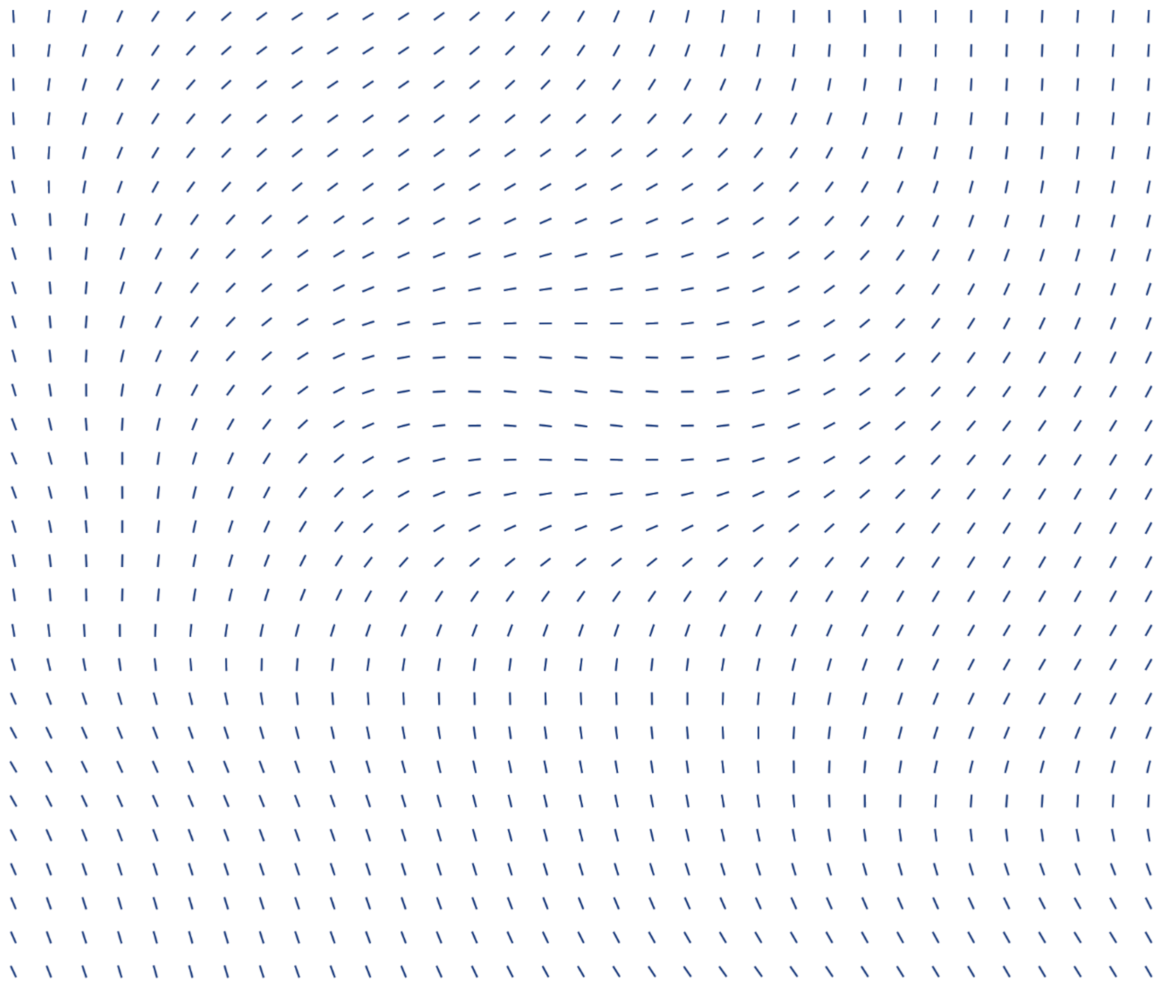
Nortek DVL Noise Testing



Intro to noise

Noise may be electronic or acoustic in origin, both of which will have a detrimental effect on DVL performance. This document presents a systematic way to characterize and measure noise sources, allowing the end user to methodically remove or isolate them. This document is by no means intended to be a complete or comprehensive treatment of the topic. It is intended to show the end user how to collect sufficient diagnostics with the Nortek DVL in order to evaluate the noise sources and begin a dialog to make improvements. The general process as follows.

1. Set transducers into a listening mode.
2. Disable all other systems on vehicle, leaving only the DVL and its intended power supply turned on.
3. Measure baseline noise.
4. Measure noise generated by other vehicle systems.
5. Use spectrum analyzer to identify the frequency and source of any noise identified in previous steps.

Electrical noise is an inherent characteristic of all electronics and power supplies, often stemming from sources such as improper grounding, power supply irregularities, or electromagnetic interference from nearby equipment. Noise from electrical sources can be conducted to the DVL or it can be radiated.

Acoustic noise is often created by other acoustic instruments that are operating in a similar frequency to the DVL. In rare cases, acoustic noise can also be generated by vehicle components oscillating.

As noise levels increase, the instrument's ability to distinguish the desired signal from unwanted interference becomes compromised. This can result in inaccurate velocity measurements, reduced range, and unreliable data processing as the noise obscures the true signal and diminishes the instrument's effectiveness. The consequence of noise picked up by the DVL may not be apparent when the DVL is operating at low altitudes over the bottom but as the altitude increases it will reduce the bottom tracking range, and in the case of “colored noise” will bias the velocity estimates, degrading the quality of the navigation.

Common noise sources and solutions

The list of devices that can create noise is extensive. Below are several types of devices that we commonly see causing issues with noise during DVL operation:

- The most common electrical noise problem for a DVL is caused by common mode noise from the power lines. This is often generated in a galvanic isolated power system, which will create an electrical field between the DVL and seawater. The best way to mitigate this is to have a good electrical connection between the negative power input to the DVL and seawater. This can be done in several ways. On standard production units, the DVL will be grounded through the housing when exposed to seawater.
    - Deep water variants achieve this through contact with seawater at any point on the titanium housing.
    - On shallow water versions, it's achieved through the grounding plate, typically located near the wet end connectors of the DVL.

- For OEM versions this must be done via the grounding cable on the wiring harness. The cable should be connected to a part of the vehicle's frame that has a good electrical connection to seawater. Because of corrosion issues, this connection is normally made through a capacitor (see Figure 1). In production units, the capacitor is built into the housing's grounding system.

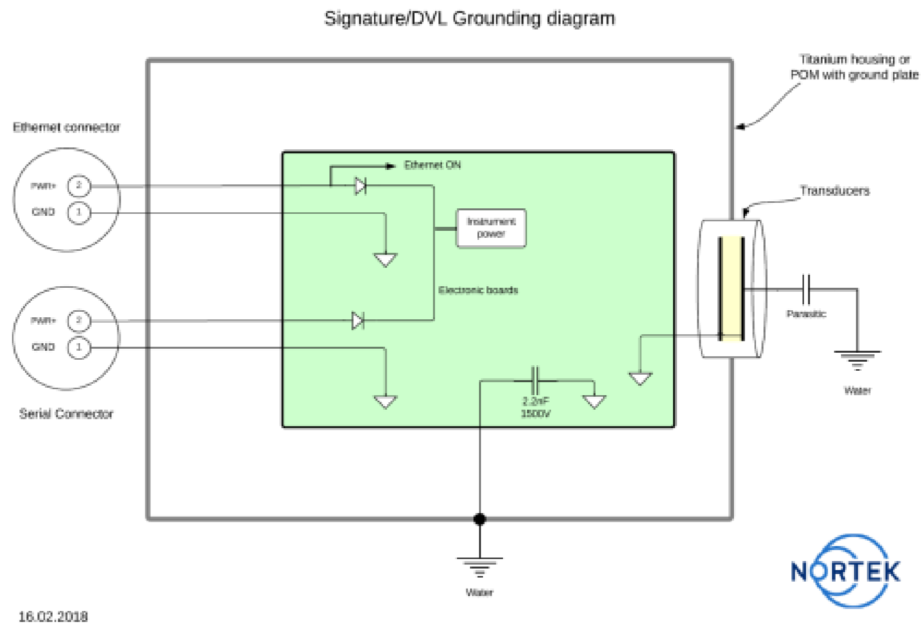


Figure 1: DVL Grounding Diagram

- DC-DC converters are a common source of noise. The switching frequency of the converter can be very detrimental if is within the operational frequency of the DVL (see table 1 in the 'Tools to identify sources' section). A DC-DC converter that features a switching frequency outside the DVL's operational frequency is key to enabling a low noise platform.

