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Role of Spectral Balancing in Signal Enhancement

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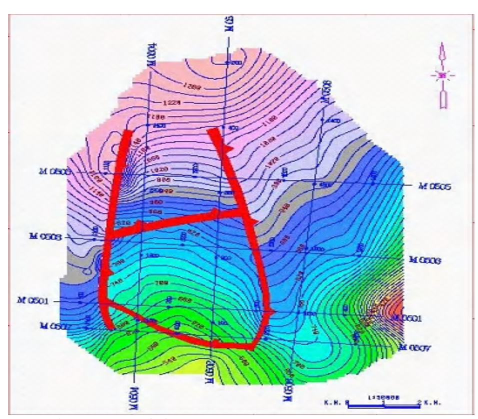
Summary

Seismic imaging in fold belt regime has always been a major challenge for acquisition and processing geophysicists in the world. Most of the time conventional processing schemes fail to produce the best possible image of the subsurface in the presence of strong noise and weak signal strength. A different processing scheme was formulated to enhance the signal strength. Moreover it was felt necessary to first understand the nature of prevailing dominant noises. First of all raw shot gathers were thoroughly analyzed for different types of source generated noise (e.g. direct, refracted, surface and air waves) masking the signal. Analysis of frequency spectra of different portions of the raw shot, figure 1(a), showed that it was contaminated with high amplitude source generated noise characterized by low and high frequencies and the signal content of the data was 10-55 Hz. These processing tests suggested that the best way to attenuate these noises and enhance the signal to useful signal band of 10-55 hertz was to apply spiking deconvolution and spectral balancing on a trace-by-trace basis.

In this study, spiking deconvolution followed by spectral balancing played a major role in enhancing the signal bandwidth by attenuating the source generated noise.

Introduction

The study area, Mizoram, falls in Tripura-Cachar-Mizoram fold belt of Assam- Arakan Basin and geographically situated in the north-eastern part of India. Mizoram fold belt area is traversed by tight and narrow anticlines and broad and gentle synclines. The area is logistically difficult due to steep hills with rapid elevation changes, thick forest and non availability of approach roads. In such logistically difficult and complex tectonic regime, seismic imaging was a challenging task for acquisition and processing. Many acquisition geometries had been tried and discarded in obtaining better data quality. Most of the time conventional processing schemes failed to produce the best possible image of the subsurface in the presence of strong noise and weak signal strength. Different processing approaches are required to get the meaningful image of the subsurface features. The initial processed sections adopting conventional processing scheme indicated chaotic reflections contaminated with noise. One of the reasons for this was large elevation variations present in the area and the inadequate sub-weathering velocity function used for initial field static correction computation. Field statics were re-computed at the processing centre by adopting an iterative technique for firming up optimum sub-weathering velocity. Secondly the raw shot gathers were contaminated with source generated noises (e.g. direct, refracted, surface and air waves) masking the signal. Application of spiking deconvolution followed by spectral balancing on a trace-by-trace basis has successfully attenuated these noises and enhanced the signal bandwidth. This process was most effective in significantly increasing the strength of reflected signals relative to the source generated noise.



Location Map of the area

Brief geology of the study area

Tripura- Cachar- Mizoram fold belt of Assam- Arakan Basin was formed as a result of six Diastrophic movements during closing of Indian and Burmese Plates. The first two tectonic disturbances that occurred during the post Cretaceous and post Eocene times were confined to the eastern parts of the region. The third disturbance of post Oligocene age had a wide spread effect on the region .The post Miocene movements gave rise to the deposition of the conglomeratic sediments of Pliocene age. The late Pliocene movements are responsible for the rise of the Arakan mounts that supplied the coarse sediments filling Molass troughs. The last folding movements occurred towards the close of the Pleistocene age, although small scale uplifts and wrapping still continue.

Mizoram fold belt composed of tight linear folds comprising of Early Miocene to Late Pleistocene clastic sediments of Surma group. Anticlines are long, tight and narrow whereas synclines are broad and gentle . Major geological trends are N-S whereas basement trending E-W suggesting thin-skin tectonics controlling the structures in the area. Gutur Syncline west of Sentet Anticline and Sairang Syncline East of Sentet Anticline merged towards the north to form Silchar Syncline in Assam. Renji and Bhuban formations are expected to provide good reservoir and source rocks whereas middle Bhuban formation forms cap-rock.

