ISAR Imaging with CN0566 - IEEE AESS Radar Challenge 2024

Research Team

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Project Summary

Inverse Synthetic Aperture Radar, ISAR, is a technique for creating images from radar data. ISAR is similar to SAR in that it employs relative motion between a radar and targets or scenes to form large synthetic apertures leading to fine azimuthal resolution. SAR and ISAR differ in that ISAR uses a stationary radar to image moving targets, while SAR uses radar motion to image (typically) stationary scenes. While SAR can typically take advantage of onboard sensors for motion estimation of the radar platform, such as a GPS or INS, ISAR must use various signal processing techniques to estimate, compensate, and take advantage of target motion.

We created an ISAR system that can be placed onshore and act as a low-cost monitoring system for an onshore team looking to observe water traffic. The benefit of this system over an optical system is that it works even in poor visibility conditions, such fog and darkness. It also has the potential to extend into a classification system, where it identifies the type of boat being tracked.

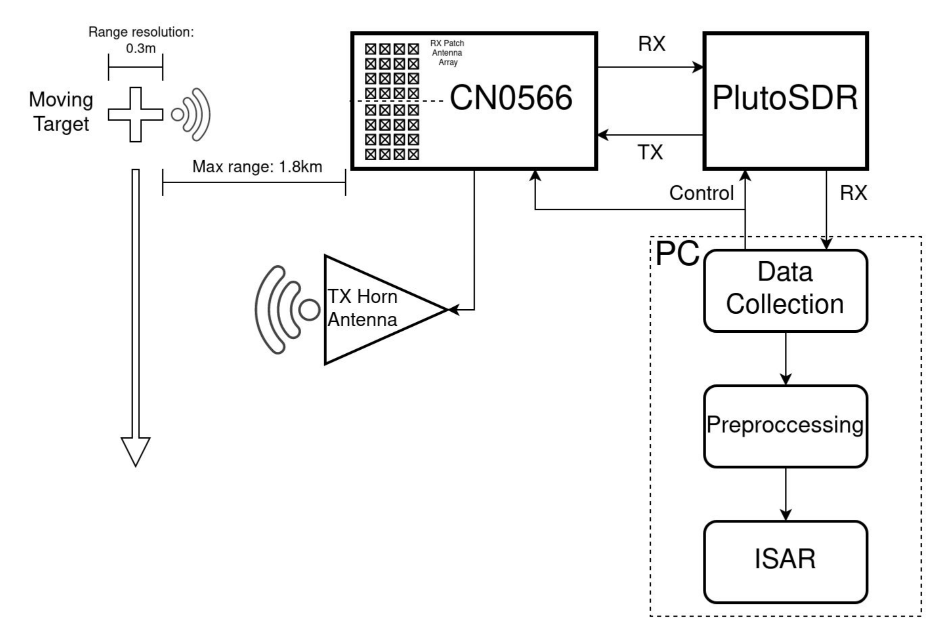

Figure 1. Block Diagram of System

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Data Acquisition

SDR Settings Summary

Sample Rate: 25Msps
TX and RX LO: 2.15GHz

Phaser Settings Summary

LO: 12.0GHz
Ramp Mode: Continuous Sawtooth
Chirp Bandwidth: 500MHz
Number of ramps per acquisition: 3
Ramp duration: 600us
RF range: 9.85GHz-10.35GHz

