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Seismic Acquisition 1: 3-D Acquisition

Wednesday Morning

Evolution of Positioning in Marine 3-D Seismic

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SUMMARY

Marine 3-D seismic surveying is performed by survey vessels with towed energy source(s) and seismic streamer(s) traversing parallel lines in order to fill a pre-defined grid with seismic information. The position of the vessel is not so critical as is the understanding of where the seismic coverage is being achieved. The development of the models for source and receiver positioning has been evolving for almost ten years. Development can be categorized into three main phases:

- 1) Fixed Offset Period
- 2) Vessel Relative Period
- 3) Integrated Positioning Network Period

Analysis of error for each period is presented as a main theme in this paper. Error ellipses have been computed for each model and a short description of each period is included.

If the requirement exists for very accurate positioning of sources and receivers the Integrated Positioning Network can offer accuracy levels at less than five meters for all in sea equipment. Other models offer accuracies which are adequate in many cases.

PERFORMANCE CRITERIA

In order to make comparisons of various models for source and streamer positioning there must be standards of expected performance for certain nav sensors. They are standardized as follows for use in our analysis:

- vessel antenna positioning is accurate to 3 meters
- tail buoy antenna positioning is accurate to 5 meters
- unmeasured tail buoy decoupling from streamer is equal to 5 degrees
- seismic cables are 3000 meters long
- if dual streamer configurations exists separation is equal to 100 meters
- one degree accuracy is expected in streamer mounted compasses
- one degree vessel gyro accuracy is expected
- one meter acoustic ranging accuracy
- 1 meter in 100 meter accuracy for ultra-short baseline systems
- one centimeter accuracy for baseline determination in short baseline systems
- all errors are uncorrelated

FIXED OFFSET PERIOD

The fixed offset period is based on a simple model utilizing nominal offset distances combined with vessel gyro and streamer compass data used as stepback bearings. The fixed offset period consists of 3 basic periods of configuration.

Fixed Offset Period 1 is illustrated in figure 1. The reference point is a radio navigation antenna on the vessel with a estimated accuracy of 3 to 5 meters. From the reference point, a gyro reading, with an accuracy estimated at one degree, is used to stepback to the tow point for guns and/or streamer. Streamer compass data is used for azimuth control to stepback from the tow point along a nominal distance to what would be considered the position of the first cable compass. There are evenly distributed compasses along the cable used in a computation to determine cable shape. The source position is determined in a similar manner to streamer front end where compass data is used as a stepback bearing from the tow point along a nominal distance to center source position. It is common practice to carefully measure the streamer and gun cables as they are being deployed to determine nominal values for offset. In addition when equipment is deployed it is common to fire single gun shots to confirm the distance from the source to the first live seismic receiver.

The main plus in Period 1 relates to its simplicity. Simplicity was desirable due to the technology which was available during this time (late 1970's, early 80's). Computer hardware and software has developed a lot in the ten years since the first 3-D surveys. Managing large volumes of data was not a simple task. Sixteen bit computer architecture limited the size and speed of onboard processing. Black and white graphics were the norm as color graphics were just becoming affordable. Streamer compass accuracy hasn't changed but the knowledge about their behavior is much better known.

Towing technology played an important role in some assumptions on the front end model for source and receiver positioning in Period 1. It was (and still is) feasible to use a simple model which closely simulates real life because the deployment and towing of in sea equipment results in a basically stable configuration. Seismic results are adequate in most cases with the simple model. While the industry has moved towards more sophisticated techniques a basic benchmark remains the simple model created in the early days of marine 3-D seismic.

Error analysis on the configuration for Fixed Offset Period 1 shows 10 meter error ellipses at the front end and twenty meters at the tail (see figure 1).

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A very basic survey practice would not be to leave an open magnetic traverse. The open magnetic traverse creates a situation where compass biases can go undetected and where variation in magnetic declination will not be noticed. It is for these reasons that the industry moved towards measuring some of the unknowns in Period 1.

Fixed Offset Period 2 involves control and confirmation of some fixed offsets and improves front end positioning. The addition of acoustic equipment for measurements of cable separation and skew at the front end increases confidence in stable towing systems. Deviations in cable separation and skew are not observed to occur at a rapid rate unless there is severe vessel movement. Comparisons of data on a line to line basis shows enough variation to instigate further development of source and receiver positioning. Seismic positioning is still accomplished with the open magnetic traverse. During this period a strong effort to improve streamer compass calibration took place.

Error analysis on the configuration of Fixed Offset Period 2 is not considered different from the previous period.

