GEORGIA INSTITUTE OF TECHNOLOGY
Office of Contract Administration

SPONSORED PROJECT INITIATION

Posted 4/6/76

Date: March 23, 1976

roject Title: Airborne Radar Test Program

roject No: A-1820

roject Director: Mr. N. C. Currie

ponsor: Naval Air Development Center; Warminster, Pennsylvania 18974

greement Period: From 2/26/76 Until 4/25/77 (Perf. Period)

ype Agreement: Contract # N62269-76-C-0232

mount: $86,845 (Partially funded @ $49,752 thru 7/31/76)

eports Required: Monthly Progress Letters; Test Data Packages (2)

ponsor Contact Person(s):

Technical Matters
(No individual specified)
Naval Air Development Ctr.
Attn: Code 2042
Warminster, Penn. 18974

Contractual Matters
(thru OCA)
ONR Resident Representative
325 Hinman Res. Building
Campus

Defense Priority Rating: DO-A7 under DMS Reg. 1

ssigned to: Systems and Techniques (~~School~~/Laboratory)

opies to:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director-EES
Accounting Office
Procurement Office
Security Coordinator (OCA)
Reports Coordinator (OCA) ✓
Library, Technical Reports Section
Office of Computing Services
Director, Physical Plant
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other ______

-3 (3/76)

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT TERMINATION

Date: May 30, 1977

Project Title: Airborne Radar Test Program

Project No: A-1820

Project Director: Mr. N. C. Currie

Sponsor: Naval Air Development Center; Warminster, Pennsylvania 18974

Effective Termination Date: 5/25/77

Clearance of Accounting Charges: 5/31/77

Grant/Contract Closeout Actions Remaining:

X Final Invoice and Closing Documents
_ Final Fiscal Report
X Final Report of Inventions
X Govt. Property Inventory & Related Certificate
_ Classified Material Certificate
_ Other ____________

Assigned to: Systems & Techniques Laboratory (School/Laboratory)

COPIES TO:

Project Director
Division Chief (EES)
School/Laboratory Director
Dean/Director—EES
Accounting Office
Procurement Office
Security Coordinator (OCA) ✓
Reports Coordinator (OCA)
Library, Technical Reports Section
Office of Computing Services
Director, Physical Plant
EES Information Office
Project File (OCA)
Project Code (GTRI)
Other ____________

CA—4 (3/76)

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

22 April 1976

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 1
26 February 1976 through 1 April 1976

Gentlemen:

Efforts during this period have centered around planning for opening the Boca Raton field site about 1 May 1976. A trip to NADC was made by Mr. N. C. Currie to discuss preliminary test plans and to determine what additional test equipment will be needed at the field site to successfully perform tests on the APS 127 radar.

During the coming month, efforts will concentrate on gathering test equipment, testing communication equipment furnished by the Coast Guard, picking up 18 foot boat to be furnished by Marine Safety Technology Division, and arranging travel plans for Georgia Tech personnel. Expenditures through the end of March 1976 were approximately $850.

Submitted by

J. C. Butterworth
Assistant Project Director

JCB:hdr

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

May 11, 1976

Command Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 2
1 April 1976 to 30 April 1976

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

Preparations for the field operations sceheduled to begin on May 3, 1976 have continued. Equipment which will be needed for the tests has been gathered up and was transported to the field site at Boca Raton, Florida on April 30, 1976. In addition, computer programs to be utilized by the on-site computing facility have been developed in order to allow rapid analysis of the test data obtained on the APS-127 Radar.

During the next reporting period, operations will commence at Boca Raton, Florida including installation and checkout of the APS-127 Radar and test equipment at the field site and preliminary testing of the radar. Expenditures on the project through May 1, 1976 were approximately $3,000.

Sincerely,

Nicholas C. Currie
Project Director

NCC/bw

A-1820

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

June 14, 1976

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 3
1 May 1976 to 31 May 1976

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

Field operations commenced at the Ga. Tech - Navy Field Site in Boca Raton, Florida on 3 May 1976. The AN/APS-127 radar was installed and data taking operations began on 12 May 1976. Tests to date have included initial check-out of the radar, nonscanning measurements on the return from an 18' boat at ranges of 1 to 8 mi, and MDS measurements on the PPI display. A 16 mm camera has been installed on the display which takes pictures at a 1 frame per 2 scan rate to document blip scan and MDS measurements. An on-site computer controlled data facility is being used to reduce the data in almost real time so that potential problems can be quickly cleared up.

Plans for the next reporting period include: a continuation of the nonscanning radar-cross-section measurements and MDS measurements and the initiation of Blip-scan tests. Sufficient pictures will be taken with the 16 mm scope camera to document the tests.

Expenditures on the project as of 1 June 1976 were approximately $32,000 of which $5,000 are personal services. Travel expenditures have been higher than anticipated because of increased support required in the field and presently equal $5,500 out of a total budget of $7,000. It is recommended that the travel budget be increased by $1,300 to cover the additional costs expected.