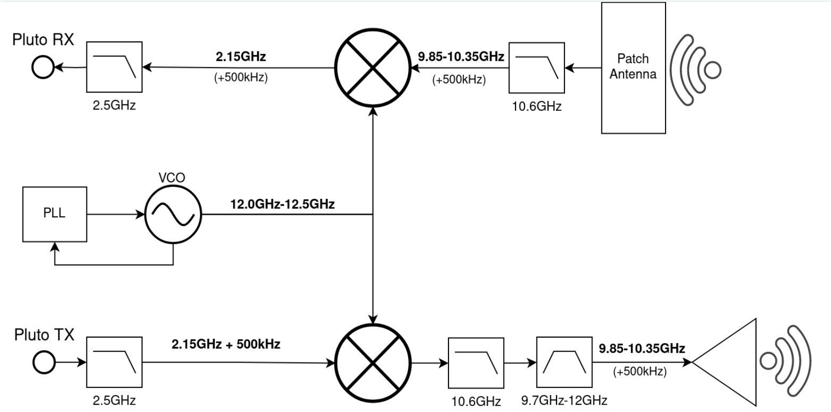


Figure 2. Phaser Block Diagram

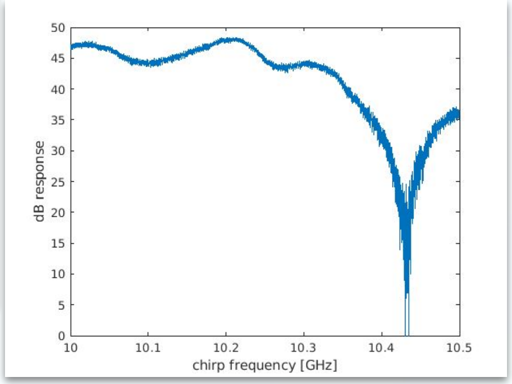


Figure 3. dB Response

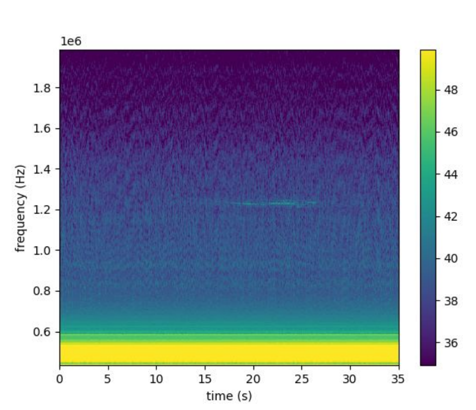
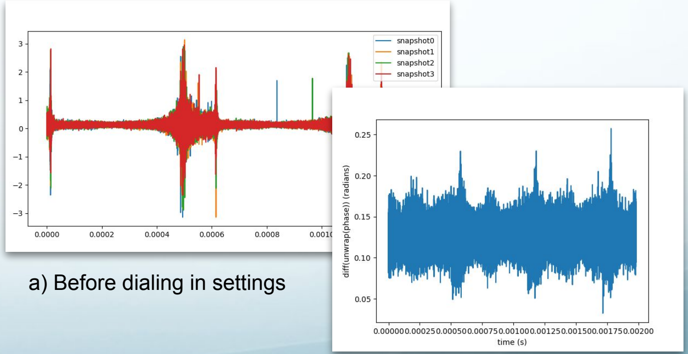


Figure 5. Flyby Waterfall Plot



a) Before dialing in settings

a) After dialing in settings

Figure 4. Diff unwrapped phase

Preprocessing

The data still needs some more corrections before it is ready to be used for ISAR. Our preprocessing significantly improved our ability to resolve our target.