Fixed Offset Period 3 is illustrated in figure 2. Radio nav is included in the tail buoy. The position derived at the tail buoy is used to close the magnetic traverse and control compass errors. The errors found using tail buoy data can not be isolated into compass and magnetic declination corrections but the net result is a rotation (set of line dependent corrections) applied to compass data so that the misclosure between radio nav and compass derived positions at the tail are minimized.

The problems with radio navigation mounted in tail buoys applies to the low level of the antennae being the cause for poor signal reception. The result is an often noisy position for the tail buoy which requires heavy filtering in post processing. It does nothing to help in positioning the guns. Radio navigation on tail buoys limits the range between base station and survey area when using line of sight systems. Tail buoys are attached to the streamers with rope and often there is no measurement of the decoupling effect of the tail buoy from the streamer.

Error analysis on the configuration for Fixed Offset Period 3 shows 4 meter error ellipses at the front end and 9 meters at the tail (see figure 2).

VESSEL RELATIVE PERIOD

Positioning of sources and front end receivers are seen as critical by many geophysicists. The emphasis on front end positioning lead to the Vessel Relative Period which utilizes sensors on the vessel for determination of range and bearing of in sea seismic equipment. The operational ease of using a single sensor attached to the vessel can not be overlooked.

Ultra short baseline acoustics (as illustrated in figure 3) rely heavily on an accurate

determination of vessel attitude and water velocity. These two factors limit the positioning accuracy which can be obtained from vessel relative measurements. Error analysis on the configuration for Ultra Short Baseline systems shows 4 meter error ellipses at the front end. Ultra short baseline systems do not significantly effect tail end error.

There are operational difficulties encountered with ultra short baseline acoustics relating to the difficult acoustic environment. The hull mounted transducer must operate efficiently thru the wake of the vessel, the propeller wash, and the bubbles from airgun firing. The resulting data requires heavy filtering unless careful attention in installation and operation is performed. The expense of the technology and time involved in installation leads to hesitation in pursuing development.

Short baseline acoustics (see figure 4) also offer interesting possibilities for front end positioning. Short baseline acoustics allows good fix geometry from the vessel to the sensors deployed on the cables and guns. The limitation again relates to the need for highly accurate vessel attitude determination. Error analysis on the short base line configuration shows 7 meter error ellipses at the front end. Short baseline systems do not significantly effect tail end error.

Laser theodolites deployed on the stern of vessels with the ability to scan for targets on the surface can also be categorized as vessel relative. The targets include reflectors on the gun and the paravane floats. The experience with lasers is still continuing and potential exists for further use of lasers. Lasers can make measurements of relative bearing in the .05 degree range and centimeter type range measurement. The drawback of the laser method relates (as in ultra short and short baseline acoustics) to the reliance on an accurate instantaneous measurement of attitude determination. In addition the laser measures range and bearing to a surface float requiring knowledge of where the in sea seismic equipment is relative to the measurements taken, thus the possible need for additional measurements. The final problem encountered with lasers relates to potential problems making range and bearing measurements in foggy conditions.

All vessel relative techniques have potential for the future when vessel attitude measurements can be more precise or in the present if there is a willingness to make heavy investments in high resolution vessel gyros.

INTEGRATED POSITIONING NETWORK PERIOD

The Integrated Positioning Network can take a multitude of shapes depending on client desire, survey configuration and operational considerations (see figures 5 & 6).

The operational problems encountered with previous models have not been heavily focused in the context of this paper. The integrated positioning networks require consideration of added

logistics due to the increased number of systems which must be operational. This creates the need for more quality control and onboard computational power for source and receiver positioning. It also means that all systems must be integrated into a single computer system for network adjustment.

The concept of network adjustment involves the use of all available sensors for source and receiver positioning input into a least squares solution. Acoustic information combined with compass and radio nav positional information are used to determine the x and y's for each node within the network. Each node can be moved in order to minimize the total network adjustment. Weighting can be applied to various sensors based on the quality of the information they offer.

The Integrated Positioning Network illustrated in Figure 5 includes the use of a buoy equipped with radio nav and acoustics towed inbetween the front of the cables. This offers excellent geometry for acoustic tracking of gun and front cable acoustic nodes. An additional acoustic network at the tail coupled with radionav on the tail buoys gives the highest degree of accuracy available with present technology for total streamer tracking. Error analysis on this Integrated Positioning Network shows 2 to 3 meter error ellipses at the front end and 5 meters at the tail (see figure 5).

