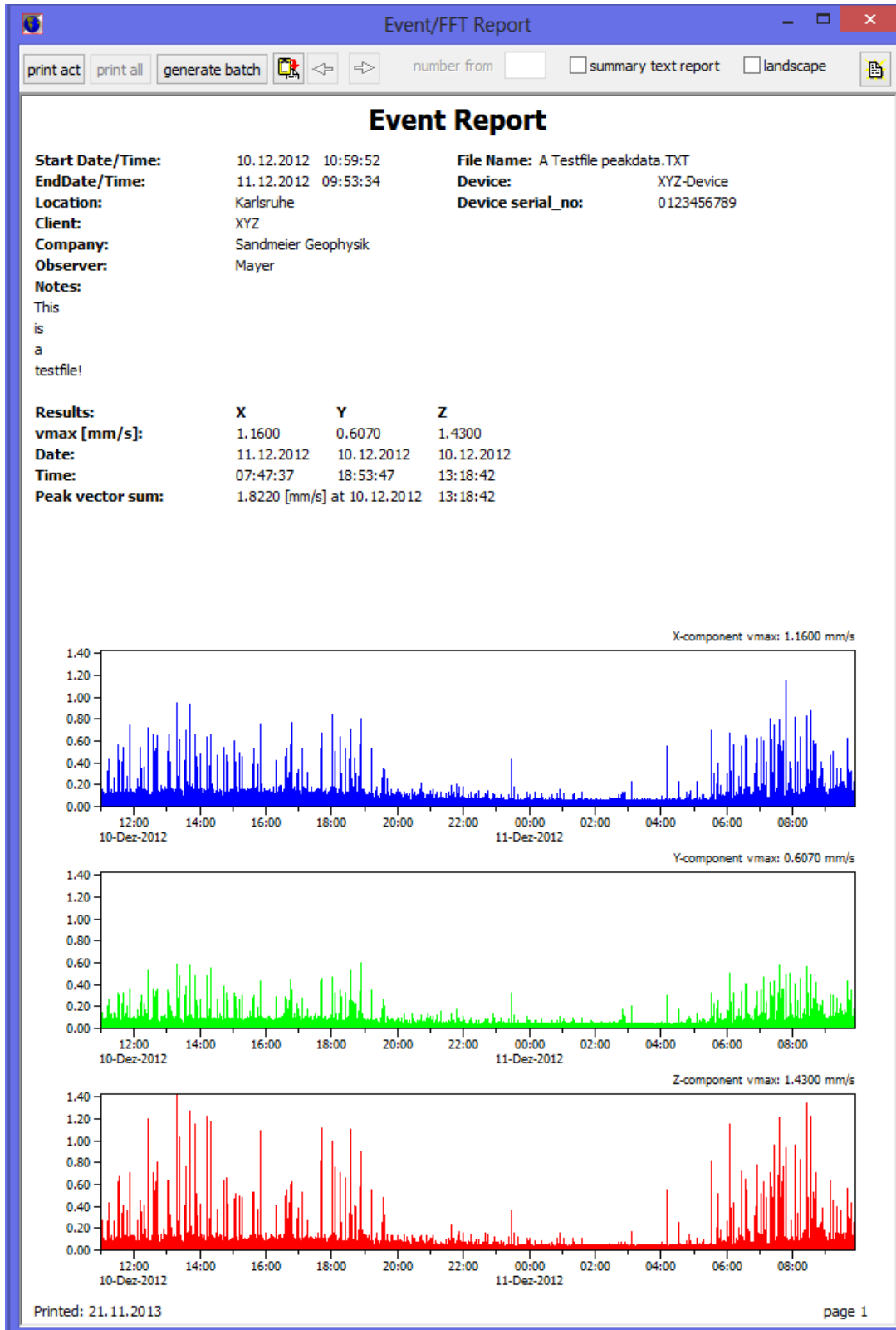
Report options for peakdata event report shown below

With the option *view values within timeseries* activated, *vmax*, *amax*, *smax*, *ZC*, *KBFMax* and *RMSmax* are plotted above the time series graphs in dependency of the chosen plot and filter options.

Activating the option *view values within FFT* allows to plot dom. freq. and ampl. above the FFT graphs. The relation between the width of the graphs of the time series to the graphs of the spectra can be modified from *1:1* (default) to *3:2*, *4:3* and *2:1*.



