Applied Physics Laboratory
University of Washington
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Award: N00014-21-1-2269

FINAL REPORT:

Kauai Source Restart 2021

Report date: May 31, 2022

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SPONSORING ORGANIZATION:
Office of Naval Research
Code 32OA Ocean Acoustics
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1 LONG TERM GOALS

Re-establish a platform for long-range, low-frequency, underwater acoustic research and development using a mothballed system located off the north shore of Kauai.

2 OBJECTIVES

The primary objective of this grant was to restart the electro-acoustic "HX554" source off the island of Kauai. The HX554 was originally cabled to shore, with command and control equipment located within the Pacific Missile Range Facility (PMRF). The shoreside equipment lost contact with the HX554 in roughly 2016 due to an apparent cable break, and was shutdown thereafter. Functionality restoration required (1) assessing that the HX554 was still healthy, (2) repairing the underwater cable, and (3) repairing and rejuvenating shoreside equipment.

3 APPROACH

- ***HX554 Functionality Assessment*** In order to determine if the HX554 was still healthy enough to support high-voltage drive levels, the APL-UW mobile van would be refurbished and shipped to Honolulu. This van contains an Instruments Inc L50 and associated control electronics, capable of generating long-range m-sequence signals and driving the HX554 with more than 500VRMS, similar to the original design range of voltage input. The mobile van would be secured to the deck of the C/S Decisive for the duration of the cable repair cruise (see below) The radiated signals from the HX554 would be monitored by APL-UW engineers who would tap into the PMRF range hydrophones and process the received data with custom S/W on a linux laptop.

- ***Cable Repair*** Once the HX554 was deemed healthy, the crew of the C/S Decisive would install new sections of cable. The APL-UW engineers at the shorestation would conduct the final TDR test from the shore end of the cable.

- ***Shoreside Refurbishment*** Old, spare, back-up hardware at APL-UW would be located and rejuvenated to provide functioning replacements for Kauai shoreside equipment. A Ling power amplifier, the sister-unit to the power amplifier at Kauai, would be pulled from storage and transferred to APL-UW at Henderson Hall.

4 WORK COMPLETED

- March 2021:
  - Backup instrumentation stored at APL-UW for both the mobile van and the Kauai shore station was refurbished and repaired. Instrumentation in the mobile van was replaced, the L50 power amplifier was brought back online, and the mobile van system was tested into a dummy load at voltages up to 500 VRMS. ATOC-era S/W was updated and installed on two identical system hard drives; one was shipped to Kauai.
  - After 10-day quarantine on Kauai, the PI installed the refurbished instrumentation and rebuilt hard drive into APL-UW equipment at the shorestation. The Ling power amplifier was powered up, and immediately blew out a surge suppressor.
  - The APL-UW mobile van was shipped to Honolulu.

- June 2021: The PI quarantined (10 days) in Honolulu and then joined the C/S Decisive to support the at-sea cable repair[1]. Two APL-UW engineers flew to Kauai and supported the repair with round-the-clock shoreside cable monitoring. They made the final end-to-end TDR measurement and confirmed that the repaired cable had no faults. They also monitored the radiated signals using PMRF range hydrophones. The blown surge suppressor was repaired.

- August 2021: The mobile van returned to CONUS aboard the C/S Decisive , was trucked to Seattle from Portland, stored again at APL-UW and reconnected to Seattle City Light power, where it remains on-line for development and testing of S/W for the Kauai Beacon.

- September 2021: An APL-UW electrical engineer, Kevin Zack, was assigned to bring the Seattle Ling back to life. 208V 3-phase power was installed in a new lab space at APL-UW, and the Seattle Ling was modified to accept it. Multiple Logic Modules were tested; 2 were found to be easily repairable. Multiple Power Modules were tested, roughly half a dozen were found to be usable without repairs.

- October 2021: The Kauai computer experienced a crash. Replacement parts were carried out and installed.

- November 2021: Replacement Ling Logic Modules and Power Modules were taken out by the PI and engineer Zack and installed and tested in the Ling. Impedance and admittance measurements made after final testing are shown in Figs. 1 and 2, respectively.

- January 2022:
  - Anomalous remotely controlled monitor tasks indicated that the Ling was likely experiencing a fault. The PI carried a replacement Logic Module to Kauai and installed it.
  - At Kauai, the PI introduced the system to an away-team from NUWCDIVNPT, demonstrated the operation of the system, and supported their access to the APL-UW hardware.

- February 2022:
  - At the request of NUWCDIVNPT, APL-UW shipped two Logic Modules and an associated installation manual to NUWC in Newport, Rhode Island. This hardware was to support upcoming exercises involving the Kauai Beacon.

5 RESULTS

All objectives were met and the system regained functionality by November 2021. Cable repair details are provided by Andrew[1]. Various components continue to fail sporadically due to age, requiring vigilant monitoring and occasional repair and/or replacement.

6 IMPACT/APPLICATIONS

The "Kauai Beacon" system has already been used in several underwater acoustics experiments. An example is shown in Fig. 3.

7 RELATED PROJECTS

Long-range, low-frequency propagation research involves collaborations with Bruce Howe (UH), John Colosi (NPS), David Dall'Osto (APL), Kevin Smith (NPS) Kay Gemba (NPS) and Shima Abadi (NPS). Ben Cray is also leading a group of collaborators from NUWC-DIVNPT.

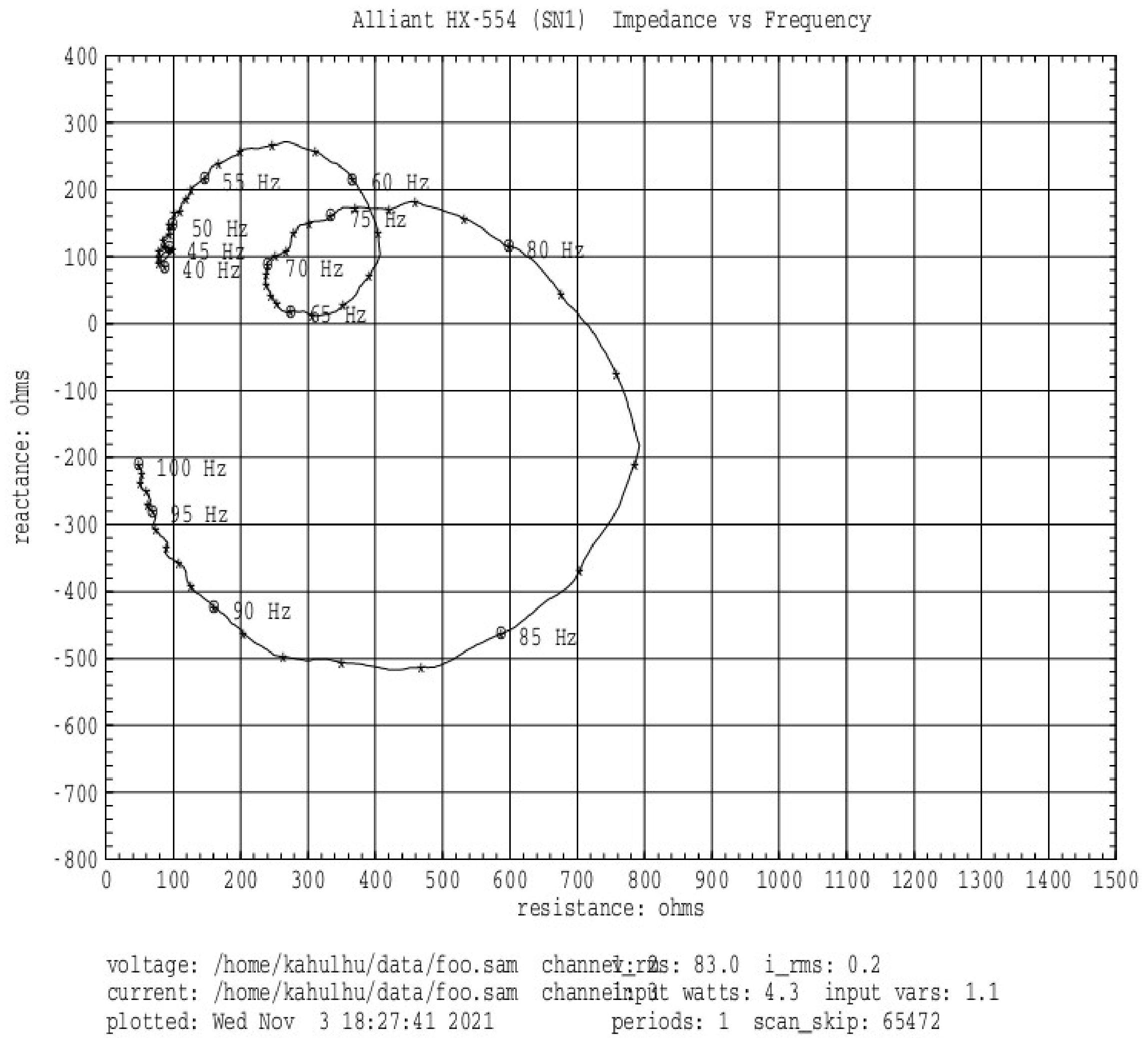

Figure 1: Capture `cth1635963931` impedance loop.

