Characterizing Underwater Acoustics Using the Techniques in McSTAR

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ABSTRACT

This project focuses on the underwater discoveries in Monterey canyon sediment transportation and quantifies the feasibility of acoustic techniques. We experimentally characterize the flow dynamics and acoustic signature associated with a remote sensing instrument McSTAR. In the method of design, we apply the beagle board C4 as an operated console and develop the Linux control system for the techniques. Also, we rebuild and pack up the McSTAR for the experimental demonstration. Three typical trials in this project are proposed to address the characterization, which are deployed in the dynamics laboratory, indoor large tank and ocean field test. The intention is to experimentally identify the underwater noises and understand the signal sources. Based on a variety of completed maneuvers, we can compare and quantify the acoustics in different frequency levels. Combined with the experimental analysis, we infer the prior field test results (2009) with the frequency of 60 Hz could be electric noises from power plants, ships or underwater vehicles. As an early result, we conclude the experimental studies with later highlights and future research.

INTRODUCTION

Submarine canyons are found on continental margins and considered to be major conduits for sediment movements. They played a significant role in transporting sediments and organic matters from the continents into the deep ocean water. Variations in the submarine canyons can influence the transport, erosion, deposition and accumulation of sediments. Presently, many research groups attached the attention to the conditions of submarine canyons, they tried to understand the occurred transport process in the deep ocean.

Our research project as part of MBARI's initiative is to develop Monterey Ocean cabled observatory. We try to characterize the sediment movements along the floors of the canyons. Simultaneously, we try to study fluid dynamics from continental margins to the deep-sea in abyssal Pacific Ocean. Fig.1 shows the map of Monterey Canyon which connects the shorelines to the deep ocean across a short continental shelf. It clearly reveals the significance of the Monterey and other canyons in carving these continental margins. Also, it provides insight into the significance of the various processes along the margins.

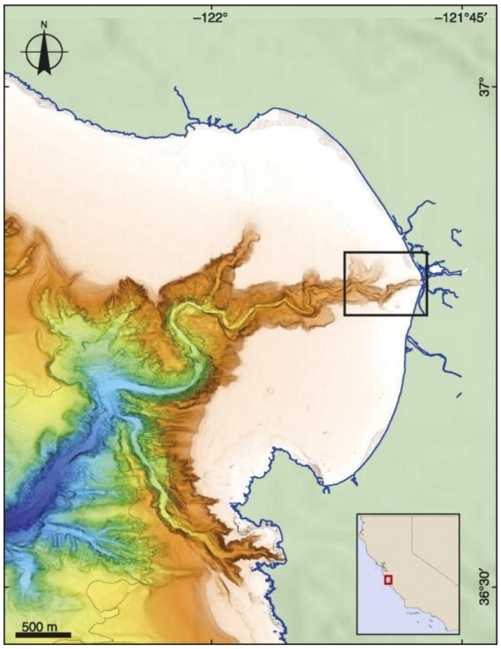

Figure 1. Map shows bathymetry of Monterey Bay and Monterey Canyon out to 2300 m water depth (Greene et al., 2002). Inset map shows the location of Monterey Bay with respect to California.

Our mission is to consider the underwater acoustics for sediment transport events, which is one of multiple techniques to provide data for understanding the dynamic process. Observations indicate that 10s of thousands of cubic meters of sediments must be moved through the Monterey Submarine Canyon, however, the known about this fundamental oceanographic process is still limited. The group in MBARI have built and deployed an underwater acoustic receiver McSTAR, as a remote sensing tool to gain a basic understanding of these high-energetic sediment transport events.

A passive acoustic array was deployed on the flanks of Monterey Canyon to receive acoustic emissions from sediment transport events through the canyons, which was calibrated by an ROV-deployed acoustic source. In 2009, the project was moved from the development to the field test and data reduction using MATLAB-based analysis packages. The research group proposed to learn how to efficiently analyze this data and how to correlate this with other efforts defining sediment transport events. Identifying the acoustic natures of sediment transport events would continue to be the trust of the research activities. This year of 2011, the project of McSTAR is restarted for the further highlighted acoustic detection and classification.

MATERIALS AND METHODS

I EXPERIMENTAL FACILITIES

i Beagle board

The core system of facility is an embedded Beagle board C4, which is an open-hardware and single-board computer capable of running Linux. It is connected by the host platform through RS232 serial port, audio input/output, a powered USB 3-port hub with Ethernet, a VGA monitor through DVI port and the booted SD card. The keyboard and mouse linked to USB hub are used as converters to distribute the beagle board system. The detailed connection of electrical circuit is shown in Fig.2.

