Measurements of Residual Currents in the Coastal Zone with the OSCR HF Radar: 
A Review of Results From the May 1985 Experiment

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ABSTRACT

Recent results from the OSCR HF radar system are reviewed with 
the intention of identifying underlying themes in data 
interpretation and, in the fashion of a technical note, of 
providing practical advice relating to the HF experimental 
approach. Outside the constraints of its current measuring 
capability (~4 cm/s resolution in the along-beam direction as 
normally operated) the OSCR system provides smoothly varying maps 
of tidal surface currents which extend and complement the view 
obtained at greater depths by current meters. Residual currents 
derived by tidal analysis of the radial current time series 
aquired during May 1985 show influences from both wind forcing 
and density gradient terms. For the former, analysis shows a 
'slab-like' response to wind forcing associated with a switching 
back and forth between roughly eastward and westward flows. The 
density gradient related flows are best interpreted in terms of 
geostrophy, with a northward flow at the surface, as measured by 
the OSCR, and a southward flow near the bed, as determined by 
current meters.

I. Introduction

An understanding of the behaviour of residual currents in coastal zones is of 
fundamental importance to oceanographic research. Likewise, for coastal 
engineering, residual currents are significant because they dictate the eventual 
fate of anthropogenic discharges into the sea. Thus, with a growing scientific and 
public awareness of environmental issues, particularly in connection with marine 
pollution, there is an acute need for accurate measurements of tidal and long-term 
residual currents within coastal regions. Such data can be obtained by various 
modelling and direct measurement techniques. Here we describe recent experience in 
using HF radar for direct measurements of residuals in UK waters.

For the shelf seas around the British Isles, water motion is known to 
be governed primarily by strong oscillatory tides and to a lesser extent by residual 
 drifts caused by wind forcing and density gradients. Away from the coast, the main 
semi-diurnal tidal terms can be accurately predicted by numerical models, though in 
the shallower regions closer to land, topographic and frictional influences make 
prediction more difficult. Again, in the shallower coastal regions, the effect of 
wind-forcing is strongly influenced by the presence of both the coastline and the 
restricted depth, and it is within such regions that estuarine discharges create
strong density gradients associated with long term drift. Density gradients are also present near complex large-scale frontal systems, some of which lie in close proximity to the coast. In summary, the situation within these coastal regions can be very complex indeed. Because the density fields are continuously changing measurement of the residual currents requires synoptic views with high temporal and spatial resolution.

The HF radar remote sensing technique has the advantage of providing surface current data regularly in time over wide areas. As one radar can only measure radial surface currents along the line of sight of its radar beams, two radar systems must be used if vector currents are required. At HF (3-30 MHz) typical 'bin' or 'cell' sizes over which current data can be obtained is normally of order 1 km. This means that present systems cannot be used to investigate currents in small-scale estuarine environments such as minor bays or coves, since there are then too few vector determinations available to build up an overall picture. At the other extreme, for large-scale surveys with a dimension of several hundred kilometers, one may be faced with an awkward trade off between range and resolution or be unable to work at long ranges in the groundwave mode given the limitations of transmitter power. There are nevertheless many applications which fall in between these two extremes and for which bin sizes of ~1 km, spacings between beam crossing points of several km and working ranges of 50 km are quite adequate.

Our practical experience has been with the OSCR (Ocean Surface Current Radar) system. This HF radar was first developed at the Rutherford-Appleton Laboratory (King et al., 1984) and has since been deployed on many occasions for both practical current survey work and for purely 'scientific' applications such as comparisons with current meters, studies of wind forcing and so forth. The important characteristics of the OSCR system are listed in Table 1. The transmitter, working at a frequency of 27 MHz, irradiates a large area of ocean uniformly. In contrast to the CODAR system (Barrick et al., 1977), a beam-forming antenna array is used to receive the sea echoes. This is composed of 16 separate elements equi-spaced over a line 90 m long oriented orthogonally to the centre line of the radar beam coverage. The beam-forming array can differentiate 16 separate beams each 6° wide. Along each beam, signals can be separated into bin lengths of either 1.2 or 2.4 km with a range along each beam of up to 40 km.

<table>
<thead>
<tr>
<th>Table 1. OSCR PARAMETERS (1985)</th>
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<tbody>
<tr>
<td>Frequency</td>
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<tr>
<td>Transmitter Power</td>
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<tr>
<td>Beam width</td>
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<tr>
<td>Bin length</td>
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<tr>
<td>Range</td>
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<td>Pulses</td>
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<td>Measurement of all bins along 1 beam in 2 min</td>
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The received echo spectra, when viewed in the amplitude versus frequency domain, normally display two well-defined peaks corresponding to Bragg resonance with advancing and receding (ocean) surface waves at wavelengths ($\lambda_w$) equal to half that of the radar signals. When an underlying current is present these Bragg peaks are offset with respect to the transmitted frequency by an amount $f$ where (Crombie, 1955)

$$f = \frac{U}{\lambda_w}$$  \hspace{1cm} (1)

so that measurement of $f$ enables $U$, the component of the current along the radar line of sight, to be determined. While some uncertainty remains in defining the depth of the surface layer to which radar current measurements pertain, a value of order 1 m (for 27 MHz radar signals) is normally assumed (Stewart & Joy, 1974).