Application of Inverse Q Filtering to Land Seismic Data to Improve Signal where there is no VSP Data Control

R. L. Basak*, S. Shanmugasamy, R. V. S. Murthy, and A. K. Roy
ONGC, Geophysical Services, Chennai

Summary

The effect of dispersion and attenuation on land seismic data can be removed by applying inverse Q filtering thus improving the seismic resolution. In this case study, the Q filter structure was designed by deterministic processing sequences on real data where there is a need to improve signal to compensate for attenuation losses. This method is useful in areas where there well data is available.

Introduction

An increasing loss of amplitude and phase distortion of the wavelet is normally seen in recorded seismic data. The loss in amplitude is due to frequency dependent attenuation while the phase distortion is due to dispersion. The high frequency components of the spectrum of the wavelet travel with a higher velocity are more quickly attenuated and phase shifted than the low frequency ones. Therefore, it is necessary to invert this attenuation by restoring the higher frequencies to increase the resolution of seismic data. An inverse Q filter when applied to data will increase the signal bandwidth and correct the signal amplitudes thus improving the reliability of data.

The earth filter, considered as a minimum phase process, could be represented by a Q model where Q denotes the quality factor of the medium. A forward Q filtering is used to test attenuation and dispersion effects generally on synthetic data, and an inverse Q filtering is used to remove them from seismic data .The application of this inverse filtering can not recover lost information, but can effectively restore the natural balance of the remaining information.

The degree of frequency loss and phase distortion are inversely related to the Q values of the medium. Large Q values imply low absorption, where as small Q values imply large absorption. The Q factor depends on the velocity, the density and the bulk modulus of the medium. It can vary from lithology to lithology.

Theoretical background

Seismic attenuation impacts the amplitude and wave shape of recorded seismic data. It is a fundamental property of subsurface media (Kjartonson E., 1979). Deducing lithological information like porosity, permeability and viscosity from seismic data, as is heavily dependant on the inversion schemes, compensating for seismic attenuation assumes paramount importance.

To remove the attenuation effect, an inverse Q filtering is designed and applied to seismic records (Bickel and Natarajan 1985; Hargreaves and Calvert 1991). The appropriate amplitude and phase deabsorption was achieved by establishing an empirical relation of Q values with the stacking velocities (Varela et al., 1993). Integration of zero offset well data with sonic log data provides the basis for Q values determination (Pramanik et al., 2000).

Q values are traditionally estimated by measuring spectral ratios between two receivers straddling a constant Q through the direct downgoing wavefield of VSP data (Leaney, 1999). This method determines spectral ratios between all possible receiver pairs in the VSP resulting in a plot of many Q values versus depth. These estimated values of Q can be used in designing the inverse Q filter for application to the seismic data to effectively compensate attenuation losses.

Harris et al. (1997) found that Q was independent of frequency over the seismic bandwidth for a North Sea VSP. In this presented study, we estimated Q structure by calculating the spectral ratio of a reference signal's amplitude spectrum with that of a data window in overlapping time windows moving down the trace. To obtain a good compromise between stability and resolution, we used the multi-taper method (Thomson, 1982).

Inverse Q filters aiming to compensate for both amplitude and phase losses are not stable as they entail a large amplification of high frequencies. To improve the stability of inverse Q filters, constant gain limited operators and high cut filters are used. By limiting the maximum gains of the inverse filters, these operators are active only on the spectrum in which signal dominates the noise.

In fact, it is never possible to completely correct for the loss of high frequencies because of limitation in dynamic range and the risk of over amplifying high frequency noise.

A stable inverse filter was designed based on the theory of wavefield downward continuation used in a layered manner, assuming a depth-dependent, layered earth Q model and the results were evaluated post application of inverse Q filtering (Wang, 2002).

Application of inverse Q filtering on real data

The 3D land data pertaining to Cauvery Basin was taken for this study where there were no spectral readings available from VSP data. Conditioning of raw data was done by removal of high amplitude noise, application of statics and surface consistent amplitude correction.

Random noise attenuation was done both before and after the application of inverse Q filtering followed by gapped deconvolution. The prior made volume stack was used to arrive at the Q structure for application of inverse Q filter on pre-stack gathers.

Figures (1-a) and (1-b) testify that inverse Q filtering has flattened the amplitude spectrum within the signal band. The amplitude spectra were subsequently band-pass filtered with (5-10-80-95) bandwidth. Flattened spectrum indicates compensation of loss of high frequencies, which in turn results in wavelet compression and the phase stability.