When all the devices are fundamentally connected, we are ready to set up the serial console in the host platform on Ubuntu and the operated system in the beagle board on Angström Linux. The software design will be discussed in the following session.

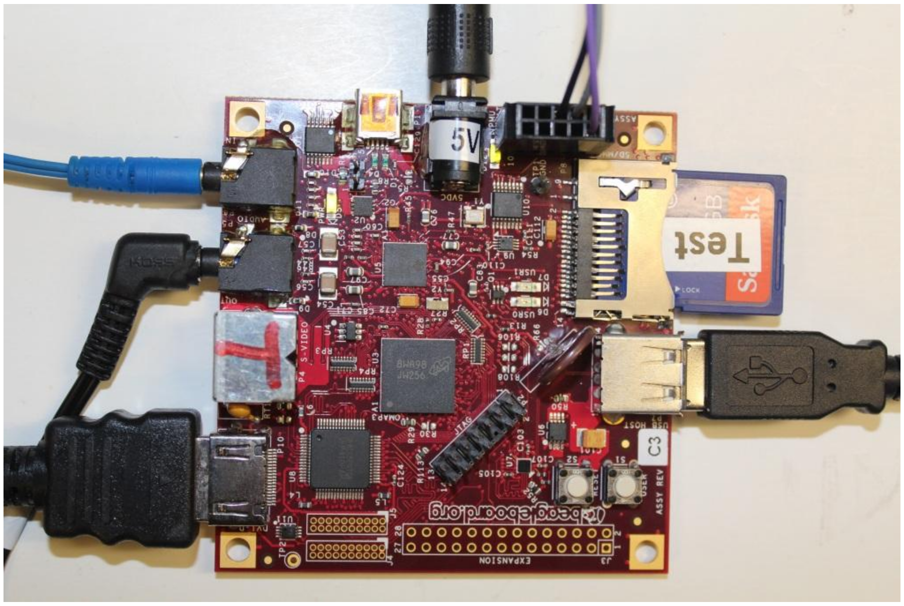

Figure 2. The Connected tested Beagle board

ii McSTAR

McSTAR is a battery powered, self logging acoustic receiver designed as an acoustic data logging and processing system, to observe sediment transport events in the Monterey Canyon. The goal of this innovation is to present the energy and destructive nature of these events. McSTAR is able to acquire a qualitative understanding of the onset, duration and periodicity of these high energetic sediment transport events using acoustic remote sensing techniques.

Fig.3 indicates the diagram of McSTAR, which consists of battery packages, the main console system container and the hydrophone. The main console system is linked to a hard drive, amplifier AD 8220, bluetooth dongle and electronic circuits with batteries. The detailed design principles can be found in MBARI past projects. In addition, the McSTAR system can acquire data at 48000 samples per second and 16 bits, the time-period of records are based on the batteries and the capacity of hard drive. We have recorded data in the laboratory and in the tank for 10 minutes to analyze the acoustic process. However, if we put the McSTAR into the ocean, the record should be as long as 3 months. The acoustic receiver, the hydrophone Model ITC-8201 has the low-noise preamplifier and robust transducer over long-term deployments. It derives a high sensitivity of -158 dB re 1V/uPa with the frequency range of 0.01 – 65 kHz. The depth of hydrophone diving into the ocean can be up to 900 meters.

