Acoustic Sensor for Measuring Slick Thickness During Oil Spill Response

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Coastal Response Research Center

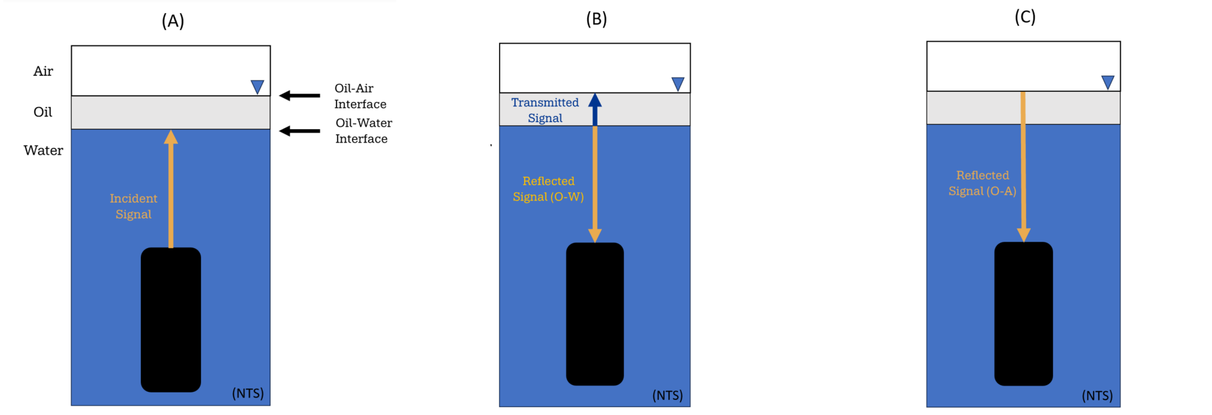
Introduction

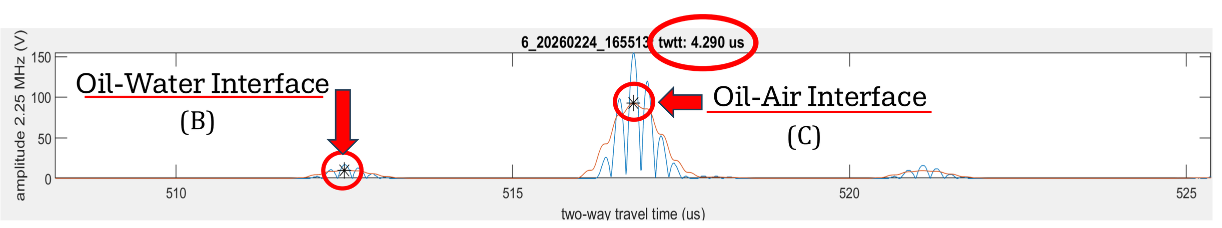
Marine diesel (MD) is the most common used fuel source in Alaska to heat homes, run generators, and fuel vessels. Due to its high demand, MD is often the primary oil that is spilled during transit in this region. In the event of a spill, MD may float on the surface, move with ocean and wind currents, and become trapped in cavities under sea ice. Responders need a reliable technology that determines MD thickness to deploy limited resources effectively. This project aims to develop and analyze the capability of an acoustic transducer sensors (AS) suite for measuring MD slicks floating on the seawater and trapped under the ice.

Methodology

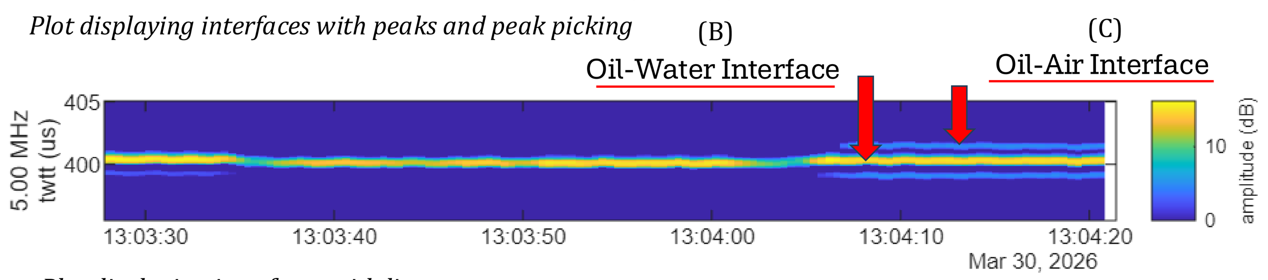
Objective 1: Develop analytical technique for rapidly determining MD thickness from acoustic signals
Objective 2: Determine a Lower Detection Limit (LDL)
Objective 3: Detect MD thickness in quiescent environment
Objective 4: Detect MD thickness in moving water
Objective 5: Detect MD thickness in sea ice cavity

