

Micro-Seismicity monitoring Instrumentation C100/SRi32L sensor/digitizer/recorder unit

In this article we present the instrumentation which have been used in several passive tomography projects, and explain why we propose such kind of instruments with special characteristics. Same type of equipment can be used for any similar project requiring local or regional seismicity monitoring.

So why chose a GEObit unit?

1. Why wide band sensor?

At micro-seismicity monitoring experiments and applications the recorded seismic events usually have a magnitude from $-2R$, up to $4R$, so their frequency spectrum is into the band 0.8Hz to 20Hz. A wide band type seismometer with the range of at least 0.5Hz(2 sec) up to 30 Hz is necessary to be used for the recording of such seismic events.

In micro-seismicity monitoring applications, we use sensors with recording bandwidth from 0.1Hz to 100Hz in order to record the seismic events with the maximum quality. The low frequency response gives us the ability to calculate moment tensors as well.

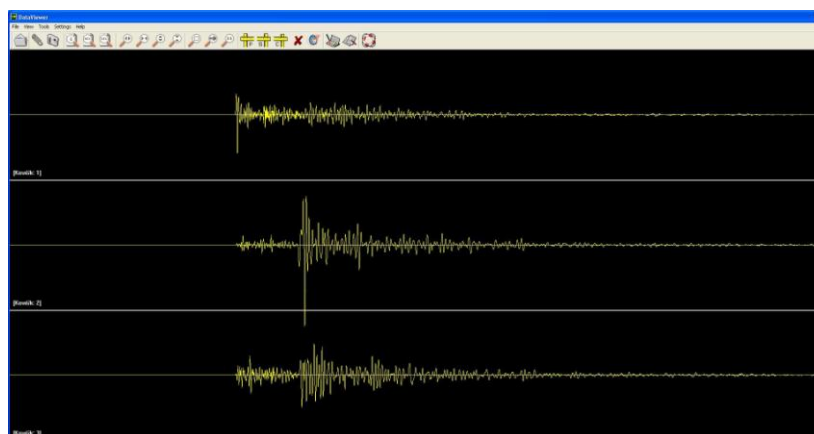


Figure 1. Seismic event

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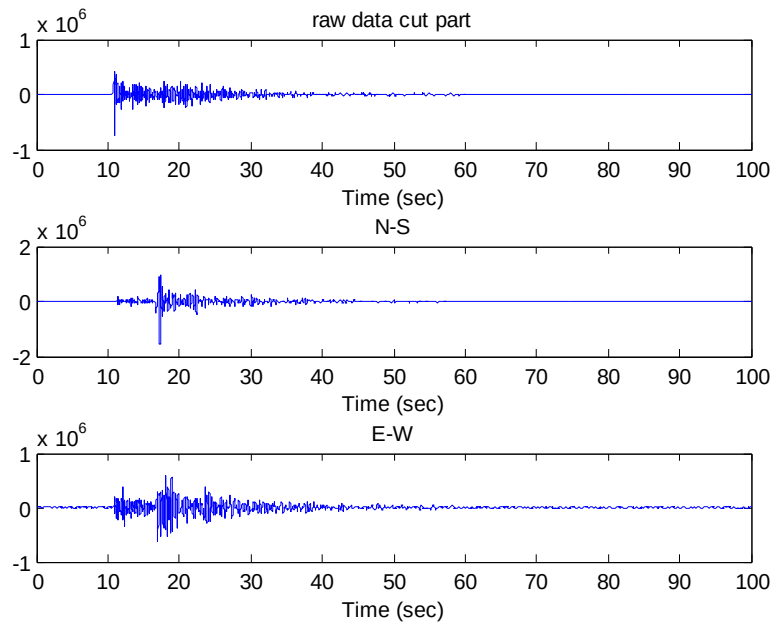


