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Pre-conditioning of data before PZ summation in OBC survey - a case study

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Summary

In the shallow marine environment, ocean bottom cable (OBC) surveying, in which the seismic cable is laid on the bottom, not towed near the surface, is gaining popularity. Some of the advantages of OBC over towed streamer surveys are the flexibility of acquisition geometry, greater surface consistency (i.e., more combinations of source and detector at different azimuths for a given midpoint, useful for resolving static delays and for amplitude compensation), more flexibility in working around obstructed zones, the use of dual sensors to remove ghosts and layer reverberations, reduced noise by eliminating cable vibration and strumming caused by towing and surface weather conditions, and better coverage due to the elimination of cable feather caused by currents. However, the major problem with OBC survey is the in- adequate deghosting. The receiver ghost for ocean bottom recording, unlike a towed streamer ghost, generates notches in the seismic pass band. Combining hydrophones and geophones at the ocean bottom essentially means using a "dual-sensor." The combined hydrophone or pressure recording (P) and the vertical geophone or displacement velocity recording (V) allows us to suppress receiver-side multiples. The concept of dual-sensors has been explored by Loewenthal et al. (1985), Barr and Sanders (1989), Dragoset and Barr (1994), and Paffenholz and Barr (1995) among others. The basic principal is that the hydrophone measures a scalar pressure response, which is unaffected by the direction of propagation, where as the vertical geophone measures a vector response, giving a polarity change between up and down going energy. The vertical component of the geophone (V) provides the major contribution to OBC image. From the very beginning, geophone noise has been the number one issue of dual sensor data. It is contaminated with Noise and /or inadequate receiver coupling. This paper dealt with the necessary pre-conditioning of the data before the PZ summation to enhance the signal to noise ratio by eliminating the various noises viz. scholte wave, trapped energy ,shear component etc. in different domain and the improvement it brought in delineating the reservoir characterization.

Keywords*: ocean bottom cable , de-ghosting, dual-sensors, PZ summation, de-noising*

Introduction

In the shallow marine environment ,Dual sensor recording provides the best method to acquire the seismic data by using co-located hydrophones and geophones. The OBC method has the advantage of obtaining coverage in congested producing fields clustered with platforms, pipelines, and drilling rigs, where towed source vessel operations are difficult or impossible. It is also suited to shallow water, lakes, bays and rivers. When geophone and hydrophone data is looked separately, they are heavily contaminated with receiver side ghost. Beside this, due to in-adequate coupling and vector in nature, geophone data also content additional noise component viz, shear leakage (converted and cable noises) in addition to background noise (swell, noise from nearby production, or interference from nearby seismic acquisition), source-generated noise (for instance direct and scattered waves or multiples), and instrument noise and can show up as coherent or incoherent energy in seismic gathers (Fig.1). The common type of noises generally encountered with the hydrophone and geophone data in OBC survey are:

1. Scholte, waves (Hydrophone & Geophone)
2. Spikes & noise bursts (Hydrophone & Geophone)
3. Trapped guided waves (Hydrophone & Geophone)
4. Bubble energy (Hydrophone & Geophone)
5. Shear Leakage (Geophone)

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Many existing techniques for processing dual sensor data assume that the recorded data composed of noise free signals recorded by ideal hydrophones and geophones well coupled to the sea floor. However, real seismic data are contaminated by receiver side reverberation as well as both random and coherent noises. These noises may represent a significant portion of the total recorded geophone energy and can deteriorate the summing process. Ocean floor coupling of the geophone may also vary significantly due to local conditions, causing wide variation in the amplitude of recorded signal and noise. It can be seen that the two spectra are complementary – where there are notches in one (hydrophones), there are peaks in the other (geophones). Hence frequencies missing from the notch in the hydrophone spectrum are supplied by a peak in the geophone spectrum. Summing the two signals removes the spectral notches yielding a much more desirable spectrum and removes the receiver ghosting effect from the data. Direct implementation of summing theory is difficult unless these various noises cited above are correctly accounted for.

If proper de-noising of the data can be made then it offers a range of benefits including higher signal bandwidth, high spatial resolution, low noise, minimum down-time, design flexibility, improved near surface solution, full coverage in obstructed areas, and virtually unlimited offsets. An additional benefit is wavelet stability. After removing the harmful effects of the receiver ghost, a stable wavelet remains, which is independent of water depth and provides for much more detailed stratigraphic analysis. A chief dual-sensor benefit is the improved frequency range, or bandwidth, achieved over other methods. Increasing bandwidth allows resolution of thinner beds. Marine streamers record a receiver ghost, which affects the higher frequency parts of the spectrum, reducing bandwidth. Since the receivers are located on the water bottom, potentially all the water layer reverberations may be eliminated with the ancillary benefit of extracting the relative water bottom reflectivity. Having eliminated the ghost, the dual-sensor data can be richer in higher frequencies. The geophone contribution usually improves low-frequency content as well. But to achieve this, the data (both hydrophone and geophone) should be free from different types of noises. This diversity of noise types with different characteristics makes separation of signal and noise a challenging process. However, efficient noise attenuation and/or removal is important for high-quality imaging.

