H019 EVALUATION OF DIGITAL ACCELEROMETER PERFORMANCE

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Summary
3C Digital Sensor Units (DSU3) based on MEMS accelerometers were compared with conventional coiled phones during a 2D point-source/point-receiver test performed in Siberia. P-wave shot point comparison in the velocity domain evidences two advantages of the new digital sensor technology: no pick-up noise, thanks to the full digital transmission from the MEMS sensors to the central unit; stronger energy in the high frequencies. Two possible methods for ground roll attenuation were tested on the DSU3 shot points. Conventional FK filtering in shot and receiver mode is more efficient than adaptive subtraction of the surface noise isolated by correlation between the vertical and the horizontal inline components. Stack section comparison, in the velocity domain, confirms the Digital Sensor Units provide better signal-to-noise ratio for frequencies above 80 Hz. However, the capabilities of the digital sensors to record very low frequency signal has not been confirmed, probably due to the insufficient number of receiver/fold used for this test.

Introduction
Three component (3C) digital sensors based on MEMS accelerometers (DSU3) were evaluated by Tyumenneftegeophysika (TNGF) in collaboration with Sercel during a 2D field test near Radushny (Siberia) in March 2003. To confirm the potential of the digital sensor technology comparison was done between the vertical component (Z) of single DSU3's and bunches of 12 geophones that mimic single geophones (no array filtering).

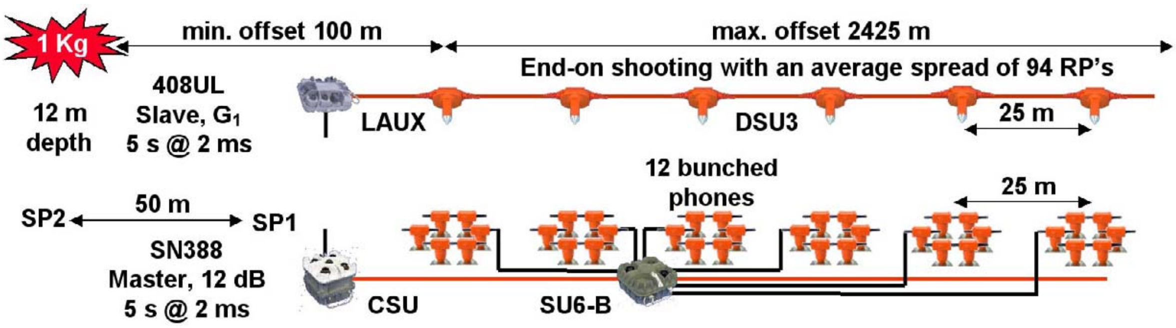

Figure 1: Geometry of the field test performed by TNGF and Sercel to compare digital sensors (DSU3) with geophones.

Test geometry
For the purpose of this test, two end-on spreads were recorded simultaneously using two recording systems in a master/slave configuration (Figure 1): a master SN388 system with 6 channel station units (SU6-B) provided by TNGF to record bunched phones; a slave 408UL system provided by Sercel to record 3C Digital Sensor Units (DSU3). The 25 m spacing between receivers was a compromise between the maximum offset and the spatial sampling of the surface noise. Shooting every 50 m (1 Kg of explosive at a 12 m depth) resulted in a maximum fold of 23 along a 12 Km line.
As designed this test is not a perfect one-to-one comparison of 3C digital vs. analogue sensors. This would have required the use of single analogue triphones instead of bunched phones. However, this test makes it possible a direct comparison of P-wave recording by point receivers based on the analogue & digital technologies.

Shot points comparison

Shot points (SP) are characterized by a low velocity dispersive ground-roll (250 to 500 m/s). Between the first arrival (1,750 m/s) and the ground roll, reflections are apparent down to 2.5 s twt (Figure 2). Since digital sensors record acceleration, corresponding records must be integrated into velocity for comparison with geophones. This integration corresponds to a 90° phase rotation, and to a high frequency (HF) attenuation of 6 dB/octave. After integration of the DSU SP's, the very low frequency (LF) noise becomes more apparent, but it disappears after a 5 Hz low cut (LC) filtering (Figure 2).

