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NETTAG+

D3.1 Enhanced transponders

Pre-production prototype transponders with core location functions (TRL 8). The tag technology fully engineered to reach TRL 8 ready for commercial exploitation. Design and test pre-production tags, with the emphasis on minimum manufacturing cost, maximum physical robustness for harsh treatment by fishers and maximising battery life. Robust but low-cost tag construction with transducer and electronics encased in a hard-plastic shell will be developed and optimised for acoustic coupling performance. Electronic circuits reviewed to further reduce power consumption using the latest ultra-low power ARM microprocessors and/or programmable logic devices, along with further cost engineering/component reduction to reduce the bill of materials.

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Summary NETTAG+ Project
NETTAG+ aims to provide a portfolio of three innovative smart and sustainable solutions to address the negative impacts of abandoned, lost or otherwise discarded fishing gear (ALDFG) on marine life and habitats. NETTAG+ will be based on synergistic activities between the fisheries industry, scientists and NGOs to develop three solutions to PREVENT, AVOID and MITIGATE the harmful impacts of ALDFG. NETTAG+ will PREVENT marine litter derived from fisheries activities, AVOID loss of fishing gears, and MITIGATE harmful impact by removing existing ALDFG. These three solutions will jointly contribute to reduce ALDFG and marine pollution, namely by: reducing the introduction of hazardous chemicals and microplastics originating from ALDFG; reducing ghost fishing, bycatch and entanglements of sensitive or endangered species on ALDFG; and improving mapping, tracking and recovery technologies to retrieve ALDFG. NETTAG+ aims to upgrade and upscale the integrative preventive approach that started in the previous NetTag project, and aims to replicate it in Mediterranean regions, providing the fisheries industry with three smart and environmentally-friendly solutions to reduce ALDFG and prevent the environmental impacts of fishing gears. The three solutions will be developed to maturity (TRL 7-8) by the end of the project, and will be tested, validated and demonstrated in real conditions in Atlantic and Mediterranean countries, namely Portugal (PT), United Kingdom (UK), Spain (SP), Italy (IT), Croatia (HR) and Malta (MT). NETTAG+'s ambition is to change the paradigm of the fisheries industry, aspiring to transform the societal perspectives about the role of fishers as Guardians and Cleaners of the Ocean. NETTAG+ will empower the sector to take effective actions to address marine pollution, promoting their role as key actors to tackle marine pollution.

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Executive Summary

This document describes the design and testing of enhanced hardware, software and protocols by UNEW for the NetTag transponder device. The technology has been developed to pre-production prototype stage (TRL 8) in conjunction with industrial partner Succorfish (SF). Enhancements to the existing NetTag design include:

- Reduced receiver self-noise for increased range and reliability.
- Improved acoustic protocol for increased range and reliability, whilst increasing the number of uniquely addressable units to > 16.7 million.
- More robust physical housing and easy access for replacing batteries.

These enhancements have been demonstrated during testing in realistic conditions in the North Sea and off the Indian coast, with accurate ranging up to 2.7 km achieved. This exceeds the design target of 2 km.

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1 Background

The previous NetTag project demonstrated the feasibility and effectiveness of fishing gear location using a low cost/power acoustic transponder (tag) developed by UNEW [1]. Prototype circuits and housings, illustrated in Figure 1 and Figure 2, were developed and successfully tested in trials in the North Sea and off the Portuguese Coast. These tags were based on acoustic modem technology for Internet of Underwater Things (IoUT), cost-engineered and adapted to the more limited task of subsea range measurement.