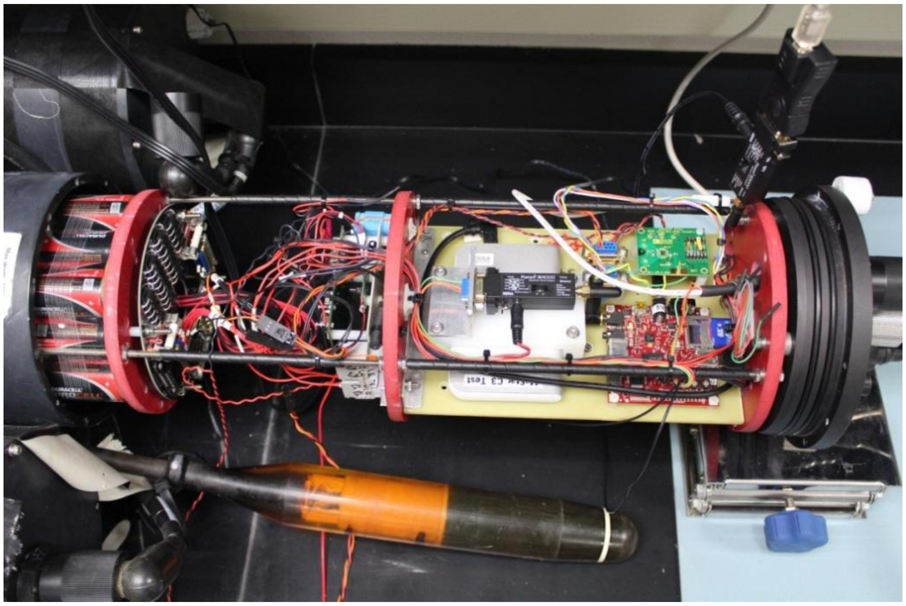

Figure 3. The Connected McSTAR in the laboratory

II SOFTWARE DESIGN

i Operating Systems

We set up a serial host console under Ubuntu/Linux with terminal emulation program, Cutecom and Picocom, which supply the methods to communicate with serial output through the console. After the beagle board is rebooted, the monitor shows the welcome screen of boot loader output, means that the host machine would be ready for the server to build the operating system.

Angström is a simple and fast Linux designed distribution (kernel, boot loader and application stack), optimized as a basis for creating embedded operating systems for small computers. It is developed by a small group project, and then spread to all different fields. The booting process for the beagle board can be detailed in references.

ii Signal Acquisition

Tera Term is a terminal emulator program for MS-Windows, which is able to control the whole system via a bluetooth dongle from the remote laptop. We set up the connection to serial port at 115200 baud rates, so the terminal can be automatically linked to the server. With the function of Tera Term, we can operate the McSTAR tests from the host laptop.

iii Acoustic Analysis

We focus on McSTAR deployments and apply prototyped MATLAB-based program for acoustic data analysis. The MATLAB program could read the acoustic data stored in the McSTAR hard disks and calculate RMS vs. Time, Power Spectral Densities (PSD) and 2D-spectrogram view. We could manually define the parameters such as record length, weighting function, overlap, and present the results as time-frequency domain spectrums and time-sequenced waterfall plots.

III APPROACH

i Room Test in Canyon Dynamics Laboratory

The experiment was initially operated in the Canyon Dynamics Laboratory in MBARI, because we needed to adjust the hydrophone and debug experimental tools. In the laboratory, we grounded the signal-input and provided 1 kHz, 10 mV steady signals to test the precision. In addition, we have checked the safety sealing conditions for all the instruments before the tank test. Fig. 4 shows the McSTAR prepared for the water test.

Figure 4. Packed up McSTAR with the fixed hydrophone, electronic container and battery container

ii Tank Test in MBARI indoor tank

For evaluating the underwater acoustics, we held the tank test to measure the acoustic emissions from McSTAR. The tank is rectangle with the volume about one thousand cubic meters. We started with tank test before the ocean field test, because the tank test was easy and convenient to set up, collect acoustic data and adjust experimental methods. First, we measured the surface noise on the shore without the underwater noise, and then we transmitted McSTAR into the water for collecting underwater noise. The hydrophone was floated by a buoy that reduced the influences from mechanical noises.

