Development and Demonstrations of a 13 MHz Bistatic Transmitter Buoy Coupled to Standard and Superdirective Shore-Based CODAR Receivers forVessel Detection Applications

Scott Glenn
Coastal Ocean Observation Lab, 71 Dudley Road, Rutgers University, New Brunswick, NJ 08901
phone: (732) 932-6555 fax: (732) 932-8578 email: glenn@imcs.rutgers.edu

Josh Kohut
Coastal Ocean Observation Lab, 71 Dudley Road, Rutgers University, New Brunswick, NJ 08901
phone: (732) 932-6555 fax: (732) 932-8578 email: kohut@imcs.rutgers.edu

Don Barrick
CODAR Ocean Sensors, 1914 Plymouth Street, Mountain View, CA 94043
phone: (408) 773-8240 fax: (408) 773-0514 email: don@codaros.com

Pete Lilleboe
CODAR Ocean Sensors, 1914 Plymouth Street, Mountain View, CA 94043
phone: (408) 773-8240 fax: (408) 773-0514 email: pete@codaros.com

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LONG-TERM GOALS

The overall long-term goal is to develop and demonstrate the combined surface current mapping, wave monitoring, and vessel tracking capabilities of multi-static networks of compact HF radars through a NOPP-style academic-industry partnership between Rutgers University and CODAR Ocean Sensors.

OBJECTIVES

The specific objective of this project is to develop and demonstrate the capability to establish an offshore network of buoy-based HF radar transmitters that will further extend the range of shore-based HF radar systems for vessel detection.

APPROACH

A) Design and construct a solar-powered 13 MHz CODAR bistatic transmitter buoy.

B) Conduct a beach test of the buoy coupled to an existing shore-based 13 MHz CODAR transmitter/receiver pair already deployed at Rutgers' Sandy Hook HF Radar Testbed.

C) Deploy the buoy for its first sea trial offshore the Sandy Hook Testbed for a short duration of about 1 month. Augment the voluntary AIS ship data acquired at the Sandy Hook Testbed with tracks from a

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dedicated test vessel. Recover the buoy for an envisioned second round of engineering adjustments before a potential long-term deployment in 2007.

WORK COMPLETED

Previous ONR sponsored research on HF radar vessel tracking culminated in the design, construction and the initial successful sea trials of two solar-powered CODAR bistatic transmitter buoys. A compact 2 m diameter surface buoy was designed and constructed by OceanSciences to handle a dipole antenna with two 8 ft sections for a 25 MHz transmitter. A larger 40 ft long spar buoy was designed and constructed, also by OceanSciences, to handle the 110 lb, 30 ft long monopole whip required for a 5 MHz transmitter. For the 13 MHz system desired here, the 10 lb, 16 ft monopole whip is easily handled by the simpler surface buoys. The comparable size of the 25 MHz and 13 MHz antennas combined with the need for additional space for batteries to maximize uptime led us to consider candidates from the 3 m diameter class of surface buoys as the most viable choice. This corresponds to the size of standard NOAA weather buoys, easing shipboard deployment and recovery operations for a wide range of vessels, and is the largest size buoy that can be transported inside standard shipping containers.

Three designs were evaluated during the fall of 2005, the surplus NOAA weather buoys no longer in use, the Woods Hole Oceanographic Institution's Modular Ocean Buoy Environmental System (MOBES), and a custom design by OceanSciences, Inc. The added difficulty and expense of refurbishing a surplus NOAA buoy led us to request cost estimates from both the WHOI MOBES and the OceanSciences custom build. With similar cost estimates in hand, and similar functionalities, OceanSciences was chosen based on there successful construction of the previous two buoys and their proximity to CODAR Ocean Sensors.

Buoy construction at OceanSciences and electronics construction at CODAR proceeded over the ensuing winter and spring. Incorporation of a new satellite-based communication system with the buoy electronics package was considered critical for this application and included in the new design. The highest rated solar panels were acquired and tested. A larger battery bank was acquired and tested. Integration of the full system and testing in the parking lot at CODAR occurred over the summer.

Site permissions and permitting for the beach test were secured at two locations, one with simplified logistics access to Rutgers and the other with an overwater direct path between the transmitter and receiver. The sites will be used as necessary during the approximately 1 month duration beach test. An AIS receiver was acquired and installed at the Sandy Hook testbed to provide the highest resolution and longest range AIS vessel tracks possible for comparison to HF Radar vessel detections (Figure 1).

