Noise Measurement Guide:

How to Measure Noise using the Nortek DVL

Overview

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" it will bias the velocity estimates and degrade the quality of the navigation.

Noise may be either acoustic or electronic. Electronic noise it may be conducted to the DVL or it may be radiated.

The most common electrical noise problem for a DVL is caused by common mode noise on the power lines. Common mode noise, which often is generated in a galvanic isolated power, will set up an electrical field between the DVL and seawater. Because of the physical nature of the DVL transducer, this electrical field will be strongest between the transducer and seawater. It will be picked up as noise in the measurement (receive mode). The easiest way to deal with this is to have a good electrical connection between the negative power input to the DVL and seawater. Because of corrosion issues, this connection is normally made through a capacitor (see Figure 10).

This document presents a systematic way to characterize and measure noise sources and allows the end user to methodically hunt the noise sources and then 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 on the Nortek DVL in order to evaluate the noise sources and begin a dialog to make improvements

The beginning assumptions are that the DVL is connected to its intended power supply and if the DVL is an OEM or custom integration, that it is grounded as prescribed.

Either serial or Ethernet may be used. Ethernet permits real time monitoring and display of data, while a serial interface limits the testing to logging to the DVL's recorder.

During testing, the vehicle ideally should 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. 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.

As an example of the benefit of saltwater, adding 0.5 kg of salt to 350 liters of water shows to reduce the noise by 10 dB. This reduction in background noise makes it much easier when trying to identify the noise source.

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 Faradays Cage (See Figure 1) to isolate from electromagnetic disturbances.

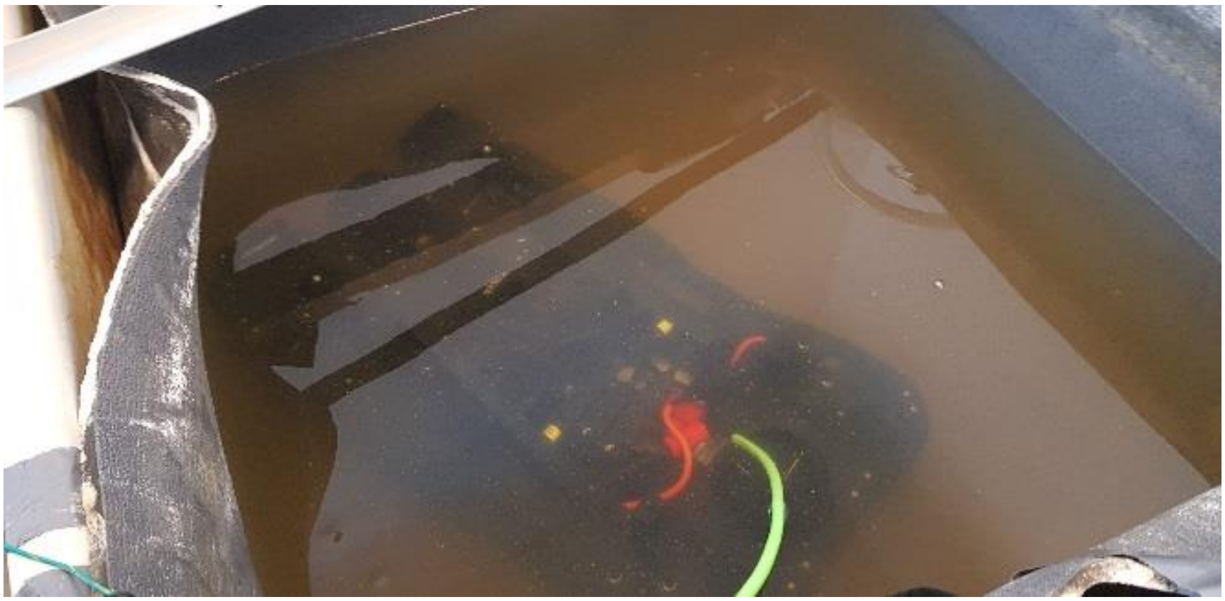

Figure 1 Example of Faradays Cage in a saltwater tank.

General Checklist

The general approach for finding noise is to:

1. Disable the DVL's transmitter in the instrument configuration.
2. Establish the environmental noise level by collecting DVL data from a direct battery power supply, if possible.
3. Configure the DVL to measure the base noise levels (noise floor) by collecting acoustic profiles. The goal is to have a noise floor of less than 30 dB and a noise free DVL if the profile achieves a flat, constant level of about 26 dB.
4. Configure the DVL to measure spectral data using the spectrum analyzer function. This step is only necessary if the noise floor is above the desired level.
5. Connect to the vehicles intended power supply and repeat steps (3) and if necessary, (4).

6. Incrementally enable the vehicle's subsystems and repeat steps (3) and (4) – a detailed written log of when each subsystem is operating must be recorded in order to correlate events and observations in the data.
7. The DVL must have firmware 4044_8 or greater.

Current Profiles

The purpose of this is to quantify the base noise levels, or more specifically, ensure that the signal 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 another acoustic system.

The instrument should be configured so that the current profile extends to the instrument's maximum range (30m for the 1 MHz and 50m for the 500 kHz). 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 becomes apparent.

The MIDAS software may be used to configure the Nortek instrument.
The amplitude from the current profiles may be viewed in real time with the MIDAS software.

1. Open MIDAS.
2. Connect to instrument, Communication -> Connect -> Network Discover

   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 step. If you are limited to a serial connection then you will have to configure the instrument and record to file. The process for this is described further down in this document.

