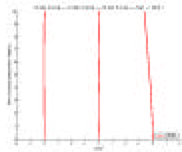
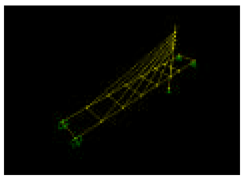
Structural Identification Project





Crossbow AD2012 Datalogger
(http://xbow.com)

Provides power for the sensors & performs the analog to digital conversion.

12-bit A/D Converter
8 Analog Inputs

Capable of Storing 540,000 Samples
Configurable Sampling Rate (1 – 500 Hz)

Crossbow CXL01L1 and CXL02L1 Accelerometers
(http://xbow.com)

Measurement Direction

CXL01L1 Capacitive Accelerometers

±1.25 g Measurement Range
DC – 100 Hz Measurement Range
0.000610 g Resolution on Channels 1-4
0.001221 g Resolution on Channels 5-8

CXL02L1 Capacitive Accelerometers

±2.50 g Measurement Range
DC – 100 Hz Measurement Range
0.001221 g Resolution on Channels 1-4
0.002441 g Resolution on Channels 5-8

Field-Testing

Using the Datalogger and accelerometers, you will need to go and record acceleration time histories at various locations on your structure.

You will need to choose these locations carefully (allowing you to capture the 1st couple of modes).

Once you have recorded your data, you will need to bring the datalogger back to the IT lab (SERF 154) and download the data.

We will then save the acceleration time histories onto a CD allowing you to perform the structural identification on your own.

Checking In and Out the Equipment

As there is only one set of testing equipment, we will set up a series of time slots. Each group will sign up for one of these and will be expected to do their testing during this time. If more time is needed, you may either trade times with another group or try to find and unused time slot.

Each group will be responsible for checking in the equipment before it is due back. This will allow us to service the equipment and ensure that everything is working for the next group.

Any data left on the datalogger will be erased once it is returned.

In order to allow sufficient time for analysis, all testing must be completed by February 28. The equipment cannot be checked out after this date!!!

One possibility: make the equipment available in 3 hour blocks

	Monday	Tuesday	Wednesday	Thursday	Friday
9:00 am-12:00 pm					
12:00 pm -3:00 pm					
3:00 pm -6:00 pm					

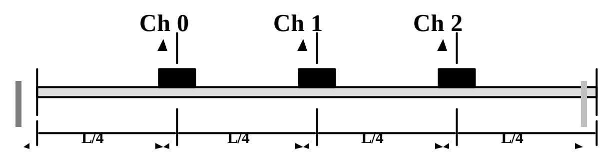
SERF Building Rm. 154

Crossbow AD2012 Datalogger

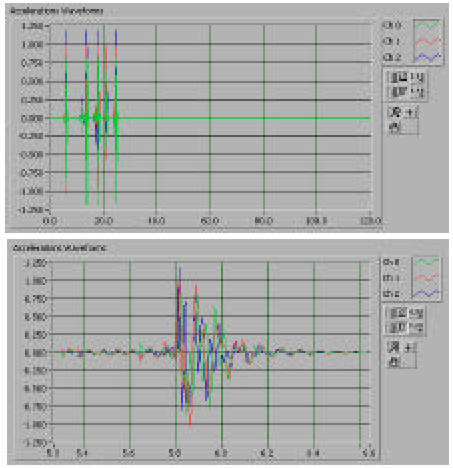
Canon A40 PowerShot Digital Camera

Crossbow CXL01L1 Accelerometer

Example



Time Domain Data



Structural Identification Tools

The Fast Fourier Transform (FFT) and the Power Spectrum are powerful tools for analyzing and measuring signals.

FFTs and the Power Spectrum are useful for measuring the frequency content of stationary or transient signals. FFTs produce the average frequency content of a signal over the entire time that the signal was acquired.

Note: the frequency resolution $\Delta f = \frac{1}{N \cdot \Delta t}$

where, N is in the number of samples and Δt is the time increment.

Additional Resource: http://zone.ni.com/devzone/conceptd.nsf/webmain/C045A890751303A6862568650061EA98/$File/AN041.pdf

Power Spectrum

The power spectrum shows power as the mean squared amplitude at each frequency line but includes no phase information.

Because the power spectrum loses phase information, you may want to use the FFT to view both the frequency and the phase information of a signal.

The units of a power spectrum are often referred to as quantity squared rms, where quantity is the unit of the time-domain signal.

Fourier Transform

The FFT returns a two-sided spectrum in complex form (real and imaginary parts), which you must scale and convert to polar form to obtain magnitude and phase. The frequency axis is identical to that of the two-sided power spectrum. The amplitude of the FFT is related to the number of points in the time-domain signal.

The phase information the FFT yields is the phase relative to the start of the time-domain signal. For this reason, you must trigger from the same point in the signal to obtain consistent phase readings. In many cases, your concern is the relative phases between components, or the phase difference between two signals acquired simultaneously.

Cross Power Spectrum

The cross power spectrum is a useful tool for determining the phase difference between two signals.