Obj 1: Methods for acoustic data analysis





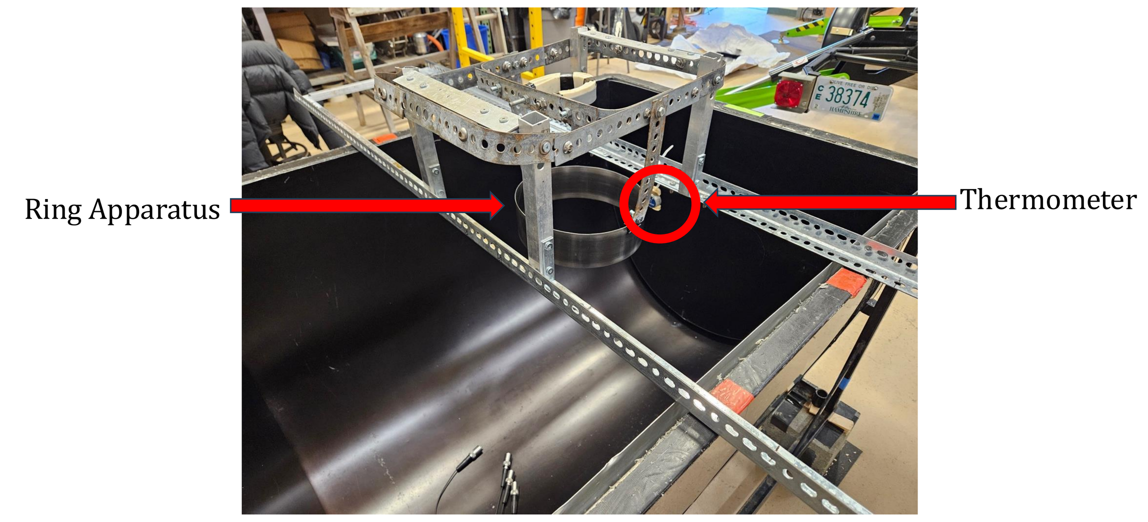
Plot displaying interfaces with peaks and peak picking