3. Select button for Instrument Configuration.

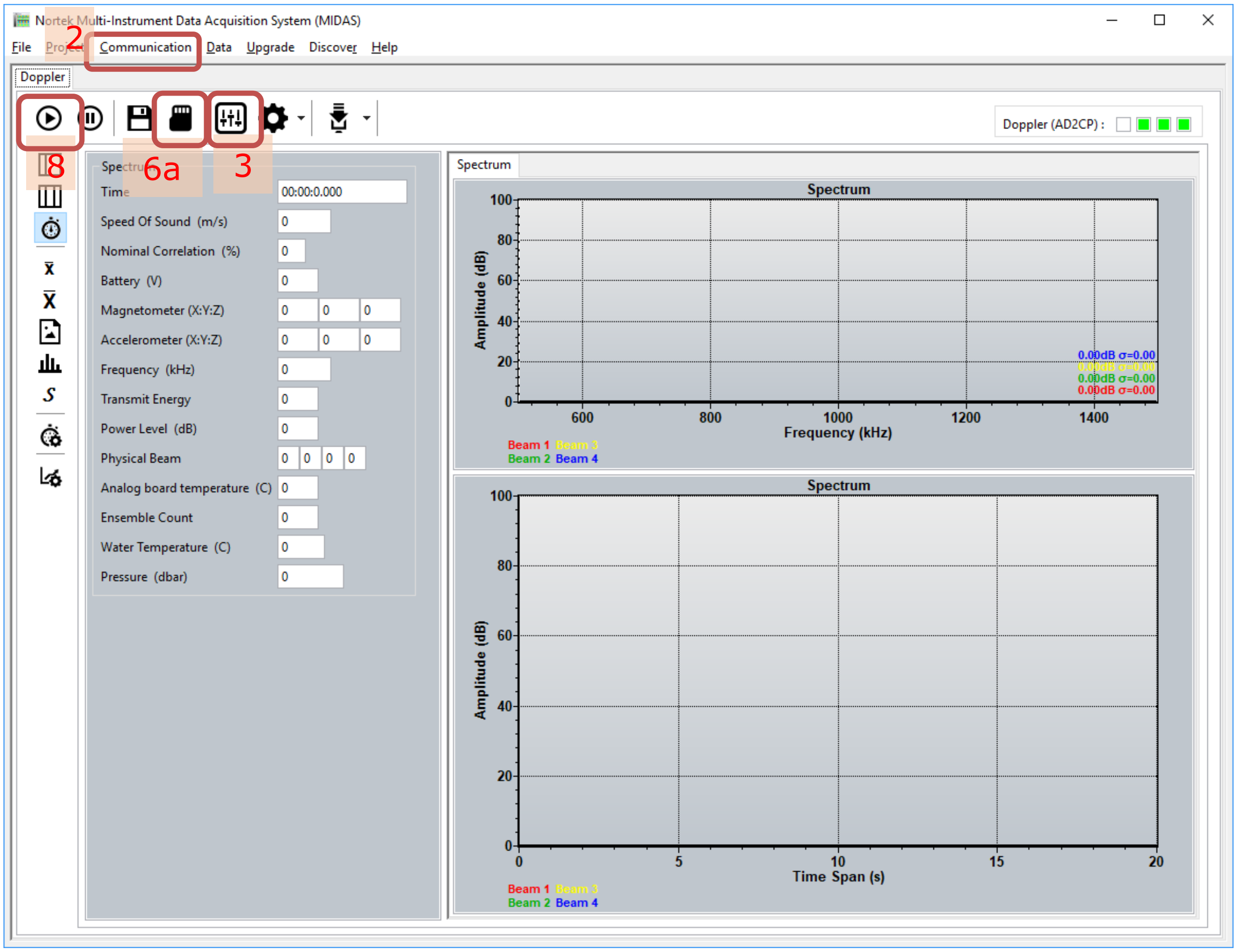

Figure 2 MIDAS software with numerical steps referenced.

4. Configure the instrument measurements, which is the bottom track here, with the settings illustrated in the following screen shot. Bottom track is always enabled for the DVL.

