ACOUSTIC STREAMER TRACKING - AST 030*

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ABSTRACT

Following the introduction of 3-D offshore seismographic surveys, there is a need for more accurate positioning of the signal source (guns) and the seismic streamer cables. We also see a development towards more complex survey schemes.

A large number of ranges (and/or bearings) is needed to describe the towed system satisfactory. A typical performance of a positioning system could be in the order of 100 updates within every 10 seconds.

Bentech Subsea has developed a short baseline positioning system meeting the above requirements. A high degree of accuracy in the position estimates is obtained by using digital correlation techniques both for range and bearing calculations. The bearing calculation is performed by the SCOT algorithm involving FFT, whitening and IFT.

The time consuming steps in the calculations are run on a DSP single board processor developed by Bentech Subsea. The DSP processor is based on a Motorola M56000 chip.

The system has been run under normal seismic operation, and examples of the results are given.

1. INTRODUCTION

AST 030 is a system for acoustic positioning of seismic streamer cables developed by Bentech Subsea A/S. The system is based on the technology used in the positioning of the Benigraph towfish* (figure 1).

The tracking method of AST 030 differs from that used in conventional systems, as both ranges and bearings are calculated by correlation techniques. This method allows the use of a large bandwidth transmit signal, and consequently an increased signal to noise ratio.

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Following the introduction of 3-D seismographic surveys, there is a need for more accurate positioning of the gun arrays and the streamer cables. We also see a development towards more complex survey spreads, where the swath width is increased by applying more than one vessel in the scheme. Another development is the use of multiple streamers towed at different depths from the same vessel.

2. STREAMER POSITIONING

The rear end of each streamer cable, which is typically 3-6000 m long, is equipped with a buoy. This buoy is usually positioned relative to the ship by surface navigation. The shape of the cable between the endpoints is deduced from compass measurements along the cable.

Between the vessel and the first active section of the cable, there may be a lead in or a stretch section. The cable is usually diverted from the ship towpoint by a paravane. At the rear end, a stretch section connects the last active section of the cable to the tail buoy.

For 3-D surveys it is inadequate to extrapolate the shape of the lead in and stretch sections from the shape of the active sections of the cable, as it has been done in 2-D surveying, and a specific positioning system is required.

A complete positioning system also includes the positioning of the gun arrays relative to the streamer cables.

In a two boat operation, the system should be able to measure in the order of 100 ranges and bearings between consecutive gun fires at typical fire intervals of 7-10 seconds.

The positions should be given with an accuracy of ± 1 m, that is ± 1 m in range and ± 1 degree in bearing at 60 m range or ± 0.5 degrees at 120 m range.

The streamer cables are towed typically 5 to 10 m below the sea surface. The transmission of acoustic waves will therefore be along the surface in the wave influenced zone. The transmission conditions between the ship and the streamer front ends are highly degraded by the gun arrays towed in the same depth as both the hull of the vessel and the streamer cables. Aside from being effective diffractors of acoustic waves, the gun arrays create turbulence, acoustic noise and introduces air into the water.

These harsh conditions along with the desired accuracy, puts very strong requirements to the performance of the positioning system.

3. AST 030 SYSTEM DESCRIPTION

The basic units of the AST 030 system are

* control & processing unit
* hull or gun array mounted transducers with transceivers
* towed units (birds) with transducers and base line hydrophones
* transponders

A block diagram of the system is shown in figure 2. The remote units of the system can be configured as shown in figure 3.

The transmitting units are trigged sequentially from the control unit, as set up by the operator. At each trig, a 20 ms precoded signal is transmitted from the addressed unit, and received at the units to be positioned relative to the transmitter.

The coding is realized by alternating between two transmit frequencies at 35 and 45 kHz in a fixed pattern. At receival the signals are f to V converted and digitized for further processing.

A replica of the initial 5 ms of the converted signal is stored in the processing unit. The time of arrival of the signal to the receiver and thus the range estimate is computed by correlating the signal with the replica. This procedure has proved to give stable range estimates in the noisy conditions experienced.

The bearings are estimated from the difference in time of arrival to the baseline hydrophones. The time difference is computed by cross correlation of the 20 ms coded traces from the pair hydrophones applying the so-called SCOT algorithm to weight the different frequency components [2].

As the baseline length is only 0.8 m, a rated accuracy in the bearing estimates of 1 degree corresponds to a required accuracy in the time difference estimate of 10 μs.

A larger baseline or a longer coded signal would improve the accuracy of the bearing estimates. The design is however made as a compromise with operability (low weight and small size) and power consumption (battery life 20-30 days of operation).

The control of the remote units, and the data acquisition is run on a Motorola M68008 processor. The processing is performed by a M68000 processor which also masters a Motorola MC56000 DSP processor dedicated to run the most time consuming algorithms such as correlation and fourier transforms.