Wave data: Example of an Event/FFT report generated with the report options shown above.

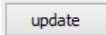


Peak data: Example of an Event report generated with the report options shown above.



Additional results are shown, if the following options are activated:

<i>view FFT frequency:</i>	The dom.frequency within the chosen time series is stated.
<i>view zero crossing frequency:</i>	ZC-frequency is shown.
<i>view max. displacement:</i>	If velocities are displayed, the max. displacement can be calculated and listed. (To avoid errors due to low frequencies during the integration of the velocity data, a <i>low corner frequency</i> can be defined, below which the frequencies are not taken into account.)
<i>view max. acceleration:</i>	The max. acceleration can be determined also, if velocities are displayed, t. (To avoid errors due to high frequencies during the differentiation of the velocity data, a <i>high corner frequency</i> can be defined, above which the frequencies are not taken into account.)

To apply modified report options, please click the button .

### **Report options/Graphical compliance:**

The option *show* has to be selected to generate a compliance graph.

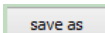
To display the data different *data symbols* (xyz or circles) can be used, which can be plotted all in black color or in these colors, which match the colors of the individual components of the data in the graphs: x/blue, y/green and z/red (option *co-lore*d activated).

According to the chosen plot and filter options the velocity, the displacement and the acceleration, resp., can be plotted in different modes:

- *max.value/FFT:* This date of the time series is plotted, which corresponds to the max. frequency value of the FFT.
- *max.value/0-cross.:* The main periods and the corresponding frequencies of all intervals bounded by consecutive zero crossings of the time series are determined and allocated to the midpoint of the intervals. The midpoint which corresponds to the max. frequency value is plotted.
- *all 0-crossings:* All midpoints are plotted.

It is possible to define up to five compliance lines manually or to choose one of the predefined *compliance curves* (DIN 4150, e.g.).

The *color* and the *size* of the compliance lines can be adjusted and they can be printed as solid or *dashed* line.

The manually defined compliance curves can be saved (and reloaded afterwards) using . A file *compliance\_curves.fil*, which contains all ever self-defined compliance curves, is generated in that directory, where the program ReflexVibro.exe is located. This file can be edited and changed manually. If one of the compliance curves is no longer needed, just erase the complete curve in the *compliance\_curves.fil*.

First self-defined compliancecurve

5	0.00	10.00	50.00	80.00	100.00	0.00	0.00	0.00	0.00	0.00
	3.00	3.00	8.00	10.00	10.00	0.00	0.00	0.00	0.00	0.00
5	0.00	10.00	50.00	80.00	100.00	0.00	0.00	0.00	0.00	0.00
	5.00	5.00	15.00	20.00	20.00	0.00	0.00	0.00	0.00	0.00
5	0.00	10.00	50.00	80.00	100.00	0.00	0.00	0.00	0.00	0.00
	20.00	20.00	40.00	40.00	50.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Second self-defined compliancecurve

5	0.00	10.00	50.00	80.00	100.00	0.00	0.00	0.00	0.00	0.00
	3.00	3.00	8.00	10.00	15.00	0.00	0.00	0.00	0.00	0.00
5	0.00	10.00	50.00	80.00	100.00	0.00	0.00	0.00	0.00	0.00
	5.00	5.00	15.00	15.00	20.00	0.00	0.00	0.00	0.00	0.00
5	0.00	10.00	50.00	80.00	100.00	0.00	0.00	0.00	0.00	0.00
	20.00	20.00	50.00	50.00	50.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

In addition to the compliance curves described above, four additional lines, which are defined in DIN 4150\_3 (see the following figure), can be designed and printed (dashed or not, color, size) independently from the compliance curves.

These lines indicate the maximum values of the vibration velocity of the major component [mm/s].

*line 1 - hor. vibration:* Maximum value for horizontal vibrations in industrial buildings and the like (40 mm/s).

*line 1/2 - ver. vibration:* Maximum value for vertical vibrations in industrial buildings and the like and in residential buildings and the like (20 mm/s).

*line 2 - hor. vibration:* Maximum value for horizontal vibrations in residential buildings and the like (15 mm/s).

*line 3 - hor. vibration:* Maximum value for horizontal vibrations in buildings, which are especially vibration sensitive (8 mm/s).