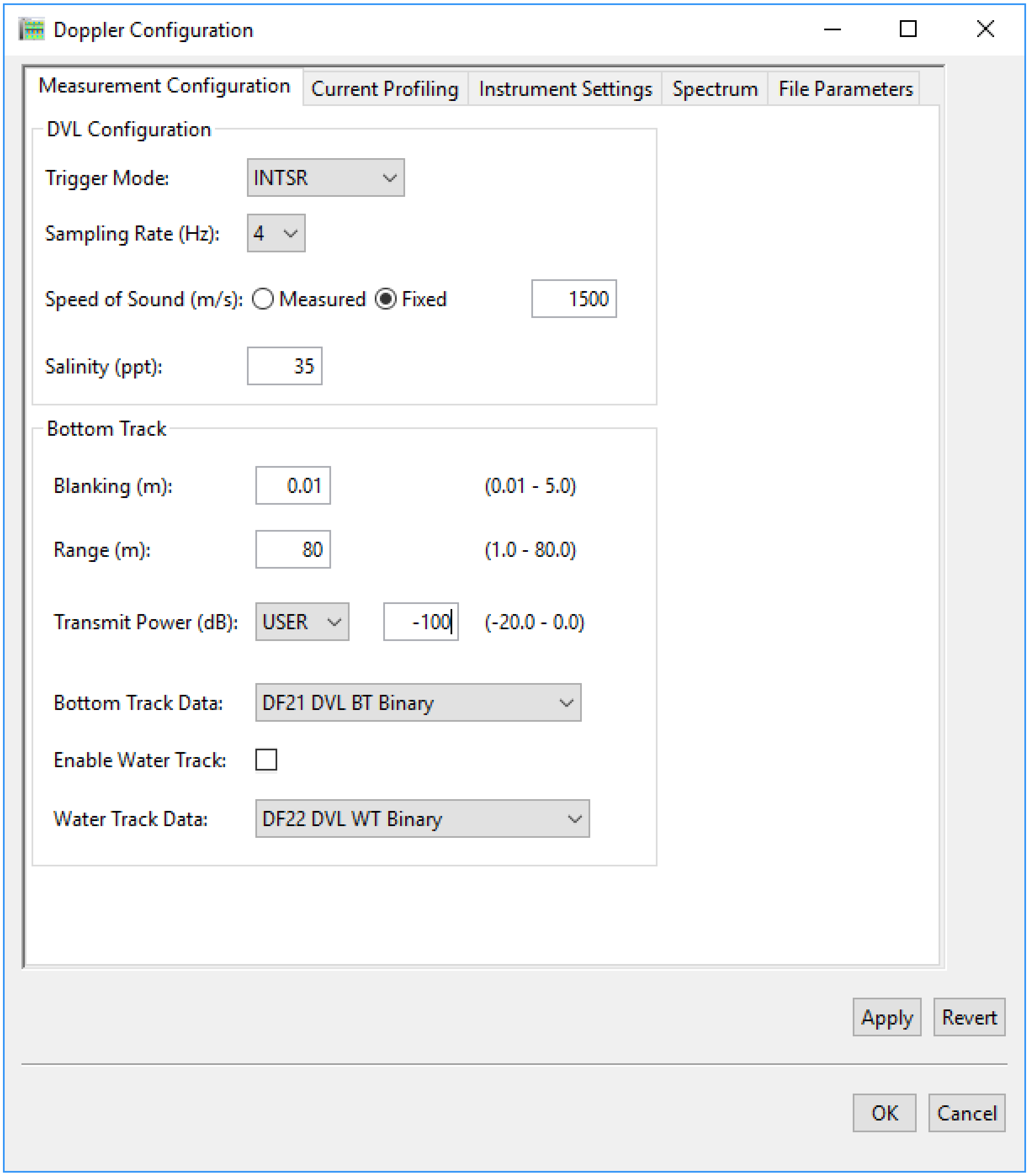

Figure 3 Measurement configuration with large range and transmit disabled with power level set to -100.