Plot displaying interfaces with lines

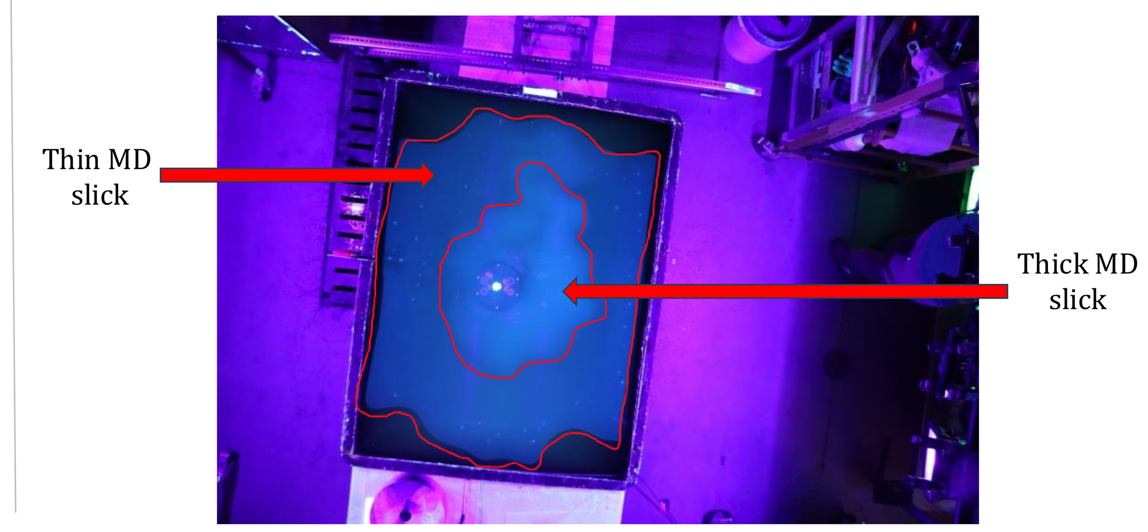
Experimental Design

Obj 2: LDL



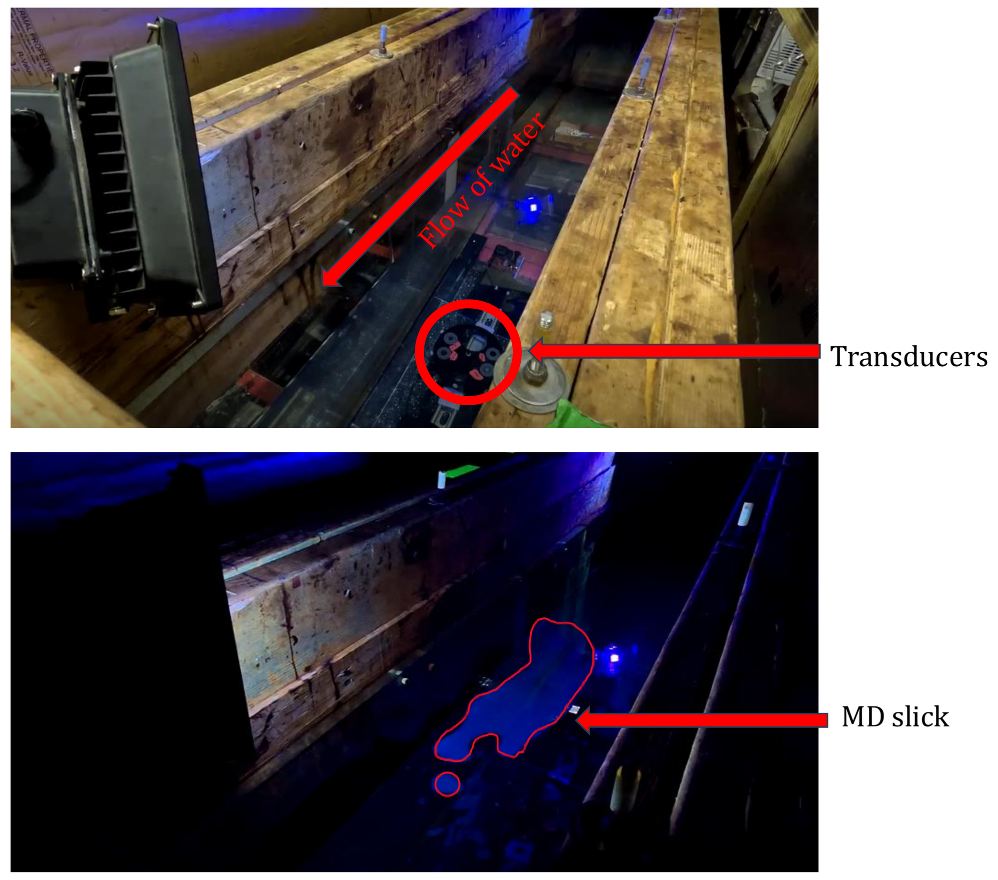
Test tank equipped with metal ring, thermometer, and AS transducer cables in bottom of tank.

Obj 3: Quiescent Conditions



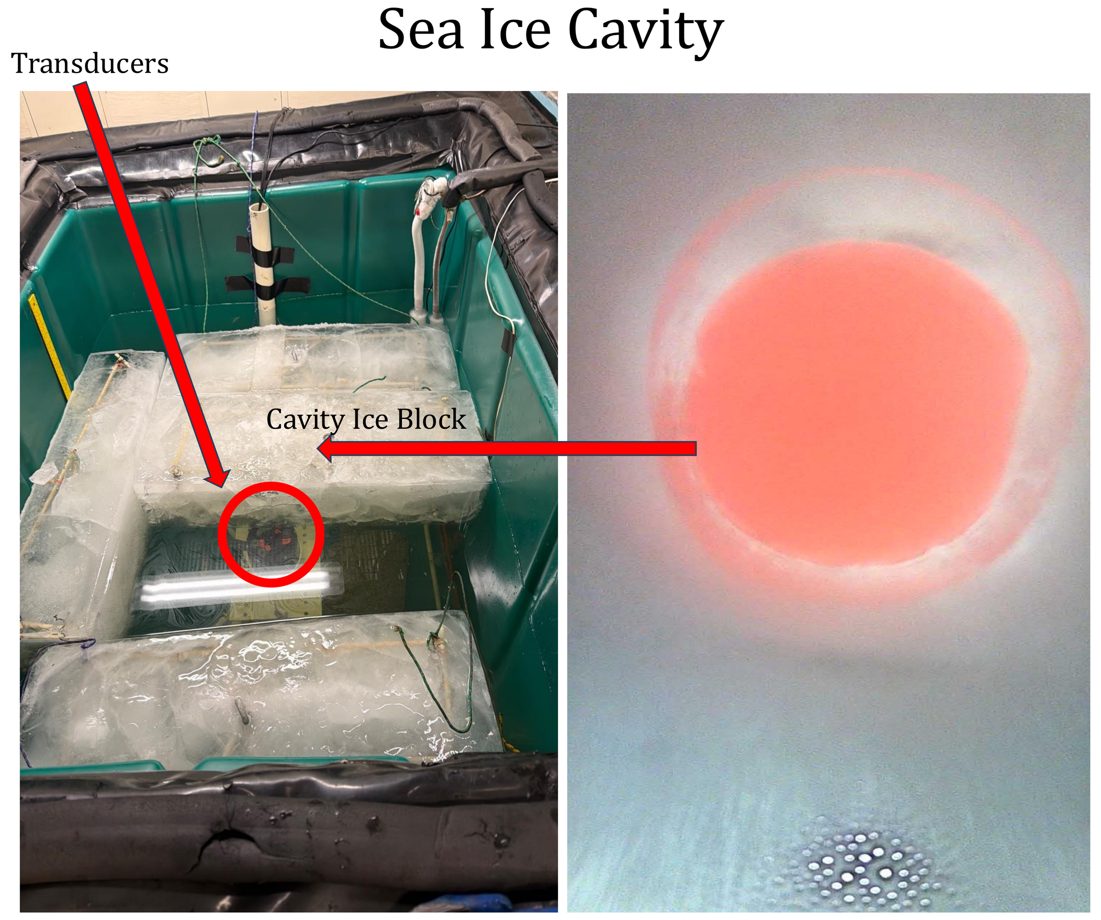
Test tank during a thickness test after the ring containing MD was lifted. Transducers are in the center of the tank.

