ADVANCED TWO-FREQUENCY OCEAN SENSING RADAR USING HIGH RESOLUTION ANTENNA BEAMS

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INTRODUCTION

The opportunity to use a large space antenna system for remote sensing applications permits the creation of an advanced ocean sensing radar that combines the abilities of previously developed techniques. The 15 meter antenna will permit much higher angular and spatial resolution at the surface that will lead to techniques of observing ocean wave heights and the directional spectrum that had not previously been feasible from space. At the same time, sensors to measure ocean surface winds can be in operation and the data from both can be combined to increase the accuracy of each individual sensor. This paper outlines the existing capabilities and sensor techniques with typical data characteristics for the individual measurement of sea surface quantities.

APPLICATION NEEDS

After the SEASAT Scatterometer demonstrated the potential of measuring global winds from space on a real-time basis, plans for more advanced ocean sensing satellites moved rapidly ahead. While instrumentation, antenna systems, and algorithms are being refined for future scatterometers, a fundamental limitation will be that the radar cross section of the surface will not depend on wind speed alone. This limitation appears as a scatter in the calibration data fig.1) which limits the precision of inverting operational data into wind speed. Recent studies (ref. 1) have shown that the radar cross section of surface will depend on sea state (RMS wave slope or height) and air-sea temperature difference in addition to wind speed. Sensors that can measure the surface wave spectrum also depend on wind speed (refs.2,3). One solution is to use a multi-sensor that can measure both quantities from space, since each sensor output depends on two variables. Then the two unknowns can be inferred from the two independent equations (or algorithms). This idea is not part of existing plans for future satellites, so the possibility of developing a new approach with a shuttle-based radar and antenna system is very attractive. A large space antenna would be a significant benefit to an ocean observing system because of its ability to provide spatial resolution in a beam-limited mode. The entire radar system could be based on processing narrow bandwidth signals, which is usually simpler than other approaches for achieving spatial resolution.

SCATTEROMETER MEASUREMENTS

SEASAT Scatterometer measurements have been processed and analyzed with the best available information on sea surface conditions, with atmospheric correction to neutral stability (see ref. 1). Inherent in these and other data sets is a random fluctuation or data scatter about a "best fit" approximation function between the radar cross section and the wind speed (fig. 1). This indicates that other sea surface variables are influencing the backscattered power, in addition to the wind. Tower-based measurements yielded backscatter data (ref. 1) along with surface wave measurements that show a strong effect of the RMS wave slope on the cross section. Work is in progress to further analyze and interpret this data set with application to future spaceborne Scatterometer measurements.

