**SUMMARY**

Spectral decomposition is very useful tools for the identification of stratigraphical and sedimentological features, especially in the characterization of thin reservoir (Mauren Paola Ruthner et. al, 2005). However, only amplitude component of the frequency decomposed seismic data has been used. The other component, i.e. phase has not been used.

Similar to phase response of original seismic record, the phase response of a single frequency can be used to enhance image for edge detection. The phase response will still show the edge of the changing phase even though the geobody has both changes from positive to negative phase and vice versa, while in the amplitude response, sometimes it is hard to show the negative amplitude if the big positive amplitude needs to be highlighted, especially if the absolute value of the negative amplitude is much smaller compare to the absolute value of the positive amplitude.

Thus, there are two advantages of the phase response in frequency slice. First, the tuning frequency effect, where the contrast of reflectivity of the lower zone and upper zone are combined constructively; and second, the phase response show the phase changes instead of the amplitude changes.

The usage of this method can be demonstrated when a geobody has variation of net sand to gross ratio, or/and the amplitude changes in the seismic response are dominated by the fluid content. Therefore the stratigraphical and the depositional setting may be masked by the fluid effect in the seismic amplitude response. In this situation, the knowledge of geomorphology can not be used as an interpretational tool of the image.

**INTRODUCTION**

One important part of the reservoir characterization is to know the outline of the reservoir laterally. The most common method used is seismic geomorphology.

The main key of seismic geomorphology is to produce images that show features that can be recognized or interpreted as one of the known stratigraphical or sedimentological features. These features are mainly caused by differences of impedances (acoustic, shear or Poisson impedances) between the rocks that making up the geomorphology features. A very common seismic attribute used to show the impedance contrast is seismic amplitude. Seismic amplitude can shows difference in lithology. However, sometimes the lithology does not really show the geomorphology. One good example is, a channel that can be filled with sand on one part and shale on the other part, so the whole picture of the river can not be imaged based on the amplitude only. Therefore, phase response is needed to show the boundary of this kind of channel system.

Furthermore, in several cases the fluid effect on impedances is bigger than the effect of the rock. In this case the image might not only shows the stratigraphical and sedimentological image but also structural (because of fluid contacts), and permeability of the zone. As a result, there is a big possibility that no known sedimentology system can be recognized from the image.

One possible solution to this problem is to use the tuning effect of the reflectors that bounding a geobody. A geobody can be outlined by the upper boundary and the lower boundary of the geobody. If the thickness of the geobody is \( \frac{1}{4} \) of the wavelength of the dominant frequency of the seismic at the depth and location of the geobody, the amplitude contrast of the upper boundary reflector and lower boundary reflector is the biggest compare to...
conditions if the geobody is thicker or thinner. This high contrast gives high amplitude response in the seismic, so the outline of the geobody can be detected. However, in general, the thickness of a geobody varies laterally; therefore, we need to have tuning effect for different frequency responses, not only the dominant frequency response.

The use of spectral decomposition will separate the seismic response based on individual frequency response.

**METHODOLOGY**

Discrete Fourier Transform is used for transforming the time domain seismic response into responses in frequency domain. The seismic response in frequency domain is then separated into responses of individual frequency, which is often called frequency slice. To eliminate the decaying effect of the amplitude from shallow to deep, spectral balancing is applied. Spectral balancing is a normalization of amplitude in frequency domain.

The phase response for each frequency slice is then calculated. Seismic geomorphology interpretation of each frequency slice is then integrated to give the complete picture of stratigraphical and sedimentological setting of the investigated area.

**WINDOWS WIDTH ANALYSIS**

Window width has a very significant influence in FFT result. There is very significant difference between the amplitude spectra with long window (long trace) and short window (short trace) one (Partyka et al., 1999). In long window analysis, convolution between frequency spectrum from reflectivity, noise and wavelet, produces frequency spectrum, which has the same character with wavelet frequency spectrum (Figure 1). However, in short window frequency spectrum from reflectivity that show geological condition acts as a filter, so the result represented the acoustic properties and thickness of the geologic layers (Figure 2).

In short window, temporal thickness \( t \) determines the period of notching in the amplitude spectrum \( P_t \) with respect to frequency. This relationship is expressed as:

\[
P_t = \frac{1}{f} \quad \text{(1)}
\]

with the same approach, the frequency component value \( f \) could be used to find temporal thickness, expressed by:

\[
T_t = \frac{1}{2 \times \text{Freq}_{1st\text{-dominant}}} \quad \text{.............(2)}
\]

where \( P_t \) is the period of notches in the amplitude spectrum with respect to temporal thickness and \( f \) is the discrete Fourier frequency.

While tuning thickness defined as:

\[
T_t = \frac{1}{2 \times \text{Freq}_{1st\text{-dominant}}} \quad \text{.............(3)}
\]

The short window phase spectrum is also useful in mapping local rock mass characteristics. Because phase is sensitive to subtle perturbations in the seismic character, it is ideal for detecting lateral acoustic discontinuities. If the rock mass within the analysis window is laterally stable, its phase response will likewise be stable. If a lateral discontinuity occurs, the phase response becomes unstable across that discontinuity. Once the rock mass stabilizes on the other side of the discontinuity, the phase response likewise stabilizes.

**CASE STUDY**

Real 3D seismic data was used to demonstrate the usage of phase response in frequency slice. Time slice of the original seismic response with dominant frequency 15 Hz is displayed in figure 3. Notice the meandering channel running from north to south. The channel outline is very clear in the clay fill (north area), but it is not obvious in sand fill area (south area.) While in the amplitude response frequency slice of 15 Hz (figure 4), the channel outline in the south area can be traced easily. However, the clay filled channel in the north is difficult to trace. While in the phase response frequency slice, both the north and the south part of the channel is more visible (figure 5).

**CONCLUSION**

Seismic response is a result of wave response from several frequencies; therefore, the original seismic response needs to be decomposed into several frequency slices to get an advantage of the bright amplitude effect of tuning thickness.

The various frequency slices can be used to get a complete seismic image of geobody with different thickness, which is not uncommon in the real world.
Amplitude response from individual frequency can give different amplitude response for different lithology. However, it is common that one particular depositional setting has different lithology, e.g. channel sand can be filled by sand or clay. Therefore, geomorphology interpretation is difficult to do on this image, because we do not get a complete picture of the sedimentology features.

Furthermore, the fluid contents of the geobody can give higher impact on the seismic amplitude or even dominate the amplitude.

The phase response shows the edge of the changing phase even though a geobody has both changes from positive to negative phase or vice versa.

Therefore, for the classic case of geomorphology interpretation where the sedimentological features consists of varies net to gross ratio geobodies with different thickness and varies fluid content laterally, the phase response from frequency slices give better seismic attributes that can be interpreted geomorphologically.

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Figure 1 - Long Window Analysis (Quoted from Partyka, 1999).

Figure 2 - Short Windows analysis (Quoted from Partyka, 1999).
Figure 3 - Original Seismic

Figure 4 - Amplitude response Frequency Slice (15 Hz).

Figure 5 - Phase response Frequency Slice (15 Hz).