OptaSense®
A LUNA company

# University of Washington OOI Offshore Cable QuantX Data Acquisition

## Summary Report

| | |
|---|---|
| Date: | November 10, 2021 |
| Issue: | 2 |
| OptaSense Ref: | NPD-21-004213-Summary |
| Original Author: | M Karrenbach |
| Revision Author: | N/A |

## Issue Record

| Issue | Date | CS Number | Written | Checked | Approved |
|---|---|---|---|---|---|
| **1** | 10th Nov 2021 | | M Karrenbach | C Minto | C Minto |
| **2** | 7th Feb 2022 | | M Karrenbach | C Minto | C Minto |
| | | | | | |

## Amendment Record

| Issue | Change Sheet / By Whom | Reason for Change | Date |
|---|---|---|---|
| **2** | Client | Requested changes to proposal | Jan 2022 |
| | | | |
| | | | |
| | | | |

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Specification is liable to change without warning – please contact OptaSense® for latest version.

Reference: NPD-21-004213-Summary

# Contents

# 1 Summary

DAS Data acquisition was carried out on the Receiver and Transmit fibers at the OOI shore station in Pacific City, OR during a maintenance shutdown of the OOI cabled observatory systems from November 1-5, 2021.

Two OptaSense QuantX systems were utilized and operated with LightAquisition 2.0. Data were stored in 3 simultaneous identical streams to different internal disk sets

The systems were set up and prepared on October 31, and short tests carried out in the morning of November 1 (after shutdown of the OOI observatory system at 08:00 am).

The two QuantX systems were connected to OOI fibers via patch cables (300m length). OptaSense used the Transmit South and North fibers for the majority of the acquisition time, and the Receive South and North fibers for a 3 hour duration on the last day of acquisition.

Nov 1, Monday 08:00 – Nov 5, Friday morning 07:00

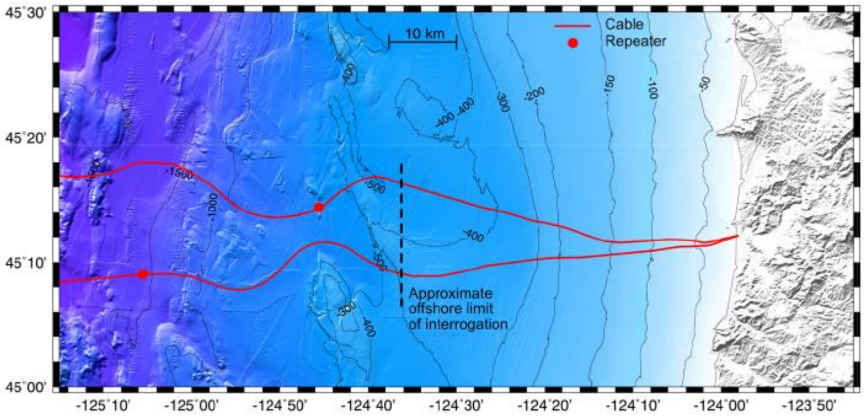
**South Patch 001 = Transmit Fiber South (96km)**

**North Patch 002 = Transmit Fiber North (65km)**

Nov 5, Friday morning 07:00 – Nov 5, Friday morning 10:00

**South Patch 001 = Receive Fiber South (96km)**

**North Patch 002 = Receive Fiber North (65km)**




*The location of the two OOI cables on the continental shelf and upper slope offshore Pacific City, Oregon.*

**Figure 1:** Fiber cable location on map with depths. QuantX Systems were configured to reach up to repeater locations

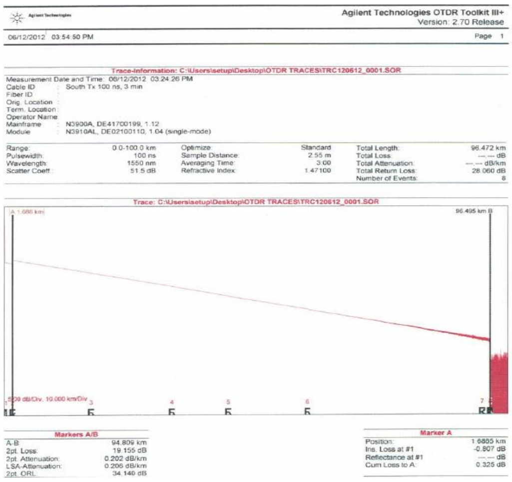



**Figure 2:** On left: Example of OTDR, South Cable; On right: fiber connection panel



# 2 Data Recordings

Test recordings were taken for short durations on Nov 1, Monday until 15:00 on both fibers. These tests utilized gauge length from 14m to 100m. Thereafter both systems recorded in the three main configurations.

## 2.1 Overview of Main Recordings

All recordings stored as H5 files in 30sec or 60 sec intervals. Spatial channel sequential storage. OptaSense systems record optical phase shift which is directly proportional to strain. This enables low frequency signal fidelity. See the Appendix Technical Note on how convert the H5 sample values into strain (based on gauge length, refraction index of the fiber, and other constants). Strain rate can be computed by differentiation of the signal in time.

| Configurations (all Ping1kHz) | **South Cable**<br>**On Transmit fiber** | **North Cable**<br>**on Transmit fiber** |
|---|---|---|
| Config-1 | **Day 1-4**<br>Length 95km at 2m channel spacing<br>Number of Channels 47500<br>Sampling frequency 200Hz<br>Gauge Length 50m | **Day 3-4**<br>Length 65.2km at 2m channel spacing<br>Channels 32600<br>Sampling frequency 200Hz<br>Gauge Length 50m |
| Config-2 | | **Day 2**<br>Length 65.2km at 2m channel spacing<br>Number of Channels 32600<br>Sampling frequency **500Hz**<br>Gauge length **30m** |
| Config-3 | | **Day 1**<br>Length 65.2km at 2m channel spacing<br>Number of channels 32600<br>Sampling frequency **1000Hz**<br>**Gauge length 30m** |
| Configurations (all Ping1kHz) | **South Cable**<br>**On Receive fiber** | **North Cable**<br>**on Receive fiber** |
| Config-1 | **Day 4 – Friday 07:00-10:00**<br>Length 95km at 2m channel spacing<br>Number of Channels 47500<br>Sampling frequency 200Hz<br>Gauge Length 50m | **Day 4 – Friday 07:00 – 10:00**<br>Length 65.2km at 2m channel spacing<br>Channels 32600<br>Sampling frequency 200Hz<br>Gauge Length 50m |

## 2.2 Recording Folders on Disk Set:

The recording folder names encode various acquisition settings and the start time of the recording, in the following manner:

ConfigType-Length-Ping-GaugeLength-Spacing-Sampling Frequency-modifier_dateTtime

for example: C1-LR-95km-P1kHz-GL100m-SP2m-FS1000Hz-test_2021-11-01T12_29_47-0700, is a Configuration-1 recording started on November 1 at 12:29:47 (Pacific Standard Time).

Note that inside these folders each recording file is tagged with the UTC time (not PST).

Folder content sizes are indicated in TeraByte (T) and GigaByte (G).

### *2.2.1 South Cable*

**Short-duration recordings** (gauge length related tests):

59G C1-LR-95km-P1kHz-GL100m-SP2m-FS1000Hz-test_2021-11-01T12_29_47-0700

3.5G C1-LR-95km-P1kHz-GL100m-SP2m-FS200Hz-test_2021-11-01T09_23_30-0700

17G C1-LR-95km-P1kHz-GL100m-SP2m-test_2021-11-01T09_12_24-0700

35G C1-LR-95km-P1kHz-GL14m-SP2m-FS1000Hz-test_2021-11-01T11_51_33-0700

31G C1-LR-95km-P1kHz-GL200m-SP2m-FS1000Hz-test_2021-11-01T12_43_24-0700

26G C1-LR-95km-P1kHz-GL200m-SP2m-test_2021-11-01T09_05_24-0700

37G C1-LR-95km-P1kHz-GL20m-SP2m-FS1000Hz-test_2021-11-01T11_59_46-0700

32G C1-LR-95km-P1kHz-GL30m-SP1m-FS1000Hz-test_2021-11-01T12_51_05-0700

643G C1-LR-95km-P1kHz-GL30m-SP1m-FS1000Hz-test_2021-11-01T12_59_21-0700

26G C1-LR-95km-P1kHz-GL30m-SP2m-FS1000Hz-test_2021-11-01T12_11_31-0700

260G C1-LR-95km-P1kHz-GL50m-SP2m-FS1000Hz-test_2021-11-01T10_57_03-0700

46G C1-LR-95km-P1kHz-GL50m-SP2m-FS1000Hz-test_2021-11-01T12_19_45-0700

3.6G C1-LR-95km-P1kHz-GL50m-SP2m-FS200Hz-test_2021-11-01T10_05_33-0700

**Long-duration recordings (5.8TB)**

4.4T South-C1-LR-95km-P1kHz-GL50m-SP2m-FS200Hz_2021-11-01T16_09_15-0700

804G South-C1-LR-95km-P1kHz-GL50m-SP2m-FS200Hz_2021-11-04T10_37_24-0700

597G South-C1-LR-95km-P1kHz-GL50m-SP2m-FS200Hz_2021-11-04T10_37_24-0700

South Receive Fiber:

179G South-C1-LR-95km-P1kHz-GL50m-SP2m-FS200Hz-ReceiveFiber_2021-11-05T07_21_18-0700



### *2.2.2 North Cable*

**Short-duration recordings (parameter tuning and gauge length tests)**

4.2G North-C1-LR-P1kHx-GL1--m-Sp2m-test1_2021-11-01T09_16_11-0700

2.9G North-C1-LR-P1kHxz-GL100m-Sp2m-test1_2021-11-01T09_17_41-0700

336G North-C1-LR-P1kHz-GL100m-Sp2m-test1_2021-11-01T09_18_44-0700

45G North-C1-LR-P1kHz-GL100m-Sp2m-test2_2021-11-01T12_28_30-0700

242G North-C1-LR-P1kHz-GL14m-Sp2m-test1_2021-11-01T10_54_10-0700

35G North-C1-LR-P1kHz-GL200m-Sp2m-test2_2021-11-01T12_40_31-0700

29G North-C1-LR-P1kHz-GL20m-Sp2m-test1_2021-11-01T11_58_48-0700

677G North-C1-LR-P1kHz-GL30m-Sp1m-test1_2021-11-01T12_50_46-0700

31G North-C1-LR-P1kHz-GL30m-Sp2m-test1_2021-11-01T12_07_48-0700

39G North-C1-LR-P1kHz-GL50m-Sp2m-test1_2021-11-01T12_17_40-0700

**Long-duration (8.8 TB)**

1.8T North-C1-LR-P1kHz-GL50m-Sp2m-FS200Hz_2021-11-03T15_06_51-0700

2.6T North-C2-HF-P1kHz-GL30m-Sp2m-FS500Hz_2021-11-02T14_51_53-0700

5.3T North-C3-HF-P1kHz-GL30m-Sp2m_2021-11-01T14_51_37-0700

North Receive Fiber :

114G North-C1-LR-P1kHz-GL50m-Sp2m-FS200Hz-ReceiveFiber_2021-11-05T07_31_00-0700

# 3 Deliverables

Delivered TDD document (trials preparation)

Delivered daily activity report (observers logs) and Data Acquisition Summary documents to William Wilcock.

Delivered raw data set on 3 sets of disks to Chuck Mcquire for review by Navy (Identical disk copies A, B, C)

# 4 Example Data Snapshots

In the following we show example snapshot taken during the data acquisition.

Fin-whale signals show up strongly in the 15-25Hz repeating every 20 seconds. The signal looks like very short sweep. An occasional probable blue whale signal is visible as well.

A small earthquake signal originating in Northern California (M4.1 EQ 2012-11-03T002310) arrives at the North Cable within 3 minutes.

Numerous cargo and fishing vessels travelled across the cables during the entire acquisition duration, with some being visible for a short duration.

The weather changed significantly after the first day of acquisition to rain and storms with gale force winds, which raised the environmental noise floor significantly.