Anhaltswerte bzw. Immissionswerte zur Beurteilung von Erschütterungen auf Gebäude gemäß DIN 4150-3 und LAI-Leitlinie. Dort Tabelle 1 aus „Hinweise zur Messung, Beurteilung und Verminderung von Erschütterungsimmisionen, Beschluss des Länderausschusses für Immissionswerte (LAI) vom 10.05.2000“.										
Spalte Zeile	Gebäudeart	2			3	4			5	6
		Kurzzeitige Erschütterungen					Dauererschütterungen			
		Fundament Frequenz***)			oberste Deckenebene, horizontal	vertikale Deckenschwingu ngen	oberste Deckenebene, horizontal*)	vertikale Deckenschwin gungen**)		
<10 Hz	10-50 Hz	50-100** Hz								
1	Gewerblich genutzte Bauten, Industriebauten und ähnlich strukturierte Bauten	20	20 bis 40	40 bis 50	40	20	10	10		
2	Wohngebäude und in ihrer Konstruktion und/oder Nutzung gleichartige Bauten	5	5 bis 15	15 bis 20	15	20	5	10		
3	Bauten, die wegen ihrer besonderen Erschütterungsempfindlichkeit nicht denen nach Zeile 1 und 2 entsprechen und besonders erhaltenswert (z.B. unter Denkmalschutz stehen) sind	3	3 bis 8	8 bis 10	8	**)	2,5	**)		
Messwerte nach DIN 4150-3		Maximalwerte der Schwinggeschwindigkeit der größten Komponente in mm/s								

\*) Bei Frequenzen über 100 Hz sollen die Anhaltswerte für 100 Hz angesetzt werden.  
 \*\*) Das Maß der noch unschädlichen Erschütterungseinwirkung ist im Einzelfall festzustellen.  
 \*\*\*) Die Immissionswerte für Frequenzen von 10 bis 50 Hz sowie von 50 bis 100 Hz sind durch lineare Interpolation zwischen den Immissionswerten der jeweiligen Zeilen zu ermitteln.  
 +) Siehe DIN 4150-3, Nr. 6.1  
 ++)) Siehe DIN 4150-3, Nr. 6.2

## 5. Appendix

### Determination of $KB_{Fmax}$

If the vibration velocity is measured, the human's perceptivity of vibration is frequency-independent in wide ranges (DIN 4150 Teil 2, 1999).

For low frequencies the frequency dependency is approximately described by the following KB-filter function (Menges, H. and Kiesel, K.-J., 2005):

$$|H_{KB}(f)| = \frac{1}{\sqrt{1 + (f_0 / f)^2}}$$

with  $f$  = frequency  
 $f_0$  = high pass frequency

As vibrations of buildings with high frequencies cannot be perceived by human beings, the high pass filter is supplemented by a high cut filter, which leads in the end to a so-called bandwidth limited filter.

Menges, H. and Kiesel, K.-J., 2005, propose  $f_0 = 5,6$  Hz and  $f_{\text{cut off}} = 80$  Hz, which are set as default values in ReflexVibro.

After filtering the data with this bandwidth limited filter the moving effective value of the data is achieved using the following formula.

$$KB_F(t) = \sqrt{\frac{1}{\tau} \int_{\xi=0}^t e^{-\frac{t-\xi}{\tau}} \cdot KB^2(\xi) d\xi}$$

with  $\tau = 125$  ms  
 $\xi$  = integration variable  
 F = Fast, abbreviation for  $\tau = 125$  ms

The time constant  $\tau = 125$  ms is the same as used when noise measurements are carried out in 'fast' mode (Menges, H. and Kiesel, K.-J., 2005).

The highest value of  $KB_F(t)$  within a chosen evaluation time,  $KB_{Fmax}$ , is a major assessment factor for vibration measurements (Menges, H. and Kiesel, K.-J., 2005).

With the help of ReflexVibro  $KB_{Fmax}$  can be calculated over the whole time range of the data or inside a moving window with 125 ms length, i.e.  $\xi = [t - 125 \text{ ms}; t]$ .

### Calculation of RMS-Values

The RMS value  $f_{RMS}$  of a set of values is the square root of the arithmetic mean of the squares of the original values:

$$f_{RMS} = \sqrt{\frac{1}{n}(X_1^2 + X_2^2 + \dots + X_n^2)}$$

The RMS value  $f_{\text{RMS}}$  can be calculated for the measured data  $v(t)$ , the acceleration  $a(t)$  or the displacement  $s(t)$ , depending on the chosen filter functions, see below. Furthermore the RMS value  $f_{\text{RMS}}$  can be calculated over the whole time range of the data or inside a moving window with 1 s or 125 ms length.

