SUMMARY

Identification of thin bed reservoirs especially with variable thickness is a classic problem in hydrocarbon exploration and production. Generally, people use seismic geomorphology to help in identification of reservoir laterally. The most common seismic attribute used for seismic geomorphology is seismic amplitude. The lateral distribution of the seismic amplitude has helped the limitation of vertical resolution of seismic by recognizing/interpreting the stratigraphical and sedimentological pattern in lateral image (time slice or horizon slice). The amplitude response of time slice/horizon slice can be processed using several images processing routine. However, the result sometimes is not good enough to be interpreted, due to the fact that the amplitude image is a response of a range of frequency bandwidth of the wave. The reservoir that is mostly affected by this problem is thin bed reservoir with variable lateral thickness, which is not uncommon as an economic reservoir.

Therefore, the seismic responses need to be decomposed such a way that it will give only response of one single frequency. Fourier transform is the most suitable algorithm to use for this purpose. The seismic response in time domain is transformed into its frequency domain, and the response of each frequency is displayed for seismic geomorphology interpretation. This single frequency amplitude response uses the phenomena of tuning thickness. If a geobody thickness is \( \frac{1}{4} \) of wavelength of the wave, then the reflectivity of the upper boundary of the geobody will be very close to the reflectivity of the lower boundary, so the amplitude contrast become very high, and some times shown as one reflector only, bright amplitude reflector.

As a result, spectral decomposition can be used to enhance the amplitude response of reservoir, and also can be used to separate the reservoir from the non reservoir that has different thickness.

Case study has been done using real data, where in the original seismic response, the thin bed reservoir has been masked by response of the background, the shale. The single frequency response successfully separates the reservoir response from the shale.

INTRODUCTION

Since the beginning of 3D seismic era, seismic attribute has been used widely in oil and gas industry as a tool to interpret stratigraphical and sedimentological setting of reservoir.

Image processing immediately started to be used after that. The image processing, just like other computer algorithm, is limited by the input data. Therefore, before doing any image processing, input data need to be enhanced to get maximum output.

Seismic attribute is a response of a wave of several frequencies. Thus, the seismic attribute is a smeared response of several frequencies wave. To eliminate the smeared effect, the seismic response needs to be decomposed into responses of single frequency.

The most suitable algorithm used for spectral decomposition is Fourier transform. The seismic response in time domain is transformed into its frequency domain, and the response of each frequency is displayed for seismic geomorphology interpretation. This single frequency amplitude response uses the phenomena of tuning thickness. If a geobody thickness is \( \frac{1}{4} \) of wavelength of the wave, then the reflectivity of the upper boundary of the geobody will be very close to the reflectivity of the lower boundary, so the amplitude contrast
become very high, and some times shown as one reflector only, bright amplitude reflector.

Spectral decomposition was used to separate reservoir from background shale using real data. The original seismic amplitude did not show separation of the reservoir from the shale.

**METHODOLOGY**

Discrete Fourier Transform is used for decomposing the time domain seismic response into responses of individual frequency. The seismic response in frequency domain is then separated into responses of individual frequency, which is often called frequency slice or tuning cube (Figure 1). Seismic geomorphology interpretation of each frequency slice is then integrated to give the complete picture of stratigraphical and sedimentological setting of the investigated area.

Partyka et all., recommends that for reservoir characterization, the most common approach to viewing and analyzing spectral decompositions is via the “Zone-of-Interest Tuning Cube”. The interpreter starts by mapping the temporal and vertical bounds of the seismic zone interest. The zone of interest is then transformed from the time domain into the frequency domain by a short window analysis. The result is tuning cube.

Spectral balancing is done to removes the wavelet overprint which contain in tuning cube. Subsequently by the application of DFT a spectral balance is performed so that different frequency slices can be compared. Then the results are combined to give the overall picture of the thin bed. (Partyka et all., 1999), (Matos et all., 2003).

**DISCRETE FOURIER TRANSFORM AS A TOOL OF SPECTRAL DECOMPOSITION**

Discrete Fourier transformation (DFT) is one of the known tools in signal analysis technologies, it transforms real data into frequency domain. For a given periodic sequence of numbers \( \{ f_k \}_{k=0}^{N-1} \) of period \( N \), the DFT of the sequence is a sequence \( F_n \) for \( n = 0, \ldots , (N-1) \) defined by:

\[
F_n = \sum_{k=0}^{N-1} f_k e^{-2\pi ink/N}, \quad \text{Where } i = \sqrt{-1}.
\]  

(1)

from the equation (1) the result consists of two parts: real \( r(f) \) part and imaginary \( l(f) \) part. Then amplitude spectrum \( (A_s) \) is defined as :

\[
A_s = \sqrt{(r(f))^2 + (l(f))^2}
\]  

(2)

**WINDOWS ANALYSIS**

The response difference of frequency between a long window and a short window amplitude spectrum is significant. While in the transform from a long seismic trace approximates the spectrum of the wavelet, the transform from a short seismic trace comprises a wavelet overprints and a local interference pattern representing the acoustic properties and thickness of the geologic layers spanned by the analysis window. The short window amplitude spectrum no longer approximates just the wavelet, but rather the wavelet plus local geologic layering.(Partyka et al.,1999) (Figure 2).

Partyka et al. have verified that the value of the frequency component, determines the period of notching in the amplitude spectrum with respect to bed thickness. This relationship is given by the expression below:

\[
Pt = 1/f
\]  

(3)

Where, \( Pt \) is period of notches in the amplitude spectrum with respect to temporal thickness (seconds) and \( f \) is discrete Fourier frequency (Hz). In the same way, the temporal thickness of the wedge (t), determines the period of notching in the amplitude spectrum (Pf) with respect to frequency:

\[
Pf = 1/t
\]  

(4)

Where \( Pf \) is period of notches in the amplitude spectrum with respect to frequency (Hz) and \( t \) is thin bed thickness. (Partyka et al., 1999)

**CASE STUDY**

A real data set was used to demonstrate the spectral decomposition capabilities in identification of thin bed reservoir with variable thickness.

Time slice of the original seismic response with dominant frequency 15 Hz is displayed in Figure 3a. 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 so clear in sand fill area (south area.) While in the frequency slice of 15
Hz (Figure 3b), the channel outline in the south area can be traced easily.

CONCLUSION

Spectral decomposition can be used for seismic geomorphology interpretation by examining the seismic response for each individual frequency. Each frequency slice shows a higher amplitude contrast of geobodies which has thickness equal to tuning thickness of the corresponding frequency. Therefore, complete seismic geomorphology interpretation can be achieved by integrating the interpretation of all the slices.

ACKNOWLEDGMENTS

The authors would like to thank the Geophysics Laboratorium of Hasanuddin University for the facility support. We also would like to thank Dr. Sri Suryani DEA as head of Physics Department for the enthusiasm support.

REFERENCES

Mauren Paola Ruthner, Adelson S. de Oliveira, Marcelo Gattass, 2005, Application of S Transform in the Spectral Decomposition of Seismic Data, 9th International Congress of The Brazilian Geophysical Society

David S. Gilliam, Discrete Fourier Transform, 2005, Course Online, Department of Mathematics Texas Tech University Lubbock, TX 79409


Figure 1 - Diagram of the spectral decomposition methodology. (Quoted from Partyka et al., 1999).

Figure 2 - Windowing spectral decomposition and its relationship with the convolution model. a) Long window spectral decomposition b) Short-window spectral decomposition (Quoted from Partyka et al., 1999).

Figure 3A - Original Seismic.  
Figure 3B - Frequency Slice at 15 Hz.