NORTEK MANUALS

# Principles of Operation ECHOSOUNDER

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# 1 Introduction

This manual is designed to give an overview of the principles of operation when using the Echosounder application in a Nortek instrument. This application is available for Signature 1000, Signature 500, and Signature 100. For more general information about current measurements using Nortek instruments, please refer to Principles of Operation - Currents

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| Version/revision | Date | Comments |
|---|---|---|
| Version 2024.1 | 31.05.2024 | First release, based on information previously found in the Principles of Operation - Signature. |

# 2 Echosounder

With the echosounder mode, Signature100, 500 and 1000 are able to measure the magnitude of the echo that is generated after the instrument transmits a ping. The traveling time of the pulse gives an estimate of the distance to the particles reflecting the signal. The aim for the echosounder can range from sediment estimation, to biological activity (fish or plankton), to studying internal waves by observing density gradients.

The Signature100 has an optional central echosounder (fifth vertical beam), with a more flexible, suitable and powerful echosounder. This is more of a classical scientific echosounder than functionality on the Signature500/1000, due to the available frequencies being in the widely used echosounder range (70-120 kHz). The Signature250 does not have a real echosounder mode, but it is possible to record raw altimeter data from the center (500 kHz) transducer.

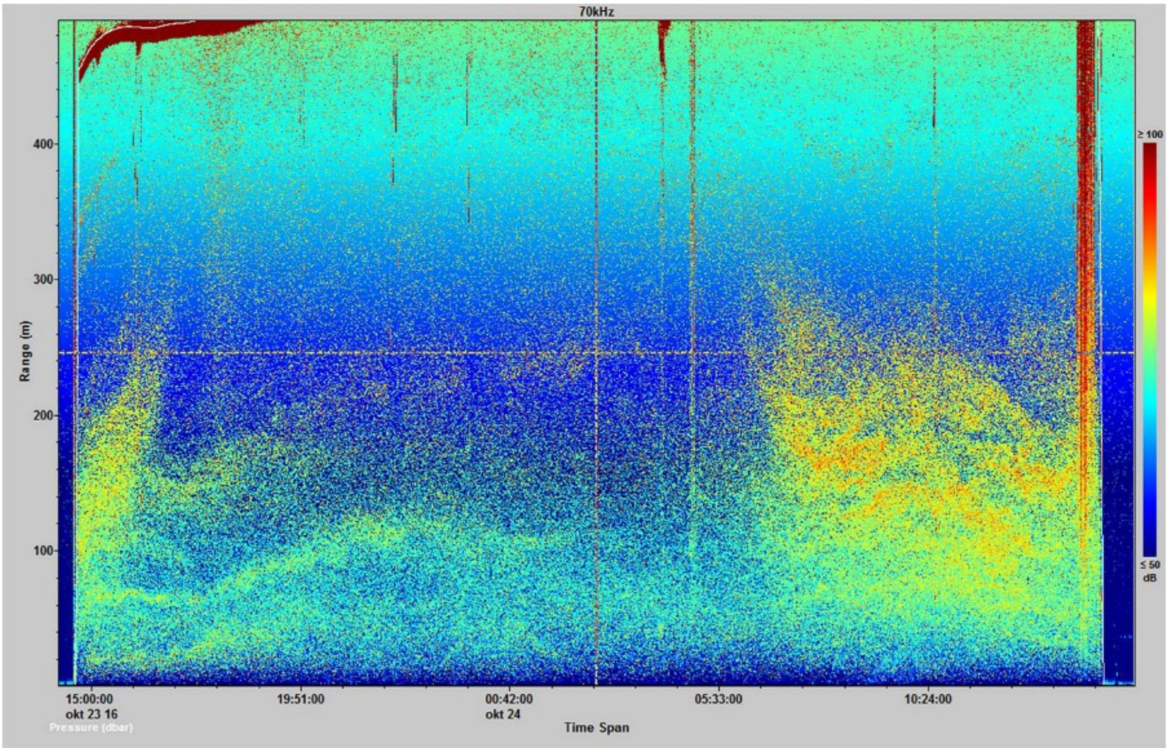



**Figure: Mesopelagic fish in the North Sea mapped with the echo sounder**

The echosounder collects data at fine resolution (along the center beam) to gather information about scattering particles in the water column. Difference in acoustic impedance and speed of sound is what determines the strength of acoustic reflection and thus what can be detected. For example, it may be very difficult to detect jellyfish since they can be >95% water, but 2 cm larval fishes could be detectable depending on their acoustic impedance. 2 cm is very large in comparison to other organisms that Signature instruments have detected.

The traveling time of the pulse gives an estimate of the distance to the particles reflecting the signal. When range-gating the receive signal, a fixed timing based on the internal sampling clocks of the Signatures is used. The corresponding range is calculated using a nominal sound velocity of 1500 m/s. The configured blanking distance and cell size are stored in each data file, and the center of the first cell is located at BlankingDistance+BinSize. Each cell is located BinSize (a cell size) apart.

