Resolution Measurement for Synthetic Aperture Sonar

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Abstract
The resolution of a sonar image determines the length scale of the smallest objects that can reliably be detected on the seabed or in the water column. Minimizing this resolution length scale is desirable for applications such as seabed surveying for oil and gas extraction, benthic habitat mapping for fisheries research, and mine detection and classification for underwater defence. When a sonar is used for Mine Countermeasures (MCM), the resolution affects the achievable detection probability and false alarm rate, with 5 cm resolution quoted as a typical value for adequate target classification performance [1].

The theoretical resolution of a Synthetic Aperture Sonar (SAS) is determined by the beamwidth of its two-way element beampattern. In practice, resolution may be degraded by unknown factors such as imperfect estimation of the platform trajectory, seabed topography, and refractive effects due to the sound velocity profile. Methods to automatically assess the resolution practically achieved are useful for quality control and for adaptive mission planning.

The resolution of an imaging system is defined in terms of the point spread function, i.e. the response to an idealized point target, or in practice, an object significantly smaller than the resolution length scale. Given that typical SAS resolutions are on the order of centimetres, it is impractical to deploy sufficiently small point targets in a realistic operating environment. Figure *1* shows a typical cube-like target deployed during a sea trial for SAS evaluation, which is significantly larger than the resolution of the sensor.

In this paper, we present a simple method for estimating the resolution of a SAS from only the autocorrelation properties of seabed reverberation. Unlike other methods such as [2], it is not necessary to assume a point-like response from discrete isolated scatterers. Instead, the proposed method only requires the distribution of scatterers to be isotropic, or similarly distributed in the along-track and across-track directions.

Theoretical and experimental results are presented for AquaPix®, a wideband 300 kHz interferometric SAS. For example, the autocorrelation functions shown in Figure *2* were measured from the featureless sandy seabed immediately in front of the target shown in Figure *1*. The method can be applied to any SAS image thereby facilitating a comparison of systems from various manufacturers using a common criterion. Additionally, the method is sufficiently simple to implement that it raises the interesting possibility of estimating resolution “on-the-fly” while adapting the mission plan of an Autonomous Underwater Vehicle (AUV) to achieve a desired probability of detection during MCM operations.

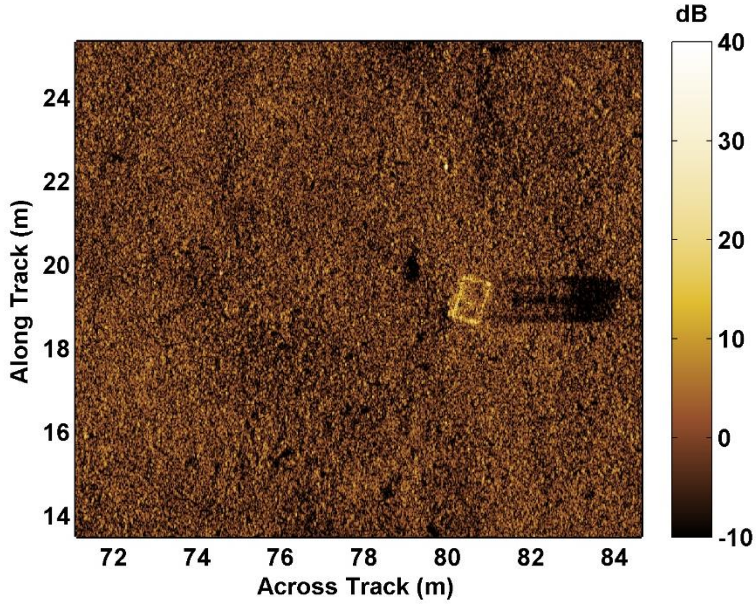

Figure 1: SAS image of cube target and a relatively featureless surrounding seabed.

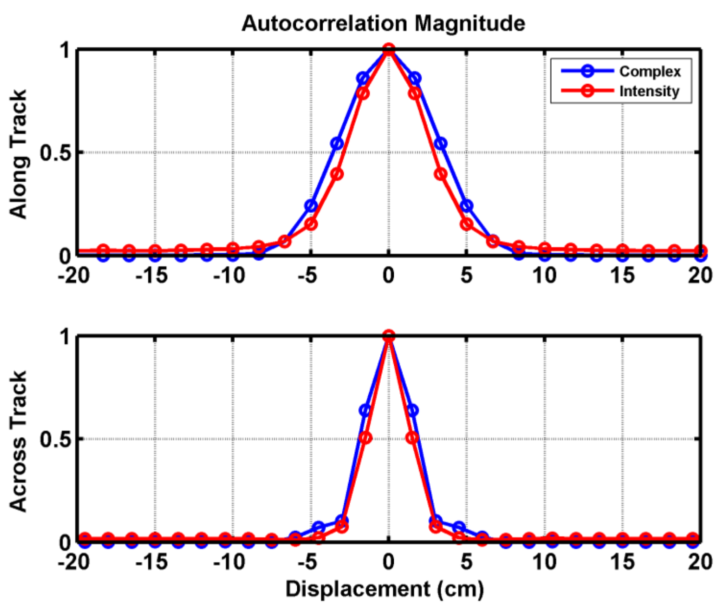

Figure 2: Along track and across track autocorrelation of complex SAS image and its intensity.

References

[1] F. Florin, F. Fohanno, I. Quidu, and J.-P. Malkasse, “Synthetic aperture and 3D imaging for mine hunting sonar” in *Proc. Undersea Defence Technology (UDT) Europe,* Nice, France, June 23–25, 2004.

[2] J. L. Prater, J. L. King, and D. C. Brown, “Determination of image resolution from SAS image statistics”, in *Proc. MTS/IEEE OCEANS Conference,* Washington, DC, USA, 2015.