Figure 1. NetTag circuit and transducer assembly

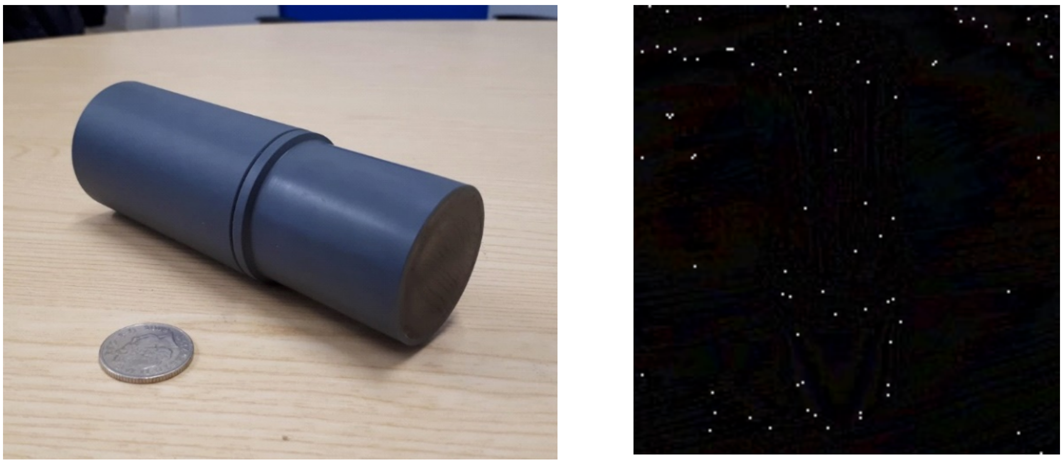

Figure 2. NetTag prototype housing and alkaline battery pack

The first phase of WP3 in the NETTAG+ project was to optimise both the hardware and acoustic protocols for the task of locating fishing gear, increasing the physical robustness of the device, ease of operation, range/reliability and vastly increasing the number of acoustic addresses to enable a globally unique ID for each NetTag device in future use.

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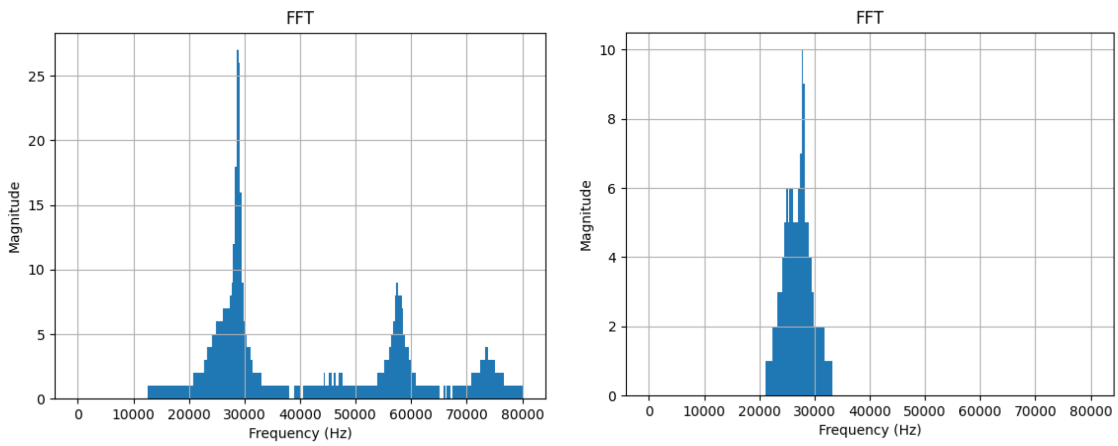
2 Circuit design

2.1 Receiver self-noise reduction

In the tag receiver and surface receiver it is desirable for the sources of electronic "self-noise" to be minimised in order to maximise received signal to noise ratio, and hence the detection range of the acoustic signals. Figure 3(a) shows the spectrum of the received signal for the original NetTag circuit with the device outside the water (no acoustic signals arriving). This is generated by performing a Fast Fourier Transform (FFT) onboard the NetTag processor and indicates substantial interfering signals both within the target frequency band (24- 32 kHz) and at frequencies above this. This interference originates from power supply circuits and processor switching on the board and the total noise power equates to 100.3 dB re 1μPa in sound pressure level, the equivalent of ambient acoustic noise in a quite high sea state. This will substantially reduce the range of the device when the ambient noise (sea state) is low to moderate.