5. Configure the current profiling, which alternates with the bottom track when the interleave ratio is set to 2.

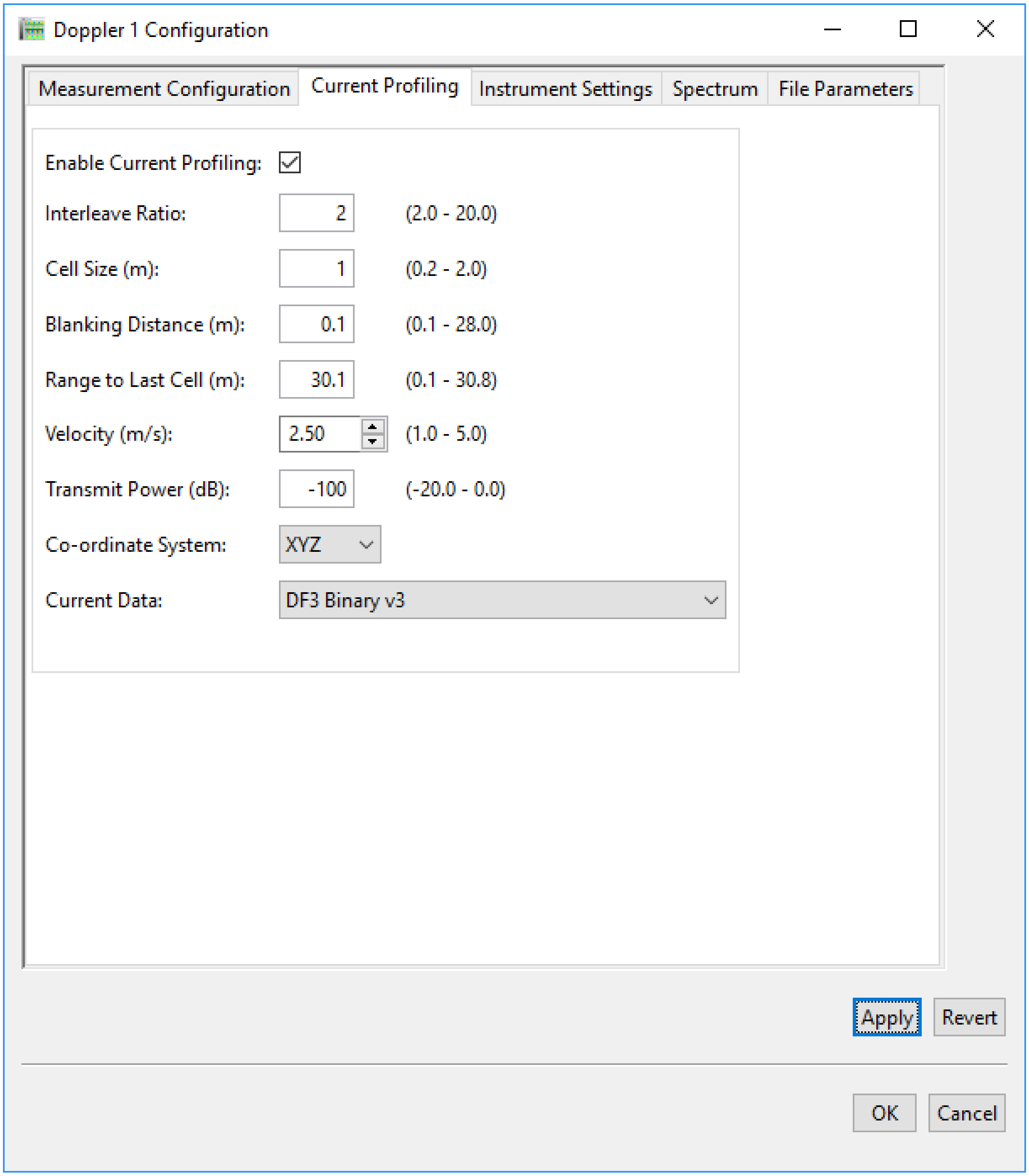

Figure 4 Current profile enabled and configured with sufficiently long profiling range and transmit disabled with power set to -100.

6. Configure recording for the DVL.
    a. Opening the Instrument configuration (as in step 3) and specifying a filename in the "File Parameters" tab.

b. 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.

7. Enable Record to instrument.
8. Start the DVL, as in step 6 above

Note: the Spectrum Analyzer is not enabled at this stage.

Spectrum Data

In order to configure and use the spectrum analyzer tool you will need to have MIDAS installed on your PC and connect with Ethernet. This is the only way to configure this function and view the data. Steps are as follows:

1. Open MIDAS.
2. Connect to instrument, Communication -> Connect -> Network Discover 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. If you are limited to a serial connection then you will have to configure the spectrum analyzer and record to file. The process for this is described further down in this document.
3. Set sampling to 1 Hz. Disable transmit by setting power level to -100 (PL = -100 in the Measurement Configuration tab.)
4. Select tab for "Spectrum".
5. Configure the spectrum analyzer based on the settings offered and described further down in this document. For starters, one may set the bandwidth to Broad, which will sufficiently over the operating band and all channels (without decimation).

   This may then be followed by switching to the full bandwidth complete overview. This means you should use 2048 bins, FULL bandwidth, Channel 1 – only one beam permitted at a time for this mode.

   Other alternatives include reducing the bandwidth to Ultra, Number of Beams 4, Channel Mapping 1234. Decimation may be used if a finer resolution in the frequency domain is desired. This is desired when one is trying to evaluate the structure of the energy distribution or resolve closely located spikes.

