Hydrographic Survey Using SEABAT

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The original was written in 1999, and our hydrographic surveys using SEABAT have now improved through the following experience.
It has been about 4 years since the SEABAT9001 (SEABAT) was installed in the survey vessels. The system has been efficiently used for the search of sunken ships and shallow sea identification, but has seldom been used for ordinary hydrographic surveys for depth sounding, in which conventional echo-sounders are used.

The reasons for this situation are the following:

- Procedures for surveying and data processing are not well established
- Practical procedures for calibration, such as bias correction of the system, and data acquisition have not yet been developed.
- Practical specifications, such as guidelines for sounding, have not yet been completed

This paper reports on the system overview, and our attempts to try to establish practical guidelines to use SEABAT and associated data processing, in order to apply this system for harbour surveys and sea bottom obstacle identification.

System Configuration and Data Processing Flow

System Configuration

The SEABAT9001 used by the department consists of a sonar component, a heave-roll-pitch sensor component, a gyrocompass, vessel positioning component and a data storage and display component. (Kokuta. et. al., 1996). The sonar has two components; a sound transducer (Sonar head), which has 60 narrow beams (455 kHz,1.5 degrees x 1.5 degrees) providing a

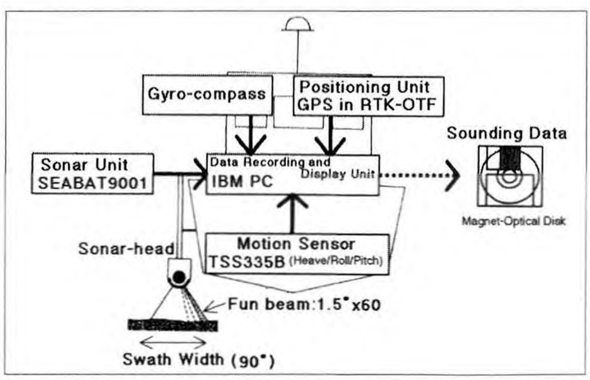

Figure 1: Composition of instruments

total of 90 degrees swath width (sometimes termed; scanning line), and an onboard controller to manipulate the beams. In addition, the sonar head is removable for convenience when underway, and fixed to the side of the survey vessel during the survey operation.

The heave-roll-pitch sensor component (TSS335B, the motion sensor) measures the inclination of the vessel in motion, and is indispensable to convert the slant depth into the real bathymetric depth.

The vessel positioning component has to be accurate as a positioning reference in order to calculate the depth from each beam projected, and the RTK-OTF GPS method is used.

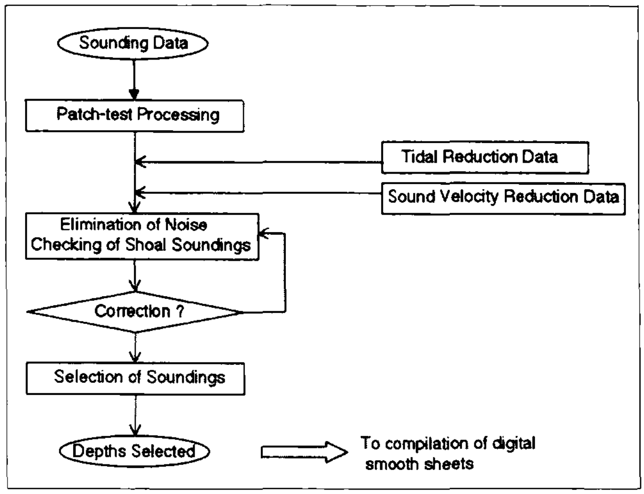

Figure 2: Work flow

The gyrocompass is also essential to provide an angular reference to measure each beam position, and the data from the gyrocompass of the survey vessel is used.

The data-storage-display component records all the data mentioned above with the measured time for a reference (HYPACK is used for recording), and to monitor the data in order to adjust each measuring device.

Data Processing Flow

Measured data is transferred to the data processing device, through an Optical-Magnetic disc, and adjusted to determine the depth through the procedures listed bellow.