Figure 2. Seismic event plot

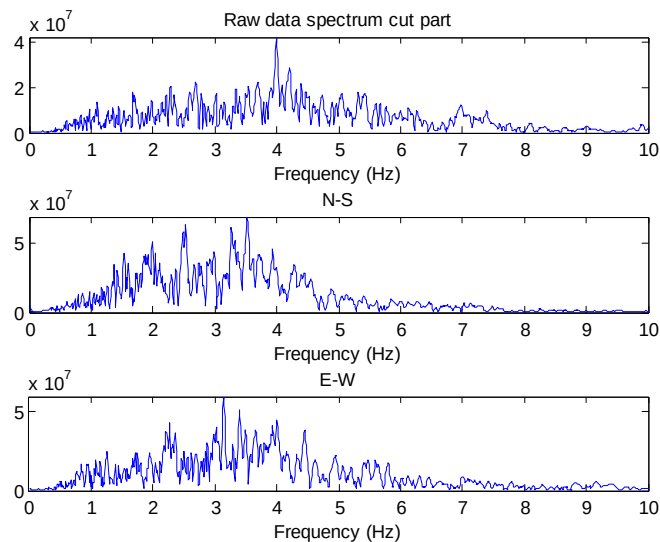


Figure 3. Seismic event frequency spectrum plot

Somebody may ask, why not broadband sensors? The answer is that the broadband sensors are much more expensive than our sensors and makes the survey inefficient in terms of cost. We do not get more information using broad-band sensors for local micro-earthquake recording. At the next experiment we have used wide band and broad-band sensors at the same seismic network. Here is an example of the signal of a recorded earthquake.

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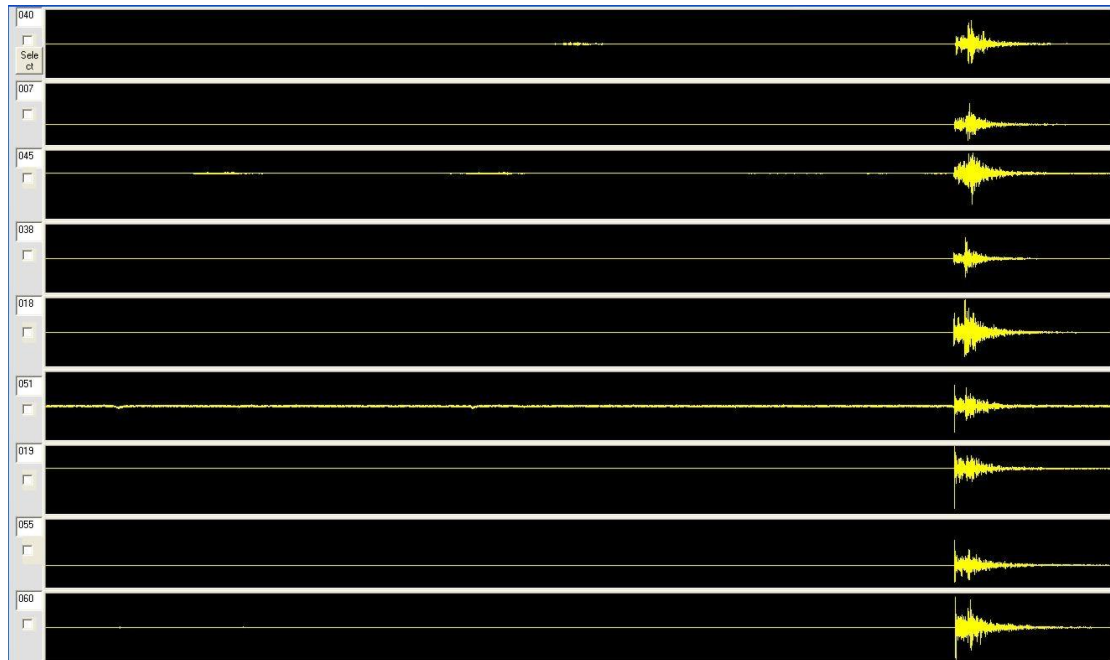