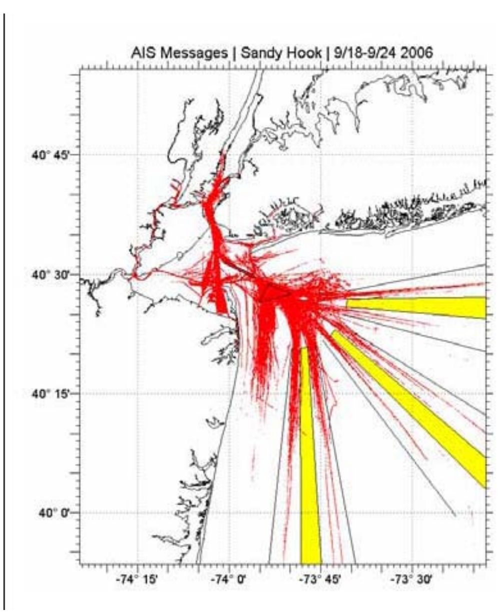

Figure 1: One week of AIS shiptracks from the Sandy Hook Testbed.

The buoy floatation collar and mooring bridle was shipped to the R/V Connecticut storage facility in preparation for deployment. The electronics box (Figure 2), solar panels, tower, and antenna was shipped to Rutgers in late September. The system was partially assembled on the back of a Rutgers flatbed truck and transported to the logistically simple beach site at the Sea Bright police station. Final assembly was completed (Figure 3).

Figure 2: Inside view of the electronics box for the bistatic transmitter buoy.

Figure 3: Bistatic transmitter with solar panels operating from the flatbed truck on beach at Sea Bright.

RESULTS

The new 13 MHz CODAR bistatic transmitter buoy was turned on at the Sea Bright Beach site on

September 21. GPS timing was set so the 13 MHz receiver would pick up the direct path from the bistatic transmitter in range cell 36. Figure 4 shows the integrated power received in each range cell for loop 1 (left), loop 2 (middle) and the monopole (right). The biggest peak is in range cell 0 associated with the collocated monostatic transmitter at Sandy Hook. The second largest peak is in range cell 36, indicating that the direct path peak associated with the Sea Bright bistatic transmitter is in the right location and the GPS timing is working. Data in range cells below 36 are the backscatter data from the

Sandy Hook transmitter. Data in range cells above 36 are the bistatic data from the Sea Bright transmitter.

A pixel plot of Doppler spectra versus frequency and range is shown in Figure 5. The direct path signal from the bistatic transmitter is the horizontal line in Range cell 36. Zero frequency is the vertical yellow line in the center of the plot. The Bragg peaks in both the backscatter and bistatic data are clearly visible. Peaks away from these are vessel detections that typically are identifed using a peak-picking algorithm that at HF is complicated by a variable background state.

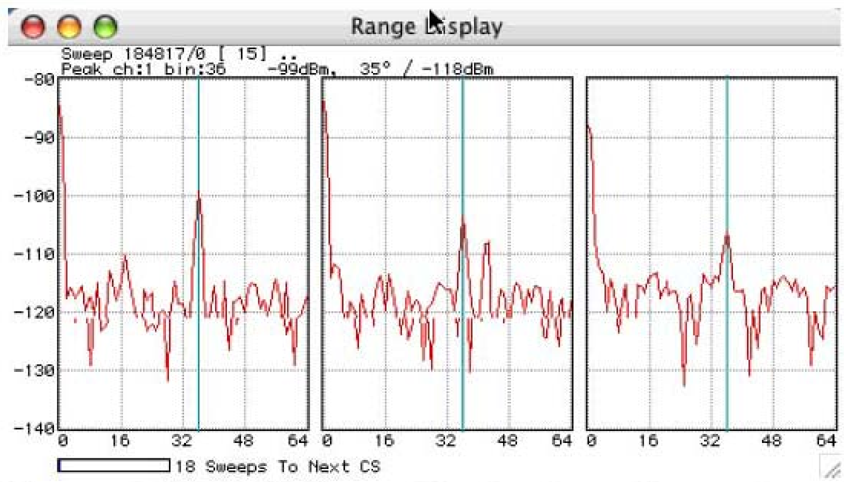

Figure 4: CODAR Range Display from the receiver at Sandy Hook showing the direct signal from SeaBright in range cell 36 in loop 1, loop 2 and the monopole.

