How CODAR Deals with Interference

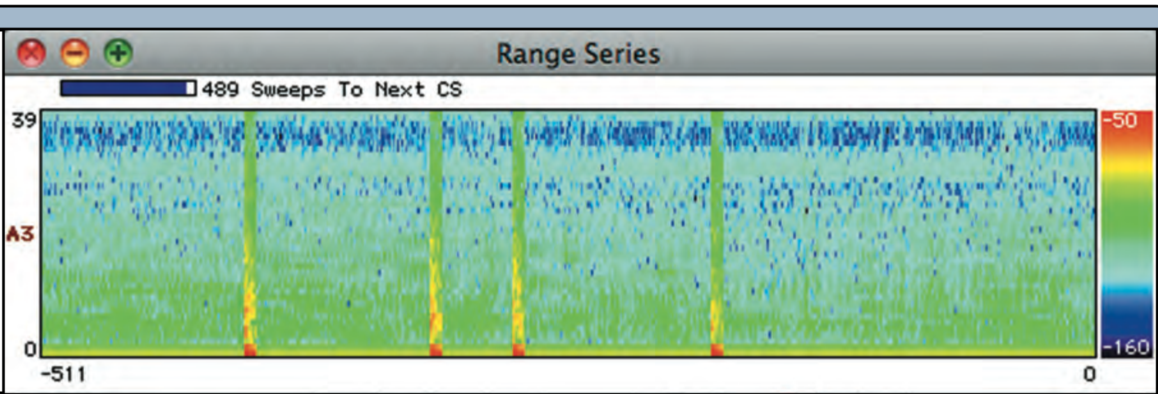
Every radar must detect target echoes against a background of unwanted noise. In our case, desired echoes may be first-order Bragg scatter (from which we get current and tsunami information); second-order (from which sea state is obtained); or ship echoes. Normal background in microwave radars is "white" Gaussian noise. White means that -- in the absence of echoes -- it is flat in frequency space. Much of the time at HF we see and deal effectively with Gaussian noise. However, all too often we see much more. Because HF radar is our only business at CODAR, we stay on top of it. Our science team has developed special, effective methods to deal with this additional unwanted background, which we refer to as interference. We review all four of them here:

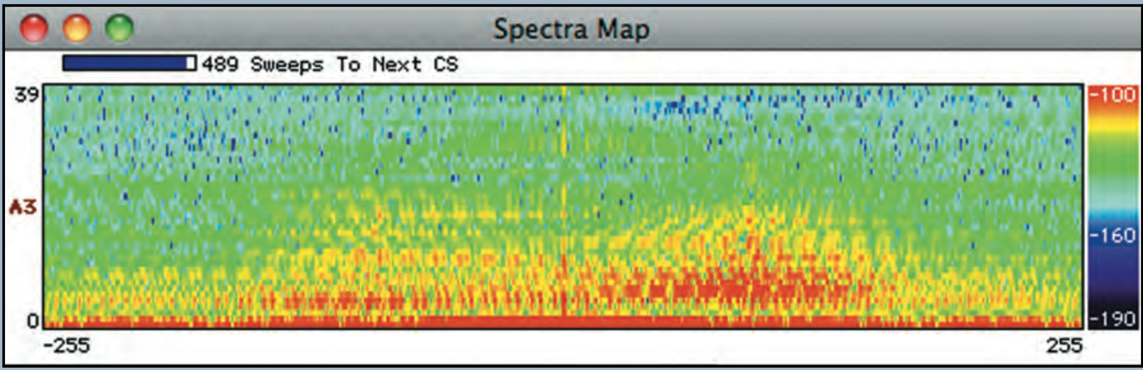
Ship-Type Echo Removal: Ship velocities span the same Doppler region as sea echoes. When present, they interfere with accurate sea-surface information extraction. Over 25 years ago, we developed an algorithm to detect and get rid of ship-type echoes. It is based on the fact that a ship with given radial velocity stays in a given Doppler bin only for a predictable period of time, based on the size of the range cell and the radar frequency. If a "blip" suddenly appears in Doppler spectral bins of interest, we test for these properties: does it stay in the bins for the correct time, or for much longer? If the former, then those bins get withheld. If much longer, then we conclude that the background has risen to a new level, and we must live with it, not withhold it or the data will get unacceptably stale. In that case, normal white Gaussian noise thresholding methods are applied. This algorithm has been used successfully well over two decades, yielding good current and wave data that are not contaminated by outliers due to these frequent "ships passing in the night" (or similar types of longer-duration interferers).
Time scale for ship-type echo interference: Several minutes.

Ionospheric-Type Echo Rejection: When our lower-frequency radars began seeing beyond 90 km about 12 years ago, we faced another nuisance. Echoes from the ionosphere directly overhead spanning from 90 km - 300 km might be seen at certain times of the day and night. These layers of charged particles ionized by the daytime sun act like a mirror. Often (but not always) they are restricted to two or three range cells, but they can be spread over many Doppler bins because the ionosphere is in motion. We developed an algorithm to find and excise this type of interference. It has been optimized by over a decade of experience. The algorithm knows what to look for, and simply removes all data from the offending range cell and Doppler bins. Often this is necessary only on one side of the positive/negative Doppler span (which fortunately contain redundant current and wave information), so that a range gap does not always occur. Without this algorithm, obviously wild "current" vectors would have appeared, spread in angle across the entire range cell -- an unacceptable contamination.
Time scale ionospheric-type echo interference: Half hour to two hours.