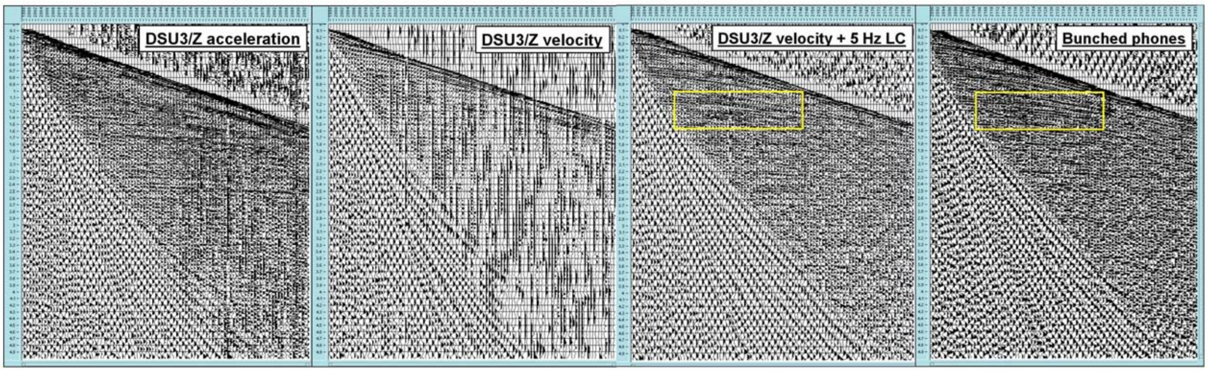

Figure 2: Shot point comparison between the vertical component of the DSU3 and the bunched phones.

A 4 Hz organized pick-up noise contaminates some bunched phone SP's. This noise is well evidenced above the first break (Figure 2, right panel), and on the FK diagram (Figure 3, central panel). It does not exist on the corresponding DSU3/Z SP's as seen on the DSU FK diagram before LC filtering (Figure 3, left panel). This difference between the two sensors illustrates the benefit of the full digital transmission that immunizes the spread against electro-magnetic interferences.
Below 5 Hz, the low frequency energy decreases as seen on the FK diagram of the geophone (Figure 3, central panel) This phenomenon is due to the attenuation that starts at the resonant frequency (10 Hz) of the geophone. Digital sensors work below their resonant frequency (~1 kHz), and provide a linear phase & amplitude response in the acceleration domain down to DC (0 Hz). Therefore, there is no attenuation of the low frequencies. Instead, we may notice an increase of the noise below 2 Hz.
A comparison of the frequency content of the reflections, in a 0.6 s twt window (Figure 2), evidences another advantage of the digital sensors: they are broader band compared to conventional geophones. This difference is obvious up to 200 Hz where the amplitude of the DSU is 10 dB above the geophone one. A 5 dB difference also exists in the low frequency part of the spectrum. However, we must be cautious with such comparison: the frequency spectrum measures the sum of signal & noise. Further processing will demonstrate: for LF, the difference between the two sensors is noise; for HF the difference is not only related to noise, but also to signal.

