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## Full Azimuth Seismic Acquisition with Coil Shooting

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### Summary

The wavefield created by a seismic source propagates in all three dimensions. Marine seismic towed streamer acquisition geometries are long and thin and consequently record only a small part of the 3D reflected wavefield, in effect measuring a small azimuth range of the full 3D wavefield. In areas where the geology is simple and homogeneous this limited surface geometry can still provide consistent illumination of the target reservoirs. However in areas where the geology is complex (due to high dip, complex structure, faulted over-burden and lateral velocity and facies changes), the ray paths are bent and scattered in the over-burden and inconsistently measured with the relatively narrow surface spread. In extreme cases large zones of the target horizon can be completely unilluminated by the towed streamer dataset. Ideally then we would not presume the preferred acquisition direction and sample the returning wavefield in as many different azimuths as possible. Coil Shooting geometry achieves this and can be shown to be effective both geophysically and economically.

### Introduction

As an industry a lot of effort has been made to mitigate the poor azimuth sampling associated with towed streamer geometries by using multi-pass (MAZ) and multi-vessel (WAZ) solutions. While these geometry solutions have proved very effective they do have some constraints. Neither solution provides full sampling in both offset and azimuth and are operationally constrained by the need for large fleets of vessels.

Coil Shooting has recently been developed and deployed as a method to acquire a full azimuth dataset with a single towed streamer vessel. With the Coil Shooting methodology a towed streamer vessel follows a circular pre-plot. This pre-plot is then repeated inline and crossline, to build-up fold, offset distribution and azimuth distribution. As well as acquiring a dataset rich in azimuth with a single towed streamer vessel, the acquisition solution is highly efficient because of the reduction in line change time. Line change is reduced from 3 hours to a matter of minutes increasing acquisition uptime by as much as 80%.

To evaluate the success of the Coil Shooting technique we will examine 2 case studies: the first in the Turkish Black Sea with TPAO and the second in the Norwegian North Sea for StatoilHydro.

### Methodology

Figure 1 details several nominal acquisition geometries and the resulting rose plots. The rose plots detail the offset and azimuth sampling, by plotting offset against azimuth with fold in each offset/azimuth bin represented by the varying colour scale. The standard towed marine streamer shows very little sampling in azimuth and so is referred to as narrow azimuth (NAZ). The second method using multiple passes of NAZ geometry on different azimuths, termed MAZ provides azimuthal coverage in 2 or more azimuths. While offset sampling in each azimuth bin is excellent, many surveys (up to six) are required to provide continuous azimuth sampling. The direction and number of azimuths, needed to sample the wavefield sufficiently, can be determined by forward modeling (ray-tracing/synthetic seismic). On review of the wide azimuth (WAZ) geometries it can be seen that the inline offsets sampled are the same as with NAZ designs with the addition of a cross line component, which varies by WAZ design, but is typically half the inline offset is recorded. Coil Shooting on the other hand samples the full offset range in all azimuths. Figure 2 details the offset and azimuth distribution for a theoretical coil survey. The azimuth distribution in the taper zones reduces at the edge of the taper zone. Understanding the offset and azimuth distribution in the taper zones, provides opportunities for additional efficiencies.



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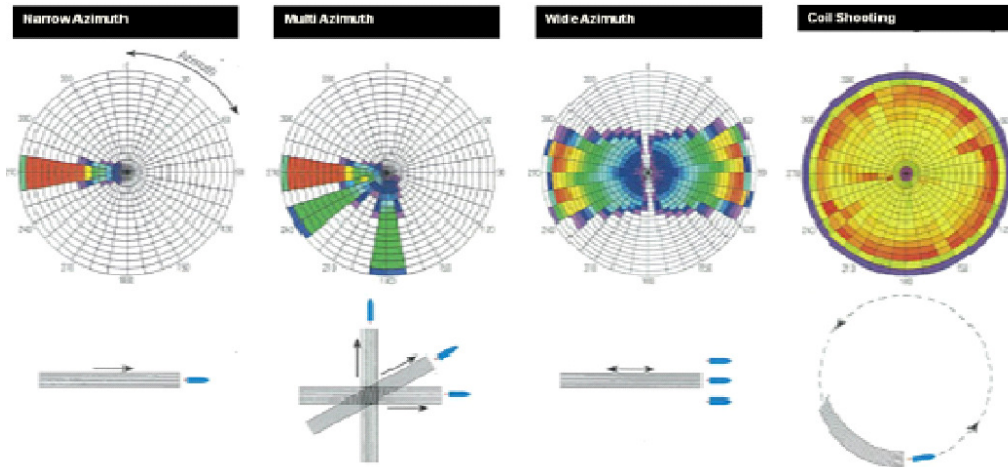