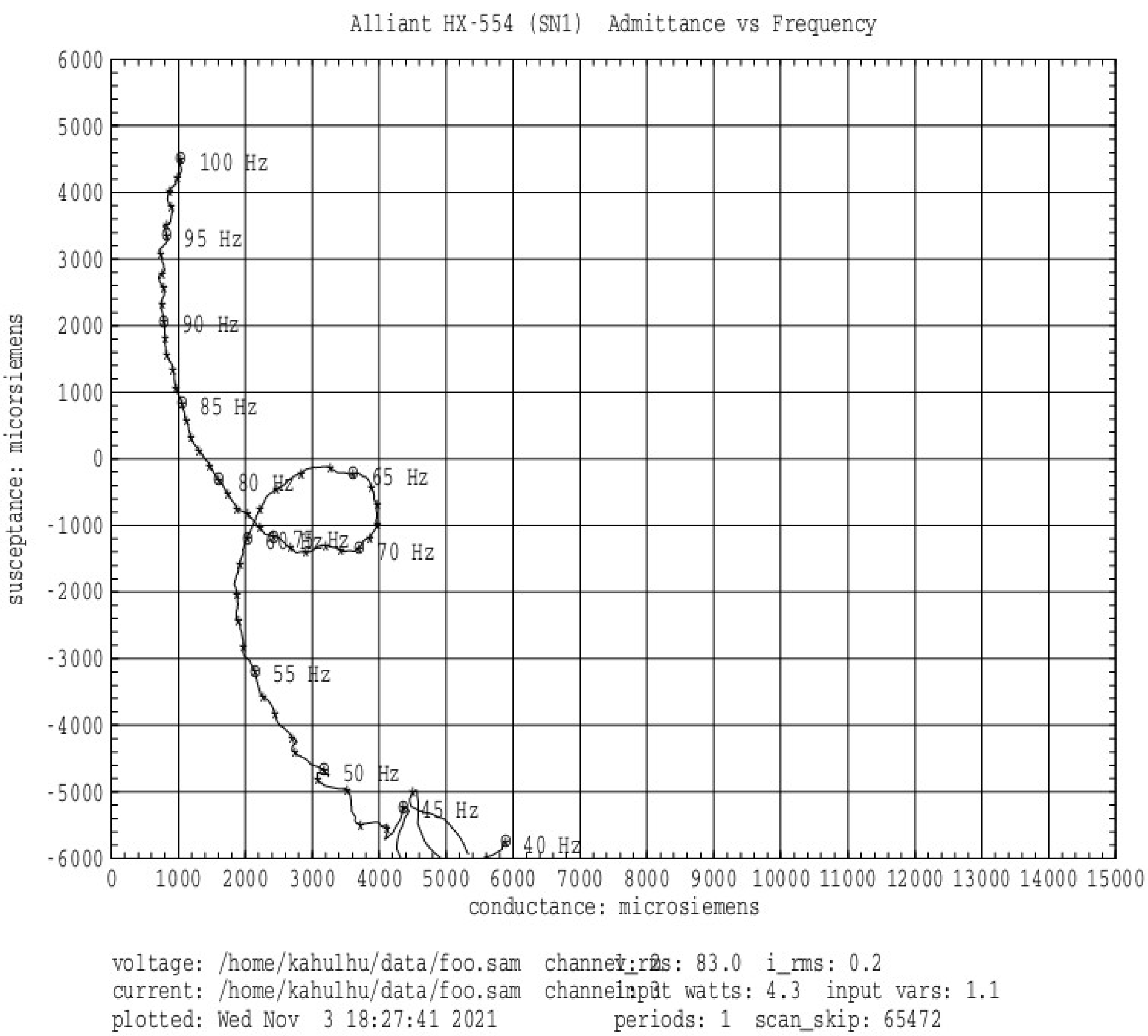

Figure 2: Capture `cth1635963931` admittance loop.

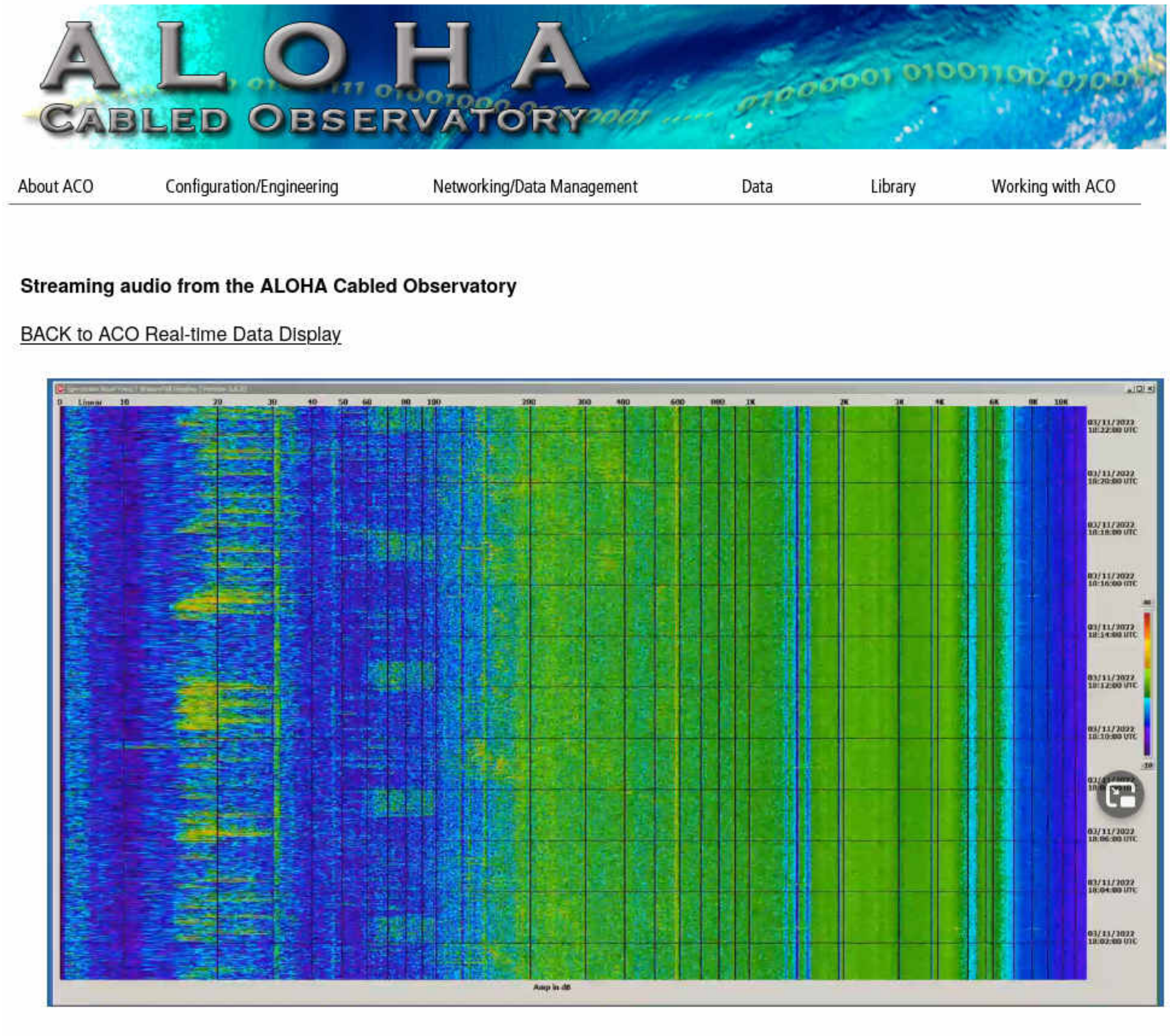

Figure 3: Screen capture of the real-time spectrogram published online by UH's ACO, showing the capture of periodic wideband signals transmitted from the APL-UW system by the NUWCDIVNPT team in January 2022. The signals span from about 65 Hz to about 100 Hz. Each transmission is about 60 s long, and 5 such transmissions can be identified.

