Polarimetric properties of radar echoes from features on the ocean surface

James Thomas Stewart Morris

THE UNIVERSITY OF ADELAIDE AUSTRALIA

SUB CRUCE LUMEN

Department of Electrical and Electronic Engineering

The University of Adelaide

South Australia 5005

Australia

A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy

September 2004

TABLE OF CONTENTS

Abstract

This thesis presents the results of an investigation of the polarimetric properties of radar echoes from features on the sea surface, including freely-propagating gravity and capillary waves, breaking waves and ship wakes. Analysis and interpretation of the data is based mainly on the Cloude-Pottier H/A/$\bar{\alpha}$ decomposition of the coherence / covariance matrix. Variations in the distribution of polarimetric entropy, scattering alpha and anisotropy of radar echoes are examined in the in the H$-\bar{\alpha}$, H–A and H–A$-\bar{\alpha}$ spaces to characterise the dominant scattering mechanisms.

First, a review of the concepts and theory of polarimetric scattering from point and distributed targets is given. A detailed examination of the theory and techniques developed to calibrate polarimetric radar systems follows, focussing on the need to calibrate in the field as opposed to the ideal laboratory environment. A new calibration scheme is described that employs a parabolic dish antenna with a dual linear feed horn with two delay lines to perform the radiometric calibration, while a rotating dihedral corner reflector is used to perform the phase calibration; this design achieves stable, accurate calibration to ±0.5 dB in magnitude and 4° in phase.

Radar scattering from the sea surface is then discussed in the context of the hydrodynamic problem of describing the sea surface and the electromagnetic problem of finding an approximate solution to Maxwell's equations. The X-Bragg model is applied to predict variations in the polarimetric parameters for progressive and breaking waves. The problem of validating polarimetric measurements of the sea surface is discussed and the possibility of exploiting a quasi-deterministic surface, in the form of a Kelvin wake generated by a moving ship, is proposed and assessed by experiment.

Investigations of the polarimetric characteristics of the near shore wave field are then reported and a comparison with the results predicted by the X-Bragg model given. Polarimetric wake measurements are analysed using (i) eigen-decomposition of the coherency matrix, and (ii) a novel method based on the distribution of the cross-polar nulls. These approaches are compared with the scattering predictions obtained using numerical wake prediction codes, combined with the Bragg scattering model. The application of wakes as a tool for studying highly nonlinear hydrodynamic processes is demonstrated using the interaction between the wake produced by a boat and ambient swell to initiate wave breaking events.