- Correction for bias error and internal time delay of a motion sensor (roll, pitch, and yaw) on the surveying vessel (hereinafter termed Patch test)
- Correction of underwater sound velocity and tidal height
- Noise identification/elimination, distribution check and mapping of shallows and sea bottom obstacles such as fish shelters
- Depth data selection

Carrying out the whole data processing using digital computing devices, we are concerned with the huge amount of data for data storage and management, so this system needs to be robust to prevent data deletion and damage.

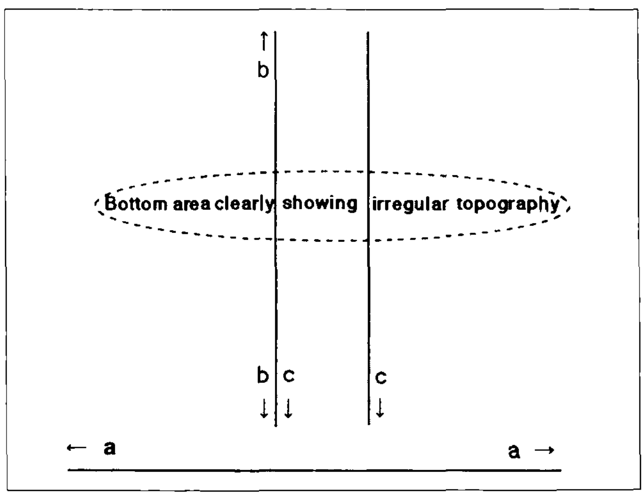

Figure 3: Patch test sounding lines

a. Detection of roll angles for correction (applying for sounding at an ordinary sounding speed on a sounding line established in areas with flat bottom)

b. Detection of internal delay and pitch angles for correction (applying for sounding at an ordinary sounding speed on a sounding line established in areas with irregular bottom)

c. Detection of yaw angles for correction (sounding on two sounding lines in parallel and in the same direction, being fan beams overlapping each other half of the swept bottom clearly showing irregular topography)

Data Processing

To efficiently process the data from the swath sea bottom survey, and to determine the depth, the following procedures are conducted:

Patch Test

The depths derived from a swath surveying system like SEABAT, are greatly affected by motion components, such as roll, pitch and yaw, in the surveying vessel motion sensors. To obtain accurate water depth, adjustments of vertical and directional axes alignments between the installation of the transducer (Sonar head) and the motion sensors, and internal time delay by the time difference between sounding, positioning, data processing and recording, are necessary. Particularly, the latter internal time delay of positioning to sounding is apparent and its correction is essential not only for this but also for every survey system.

The correction values mentioned above are calculated from the data taken in the examination of sounding lines as shown in Figure 3, using software for the Patch Test program by HYPACK.

Correction for the internal time delay with positioning to sounding is sometimes computed using the differences of sea bottom target detection due to the survey vessel speed. But as Figure 4 shows, it is practical to calculate correction time from a dataset along two tracks, which follow a same sounding line in opposite direction at specific places and shallow sea area using the coincidence of the objects. The correction of this approach can cover other error factors such as antenna positioning error, and so on.

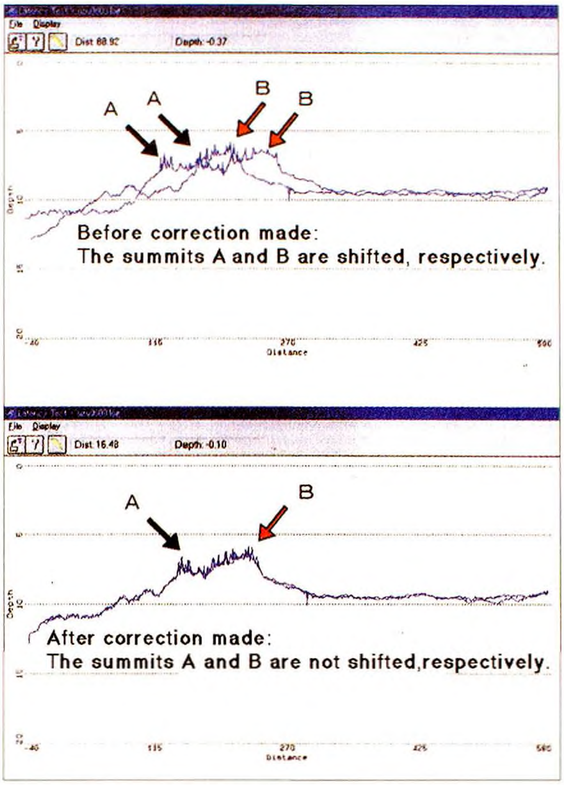

Figure 4: Detection of internal delay of the positioning system. A both-way observation of time difference between time of position fixing and time of position recording on an observation line. The difference in time obtained is an internal delay

