Technical Note

Feature Detection with an EdgeTech Side Scan Sonar

This Technical Note is designed to address some of the questions that typically arise when trying to determine the ability of an EdgeTech Scan Sonar to meet the IHO and NOAA requirements for feature detection.

Background

There is a common mis-conception when reviewing side scan sonar specifications that resolution equates to feature detection. There are a wide range of factors that influence detection, and whilst resolution does play a part it is by no means the dominant factor. In fact, resolution can generally be more closely associated with the classification or identification of targets, rather than their detection.

To expand on this, object detectability depends on factors that include, but may not be limited to:

- The ‘target strength’ of the object, and probably most significantly, the relative target strength of the object compared to the seabed it is sat on.
- Whether the object has height above the seabed, and that height.
- The general seabed environment
- The relative size of the object to the beamwidth at that range – remembering it is possible to detect an object that is smaller than the beamwidth.
- The number of pings on a target. Bearing in mind that the wider the beamwidth, the more pings you can potentially get on a target, or put another way, the smaller the target you can get a defined number of pings on.

Overall, this means that unfortunately it is not simply a case of being able to have a number that can plugged into spreadsheet to say whether an object of a given size will be detected.

Or as outlined in the Carbon Trust / OWA Guidance for geophysical surveying for UXO and boulders supporting cable installation:

> “*While it is not appropriate to guarantee performance in terms of detection of hazards (there are too many variables outside the control of a survey contractor to provide a commercially viable guarantee of this), a clear set of DQOs (Data Quality Objectives) can be a firm requirement for the aspects of the geophysical survey which can be controlled*.”

However, the frequency, beamwidth, and the number of pings on a given target size, are clearly measurable quantities that in conjunction with the range / line spacing to be used, can form part of a specification that will give you confidence that the system has the capability to detect objects where the other (less measurable) factors are also favourable.

It is the number of pings on a target that form the basis of the IHO and NOAA requirements for feature detection.

IHO and NOAA Requirements

The specifications laid down in the IHO and NOAA requirements for feature detection are as follows:

NOAA

The requirements state:
"The hydrographer shall tow the side scan sonar at a speed such that an object 1 m on a side on the sea floor would be independently ensonified a minimum of three times per pass."

IHO

The Manual on Hydrography M-13 Ch 4 states:
"What is used for calculations is the maximum length of feature that just fails to receive five 'pings', this being considered the minimum to achieve feature detection"

Although this is can be qualified by a statement that the five returns is spread over two passes, so this is sometimes interpreted as 3 returns per pass, as with the NOAA requirements, these being required on a 1m target for IHO-S44 Special Order, the most stringent of the IHO requirements.

The general rule is therefore 3 'hits' on a 1m target per pass

<u>Method of Calculation</u>

The IHO manual gives that the smallest feature that must (theoretically) receive N pings has a length L (metres) given by:

$$L = (V\ t\ N) - B_r$$

Where:

V	is ships speed (over the ground) in metres per second
t	is the pulse interval in seconds
B_r	is the beam width in metres at the range in question

Accounting for the fact that it may be a multi-pulse system, then:

$$t = \frac{2\ R_{op}}{C\ P}$$

Where :

R_{op}	is the operating range selected in metres
C	is the speed of sound in water in metres per second.
P	is the number of pulses in the water column the system can handle at any one time