Figure 1 Rose diagrams of acquisition geometries

The red zone details the area with 360 degree azimuth distribution while the light blue area details the area with 180 degree continuous azimuth distribution. If we accept reciprocity then the survey can be designed to achieve 180 degree azimuth distribution over the image area. The additional taper zones, with azimuth distribution varying from 180 degrees to zero, will then provide the aperture necessary for migration.

An important factor to consider in acquisition geometry is the time/cost factor relative to survey size. This is because the efficiency of Coil Shooting relies on near zero line-change time but for large MAZ and WAZ surveys the linechange time relative to the acquisition time decreases and so the economics change from one type to the next. The variability of Coil Shooting and WAZ geometries and additionally the number of passes for a MAZ survey means that only broad generalisations can be made on optimum survey size relative to time/cost. While full azimuth ocean bottom cable surveys can be efficient for sub 200km<sup>2</sup> surveys, for surveys larger than this but smaller than 800km<sup>2</sup> Coil Shooting is the most cost effective and beyond this MAZ geometries can be very efficient. For very large surveys (or multiple surveys) then WAZ can be considered even with the associated logistical considerations.

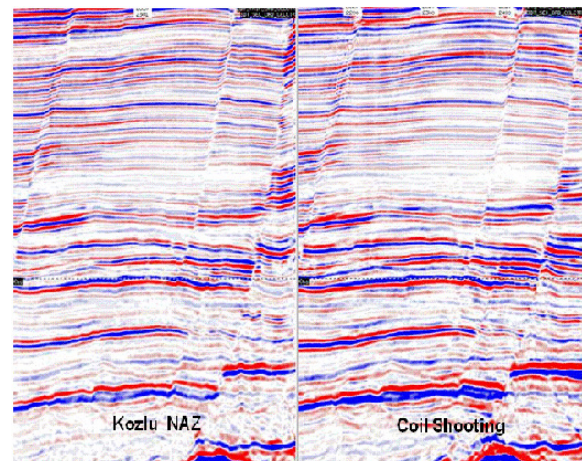


Figure 2 NAZ versus Coil Shooting -improved illumination and fault definition

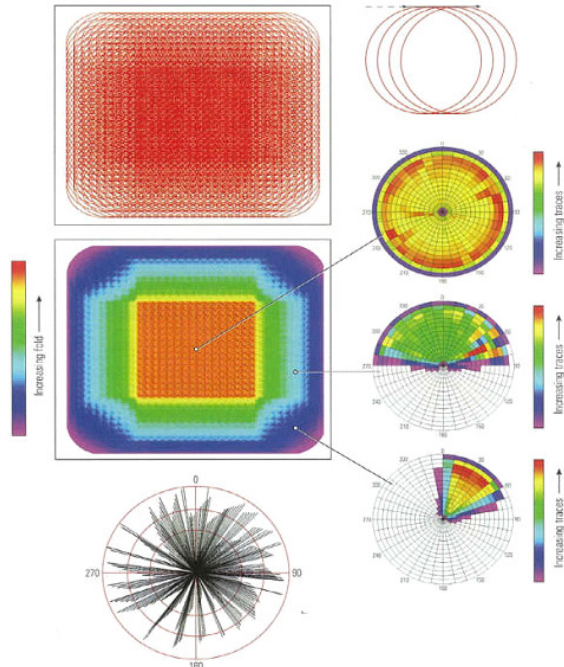


Figure 3 Coil Pre-Plot and Coverage Distribution

TPAO is the national oil company of Turkey and they are the operators of the Kozlu block which is located in the south-western sector of the Black Sea. The main seismic objective is the definition of the base of limestone reef structures, which overlay volcanics at a depth of 3.5-4kms. Additional objectives include imaging the overlying Oligo-Myocene Mycop shales and synrift deep marine deltaic shales.

