

AMULET: Acoustic Metastructure for Direction-of-Arrival Estimation Underwater using a Single Hydrophone

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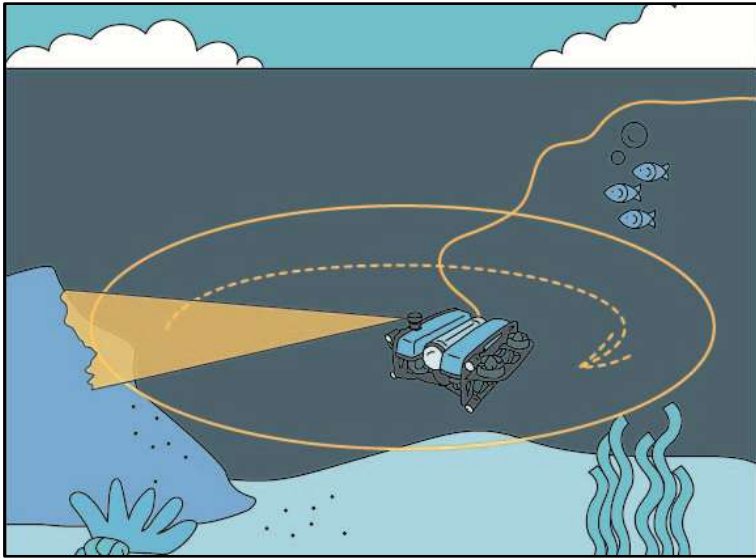
Rice University

Akshay Gadre

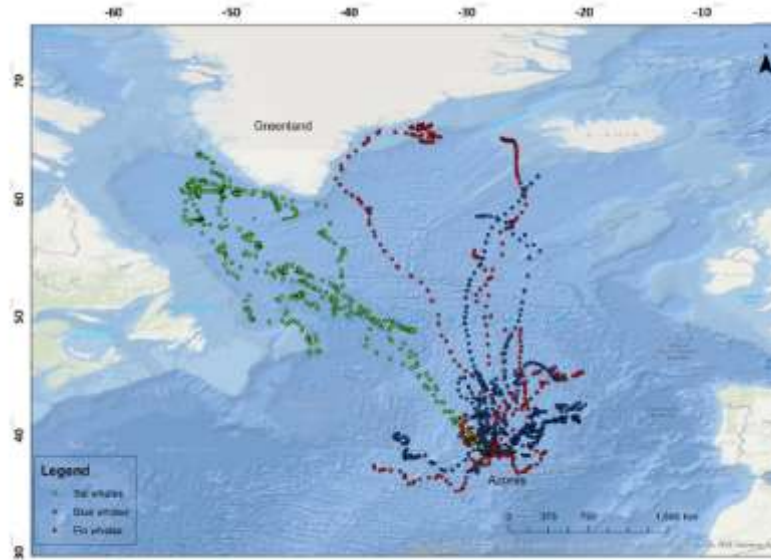
University of Washington



Underwater Acoustic Localization



Underwater Vehicle
Navigation



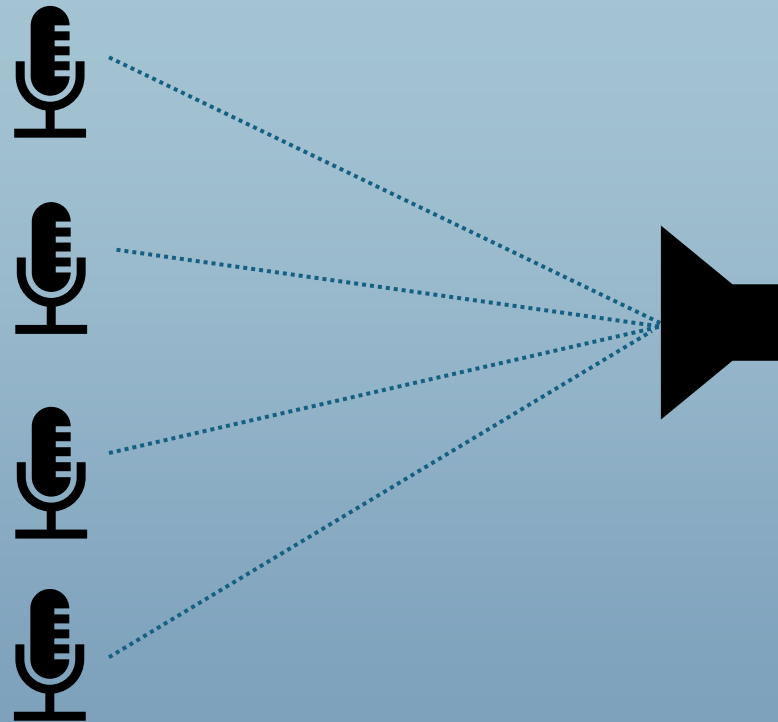
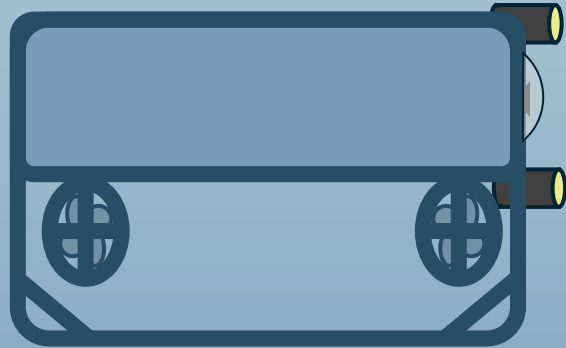
Marine Research



