ISAR IMAGING OF NEAR-SHORE MARITIME VESSELS USING A LOW-COST X-BAND RADAR

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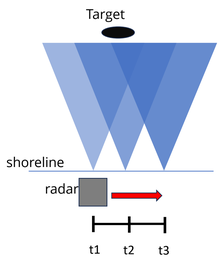
Introduction

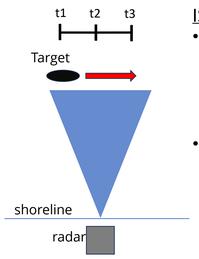
- Objective: Demonstrate the use of emerging low-cost radar chips for coastal sensing by imaging near-shore vessels.
- Motivation: Existing studies on using low-cost radar hardware for imaging focus on classroom/laboratory applications. This project studies how existing off-the-shelf radar systems have real-world utility as inexpensive and quickly deployable imaging tools.
- Pictured to the left is the kit used in the study: Analog Device's CN0566 Evaluation Kit, a $2500 X-band (10 GHz) low-power phased array radar board.

Background

Synthetic aperture radar imaging (SAR), is a technique to get high-resolution images without using physically-large antennas. Each look angle along the synthetic aperture builds the cross-range axis of an image. In SAR, the radar platform moves relative to the target. In inverse SAR (ISAR), the target moves while the radar remains stationary. For coastal surveillance, ISAR using stationary radar to image moving boats becomes an attractive imaging modality.

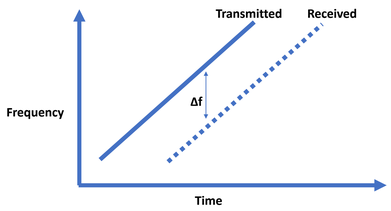


SAR
- Uses the motion of the radar platform to create the synthetic aperture
- Imaging is simplest when target is stationary



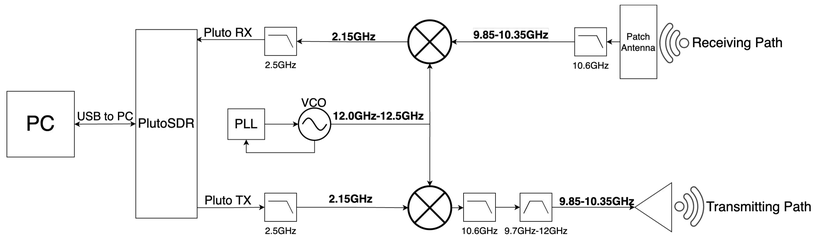
ISAR
- Uses the motion of the target to create the synthetic aperture
- Radar platform is stationary

The system was configured to be a frequency modulated continuous wave radar (FMCW) to get range information. The radar continuously sends out ramped pulses and then listens for echoes to calculate the "difference frequency."



The difference frequency corresponds to the round-trip travel time of the signal, and from the echo time, range can be derived. Therefore, the range axis of a SAR image comes from the frequency spectrum of the received signal.

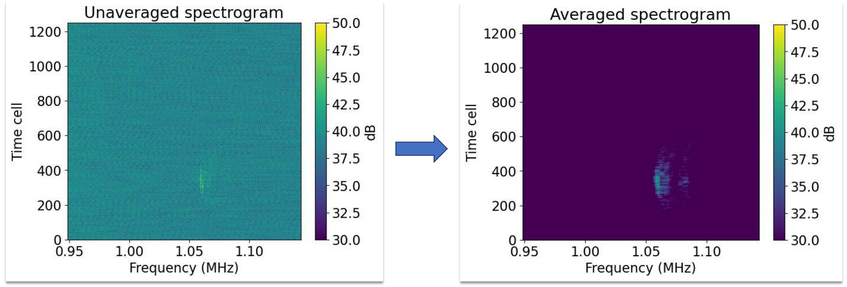
Hardware Configuration



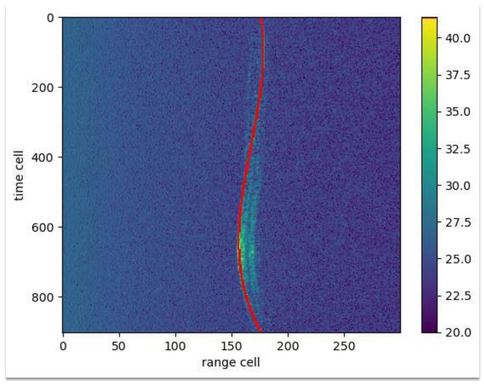
The system was configured to have a theoretical maximum viewing range of 1.8km. The hardware supports a 500MHz bandwidth frequency ramp for a range resolution of 0.3m.

Spectrogram Averaging

Before the final ISAR images, the spectrum of the received signal first needs to be averaged. Averaging over multiple radar pulses ("chirps") is used to improve the signal-to-noise ratio of the received signals.

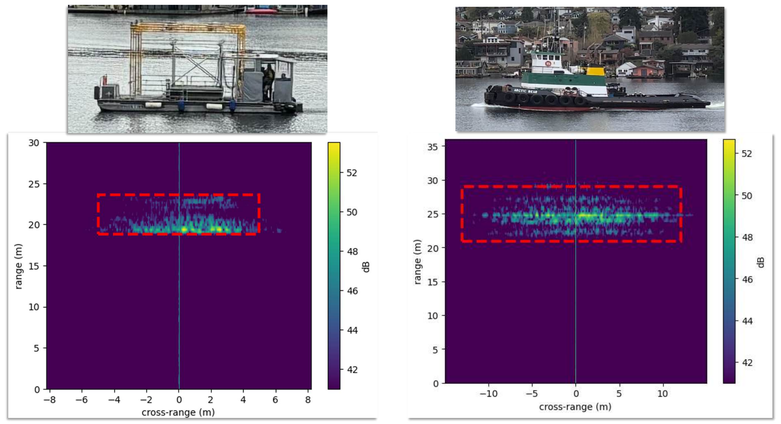


Vessel Tracking And Motion Estimation



To focus the ISAR image, the position of the vessel relative to the radar must be known at each measurement time. The vessel motion was fitted to a third-order polynomial model whose coefficients are derived from the measured radar range data. This track was used to invert the vessels' range profiles.

Results



Two vessels were imaged during data collection. The vessel on the left is the RV Lee Thompson, which is 10 meters long and 5 meters wide. The vessel on the right is the Arctic Bear, which is 25 meters long and 9 meters wide.

In the ISAR images, the range and cross-range axes correspond to a top-down view of each vessel. The specular highlights align well with the true dimensions (outlined in red). Additionally, there is some definition of the rectangular (RV Lee Thompson) and rounded (Arctic Bear) footprints.

Future Work

- Distributed radar imaging systems for wide-area surveillance of ports and coastlines
- Advanced motion compensation and autofocus
- Wake sensing

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