

## **THE SWEDISH PARALLEL SOUNDING METHOD STATE OF THE ART**

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### **ABSTRACT**

In the sixties the Swedish Hydrographic Department developed a new method for hydrographic surveys. Instead of a single ship, a formation of up to nine vessels, navigating along parallel lines, was used for the echo sounding work. The formation consists of a mother vessel, positioned from the shore stations, and the satellite boats, positioned from the mother vessel.

During the years the method has been refined in various aspects and is today a powerful instrument with an efficiency remarkably superior to that achieved in earlier days. The contributions to the increase in efficiency derive from such sources as equipment, like vessels, positioning systems and echo sounders, from computer and computer programs, and from new methods for calibration, surveying, evaluation of collected data, etc.

### **HISTORICAL BACKGROUND**

Unlike ordinary topographic mapping on land, hydrographic work is a very tedious business. This is, of course, due to the well-known fact that the topography is invisible to the surveyor. Another problem facing the hydrographer is positioning; it is quite impossible to mark a point at sea.

The solutions to these problems are found in electronics, echo sounders and electronic positioning equipment. Even with these, hydrographic surveying is still a time-consuming affair and large efforts have been and are still being made, to increase both accuracy and efficiency.

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Around 1960, a new method of hydrographic surveying was developed at the Swedish Hydrographic Department. The method is called parallel sounding and has, since that time, been the standard method in Sweden. Instead of just one vessel, and hence only one surveyed line, several vessels in formation are used. The main feature and advantage is that only the mother vessel is absolutely positioned from geodetic control points ashore, the satellite boats in the formation being positioned relative to the mother vessel. In this way, up to nine tracks are covered simultaneously. The difference in cost, both investment and operational, between a fully equipped hydrographic vessel and a small boat, creates the economic advantages of this method.



FIG. 1.— HSvMS *Johan Nordenankar* with satellite boats.

During the first trials, standardized satellite boats were not available. The first formations consisted of various types of boats, giving birth to the nickname “The Gipsy Fleet”.

Each boat had a crew of two, one helmsman and one echo sounder operator. The distance to the mother vessel was checked with simple prisms. On each side of all boats were vertical stripes attached at even spacings. Looking at them with one eye through the prism and the other unaided, an observer on the ship could tell from the resulting pattern if the predetermined separation was being maintained or not.

The position of the mother vessel was, in the beginning, established by horizontal angles, measured with quintants onboard. Later, theodolites and Hydrodists, Decca main chain or Sea-Fix were used. The predetermined courses available were towards or from the theodolite, line of equal distance from the Hydrodist, or lanes from Decca or Sea-Fix.

Although, compared with modern standards, the method was rather crude, it gave an enormous advantage over the old single-ship method. The impact was considerable for the chartmakers; they were suddenly flooded with data, box after box of paper rolls from the echo sounders.

Today, a quarter of a century later, the parallel sounding method is still being used, although immensely improved. Virtually no piece of equipment is the same today and with computers, and methods made available by computers, we might almost talk about the New Parallel Sounding Method.

## GENERAL METHOD DESCRIPTION

The ultimate goal for hydrographic work is to map the bottom topography accurately; the depth at each single point should be known. Reaching this goal is unfortunately out of the limits for today's surveying technique. At best, all depths to protruding points will be found. This demands, however, complete coverage of each area with the echo sounder beams touching or, preferably, overlapping. Even so, as some targets are positioned off-side from the beams centre line, their recorded depth is in error.

Use of a side scan sonar may ensure complete coverage but lacks accuracy. Other methods, such as laser bathymetry, have other shortcomings.

The conclusion must be that the ultimate goal in hydrography is, at least for the time being, out of reach. For shallower waters, the only reliable approach is to use transducers with a moderate beam angle and to pack the surveying lines closely.

This is the fundamental criteria for the parallel sounding method. Closely packed lines means many lines for a certain area and a very time-consuming task for a single ship. With up to nine simultaneous tracks, the reduction in time is immense. Using nine similar, fully equipped ships would, on the other hand, increase the costs ninefold. That is why small, cheap and sparsely equipped boats are used working together with the mother vessel, creating a single surveying unit.

A formation like this raises problems of its own, problems which are not encountered with single ships. Interference between the echo-sounders is one of them. When spacing between the surveying lines must decrease due to shallow waters, safe navigation is impossible as the boats get too close to each other. In Swedish waters, surveying lines are often required to be as close as six metres.

For this reason, the formation space is never less than 25 metres and the whole formation is instead moved to cover the tracks in between. In this way an area is sometimes surveyed up to four times, although the boats never run in the same tracks.

For our new ship, HSwMS *Nils Strömcröna*, the safety margin of 25 metres has been overcome. As the ship is of double-hull construction she carries two transducers, 10 metres apart. Furthermore, she is equipped with two more transducers, each in a miniature hull mounted on a beam on each side. This gives her the ability to cover four tracks simultaneously with a spacing of 10 metres between each.

Under certain conditions, when a sparsely surveyed area is to be completed, lines not parallel but at right angles to the old ones are chosen. This eliminates the risk of the old and the new tracks getting stacked on top of each other. Conditions for this might be rough seas or positioning methods with low repeatability.