(a) (b)

Figure 3. Spectrum of receiver self-noise (a) original NetTag circuit (b) enhanced NetTag circuit

To reduce this self-noise several improvements were made to the circuit design including:

- Changing power supply arrangements for the analog-digital converter to provide a supply with less ripple/noise.
- Adjusting the receiver band-pass filter response.

The resulting spectrum for the modified circuit is shown in Figure 3(b) with the noise components both inside and outside the target frequency band substantially reduced. The remaining noise (largely unavoidable thermal noise for amplifier electronics) equates to a sound

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pressure level of 92.6 dB re 1μPa and is the equivalent of a substantially reduced sea state, enabling increased detection range (to be confirmed in trials).

2.2 Power supply protection and management

The widespread use of the NetTag device by unqualified users requires measures to protect against likely causes of damage to the circuit. The most obvious of this is when batteries are changed and the possibility of reverse polarity (batteries inserted the wrong way). Hence a MOSFET based reverse polarity protection circuit was added to the NetTag board to ensure that no current can flow in this event.

Additional changes were made to protect against power up transients that can potentially damage the circuit should other voltage sources and switching arrangements be used.

A further function has been added to enable the circuit to entre a low power state when required, opening up the possibility to extend the listening life of the device, operating from 4 standard alkaline AA cells, from approximately 2 months to up to 12 months depending on operating duty cycle.

2.3 Pre-production circuit prototypes

The design of the enhanced NetTag printed circuit board (PCB) was finalised between UNEW and SF and an initial run of 50 circuits were manufactured by SF. The dimensions match the previous 34 mm diameter of the original prototypes. These have been verified in laboratory tests and then integrated in several test units used in various sea trials described in section 5.

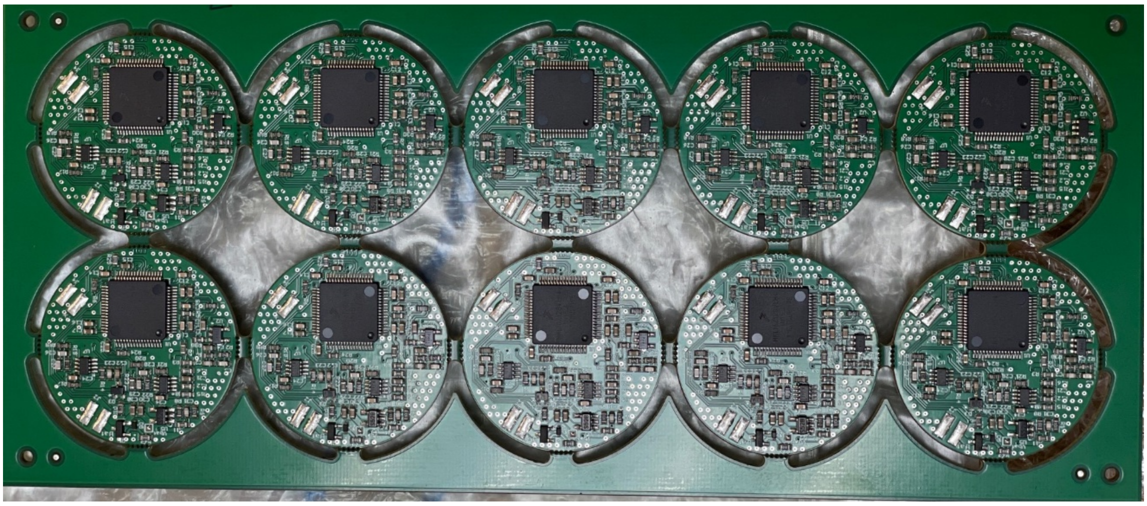

Figure 4. Pre-production prototype NetTag transponder circuits

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3 Acoustic Protocol Design

3.1 Legacy acoustic protocol

The acoustic protocol used in the previous NetTag devices was adapted from general purpose acoustic modems [2] intended for data transfer as well as ranging. This protocol supports functions well beyond what is required for the NetTag transponder and only a subset of the functions were used, since only ranging is required. The packet structures provided in the modem protocol are shown in Figure 5, with NetTag communication/ranging based only on the short command packets for range request and reply. These short command packets have two limitations:

- Relatively weak error correction and detection via a simple triple redundant code which compromises packet delivery rate and probability of undetected errors.
- 8-bit destination address means that only 256 possible NetTag IDs are supported and this is clearly not sufficient for widespread adoption of the technology.