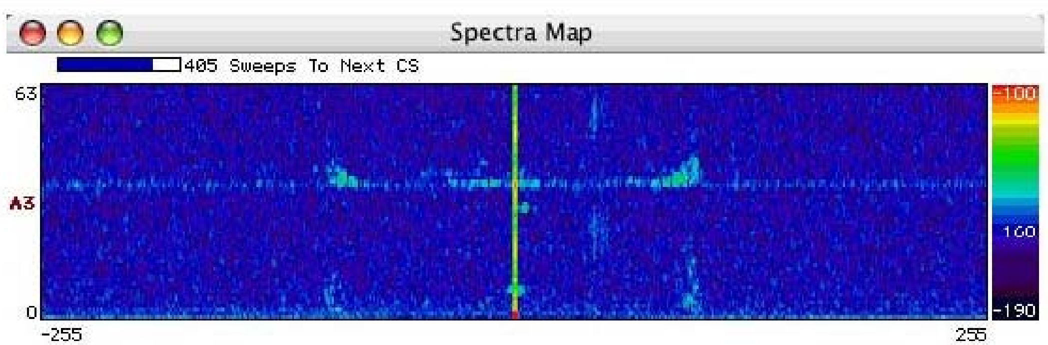

Figure 5: CODAR Doppler Spectra map for the receiver at Sandy Hook illustrating backscatter data in range cells below 36 and bistatic data in range cells above 36.

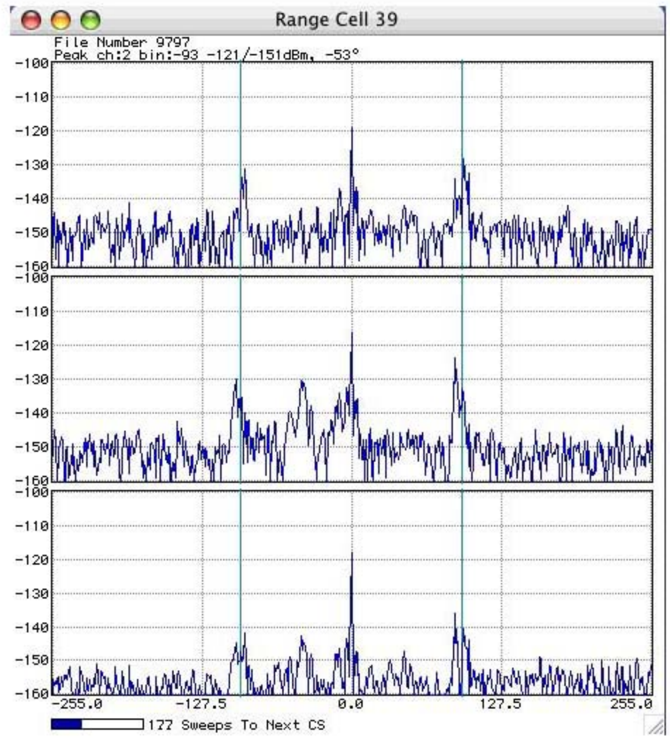

Figure 6: CODAR Doppler Spectra for loop 1, loop 2 and the monopole. A ship is observed between the zero Doppler peak and the negative Bragg peak in loop 2 and the monopole.

A plot of the bistatic spectra from range cell 39 for loop1 (top), loop 2 (middle) and the monopole is shown in Figure 6. Peaks at 0 Doppler and the positive and negative Doppler Bragg peaks associated with the surface waves as highlighted by the two blue lines. Loop 2 and the monopole both have a ship in between the zero Doppler peak and negative Doppler wave peak, indicating that the large ship in range cell 39 is directly in the look direction of the loop 2.

The beach test of the bistatic buoy will continue for about 1 month. Barring unforseen problems or weather, the offshore deployment of the full buoy system is scheduled for the week of October 23. The buoy electronics will be broken down and rigged for transport to the R/V Connecticut. The full system will be assembled and tested onshore with the boat scheduled to leave the dock Thursday, October 26. The planned deployment location is show in Figure 7, along with the backscatter coverage with a recognizable Bragg peak from Sandy Hook, and the vessel tracking data from the Sandy Hook AIS. The buoy will be deployed in between the shipping lanes so that AIS tracked vessels will pass on either side of it. The first dedicated ship tracking test will be along a straight line extending from the Sandy Hook reciever through the bistatic transmitter buoy and continuing offshore. This places the ship in the region where the maximum difference between the backscatter and bistatic radars is expected. The first ship should be over ¼ wavelength high (ship height about 18 ft or

greater) to ensure a strong scattering signal, and should travel at twice the Bragg peak wave speed (ship speed about 16 knots or greater) to ensure that it is out of both the first and second order Bragg peaks for this initial dedicated test.

