An Ultra Wide Band Radar for the Study of Air/Sea Interaction

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Abstract - **While wind scatterometry is a well developed technique, further research into the geophysical model function relating radar backscatter to the near-surface wind vector is needed. To support such research we have built a tower-based radar scatterometer system capable of directly measuring both the ocean radar backscatter (σ^o) and the long wave field simultaneously in order to study the modulation of σ^o by long gravity waves as a function of environmental parameters. Operational characteristics of the instrument include (1) a continuous, very wide operational bandwidth (2-18 GHz) and (2) a frequency-independent antenna illumination pattern. Rapidly scanning the operational bandwidth provides essentially instantaneous σ^o measurements as a function of frequency. A Δk technique will be used to measure the long wave spectrum. An extended field experiment is planned for 1994. A rich data set containing a variety of conditions is anticipated to support research in ocean scattering and air/sea interaction.**

I. INTRODUCTION

Winds over the oceans modulate all air-sea fluxes and thus are crucial to the understanding of global climate and air/sea interaction. The limitations of conventional techniques, however, will require increased reliance on remote sensing to measure oceanic winds. In 1978, the SeaSat Scatterometer (SASS) demonstrated that vector winds over the ocean could be measured from space using radar scatterometry. The dramatic success of SASS has lead to the development of advanced scatterometers by both the United States (NASA) and the European (ESA) Space Agencies. However, further improvements in the models relating radar backscatter and wind are needed.

A wind scatterometer does not directly measure the wind. Instead, it measures the normalized radar backscatter cross-section (σ^o) of the ocean's surface from which the wind is inferred. Using multiple measurements of σ^o, the wind vector is inferred using a "geophysical model function" which relates the radar backscatter and the vector wind. σ^o is primarily a function of wind-generated capillary waves but is modulated by long gravity waves and other environmental parameters (e.g. [2]). However, the details of this modulation are not fully understood.

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Because the underlying physics of ocean scattering remains poorly understood, a theory-based geophysical model function has been illusive. However, remarkably successful empirical model functions based on tower- and aircraft-based as well as spaceborne measurements have been developed (e.g. [1,4]) though further research is required [2].

Most empirical studies to date have used fixed frequency scatterometer systems without wave field measurement capability. Recently, [3] demonstrated that long wave fields could be directly measured by a radar using a Δk multi-frequency technique. Using this technique measurements of the long wave field and σ^o can be made using the same radar system. This enables detailed studies of the influence of the background wave field on σ^o in order to further understand the modulation of σ^o by the wave slope and swell direction. Understanding the sensitivity of σ^o to the background wave field is crucial to the development of improved geophysical model functions.

To support research into geophysical model functions, we have developed an innovative radar scatterometer system which will make simultaneous measurements of the long wave field and σ^o over the full bandwidth of 2-18 GHz. The instrument is now in final test and calibration. In this paper we briefly describe the radar scatterometer system design. Initial results will be presented at the conference.

II. DESIGN DESCRIPTION

In this brief paper it is impossible to describe the design of the proposed system in any depth. However, in this section we provide an overview of the system. A simplified block diagram for the system is shown in Figure 1. Key goals for the instrument are measurement accuracy and system reliability. We have used off-the-shelf equipment wherever possible to ensure a reliable, low-cost design.

The chief innovations in this instrument are (1) a continuous, very wide operational bandwidth and (2) a frequency-independent antenna illumination pattern. While most of the design features have been previously demonstrated, integrating all of these elements into a single, integrated system represents an innovation in tower-based scatterometer system design, i.e., the instrument is an integrated system for the study of ocean scattering, simultaneously measuring σ^o, waves, and environmental parameters. Because of the integrated nature of the instrument system, the system can be deployed independently in conjunction with other instruments.

The instrument is a multi-octave FM CW (homodyne) radar using a Δk (three-tone) technique for long wave spectrum measurement [3]. An FM homodyne design was selected to permit simultaneous transmission and reception, allowing for very short range operation (required for a tower) at minimal cost and complexity. This also simplifies external calibration since a calibration target can be placed on the tower close to the radar. This will enable frequent calibration.

Spectral diversity is obtained as a side effect of the rapid scanning of the operational frequency and the multiple tones. Scanning in azimuth will permit the measurement of the long wave directional spectrum. The low-power transmitted signal consists of two to three closely spaced (10-50 MHz) tones which are swept over the 2-18 GHz operational bandwidth to provide both spectral diversity and multiple frequency observation. The received signal consists of the return echo from the ocean surface (which will have been dispersed in time and frequency) and transmitter leakage between the transmit and receive antennas. The received signal is mixed with the RF center frequency of the transmitted signal and filtered. Due to the time-of-flight of the return echo, there is a net frequency offset in the return echo. This permits filtering out any contaminating leakage from the transmitted signal as well as providing additional range resolution. The filtered return echo power provides the measurement of σ^o. The closely spaced tones in the transmitted signal are used to measure the long wave spectrum using the beat frequency (see [3]).