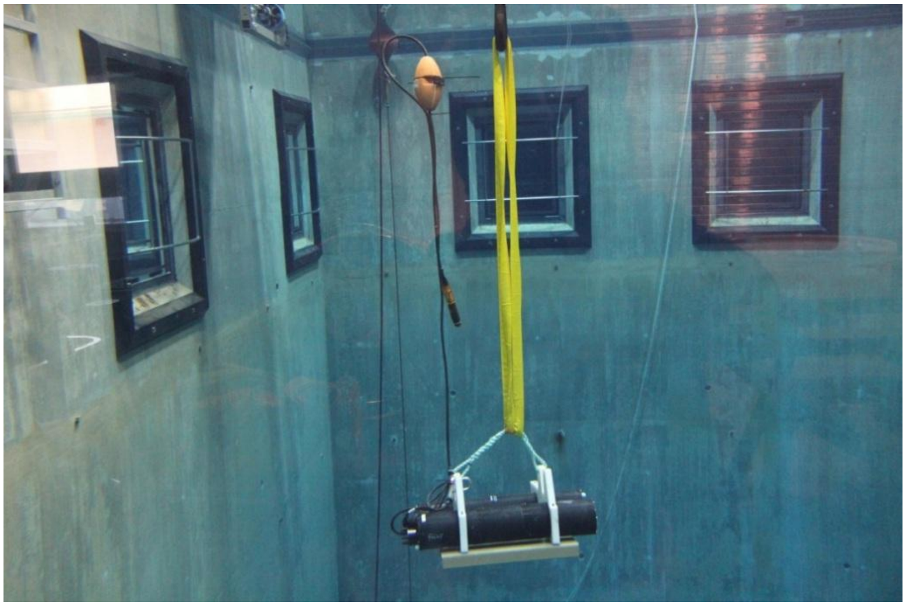

Figure 5. The deployment of McSTAR in the MBARI test tank, McSTAR is located in the middle level of tank with the floated hydrophone

iii Field Test (In progress)

Based on the previous experiments, we have general ideas about acoustic signature, so we can move the trials toward the open-sea and collect acoustic data in the Monterey canyon. The field test is still in process, Fig. 6 shows the old-version McSTAR trial deployed in 2009, we can compare this field test with the tank test and find out the results of acoustic signatures.

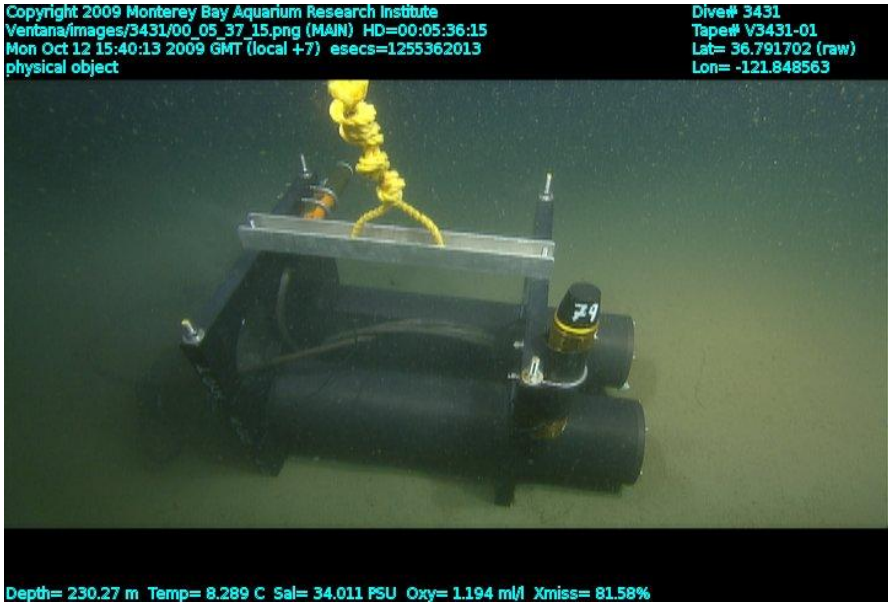

Figure 6. McSTAR field test in Monterey canyon (on Oct. 12th, 2009)

RESULTS

I LABORTARY TEST RESULTS

i Ground the signal-input

To adjust the hydrophone and check the beagle broad, we connected signal-input to the ground, so the noise should be defined by ambient noise from the environment. First, we did the test in the Canyon Dynamics Laboratory, and then we moved the McSTAR out of the laboratory and recorded the signals outside. Fig. 7 clearly shows the comparison of PSD in both conditions. We found that the ambient noises were similar in both high and low frequencies but the signals in 60 Hz. The difference of two measurements was large with the amplitude of 17 dB. Based on the experience, we could identify they were from electric devices in the laboratory, because all the equipments were running in 60 Hz frequency. Other than this, all the signals in high frequency were in a low amplitude level and the signals in low frequency were originally from flow noise and bubble noise.