Obj 4: MD Thickness in moving water



Top: Flume (moving water) before MD was added. Bottom: MD as it moved over the transducers.

Obj 5: MD Thickness in Sea Ice Cavity



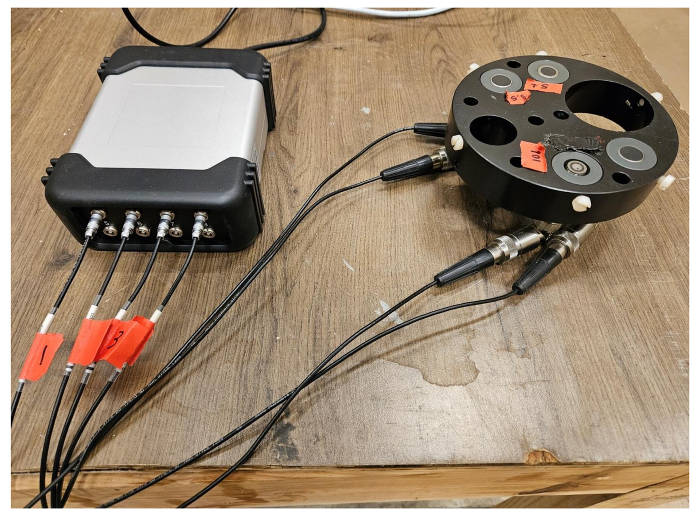
Ice tank with transducers placed in center of tank. Right image is the cavity filled with MD (dyed red) as viewed beneath the ice.

Equipment

Left: Pulser Receiver

Right: Collar with AS transducers plugged into pulser receiver

AS: 2.25, 3.5, 5, 10 MHz



Conclusions

Obj 1: Refined a MATLAB peak picking code to increase processing efficiency and speed for AS MD spill data analysis.

Obj 2 & 3: In quiescent water, the 10 MHz sensor could measure thicknesses from 400 – 2100 microns, while the other sensors could detect MD ≥1000 microns but not quantify them. At 5000 microns, the entire AS suite could quantify thickness.
- ➢ The 10 MHz sensor could be helpful in determining thicknesses for emergency response.

Obj 4: Analyzed the AS suite accuracy in dynamic conditions, confirming the sensors could detect slick thickness as MD floated over them.
- ➢ Useful for response methods since currents move slicks.

Obj 5: The AS suite was able to provide reliable estimates of MD slick thickness within a sea ice cavity.
- ➢ Suitable for tactical emergency response decision-making since less refined thickness estimates are needed.

Future Recommendations

- The 2.25, 3.5, and 5 MHz sensors could detect the presence of MD; further testing should be completed to determine each sensor's LDL.
- Modify equipment to align sensors in a single file line to ensure all sensors pass through the same cross-section.
- Conduct more experiments in the ice tank to refute thickness measurement capabilities
- Test different types of oils with varying properties (e.g., temperature)

Results

Obj 2: LDL

Target (µm)	Nominal Calculated (µm)	Measured 10 MHz (µm)	Measured 5 MHz (µm)	Measured 3.5 MHz (µm)	Measured 2.25 MHz (µm)
200	347	386	-	-	-
400	521	510	-	-	-
600	758	647	-	-	-
800	910	927	-	-	-
1000	1095	1057	1076	1001	983
1200	1291	1269	1064	1001	995
1400	1470	1431	1064	995	995
1600	1568	1592	1070	1051	1014
1800	1674	1717	1082	2090	1020
2000	1810	1841	1064	1008	1008
2200	1791	2015	1064	995	1033
2400	1953	2189	1076	1008	1020
2600	2115	2364	1070	1008	1008