4. THE AST 030 DSP PROCESSOR

The BS16A DSP is a single board vector processor unit developed by Bentech Subsea for high speed multi purpose signal processing. The BS16A DSP is fully VME compatible on P1-connector requiring a system master controller. The system is based on DSP 56000 from Motorola run at 20 MHz clock rate. A block diagram of the processor unit is shown in figure 4.

The on-board memory is expandable to 64 k words data memory and 16 k program memory. In addition, 4 k-16 bit words of dual port RAM, is mapped into the VME bus memory space allowing simultaneous access from both DSP and VME side. The upper 16 words of the common (PPRAM) area contains control registers. These registers includes instruction vectors, RT-clock, macro counter and memory/IO configuration registers. The macro program memory contains single word macro instructions with direct IO-reference to the EPROM resident macro program library.

After loading the macro program and setting the appropriate bit command, the VME computer forces program execution by writing to the IRQ vector address.

The internal program memory contains a macro library resident in EPROM. The Macro library is down loaded into internal program memory on power up reset, thereby the advantage of zero unit state program execution is utilized. The library consists of 43 primary macro calls, all accessible from the VME host computer via the dual port program memory.

Some execution time estimates for the BS16A DSP are given below:
(at zero wait - and cycle processing)

128 points complex (I) FFT	0.5 ms
4096 points complex (I) FFT	20 ms
1000 points x 1000 points correlation (with end lobes)	50 ms

128 points x 1000 points replica correlation (without end lobes)	13 ms
MOVE data BLOCK from DPRAM: 1000 W, data trace	0.2 ms
MOVE data BLOCK from/to INTERN RAM: 1000 W, data trace	0.1 ms
ARCSIN 1000 W, data trace	2.5 ms
RMS 1000 W, data trace	0.25 ms

By applying an array processor to the system, we do not only obtain the advantage of parallel computation, but increased performance compared to a pure 68000 based solution is also given by:

1) true parallel processing by complete disconnecting the VME host computer

2) clock cycles savings by a factor of 10 for arithmetic instructions

3) increased word length (i.e. signal dynamics) from 16 bit to 24 bit

4) modularity and user friendly program language, i.e. debugging and test on Macro program level.

5. RESULTS

The system has been calibrated and tested with transmitter and receiver in fixed positions as well as mounted on a production streamer under normal operation.

The range measurements are consistent, as shown in figure 5, with a standard deviation of 0.3 m including also the physical variations during the recording period (typically 1-2 hours). The deviation is calculated relative to the average value. Close to 100% of the data are within physically acceptable limits, as shown in figure 6.

Higher standard deviations are found when the transmission path is through the gun array or the receiver is located directly in the ship's wake.

Reliable bearing estimates can be obtained by proper location of transmitters/receivers. If the receiver was located too close to the gun array with the transmission path through the array, two-peaked or very wide bearing distributions were observed.

With the receiving bird in a position further back, the bearing data were greatly improved. An example from the results is shown in figure 7. The application of a following filter rejecting unphysical values removed only 6% of the data. The remaining 94% shows a standard deviation of 1.7 degrees about the mean value, again including all physical variations during the 45 minutes recording period.

6. CONCLUSION

The use of a dedicated DSP processor makes it possible to perform high level signal processing on the large number of ranges and bearings measured. The performance of the system can be still increased by implementing more of the existing algorithms on the DSP, and by developing and/or implementing more sophisticated signal processing algorithms.

More powerful algorithms for removal or suppression of indirect signal from the traces should especially be considered.

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7. REFERENCES

[1] Løvik, A. 'The Benigraph: A Sea-Floor Mapping System', Advances in underwater technology and offshore engineering. Vol. 3. Offshore Site Investigation. Proc. of int. conf. organized by the Soc. for Underwater Techn. London UK, 13-14 March 1985.

[2] Knapp, C.H, Carter G.C. 'The Generalized Correlation Method for Estimation of Time Delay' IEEE Trans. Vol. ASSP-24, No 4, Aug. 1976

Captions to figures:

1. The Benigraph towfish with positioning system.

2. AST 030 - block diagram.

3. AST 030 installation.

4. BS16A DSP processor - block diagram.

5. Corresponding range measurements from port (P) and starboard (S) hull transducers to port front bird.

6. Range from port tail bird to transponder on tail buoy, and back to port tail bird.

7. Bearing to port hull transducer measured from port front bird. 95.8% of the data are within accept limits with a standard deviation of 1.7 degrees. The result of different degrees of smoothing is shown by fully drawn lines.