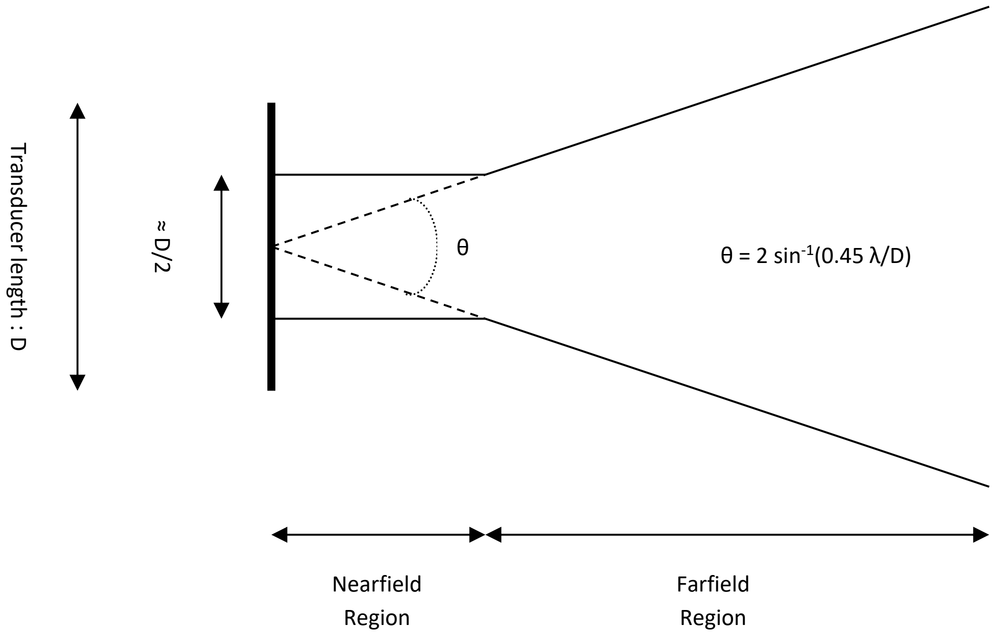
What should also be pointed out, is that a larger beamwidth allows a smaller feature to receive the requisite number of hits. This reinforces the point that high along track resolution (narrow beamwidth) should not be confused with the ability to detect small features. Although it initially can seem counter intuitive, it can have the reverse effect.

However, equally this does not mean that wide beamwidths / low along track resolution is desirable either, as better resolution significantly aids with the classification / identification of targets.

It is precisely this sort of trade-off, in conjunction with the longer range achievable with lower frequencies (which have lower resolution) that has led to the predominance of dual frequency side scan sonar systems, where the lower frequency is used for detection, and the higher frequency provides a classification / identification capability.

Beamwidth Model

A generalised beamwidth model for a side scan sonar is based on a fixed beamwidth in the near field region, and a linear increase of beamwidth with range in the far field region;



The actual values formula being something like:

$$B_r \approx \frac{D}{2} \qquad \text{for the near field case}$$

$$B_r = 2r\ \tan\left(\sin^{-1}\left(\frac{0.45\ \lambda}{D}\right)\right) \quad \text{or} \quad B_r \approx \frac{0.9\ r\ \lambda}{D} \qquad \text{for the far field case}$$

Applying a factor of 0.83 for the far field case, this being derived from the factor of 0.72 applied to get the two way beam width, and an increase of 15% which is typical of the effect of the side lobe suppression usually applied, you get .

$$B_r \approx \frac{0.75\, r\, \lambda}{D} \quad \text{or} \quad B_r \approx \frac{1125\, r}{fD} \quad \text{for the far field case}$$

Where :

r	is the range in metres the bandwidth is measured at
D	is the active length of the array in metres
f	is the frequency of the transmission in Hertz.

However, in general the requirement is to achieve the required feature detection over the entire operating range selected, rather than having to consider a function which is dependent on the range the feature appears at in the record.

If we drop the beamwidth component from the IHO formula, the formula becomes independent of where the target is within the range window. A secondary benefit, is that this is a very conservative approach as it actually results in us reducing the speed at which the requirement is met, so errs very much on the side of caution.

Simplified Calculation

So dropping the beamwidth component from the IHO formula, which results in us reducing the speed at which the requirement is met, but makes the formula independent of where the target is within the range window, we get:

$$L = (V\ t\ N) = V\ \frac{2\, R_{op}}{C\ P}\ N$$

Which rearranging to get the maximum speed and converting the speed to knots (V_{maxkt}), gives:

$$V_{maxkt} = 0.97\ \frac{L\ C\ P}{N\ R_{op}}$$

Example 1: 4125

For a 4125, a single pulse system, to achieve three pings on a one metre target ($L = 1$, $N = 3$, $P = 1$ and taking $C = 1500$) then;

$$V_{maxkt} = \frac{485}{R_{op}}$$

So for a 4125 system set to operate on the 100m range, the maximum speed to still maintain the NOAA requirements across the full range is 4.85 knots.

Example 2: 4205 in HSM (High Speed Mode)

For a 4205 in High Speed Mode, a 2-pulse multi-pulse system, to achieve three pings on a one metre target ($L = 1$, $N = 3$, $P = 2$ and taking $C = 1500$) then;

$$V_{maxkt} = \frac{970}{R_{op}}$$

So for a 4205 system set to operate in HSM on the 100m range, the maximum speed to still maintain the NOAA requirements across the full range is 9.7 knots.