Technical Information

IHO Standards & Data quality

IHO Standards

S44 sets out the standards required for the execution of hydrographic surveys for the collection of data primarily intended for the compilation of navigational charts to be used for the safety of surface navigation and the protection of the marine environment.

You will find more information about IHO standards and in particular about S-44 IHO standard for hydrographic surveys here:

- www.iho.int
- www.iter-systems.com

Interferometric sonar data quality

The quality of the data from a swath bathymetry survey is measured as Total Propagated Uncertainty (TPU). Components of the TPU include:

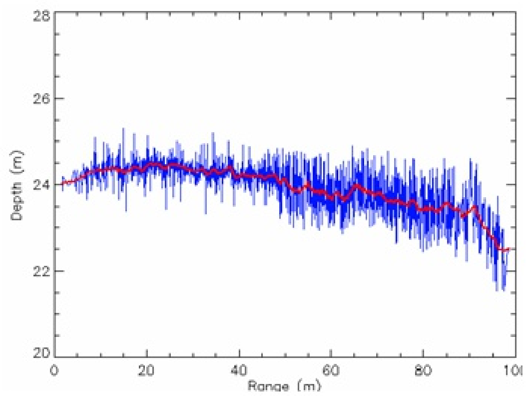
- Random statistical variation in depth measurements by the sonar.
- Angular offsets due to misalignment between motion sensor and sonar, and static errors in angular measurement: these are largely removed using Patch Test Calibration procedures.
- Dynamic accuracy of the motion sensor.
- Position and GPS height measurement accuracy.
- Tide accuracy.
- Speed of sound ray-bending.

All of these except the first are common to all types of swath sonar. Interferometers (PDBS - Phase Differencing Bathymetric Sonar) have a very different statistical "signature" to that of beam-forming sonars (MBES). Interferometers give many more data points per side (2000 to 8000) than beam-forming sonars (100 – 200), but the uncertainty of raw data points is also greater. Software filtering reduces this uncertainty to internationally acceptable survey limits, at the expense of survey resolution.

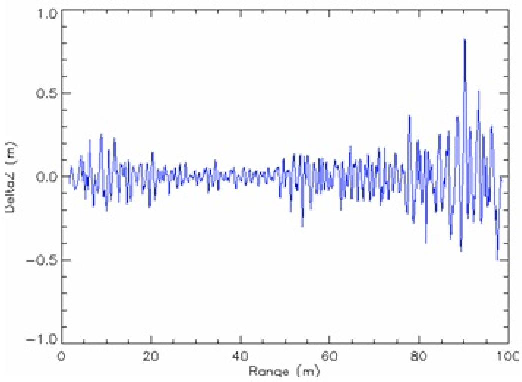
Data quality analysis

Analysis of real data and mathematical modelling demonstrates that interferometers can meet tight international data standards, such as the International Hydrographic Organisation (IHO) S44 specifications. A simple analysis demonstrates this. A set of SWATHplus (now called Bathyswath) sonar depth profiles was extracted from the data sets that were submitted to the 2008 Shallow Water data set. These data sets were collected by USGS, using their own SWATHplus systems and normal operational survey procedures (speed, line spacing, etc.).

Profiles were analysed at all three SWATHplus frequencies: 468 kHz, 234 kHz and 117 kHz. Depth error was first estimated by comparing raw data points with an averaged profile; see Figure 1 & 2 below.



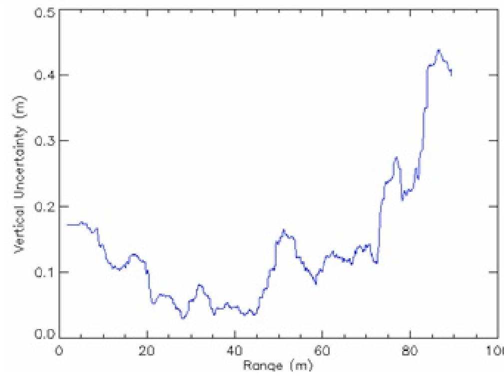
(Figure 1) Depth profile
Blue: raw data, red: average



