ACOUSTIC RESEARCH FOR PORT PROTECTION AT THE STEVENS MARITIME SECURITY LABORATORY

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Abstract: Stevens Institute of Technology has established a Maritime Security Laboratory (MSL) as a national laboratory resource for government, industry, and universities to advance technologies for the protection of USN maritime infrastructure. Experiment instrumentation includes research vessels, a multiplicity of hydrophones and emitters, stand alone acoustic buoys, diver acoustic simulators, unmanned underwater vehicles (UUVs), and precision instrumentation placement capabilities. The in-river experiments are controlled remotely from a Visualization Centre on campus. Acoustic research is supported by sound speed profile measurements, integrated video and acoustic tracking of surface events, and global positioning system tracking of live divers. Recent results include determination of parameters defining the detection distance of a threat: source level, transmission loss, and ambient noise. The combination of acoustic noise with video data for different kinds of ships in the Hudson River enables estimation of sound attenuation in a wide frequency band. The establishment of a library of various estuarine signatures, including divers, boats, ships, UUVs, construction equipment, and so forth, is underway. This knowledge can be used in a variety of intruder detection scenarios and for optimal methods of threat detection.

Keywords: Passive acoustics, port security, intruder detection.
1. INTRODUCTION

In 2006, Stevens Institute of Technology established a research laboratory environment in support of the U.S. Navy in the area of Anti-Terrorism and Force Protection (AT/FP). Called the Maritime Security Laboratory, or MSL, it provides the capabilities of experimental verification of AT/FP research in the realistic environment of the Hudson River Estuary. The goals of MSL are:

- To continuously advance the state-of-the-art in technologies key to maritime security in an estuarine environment
- To develop transportable intruder detection prototypes embodying results of new maritime security research, deployable to harbors around the world for military and commercial applications
- To become a national resource in the maritime security for the US Navy and also for the domestic security, maritime industry, and natural hazards mitigation communities.
- To develop a work force for the future through extensive involvement and education of students, post-doctoral, and academic and research faculty in the area of maritime security.

Initially, the focus of MSL was on threats posed by surface and subsurface intruders including SCUBA divers and small boats by using passive acoustic techniques [1-3]. Using these initial capabilities, MSL investigated the set of acoustic parameters fundamental to underwater acoustic threat detection including: diver acoustic signature, acoustic transmission loss, and acoustic environmental noise. The initial infrastructure has since been extended to include computer optic and infrared vision capabilities, and to enhance acoustic experiments by combining them with these capabilities.

These integrated capabilities have enabled experiments in determining the positions and trajectory of surface traffic, which may be both a sources of acoustic noise in intruder detection as well as possible targets themselves. This knowledge can be used for measurements of acoustic noise of various ships and their classification, determination of sound attenuation in a wide frequency band, and the development and testing of methods of passive acoustic triangulation and location of sources of sounds [4,5].

2. THE MARITIME SECURITY LABORATORY

Part of the uniqueness of Stevens’ Maritime Security Laboratory is its location on the Hudson River tidal estuary, which is a key waterway that defines the Port of New York/New Jersey, one of the busiest harbors in the U.S. From a scientific perspective, this harbor embodies a high degree of complexity due to variability of the current, salinity, temperature, winds, turbidity, as well as man-made factors including ambient noise due to surface and air traffic, construction noise, and various forms of electromagnetic radiation. All of these enter into the analysis of above and below surface threats.

Hence the estuary itself is an integral part of the laboratory. As discussed above, the estuary is equipped with instrumentation to collect weather and environmental data, and through modeling, to predict their characteristics. For the actual MSL execution of
experiments, the test site has been chosen based on its scientific characteristics and its accessibility both by radio communications and by safety considerations. The MSL research vessels and other MSL assets are shown in Figure 1. The larger boat is the RV Savitsky. It is specially constructed and fitted out for maritime research purposes. Towards the stern is an A-frame for loading large and heavy items onto and off of the boat. Radio antennas are affixed to the mast to transmit real-time experiment data to the MSL Visualization and Analysis Center (VAC). The smaller boat, the Phoenix, is a support boat. It is used to deploy sensors while they are cabled to the Savitsky. It is also used to deploy remote instrumentation, divers, and provide for safety. In addition, it is used as the point of radiation in experiments involving acoustic propagation between two points and measurements of temporal variability of acoustic field.

![Boats](image1)

The MSL key components are shown in Figure 2. Starting at the left, various sensors are deployed at the test sites. Depending on the experiment, these may include hydrophones, sound emitters, CTD’s (for conductivity, temperature, and depth), Acoustic Doppler Current Profilers, inclinometers (to measure the roll of the boat), various radio link instrumentation, and so forth. Experiment-specific instruments are cabled to an on-board boat computer, or are connected wirelessly.