The two-sided cross power spectrum of two time-domain signals A and B is computed as:

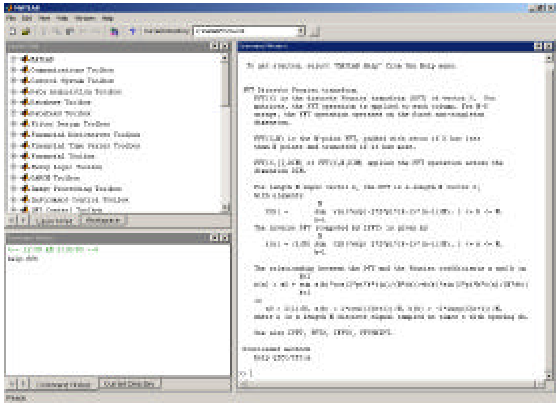
$$\text{Cross Power Spectrum } S_{AB}(f) = \frac{FFT(B) \times FFT^{*}(A)}{N^{2}}$$

These operations can be done in:

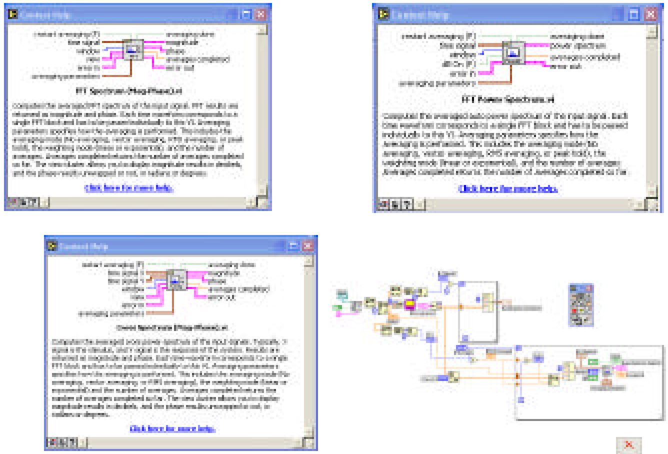
- **Matlab**
- **LabVIEW**
- **Excel**
- **Fortran**

Matlab

Type "help fft"

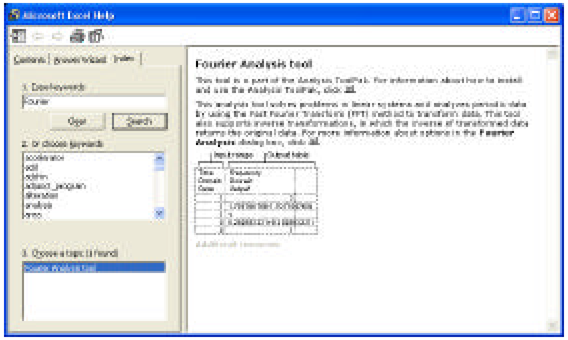


LabVIEW

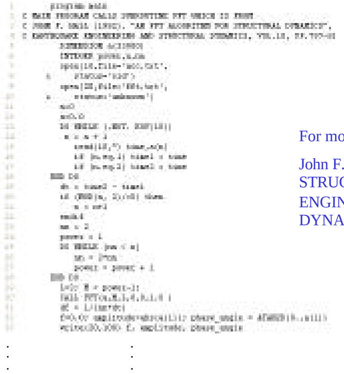


Excel

This operation requires the Analysis ToolPak



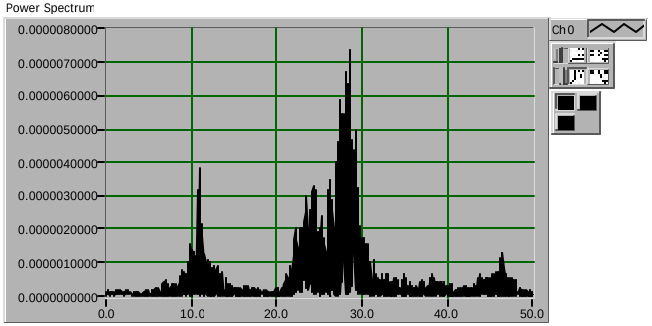
Fortran (or similar)



For more information see:

John F. Hall (1982). "AN FFT ALGORITHM FOR STRUCTURAL DYNAMICS", EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS, VOL.10, PP.797-811.

Example: Power Spectrum



Averaging

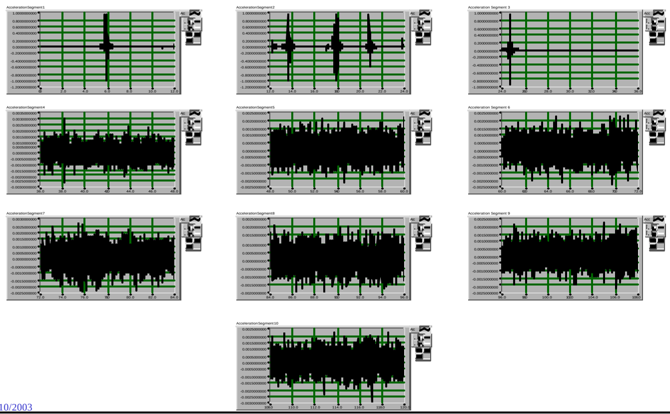
To smooth the spectrum, we need to average the data.

This can be done by:

1. **Splitting the time history into a number of equally sized segments.**
2. **Performing an FFT (or Cross Spectrum) on each of the segments.**
3. **Averaging each of these segments (Magnitude & Phase).** Start by converting to complex form (Real and Imaginary). Then sum the two real components at each increment of frequency and then divide by the number of averages. Do the same for the imaginary. When you are done, convert back to magnitude and phase.