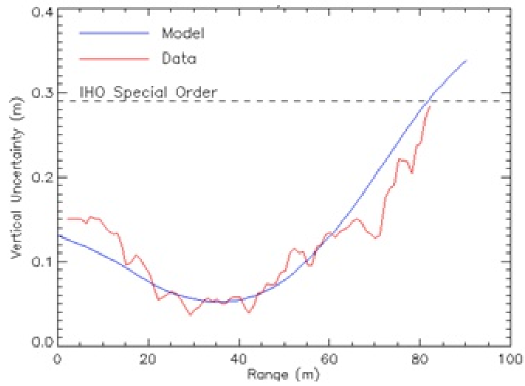
(Figure 2) Estimated error of raw data

Next, the software filtering was mathematically modelled using a sliding window filter. The width of this window was selected to satisfy the S44 requirement for a given number of accepted data points per square metre, using the across-track criterion (along the profile) and along-track criterion (profile separation, from vessel speed and ping repetition frequency).

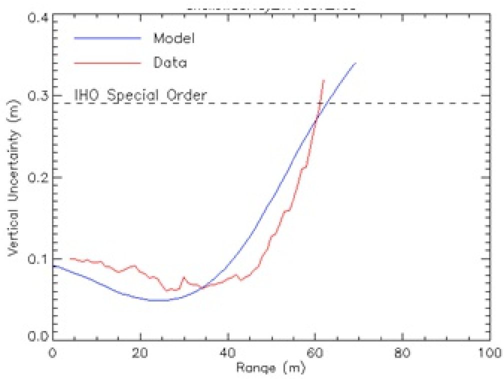
- The smoothed points were converted to 95% uncertainty, using the statistical method recommended in IHO S44; see Figure 3 below
- This procedure was repeated for a number of "pings" in the data set, and averaged by range: see the red line Figure 4.
- A mathematical model of phase error in SWATHplus was created, and validated against the observed uncertainty; see the blue line in Figure 4.
- The process was repeated for all three SWATHplus sonar frequencies (the Shallow Survey data set includes data from all three). The 468 kHz data and model are shown in Figure 5.



(Figure 3) 95% Uncertainty of smoothed data

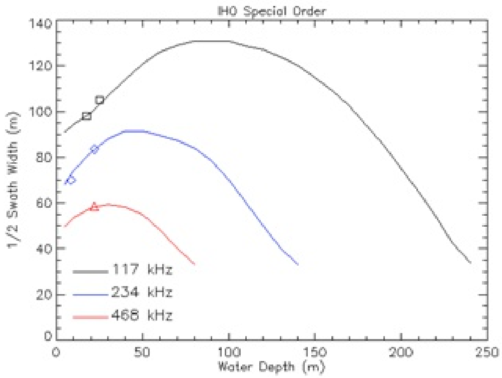


(Figure 4) Average data uncertainty, 234 kHz

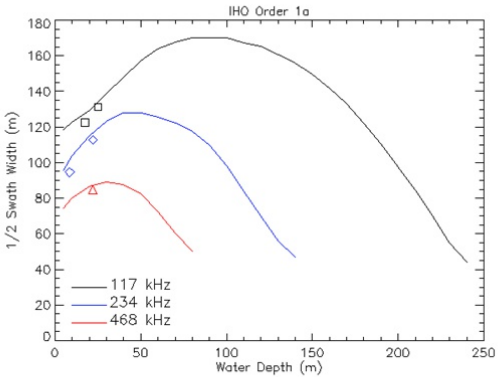


(Figure 5) Average data uncertainty, 468 kHz

Finally, the models were used to graph the maximum range (half swath width) at which the IHO S44 Special Order is met; Figure 6 & 7.



(Figure 6) Horizontal range at which IHO S44 Special order is met



(Figure 7) Horizontal range at which IHO S44 order 1a is met

In conclusion, error modelling, validated with real survey data, shows that interferometric sonars are capable of providing survey depth accuracy within the requirements of IHO S44, Special Order, at good ranges. Longer ranges are achieved with the lower-accuracy Orders.