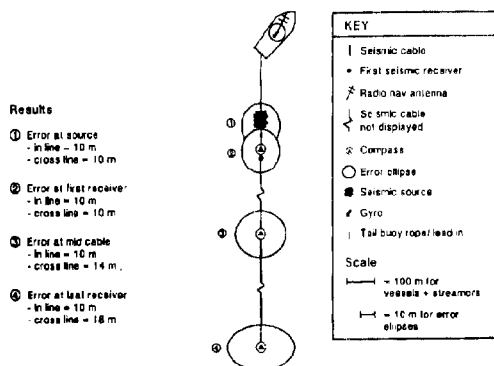


FIG. 1. Fixed offset period 1, nominal offsets. Measured lay-back with compass bearings.

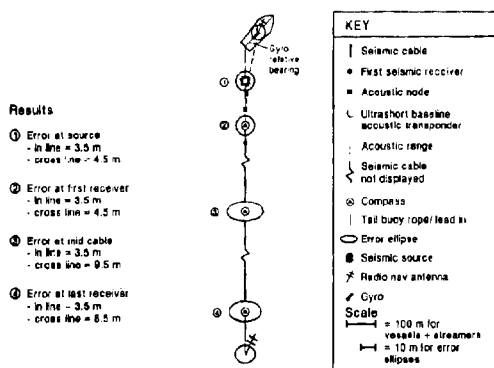


FIG. 3. Vessel relative period, ultra-short baseline.

The use of more than one vessel in seismic operations creates a large integrated positioning network as illustrated in Figure 6. The amount of computing done for solving and quality controlling all information input in this network becomes quite large. The operators require access to QC information which can be easily interpreted thus requiring development of expert type systems for real time monitoring. The inter vessel acoustics offer valuable control between vessels for highly accurate inter vessel positioning. The amount of in sea positioning equipment creates logistical considerations and network design includes redundancy.

Error analysis of this model shows 4 meter ellipses at the front end and 5 meters at the tail (see figure 6).

Conclusions

A variety of techniques for source and streamer positioning exist. The selection of the technique to be used on any given survey depend on a number of factors including geophysical objectives, geometry limitations and operational logistics. If the requirement exists for the most accurate positioning of sources and receivers an Integrated Positioning Network should be used.

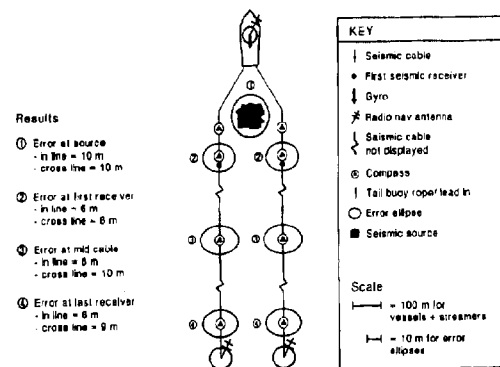


FIG. 2. Fixed offset period 3, closed magnetic traverse.

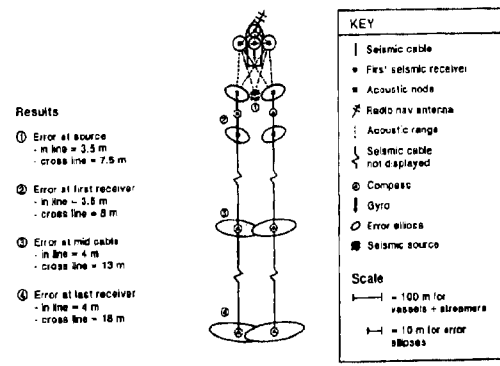


FIG. 4. Vessel relative period, short baseline.

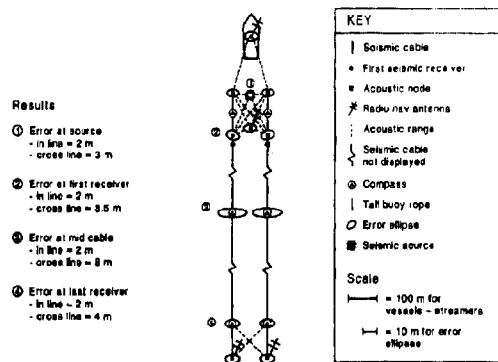


FIG. 5. Integrated positioning network with centrally towed buoy, single vessel.

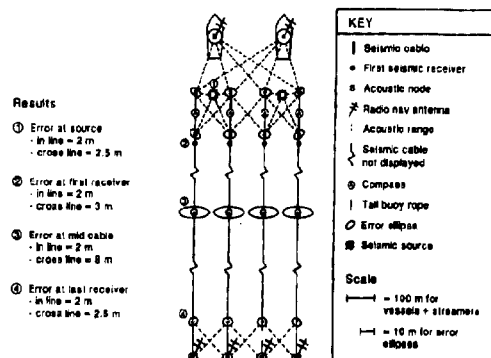


FIG. 6. Integrated positioning network, 2 vessel operation.