Diver Tracking

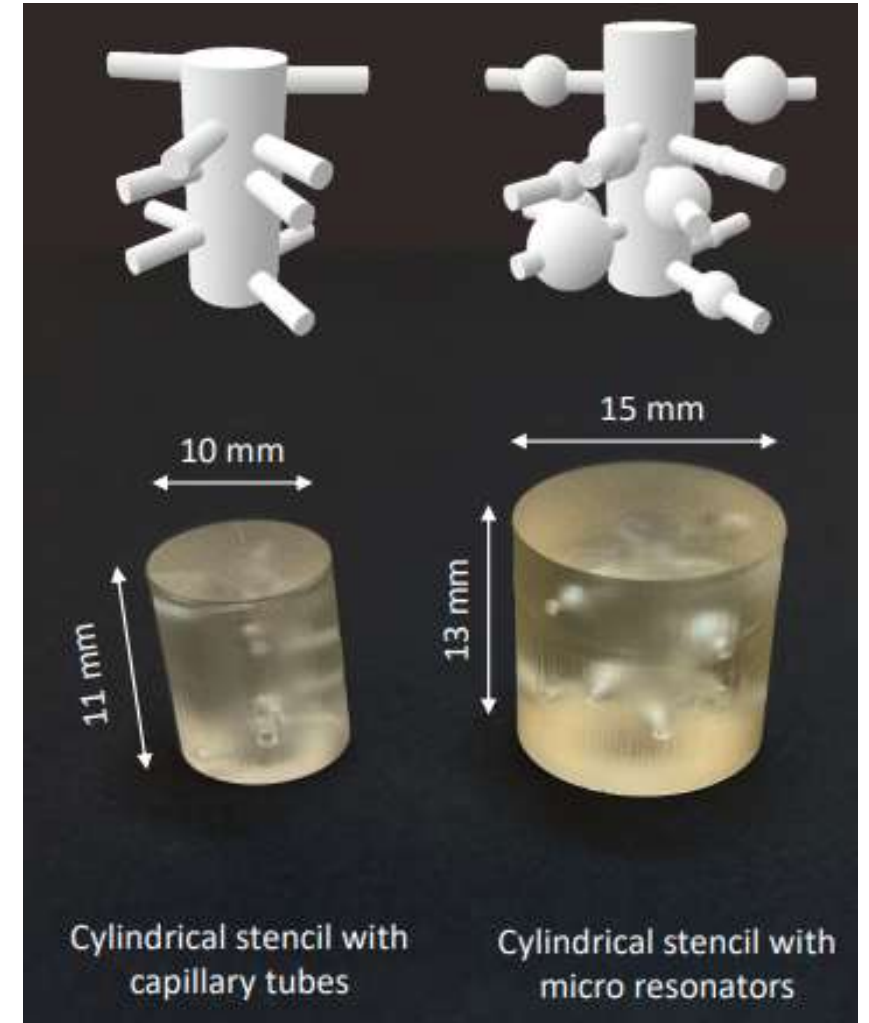
Acoustic Spatial Sensing

Highly SWaP constrained



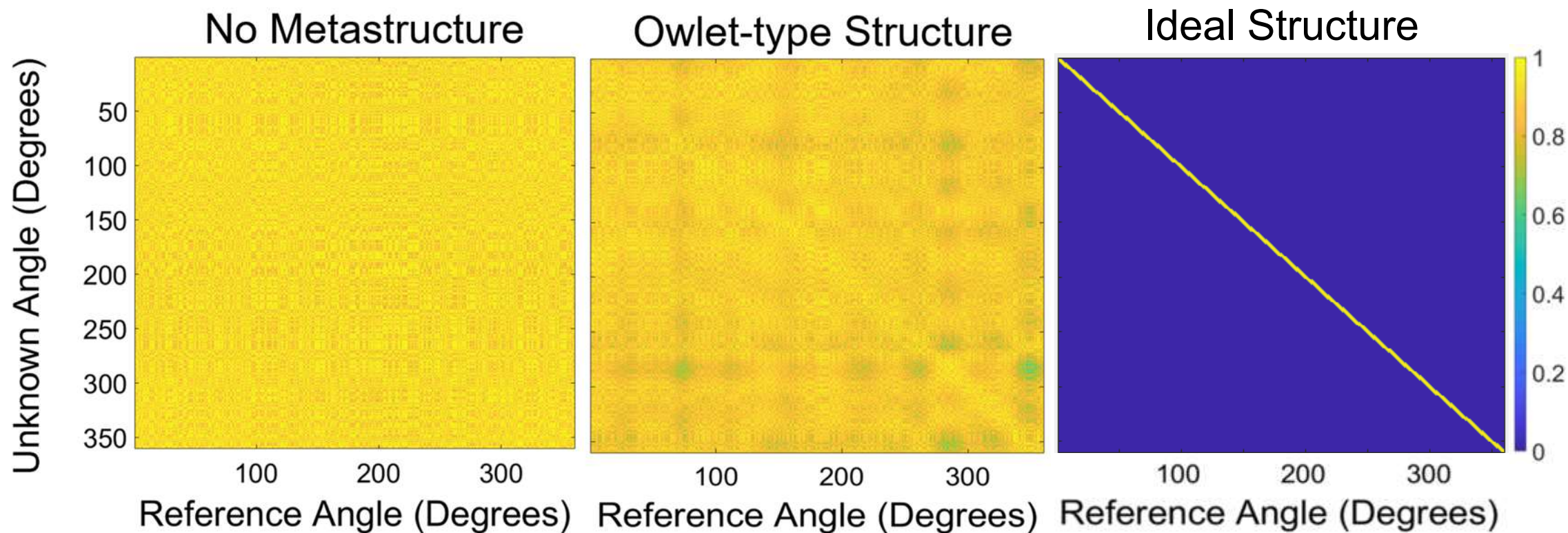
Acoustic Metastructures

- Structures engineered to have desirable acoustic properties
- Recent work (Owlet) demonstrated compact and low power DoA estimation in air