- Power lines must be kept clear of the DVL and placed in areas that will minimize the exposure of noise to the DVL. An example of increasing the risk of noise exposure is when power cables for thrusters (or other sources drawing large currents) are routed close to the DVL. The DVL's sensor head (i.e. transducers) are the most sensitive to electrical noise.

- Other acoustic sensors can have a detrimental effect on DVL performance if they are operating in a similar frequency band as the DVL. This can be identified by checking specifications of different devices before installing or by following the spectrum analysis steps below. If using devices with a different frequency is not possible, the interference can be mitigated by utilizing a trigger to ensure the acoustic signals are offset and do not interfere with each other.

Testing environment

During testing, the vehicle should ideally be submerged in saltwater in an open environment free of noise sources. This, however, may not be practical and so an inside location may have to be used. If an inside location is used, then it is necessary to submerge the DVL in saltwater to allow for proper grounding (freshwater is often not sufficient). As an example of the benefit of saltwater, adding 0.5 kg of salt to 350 liters of water has shown to reduce noise levels by 10dB. Note that if the tank is isolated from earth (e.g. plastic), then a ground path needs to be included. Depth of submergence is not important. The testing platform should not be exposed to electronic noise sources. This means that testing indoors requires ensuring that noise sources from lights, motors, etc. are minimized. It may be necessary and easier to control the noise by employing a simple Faraday Cage to isolate from electromagnetic disturbances. Ensuring low noise levels in the testing environment will help make testing easier when trying to identify noise sources.

Measuring baseline noise level

The purpose of this is to quantify baseline noise levels with the goal of ensuring the DVL reaches the desired noise floor. This test may also provide the opportunity to evaluate if there are any signs of periodic signals present during the bottom tracking ping's travel time.

The test involves enabling the current profile feature with the transmit power turned off. This allows for one to place the instrument in receive mode only and collect data describing the received amplitude and measured correlation. This is particularly useful when one wants the see the result of a particular action – such as enabling a thruster or another acoustic system.

The DVL should be connected to its intended power supply, and if the DVL is an OEM or custom integration, is grounded as prescribed. Either serial or Ethernet may be used during this process. Ethernet permits real time monitoring and display of data, while a serial interface limits the testing to logging to the DVL's recorder. The instrument should be configured so that the current profile extends to the instrument's maximum range. The cell size may be between 0.5 meters and 2 meters, where the difference is the spatial resolution. The blanking distance should be set to its minimum. This allows for any transmitted pulse to die out and the noise floor to become apparent. MIDAS software may be used to configure the Nortek instrument. The amplitude from the current profiles may be viewed in real time with MIDAS software. MIDAS software can be downloaded from the DVL's Web Browser Interface under the applications tab. Please contact Nortek if the Web Browser Interface is unavailable and we will provide the latest version of Midas.

Setup

A noise free environment is critical to a successful test. Details of how to create a noise free environment can be found above in the Testing environment section above. It is also critical to keep a detailed timestamped log (excel file is recommended) of all events while collecting data. This will allow for an effective analysis of the data to identify noise in vehicle systems. Note: please ensure DVL firmware is up to date. Contact Nortek for new firmware if required.

1. Connect DVL via Ethernet and apply power to break out cable.
2. Open MIDAS.
3. Connect to instrument via Communication -> Connect -> Network Discover. Network Parameters will then come up. The address box should be highlighted in green. Click apply to connect. The software will likely ask if you would like to put the instrument into command mode which should be accepted.

This will allow you to find the DVL on your network and access it via Ethernet. Operating MIDAS with a serial connection is not an option because of the large bandwidth that the Spectrum Analyzer requires in the subsequent steps. If you are limited to a serial connection, then you will have to configure the instrument and record to the internal DVL memory. The process for this is described further down in this document.