Figure 4. Seismic event recorded from wide-band and broad-band sensors

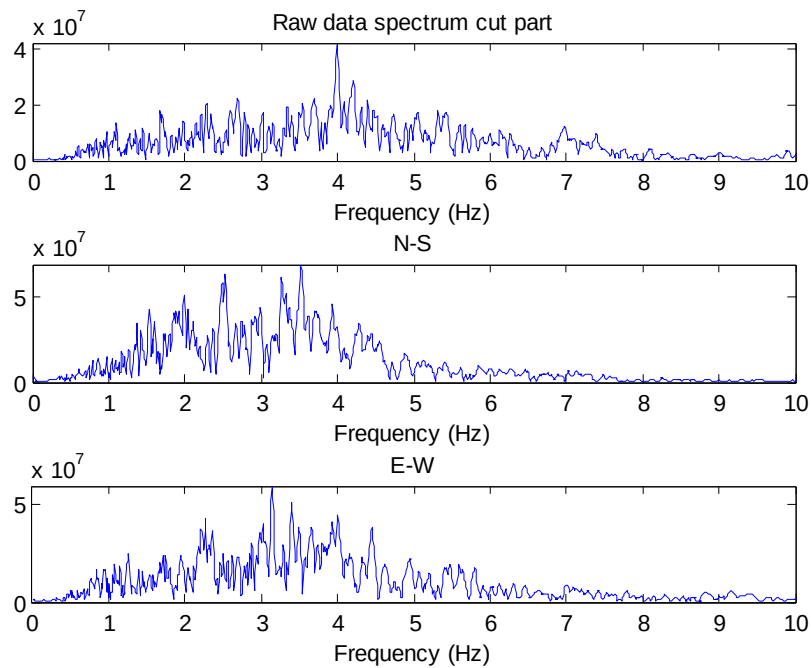


Figure 5. Seismic event spectrum plot from the BB sensor

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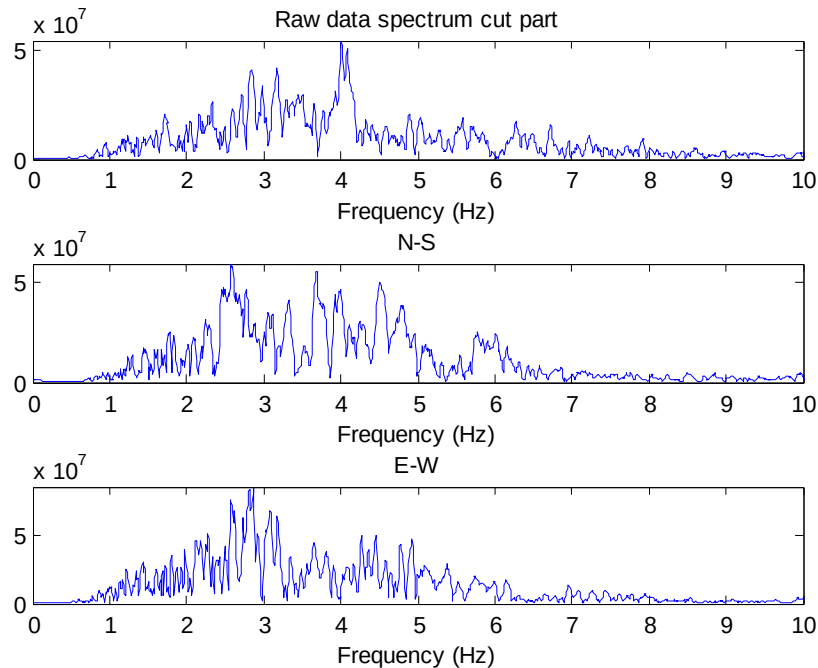


Figure 6. Seismic event spectrum plot from the S100 wide-band sensor

The figure 4 shows a typical small seismic event recorded from eight wide-band S100 sensors and one broad-band (Nanometrics – Trillium 40T) sensors. Trace 19 is the broad-band one and it could not be recognized from others having a first look at the signal plot. The frequency spectrum of the BB sensor and the spectrum of the wide-band sensors are presented at figures 5 and 6 respectively. These spectrum plots represent frequencies of the recorded signals of the same earthquake. Clearly, both are similar, therefore even with the use of wide-band sensor, the recording result is great.