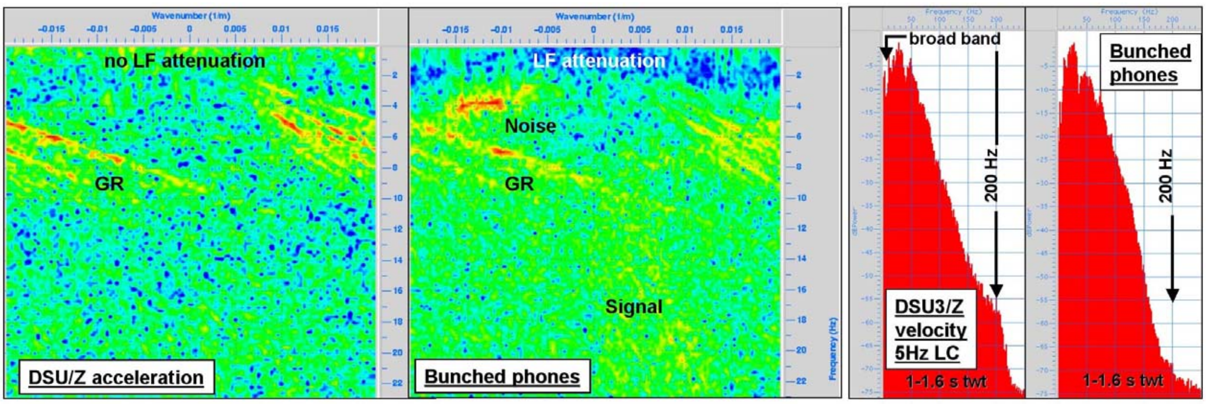

Figure 3: Comparison of FK diagrams of the whole DSU3/Z & geophone SP, and of amplitude spectra in a 0.6 s window.

Noise attenuation
Since point-source/point-receiver acquisition does not suppress surface noise, it is important to attenuate this noise at a later stage (i.e. during processing). For organized noise, spatial sampling should be small enough to prevent from aliasing. The 25 m spacing used for this test was not short enough to avoid aliasing of the very low apparent velocity ground-roll (Figures 2 & 3). For ambient noise, the fold coverage should be high enough to improve signal-to-noise while stacking traces. In this test, fold at maximum offset is low (23), and random noise is attenuated less than 13 dB.

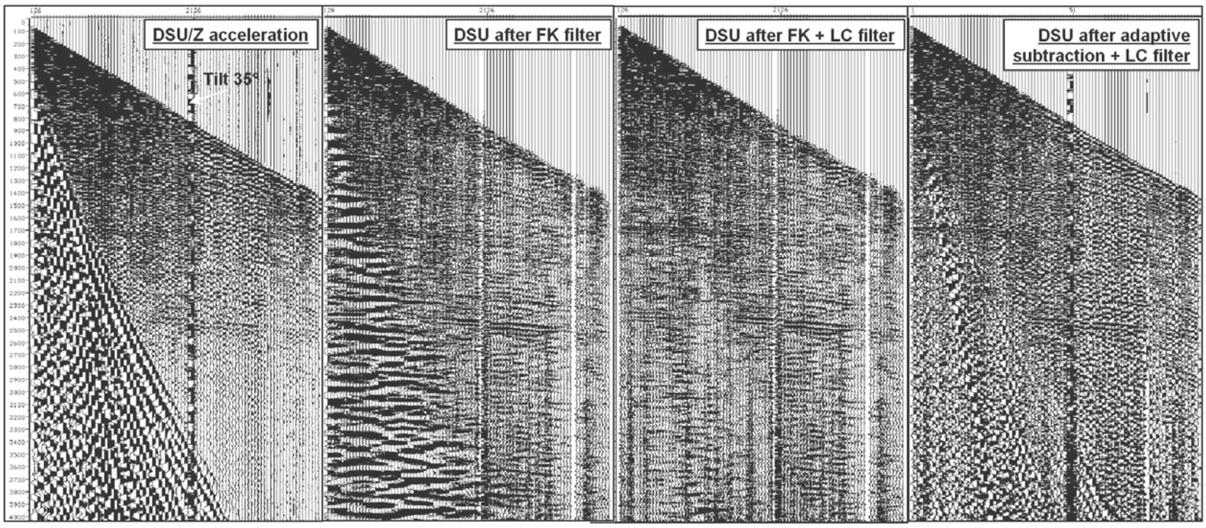

Figure 4: Comparison of double FK filtering and adaptive subtraction on a DSU/Z shot point in acceleration.