When transmitting a pulse, it is of interest to have it as short as possible, as the length of the pulse affects the range resolution. However, we may also want the pulse to be long enough so that the measurement range is improved. Therefore, there are two ways of processing the signal, either with or without pulse compression.

**With pulse compression**: With pulse compression enabled, the center transducer transmits a chirp sound wave (pulse) with a bandwidth of 25%. Each part of the pulse has a unique frequency, and the return pulse can be separated and integrated into a shorter single output pulse. Practically, that means that the return echo is compressed in its pulse duration in special filters, which results in very high-resolution data. Pulse compression thus provides a method to further resolve targets compared to “normal”.

Benefits:
- The best resolution is achieved with pulse compression; minimum resolution is 3mm for Signature1000 and 6mm for Signature500.
- SNR increases because the length of the transmit pulse can be increased without affecting the resolution.
- Pulse compression works best with small scatterers.

Disadvantage:
- May introduce sidelobes in the presence of large scatterers and when measuring close to boundaries, due to the larger pulse length.

**Without pulse compression**: Bandwidth of a transmit pulse without pulse compression: ~1/T. The length of the return echo will be a convolution of the rectangular transmit pulse and receive window. If the transmit pulse length is set to bin size/(c/2) or nominally bin size/750, the bins will consist of triangularly weighted echoes, similar to the classical ADCP cells. In this case the resolution depends on both the length of the transmit pulse and the cell size.

The best resolution is achieved with the shortest allowable transmit pulse but still limited by the bandwidth, which corresponds to a resolution of 12 mm for the Signature1000 and 24 mm for the Signature500.

Benefits:
- Reduced chance of sidelobe interference with a narrowband pulse
- Better results when measuring in bottom boundary conditions (where SNR is generally high enough)

Disadvantage:
- The effective resolution will be limited by the receive filter, so you will see 1.2 cm resolution in the data even though the bin size is 3 mm.

**Reception:** The receiver divides the sampled receive sequence into bins through range gating. The power in each bin is averaged in the linear domain before the resulting power is converted to dB with a resolution of 0.01 dB/count. The receiver has sufficiently large dynamic range so there is no TVG (Time Varying Gain) applied. There is no user calibration applied to these values. The supported commands for setting calibration values serves the purpose of having calibration values stored together with the data set.

It is possible to enable three echograms, but only one of them may be using pulse compression. If unsure, it can often be a good idea to enable one echogram without pulse compression and another echogram with pulse compression enabled. Then you get both results at the same time and can decide later which one to use. Echograms can be combined so that the instrument measures both with and without pulse compression, or with different strength on the transmit pulse.

The instruments can sample echosounder data together with Burst measurements. Burst with echosounder means that the instrument burst samples data with the vertical beam (just as the plan called "Burst using Vertical beam") and samples echosounder data at the vertical fifth beam too. Note the difference in memory and sampling rate, and thus burst duration, between these.

➲Example: For short range, looking at bed changes and bottom boundary conditions, we suggest configuring the minimum cell size and the minimum transmit pulse length. The effective resolution will be limited by the receive filter when pulse compression is disabled so you will see 1.2 cm resolution in the data even though the bin size is 3 mm.

➲Example: For 100 m measurement range the Signature500 will have problems getting the full range. It is possible to configure the Signature250 to store raw altimeter data to the recorder, similar to what was previously done with the AWAC. In order to do this at a higher rate (more often than 60 seconds), the echosounder license is required. The other option is the Signature100; this has an effective range of 300-400 m for both current profiles and biomass measurements.

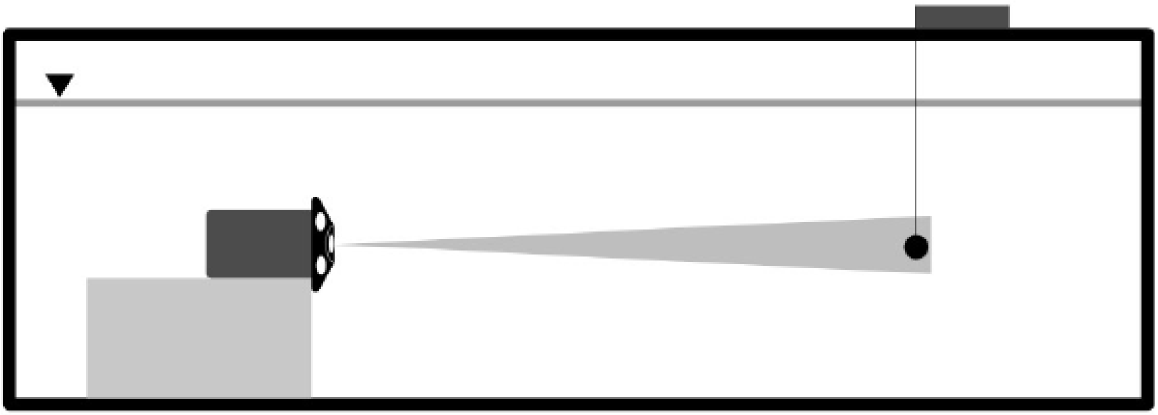
**Corrections**

As mentioned earlier, the measurement range is calculated using a nominal sound velocity of 1500 m/s. This means that to accurately position the cells in the vertical direction, the distance must be remapped to account for deviations in the sound velocity from 1500 m/s. Based on a salinity value entered by the user and the measured temperature, we calculate and output the sound velocity at the location of the instrument so this is the first order of correction one could use.