Why not use simple geophones? Commercial geophones with small dimensions have usually natural frequency 4.5Hz or 10Hz. Using these kind of geophones, the lower part of the spectrum of the signal is lost (low frequency part), because the geophones cannot respond in the low frequency area (below 4.5 Hz), and the geophone sensitivity falls dramatically. There are also geophones in the market with natural frequency of 2.0Hz or 2.5Hz, but their dimensions do not allow to be used in small diameter boreholes. Tilt tolerance is also less for the 2Hz geophones while tilt tolerance for the S100 sensor is greater than 10 degrees. Their bandwidth is quite enough for magnitude 1 or 2 local events, but not enough to cover low frequency, below 1Hz.

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2. Why force-balance sensor?

The S-100 sensor is based on force-balance principle. Special electronics provide feedback at 4.5Hz geophones, plus additional electronic bandwidth correction and provide a 10sec-98Hz sensor unit. The 4.5Hz geophones are not so tilt sensitive. Usually they respond perfectly at 5 - 10 degrees of tilt. This means that the sensor can be installed into the borehole without any need of special leveling. An elastic packer provided from us, is more than enough to block the sensor inside the borehole. It is leveled according the casing verticality and it is still operational responding within its specifications even there are some degrees of tilt at the borehole casing.

So, the ideal solution for fast and precise installation is using wide-band seismometers consisted of 4.5Hz geophones, with small dimensions and low cost, designed according the force-balance principle. Our wide-band sensors meet all the requirements for local micro-earthquake monitoring or seismic tomography applications. Our SRi32L digitizer/recorder unit integrates the sensor electronics providing an ultra low power, low noise, low cost and high performance seismograph.

3. Why borehole type sensor?

Many seismic sensors are surface mounting type. For their installation, usually seismic vaults have to be created where the noise level is less than the surface. Our instruments are mostly borehole type, so they can be easily installed in a typical depth of 20 meters. The noise level at this depth is much less than the surface. The borehole can easily be (in the most of the cases) opened using a drilling machine with low cost, requiring some working hours. Small diameter boreholes can be opened by hand in rough areas where no vehicles can access.