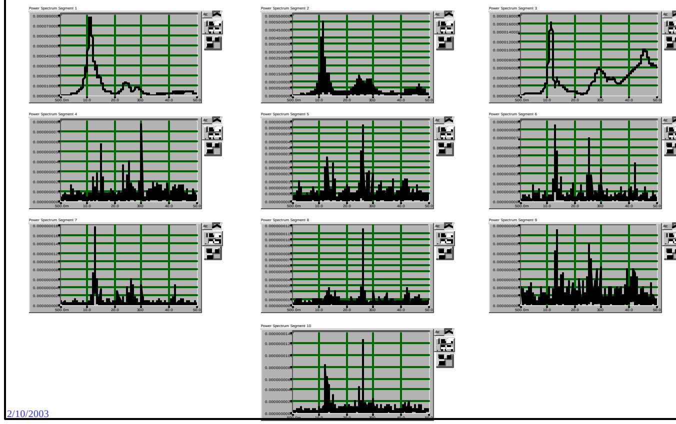
For our beam example:

1. Split the time history into 10 segments each 12 seconds long.



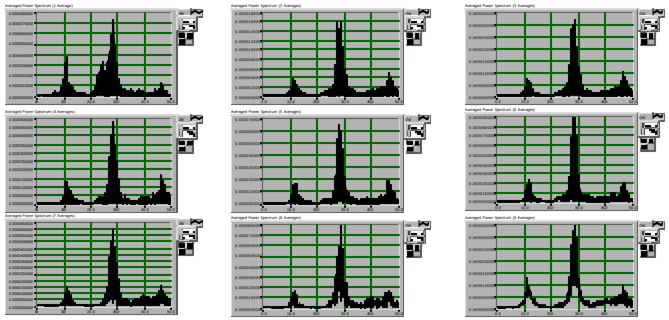
For our beam example:

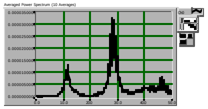
2. Perform the Power Spectrum on each of the segments.



For our beam example:

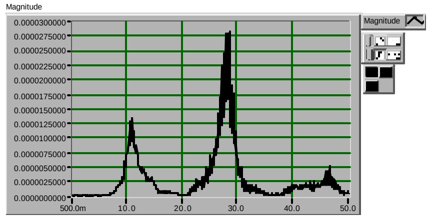
3. Average each of the segments

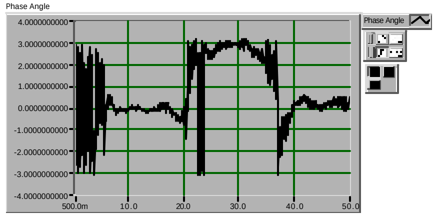




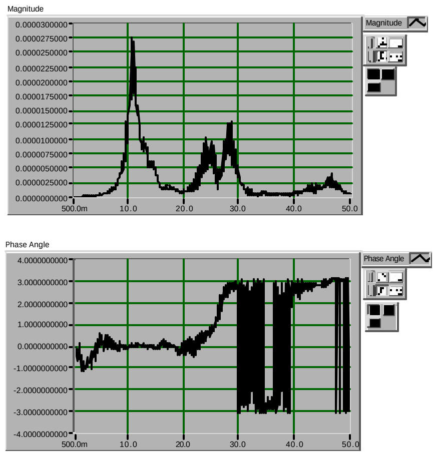
Do the Same for the Phase Angle

Cross Spectrum Channels 0 & 2





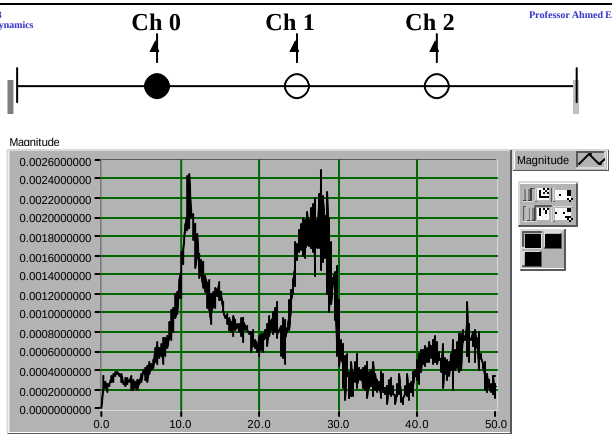
Cross Spectrum Channels 0 & 1



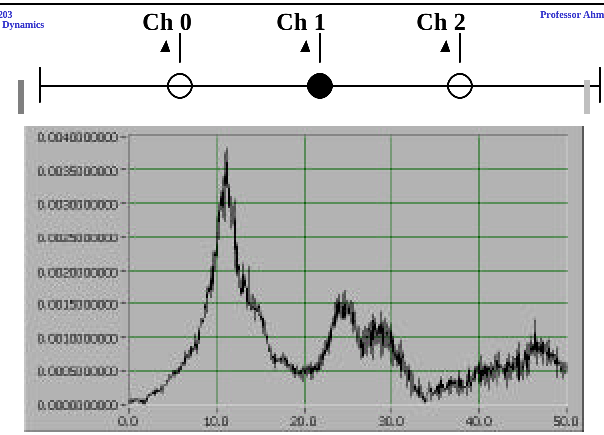
Construct the Mode Shapes

1. From the Magnitude, determine the relative amplitude.
2. From the Phase Angle, determine the sign.

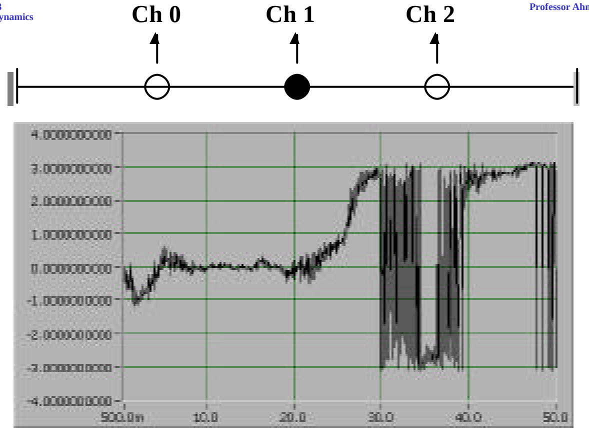
For our example, let's start with the 1st mode



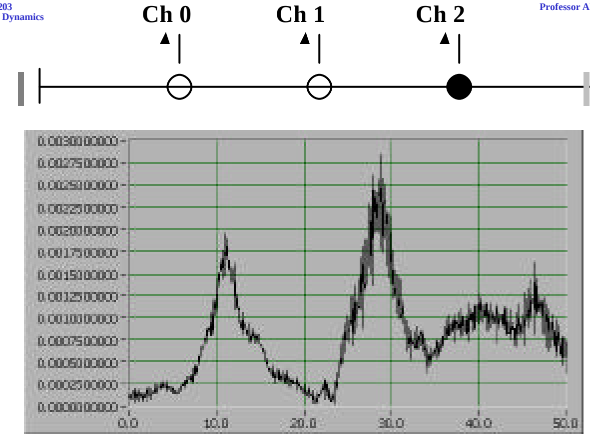
At 11 Hz, the amplitude at Ch 0 is 0.00245. We will let this location be our reference location.



