Benefits of Multiple Antenna Pattern Measurement Methods for Maintaining a Regional HF Radar Network

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1. Introduction

CODAR Ocean Sensors (CODAR) operates and maintains 17 SeaSonde HF Radar (HFR) stations in the Central and Northern California Ocean Observing System (CeNCOOS) network. The data from this network are used for search and rescue, spill response and scientific study, among others. A key responsibility for maintaining the quality of the surface current outputs is to provide updated antenna pattern measurements (APMs) for all stations as needed and no less often than once per year. HFR antenna systems, whether compact cross loop like the SeaSonde or others such as phased arrays, have an "ideal" or "textbook" receive pattern based on the directional characteristics of the antennas employed that is used to determine the direction of arrival of Doppler-shifted sea echo. At HF wavelengths, however, antennas can interact strongly with conductive or ferromagnetic materials within tens of meters either above or below ground. These interactions alter the real world antenna response characteristics from the ideal in a manner and degree that is unique to each site. While not required for HFR to produce currents, APMs have been shown to improve the quality of radial surface currents by more accurately determining the direction of arrival of sea echo[1][2][3][4]. It is now such a standard practice that it is listed in the HFRNet best practices guide for HFR operators providing data to NOAA IOOS[5]. The broad range of HFR site conditions in the CeNCOOS network from San Francisco Bay to the Big Sur coast includes variations in station electromagnetic characteristics, technician and boat accessibility, terrain, and activity regulations. Having a suite of available APM methods provides CODAR a more effective approach to performing antenna pattern monitoring and measuring.

2. Methods for Measuring Patterns

All methods for measuring antenna patterns involve receiving a signal from a source or sources located at positions across the range of bearings from which sea echo will arrive. The antenna system response at all bearings, typically with a resolution of 1 – 5 degrees, constitutes the antenna pattern. The following methods each have their own advantages and limitations.

2.1 Transponder

In the 1980's, CODAR recognized the utility of measuring antenna patterns and designed a transponder for FMCW systems[1]. The transponder can be programmed to precisely alter the FMCW signal received from a nearby HFR transmission and rebroadcast it at very low power so that it can be received and processed by the HFR system such that the signal remains stable in range and Doppler for tracking. The transponder can be placed on a boat with the boat traveling in an arc around the receive antenna, usually at a distance of 500m – 2 km[4][6]. It can also be carried by hand if there is more than a wavelength between the antenna and the footpath. The transponder has even been carried by helicopter in one case. This has been the standard method for APM's for the last 20 years. This method is limited by the ability to navigate a small vessel around the antenna due to sea state or coastal characteristics such as rocks and shallow water. Many sites do not have enough land between antenna and ocean to perform a "walking" APM.

2.2 AutoAPM (AIS)

Originally developed under a NOAA Small Business Innovative Research (SBIR) award in collaboration with UCSB, AIS AutoAPM software is now installed on all stations in the CeNCOOS network (over 100 worldwide) to exploit surface vessel echoes in the Doppler spectra as far field sources with AIS positions providing the associated bearings[7][8]. With these tools, CeNCOOS technicians can monitor for changes in the antenna pattern response remotely. Antenna pattern data is collected and processed with each passing vessel. At intervals chosen by the user, this data can be processed into a measured pattern for use in real-time processing. In situations where the local vessel routes allow, new complete antenna patterns can be produced from this method alone. At stations where the vessel traffic conditions do not provide a continuous level of data at all bearings, other methods can be used to complete the pattern. CODAR's second generation of AutoAPM software now has the capability of testing the performance of the measured pattern used in real-time processing against new vessel echoes and positions to determine if a new pattern is required and creates a new pattern for the user to evaluate.

2.3 Aerial Drone (Quadcopter)

An emerging approach for APMs employs small aerial drones[9]. Engineers at the University of California, Santa Barbara (UCSB) have developed an APM technique using a programmable quadcopter that allows a single technician to visit an HFR station and measure an antenna pattern without putting a vessel in the water, saving both time and money. UCSB has developed their own lightweight signal source that is suspended below the quadcopter and flown in an arc at a distance of a few hundred meters from the antenna. This has the advantage of not requiring a boat, not being subject to sea state or bathymetric issues, but use may be limited in areas with drone restrictions, crowded beaches, close proximity to other aircraft or licensing/insurance issues. Also, optimal height of the drone for best approximating surface wave signals from beyond the horizon is still under investigation.

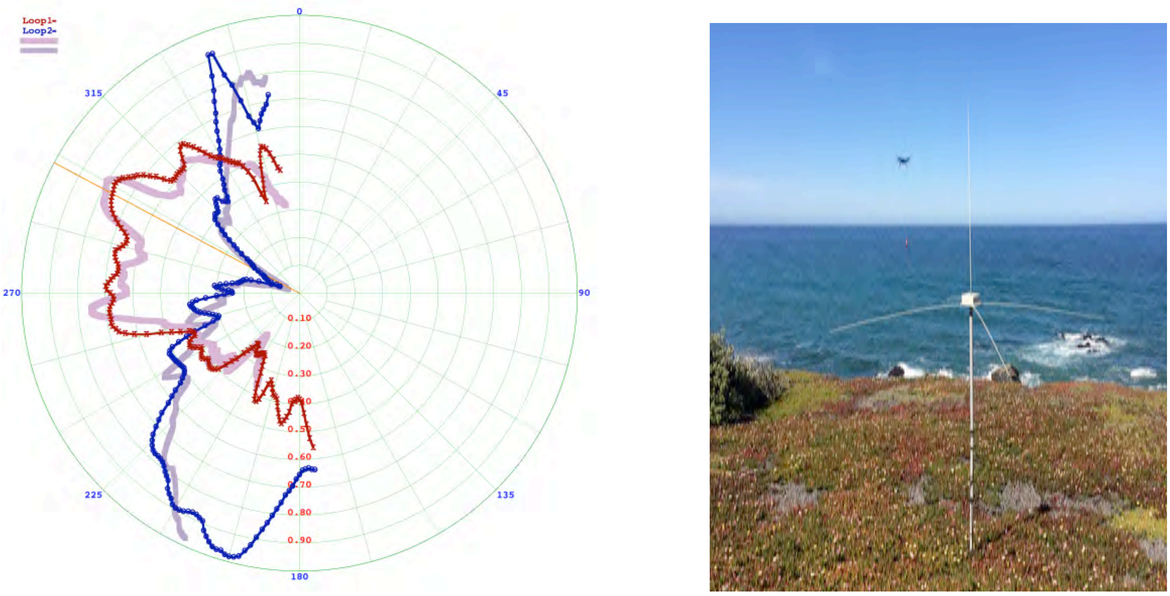

Figure 1: Antenna pattern from drone in red and blue plotted overtop transponder pattern (left) and drone flying in front of SeaSonde receive antenna (right)

3. Summary

Each of the above measurement methods has advantages and limitations. As an HFR network size increases, so do the variety of site conditions.

Having a variety of pattern measurement techniques at the operators' disposal is important to manage Quality Assurance (QA) of the outputs. The advantage of the different methods will be discussed and patterns measured at the same site with different methods will be compared, as shown in Figure 1.

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