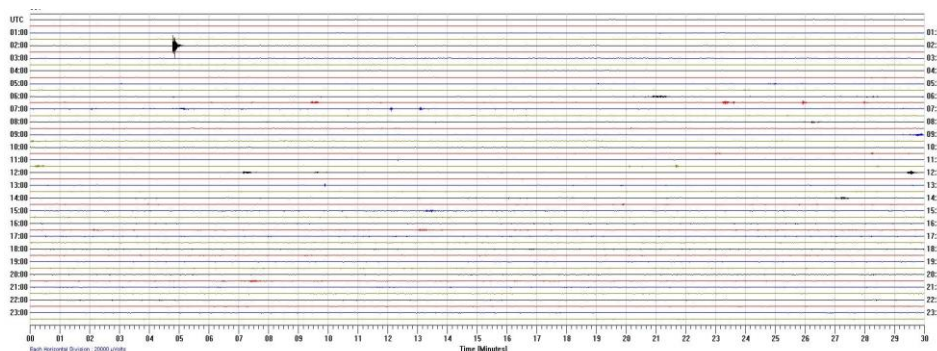


Figure 7. Seismic noise at 20 meters depth borehole

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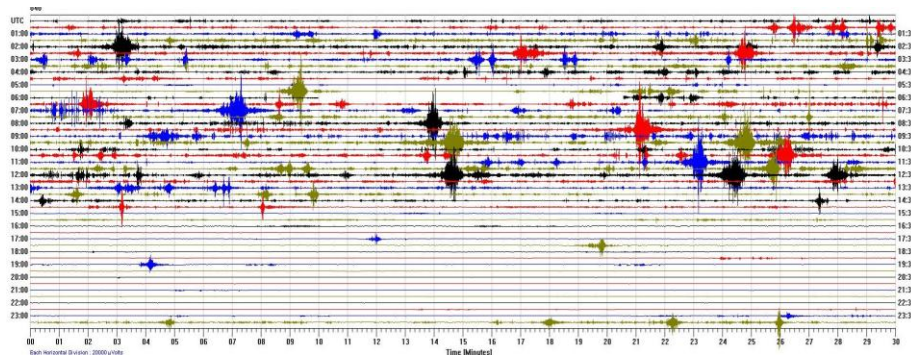


Figure 8. Seismic noise at the surface

4. Why high sensitivity sensor?

The magnitude (Richter Scale) of the recorded events for a seismic tomography exploration, range from $-2R$ to $3R$. For the recording of such small events, the sensor must be very sensitive. Our instruments provide high sensitivity such as $1500V/m/sec$.

5. Why in-build sensor self test?

The operator needs a way to apply a fast signal test to the equipment in order to verify proper operation. Most of the clients are asking for such kind of tests to be performed from the instruments by themselves. The SRI32L datalogger provides a build-in signal generator combined with a micro-controller, and injects signal to the sensor. The square wave or sinusoidal signal that injected to the sensor with constant amplitude, forces the masses of the geophones to move. The geophones produce a seismic signal to their output proportional to their movement. The shape of this signal that the user should see is shown at the figures 9 and 10.

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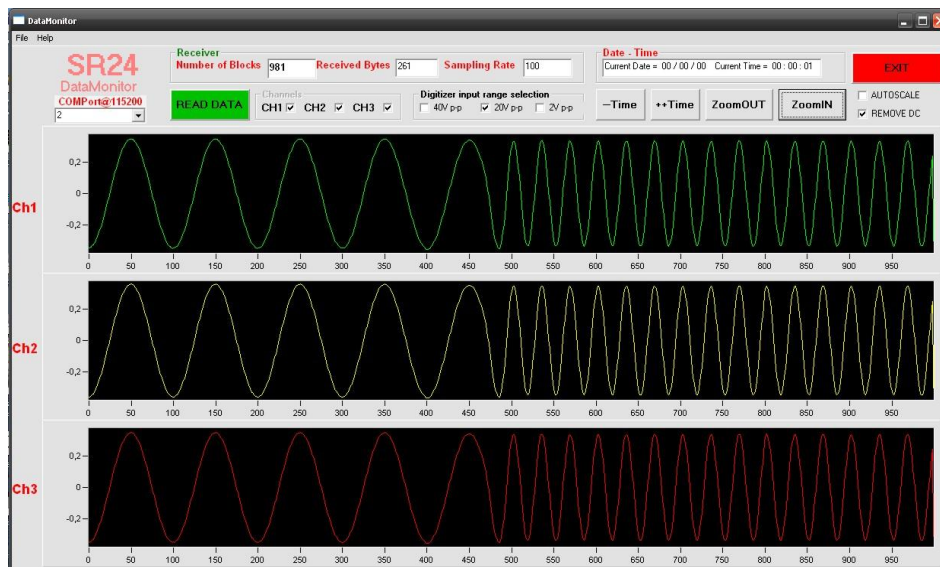


