VIEW 2002 – the new Analysis Software for the MR2002 CE

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VIEW2002 is the data evaluation software specifically developed for the MR2002 Strong Motion Recorder. VIEW2002 is the tool to view and process the data signals recorded with the MR2002 and to carry out a large number of evaluations like integration, frequency analysis or calculation of damping. The following chapters give a short introduction into VIEW 2002 using three typical examples of vibration measurement tasks. They are primarily meant as a guided tour when using the Demo-CD attached to this brochure.

1.1 Eigenfrequency of a pedestrian bridge

The first example is taken from the vibration evaluation of a pedestrian bridge with a main span of 50 m (see Fig. 3.1). The tri-axial sensor MS2003 has been placed in the middle of the main span. We will use these measurements to introduce the main features of VIEW 2002.

Fig. 1.1

We open the program VIEW 2002 and start with the main window of Fig. 1.2. From here all main tasks in VIEW 2002 are invoked.
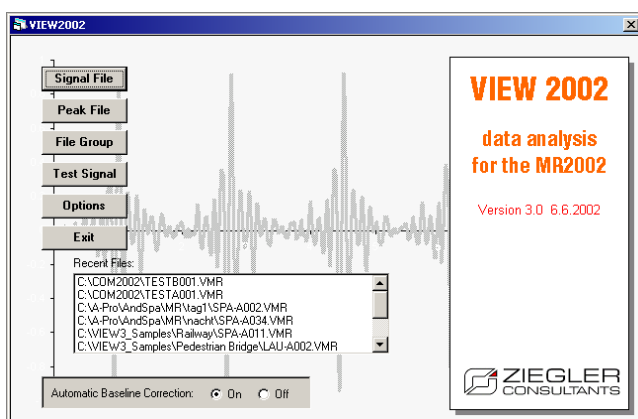

Fig.1.2

Click on **Signal File** to open the main window for signal file representation. An empty window as shown in Fig. 1.3 appears.
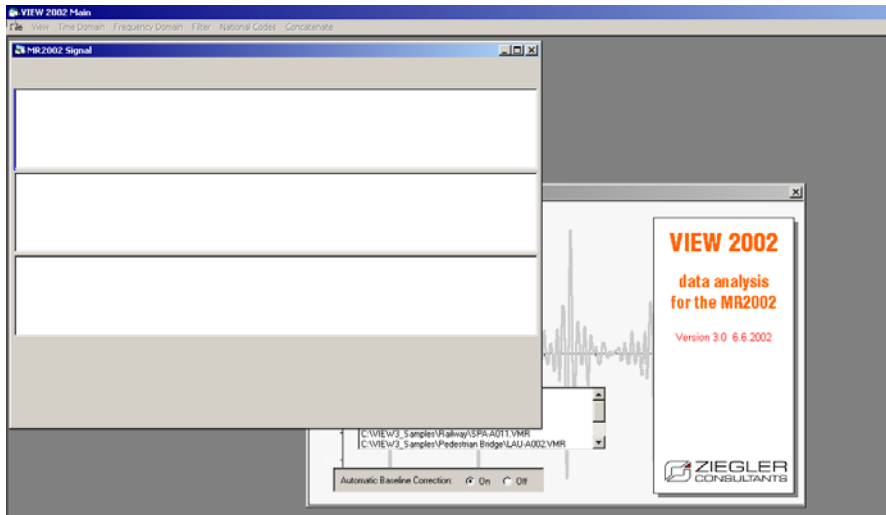
Fig 1.3

In the menu bar we select **File**, **Open VMR-File** and select **LAU-A002.VMR** in the File Selection Window (Fig. 1.4) to display the vibrations of the pedestrian bridge as shown in Fig. 1.5.
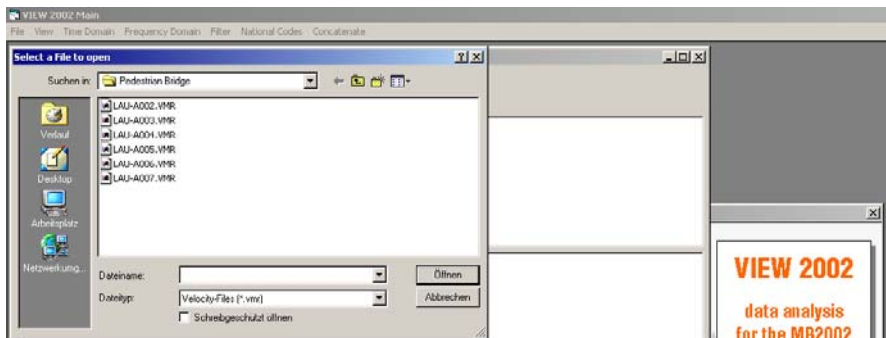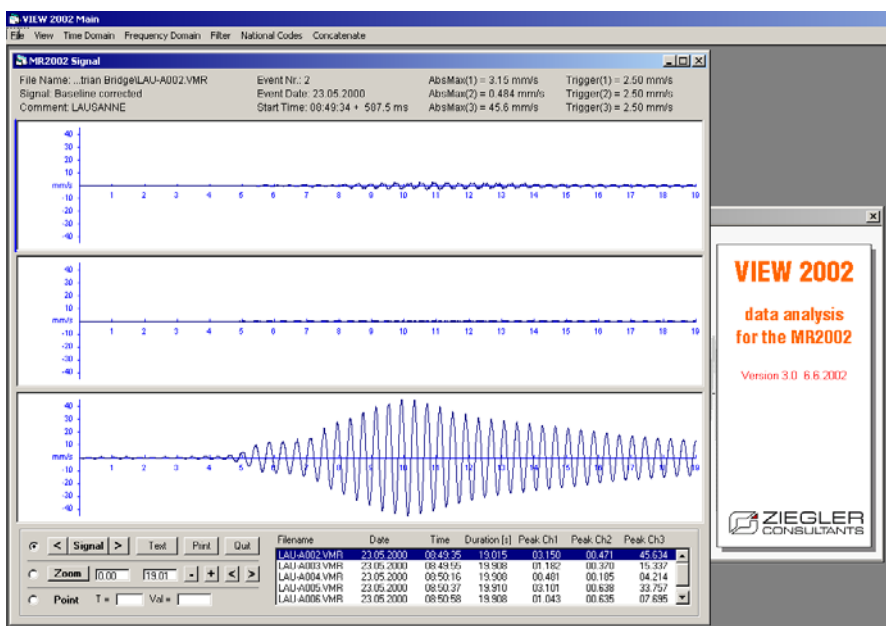

Fig. 1.4

Fig. 1.5

The signal window has all relevant information about this measurement. The window can be adjusted in size in the usual way. Note that the character size changes with the window height. The three diagrams in the center part display the vibrations measured by the three

Channels, i.e. Channel 1 (X), Channel 2 (Y) and Channel 3 (Z). The header shows time of measurement, maximum values and the trigger used for the measurements. The lower part is the command section of the window: On the left all the command buttons are assembled, on the right all the files of our file group (i.e. files with the same file name root) are listed.

To get used to WIEW 2002 we will start with the command buttons. These buttons will be found on almost every window and have almost everywhere the same purpose. By the way the vibration displayed in the Z-diagram represents the vertical vibration of the pedestrian bridge being excited by three persons in its eigenfrequency.

Make sure that the option **Signal** is selected and use the ◁ Signal ▷ buttons to step through all signals recorded on the pedestrian bridge. To view part of a signal, select the option Zoom (i.e. click the small circle left of the button **Zoom**) and mark the zoom range with the mouse using the left mouse button (press the left mouse button to start and release the button to end the zoom range). Then press **Zoom** to display the selected zoom range.
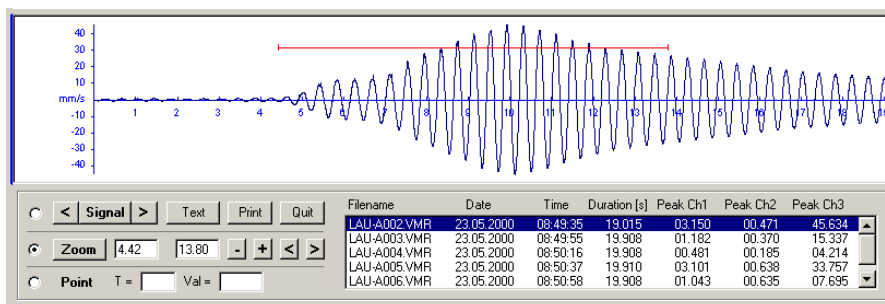

Fig. 1.6

You can enter numerical values for the zoom range in the text boxes right of the button **Zoom**, you can decrease or increase the zoom range with the buttons ⊟⊞, or you can move the signal towards left or right with the buttons ◁▷.