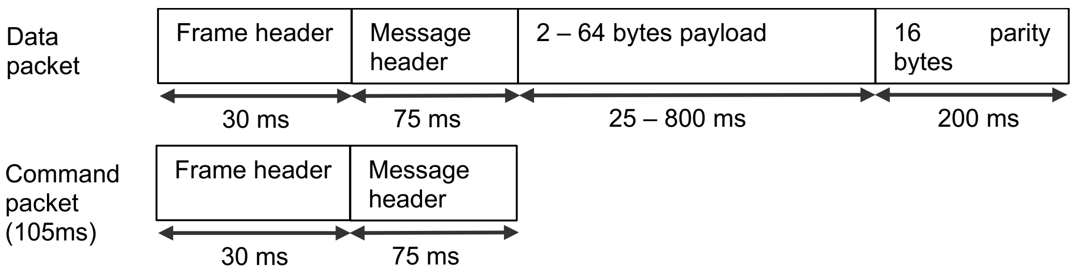

Figure 5. Legacy acoustic modem protocol – packet structures

3.2 Custom NetTag acoustic protocol

To address the limitations of the above protocol and optimise performance in the NetTag system, a custom acoustic protocol has been developed which provides:

- Support for a 24-bit address, enabling up to 16.8 million globally unique tag ID codes.
- Provides a range request packet that accommodates the expanded addresses along with a much stronger error correction/detection coding scheme to increase range and reliability of tag interrogation.
- A simplified but inherently more robust range reply message to maximise detection range.

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The custom range request packet consists of a 4-bit command code and a 24-bit destination address (Tag ID). A Reed Solomon (RS) error correction code is used to protect this data, with the code able to any combination of up to 4 symbol errors occurring within the packet and detect almost all cases where errors cannot be corrected. The total duration of the custom range request packet is 120 ms meaning the expanded addressing and improved error correction has been achieved with only 15 ms extension to the original "ping" command.

The 4-bit command code enables up to 16 commands to be issued to the tag of which only 1 is currently used (range request), leaving 15 command codes for implementation of future functions such as a release mechanism. The 24-bit address is automatically generated from a unique number hardwired into each processor chip used in a NetTag circuit. This will be registered by the manufacturer and provided to the users to enter into the location app.

The range reply signal used in the custom protocol has been completely redesigned in order to achieve the maximum possible detection performance without increasing the complexity/cost of the surface locator unit (SLU). This consists of a simplified 80 ms duration signal which increases the spread spectrum processing gain by 4.3 dB, whilst removing the need to accurately decode any data for an address etc. Given the reliability of the request message and 16.7M unique codes, we can be confident that only the requested unit will respond to any range request.

Code to implement the new protocol has been developed and deployed on the NetTag and SLU hardware and the expected improvement in range and reliability were demonstrated during sea trials (results are shown in section 5).

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4 Packaging design

4.1 NetTag subsea housing

Pre-production, injection moulded plastic housings, illustrated in Figure 6, have been designed and produced by SF in consultation with UNEW. Key features of this NetTag housing are:

- Shroud and reinforcement ribs to provide impact protection for the delicate acoustic transducer (piezo-ceramic ring).
- Screw thread opening with double o-ring waterproof seal for easy access to change batteries.
- Standard 4 x Alkaline AA cell battery holder (cells easily available worldwide). Also can be operated with rechargeable AA cells.
- Robust, integrated loop for attachment to nets and other gear.
- Air void in enclosure provides positive buoyancy to ensure the transducer is held in ideal orientation and raised clear of obstructions.