Figure 9. Sinusoidal signal for sensor calibration

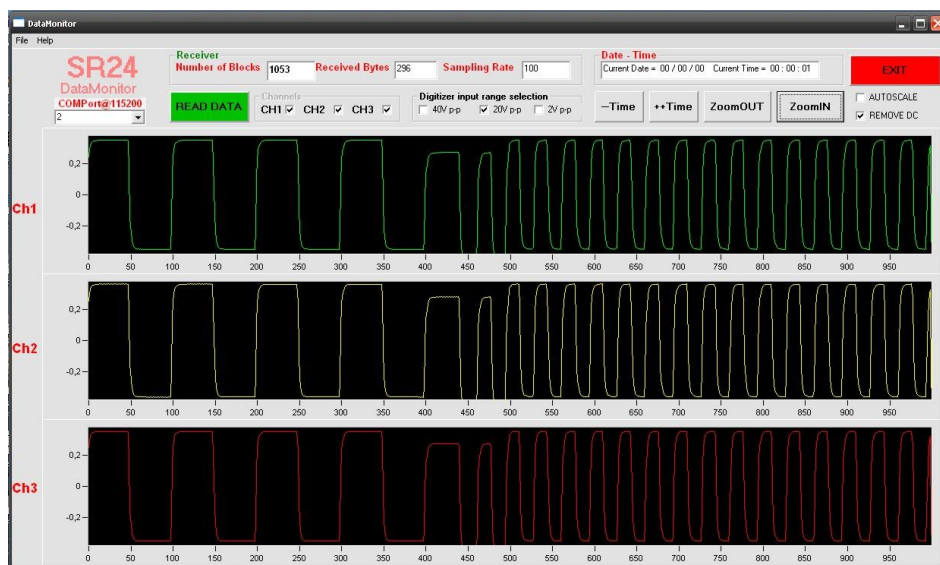


Figure 10. Pulse signal for sensor calibration.

Once the user connects with the SRI32L unit through the DataMonitor, he can verify the proper operation of the sensor. In parallel, the processor of the digitizer uses this signal to perform auto-calibration function of the system. So, all the seismic stations of a microseismic network will always be calibrated during the recording period.

6. Why high resolution digitiser?

The resolution of the digitizer is one of the most important parameters of the seismic instrumentation. 24bits digitizers are mostly used in seismic exploration. The

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SRI32 unit is based on a 4th generation 32bit digitizer, with dynamic range 136dB at 250sps, while dynamic range is 142dB at 10sps