References

[1] *APL-UW 2021 Kauai Cable Repair Support Trip Report*, RK Andrew, September 2021. (Attached.)

8 PUBLICATIONS

[1] IS Letsheleha, KP Findlay, FW Shabangu, D Farrell, RK Andrew, PL la Grange, "Year-round acoustic monitoring of Antarctic blue and fin whales in relation to environmental conditions off the west coast of South Africa", *Marine Biology*, **169**(41), January 2022.

[2] MA Ainslie, RK Andrew, BM Howe, JA Mercer, "Temperature-driven seasonal and longer term changes in spatially averaged deep ocean ambient sound at frequencies 63-125 Hz", *J. Acoust. Soc. Am.*, **149**(4), pp 2531 – 2545, April 2021.

ATTACHMENT 1

APL-UW 2021 Kauai Cable Repair Support Trip Report, RK Andrew, September 2021.
(Attached.)

APL-UW 2021 Kauai Cable Repair Support Trip Report

C/S *Decisive*

16 June - 30 June 2021

(Engineer-in-Charge: John Gronbeck)

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git hash: 7907dc808b96165a9e40c51b1419bee946507ed2
Compile date: Wed Sep 15 07:02:28 PDT 2021

Contents

1 Summary

APL-UW provided support for an effort to repair the damaged Kauai cable. The APL-UW team consisted of Andrew on the cable ship C/S Decisive and Michel-Hart and Zack on shore on Kauai at PMRF. In the first repair step, the cable was brought on deck, connected to the APL-UW signal generator, and the HX554 proofed. The HX554 was tested at equivalent source levels of 171 to 187 dB for cumulatively 92 minutes. Impedance and admittance diagnostics were excellent for all cases. In parallel, the shore team monitored the radiated acoustic signal with a PMRF range hydrophone located roughly 30 km from the HX554 and observed satisfactory pulse-compressed signal signatures.

Next, the C/S Decisive tried to find the SDL1/SDL3 splice, but could not locate the cable. The C/S Decisive then relocated to the shorecable/SDL3 splice and recovered the shorecable to the deck. A repair cable, pre-assembled several days earlier, consisting of 8 km of SDL3 and 24 km of SDL1, was spliced onto the shorecable and laid out over the existing cable. TDR testing by the APL-UW shoreteam verified that the entire end-to-end cable was now clear of faults, with a single reflection from the HX554 seen at 557 μs.

In parallel, the APL-UW shore team diagnosed the faulted shore station Ling amplifier. A damaged "soft-start" circuit was found, and replacement hardware ordered, received and installed. The Ling was successfully powered up, however now presents multiple diagnostic fault indicators. The Ling remains off-line.

References

1. Andrew, "APL-UW 2021 Kauai Cable Repair Support Plan", May-June 2021.
2. Gronbeck, Method of Procedure "Acoustic Thermometry of Ocean Climate — Kaua'i ATOC Repair", issue 2 dtd 2021.5.11.
3. PMS485, "CATEGORICAL EXCLUSION FOR THE REPAIR TO AN UNDERSEA CABLE OFF THE NORTH SHORE OF KAUAI", Ser PMS485/129, dtd 17 May 2021.
4. "Kauai Source Cable Repair June 2021 Test Report", Royce Decker, initial release dtd 2021.07.01.
5. Gronbeck report (forthcoming?)
6. RPL (Route Position List) (forthcoming?)

2 Acknowledgments

Thanks to CPT Ellsworth and his skillful crew on the C/S Decisive, the cable engineers, testers and splicers, and also the Chief Mate who additionally took care of us while in quarantine at Waikiki. Mike Dick and Jon Winsley at PMRF provided significant support throughout, particularly integrating us into PMRF range schedules, and also facilitating APL-UW shoreteam access. Prof Bruce Howe, University of Hawaii, provided support and staging at UH Marine Center for APL-UW equipment. APL-UW IT built a hardened laptop that passed critical security checks at PMRF and allowed capture of validating signals. The APL-UW effort was funded under ONR Grant N00014-21-1-2269.

Section	Start	End	Type
Underground	Cal Lab (BLDG 515)	BLDG 539 (Cable hut)	"SD" (probably SDL1)
BSUREB77	BLDG539	BSUREB77/SDL3 splice	SDL5 (double armored)
SDL3	BSUREB77/L3 splice	L3/L1 splice	SDL3 (single armored)
SDL1-shoreward	L3/L1 splice	2019 cut point	SDL1 (unarmored)
SDL1-seaward	2019 cut point	HX554	SDL1 (unarmored)

Table 1: Components of the Kauai cable at the start of this effort, identified by the nomenclature used in this report. Components listed in order from the shore station to the HX554.

3 Overview

The entire cable (Fig. 1) consists of multiple segments; nomenclature for these segments is shown in Table 1. Measurements from the Cal Lab in 2016 indicated a shorted fault several hundred meters seaward from the BSUREB77/SDL3 splice. At the start of this effort, the fault had migrated shoreward to the splice.

ONR Code 32OA rounded up support for repair from other components of the US Navy. Unused SDL3 cable and salvaged SDL1 cable were located at a cable depot in Baltimore, and pre-placed in wet storage north of Kauai by the cable ship C/S Global Sentinel in May 2021. In June 2021, the cable ship C/S Decisive (see Fig. 2) picked up the cable and moved to the site of the Kauai cable to effect repairs.

Two critical measurements were made before the replacement cable was committed to the repair: a "proof test" was conducted against the HX554 to determine if it could still sustain useful power levels, and the BSUREB77 shore cable was interrogated to determine if it was still viable out to the BSUREB77/SDL3 splice. The cable repair plan would be aborted if either asset (HX554 or BSUREB77 cable) was faulted. There was no plan to repair either asset if it was bad.

Section 4 describes the test of the HX554 and section 5 provides the reflectometry traces made from the shore station before, during, and at the completion of the effort. The final cable configuration is shown in section 6. Details regarding the power amplifier are provided in section 7. A permit was secured for this repair operation, see section 8. Finally, a chronology of important events is provided in section 9. The appendix lists the primary performers, some lessons learned, and an acknowledgment for APL-IT for their efforts in building a hardened laptop that met cybersecurity requirements at PMRF.

4 HX554 Proof Test

The HX554 was proofed by driving it with instrumentation resident in the APL-UW "science van" secured to the C/S Decisive aft B deck. The van was provided with 440V 3-phase Delta power; a Larson Electronics 9 kVA 3-phase delta-delta isolation transformer (purchased by APL-UW for this purpose) converted the 440V to approximately 237V for van power needs. Instrumentation in the van provided precise signal launch via GPS-locked

