

Geological features based on Spectral Decomposition: Techniques and examples from the Malay Basin

A Shamsuddin¹, D Ghosh² and S Shahar³

PETRONAS University of Technology (Universiti Teknologi Petronas – UTP), 31750, Tronoh, Perak, Malaysia ^{1,2}

PETRONAS Carigali Sdn. Bhd., Kuala Lumpur City Center, Malaysia ³

E-mail: anassash@gmail.com, dr.deva@petronas.com.my, suhaile@petronas.com.my

Abstract. Seismic resolution is of interest in exploration and production of hydrocarbon area as it may hinder geological understanding. A frequency study-spectral decomposition was implemented in order to enhance geological understanding in the study area as it is related to the seismic resolution. Spectral Decomposition based on Fourier Transform analysis was conducted in the study area which is located in the Malay Basin. Four geological features were determined in the analysis 1 and three geological features were determined during analysis 2. The thickness and appearance of the geological features such as sharp edges, discontinuity were detected based on this analysis. The abandoned channel can be identified in the southeast part of the study area and was detected based on the modulation of the spectral decomposition analysis.

1. Introduction

Geophysical challenges in the Malay and adjacent basins have been addressed by Ghosh et. al (2010) including the appearance of seismic imaging below gas clouds, carbonates, basement and the geological features which are beyond seismic resolution. This paper is related to the seismic attributes - frequency in order to improve geological understanding in the South part of the Malay Basin as it requires higher seismic resolution and interpretation or can be known as spectral decomposition.

Spectral Attributes	
<i>E&P Application</i>	<i>Algorithms</i>
Seismic resolution	Wavelet Transform, Cepstrum, Instantaneous Frequency & Instantaneous Phase
Thin bed tuning	Spectral Decomposition
Absorption, Saturation	Qp/Qs

Table 1: Spectral attributes (Ghosh et. al, 2015)



Annur (2016) refers the classification of seismic attributes based on Ghosh et. al (2015) as he divided seismic attributes into three principal categories which are structure/geomorphological attributes, spectral attributes and fluid/lithology attributes. Main analysis of seismic attributes which are applied in this study is characterized in the class two (2) which is spectral attributes (Table 1).

2. Spectral Decomposition

Spectral decomposition is a tool for interpretive use, which is below resolution such as detecting stratigraphic features - sand thickness estimation and enhanced channel features especially abandon channel. The fourier transform is a one of spectral decomposition types which is calculated by using short window and a step size between the analysed frequencies. The other types of spectral decomposition are continuous wavelet transform, matching pursuit and exponential pursuit (Rocky et. al 2015).

2.1 Red-Green-Blue (RGB), Cyan-Magenta-Yellow (CMY), Hue-Saturation-Value (HSV) and Hue-Saturation-Lightness (HSL)

Corendering more attributes were a significant study that had been highlighted by Marfurt (2015) as it may enhance geologic insight. Red-green-blue (RGB), cyan-magenta-yellow (CMY), hue-saturation-value (HSV) and hue-saturation-lightness (HSL) are synonymous in corendering the attributes colour model. The red-green-blue (RGB) colour model is known to be used as a mixing light, for example, television screen or computer monitor, the cyan-magenta yellow- black (CMYK) colour model is important in printing and painting (Marfurt, 2015). The hue-lightness-saturation (HLS) model is more mathematical offers a means of modulation of one attribute of another, and hue-saturation-value as an alternative representation of the HLS model (Marfurt, 2015).

3. Frequency Modulation – Fourier Transform

Frequency modulation for this study is detected in the range of the target area. Three frequencies had been chosen in this study through the analysis of seismic are displayed with associate red in a lower frequency, green with a middle frequency, and blue with a higher frequency. Figure 1a-1c show three frequencies timeslices through the 10Hz - plotted against red, 45Hz - plotted against green, and 60Hz -plotted against blue for spectral magnitude components. For simplicity, the background was set to black. The simple addition of these color bars obtains an image such as that shown in Figure 1d. The other frequency modulation can be referred at Figure 2a-2c three frequencies timeslices through the 30Hz - plotted against red, 38Hz - plotted against green, and 40Hz - plotted against blue for spectral magnitude components. The addition of these color bars can be obtained an image such as that shown in Figure 2d.