An attempt was made to remove such noises of an OBC data of Western Offshore Basin, ONGC, India. To achieve this, various noise eliminating process had been applied to hydrophones data and geophones data separately which yielded a better reservoir characterisation in comparison to vintage data. The results are very encouraging as is evident from the horizon slices generated through 3D cube as well as in sections.

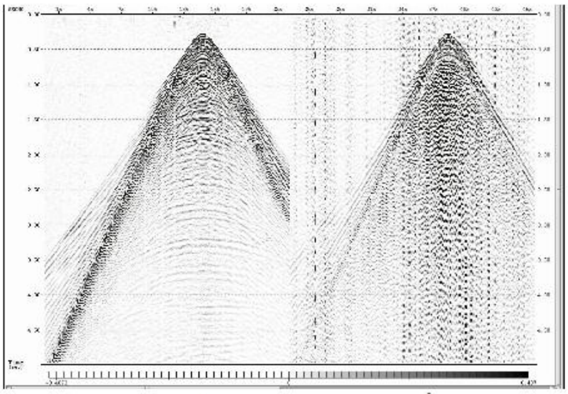


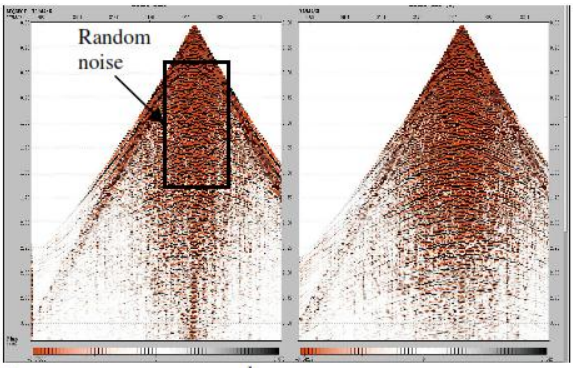
Fig. 1. Raw shot gather- a) hydrophone and b) geophone

Pre-conditioning of data

As already mentioned that various types of coherent and random noise are present in both hydrophone data and geophone data. These includes Scholte Wave, trapped energy, guided wave , noise bursts, spikes , shear leakage (converted), cable noises etc. The general approach of almost all de-noising methods is that they transfer the data to a domain where the signal and the noise component can be separated. The presumed noise is subsequently removed, before the data component is transformed back to normal physical x-t domain. Thus, the challenge is to find a domain where the noise and the signal are well separated. Below we will briefly describe some noise elimination procedure adopted in different domain for this 3D OBC survey.

Shot domain de-noising

The first data example in Fig.1 shows a shot gather from the survey. The data is contaminated with scholte waves, noise burst, trapped energy as it is clearly visible in shot gather of both hydrophone and geophone. There are hardly any visible hyperbolic events seen on the geophone data (Fig. 1b). In shot domain the geophone data seen to be full



a b

Fig. 2. Geophones gather in shot domain- a) raw, b) de-noised

of random noise. The data were de-noised by means of the time-frequency algorithm and f-x dip filter along with the median filter. Note that the abnormal amplitudes, sholte waves and trapped energy found in the data have almost completely been attenuated by this approach (Fig.2,3).

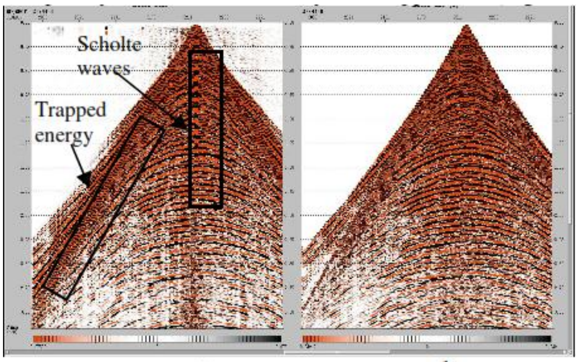


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Fig. 3. Hydrophones gather in shot domain- a) raw, b) de-noised

Receiver domain de-noising

In Figure 4b the geophone records (after shot domain de-noising) in receiver domain is shown . This data is showing full of shear wave leakage due to poor coupling at sea-floor in the OBC survey. This data when seen in shot domain appears as random noise but in receiver domain it appears