## 4.1 North Cable

### *4.1.1 North Cable Wave Form Displays*

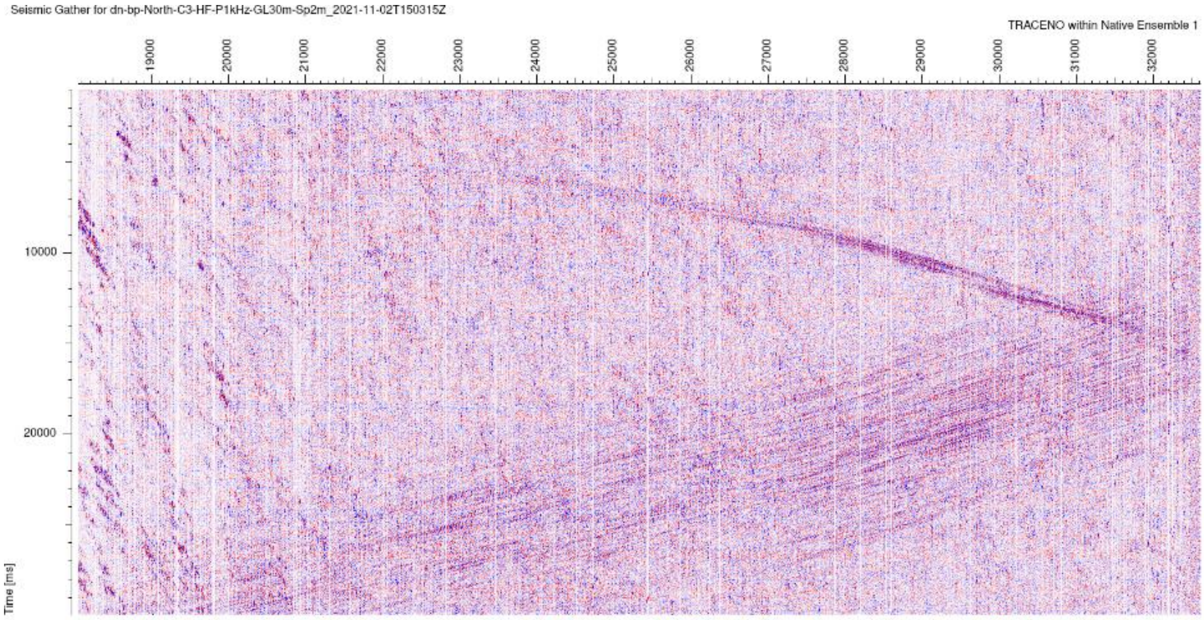



**Figure 3:** Fin whale and blue whale signals on array segment 38km – 64km.

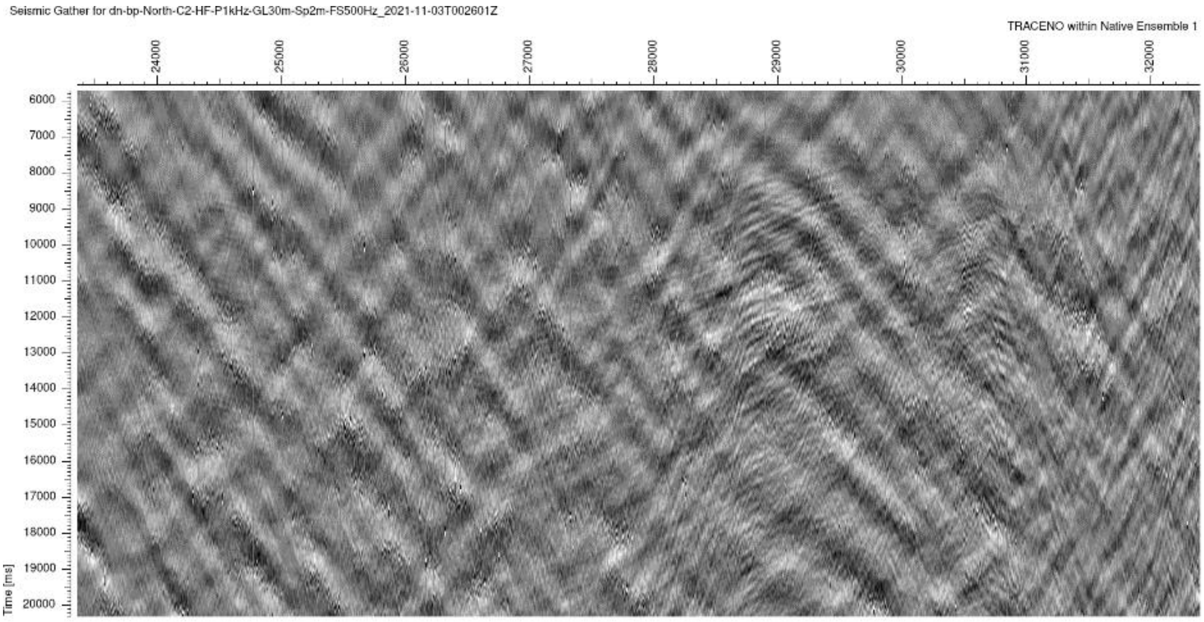



**Figure 4:** High frequency arrivals of Northern California earthquake M4.1.

### 4.1.2 North Cable Waterfall Displays (November 2), All in ~12-25Hz band

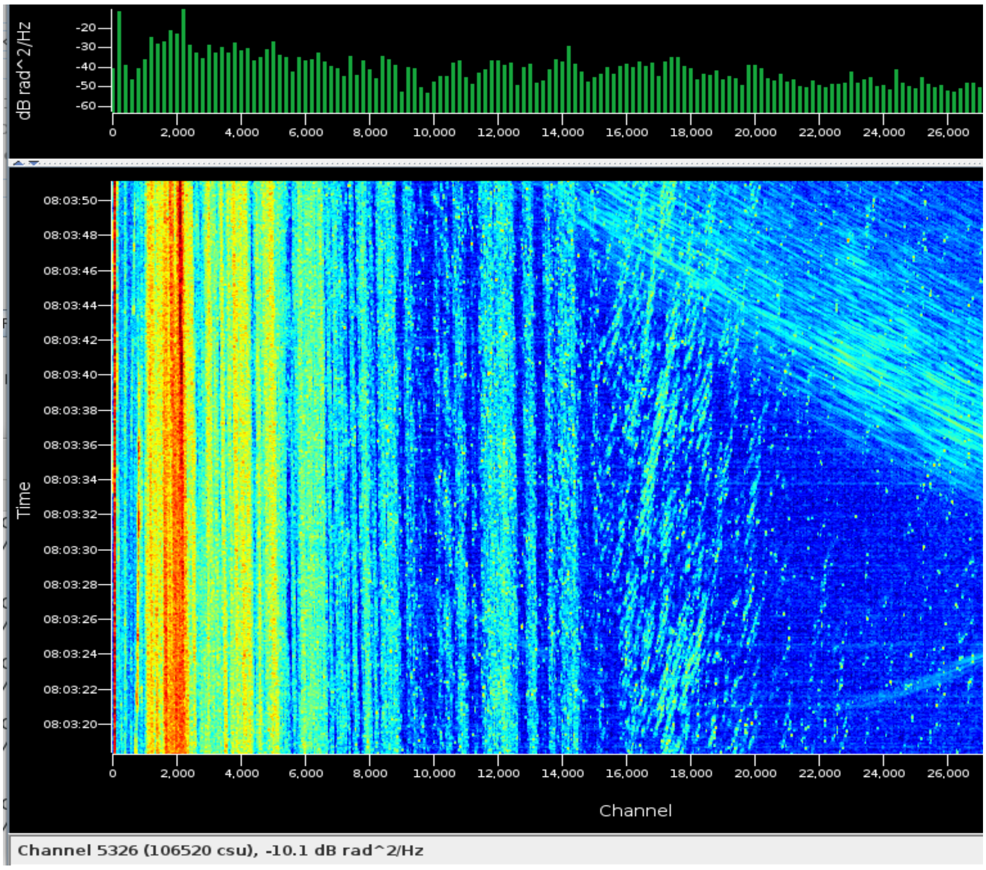



**Figure 2**: An inferred T-phase from a regional earthquake arriving from offshore and a fin whale signal from 28-64 km.