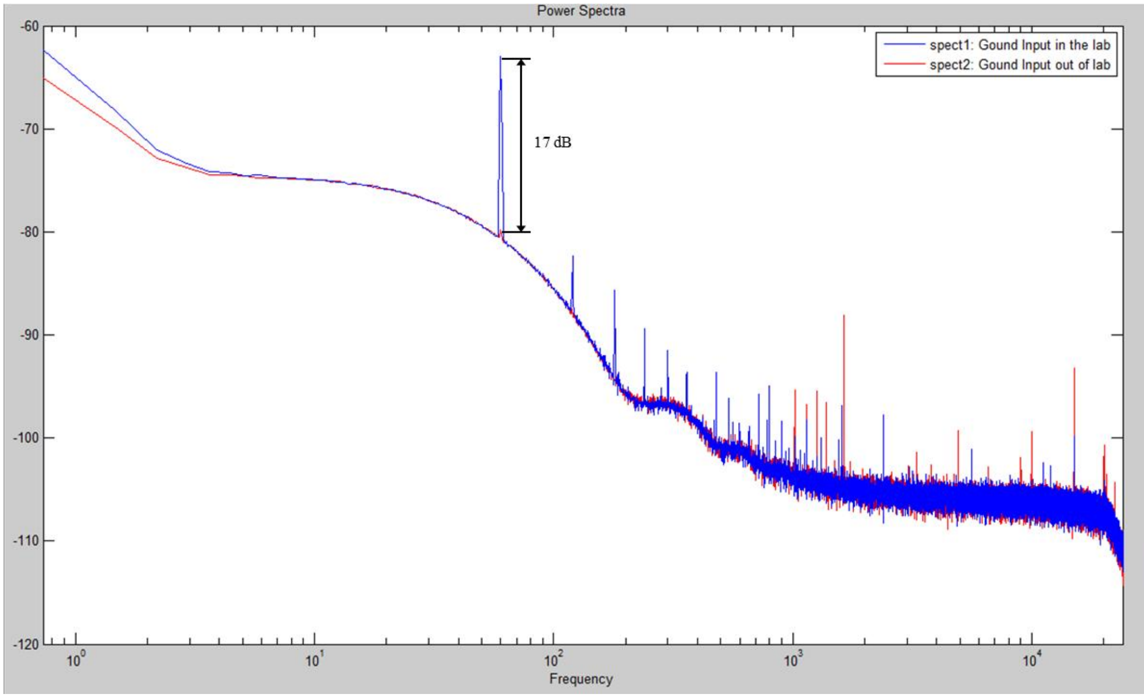

Figure 7. Ground signal-input test in the laboratory

ii 1 kHz and 10 mV signal source

Based on the prior tests, we used the standard scope as a reference signal to adjust the signal output. From Fig. 8, the signals in 60 Hz are still found with another addition signals at 1 kHz. Moreover, there are a number of multi-signals in 120 Hz, 240 Hz and 2 kHz, 4 kHz. From the reference signals, we could diagnose the hydrophone range and precision. There are still unknown issues of high multi-signals in high frequencies of 100 kHz and 200 kHz, which require more research.