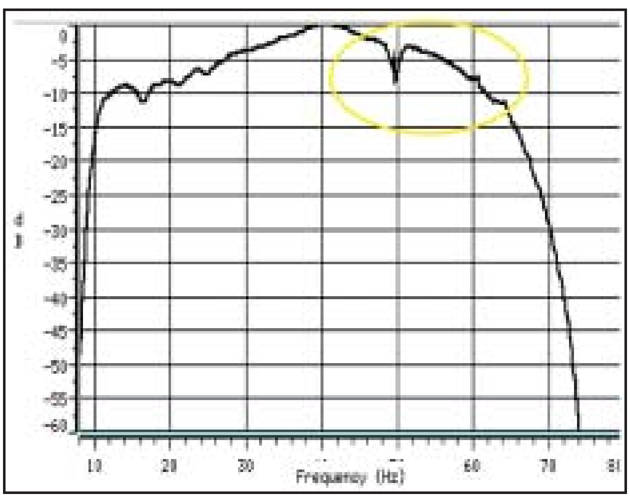

Figure (1-a): Amplitude spectrum before inverse Q filtering.

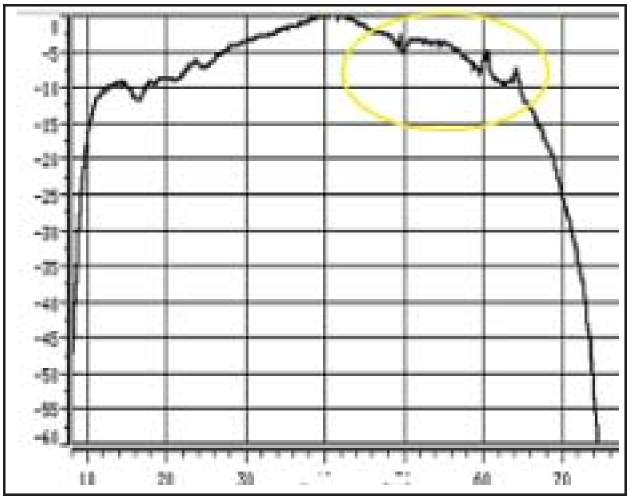

Figure (1-b): Amplitude spectrum after inverse Q filtering.

Figures (2-a) and (2-b) show the time-variant amplitude strength for different frequency components both before and after inverse Q filtering indicating that amplitudes have been sufficiently recovered after inverse Q filter application.

Figure (3-a) shows the stack section before inverse Q filtering and Figure (3-b) the same section after the filtering. The inverse Q filtered section shows higher dominant frequency than the other. The lateral coherence of the events also is better in the filtered section.

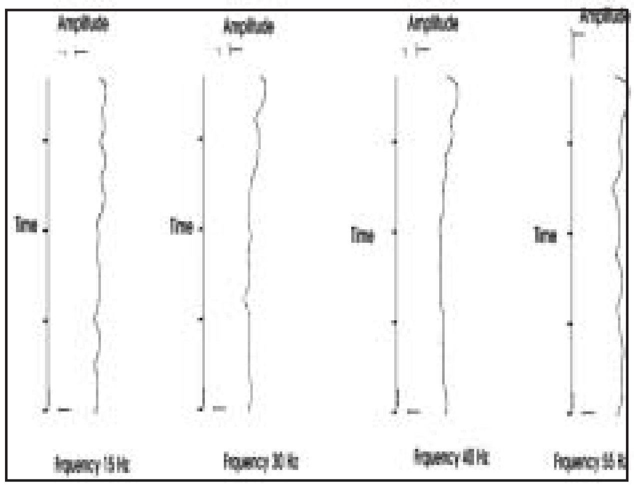

Fig. (2-a): Amplitude curves before inverse Q filtering. (Time window 0 - 4000 msec., Amplitudes in centibel).

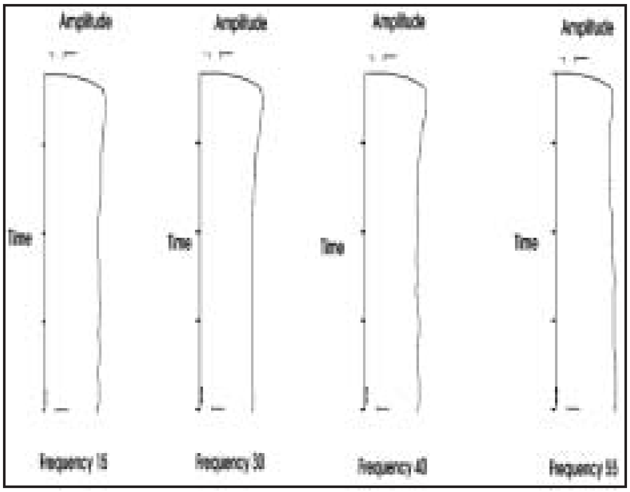

Fig. (2-b): Amplitude curves after inverse Q filtering. (Time window 0 - 4000 msec., Amplitudes in centibel).