Two processing flows were tested for ground roll attenuation: FK filtering and adaptive subtraction. After testing different apparent velocities for FK filtering (from 600 to 3000 m/s), the best result was obtained with a 2500 m/s filter applied in both source & receiver modes (Figure 4). This apparent velocity, much higher than the ground roll, makes it possible the suppression of a ~2000 m/s noise that contaminates SP's. After FK filtering, the remaining aliased noise is efficiently removed by low cut filtering in the ground roll area (Figure 4, central panels).
The second processing flow applies only for 3C data (DSU3). It is based on the ellipticity of the particle motion of the ground roll that should be identical on the vertical (Z) and on the horizontal (X) components (except for a 90° phase shift). Ground roll is first isolated by correlation between the X & Z SP's. Then, this noise is adaptively subtracted from Z. On this dataset, the second methods is less effective in attenuating ground roll than the FK filtering (Figures 4 & 5). Below 1.2 s twt, the stack after adaptive subtraction displays more oblique noise and less continuous reflections. This limited efficiency is probably related to the ground roll that is not as identical as expected on the X & Z components, particularly at longer offsets.

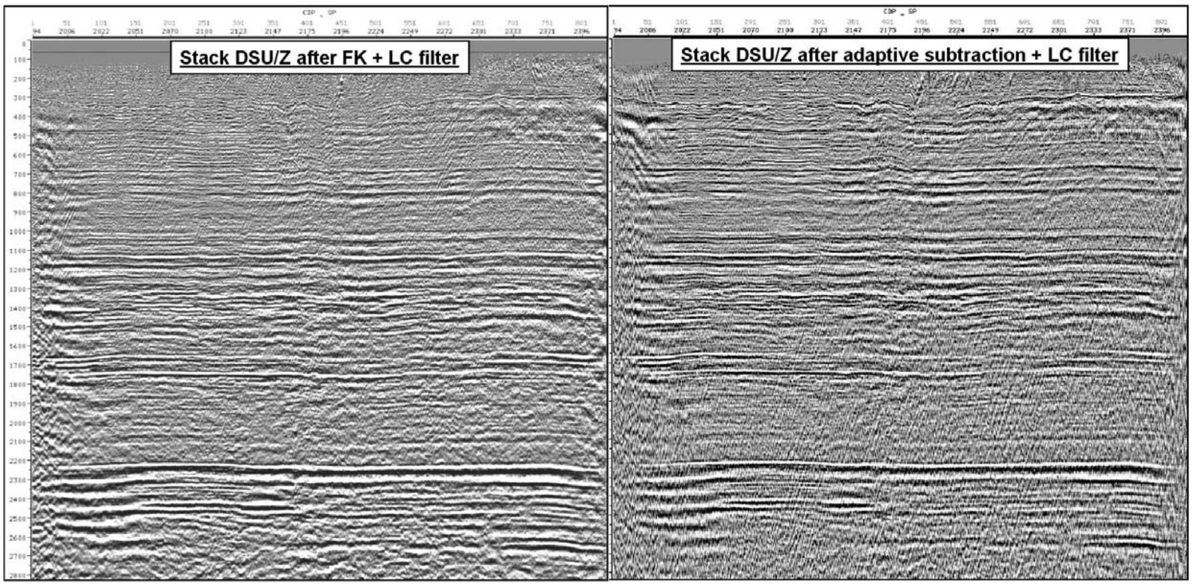

Figure 5: Comparison of double FK filtering and adaptive subtraction on a DSU/Z stack in acceleration.