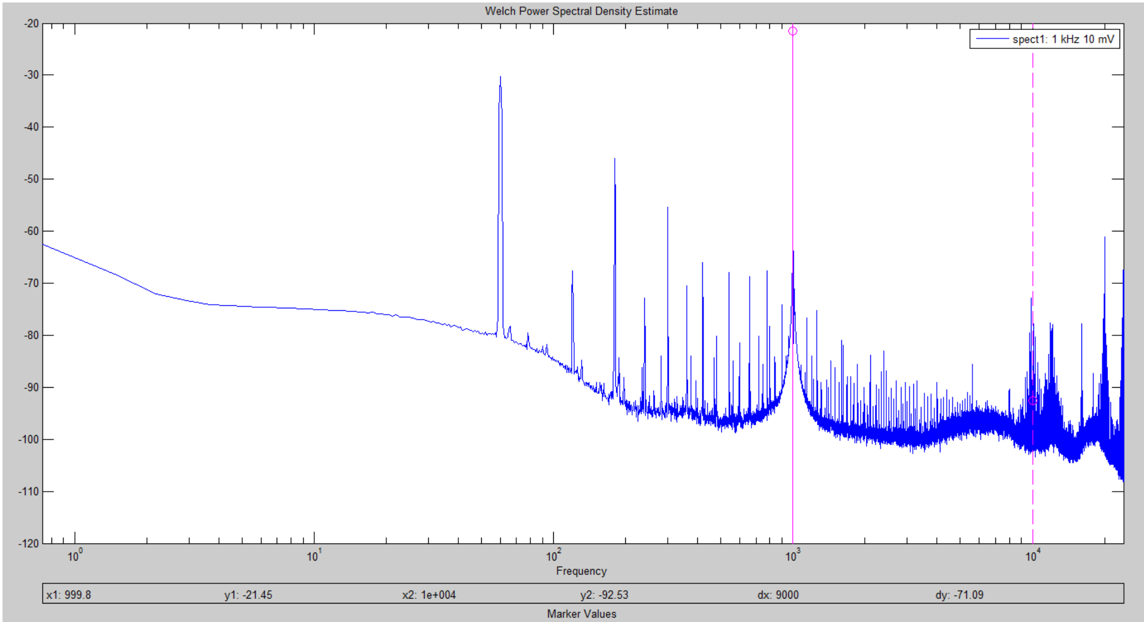

Figure 8. 1 kHz, 10 mV stationary signals test in the laboratory

II TANK TEST RESULTS

Based on the test results in the laboratory, we had a brief overview about the acoustic signature recorded from McSTAR. For further understanding the signals in the ocean, the real water test was needed to be prepared. This tank test was deployed on Aug. 14th, 2011, around 3 pm (PST). First step of the operations, we measured the signals on the surface water, and then we used the high-bay elevator to lift the McSTAR into the water. Fig. 9 shows the spectrogram of McSTAR transport process in 10 minutes, we can clearly identify the signal sources in different frequency levels. This 10-mins transport process is detailed in the following table I, which brings an easy way to observe the signal changes.

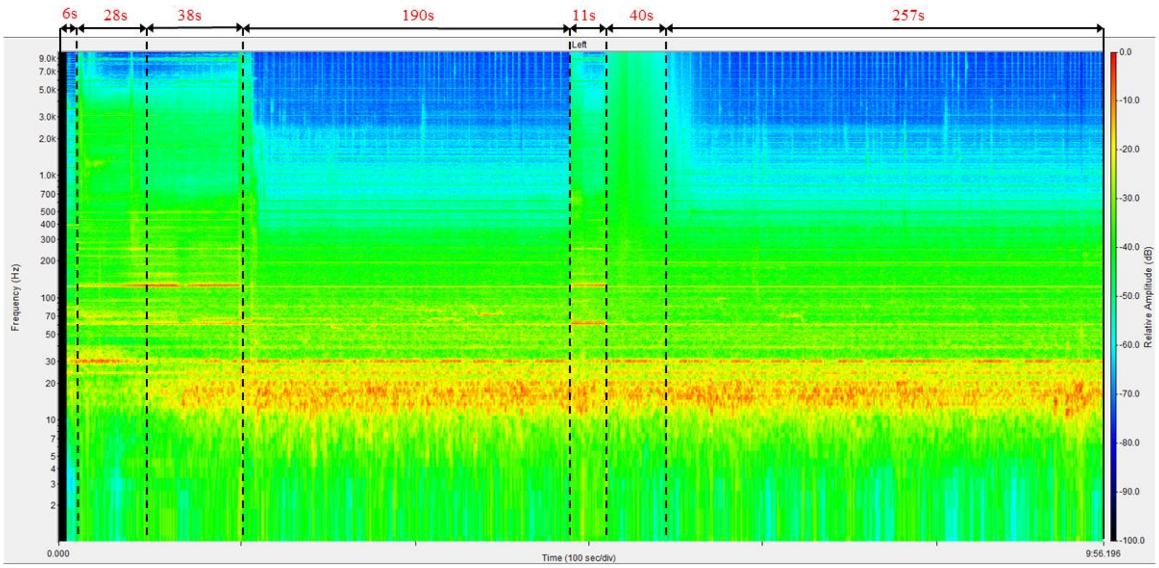

Figure 9. The transport process in 10-mins spectrogram

TABLE I. The 10-mins transport process of McSTAR

Events	Time (s)	Description
Startup	6	McSTAR with background noise
Transportation	28	Lift down to the tank, hydrophone on the surface
Transportation	58	Lift down to the tank, hydrophone in the water
Steady	190	McSTAR sat at the bottom recorded Underwater noise
Transportation	11	Lift up to the middle level of tank
Unsteady	40	Flow Dynamic noise with multiple reflection
Steady	157	McSTAR stood at the middle of tank

In this transport process, we can find out the signals in 120 Hz that were from the elevator noise, and 60 Hz from electric devices in the background. Also, we find out the low frequency noise in 0-50 Hz, most of which were from flow noise. Since when the hydrophone was dived into the water, the noises showed up immediately with high amplitudes. In addition, we have recorded two groups of signals, one was the McSTAR in the bottom, and the other was McSTAR lifted in the middle of tank. Looking into Fig. 10, I compared the signals in three conditions: on the shore, under the bottom and in the middle of tank.