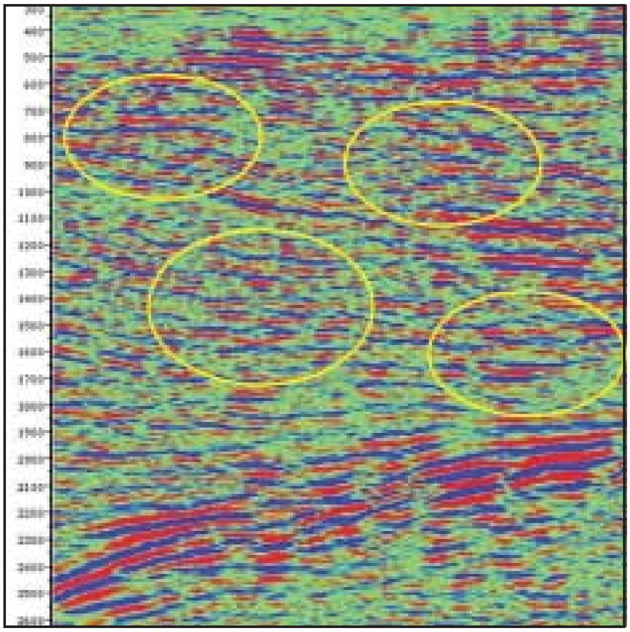

Figure (3-a): Stack section before inverse Q filtering.

Conclusions

The 3D land data processed with inverse Q filtering not using any well data has shown significant improvement over the data processed without using inverse Q filter. The filtering has improved the amplitude spectrum, strengthened the time-variant amplitudes of respective frequencies in the signal band, improved the S/N ratio, and thus increasing the resolution in the stack section. Further, improvements are possible with improved velocities that are necessary for computation of Q structure. This method is suitable especially when the signal to noise ratio is low.

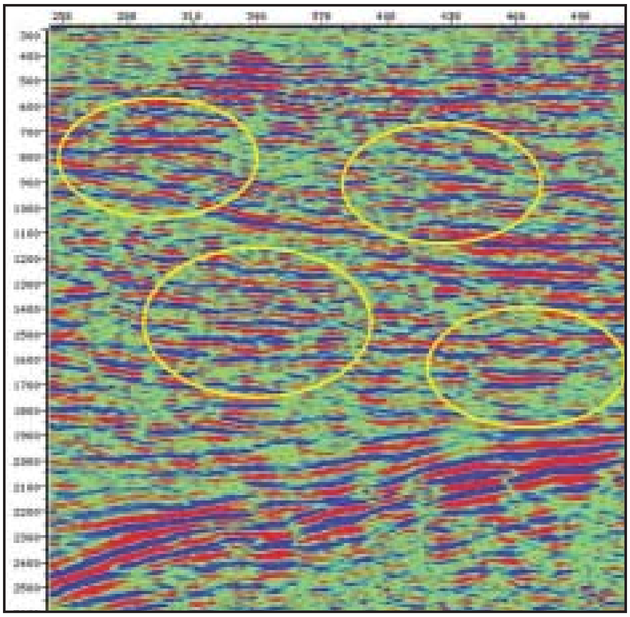

Figure (3-b): Stack section after inverse Q filtering.

Acknowledgements

The authors sincerely thank Shri D. Dutta, GM-HGS and Shri Chaman Singh, DGM-SAOM for their help and constant encouragement to carry out this work and permitting to publish the same.

References

Bickel S.H. and Natarajan R.R., 1985. Plane-wave Q-deconvolution: Geophysics **50,**1426-1439.

Hargreaves N.D. and Calvert A.J., 1991. Inverse Q filtering by Fourier transform: Geophysics **56,** 519-527.

Harris,P.E.,et al.,1997. Multichannel estimation of frequency-dependent Q from VSP data:Geophysical Prospecting, **45**, 87-109.

Kjartonson E., 1979. Constant Q wave propagation and attenuation: J. Geophys. Res. **84,** 4737-4748.

Thomson, D.J., 1982. Spectrum estimation and harmonic analysis. Proc IEEE, **70**, 1055-1096.

Pramanik et al., 2000. 70th Annual meeting and International Exposition, Expanded Abstract, pp 2013-2016.

Carlos Lopo Varela et al., 1993. Modeling of attenuation and dispersion: Geophysics **58**, No.8, 1167-1173.

Wang Y., 2002. A stable and efficient approach of inverse Q filtering: Geophysics **67**, No.2.

Wang Y., 2002. The effectiveness of stable inverse Q filtering to land seismic. EAGE 64th Conf. & Exh - Florence.