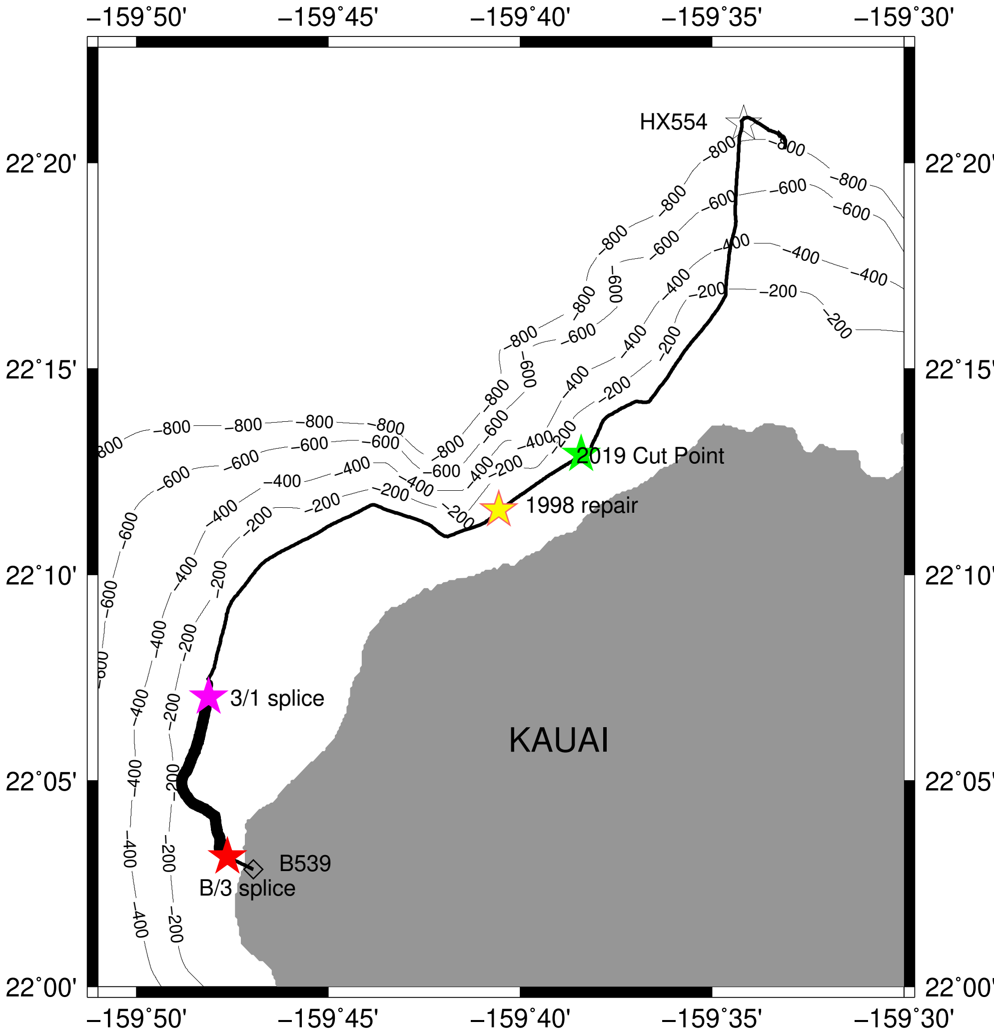

Figure 1: Entire in-water cable route. The armored SD list 3 cable section is shown with a heavy black line. The unarmored SD list 1 cable shown with a normal black line. The magenta star indicates the SD3/SD1 splice. The yellow star is the site of the 1998 fault. The green star is the site of the 2019 test. The very short segment from hut 539 to the SDL3 armored cable is the "BSUREB77 string". The red star is the splice from the BSUREB77 cable to the SDL3 cable.

Figure 2: The cable ship C/S Decisive.

Carrier	75 Hz
Law	3471
Sequence Length	1023
Cycles/digit	2
Sequence duration	27.28s
Pase mod angle	88.209°
Bandwidth	37.5 Hz

Table 2: Principle parameters of the test waveforms. Multiple amplitudes were used.

D/A triggering (the van had its own GPS antenna and receiver) and a 6.5 kVA Instruments Inc L50 power amplifier. (The L50 input taps were wired for 240V; 237V proved adequate.) All test waveforms were m-sequences with parameters given in Table 2. The proof test protocol began with low-level signals and gradually increased in amplitude and duration. The exact transmissions are shown in Table 3. The Instruments Inc L50 was set to maximum voltage: 1200V and a resistive source.

4.1 Admittance and Impedance Measurements

Admittance and impedance loops were captured for each transmission. In all cases, the loops resembled each other. Example admittance and impedance loops are shown in Fig. 3 and Fig. 4, respectively.

4.2 HX554 Monitoring

The acoustic signal radiated from the HX554 was monitored using one of the deeper hydrophones in the PMRF underwater range. This hydrophone was at a depth of roughly 3000 m at a range of about 30 km. The “raw” analog hydrophone signal was made available for use in PMRF Bldg 105. The analog signal was injected into a Behringer U-PHONO UFO202 USB digitizer, and then passed to custom software in an APL-UW Dell Latitude

Output File name	cfg file	Run-start UTC	marktime UTC	human readable UTC	duration sec	V RMS	I RMS	SL dB
cth1624568279.xml	cth1624568279.cfg	Thu Jun 24 20:56:55 2021	1624568279	2021.06.24Z20:57:59	N/A	test	test	N/A
cth1624568493.xml	cth1624568493.cfg	Thu Jun 24 21:00:28 2021	1624568493	2021.06.24Z21:01:33	120	56	0.28	171.4
cth1624569334.xml	cth1624569334.cfg	Thu Jun 24 21:14:30 2021	1624569334	2021.06.24Z21:15:34	120	57	0.29	171.4
cth1624570176.xml	cth1624570176.cfg	Thu Jun 24 21:28:31 2021	1624570176	2021.06.24Z21:29:36	240	110	0.49	177.4
cth1624571123.xml	cth1624571123.cfg	Thu Jun 24 21:44:22 2021	1624571123	2021.06.24Z21:45:23	240	110	0.50	177.4
cth1624572044.xml	cth1624572044.cfg	Thu Jun 24 21:59:39 2021	1624572044	2021.06.24Z22:00:44	1200	273	1.18	185.4
cth1624574539.xml	cth1624574539.cfg	Thu Jun 24 22:41:14 2021	1624574539	2021.06.24Z22:42:19	1200	273	1.15	185.4
cth1624577055.xml	cth1624577055.cfg	Thu Jun 24 23:23:11 2021	1624577055	2021.06.24Z23:24:15	1200	324	1.38	187.0
cth1624579834.xml	cth1624579834.cfg	Fri Jun 25 00:09:31 2021	1624579834	2021.06.25Z00:10:34	1200	327	1.36	187.0

Table 3: Transmissions from the HX554 during the test. All entries are yearday 175 except the last, which is yearday 176. Source levels are "designed" levels, see Ref. 1.

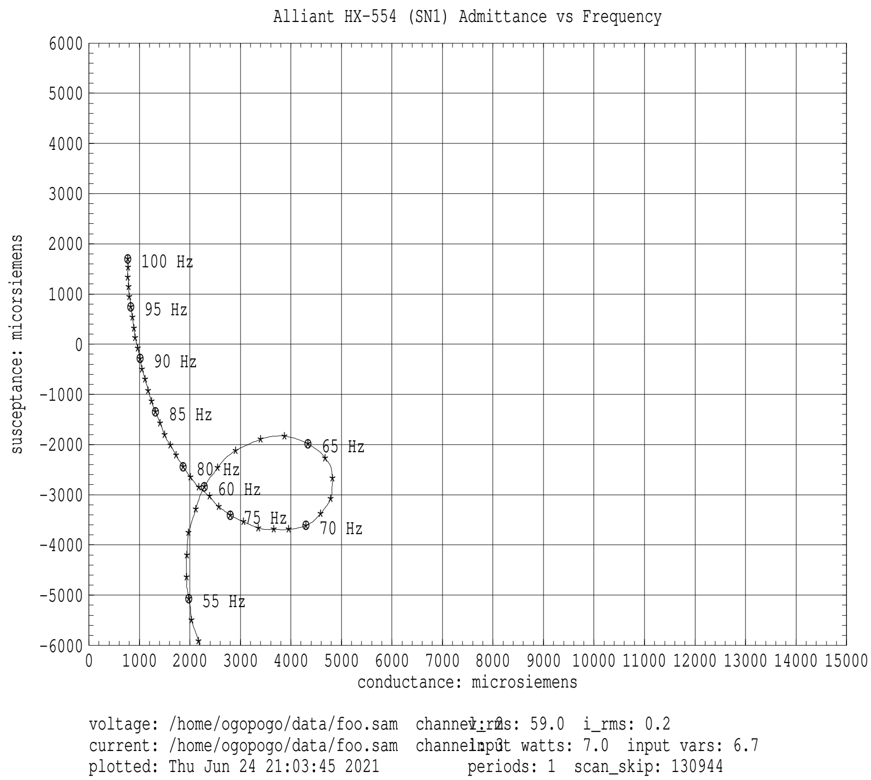

Figure 3: Measured admittance loop captured aboard the C/S Decisive.

