Ocean Wave Measurements with Coherent Marine Radars using VV Polarization

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Wave measurements have traditionally been done by point sensors, where estimates of the sea state and energy distribution for both directional and non-directional waves are estimated for a fixed point on the sea surface. Standard technics include a wide range of sensors which are either following the sea surface, such as wave following buoys measuring acceleration and orientation, or mounted subsurface while measuring pressure, distance to surface, and velocity. The majority of sensors measure one or more wave property and the information is then processed to estimate the sought after statistical wave parameters such as wave height, period, direction, etc. It would be fair to say, that with good calibration and an understanding of the measurements limits, these sensors generate accurate wave estimates. Many are now standard and serve as the reference for further work in measuring and understanding ocean waves.

Standard marine navigation radars (X-band) offer a different type of information through the imaging of the sea clutter, which is modulated by the surface waves and provides a spatial image of the wave field. Dark areas in the images correspond to wave troughs and the lighter areas correspond to wave crests. From this, it is straightforward to estimate wave length and wave direction. Wave period can be calculated by correlating a series of images that are collected with a constant time lag (rotating antenna). However, estimating the wave energy from these amplitude modulated images is possible only if one can establish the relationship between wave height and the variations in the backscattered echo. In practice, this requires sophisticated calibration procedures that cover a wide range of wave and wind conditions before it can provide results with an acceptable accuracy. This again leads to long and costly installation procedure where data both from the radar and from reference instrumentation is required in order to calibrate the specific radar at its local position and under all dominant weather conditions. Clearly, these practical aspects hinders the broad application of marine radars for wave height measurements and it would be of real benefit to find a solution that does not require complex calibration and more specifically, one that can directly measure wave properties that directly relate to wave height or the wave energy distribution.

“Coherent” is a collective description for systems that measure the phase information in signals and not only signal strength, which is what we see in the ship bridge displays. The term “coherent” actually describes a property of the radar transmitter because phase shifts can be accurately estimated only if we know the exact time when each electro-magnetic pulse is transmitted. If we can access phase information in the signal we can also measure phase change, which again leads to Doppler shift and thus velocity. Coherent radar provides both backscatter intensity and radial surface velocities. The velocities are estimated with broadband

Doppler processing applied to a series of successive, coded pulses. The ability to perform this calculation is permitted by the coherent hardware, which has accurate control over the timing of the transmit pulses. Coherent radars performing Doppler measurements is well established for military, air traffic, and weather applications but it is relatively new for the purposes of ocean wave measurements. This is especially true for digital system that can collect all the raw velocity data.

The road from radial velocities to an estimate of wave height (bearing in mind that all other interesting wave parameters can already be estimated from the images of radar echo strength) goes through the dispersion relationship, which effectively acts as a filter to remove noise, whatever the source may be. In other words, only velocities that behave in a way that is consistent with the propagation behavior of ocean waves are considered when accumulating the spectral wave energy over all propagation directions.

Initial tests by Image Science Research (ISR), who has pioneered wave measurements with coherent radars, showed the ability to estimate non-directional wave energy Hm0 reasonably well over wave heights from 0 to 4 m but the system broke down for larger waves. In a later set of tests, it turned out that modifying the antenna polarization from horizontal to vertical improved the performance and reduced the scatter between estimates and ground truth. When Hurricane Irene passed the demonstration site in 2011, the ability to estimate Hm0 up to through the peak of the storm agreed well with other field sensors over the three-day test period.

The next step in the current NFR project is to analyze the results from a planned field study off the coast of Norway. A coherent radar will be installed late 2013 off the West Coast of Norway (exact site yet to be determined) and collect data both during storm and non-storm events. As reference data we will use the AWAC, a Nortek directional wave system that is installed subsurface. In parallel, existing data collected at the Duck Research pier will be analyzed in detail to generate a more complete understanding of the characteristics of the radar measurements. This work should derive a functional description of expected the accuracy as a function of wave and environmental conditions. More specifically, we are interested in understanding exactly what the coherent radar is measuring and how the spatial velocity data is modulated by the scattering properties of the waves at varying incident angle.

If successful, we expect the coherent radar to be a good tool for wave studies related to horizontal wave propagation. We also expect the system to be of utility in areas where buoys or subsurface sensors cannot be installed or are impractical.