Geophone and MEMS Accelerometer Comparison at Spring Coulee, Alberta

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Summary

Multicomponent seismic data, from a geophone and accelerometer test at Spring Coulee, Alberta, are compared and inspected for frequency content and differences in signal-to-noise ratio (SNR). Amplitude spectra show general similarity between geophones and accelerometers with differences in ambient noise appearing to be consistent with the theoretical modeling. Estimating the SNR at far offsets by comparing ambient noise to reflection energy suggests a small advantage for geophones at low frequencies (<20 Hz), and a small advantage for MEMS accelerometers above 150 Hz. Further analysis of NMO-corrected receiver gathers shows there is greater frequency content in the MEMS accelerometer gathers at high frequencies, but the a phase coherency analysis shows that the bandwidth of coherent information is very similar.

Introduction

Sensor responses relate a physical input to a sensor's output. They do not, by themselves, offer any information on the quality of that output. As long as the data can be processed to recover all available signal, what defines the data quality is the deviation from the response, especially if that deviation alters the signal nonlinearly or masks it. Deviations are most likely to occur at extremes in amplitude (e.g. noise floors at low amplitude, clipping and harmonic distortion at high amplitude), and frequency.

A 2D-3C seismic line was recorded at Spring Coulee, Alberta in January, 2008 to evaluate hydrocarbon potential of two sections where the University has subsurface mineral rights. Included in the survey was a small side-by-side sensor test of Sercel DSU-428 sensors and analog geophones also recorded through the Sercel 428XL system. Both sensors recorded the same dynamite shots. The test day was quite blustery, and some periods of significant wind noise were recorded.

Theory

Correction of geophone data to acceleration can be accomplished simply through the geophone response (Hons et al., 2008). All geophone data presented here has been corrected to acceleration to match the DSU data. When this correction is performed, the noise imbedded in the data by the recording system will also be altered. A plot of the noise specifications of the geophone and DSU systems, also in acceleration domain, is shown in Figure 1.

The frequency content is evaluated initially by comparing amplitude spectra of different parts of traces of varying offsets. To more fully attempt to estimate the signal-to-noise ratio over the whole bandwidth, spectra of intervals before the first breaks are compared with spectra of intervals where good reflection energy is dominant. The interval before the first breaks represents noise (both ambient and contributed by the system's noise floor), while the interval dominated by reflection energy is assumed to represent shot-related signal with all the noise before the first breaks still present. The minimum length required to record an accurate noise representation (from 1 Hz to Nyquist) was 450 ms, and only traces where this interval exists before the first breaks (far offsets) were used in the analysis. The ratio of the two intervals, with signal and noise defined above, can be represented by:

$$\frac{reflection\_spec}{noise\_spec} = \frac{S+N}{N} = \frac{S}{N} + 1,$$

so the signal to noise ratio is given by

$$\frac{S}{N} = \frac{reflection\_spec}{noise\_spec} - 1.$$

In addition, NMO velocity analysis was performed on the data to flatten the reflectors. The same velocities were for both sensors. The signal was then evaluated using FX coherency plots (Margrave, 1999). These estimates will not be necessarily be representative of the SNR expected in final processed sections, but are intended to provide an indication of where in the frequency band one sensor may have an initial advantage.

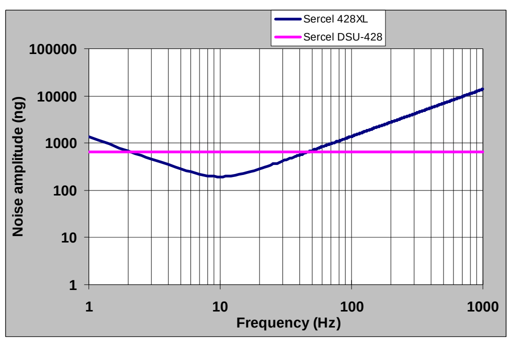

Figure 1: Modeled noise floor of a geophone and DSU recorded with the Sercel 428XL system, based published specifications of the DSU-428, the 428XL recording system and the SM24 geophone element.

Examples

The field data considered here is a small subset of the total multicomponent seismic survey recorded at Spring Coulee, Alberta. This subset test consisted of 40 stations of collocated, single sensor geophones and DSUs, all recorded by the Sercel 428XL system. The sensors simultaneously recorded the same 54 dynamite shots, which were each 2 kg at 18 m depth. A cartoon of the acquisition geometry is shown in Figure 2. Some receiver gathers show better coupling for the geophones, but in general data quality was good as acquired by both sensors (Figure 3).