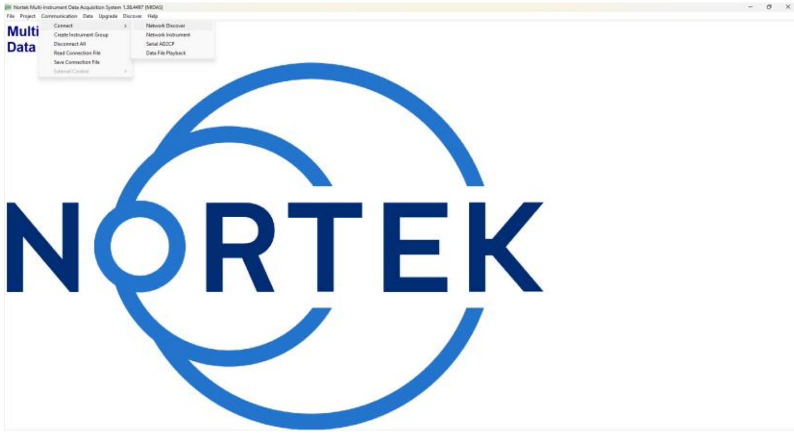


Figure 2: Midas Communication Setup

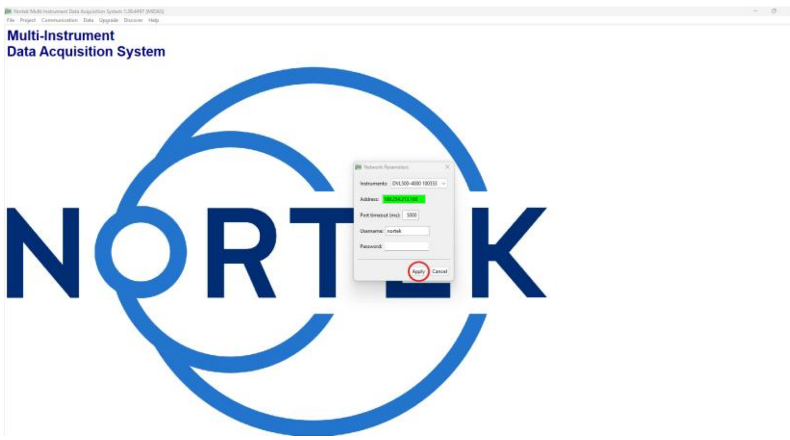


Figure 3: Midas Network Setup

4. Select button for Instrument Configuration.

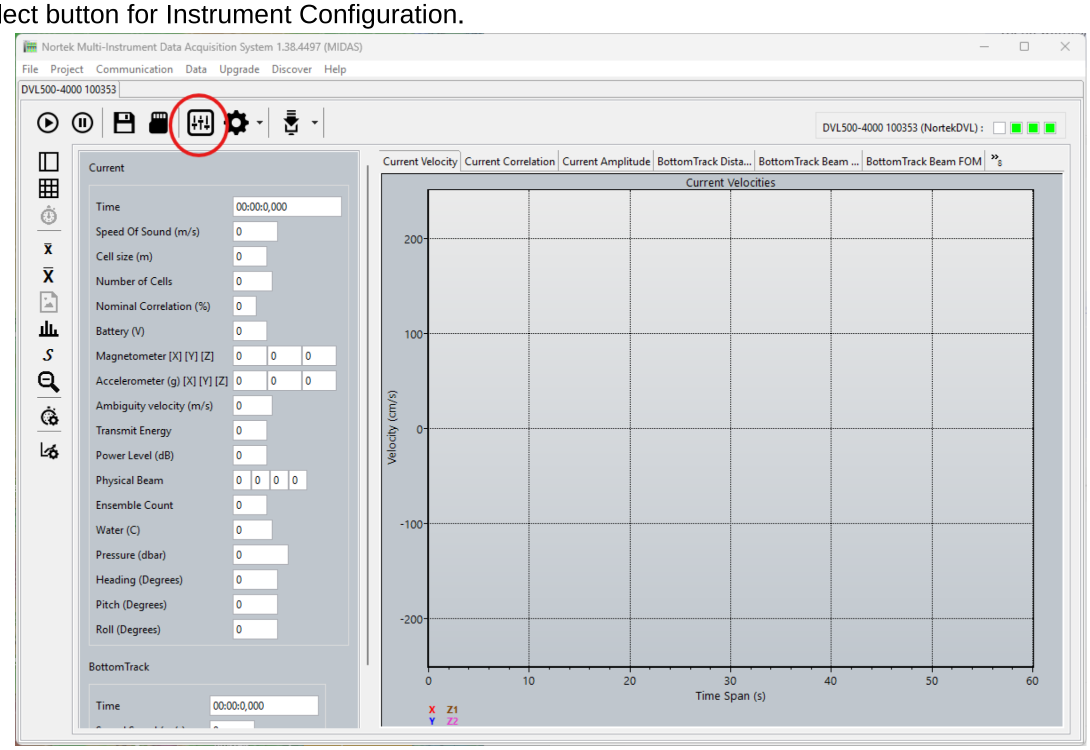


Figure 4: Midas Instrument Configuration

5. Configure the instrument measurements (bottom track) with the settings illustrated in figure 5. Bottom track is always enabled for the DVL but note that the transducers are turned off when power level is set to -100dB. It is critical that the transducers are turned off so the DVL will be in listening mode.
6. Configure the current profiling with the settings shown in figure 6. Current profiling will alternate with the bottom track when the interleave ratio is set to 2.

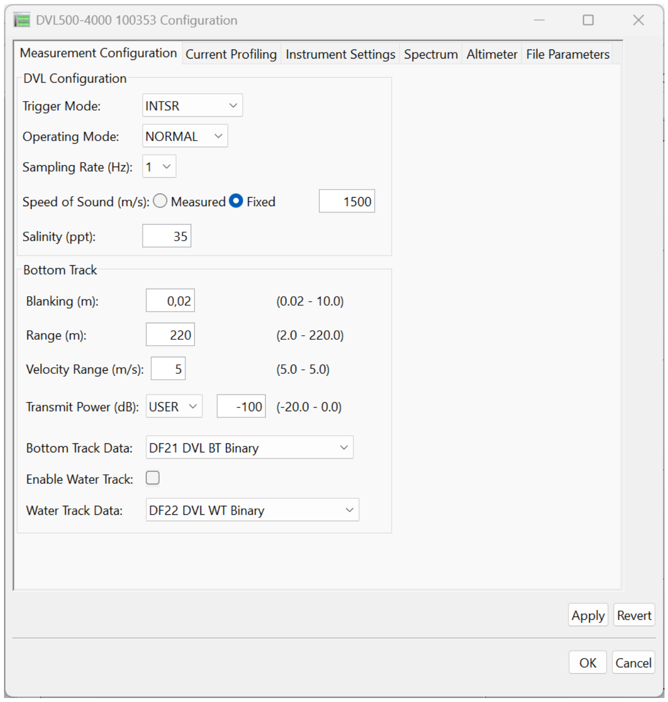


Figure 5: Midas Measurement Configuration

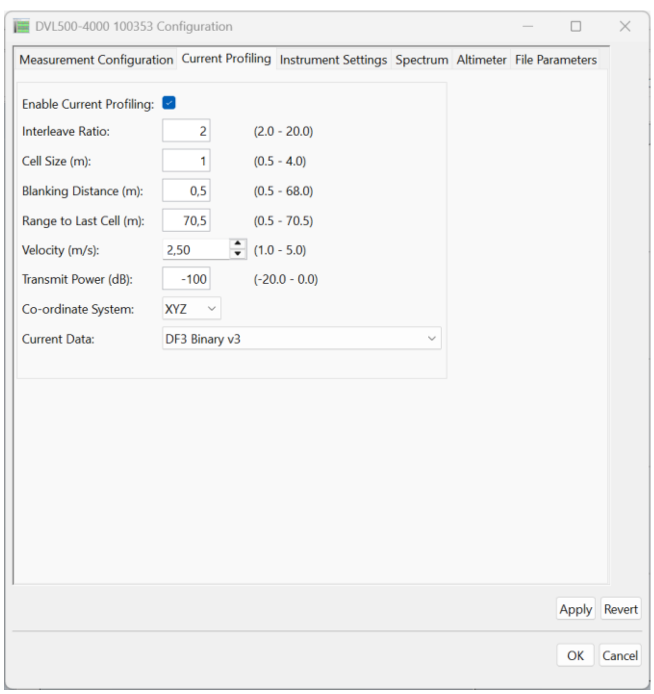


Figure 6: Midas Current Profiling Configuration

7. Configure recording for the DVL, specifying a file name in the “File Parameters” tab. Click OK to save configuration and file name. Select the floppy disk drive on the homepage (see figure 8) to enable saving to computer.