200 µm Aliquot Additions

Obj 3: Quiescent Conditions

Recordings	ImageJ (µm)	Measured 10 MHz (µm)	Measured 5 MHz (µm)	Measured 3.5 MHz (µm)	Measured 2.25 MHz (µm)
At Release	4859	5179	5129	5243	5158
5 Mins After	4829	5136	5108	5136	5129
10 Mins After	4793	5073	5044	5073	5073
20 Mins After	4774	5059	5037	5066	5066
40 Mins After	4698	5073	5037	5073	5073
60 Mins After	4711	5073	5037	5066	5066

5,000 µm Dispersion

Obj 4: Flume Tank

Nominal Detection (µm)	Measured 10 MHz (µm)	Measured 5 MHz (µm)	Measured 3.5 MHz (µm)	Measured 2.25 MHz (µm)
1000	1174	1268	1363	1086

1,000 µm Detection

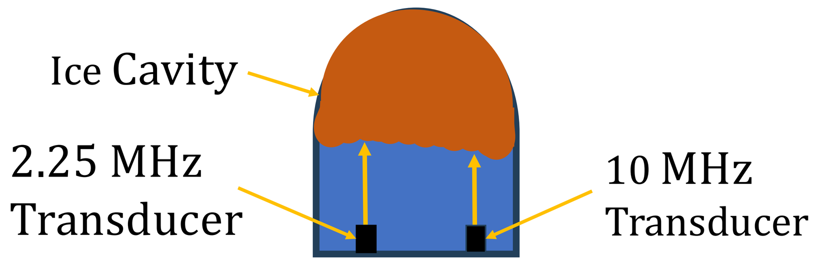
Nominal (µm)	Measured 10 MHz (µm)	Measured 5 MHz (µm)	Measured 3.5 MHz (µm)	Measured 2.25 MHz (µm)
1000	1691	1837	1888	1655

1,000 µm Release

Obj 5: Ice Tank

Nominal (µm)	Measured 10 MHz (µm)	Measured 2.25 MHz (µm)
8600	8748	4811
12100	12612	11445
15250	19683	13414

8,000 µm Aliquot Additions



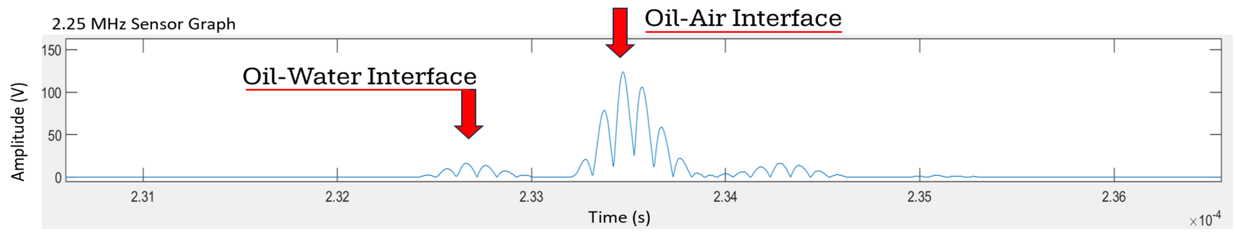
MD interface in cavity was rough

Acknowledgements

- Advisors: Nancy Kinner and Gabriel Venegas
- *NOAA's Office of Response and Restoration*
- *U.S. Coast Guard Great Lakes Center of Expertise for Oil Spills*

References

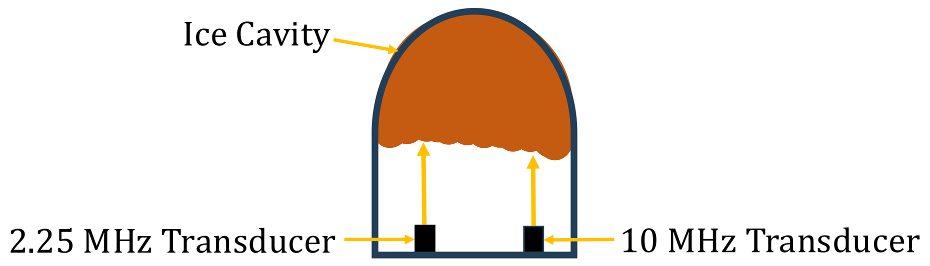
- *"Immersion Transducers | Evident Scientific."*
- *"MicroPulse LT2 | Ultrasonic Inspecting Equipment | Peak NDT."*
- *"Sector Lake Michigan Public Affairs."*
- *US Department of Commerce, NOAA "Coastal Pollution Tutorial: NOAA's National Ocean Service Education."*
- *Berg, Sara. "Underwater Remote Sensing of Oil: Validation Testing of a Commercial-Off-The-Shelf Acoustic Sensor for Remote Sensing,"*