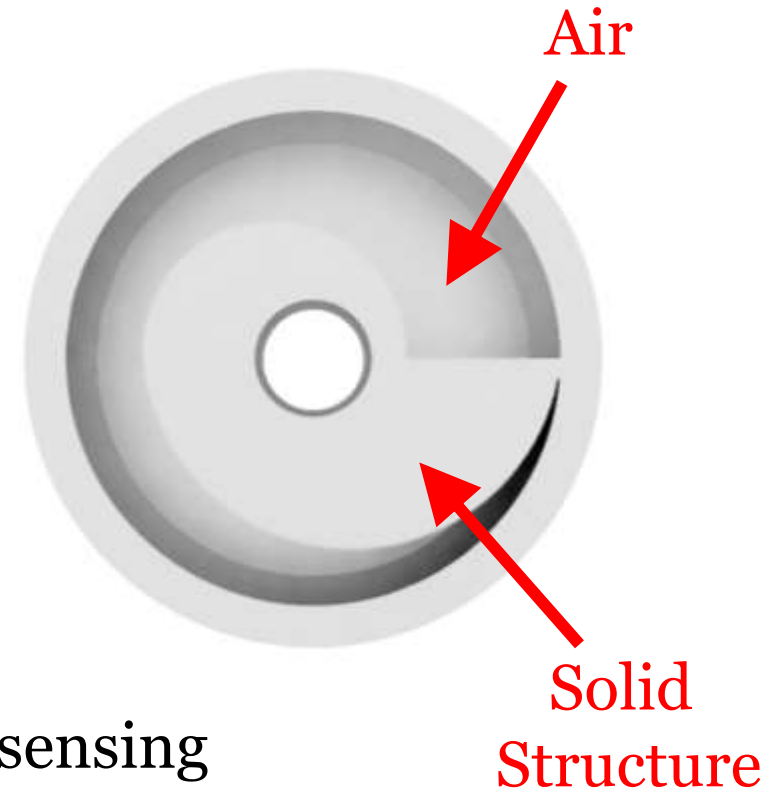


Garg et. Al. 2021. Owlet: Enabling Spatial Information in Ubiquitous Acoustic Devices. In The 19th Annual International Conference on Mobile Systems, Applications, and Services (MobiSys '21),

Motivation Study



What About Nature?



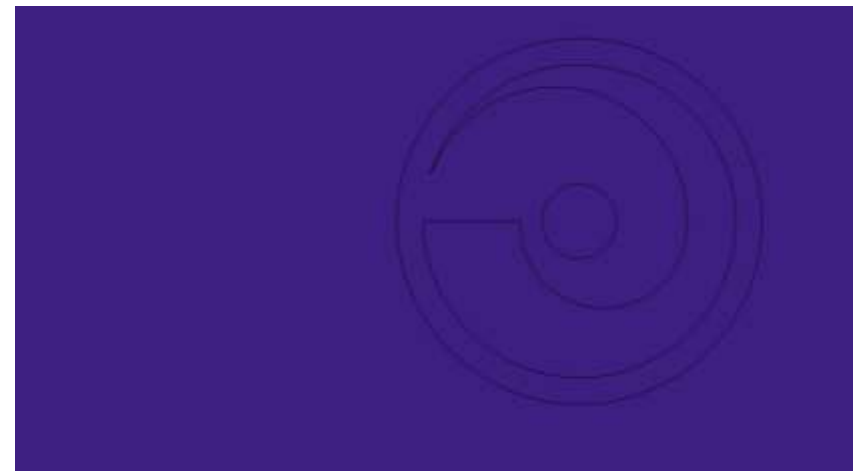
Several species use sea shells for acoustic sensing

Our design takes its inspiration from these creatures to use air as a metamaterial

