Application of FK Filtering for Coherent Noise Removal in High Frequency Shallow Marine Data

Maman Herman[1], Hazwan Syahmi Hashim[1], Abdul Halim Abdul Latif[1] and Deva P. Ghosh[1]

[1]Centre of Seismic Imaging and Hydrocarbon Prediction, Universiti Teknologi PETRONAS

Email: maman.hermana@utp.edu.my, mherjody@yahoo.com

Abstract. The use of seismic reflection to study earth subsurface is commonly troubled by the presence of the coherent noise in the seismic data. This unwanted signal were generated by various sources and therefore had their own noise characteristic. The acquisition of the shallow marine seismic survey were done using a sparker source to obtain a high frequency seismic data. This however results in a stronger noise level in the recorded data. The application of FK filter were used to eliminate this unwanted noise using the data obtained from the Malacca Strait and Terengganu Bay. The result obtained prove to be successful in reducing the coherent noise while preserving the frequency content of the seismic data.

1. Introduction

Coherent noise is a common problem especially in shallow water area. As this area are consist of water-bottom which are mostly hallow and hard, the primary signal that were acquired are usually mixed with various type of seismic noise which results in a poor quality seismic data. Moreover, as the seismic data were acquired in a high resolution using a high frequency sources, it results in a much higher level of noise at the receiver compare to the conventional acquisition [1].

By observing the field record, we can determine the type of coherent noise [2]. This unwanted signal can comes from various sources such as scattered noise, guided waves, cable noise, ship's propeller and also multiples. Knowing the noise mechanism are important as it helps to determine the best possible way to eliminate this unwanted signal based on their specific characteristics.

In current technology, *F-K* filtering is used as an effective tool to separate noise from a main signal. However this technique is applied on pre-stack seismic data. In the other hand, the zero offset data is commonly used in shallow marine survey to observe the subsurface. Hence it is difficult to apply this technique into zero offset seismic data for same purposes. Some modifications in the processing workflow need to be done to make the FK-filtering is applicable for this data condition.

We enhanced the processing workflow by involving the FK filter to be applicable for our zero offset of shallow marine seismic survey. By applying the FK filter, the frequency content of zero offset seismic data can be maintained, while the coherent noise embedded in this data can be eliminated. Therefore, this technique can be used as an enhancement for the common processing workflow of zero offset data which in current technology is still not inserted.

The main purpose of shallow marine seismic survey is to obtain the shallow marine data of the Terengganu Bay and Strait of Malacca to study the seismic stratigraphy of the Quaternary depositional and paleo-channel. To achieve the objective, we required a high frequency seismic data in order to obtain the highest resolutions possible which were done by using the sparker source. However, the drawback of acquiring the seismic data in a high frequency results in a more prominent coherent noise cause by the ship movement. Therefore a proper noise removal technique must be choosing to eliminate this noise while preserving the frequency bandwidth of the seismic data.

2. Methodology

The algorithm was tested using the shallow marine data acquired at the Malacca Straits and Terengganu Bay. The main target of this survey was to image the shallow marine subsurface of the Malacca Straits and Terengganu Bay.

A zero offset marine survey was later carried out through the collaboration between Universiti Teknologi PETRONAS (UTP) and Universiti Malaysia Terengganu (UMT) to evaluate the seismic stratigraphy of the Quaternary depositional system and paleo-channels of Terengganu Bay and Straits of Malacca in 2013 and 2014 respectively. These data were collected using a high frequency source and high frequency sampling. The sampling intervals were set at 250 micro seconds and the number of samples per trace were 1200. A sparker source was used as a marine seismic impulsive source to produce high resolution seismic data [3][4]. The location of this survey area is shown in Figure 1.