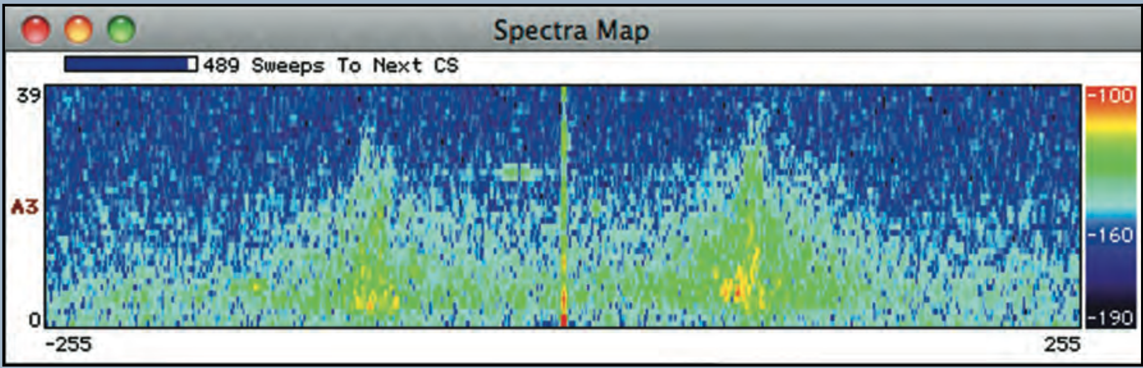
Impulse Removal: Much external noise seen at HF comes from the atmosphere: thunderstorms worldwide generate radio noise that originate far away. Typically 2000 thunderstorms are active in the world at any given time, producing 100 lightning strikes per second. When these lightning sources are distant, they add up to a noise that looks continuous and Gaussian. Those closer to the radar are impulsive in nature, and Gaussian methodologies no longer work in this case. A single blast from a nearby strike can ruin an entire Doppler spectrum collected over several minutes, even though the impulse duration is only a millisecond. Some time ago CODAR developed and optimized an impulse detector, done after range processing before Doppler processing (typically every 0.5 - 1 second). When it detects a burst exceeding a preset threshold above the background, it excises that time sample and replaces it with an interpolated value across this gap. An example of "before and after" is shown below for West Florida, which is "thunderstorm alley" among our U.S.-based SeaSondes and was used in this development. This technique can reduce impulsive background interference as much as 15-20 dB when storms are nearby.
Time scale for impulse noise interference: Less than a second.

Plot of signal strength (color) vs. time (horizontal axis) and range (vertical axis) showing four lightning/impulsive interference bursts over 256 seconds.





Sea-echo Doppler spectrum contaminated by the impulse bursts shown in prior time series.



Acceptable sea-echo Doppler spectrum after excision of impulses in first time-series panel.

- **Radio Station Interference Rejection:** The HF band has been used historically for radio communication and broadcasting -- HF radar is a newcomer to the this frequency region. Although radio broadcasters as well as radars have frequency licenses, all too often distant radio stations interfere with us. These may be radiating illegally, or may result from unavoidable duplication of authorizations on the same channel because of the scarcity of separate spectral spaces for everyone. Usually the signals that interfere with us are propagated by skywave (purposely reflecting from the ionosphere), because this is where HF excels for radio broadcasters by reaching great distances. They therefore adjust their frequency throughout the day to take advantage of the best propagation conditions. As a result, when we hear radio interference, it typically may last for a couple hours before the broadcaster moves on to a more favorable frequency. With the FMCW modulation that we all use, these interfering radio signals appear spread in range but confined in Doppler. Therefore, they can at times look like a Bragg peak, second order echoes, or mask a ship while appearing like a ship echo themselves. However, based on their range-spread nature, we can identify and deal with them. This is done by recognizing that -- because of our I/Q processing -- radar echoes are seen only for "positive" range cells, while interference bands appear symmetrically at both positive and negative ranges. Unlike others, we don't simply subtract all negative from positive cells, for this too often actually increases other types of background interference. We do a careful search for the expected patterns of this radio-signal interference, subtracting just that portion, but only if it exceeds a threshold based on background levels and expected I/Q balances. Check out the example below to observe how effective this can be, when done properly.

Time scale for radio signal interference: A broadcaster may use a given frequency for two-three hours. The interfering constant-range bands will move in Doppler spectral position every processing period (e.g., 4 - 17 minutes).

Color spectral plot on left shows significant vertical interference stripes over range, with radial velocity from the Doppler spectral shift as the horizontal axis, for the three antennas of the 13 MHz SeaSonde at Nordoy in Norway. Plot on right shows same spectra using suppression method described here. The first and second order Bragg areas are seen more clearly, and several ship echoes are uncovered when this interference is excised. The very top of the right plots purposely retains interference levels before removal for reference.