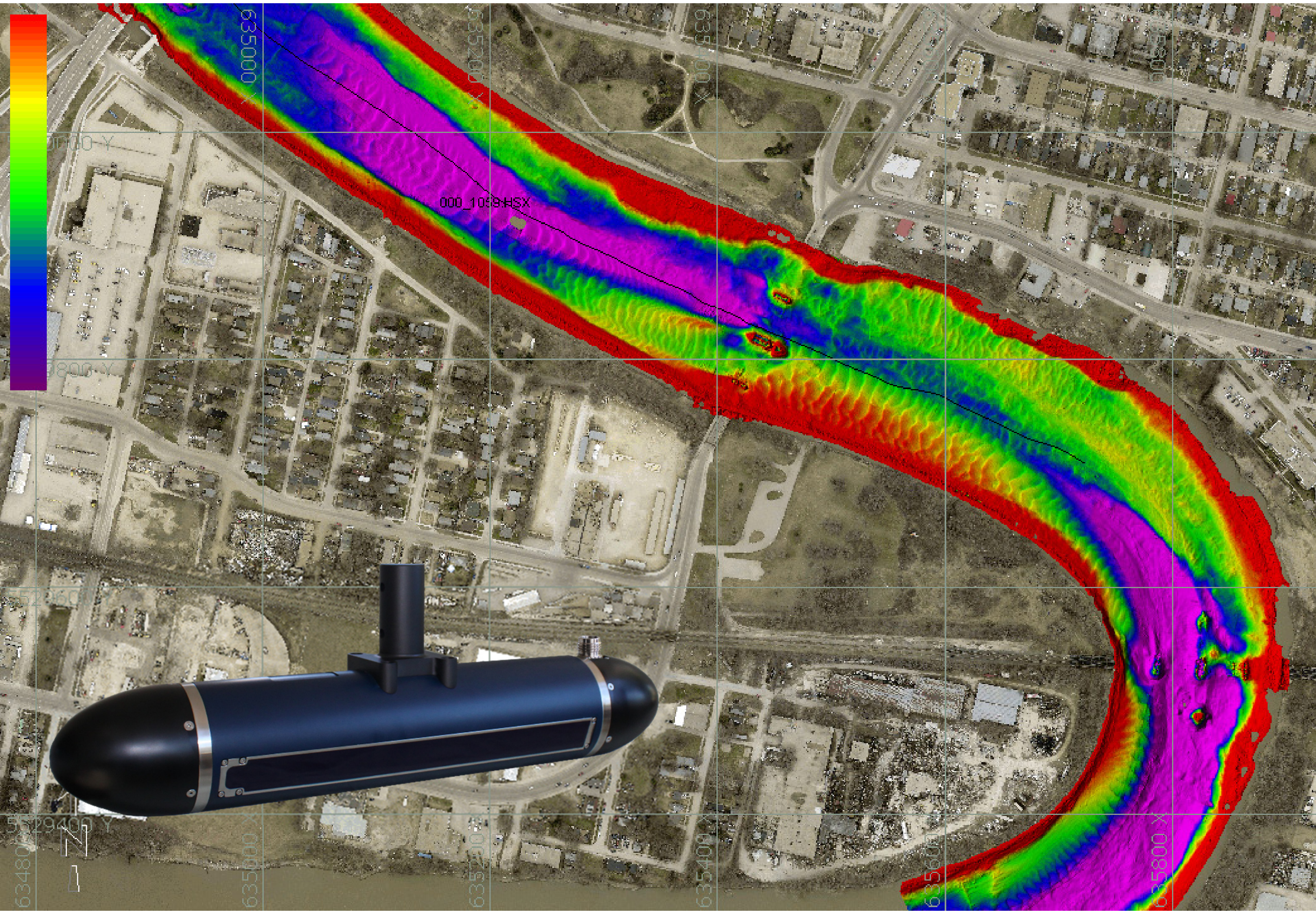

3DSS™ MBES Bathymetry Engine

By Ping DSP, Inc.

Ping DSP

Ping DSP Inc.
10990 Madrona Drive
North Saanich, BC
Canada, V8L 5R7

Introduction

Ping DSP introduced the MBES Bathymetry Engine in September of 2017 to provide users of the 3DSS™ within the hydrographic community with reliable swath bathymetry. The 3DSS™ MBES Engine takes advantage of Ping DSP's patented CAATI processing methodology while providing accurate bathymetry and full vertical coverage to users.