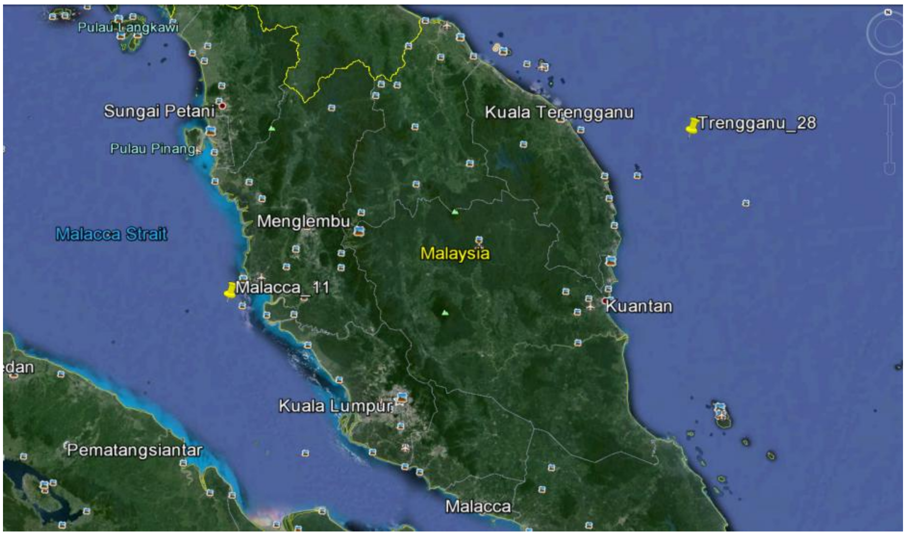

Figure 1: Location map of marine seismic survey of Malacca Strait and Terengganu [5].

Information about the subsurface of shallow marine were crucial for geo-acoustical modelling studies and engineering applications, such as foundation design for offshore structures and also as a preliminary study for shallow gas delineation studies [6]. However, the recorded seismic data were contaminated with random and coherent noise which directly reduce the quality of the data recorded. These noises were generated by the waves and current, as well by the vortexes of the ship's propeller which appear to be more dominant than the primary signal.

Several basic processing steps were applied to remove this unwanted signal from the seismic data. The steps of the processing applied to this seismic data includes: header manipulation, conducting the transformation from time domain to frequency-wavelength (F-K) domain, conducting the filtering in the F-K domain, Q-compensation and conducting the transformation from FK back to the time domain.

Seismic noise can be properly removed by looking at the characteristic of the noise. For example, coherent noise that was cause by the ship movement can be identified by its high frequency range usually more than 80 Hz. The common method used to remove this noise are by using the frequency filtering, where the noise are removed by designing a low pass filter which remove any signal that were above the normal frequency content of a seismic signal which are around 10 – 80 Hz. However, as we need the data in high frequency, this method cannot be implemented as we will also reduce the bandwidth frequency therefore reducing the resolution of the seismic image. The important signal which were needed appeared in the same frequency range with the coherent noise and thus it will be mixed up. Therefore we must find a proper way to eliminate the coherent noise while preserving the frequency bandwidth.

Frequency-wavenumber filtering or better known as *F-K* filter is a process of noise attenuation in the *F-K* domain. This method was applied by transforming the seismic data in the t-x domain into the *F-K* domain using the Fourier transform. As the seismic data were transformed in the *F-K* domain, the linear event will remain the same in both domains, however the signal and noise can now be separated based on the dipping angle [7]. This way we can properly separate this two different signal and later mute the unwanted seismic noise. Although it was more computational extensive compare to the frequency filtering, this method allows the elimination of the coherent noise without reducing the frequency content of the seismic data. This method also gave better results as we can now identify the coherent noise and therefore gave a better noise attenuation without damaging the primary signal.

3. Results and Discussions

The examples of the seismic data from the Malacca Straits in the time domain, *F-K* domain and the filter design in *F-K* domain are shown in Figure 2**Error! Reference source not found.**. In Figure 2a, the recorded seismic data are dominated with coherent noise. The reflectors of the subsurface is masked by this noise, hence the interpretation of this data to pick the boundary of small basin structure is mostly very hard to be done. the coherent noises appear in all traces of zero offset data from beginning to the end of recording. Figure 2b shows the processed data with our workflow. The results showed that the algorithm was effectively removing the coherent noise. The quality of seismic section was improved, now the reflectors of subsurface can easily be interpreted.

In F-K domain, the original seismic data is shown in Figure 2c, the signal was concentrated in the centre of the K domain (K=0). The filter was designed to keep the signal and to remove the noise. Hence, a symmetrical parallelogram filter in FK domain was created. The frequency ranged from around 100 Hz to 2000 Hz and kept the K from -500 to 500 and everything outside that filter was muted. The FK filter design is shown in Figure 2d and the final result is shown in Figure 2b. From that figure, it can be seen clearly that the noise is successfully removed.

