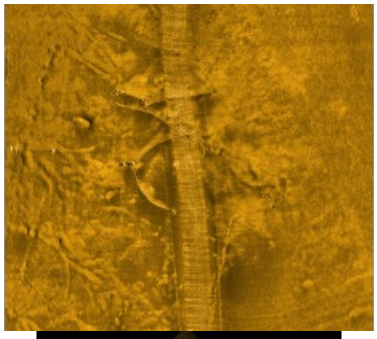
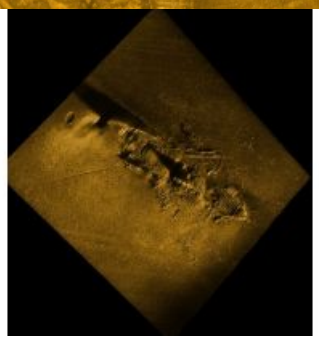
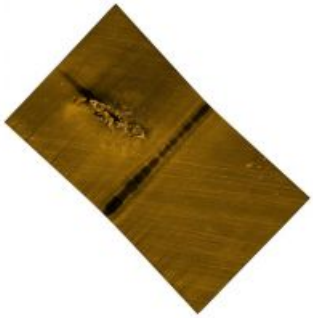
SIDE-SCAN SONAR OR SYNTHETIC APERTURE SONAR

Towards a New Sonar Imaging Concept for Survey







Since the 1970s and the emergence of the first analogue systems, the sidescan sonar (SSS) has experienced several major revolutions. Signal digitization in the 1990s has significantly improved signal quality and robustness. Dual-frequency and interferometric systems have allowed better analysis of the seabed. In the mid-2000s, a significant development was the appearance of multibeam SSS with dynamic focusing. These systems, as well as the integration of the first gap fillers, have allowed considerable productivity gains and improved imaging quality.

(by Frédéric Mosca and Didier Charlot, iXblue, France)

SSS Limitations

But SSS has not evolved much over the past decade. Although the progress made by multibeam echo sounders (MBES) for shallow-water backscatter imaging should not be overlooked, SSS remains the tool of choice for seabed imagery despite several limitations:

- **Variation of the along-track resolution with range:** related to the diffraction of the beams and to the limit of platforms payload capacity in term of antenna length. This range/resolution tradeoff imposes, according to the needs, to work at high frequency (a few hundred kHz) to optimize the resolution, or to work at low frequency (a few tens of kHz) to optimize the coverage.
- **Sensitivity to platform motion:** working with a SSS means using beams of very small aperture to get good along-track resolution. This leads to severe navigational constraints in terms of platform stability which, if they are not respected, generate distortions in the image and thus affect object detection capabilities. [Blondel, 2010]
- **Pixel positioning inaccuracy:** although some SSS are equipped with positioning systems (acoustic and/or Inertial Navigation Systems), the standard methodology of image construction in the platform's reference frame (waterfall) and the projection onto a map (mosaic) does not allow precise georeferencing and platform motion compensation. Consequently, the produced mosaic may show shifts and distortions leading to a lengthy contact repositioning and interlines management process for surveyors.

SAMS mosaic at 10cm grid resolution: full coverage SAS + gap filler.

A New Type of Sonar to Solve Traditional SSS Issues

If standard Synthetic Aperture Sonar (SAS), based on micronavigation [Belletini, 2002], seems the most appropriate system to solve the first limitation, it only partially addresses the other two. Indeed, SAS on Autonomous Underwater Vehicle (AUV) is gaining ground in areas where resolution is critical: Maritime Mine Counter Measures. However, executing this system is complex and it remains extremely sensitive to the platform motion, hence its use on more stable platforms such as AUVs or

actively stabilized towed fish. Furthermore, an important overlap between two successive acquisitions is needed with micronavigation, which limits survey speed. Finally, the large amount of data generated does not always make real-time processing possible as well as raw data storage.

iXblue has thus developed a new type of sonar system, a Synthetic Aperture Mapping Sonar (SAMS), to solve those issues. SAMS is based on the following 3 features:

- **Fine coupling between acoustic data, inertial navigation and acoustic positioning:** it allows focussing on each pixel in the mosaic, avoiding distortion of the projection of the waterfall on the mosaic. The pixels relative positioning precision is almost perfect thanks to the coupling with the INS while the absolute precision equals to that of the acoustic positioning system.
- **Wide aperture in transmission coupled to multi-channel reception and multi-ping integration:** this architecture ensures full coverage even on passive platform in bad conditions of navigation. Multi-channel reception allows dynamic focussing as for a multibeam SSS. Accurate measurement of the relative displacement combined with the wide transmission aperture makes it possible to perform integration over several recurrences.

SSS and SAS mosaic produced by DELPH software at 10cm grid resolution.

This multi-ping integration capability makes it possible to perform the two following synthetic aperture processing simultaneously and in real-time:

- **Non-coherent integration (summation of signal amplitudes)** [Allais, 1998]: allowing for significant improvement of image quality thanks to signal-to-noise ratio gain and coherent noise reduction.
- **Coherent integration (summation of signal amplitudes and phases):** allowing for significant improvement of the resolution. iXblue warrants a SAS gain of a factor of 6 on passive tow fish. For instance, SAMS MT3000 has the range of a 100kHz SSS with the resolution of a 600kHz SSS.
- **A truly integrated survey platform:** SAMS exploits the synchronous acquisition and positioning capabilities of multi-sensor data to offer a fully integrated survey platform. In addition to positioning systems and SSS, SAMS platforms can embed an interferometric system, a MBES serving as a gap filler, a Subbottom Profiler, a pinger locator and a magnetometer. All of the synchronized sensors and navigation data are processed and displayed in real-time in a 3D environment using iXblue's Delph Software. This allows the implementation of data fusion method to improve the survey area analysis.

A Full Product Range for All Applications

The SAMS Series, that can be integrated on various platforms such as towed fish, ROVs or AUVs, thus addresses all the increasingly demanding needs of surveyors:

- **SAMS ST1000** is a plug-and-play SAS interfacing with all types of positioning systems (INS & acoustic). No optical link is required and its implementation is as easy as a conventional SSS. Along-track resolution is better than a decimetre with a 500m swath and is ideal for use in shallow-water or continental shelf applications.
- **SAMS MT3000** is a hydrographic survey platform submersible down to a depth of 3000m. It offers a full swath of 800m for a constant resolution of 15cm. This sonar is best suited for cable route or site survey and has unique capabilities in strong current conditions (Marine Renewable Energy site survey).
- **SAMS DT6000** is a deep towed platform (6000m depth rating) with positive buoyancy incorporating a dead weight and an emergency recovery system. It allows a full swath of 1800m for a constant resolution of 40cm. SAMS DT6000 is the state of the art tool for deep geophysical or search and rescue surveys.

Coherent SAS high resolution mosaic at 3cm grid resolution.

Several marine institutes and hydrographic services are now equipped with SAMS systems and operate it to fulfill their advanced missions, exceeding the traditional limits of SSS while avoiding excessive constraints of use of commercially SAS.

The SAMS series thus expands the capabilities of conventional imaging SSS by integrating positioning and navigation capabilities and performing real-time coherent and non-coherent SAS integration, making SAS technology available to all hydrographic surveyors. The combination of all these technologies gives SAMS systems optimal imaging performance with respect to environmental conditions in terms of swath, resolution, image quality, coverage rate and absolute pixel positioning accuracy.

Further Reading

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Blondel, P. (2010). The handbook of sidescan sonar. Springer Science & Business Media.

Bellettini, A., & Pinto, M. A. (2002). Theoretical accuracy of synthetic aperture sonar micronavigation using a displaced phase-center antenna. *IEEE journal of oceanic engineering*, *27*(4), 780-789.

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This article was published as a sponsored article in the January/February issue of Hydro International.

https://www.hydro-international.com/content/article/towards-a-new-sonar-imaging-concept-for-survey