To display numerical values of the signal, select the option **Point**. Mark the desired peak of your signal with the left mouse button. A red circle will be displayed, as shown in Fig. 1.7. The corresponding values for time and amplitude will be displayed in the textbox. You can move the selected point using the buttons ◁▷.
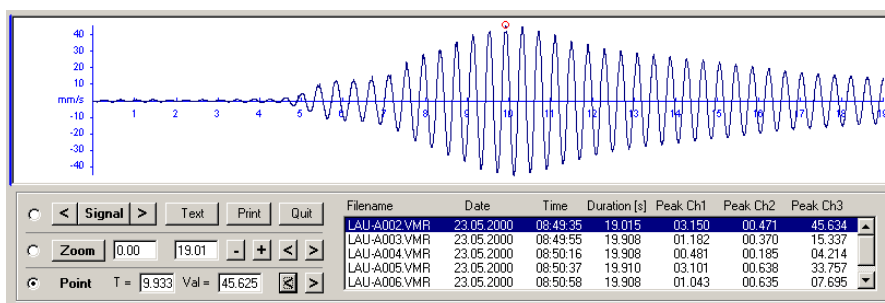

Fig. 1.7

Being more or less familiar with the functionality of VIEW 2002 we will now proceed with our task and compute the following properties of the pedestrian bridge:

- Maximum velocity
- Maximum acceleration
- Maximum displacement
- Eigenfrequency and damping

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The maximum velocity is already displayed in our signal window in the header as 45.6 mm/s. A check of the file list (Fig. 1.8) shows that the displayed file nr. 2 is really the file with the highest velocity value.

Filename	Date	Time	Duration [s]	Peak Ch1	Peak Ch2	Peak Ch3
LAU-A002.VMR	23.05.2000	08:49:35	19.015	03.150	00.471	45.634
LAU-A003.VMR	23.05.2000	08:49:55	19.908	01.182	00.370	15.337
LAU-A004.VMR	23.05.2000	08:50:16	19.908	00.481	00.185	04.214
LAU-A005.VMR	23.05.2000	08:50:37	19.910	03.101	00.638	33.757
LAU-A006.VMR	23.05.2000	08:50:58	19.908	01.043	00.635	07.695

Fig. 1.8

Before we proceed to acceleration make sure that the entire and original signal nr. 2 is displayed by pressing **Signal** or by double-click on the file **LAU-A002.VMR** in the file list. Select the option **Signal** to disable Zooming and Pointing.

To compute acceleration we select (in the menu bar) **Time Domain** and then **Acceleration**. Accept the default in the "Settings for Acceleration" and press **OK**.
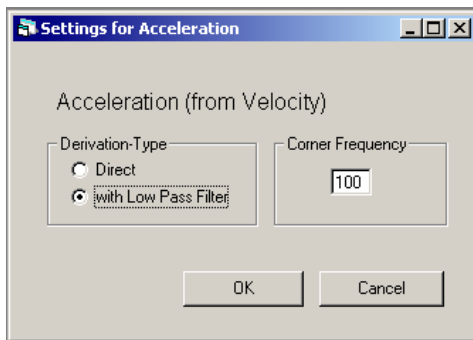

Fig. 1.9 shows the acceleration signals for the three channels. The bridge reaches a peak acceleration of almost 1 m/s^2. Double click on the diagram 3 to view the vertical axis enlarged.
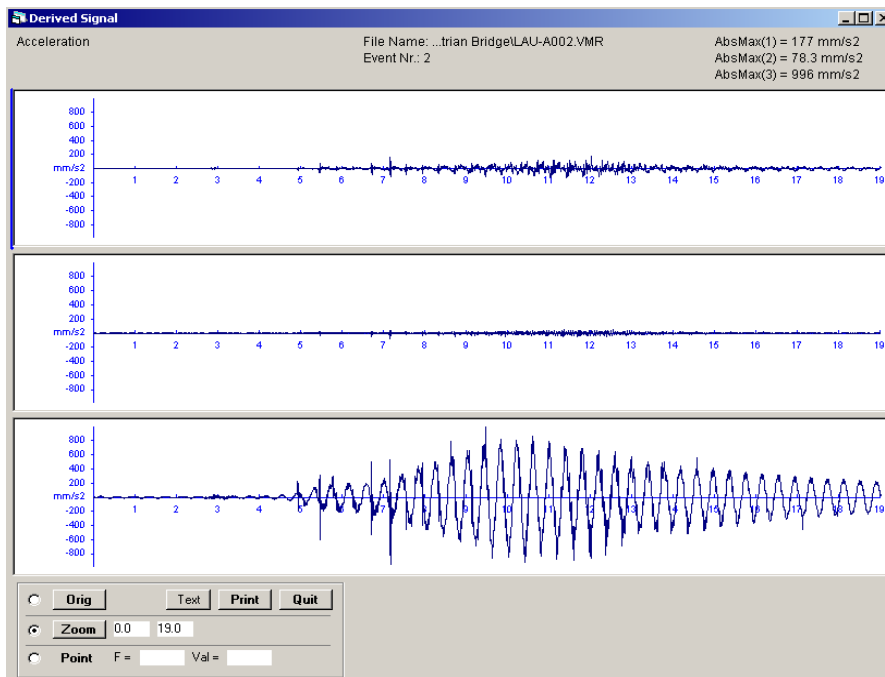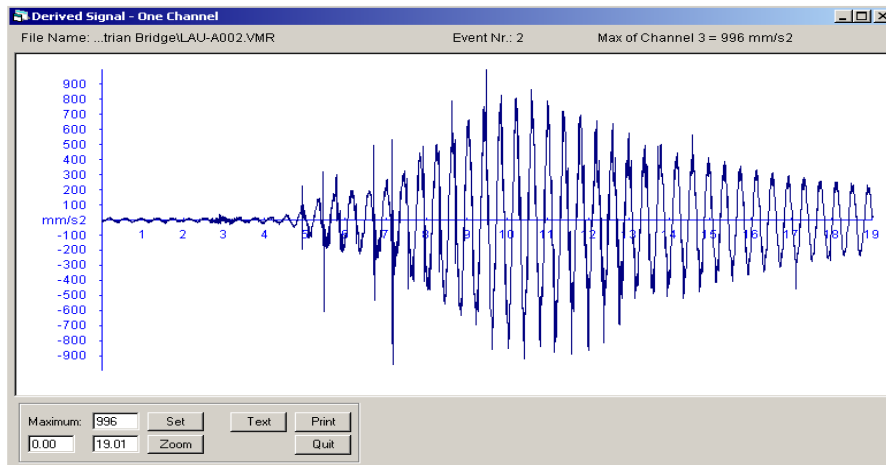

Fig. 1.9a

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Fig. 1.9b

We close now the two windows displaying acceleration and return to the principal signal window with the velocity signal. To compute the displacement we select (in the menu bar) **Time Domain** and then **Displacement**. Accept the default in the "Settings for Displacement" and press **OK**. In the window with the displacement for the three channels double-click on the third diagram to display the displacement signal for the vertical vibration of the bridge as shown in Fig. 1.10. The bridge reaches – when purposely excited at its own frequency – a maximum displacement of almost 3 mm.
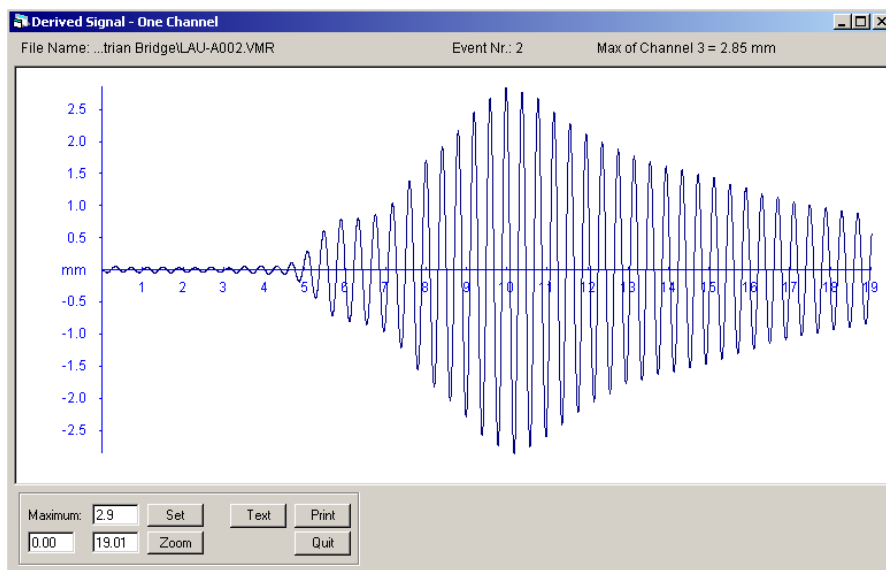

Fig. 1.10

We close again the two windows displaying displacement and return to the main signal window with the velocity signal.