3.1 Fourier Transform

The Fourier Transform analysis requires a short time-gate window and also a step-size between the analyzed frequencies which can be interpreted as the frequency resolution. Time gate in between -20ms and 20ms with 5 steps were applied in this study.

The output frequencies were divided into low, middle and high frequencies before modulation process. Analysis 1 involves 10Hz, 45 Hz and 60 Hz, while analysis 2 involves 30Hz, 38 Hz and 40 Hz. Analysis 1 can be defined in all three frequencies (low, middle and high) and analysis 2 only can be defined in two frequencies (low and middle) as the division of the frequencies are 10Hz-20Hz for low frequency, 20-40Hz for middle frequency and 40-60 Hz for high frequency.

4. Application: Malay Basin

A spectral decomposition study was conducted in the Malay Basin, which is located in the Southern part of the Gulf of Thailand, between Vietnam and Peninsular Malaysia with 80000km² coverage areas (Petronas, 1999) as there is appearance geological features that can be identified based on seismic analysis. It has a complex structural origin because of the combination of strike-slip and extensional regimes (Mansor 2014).

4.1 Geological identification

Based on the analysis - spectral decomposition (fourier transform), four geological features had been obtained. The first analysis is based on 10Hz-45Hz-60Hz and 30Hz-38Hz-40Hz for a second analysis. Figure 1 till figure 2 show the results in orange circles for geological features that can be analysed in this study. Based on the first analysis, feature 1 – northwest, feature 2 – southwest, feature 3 - center as well as feature 4 – center part of the study area can be defined in 10Hz-45Hz-60Hz and based on the second analysis feature 4 is absent with the appearance only for feature 1 till feature 3 (Table 2).

Analysis	Analysis 1 10Hz-45Hz-60Hz	Analysis 2 30Hz-38Hz-40Hz
Feature 1	10Hz (Red)	30Hz-38Hz
Feature 2	10Hz-45Hz	30Hz-38Hz
Feature 3	10Hz-45Hz	30Hz-38Hz
Feature 4	60Hz	None

Table 2: Results from Spectral Decomposition – Fourier Transform. Analysis 1 with 10Hz-45Hz-60Hz and analysis 2 with 30Hz-38Hz-40Hz.

4.2 Geological characterization

Analysis of geological features in this study is based on the thickness and also the appearance of the geological features.

i) Thickness of geological features

Based on the frequency, variation of thickness can be defined, especially at 10Hz-45Hz-60Hz (Figure 3d) and 30Hz-38Hz-40Hz (Figure 4d). The geological features are expected to be thicker at 10Hz-red in analysis 1 at 10Hz-45Hz-60Hz analysis compared to analysis 2 at 30Hz-38Hz-40Hz. The thickness is getting moderately thick at 30Hz-38Hz-40Hz in analysis 2 and 45Hz-60Hz in analysis 1.

Analysis	Analysis 1 10Hz-45Hz-60Hz	Analysis 2 30Hz-38Hz-40Hz
Thickness 1	10 Hz (Red): High	30Hz-38Hz-40Hz (Red, Green, Blue): Low
Thickness 2	45Hz-60Hz(Green, Blue): Moderate	30Hz-38Hz-40Hz (Red, Green, Blue): Moderate

Table 3: Results for thickness in analysis 1 with 10Hz-45Hz-60Hz and analysis 2 with 30Hz-38Hz-40Hz.

ii) Architecture of geological features (Sharp edge and discontinuity)

- Sharp edge: Sharp edge of the geological features can be determined at 10Hz for analysis 1: 10Hz-45Hz-60Hz) – white arrow (3a) and this feature is expected to be classified as a structural feature – fault.
- Discontinuity: The appearance of discontinuity at 30Hz (4a) and 38Hz (4b) at analysis 2: 30Hz-38Hz-40Hz can be determined.