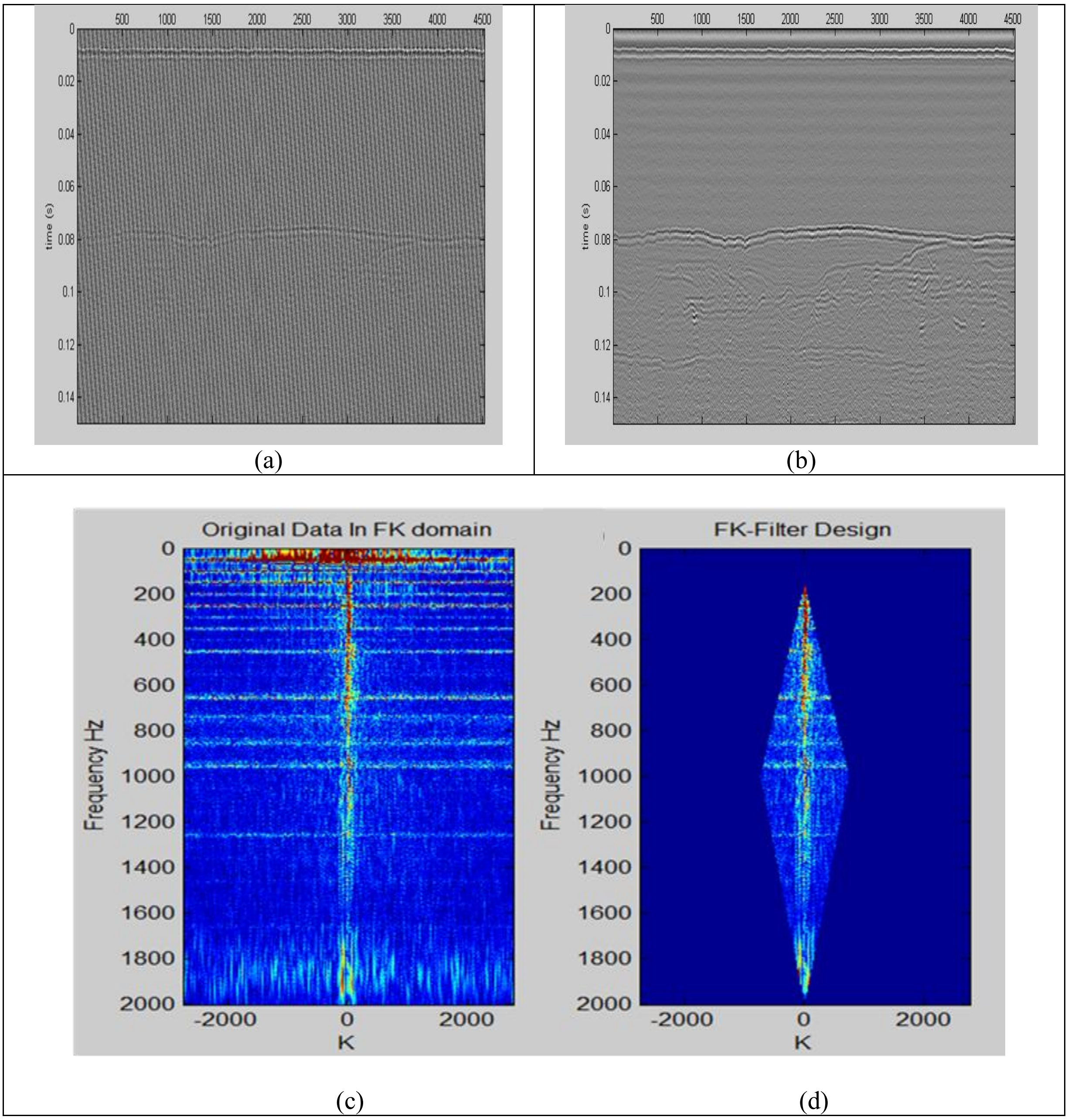

Figure 2. Seismic section from Malacca Strait survey, a) original seismic data, b) seismic data after processing, c) original seismic data in FK domain, and d) Filter design in FK domain.

Another example is coming from Terengganu survey, where all the survey parameters during collecting data are similar as Malacca survey. The characteristic of coherent noise resulted from ship's propeller and current are dominant in the recorded data as shown in Figure 3a.