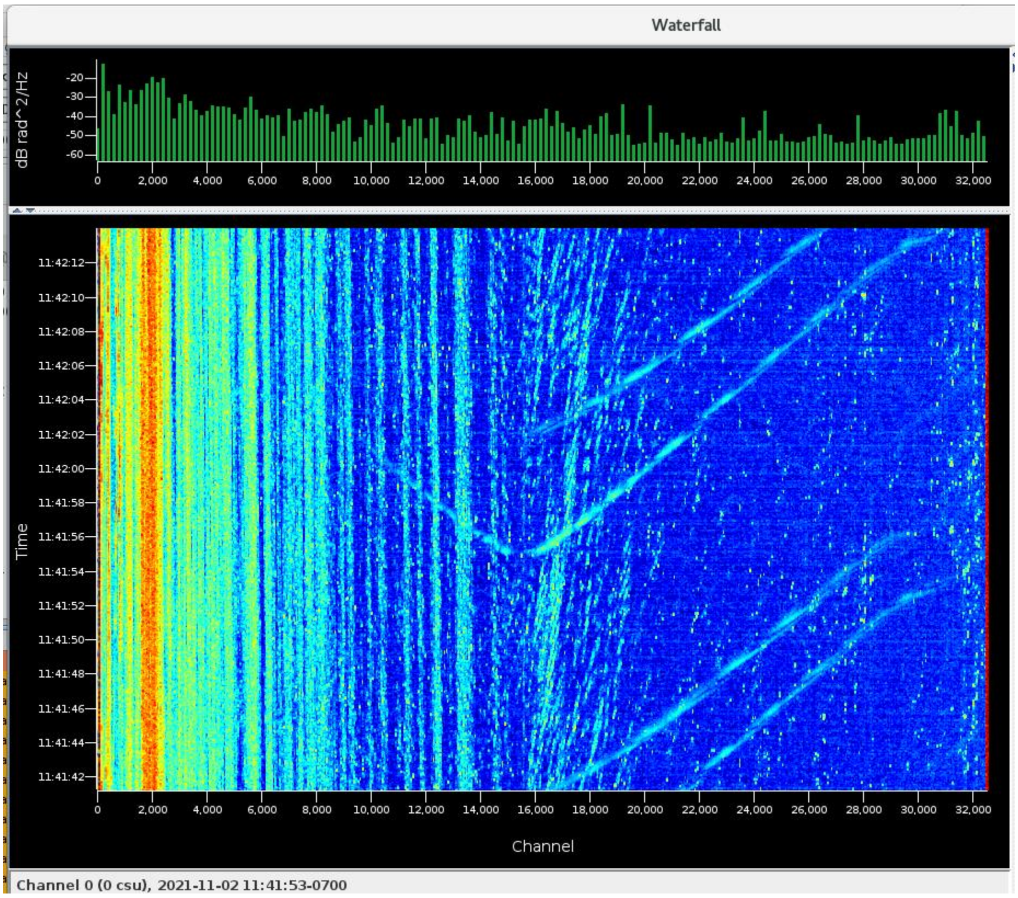



**Figure 3:** Multiple fin whale signals repeating

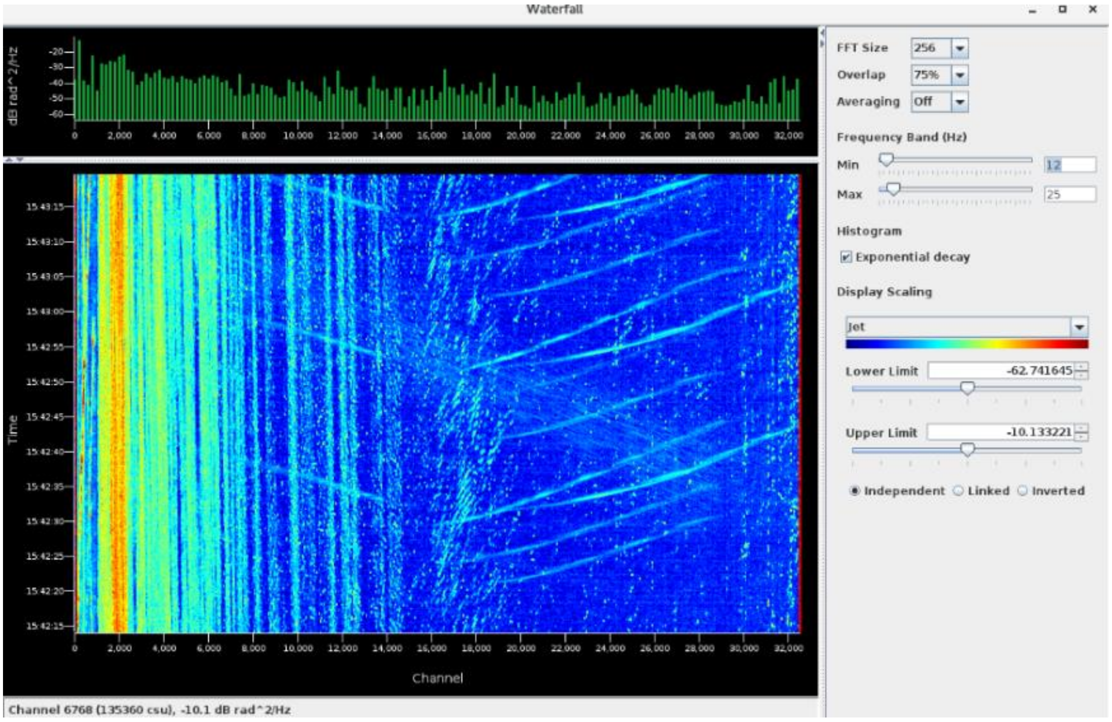



**Figure 4:** Multiple repetitive fin whale and probable weak blue whale signal.

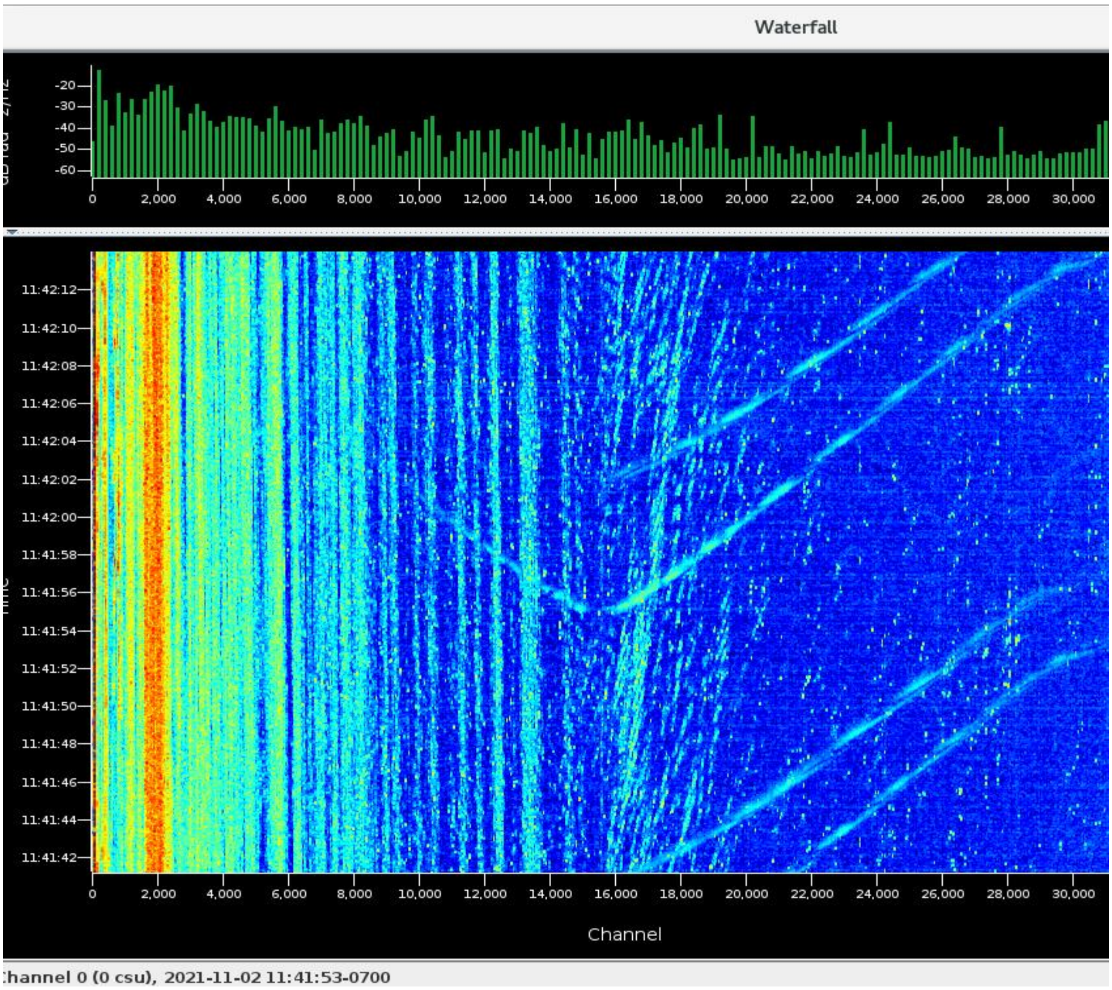



Figure 5: Multiple fin whales.



