Merging inverse-Q filtering and deconvolution

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Introduction

Anelastic attenuation affects seismic data in a time-variant manner. A pulse travelling through an anelastic medium simultaneously experiences a decay that increases with time and diminishes both amplitude and bandwidth. Traditionally, anelastic attenuation has been separated into two different issues and each is treated separately. A gain is applied to correct for the amplitude decay and deconvolution is used to increase the bandwidth of the seismic data. Although each of these methods have shown reasonable success, a method which encompasses and attempts to correct for both the time and frequency domain decay simultaneously is needed. To accomplish this, inverse-Q filtering has been developed. Theoretically it is more accurate than the gain/deconvolution combination, however industry has been slow to embrace it as Q is notoriously difficult to estimate accurately.

Method

We have developed a method which merges inverse-Q filtering with deconvolution in a technique which we call time-variant spectral inversion (TVSI). This new processing technique attempts to correct for the effects of anelastic attenuation, amplitude and bandwidth decay, and phase dispersion as well as source waveform and multiples. A seismic trace is first decomposed onto a time-frequency grid called the spectrogram or time-variant spectrum (TVS). An estimation of the source signature and the corresponding decay in time and frequency can then be derived from the TVS by smoothing out the effects of reflectivity. (Smoothing the spectrum to form an estimate of the source signature is a common part of stationary deconvolution.) The time-variant deconvolution operator is formed by inverting this estimate of the source waveform and decay effects and combining it with a digital minimum phase spectrum. The operator is applied using nonstationary convolution (Margrave, 1998). The TVSI algorithm is explained in more detail in Margrave and Schoepp (1997).

Similar to inverse-Q filtering, TVSI requires an estimate of Q to assist in separating attenuation effects from normal variation of reflectivity. However, the strength of TVSI over conventional inverse-Q filtering methods is that the operator in the TVSI method is determined directly from the data. It turns out that TVSI is not very sensitive to errors in the estimate of Q. Figure 1 shows a trace of the Blackfoot broadband survey that has been deconvolved several times with varying estimates of Q to examine the sensitivity of TVSI to this parameter. Differences exist between the output traces, however they are not dramatic considering the range of Q involved. Currently there is no method of Q estimation within the TVSI algorithm, although this work is in progress.

Examples

The Blackfoot broadband survey was processed to form a brute stack. The data was first corrected for spherical divergence. Next elevation statics, a bandpass filter (4-8-90-120), mute and trace equalization were applied and the data was stacked (Figure 2). A stationary Wiener deconvolution was then applied to the stacked data. The resulting section is shown as Figure 3a. The data was processed a second time with the same processing flow, however TVSI was applied after stack instead of Wiener deconvolution. The result is shown in Figure 3b. An estimated Q value of 100 was used in the TVSI algorithm. The same time variant filter was applied to both deconvolved stacks after the deconvolution. The processing flow was designed to avoid pre-stack applications that would affect the natural nonstationarity of the data.

As expected, the section without deconvolution has poor vertical resolution and is contaminated by low frequency noise at each end of the section. Both types of deconvolution improve the resolution, however the section processed with TVSI shows a higher vertical resolution than either of the others. For example, the arrow on figure 3b, points out an extra reflector that has not been resolved in section 3a. In addition, directly below the arrow, TVSI has separated what appears as a single event on the other sections into two distinct events. A trace with a segment of very strong amplitude, deconvolved with Wiener deconvolution, will appear weaker along the rest of the trace relative to the other traces. This effect occurs near the edges of Figure 3a and is absent from Figure 3b because TVSI has a time-variant amplitude adjustment which corrects for amplitude decay. Another striking difference between the sections is that the events in the section deconvolved with TVSI are shifted to earlier times relative to the other sections. This is a result of the minimum phase TVSI operator, however it is the subject of ongoing investigation.
Conclusions
Time variant spectral inversion is a processing technique which combines inverse-Q filtering and deconvolution to remove the effects of source signature, multiple contamination and anelastic attenuation effects, including amplitude and bandwidth attenuation, and phase dispersion from seismic data. It can be successfully applied as a post-stack deconvolution to increase vertical resolution and enhance events. Unlike the inverse-Q filtering methods, TVSI is relatively insensitive to the estimate of Q.

Acknowledgements
We would like to thank the sponsors of the CREWES project for their support.

References
Margrave, G. F., 1998, Theory of nonstationary linear filtering in the Fourier domain with application to time variant filtering: Geophysics, 63, 244-259

Figure 1: A trace from the Blackfoot broadband survey that has been deconvolved with TVSI. The Q estimate was varied to compare how changing this parameter affects the output trace.

Figure 2: An undeconvolved stacked section of the Blackfoot broadband survey.

Figure 3: The stacked section of figure 2 was deconvolved first with a stationary Wiener deconvolution (3a) and then with TVSI (3b).