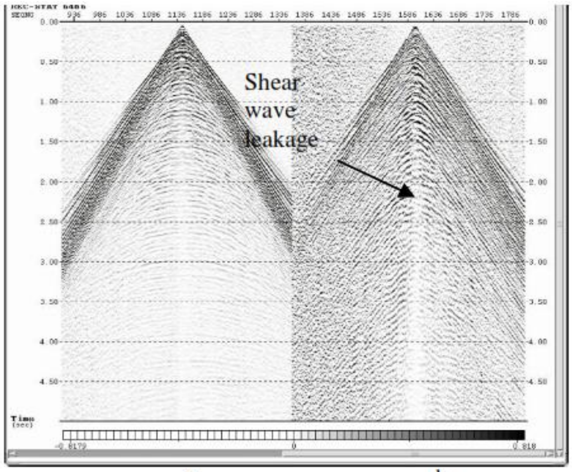

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Fig.4. Gathers in receiver domain- a) hydrophone, b) geophone

as semi-coherent to coherent noise. When such data is used for PZ-summation before de-noising, it deteriorates the summing process and the resulted output. The objective of the re-processing was to improve the signal-to-noise ratio

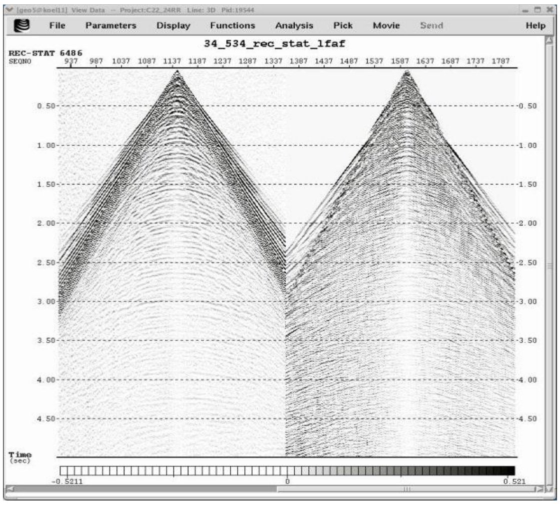


Fig.5. Gathers in receiver domain after de-noising- a) hydrophone, b) geophone

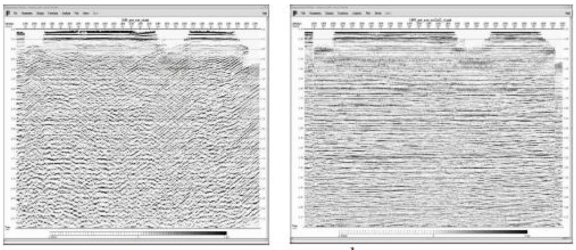
the hydrophone records. De-noising through the use of a time-frequency algorithm, f-x dip filter and median filter in receiver domain was then applied to further suppress the noise. The result was a dataset with all visible hyperbolic events with a very good quality is seen (Fig. 5a, 5b), which allowed to get the major success in this project. After removing the random noises and coherent noises from hydrophone and geophone , the data is summed.

Other domain de-noising

In Fig.6, the processing sequence is shown. The other domain means the cmp and the offset domain. For further elimination of noises and boosting signal level, tau-p decovolution is carried out. It increases the resolution and attenuates the multiples in cmp domain. The data is transformed to offset domain to fill the missing offset and random noise attenuation algorithm is applied to remove the residual random noise. The data is then finally brought to t-x domain for PSTM.

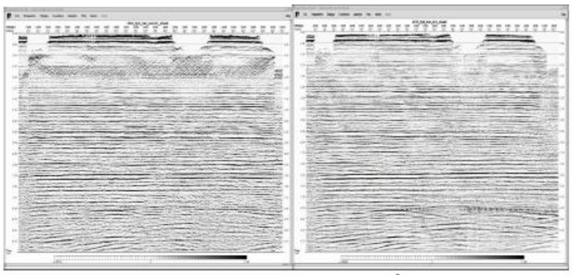
1. REFORMATING (SEGD to Internal format)
2. SPS MERGE, DELAY CORRECTION, EDITING
3. SEPARATION OF HYDROPHONE AND GEOPHONE DATA
4. FX-DIP BASED FILTERING IN SHOT DOMAIN
5. TIME FREQUENCY BASED NOISE REMOVAL
6. NOISE BURST ELININATION
7. ENSEMBLE EQUALISATION
8. RANDOM NOISE ATTENUATION
9. FX-DIP BASED FILTERING IN RECEIVER DOMAIN
10. TIME FREQUENCY BASED NOISE REMOVAL
11. NOISE BURST ELININATION
12. SUMMATION OF HYDROPH, & GEOPHONE IN SHOT DOMAIN
13. CDP SORT
14. MINIMUM PHASE CONVERSION
15. SPHERICAL DIVERGENCE CORRECTION (T**1.5)
16. TAU-P DECONVOLUTION (TWO WINDOW PD=06 & 12)
17. XLINE OFFSET INTERPOLATION
18. HORIZON BASED VELOCITY ANALYSIS
19. PSTM (KIRCHOFF'S EIKONAL): APER 6KM X 6KM
20. RADON DEMULTIPLE
21. MUTE
22. STACK
23. SIGNAL ENHANCEMENT (SLANT APPROACH)
24. TVF 0-1200: 5-10-80-100, 1400 2500: 4-8 70-90; 300 5000:3-6-60-80

