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Broadband seismic : case study modeling and data processing

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Abstract. Seismic data with wide range of frequency is needed due to its close relation to resolution and the depth of the target. Low frequency provides deeper penetration for the imaging of deep target. In addition, the wider the frequency bandwidth, the sharper the wavelet. Sharp wavelet is responsible for high-resolution imaging and is very helpful to resolve thin bed. As a result, the demand for broadband seismic data is rising and it spurs the technology development of broadband seismic in oil and gas industry. An obstacle that is frequently found on marine seismic data is the existence of ghost that affects the frequency bandwidth contained on the seismic data. Ghost alters bandwidth to bandlimited. To reduce ghost effect and to acquire broadband seismic data, lots of attempts are used, both on the acquisition and on the processing of seismic data. One of the acquisition technique applied is the multi-level streamer, where some streamers are towed on some levels of depth. Multi-level streamer will yield data with varied ghost notch shown on frequency domain. If the ghost notches are not overlapping, the summation of multi-level streamer data will reduce the ghost effect. The result of the multi-level streamer data processing shows that reduction of ghost notch on frequency domain indeed takes place.

1. Introduction

There are some important things that effect survey design for seismic acquisition, such as depth of target, resolution, and objective of the seismic survey. Resolution is related to frequency bandwidth of seismic signal. Broader frequency bandwidth will give better resolution. Acquisition technique to get wide frequency bandwidth is known as broadband seismic. One obstacle on marine seismic to get broadband seismic signal is ghost. Ghost is a phenomenon due to depth position of source and receiver below the sea surface. Ghost on seismic records can cause missing certain value of frequency bandwidth (ghost notch) therefore seismic data will become band-limited. To reduce this effect, an acquisition technique for marine seismic is to use receiver or streamer for more than one level of depth (multi-level streamer). The usage of multi-level streamer can reduce the effect of ghost to get broadband seismic data. This method was introduced by Parrack in 1976 and during mid-1980s this method is used to reduce weather noise [1]. In 2010, a study about variable-depth streamer was conducted [2]. The result shows variable-depth streamer acquisition data increase in bandwidth. There was also a study that compare some acquisition technique (conventional streamer, deep streamer, slanted streamer, and dual streamer) to get broadband seismic data [3]. After processing data, the result shows that dual streamer technique provides the broadest bandwidth. In this study, seismic modeling is used to understand ghost phenomenon and technique to reduce ghost to get broadband seismic with multi-level streamer acquisition technique.

2. Wavelet modeling

Input of wavelet (figure 1), used in this modeling, is a source signature without ghost. In this modeling, source depth is 5m, and the receiver depth varies from 7.5m, 10m, to 15m. The first step of wavelet modeling is calculation of ghost operator for ghost source and ghost receiver, followed by convolution between wavelet and ghost operator to produce wavelet with source ghost and receiver ghost. Then Fourier Transform is done to see the ghost notch in frequency domain.

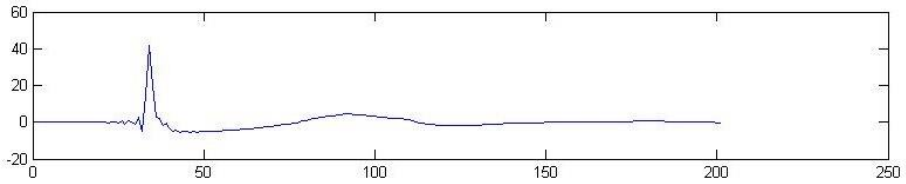


Figure 1. Wavelet without ghost.

3. Synthetic data and data processing

Forward modeling process in this study is done to get synthetic data. A simple geology model consisting of three layers is used in this forward modeling process. The synthetic data contains three data with variation of streamer depth: 7.5m, 10m, and 15m, and each streamer has 120 channels with receiver interval 12.5m. 110 source is towed at depth of 5m with source interval 25m. Figure 2 is data processing workflow to get broadband seismic data.