Assembled prototypes were tested in UNEW's acoustic test tank to assess acoustic performance of various design iterations to obtain an acceptable level of impact protection without compromising acoustic performance.

Figure 6. Pre-production NetTag housing, battery enclosure and tank testing

This version of housing has been designed to cover a range of gear including trawl nets and pots/traps used in shellfish fisheries. However, after consultation with users and manufacturers of gill nets and trammel nets, it is likely that a second, more compact housing option will also be produced without the air volume and buoyancy, allowing similar mounting to existing cetacean deterrent pingers.

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4.2 Materials

To contribute to circularity of the fishing gear, the NetTag plastic housing is manufactured from a nylon material which is sourced from 100% mechanically recycled post-consumer (PCR) fishing nets and ropes [3].

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5 Field Testing

5.1 North Sea Trials

During February 2024, trials were carried out in the North Sea, sailing out of the Port of Blyth, Northumberland, UK. The objectives were as follows:

- Verify the increased range from improvements to the self-noise of the NetTag receiver electronics.
- Compare the ranging performance of the legacy modem protocol with the custom NetTag protocol and quantify the benefits in realistic sea conditions.
- Record acoustic traffic on a hydrophone to enable post-analysis of channel response and background noise.

Figure 7. Rigging and deployment of mooring carrying NetTags

A mooring was assembled (Figure 7) containing two NetTags, close together (<0.5m spacing) and within 2 m of the seabed. One tag was running the legacy modem protocol and the other was running the custom NetTag protocol. The mooring was deployed approximately 3km from shore in 30m water depth, at location 55°08'17.9"N 1°28'06.6"W. Likewise, two surface locator units (Figure 8) were deployed from the vessel, closely spaced at a depth of ~3m, with each

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running the different protocol. A hydrophone was also attached to the same line in order to monitor the signals in the water in real time (Figure 9) and record the raw acoustic data.

Figure 8. Deployment and configuration of surface locator units

Figure 9. Monitoring of acoustic signals on hydrophone

The vessel carrying the SLUs was moved to a starting location 250m from the mooring and then then the SLU's were activated to alternate ranging requests using the legacy protocol and the

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custom NetTag protocol. The vessel was then allowed to drift (at approximately 1 kt = 0.5 m/s) until the maximum range was reached.

