FK-filter and radon transform methods comparative study on 2D pre-stack migration gather of Kangean Waters data

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Abstract. The main problem in marine seismic exploration are multiples. Multiple is coherent noise appeared by the difference of impedance between water and seabed layer which is lead to secondary reflection wave acts as new reflector source point. Multiple appearance in seismic cross section can cause misinterpretation so multiple attenuation is required. Both F-K Filter and Radon Transform methods can be used to attenuate multiple by isolating signal and noise data. Both methods have similarity in domain transform, F-K Filter transforms offset (x) - time (t) domain to frequency (f) - wavenumber (K) and Radon Transform operates in \( \tau - \rho \) domain to separate moveout between signal and noise. Both methods are applied on 2D marine seismic data on Kangean waters shallow depth 200-500 meter. Radon Transform shows better result on attenuating multiple compare to F-K Filter on migrated cross section line L09 and L16. Multiple attenuation increases signal to ratio (SNR) of both line L09 and L16 which lead to more accurate in interpretation.

1. Introduction
Seismic method can be done in two zone that is zone of land and sea zone but both of them have differences in acquisition and data processing. Measurements on land use dynamite as a source of waves and geophones as wave receivers while in the sea using air gun as source of wave and hydrophone to receive wave. These two seismic measurement zones have noise when measured data. Noise is external or foreign data that can affect the seismic primary data [1]. Ocean zone has more noise than the mainland that is the movement of the ship, bubbles that appear due to the shooting of the ship airgun, and multiple which are the main noise in sea seismic measurement.

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Multiple is the noise that occurs due to the traveling seismic wave reflecting on the reflector more than once. Figure 1 shows the primary and multiple waves in a single shot. A red line that has only one reflection in the reflector is the primary wave while the reflected black line 2 times in the reflector is a multiple wave that causing the appearance of an imaginary reflector and can’t be interpreted well.

2. Multiple Attenuation

2.1 FK Filter

In this method, multiple is attenuated on the F-K domain (frequency-wave number). The original seismic data domains on x-t (offset-time) are transformed into F-K on CMP gather domains using the 2D-Fourier Transform principle. Seismic events can be described using the equation:

\[ f(t, x) = s(t) * \delta(t - \tan(\alpha)x + b) \]  

The equation is an event equation where * denotes the convolution in the time variation \( t \), \( s(t) \) is a seismic wave, \( \alpha \) is the angle between the seismic event and the space axis, and \( b \) is constant value of intercept time axis. By using 2D-Fourier Transform, the above equation is transformed into the following equation:

\[ F(\omega, k) = S(\omega) e^{ib} \delta(k - \omega \tan(\alpha)) \]  

Where \( S(\omega) \) is the result of the transformation \( s(t) \) of the first equation. With the equation above then noise on linear event can be separated from the primary data. Figures 2 and 3 show the seismic data on the x-t and f-k domains. The green color is the primary data, blue is the direct and red wave representing multiple.
2.2 Radon Transformation

The primary and multiple data can be distinguished from the speed at which the primary data event has a flat event while the multiple data have an undercorrected event. Radon transformation is one technique to eliminate multiple by looking at differences in residual moveout values in the τ-p domain. Figure 4 and 5 show the seismic data on the x-t and τ-p domains. The blue line is the primary data while the red line is multiple.

Radon transformation used is parabolic can be shown by the equation:

\[ t = \tau + qx^2 \] (3)

This parabolic radon transformation can be formed by a NMO corrected CMP gather by summing the data along the stacking path defined by the equation:

\[ u(\tau, q) = \sum_x d(t = \tau + qx^2, x) \] (4)

Where \( q = \frac{1}{2} t_0 V^2_r \).

After separated, the data must be returned to the T-X domain.

\[ d'(t, x) = \sum_q u(\tau = t - q\phi(x), q) \] (5)

3. Methodology

3.1 FK-Filter

The output of velocity analysis will be used to process filter and radon FK to eliminate noise contained in the data. To perform FK filter on data, firstly done FK analysis process to distinguish primary data with multiple. In the FK domain, multiple are at wavenumbers \(-0.04 > k > 0.04\) and \(f < 100\) where \(k\) is wavenumber and \(f\) is frequency so polygon designs to limit the data which is the primary and multiple data [6].
3.2 Radon Transformation

Radon transformation uses tau-p domain to attenuate multiple. In the domain tau-p is created a line to limit the primary and multiple data. After that muting is done to eliminate data that is larger than moveout 0. Primary data on the initial reflector is not fully in moveout 0 because the initial reflector has strong data and firmly therefore when changing domains, this primary data will be around moveout.

4. Result & Discussion

4.1. FK-Filter and Radon Cross Section

Figure 9 shows a seismic cross-sectional image without using an attenuation filter. From the image in the identification there are 2 zones that have multiple types of water bottom. Multiple zone 1 is at time 900 ms – 1300 ms in time and 3251 – 4551 in CDP. Multiple zone 2 is at 400 ms – 700 ms in time and 4876 – 6176 in CDP. Both of this multiple will be attenuated using FK-Filter and Radon Transform.
Figure 9. Seismic cross section non-filtering with 2 multiple zone

Figure 10. Seismic cross section using FK-Filter

Figure 11. Seismic cross section using Radon Transformation
The data in the FK Filter is in the frequency - the wave number domain. In this domain it appears more clearly the primary data and noise multiple noise. Figure 4 shows that the red color indicating the dominant frequency is the primary data. The primary data is at 10 Hz > f > 110 Hz and -0.04> k> 0.04 where f is the frequency and k is the wave number. This primary data will be kept from noise multiple using polygons. Beside polygons in the fk domain, the value of the ramp frequency parameter affects in attenuation. The ramp value used in this research is 100.

Figure 5 shows the radon muting design. Muting marked with red limits the primary data on moveout 0 and the multiple noise. The muting line is shaped as well as multiple are identified close to the reflector so that the area must be muted even if there is a chance of cutting off the main reflector. determination of radon muting line is done on every CDP because moveout value in data will be different according to travel time (t).

Determination of p value greatly influence in attenuation of this multiple noise. The bigger the p value will be better also in noise attenuation but will take a lot of time in the process. This research used the p value of 150 because it is better in noise attenuation compared with the small p value which is used as comparison that is 20. Stacking with p value is used in migration stage that showed on figure 11.

5. Conclusion
Multiple attenuations in the waters of Kangen are identified in two zones using FK-filter and radon transformation. Region 1 zones located at depths of 900 ms - 1300 ms and CDP 3251 - CDP 4551 patented better using radon transforms compared to fk-filters especially in far offsets. While in zone 2 which is at a depth of 400 ms - 700 ms and CDP 4876 - CDP 6176 radon transform is better in attenuation but there is data in far offset is missing.

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