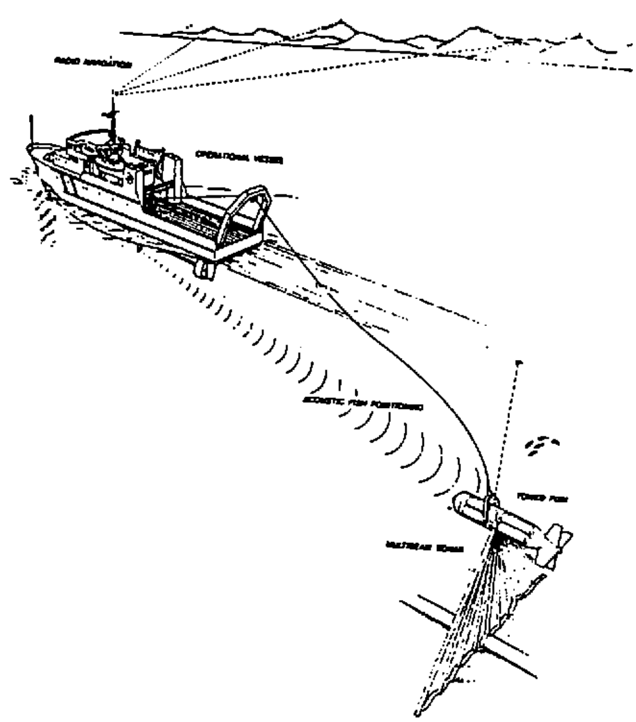

Fig. 1

ACOUSTIC STREAMER TRACKING - AST 030

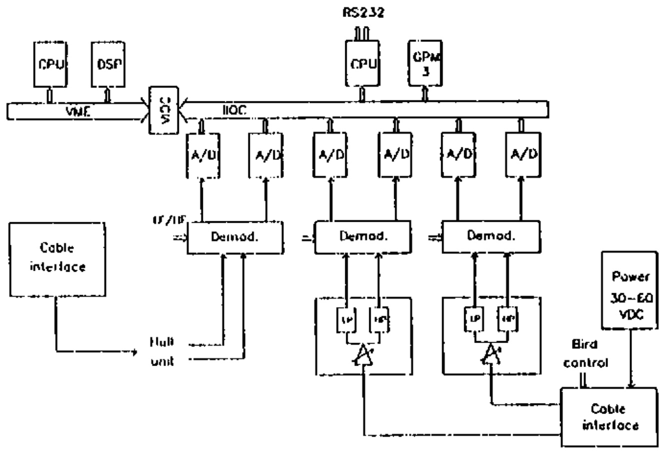

Fig. 2

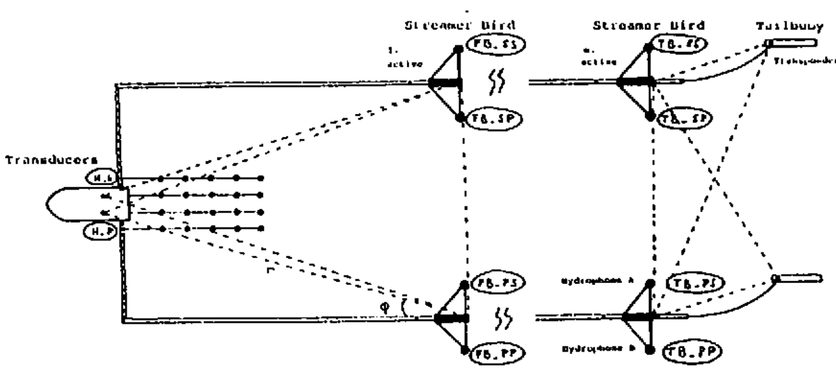

Fig. 3

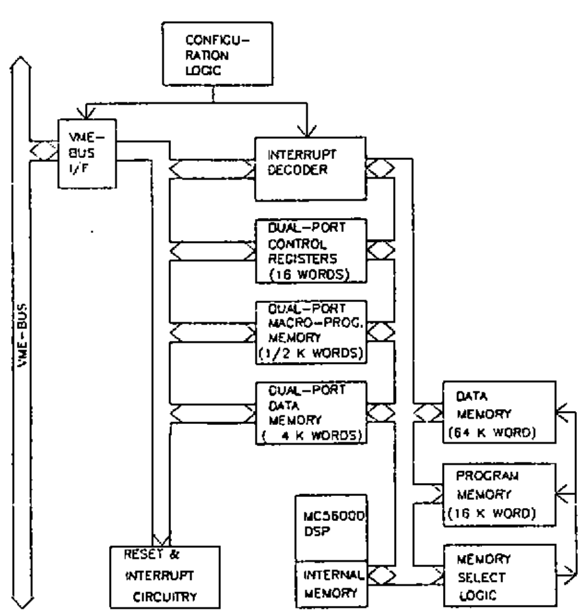