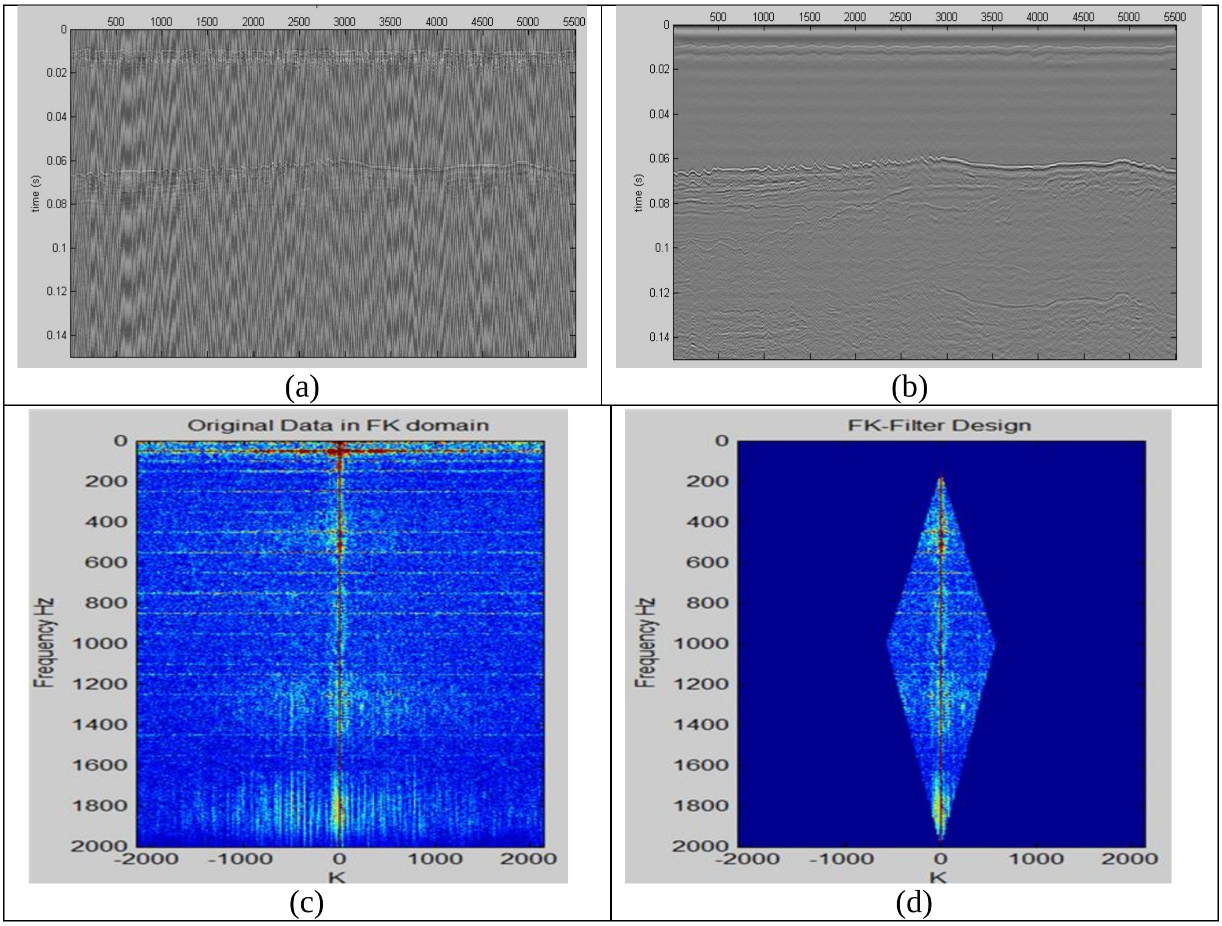

Figure 3. a) The original Seismic section from Terengganu survey, b) seismic section after applying FK filtering and Q-compensation , c) seismic data in FK domain, and d) Filter design in FK domain.

In Figure 3a, the character of random noise in the Terengganu survey is the same as the Malacca survey although the wavelength of this noise was lower. Hence, the picking of subsurface reflectors are mostly impossible especially in the area below see bottom. In FK domain, this seismic data is shown in Figure 3c. To preserve the signal energy around central of K axis, the FK filter as shown in Figure 3d was applied. In this filter, the frequency was kept from 200 Hz to 2000 Hz and the wavelength from -500 to 500. The final result of our workflow is shown in Figure 3b. This figure shows that noise has been removed successfully from the data and the detail of subsurface reflectors below seabed can be identified clearly. The channel or small basin of this area can be recognized nicely.

4. Conclusion

Coherent noise resulted from ship's propeller usually embedded in the recorded seismic data especially in the high frequency shallow marine survey. This noise affects the quality of seismic data that cause several difficulties during the interpretation of the subsurface, which usually mask the geological structure and stratigraphy channel of the subsurface. Since the marine data were required in a highest resolution possible, we must find a proper noise removal technique which does not reduced the seismic bandwidth.

Implementation of FK filter design on high frequency shallow marine data was successfully removing the coherent noise resulted from ship's propeller while preserving the frequency content of the marine seismic data. Reflectors of subsurface in Malacca and Terengganu surveys can be improved. Picking horizon and interpretation of subsurface of this area therefore can be performed without any further difficulties.

With the success of implementation of this work flow in high frequency data, it is therefore possible for it to be practised in the common seismic survey with some adjustment. However, further testing on other real seismic data with different condition of noise will still be required.

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