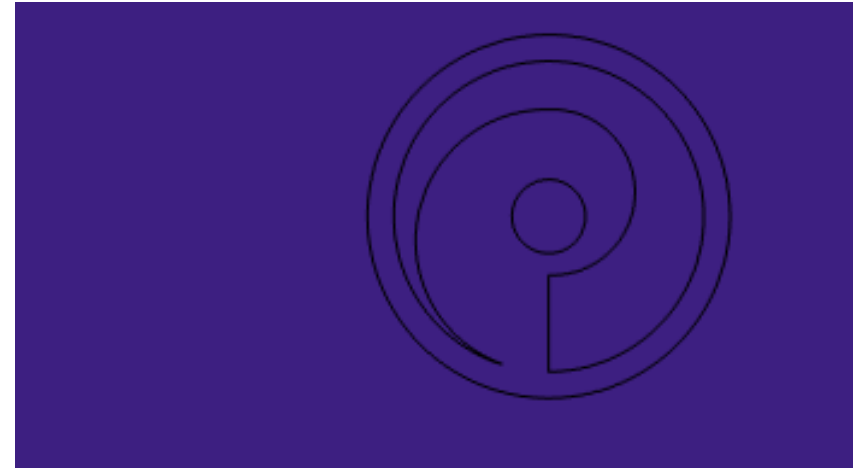
Simulation

- Simplified 2D cross section

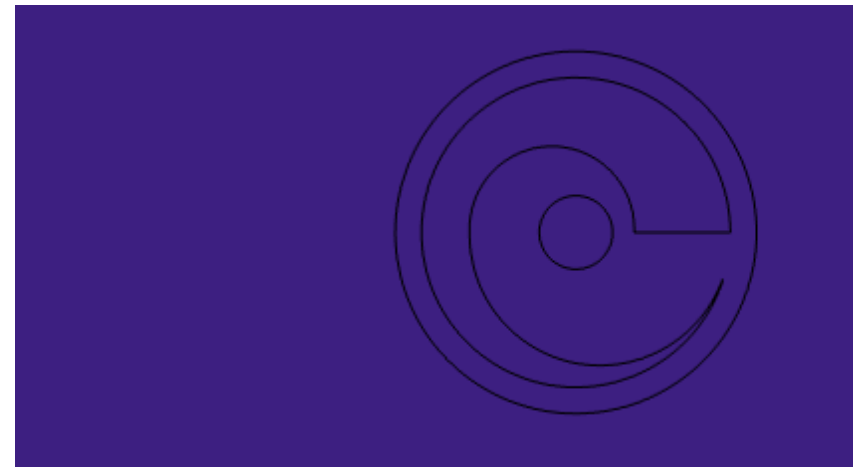
0 Degrees



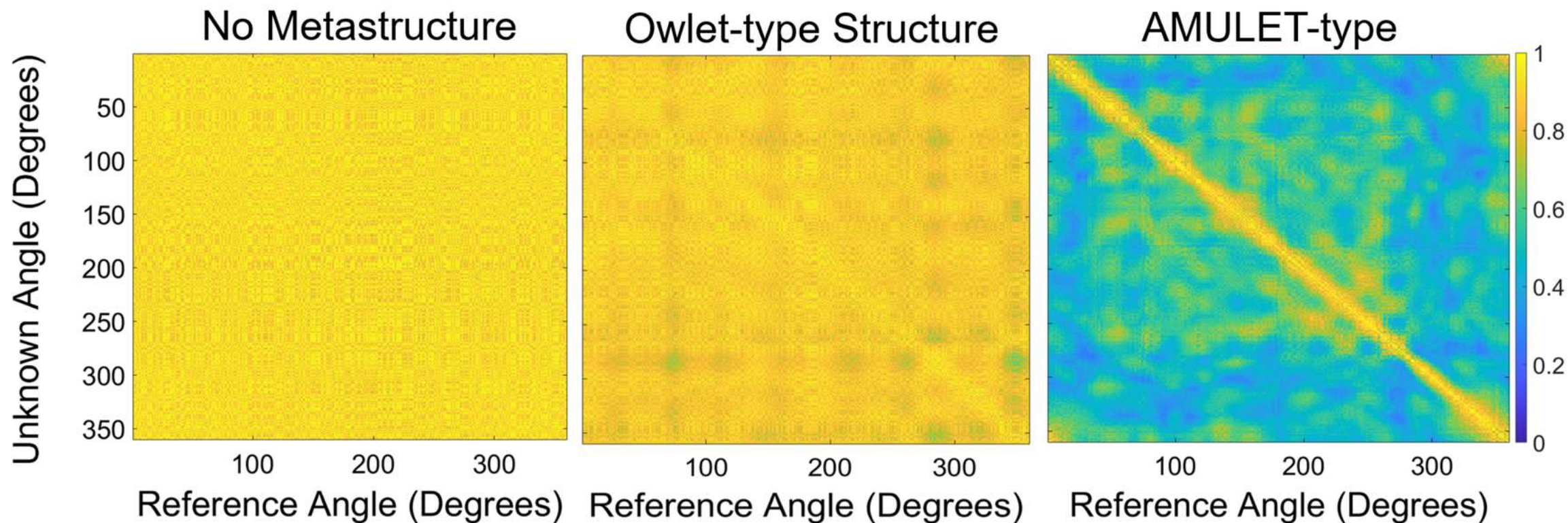
90 Degrees



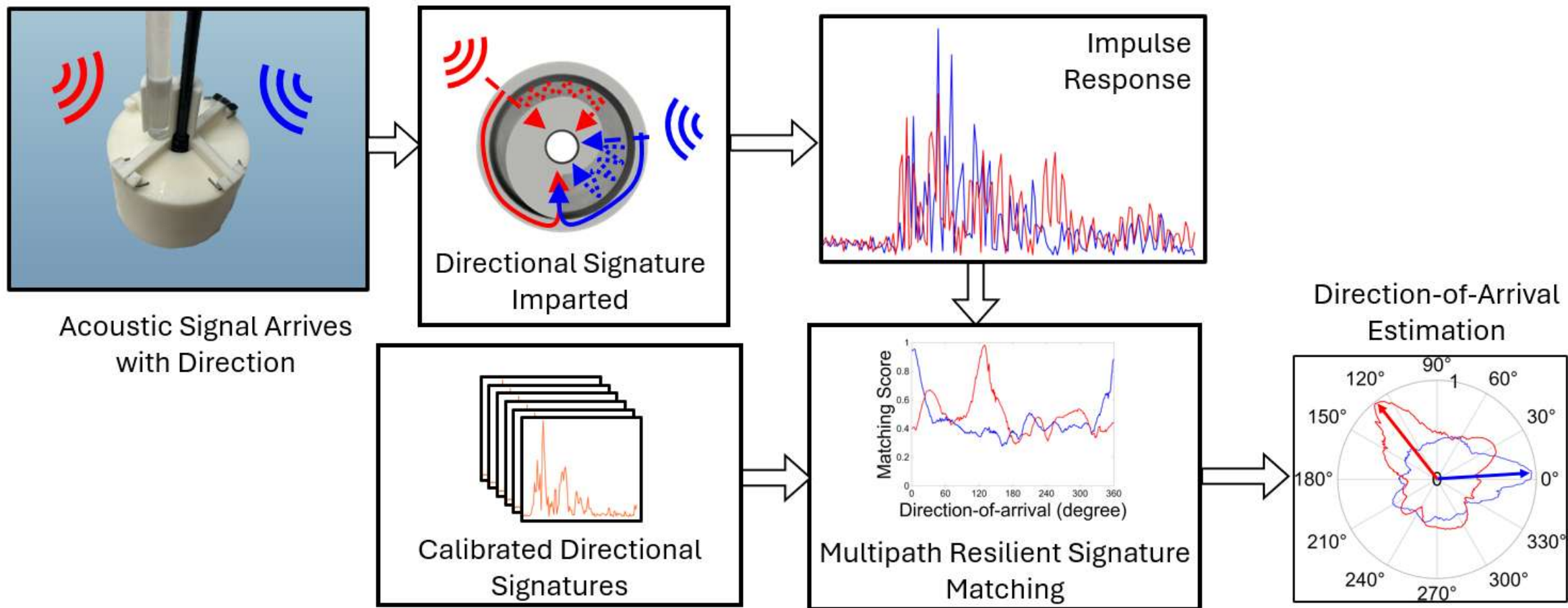
180 Degrees



Motivation Study

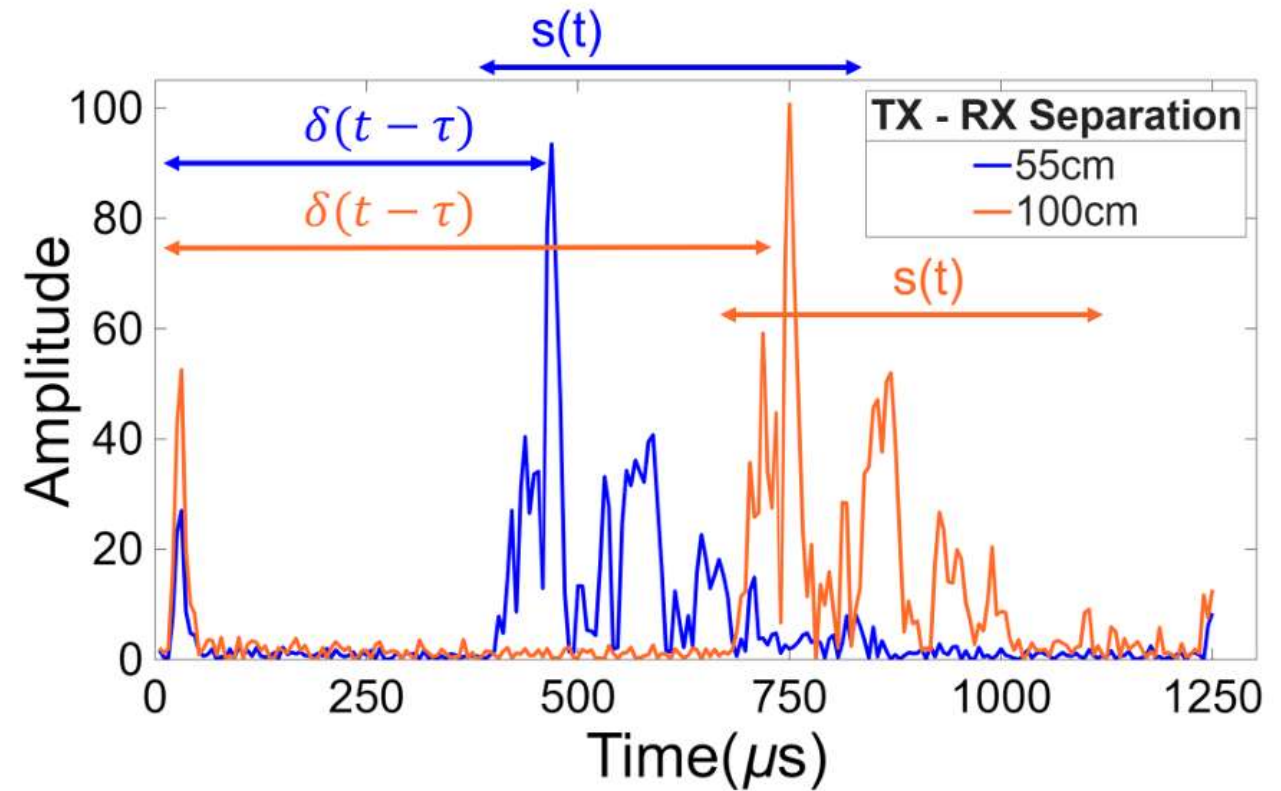


System Design