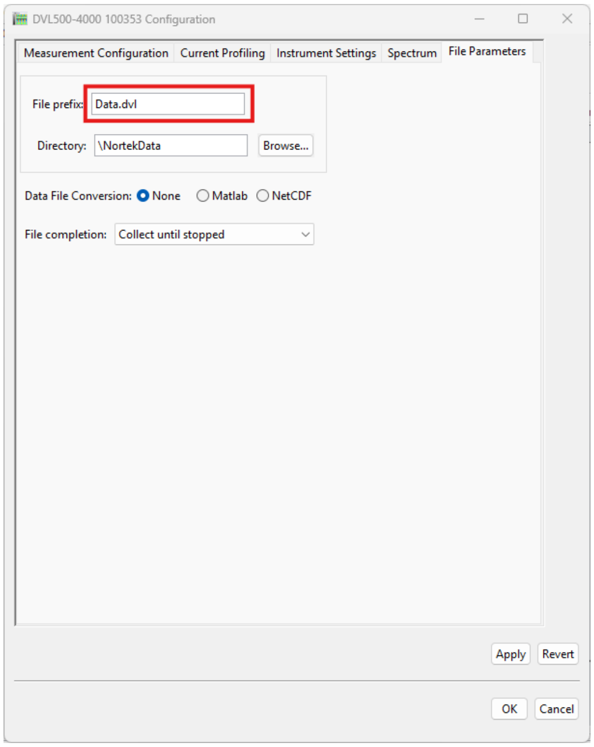


Figure 7: Midas File Parameters

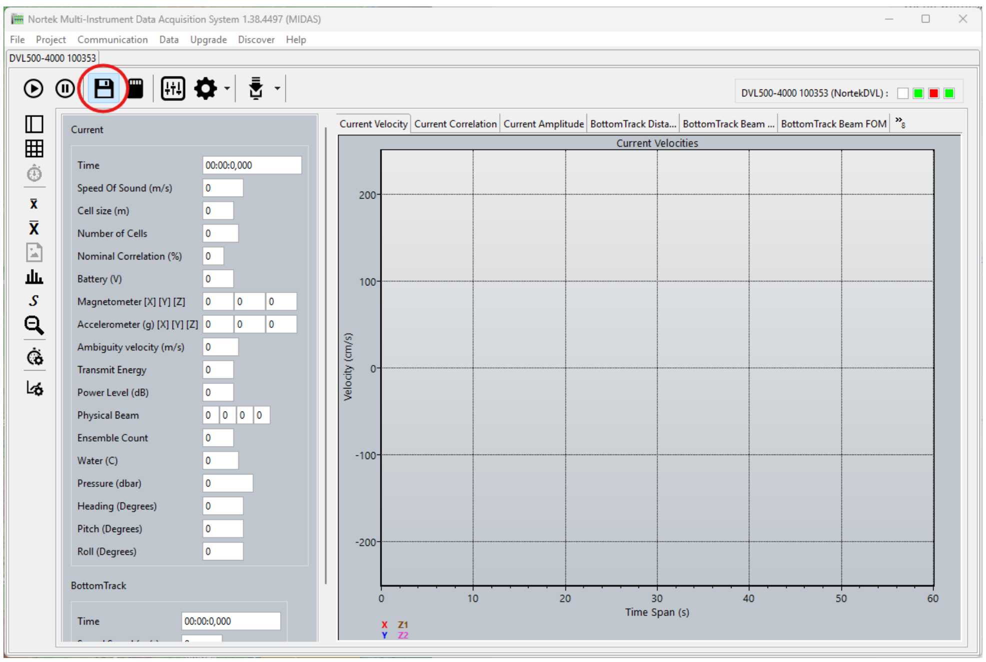


Figure 8: Midas Save to File

8. Alternatively, one may configure recording the spectrum to file on the DVL’s recorder. Naturally the recording option is more sensible if there is not a suitable, real-time, communication channel and the

DVL/Vehicle is below the surface. This is done by selecting the SD card icon on the Midas home screen (figure 9).

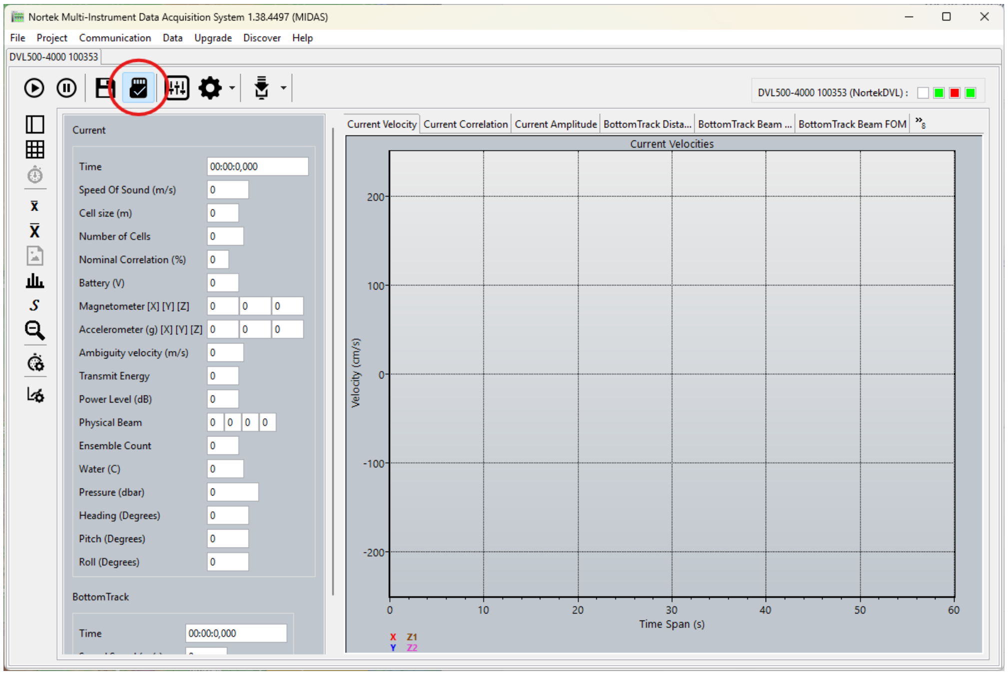


Figure 9: Midas Save to Internal Recorder

Note: Everything in the vehicle should be powered off except for the DVL and power supply. The DVL should be powered by the power supply that is intended for use during the mission.

Conducting base level noise test

1. When ready, click the play button to start the instrument. Note: Do not forget to start the external timestamped log to record events while testing.
2. With only the DVL powered on and the vehicle submerged in a noise free saltwater environment, the noise floor should be below 30dB, falling ideally between 23-26dB. Select 'Current Amplitude' tab (Figure 10) to view real time data. It's also possible to view data after testing. Please contact Nortek for software and assistance in processing recorded data.

Figure 10: Midas Starting and Current Amplitude

If noise floor is below 30 dB, move on to step 6. If noise floor is above 30dB, some further checks will need to be made.

3. A noise free environment is key for a successful test. Ensure that all guidelines in the *“Testing environment”* section are fulfilled and all vehicle systems are powered off.
4. Check *“Common noise sources and solutions”* section above to troubleshoot common sources.
5. Preform necessary modifications to vehicle. If no noise sources can be identified, contact Nortek support for further advice.

Now that an acceptable baseline noise floor has been verified, testing can begin to see how other vehicle systems interact with the DVL.

6. Systematically turn on one vehicle system at a time (other acoustic device, thruster, manipulator, etc.) while monitoring the noise level output from the DVL. Record the time and results in the log. Turn off each system before moving to the next one.
7. When a system impacts the baseline noise level of the DVL, make a note in the log. The frequency of the system will be investigated further in the spectrum analysis section below.
8. If all systems have been tested with no impact on the noise floor, the vehicle is considered to have low noise generation and no further testing is required. If systems were found to impact the baseline noise levels, continue testing with the following sections.

Tools to identify sources

Spectrum analysis is a valuable diagnostic tool for assessing the performance of a DVL by providing a visual representation of its bandwidth and any electrical noise affecting its operation. By plotting the frequency components of the signal, the analysis can highlight noise as distinct spikes in the data. These spikes are particularly problematic when they fall within the instrument's operational frequency band, as they can interfere with signal detection and reduce measurement accuracy. The operational frequency bandwidth refers to the frequency band within which an instrument operates effectively. Operational frequency is typically +/- 12.5% of the stated DVL frequency.

DVL Frequency (kHz)	Operational Frequency Bandwidth (kHz)
333	290 - 375
500	435 - 565
1000	875 - 1125

Table 1: DVL Operational Frequency

Spectrum Data Configuration

In order to configure and use the spectrum analyzer tool you will need to have MIDAS installed on your PC and connected to the DVL via Ethernet. This is the recommended way to configure this function and view the data. Operating MIDAS while viewing spectrum analyzer with a serial connection is not an option because of the amount of data transmitted. If you are limited to a serial connection, then you will have to configure the spectrum analyzer and record to the internal DVL memory. The process for this is described further down in this document.

Setup

1. Open MIDAS.
2. Connect to instrument, Communication -> Connect -> Network Discover (see 'Baseline noise testing setup' section for details)
3. Open the configuration menu and set Measurement Configuration' tab with values shown in Figure 13. Note: Settings displayed below are for a 500kHz DVL. Other types of DVLs should be set with a similar value with respect to the DVL's performance.

