The Use of HF Radar for Resource Assessment

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Motivation

Commercial development of the generation of renewable energy in the marine environment (MRE) will be predicated on the implementation of reliable methods for the assessment of the in situ energy resource. The most commonly utilised methods for assessments of the wave and current fields currently involves the deployment of in situ sensors. While the deployment of such instrumentation has a long pedigree and has led to numerous advancements in oceanography, there are significant shortcomings associated with the use of in situ instrumentation for resource characterisation related to MRE. Operationally, deployment and maintenance costs are high and reliability is low. Technically, the information is spatially constrained and, as relates to the horizontal plain, typically only provides point measurements. The identification of reliable measurement systems which overcome these limitations will act as an accelerator for the development of MRE.

BACKGROUND

HF (High Frequency) radar in a beam forming configuration holds the potential to provide one such solution for resource assessment and monitoring of both currents and waves. In order to evaluate this application, a WERA HF radar system has been recently installed on the North Coast of Cornwall in the UK to provide measurements of surface currents as well as complete directional wave spectra in a high resolution (1 km spacing) grid around the Wave Hub site (Figure 1,2 & 3).

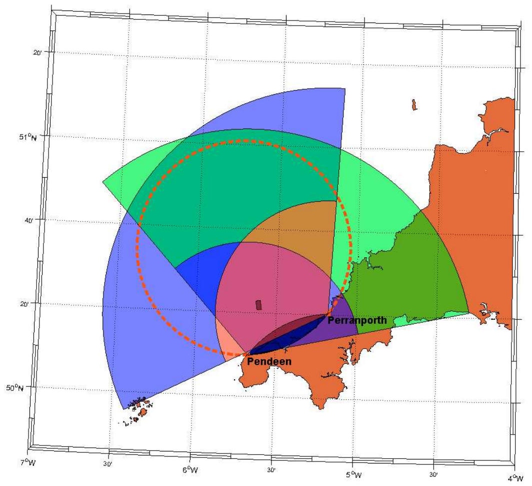


Figure 1: HF radar coverage map for Wave Hub site. Each station covers a 120 degree sector and surface velocity measurements are available for full range of sector while directional wave measurements can be obtained from inner region.

SENSOR CHARACTERISTICS

Figure 2: Photo of the receive antenna near Pendeen Light House on the western extent of Cornwall. Sixteen individual antenna elements are visible as well as the lab for the system electronics.

Figure 3: The Pendeen transmit antenna has 4 elements which operate as a phased array. Sensitive receive arrays permit very low transmit antenna operating power (15 Watts typical).

HF radar is based on Bragg scattering (Figure 4) off of surface gravity waves with half the wave length of the radar carrier wave. The strong returns derived from this Bragg scattering should be detected at a known Doppler phase shift related to the scatterer's phase velocity which is readily available from linear theory (Figure 5). Deviations from the expected Doppler shift are interpreted as additional radial currents (Figure 6).

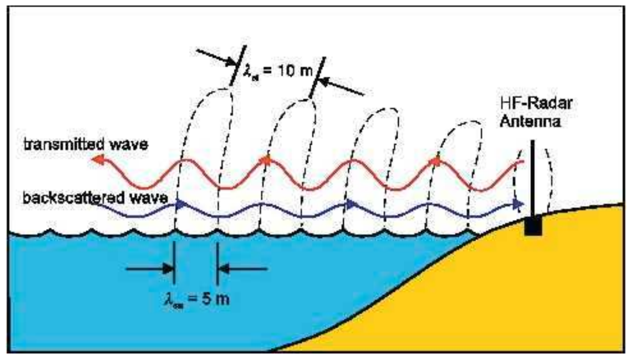


Figure 4: Bragg scattering of transmitted HF radar signal results in strong return at Doppler frequency related to phase speed of gravity waves with half the λ of the radar waves. *(© Klaus-Werner Gurgel, University of Hamburg, Germany)*

Surface currents (Figure 6) can be resolved from the Doppler shifts of the first order Bragg returns from two separate stations (Figure 1) and can be obtained from significantly less onerous installations than the type exhibited in Figure 2. However, in order to obtain directional wave spectra, the secondary returns are critical and phased array receive antennas with a high number of elements (~16) is required for beam forming.

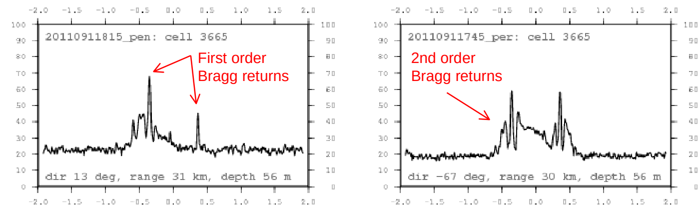


Figure 5: Frequency spectra from detected signal (beam formed) at Pendeen and Perranporth. Strong peaks from Bragg scattering are easily identified (+/-) and deviations from symmetry indicate additional radial current. Returns from two stations permit the resolution of current direction.

