Intermediate Wave Effects in Microwave Backscatter from the Ocean

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LONG-TERM GOALS

Our long-range objective is to understand ocean backscatter sufficiently well to design a compact radar which can fly on remotely piloted vehicles and measure winds, waves, and currents in denied coastal zones

SCIENTIFIC OBJECTIVES

The scientific objectives of this research are to understand the interaction of microwave radiation with the ocean surface at a variety of incidence angles and to apply this understanding to extract information about the air/sea interface. This implies that we must understand the effects of intermediate-scale surface waves on backscatter over a wide range of incidence angles.

APPROACH

Our approach has been both theoretical and experimental. Our past studies have shown that intermediate-scale waves can have two effects. First, they can tilt, advect, and modulate short waves on the ocean which have been generated by the wind. Second, they can produce short, bound waves themselves and these waves can have properties very different from the wind-generated waves. In both cases, the short waves are the primary scatterers of microwaves at moderate to large incidence angles. This year’s work has demonstrated a third role for intermediate-scale waves: they can themselves become the primary scatterers at low incidence angles or high wind speeds. Our theoretical work has concentrated this year on properly accounting for intermediate-scale wave effects at low to intermediate incidence angle. On the experimental side, we have concentrated on finishing the analyses and reporting results from previous wave tank and airship experiments and on adapting our radar for use on light aircraft in order to study intermediate-scale wave effects at high incidence angles, that is, bound, tilted waves.

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WORK COMPLETED

We have submitted three articles on previous airship work to journals and one has been accepted for publication (Hesany et.al, 1998, Plant et.al, 1998a, Plant et.al, 1998b). We have also submitted results of our wavetank work to a journal for publication and it has been accepted (Plant et.al, 1998c). In addition to this, we have developed a new, multiscale model for microwave backscatter from the ocean that we eventually want to validate for incidence angles from 0° to 80° and for the high-resolution spatial and temporal display of Doppler spectra and cross sections. To date, only mean cross sections predicted by this model have been checked against data.

We have nearly completed the modifications to our coherent, X-band radar (called CORAR) to make it compatible with the speeds of light aircraft, which are substantially higher than those of the airship. Our modifications will also allow us to operate in the rotating and imaging mode simultaneously. For this project we are particularly interested in operating the rotating antenna at a large incidence angle in order to measure Doppler and cross section effects of bound, tilted waves as a function of azimuth angle. The rotating mount for this operation is in the final stages of check out but we have so far received only the vertically polarized antenna. The horizontally polarized one is expected soon. Our power level has been boosted through the purchase of a microwave power module and the data acquisition system has been upgraded to operate under Windows NT with new A/D and DSP boards. We expect to make initial flights with the complete system in February 1999.

RESULTS

The three papers on airship results have demonstrated the following properties of near-surface airflow and microwave backscatter from the air/sea interface:

1. Backscattering cross sections at a 10° incidence angle depend on both wind speed and wind direction and this variation can be described by quasi-specular scattering theory with reasonable parameters.

2. Neutral drag coefficients derived using the Bussinger/Dyer formulation from drag coefficients measured under stable stratification exhibit a strong, residual dependence on stratification.

3. Friction velocities at low wind speeds are higher than expected if viscosity supported the flux of momentum across the air/sea interface. We suggest that wave-supported momentum transfer is responsible for the observations.

4. A low-wind-speed threshold exists for the microwave cross section as suggested by Donelan and Pierson (1987). The cross section is very low below this wind speed, grows very rapidly near the threshold, then grows more slowly at higher wind speeds. This means that the cross section does not follow the friction velocity at low wind speeds although it does at higher ones.

Our wavetank paper demonstrates that bound, tilted waves provide a good explanation for both the cross sections and Doppler shifts measured in microwave scattering in a wavetank, even at moderate incidence angles. The results support Plant (1997) and show that bound, tilted waves are much more important in wavetanks than in the field.

The new, multiscale model, built on the work of Fung et.al. (1992), has been tested for its mean cross section predictions. The model predictions have thus far shown good agreement with our airship data set and with altimeter data from TOPEX collocated with buoys. Some interesting predictions of the model are the following: very long waves on the ocean do not directly backscatter except in very special cases; scattering from intermediate-scale waves via the Kirchhoff integral may be important at relatively high incidence angles (20° and above) at high wind speeds; and Bragg scattering contributes even at very low incidence angles (10° and below) . The model shows that the change from Bragg scattering to Kirchhoff integral scattering occurs gradually and depends on wind speed. For instance, at Ku band, a 10° incidence angle, and a wind speed near 7 m/s, the backscatter is composed equally of Bragg and Kirchhoff integral scattering.

IMPACT/APPLICATION

Our results shed new light on microwave backscattering from the ocean under a variety of environmental and system conditions. Thus they are applicable to any microwave radar which senses the ocean surface. In particular, they promise to aid our understanding of the imagery of signatures of surface and subsurface vehicles, especially in the higher incidence angle region. They also indicate that a small, low-power, coherent radar system on a remotely piloted vehicle could potentially monitor ocean conditions along a hostile coastline. With the proper choice of dielectric constant, our results are also applicable to acoustic scattering from the air/sea interface and could be used to model surface reverberation.

TRANSITIONS

The results of this project have not yet been transitioned for operational use.

RELATED PROJECTS

This project is directly related to NASA scatterometers, such as the NSCAT, QuikScat, and SeaWinds. The Ku band data from the airship flights were taken simultaneously with high-quality environmental data from a platform suspended below the airship. These data have been used in an NSCAT-related project to attempt to develop better model functions and retrieval methods for scatterometers.

The radar system, CORAR, which was developed under this project was operated in 1996 in NRL’s Chesapeake Bay Outflow Processes Experiment and will be flown next year in ONR’s Shoaling Waves Experiment.

Finally, this project has many parallels with a project run by the Office of the Secretary of Defense, now being transferred to the Navy, to investigate the microwave signatures produced by submarines. The basic understanding of microwave scattering, especially at high incidence angles, produced in this project furthers these attempts to detect submarines.

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