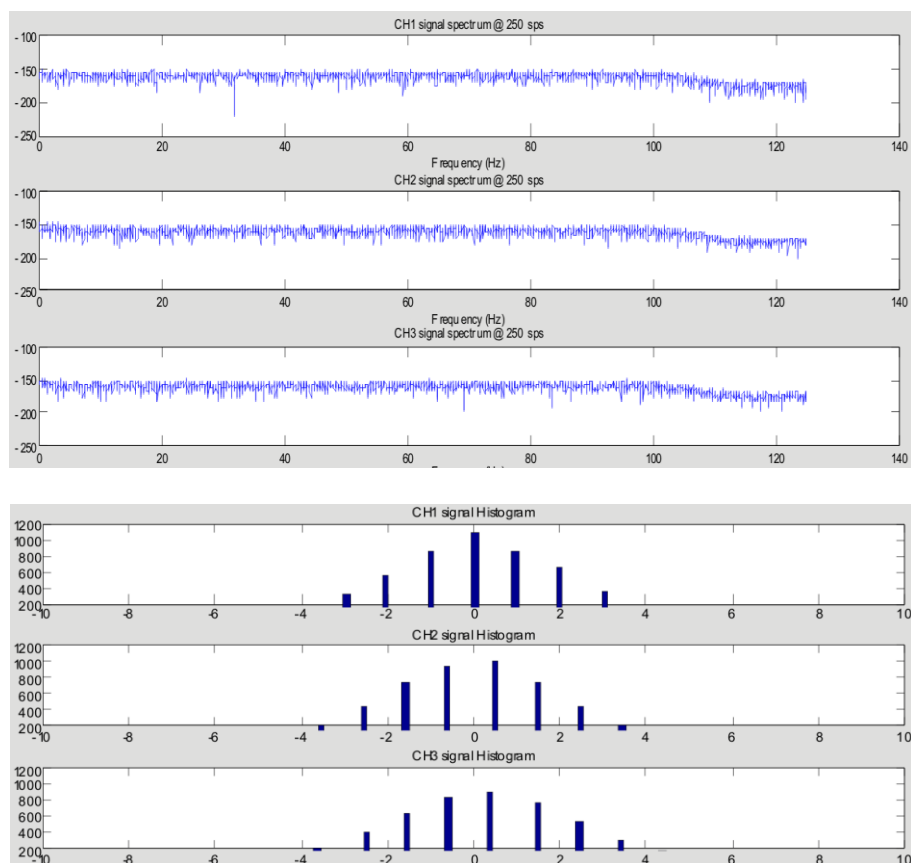


Figure 11. SRI32 noise spectrum & histogram plot.

7. Why big capacity storage media?

Our standalone seismic station dataloggers are getting powered from a typical 12V battery which may be cycled from seismic crew or charged by a solar panel.

The seismic crew usually visits the stations once per month or later for changing battery and retrieving the data. For places that a routine visit program is difficult to be followed because of accessibility, the storage media must have enough capacity to store the data for even longer period. Using a 2Gb microSD the recording duration for 3ch, 100sps will be up to 26days. Larger capacity Compact Flash Card will be used for larger recording period. The units support up to 64Gbytes flash card.

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8. Why very low power consumption?

One other important characteristic of a standalone seismic station is the power autonomy. Given that it is getting power from a simple 12V lead acid battery, the power cycle must be as many days as the seismic crew needs to visit the seismic station. Seismic networks usually consisted of 50 seismic stations, spread in an area of 1000 – 2000 Sqm². Assuming accessible terrain it usually takes a few weeks to the seismic crew for visiting all the stations. The power autonomy of each seismic station (recorder + sensor) must be enough to keep the station in operation for at least one month. Our seismic stations can operate for this time interval, getting powered from a single 12V/62Ah lead –acid battery.



Figure 12. Seismic station.

9. Why smart automatic event detection software?

One of the most critical problems of the data processing is the seismic event detection. It is simple when the seismic data are free of noise, but in many cases the micro-seismic network is installed very close to residential regions like cities or industrial areas. There, even the sensors are installed in 20m depth, the noise which is inside the seismic band will be propagated into the seismic signal. In places also that the sensors are not installed into the bedrock, noise is generally higher. For this reason, GEObit engineers have designed and developed a very special event detection software tool, based on a modified and patented recursive STA/LTA and curtosis algorithm. Adaptive filtering of the data is applied from the software prior to processing, in order to reject noise components outside of the recording band.

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It operates processing the data from neighboring stations and searches if any seismic event has been recorded. Searching all the station's data, one by one into their neighborhood, the event detection software can detect and extract all the recorded seismic events, even its magnitude is very small and even the data are noisy. This software has been tested and evaluated in the most noisy environments, where seismic networks had to be installed around cities and industrial areas.