MBES Processing Methods

Multi**b**eam **E**cho **S**ounders (MBES) with a cross-track mounted RX array operate by sampling acoustic returns across the array and by altering the direction of maximum acoustic response, beamsteering through tens or hundreds of beams across the swath.

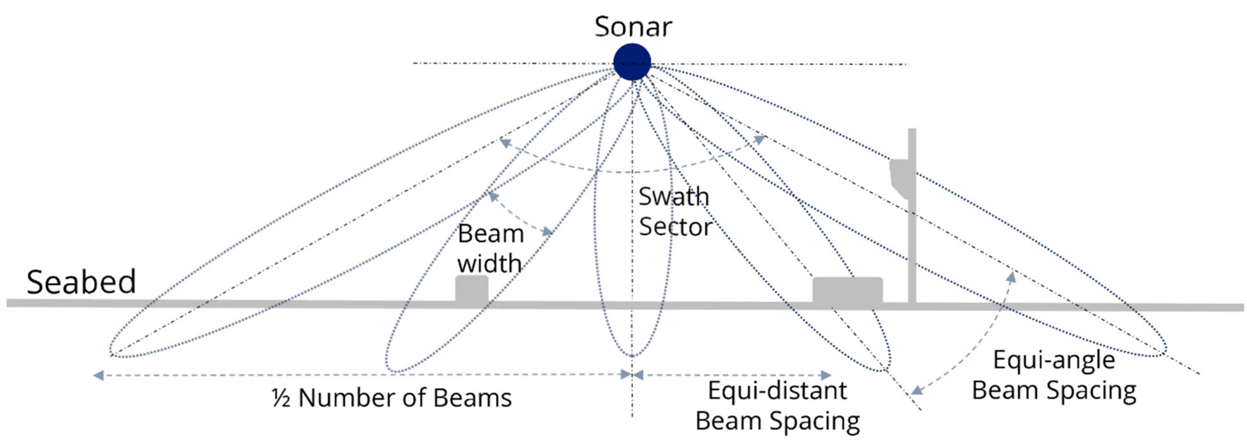

FIGURE 1: MBES BEAM GEOMETRIES

MBES beam geometry is generally given by:

1. Number of Beams (N_{Beams})
2. Beam Width of each beam (θ_{Beam})
3. Swath Sector spanned by the beams (θ_{Sector})
4. Spacing between beams equidistant or equi-angle.

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Multibeam echoes are measured as a function of time (range) for each beam. A *sounding* is an estimate of the center weighted average range to the section of seabed lying within the beam footprint. MBES soundings are estimated using only the time varying echoes for each beam. A short, simple rise and fall echo yields the most accurate and reliable sounding estimate of the center weighted range within a beam. An error in the sounding estimate becomes more likely with increasing echo duration at increasing beam angles and with increased echo complexity resulting from increased bottom complexity.