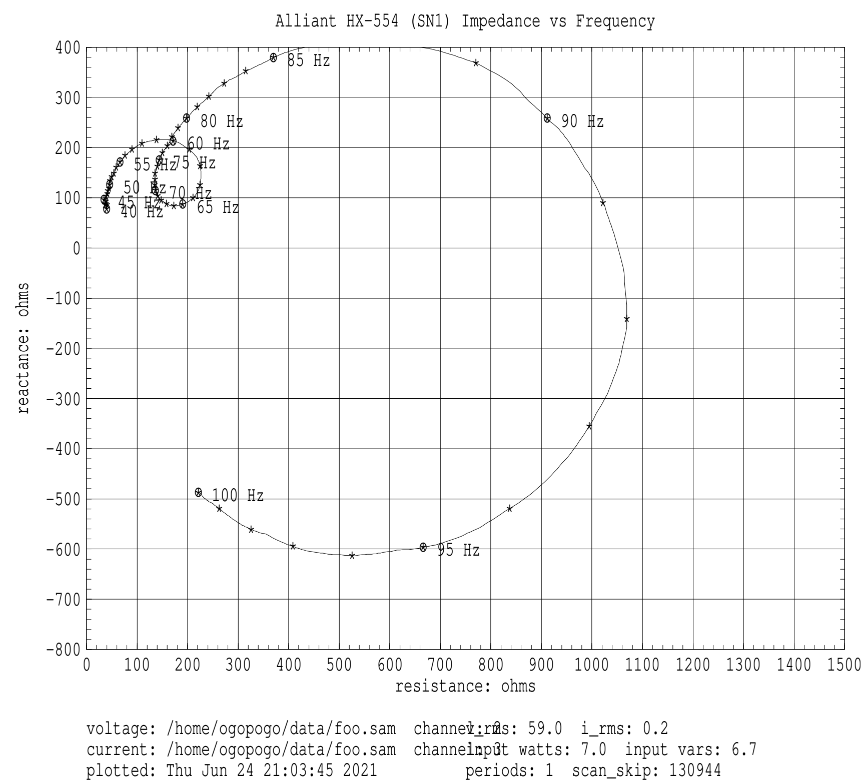

Figure 4: Measured impedance loop captured aboard the C/S Decisive.

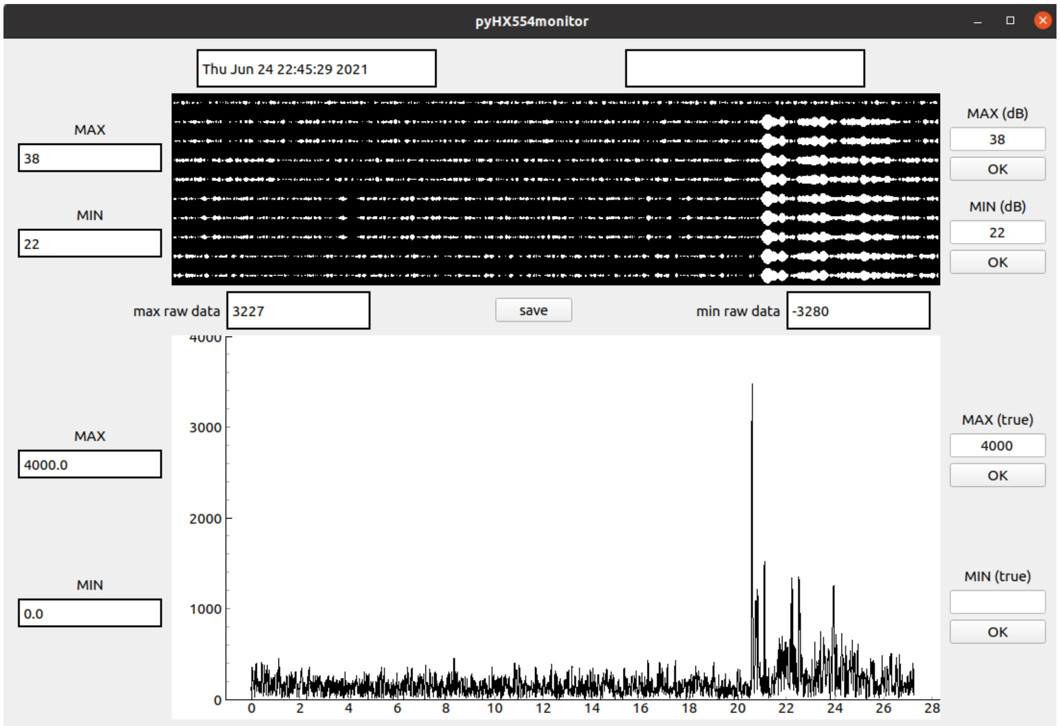

Figure 5: Screen capture of the presentation of code `hxmonitor.py` during a 185.4 dB transmission. The bottom panel shows the pulse-compressed signature of a single m-sequence. The top panel shows a scrolling, "lofargram-like" series of pulse-compressed data capture strips, with intensity rendered as white dot radius. The most recent arrival strip is the lowest strip, those above are older. One new strip every m-sequence period. The primary arrival occurs at roughly 20.5 s (arbitrary reference) in the bottom panel. If the "noise level" is eyeballed from the early part of the record to be 100, and the highest peak to be 3500, then the SNR is roughly $10\log_{10}(35) \approx 15$ dB.

5420 laptop, S/N B5JYL73, Ubuntu 20.04.2 LTS (Focal Fossa) running custom multi-threaded digital data packet acquisition (via ALSA) and pulse-compression software. The laptop also ran a python-based visualization code `hxmonitor.py`.

The acoustic transmissions were clearly observed at the selected hydrophone; even the transmission at 177.4 dB was seen. A snapshot of the visualization output during one of the stronger transmissions is shown in Fig. 5.

The acoustic transmissions were also monitored at the Aloha Cabled Observatory (ACO) (`http://aco-ssds.soest.hawaii.edu`) at 22° 45′N, 158° 00′W, at 4728m depth. ACO is roughly 176 km ENE of the HX554. The transmissions for 185.4 dB at 22:00:44 are shown in Fig. 6.

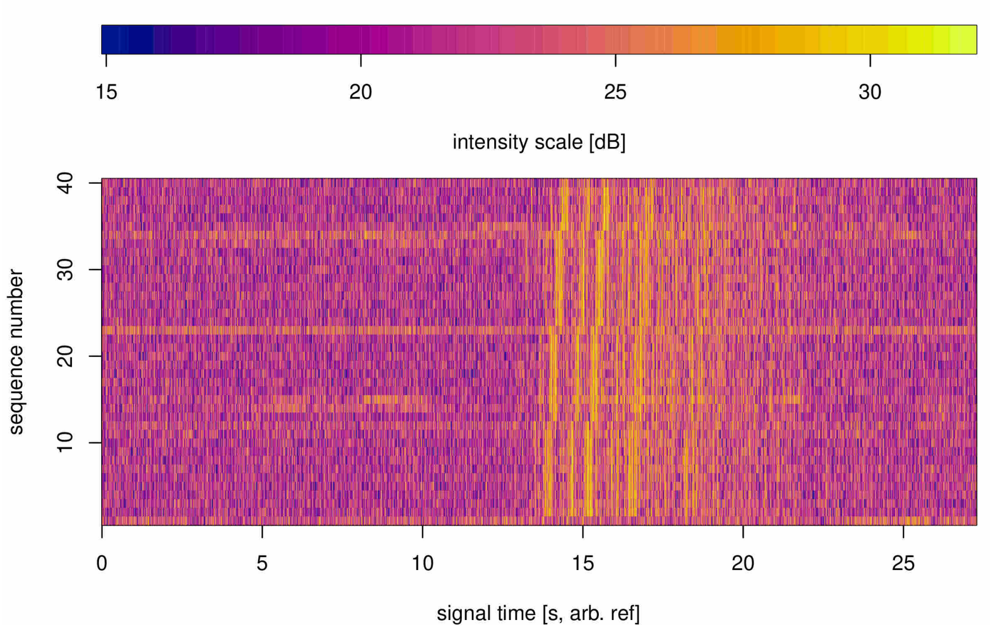

Figure 6: Transmission at 22:00:44 (185.4 dB) as captured on the deep hydrophone at ACO. The arrivals have about 9 dB SNR. Data courtesy Prof. Bruce Howe, UH.

5 Shoreside Reflectometry

Reflectometry measurements were were made by the APL-UW shore team from the Cal Lab throughout the repair. (Agilent 33220A 20MHz Function/Arbitrary Waveform Generator S/N MY44046410 and Agilent MS07014B Mixed Signal Oscilloscope 100 MHz S/N MY50340419.)

Fig. 7 shows the cable condition before the C/S Decisive came on station. The reflection at 21.99 μs has been seen before (e.g., in December 2020) and is thought to be at the BSUREB77/SDL3 splice. Fig. 7 also shows the cable condition after the BSUREB77 cable was cut just a few meters shoreward of the buoys. There is a new and distinct short fault at 20.99 μs. This suggests that the BSUREB77/SDL3 splice was in fact about 100 m further from the buoys (i.e., not at the buoys) and therefore located in the cable loops in the seabed.

Fig. 8 shows the cable condition after the final splice had been made and lowered into the seawater. The trace is now clear of faults (either open or shorted) and the reflection at 557 μs is the HX554.