Steps

- Phase correction
- Windowing

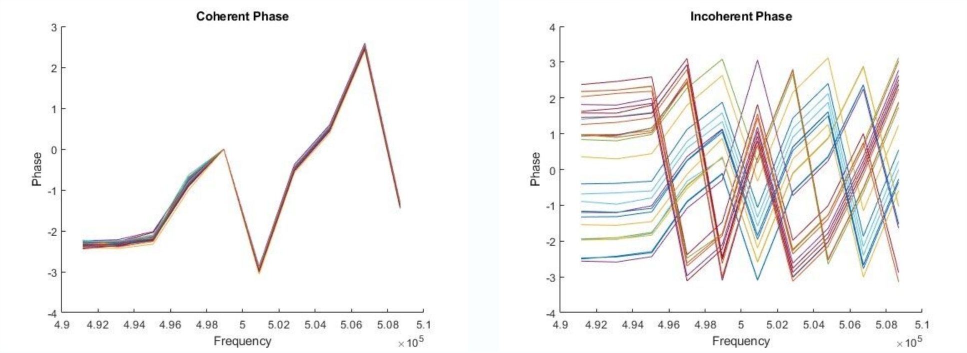


Figure 6. Phase alignment

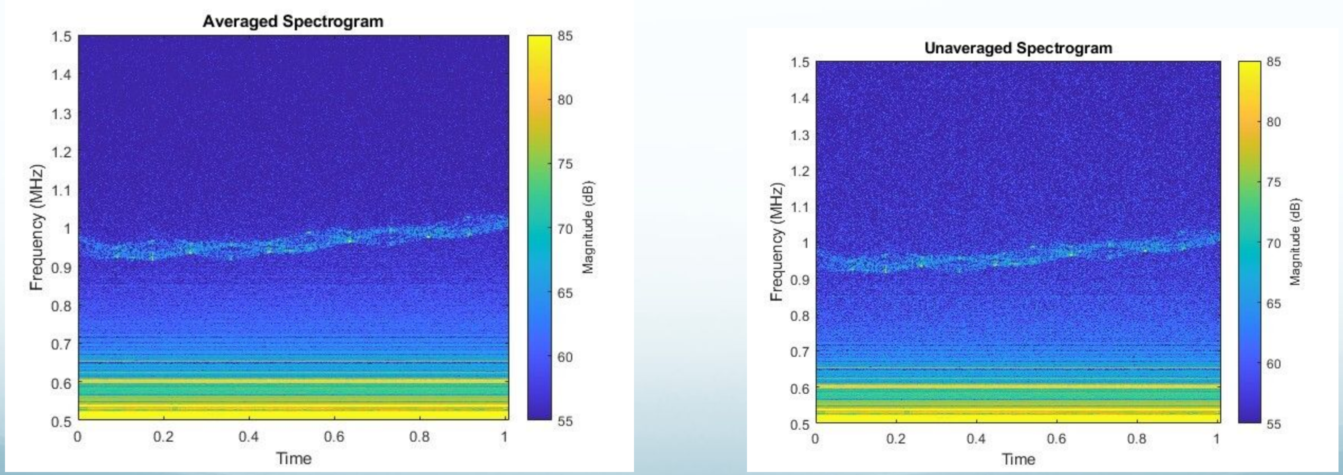
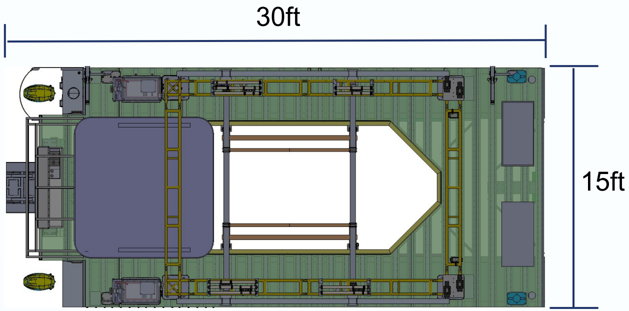


Figure 7. Spectrograms

ISAR

Step 1: Understand your target dimensions



Step 2: Find frequency bandwidth (range) and angular width (cross-range)

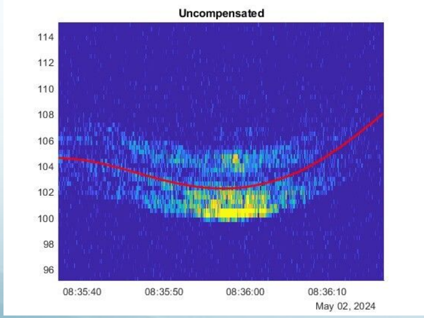
$$\Delta R = \frac{c}{2 * BW_{RF}} = 0.3m \longrightarrow N_{pixels_x} = \frac{R_{max}}{\Delta R}$$