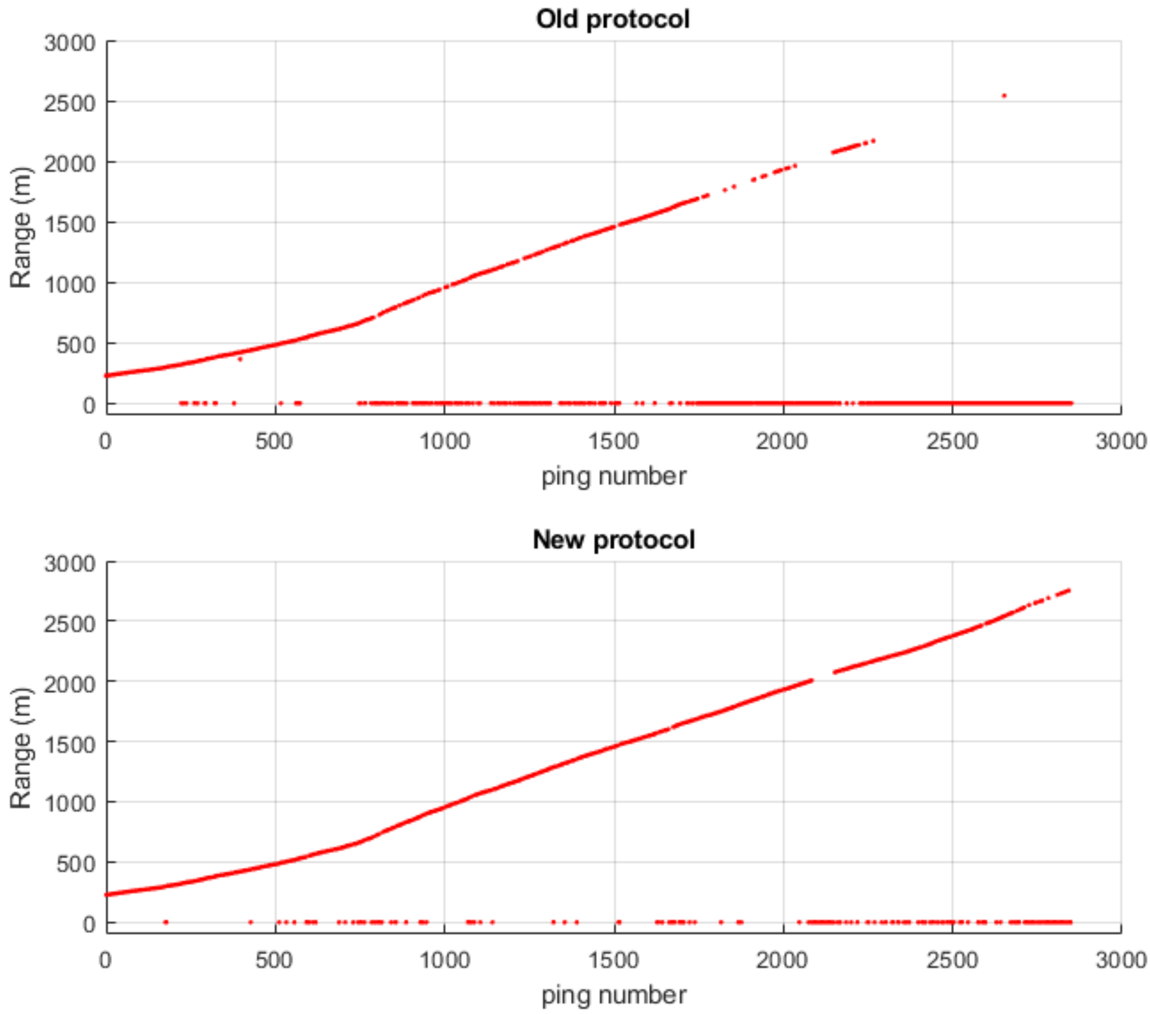

Figure 10. Ranging results of legacy modem protocol (top) and new custom NetTag protocol (bottom)

Figure 10 shows ranging results for the two protocols, with 950 ping requests transmitted on each. Each red dot on the plots indicates a ranging result, with either a range in meters if successful or a value of -1 (dots along the x axis) if the response from the tag was not received. It is evident from these results that:

- The success rate and maximum range is substantially higher for the custom protocol compared to the legacy protocol.
- The legacy protocol is effective up to **1.7 km** range with 74% success up to this range, which indicates an improvement over previous results due to circuit improvements.
- The custom protocol remains effective up to at least **2.7 km** range with 82.6% success up to this range.

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These tests encompassed a wide range of multipath channel conditions and significant boat traffic and so represent entirely realistic operating conditions for the technology. The above process was repeated twice with the SLUs at different depths with consistent results.

