Low cost, low power acoustic communication and sensing networks

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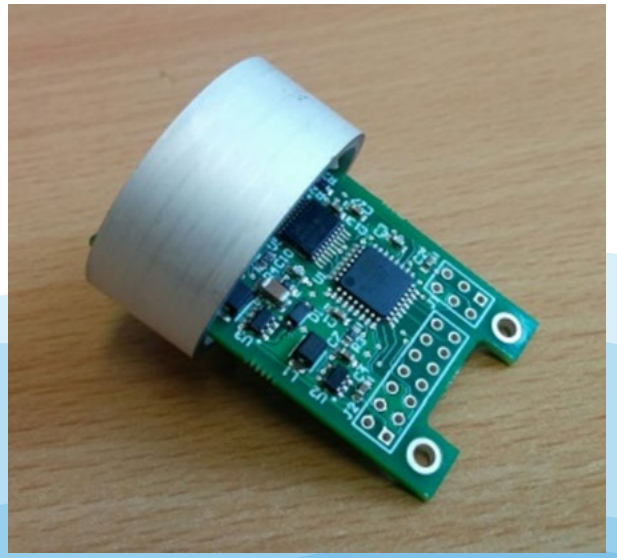

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Outline

- Acoustics at Newcastle University
- Low cost/power acoustic modem platform.
- Underwater passive sensor networks:
  - Marine mammal detection
  - Vessel detection

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School of Engineering

SEAlab

Sensors, electromagnetics and acoustics laboratory

Main activities

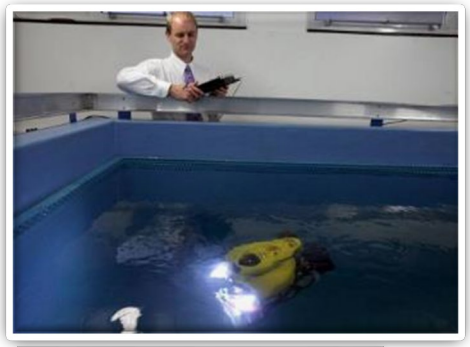
- 25+ years experience in acoustic signal processing.

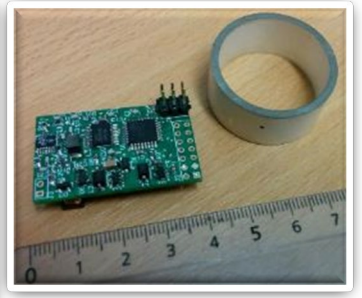
Expertise

- Underwater acoustic communication and navigation.
- Waveform and receiver design.
- Sonar systems and transducer design.
- Wireless sensor networks.
- Acoustic sensor development.
- Through metal communications.
- Medical ultrasound imaging.
- Low cost and low power solutions.

Commercialisation

- Licenced products for underwater acoustic communication and positioning - Blueprint Subsea (Seatrac), Tritech (Micron Nav), Succorfish (SC4), WSENSE.



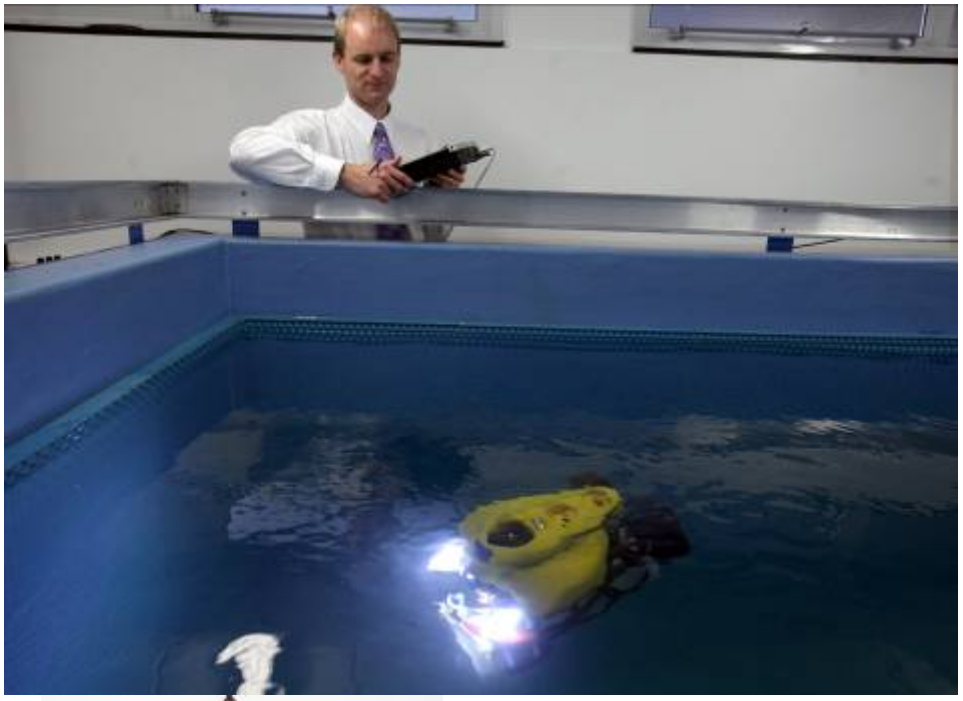


Recent projects

CADDY - Cognitive Autonomous Diving Buddy	FP7-ICT
PHORCYS – Secure and interoperable underwater acoustic communications	UK - DSTL
USMART – smart dust for large scale underwater wireless sensing	UK - EPSRC
Full-Duplex for Underwater Acoustic Communications	UK - EPSRC

Facilities - SEAlab

- Anechoic test tank.
- 3 ROVs
- Acoustic transducers & instrumentation.
- Offshore acoustic databuoy
- Research vessel.



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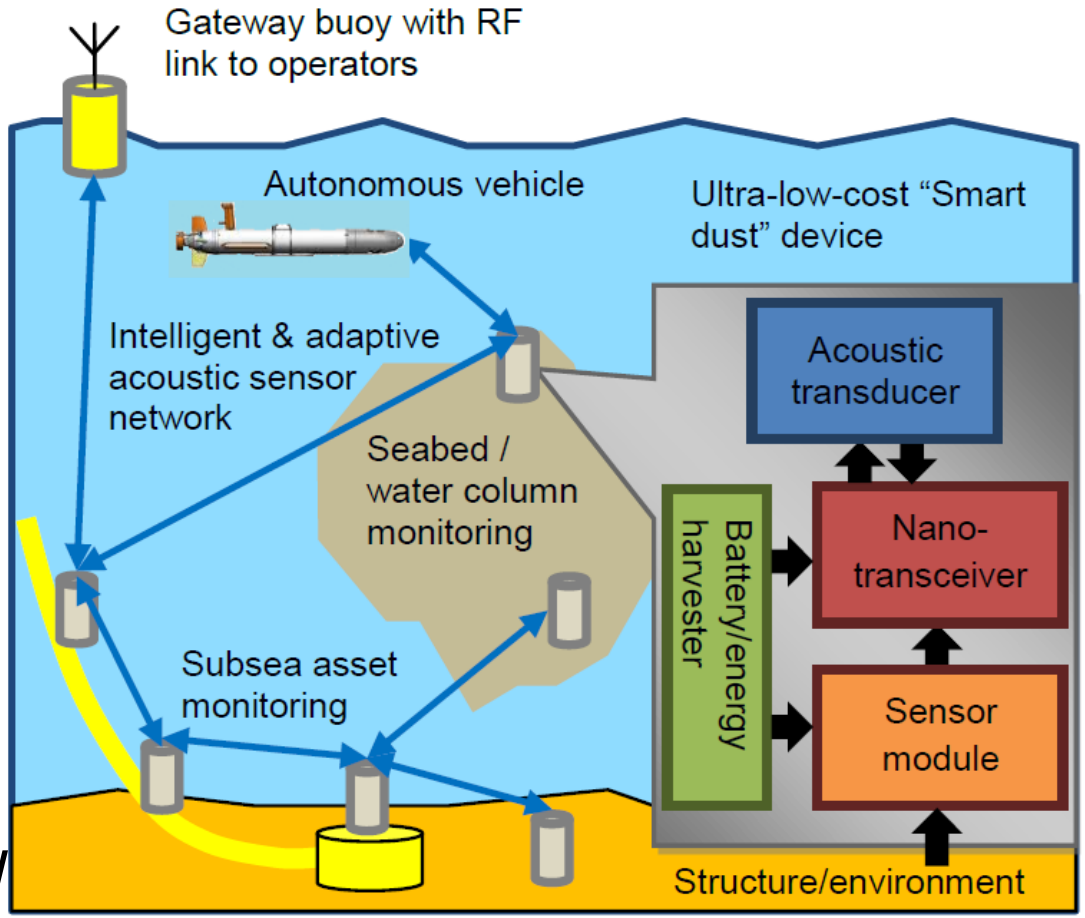
USMART