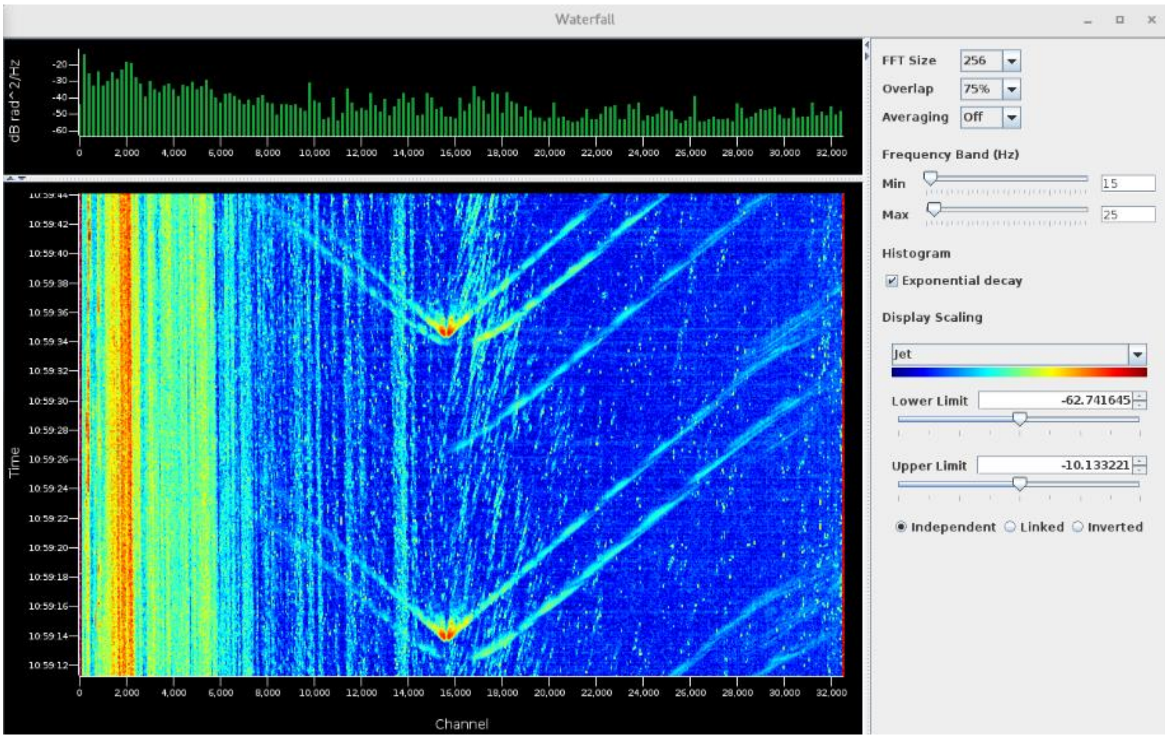



**Figure 6:** Multiple fin whales, one very close to fiber.

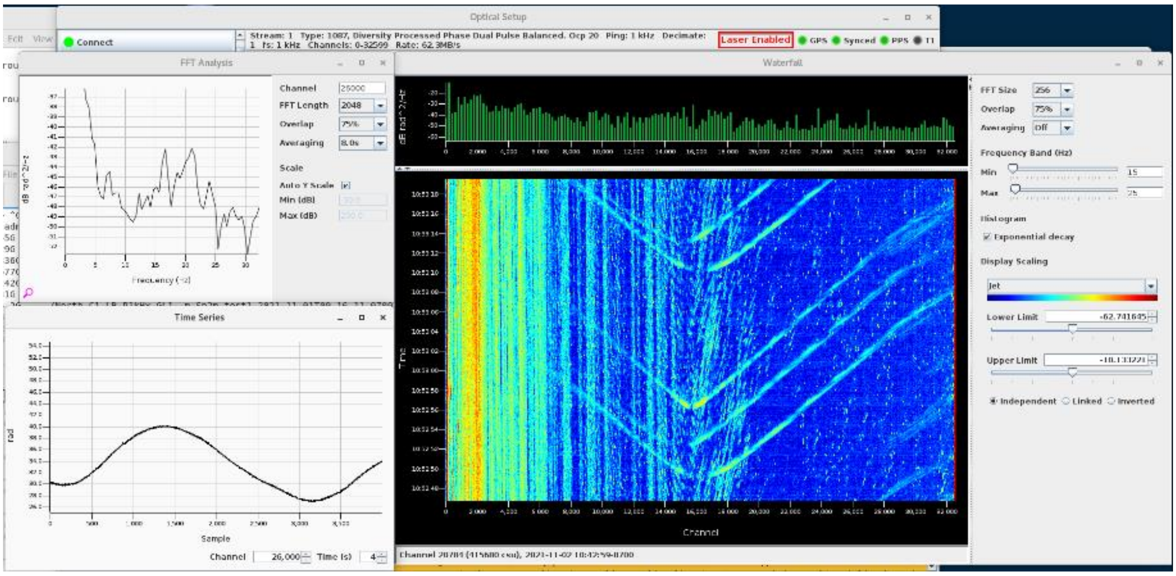


**Figure 7:** three fin whales in vicinity of 32km. Spectral peaks within 10-25 Hz.

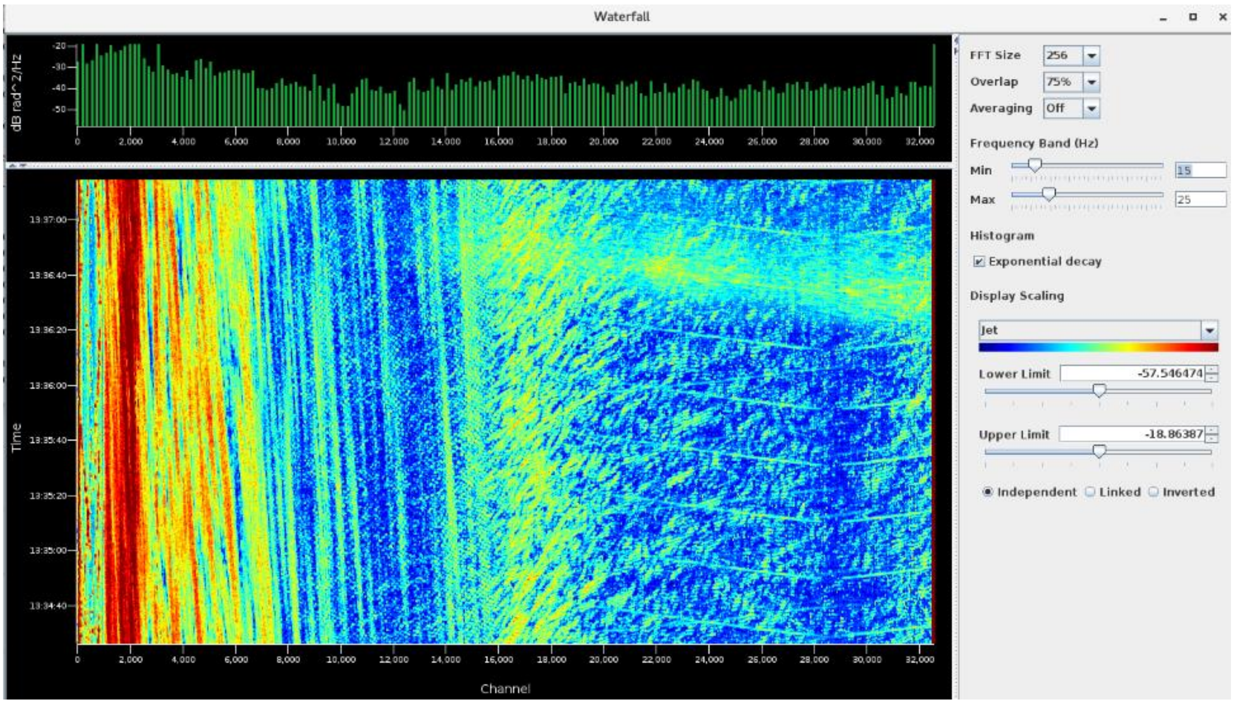



**Figure 8:** Fin whales at 57km and an inferred T-phase arriving from offshore. Raised noise floor due to sea state, storms and gale force winds.