As 100% bottom coverage is sometimes very costly to achieve and is not always required, the surveying operations are often planned in such a way that the risk of not finding an underwater obstruction is minimized. The spacing of the surveying lines is a function of water depth, largest draught, etc. For planning purposes a statistical model is used.

## Positioning

### *Equipment*

The Swedish Hydrographic Department have today (1986) access to the following positioning systems :

- Sea-Fix :        2 receivers + 1 spare  
                  1 master unit + 1 spare  
                  5 slave units
- Syledis :        1 mobile unit type B  
                  1 mobile unit type A upgraded to almost B  
                  7 beacon units type B
- Mini-Ranger : 4 console units  
                  16 reference units.

As a minimum of three distances are always used in each area and as each receiver can only handle two distances, the two Sea-Fix receivers are always working together. This means that a total number of seven ships can be independently positioned

### *Calibration*

The calibration of the positioning system is performed with different methods depending on the circumstances. Apart from classical methods with baselines or theodolites and EDM's a new method has been developed. It was presented at the IHTC in Plymouth 1984 and utilizes no external instruments. Redundant observations from the shore stations are used in a least squares solution that yields the calibration values.

Calibration of the systems in the physical sense is never done. The calibration values are used as corrections in the positioning program which saves a lot of time. No calibration is done without redundant observations. This means three theodolites, two theodolites and one EDM, etc. Check of the calibration values is done automatically as the surveying is also done with redundant observations. At the moment only three lines of position are used. Four lines will not only increase the accuracy but will indicate which line is in error and so save a considerable amount of time.

### *Navigation*

Navigation is never, as earlier, confined to lines of equal distance, equal bearing, along lanes, etc. Regardless of the location of the shore station, as long as the intersecting angles are good, a pattern of equidistant lines is constructed over the area.

Parallel to the lines a local co-ordinate system is created with the co-ordinates denoted R and S. This gives total freedom in the planning of the survey and ensures the best logistic/economic solution. The mother vessel steers along a line with constant R or S value and with increasing or decreasing S or R values.

For navigation, a positioning program is run on a Databoard 4680 micro computer. The program language is Assembler in order to make best use of the limited memory of this machine.

The output from the positioning systems, consisting of the three uncorrected distances, is corrected in the program for calibration and antenna heights. Projection corrections are applied and X/Y co-ordinates calculated. These are then transformed to R/S co-ordinates in the local system.

These co-ordinates, together with entered information about the local co-ordinate system and data regarding the predetermined lines, are used to calculate information for the EMRI analogue autopilot system. The computer control of the survey is almost total. No helmsman and, practically, no echo sounder operator are required, since markings on the echograms are also controlled by the computer program.

At different locations on the bridge, groups of up to four displays show valuable information. The displayed information is selectable from the following list.

1. Predetermined cross track co-ordinate value
2. Current cross track co-ordinate value
3. Distance off track (1. minus 2.)
4. Current co-ordinate value along track
5. Distance to next marking
6. Distance from station A
7. Distance from station B
8. Calculated error in distance to station C
9. Time
10. Speed over ground
11. Compass course.

The program runs through different loops with different priorities, the main loop handling the computation of position and feeding the auto-pilot. Other loops check the shore stations for signal strength and intersecting angles. If one station fades out or if a pair with a better angle is found, the program automatically selects a new pair.

### *Satellite boat positioning*

The satellite boats are positioned at regular intervals on both sides of the mother vessel. The spacing is usually 25 or 50 metres. Trials with other spacings have been started in order to increase the efficiency of surveying.

By measuring the return time of a transmitted burst of 455 kHz signals with a 20 MHz clock, each boat knows its distance from the mother vessel. A left/right indicator in front of the helmsman gives him analogue visual information about his offset. This signal is also transmitted to the mother vessel where, on a CRT colour display, the offsets of all satellite boats are shown. In the future this information will be stored together with the depths in the data logging system.

To hold the satellite boats in place, along track, a moiré beacon is mounted on each side of the mother vessel. That beacon consists of two planes, the one closest to the

observer vertical and the other with its top tilted towards the observer. The planes are illuminated from behind. For an observer positioned in a plane perpendicular to the front of the beacon, the moiré pattern from the threads will look like vertical lines. When the position is altered the moiré lines will tilt, with the degree of tilt indicating the distance from the perpendicular and the direction of tilt indicating on what side the observer is situated.

### **Echo sounders and transducers**

The Swedish Hydrographic Department uses exclusively the Atlas DESO 20 echo sounders. As will later be explained, these are modified to suit the special demands of formation sounding.

Two types of transducers are used in formation sounding. Atlas SW6016 and Reson TC6. The SW6016 works at the 100 kHz frequency and has a beam angle of 13°. The TC6 operates similarly on 100 kHz but can be switched between 13° and 19°.

The satellite boats carry the transducer, transmitter, receiver and some controlling electronics, while all recording equipment is carried onboard the mother vessel. This spares the equipment the often harsh environment aboard the small boats. It also saves personnel, as only a helmsman is needed for each satellite boat. The operation of the recorders is much easier on the mother vessel and two persons can service the recording equipment for the whole formation.