We are now going to compute the eigenfrequency and the damping of the pedestrian bridge. For this purpose we select **Frequency Domain** in the menu bar. The settings for frequency analysis appears as shown in Fig. 1.11.
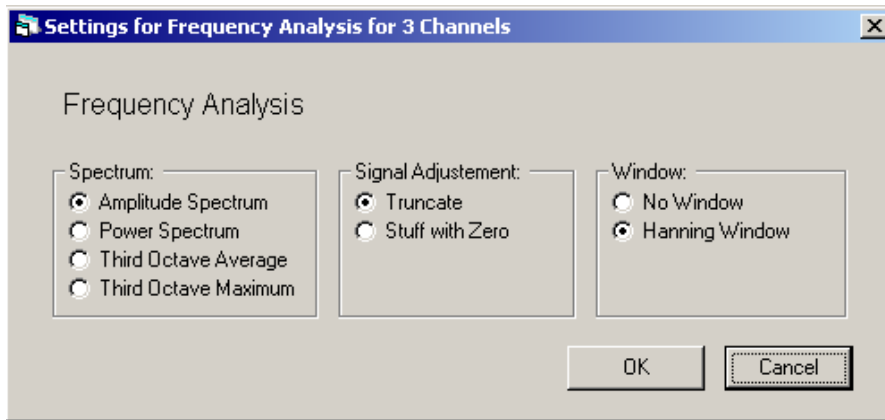
Fig. 1.11

For our purpose we can leave the settings as shown in Fig. 1.11, but let us have a quick look at the options given in these settings. We can chose among different types of frequency analysis, i.e. amplitude spectrum (which is just the square root of the power spectrum), the power spectrum and the third octave spectrum. We can adjust the length of the signal (because the computer needs a number of data points which corresponds to the power of 2 to perform the frequency analysis) by using "truncate" (i.e. cut the signal) or "stuff with zero's" (make it artificially longer). Eventually we can apply a "Hanning Window", which smoothes any sharp edges at the start or the end of the signal by multiplying the signal with sort of a cosine.

For the moment we accept the default settings and press **OK**. In the next window we see the amplitude spectrum over the entire frequency range. Let's zoom to the interesting part by entering the upper zoom limit of 20 Hz in the second zoom text box and press **Zoom**. Double-click on the third diagram to obtain the window in Fig. 1.12. The eigenfrequency of the pedestrian bridge is obviously 2.54 Hz.. The labeling of the peak is obtained by the following procedure: Mark the *Point check box*, point to the desired location (use the ◁ ▷ buttons to adjust the position) and press **Label**.
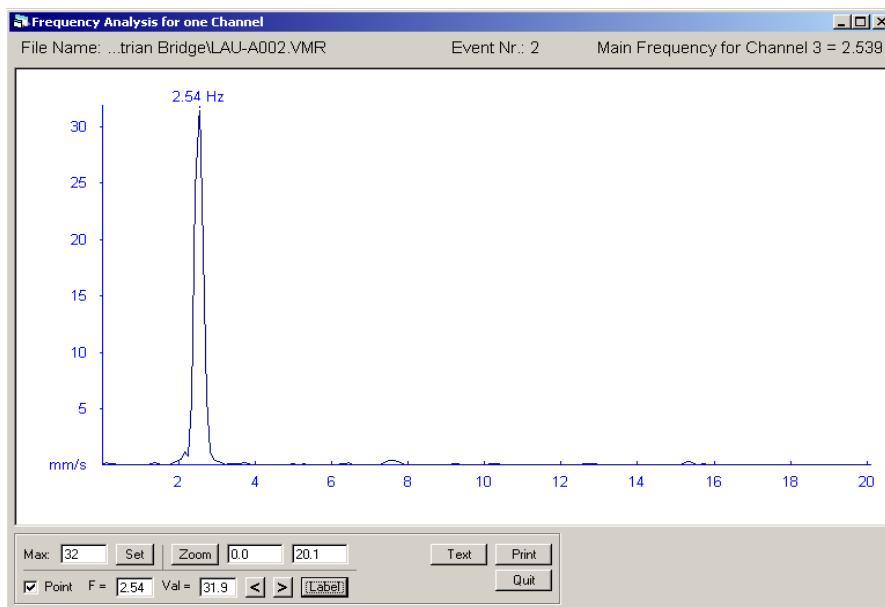

Fig. 1.12

To conclude our first session we will now determine the damping of the pedestrian bridge. We close all windows opened for the frequency analysis and return to the main window with the original velocity signal. Double-click on the third diagram to obtain the "One Channel"-window as shown in Fig. 1.13.

The damping curve is obtained in the following way:

1. Use the left mouse button to indicate the range of interest, i.e. press the button at the start and release it at the end of the portion for which you want to calculate the damping. This range is marked by a red line on the time axis.

2. Press **OK** to have VIEW 2002 calculate and draw the damping curve. If the damping curve does not look right, press **Clear** and start again.
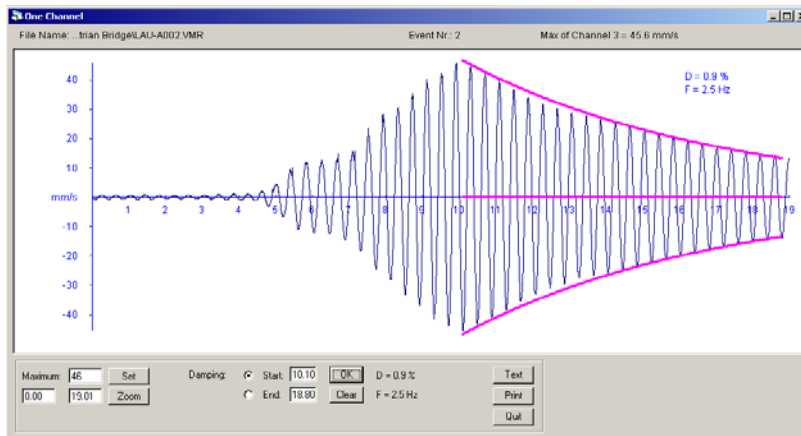

Fig. 1.13

The damping of the pedestrian bridge is 0.9 % of critical damping, the corresponding frequency is – as we have determined before – 2.5 Hz. VIEW 2002 computes the damping value using the model of a single degree of freedom system. The frequency in Fig. 1.13 is obtained by counting the zero-crossings and not by frequency analysis.

Before we conclude this session we will introduce a few general features of the program that are used in all parts of VIEW 2002, i.e.:

- Printing reports
- Copying diagrams into other documents
- Exporting data

We close the window with the damping curve and return to our main window with the original velocity signals. Before we print a signal we might want to add some text. So press **Text** to open the window of Fig. 1.14 and enter some comment you want to print along with your signals. Save the text with **Save** and close the text dialog box with **Quit**. Press **Print** to open the *Print Preview* (Fig. 1.15) and use the buttons in the toolbar to view your document and get it sent to your printer.
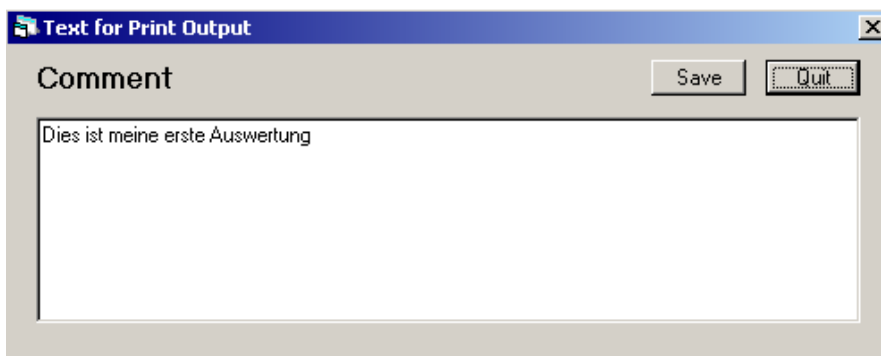