Concept of spectral balancing

The basic methodology of spectral balancing can be known by dividing and filtering the useful signal in small frequency bands to describe the frequency attenuation decay rate for each frequency band and by designing and applying an inverse operator for compensating attenuation losses. For better understanding, let us take a raw shot record and apply a series of narrow band-pass filters (e.g. 10-15 Hz, 15-20 Hz, 20-25 Hz, 25-30 Hz, ……65-70 Hz) and analyze these filtered shot records then we find that low frequency component has a lower decay rate than the high frequency component of the signal. This suggests that earth works as a low pass filter. To describe the decay rate for each frequency band, a series of gain function are computed. This is done by computing the envelope of band-pass filtered traces. The inverse of these gain functions are applied to each frequency band and the results are summed and thus the resultant trace is spectrally balanced. This process compensates for attenuation effects and the aforesaid process is better known as spectral balancing. One of the main difference between spectral balancing and conventional deconvolution is that former does a better job of broadening the frequency spectrum and enhancing the signal strength by suppressing the shot generated noise without touching or altering the phase of the wavelet while the other compresses the wavelet and tries to suppress any ringing energy present in the data.

Data acquisition

The data was acquired adopting symmetrical split spread shooting geometry with following acquisition parameters.

(1)	Type of Shooting	: Sym. split spread
(2)	Spread Length	: 6600 mts.
(3)	No. active Of Channels	: 256
(4)	Foldage	: 2*32
(5)	Group Interval	: 25 mts.
(6)	Shot Point Interval	: 50 mts.
(7)	Record Length	: 6 sec.
(8)	Sample Interval	: 2 ms
(9)	Anti-alias Filter	: 128 Hz/ 72 dB
(10)	Low-cut Filter	: out
(11)	Charge Size	: 5-7.5 kg
(12)	Charge Depth	: 15-25 mts.
(13)	Geophone Array	: Bunched
(14)	Shot Pattern	: Single hole
(15)	Near offset	: 100 mts.
(16)	Far offset	: 3275 mts.

Data processing

The following important processing steps were significant in improving the data :

- Statics were re-computed at the processing centre by adopting an iterative technique for firming up sub-weathering velocity. This method placed the source and receivers at the common reference datum accurately by resolving the ambiguity in sub-weathering velocity caused by the large elevation variation present in the study area.
- The application of spiking deconvolution and spectral balancing has significantly improved the section by suppressing ground roll, broadening signal bandwidth and removing ringing energy. Spectral balancing was the most useful and effective tool in improving the data in this study. This process effectively eliminated frequencies below ten Hz and above sixty Hz and substantially reduced the spectral peak attributed by the guided waves.
- Stacking velocities were determined from composite velocity analysis at a very close interval of 125 mts to produce best stack and bring out the events that were often missed by coarse velocity analysis because of the rapid lateral velocity changes. This procedure yielded the most improvement in stand out, continuity and resolution of reflection events. Spectral balancing proved very effective in bringing out quite good resolution of stacking velocities and their easy interpretability.
- Application of surface-consistent residual static corrections further improved the continuity of reflections by resolving the statics caused by rapid variations in near surface.
- Dip move out (DMO) invariably helped to resolve structures in areas having conflicting dips and improved the imaging. It also made the interpretation of the velocity analysis easier and suppressed the over all noise level.

Processing steps

Data Conversion
Geometry
Editing
Spherical divergence correction
Spiking deconvolution
Spectral balancing
Velocity analysis-I
Residual statics-I
Velocity analysis-II
Residual statics-II
DMO Velocity analysis
DMO stack
Random noise attenuation

Results and discussions

Raw shot gathers were analyzed for different type of source generated noise masking the signal. Frequency spectra of different portions of the raw shot gather, fig. 1(a), were generated as shown in fig.1(b) and 1(c). Analysis of these frequency spectra resulted in formulating a different processing approach.