Signatures

- TX signal is known
 - 1-88 kHz linear chirp
 - 0.1 second duration
- Compute approximate impulse response
- Isolate a fixed number of samples around the LoS maximum
- Distance agnostic



Evaluation



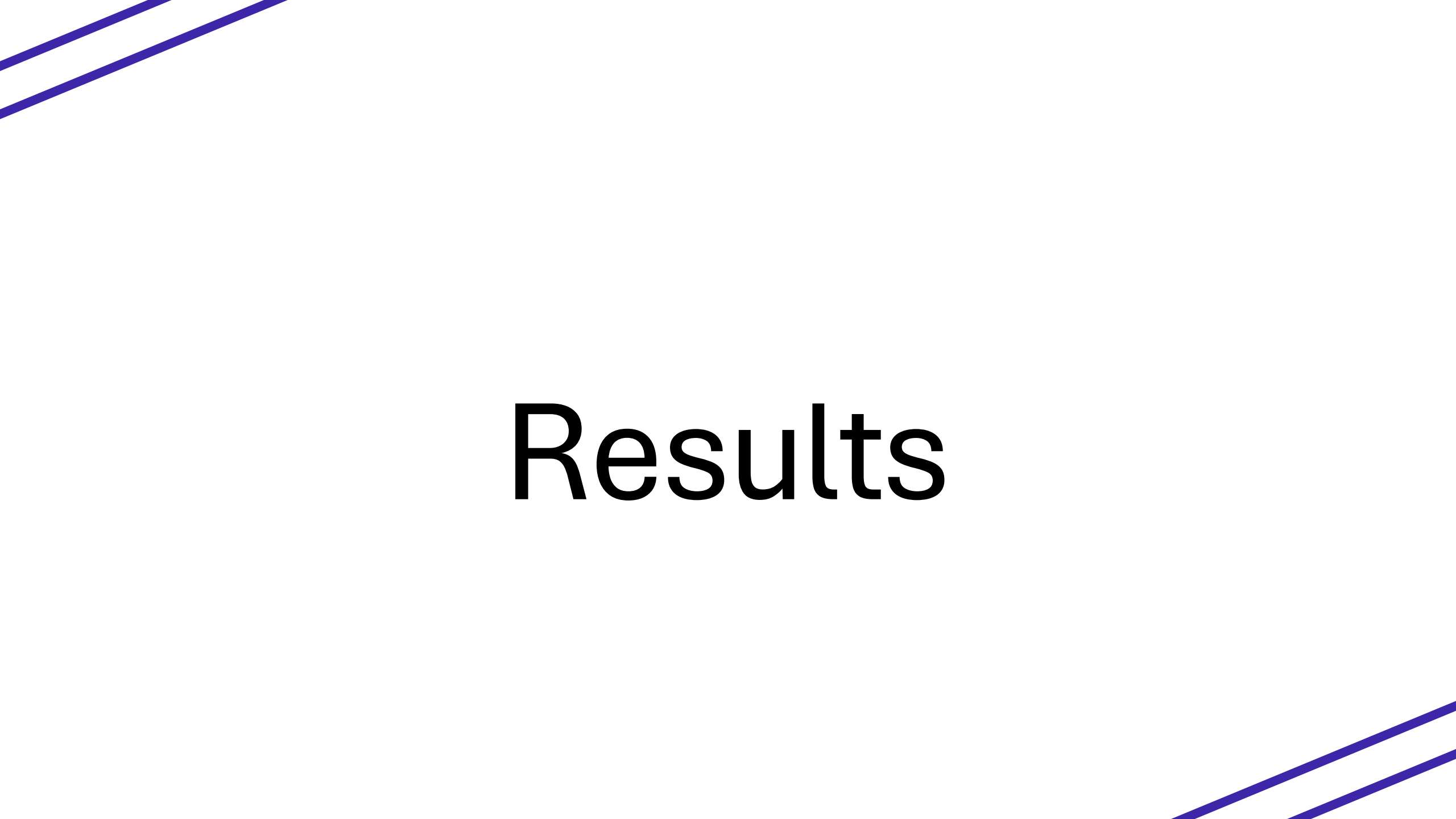
Desktop Aquarium



Saltwater Tank



Lake Pier



Results

Average Error:

