So Many Challenges – But So Many Choices

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The previous three Geophysical Corner articles have focused on the spectral decomposition of seismic data, describing some of the methods and their applications. This month we add another one on the same topic, showing the comparative performance of some of the methods commonly available in the interactive interpretation software packages. Each of these methods has its own applicability and limitations, and the choice of a particular method also could depend on the end objective.

The most basic and perhaps the simplest method is the traditional Fourier transform method, also known as the short-window discrete Fourier transform (SWDFT) method. As the name implies, when using a fixed time window the seismic data is transformed into the frequency domain, and the output spectral amplitudes and phase volumes are visualized at different frequencies. The choice of the time window has a bearing on the frequency, temporal and spatial resolution of the output data. A shorter time window could result in a reduced frequency resolution on the output and vice-versa.

Figure 1a shows a comparison of stratal slices from the input seismic data volume from western Canada and the equivalent slices at 55 Hz from the SWDFT spectral decomposition method using a time window of 30 ms (figure 1b) and 60 ms (figure 1c). The stratal slices were chosen 24 ms below a marker seismic reflector close to 960 ms on seismic data processed with 5-D interpolation used to regularize offsets and azimuths.

The shape of time window also is important. Careful tapering (rounding the edges) avoids artifacts called the Gibbs phenomenon. The "smoothest" taper would be to use a truncated Gaussian window; this particular implementation of the SWDFT is named the Gabor transform, after its originator.

A common pitfall for the SWDFT is to use an analysis window that is smaller than the period of interest, such that Gibbs artifacts dominate the result. A fixed window will include more cycles of a higher frequency than of a lower frequency sinusoid, suggesting that one could design the window length to be proportional to the period. This construct gives rise to the continuous wavelet transform (CWT).

In figure 1d we show a 55 Hz spectral magnitude display, using CWT equivalent to the previous stratal slices – and notice the superior definition of the channel morphology. If in turn, the window is a Gaussian whose standard deviation is the period being analyzed, we obtain (omitting a few key mathematical details) the S-transform. This choice avoids picking a window that is too small.

One can implement these transforms...
Longer window algorithms like the S-transform will often cause more vertical mixing of stratigraphy, providing images with “more channels” than a shorter window S transform. While these channels exist in the data, they may be more properly associated with shallower or deeper horizons than the one being examined.

Conclusions
Different spectral decomposition methods provide an effective way of examining the seismic response of stratigraphic geologic features in terms of spectral components and so help in the interpretation. Each of the methods described above have their own advantages and limitations. The user is expected to understand these characteristics of the methods before making their application.

We hope this article helps provide some insight into this aspect.