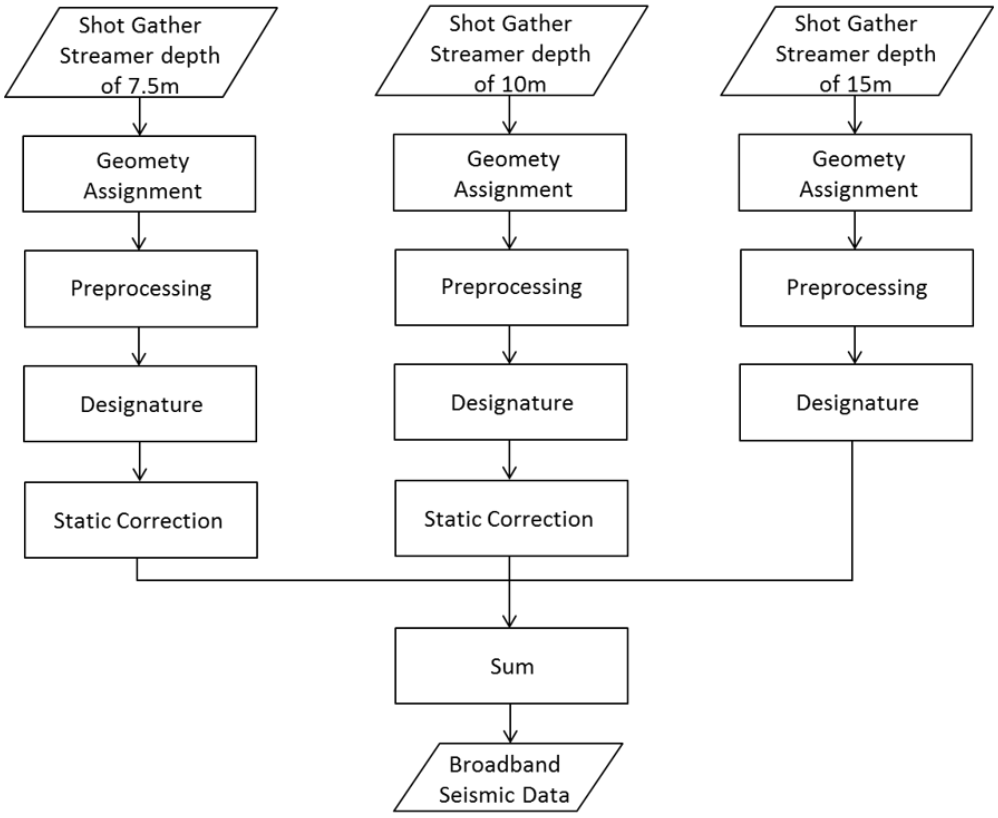


Figure 2. Data processing workflow.

Geometry assignment is a process to combine seismic data and its survey navigation information. Preprocessing is used to reduce noise in data such as direct wave. Designature is done to remove source effect in seismic data. Variation of streamer depth give a consequence as delay of arrival time for deeper streamer, therefore static correction is done as an effort of time shifting to a time reference. After each data has same reference time, summation mode is used to get a broadband data. The idea of this summation mode is the same as stacking, that is averaging the same trace with the same position for every streamer depth.

4. Result and analysis

4.1. Wavelet modeling

Each wavelet that contains source ghost and receiver ghost with variation of streamer depth results in different form of wavelet both in time domain and frequency domain. The result of wavelet modeling in time domain, as shown in figure 3, shows that the deeper the streamer, the longer composite wavelet will be produced, this shows the delay time is greater as the deeper depth.

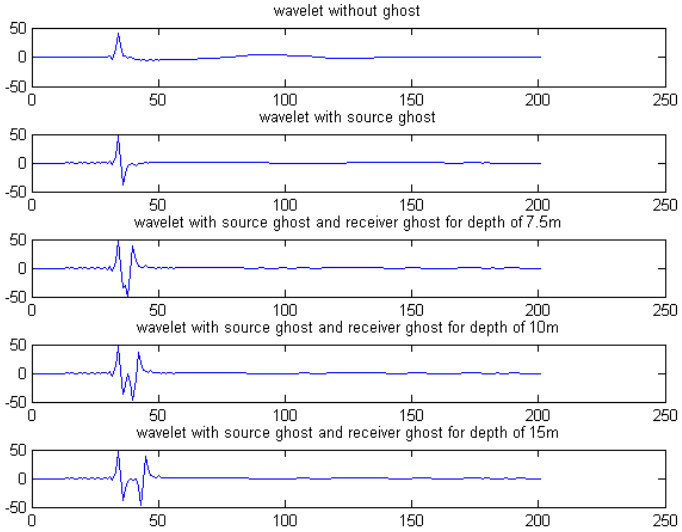


Figure 3. Wavelet modeling result in time domain.