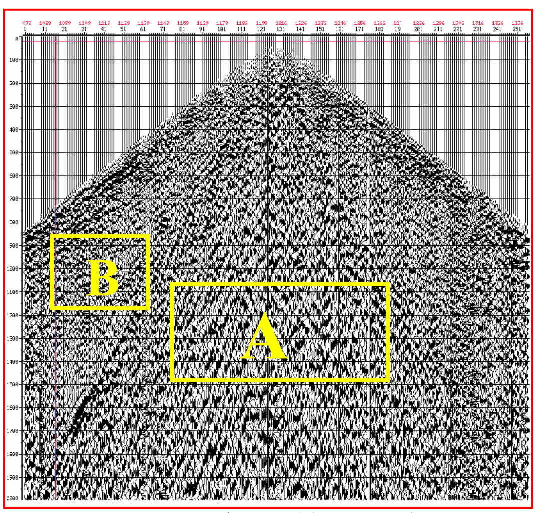


Figure1(a) : Raw shot

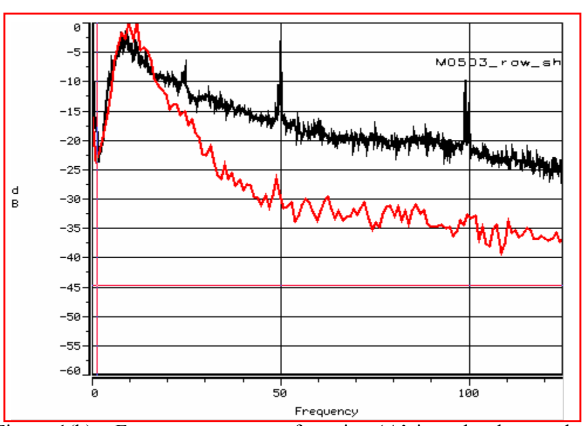


Figure 1(b) : Frequency spectra of portion 'A' in red colour and black is spectra of full raw shot raw.

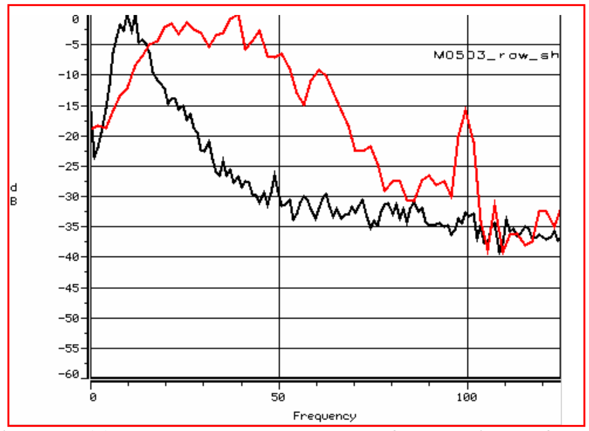


Figure 1(c) : Frequency spectra of raw shot of portion 'B' in red colour

In fig. 1(b) Black colour shows the frequency spectra of full raw shot (fig. 1a) contaminated with low and high frequencies and the red colour represents the frequency spectra of raw shot of portion 'A' which shows that ground rolls masking the signal are having frequency range of 5-20 hertz at 15 db down. Both the spectra are showing more less similar trend. Fig. 1(c) red colour frequency spectra of portion 'B' in raw shot demonstrates that data contains signal frequency in the range of 10-55 hertz which is normally considered as useful signal bandwidth. It suggested that signal bandwidth can be enhanced to this level faithfully without smearing the wavelet.

These processing tests on the raw shot gather suggested that the best way to attenuate ground roll and other noises was to apply spiking deconvolution and spectral balancing on a trace-by-trace basis. A comparison of the raw field record, fig. 1(a) and spectral balancing, fig.2(a), shows significant degree of amplitude balancing that has helped to suppress the ground roll and had enhanced the signal strength. This was achieved without sacrificing lateral continuity and resolution.

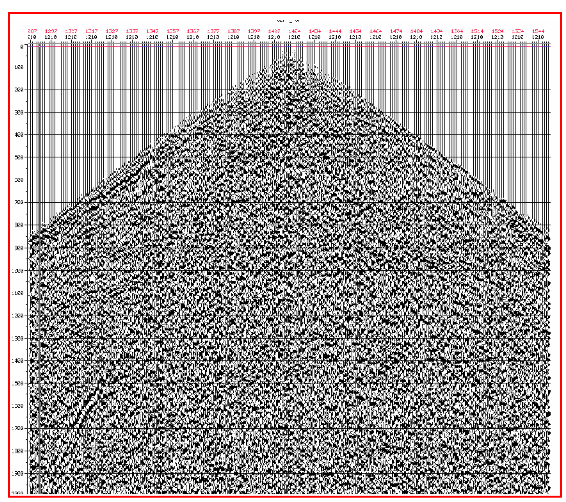


Figure 2(a) : Shot after application of spiking decon. and spectral balancing.