Spectra from the noise before the first breaks shows the trends expected in the noise floor modeling (Figure 4). The average spectra across all the recorded traces are also very similar, suggesting overall differences between the data from the two sensors will be fairly small. Comparing the noise window before the first breaks to the signal window for all eligible yields the estimated SNR at each frequency shown in Figure 5. It shows the difference in system noise has a small influence relative to the reflections over the strongest signal band (20-120 Hz).

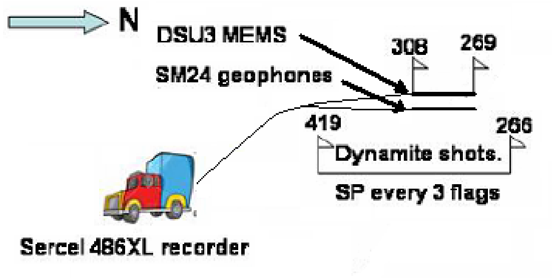

Figure 2: Geometry of the dynamite shot comparison at Spring Coulee, Alberta.

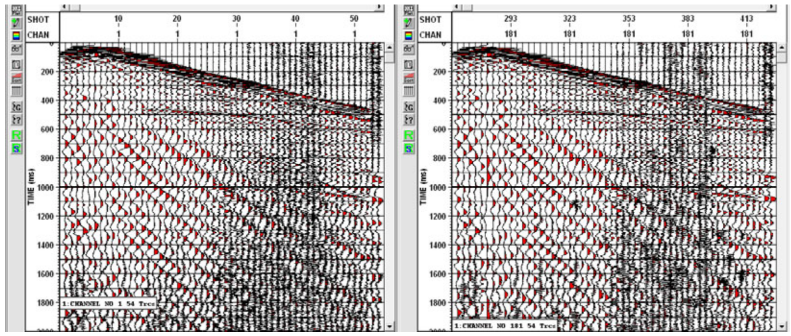

Figure 3. Acceleration domain receiver gathers. Left: Geophone. Right: DSU.

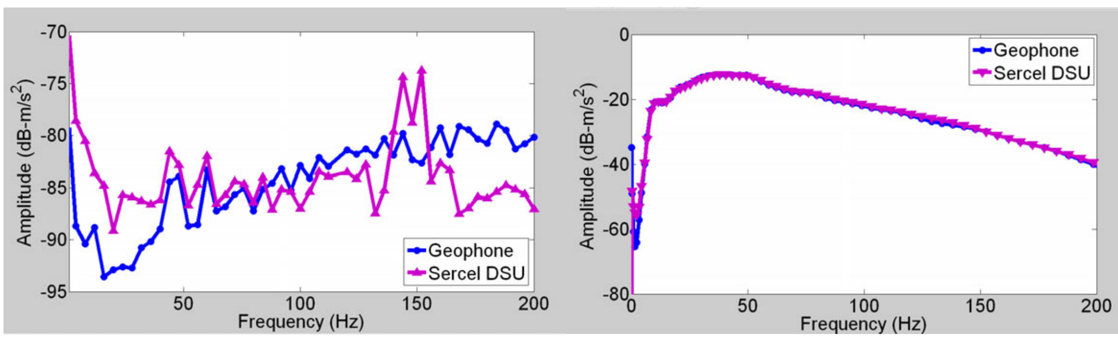

Figure 4. Acceleration amplitude spectra. Left: Noise before first breaks. Right: Average of all traces (0-4 sec).

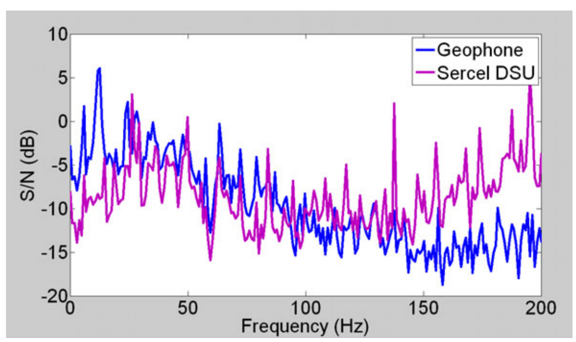

Figure 5. Acceleration domain spectra, noise before first breaks.

After NMO correction, several strong reflectors were evident (Figure 6). The FX amplitude and phase coherency can be interpreted to suggest what frequencies are dominated by signal or noise. The FX plots (Figures 7 and 8), averaged over all stations, show overall similar coherency and frequency content. The DSU appears to have greater content toward far offsets and high frequencies. Inspection of the coherency plots, however, suggests that this additional content is not strongly coherent in phase, and there appears to be greater coherency in low frequencies (<5 Hz) in the geophone data. Overall, it appears that the data quality as represented by the geophone and accelerometer sensors is quite comparable.