Qualifying data for charting

When surveying to collect data that will be used for type-approved charts, the approval authority may require that the survey is run in a way that allows them to be sure that the data collected meets their data quality requirements. The following concepts have been designed in discussion with the United Kingdom Hydrographic Office (UKHO) and Maritime and Coastguard Agency (MCA), in order to meet the needs of the International Hydrographic Organisation (IHO) Special Publication 44 (S-44). However, no automatic approval of these or any other approval authority can be assumed; discussions may be required with the approval authority for each new case.

The design of a SWATHplus survey needs to consider two basic quality criteria:

- Depth accuracy
- Spatial resolution

These two parameters can be traded off against each other, using statistical processing.

Accuracy (uncertainty) is defined by IHO S44. This defines:

- Total propagated uncertainty (TPU),
- Resolution (detection of small objects),
- Data coverage (accepted soundings per metre)

The TPU is reduced using the filters in swath software, but these filters will also reduce the effective resolution and data coverage statistics.

The Bathyswath software provides two main types of filter:

- Removing data points that are unrelated to the seabed. These might be valid mid-water targets, or they could come from external "noise" sources. They are removed by filters that consider signal strength and integrity, and filters that require geometrical consistency.
- Down-sampling filters, which reduce data volume and statistical variation. A simple binning filter, which averages all depth measurements that fall within a horizontal "bin", is useful for this. The spatial resolution and the smoothing are both driven by a single, easily understood criterion: the width of the bins.

The IHO S44 standard refers to "soundings" to mean individual depth measurements. It is proposed that raw interferometric data samples are not "soundings" in this sense, any more than the raw electronic data recorded by other sonars, for example before beam-forming.

Rather, a "sounding" is a depth measurement after all statistical filtering and combination, as delivered to the authority for approval.

To achieve approval of data for charting, the following need to be ensured:

- The filters are set so that the statistical variation (TPU) of the data is constrained: this is also a factor of the sonar range, so swath widths need to be kept within suitable limits at survey time
- The filter settings are not so wide that the resolution and data coverage criteria are no longer met
- It can be shown that filter settings used for a particular data set were appropriate for the above

The first criterion (uncertainty) is checked in the delivered data by the approval authority using data quality tools in their charting software. However, this is rather late to discover a problem! Therefore, the Bathyswath software provides real-time data quality views, including standard deviation and uncertainty graphs. As uncertainty is a function of range, the surveyor may need to re-plan the survey with shorter survey line spacing if conditions on site cause a lower data quality than that which was allowed for in planning the survey.

The second criterion (resolution) is assessed by comparing the spatial properties of the filters with resolution requirements of the survey standards being applied. For example, suppose a data density of nine soundings per square metre is required. At typical survey speeds, the along-track density is approximately three pings per metre. Therefore, no less than three soundings per metre across the ping profiles are needed. A typical final stage in data filtering is a down-sampling filter, which averages data samples into horizontal "bins". The maximum size for the width of these bins in this case is therefore 1/3 metre. Resolution is usually defined in terms of detecting a cube of given size: IHO S44 special order requires detection of a 1-metre cube; clearly the filter width should be set significantly smaller than this.

The approval authority may also require to be given samples of un-filtered data sets for comparison, to ensure that hazards to shipping are not being filtered out by the process. To this end, the Bathyswath processing software is capable of providing data in a statistically raw state to tools such as Caris, as well as the processed and filtered data sets.

The third criterion (validating the settings) can be demonstrated if the sonar settings, including the filter parameters, are logged with the survey data that is delivered to the approval authority. However, checking that the settings remain within acceptable limits would be very time-consuming for the approval authority if these settings are changed often. One approach that has been suggested is to use a "black box" approach, in which the settings of the sonar and filters are locked into one "approved" state and never changed. However, in discussions between surveyors and approval authority personnel it was agreed that this would be likely to reduce survey efficiency and accuracy, and therefore in no-one's interest. Therefore, the following process has been agreed:

- At the start of the survey, the surveyor selects the best settings for the sonar and filters. A command in the sonar's software is then set to "lock" these settings.
- The "lock" has two main effects:
  - The settings are written to a log file when the lock is set, and after any other changes
  - Changing any settings causes an "Are You Sure" dialog box to appear, thus discouraging any changes that are not essential.
- The settings log files are time-stamped, and so can easily be compared with the data sets that are delivered.

This process was designed to be similar to that already used with beam-forming multibeam systems.

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