

# Seismic Illumination Analysis in Poor Oil & Gas Field Data by Using Focal Beam Method

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**Abstract.** The area underneath shallow gas cloud is an area where the image of subsurface data is generally poor. This distorted image underneath gas zones usually contains precious information of hydrocarbon accumulation. Previously, we analyse the factors contribute to poor subsurface seismic image underneath the gas cloud model and use focal beam technique to understand subsurface illumination information. Encourage by model-based success, we shift our focus to data-based application by applying the focal beam technique into a real field data. The results from this field were analyse in term of resolution function and amplitude versus ray parameter (AVP) imprint for different reflector depth, followed by acquisition analysis on the surface level. For this purpose, a velocity data of a field located in Malay Basin was built before applying the focal beam calculation. We will demonstrate that by using focal beam analysis for this field, we will able to obtain good imaging particularly for target reflector at 2000ms, 4000ms and 6000ms depth, provided the full 3D acquisition geometry was used during focal beam application.

## 1. Introduction

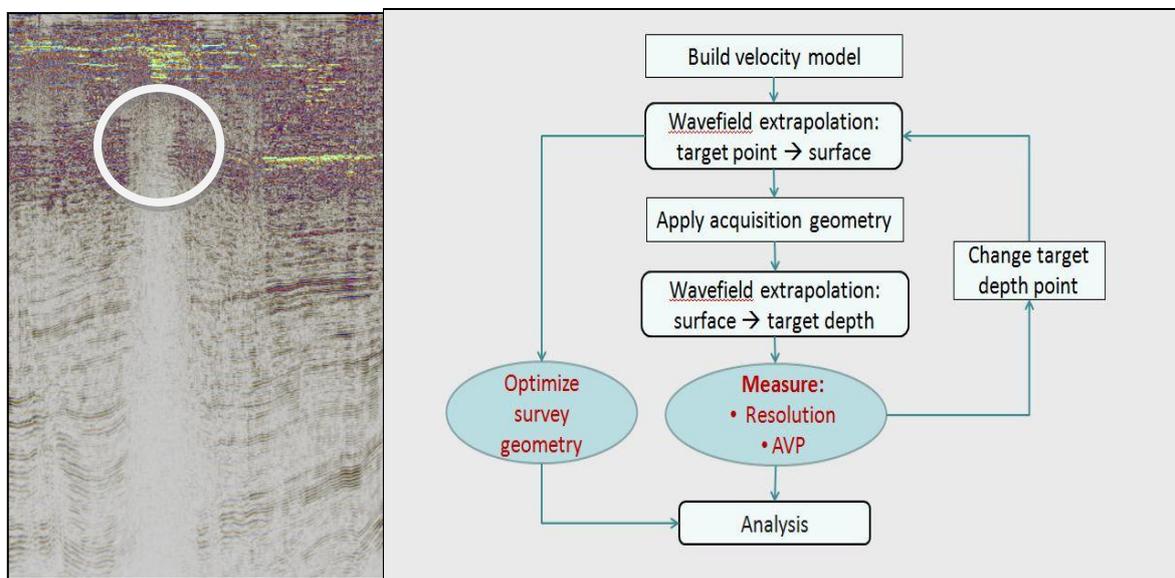
In seismically complex area such as shallow gas clouds and salt dome, acquiring and processing the seismic data using ordinary techniques normally will result in low illumination data. This is due to complex wave propagation behaviour, as severe wave distortion was detected from both scattering and attenuation phenomenon which resulted in blur subsurface seismic image, particularly underneath the gas accumulation. In order to restore the true earth cross section in seismic data, research had been focused in developing sophisticated imaging method, for example depth migration and reverse time migration, or by initiate some innovative way of survey design, like coil shooting technique and blended acquisition. This follows the forward path of seismic value chain, where a distinctive connection can be established between seismic acquisition and structural imaging. However, current imaging procedure require a lot of computational power and data space to determine viability of an acquisition design. With this constraint in mind, an integrated approach was develop in focal beam analysis [2] which enable faster evaluations of an acquisition design.

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The principle in focal beam is similar to downward continuation migration technique as both use shot and receiver profiles as their base. This method works by forward propagate shot profiles and cross-correlate with backward propagate receiver profiles. Once both profiles arrived on target point, an imaging condition will be applied to detect their similarity. Focal beam technique expand this idea as survey configuration was taken into consideration as well, to make the result more comprehensive. The beam will be produced by summing up all frequency content in a single wave propagation direction. Focal beam concept also relate to pre-stack migration formulation as both having double focusing process with the difference is in its output process. In pre-stack migration method, we need to simulate all shot records and before migrating the data while focal beam technique does not need to apply any prior processing algorithm. In addition, end user of focal beam method will get an insight of seismic data quality in shortest possible time while assess separately source geometry and receiver geometry configuration.