Ice Tank: Cavity

Nominal (µm)	Measured 10 MHz (µm)	Measured 2.25 MHz (µm)
8600	8748	4811
12100	12612	11445
15250	19683	13414

8,000 µm Aliquot Additions



Oil interface in cavity was rough

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Introduction

Increased shipping routes in the Arctic Sea have left the region vulnerable to oil spills that require nuanced cleanup response due to sub-zero temperatures and the presence of sea ice. In the event of a spillage, oil may become trapped in cavities under sea ice and move through the environment faster due to harsher winds. Responders, therefore, need a reliable technology that determines oil slick thickness in sea water to assess a spill and deploy response accordingly. This project aims to develop and analyze the capability of an acoustic sensor suite for measuring oil slick thickness in Arctic conditions.

Equipment

Olympus Immersion Transducers: 2.25, 3.5, 5, 10 MHz

PeakNDT MicroPulse LT2

Experimental Design

Control Tank: Ring Apparatus

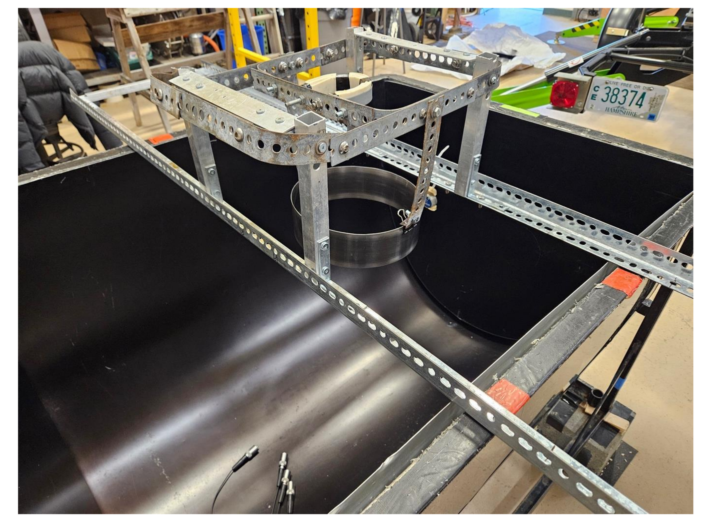


Image #1 Control Tank apparatus equpped with metal ring, thermometer, and transducer cables in bottom of tank.

Control Tank: Dispersion

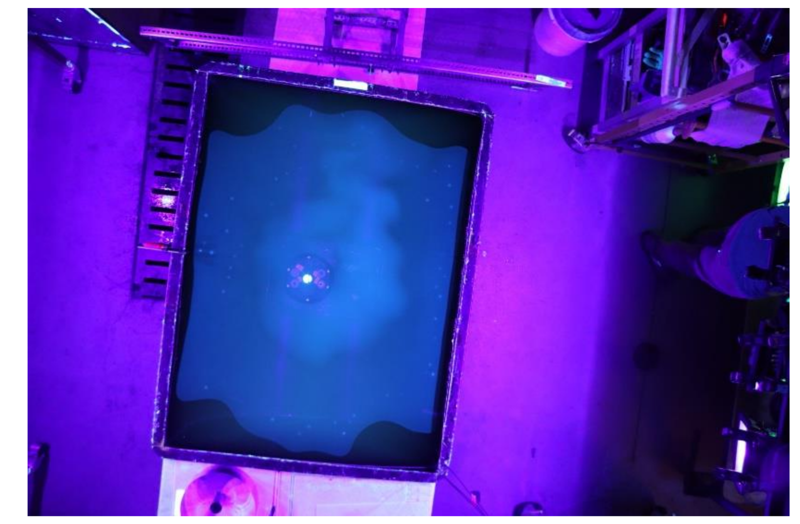


Image #2 Control tank during a dispersion test. After the ring was lifted. Transducers are in the center of the tank.