At any rate, the maximum of the determined RMS values is indicated.

### ***Vector sum of a time series***

The *vector sum*  $s_{\text{vec}}$  is defined as the absolute value of the three-dimensional vector of the time series  $v = v(x,y,z)$ :

$$s_{\text{vec}} = |v| = \sqrt{x^2 + y^2 + z^2}$$

## Filter functions

*apply calibration factor:* allows to specify different calibration factors for the 3 components with which the data will be multiplied.

*baseline-correction:* Corrects a shift of the baseline as a consequence of a DC-current crossfeed.

*50 Hz Notchfilter:* Corrects the data in relation to 50 Hz AC-current crossfeed.

*integrate:* The measured velocity data  $v(t)$  is integrated to achieve the acceleration  $a(t)$ . It is recommended to apply a highpass bandpass filter in addition (set low e.g. to 2 Hz and high to the overall max. frequency value) in order to remove a possible very low frequency processing noise.

*differentiate:* The displacement  $s(t)$  is calculated by differentiating the velocity data  $v(t)$ . It is often recommended to apply a highcut bandpass filter in addition (set low e.g. to 0 Hz and high to the max. relevant frequency value within the original spectrum of the measured data) in order to remove a possible high frequency processing noise.

*bandpass:* The data is filtered according to the arbitrary *low* and *high* cut frequencies. Note: To avoid cut-off effects, the bandpass is tapered by an fixed cos-function, so that the frequency band is a bit wider than the set low and high cut frequencies.

## Spectrum types

*amplitude spectrum:* Amplitude of the FFT of the measured data.

*power spectrum:* Square of the amplitude spectrum.

*octave spectrum - mean aver.:* Octave spectrum using the mean average

*octave spectrum - RMS aver.:* Octave spectrum using the RMS averga

*1/3 octave spectrum - mean aver.:* Third octave spectrum using the mean average

*1/3 octave spectrum - RMS aver.:* Octave spectrum using the RMS average

## Transfer function

Is  $D_v(\omega)$  the spectrum of the vibration's source,  $D_g(\omega)$  the spectrum of the ground data,  $D_s(\omega)$  the spectrum of the structure data,  $T_g(\omega)$  the ground's transfer function and  $T_s(\omega)$  the structure's transfer function. According to the filter theory, the variables are related with one another in the following way:

$$\begin{aligned}D_g(\omega) &= D_v(\omega) \cdot T_g(\omega) \\D_s(\omega) &= D_g(\omega) \cdot T_s(\omega) = D_v(\omega) \cdot T_g(\omega) \cdot T_s(\omega) \\T_s(\omega) &= \frac{D_s(\omega)}{D_g(\omega)}\end{aligned}$$

In time domain, the corresponding variables would have to be convoluted and deconvoluted resp..

### **Nyquist-Theorem and frequency resolution**

The Nyquist-Theorem has always to be taken into account. The *timeincrement*  $t_d$  and the *nyquist frequency*  $f_0$  have to be suited to one another:

$$t_d < 1 / (2 \cdot f_0)$$

Therefore the frequency content of the measured data must no contain frequencies above the nyquist frequency which is defined by the given timeincrement of the acquisition device. (Rumdrehen der Formel) Otherwise a convolution of the high frequencies into the lower frequency range occurs and may lead to a wrong interpretation.

The frequency resolution  $\Delta f$  is given by the inverse of the time *duration*  $T$ :

$$\Delta f = 1 / T$$

The longer the *duration* of the test signal the detailed is its spectrum.

If a testsignal is generated the Nyquist theorem must also be considered. Therefore you must restrict the frequency range depending on the entered timeincrement (or vice versa) according to the formula given above.

## **6. Literature**

Aymans, J.-P. And Breuer F.: Erschütterungen aus oberirdischem Bahnverkehr, Beispiel Ausbaustrecke Köln - Aachen: EI - Eisenbahningenieur, v.57, p.10-14, 7/2006.

DIN 4150, Teil 1: Erschütterungen im Bauwesen, Grundsätze, Vorermittlungen und Messung zu Schwingungsgröße, Juni 2001.

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