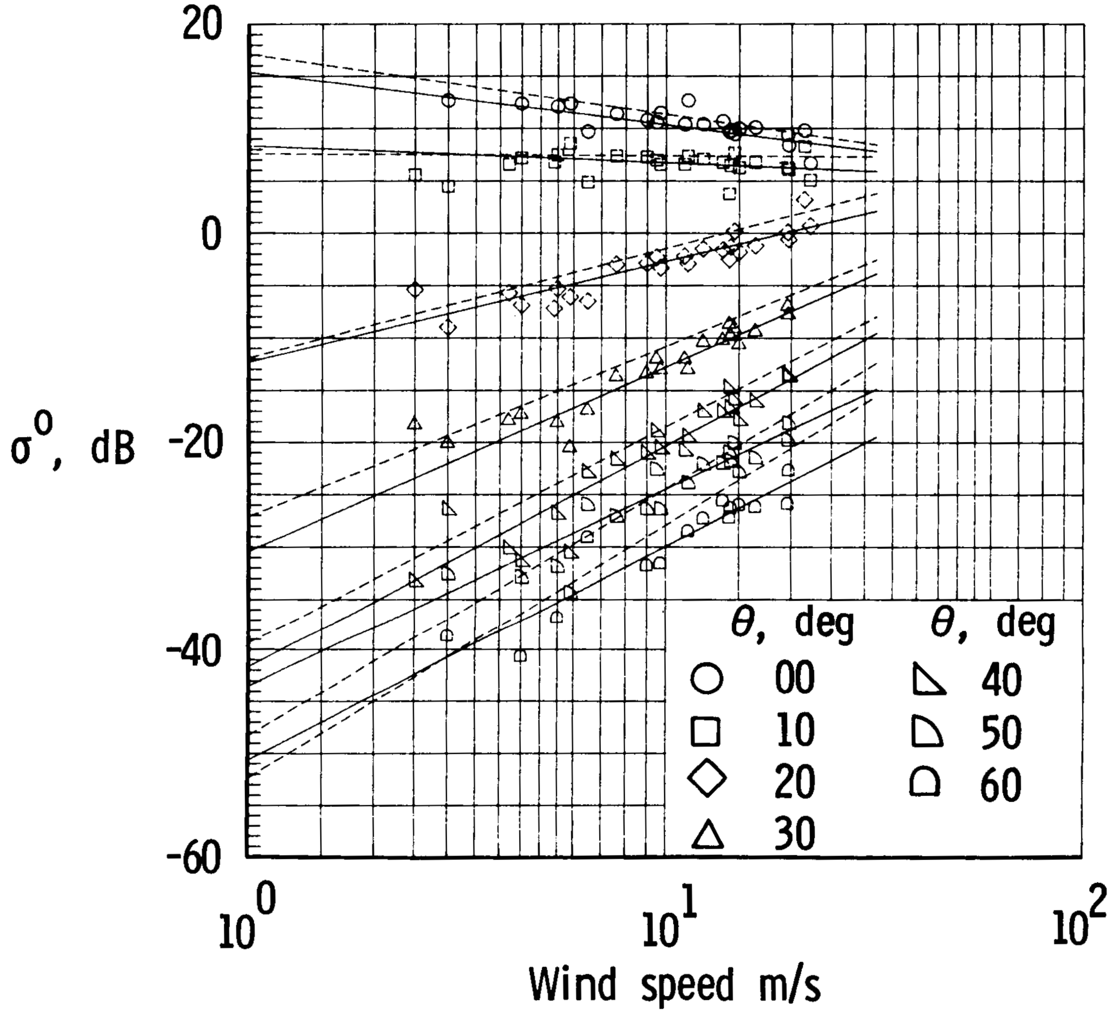

Figure 1

WAVE HEIGHT MEASUREMENTS

An excellent example of sea state measurements using a narrowband beam-limited radar is the nadir looking Dual Frequency Correlation Radar that requires a narrowbeam antenna to measure RMS waveheight (ref. 4). These previous measurement programs using this radar from an aircraft platform showed the capability of measuring wave height over a variety of sea conditions. The known limitations for higher altitudes were more narrow beamwidths with altitude and near nadir pointing control. The normalized correlation function between two closely spaced frequencies decreases as the RMS wave height increases (see fig. 2 -theoretical function for aircraft conditions with different sea state values). In the past, space applications were considered but the required antenna technology was not available. The current new Large Space Antenna technology creates an opportunity to achieve the required beamwidth and near nadir pointing control that can make the system feasible. There is also the prospect that with a sufficiently narrow beamwidth, a wider swath than the "near nadir" region will be accessible, making coincident measurements with the Scatterometer possible.

