Z-99 Seismic Noise Without a Seismic Source

J. MEUNIER*, J.P. MENARD**
*Compagnie Générale de Géophysique Massy France
** SERCEL Carquefou, France

Summary

This paper relates two experiments conducted by CGG and SERCEL in order to better understand ambient noise. The first experiment questions the adequacy of receiver sensitivity for single receiver acquisition. The second experiment confirms the interest of digital accelerometers for recording high frequencies in low noise environment. Both experiments showed unexpected events unrelated with oil and gas exploration. A possible interpretation is proposed.

Introduction

Ambient noise may not be the least of the obstacles that must be overcome on the road toward finer spatial sampling and ultimately toward single sensor acquisition. Our favoured method for solving this problem has been to increase the source strength in a proportion that might not have been always needed. As long as this solution did not call for a lengthening in acquisition time, it was economically acceptable. However, with the reduction in array size that must inevitably accompany finer spatial sampling, this solution may no longer be technically possible. Since our industry does not appear today ready to accept the jump in seismic costs that would be generated by longer acquisition times, we must take a closer look at ambient noise.

Single geophone recording. Is its sensitivity adequate?

The ideal geophone should be able to faithfully record the lowest seismic noise. The seismic noise floor has been evaluated by earthquake seismologists. The USGS New Low Noise Model introduced by Peterson[(1)] in 1993 is often used as a reference. It is a power spectral density (PSD) and can be expressed in $(m/s)^2/Hz$ or in dB relative to 1 $(m/s)^2/Hz$ as in figure 1. This model presents the advantage of extending up to our usual frequency range. After a maximum around 0.2 Hz corresponding to marine micro-seismic noise, it decreases at a rate of almost 4 dB/octave. In our first experiment, werecorded noise during a quiet winter night. The geophone was a FDU-3C consisting of a polyurethane case including three 24-bit SERCEL 408 recording channels and three analog 10 Hz geophones. The recorder gain was set to 12 dB. These parameters and settings are very close to the highest commercially available sensitivity for a single sensor in our industry. Figure 2 shows the variation in the noise power spectral density seen by a vertical component during the night. The increase in noise in the morning is significant. It is very clear that apart from some amplitude bursts, the PSD curves are very flat at –185 dB above 30 Hz at 2 o'clock and above 75 Hz at 8 o'clock. This value,

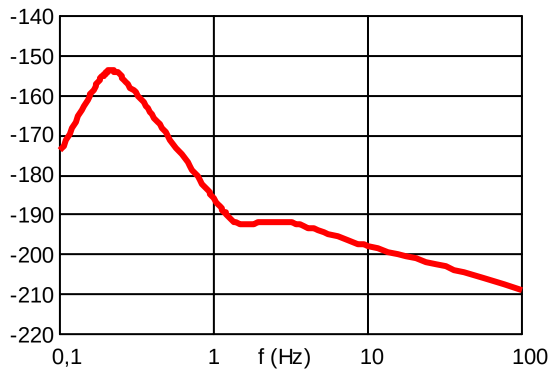

Figure 1 USGS New Low Noise Model in dB / 1(m/s)²/Hz from Peterson, 1993

which represents the recording system noise floor (electrical noise in the amplifier), is 18 dB above the NLNM at 30 Hz and 23 dB above it at 100 Hz. It does not necessarily mean that the geophone sensitivity is not adequate: this electrical noise is essentially random and therefore