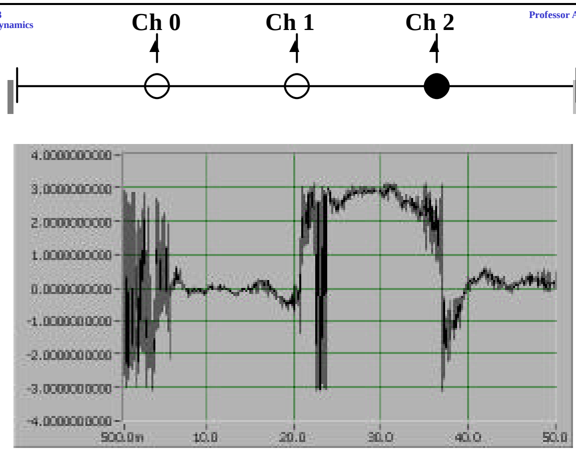
At 11 Hz, the amplitude at Ch 1 is 0.00382.



At 11 Hz, the Phase Angle is 0; therefore, locations 0 & 1 are in phase (we will define this as positive).

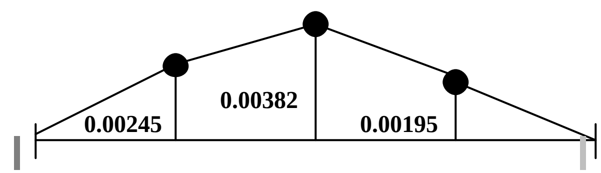


At 11 Hz, the amplitude at Ch 2 is 0.00195.



At 11 Hz, the Phase Angle is 0; therefore, locations 0 & 2 are in phase (positive sign).

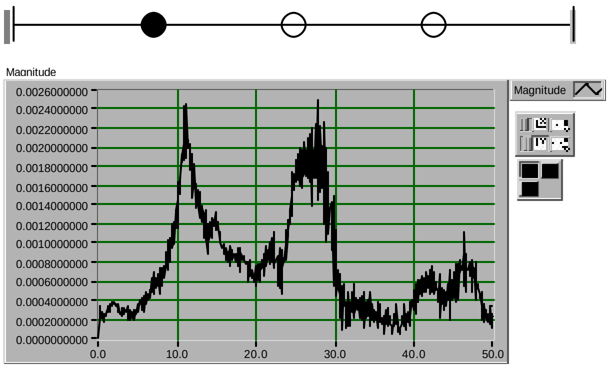
First Mode Shape



SE 203
Structural Dynamics

Professor Ahmed Elgamal

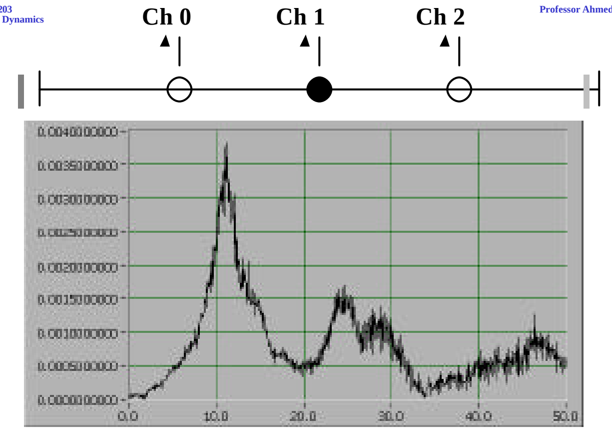
Repeat for the 2nd Mode



At 28 Hz, the amplitude at Ch 0 is 0.0022. We will let this location be our reference location.

SE 203
Structural Dynamics

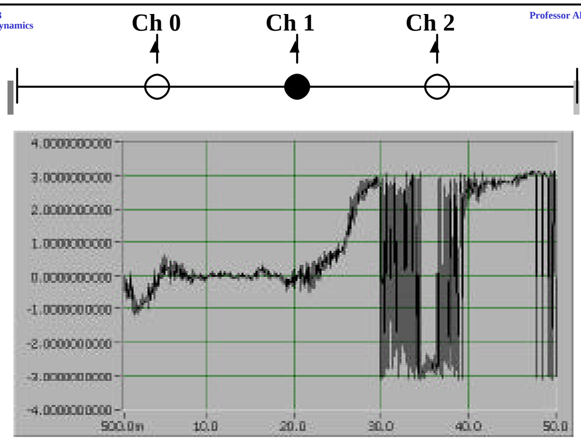
Professor Ahmed Elgamal



At 28 Hz, the amplitude at Ch 1 is 0.0013.