## 4.2 South Cable

### *4.2.1 South Cable Wave Form Displays*

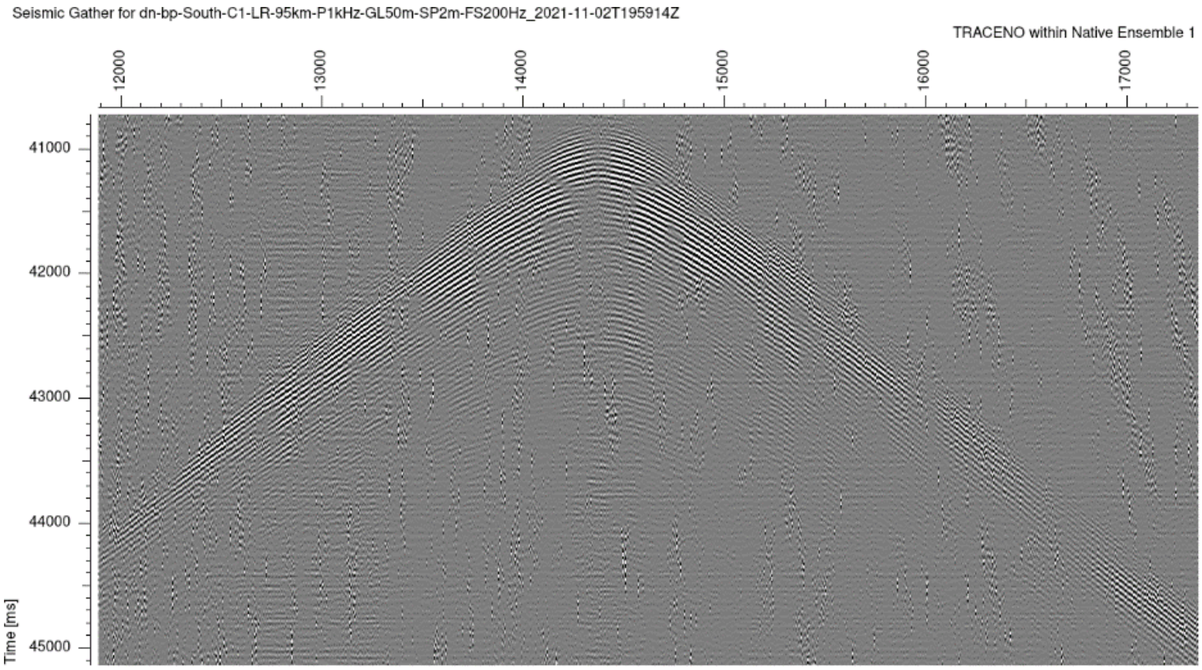



**Figure 9**: Fin whale signal near apex. The narrow band sweep lasts for about 1 second.

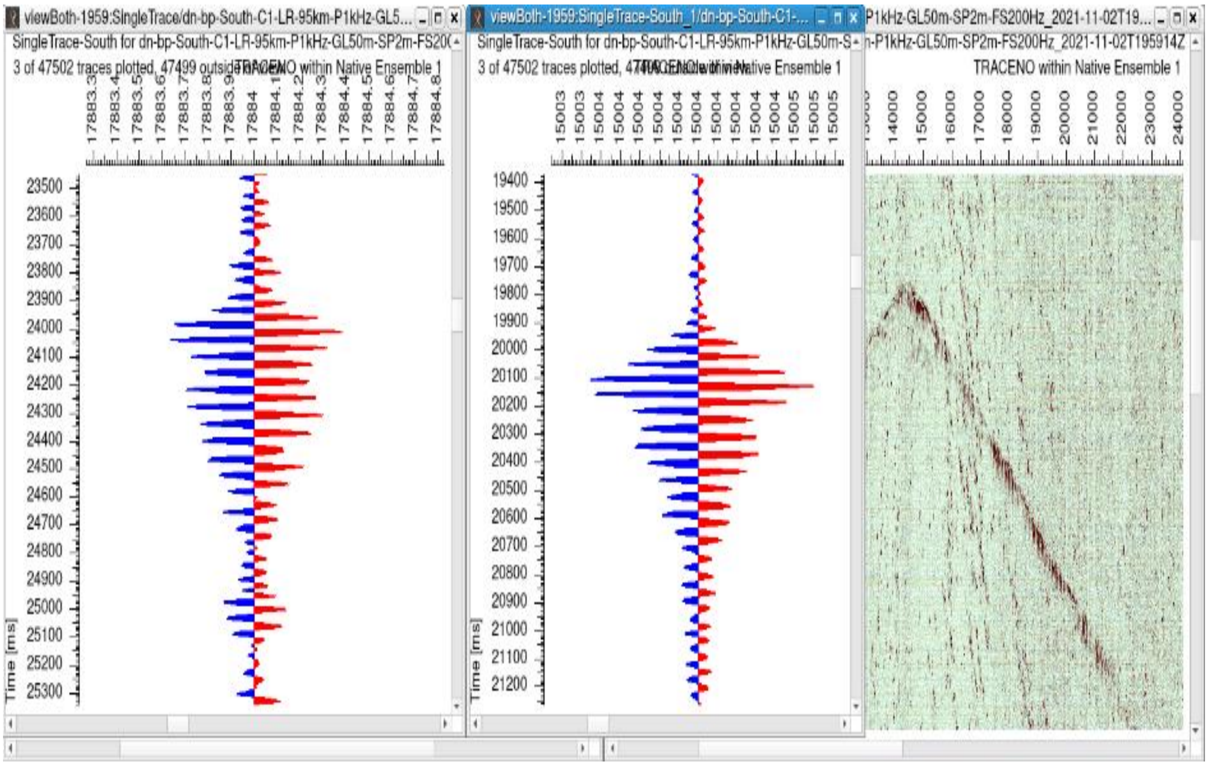


**Figure 10**: Fin whale signal with two individual channels 15004 (near apex) and 17884 (on flank).

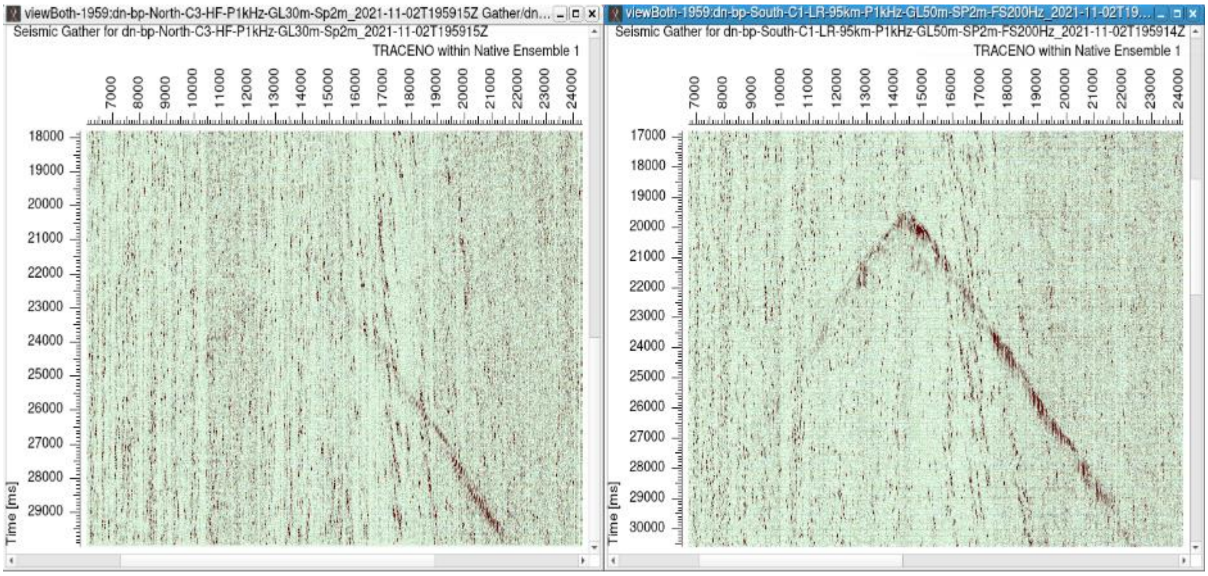


**Figure 11**: Fin whale signal on both, north (left) and south (right) cables.

### 4.2.2 South Waterfall Displays

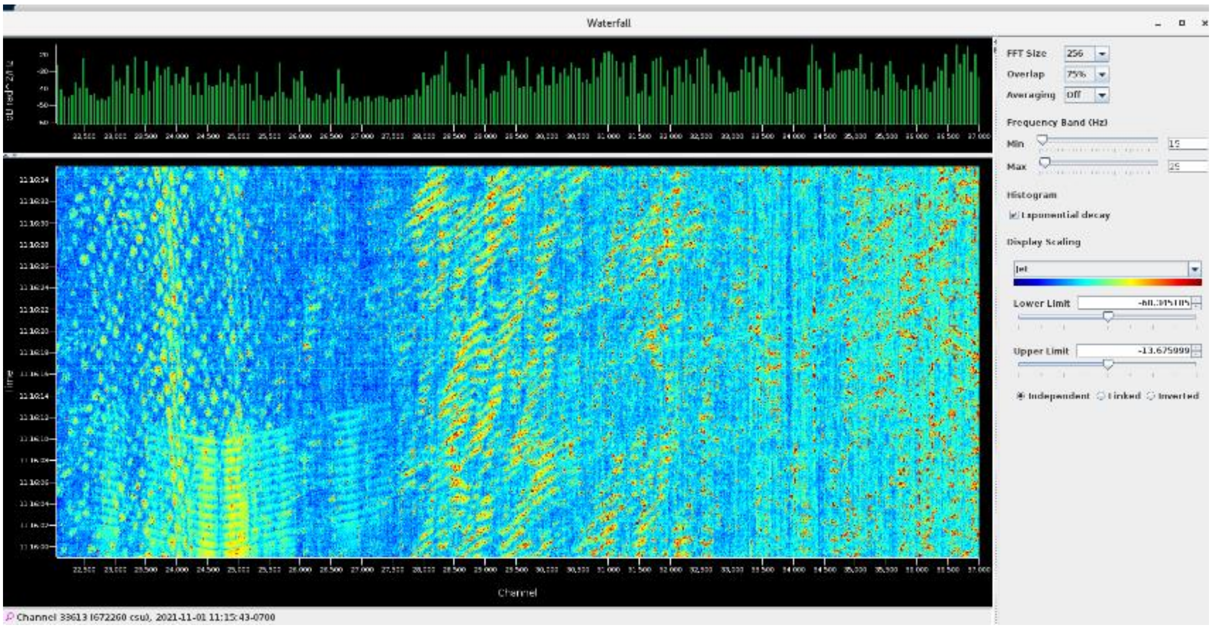



**Figure 15**: Whale call tentatively identified as a northeast Pacific blue whale A call.

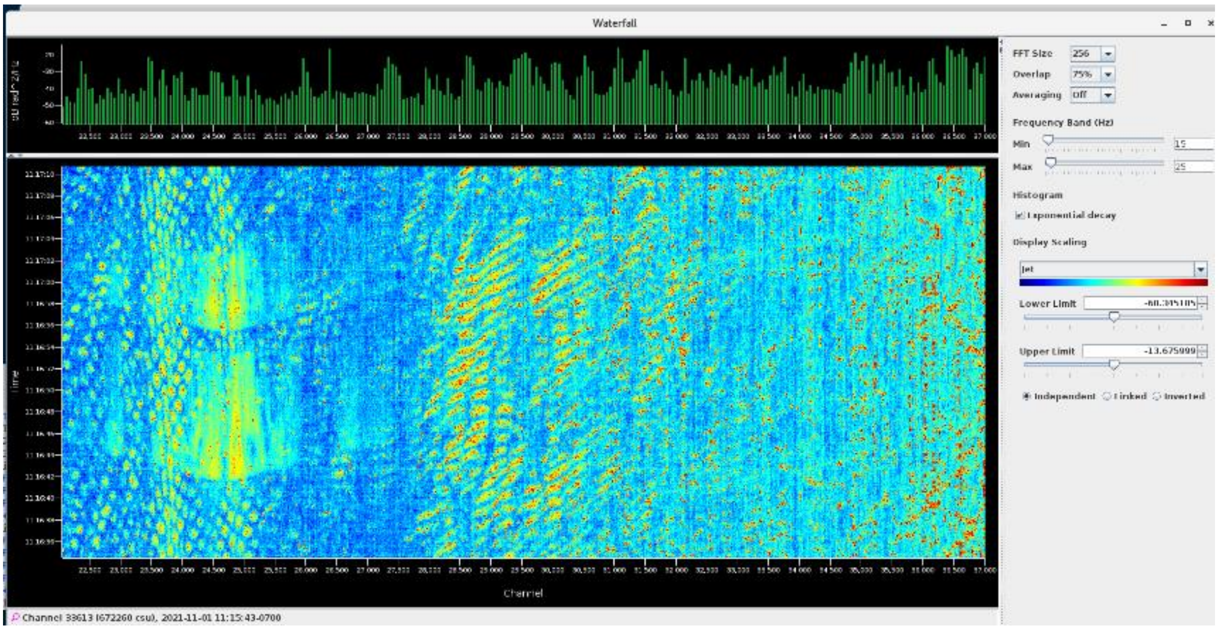



**Figure 16**: Whale call tentatively identified as a northeast Pacific blue whale B call.

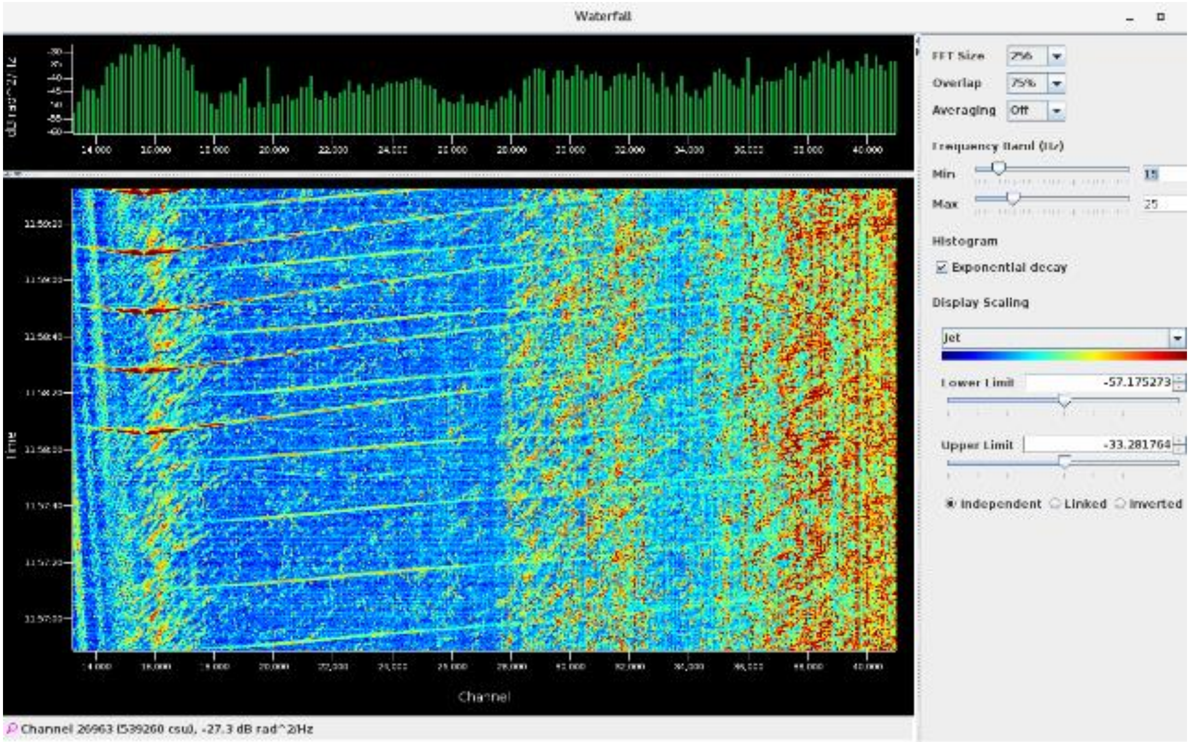



**Figure 12**: Repetitive fin whale signals.

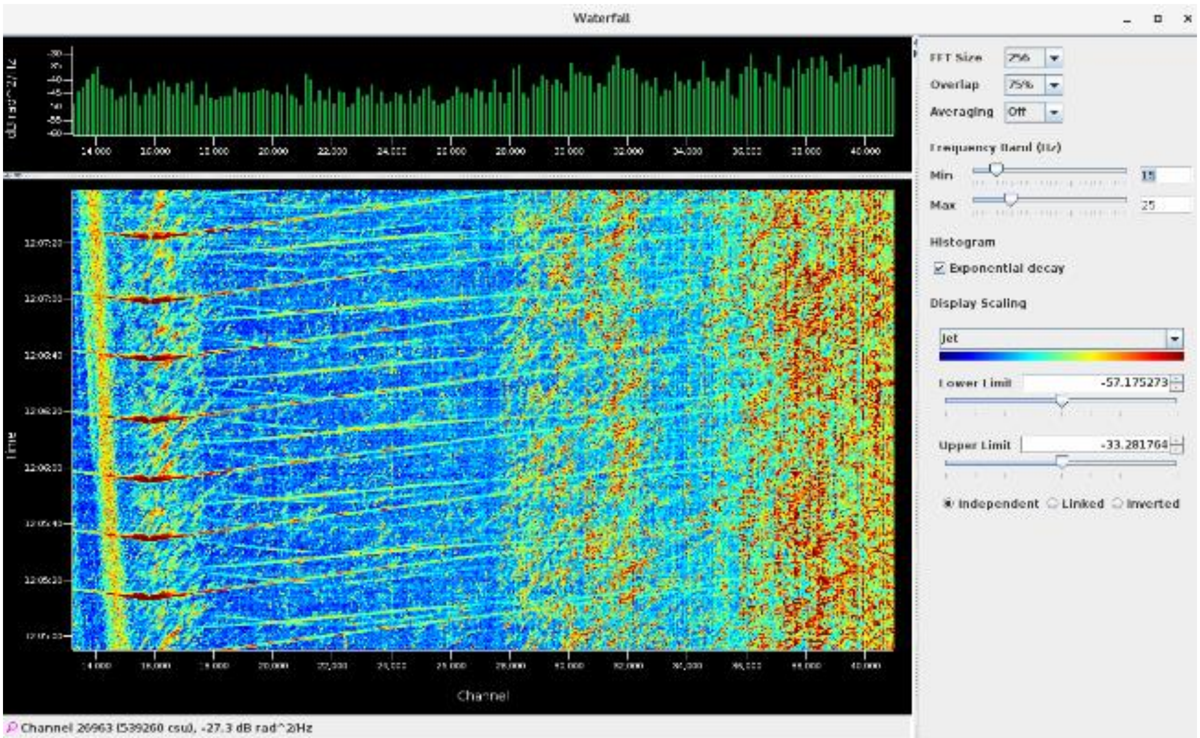



**Figure 13**: Repetitive signals of multiple fin whales.

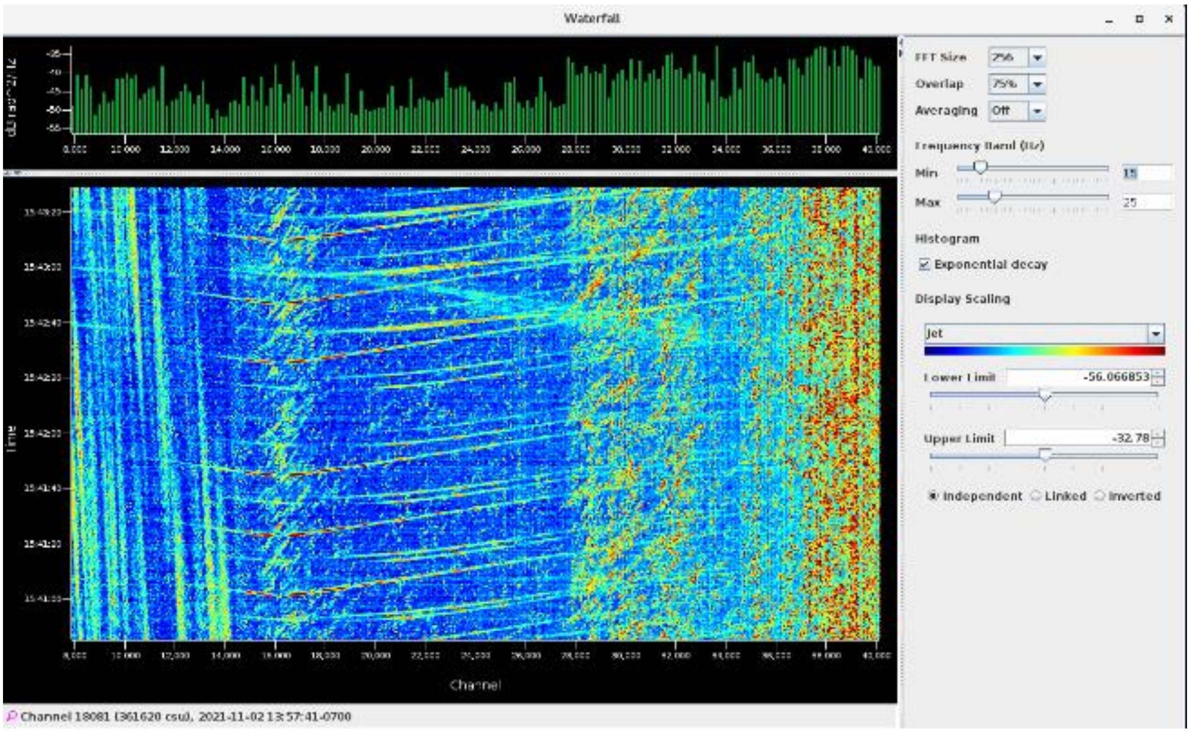



**Figure 14**: Fin whales with probable blue whale.

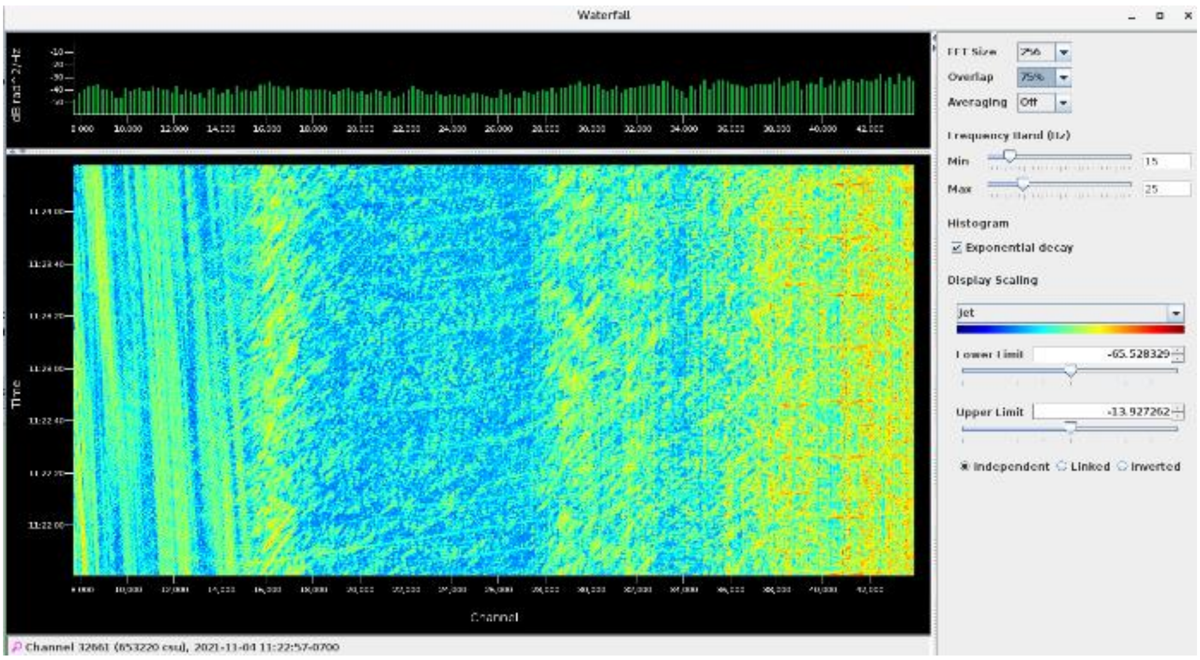