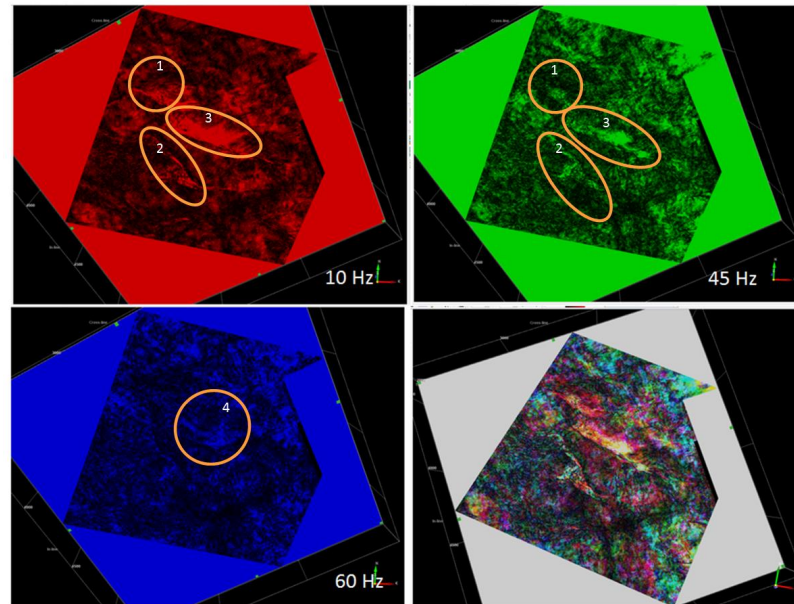


Figure 1: Timeslice through spectral magnitude components at (1a) 10 Hz plotted against red, (1b) 45 Hz plotted against green, and (1c) 60 Hz plotted against blue. (1d).The desired image obtained by color addition of the RGB components shown in panels (1a-1c) using external software.

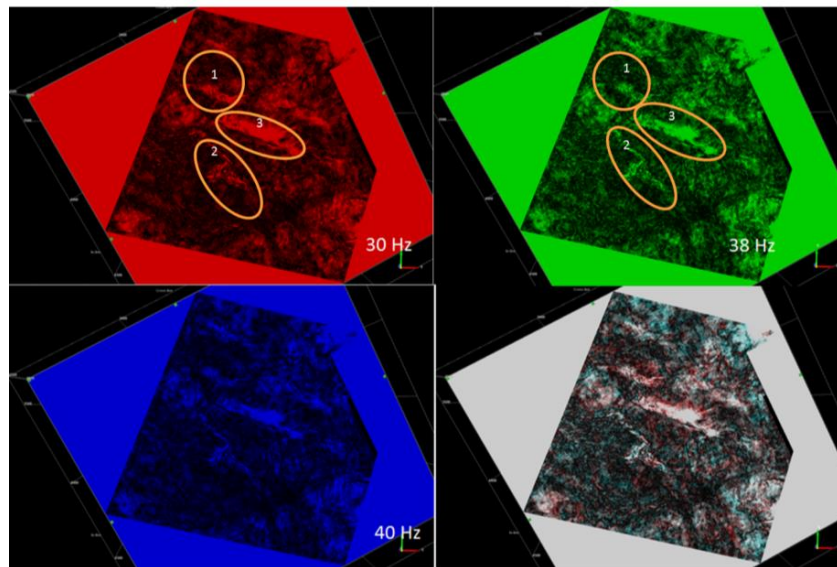


Figure 2: Timeslice through spectral magnitude components at (2a) 30 Hz plotted against red, (2b) 38 Hz plotted against green, and (2c) 40 Hz plotted against blue. (2d).The desired image obtained by color addition of the RGB components shown in panels (2a-2c) using external software

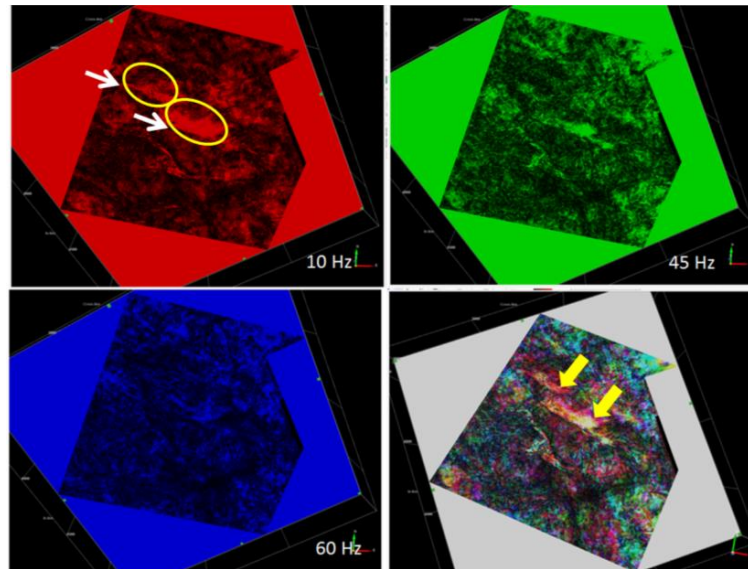


Figure 3: Time slice through spectral magnitude components 10Hz-45Hz-60Hz with a sharp edge – white arrow at 10Hz (3a) and variations of thickness can be analysed – yellow arrow in (3d).