Smart dust for large scale underwater wireless sensing

£1.3M from EPSRC
08/2017 – 07/2020

"The ultimate measurable objective will be to demonstrate a step change in the cost efficiency of subsea data gathering."

http://research.ncl.ac.uk/usmart/



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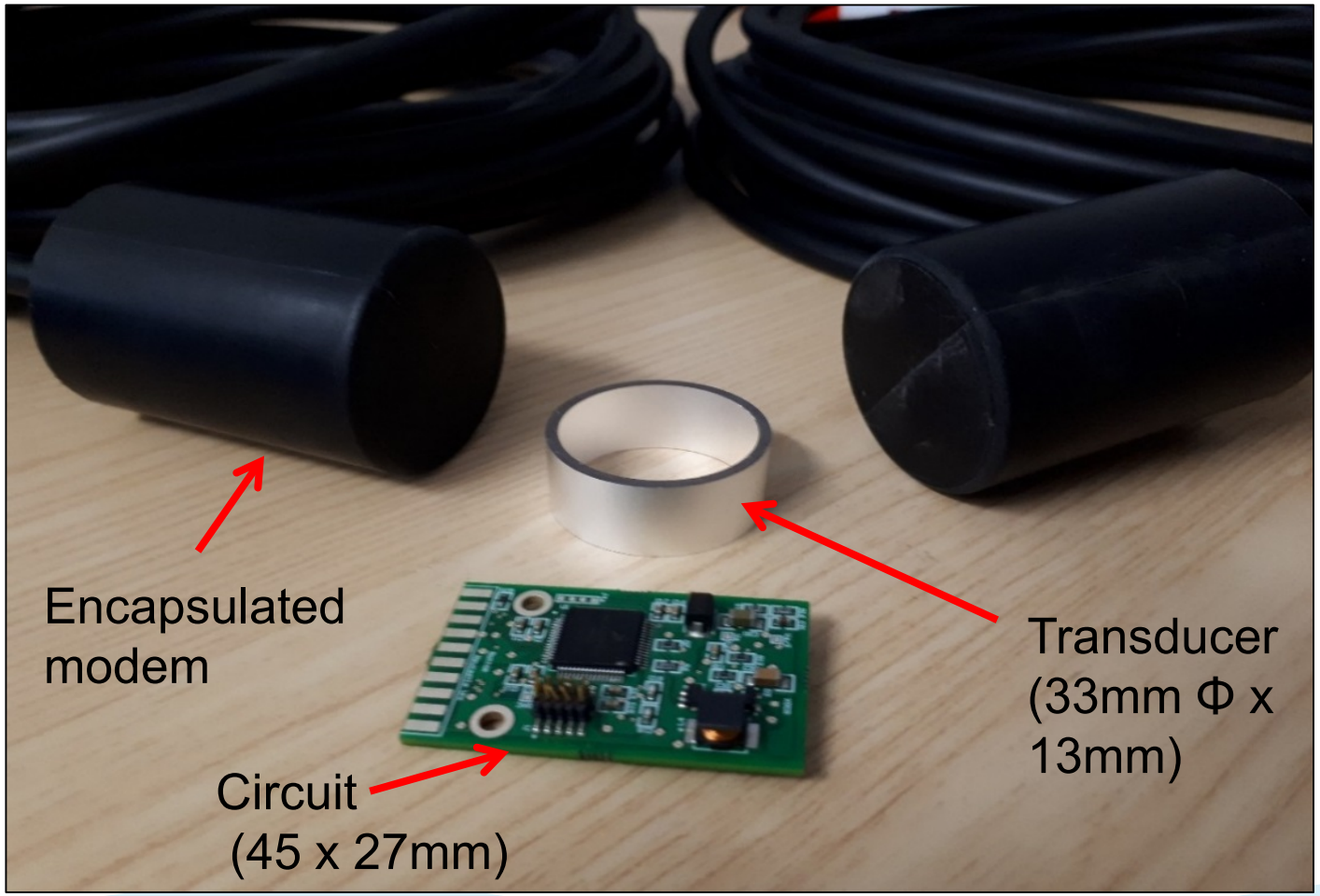
Ultra low cost/power – “Nanomodems”



Transducer and electronics can be separate or encapsulated together (40mm x 60 mm)

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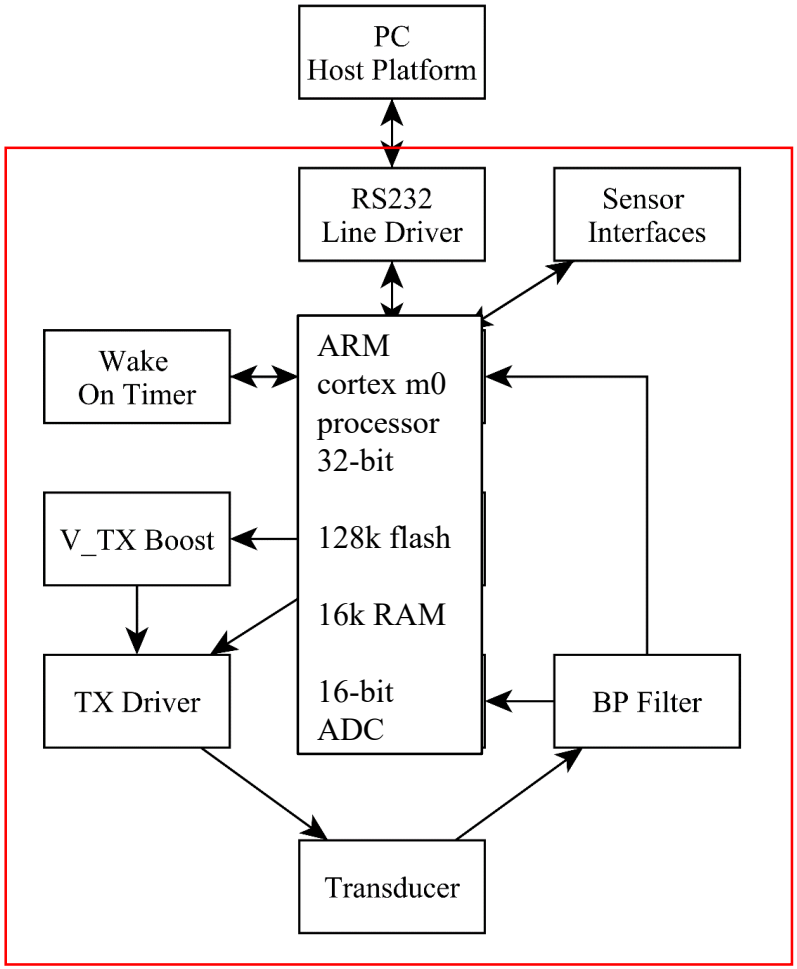
Nanomodem v3 Architecture

- Upgraded to 32-bit ARM Cortex-M0 with 128K flash and 16K RAM
- ARM most time in low power mode - sparse correlation processing.
- Acoustic band 24-32kHz
- On-chip 16-bit ADC + higher clock for packet demodulation.
- Sensor interfaces to uC – analog in, SPI, I2C
- Room for more complex protocols.