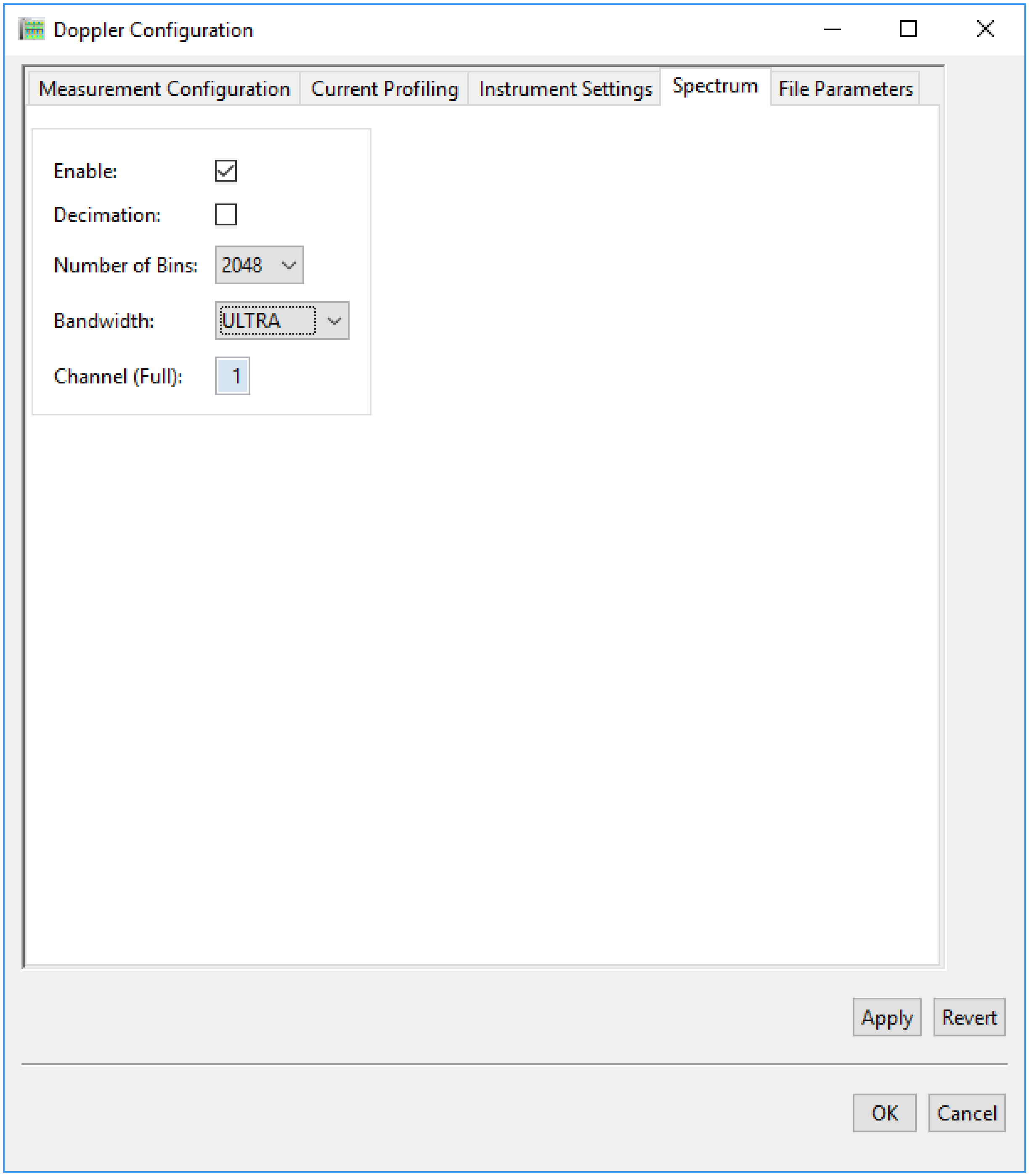

Figure 5 Configuration interface for DVL Spectrum mode.

6. Configure recording for the DVL.
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7. Enable Record to instrument.

8. Start the DVL, as in step 6 above.

Recorded data may be exported to MatLab by selecting the Data menu item then first converting AD2CP to NTK and then exporting to MatLab. Opening this resulting MAT file will provide a "Data" data structure, which contains the relevant information and definitions of the fields.

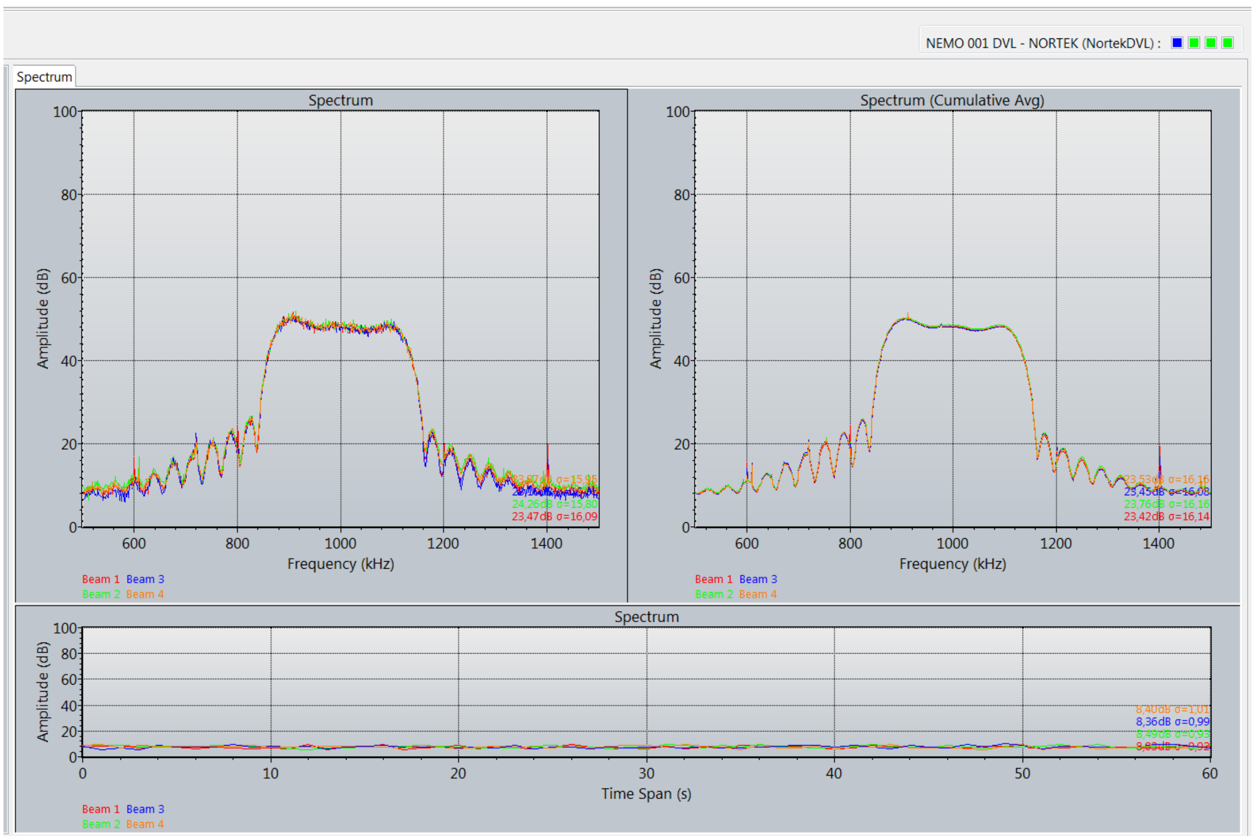

Figure 6 Example of a noise-free spectra

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.

In order to record to the SD card recorder, one needs to specify a filename in the "File prefix" found under the "File Parameter" tab. This will be the same for both recordings to the local computer and the SD card recorder.

Finally, you will want to enable recording on the Instrument and/or PC and then start the measurements. Note that the recording buttons are highlighted when enabled

For live displays you may want to change the view so the screen layout is as follow. The change is done by selecting the "switch display modes" button on the vertical right button bar (see Figure 6).

It may also be interesting to change the view to spectrogram which is the button with the label, "enable imaging".