As the DESO 20 is a two channel echo sounder it has been possible to redesign it. A Databoard 4680 micro computer is built into the recorder. It controls the transmission, stores the depth figures and controls different corrections. It divides the paper into an upper and a lower half, each half representing one transducer so that two separate graphs are registered on the paper. The number of recorders is thus strongly reduced, which saves space and money as well as operators.

To overcome the problems with interference a special solution is applied. As long as the echograms were manually evaluated this was a small problem as the human eye could easily sort out the false echoes. Today, when the signals are digitized, the problem is more serious. The solution is what is called stochastic transmission. Transmission time for each pulse is composed of two parts. The first is a fixed time delay of 8 milliseconds duration from the return of the previous pulse. The second part is a stochastic time interval derived from a random number generator. This has a duration of between zero and 1.5 times the time it takes for the pulse to reach the bottom.

### **Data link**

Communication between the mother vessel and the satellite boats is handled by a microwave data link. It operates in the 10 GHz band (3 cm), one channel for each satellite boat. The transmitter in the satellite boat is triggered by the echo sounder computer in the mother vessel over the data link. The echo from the receiver is then, in analog form, sent back the same way to the echo sounder computer.

## Digitizer

The digitizer can, in some aspects, be regarded as the brain supervising the echo sounding. It receives the return signals, samples them and decides what is the most probable depth if there are contradictions. It converts the analogue signals to digital format and feeds the data logging system. The signals to the recording amplifier in the echo sounders bypass the digitizer and will look like analogue ones.

The digitizer, in order to avoid locking on a false bottom, has for each emitted pulse from the transducer the ability to register four different echoes. The last 32 groups of echoes are always stored. By looking back, the digitizer can decide what is the true bottom and what is false echoes (from fish, etc.). To do this it utilizes a continuity algorithm.

To perform all these tasks, the digitizer is equipped with a Databoard 4680 micro computer, the same as for navigation purposes. This type of computer is also used in the echo sounders as well as in the water level gauge. Working with the same type of computer for different purposes makes development and service easier.

## Water level gauge

Finding a reliable, accurate, transportable and easy mountable water level gauge proved difficult. Finally, a private company was given the task of developing one according to our specifications. A prototype was first tested and the final version, after some modifications, is now working satisfactorily.

The water level gauge operates by measuring the capacitance of a length of wire, halfway submerged in the water, mounted in a slotted pipe. On the control panel the time interval between measurements can be set. Output is on a roll of paper from a small printer and gives date, time, water level and battery voltage.

The output is also broadcast to the ship or ships operating in the area. The message consists of two parts and is repeated twice. The first part is digital and goes to the positioning computer. The second part is synthetic voice which means that no computer has to be involved.

As the radio is two-way, a measurement can be triggered from the ship at any time, regardless of the chosen time interval.

Before operation, the gauge is calibrated, both internally and against a benchmark of known height above mean sea level.

Each measurement is done over a one-minute period. Using auto-correlation the waveform is reconstructed and from this the sea level determined. The advantage of this procedure is that the pipe does not necessarily have to be placed in calm water.

## Data logging

Finally, as far as the field work is concerned, all data from up to nine digitizers, the positioning computer and the water level gauge are collected by the data logging computer system. Once again the computer is a Databoard 4680 system with its own CRT terminal, disc and printer.

The main task is to collect all relevant data and store it on a 1/2" magnetic tape 1600 BPI. The data can be divided into three main groups, general information, track information and point data.

### *General information*

The general information consists of type of positioning system, positions of the shore stations, area limits, reduction information and information concerning the vessels. This last item consists of transducer depth, antenna elevation, serial number of datalink, digitizer and echo sounder, surveying method, projection, spacing, water level and type of measurement. This information is valid for all tracks and does not have to be repeated.

### *Track information*

This consists of number in formation, position across track, offset from predetermined track and position along the track together with date and time information.

### *Point data*

This is really what we are out there looking for, the depths. As the number of all depth figures coming from the digitizers would soon fill up the tape if all depths were saved, a reduction is done before storing. The reduction is based on a simple algorithm where only three depths are stored as the bottom profile passes between two levels predetermined by the operator. The registered depths are those on the passage of a level and the min. and max. values found between this level and the previous one. The choice of levels is arbitrary and can be set with smaller intervals for particularly interesting depths. If no level is passed within a certain time predetermined by the operator, a time-out occurs and the instantaneous depth together with min. and max. values since the last storing is stored.

Each depth is stored together with information on number in formation and position of leader vessel and constitutes a unit on the tape.

All depth levels and time-out limits chosen by the operator are stored in a parameter file.

## CONCLUSION

This is, almost, the end of the field work. A preliminary evaluation of the surveyed area is done during field operation. This is done in order to ensure that no part of the area has been surveyed with a larger spacing than the depth demands. This evaluation is done manually from the echograms with, sometimes, only preliminary information about the water level. The final evaluation is done at the department in Norrköping, where the rest of the process, ending in a completed chart, is carried out.