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V3 modem specification

Supply voltage	3 – 6.5V dc
Supply current (5V supply)	Listening: 2mA Receiving data: 4mA Transmitting: ~ 250mA
Acoustic signals	24-32kHz, SPL = 168 dB
Acoustic data rate	640bps, 16-ary orthogonal signalling. Broadcast & unicast packets up to 64 bytes
Addressing	up to 255 nodes (programmable)
Ranging (ping command)	5cm increment,~10 cm variance
Maximum Range	2 km sea water, 4km fresh water
RS232 interface	9600 Baud, 8-bit, no parity, 1 stop bit, no flow control
Cost of assembled board	<$19 in quantities of 500.
Dimensions	40 mm diameter, 60 mm long

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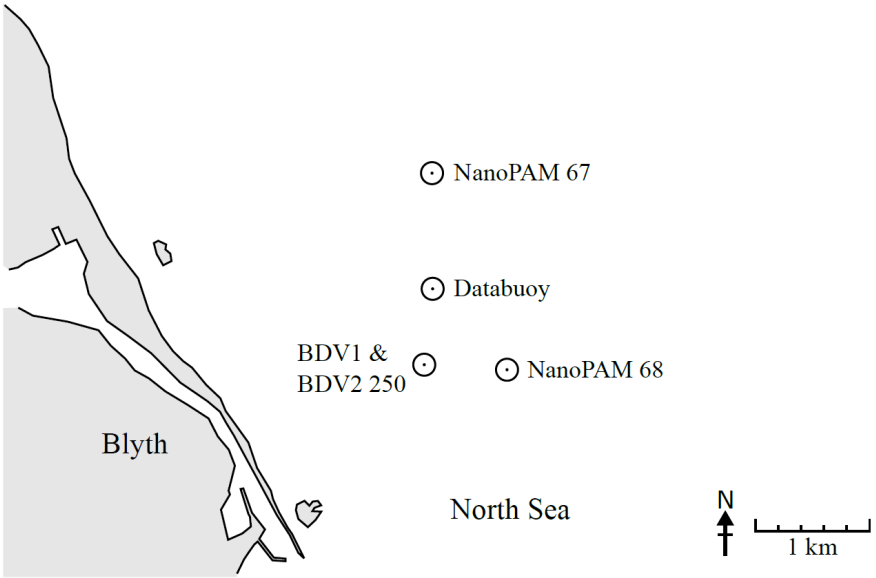
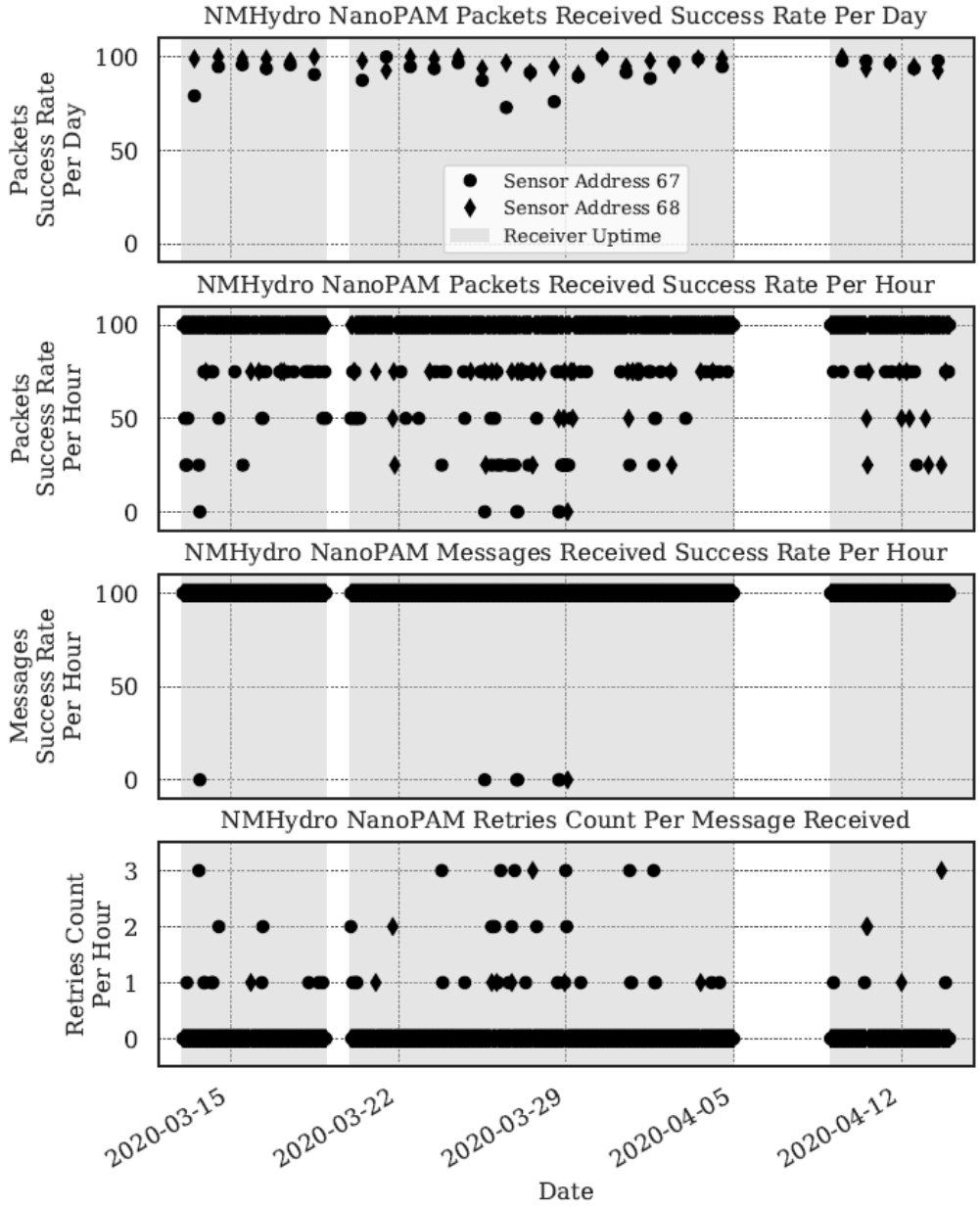
North Sea sensor deployments





- Near 100% delivery of data by modems.
- > 6 months battery life from 2 D cells

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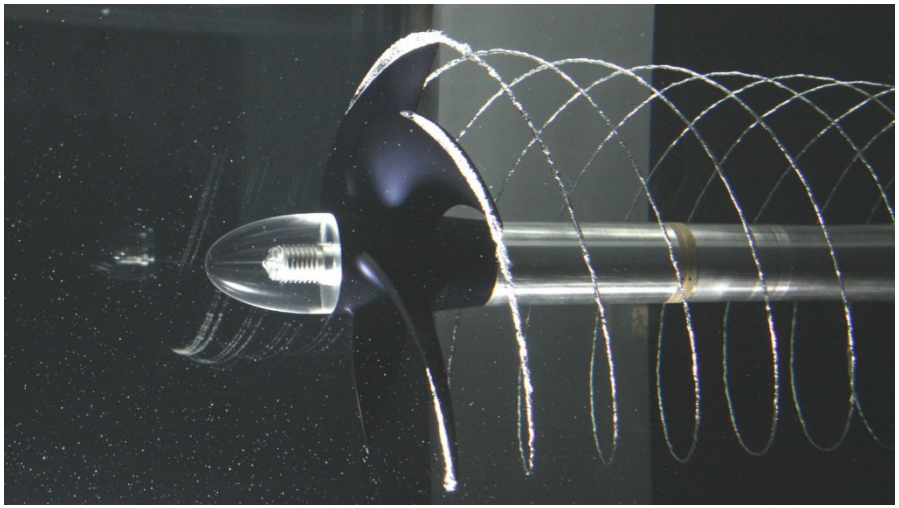
Low cost/power vessel detection network