From the comparison, I find multiple low-frequency noises in the water were between 1 Hz and 30 Hz. There were still 60 Hz signals in the water due to electric power machine. In addition, the experimental results showed that the signals both under the bottom and in the middle of tank were not much different, both of which indicated the signal amplitude in the high frequency was much lower than the ones in the low frequency.

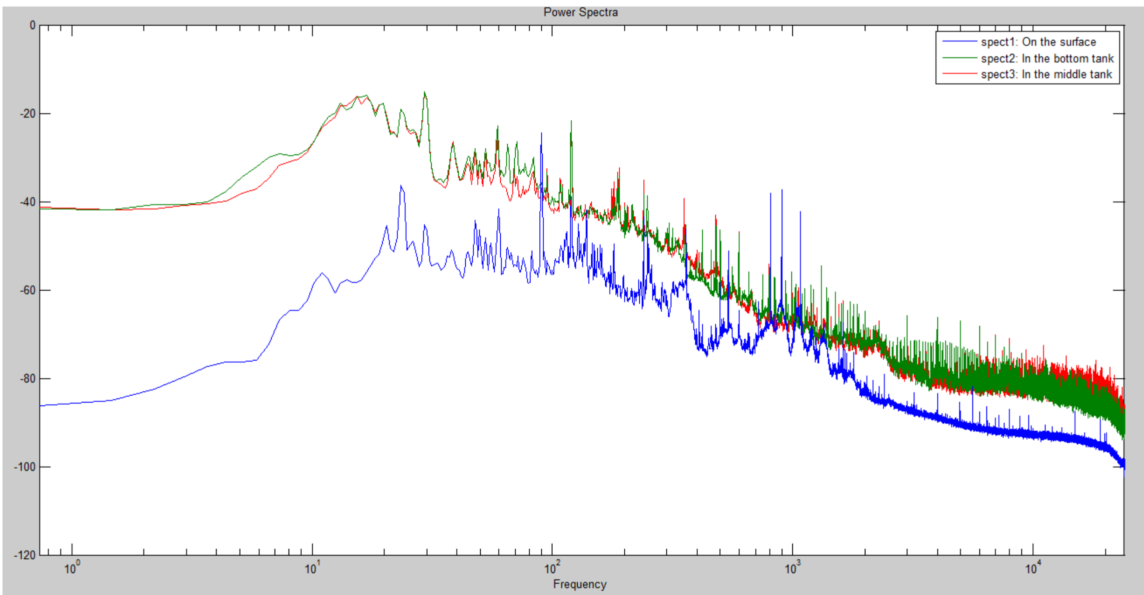

Figure 10. Acoustic PSD in three different conditions

Based on the experimental results in the tank, we could compare the data with ocean field test and figure out the differences. Fig. 11 shows the data comparison in the tank and in the deep ocean. There are strong underwater noises in high frequency from the deep ocean compared to the tank test. This acoustic sources could be from such as sediment transport, underwater marine animals and earth movements, which are quite complex for current technology to understand the ongoing process due to the acoustics is variable and invisible. Relatively, the tank test had comparable low noise levels in high frequencies. In the deep ocean, we find the unknown strong 60 Hz low-frequency signals.

One assertion that was from the ships or power plants in a long-distance away, because the 60 Hz signal was a typical electric noise in a low frequency which can be transferred from long distances without loss. Another assertion it could be from the McSTAR or other experimental instruments, because all the equipments were running at the same time, which was possible to bring some unexpected noise for the acoustic receiver. Also, there may be another reasons to explain these signals.