Fig. 1.14
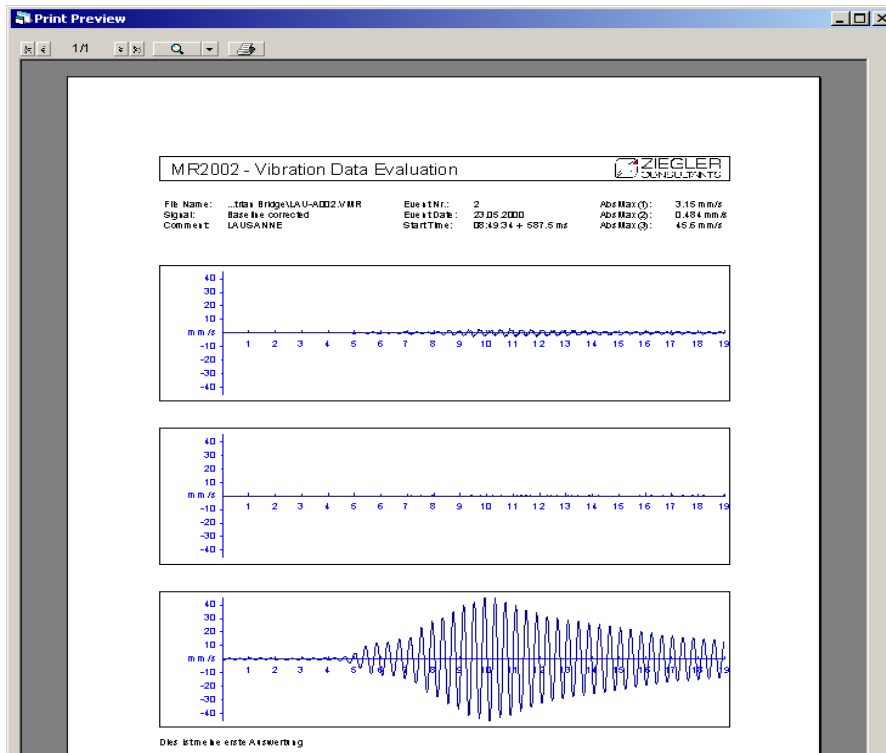
Fig. 1.15

Quite often we want to include VIEW 2002 diagrams in other Windows documents. VIEW 2002 uses the standard method "copy and paste" to transfer diagrams. With the key combination CTRL-C diagrams are copied into the Windows clipboard and may be pasted into other documents with CTRL-V. Note that the clipboard can only take one diagram at the time. For windows with three diagrams the active diagram, i.e. the diagram with the blue left border as shown in Fig. 1.16, will be copied into the clipboard.
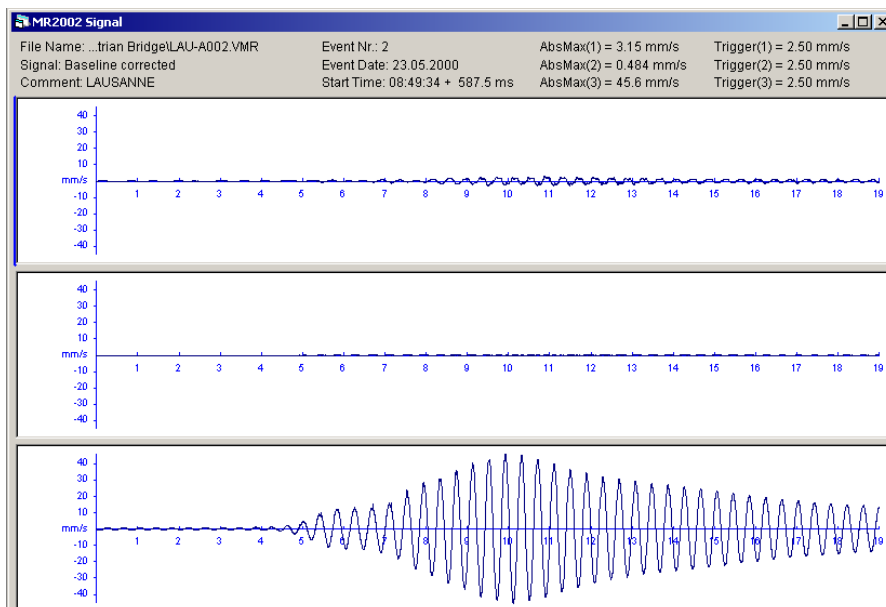
Fig. 1.16

VIEW 2002 is an open system, i.e. all data used or computed in VIEW 2002 can also be exported and used for further computations in other programs. For this purpose every window has a menu option **List** in the menu **View**. Selecting these items in the signal window you obtain the listing of Fig. 1.17. Press **Save as ..** to save these data as text file under the file-

name of your choice. Text files can easily be imported into programs like EXCEL or ACESS for further analysis.

Fig. 1.17

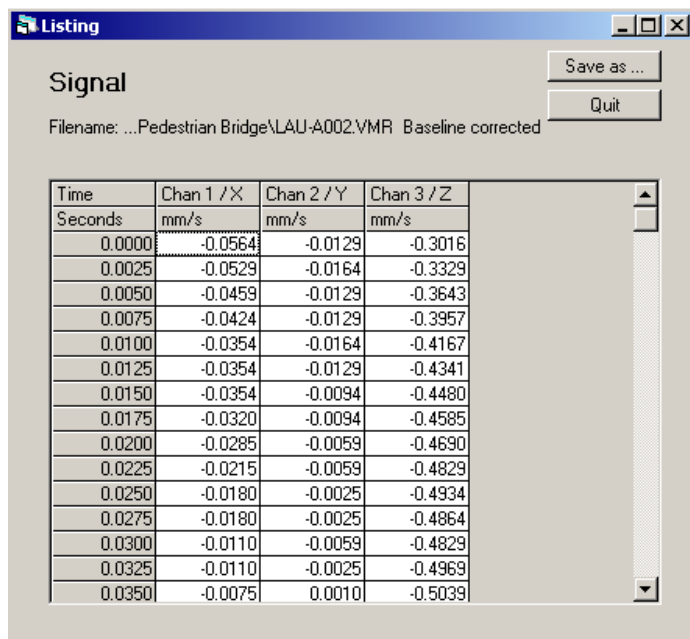This concludes our first session with VIEW 2002. We have introduced the most important features of the program and have seen, that - with just a few keystrokes - the dynamic behavior of a pedestrian bridge can be evaluated.

1.2 Vibration monitoring on a building site

The second example is taken from a vibration monitoring project for a building site (see Fig. 1.21). One tri-axial sensor has been placed on the man hole lid of a nearby underground petrol tank (Fig. 1.22). We will use these measurements mainly to introduce the evaluation of background monitoring with VIEW 2002.

Fig. 1.21

Fig. 1.22

As in the first session we open the program VIEW 2002 but select this time **Peak File** in the *Start Window*. With the menu options **File**, **Open VMX-File** we get to the file selection window as shown in Fig. 1.23. There we go to the directory **Building Site** and open the file **0416T001.VMX** and get Fig. 1.24.
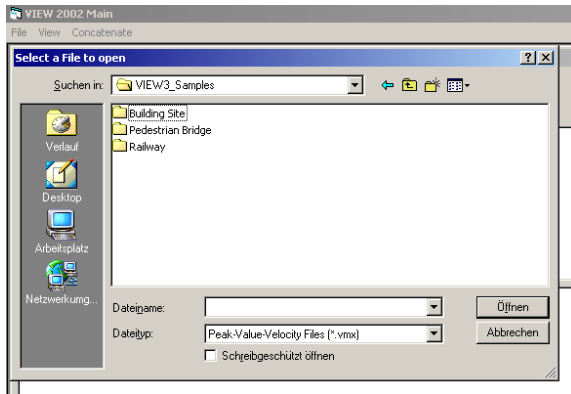
Fig. 1.23
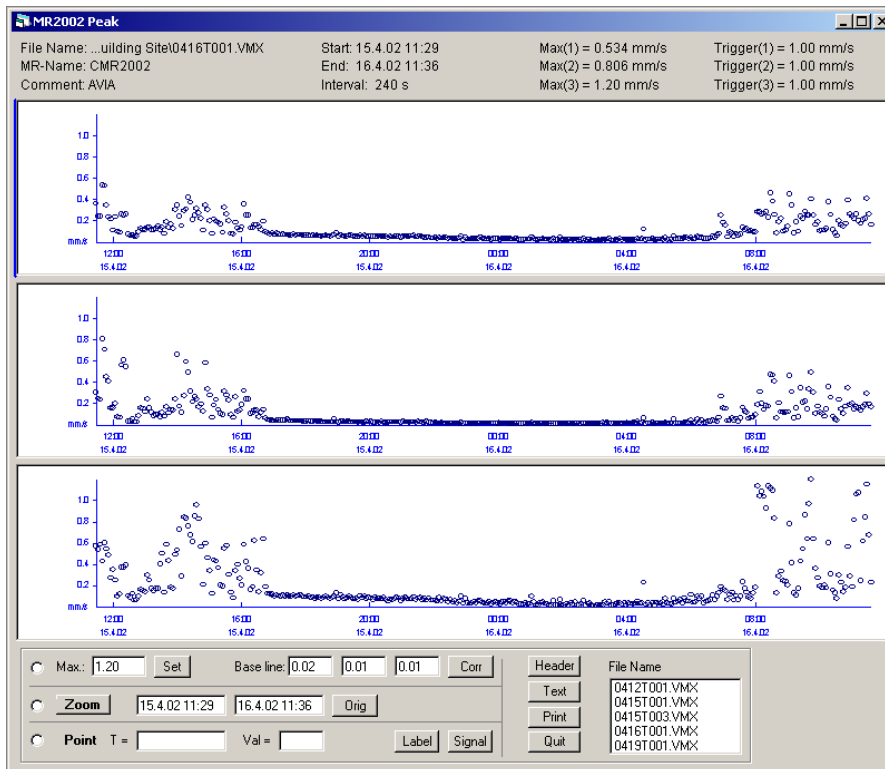
Fig. 1.24

Fig. 1.24 contains all relevant information about our background recording. The three diagrams show the maxima of the intervals for the three channels. In the header we find start time, end time and the interval length as well as the channel maxima and the trigger levels. The command buttons and the list of files are again arranged in the lower part of the window. We will first go through all the command buttons as they differ in their functionality somehow from the command buttons in the signal window.

