Why wait for the seventh wave?

The Royal Netherlands Navy, NLR (the Dutch Aerospace Laboratory), RADAC, Amarcon/ABB and MARIN joined in the 'Salute' project to work out a demonstrator system to anticipate quiescent periods for helicopter landing operations. And now the new 'DoIT' JIP aims to turn the system into a product.

Jos Koning, j.koning@marin.nl

Surfers choose the next wave to ride by waiting for the seventh one after the previous best wave. In working environments the objective is often to await a set of low waves to perform a motion critical operation. It would be perfect for such applications to have an automatic and accurate prediction of the approaching wave train based on measurements.

Recent commercial systems can make one-minute, deterministic wave train predictions using sea clutter information from standard pulse type navigation radars. However, continuous tuning is needed. The Salute project aimed to demonstrate the merits of Frequency Modulated Continuous Wave (FMCW) radar technology that enables direct physical measurements of wave elevations in addition to the well-known features of pulse type radars.

Deterministic wave train The MARIN focus was on the inversion of the radar information into a deterministic wave train, as well as the validation of the performance of the FMCW system and a stereo photographic approach for nearby waves.

FMCW technology enables the derivation of surface velocity as a function of distance to the radar antenna in small grid cells. The velocity profile of the wave surface captured in the radar beam is the combination of ship sailing speed, surface current and orbital wave velocity. Orbital wave velocity is directly related to wave height; ship speed through water is known; so in principle just 'one small step ...' is needed. Of course, real world systems are more complicated. Electronics have noise floors, interference from regular ship radars is present, wave crests obscure the radar view into the valleys behind them, signal strengths drop quickly with range and there is also the effect of white capping. The proper performance of the method for deriving the surface speed, versus range was considered essential. Therefore, the demonstrator was configured as a non-revolving or 'staring' FMCW unit. In this way the quality and performance of the captured data could be thoroughly assessed along the steps in the algorithms, although this was at the cost of detailed directional information.

The processing algorithm included a 'valid data selection' step followed by a 'wave model inversion' step, and an 'extrapolation' in time and location to the point where waves were to be predicted. The process is continuous. Data from each new step is added to the previous dataset, while older data is discarded.

Two validation campaigns The system was verified in two validation campaigns. The first was done from a stationary location at Scheveningen Pier in the Netherlands. These recordings already showed good results for individual wave crests but could not be compared to a theoretical wave model because of complicated behaviour of waves shoaling and breaking in the surf zone.

Open water tests were then done on board Royal Netherlands Navy Zr. Ms. Karel Doorman off the coast of IJmuiden around a permanently moored wave rider buoy. Tested conditions included zero-, five- and ten-knot speeds in up and downwind directions. Comparisons between the results of the FMCW system, the wave rider buoy, on board down looking radars and stereo photographic data confirmed the ability of both the FMCW and the stereo photographic systems to capture remote wave elevation maps deterministically. The results clearly showed the proper handling of signal to noise ratio and shadowing at longer ranges. The wave inversion and wave propagation models dealt with the data gaps by relying on the clear crests around them.

Operational efficiency Longer range radar observations made it possible to capture waves inside the propagation window and predict them some distance outside of it. The short-range stereo imagery approach was found to be accurate only inside the observation window. The accuracy of the extrapolated, wave model typically relies on the extent of the observed data in time and space. A long observation period in a short range can provide good statistics and spectra. A wide spatial window is also needed to provide enough information for a wave propagation model.

The new DoIT JIP combines FMCW radar concepts with proven wave sensing technology in a prototype system. The objectives are to implement deterministic wave feed forward for offshore operations and short range ride control for small craft. Having the ability to anticipate wave trains will ultimately help make operations more efficient.