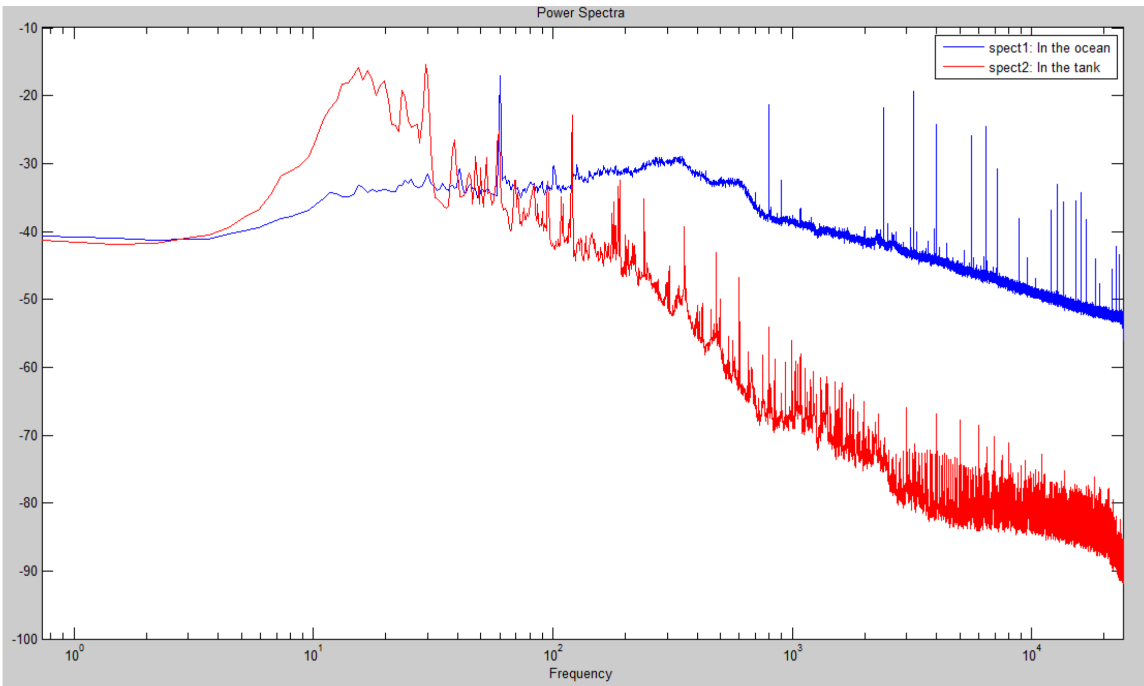

Figure 11. Comparison between tank and ocean tests

DISCUSSION

Based on the analysis of this paper, we developed the research with further improvement from simple to complex conditions and showed different experimental results. These comparable tests were started at a laboratory test, extended to the indoor tank and finally to the field test in the ocean. These showed the characterization of acoustic signature from underwater environments. However, variable ambient noises in typical environments were irregular and hard to control. That would be issues for research and discoveries. Therefore, a long-time acoustic record is in need instead of a short-time period, so that will be significant to understand more acoustic information.

For the experiment in the laboratory, an insulation room will be more helpful for researchers to understand the signals instead of a noisy laboratory. Unfortunately, MBARI does not have an insulation room for the dynamic tests.

In all, more trials and continuous analysis depended on current results will be required, because we need more experimental data for comparison. Based on a large dataset and statistics, we can find out more information related to underwater acoustics and sediment movements.

CONCLUSIONS

Underwater acoustics is a specialized technique for exploration. Numerous studies show that acoustic detection is a promising and developing research topic of interests in the marine discovery. This paper addresses the background review and summarizes the current progress of Monterey canyon research. For the development of McSTAR, we have rebooted embedded system for the core Beagle board C4 and succeeded to make the console system working. Also, we have packed up McSTAR and realized the tests in the laboratory and indoor tank. For the analysis of acoustic techniques, we have used MATLAB signal processing tool to track the transportation of McSTAR in spectrogram, and analyze the PSD to understand the signal properties.

In addition to this, I present the early results using acoustic techniques by McSTAR, which indicate that flow noise is mostly from the fields in low-frequency between 1 and 50 Hz; The 60 Hz noise in the ocean is inferred from electric power such as ships, power plants, submarine cables and underwater vehicles. However, they are still under study and expected more discoveries later. Also, multiple high-frequency noise in deep-ocean can be clearly observed, which can be considered as marine ecosystems.

Based on current understanding of McSTAR research project, there still has quite a long range to improve experiments. In my opinion, some aspects of research have a certain space to strengthen and optimize with respect. For example, another group of field test in Monterey Canyon should be done in the continuing research, which will bring more data and planned methods to compare current results; We can continue to provide detailed acoustic characterization, like marine animals, ships and transport sediments; We can setup more hydrophones to improve acoustic precision and compensate for signal loss. In addition with acoustic analysis, we need to better the beagle board as a core control system. If we can build FTP server, set up self-clock and improve startup function, these will be more helpful in the operated methods. Bluetooth communication is not available in the water, so we need an improvement method to communicate in the ocean environment. McSTAR batteries packages are not rechargeable, so that would provide test limitations when the power is dead. Finally, we expect to build a real-time observation system in deep ocean. If that is possible, we can observe the dynamics systems process synchronously and help further understand the underwater sediment movements.

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