Coastal Engineering Technical Note

HIGH FREQUENCY RADAR MEASUREMENTS OF COASTAL OCEAN PARAMETERS

PURPOSE: To describe a method of measuring coastal ocean surface parameters, such as surface currents and directional wave height spectra, using a specialized, high frequency (HF), coastal radar known as CODAR (Coastal Ocean Dynamics Applications Radar). CETN-I-26, March 1985, provided an overview of remote sensing techniques for measuring ocean waves. This CETN provides more complete information on the CODAR system.

BACKGROUND: When a rough ocean surface is illuminated with a high frequency signal, a portion of the incident energy is scattered back toward the source. At low elevation angles, the primary scattering mechanism is called Bragg scattering. It is a selective process in that it provides the strongest return from ocean waves that are traveling directly toward or away from the radar and that have wavelengths one-half that of the transmitted radar wave. For a 25.4 MHz CODAR signal, this represents waves of approximately 6 m (20 ft) in length with a period of about 2 seconds. These waves are almost always present and have a known deep water phase velocity of approximately 3 m/sec (9.8 ft/sec).

Spectral analysis of the return signal provides the sea-echo Doppler spectrum, which, as seen in Figure 1, is characterized by two dominant peaks surrounded by a continuum. These peaks represent the primary return from the 6 m (20 ft) waves and occur at distinct frequencies. Displacement of these peaks away from their known frequencies represents the radial component of a surface current, the strength of which is proportional to the amount of displacement.

In addition to surface currents, CODAR can also provide valuable directional wave information. The wave height directional spectrum is theoretically related to the return signal and can be recovered by a numerical inversion of the sea-echo Doppler spectrum.

U. S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center
P. O. Box 631, Vicksburg, Mississippi 39180

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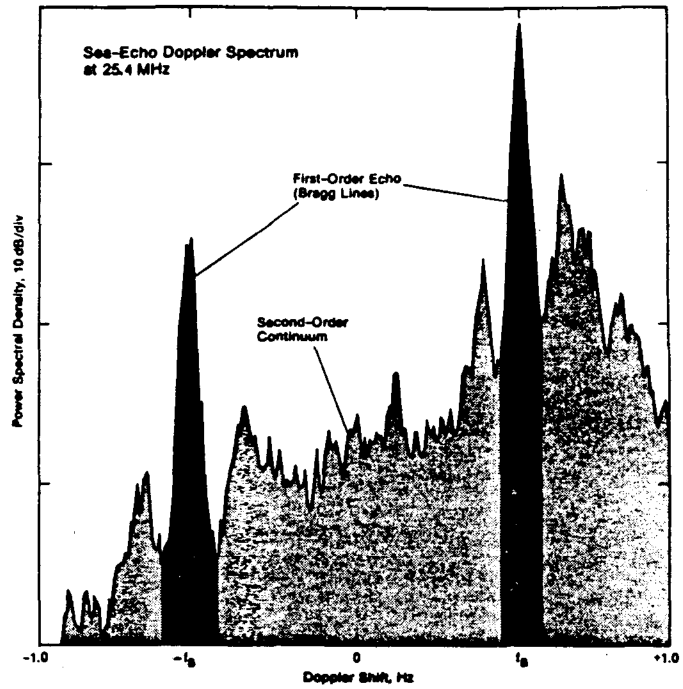
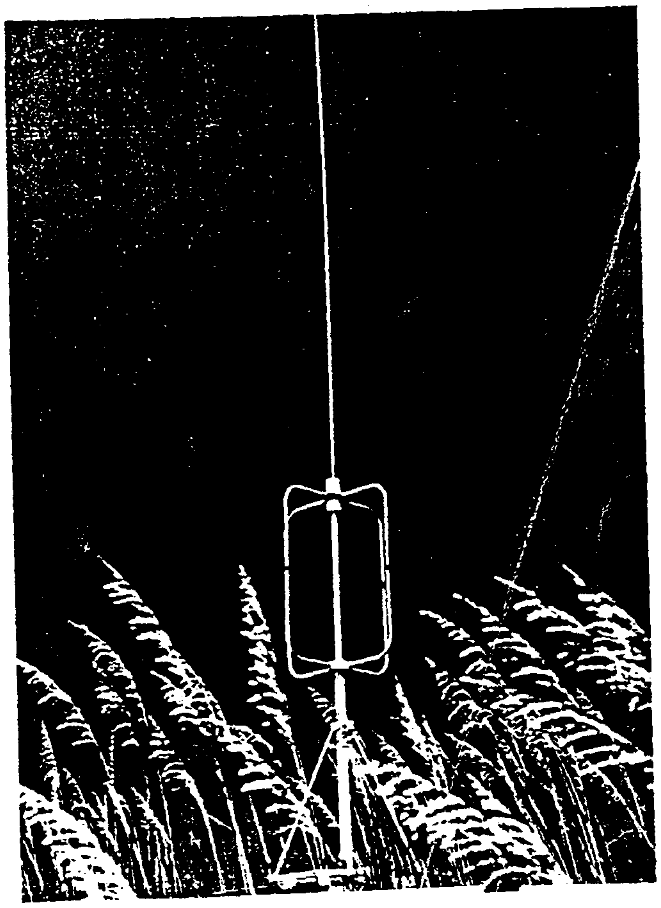


