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Innovative high trace density survey design for broadband seismic data acquisition – insights and lessons learned for Symphony® (DSA) and Compressive Seismic Imaging

Howard J. Watt & John Archer, SAExploration

Summary

The economic realities of unstable commodity pricing have applied increasing pressure on acquisition geophysicists to produce more with less. The optimization of survey design for increasingly diverse and demanding geologic objectives is now commonplace. Many projects are complicated by environmental, operational and geologic encumbrances. The utilization of new acquisition geometries, methods and processing tools are paramount in addressing these issues. The application of two such methods, Dispersed Source Arrays and Compressive Seismic Imaging will be reviewed.

Low Frequencies

Since 2014, SAExploration and Geokinetics have acquired several onshore surveys utilizing either dispersed source arrays (Symphony®) or compressive seismic imaging. Initial trials utilizing Symphony® focused on the ability to efficiently acquire a data set with what we would define as "Ultra-Low" frequencies or those less than 3 Hz. Previous projects, depending on the geographic area, typically had starting frequencies between 5 and 10 Hz. Decreasing the start frequency to 1.5 Hz can come at considerable cost due to limitations in vibrator performance (Winter et al., 2014). Figure 1 illustrates the increase in sweep time required to compensate for the reduction in drive level needed to mitigate damage to the vibrator (Dean et al., 2016). Considering the spatial sampling requirements of "Ultra-Low" frequencies are less than those at higher frequencies (Bell et al., 2015), we can take advantage of the fact that historical design geometries typically over sample the low to mid-range frequencies and redistribute that effort or sweep time as shown in Figure 2 (Archer et al., 2018). Subsequent projects investigated an additional means of reducing the need for increased sweep time by the coordinated combination of single vibrator fleets. This increase in bandwidth (low frequencies) provides many benefits, however it also introduces certain challenges such as ensuring slow velocity surface waves are properly sampled (Denis et al., 2013).

Improved sampling

The balance between economic and equipment considerations have typically influenced or constrained our ability to improve sampling. Since the mid to late nineties, vibroseis operations have benefitted from the introduction of methods such as slip sweep (Rozemond et al., 1996) and subsequently Independent Simultaneous Sweeping (Howe et al., 2008). The adoption of these Source Driven Shooting (SDS) methods resulted in a shift where the acquisition geophysicist looks at tighter source geometries, single vibrator fleets and considers designs based on “energy per unit area”. Meunier discusses this subject in his 2011 Distinguished Instructor Short Course. The practical introduction of compressive seismic imaging for land seismic data acquisition by ConocoPhillips (Mosher et al., 2017) has led to several other companies use of the method to further improve sampling. It’s application can have a significant impact on addressing initial processing, migration and gather analysis (Millis, 2018).

Insights and lessons learned

Recent North American project designs routinely show an uplift in source density of 4 times through the utilization of SDS and an increase in bandwidth of approximately 2 octaves with the introduction of custom low dwell sweeps. In addition, Non-Uniform Optimized Sampling (NUOS) and subsequent CSI reconstruction (Mosher et al., 2012) have further improved the trace density by an additional 2 to 4 times. After reconstruction, the trace density of a typical project is over 53M traces/mi^2 (>20.4M/km^2). As one would expect, there are many benefits with these design improvements however, we still need to be mindful of the wavefield we are recording. We will look at the Symphony® method and examples of its ability to efficiently acquire high trace density broadband data. We will also discuss reconstruction including examples of the benefits with respect to noise analysis and consider some limitations. As with any new technology there are various motivations when companies look at implementation, some good, some not so much. Careful consideration of the environmental, operational and geologic objectives need to be taken when deciding which method or combination of methods is most appropriate.