Ice Tank

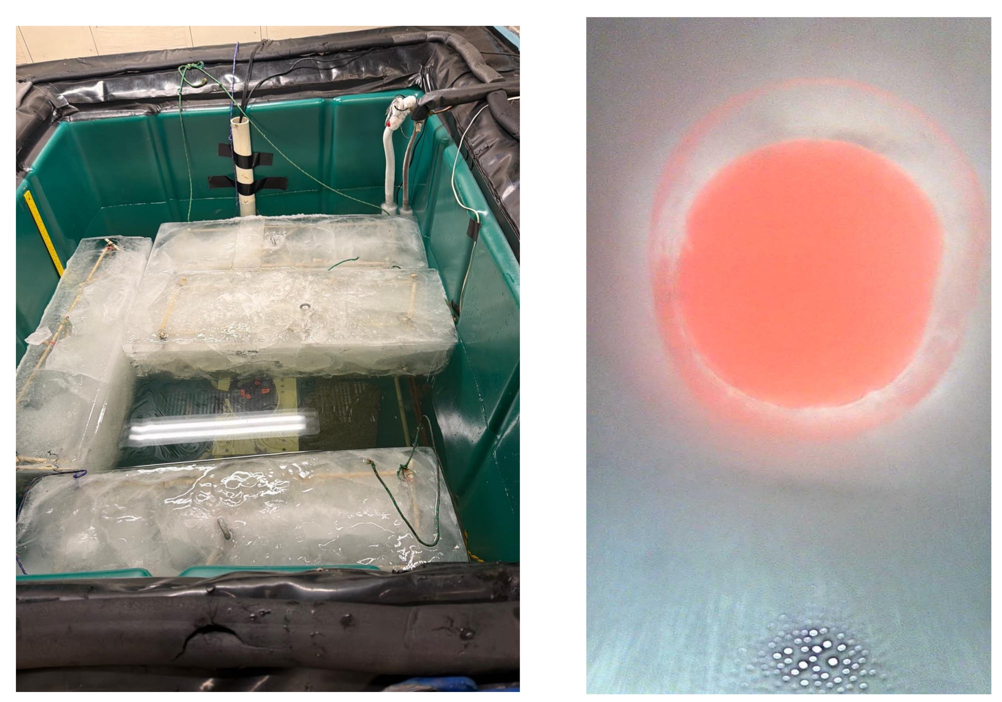
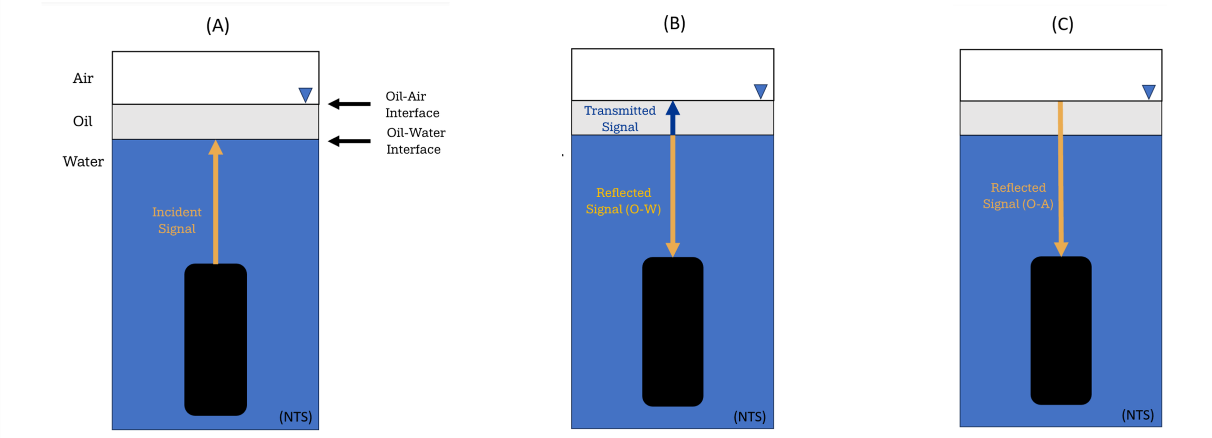


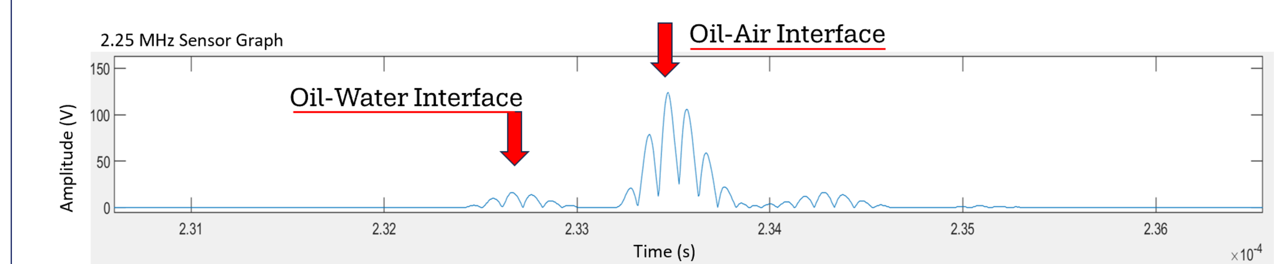
Image #3 & 4 Ice tank with transducers placed in center of tank. Right image is the cavity filled with oil from the transducer POV

