# *Evaluation of Three Antenna Pattern Measurements for a 25 MHz SeaSonde*

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*Abstract* – **The need for reliable surface current measurements from the SeaSonde high-frequency radar network is essential for Coast Guard search and rescue missions, oil spill mapping, and algal bloom tracking. To ensure the advancement of accurate surface current maps, antenna calibrations need to be performed to correct for bearing errors at the radial level. Due to environmental interference, three different antenna pattern measurements were performed at a 25 MHz radar site located in Staten Island, NY (SILD). Spectra taken over a three-day period starting from Oct. 15, 2014 were reprocessed using the different pattern methods and analyzed with the ideal radial measurements from the same time period at three separate bearing locations 9 km offshore in the New York Harbor.**

*Index Terms* – **HF (high-frequency) radar, antenna pattern measurements, SeaSonde**

## I. INTRODUCTION

Antenna calibrations play a major role in correcting for bearing errors. At the radial level, bearing errors result from several known factors such as limitations resulting from noise and interference in the received signals, distortions in the antenna sensitivity patterns, limitations in the signal processing methods, and limitations in the frequency resolution [1]. This paper focuses on pattern sensitivity by analyzing different antenna pattern calibration methods.

Two 25 MHz direction-finding CODAR (Coastal Ocean Dynamics Applications Radar) systems are located in Port Monmouth, NJ and Staten Island, NY that measure surface currents within the New York Harbor. Each of these high-frequency radars within the network measure the scattered return radio signal off of a 6-meter-long surface gravity wave [2] and produce hourly radial maps of current velocities. When hourly radial files are inputted into the totals processing, a high-resolution (1-km range bin) current map is produced to get a velocity and directional component of the surface currents. Since there is no third high-frequency radar site operating within the harbor, it is important that the radial field from each site is as accurate as possible.

Three different antenna pattern calibrations were performed for the 25 MHz high-frequency radar site in Staten Island, NY. The first pattern generated from the site was processed through new software that takes AIS information and creates TRAK files to be inputted into the AIS-pattern generation algorithm. In order to measure an accurate pattern, the AIS system on site must run for an average of a few days. Daily loop files are created that are then processed through the application CrossLoopPatterner. Based on the file sizes, more than one loop file can be processed at one time. Through the AIS filter tab in CrossLoopPatterner, the loop files can be refined by altering the local and IIR signal to noise values, bearing hits, Doppler width, range width, and time of day.

The second and last antenna calibrations that were completed were walking and boat patterns, respectively. Both of these antenna pattern measurements are still much more common than AIS-generated patterns and are used for many CODAR sites. These calibrations are accomplished by completing a semi-circle path (equidistant) around the receive antenna with a small battery-operated transponder [3]. The magnified signal from the transponder is echoed off the surface gravity wave (typically between range cells 8-10) for each bearing value, which is every 5 degrees. In both the walking and boat patterns, one loop file is processed with the CrossLoopPatterner application and implemented in the configurations folder.

We examine all three of the discussed antenna calibration methods and analyze the quality of the radial and surface current data. The purpose of this examination is to determine limitations and accuracy of each pattern method. Future work includes combining different pattern calibration methods to limit bearing errors at the radial level, while increasing measured radial coverage.

## II. METHODS

Pattern measurements were conducted for the 25 MHz CODAR site SILD. The pattern calibrations were performed and processed within less than two weeks of each other. The dates of the antenna pattern calibrations are displayed in table 1. No changes to the hardware or processing parameters were made during the duration between pattern calibrations.

Spectra files were reprocessed with each pattern between October 15, 2014 and October 18, 2014 with no changes in the first order line settings. Reprocessing was accomplished with an offline batch-reprocessing application written by CODAR Ocean Sensors [4]. The app outputs a folder containing the configuration settings and radial files.

| Pattern Method | Date |
|---|---|
| Walking | August 26, 2014 |
| Boat | August 28, 2014 |
| AIS | August 20, 2014 |

Table 1. Dates when pattern calibrations were conducted.