**Figure 15**: Fin whales at 30km, 72km and 83km.

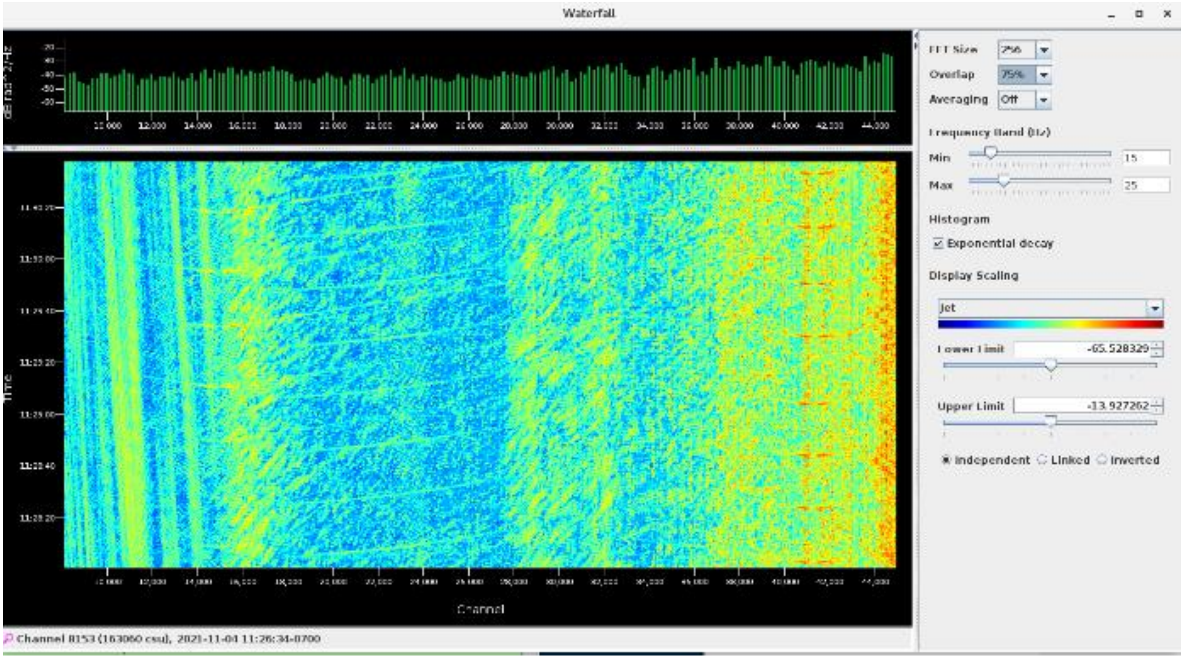



**Figure 16**: Fin whales at 32km and 83km.

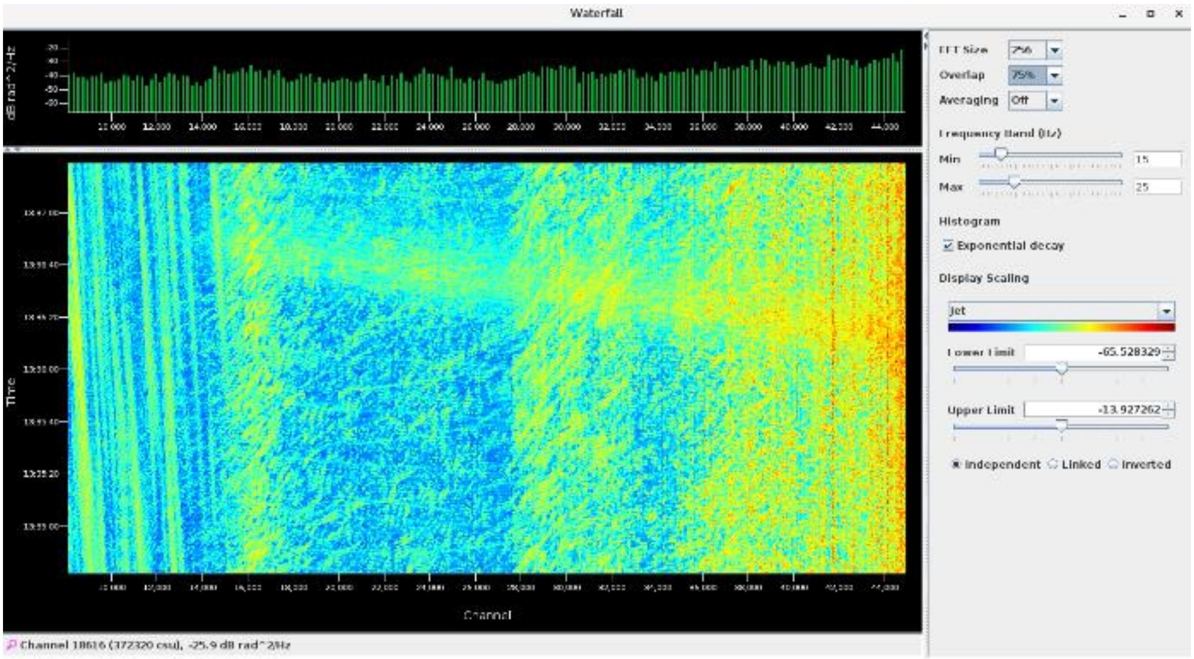



**Figure 17**: Fin whales and T-phase.

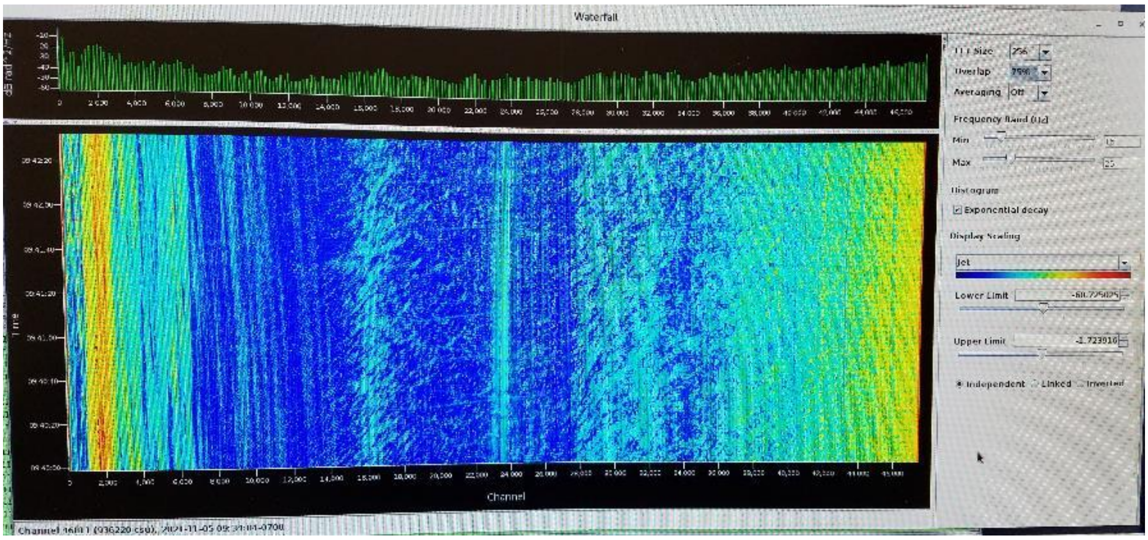


**Figure 21:** Cargo vessel crossing the South fiber at 47km (channel 23500).

# 5 Appendix

OptaSense QuantX/ODH5 distributed sensing systems record the optical phase obtained between the end points of the gauge length as a function of time. This optical phase is proportional to strain (not strain rate).

The actual value stored in the H5 file formats is the optical phase shift and depending on the file format might need to be scaled by a scale factor to produce values in radians.

**HDF5 PRODML** can store values in either the original unscaled 32 bit integer, or already scaled to radians in IEEE floating point formats. Both the PhaseLSB value and sample values' unit are stored as attributes in the HDF5 file, the latter as attribute "RawDataUnit". If samples are stored as integer values the sample value's unit is "rad*10430.378850470453". To obtain phase shift values in "rad" divide each sample value by 10430.378850470453.

The conversion of optical phase shift to strain is in detail described in this SEAFOM report https://seafom.com/mdocs-posts/seafom_msp_02-august-2018-pdf , as shown in equations 9 and 10 on page 26. Besides the basic phase shift – strain relation, we recommend reading through the general background information on DAS system performance.

OptaSense's QuantX/ODH5 DAS systems operate at a wavelength of ~1550 nm and typical gauge lengths of 1m - 40m. While the fiber's refractive index can vary with fiber type, it is typically in the vicinity of 1.468.

The basic optical phase shift – strain relation (eqn. 9 in SEAFOM document) is shown below.

$$d\phi = \frac{4\,\pi\,n\,G\,\xi}{\lambda}\,\epsilon$$

$with:$
$\lambda = operational\ optical\ wavelength\ in\ vacuum$
$n = refractive\ index\ of\ the\ sensing\ fiber\ (groupindex)$
$G = Gauge\ length\ employed\ in\ the\ DAS\ system$
$\xi = photo\text{-}elastic\ scaling\ factor (= 0.78)\ for\ longitudinal\ strain\ in\ isotropic\ material$
$\phi = optical\ phase\ shift\ in\ radians$
$\epsilon = strain$