With the **Set** button the scaling of the diagram can be set to a specific value. Enter a value of 2 in the *Max text box* to have all diagrams scaled to the desired value. This feature might be useful if your background recording contains just one very high value, which has been created by inadvertently moving the sensor. Use the button **Orig** to restore the original scaling.

The three *Base line text boxes* are useful if a base line error is present. However this option has to be used with judgment, as the base line error cannot be determined from the background recording alone. VIEW 2002 enters the lowest value of each channel into these text boxes and subtracts these values from each peak value upon pressing the button **Corr**.

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The Zoom function works the same way as in the signal window. Select the zoom option and use the left mouse button to mark the desired range. Then press **Zoom**. The **Orig** button brings you back to the full size.

The point function has enhanced possibilities in the Peak window. Select the option **Point** and use the left mouse button to mark the peak value for the time interval of 16.4.02 9:44. A red circle is drawn and the numerical values are displayed. You may use the ◄ ► buttons to adjust the marker. You can remove individual points using the button **0**. Press **Label** to have the point labeled with date and time. Quite often you would like to see the signal corresponding to the selected point. If a signal file exists and if it is in the same directory as the VMX-file VIEW 2002 will find it for you. So press **Signal** and the signal corresponding to the marked point is displayed as shown in Fig. 1.25.
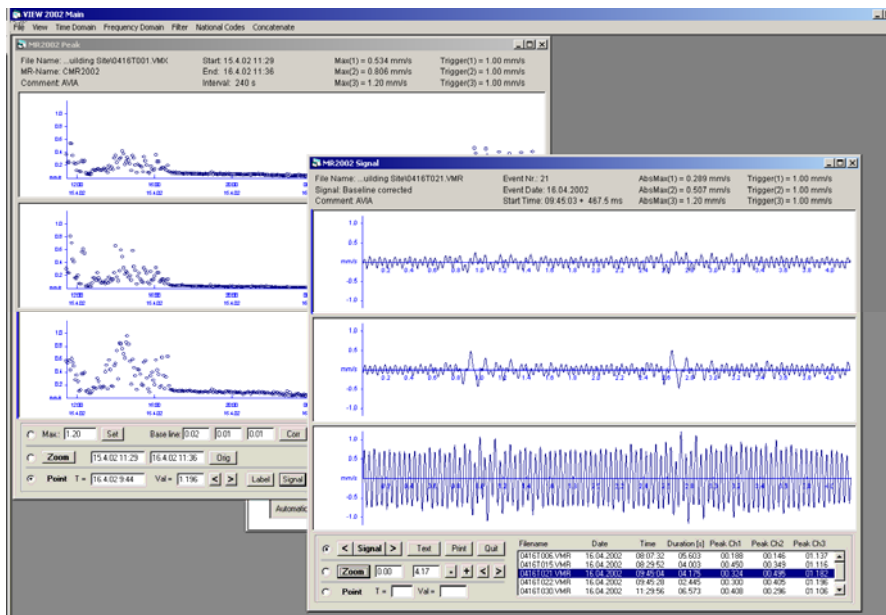
Fig. 1.25

The buttons **Header**, **Text**, **Print** and **Quit** work much in the same way as in the Signal window. A very useful feature is the concatenation of peak files. Quit often the monitoring period is split in several peak files but we would like to show it as one diagram. To demonstrate this option we close the Signal window and return to the Peak window.

The file list box displays all the peak files in the active directory. In order to concatenate them to one single file we have to open each one and add it to a so called "concatenated file". The process is done in the following way:

1. Double click the first file (0412T001.VMX) in the file list box.

2. Select **Concatenate** and **Append** in the menu bar. A message box appears, informing you about the status of the concatenated file. Press **OK**.

3. Repeat step 1 and 2 for all files in the file list box.

4. All peak files are now concatenated and have only to be displayed. To this purpose select **Concatenate** and **Display** to get the window of Fig. 1.26.
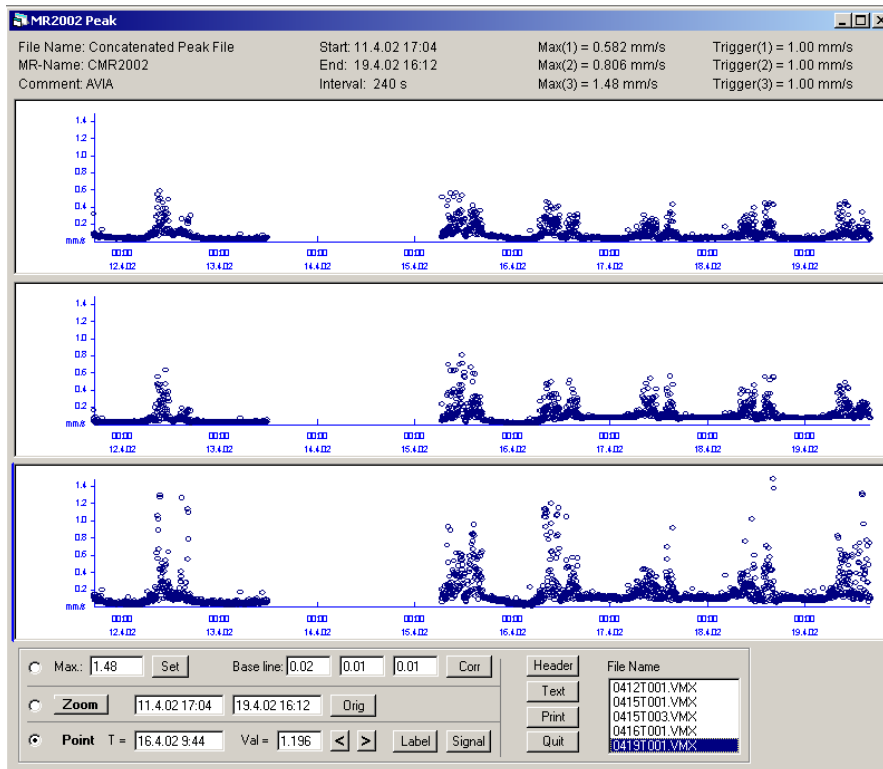
Fig. 1.26

We have now in one diagram the background monitoring for an entire week. We see also that the measuring instrument has been switched of over the weekend.

This concludes our second session with VIEW 2002. We know now how to work with peak files and have seen, how easy background recording can be evaluated.

1.3 Evaluation of train vibrations

The third example is taken from a vibration measurement project carried out for Swiss Rail. The house in Fig. 1.30 will receive a new bifurcation in front of its doorsteps. Swiss Rail – and probably also the house owner - are concerned about the increase of vibrations and ordered vibration measurements. We will use part of these measurements to introduce the evaluation of entire file groups.