6 Final Repaired Cable Configuration

A diagram of the final cable configuration is shown in Fig. 9. This has been reproduced from Ref. 4. Notation in Fig. 9 is explained in Table 4.

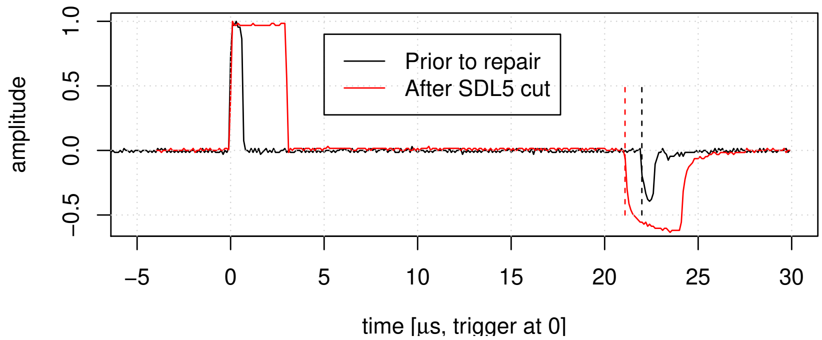

Figure 7: Traces before and after BSUREB77 (SDL5) cut. Vertical dashed lines show the change (to earlier time) in the leading edge of the fault. The black curve is the furthest shoreward migration of seawater intrusion from the severed SDL3 cable, and is believed to indicate the location of the BSUREB77/SDL3 splice. The red curve is the reflection from the BSUREB77 (SDL5) cable where it was severed by the ROV hydro-shear. The two measurements had two different pulse widths. There is no perceptible reflection at the cable hut splice (SDL1/BSUREB77, BLDG 539). At this time, there are no discernable faults in what remains of the BSUREB77 shore cable.

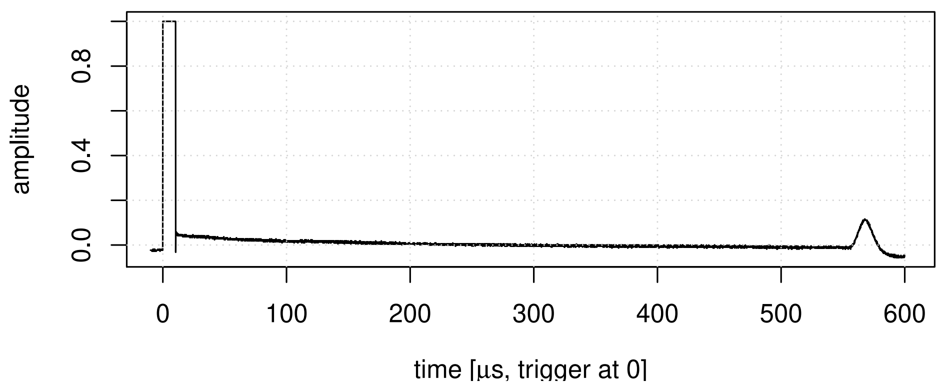

Figure 8: Final TDR measurement from the Cal Lab.

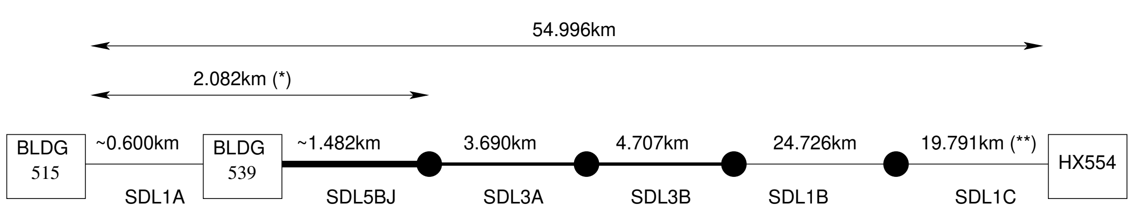

Figure 9: Straight line diagram of the system after repair. Taken from Ref. 4. Black dots are splices made on the C/S Decisive. Notes: (*) Distance from BLDG 515 to the cable hut BLDG 539 is unknown. Total distance from BLDG 515 to the SDL5/SDL3 splice is 2.082 km (deduced from reflectometry.) (**) Distance from the last splice to the HX554 deduced from reflectometry.

Section	ID	Length
SDL1A	Unknown	≈ 0.6 km
SDL5BJ (BSUREB77)	Unknown	≈ 1.5 km
SDL3A	9300044D	3.690 km
SDL3B	9300044C	4.707 km
SDL1B	Unknown	24.726 km
SDL1C	Unknown	19.791 km

Table 4: Components of the Kauai cable at the end of this effort. Components listed in order from the shore station to the HX554. See also Fig. 9.

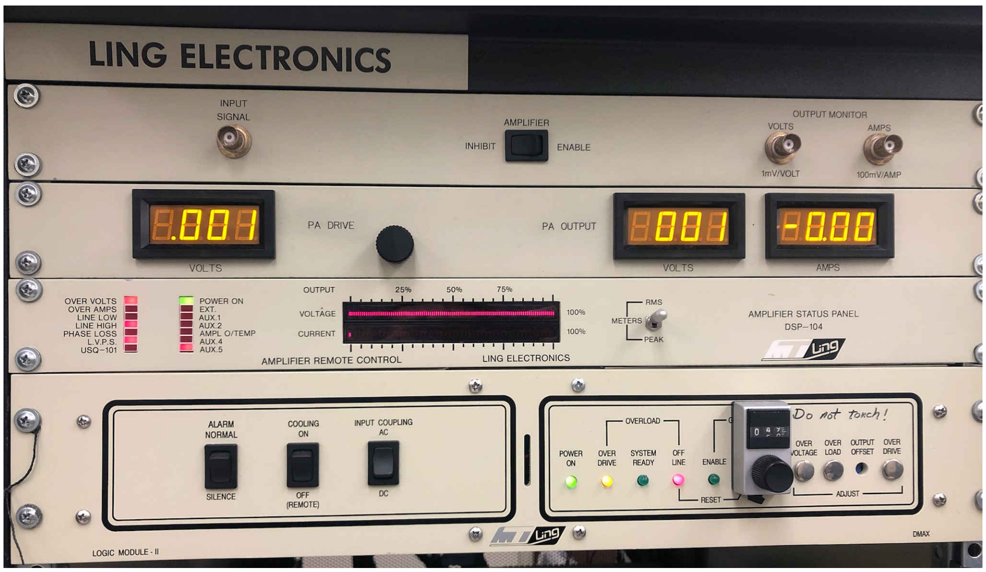

Figure 10: The Ling control panel, after start-up circuitry repair. Fault lights on.

7 Power Amplifier Investigation and Repair

Over 18-30 June the APL-UW shore team diagnosed the faulted shore station Ling amplifier. A damaged “soft-start” circuit was found, and replacement hardware ordered, received and installed. The Ling was successfully powered up, and now presents multiple diagnostic fault indicators. See Fig 10. The Ling remains off-line.

8 Permit

An environmental analysis was performed by NUWC/NPT for this repair, and a CATEX permit was secured. (Reference 3).

Figure 11: The APL-UW science van secured to the B deck.

9 Chronology of Significant Events

16 June 2021

The APL-UW science van is loaded onto the B deck of C/S Decisive. See Fig. 11.

17 June 2021

APL-UW shoreteam arrives on Kauai, checks in to Pass & ID (good thing, the following day was suddenly a federal holiday.) Initial TDR testing of the cable determined that the cable had not deteriorated further. See Fig. 7. (This implied that the BSUREB77 cable was still viable out to the splice.)

20-23 June 2021

Recovery of the wet stow SDL1 and SDL3 cables north of Kauai. Several hockles develop in the SDL3, and are cut out. See Fig. 12. Two segments of SDL3 are spliced together to form one segment 8.400 km long. See Fig. 13.

21 June 2021

Initial diagnostics of the Ling amplifier determine that the fault was a blown "soft start" circuit.

Figure 12: One of the hockles in the SDL3 after being pulled tight during recovery.

Figure 13: The SDL3 to SDL3 splice (armored to armored), after completion.