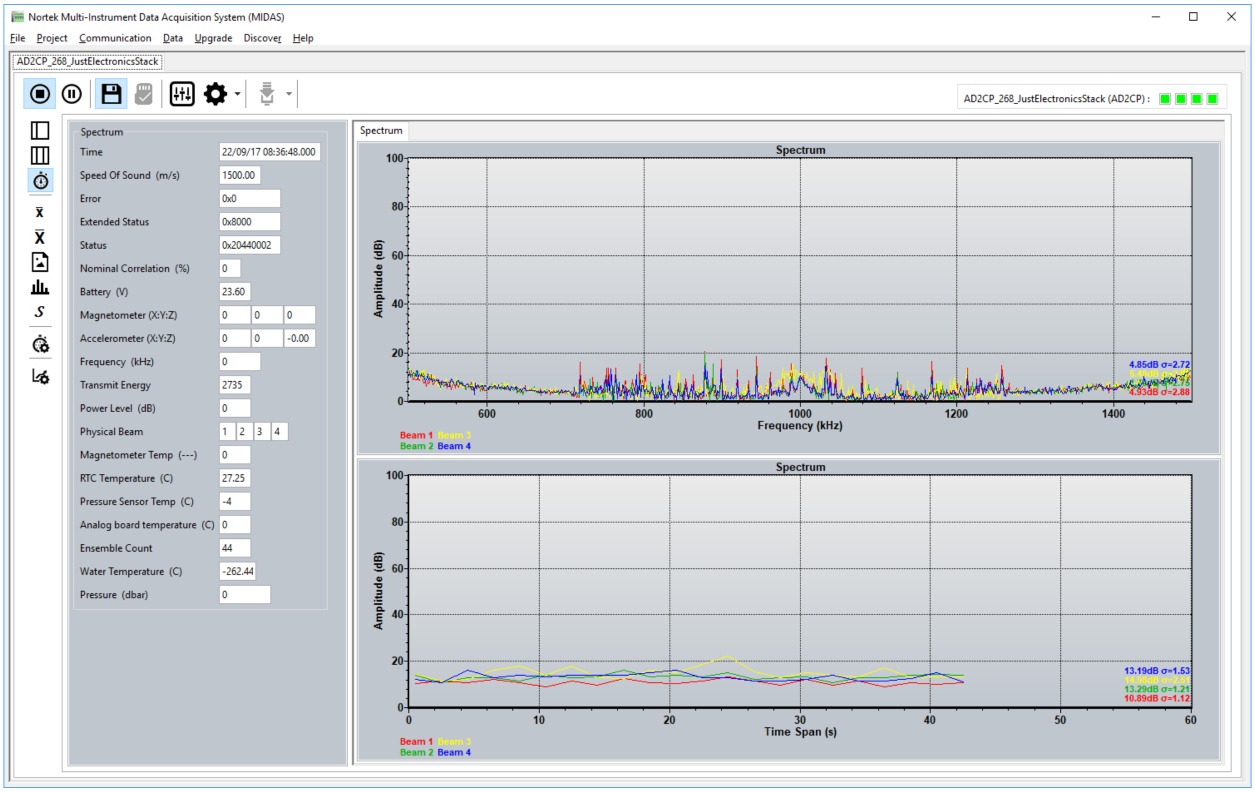

Figure 7 Example of spectrum analyzer display.

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 of the Spectrum Analyzer operation.

Alternatively, one may convert the raw data file in the menu item Data->Convert ADCP to NTK. This is then followed by Export to MatLab or Export to ASCII.

Data Visualization

Data from the both the current profiles and the spectrum analyzer may be viewed in MIDAS in real-time. The recorded data is best viewed with the Ocean Contour software; this software is free to download if only the data display options will be used, which is the case here.

The objective is to identify when the amplitude profiles reaches a constant value, or noise floor. This should be around 23-26 dB. The profiles in figure 6 shows that it hops around 42-50 dB, which means the bottom detection will have limited range, because of the elevated noise floor.