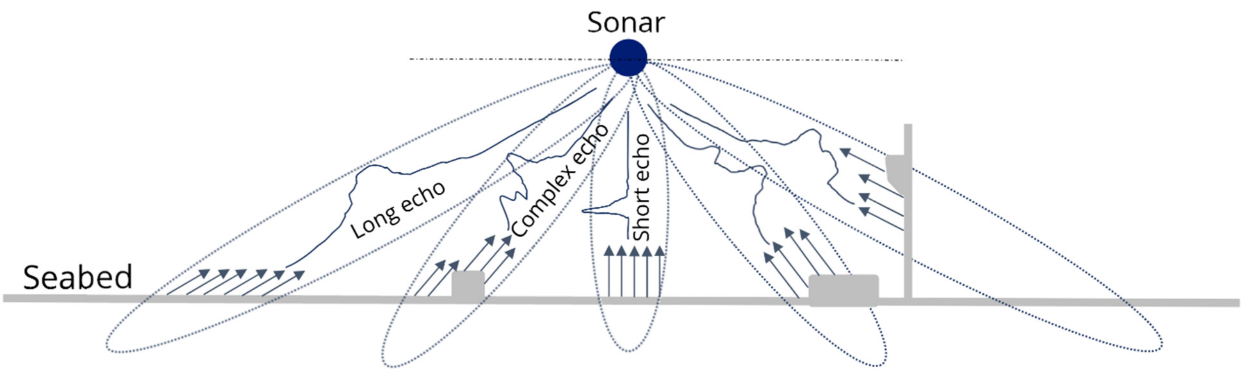

FIGURE 2: MBES SOUNDINGS

Beam patterns are non-ideal and do not have well defined boundaries at the beam width and instead are graduated. Sidelobes that contribute non-uniformly to beam footprint vary asymmetrically with beam angle along with beam boundaries. This asymmetric variation in beam pattern yields non-uniform beam echo contributions across beam footprints at different beam angles. The likelihood of a difference between the sounding estimate and the true center weighted range increases with:

1. Less uniform echo weighting particularly at increase beam angles
2. Increased surface complexity

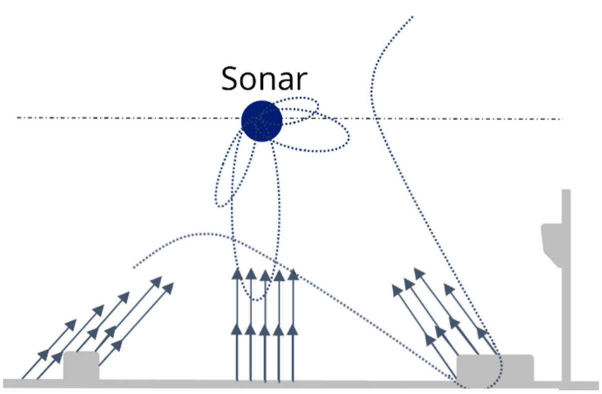

FIGURE 3: ANGLED BEAM AND NON-UNIFORM SIDELOBE BEHAVIOR

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3DSS™ Bathymetry

The 3DSS™ employs patented **C**omputed **A**ngle-of-**A**rrival **T**ransient **I**maging (CAATI) to provide low variance swath bathymetry. This technology takes advantage of multi-channel phased transducer arrays developed in house, along with proprietary signal processing methodologies to resolve multiple simultaneous backscatter arrivals in real time. This technique provides high sounding densities and 3D imagery in addition to bathymetric data.

Pulse Footprint Sounding

At each instant in time an echo from the transmit pulse originates from a small footprint on the seabed. A *pulse footprint sounding* is the Range, Angle and Amplitude of the echo from the seabed within the pulse footprint. Pulse footprints have well defined boundaries, are uniformly weighted and have no sidelobes. Echoes from pulse footprints are short and simple (i.e. have a single time sample).

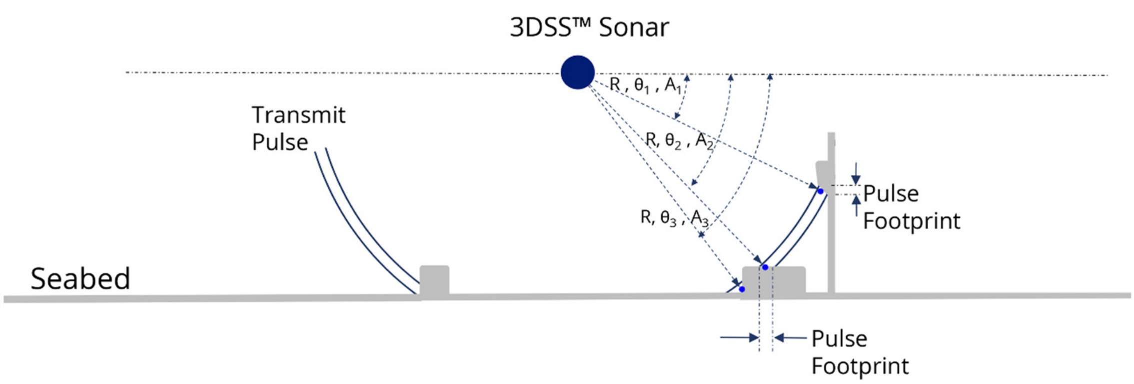

FIGURE 4: PULSE FOOTPRINT GEOMETRY

Pulse footprint soundings provide a high-resolution profile of the seabed and fine scale features. Multiple simultaneous pulse footprint soundings are accommodated using the CAATI algorithm (note that this is not possible using interferometry or phase differencing methods). The density of pulse footprint soundings increases as the grazing angle decreases and with increasing complexity of features on the seabed.