Figure 1. Sea-echo Doppler spectrum showing first order Bragg peaks and higher-order continuum. Bragg frequency (f_B) is 0.514 H_z for a 25.4 MH_z signal.

METHOD: CODAR is a compact, portable, land-based radar system consisting of a three-element, crossed-loop antenna and an electronics package that houses the system hardware (Figure 2). It is capable of operating in virtually all weather conditions and can be programmed for unattended operation for periods of up to two weeks.

The system is easily deployed. Rapid signal attenuation by land dictates that the antenna be mounted as close to the water as possible. It is then cabled to the electronics, which are housed near-by in a sheltered environment. When activated, the radar transmits a 25.4 MHz signal, receives and samples the backscattered signal, and spectrally processes the return to yield the sea-echo Doppler spectrum. This information is provided for 64 range cells, each 1.2 km (0.7 nautical miles) in extent, at pre-selected time intervals, and stored on magnetic tape. Further processing of this "raw" spectral data can be accomplished either on-line, producing near real-time products, or off-line at a later date. Final data products can then be displayed on a graphics terminal or outputted to a hardcopy printer/plotter. At present, only radial surface currents can be obtained in real-time, with on-line wave processing being implemented in the very near future.



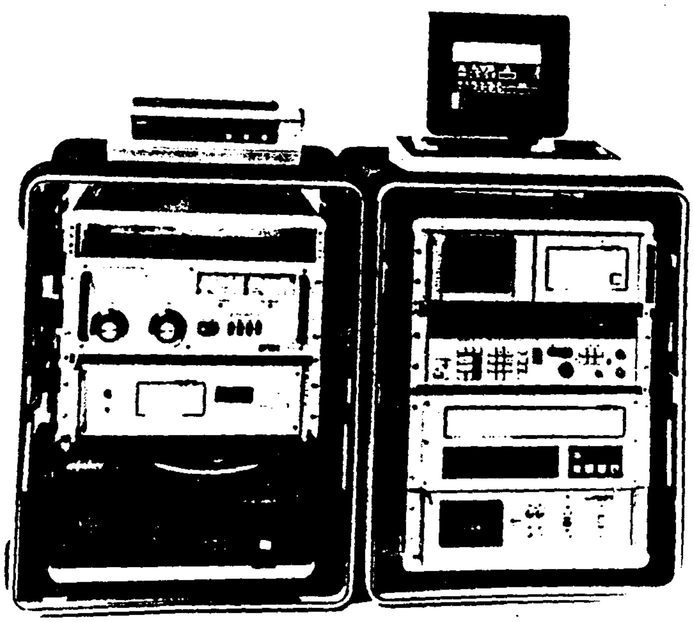


Figure 2. a) Crossed-loop antenna b) electronics

Measurement of directional wave parameters is accomplished using a single CODAR system. However, a single system provides only that component of surface current traveling toward or away from the radar, making the determination of total, umambiguous surface current vectors possible only by using a two-system set up, with spatial separation on the order of 30 km (16 nautical miles).