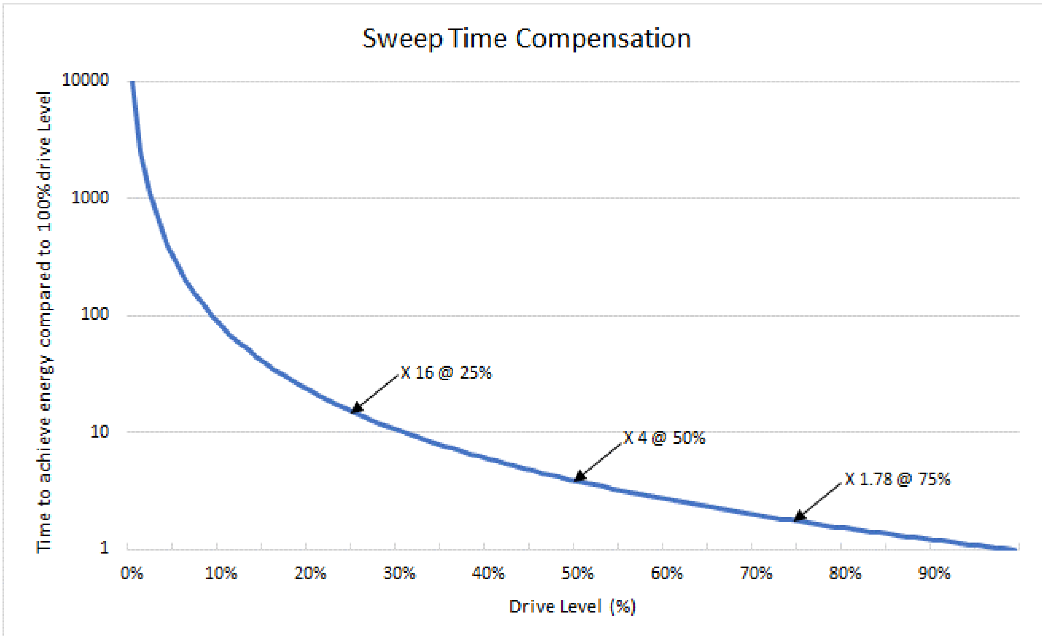

Figure1: The amount of sweep time required to compensate for a reduction in vibrator drive level. (after Dean et al., 2016)

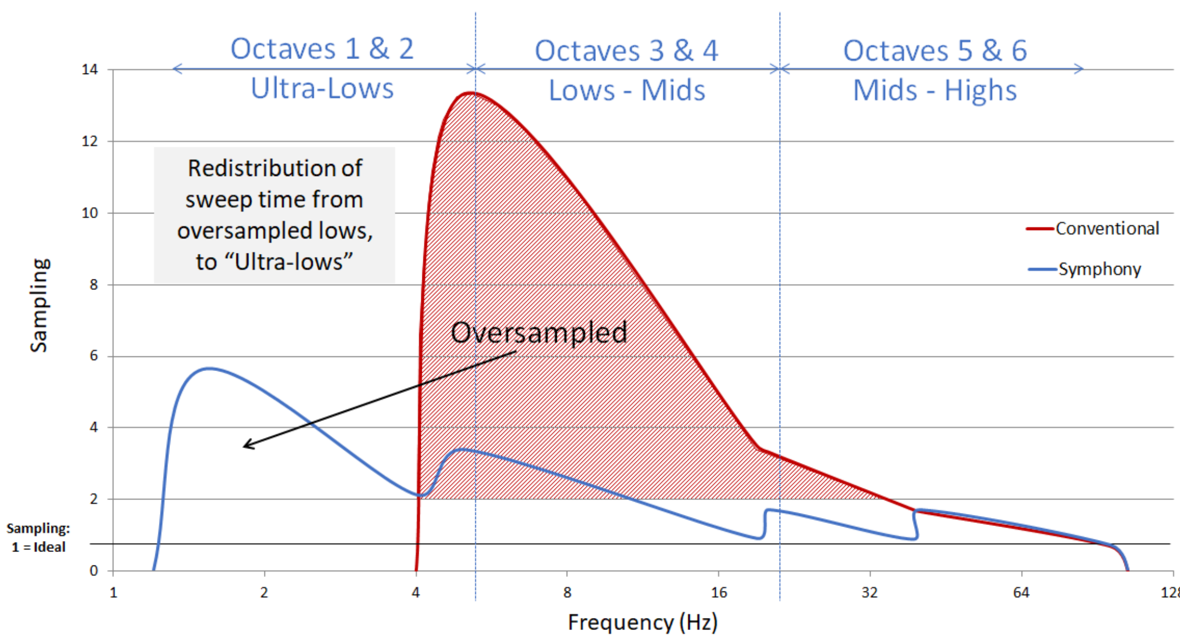

Figure 2: Chart illustrating the oversampling of the low-mid frequencies in conventional surveys, and how this sweep effort is redistributed to the "ultra-low" frequencies with Symphony® - DSA (after Archer et al., 2018).

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