3DSS™ Binned Bathymetry (Legacy Processing)

Pulse footprints can be combined to yield soundings from larger footprints with increased noise immunity. Computing the average of the pulse footprint soundings included within equidistant cross track bins produces simple *Binned Soundings*. Binned soundings are statistically independent if the bins are non-overlapping since individual pulse footprint soundings are independent. This approach does not preserve vertical or water column structures well. Resultant bathymetric data is not easily compared to MBES bathymetry due to differences between cross track bin footprints and MBES beam footprints in terms of how each sounding is derived.

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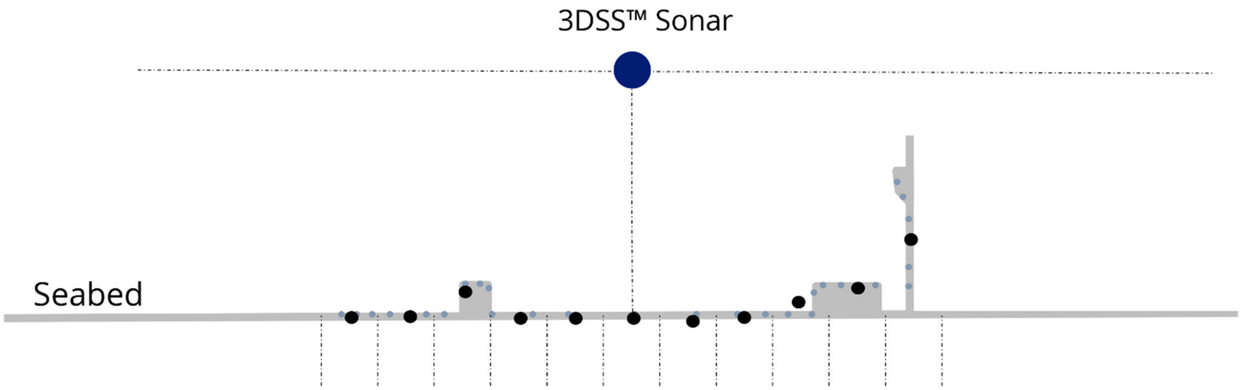

FIGURE 5: BINNED PULSE FOOTPRINT MODELLING DOES NOT ADEQUATELY PRESERVE VERTICAL TARGETS

3DSS™ MBES Engine Processing

The 3DSS™ MBES Engine uses the fine scale seabed profile from pulse footprint soundings to compute *Beam Soundings* without MBES Echo limitations or beam effects. A proprietary detection algorithm computes the seabed profile from the pulse footprint soundings. Each beam sounding is computed as a center weighted an amplitude weighted average of the seabed profile within the beam. Beam are identical at each beam angle with uniform, symmetric beam patterns, well defined boundaries and no sidelobes. Accurate bathymetry over a wide swath sector is achieved using the fine scale seabed profile from the high-density pulse footprint soundings. Vertical features on the seafloor are well represented in the resultant data.

3DSS™ MBES Engine Bathymetry Engine allows for:

1. Beams defined by user specified MBES settings; N_{Beams}, θ_{Beam}, θ_{Sector}.
2. Identical beams with well-defined boundaries, uniform weighting and no sidelobes.
3. Equidistant, equiangle or equidistant+equiangle beam distributions.
4. A wide range of MBES configurations (e.g. 1˚, 512 beams) and including statistically independent (i.e. non-overlapping) beam geometries.
5. Accurate bathymetry with full vertical coverage over extremely wide swathes.
6. Bathymetry results that can be readily compared with results from similarly configured Multibeam systems.