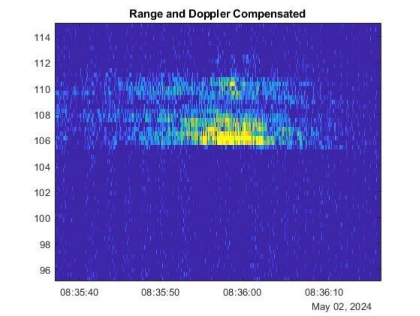
$$\Delta XR = \frac{\lambda_c}{2 * \Omega} \longrightarrow N_{pixels_y} = \frac{XR_{max}}{\Delta XR}$$

$$B = N_{pixels_x} * \Delta f$$

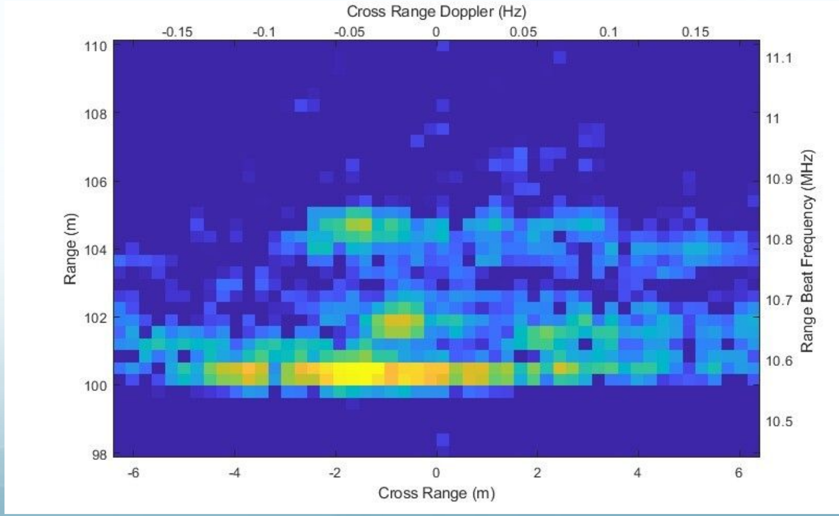
$$\Omega = N_{pixels_y} * \Delta \phi$$

Step 3: Compensate range of preprocessed data using tracking (as needed)