SE 203
Structural Dynamics

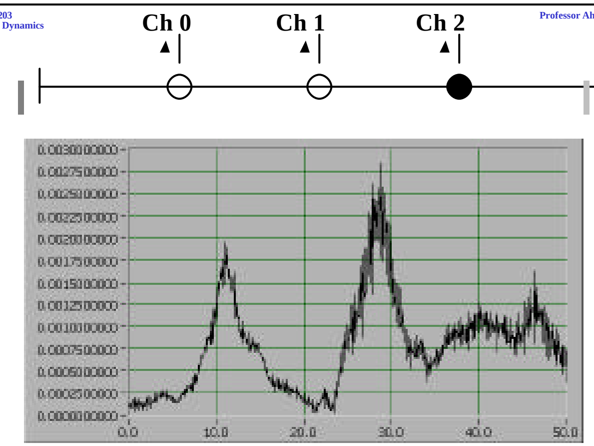
Professor Ahmed Elgamal



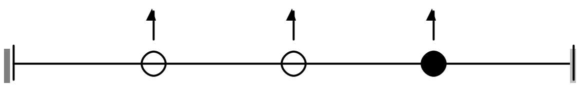
At 28 Hz, the Phase Angle is p; therefore, locations 0 & 1 are out of phase (we will define this as negative).

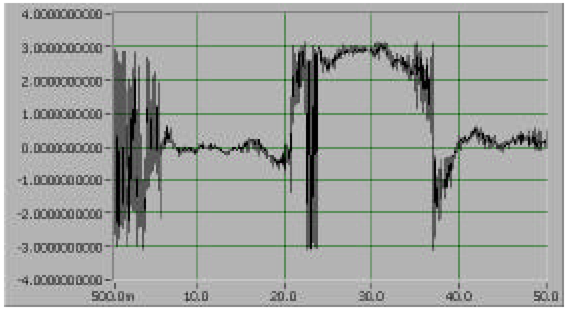
SE 203
Structural Dynamics

Professor Ahmed Elgamal



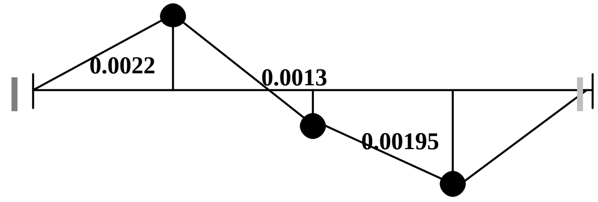
At 28 Hz, the amplitude at Ch 2 is 0.0026.





At 28 Hz, the Phase Angle is p; therefore, locations 0 & 2 are out of phase (negative sign).

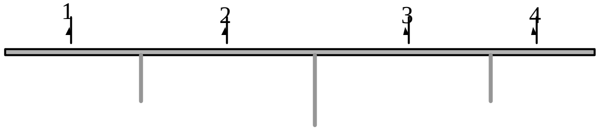
Second Mode Shape



Hints

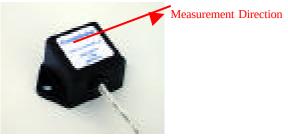
1. In order to determine the mode shape, you will need to establish a reference location on your structure.

Depending on the geometry of the structure, you may not be able to keep the same reference point. In this case, you will need to use a moving reference. For example on the bridge below, you would probably need to take a data sets with a repeated sensor location. One possibility is to record at 1&2, then 2&3, and finally 3&4.



Hints (continued)

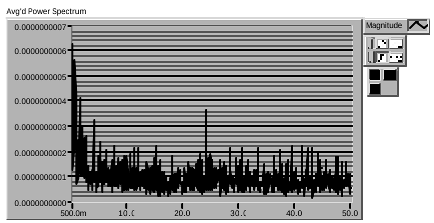
The Crossbow CXL01L1 and CXL02L1 are capacitive accelerometers. Therefore, they will record a DC signal when used for measuring vertical acceleration. In a vertical configuration, the CXL01L1 has only a 0.25 g measurement range.



When measuring vertical acceleration on a horizontal surface, you may need to use one of the anchor plates.

Hints (continued)

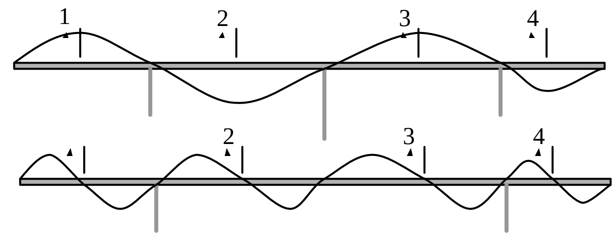
Before you get very far into your testing, you may want to check to ensure that you are measuring a meaningful signal. This can be done by making a simple preliminary test at one or two locations and checking the Power Spectra of the data.



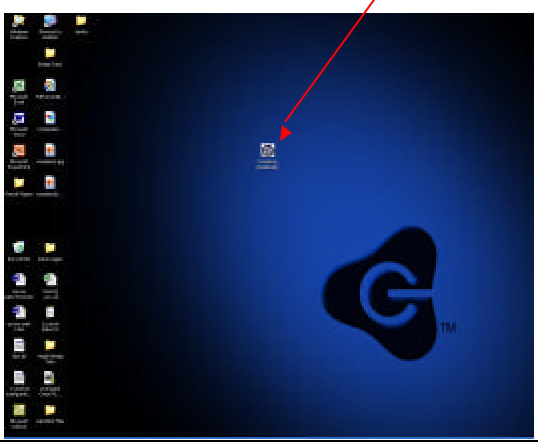
Hints (continued)

When choosing the location for your sensors, make sure you choose locations that will allow you to capture the first few modes.