Motion Correction Anomaly

Recently some troubles of anomaly measurement caused by errors of the motion sensor were reported. Incorrect values of the motion sensor lead to abnormal sea depth. Figure 5 shows a sample how the data containing an anomaly in the motion sensor introduces a wrong correction and a false object on the record. At present, a conventional sounder (PDR601) is operated simultaneously, the data from the swath system may be checked with its data. As PDR601 does not cover all the swath area, a false shallow sea area may occur on the record. So checking of the motion sensor is important to counter any false data, and the motion sensor record should be monitored on board utilising illustrative displays such as Figure 5 if necessary.

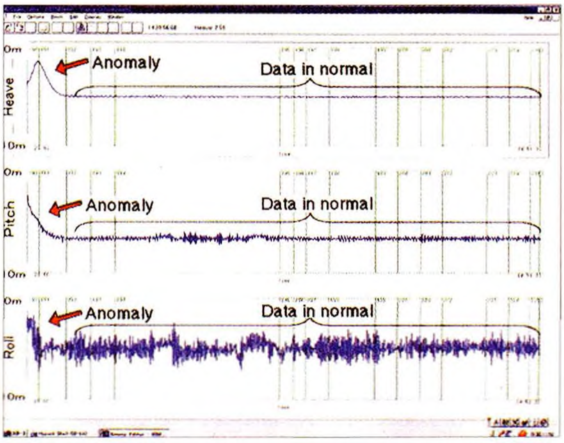

Figure 5: Motion sensor record. As shown in the illustrations above with three arrows, a projecting portion with a relative height of 8 metres may appear if the data containing anomalous ones are processed

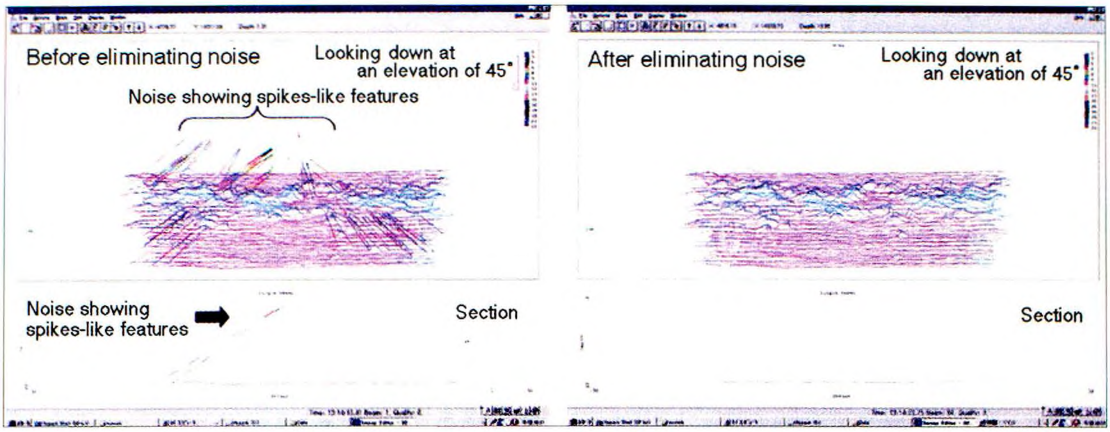

Figure 6: Elimination of noise. Clear noise as shown on the sample record above can be eliminated easily. Distinction may however be quite difficult for a shoal of fish on fish havens, etc

Noise Elimination and Shallow Detection

The digital record could not detect reflection strength, or distinguish from the sea bottom, floating objects and noise. At present, a PDR-601 record and field note are used for this kind of identification and detection. Considering the swath bandwidth, the current approach is not yet complete. As Figure 6 shows, spike noise (resulting from aeration caused by ship's motion) could be unconditionally eliminated, but in those places where shallow area and fish shelters exist, the system fails to record the sea bottom because of floating objects and noise.