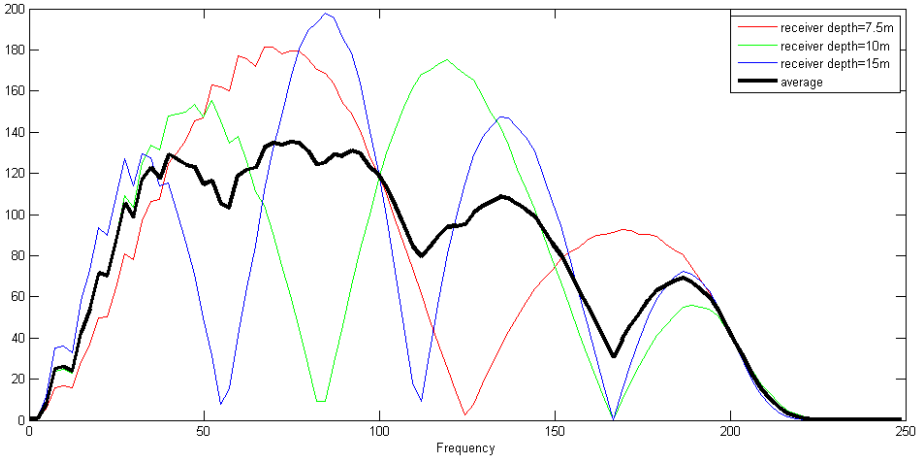
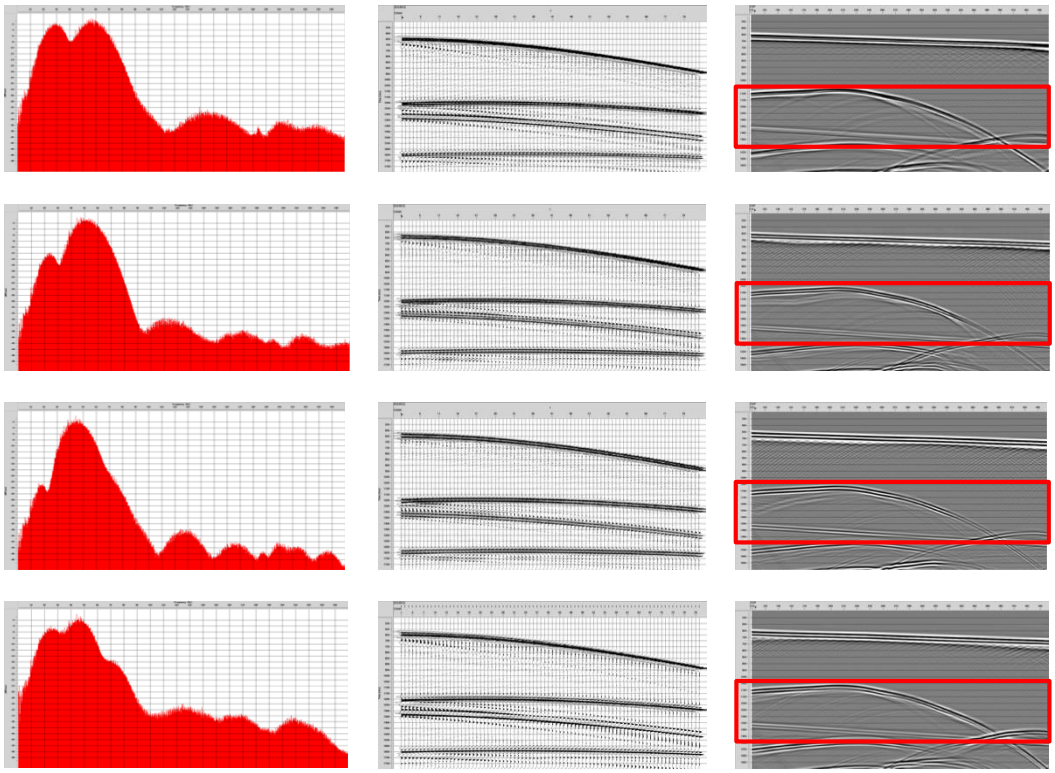


Figure 4. Wavelet modeling result in frequency domain.

In addition, in the frequency domain, as shown in figure 4, shows that variation of streamer depth will result on variation of ghost notch that is not overlapping and there will be more ghost notch for deeper receiver. The average of each frequency spectrum give ghost notch recovery. In addition, averaging spectrum provide increment of frequency content.

4.2. Synthetic data processing

The shot gather show the same result as previous wavelet modeling, data with deeper streamer has a wider composite wavelet recorded on seismic data. After data processing, frequency spectrum shows ghost notch is reduced. From shot gather, broadband seismic data have sharper wavelet. In addition, stack section give better imaging. The result of data processing is shown in figure 5.



(a) (b) (c)

Figure 5. Comparison of (a) frequency spectrum, (b) shot gather, and (c) stack section for synthetic data (sequentially from top to bottom) with steamer depth of 7.5 m, 10.m, 15m, and the result of summation mode.

5. Conclusion

Ghost appears due to source and receiver position in some range of depth below the sea surface. Variation of its depth will give different seismic response, both in time and frequency domain. Multi-level streamer technique will give us seismic data with variation of ghost notch, therefore by using summation mode, ghost notch is reduced and frequency content is increased. Multi-level streamer technique could be a solution to get broadband seismic data.

References

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