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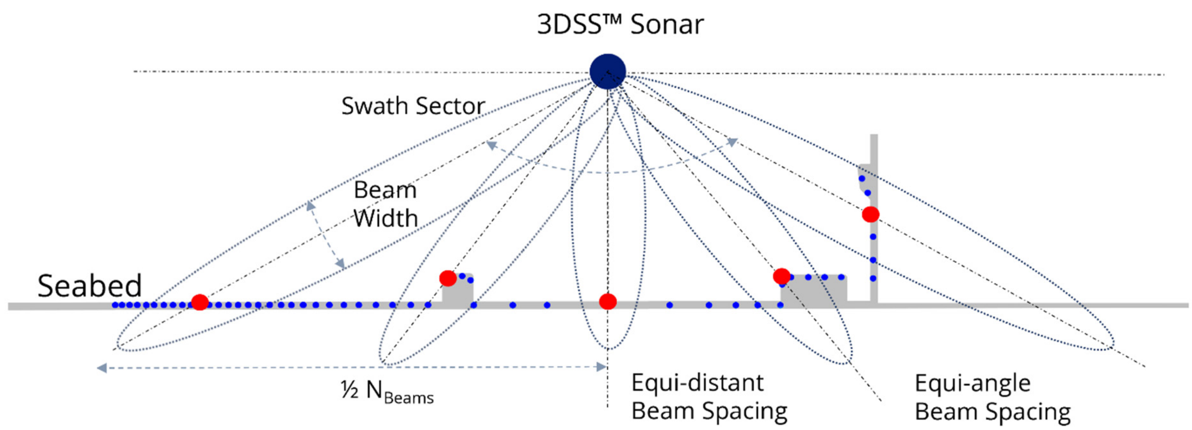

FIGURE 6: 3DSS™ MBES ENGINE GEOMETRY

3DSS™ MBES Engine Display

The 3DSS™ Profile Display provides cross section imagery for each pulse and indicates MBES Mode Filter Settings configured within the 3DSS™ Sonar Control applications. All 3DSS™ data is readily integrated into third party processing software for analysis and processing.

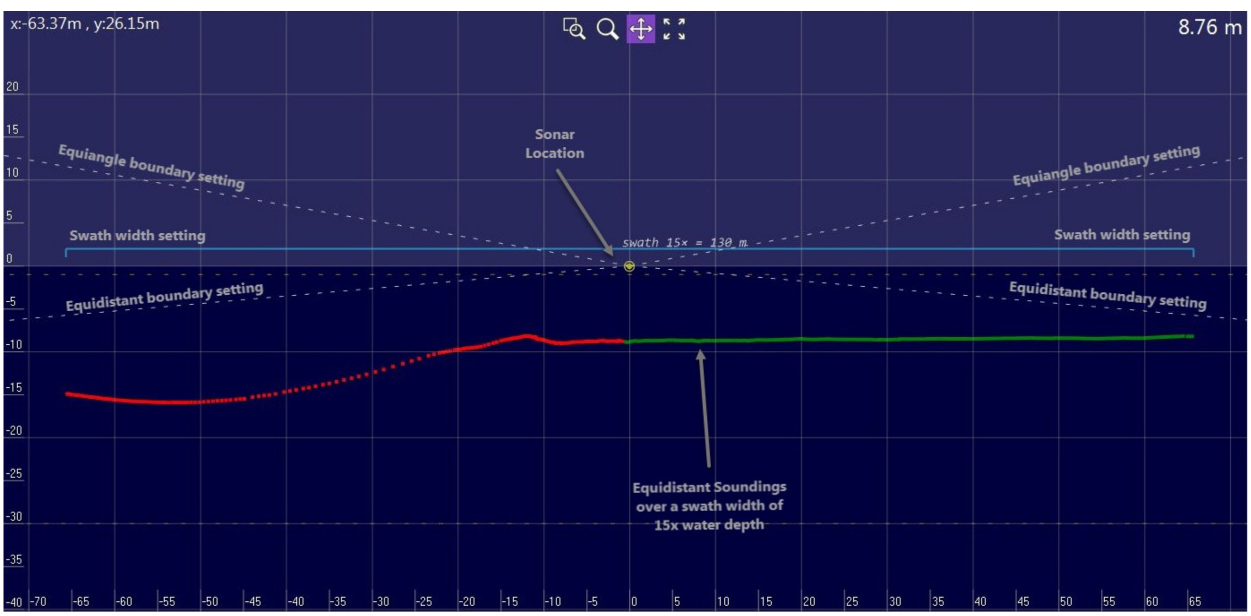

FIGURE 7: 3DSS™ PROFILE DISPLAY