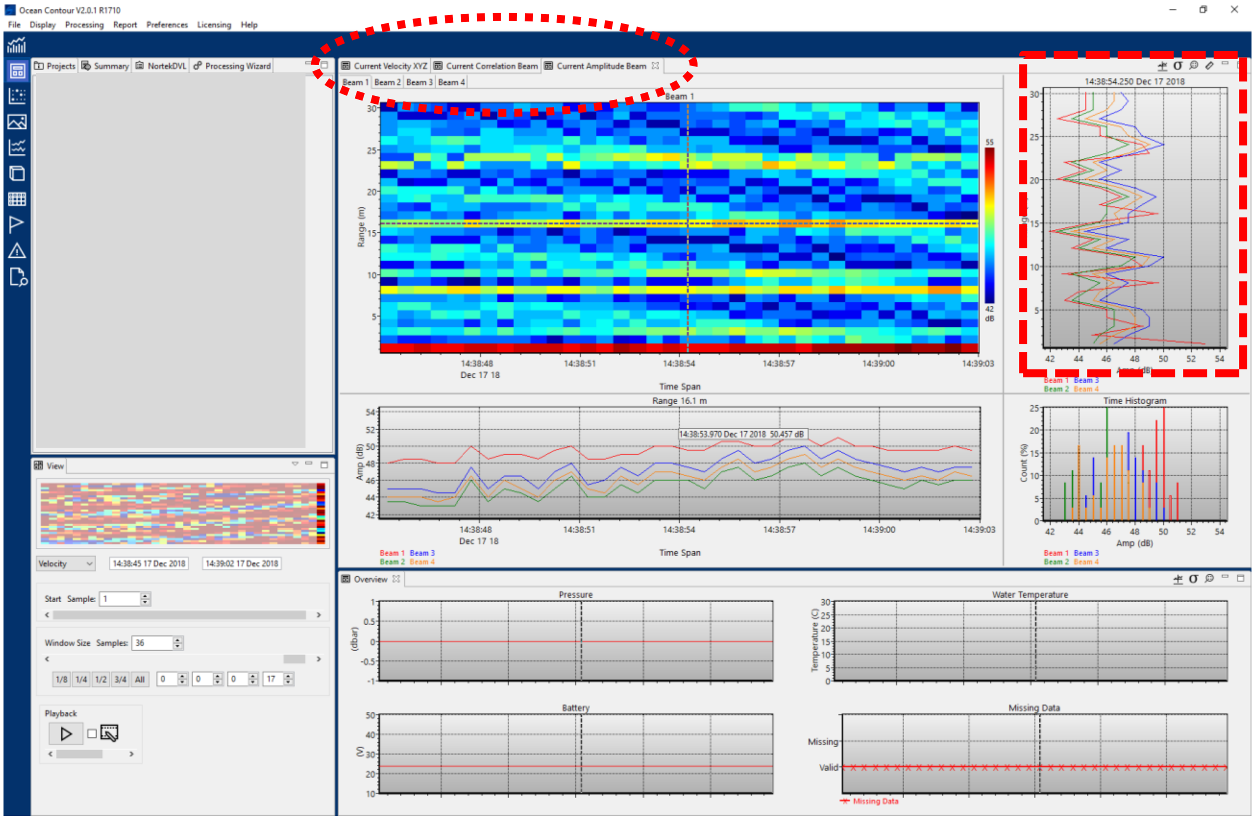

Figure 8 The tabs indicated by the ellipse provide a means to evaluate the amplitude levels as well as the correlation. The plot enclosed by the box shows profiles of the four beams and is a good method for finding the noise floor at the maximum range.

The spectral plots help to identify the sources of noise, which often appear as spikes in the spectrum. One should expect to see a broad elevated level for the band of operation for the DVL.

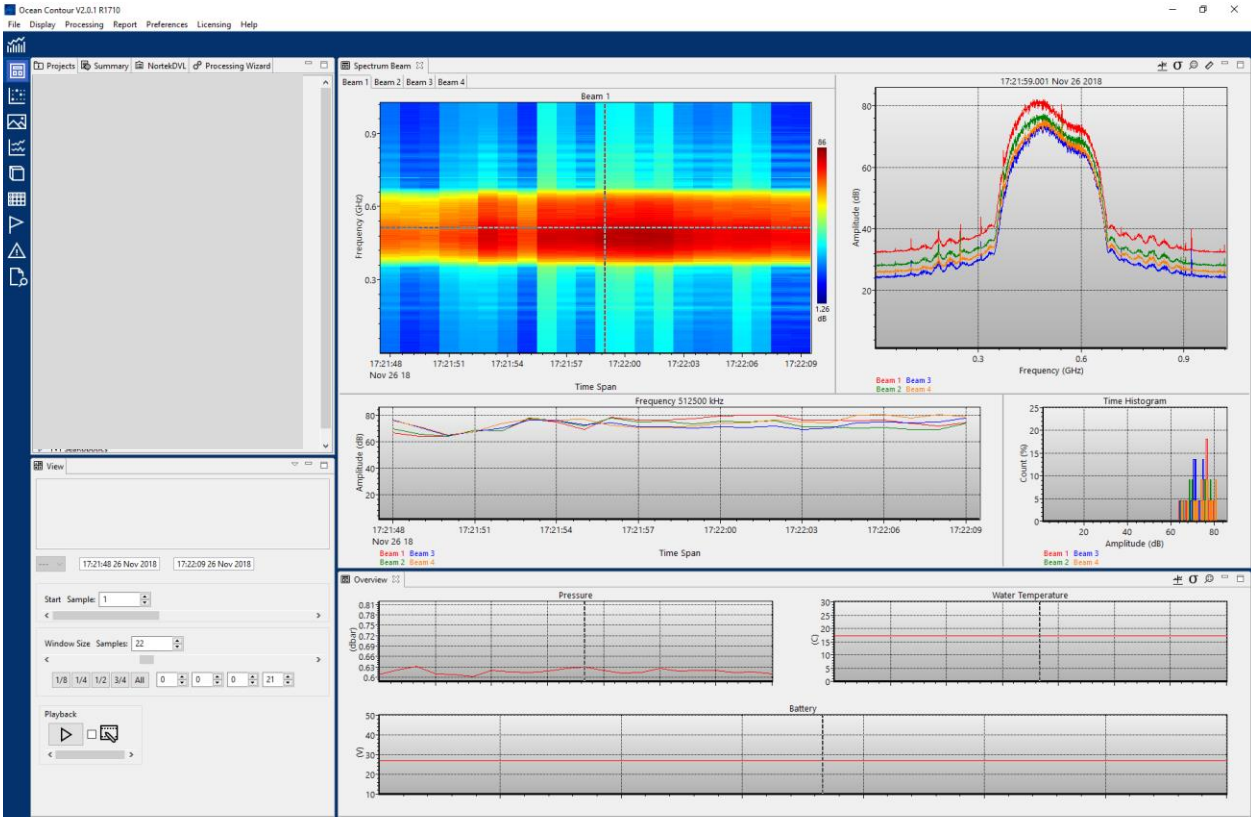

Figure 9 Example of a relatively clean spectrum for a 1 MHz DVL.