1.1°

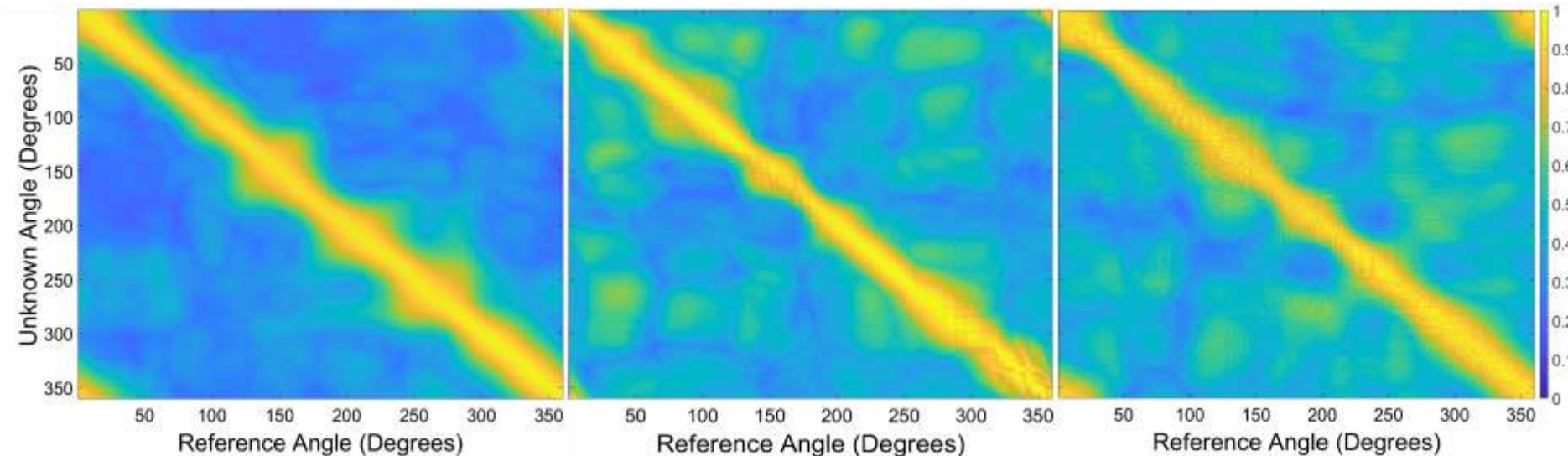
1.7°

2.2°

Desktop Tank

Saltwater Tank

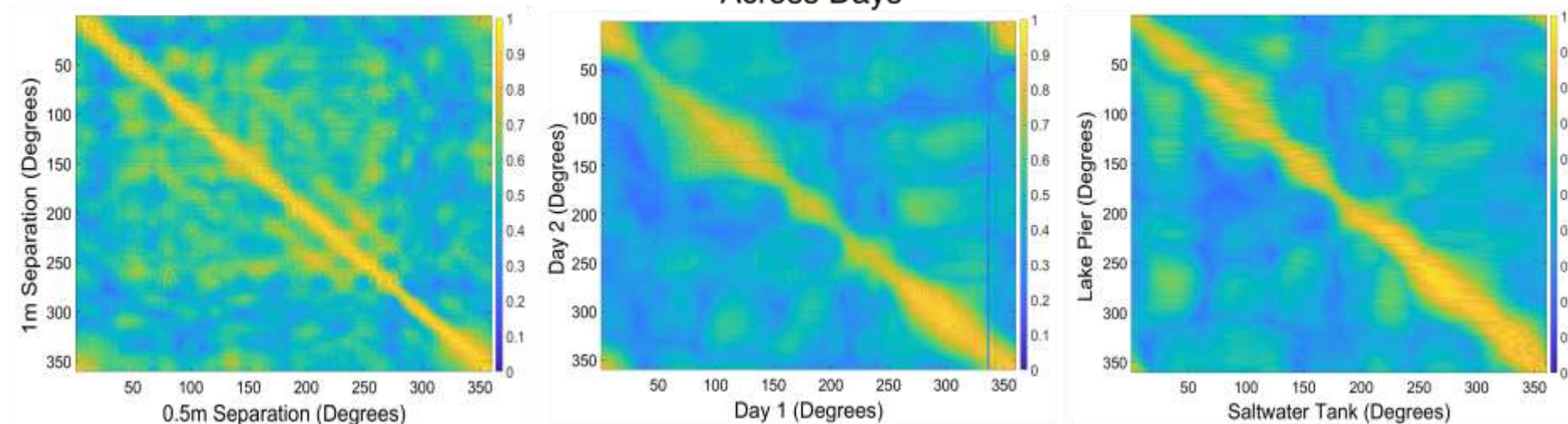
Lake Pier



