

## Development of an educational tool for seismic exploration study using piezoelectric buzzer and general-purpose laptop

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I have developed an inexpensive ground motion detecting system as an educational tool for seismic exploration study, consisting of geophone which uses a piezoelectric buzzer as a sensor and general-purpose laptop.

Piezoelectric buzzer, which is used to transmit electric signal to sound in general, excites electric pressure when an external force is applied. To catch the ground motion it is fixed on the bottom of a cylindrical plastic bin, and a nail is put into the open mouth of the buzzer through a hole opened on the bin lid. When the vertical motion hits the bin from beneath, the nail behaves as a fixed point by its inertia, push the buzzer, and then the electric pressure is excited. We install these sensors near the shot point and the observation site, and record the signal from them synchronously. From the distance and the signal arrival time delay we can determine the elastic wave velocity of the ground.

We need high rate sampling multi-channel data logger for recording, which is not necessarily inexpensive. Instead of it we use a laptop whose audio stereo inlet is available for synchronous recording. A sound recording software may be preinstalled in PC, but it depends on the OS. Because the laptop differs from student to student, and to unify the instruction, we adopt a freeware *Audacity* for recording. A wav format signal file recorded by *Audacity* will be transformed into text format using a freeware *WaveGraph*. Another compatible software may be available for recording and transforming. You should notice there is another *WaveGraph*, which does not have a function for wav to text transform and is not available for our purpose. The transformed text file can be opened by some graphic software to read the time delay between the two sites.

In the classes students firstly constructed the sensor, and then confirmed the utility of their laptop for signal recording. At the field we hit the ground by large wooden hammer to excite the ground motion for one minute with five seconds interval. In case the sensor was far from the shot we heightened the gain by putting some amount of clay on the nail to enhance the inertia. Twelve signals by one-minute recording were stacked to confirm the noise reduction. We confirmed the arrival time to the sensors delayed linearly with distance between 3 and 24 m from the shot point with 3 m interval, and obtained direct wave velocity as 560 m/s. We did not detect refractive wave, it may be because the test field in the university campus was not appropriate for this purpose.

The present system, consisting of inexpensive hand-built sensors and general-purpose laptop, is an educational tool not only for seismic exploration study but to show students the possibility of overcoming the difficulty from the lack of expensive sophisticated equipment for experiments by their ingenuity. On another front this system obviously has some weak points. For examples, it is unclear our sensor is really suitable for ground motion detection, because we have no data on its frequency response, which may depend not only on the property of piezoelectric buzzer and the inertia of the nail but on the manufacturing precision such as the position of the hole on the lid to insert the nail. Due to the insufficient electrical insulation between right and left channels of most laptop stereo inlet we have to attenuate the intense signal from the shot using a resistance to prevent it from interfering. We have found the signal through the laptop stereo inlet is low-cut filtered and is not suitable for precise recording, although it does not seem to affect our present use seriously. If we count the performance evaluations of the present system in a part of the experiment, it may improve the education effect more.