Fig. 1.30

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As in the previous sessions we open the program VIEW 2002. In the *Start window* select **Signal File** and in the menu bar of the Signal window **File**, **Open VMR-File**. Find your way to the directory *Railway* and open the file **SPA-A002.VMR**. You should see now the signal shown in Fig. 1.32. These signals have been recorded with three vertical uni-axial sensors, the first channel (X) being mounted in the middle of the living room floor, the second (Y) on the foundation and the third (Z) in the garden (representing free-field vibration).
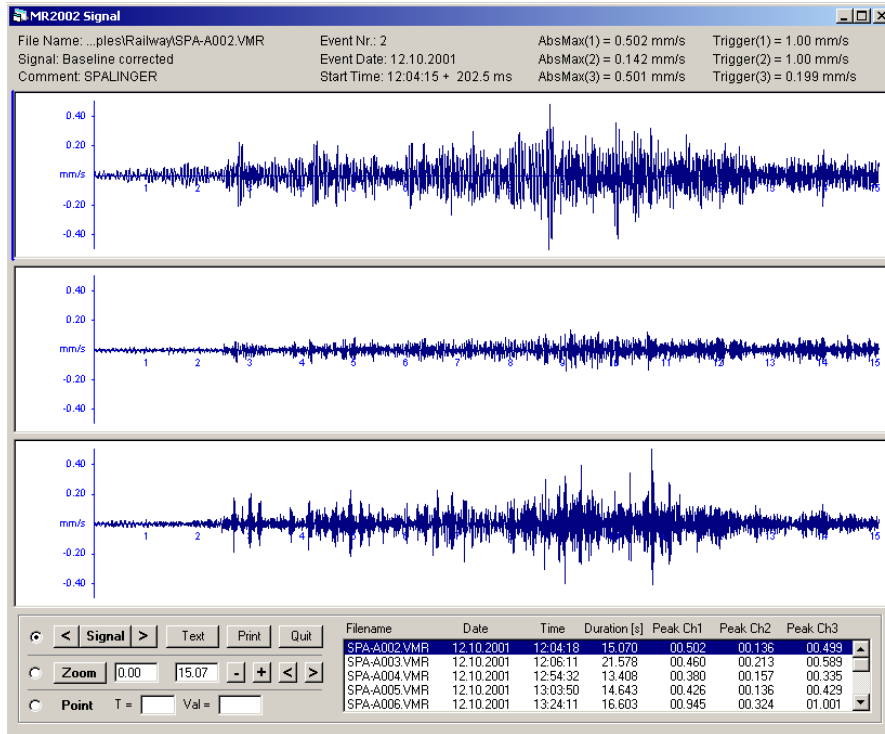
Fig. 1.31

Use the [< Signal >] - buttons to step through the signals. The signals represent the trains between 12:00 and 16:00. File Group Analysis in VIEW 2002 is a very powerful tool to evaluate large amount of data in a very short time. File Group Analysis treats always all files in a selected directory. Make sure that all required files (and not more) are in the directory you are going to work with.

Directory *Railway* contains the 12 files we want to analyze. We select **File Group** in the Start window to get to the File Group Selection window as shown in Fig. 1.32. Select the File Type *vmr*, select the appropriate drive and navigate your way to the directory *Railway*. The 12 files SPA-A002.VMR to SPA-A013.VMR should be listed in the file list box. They are listed there just for your convenience and you cannot select or deselect some of them. If you want to deselect some of them you have to remove them from the directory.
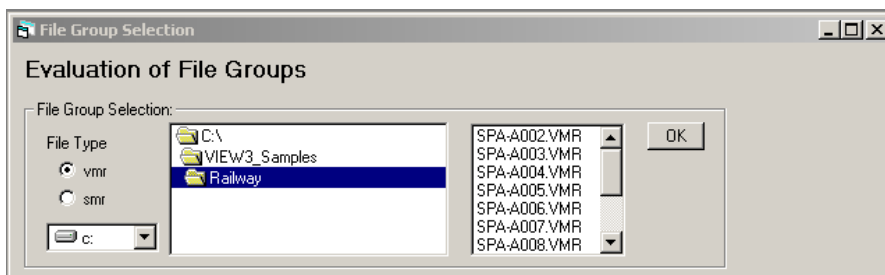
Fig. 1.32

Press OK to accept your selection and have VIEW 2002 fill the list with the signal file information as shown in Fig. 1.33. The File Group Selection window becomes now clustered with buttons, usually a bad sign announcing complexity.
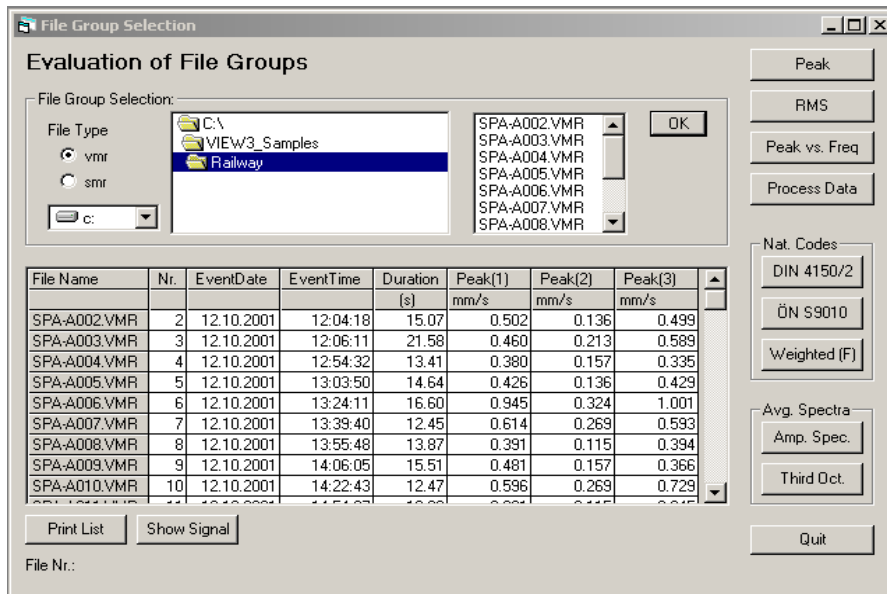
Fig. 1.33

As a first step we want to see an overview of all trains recorded, showing the peak velocity and the corresponding time. Press **Peak** to obtain the list and the statistic evaluation as shown in Fig. 1.34.
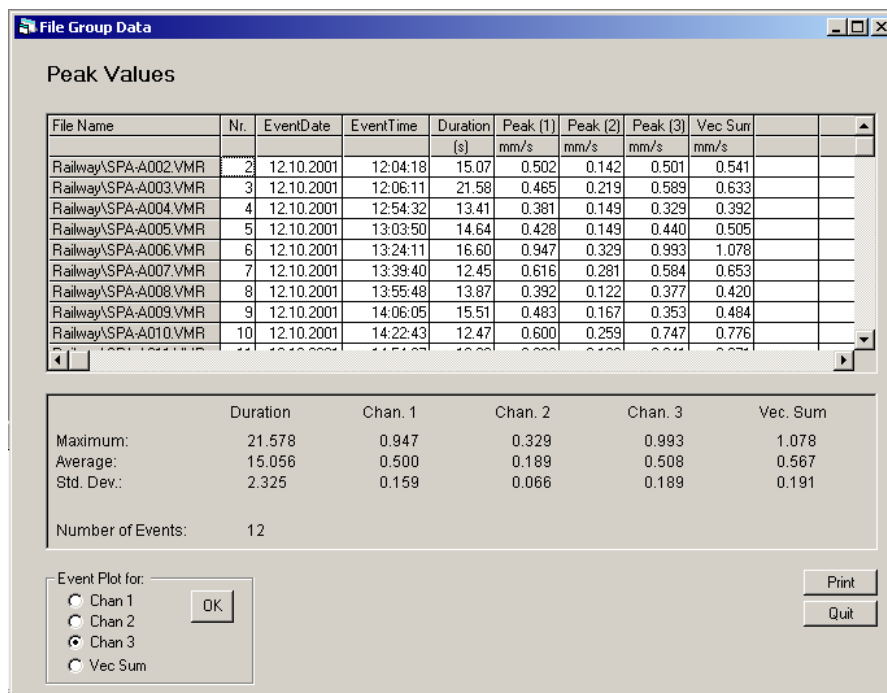
Fig. 1.34

Note that the peak values in Fig. 1.34 differ slightly from the peak values in Fig. 1.33. The reason for this discrepancy is the *base line error*. Fig. 1.33 displays the original data while Fig. 1.34 displays the processed data, which are base line corrected, if this option is selected in the Start window.

To obtain a graphical representation of these data select the desired channel in the Event Plot option box and press **OK**.
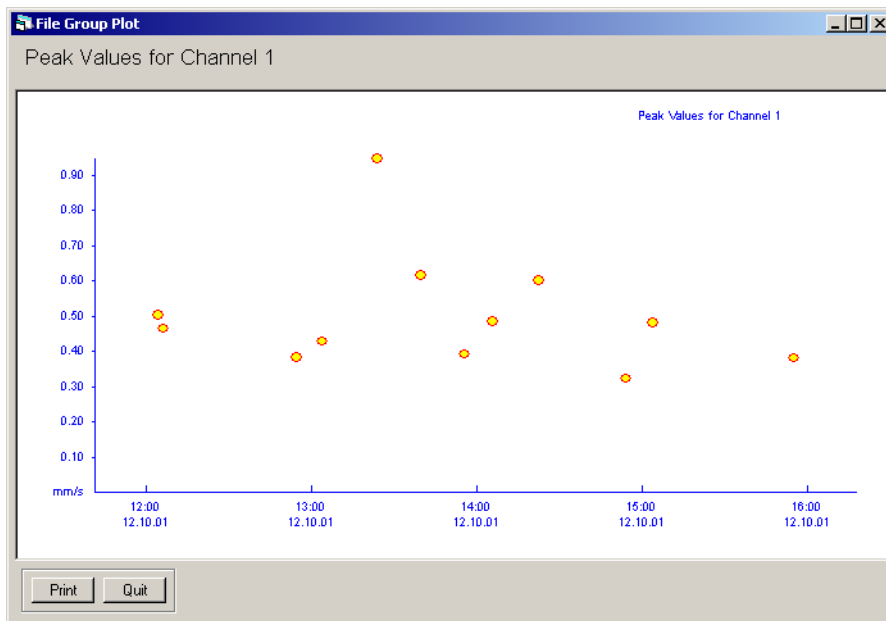
Fig. 1.35

We close now the *Plot window* and the *File Group Data window* and return to the *File Group selection window*.

