Synthetic Aperture Sonar Nadir Gap Coverage with Centimetric Resolution

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Abstract
Side-looking imaging sonars map the seabed by transmitting acoustic pulses and processing the backscattered signals. In the across-track direction centimetric resolution is obtained using a wideband pulse, such as a linear frequency-modulated chirp, with a bandwidth of several tens of kilohertz. Although across-track resolution is constant in slant range coordinates, resolution deteriorates near nadir when imagery is projected onto the seafloor. Furthermore, side-looking systems are often designed with narrow vertical beams to mitigate multipath interference in shallow water [1], in which case there is no acoustic return from the seabed in the nadir region. While surveying a large area, for example with a lawnmower pattern, gaps may be eliminated using overlapping tracks with a corresponding reduction in area coverage rate. However, for applications such as mine countermeasures and pipeline surveying, it is often desirable to perform single-pass coverage while filling the nadir gap with centimetric resolution.

The gap fill problem is especially challenging for high resolution side-looking Synthetic Aperture Sonar (SAS). For SAS, the along-track motion of the sensor platform is used to synthesize an aperture with a length that increases with range, thereby achieving constant centimetric resolution in both the along-track and across-track directions. Because SAS resolution is independent of frequency, extremely high area coverage rates are realized by operating at lower frequencies than conventional sidescan sonar to reduce acoustic absorption. As a result, SAS systems are typically operated at altitudes of 10-30 m with near-range imagery beginning at depression angles of approximately 45°, leaving a double-sided nadir gap of at least two times altitude. The combination of relatively high altitude and a nadir gap with angular extent of at least 90° implies that there are no commercially available sensors that can fill the gap with centimetric resolution comparable to SAS [2].

In this paper, we describe and demonstrate the capabilities of a unique gap reduction technique for the KATFISH™, an actively controlled smart towfish with SAS imaging, bathymetry and navigation sensors (Figure *1*Figure *1*). The KATFISH also includes a launch and recovery system, an operator console, and real-time visualization software. One advantage of towed systems is that they achieve high area coverage rates at low altitude by increasing the survey speed compared to self-propelled Autonomous Underwater Vehicles (AUVs). The KATFISH nadir gap solution utilizes an auxiliary transmitter operated at lower frequency with a relatively wide beampattern. The gap fill signals are recorded and digitized simultaneously with the long-range SAS using a single wideband receiver array. The angular extent of the gap is reduced to 60° while maintaining the same along-track resolution of the long-range SAS, as shown in Figure *2*. We present sonar modeling results for the range and resolution performance of the SAS gap fill sensor. Model results demonstrate that gap reduction using an auxiliary SAS transmitter is an enabling technology for maximizing the single-pass area coverage rate with minimal additional hardware complexity and centimetric resolution across the entire swath. Additionally, we will discuss two commercially available sensors for filling the remainder of the

nadir gap: Kraken's SeaVision® 3D laser imaging system with sub-centimeter resolution, and a multibeam echosounder with along-track resolution of approximately 10 cm at the edge of the nadir region in Figure *2*.

Figure 1: KATFISH actively controlled towfish with AquaPix® MINSAS side-looking sonar.

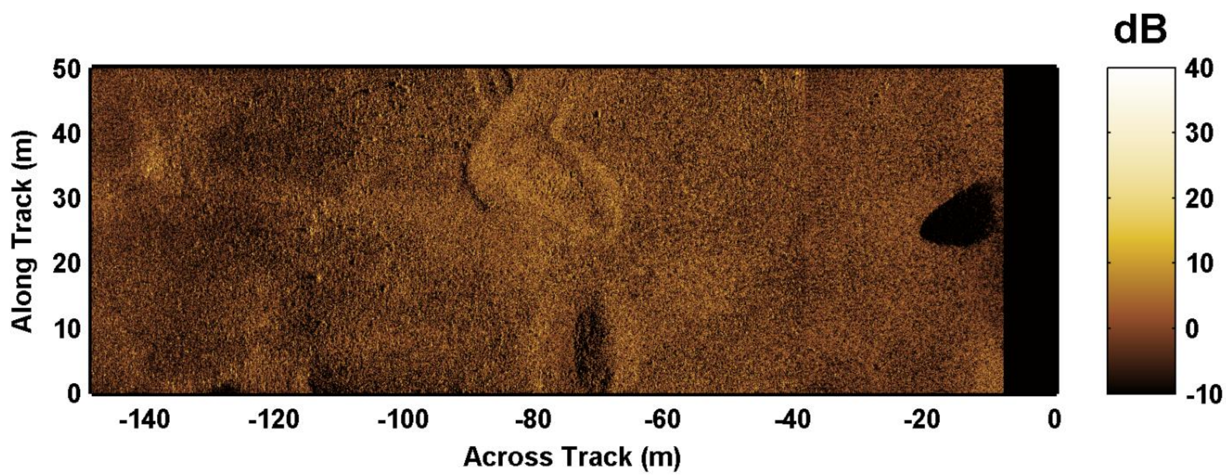

Figure 2: MINSAS and gap fill SAS images superimposed, with nadir gap shown in black.

References

[1] M. Pinto, "Interferometric synthetic aperture sonar design optimized for high area coverage shallow water bathymetric survey", in *Proc. 4th International Conference and Exhibition on Underwater Acoustic Measurements,* Kos, Greece, 2011

[2] P. E. Hagen, "Gap Filler Sensors for SAS", in *Proc. MTS/IEEE OCEANS Conference,* Waikoloa, HI, USA, 2011.