MEASUREMENTS

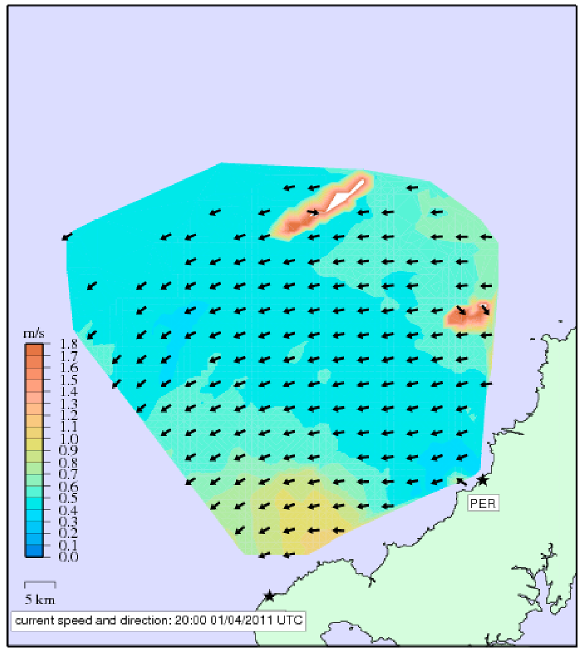


Figure 6: Surface current pattern around Wave Hub at 20:00 on 01 April 2011 as measured by HF radar. Notice the ebb current intensification around the headlands of the Cornwall Peninsula.

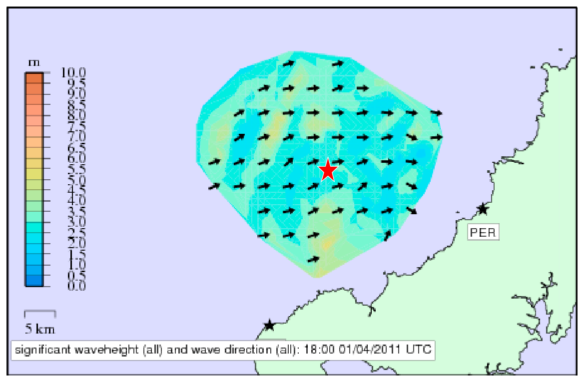
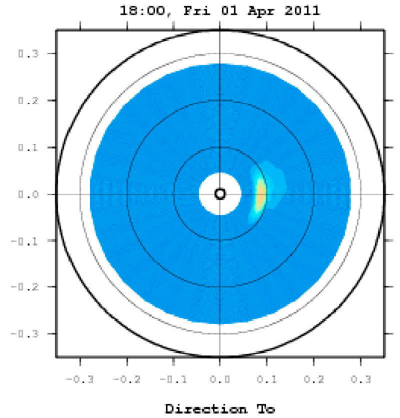


Figure 7: Spatial H_{σ} pattern around Wave Hub at 18:00 on 01 April 2011 as measured by HF radar. Values represent values derived from integrated directional spectra (Figure 8). Notice the reduced spatial coverage relative to surface currents. Red star represents location for point measurement examples elsewhere in the presentation.

Figure 8: Directional wave spectra for the point highlighted in Figure 7. Radial position indicates frequency and colour indicates amplitude. Spectra is determined from the inversion of the second order Bragg returns (Figure 5).



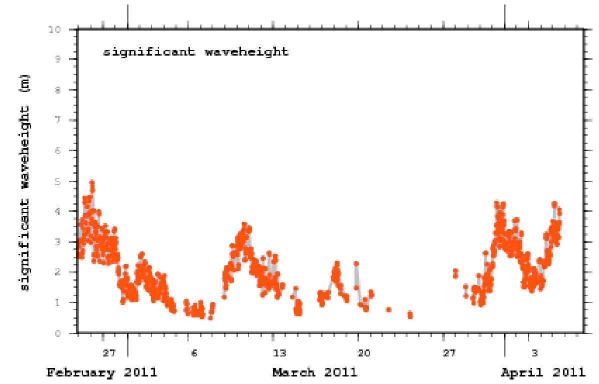


Figure 9: Time series of two station significant wave height for a location (Figure 7) near the Wave Hub. Intermittency is partially due to operational spin-up and partially to environmental conditions which degrade the radar returns under unfavourable conditions. Preliminary comparison with nearby coastal buoy measurements suggest the measurements are dependable.

CONCLUDING REMARKS

Initial observations of the performance of an installed HF radar system suggest that this may be an advantageous method for the collection of spatial fields of wave and current information which would be of great utility for resource assessment and environmental impact detection applications in MRE. Ongoing work which is being performed to determine whether the data quality is sufficient for this application.

Figure 10: An intensive planned measurement campaign around the Wave Hub site will provide a unique opportunity to quantify the spatial characteristics of HF reliability and to observe whether errors are fully independent or if relative accuracy is greater than absolute.