Some codes (such as the SBB-Richtlinie) require the calculation of the RMS-values over the entire train duration. To obtain this evaluation we press **RMS**. The dialog box "Settings for RMS-Computation" (Fig. 1.36) allows to include just the relevant part of the signal by entering an appropriate threshold value. The RMS-computation starts at the point, where the threshold value is exceeded the first time by any of the three channels and ends when it is exceeded the last time. In the RMS-evaluation (Fig. 1.37) the effective duration is shown in the column "duration".

Fig. 1.36

RMS-Values

File Name	Nr.	EventDate	EventTime	Duration (s)	RMS (1) mm/s	RMS (2) mm/s	RMS (3) mm/s			
Railway\SPA-A002.VMR	2	12.10.2001	12:04:18	11.30	0.093	0.033	0.070			
Railway\SPA-A003.VMR	3	12.10.2001	12:06:11	19.74	0.087	0.042	0.086			
Railway\SPA-A004.VMR	4	12.10.2001	12:54:32	10.90	0.087	0.036	0.074			
Railway\SPA-A005.VMR	5	12.10.2001	13:03:50	7.98	0.108	0.035	0.079			
Railway\SPA-A006.VMR	6	12.10.2001	13:24:11	10.92	0.195	0.080	0.186			
Railway\SPA-A007.VMR	7	12.10.2001	13:39:40	6.32	0.158	0.074	0.156			
Railway\SPA-A008.VMR	8	12.10.2001	13:55:48	10.79	0.091	0.031	0.062			
Railway\SPA-A009.VMR	9	12.10.2001	14:06:05	9.36	0.099	0.031	0.065			
Railway\SPA-A010.VMR	10	12.10.2001	14:22:43	7.42	0.149	0.076	0.153			

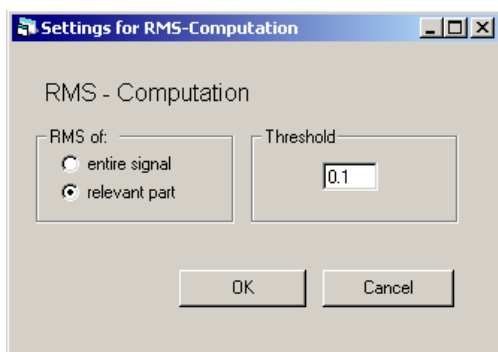|	Duration	Chan. 1	Chan. 2	Chan. 3
Maximum:	19.735	0.195	0.080	0.186
Average:	10.781	0.111	0.045	0.095
Std. Dev.:	3.228	0.035	0.019	0.042
Number of Events:	12			

Event Plot for:
- Chan 1
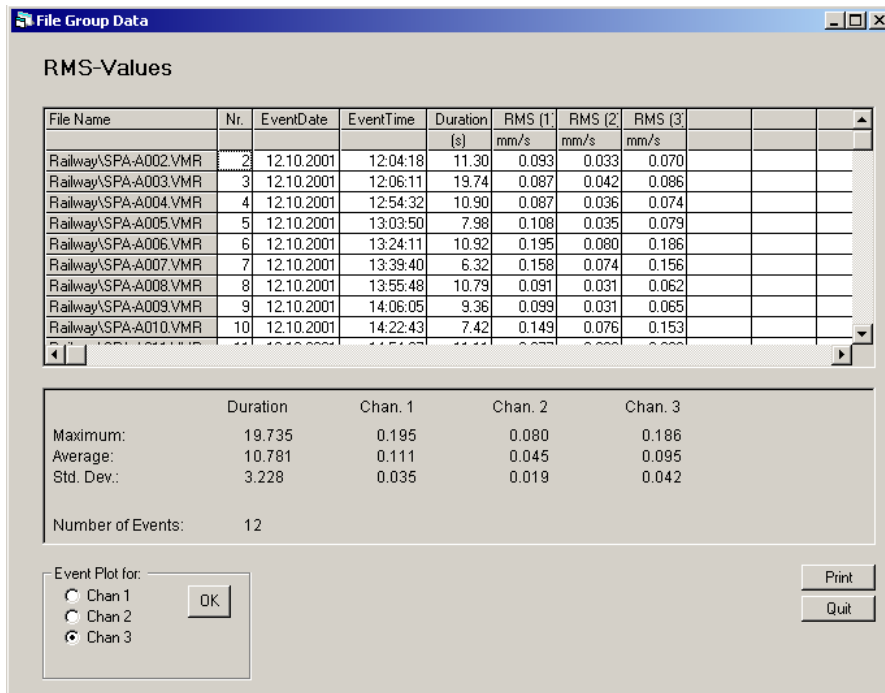- Chan 2
- Chan 3

OK   Print   Quit

Fig. 1.37

We close now the *File Group Data window* and return to the *File Group selection window*.

Many codes dealing with railway vibrations refer to DIN 4150/2. VIEW 2002 includes this evaluation in the File Group Processing. Press DIN 4150/2 to open the *Time Interval Dialog box* as shown in Fig. 1.38. VIEW 2002 takes the default values for *start* and *end* time from the first and last record respectively in the file group. This may not be correct. In our case we have to enter 12:00:00 for start time and 16:00:00 for end time.
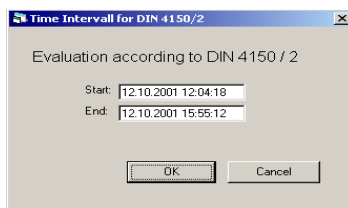

Time Intervall for DIN 4150/2

Evaluation according to DIN 4150 / 2

Start: 12.10.2001 12:04:18
End: 12.10.2001 15:55:12

OK   Cancel

Fig. 1.38

Enter these values in the text boxes provided for and press **OK**.

KBFTi-Values according to DIN 4150/2

File Name	Nr.	EventDate	EventTime	Duration (s)	KBFTi (1) KB	KBFTi (2) KB	KBFTi (3) KB			
Railway\SPA-A002.VMR	2	12.10.2001	12:04:18	15.07	0.242	0.059	0.177			
Railway\SPA-A003.VMR	3	12.10.2001	12:06:11	21.58	0.192	0.087	0.237			
Railway\SPA-A004.VMR	4	12.10.2001	12:54:32	13.41	0.147	0.066	0.141			
Railway\SPA-A005.VMR	5	12.10.2001	13:03:50	14.64	0.209	0.061	0.167			
Railway\SPA-A006.VMR	6	12.10.2001	13:24:11	16.60	0.430	0.135	0.425			
Railway\SPA-A007.VMR	7	12.10.2001	13:39:40	12.45	0.247	0.112	0.256			
Railway\SPA-A008.VMR	8	12.10.2001	13:55:48	13.87	0.184	0.046	0.126			
Railway\SPA-A009.VMR	9	12.10.2001	14:06:05	15.51	0.230	0.058	0.138			
Railway\SPA-A010.VMR	10	12.10.2001	14:22:43	12.47	0.230	0.124	0.289			

	Duration	Chan. 1	Chan. 2	Chan. 3
Maximum:	21.578	0.430	0.135	0.425
Average:	15.056	0.224	0.077	0.199
Std. Dev.:	2.325	0.069	0.029	0.085
KBFTm.:		0.036	0.010	0.033
Number of Events:	12			