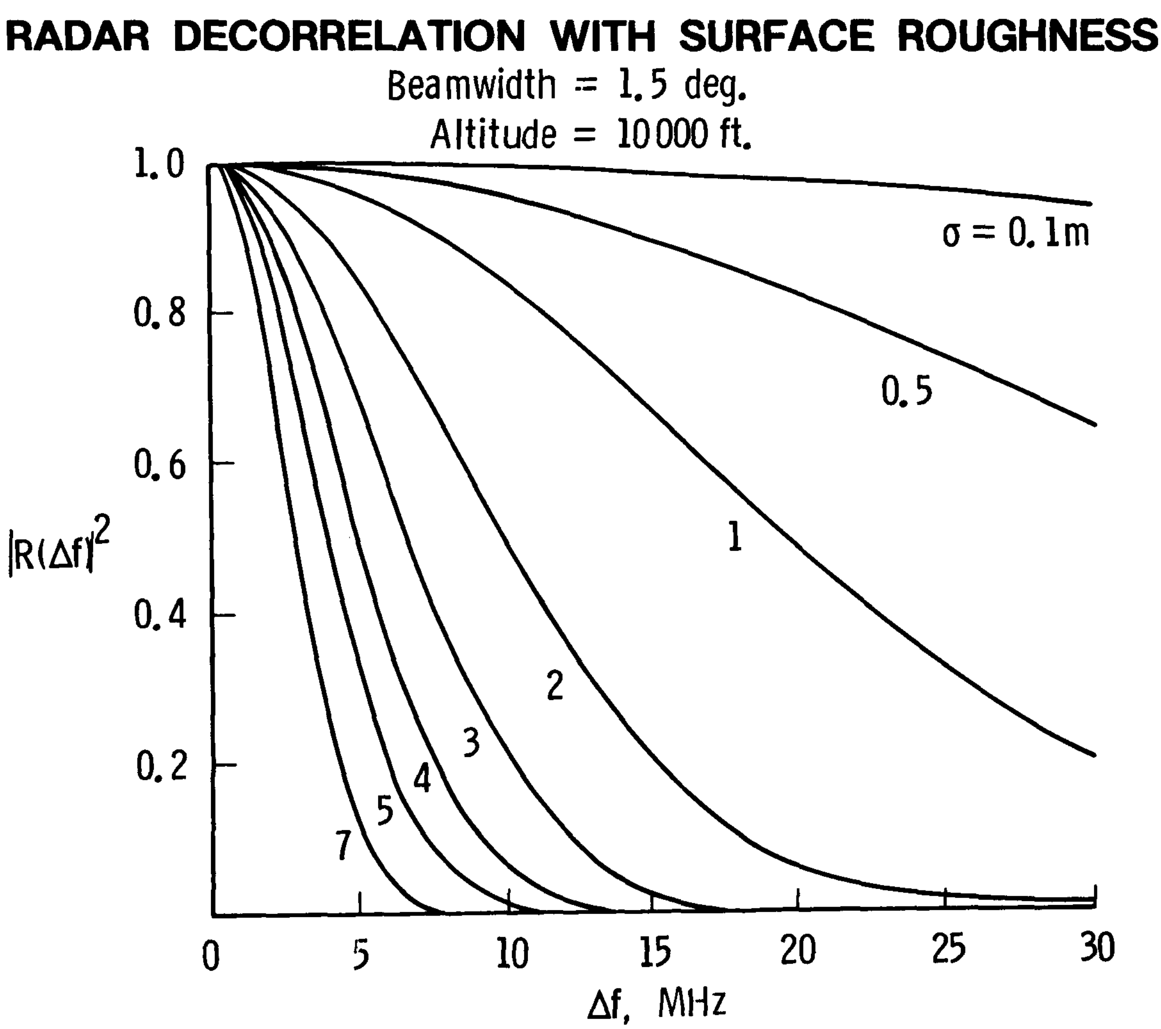

Figure 2

WAVE SPECTRUM MEASUREMENTS

Ocean wave spectrum measurement with microwave sensors is becoming a more accurate art, with a sounder physical basis, as several sensor techniques (synthetic aperture radar, short pulse spectrometer, and Delta-K) continue to improve. The measurement of ocean wave spectra from space is considered feasible. Consistent and compatible with the present narrowband radar mode under discussion here is the Delta-K radar (ref. 2,3). This instrument responds to one ocean wavelength at a time, within a sweep of measurements that spans the ocean spectrum. One set of results is shown in fig. 3, where the radar inferred spectrum compares well with that obtained by a highly accurate radar system (surface contour radar). However accurate results with the Delta-K instrument (and other oblique incidence sensors) require wind speed information in order to provide a reliable estimate for the modulation transfer function. The significant conclusion from these facts is that a wave sensor and Scatterometer (radar cross section) measurement can be combined "synergistically".