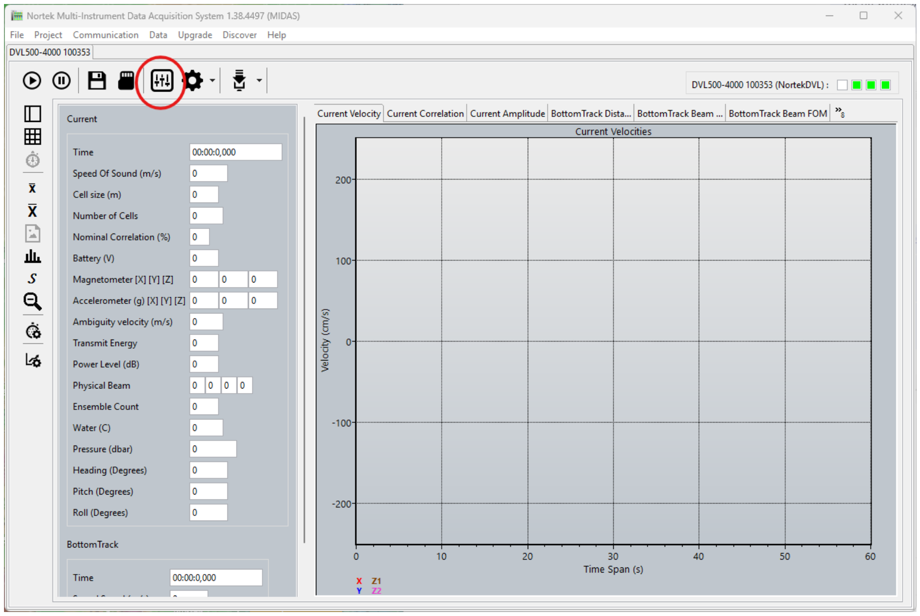


Figure 11: Midas Configuration Tab

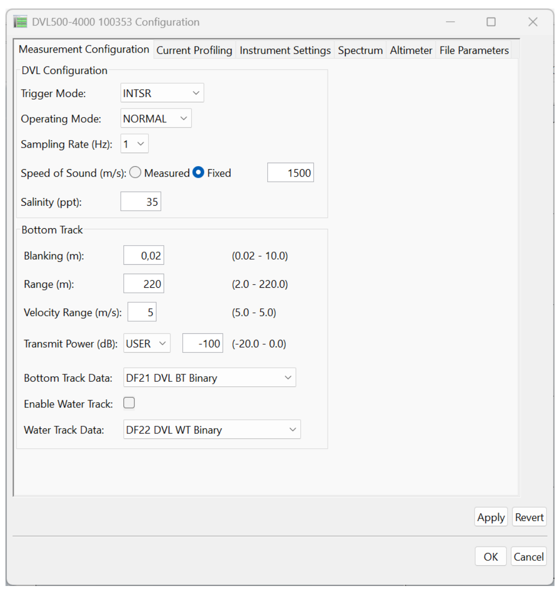


Figure 12: Midas Measurement Configuration

4. Select tab for “Spectrum”.
5. Configure the spectrum analyzer and apply settings shown in Figure 13.
   Note:199 data cannot be used in combination with the spectrum analyzer (see figure 14 for error message). Contact Nortek if assistance is needed to disable 199 data.

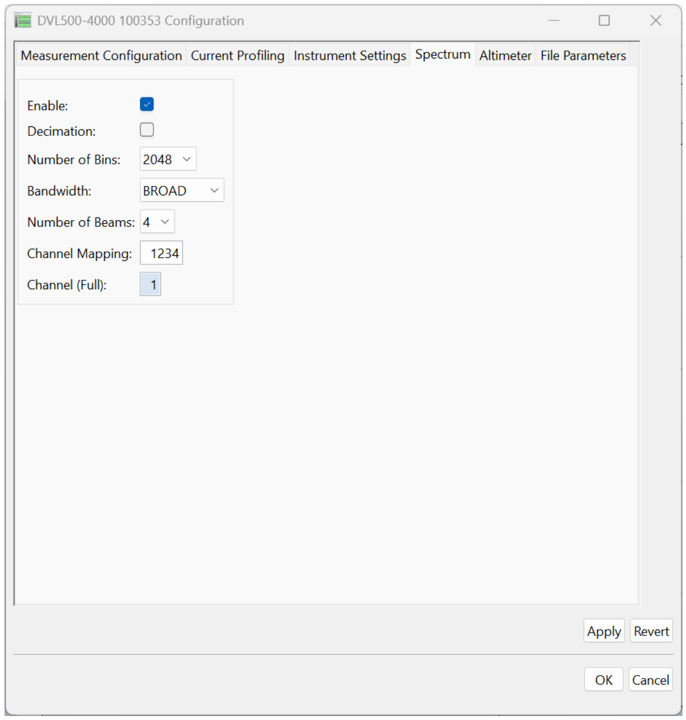


Figure 13: Midas Spectrum Tab

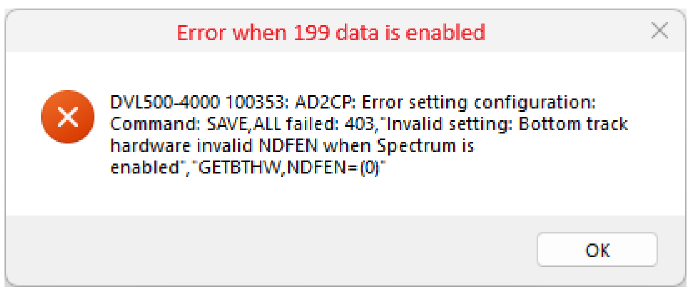


Figure 14: Midas 199 Data Error

6. Configure recording for the DVL, specifying a file name in the “File Parameters” tab (figure 15). Click OK to save configuration and file name. Select the floppy disk drive on the homepage to enable saving to computer (figure 16).