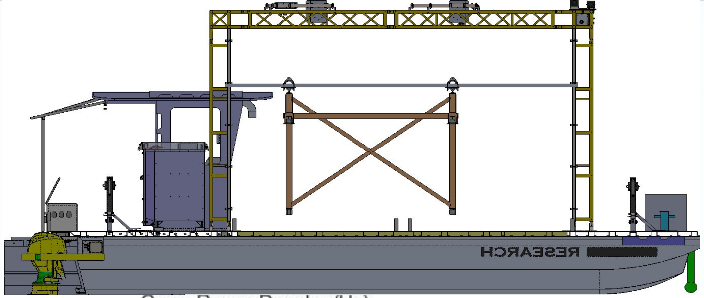


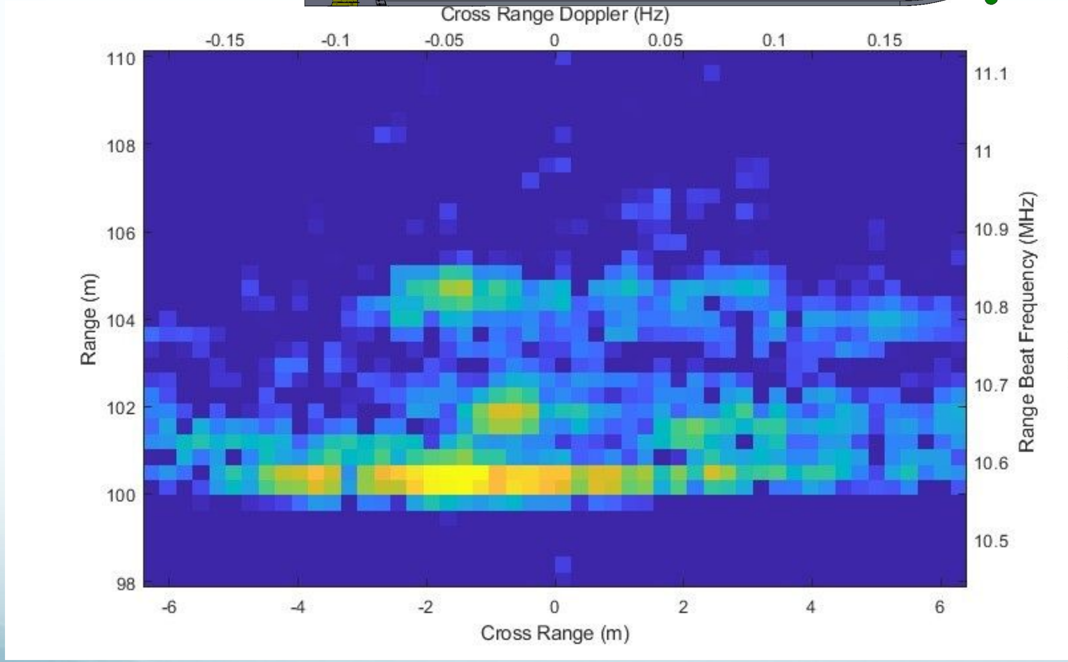


Step 4: Perform 2D FT on our backscatter data

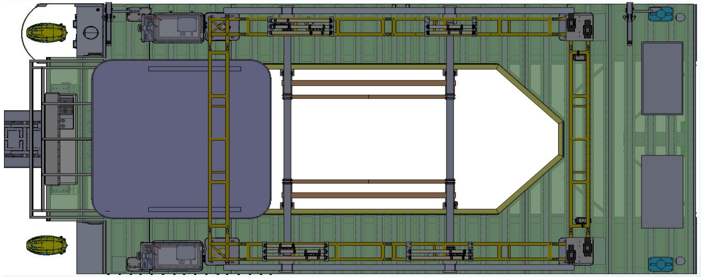


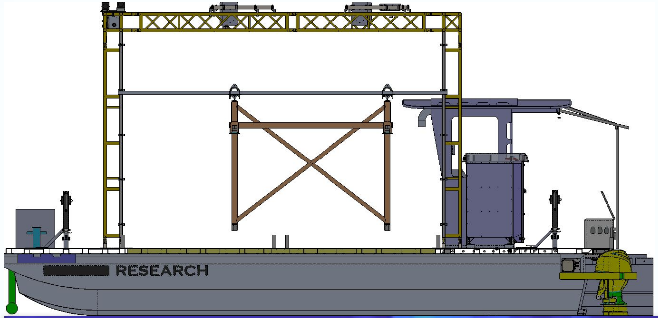
Fly-By Image

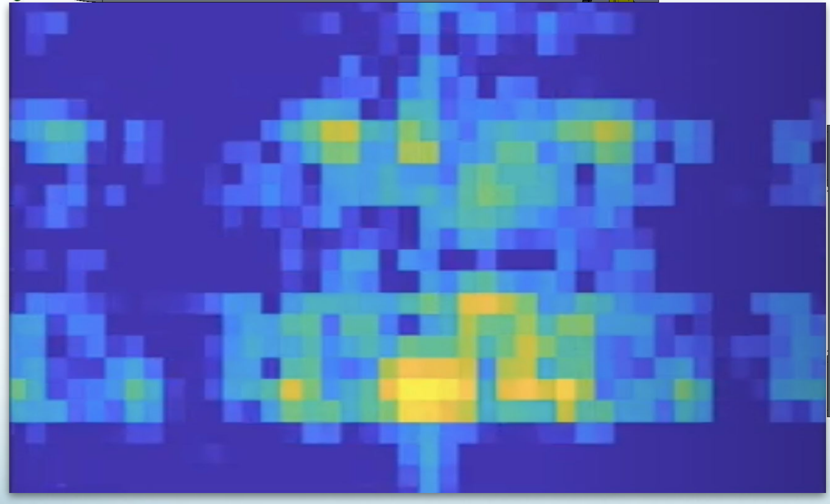


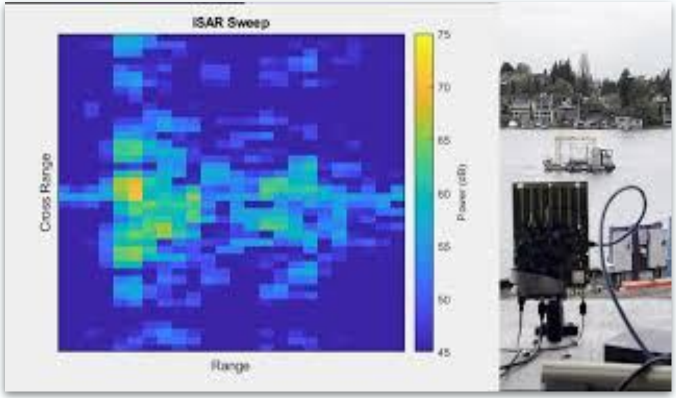


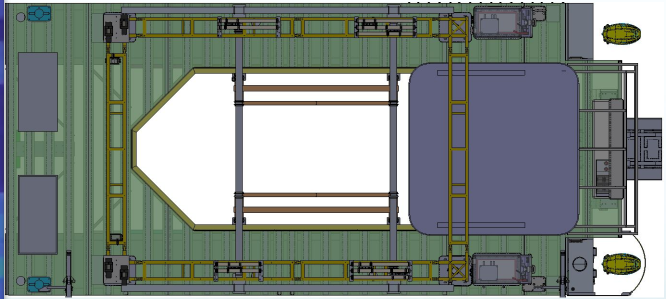
Cross Range Doppler (Hz)
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
110
108
106
104
102
100
98
Range (m)
11.1
11
10.9
10.8
10.7
10.6
10.5
Range Beat Frequency (MHz)
-6
-4
-2
0
2
4
6
Cross Range (m)











Fixed Rotation Image

Future Work

- Advanced motion compensation and autofocus