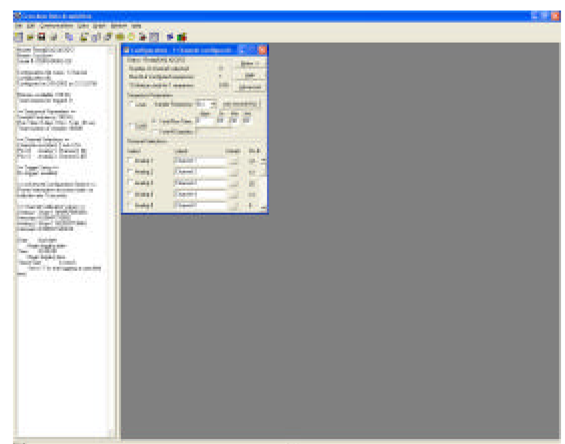
While the configuration shown below may work well for the 1st Mode, it may not work for higher modes.



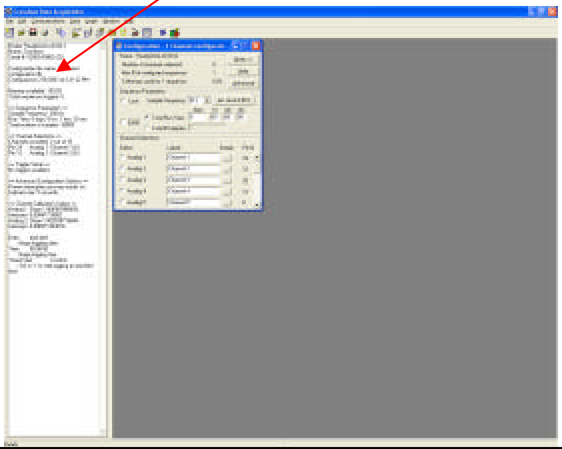
Running the Crossbow DataReady Software



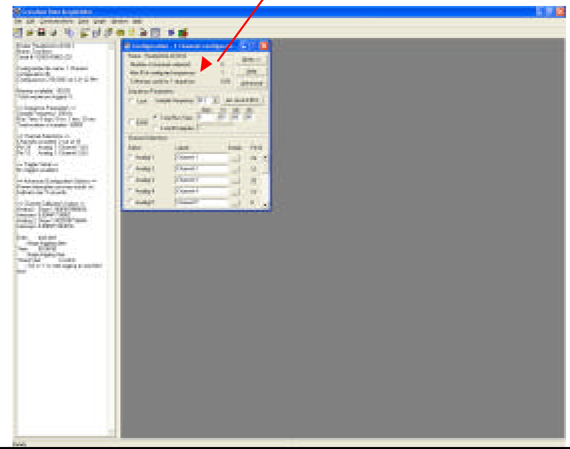
Crossbow DataReady Startup Window



Datalogger Status



Current Datalogger Configuration



Configuring the Datalogger

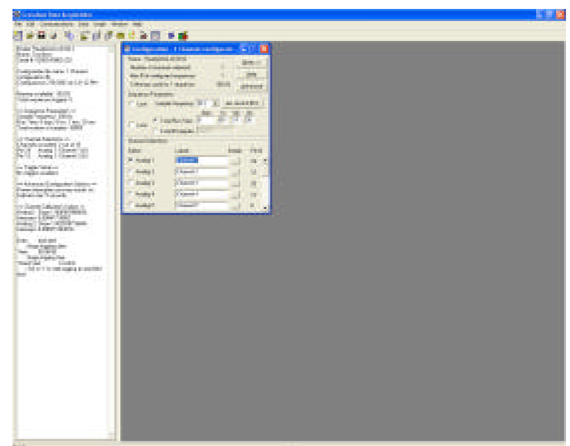
Select Active Channels

Configure each of the channels

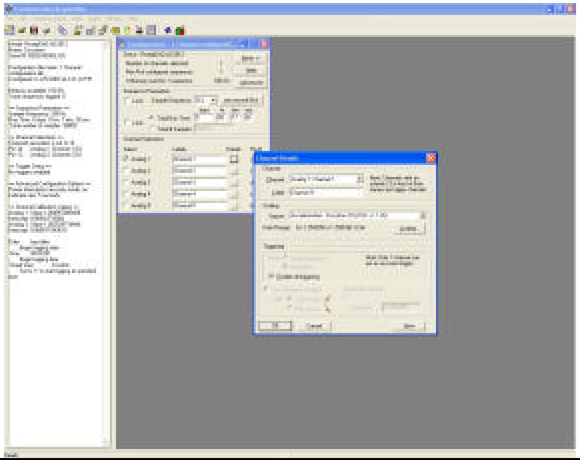
Set Sampling Frequency

Set Total Run Time

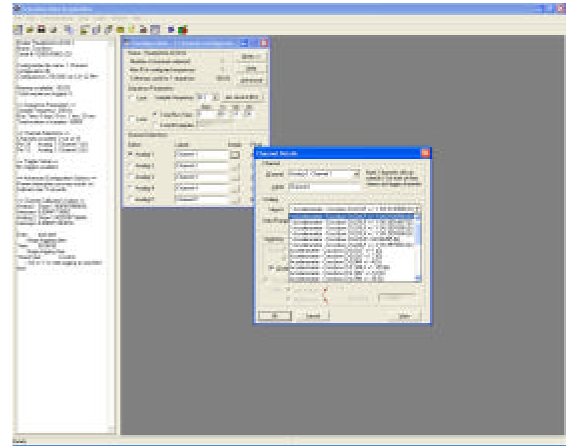
Step 1 – Activate Channel 1



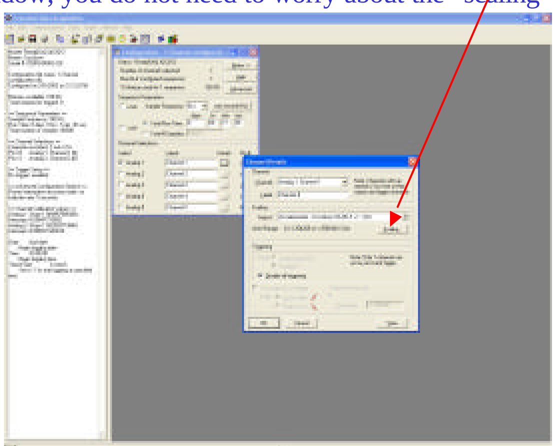
Step 2 – Enter Channel 1 Details



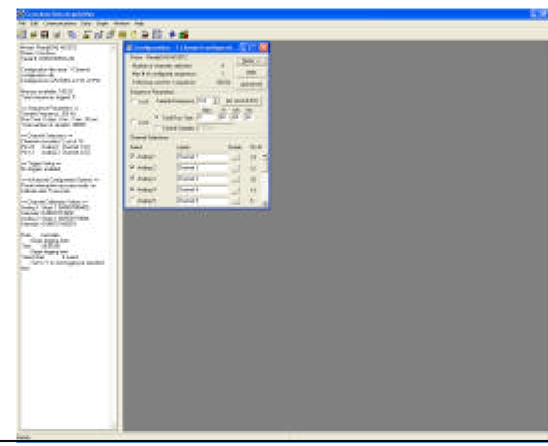