![Boats](image2)
Communications with the boat is accomplished with an IEEE 802.11 (WiFi) radio link. This link is used to enable real-time data to be transmitted to the Visualization and Analysis Center (VAC). This enables experiments to be controlled from the VAC, in terms of when and how long data is recorded. Perhaps most importantly, it provides Data Quality Assurance, to assure that at the end of the day, good data has been collected. Another important application of the radio link is to maintain real-time communication with the boat crew during experiments. This is accomplished by establishing a chat line with the boat, and is critical to the logistics and administration of experiments. The radio link is connected to the VAC over the campus network.

The Visualization and Analysis Center has several major purposes:

- To provide the capability to administer and control experiments, whether on the boat, or elsewhere
- To ensure data quality assurance during experiments
- To enable the ability to reconfigure experiments in response to the data received. (This capability will become more significant as we undertake experiments in adaptive learning)
- To provide an environment for research, algorithm development, and laboratory infrastructure improvements
- To provide a demonstration capability for key stakeholders and potential customers and users.

In addition to real-time data feeds into the VAC, six video cameras have been deployed to provide real-time visual observation of experiments, as well to provide a video data source to automatically collect data, and to analyze surface and low flying aircraft traffic, as well as intruder activity. Surface Traffic Tracking System has been developed by Stevens’ scientists utilizing these video cameras, which automatically detects the entry of surface craft into a calibrated sector of the estuary. Utilizing this system, the position, bearing, and velocity of
traffic can be automatically detected and recorded. Path information on detected traffic is projected onto a Google map as well as stored in a database. By observing the acoustic signature of passing craft via hydrophones, and correlating that with the position information recorded by the Tracker, one can determine, for example, the transmission loss of the path between the source (the passing craft) and the receiver (the hydrophone) [4,5].

The intruder detection problem is complicated by the high degree of spatial and temporal variation of an estuary due to tides, winds, currents, precipitation, traffic, power plants, and so forth. The complexity of this environment requires that real data be used in its modeling. Such data-driven mathematical models have been built by Stevens and are used to predict oceanic and atmospheric environmental factors. The model, the Stevens New York Harbor Observation and Prediction System (NYHOPS), can be found at [http://hudson.dl.stevens-tech.edu/NYHOPS/](http://hudson.dl.stevens-tech.edu/NYHOPS/). The interrelationship between NYHOPS predictions of acoustic parameters and MSL experimental measurements was studied over a 12 hour tidal cycle. Results of sound speed and Transmission Loss calculation are placed at Stevens website and Fig. 3 presents the example of this calculation.

![Graph](image1)

**Fig. 3.** The example of sound speed prediction and calculation of Transmission Loss placed at [http://hudson.dl.stevens-tech.edu/NYHOPS/](http://hudson.dl.stevens-tech.edu/NYHOPS/)

3. BRIEF OVERVIEW MSL ACOUSTIC EXPERIMENTS

In our tests, hydrophones were placed at various heights in the water column, or on the river bottom on stands. All deployed hydrophones were connected by cable to the on-board computer for data processing and storage. The signals from the hydrophones were amplified and filtered for suppression of the high acoustic noise level in the low frequency band, which limits the dynamic range of measurements and for elimination of spurious aliasing signals.
produced by electromagnetic noise at frequencies above 100 kHz. The amplified and filtered signals were digitized by an 8 channel data acquisition system and recorded. The boat computer was wirelessly connected with MSL Visualization and Analysis Center, so all information displayed on the boat computer was displayed simultaneously in VAC. This allowed scientists in the VAC to control the experiments.

The acoustic propagation experiments were conducted by radiating an acoustic wave between a transmitter and receiver. The radiating wave was generated by a calibrated emitter. The following experiments were conducted in this way:

1. Measurements of transmission loss in a wide frequency band (20-100 kHz) in Hudson River were carried out, including the effects of tidal variation.
2. Determination of the shallow channel impulse response using correlation techniques. The measured impulse response is used by Stevens’ researchers for estimation and prediction of underwater acoustic communication systems performance.
4. Ambient acoustic noise was measured in various environmental conditions and for water traffic. The joint application of acoustic measurements and video surveillance allows determination of acoustic noise produced various kinds of ships and application of ship noise for acoustic attenuation measurements. Some of these results are presented in the current paper and the paper. 5
5. The received data for diver source level, acoustic attenuation and noise were applied for estimation of a diver detection distance [3]

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REFERENCES