TWO-FREQUENCY RADAR SURFACE SPECTRUM MEASUREMENTS

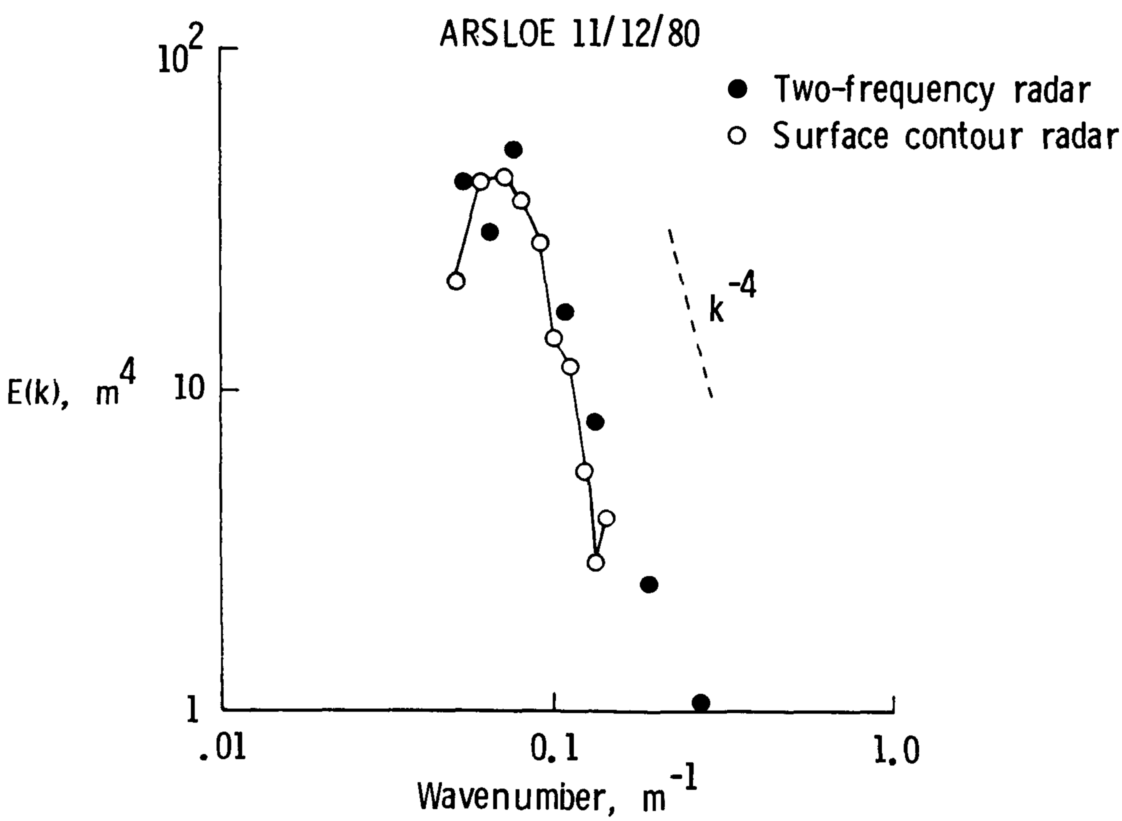

Figure 3

SUMMARY

This paper seeks to call attention to a coherent set of facts that are interesting and important to existing and planned oceanographic remote sensing programs and which may open up a new sensor approach in this field. To demonstrate the feasibility of using a large space antenna (up to 15 meters in diameter) from a shuttle platform, a set of calculations were conducted using existing theoretical models of the nadir dual frequency scatterometer (ref. 4). These are basically design calculations to determine the necessary size (diameter) of a single aperture antenna as a function of altitude which would be needed to achieve an acceptable accuracy (an error correlation factor of 0.5 can be removed from the data with acceptable losses). The results of these calculations are shown in fig. 4 for a given set of radar and sea parameters (frequency = 14 GHz, RMS wave height = 0.25 meter and 1.0 meter). These show that for shuttle altitudes (200 to 400 km) antenna diameters less than 15 meters are capable of providing the desired performance.

This survey advocates that interesting and rewarding possibilities exist if we consider combining individual sensors into multi-sensors with the new large scale antenna technology that is on the horizon. We are in a fortunate position because much data is available from previous studies that could be used in a more focussed and integrated study of this approach. And many of the earlier individual system studies can serve as the basis for a new combined system study.

ANTENNA SIZE REQUIREMENTS FOR 50% ERROR AT $R(\Delta f)^2 = 0.5$

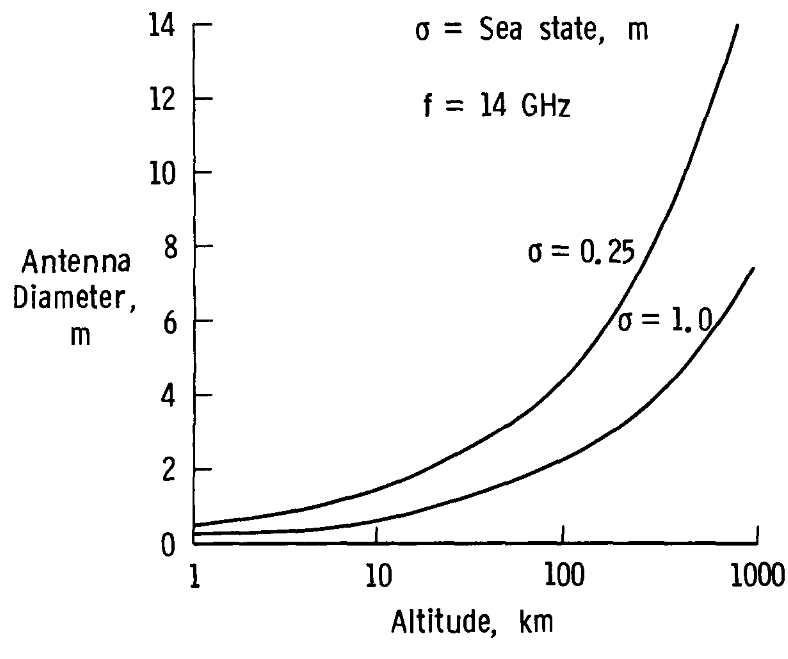

Figure 4

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