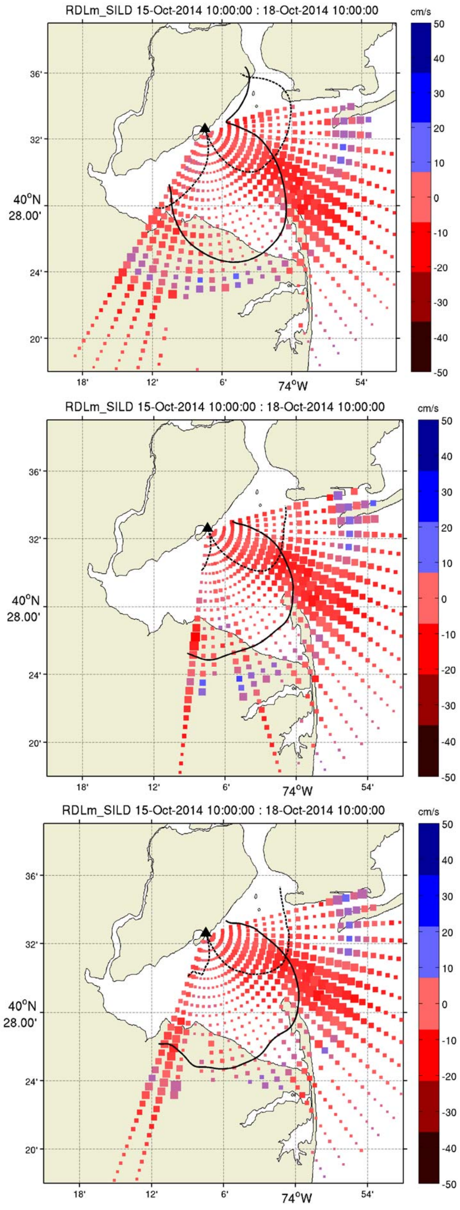

Figure 1. From top to bottom - patterns measured for 25 MHz CODAR SILD by walking, boat, and AIS, respectively averaged over 3-day examination period.

Figure 1 shows the processed patterns overlaid on top of an averaged radial velocity plot with an applied standard deviation. The color bar indicates whether the surface current is moving towards (blue) or away (red) from the radar and the size of the icon signifies the standard deviation value (large dot means higher standard deviation). Some locations within the channel will inevitably have higher standard deviation values with the M2 tide.

Three bearing locations were chosen 9-km offshore as a way of comparing temporal variability between each pattern method. The bearings chosen for the examination were 102, 132, and 167 (degrees true) with respect to the antenna location. Figure 2 shows the site and bearing locations within the harbor.

The bearing of loop 1 (loop 2 null) is 167 degrees, which was one of the bearings chosen for this study. A bearing of 132 degrees is nearly perpendicular to the coastline and is also close to where loop 1 and loop 2 intersect. The last bearing of 102 degrees was chosen because of the higher current velocity shifts in that area from the M2 tidal constituent. Range cell 9 was selected because the Bragg starts to split after range cell 10 and first order processing can be challenging, which would make it difficult to compare antenna pattern measurement methods.

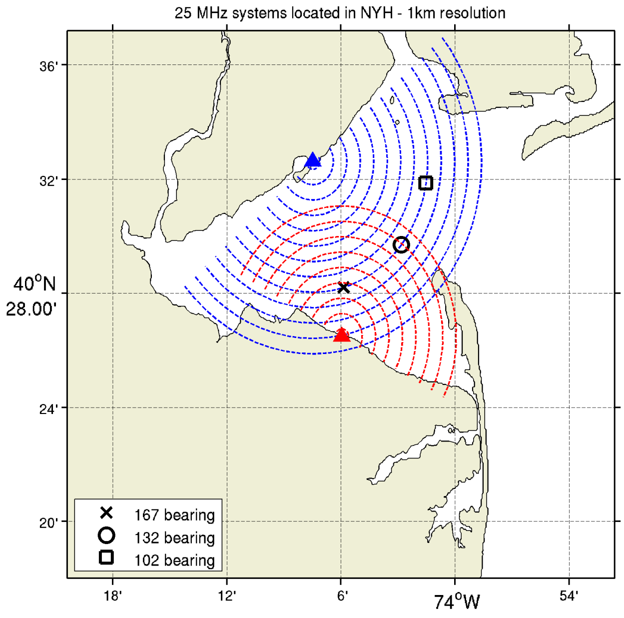

Figure 2 Location of the two 25 MHz site locations (blue - SILD, red - PORT) and bearings chosen 9-km offshore for the examination.