PP stack comparison

The same processing flow, including FK filtering, was applied to the DSU/Z & geophone data. Integration of acceleration into velocity and LC filtering were automatically performed during the 0-phase surface consistent deconvolution. Field & refraction statics and stacking velocities were identical on the two datasets. Only the small residual statics were specific. From the final sections, after post-stack random noise attenuation and time variant filter, two differences were noticed (Figure 6). The continuity of the deep reflection, at 2.6 s twt, is better on the geophone stack. However, as shown by the amplitude spectra (1 - 2.7 s window), the signal from DSU (noise is supposed to have been attenuated) is stronger above 80 Hz than the geophone one. This confirms the potential of digital sensors for recording higher resolution data.

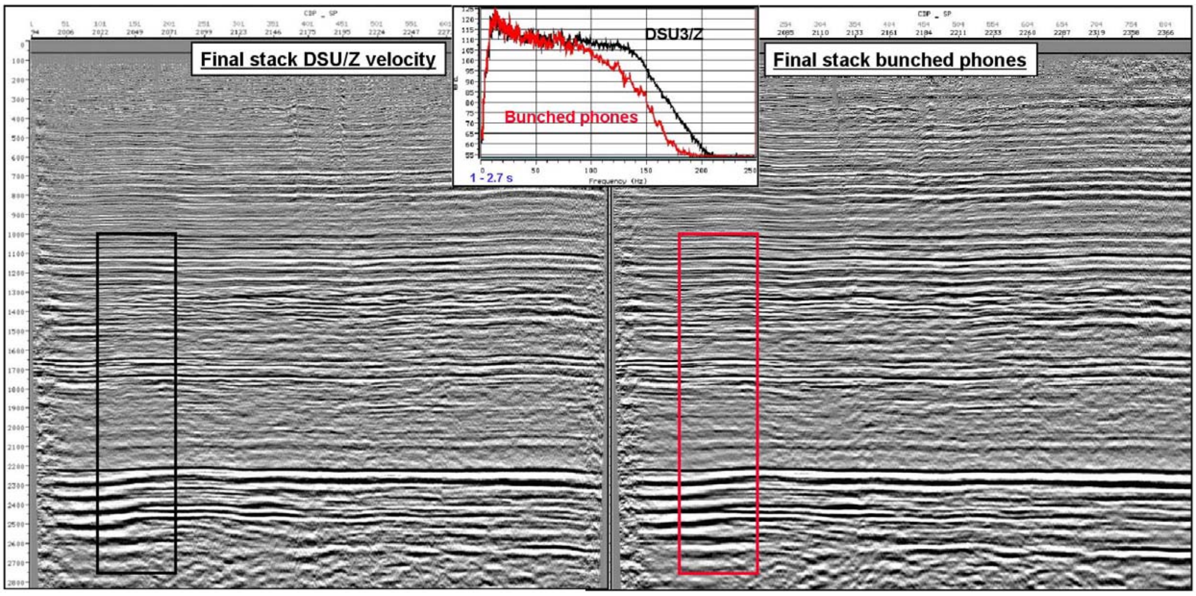

Figure 6: Comparison of the final stacks in the velocity domain after random noise attenuation and time variant filter.

Conclusion

Comparison of the seismic data provided by bunched geophones and digital sensors at the same location demonstrates the capability of the digital sensors to improve P-wave data. Digital sensors are not sensitive to pick-up noise thanks to the full digital transmission from the MEMS sensor to the central unit. They have also the potential to record broadband data. During this test, the improvement of the signal-to noise ratio towards the high frequencies, already detected on pre-stack data, has been verified by comparison of the final sections. However, the potential of the digital sensors to record very low frequency signal, which is as important as the high frequency signal for vertical resolution and seismic inversion, has not been confirmed. This is due to the high noise level of this dataset at low frequencies.

Digital sensors are sensitive to any surface noise due to their recording as single sensors. Therefore, a shorter spatial sampling than the one of this test (25 m) would have been recommended to de-alias ground roll. More sensors would have also permitted to increase fold for better ambient noise attenuation. Such denser sampling would have probably improved signal-to-noise ratio at low frequencies, and would have confirmed the potential of the digital sensors to record signal in this domain.

Acknowledgements

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