**Figure 1 (Left):**Theaffected gas cloud field in offshore Malaysia. It’s clearly shown here the reflector underneath the gas cloud (circled) experience low illumination effect.

**Figure 2 (Right):** Workflow for application of focal beam analysis in gas cloud region.

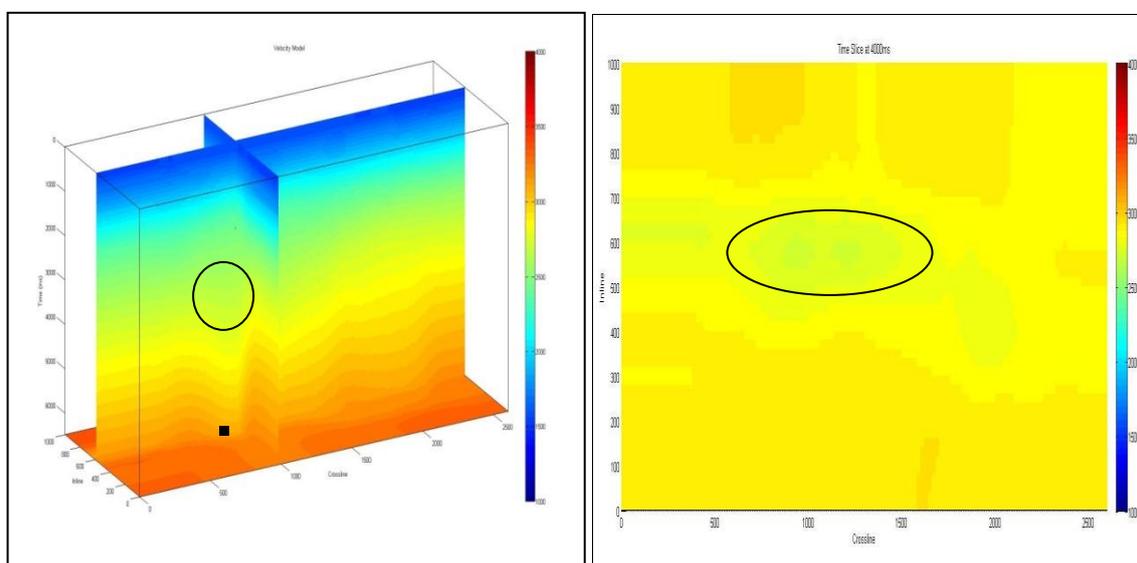
The main importance of producing focal beam result is in term of active reservoir quantitative assessment through subsurface structure information, designing acquisition geometry and choosing a migration operator. The workflow start by propagate each wave field frequency component from chosen target reflector towards surface position. On the surface, we design the desirable survey configuration, before the wave field being propagate back to target reflector. From both upward and downward wave, we analyze the result in spatial domain by multiplying both focal function, which producing a resolution function. Another option is to transform seismic data into radon domain, and analyze the result in amplitude versus ray-parameter function and this will indicate our illumination coverage of subsurface.

## 2. Methodology

In the shallow gas cloud affected area, a seismic image was affected in term of its kinematics (time sag) and dynamics (low amplitude). To restore its true reflectivity, the wave field propagation effects need to be removed by adding double focusing operators to remove downward and upward propagation. Continuation from beam concept, a procedure was develop which aim to integrated

seismic acquisition analysis into structural imaging of subsurface [3]. The steps being used in this study contain slight modification from our previous work [1], as now we will look into obtaining an suitable and practical acquisition configuration, and workflow in **Figure 2** summarise the sequence of our analysis.

The field velocity model used in the analysis (**Figure 3**) was built from smooth interval velocity file of 12.5m x 25m bin. The velocity measured for every 40 inline interval, each Common Depth Point (CDP) location and at 50ms time step. It means the distance between two consecutive velocity lines (y-direction) is 500m compared to 25m interval between two consecutive CDP locations (x-direction). Due to large gap in inline, it is important to interpolated y-direction velocity in our model, to prevent any discrepancies. However, due to limited computational power and resources, we limit our focal beam analysis into existing velocity points with modified bin of 20m x 20m. This give total dimensions for survey model approximately at 2.6km x 1km x 6 second.



