Lab #8. Table-top seismic recording

In this lab, you will conduct seismic recording on the lab table in room Geology 265, look at the seismograms, and analyze the data. The small survey will simulate the procedure commonly used in shallow seismic investigations: laying out the receiver spread, measuring its coordinates, activating several types of sources, recording and display of the data, filtering the seismogram, and looking for their features related to some useful properties of the subsurface. You will:

- examine the waveforms at different locations on the table and relate them to the structure of the "subsurface";
- compare the waveforms produced by different sources and measure their spectra;
- estimate the wave speed within the table;
- apply filtering and deconvolution to the records.

In labs #9 and #10, we will utilize the experience from this lab to conduct different types of seismic experiments on the floor of this classroom: seismic event location, Vibroseis recording, surface-wave dispersion analysis, and with some luck, try "passive" noise recording.

Equipment and software

We will use an 8-channel recording system we built ourselves recently. As receivers, we will use 40-Hz accelerometers. The recording system will digitize the signal at nearly 10 kHz frequency, and therefore we will have a fairly broad band of about 4.5 kHz for recording (recall the Nyquist frequency principle!). Note that in real seismic work on the ground you will unlikely get frequencies over 1 kHz, and so the 4.5-kHz band is actually very good. However, because of working with short distances and hard materials (fast wave speeds), we need to try getting as high frequencies as we can. Recording times will be 2 seconds, and this duration can be easily changed.

The display in the seismograph software allows some basic processing: filtering, cross-correlation of the record with a selected channel, auto-picking arrivals, and time-shifting the records by these picks. These options are available under button "Display settings".

This recording system is a work in progress, and these labs are new, and so I welcome any questions or suggestions for inclusion in the labs.

Things to do

1) Help setting up the recording equipment and video connection to the screen projector in the classroom. **Place the 8 receivers in a line** along the middle of the lab table and plan locations of 4–5 source points around this line. Use measuring tape to **measure the coordinates** of receivers and source points. **Sketch the layout in your workbook** and provide the coordinates for entry in the recording computer.
2) **Use a light hammer or a small piece of rock** to lightly strike the table at each of the source points.

Before each strike, the recorder will need to be "Armed", and then the recording is started button "Trigger now". Because we still have no proper triggering device to start the records automatically, we will have to simply strike within the 2-second time window, and measure the actual time of the strike from the records.

In the following steps, **make screen captures**[1] to illustrate the important observations and include the screenshots in your report.

3) For each recorded source, **carefully look at the records**. Select display parameters which would allow the best view of the records.
    a. **Identify the time of the arrival** in each channel and evaluate how accurately it is picked with the available automatic methods.
    b. **Evaluate at what time the source should be** (this time from auto-picking may also be available in the software).
    c. Examine the waveforms: **Measure the duration of the primary pulse between zero crossings** t_{pulse} and the period or reverberations. From t_{pulse}, **estimate the frequency bandwidth** of recording as $f = 1/t_{\text{pulse}}$. Make sure to use correct units of this quantity.
    d. Note that the recorded waveforms consist of initial pulses (with fast oscillations) followed by steadier and lower-frequency oscillations. These oscillations should be produced by resonances within the structure of the table. **Do these resonances correlate with sensor positions on the table**? **Try using low-pass or high-pass filtering** in the display to emphasize or suppress these resonances.
4) Using your sketch of experiment geometry and screen snapshots or the records from sources conducted off the line, **estimate the wave velocity within the table**. Try seeing whether

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[1] I will be operating the recorder and making snapshots for your data analysis.

your can recognize P- and S-waves in the records. This may be difficult; I think you will likely only see the S-wave. **Answer this question**: why do I say this should be the S wave?

Hint: note the direction of displacements (vertical) which we are recording.

Note that you may see correlations of these resonances with positions of wooden reinforcing bars under the surface of the table.

5) Look at the "Amplitudes in channels" plot at the bottom of display. Note that this plot is in dB. **How does the amplitude of accelerometer shaking vary** with their positions on the table and distances from the source? Does this variation make sense to you? **Calculate the amplitude ratio** between the strongest and weakest signals recorded on the table.
6) For the records from steps 3)–4), use "Processing" -> "Current Record" -> "Spectra and Export" tool in the seismograph software to look at their spectra. This tool uses the main display time window and frequency range and also allows selecting groups of records and time ranges for spectral analysis. Test earlier and later portions of the records. **Determine the usable frequency band** in the records **at closer and farther away distances from the source**. Note spectral peaks related to resonances discussed in step 5).
7) **Repeat steps 3) and 5)–7) from one source position using different sources**: a heavier strike with a rock, strike with a wooden peg, or strike with your fist. **Compare the records and spectra** for the different sources.
8) **Repeat recording using the first accelerometer as the source.** Just lift it by ~5–10 cm and drop on the table. **Describe the differences in the records.**

This type of source is called the "weight drop". It is commonly used in shallow seismic work (only it is then accelerated by a spring and called the "accelerated weight drop", or AWD). In this case, you will see on channel #1 (red in displays) a more accurate record of the actual source signal (although likely clipped). Note how much sharper it is compared to what was recorded at ~10 cm from the source during the first tests.

This last experiment will introduce the so-called VibroSeis seismic recording, which is broadly used in exploration reflection seismic imaging. Compared with using explosives, this source is very efficient and nondestructive for the surface. The idea of this method is to replace the very fast and strong impact with a broad-band signal produced by a vibrator and extended over time.

In the exploration case, the vibrator would be an about 12-ton truck and the sweep would be from about 8 to 80 Hz (or ~140 Hz and mini truck or trailer for shallow work). Smaller and higher-frequency vibrators are used to study road pavement and for cross-well seismic imaging in boreholes (with frequencies up to ~300 Hz). In this lab, we will use a loudspeaker transducer (driver) designed to play sound through tabletop surfaces in conference rooms.

9) Again **repeat recording as in step 2), this time using a small tabletop vibrator** powered by a signal function generator. Use a 100 Hz to 2000 Hz upsweep (a 1-s long signal with frequency gradually increasing with time).
10) Look at the sweep record in the time and frequency domains. **Describe in the report** how the frequency changes with time and how the bandwidth is seen in the spectra.
11) Finally, select "Cross-correlation with chan#1" in the display of sweep records. This is called the "vibroseis correlation". **Describe whether (and how closely) the records resemble the results of using impulsive forces above**. **Try measuring the moveout of the wave** traversing the accelerometer spread. **Are the moveout and wave velocity close to those measured in step 2**?

Hand in:

Zipped directory, Word, or PDF document containing answers to the above questions and images.