Acoustic source



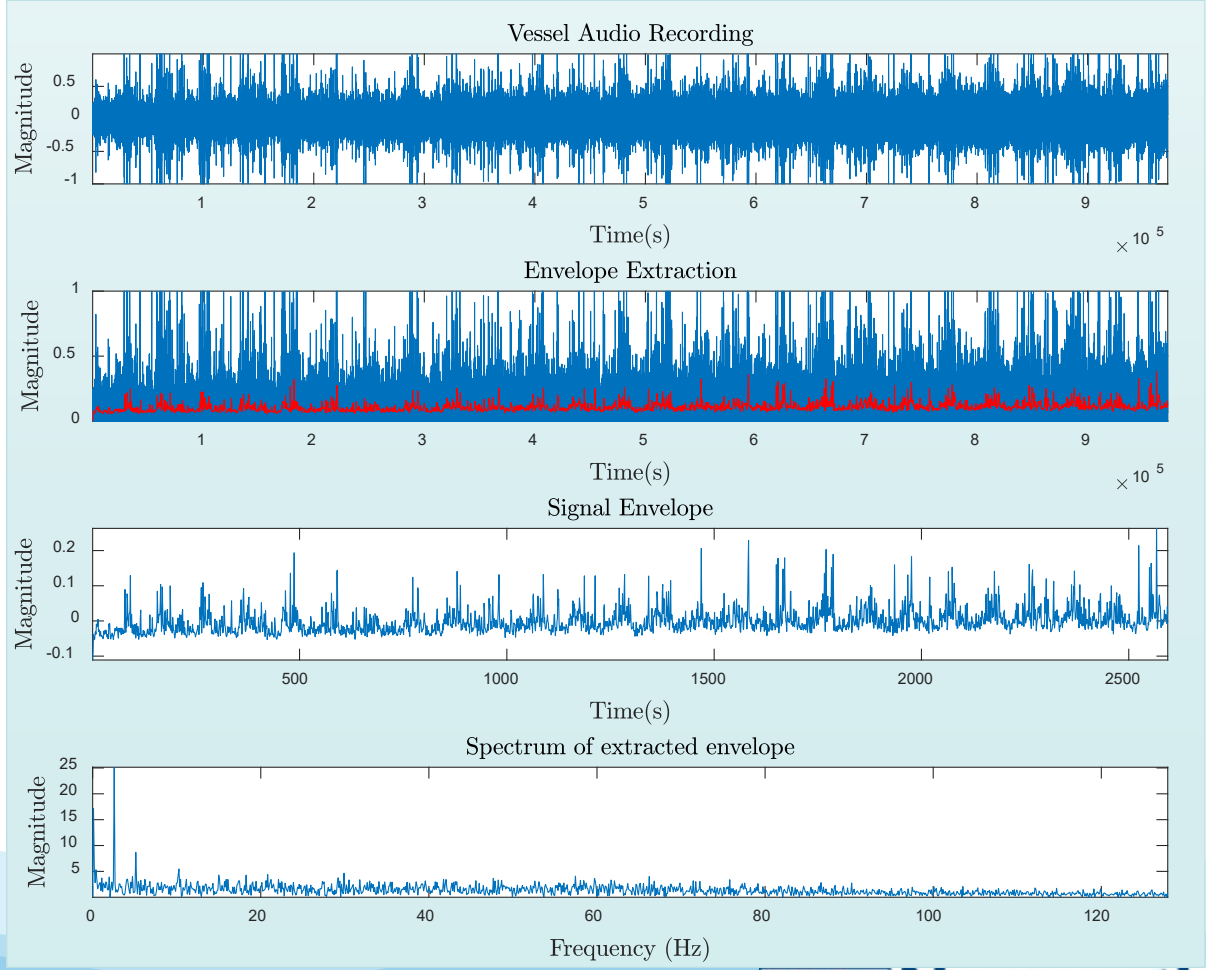
Propeller Cavitation - Formation and collapse of bubbles in water at or on the surface of a rotating propeller, occurring when the pressure falls below the vapour pressure of water.

Applications

- Impact and noise assessment
- Detection of illegal vessel activity e.g. people/drug trafficking, unlicensed fishing.

Detection of Envelope Modulation of Noise (DEMON)

- Cavitation Signal
- Band Pass Filter
- Rectifier
- Envelope Tracker
- Fast Fourier Transform
- DEMON Spectrum



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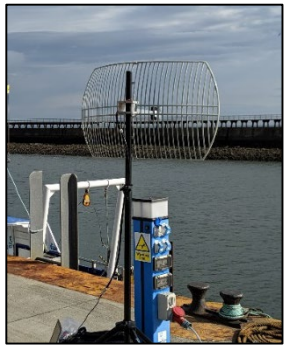
North sea deployment

DATA BUOY



WIFI LINK

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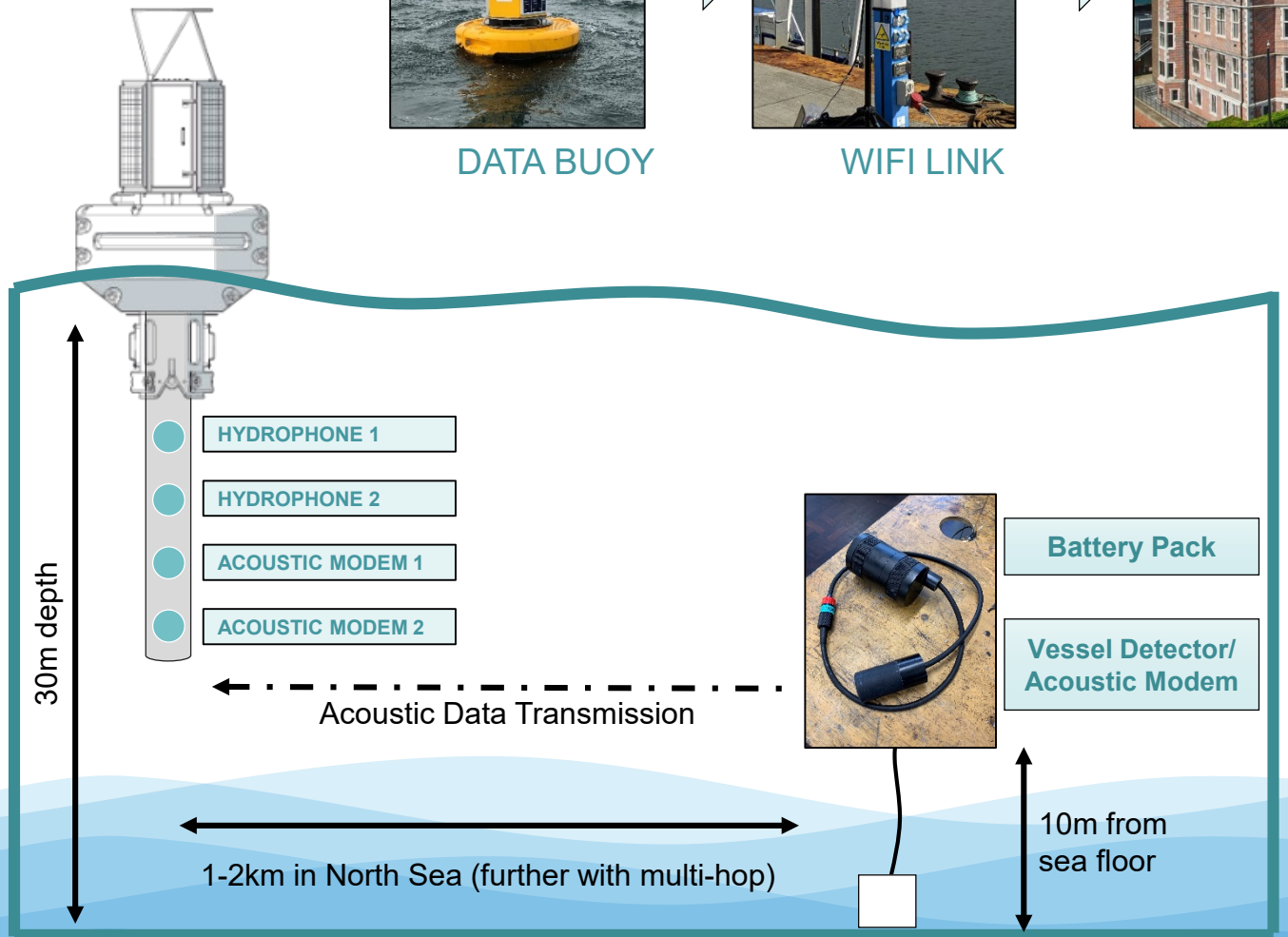

- V3 modem hardware repurposed (via software) to implement vessel detection.
- Reverts to modem when detections need to be reported.