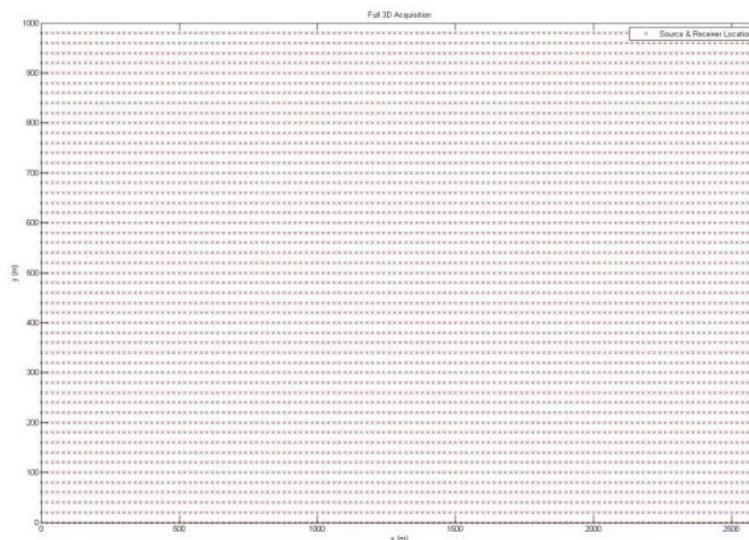
**Figure 3 (Left):** An inline slice and crossline slice of velocity model for a survey area in offshore Malaysia. The slices prove the existence of a shallow gas cloud field as the velocity value experience sudden ‘pull-down effect’ which indicate the low velocity region (circled). Black dot represent the lateral target point for illumination analysis.

**Figure 4 (right):** A time slice at time 4000ms depth was shown. Low velocity region indicate here in the circle.

For the purpose of investigation of illumination strength, three different depths of target points were chosen: depth at 2000ms, depth at 4000ms, and depth at 6000ms. These three points were chosen based on different reasons: 2000ms point is located just after the gas cloud region and provides clear idea how illumination behave in these zone. Meanwhile 4000ms point fall on a reflector, hence the illumination effect of the reflector can be understood thoroughly. The 6000ms point is at the end of recording data, means the significant comes in term of minimum illumination can be achieve in gas-affected data. The lateral location of the target points at each depth set just underneath the gas cloud area, i.e. [600, 1000] coordinate as indicate by black dot in **Figure 3**. It should be note that wave propagation at different depth level are independent of each other, means that there will be no interference between computation of 2000ms point reflector to 4000ms, and 6000ms point reflector and vice versa.

The gas cloud area fall in the region between 2000ms to 4000ms depths with velocity slightly deviated from surrounding sediments. In Figure 4, the area of gas cloud can easily identified as the velocity of those affected are much slower than similar depth sediments. Also it clearly shown in **Figure 4** that the accumulation of gas in shallower sediments has ‘pull-down effect (black circle) which indicate the loss in its kinematic property. In order to investigate model’s dynamic effect, forward modelling need to be simulated first before detail analysis can be carried out. Throughout focal beam computation, operator parameters used was chosen after consideration of earlier investigation and set constant for each depth point locations. The position of each target depth position will not affect other reflector point focal beam analysis. However, during the analysis we notice that more wave propagation was affected if the position is close to gas cloud due to bigger propagation angle during focal beam calculation. From the end result, we focus primarily on amplitude distribution and resolution function of the image compare to data quality as normally used in any commercial software.

For analysis purposes, we fix the acquisition to full 3D survey configuration during the focal beam calculation on the surface. Full 3D geometry has a unique characteristic where all sources and receivers will be located at the same coordinate and having the source / receiver lines spacing as minimal as possible. The advantage of having dense source-receiver network enable full wave field coverage on the surface level, while removes the possibility of missing out any upward wave. In the following design as shown in Figure 5, the geometry designed to follow the velocity model build up area of 2.6 km x 1 km with spacing of 20m in both x and y direction.



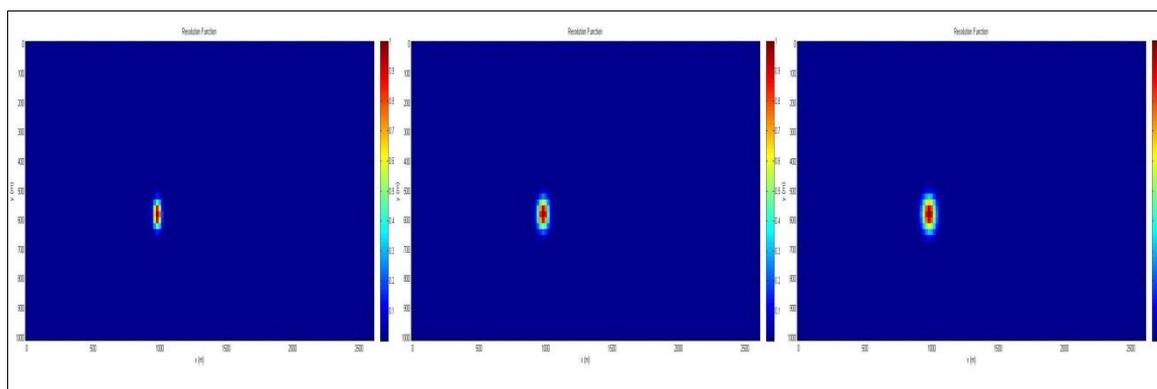
**Figure 5:** Top view of full 3D acquisition geometry used for illumination study.

