Multimeasurement Wavefield Reconstruction for Broadband Imaging and Interpretation

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Recently, the seismic industry has seen a variety of acquisition and processing solutions developed to provide broadband marine data from towed streamers. A key driver has been extending the temporal bandwidth at both the low and high ends of the frequency spectrum; for example, to improve the overall resolution for interpretation, as well as enable additional information to be extracted from 3D attributes and seismic amplitude inversion.

Techniques to attenuate the receiver-side ghost include variable-depth streamers (Soubaras and Lafet 2013) that exploit notch diversity caused by non-uniform tow depths at different offsets, as well as streamers that combine multimeasurements – typically total pressure (P) and particle velocity (V) – to infill the ghost notch (Tenghamn et al. 2007; Robertsson et al. 2008). This latter class of acquisition and processing techniques benefits from an increased low-frequency contribution from hydrophone data enabled by a consistent, deep tow across all offsets. The deep tow also provides the potential for a seismically quieter acquisition environment and buffer against adverse surface weather conditions.

This paper reviews the fundamentals of a marine seismic acquisition system comprising point-receiver multimeasurement sensors to record scalar pressure (P) and both vertical (Z) and horizontal crossline (Y) components of particle acceleration. Particle acceleration is measured using densely spaced microelectrical mechanical system (MEMS) accelerometers across the full bandwidth. A linear relationship links the vector properties of particle acceleration with the gradient of the pressure wavefield. Together, these obtain direct measurements of the total pressure wavefield as well as its derivatives at the streamer locations. These, in turn, enable simultaneous 3D deghosting and reconstruction of the seismic wavefield using a process referred to as generalized matching pursuit (GMP), as described by Özbek et al.(2010). Complementary source configurations and processing methods target the source-side ghost notch, however, this aspect is not addressed in this paper.

The combination of vector pressure measurements and GMP reconstruction is used to mitigate high-order spatial aliasing in the sparsely sampled crossline direction between streamers. The aim of the technology is to provide a broadband, isometrically sampled, seismic data set. Isometric refers to equal sampling in all directions, and is derived from the Greek isos 'equal' and metrica 'measuring,' and thus provides a step towards broadband referring to high spatial resolution in three dimensions: vertically and horizontally - both inline and crossline to the acquisition orientation.

A series of short case studies are presented that illustrate the performance of this system under different conditions, geographical locations, and varied geophysical objectives. Examples cover uses of both dual-measurement (P and Z) plus the full P, Z and Y measurement combination:

Synthetic modelling study of wavefield reconstruction from shallow-water carbonate reefs in southeast Asia, comparing multimeasurement wavefield reconstruction against a singlemeasurement interpolation technique (matching pursuits Fourier interpolation).
3D imaging using P and Z measurements for appraisal well planning offshore West Africa, illustrating detailed sand channel interpretation and the contribution of the Z measurement at low frequencies below 10 Hz using the optimal deghosting (ODG) technique described by Caprioli et al. (2012).
Comparison of P and Z combination versus slanted streamer from the Barents Sea, demonstrating the extended acquisition window of deep tow streamers under marginal weather conditions.
Interpretation and inversion results from a reservoir development case study in the North Sea, comparing the uplift from near surface to the reservoir, of the full multimeasurement data set versus a more conventional hydrophone-only equivalent.

References

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