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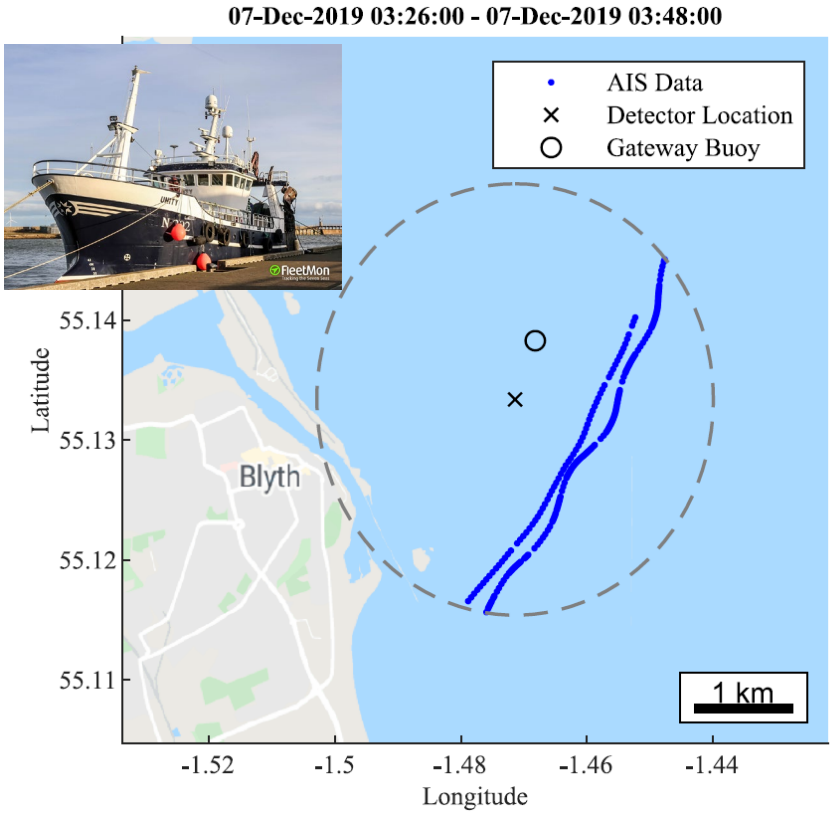
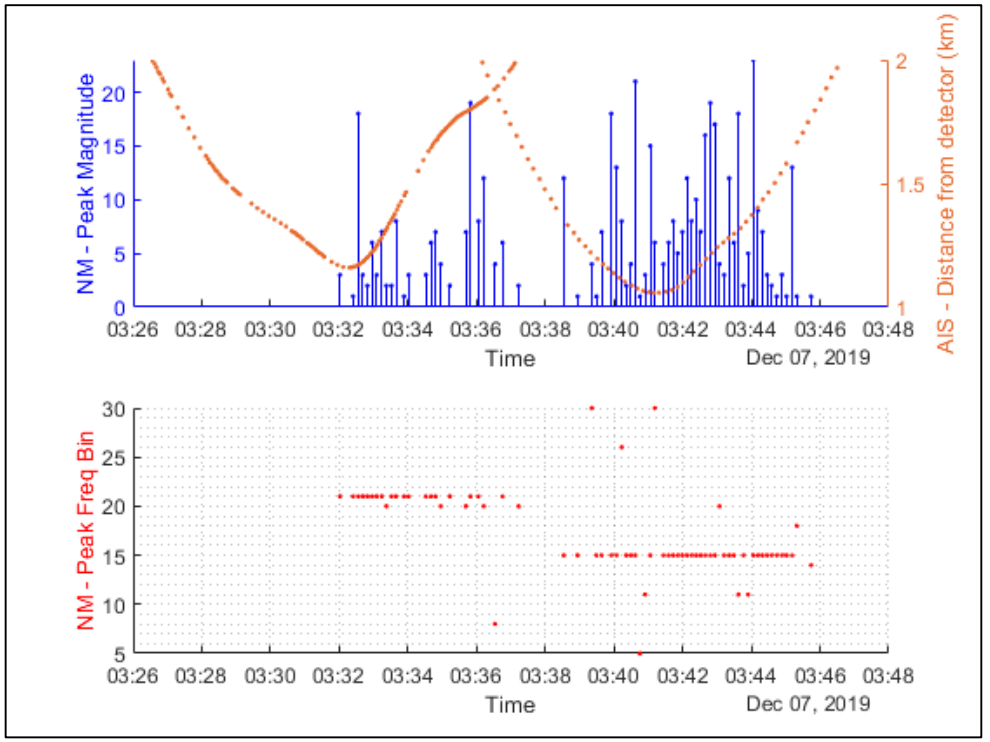
Vessel detection example





- Acoustic detections compared with AIS data from local receiver.
- Detection radius up to 2km for small vessels/RIBs.
- Ground truth for small vessels is hard to obtain.

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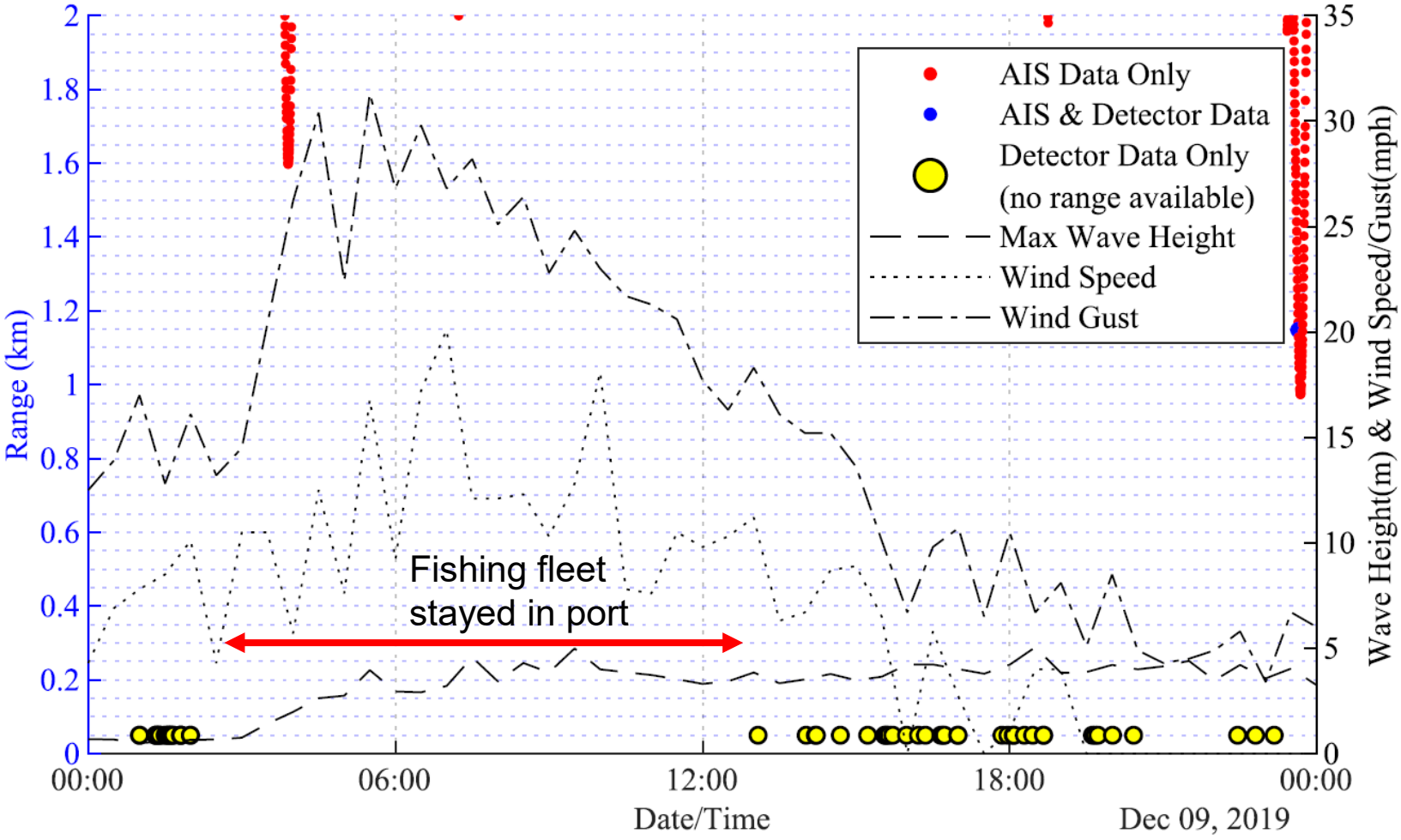
Weather and noise sensitivity?