Across Distances

Across Days

Across Environments

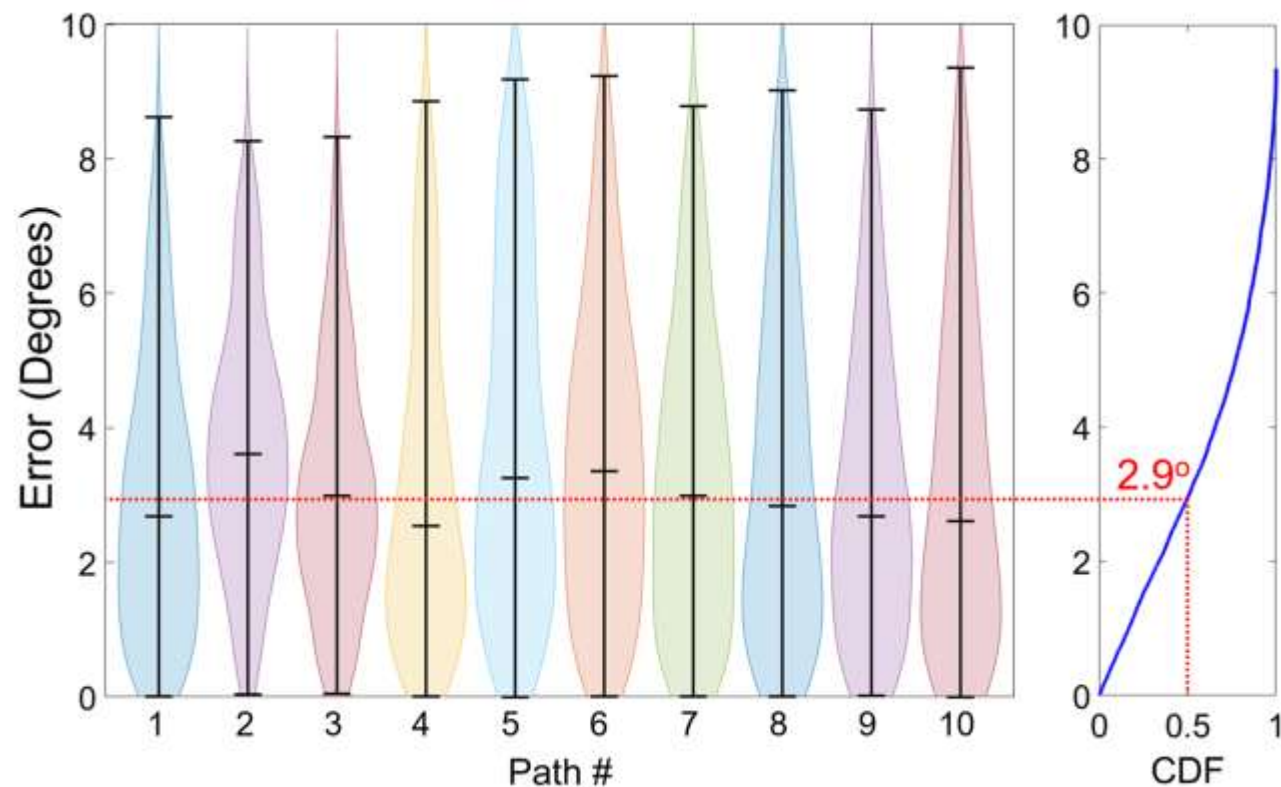
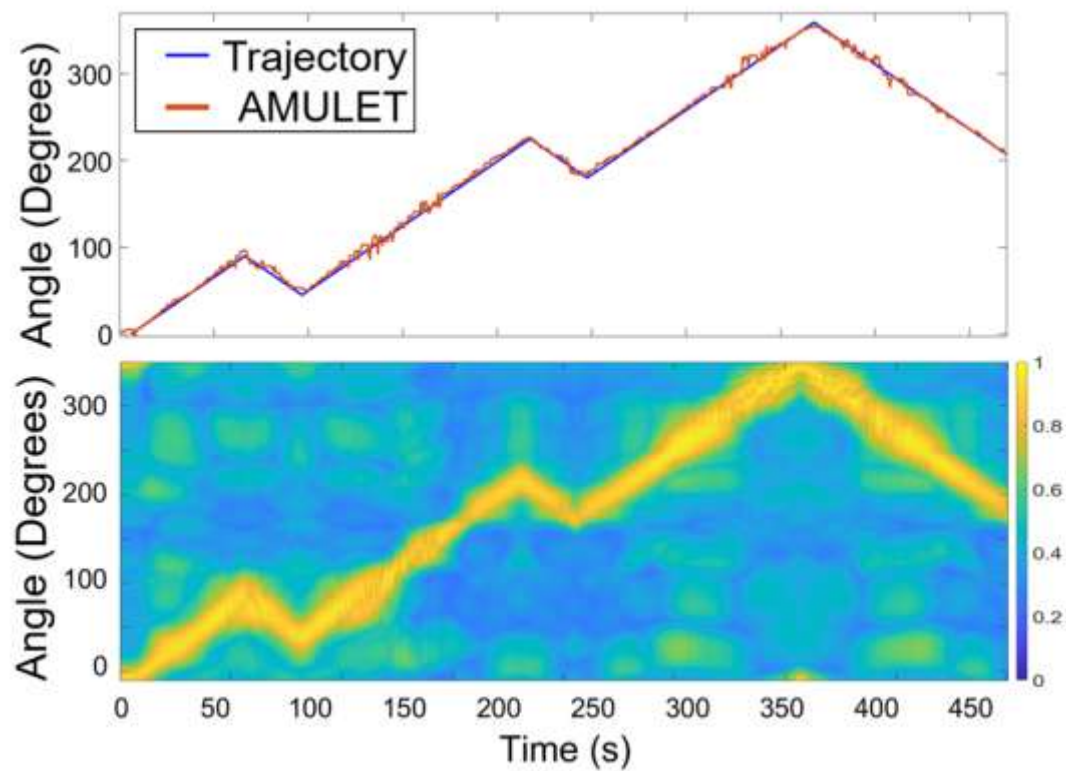