Ocean Contour has some echo correction algorithms included. The user can enter the noise level for the echosounder data and the salinity, and Ocean Contour will then automatically correct for transmission loss and absorption. That means that with a constant scattering level, the amplitude profile should be a vertical line. In addition, it corrects for surface pressure, and if the instrument is mounted on a subsurface buoy, the software corrects for depth variations due to tidal flow. The latter is done by using the pressure readings to adjust the cells in each single ping profiles such that they maintain a constant depth. Upon completion, the range axis is converted into absolute depth using the corrected pressure values.

# 3 Calibration

The echosounder calibration has two purposes: confirm that the equipment works in accordance with the specification, and adjustment of the performance level. By lowering a calibration goal (reference sphere) with known echo force down into the sonar beam and placing it in the middle of the beam (acoustic axis), the measured echo force can be compared with the known echo force, just the same way as one can calibrate a weight. One standard procedure is documented in fisheries acoustics literature (Simmonds and MacLennan, 2005).



**Echosounder calibration setup. A tungsten carbide sphere encased in a monofilament net is suspended by a monofilament wire in the beam of the echosounder. (Reproduced with kind permission from Andrew Stang, University of California, Davis)**

The Signature does not have a calibration routine for the echosounder mode. At the moment, the procedure for those who are interested in calibration will be to include calibration values together with the measurements and do the mathematics as a post processing step. Put in another way; the Signature echosounder does not use any of these values in its processing, but they provide users a way to store their calibration values together with the measurements. These only serve as an option for storing calibration data in the instrument which are then output in the data file header.

The calibration values can be saved as polynomials, where the polynomials can be enabled or disabled as needed. The polynomials are presented in the Integrators Guide - Signature together with the commands that are needed to enable them, and it is recommended to take a look in this manual to get an understanding about how to use the commands.

The intention is to calculate the polynomial over the frequency range of the transducer where you use the center frequency from the beam list as origin. The following expressions are needed: $S_v$ is volume backscattering strength (dB re 1 m$^{-1}$); *TS* is point backscattering strength data (dB re 1 m$^2$) (Target Strength); *Ψ* is the two way beam angle (dB re 1 Steradian)

$$S_v = 10\log_{10}\left(10^{\frac{Pr}{10}} - 10^{\frac{Nt}{10}}\right) + 20\log_{10}(R) + 2\alpha R - PL + G_{cal} - 10\log_{10}\left(\frac{c\tau}{2NBINF}\right) - \psi$$

$$TS = 10\log_{10}\left(10^{\frac{Pr}{10}} - 10^{\frac{Nt}{10}}\right) + 40\log_{10}(R) + 2\alpha R - PL + G_{cal}$$

- *Pr* = 0.01 dB * *i* where *i* is the signed integer value read from the data file
- *Nt* is the noise threshold
- *c* is the speed of sound

- $G_{cal}$ is calculated over frequency using the values in the polynomials (ref: GETUSERECHOGAIN in the Integrators Guide)
- $\Psi$ is calculated over frequency using the values in the polynomials (ref: GETUSERECHOTWOWAYANGLE in the Integrators Guide, and this FAQ)
- *PL* is the configured transmit power level which is stored in the file header section. (ref: GETECHO,PLx where x is the echogram number)
- $\tau$ is the configured transmit pulse length which is stored in the file header section. (ref: GETECHO,XMITx where x is the echogram number)
- *NBINF* is the number of frequency bins in the echogram
- $\alpha$ is the absorption
- *R* is calculated in the instrument using the sample timings and a nominal sound velocity of 1500 m/s, see Corrections above.

The Target Strength of your calibration sphere can be calculated by using a calculator like this one https://swfscdata.nmfs.noaa.gov/AST/SphereTS/. With a known *TS*, one can use equation 2 to calculate $G_{cal}$. By moving the sphere around in the main lobe of the transducer in the far field region, the values above some percentile (90-95%) are used as the measured value. To calculate $S_v$ one needs a number for the two-way beam angle also; we rely on the theoretical value for the two way beam angle since it is difficult to calibrate it unless you have a split beam echosounder. The distance, *R*, can be found precisely through the pulse compressed echogram through the use of the raw data and correction for the sound velocity. The $G_{cal}$ value can then be established together with an estimation of the absorption.

Before introducing the sphere, the echogram noise level should be measured to make sure that there is sufficient SNR for the sphere measurement; clear water should be used. Note also that the measured *A* is *S*+*N* (Signal + Noise). At low SNR, the noise must be subtracted in the linear domain in order to find the signal strength, *S*, of the target. This also applies to volume scattering estimates so field data must be corrected in this way.