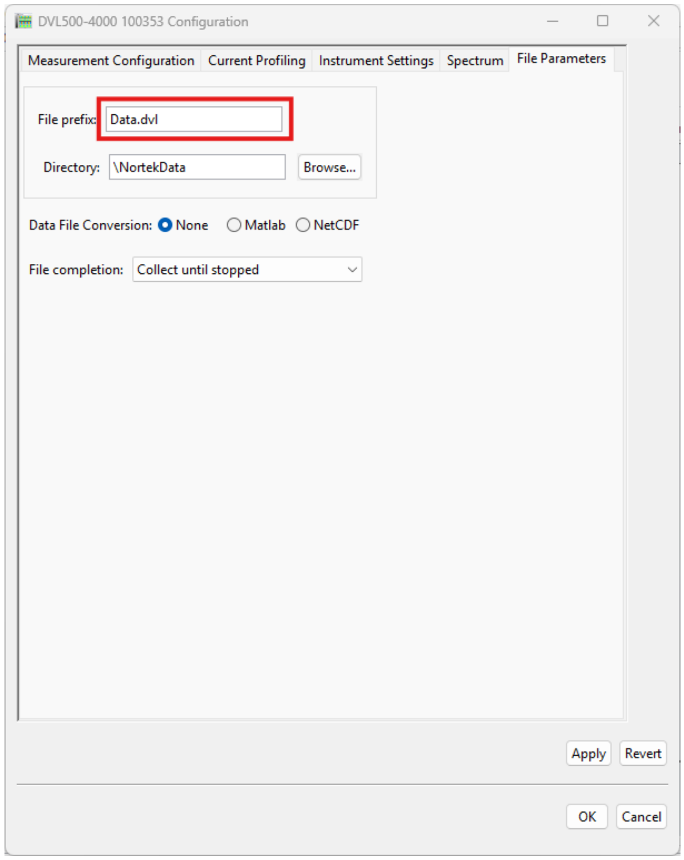


Figure 15: Midas File Configuration

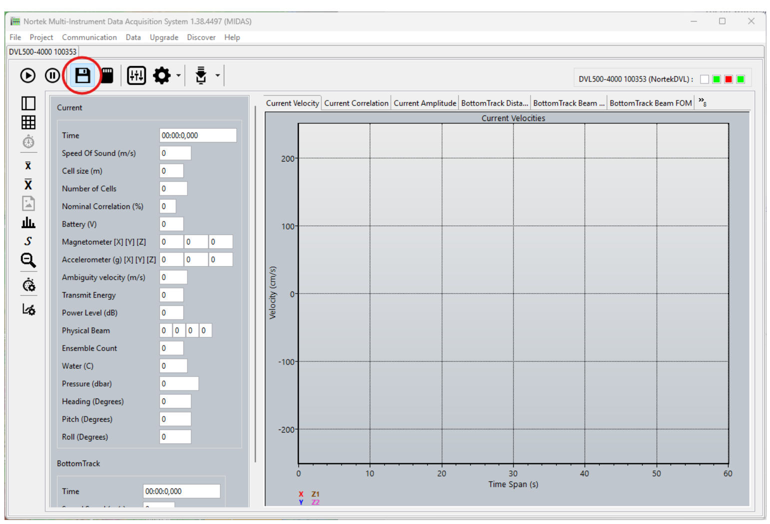


Figure 16: Midas Save to File

7. Alternatively, one may configure recording the spectrum to file on the DVL's recorder. Naturally the recording option is more sensible if there is not a suitable, real-time, communication channel and the DVL/Vehicle is below the surface. This is done by selecting the SD card icon on the Midas home screen (figure 17). Please contact Nortek for software and assistance in processing recorded data.

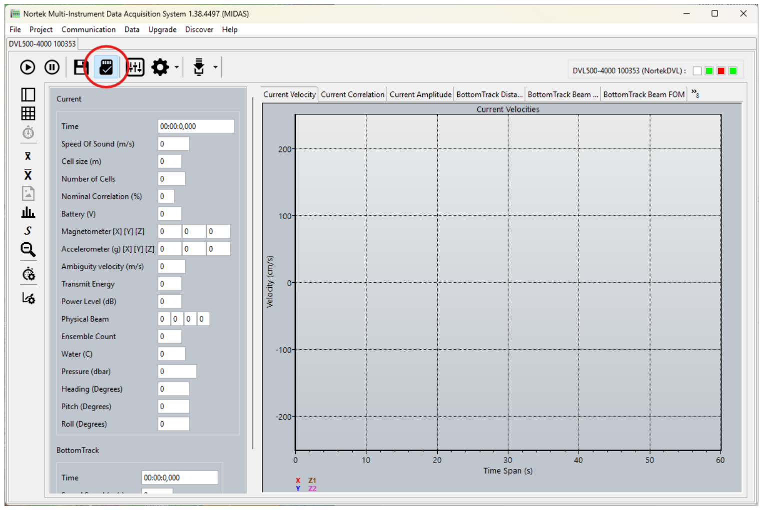


Figure 17: Midas Save to DVL Recorder

8. Submerge the DVL into the testing environment and start the DVL by selecting play button in the top left corner.

Running test and interpretation

1. Begin testing with only the DVL and vehicle power supply powered on. The most important tabs shown on Midas while testing are 'Spectrum' and 'Current Amplitude'.
2. If the 'Frequency vs Amplitude' graph looks similar to the graph in figure 18 and figure 20, proceed with the testing. If the graph looks more similar to the graph in figure 19 and figure 21, return to the *“Back-ground noise testing”* section to identify and remove sources.

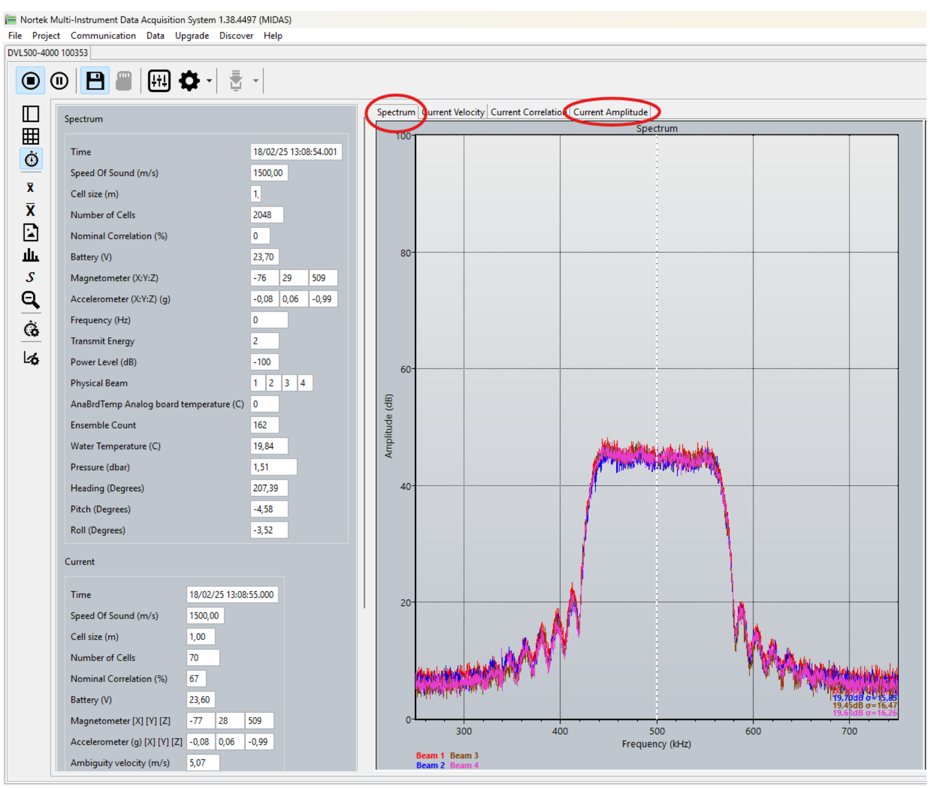


Figure 18: Midas Good Frequency vs Amplitude

Figure 18 is a good example of the 'Spectrum' tab in a low noise environment. Looking at the Amplitude vs Frequency graph, one can see a nice flat bandwidth plateau with a steep rise on both sides. The flatness of the plateau shows there are minimal noise sources within the DVL's bandwidth. The steepness of the sides shows there is low baseline noise in all frequencies near the DVL's operating bands. The 'Amplitude' on the y-axis should be ignored as it is not important, only the shape of the bandwidth should be analyzed.