2.1°

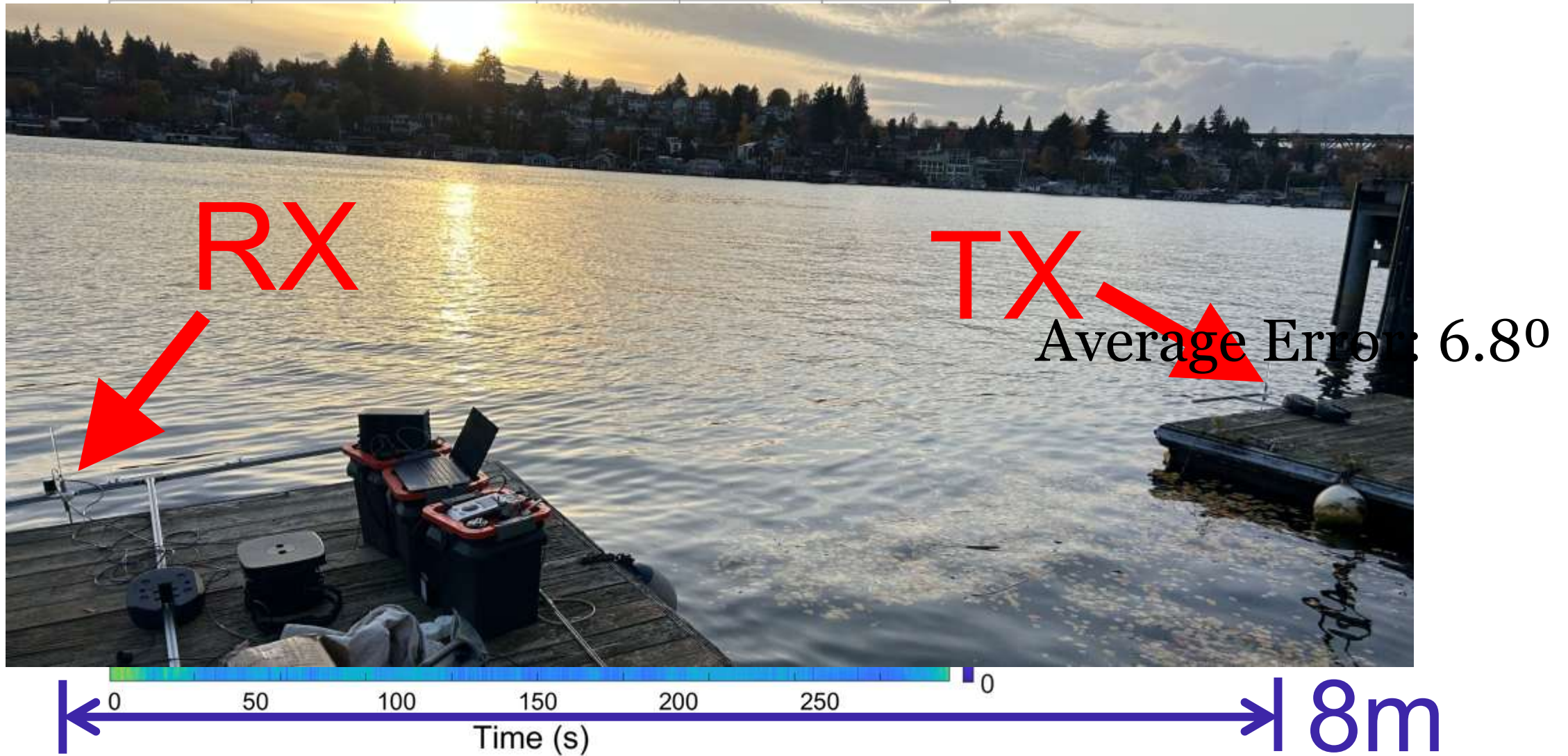
3.6°

4.1°

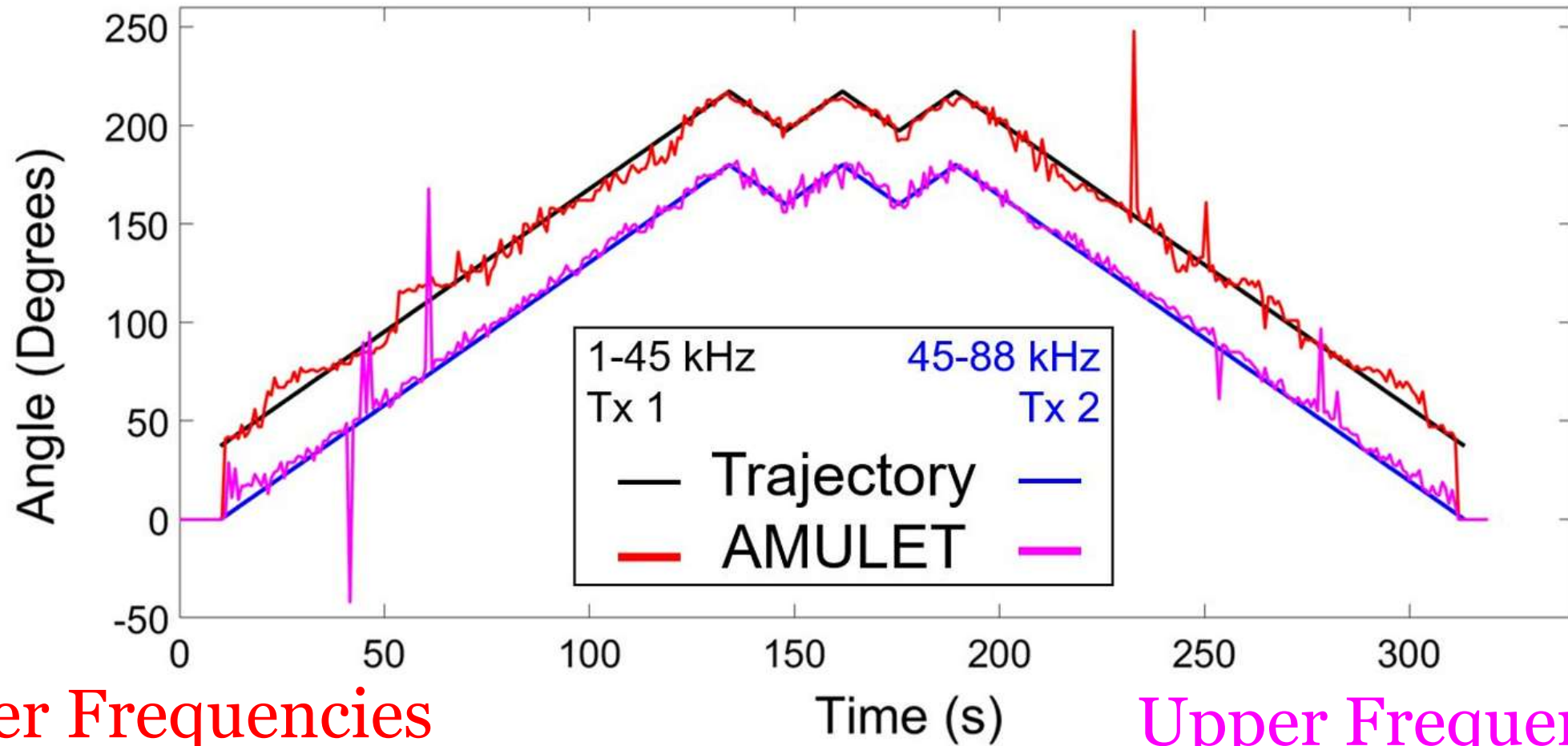
Tracking Results



Distance Tracking



Simultaneous Tracking



Lower Frequencies
Average Error: 4.2^0

Upper Frequencies
Average Error: 4.6^0

Summary

- Developed a novel acoustic metastructure concept for direction of arrival estimation underwater
- Thoroughly evaluated the prototype system across multiple environments
- Please checkout the paper for full details

Code, dataset, and metastructure 3D models →