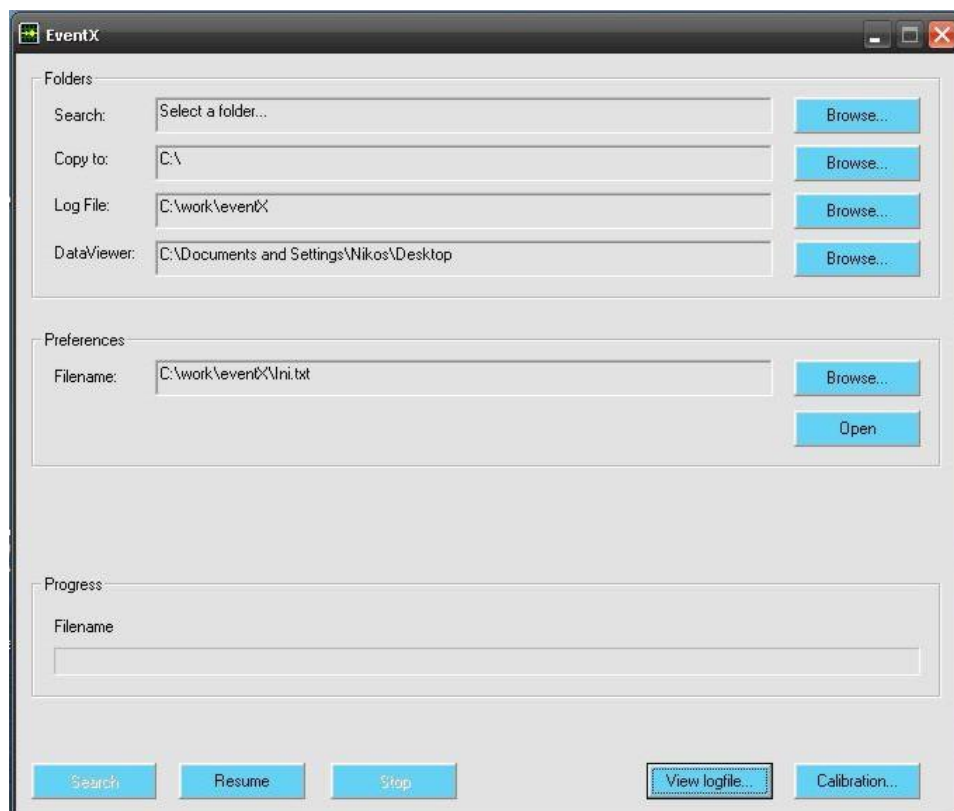
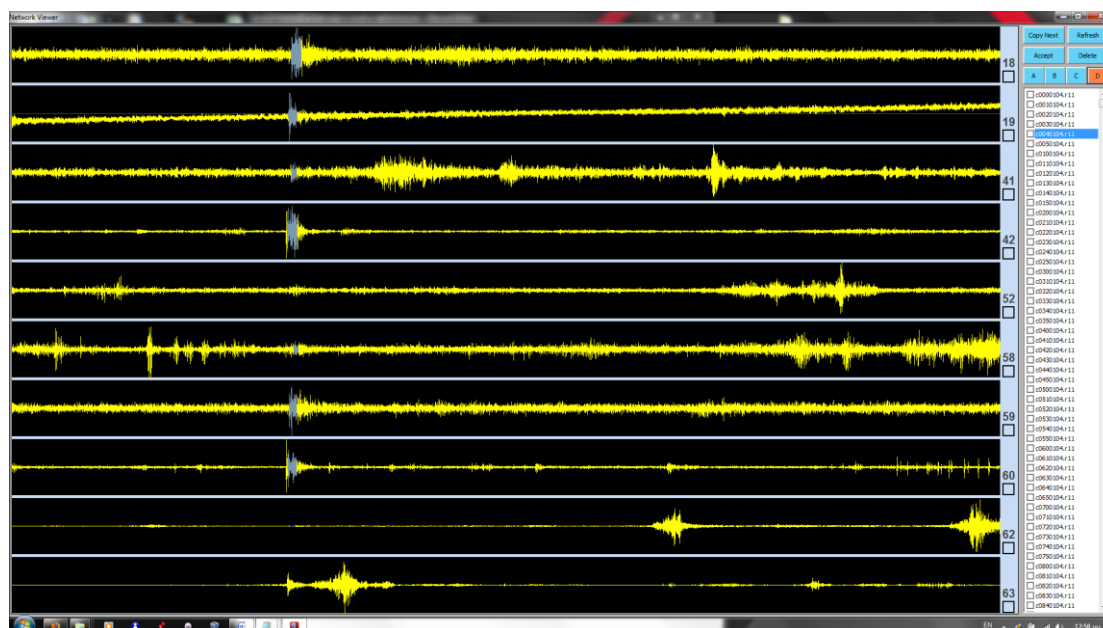


Figure 13. Event Detection Software.



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Figure 14. Event Detection Software.

10. Conclusion

In order to make a successful micro-seismicity monitoring application, the recording equipment should have the special characteristics. The design of the SRi32 integrates fifteen years of technology in micro-seismicity monitoring.