Step 3 - Select the Appropriate Sensor Type & Serial Number from the Drop Down Window



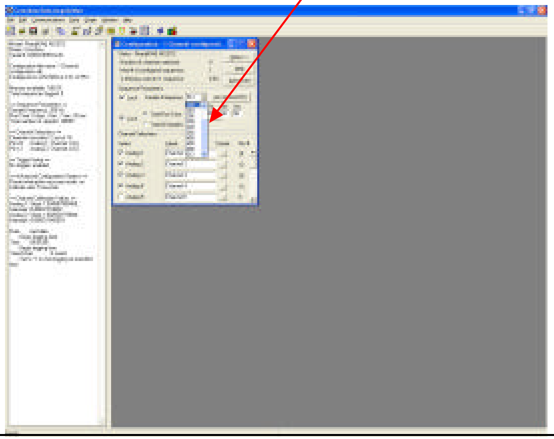
If you select a serial number from the drop down window, you do not need to worry about the “scaling” tab.



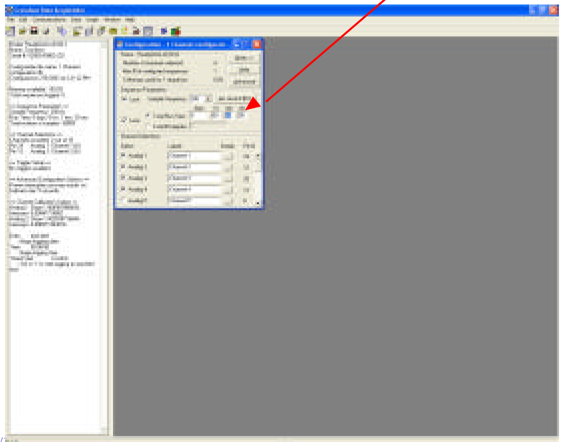
Step 4 – Select Additional Channels (Repeat Steps 1-3 For Each Additional Channel)



Step 5 – Set Desired "Sample Frequency" In the Drop Down Window

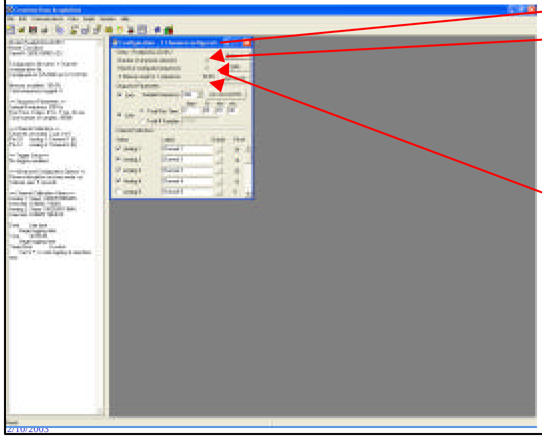


Step 6 – Enter "Total Run Time"



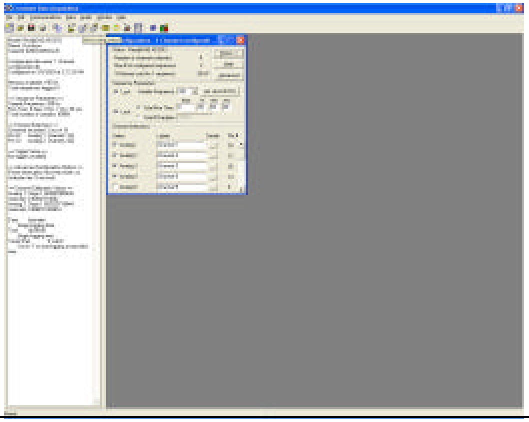
The "Total Run Time" is limited by the maximum number of samples that the data logger can store.

Configuration Details

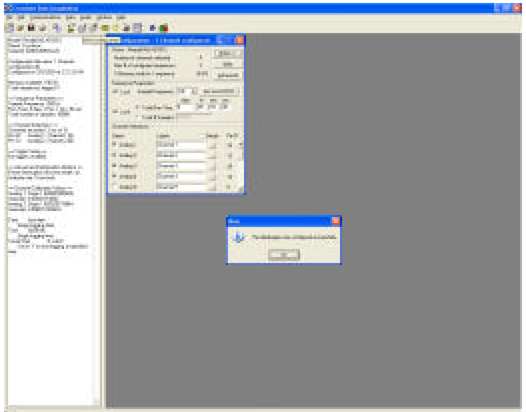


Click "Send Configuration" to Datalogger and Then Click "OK".

Note: this will erase any data stored on the logger.