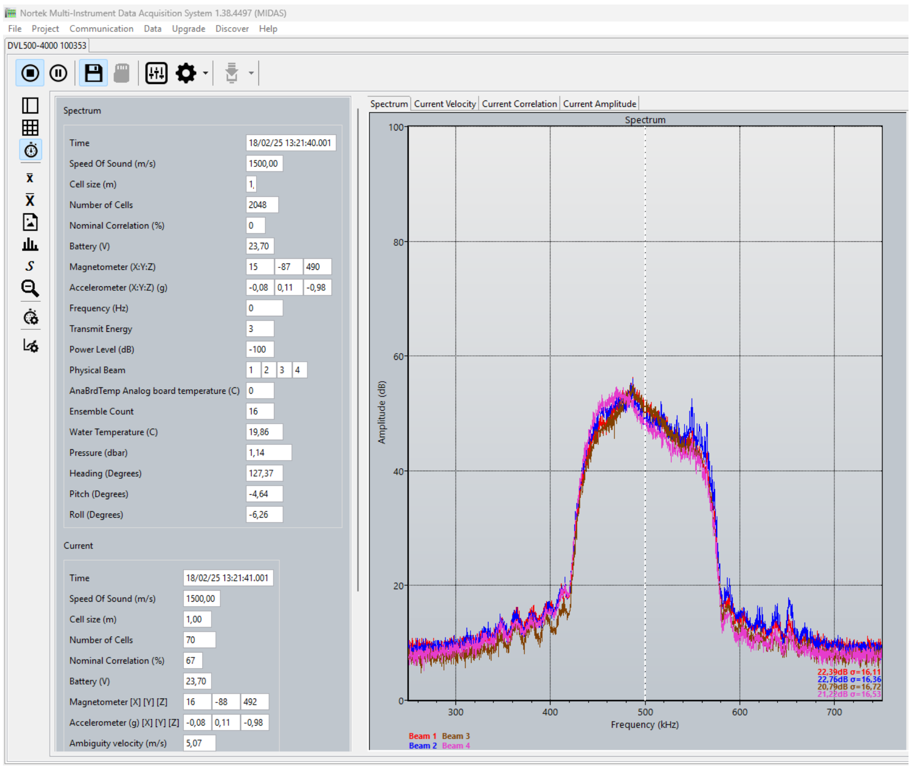


Figure 19: Midas Poor Frequency vs Amplitude

Figure 19 shows a spectrum tab with the DVL in air. This is a noisier reading with small peaks throughout the frequency band. The bandwidth plateau is also worse, with two prominent peaks with a substantial slope in between.

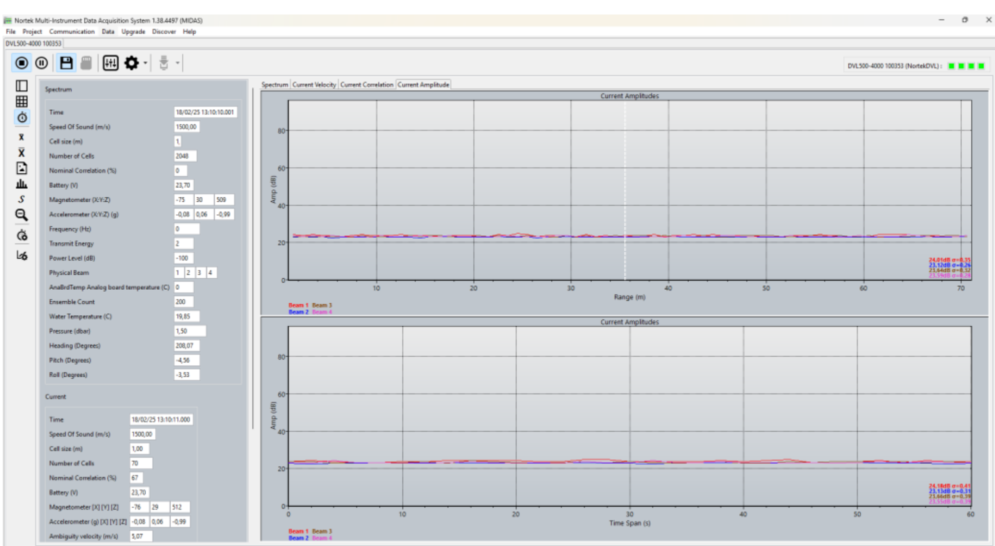


Figure 20: Midas Good Range vs Amplitude

Figure 20 shows the 'Current Amplitude' tab from the same data set as figure 18. The Range vs Amplitude graph quantifies the noise floor, which in this case is shown to be very good at around 25dB.

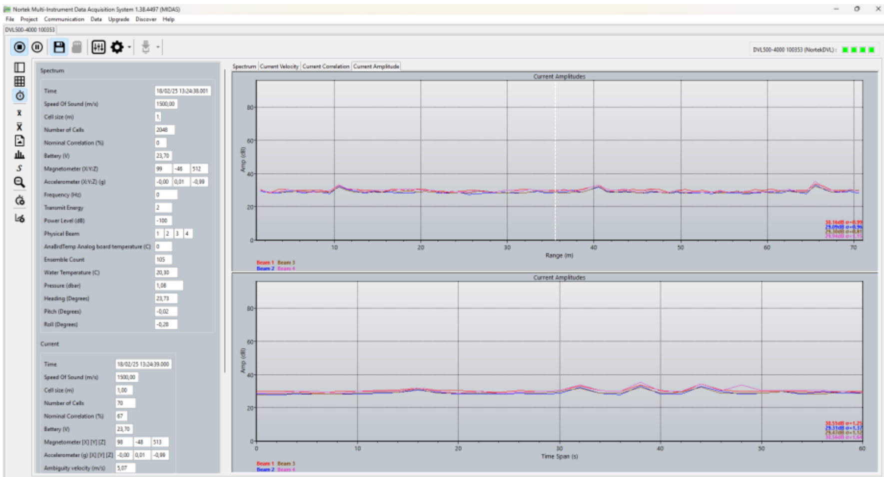


Figure 21: Midas Poor Range vs Amplitude

Figure 21 shows the 'Current Amplitude' tab from the same data set as figure 19. In this graph we can see an elevated noise floor hovering around 30dB. This shows the impact from the deteriorated noise band-width plateau as an overall higher noise plateau of roughly 5dB.

3. Once satisfied with steps 1 and 2 above, we can move onto testing noise sources identified in the baseline noise level testing. Turn on one of the systems that was identified to generate noise. View the 'Frequency vs Amplitude' graph on the 'Spectrum' tab and compare to examples below. Note: Data shown below comes from various instruments but are applicable for all DVL models.

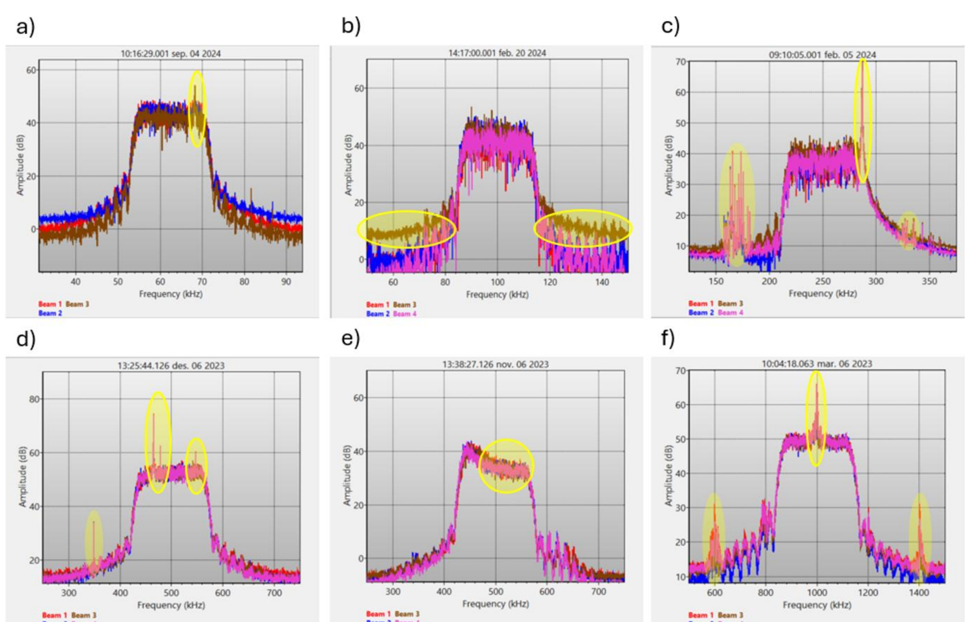


Figure 22: Spectrum Examples

Figure 22 displays a compilation of Nortek Signatures with different frequencies. Multiple types of interference features are highlighted. Yellow circles indicate areas of electrical noise: (a) Frequency peak within the 55 kHz bandwidth; (b) Elevated noise floor in beam 3 of the 100 kHz signature; (c) Multiple peaks across the 250 kHz spectrum; (d) Frequency peak within the 500 kHz bandwidth; (e) Spectrum indicating improper grounding in water; (f) Frequency peak within the 1000 kHz bandwidth.