The test involved shooting 11 coils. The primary objectives of this preliminary test were to validate the acquisition technology and to confirm the quality of the measured signal. The acquisition system used was Q-Marine which specifically benefits from high density noise sampling, realtime processing at the single sensor level and streamer steering. These technology components have benefit both in terms of data quality and HSE. Figure 3 details a comparison of sections from the Coil survey and the recently acquired NAZ survey, demonstrating the expected improvements in imaging, fault resolution and illumination.

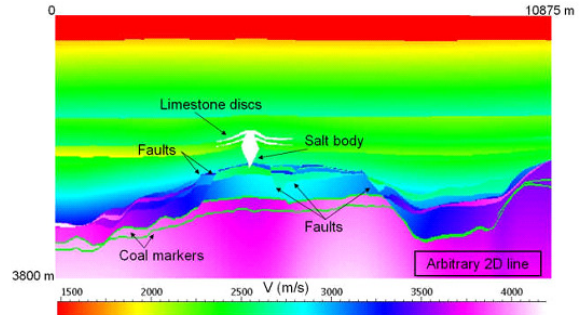


Figure 4 Heidrun Geological Model with the dome structure shown in this case as a salt body –picture courtesy StatoilHydro

## StatoilHydro Heidrun Synthetics and In-field Test

The Heidrun field is situated in the Norwegian North Sea on the continental shelf, about 100km from the coast of Norway. In the reservoir area the strata below the BCU horizon at Heidrun are extensively faulted compartmentalising the reservoir. The reservoir is contained in the tilted fault blocks and in the narrow azimuth image the fault locations, fault block illumination and dip direction are unclear with conflicting dips in the final image. Additionally a significant proportion of the reservoir is over-layed by a dome shaped structure which acts to disrupt the reservoir image.

StatoilHydro considered the options to resolve these issues based on Gulf of Mexico studies which showed that such imaging issues can be solved by an azimuth rich acquisition. However, the differences in the geology – notably the more complex overburden and shallower target – may be better resolved with different designs. At the time the options being considered were OBC or WAZ type surveys, and given the complexity of both survey types, StatoilHydro started a collaboration project (Heidrun FAZ study) with WesternGeco in order to determine the optimum acquisition geometry. This study involved modeling the seismic data using a 3D acoustic one-way algorithm with the geological model provided by StatoilHydro, and defining the cost in terms of relative acquisition effort (vessel time.)



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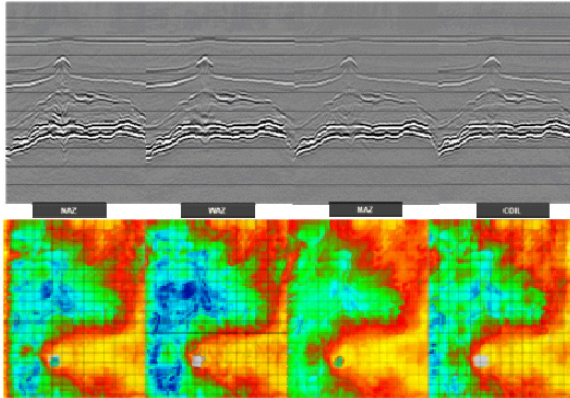


Figure 5 Synthetic Data after pre-stack time migration and below horizon amplitude (approx 1500ms), geometries shown, from left to right -NAZ, WAZ, MAZ, Coil

A number of geometries were modelled including several WAZ designs (using three or four vessels with various cable and source configurations), a three azimuth MAZ design and a NAZ design as the reference for evaluation. After synthetic gather generation the data was processed using regularisation, pre-stack Kirchhoff time migration, NMO, mute and stack. During the project Coil Shooting became an option and so was also included in the modelling effort. Figure 5 compares four options: NAZ, one WAZ option, MAZ and Coil Shooting. From this one can see that the imaging improves below the dome structure with increasing azimuthal content. MAZ and Coil Shooting have similar imaging of the reservoir but MAZ results in acquisition footprints at the seabed down to 1500ms below the mudline.