Fig. 4

ACOUSTIC STREAMER TRACKING - AST 030

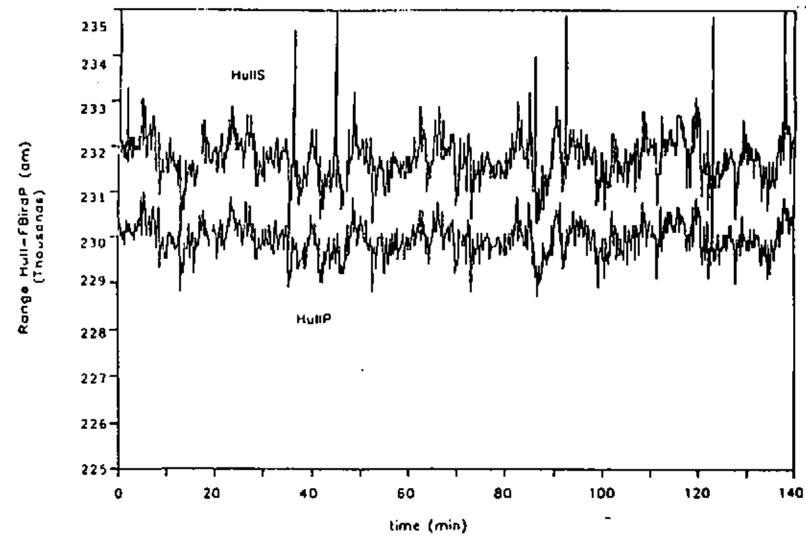

Fig. 5

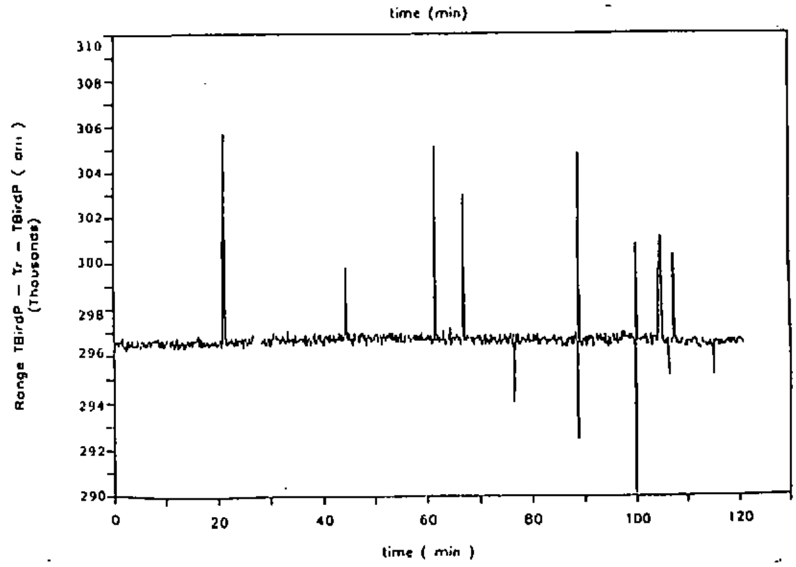

Fig. 6

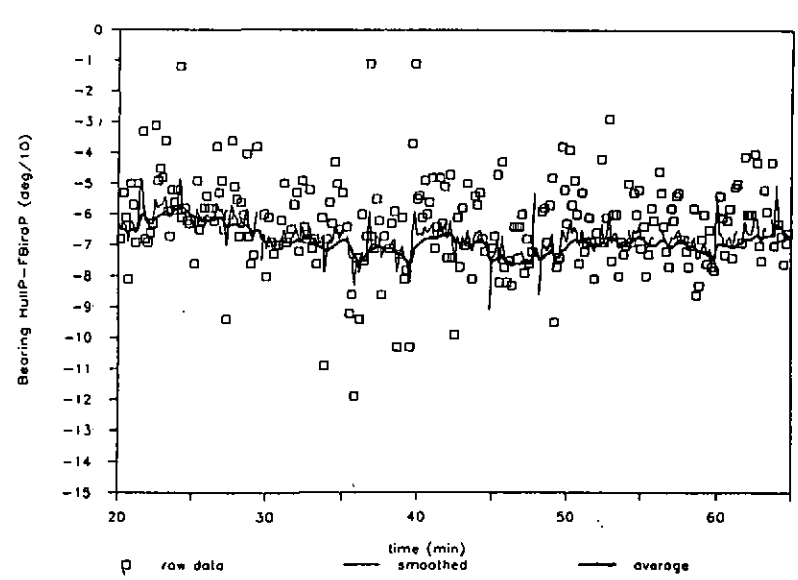

Fig. 7