Adjusting Spectrum Bandwidth

Adjusting the spectrum bandwidth can assist when diagnosing some types of noise found in previous sections. Switching to Ultra or Full allows for analysis of a boarder perspective of frequencies outside the operational band which can help to identify harmonic noise sources. Due to the large data rate, only one channel (beam) can be selected at a time.

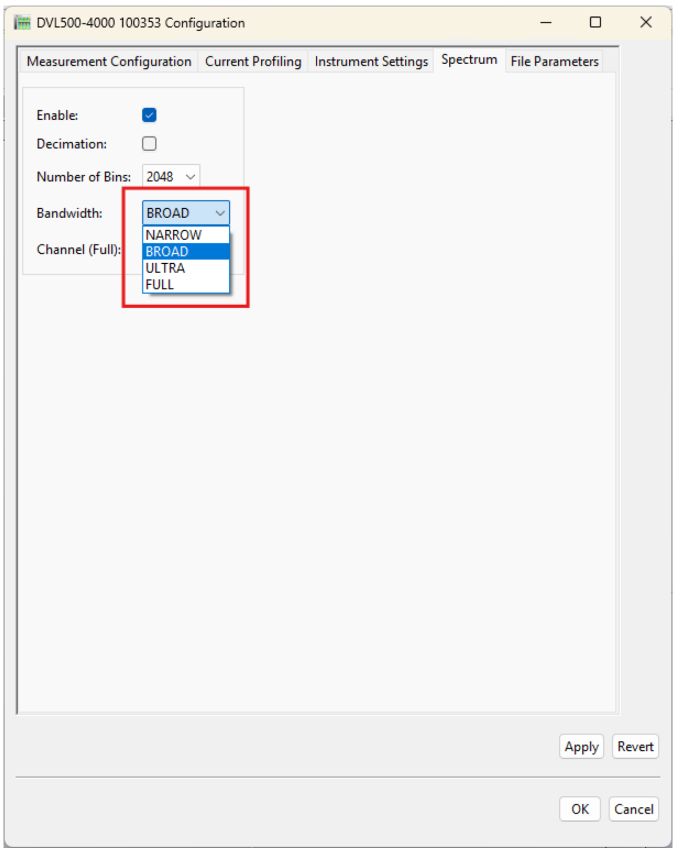


Figure 23: Midas Spectrum Bandwidth

Settings Overview

The following is an overview of the settings (from MIDAS help documentation):

Enable: Turns on the collection of spectrum data. Note that spectrum data replaces bottom track data when enabled (i.e. no bottom track data will be collected).
Decimation: Decimate the raw data before performing the spectrum calculation. The decimated and filtered data is equivalent to the demodulated data after the front end processing.
Number of bins: Number of frequency bins to calculate for the spectrum
Bandwidth: Selects the appropriate frequency range for the spectrum calculation. The FULL bandwidth outputs the spectrum of the raw analog input signal from 0 Hz (DC) to 4 MHz. The other bandwidths output the spectrum of the complex demodulated signal with the center frequency equivalent to the transducer center frequency. The relative filter bandwidths are shown below. Note that due to processing constraints, FULL only allows data from a single beam to be collected.
NARROW: 6.25%
BROAD: 25%
ULTRA: 50%
FULL: 0 – 4 MHz
Number of Beams: Number of beams on which to collect a spectrum when the bandwidth isn't FULL (not applicable to the DVL).
Channel Mapping: The beams to collect a spectrum when the bandwidth isn't FULL (not applicable to the DVL).
Channel (Full): Selects the channel (beam) to use when a bandwidth of Full is chosen.

Command Line Operation

SETDEFAULT, ALL
SETDVL,CP=2
SETCURPROF,NC=50,CS=1,BD=0.1,DF=3,PL=-100
SAVE,CONFIG

Command line operation of the spectrum analyzer is the option for DVLs operating with a Serial interface. The command follows the structure documented in the System Integrators Guide and is invoked with SETSPECTRUM/GETSPECTRUM. The following is an example of how we explicitly set the spectrum analyzer.

SETSPECTRUM,EN=1,BW="BROAD",NFFT=2048,DEC=0,NB=4,CH=1234,CHFULL=1
Or more succinctly:
SETSPECTRUM,1,"BROAD",2048,0,4,1234,1

EN is enable spectrum analyzer.
BW is the bandwidth and may be NARROW,BROAD,ULTRA,FULL.
NFFT is the number of bins and may be 512,1024,2048.
DEC is enable decimation or not.
NB is the number of beams.
CH is the beam selection, an example of four beam is 1234.
CHFULL is the beam selection for the full spectrum analysis.

Once this command has been issued then a SAVE,ALL command is necessary and then the process may be started with the START command.

Data Export

The data that is collected may be exported to a more user-friendly format such as text or MATLAB. For operators using MIDAS to collect data, they may enable data conversion which is done in real time with the Spectrum Analyzer operation. See MIDAS manual for information on how to enable this feature.

Alternatively, recorded data can be exported to MATLAB by selecting the Data menu item, converting AD2CP to NTK and then exporting to MATLAB or ASCII. Opening this resulting MAT file will provide a "Data" data structure, which contains the relevant information and definitions of the fields.

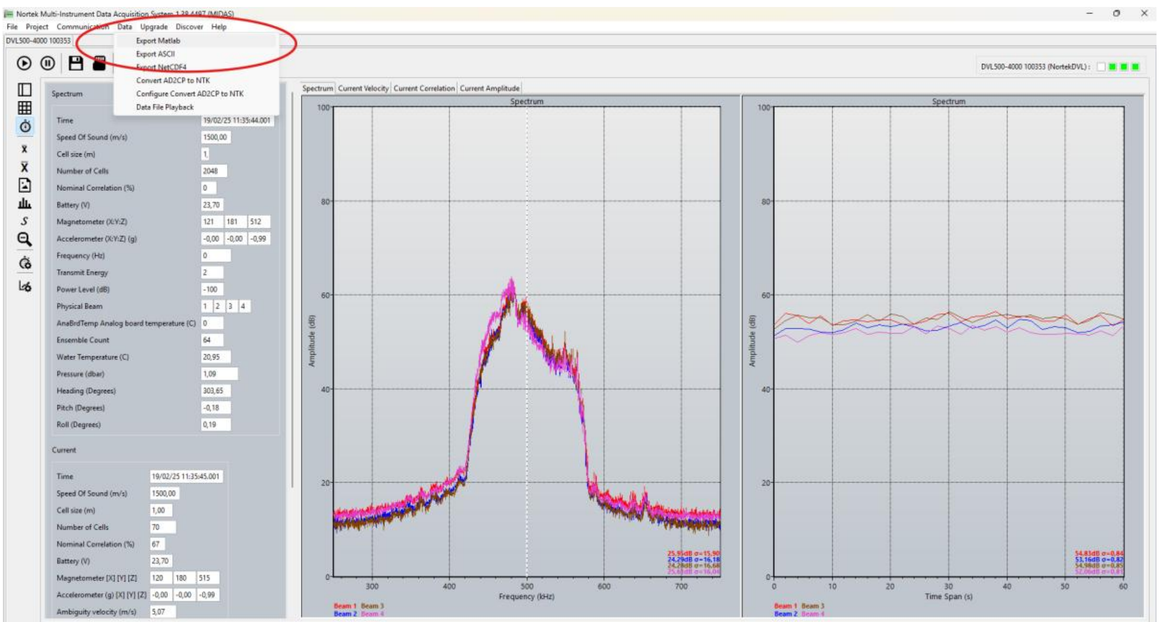


Figure 24: Midas Data Export