SYNTHETIC APERTURE SONAR: TECHNOLOGY OVERVIEW AND FUTURE TRENDS

Roy Edgar Hansen Norwegian Defence Research Establishment (FFI), Kjeller, Norway
e-mail: Roy-Edgar.Hansen@ffi.no

EXTENDED ABSTRACT

High resolution sonar imaging has numerous applications in the underwater domain in fields such as marine research, offshore construction, and in the military sector. A trend as in other imaging technologies, is the desire for higher resolution, better image quality, better efficiency (more area coverage), and lower cost and/or smaller hardware footprints.

Synthetic aperture imaging technology uses coherent combination of data collected over multiple locations such that the along-track resolution is improved. The technology is well established in the radar community, both in spaceborne and airborne synthetic aperture radar (SAR)-systems[1]. Synthetic aperture sonar (SAS) technology has also been known in the sonar community since the '70s[2]. However, the technology has been limited to a few groups and not readily available until recently. The reason for this has been various challenges, especially in acquiring the required navigation accuracy. Today, SAS technology is becoming more available and starting to be used in many applications.

SAS imaging is essentially the process of transforming timeseries data into spatial coordinates, similar to SAR, and other phased array imaging techniques[3]. An overview of the signal processing flow including interferometry is shown in Fig. 1.

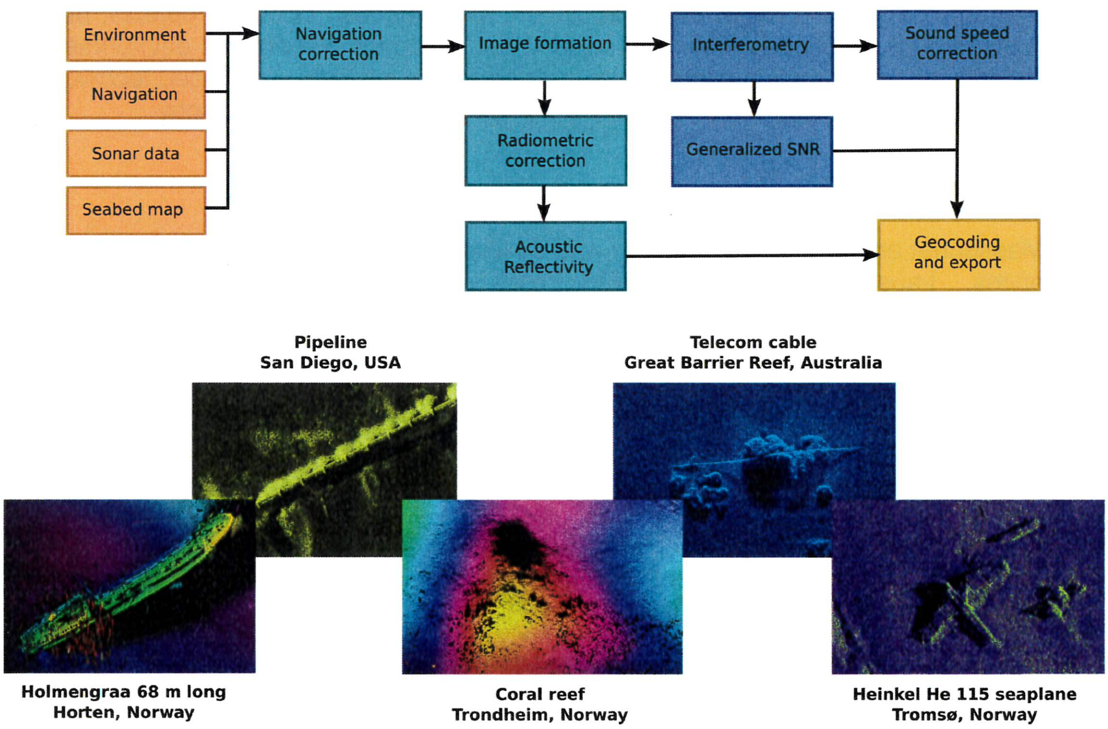

Figure 1: SAS processing flow including interferometry with example images collected by the HUGIN autonomous underwater vehicle carrying the HISAS 1030 interferometric SAS.

For successful SAS image formation, different challenges must be overcome[4]. The along-track sampling criterion must be fulfilled wich leads to multi-element receiver designs. The elements along the synthetic aperture must be positioned with an accuracy better than a fraction of a wavelength. The ocean environment (especially the sound speed profile) must be estimated with a sufficient accuracy. For non-linear synthetic apertures, a terrain model of the seabed must be present under the image formation. When operating on small platforms in harsh environments and rough terrain, the data acquistions should be adapted to environment, and the signal processing should be adapted to the actual data collected[5].

Current state-of-the-art in SAS[6] includes systems that provide centimetre resolution over hundreds of meters of range, giving a real-to-synthetic aperture resolution gain of more than 100. Advanced interferometry processing gives these systems the potential for seabed mapping in addition to imaging. In the future, it is likely that SAS will become an important tool for detailed seabed imaging and mapping for widespread use in marine research, offshore construction, and in military applications.

There are several recent developments that affect the future of SAS: Modern computers (CPU, GPU etc) allow for high performance computing at small and affordable hardware footprints, which can improve SAS image quality and facilitate onboard processing. Broadband transducer technology provides larger frequency agility and more bandwidth. The platforms carrying SAS, autonomous underwater vehicles (AUV) in particular, has become more reliable and more stable. The AUVs carry improved underwater navigation systems, which eases the workload and improves the robustness of SAS. Finally, the key understanding of SAS and how to do SAS processing has made great progress the last years.

Future developments in SAS technology will likely include the following: Absolute calibrated SAS systems for direct estimation of target strength. This has proven very important in SAR, and may be used in many applications in SAS; More frequency agility and larger bandwidth for seabed and target characterization, and detection of buried objects; Better robustness in SAS, especially when operated in rough terrain and difficult environments; Higher resolution and mapping accuracy for interferometric systems; Advanced techniques including use of circular apertures, repeat-pass interferometry and tomography.

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