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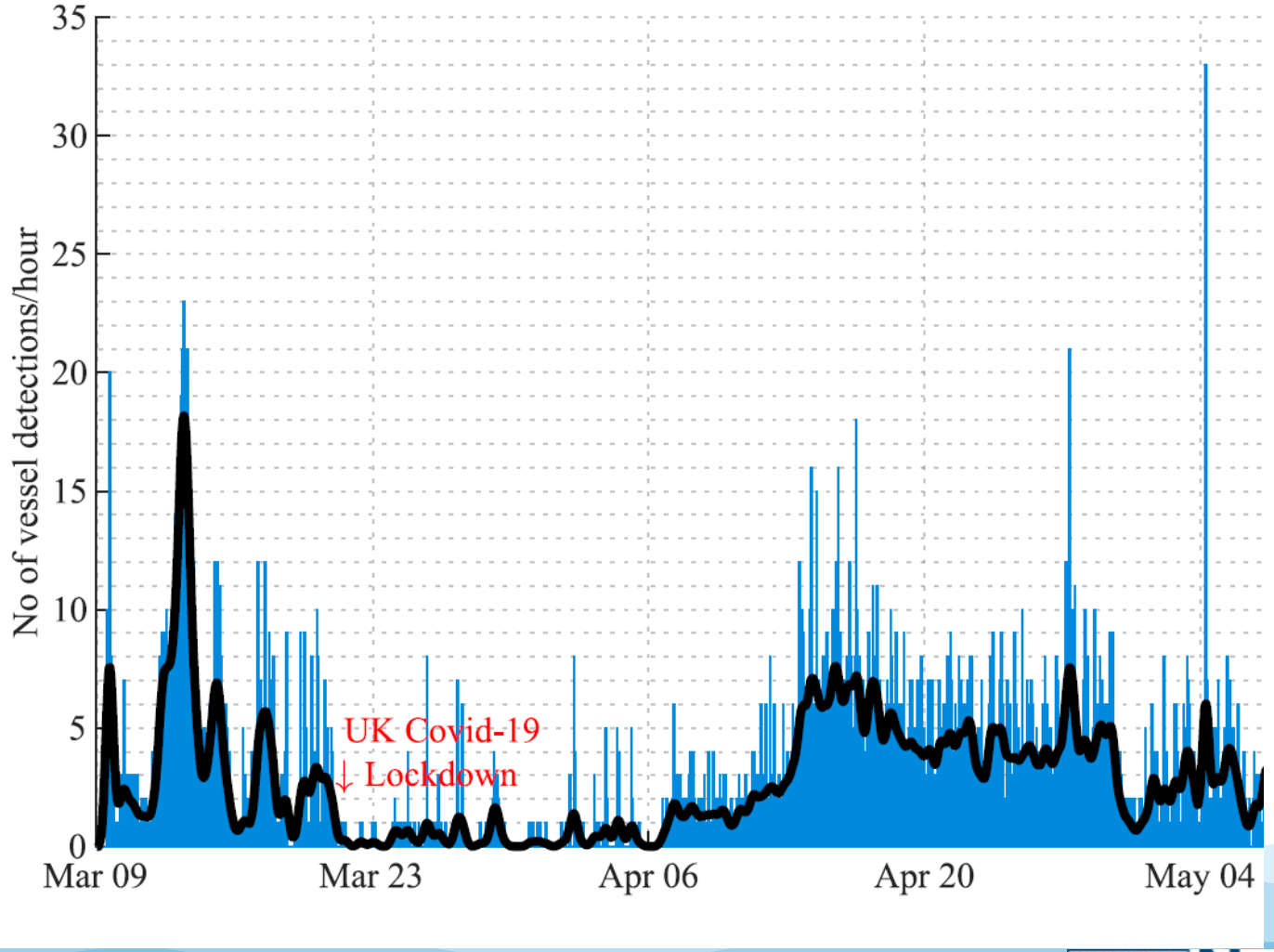
Impact of Covid 19 lockdown was measured by our underwater network



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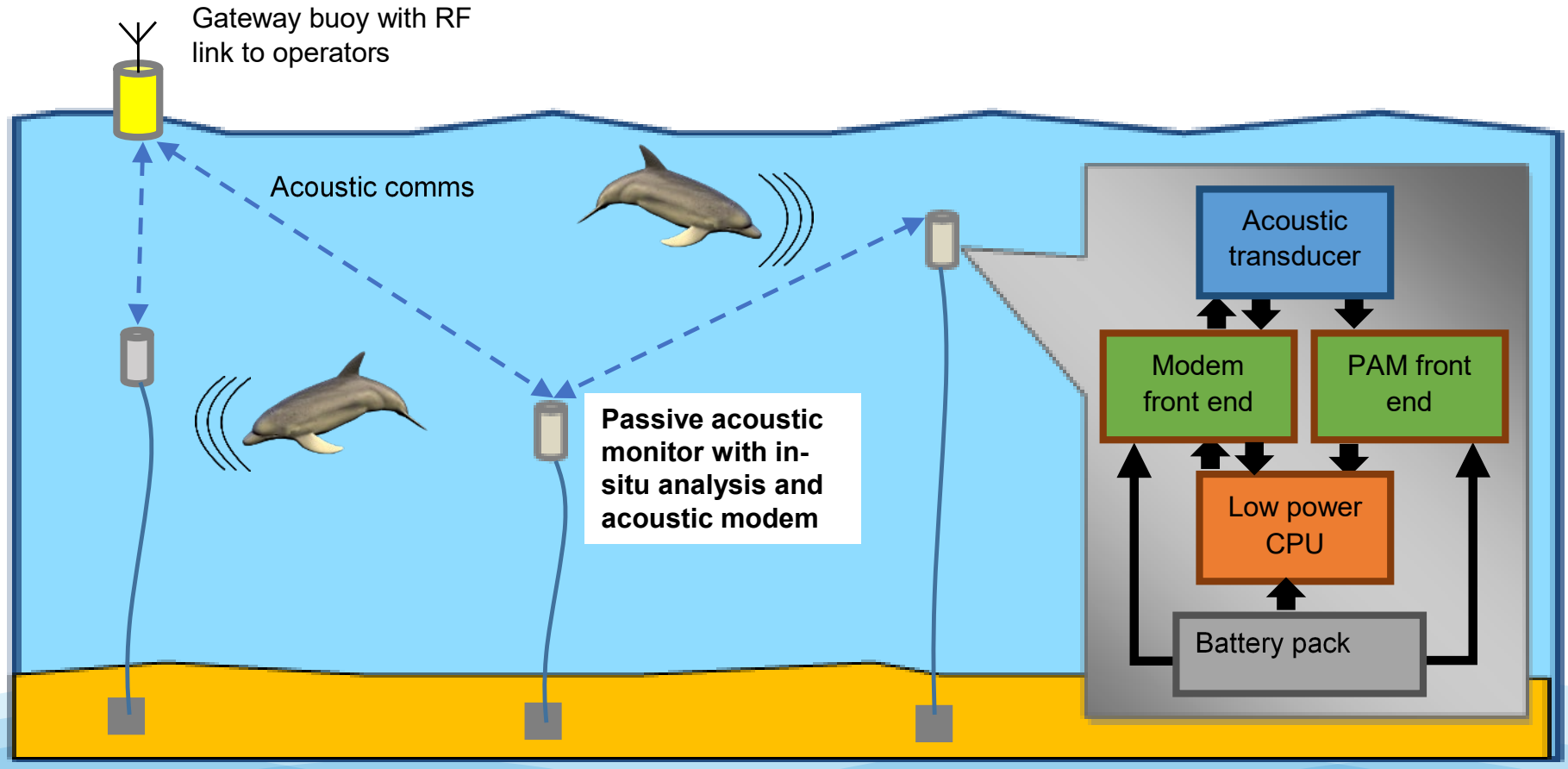
NERC – Novel low-cost methods for marine mammal monitoring