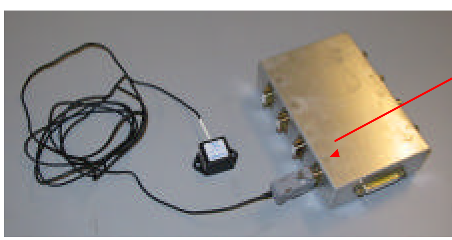


When the upload is complete it will display "The datalogger was configured successfully"



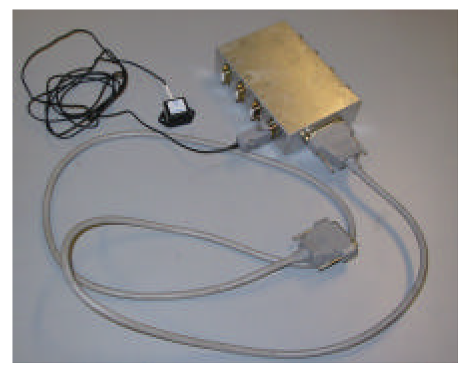
Connecting the Accelerometers to the Datalogger

Plug the accelerometer into the desired port on the junction box.



Ports on the junction box are numbered

Plug the 25 pin cable into the junction box.



SE 203
Structural Dynamics

Professor Ahmed Elgamal

Plug the 25 pin cable into the datalogger.

Note: Once the datalogger is connected to the junction box, the datalogger will start supplying power for the sensors. Please conserve the battery by not connecting to the datalogger until you are ready to start taking measurements.

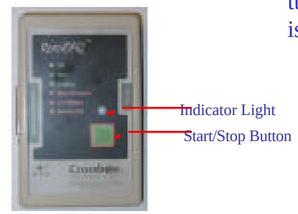
2/10/2003 61

SE 203
Structural Dynamics

Professor Ahmed Elgamal

To start collecting data, press the green "Start/Stop" button.

Once, the "Start/Stop" button is pushed once, the indicator light will turn green. When the measurement is complete this light will turn off.



2/10/2003 62

SE 203
Structural Dynamics

Professor Ahmed Elgamal

Uploading Recorded Data

1. Connect the datalogger to a PC using the RS-232 cable

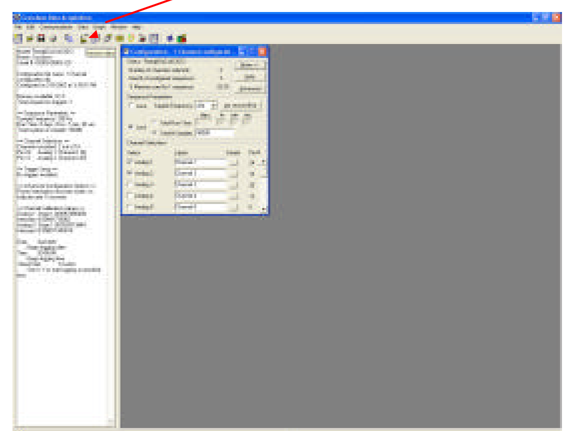
2. Run the Crossbow DataReady Software

2/10/2003 63

SE 203
Structural Dynamics

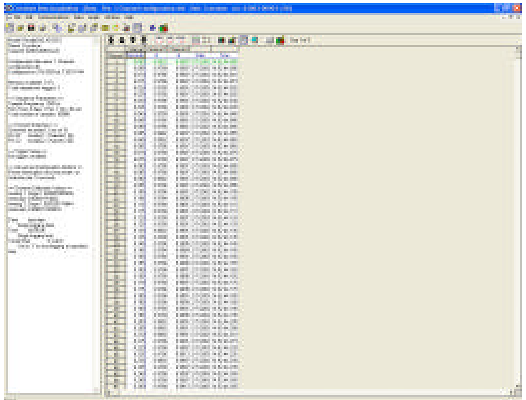
Professor Ahmed Elgamal

Click on the "Receive Data" Button

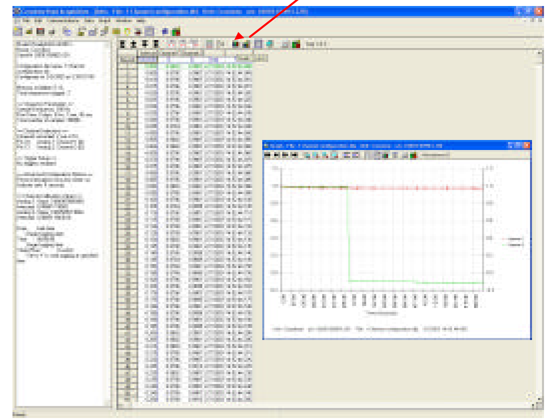


2/10/2003 64

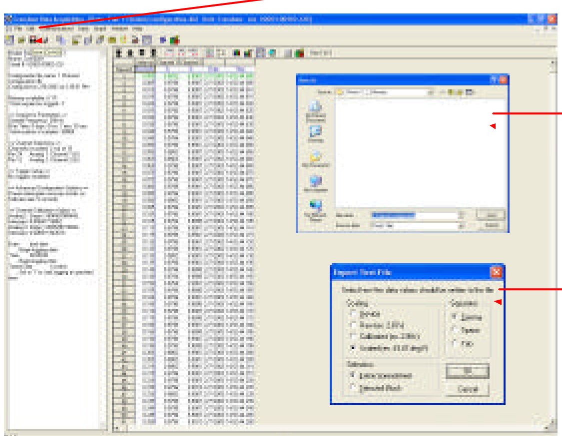
Recorded Data



To plot the data, press the "Graph (Quick)" button



To save your data, press the "Save" button.



Location
(Choose save as
.txt type)

Export File
Option