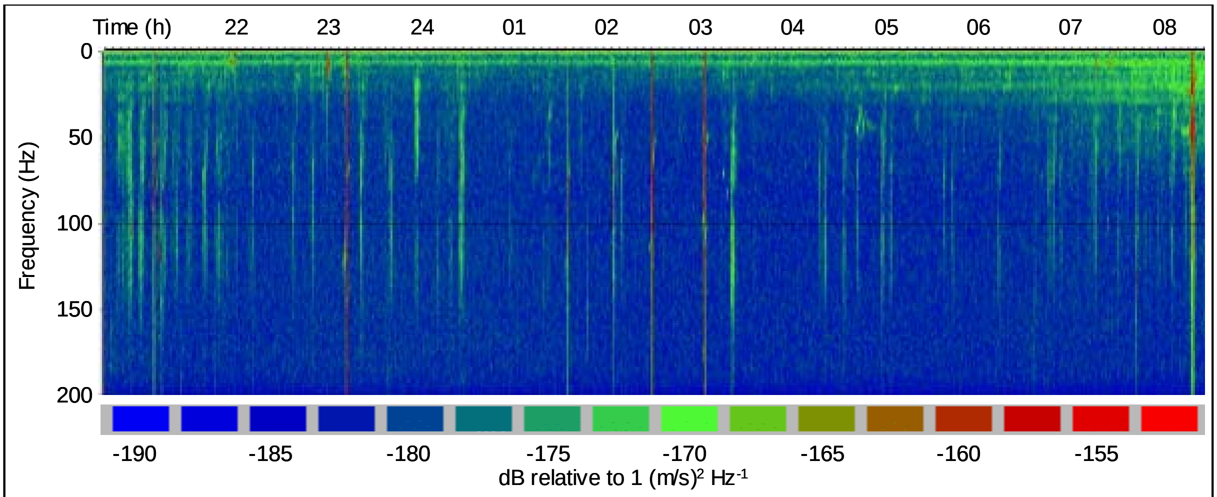

Figure 2 *Power spectral density of ambient noise (surface geophone)*

its level in the final seismic image will be divided by the square root of the number of seismograms used to build this image. For a stacking fold of 1000 the corresponding noise reduction amounts to 30 dB.

Digital accelerometers

Newly introduced digital accelerometers are expected to provide a better sensitivity above 30 to 50 Hz. They could therefore become a better choice in very quiet environments for projects requiring high frequencies. Such an environment is a shallow well.

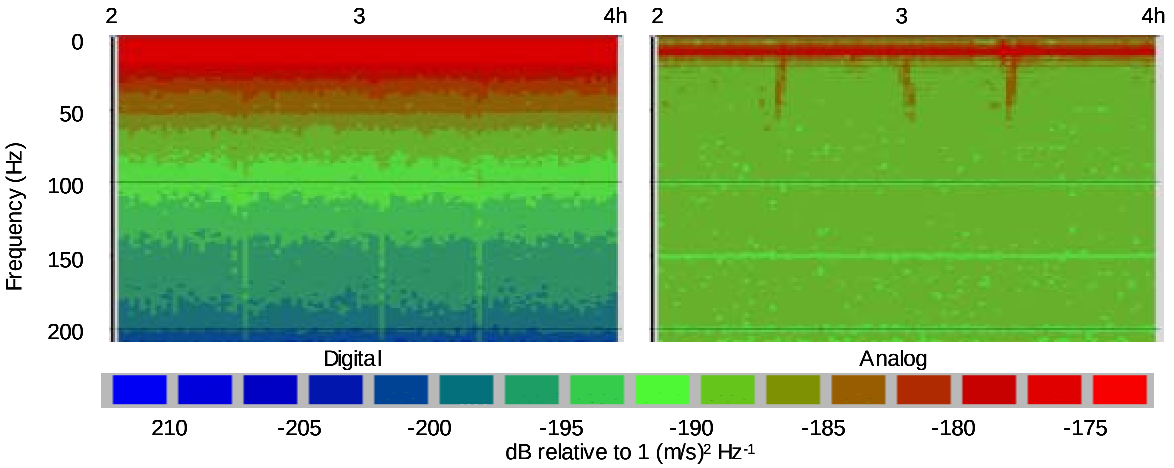

Figure 3 *spectral density of ambient noise (buried receivers, depth 200m) A notch filter is applied to analog data*

We cemented 12 digital 3-C accelerometers together with analog vertical geophones and hydrophones in a 7-inch well at depths ranging from 140 to 200 m. Figure 3 compares analog geophones and digital accelerometers. It confirms that below 50 Hz, conventional geophones are quieter than digital accelerometers and that above this frequency, the situation is the opposite: The three noise bursts recorded between 2 and 4 o'clock can be observed up to 200 Hz on the digital accelerometers. Another obvious advantage of digital sensors is their total immunity to electrical leakage. This experiment was conducted in a gas storage area close to wells protected by cathodic tension emitting a very cumbersome 50 Hz and its harmonics.

Despite all the care taken to minimize this leakage, it was not possible to keep it at the level of instrument noise; for this reason, it was necessary to apply a notch filter to the analog data on figure 3.