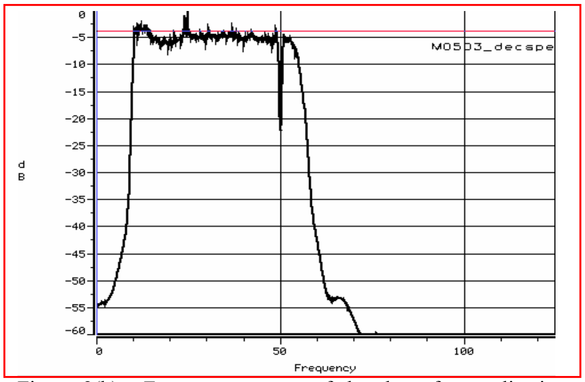


Figure 2(b) : Frequency spectra of the shot after application of spiking decon. and spectral balancing.

Spectral balancing not only helped in improving the signal bandwidth but it also helped a lot in determining the stacking velocities more accurately and confidently which in turn produced best stack. Composite velocity analysis, fig. 3(b), demonstrates the easy interpretability of velocities.

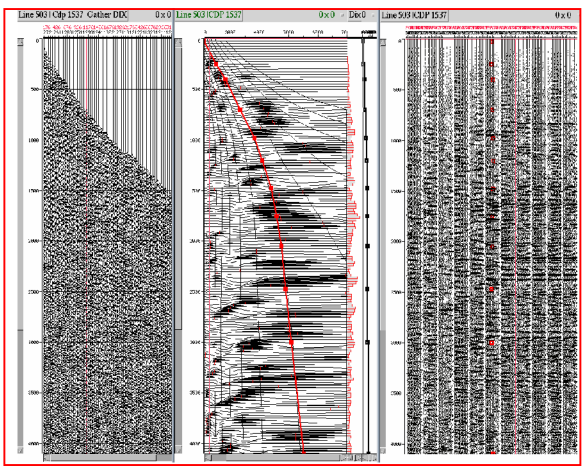


Figure 3(a) : Composite velocity analysis plot on DMO gathers with conventional processing shows no clear cut velocity trend and is masked with noise.

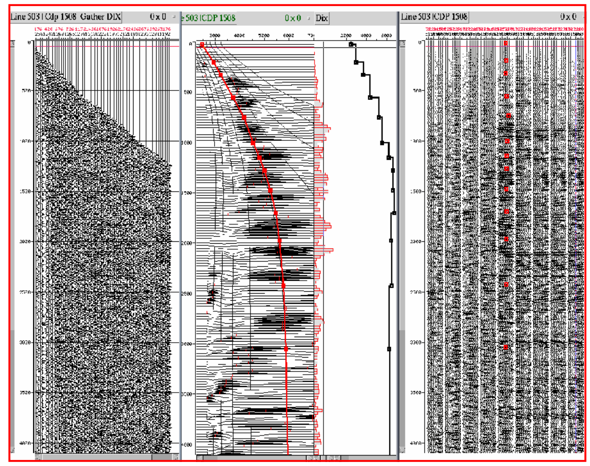


Figure 3(b) : Composite velocity analysis plot on DMO gathers after spiking decon. and spectral balancing.

The final section, figure 5(a), shows significant overall improvement in stand out, continuity and resolution of reflection events brought out by spiking deconvolution and spectral balancing. Sub thrust images were also clearly seen in the section which were absent in the conventional processed section figure 4(a). The frequency spectra, figure 5(b), demonstrates the enhanced signal content of the processed data which is more balanced in comparison to figure 4(b).The detailed velocity analysis at an interval of 125 mts paid rich dividend in imaging the subsurface features more accurately in complex geological setting.