- Wake sensing
  - The phaser being X-band and vertically polarized make it very suitable for water surface scans
  - APL has extensive lineage in wave reconstruction and wake sensing research
- Classification of ISAR images using machine learning
  - Boat identification
  - Feature identification

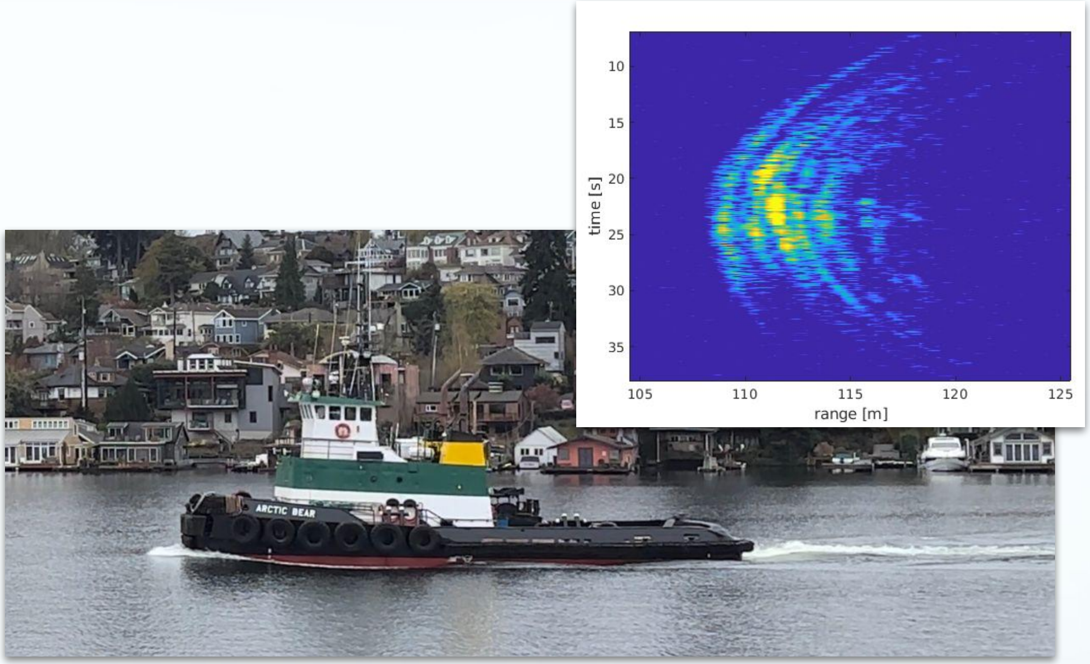


Figure 8. Future wake sensing work

Huge thanks to

- *Tony Ha and Tea Tran for being our Analog mentors*
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- *Office of Naval Research for graduate financial support*
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