Fig.6. Processing sequence



a b

Fig.7. Stack response- a) raw geophone, b) de-noised geophone

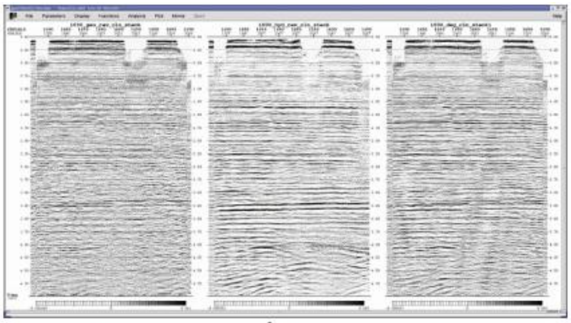


c d

Fig.7.Stack response- c) raw hydroph., d) de-noised hydroph.

Results

Processing the hydrophone and geophone data separately as well as in different domain to eliminate noises, gives a very good quality of data which can be treated as noise free data and their summation removes water column reverberation effectively. Figure 7 & 8 shows the



a b c

Fig.8.Stack response- a) de-noised geophone, b) de-noised hydrophone, c) after PZ summation

Improvement in de-noising procedure and their effectiveness in P Z- summation process. Frequency spectrum (FIg. 9) taken from geophone, hydrophone and their deghost data depicting the reduction of notches and the resulted broadband, high resolution reflection data free from contamination of water-column reverberations.

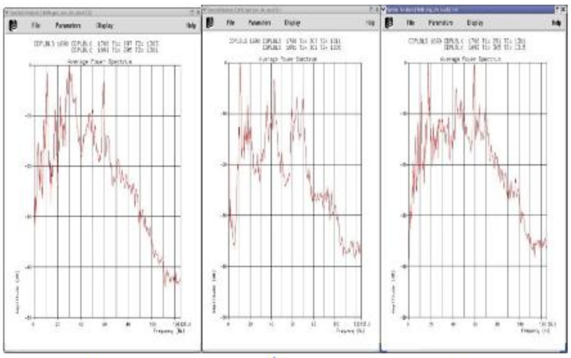


Fig.9.Spectrum of a) geophone ,b) hydroph,, c) summed data

Fig.10 is the PSTM stack response of the data indicating the improvement over the vintage data where no noise removal process was carried out in receiver domain. As the data quality has improved significantly and therefore, quantitative analysis based on seismic inversion is feasible.

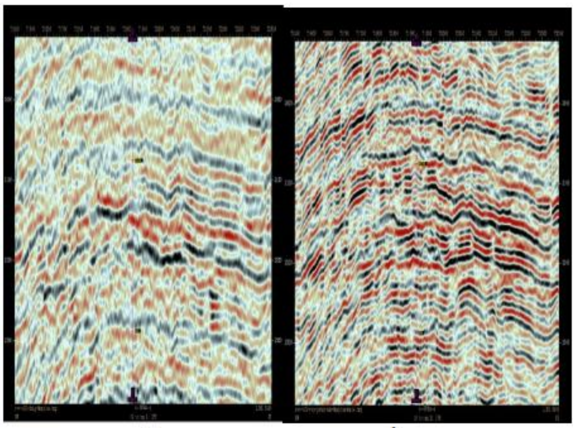


Fig.10.PSTM Stack - a) vintage data., b) re-processed data.

Well tie, consistency check, comparison between old and new sand maps based on amplitude from the vintage data and the re-processed data respectively shows the success of the method (Fig.11).

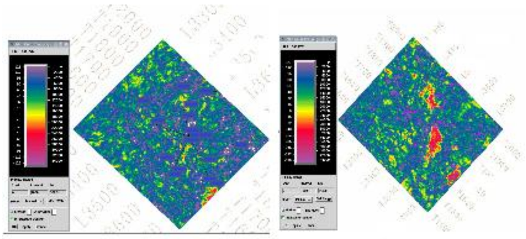


Fig.11. Map from Max.Pos.Amp - a) vintage data., b) re-processed data.

Conclusion

There is no single algorithm that can remove all types of noise in seismic gathers. It is rather the combination of a number of different techniques, each adapted to the specific problem at hand, that will lead to optimal de-noising results. The result after de-noising hydrophone and geophone data separately for all possible noises and then summing the data has tremendously improve signal to noise ratio in the gather and thus helps in pre-stack attributes generation for modelling in reservoir characterization

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