Event Plot for:
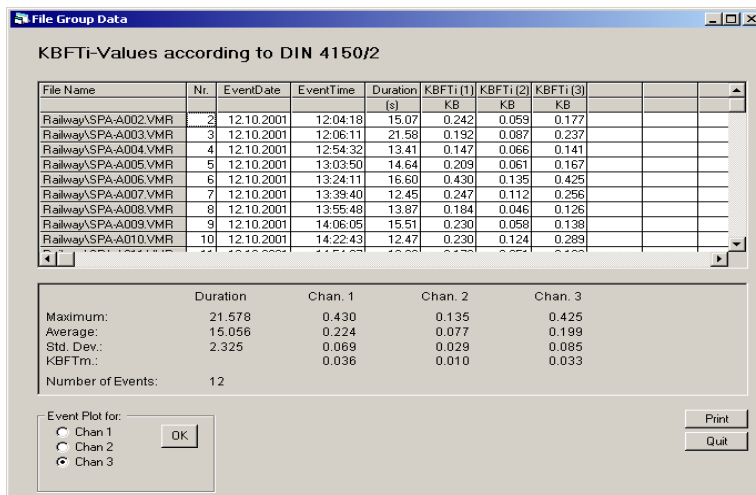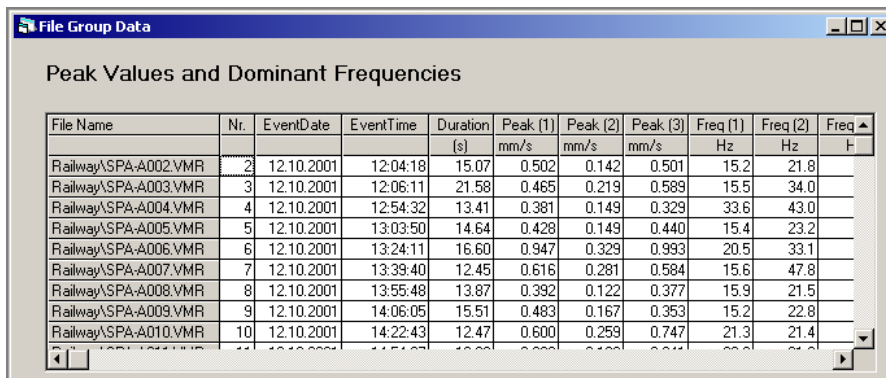- Chan 1
- Chan 2
- Chan 3

OK   Print   Quit

Fig. 1.39

Fig. 1.39 contains a complete evaluation according to DIN 4150/2. The data can be printed using the button **Print** or can be exported into other programs using **File**, **Save as..** in the menu bar. For the moment we close the window *File Group Data* and return tot the *File Group Selection* window.

Sometimes the question arises, whether the vibrations we measure are affecting the safety of the building. In our example this was never an issue but for the sake of completeness we will check this. We have to compare the vibrations at the foundation with the pertinent building codes.

In the window *File Group Selection* we press **Peak vs. Freq** to obtain the list in Fig. 1.40 with the maximum velocity and the dominant frequency for each file. Note that the dominant frequency has been computed by a simple and automatic algorithm taking the highest amplitude as the dominant frequency. Usually this is correct but can be misleading in some cases.

File Group Data

Peak Values and Dominant Frequencies

File Name	Nr.	EventDate	EventTime	Duration (s)	Peak (1) mm/s	Peak (2) mm/s	Peak (3) mm/s	Freq (1) Hz	Freq (2) Hz	Freq F
Railway\SPA-A002.VMR	2	12.10.2001	12:04:18	15.07	0.502	0.142	0.501	15.2	21.8	
Railway\SPA-A003.VMR	3	12.10.2001	12:06:11	21.58	0.465	0.219	0.589	15.5	34.0	
Railway\SPA-A004.VMR	4	12.10.2001	12:54:32	13.41	0.381	0.149	0.329	33.6	43.0	
Railway\SPA-A005.VMR	5	12.10.2001	13:03:50	14.64	0.428	0.149	0.440	15.4	23.2	
Railway\SPA-A006.VMR	6	12.10.2001	13:24:11	16.60	0.947	0.329	0.993	20.5	33.1	
Railway\SPA-A007.VMR	7	12.10.2001	13:39:40	12.45	0.616	0.281	0.584	15.6	47.8	
Railway\SPA-A008.VMR	8	12.10.2001	13:55:48	13.87	0.392	0.122	0.377	15.9	21.5	
Railway\SPA-A009.VMR	9	12.10.2001	14:06:05	15.51	0.483	0.167	0.353	15.2	22.8	
Railway\SPA-A010.VMR	10	12.10.2001	14:22:43	12.47	0.600	0.259	0.747	21.3	21.4	

Fig. 1.40

In the *event plot* option box we select Channel 2, i.e. the sensor in the cellar close to the foundation, and press **OK**. We get to Fig. 1.41 where we see that the dominant frequencies are between 20 and 50 Hz having amplitudes in the order of 0.1 to 0.4 mm/s. With the threshold of perception being at 0.2 mm/s these values are just noticeable but would never affect the safety of a building. Nevertheless we want to see the code limits plotted in our diagram of Fig. 1.41 and press **Nat. Codes**.
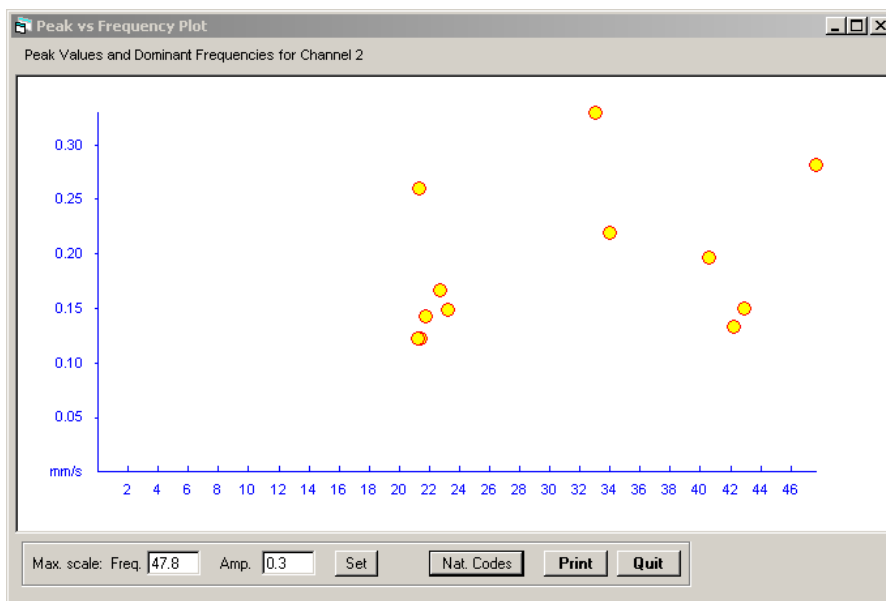
Peak vs Frequency Plot

Peak Values and Dominant Frequencies for Channel 2

Max. scale: Freq. 47.8   Amp. 0.3   Set   Nat. Codes   Print   Quit

Fig. 1.41

In the dialog box of Fig. 1.42 we select the items shown and press **OK**. As expected Fig. 1.43 shows that the vibrations at the foundation are way below the code limits.
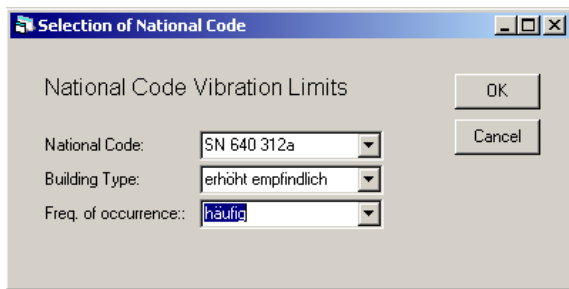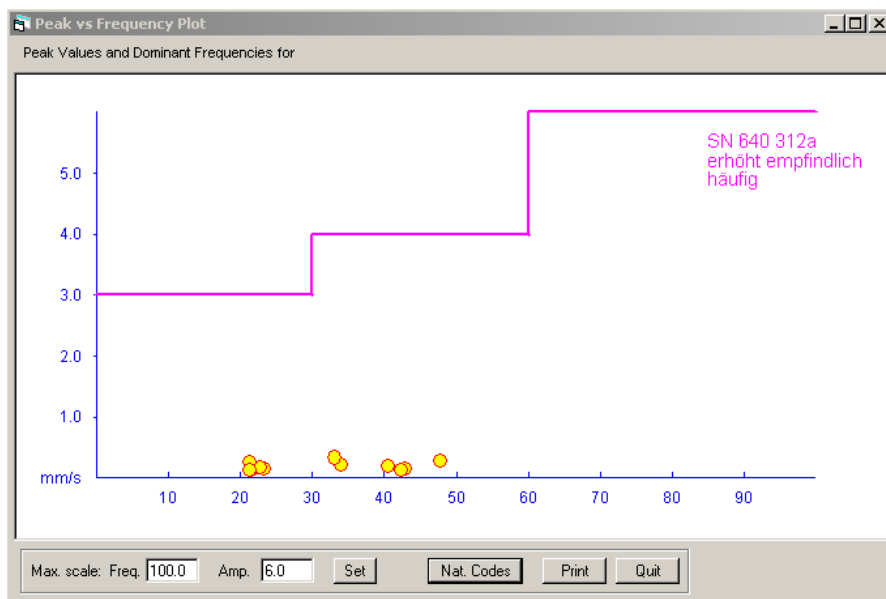

Fig. 1.42

Fig. 1.43

As with all diagrams in VIEW 2002 Fig. 1.43 can easily be printed or pasted into your document.

With this we conclude our last session with VIEW 2002.