Conclusions

Despite apparent differences in the ambient noise before the first breaks, the data from the DSU and geophones appears to be of similar quality. The DSU has greater high frequency content, especially at further offsets. This content appears to be generally incoherent in phase, and represents noise in these data. Overall, the coherent bandwidth from both sensors seems to be very similar.

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References

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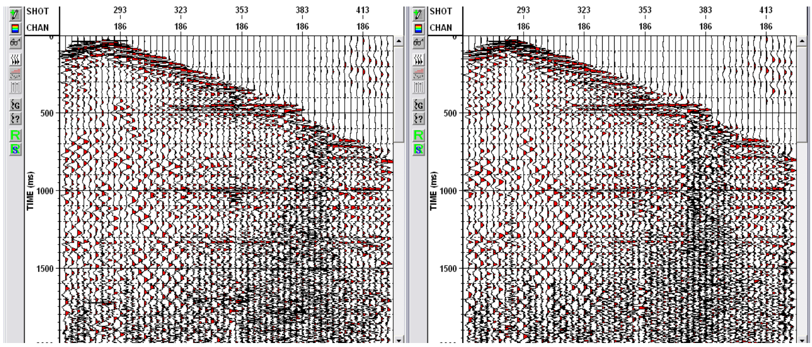

Figure 4. Acceleration domain receiver gathers, NMO corrected, with a 20 Hz lowcut for display. Left: Geophone. Right: DSU.

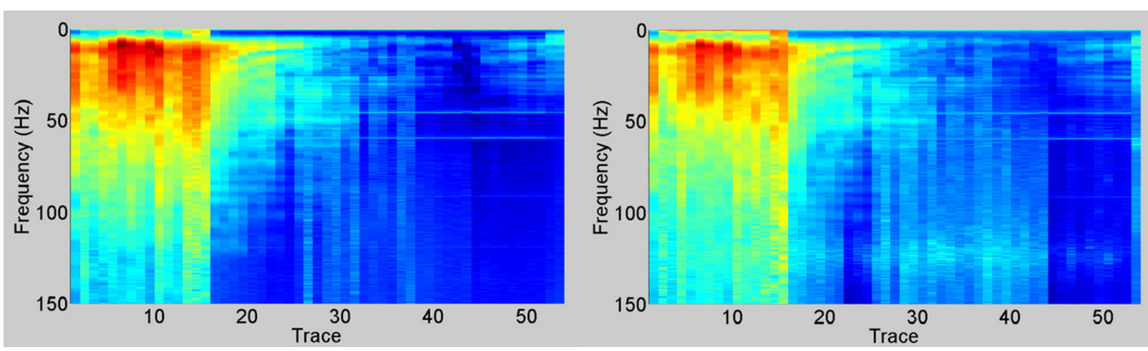

Figure 7. FX amplitude, average of all receiver gathers, dB scale. Left: Geophone. Right: DSU.

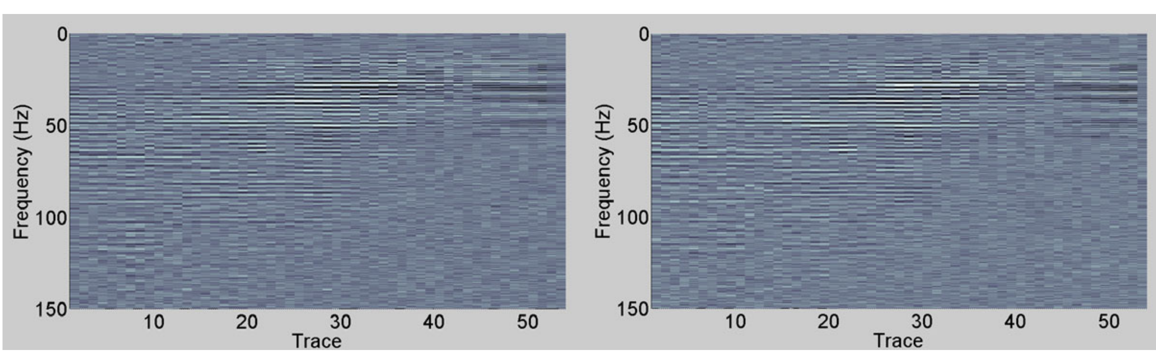

Figure 8. FX phase coherency, average of all receiver gathers. Left: Geophone. Right: DSU.