SUMMARY OF CAPABILITIES: In addition to its ability to measure surface currents and directional wave parameters, CODAR is also capable of tracking the instantaneous radial velocity of and range to floating transponders and of providing an indirect measure of local wind direction. A summary of its full potential is given in Table 1.

APPLICATION: CODAR has been tested in a variety of locations and circumstances over the last ten years. Included are several wave measuring experiments conducted on the West coast (Lipa et al, 1981) and the ARSLOE experiment of 1980 (Lipa and Barrick, 1982, 1983). Comparison with available wave gages has, to date, shown good agreement. In November 1984, the Coastal Engineering Research Center (CERC), in conjunction with the National Oceanic and Atmospheric Administration (NOAA), conducted an initial experiment designed to demonstrate CODAR's unique capabilities. Surface currents in the Delaware Bay were measured and mapped (Figure 3) every 1.5 hours for a period of three weeks (Driver, 1985). Experiments designed to demonstrate CODAR's ability to measure wave height directional spectra are being planned for southern California for FY 86 and FY 87 under the CODAR Remote Sensing Demonstration Program funded by the Operations and Readiness Division, Chief of Engineers. Upon completion of this program and verification of CODAR's readiness for operational use, the system will be made available to the Districts. Typical applications would be those that require either long-term monitoring of coastal wave climate or short-term wave and current data collection in areas consistent with CODAR's resolution.

CODAR's unique capabilities will greatly enhance coastal wave and current data collection. There are, however, several limitations inherent to the system that exclude certain applications. A thorough understanding of these limitations is essential to a successful data collection effort.