IMPACT/APPLICATIONS

Two HF radar design alternatives have been proposed for a potential National HF Radar vessel tracking network, a large multi-static network of many inexpensive compact CODARs would be less expensive to build and operate, less vulnerable to countermeasures, and provide redundancies that reduced risk than a small network of expensive and large linear phased arrays. CODAR offers the dual-use advantage of leveraging off the rapidly expanding National HF radar network for surface current mapping, which is predominantly CODAR based. Compact CODAR antennas also are much more likely to be deployable in high value regions where premium waterfront real estate is often the economic engine we are trying to protect.

TRANSITIONS

The HF Radar vessel tracking work at the Sandy Hook test bed was initiated as an ONR research project in 2003. The results of that effort have led to funding from other agencies, including the DoD Counter NarcoTerrorism Project Office (CNTPO), the Department of Homeland Security (DHS), and the Regional HeadQuarters for Northern Norway (RHQNN).

Leveraging off the ONR program results, there are two methods to increase the range of vessel

detections, putting more energy on the target from the HF radar transmitter, or building a bigger receiver that gathers the scattered energy. CNTPO has funded the development and testing of a Superdirective receiver where an odd number of vertical elements are configured in a circular pattern to provide the directivity of a linear phased array but in a compact footprint that still fits on a single vertical post. The objective of the CNTPO project is to develop the superdirective capability at the Sandy Hook testbed in preparation for remote deployments in the Caribbean. This DHS project is working to put more energy on the target by moving the transmitter offshore onto a compact buoy-based system.

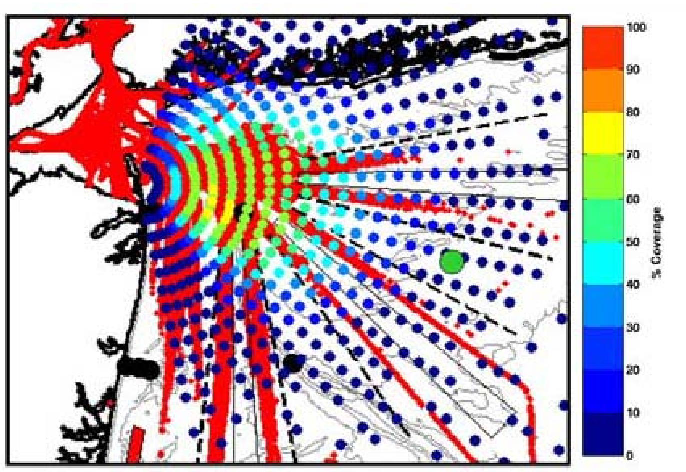

Figure 7: Proposed buoy deployment location based on the vessel tracks, the shipping lanes, and the range at which the Bragg peaks are visible in the 13 MHz CODAR at Sandy Hook.

RELATED PROJECTS

Data from the Sandy Hook HF Radar Testbed established by ONR is being shared with independently funded researchers working on improvements in vessel detection and tracking algorithms specifically for over-the-horizon HF Radar. NorthWest Research Associates (NWRA) has developed the SIFTER algorithm that decomposes the HF Radar signals into components associated with ships, background noise, and wave clutter. NWRA is using the Sandy Hook Tesbed data to determine how well they can detect vessels that pass through the wave Bragg peak, and how multiple radar sites can be combined to further refine vessel location estimates. Standard peak picking algorithms will loose all but the largest close-in vessels near the Bragg peak. An eventual operational system is likely to use both techniques of peak picking in the frequency domain and SIFTER in the time domain to provide ship detections to tracking algorithms. IFR in Norway is applying tracking algorithms to detections to determine what is now required to go from vessel detections at individual HF Radar sites to vessel tracks on the operational computer screens at RHQNN.

Offshore Power Technologies (OPT), a small business in New Jersey, is separately funded by DHS to develop wave power generation buoys for homeland security applications. The smaller OPT spar buoy currently generates about 120 Watts of power in Seastate 2-3. The CODAR HF Radar transmitter that is being deployed on the solar power buoy in this project draws about 80 Watts. The combination of solar and wave generation systems that could be deployed on the smaller OPT spar buoy along with a CODAR bistatic transmitter is a candidate design for an operational system.