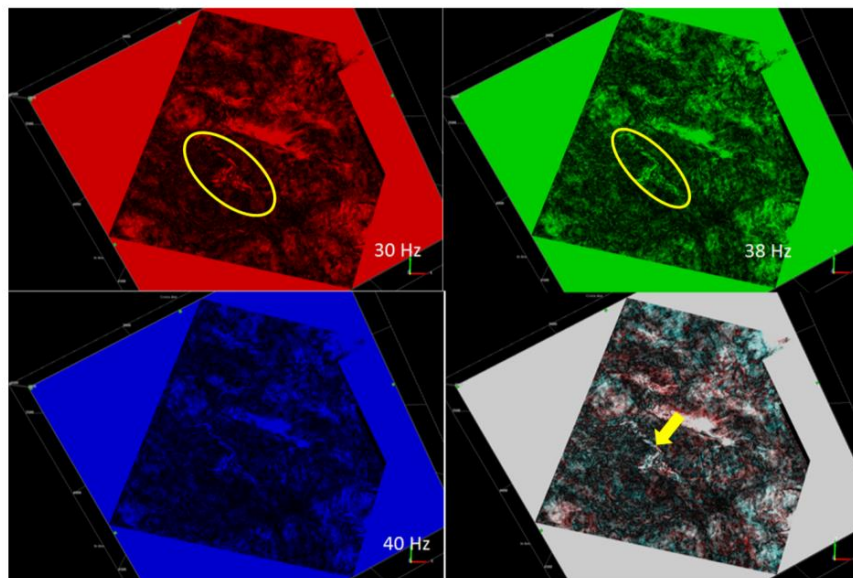


Figure 4: Time slice through spectral magnitude components at 30Hz-38Hz-40Hz with the different geological feature appears in yellow circle (4a and 4b) and yellow arrow for the combination (4d).

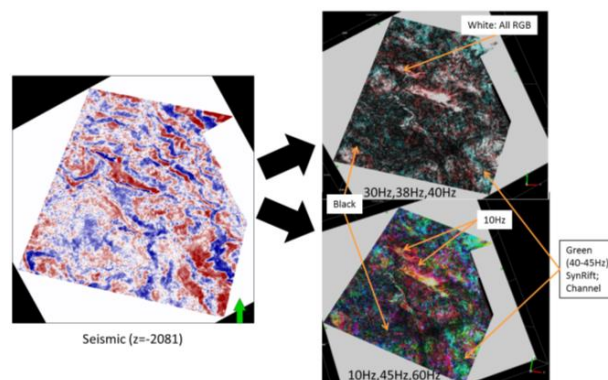


Figure 5: The analysis of 10Hz-45Hz-60Hz and 30Hz-38Hz-40Hz show the appearance of black colour and white colour with channel can be detected at 40Hz-4Hz

4.3 Frequency Analysis and Channel

Modulation of the frequency can be referred in figure 5 with the addition of the all three frequencies - red in a lower frequency, green with a middle frequency, and blue with a higher frequency. White colour shows all frequencies are represented while the black colour means the absence of all the frequencies. The interesting features that can be defined by the combination of all colour is a channel which is about 40Hz-45Hz. It might be the abandoned channel during synrift.

5. Discussion and conclusion

Spectral decomposition reveals the thickness, sharp edge and also discontinuity of the geological features and also channel as shown in the figure 1 to 5. As a conclusion, there are four geological features for analysis 1 and three geological features can be determined during analysis 2. The variety of thickness appearance of the geological features which is based on frequency can also be determined based on the spectral decomposition analysis. The appearance of sharp edge, discontinuity of the geological features which might be fault or fold enhanced the understanding of the study area. Based on the modulation, the abandoned channel can be detected in the southeast part of the study area.

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7. References

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