Ghostbusters!

M.G. Lamont (DownUnder GeoSolutions), B. Müller (DownUnder GeoSolutions) & T.A. Thompson (DownUnder GeoSolutions)*

Summary

Broad bandwidth data is becoming increasingly more desirable driven by the needs of seismic reservoir characterisation. There are now a range of solutions on offer to the free-surface ghost problem and its effects on seismic bandwidth. We present a new de-ghosting processing technology (DUG Broad) and provide examples of its application on a range of real data sets.

Introduction

Petroleum reservoirs are complex systems. Our need to characterize these reservoirs continues to drive the demand for high-resolution seismic data. Resolution of course, is a function of bandwidth. Obtaining broadband data (in particular at the lower frequency end) via the suppression of ghost reflections is now a hot topic in our industry. Recent improvements in acquisition technology are addressing this issue more directly (e.g. over-under / slant / multi-sensor streamers). It is true, however, that the majority of new and existing data have bandwidth limitations as a result of interference from free-surface ghost reflections.

The ghost problem has been known for many decades and there have been a variety of solutions proposed over the years (e.g. Lindsay, 1960). Acoustic signals travelling upwards in the water layer will be reflected (with opposite polarity) from the water-air interface. These are termed ghost reflections. We record not only the desired (single reflection up-going) wavefield but also these down going reflections from the sea surface. Ghost reflections interfere with the primary reflection of interest resulting in notches in the recorded amplitude spectrum. These notches limit the useable bandwidth of the data, as well as distorting the phase spectrum, and are thus undesirable. The effects of source and receiver ghosts are influenced by a number of variables which include the source and receiver depths, sea state, obliquity, signal to noise ratio (SNR) and receiver offset. Variations in all of these parameters mean that the location (and severity) of spectral notches (notch diversity) can vary considerably in each (of the four) pre-stack dimensions. The DUG Broad "ghostbusting" technology can add significant value to both the processing of data from the latest broadband acquisition systems and conventional streamer data.

Method

DUG Broad deals with the reality of notch diversity in the pre-stack domain. It is important for both quantitative and qualitative interpretation studies that the adverse effects of ghosts, with respect to both amplitude and phase, are dealt with before any stacking takes place. Following relevant initial pre-processing (transcription / nav-merge / gain / noise removal) the spectral signature of the ghosts is forward modelled using the best estimate of all known parameters. These signatures are modelled in windows where each of the relevant variables is practically constant. Each shot record is divided up into many windows as a function of both offset and time. Observed spectra from windows with common values for the variables affecting the notch locations are stacked to increase the signal to noise ratio of the observed signatures. Every window will then have an observed and a (prior) modelled signature. An optimisation is then performed to match the modelled to the observed and refine the parameter choices in every window. The parameters are geophysically constrained to ensure the fitted values adhere to the expected uncertainty in the known values as well as expected trends as a function of offset and time (for example the source depth should be constant for any one shot). Following the optimisation an inverse operator is calculated that corrects the spectral notches in every window. All of the processed windows are then recombined to produce the final set of shot records. Tapered and overlapping windows also ensure that the operators are well constrained. This process removes the adverse effects of the ghosts, correcting both amplitude and phase distortion caused by pre-stack notch diversity.

DUG Broad is a de-ghosting technology. It does not address attenuation (Q) or additional spectral shaping. Of course both Q corrections and spectral shaping can be addressed later in the processing flow. DUG Broad removes the amplitude and phase distortion caused by free surface ghost reflections. De-ghosting naturally results in a broadening of the spectrum as frequencies (both high and low) suppressed by destructive interference have their amplitude (and phase) restored.

In summary the DUG Broad workflow can handle cables towed at any depth including deep tow data; both amplitude and phase corrections; uncertainly in source and receiver depths; varying SNR; varying water depth; varying sea state and pre-stack notch diversity.

Examples

A selection of examples will be shown which illustrate results before and after application of DUG Broad for a range of different data sets. One example of a full stack section before and after deghosting is shown in Figure 1.

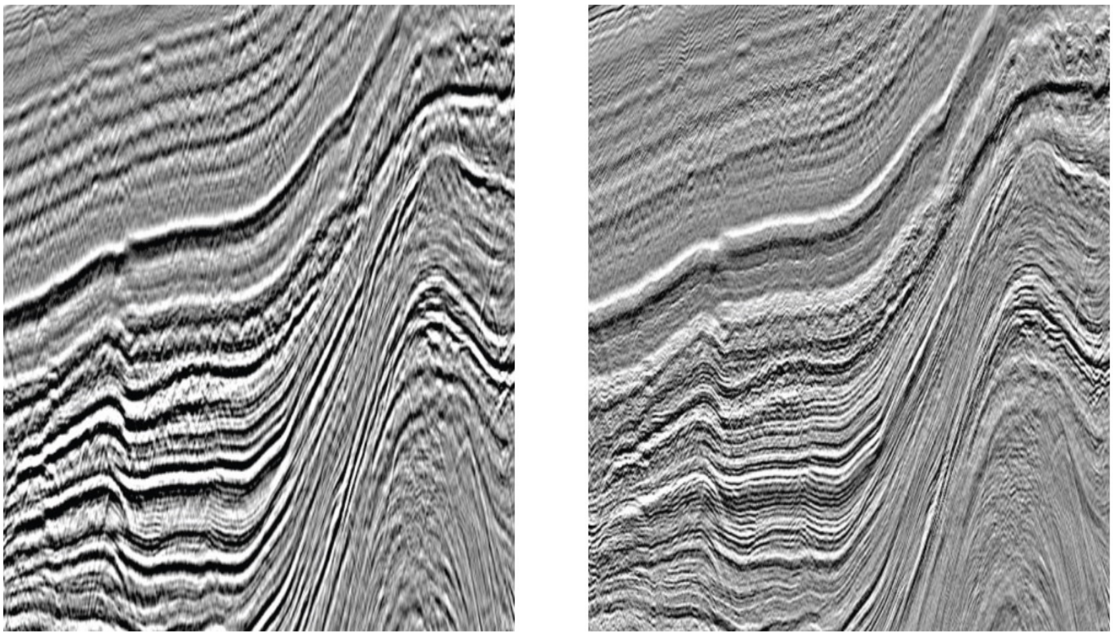

Figure 1 *Full stack section prior to (left) and after (right) DUG Broad. Gun and cable depths were 11m and 12m respectively (data courtesy of Polarcus).*

Conclusions

DUG Broad is a pre-stack processing technology that produces broadband data by correcting both amplitude and phase variations resulting from source and receiver ghosts. Recovering both high and low frequency information and restoring a broad and balanced spectrum has significant advantages from general interpretation through to more quantitative analyses.

Acknowledgements

We would like to acknowledge and thank Polarcus for supplying data and Apache Energy for permission to show data examples.

References

Lindsay, J.P. [1960] Elimination of seismic ghost reflections by means of a linear filter. *Geophysics*, **25**, 130-140.