In those cases, adjacent swaths should have a good overlap and searches carried out from different directions, to detect the same object. For example, as Figure 7 shows, a northing course record shows that fish shelter like objects appear underneath in A, starboard in B and C. On the half overlapped scanning course in the east side, southing course records shows similar objects appear starboard in A, underneath in C, and B. Judging from these records, either a fish shelter or noise may be identified by the shape, distribution and the difference in height.

A dredged area and adjacent area to a pier are also handled in a similar way.

Swath Width Effective for Depth Interpretation

The interpretation of depth ideally needs the whole range of 90 degrees swath width and this makes field operation most efficient in a short time. As motion corrections are not so accurate at the edge of the

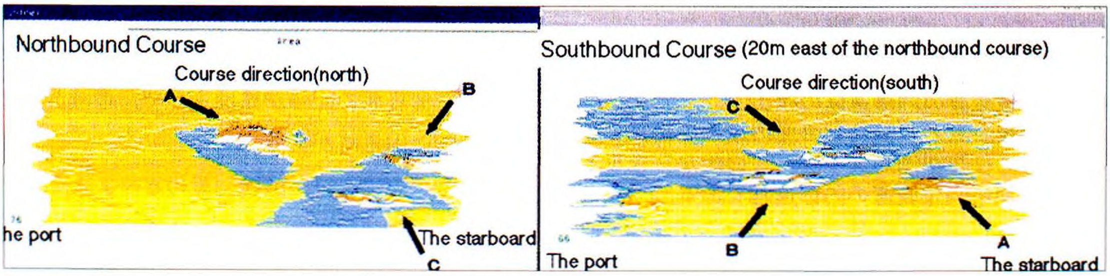

Figure 7: Comparison of adjoining courses (An interval of sounding lines is 20m; and the depth of water is 20m.) Distribution and relative height of obstructions or foul bottom should be confirmed on the echograms, on which these obstructions on the bottom are shown reversely in the northbound course and the southbound course, overlapping half of the zone of the swept area

swath area where the beam angle is large, depth is accordingly much more influenced by the error of motion correction, and in practice the discrepancy from true depth reaches 1m (cf. Figure. 8). Figure 9 shows an example, in which adjacent survey lines introduced a false mound or furrow shape at the conjugate parts, in case the full amount of data with the total range of swath was used.

Side scanning sonar could be used for recognition of sea bottom terrain, but for depth interpretation for chart production some acceptable range of the swath should be applied.

Acceptance range for depth measurement requires 20cm(+- 10cm) difference between measured and true depth in the flat sea bottom surface area (cf. Figure 8). Measurements out of this criterion are regarded as reference depth, similar to the slant depth of the PDR601, for sea bottom terrain recognition.

Our empirical data show that measurements less than 45 degrees is mostly within a 20 cm limit and acceptable for measuring depth. But in the extreme cases with large motion correction due to a rough sea surface, measurement less 30 degrees may be recommendable, and it should be selected checking the all correction data.

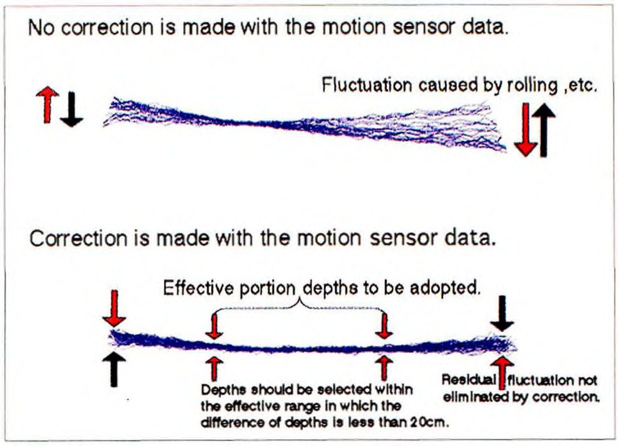

Figure 8: Effective range of depths to be adopted

Bathymetric Measurement Operation

Based on the previous considerations, bathymetric measurements to pursue precise hydrographic survey are summarised in the following items:

General Bathymetric Survey Area on Sandy-Muddy Bottom

The scanning beam has a wider reflection area (footprint) according to a wider angle of scanning, and is affected by sound velocity, so it tends to have anomalous data not acceptable for water depth. If unmeasured breadth were assumed in the planning phase of operation, additional measurements would be required to ensure data quality during operation. Therefore full coverage swath survey is recommended for an area shallower than 30m with sandy-muddy terrain surface.