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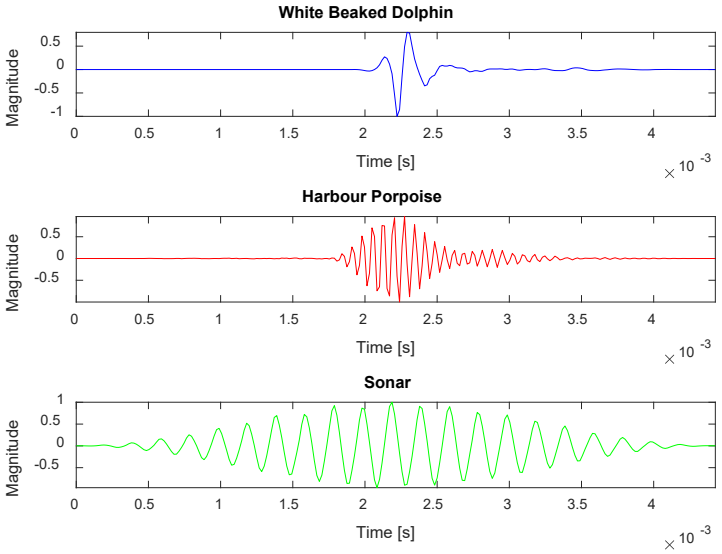
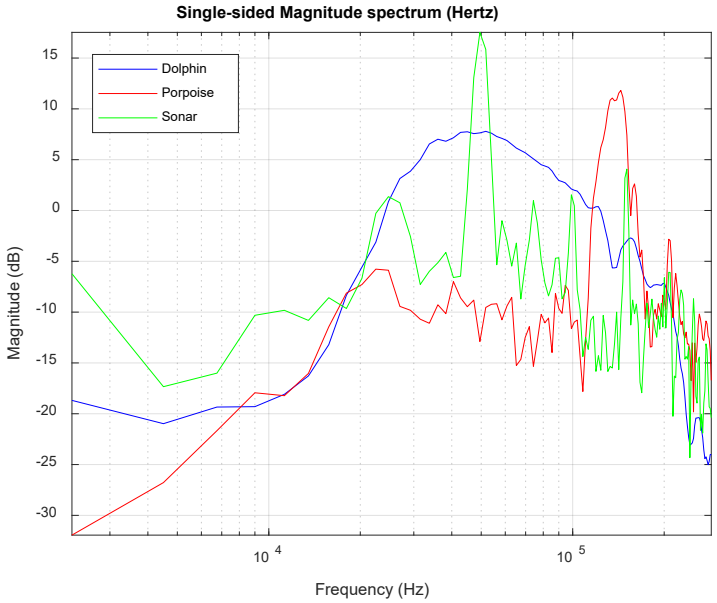
Click detection and classification





- Dolphins and porpoises can be detected and discriminated by echolocation signals.
- The challenge is **real-time** detection with **low energy.**

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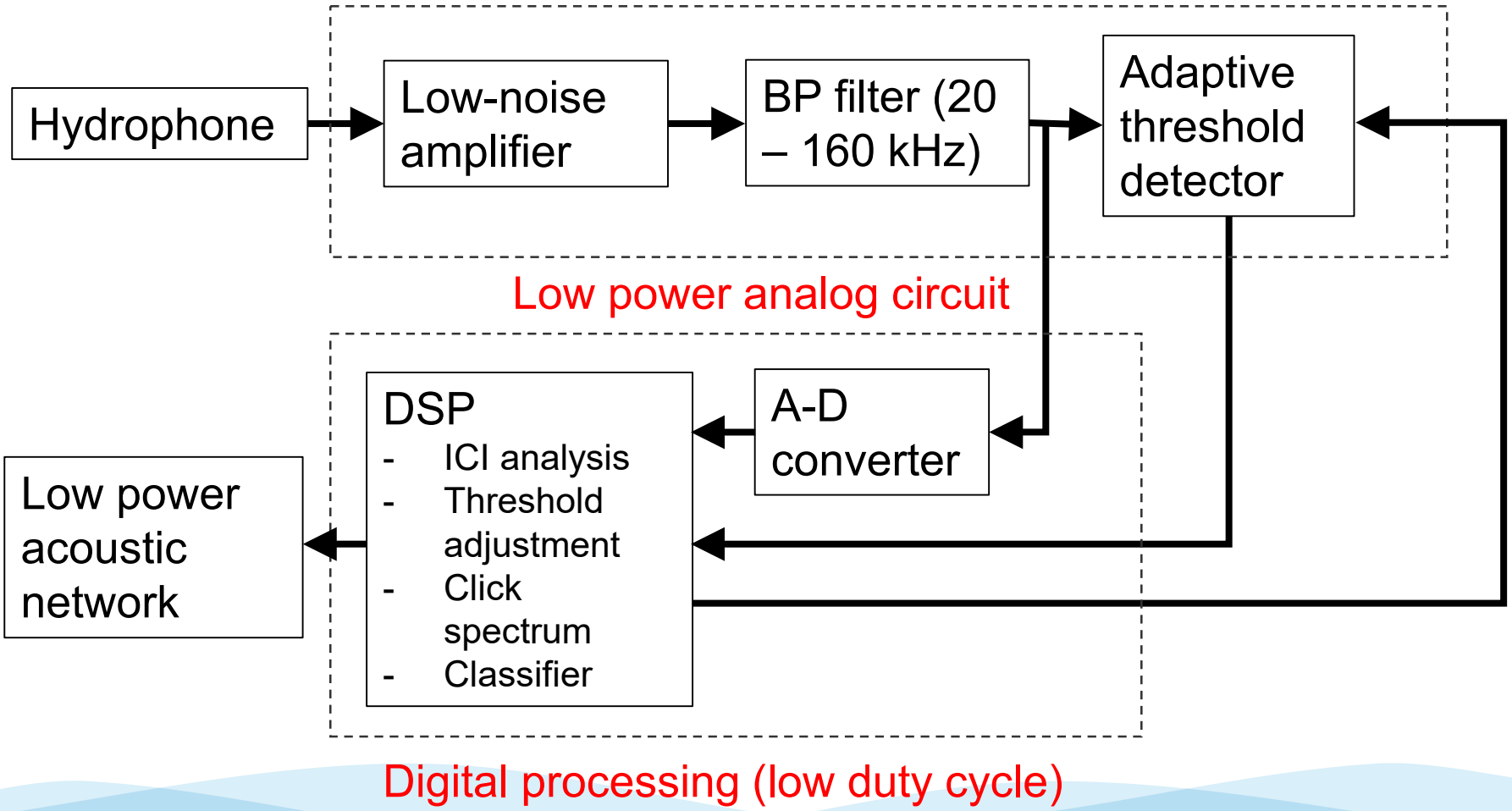
Low energy signal analysis overview



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Digital analysis and classifier

1. DSP measures inter-click intervals (ICI) in ultra-low power standby mode (<1mW).
2. Curve fitting algorithm looks for deterministic click trains and rejects random impulsive noise.
3. DSP wakes up to fully sample clicks and perform time and frequency domain (FFT) analysis (~ 50 mW).
4. Classify clicks based on spectral centroid, RMS bandwidth, peak-to-average ratio and ICI statistics.
5. Transmit detection data, either immediate or an hourly summary of detection positive minutes for each species.

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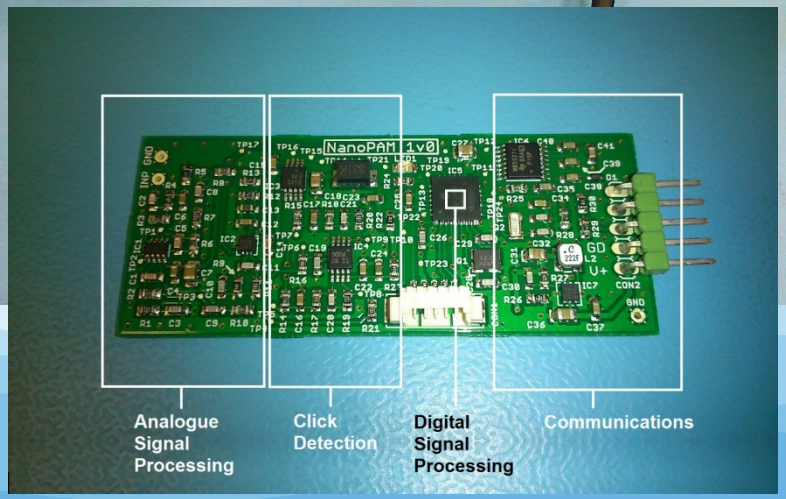
NanoPAM prototype construction