### 3. Result & Discussion

#### 3.1 Spatial Domain Analysis

Focal beam analysis was conducted after applying acquisition geometry to upward wave propagation, and propagate back to target reflector. Throughout the focal studies in both spatial and radon domains, the full 3D layout was used as the main objective is to find best achievable illumination of the target subsurface location. Note that in full 3D acquisition setup, source position is at the same place as receiver position, producing similar focal beam characteristic.

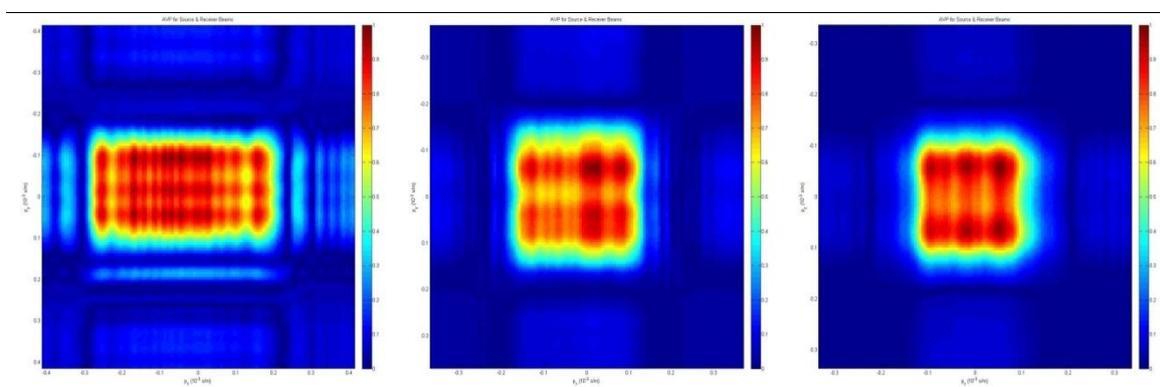
By multiplying both source and receiver beams for a monochrome frequency of 35Hz, the lateral resolution shown in **Figure 6** as it would be obtained for three different depth positions. Comparing focusing function obtained at different depths, the point which located closer to the surface has sharper resolution, whereas the response for target point at deeper locations is weaker due to waveform geometrical spreading effect. Note that throughout the analysis, attenuation factor and scattering effect has not been incorporated in the computation; hence the amplitude strength for deeper position is almost similar to shallower position.



**Figure 6:** Resolution function for three different depth, at 2000ms (left), at 4000ms (middle) and at 6000ms (right). The resolution functions produce after multiplying focal source beam and focal receiver beam, which obtained at target reflector lateral position of [600, 1000]

### 3.2 Radon Domain Analysis

The product of focal source beam and focal receiver beam in radon domain will yield amplitude versus ray-parameter imprint (AVP). In **Figure 7**, AVP imprints for three target points at 2000ms, 4000ms and 6000ms has been analysed, repeating the procedure as in spatial domain. From the result, shallower position has wider illumination coverage due to fact less geometrical spreading occur compare to deeper position. However, all three AVP show common trait and similarities as wave propagation are less affected by deeper or shallower target locations. In addition, the weak velocity contrast between gas clouds to surrounding contributes to good AVP image of subsurface.



**Figure 7:** AVP function for three different depth, at 2000ms (left), at 4000ms (middle) and at 6000ms (right). Amplitude versus ray-parameter calculated by multiplying focal source beam and focal receiver beam in radon domain, which obtained at target reflector lateral position of [600, 1000]

#### 4. Conclusion

In summary, the focal beam analysis in this particular field shows good imaging can be achieved particularly for our target points at 2000ms (located just underneath the gas cloud), 4000ms (falls on a target area of interest) and 6000ms (end of seismic data) depth, with justification of each chosen point explained in section two. However the good illumination coverage as shown in section three were obtained using the perfect acquisition geometry setup which not realistic given the constraint of time and resources of real worlds. Collectively, focal beam analysis in shallow gas cloud area can be summarised as follow:

1. Shallower depth point (2000ms point depth) will give better illumination coverage compare to deeper location (4000ms and 6000ms).
2. Weak gas cloud velocity is hardly affecting the illumination coverage of target subsurface due to less wave scattering and minimum attenuation occurred during wave propagation.
3. Full 3D acquisition produces high illumination coverage and good focusing for a particular survey area, albeit not possible in real practice.

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