Flume Tank

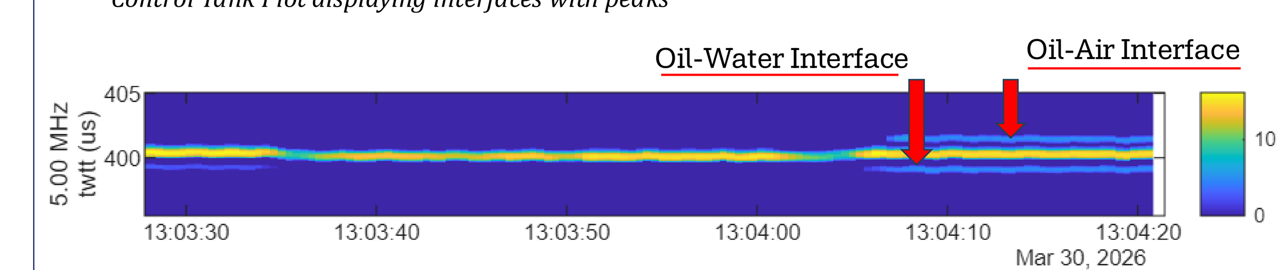
Image #5 & 6 Above is the flume tank before oil was added. Bottom image shows the oil as it moved over the transducers.

Methodology





Control Tank Plot displaying interfaces with peaks



Flume Tank Color Plot displaying interfaces with lines

Conclusions

- Constructed a custom transducer collar to adapt acoustic sensors for variable experimental mounting and proper alignment throughout data collection.
- Refined a MATLAB peak picking code to increase data processing efficiency and speed.
- Conducted control ring and dispersion experiments in still water that showed the sensors could accurately measure specific oil slick thickness.
- Evaluated ice tank trials, which detected the presence of oil in ice cavities, but failed to measure the thickness.
- Validated the sensor's accuracy in dynamic conditions using flume tank wave simulations, confirming the system's viability in turbulent waters.

OLD

Results

Control Tank: Ring

Target (µm)	Nominal (µm)	Measured 10 MHz (µm)	Measured 5 MHz (µm)	Measured 3.5 MHz (µm)	Measured 2.25 MHz (µm)
200	347	386	-	-	-
400	521	510	-	-	-
600	758	647	-	-	-
800	910	927	-	-	-
1000	1095	1057	1076	1001	983
1200	1291	1269	1064	1001	995
1400	1470	1431	1064	995	995
1600	1568	1592	1070	1051	1014
1800	1674	1717	1082	2090	1020
2000	1810	1841	1064	1008	1008
2200	1791	2015	1064	995	1033
2400	1953	2189	1076	1008	1020
2600	2115	2364	1070	1008	1008

200 µm Aliquot Additions

Control Tank: Dispersion

Recordings	ImageJ (µm)	Measured 10 MHz (µm)	Measured 5 MHz (µm)	Measured 3.5 MHz (µm)	Measured 2.25 MHz (µm)
Full Ring	-	277566	277715	278147	276137
At Release	4859	5179	5129	5243	5158
5 Mins After	4829	5136	5108	5136	5129
10 Mins After	4793	5073	5044	5073	5073
20 Mins After	4774	5059	5037	5066	5066
40 Mins After	4698	5073	5037	5073	5073
60 Mins After	4711	5073	5037	5066	5066

5,000 µm Dispersion

Ice Tank: Cavity

Nominal (µm)	Measured 10 MHz (µm)	Measured 5 MHz (µm)	Measured 3.5 MHz (µm)	Measured 2.25 MHz (µm)
8600	8748	-	-	4811
12100	12612	-	-	11445
15250	19683	-	-	13414

8,000 µm Aliquot Additions

Nominal (µm)	Measured 10 MHz (µm)	Measured 5 MHz (µm)	Measured 3.5 MHz (µm)	Measured 2.25 MHz (µm)
8500	131	-	-	-
17000	5293	5263	5293	5285
23000	38477	32718	-	38229

8,000 µm Aliquot Addition

Flume: Release

Nominal (µm)	Measured 10 MHz (µm)	Measured 5 MHz (µm)	Measured 3.5 MHz (µm)	Measured 2.25 MHz (µm)
3000	1174	1268	1363	1086

3,000 µm Release

Nominal (µm)	Measured 10 MHz (µm)	Measured 5 MHz (µm)	Measured 3.5 MHz (µm)	Measured 2.25 MHz (µm)
1000	1691	1837	1888	1655

1,000 µm Release

Acknowledgements

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References

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