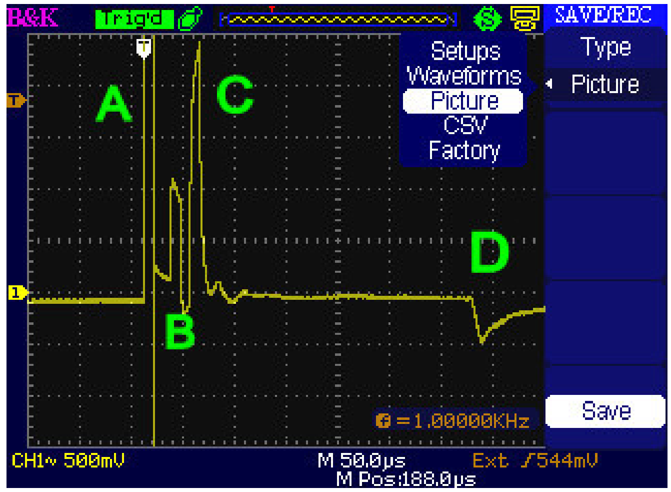

Figure 14: Shoreward TDR from the 2019 cut point. A) Initial outgoing pulse. B) Two closely spaced open conductor returns (not resolved in this image) at about 26.148 and 27.104 μs (respectively, left to right, equivalent to about 2.6 to 2.7 km away). C) Strong open conductor reflection at 45.164 μs (about 4.5 km away). D) The cable short fault, 318.4 μs away (about 31.5 km.) [Measured with Keysight 3321A Function / Arbitrary Waveform Generator and a BK Precision 2530B Digital Storage Oscilloscope.]

24 June 2021

APL-UW shoreteam gains access to PMRF BLDG 105 to monitor a range hydrophone. HX554 tests from the C/S Decisive, all operations appear normal. Shoreteam reports loud and clear signals from the range hydrophone.

25 June 2021

Shoreward TDR testing from the 2019 reconnaissance site shows a number of open conductor faults within a few kilometres. See Fig. 14.

26 June 2021

ROV survey at expected location of SDL3/SDL1 splice; cable buried under sediment, cannot be found.

The decision is made to splice in a long segment (at least 20 km) of SDL1 from the seaward end of the new SDL3, past the current location of the SDL3/SDL1 splice, past the faults seen in Fig. 14, to the 2019 reconnaissance site, to reach the section of SDL1 known to be good all the rest of the way to the HX554. The SDL1 necessary for this repair had already been recovered 20-23 June and was in the ship's cable tank. This choice would minimize the additional number of splices that would be needed.

27-28 June 2021

Transit to the seaward end of the BSUREB77 cable. ROV survey locates the two buoys marking the cable, but the buoys were adjacent to a big tangled mess of cables. Fig. 15 and Fig. 16. Concern over operating near the tangle persuades the crew to try to recover

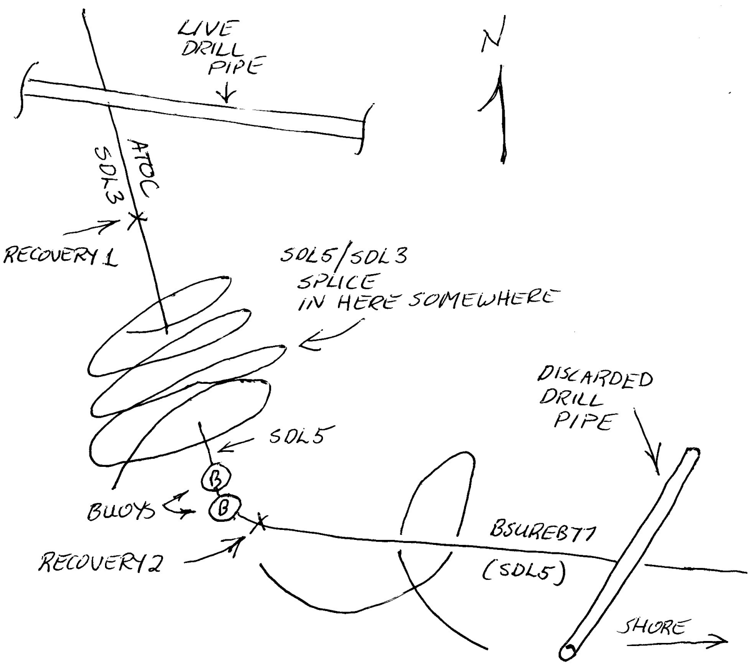

Figure 15: Map of the BSUREB77/SDL3 splice area.

the fault from the seaward side of the tangle. ("RECOVERY1" in Fig. 15.) This turns out to be SDL3 cable; as expected, it was severely abraded in multiple areas. (Fig. 17.) Quite unexpected, a bitter end of the SDL3 is recovered; inspection suggests the cable had been cut. (Fig. 18.)

The C/S Decisive repositions to the two buoys and redeploys the ROV, cuts away the two buoys, and cuts the cable about a meter shoreward of the buoys. ("RECOVERY2" in Fig. 15.) The APL-UW shoreteam interrogates the cable seaward from the Cal Lab, and immediately detects a noticible change; the distance to the first (and only) observable fault is shorter (by about 88.5 m, i.e., 0.89 μs.) (See Fig. 7.) The largest gripper is deployed on the ROV, and is able to get a secure bite onto the cable. The cable is recovered to the deck. (Fig. 19.) Upon inspection, this cable is determined to be SDL5BJ. (Fig. 20), i.e., the BSUREB77 shorecable. This cable is interrogated shoreward, and is found to (still) be viable.

This implies that the SDL5/SDL3 splice was somewhere in the tangle.

A 8.400 km segment of SDL3 cable (built up from sections recovered a week earlier) is spliced on to the BSUREB77 cable. This was a "transition splice" and is only slightly larger than the cables themselves.

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Shoreteam repairs Ling soft-start circuit, brings up amplifier. Various fault LEDs are now active.

Figure 16: The tangle of cable (mostly SDL3, some SDL5) at the BSUREB77/SDL3 splice, as seen from the ROV. The actual splice is probably in the tangle somewhere.

Figure 17: Abrasion damage in the shoreward end of the SDL3 cable. The armor on the top example is completely gone in the middle.

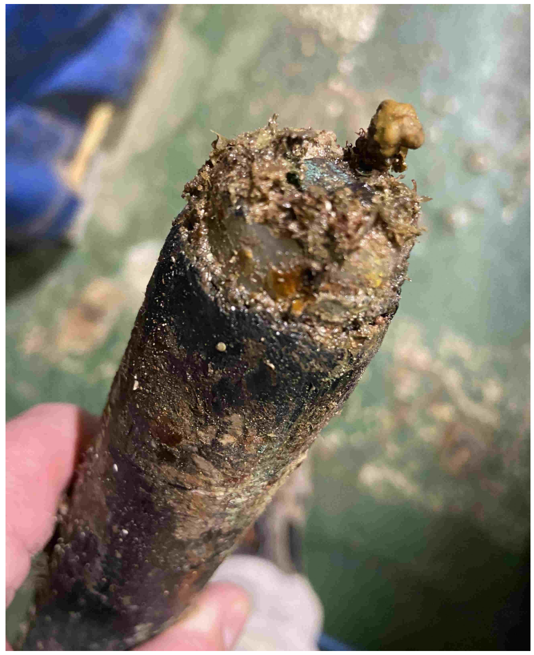

Figure 18: The unexpected end of the SDL3 we recovered.

Figure 19: ROV gripper recovered onto the deck, after the BSUREB77 cable has been cut away. The gripper at maximum opening was just barely able to grab the cable (which is SDL5 cable, double armored.)

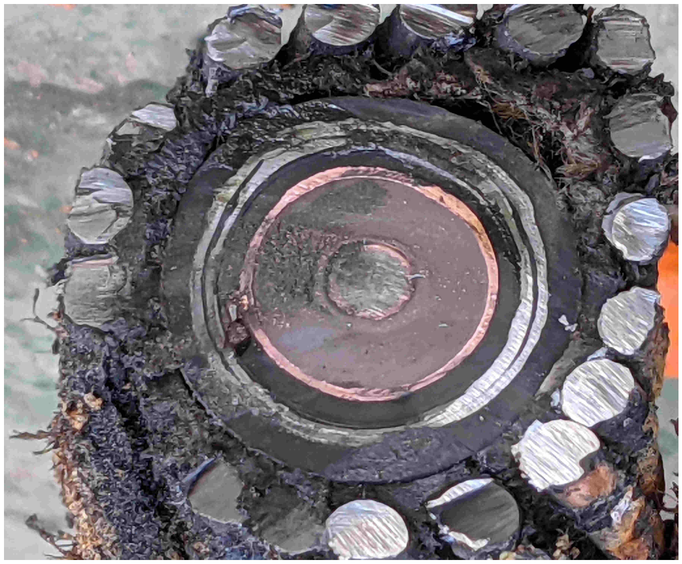

Figure 20: Cross-sectional view of the BSUREB77 shore cable.