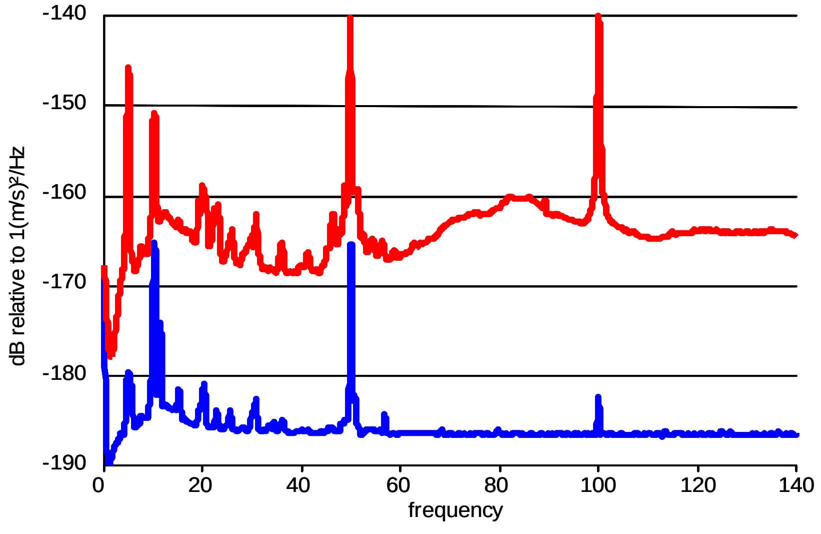

Figure 4 *Power spectral density of ambient noise*
Red: Surface *Blue buried at 190m*

Whithers[2] cited by Bormann[3] reports a 20 to 40 dB drop in the noise level at a depth of 43m. Figure 4 compares the power spectral densities of the analog component at 190m and of a surface geophone We found a reduction in seismic noise of 20 to 24 dB at frequencies lower than 30 Hz. Above 30 Hz, electrical noise dominates and the comparison becomes irrelevant.

Non-petroleum applications.

Passive seismic listening is becoming more and more popular for monitoring reservoirs during oil and gas production. During our short experiments, we have not observed any production induced micro-seismic event but we have observed other phenomena that could present some openings for seismic listening.

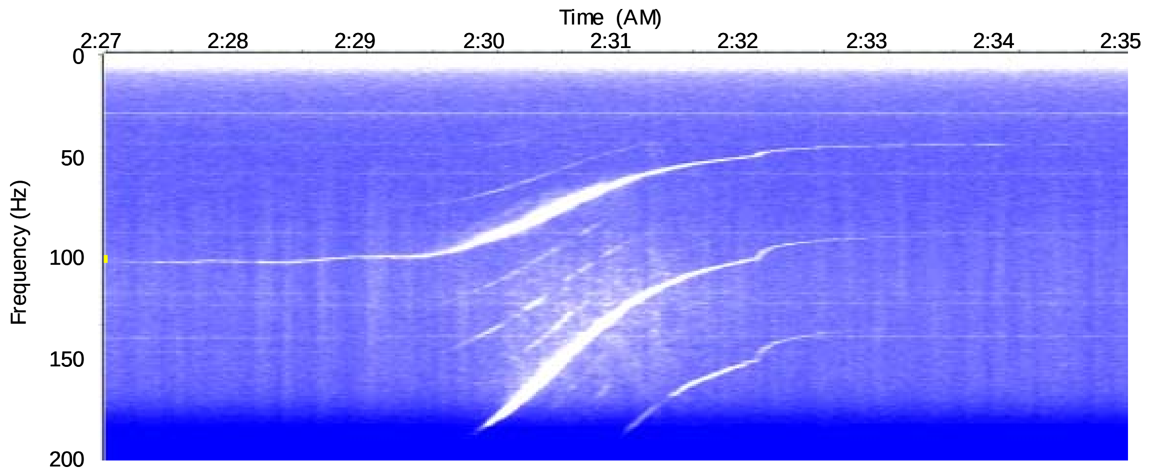

Figure 5 *Doppler effect associated to a plane*

Air traffic control

Figure 4 is a zoom of figure 2 starting at time 2:27. The color scale is changed in such a way that white represents high values and blue low values of noise power spectral density. It clearly represents a Doppler effect associated with a moving object emitting a fundamental frequency, its harmonics and sub-harmonics. The fundamental frequency (75 Hz = 4500 RPM) is the mean of the asymptotic frequencies. The velocity of this object (480 km/h) can be extracted from the frequency variation and the distance between the trajectory and the observation point (7500m) from the shape of the curve. The anomaly at 2:32 is interpreted as a change in direction. It is also quite remarkable that, because it generates a continuous signal, the airplane can be heard from as far as 30 km away.