Bathymetric Area on Rocky Bottom

The SEABAT may be used for general bathymetry to identify the distribution of rocky dangers, their shape and shallowest points. Depending on the shape of the obstacles, the record may include shadow zones, Bathymetric surveys in these area should be conducted with the utmost caution because noises and real reflections from obstacles may confuse each other. But survey lines should be planned to the close enough, taking into consideration the effective swath width (Figure10 a).

Bathymetric Area on Sea Bottom Obstacle, Such as Fish Shelter and So On

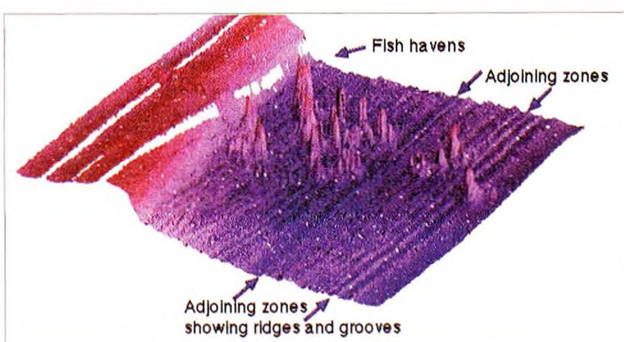

Figure 9: A whale-eye view produced by using bathymetric data A sample of 3-D CG showing ridges and grooves on the marginal zone of the adjoining sounded areas. The height of ridges should be less than ±10 cm

Basically similar caution should be paid with the above mentioned rocky bottom area. Backscatter from fish shelters on the sandy-muddy shallow bottom within 4m deep causes gaps in the data or strong second echo. Adjustment of sensitivity improves this problem, but sometimes dual measurements focused on both sea bottom and fish shelter are needed.

Dredged Area

According to swath width, 2 or 3 survey lines may be enough to cover the surveying area, but overlapping lines are needed to detect specific objects on the sea floor. Special care is necessary for slant slope of dredged area for the shaded parts. Even along the pier bottom surface distribution of substratum rocks are to be detected (Figure 10 b, c, d).

Patch Test

Whenever the sounding transducer is equipped on the vessel, the Patch test is compulsory. Then operation planning for time and place is to be combined with bathymetric lines for efficiency.

Further Subjects

Our attempts have made the SEABAT system feasible for practical hydrographic survey operation. But the data from the swath margins are not yet acceptable for measuring true sea depth. However, comparing our data, incomplete motion correction according to the sea surface circumstance was not so critical on the data