29-30 June 2021

Cable pay-out along the original path of the SDL3 cable. The SDL3 is laid out "under tension" to avoid hockles. This is followed by 24 km of SDL1 cable, to the 2019 reconnaissance site, bypassing faults observed earlier, and then spliced onto the seaward SDL1 cable to the HX554. TDR testing by the APL-UW shoreteam verifies that the entire cable is now clear of faults, with a single reflection from the HX554 seen at 557 μs. (See Fig. 8.)

A Engineering Team

Name	Affiliation
Dr. Rex Andrew	APL-UW; rex@apl.washington.edu (ship)
Mr. Nick Michel-Hart	APL-UW; nickmh@apl.washington.edu (shore team)
Mr. Kevin Zack	APL-UW; kzack@apl.washington.edu (shore team)
Mr. John Gronbeck	Subcom; john.gronbeck@subcom.com (Engineer-in-Charge)
Jordan, Samantha	Cable Engineers
Royce	Tester Team Leader, Safety Officer
Mike, Andy	Testers
Chris, Anthony	Splicers

Table 5: Engineering team. Surnames withheld to preserve anonymity.

B Lessons Learned

1. Add lifting loops to a cable if the cable can be reached by divers.
2. Lay armored cable under tension, recover under tension. Slack tension will allow the cable to twist into hockles. It may be difficult to do this in the Hawaiian islands due to steep slopes and rough bottoms.
3. A heavy load (i.e., a pallet with a 1 ton amplifier) can be wheeled in from the deck into, say, the joiner shop, with a pallet jack. Had the L50 & instrument rack been crated up separately, it would have been feasible to crane it onboard with the ship's crane, uncrate it, and roll it inside and strap it down somewhere along the cable highway. (The APL-UW van, however, was a convenient container for all the spare parts.)
4. UHMC needs to know the date of delivery and company name of trucking companies delivering items of picking up items (for staging) in order to provide (hassle-free) gate access to the pier.
5. The APL-UW science van is seriously unbalanced, with the winch and associated cable almost outside the fork pocket. UHMC personnel called it "dangerous". (But they managed. Probably best to forewarn people in the future.)
6. The APL-UW Conex van should be considered "vessel equipment" and therefore not subject to the Jones Act relative to transport on non-US flagged vessels. The van does not contain "merchandise" but rather instrumentation and equipment needed to aid in the ship's mission of inspection and repair of underwater systems.
7. APL-UW IT and security can indeed build a Linux laptop and generate associated SCAP scans that pass PMRF cybersecurity for analog-only attachment to their hydrophone outputs. (Attaching to their base-wide intranet is a different matter.)

8. Various contractor-controlled (?) rooms on base are off-limits to APL-UW people after hours, on weekends, and on holidays. This includes the underwater room (hydrophone taps) in BLDG 105, and much of the Cal Lab. The "underwater room" at the Cal Lab (where our instrumentation is located) is not off-limits when the contractors leave. Thus, watchstanding all night is permitted.
9. Landline phone in BLDG 105 is 808-335-4330.
10. The "underwater room" in the Cal Lab is too cold for hours-long watchstanding. Operators either would need to stay outside the room, in the Cal Lab's break room (during working hours) or outside during off hours (i.e., at night.) There are not really places to sit in the equipment store room next to the underwater room. Chairs, a table, maybe a microwave, an extension cord, all are useful if watchstanding at night (i.e., outside).
11. Although HX554 signals are not classified, a secret clearance is required for (unescorted) access to BLDG 105. This is needed in case some kinds of secret operations take place on the range which do not affect the acoustic records. (Subs on range would be a different matter.)
12. Base pass: If working on base for several days, possible to get a gate pass, allowing vehicle entry for specified days with no government escort. To get this, need to submit a SECNAV5512 form to PMRF POC a week (or a bit more) in advance. This form has SSN, so should be sent encrypted. Hence, need to get the encryption certificate from the PMRF POC. Email agents (e.g. Thunderbird) may not have the appropriate DoD Certs loaded, so it may be necessary to download the necessary DOD cert to accept the PMRF POC certificate and signature. Start this process early, in case there are certificate problems, these can take hours to figure out.
13. Also, to get a gate pass, need to show up first time at Pass & ID during their working hours.
14. When riding a non-US-flagged ship, need to have passport. (The ship is technically a foreign country.) They may not be happy with a passport card. The master will hold the passport while on board.
15. No cell phone coverage at the L1/L1 splice location, close to the Napali cliffs. Sat phone works well.
16. The "Owner's rep" stateroom on the C/S Decisive has a VOIP phone on the desk, usable to call ship–to-shore.
17. The breaker for the Ling is located in the main building 208V panel in the air handler/air conditioner room, which has a separate entrance from outside. It is breaker #4 and is labeled "Ling Rack".

C Acknowledgment for APL-UW IT

SUMMARY: (for the impatient and/or really busy)

APL-UW IT (mainly Yancy Burns) built up a Ubuntu linux laptop for me for use at PMRF on Kauai. The laptop was used by Kevin Zack (OE) to monitor acoustic signals using a PMRF range hydrophone. Although the data was unclassified, a million hurdles occurred. Nevertheless, Kevin captured valid signals, which was a critical step for proceeding with a $8M undersea cable repair, and he captured some killer data product images, which has ONR sponsors all excited.

EXTENDED PLAY VERSION:

The saga:

A mission supported by ONR, NUWC/NPT, and N97 to repair the undersea cable from PMRF on Kauai to APL-UW's HX554 projector located deep off-shore of Kauai had a critical proof test as step 1: prove that the HX554 could still work operationally. To do this, I would attach to a good section of cable and power the HX554 with traditional signals. But I would not be in a good location to hear the radiated acoustic signal.

There were several hydrophones in PMRF's underwater range that were propitiously located to pick up the signal. These hydrophones are cabled to shore; raw analog signals are available, but in a classified workspace. Bringing a laptop into such a space elicited serious concerns; permission to connect the laptop to *anything* apparently needed an Act of Congress.

Fortunately, the effort did not require an intranet or internet connection, just a simple analog signal, which we could capture with a digitizing audio USB dongle. Nevertheless, I was told I would need a cyber-hardened laptop built by ONR: I argued that APL-UW can build a compliant laptop.

The Acoustics Dept graciously provided a new Dell Latitude laptop, and Yancy Burns installed a custom CUI-compliant Ubuntu image. He then did a SCAP scan, and forwarded that to Andrew Rego to check. Some back and forth occurred, and then the laptop was blessed adequate.

Meanwhile, the cable repair ship was having a few at-sea delays on its prior assignment. It appeared that the target date for the proof test would be 20 June. That is a Sunday. The classified workspace is not open on weekends. I did not tell APL-UW IT about this development. We carried it to Kauai anyway.

As things go at-sea, another delay was forecast for the cable ship while still in port at Honolulu. This moved the projected proof test day to Monday 21 June. Monday would be better than Sunday.

However, it turned out that PMRF IT security wanted to inspect the laptop. The laptop arrived late 17 June on Kauai, a Thursday. The day before, President Biden signed into effect the Juneteenth Federal Holiday. At PMRF, government workers, including the

IT Security staff, would be taking off Friday, 18 June. The laptop could not be inspected until Monday, 21 June. But still could be ready if the test date slipped again.

Then another delay occurred at-sea, moving the scheduled proof test time to late on 23 June, around midnight.

But the classified workspace was only open 0700 - 1530 each day. It would be closed during a midnight proof test. Nevertheless, we took the laptop in to PMRF IT Security on 21 June, and they blessed it.

And then another at-sea delay occurred, moving the proof test to the late morning of 24 June. Bingo! Kevin got in, powered it up, captured our signals.

Job done. Just like I planned.

Many thanks to the APLers who played their part in this touch-and-go saga: Adam Morehead, Yancy Burns, Andrew Rego and Kevin Zack. Excellent data captured. Sponsors are happy. More funding is in the offing.

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14. ABSTRACT
The legacy Kauai beacon system was repaired and tested and brought back to full functionality. Repairs in 2021 involved (1) replacing severed undersea cables, (2) repairing blown circuits in the shore station, (3) updating and testing shore station software, and (4) repair and reinstallation of power amplifier control modules. The beacon was operated, conservatively, up to a source level of roughly 190 dB. Consistent beacon signals were captured on receivers in the Hawaiian Islands and on several West coast receivers.

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