Sincerely,

J. Clark Butterworth
Associate Project Director

JCB/gg

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

28 July 1976

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 4
1 June 1976 to 30 June 1976

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

Field operations at Boca Raton, Florida have continued throughout the month. Nonscanning measurements using small boats have continued using three different boats. In addition, several test films have been made to document the display performance. Also MDS measurements have been performed utilizing an artificial target for both noise and clutter backgrounds.

On-site data analysis is continuing using the mobile data reduction facility. In addition, to voltage-height distributions on the various target and clutter runs, other programs have been developed including a plot routine of radar cross-section versus range using several voltage height distributions as input and a program which generates receiver operating curves (ROC) given a probability distribution for a target run and a corresponding clutter run.

Plans for the next reporting period include a continuation of the tests presently being conducted including acquiring measurements on a "flotilla" of different size boats for comparison purposes. Present plans are to terminate the tests on 20 July 1976 and to continue the data analysis back at Georgia Tech for the remainder of the period.

Expenditures on the contract as of 1 July 1976 were approximately \$32,000 of which \$10,000 are personal services. In addition there were approximately \$5,000 more in travel costs incurred during the month which have not officially been charged to the contract making a total of \$37,000. With the tests presently scheduled to run through the first three weeks of August, an overrun is expected of approximately \$11,000 for Phase I of contract due to the requirements for increased length of the test period and increased support during the tests by Georgia Tech personnel over that originally proposed.

A separate letter concerning this matter will be sent to NADC in the next few days.

Sincerely,

Nicholas C. Currie
Project Director

NCC:hg

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

23 August 1976

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 5
1 July 1976 to 31 July 1976

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

Field operations at Boca Raton, Florida continued into July and were completed on 20 July 1976. Nonscanning measurements were performed on a number of different small boats including a "Flotilla" of about 20 boats of different sizes ranging from 18' length to 60' length. MDS measurements, blip-scan measurements, and 16mm films of the display were also made during the last three weeks.

Analysis of the data is now continuing and summaries of the data are being prepared. The analyzed data includes probability distributions, receiver operating curves, plots of cross-section versus range, and auto-covariance functions for the AN/APS-127 and the GT-X radar which was used for comparison purposes. In addition, predictions are being calculated for comparison with the data obtained, and also for extrapolation to the airborne platform case.

Plans for the next reporting period include completion of the preliminary data analysis and initiation of preparation of the final report on the Phase I tests. Expenditures on the contract as of 1 August 1976 were approximately $44,000 of which $15,000 were for personal services. It is still apparent that an over-run will be incurred on Phase I of the project of approximately $11,000. This was explained in a letter from Mr. Milton W. Bennett of the Georgia Tech Research Institute to the contracting officer for Contract N62269-76-C-0232. A copy of this letter is enclosed, for references purposes.

Sincerely,

J. Clark Butterworth
Associate Project Director

JCB/hg
Encl: 1

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

September 23, 1976

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 6
1 August 1976 to 31 August 1976

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

Analysis of the data obtained during the recent field tests at Boca Raton, Florida has continued and the initial analysis of the magnetic tapes has been completed. Target cross-sections have been computed from the received power distributions, and range cross-section plots have been constructed for various targets and sea states. The Georgia Tech Prediction Program was exercised to generate predicted target cross-section curves plotted on the same graphs as the measured data. Clutter profiles (both σ_c and σ^o) were plotted for the higher clutter days. Target cross-section data on the Coast Guard Auxilliary Flotilla taken by the AN/APS-127 and by the GT-X radar have been collated and tabulated. Receiver operating characteristics (ROC) have been computed for various signal-to-background ratios for the AN/APS-127, the digital clutter envelope processor (CE), the analog CEP, and GT-X. Autocovariance functions have been obtained for selected corner runs, boat runs and clutter.

A summary of the results was presented on 1 September 1976 at a meeting at NADC attended by NADC, the U. S. Coast Guard, Texas Instrument, Inc., and Georgia Tech personnel.

Questions were raised about the validity of the calculated receiver operating curves. The shape of the clutter distribution was distorted by bottom-clipping apparently due to the STC implemented on the AN/APS-127. The distortion causes the median clutter level to be raised, therefore causing a lower probability of detection for a given signal level than would be calculated assuming log-normal clutter. However, since the radar is normally operated in this clipping mode, ROC's calculated using the data recorded from the radar are more valid than theoretical calculations. Upcoming efforts will be directed toward plotting ROC's reflecting a minimum amount of STC bottom-clipping in the background distribution for comparison with theoretical calculations. One further observation on the ROC's calculated by GIT is that since the data for the calculations was obtained empirically, the independent parameter is not signal-to-noise ratio but rather signal plus noise-to-noise ratio. This difference can strongly affect the results for low signal-to-noise ratios.