5.2 Testing in India by SF

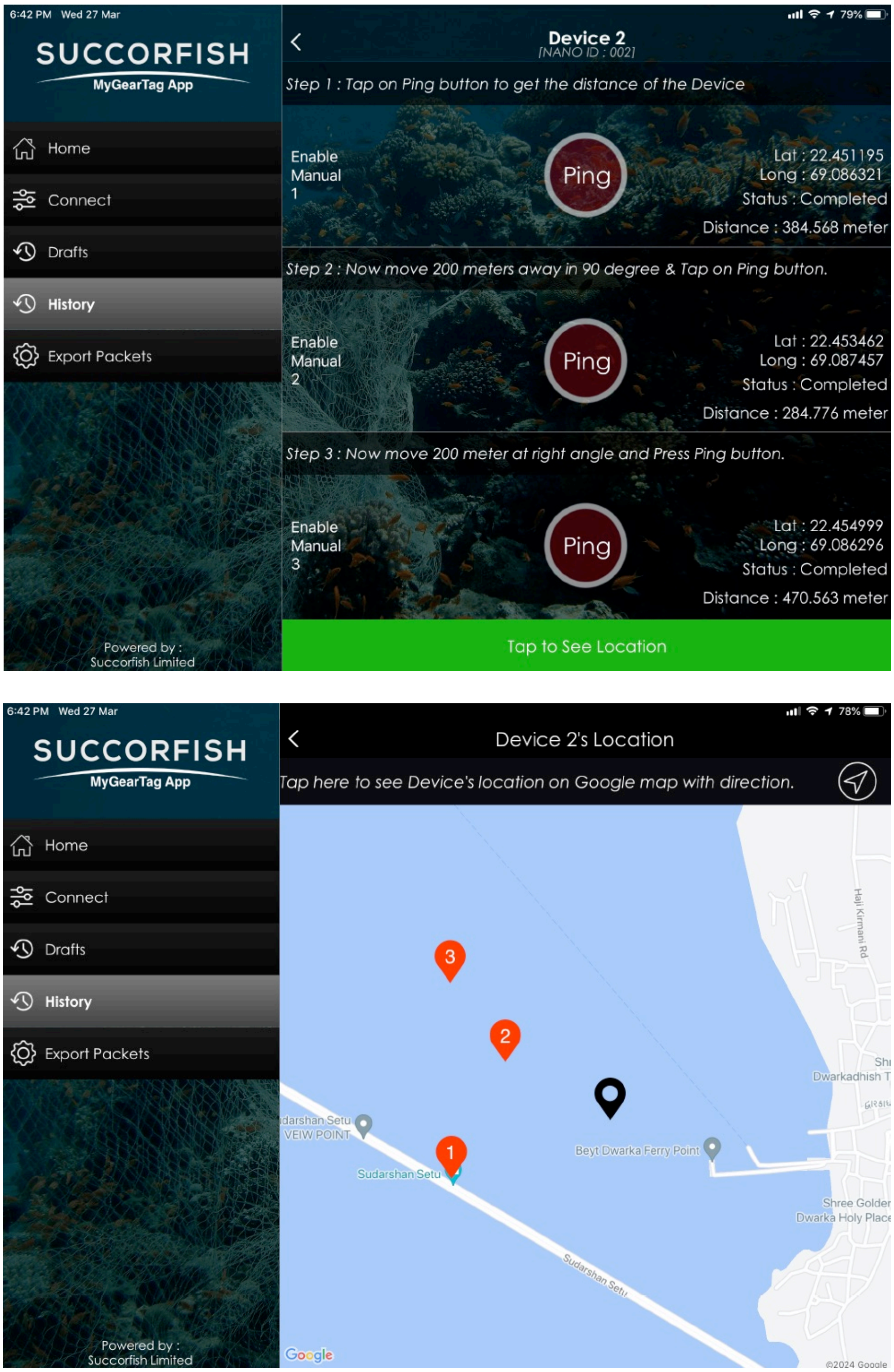

Figure 11. Example output of location app for test in India

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The latest NetTag devices have also been tested/demonstrated during a visit to Gujarat, India by SF. This was an opportunity to test an early version of the location app on an IOS tablet, using the virtual long baseline technique [1]. The tag was successfully located in two different locations using the app. This also demonstrated operation of the tags in very different environmental conditions compared to a North Sea Winter, operating in a river estuary with air temperature as high as 44 degrees C.

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[2] Sherlock, B.; Morozs, N.; Neasham, J.; Mitchell, P. Ultra-Low-Cost and Ultra-Low-Power, Miniature Acoustic Modems Using Multipath Tolerant Spread-Spectrum Techniques. Electronics 2022, 11, 1446. https://doi.org/10.3390/electronics11091446

[3] https://oceanmaterial.com/our-products/ocean-plastic/pa6/pa6-fishing-nets/

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