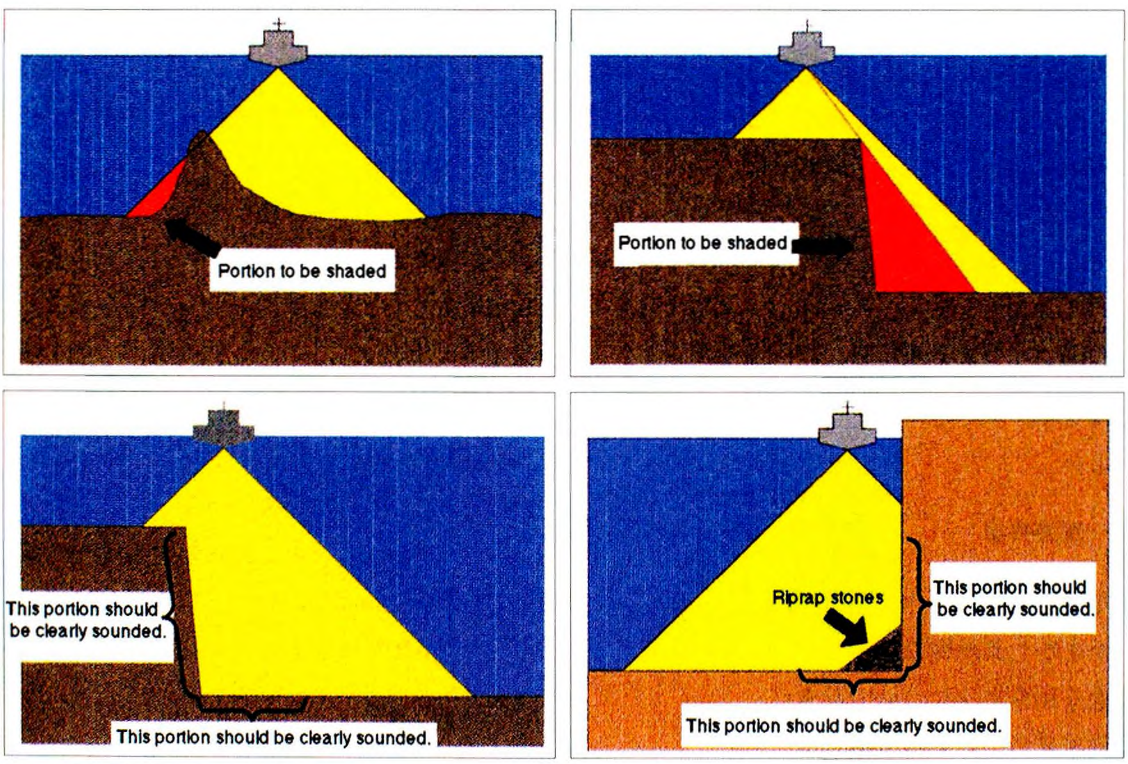

Figure 10: Remarks on sounding operations

a) In case where an area on the seafloor is shaded by some features, another sounding line should be run to cover such an area by echo sweep

b) In case where an area on the seafloor is shaded by a side-slope of dredged passages, such shaded areas cannot be sounded leaving the seafloor veiled

c) In case of b) above, another sounding line should be run to cover such shaded area. For sounding to be carried out by using the SEABAT system, sounding lines should be so established that the beam fan should cover the wharf frontage to check riprap stones as shown on the illustration above

of the SEABAT8101 (Swath width 150 degrees, mounted on the survey vessel *Okishio*) installed in March 1999.
The reasons why the data of our SEABAT differs this model, might be the following and are to be solved in the future:

- Mounting iron pipe with Sonar head on broadside vibrates with the water wave resistance, and its vibration may affect the sounding
- Motion sensors are not located above the Sonar head
- Sound velocity measurement is carried out once a day at one place, and sound refraction correction may be incomplete
- Performance of motion component sensors (response and inner delay etc.)
- Huge amount of data to be processed, displayed and corrected, requiring a high-performance computer or management

Summary

Hydrographic surveying using SEABAT is expected to reduce the number of survey lines and to produce the digital survey original chart efficiently.
Since the sonar transducer head is removable, it needs time for installation and a Patch test, and survey vessel velocity is limited to less than 5 knots because of water wave resistance. The sonar head should be mounted on the ship bottom to avoid these limitations.
The Hydrographic Department has now 6 sets of SEABAT (9001 type; swath breadth 90 x 3 sets, 8101 type swath breadth 150 degrees x 3 sets).
Some private and public organisations introduced, or have plans to introduce narrow multi-beam sounding systems for shallow water. As a leader and an examiner for hydrographic surveys, in order to qualify SEABAT and evaluate similar systems in practice, official operational rules and guidelines are desirable for our Hydrographic Department.
In concluding this paper, the authors would like to express their personal thanks to various supports and kind advise for this research work.

Biography

Hirokazu Mori is Chief, Hydrographic survey section of Hydrographic Division of 1st Regional Coast Guard Headquarters since 2000. He had been belonged to Hydrographic survey section of Hydrographic Division of 5th Regional Coast Guard Headquarters in KOBE from 1990 to 2000. He has carried out a hydrographic survey with a multi-beam for shallow waters from 1995.