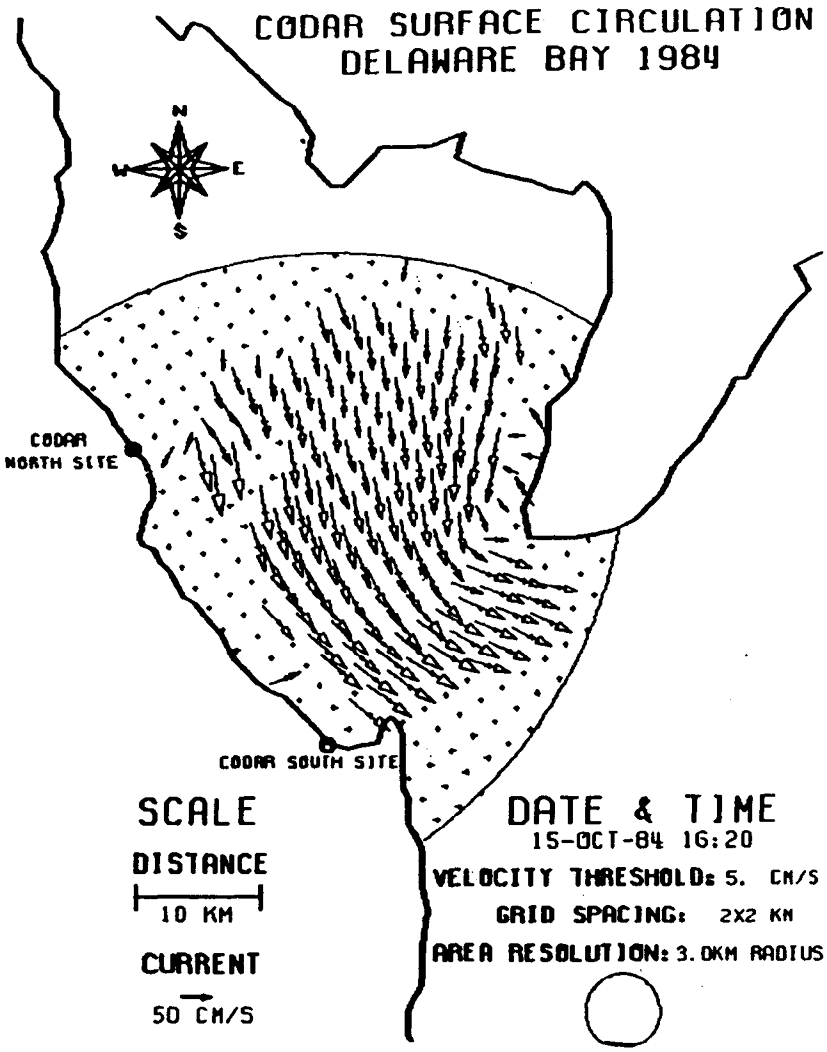


Figure 3. Surface currents in Delaware Bay as mapped by a dual-CODAR configuration.

LIMITATIONS:

a. CODAR is unable to measure waves and currents in the area closer than 2 km (1.1 nautical miles) from its location. This "blind zone" results from the fact that during pulse transmission, the receiver is turned off to allow the transmitted pulse time to escape the area. Any signal backscattered during transmission is lost.

b. The resolution cell size (>5 sq km) prohibits the use of CODAR for most inlets and harbor entrances. However, current data can be acquired in these smaller areas by utilizing the transponder tracking capabilities.

c. Wave processing is presently limited to scattering regions where the directional spectrum is homogeneous or where the inhomogeneities can be mathematically modeled. This limitation excludes from consideration wave data collection in most rivers, straits, and estuaries. This constraint does not apply to current measurements.

AVAILABLITY: CERC presently owns one complete CODAR system and the software required for surface current processing. Wave processing software is currently being streamlined and readied for installation on the CERC system in early 1986. CERC plans to acquire an additional CODAR in the near future. CODAR systems may be purchased for approximately $150,000-$200,000 or leased on an as-needed basis for about $12,000/month.

ADDITIONAL INFORMATION: For further information, contact Mr. David B. Driver, U.S. Army Engineer Waterways Experiment Station, Coastal Engineering Research Center, Research Division, Coastal Oceanography Branch, at (601) 634-3040.

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Driver, D. B. 1985. "HF Radar Measurements of Surface Currents in the Lower Delaware Bay," Proc. Nineteenth Int. Symposium on Remote Sensing of Environment, Ann Arbor, Michigan.

Lipa, B. J., D. E. Barrick, and J. W. Maresca, Jr. 1981. "HF Radar Measurements of Long Ocean Waves," J. Geophysical Research, Vol. 86, No. C5, pp 4089-4102.

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Lipa, B. J., and D. E. Barrick. 1983. "Least-Squares Methods for the Extraction of Surface Currents from CODAR Crossed-Loop Data: Application at ARSLOE," IEEE J. of Oceanic Engineering, Vol. OE-8, No. 4, pp 226-253.

Table 1
Summary of CODAR Capabilities

I. Directional Waves	
A. Range	36 km (20 n mi) radius
B. Range cell	1.2 km (0.7 n mi)
C. Parameter uncertainties	
1. Height	+/- 5%
2. Period	+/- 0.5 sec
3. Direction	+/- 7 deg
D. Products	- non-directional wave height spectrum - mean direction - peak period - angular spread of wave field - directional wave height spectrum
II. Surface Currents	
A. Range	60 km (33 n mi) radius
B. Resolution cell	
1. Range	1.2 km (0.7 n mi)
2. Azimuth	5 deg
C. Parameter uncertainties	
1. Radial velocity	3-5 cm/sec (0.1-0.16 ft/sec)
2. Direction	1-3 deg
D. Products	-2 dimensional map of radial current vectors
III. Transponder Tracking	
A. Range	60+ km (33+ n mi)
B. Parameter uncertainties	
1. Position	+/- 30 m (100 ft)
2. Velocity	+/- 1 cm/sec (0.03 ft/sec)
C. Products	- range to transponder - instantaneous radial velocity of transponder