Security

Zooming in on figure 3 provided us with another type of information. It so happened that the night we chose to evaluate the seismic noise floor in our well was also chosen by a couple of burglars to visit our test site and steal a 1000€ personal computer.

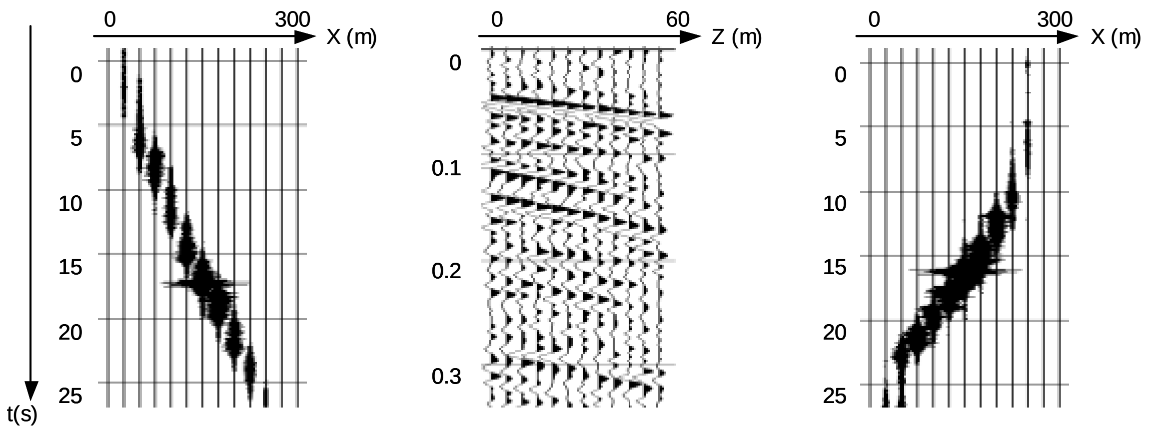

Figure 6 Intrusion monitoring

Left: Incoming vehicle at 32 km/h (surface geophones 01:41:25)
Center: jump from a fence (down hole geophones 02:43:44)
Right: outgoing vehicle at 48 km/h (surface geophones 02:45:34)

In fact the data in figure 6 are represented in the time domain, which is best suited for interpretation: the first and last panels use surface geophones at 1:41 and 2:45 respectively. We can see the burglars' vehicle arriving at a quiet 32-km/h speed and leaving at a not so quiet 48-km/h speed. The center panel is recorded by down-hole geophones at 2:43. It is interpreted as the burglar jumping over the fence. Since four jumps were observed, we believe that two burglars broke into our site that night. It is worth mentioning that a burglar jump not only generates down-going waves but also reflections. However, compared to its high cost, the energy is rather weak and we do not recommend the use of such a source!

Conclusion

The sensitivity of conventional geophones does not allow to record seismic noise over the full seismic bandwidth when a single geophone is used in a quiet environment.
In such an environment, when high frequencies are required, digital accelerometers offer an attractive solution.
In wells, ambient noise is significantly reduced and geophone sensitivity may limit our ability to observe very low amplitude events.
Looking carefully at seismic data still is a very enlighting business. Sometimes it even brings fun.

References

[1] Peterson, J., 1993. Observations and modelling of background seismic noise. Open File Report 93-322, U. S. Geological Survey, Albuquerque, NM
[2] Withers, M.W., Aster, R.C., Young, Ch.J. and Chael, E.P. (1996). High-frequency analysis of seismic background noise as a function of wind speed and shallow depth. Bull. Seism. Soc. Am. 86, 5, 1507-1515.
[3] Bormann, P. (1997). New manual of seismological observatory practice (web edition at http://www.seismo.com/msop/msop_intro.html)