After the results of the synthetic study SatoilHydro decided to perform an infield test to confirm the improvements seen. This test gave enough coverage for a 5x5km cube of migrated data, albeit with a limited migration aperture. The test area was chosen with a future drilling programme in mind and so had to be acquired and processed in a short time span (5 months) with an additional month for analysis by the asset team. The placement of the test near production platforms meant the limited full azimuth area was slightly skewed in terms of coverage. In order to provide comparison to the vintage NAZ survey the acquisition and processing parameters were identical (cable number, source number and volume, source and cable depths.) Data processing was also identical except

for the substitution of tau-p demultiple with 3D GSMP (SRME) in the Coil Shooting test. Identical velocity fields were used for migration and stack however due to the limited data available for Coil the migration aperture was limited to 1700m (compared to 3000m for NAZ.)

The results show that the coil datasets results in better fault resolution, better dip discrimination in the fault blocks and improved multiple attenuation. An area of reduced vertical resolution can be seen on the east flank of the structure but this can be attributed to the very limited migration aperture at this point. The Coil Shooting test, backs up the modelling results, and demonstrates that the original requirements were met: fault resolution, fault block illumination, dip discrimination, and dip direction. The area chosen for the test did not include the dome structure.

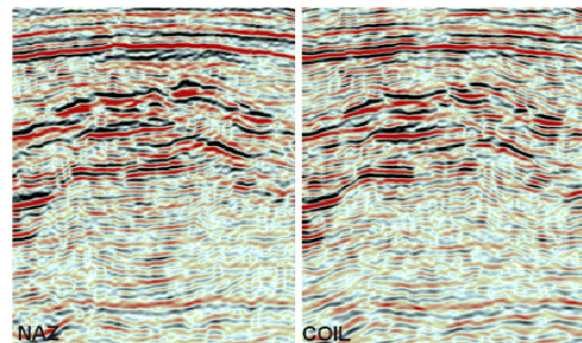


Figure 6 Heidrun NAZ (left) versus Coil Shooting test

### Conclusion

It can be seen from the Coil Shooting tests that it is a realistic solution to complex imaging problems. The economics of Coil survey design show that surveys are competitive to 3 azimuth MAZ surveys but with additional benefits in terms of azimuthal sampling and nearly double the data volume to aid signal-to-noise. A full survey has also been completed in the Tulip field, Indonesia for ENI. The complex nature of the Coil Shooting design means that forward modeling would always be recommended to ensure that survey requirements are met.



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### References

M. Houbiers\* (StatoilHydro Research Center) & M. Thompson\* (StatoilHydro Research Center) EAGE 2009 **Full Azimuth Field Trial at Heidrun**

D.I. Hill\* (WesternGeco), G. Brown (WesternGeco), R. Campbell (WesternGeco) & E. Hager (WesternGeco) EAGE 2009 **A Highly Efficient Coil Survey Design**

M Houbiers\*, B Arnsten, J Mispel, E Hager, G Brown, D Hill SEG 2008 **Full azimuth modelling in the Norwegian Sea**

M Houbiers\*, B Arnsten, M Thompson, E Hager, G Brown, D Hill Petex 2008 EAGE and SEG 2009 WAZ workshops **Full azimuth modelling at Heidrun**

Oilfield Review Autumn 2008 **Shooting Sesimic Surveys in Circles**

E Hager\*, J Sansom, J Penwarden Gatwick DP E Palmer, G Brown, R Campbell Integrated Solutions WesternGeco Cairo International Geophysical Conference 2008 **TPAO Black Black Sea Case Study**