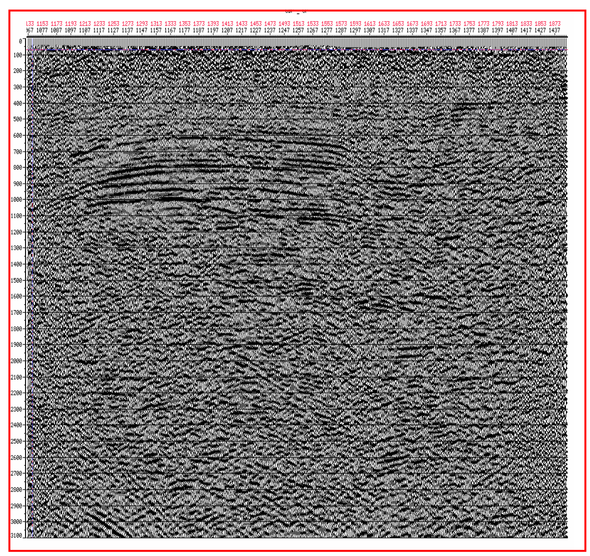


Figure 4 (a) : DMO stack with conventional processing.

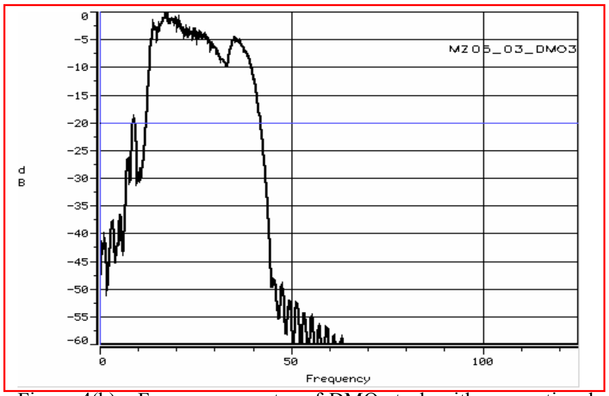


Figure 4(b) : Frequency spectra of DMO stack with conventional processing approach.

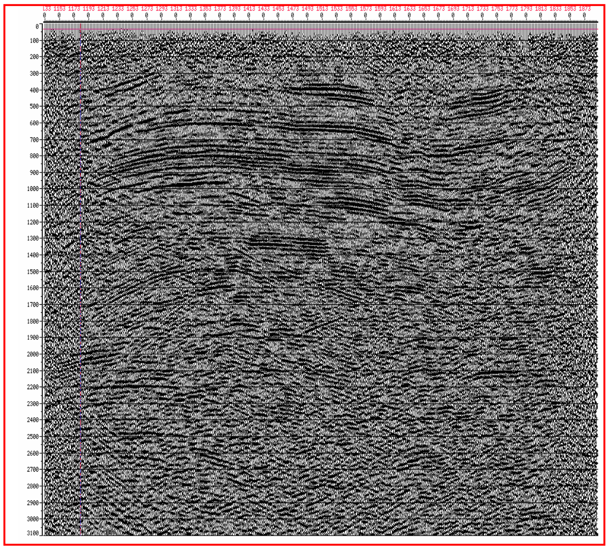


Figure.5(a) : DMO stack with spiking deconvolution and spectral balancing.

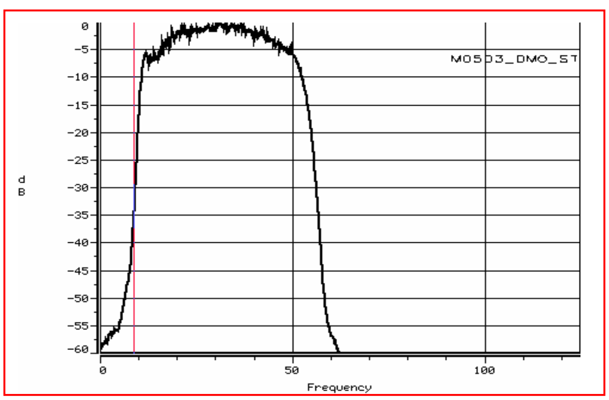


Figure 5(b) : Frequency spectra of DMO stack with spiking deconvolution and spectral balancing.

Conclusions

- Spiking deconvolution and spectral balancing proved to be an effective tool for enhancing the reflected energy at the expense of surface waves.
- Spectral balancing not only helped in improving the signal bandwidth but it also helped in precisely determining the stacking velocities which in turn produced best stack, enhancing the seismic imaging of the subsurface in the area of study.

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