Radial velocities for each bearing were compared with the ideal measurements for each hour over the 3-day examination period. Correlation values were calculated between each pattern method and the ideal radial measurements. Surface current maps were then created with each pattern with the Port Monmouth 25 MHz CODAR site.

## III. RESULTS

The radial velocities for each of the selected bearings within each pattern method were analyzed over the 3-day time period. No averaging was done since we are comparing hourly velocity measurements for each hourly radial file. Figure 3 shows the hourly radial measurements for bearings 102, 132, and 167. The variation in radial velocities differ greatly in the 167 bearing bin, which is related to the flow of the current and the radar's inability to depict a clear Doppler shift at that location. For a majority of the time-span, the radial velocities did not differ much at bearing locations 102 and 132, with the exception of a few outliers, which are evident mostly in the AIS-generated pattern.

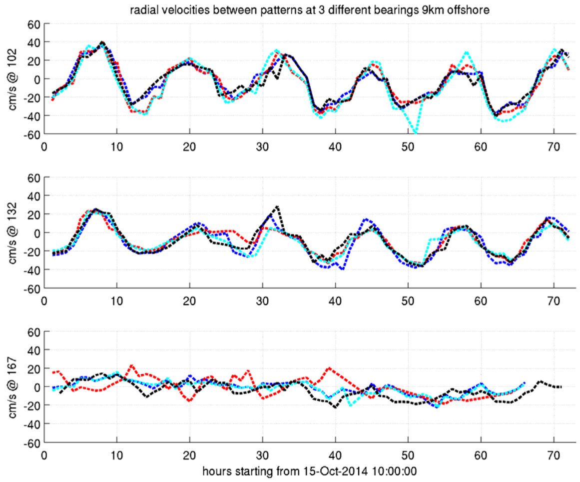

Figure 3. Radial velocities for each pattern (blue - walking, red - boat, cyan – AIS, black - ideal) at 3 different bearings.

Table 2 shows the associated correlation values (r) comparing each measured hourly measured radial velocity component with the ideal measurements at each bearing. The highest correlation was witnessed with the walking pattern measurement at 0.96 with a bearing of 102, 9-km offshore. The least amount of variation in the correlation values was seen in the 132 degree bearing location, which is nearly perpendicular to the coastline. The correlation values decreased by more than 20% for the walking and AIS patterns for the radial measurements recorded at 167 degrees. The boat pattern experienced a significant drop to the point where there is a slight negative correlation of 0.14. This bearing location is very close to the baseline between the two New York Harbor sites, which can validate the drop in correlation.

Figure 4 shows the correlation between the hourly radial velocities for each pattern at each bearing location with the ideal hourly radial velocity components. Each pattern showed a strong correlation with the ideal measurements at bearing locations 102 and 132, but the correlation drops for bearing 167. The walking and AIS antenna pattern measurements show a significant decline in correlation but the most notable is the boat-generated pattern, which actually shows a negative correlation.

| Bearing | Walking | Boat | AIS |
|---|---|---|---|
| **102** | 0.96 | 0.90 | 0.89 |
| **132** | 0.90 | 0.92 | 0.91 |
| **167** | 0.73 | -0.14 | 0.70 |

Table 2. Correlation coefficients between measured and ideal radial velocities.

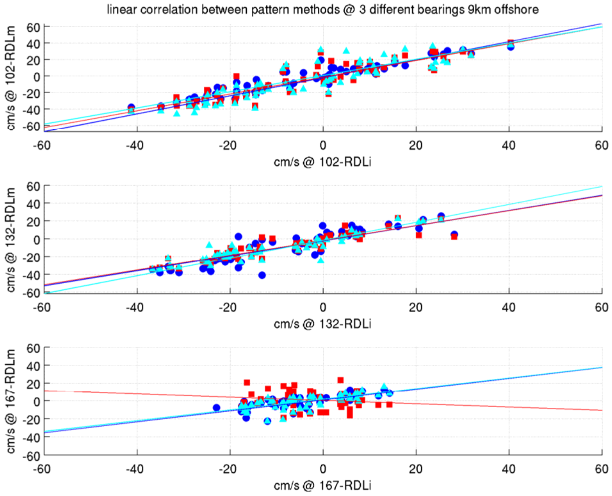

Figure 4. Correlation between ideal (x-axis) and measured (y-axis) radial velocities at each hour for different patterns (blue - walking, red - boat, cyan- AIS).