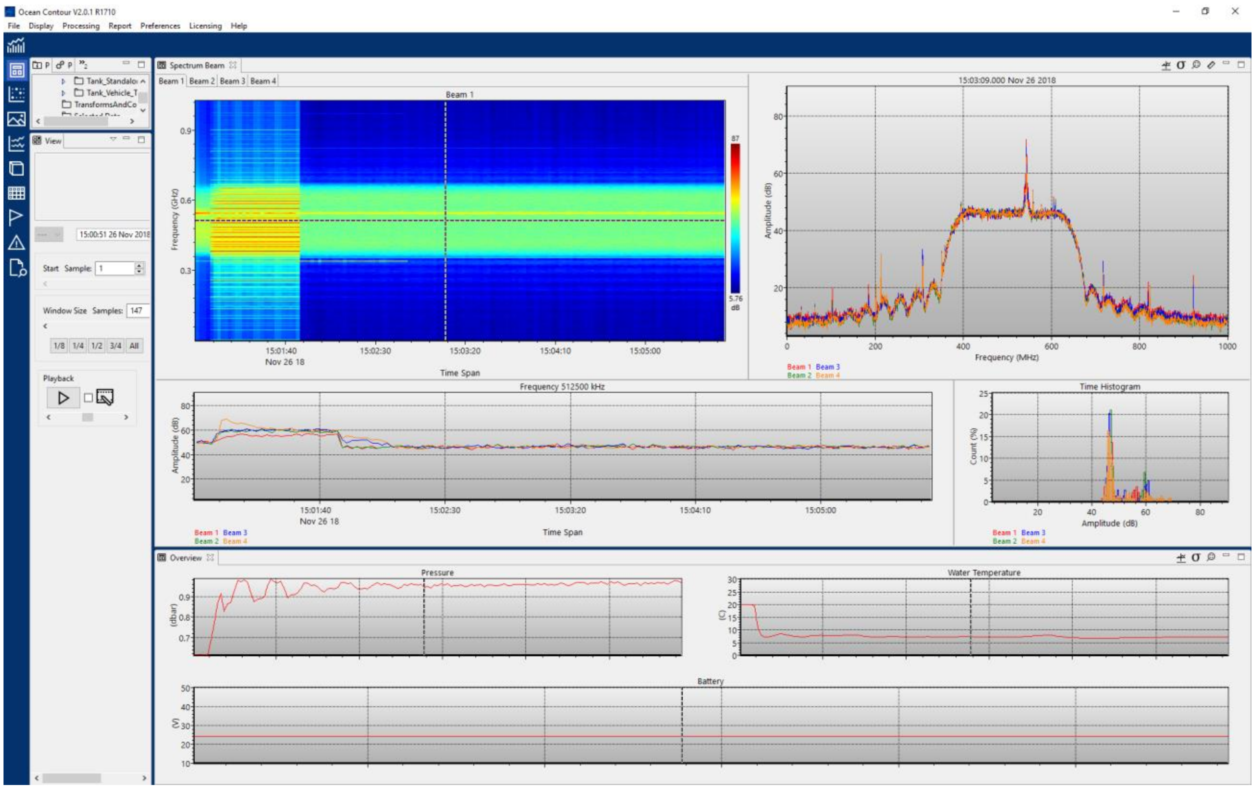

Figure 10 Example of a Spectrum showing a noise spike in the operating band.

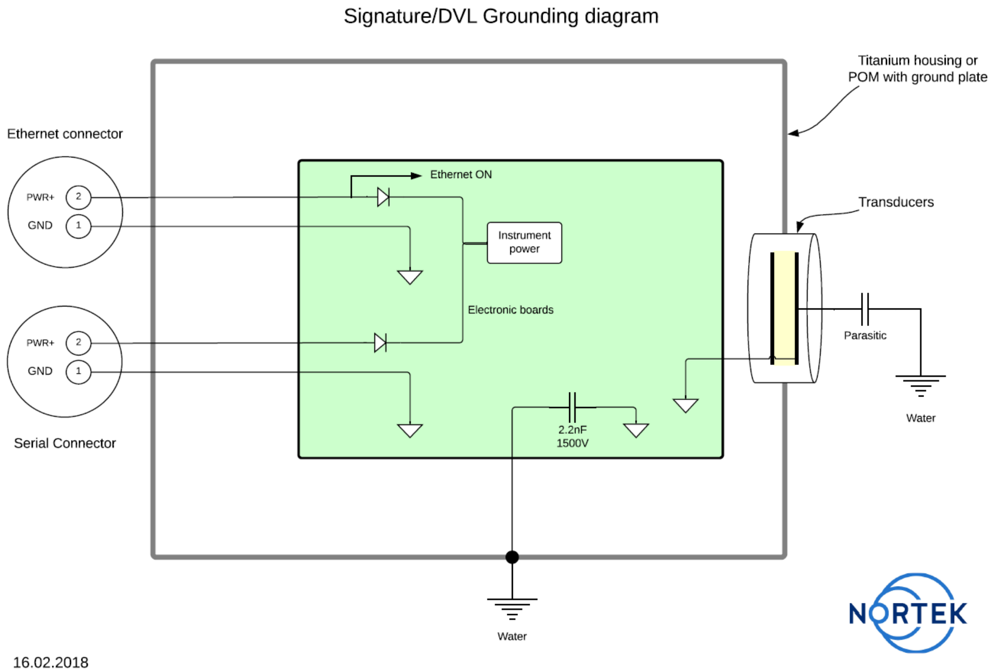

Figure 11 Grounding scheme for the Nortek DVL. The drawing shows a capacitor of 2.2 nF which would be for the DVL1000. The DVL500 requires a larger capacitor. This is to avoid corrosion when grounding to seawater. This capacitor and contact to the surrounding seawater is included for off the shelf Nortek DVLs. The OEM require system integrators to complete this.