Rapidly scanning the operational bandwidth provides the essentially instantaneous σ^o measurements and spectral diversity for the wave spectrum measurement. A very wide frequency range with multiple incidence angle capability will permit measurement of the Bragg spectrum from small waves ranging from approximately 1.5 to 10 cm. To cover the desired frequency range, very broad-band off-the-shelf signal generators and mixers have been used. The antenna represents a new design developed especially for this project. A dual antenna system (one antenna for transmit and one for receive) is used. The dual-polarization transmit antenna consists of a 3 foot elliptical cross-section reflector with a sinuous feed. This antenna is designed to provide essentially constant 5° beamwidth over the entire operational bandwidth. The conventional dual-polarization receive antenna has a larger beamwidth than the transmit antenna and is boresighted with the transmit antenna. A custom antenna positioner has been developed as a student project to provide both azimuth and elevation pointing.

Calibration is provided by using internal calibration loops and an external calibration target. Two internal calibration loops are used. The first, which operates continuously, directly measures the receiver/transmitter gain using the coupling between the transmit and receive antennas. The second loop feeds the transmitter directly into the receiver to make a precise RF gain measurement. For external calibration a fixed calibration target is mounted so that the antenna positioner can target it. A 12" precision aluminum sphere is used as a calibration target to verify pointing and measure the end-to-end system gain. In operation the radar periodically makes calibration measurements. The frequent absolute calibration with an external target simplifies the requirements for long-term instrument stability and insures well-calibrated σ^o measurements

The entire system is controlled by a 486-based PC system which handles data collection and real time data processing. The computer also collects data from meteorological and ocean sensors. These sensors include anemometers; wind vanes; pressure, temperature, and humidity sensors; and an experimental wire wave gauge.

III. CONCLUSION

As of this writing, we are in final calibration and test. Engineering deployments in near-by fresh and salt water lakes are underway as part of the test and calibration program with a two month deployment in a larger freshwater lake planned for late 1993. An extended (6 months or more) deployment is planned for 1994. A rich data set containing a variety of conditions is anticipated to support research in ocean scattering and air/sea interaction. We hope to present preliminary results at the conference.

IV. REFERENCES

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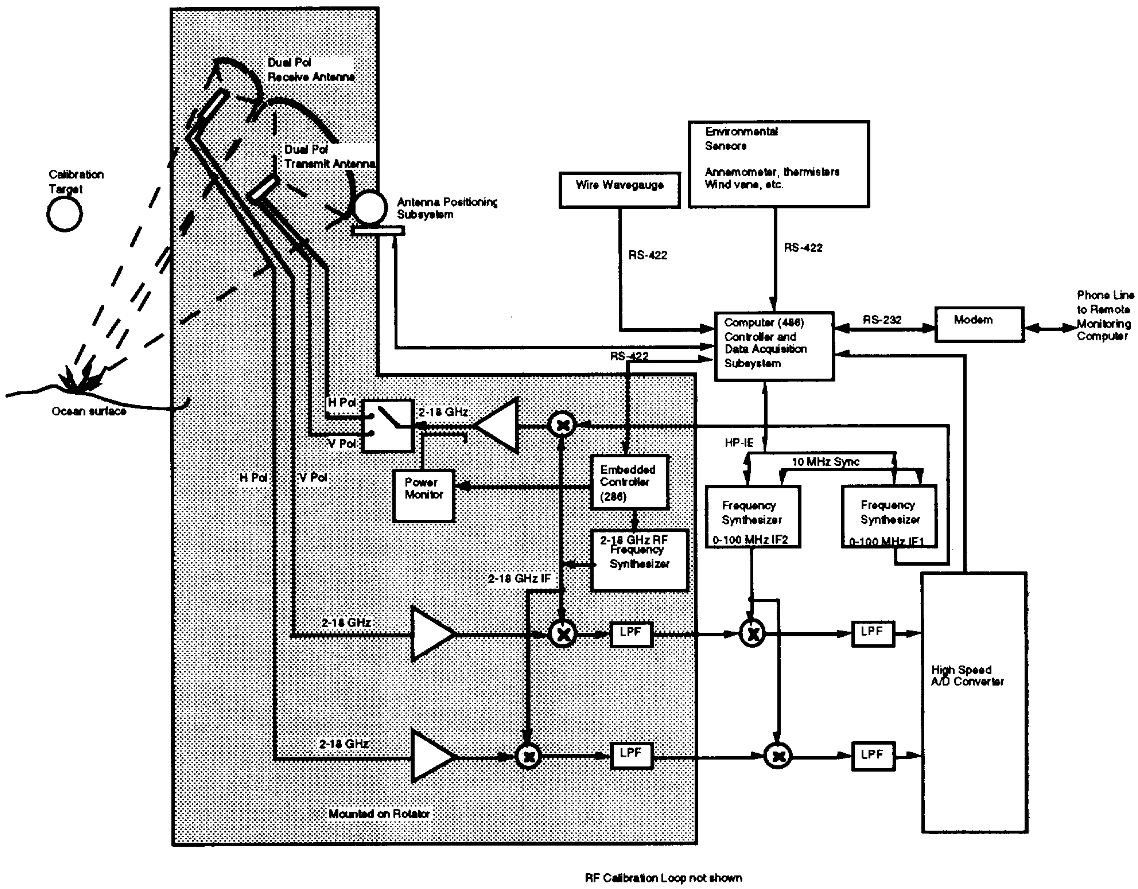

Figure 1. Simplified Block Diagram.