Figure 5 shows the 24-hourly averaged surface current maps between Oct 16, 2014 at 10:00 GMT and Oct 17, 2014 at 10:00 GMT. The spatial variability of the surface currents for each pattern differs minimally for each pattern method combined with the measured radials measured from PORT (Port Monmouth, NJ). On a temporal scale, there is small variability at bearings 102 and 132 (localized more in the center of the channel). Bearing 167 (max. of loop 1) shows a larger variance in the surface current velocities with respect to time. Without a third New York Harbor site operating at 25 MHz, baseline biases are inevitable which is near the location of the 167 bearing location. Rutgers is currently operating mobile test runs for a third 25 MHz radar site.

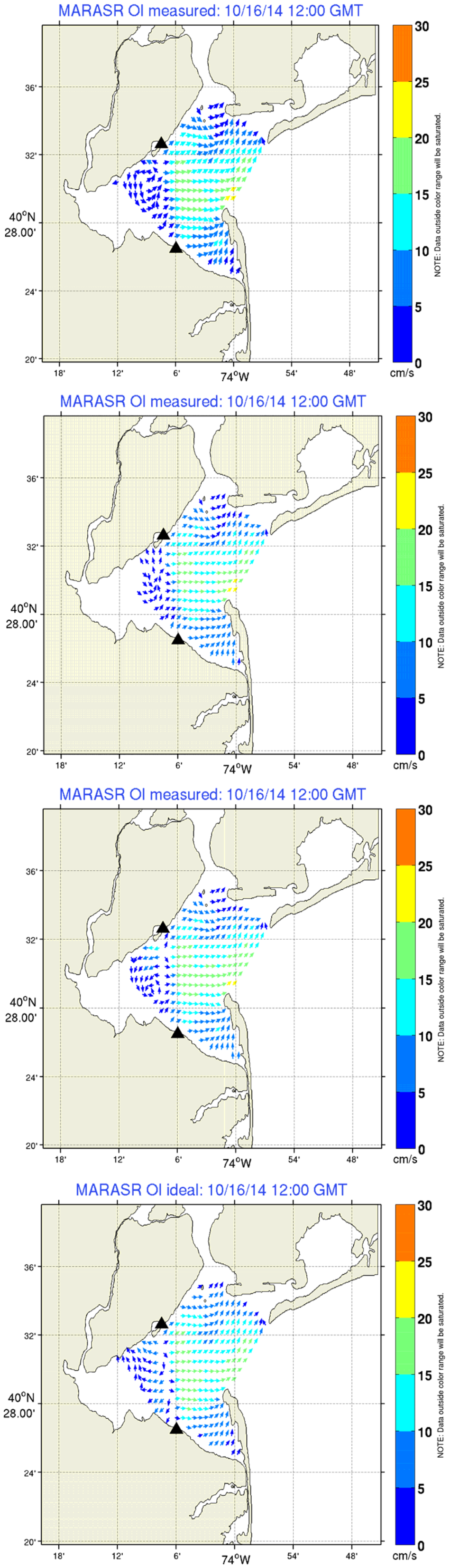

Figure 5. From top to bottom: Surface currents measured with walking, boat, AIS, and ideal patterns.

## IV. CONCLUSIONS

Three different pattern calibration methods were examined for a 25 MHz CODAR system. The calibrations were performed with no changes in the hardware or spectra processing parameters. The correlation between ideal radial velocities and measured radial velocities was strong in the middle of the channel (bearing values of 102 and 132) with the lowest correlation being 0.89, seen in the AIS-generated pattern.

However, the correlation weakened at bearing 167. This bearing lies nearly along the baseline between the two 25 MHz systems, which proves to be challenging in depicting surface currents with two radar stations within the network as discussed in [5].

Measured radial coverage decreased most with the boat pattern, mostly due to our inability to complete a full semi-circle path with the shallow bathymetry. Radial and total coverage differed minimally between the walking and AIS-generated patterns. Further research includes combining different pattern methods to improve both coverage and surface current accuracy.

## ACKNOWLEDGEMENTS

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