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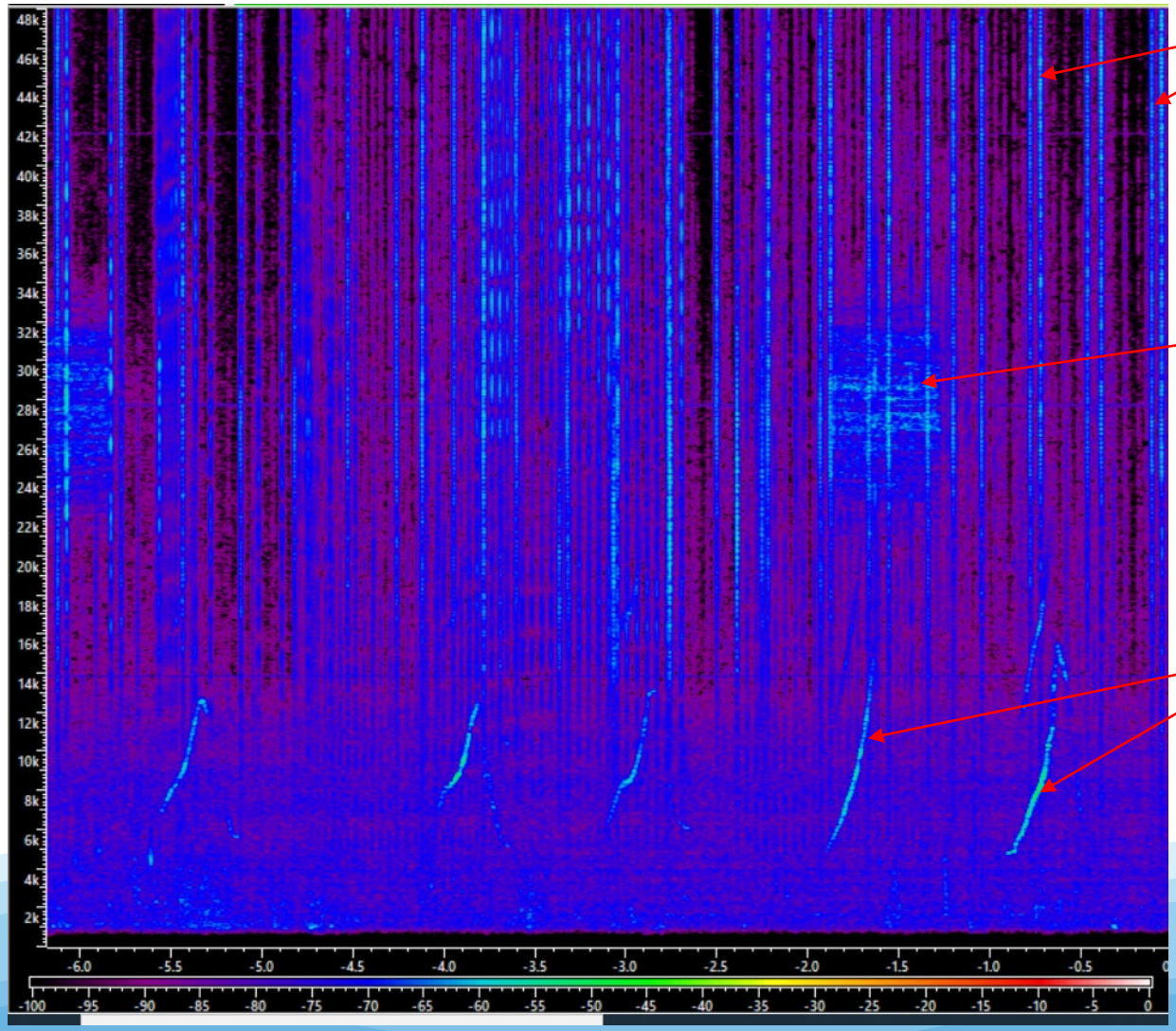
Example spectrogram from hydrophone recordings



Dolphin clicks

Acoustic modem transmission

Dolphin whistles

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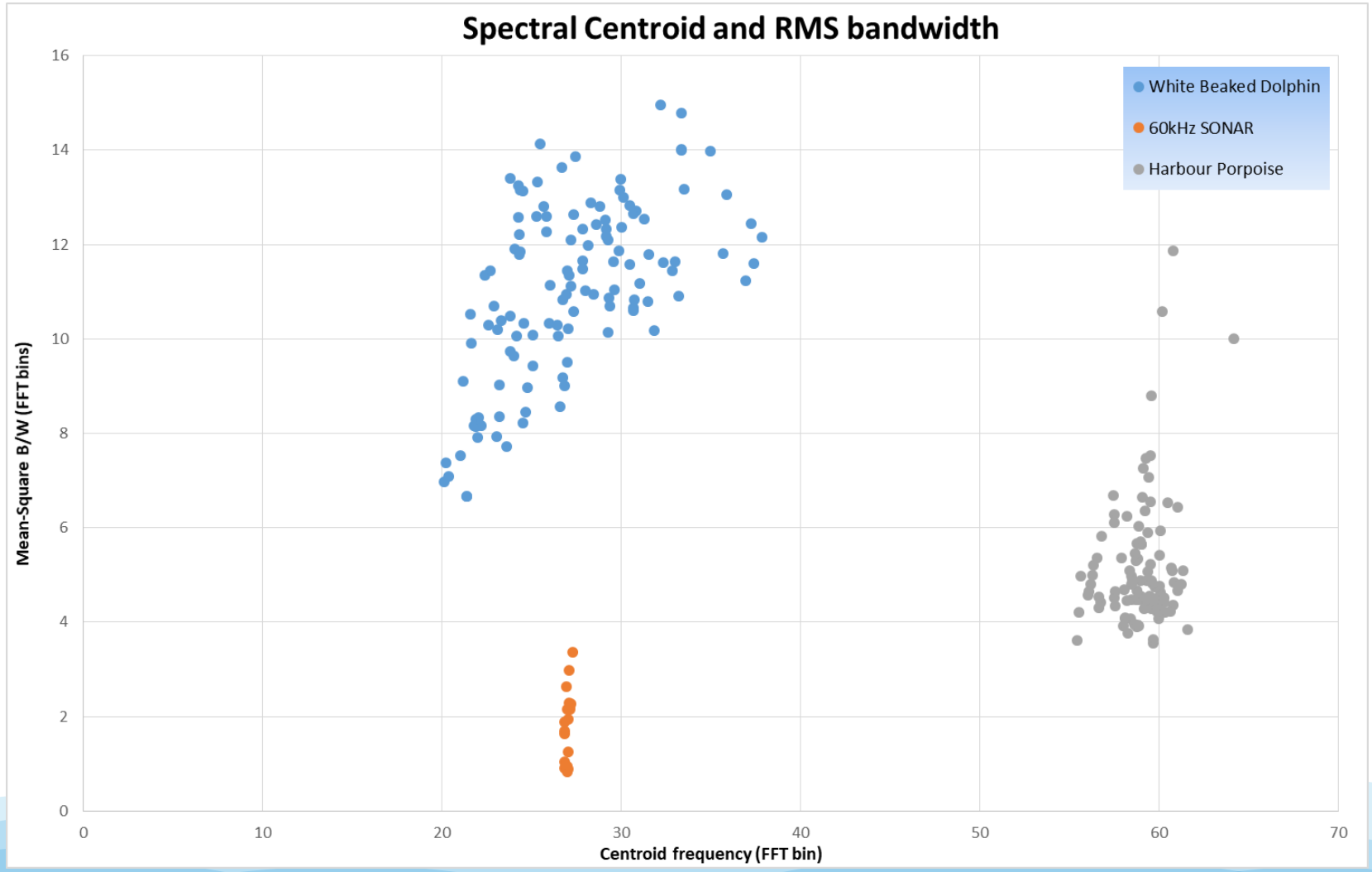
Example clustering of click trains



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Detection results in North Sea 2020

- 3317 detector-hours analysed (199,020 detection minutes)
  - 55 minutes dolphin low click rate
    51 minutes dolphin high click rate
    301 minutes porpoise low click rate
    14 minutes porpoise high click rate
- So 99.4% of minutes detected nothing
- Co-located Soundtrap recorders corroborate 100% of detections by manual analysis and many by sightings.
- Some false negatives – due to low SNR and/or short erratic click trains.

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Future work

- Large area coverage via multi-hop networking.
- Front end refinement to increase detection range.
- Algorithm enhancements to further reduce false positives.
- Additional target signals – e.g. whistles, more complex sonar signals, communications.
- Multistatic operation – with limited comms bandwidth, large delays and poor time synchronisation (EPSRC COUSIN project).

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Thank you for listening

Any questions?

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