Plans for the next reporting period include a continuation of the analysis of the radar performance and completion of the rough draft of the Phase I Technical Report. Expenditures on the contract as of 1 September 1976 were approximately $51,000 of which $18,000 were for personal services. The present contract is now overrun as was projected previously, and by the time the report is completed, the overrun will equal approximately $10,000 or $11,000 as projected.

Sincerely,

Nicholas C. Currie
Project Director

NCC:njl

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

1 December 1976

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 8
1 October 1976 to 31 October 1976

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

The preparation of the rough draft of the Phase I Test Results Report has been completed and the report has been submitted to the Contract Monitor. This report includes summaries of the measured radar cross-sections of a number of different size boats, measured signal-to-clutter ratios as functions of sea state, auto correlation functions for targets and clutter, and blip-scan ratios obtained from the PPI. In addition, predictions of the airborne detection performance are included for use in planning the airborne test program.

Preparations have begun for the upcoming airborne field tests to be held in the Boca Raton, Florida area beginning in early November. Present plans are to provide an 18 ft. boat as a test target for the airborne tests, and to make measurements on σ^o and the radar cross-section of the boat from the ground using the GT-X radar at the same time the airborne tests are being conducted. In addition, estimates of wind direction and sea state will be relayed to the airborne platform throughout the tests.

Plans for the next reporting period include the start of the airborne tests at Boca Raton. Expenditures on the contract as of 31 October 1976 were approximately $62,000 of which $22,000 was used for personal services. This represents an overun of approximately $11,000, and the Phase I work is completed with the submission of the report.

Sincerely

Nicholas C. Currie
Project Director

NCC:-me

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

14 December 1976

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 9
1 November 1976 to 30 November 1976

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

The Phase II airborne tests were begun on November 4, 1976, at Boca Raton, Florida. The Georgia Tech/U.S. Navy field site was used as a central communications center between the aircraft and the 18 ft. boat used as a test target. In addition, ground radar measurements of the cross-section of the boat and σ^0 were obtained during the flight tests along with estimates of weather and sea conditions. The tests were temporarily suspended on 20 November 1976 so that the preliminary data could be analyzed before the start of the second phase of the tests on January 12, 1976.

Plans for the next reporting period include completion of the data analysis of the cross-section measurements which will be summarized in a letter report. Expenditures on the Contract as of 30 November 1976 were approximately $72,000 of which $27,000 was for personal services.

Sincerely,

Nicholas C. Currie
Project Director

NCC:mme

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

19 January 1977

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Subject: Monthly Progress Letter No. 10
1 December 1976 to 31 December 1976

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period summarized below.

The analysis of the shore data obtained during the first phase of the flight tests in November was completed, and the results were communicated to NADC in a letter report. The data include a summary of radar cross-section values obtained on the 18' target boat with the GT-X radar, range profiles of σ^o data measured from the field site, and a log of the wind and sea conditions as a function of time during the airborne testing periods.

Plans for the next reporting period include the continuation of the flight test program at Boca Raton, Florida and the analysis of the data from this second phase of the tests. Expenditures on the contract as of 31 December 1976, were approximately $77,000, of which $30,000 were for personal services.

Sincerely,

Nicholas C. Currie
Project Director

NCC:sf

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

25 February 1977

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Subject: Monthly Progress Letter No. 11
1 January 1977 to 31 January 1977

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

The second phase of the flight test program was conducted on January 11, 1977 through January 25, 1977 at Boca Raton, Florida. An 18 foot boat and a 45 foot boat were provided as test targets during the flight program. Weather data and radar cross-section data on the boats and sea surface were gathered in support of the airborne tests from the Georgia Tech/U.S. Navy field site. These data are presently being reduced and will shortly be submitted to NADC.

Plans for the next reporting period include submission of a summary of the radar support data, obtained during the flight tests, to NADC. Expenditures on the contract as of 31 January 1977, were approximately $92,000, of which $36,000 were for personal services.

Sincerely,

Nicholas C. Currie
Project Director

NCC:sf

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

31 March 1977

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 12
1 February 1977 to 28 February 1977

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

The analysis of the shore radar data obtained during the second phase of the flight test program conducted in January 1977 has been completed, and a summary was submitted to NADC on 11 February 1977. The data includes radar reflectivity values of the sea (σ^{o}) along with wind and sea conditions at the shore test site during the times of the flight tests and radar cross-section values of the 18 ft. and 45 ft. boats that were used as test targets.

The corrected rough draft of the report on the Phase I test data results was returned to EES by NADC and the appropriate corrections are being performed.

Plans for the next report period include completion of the changes in the Phase I test report draft and its publication. Expenditures on the contract as of 1 February 1977 were approximately $87,850 of which $35,800 were for personal services.

Sincerely,

Nicholas C. Currie
Project Director

NCC:mme

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

7 April 1977

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 13
1 March 1977 to 31 March 1977

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

The corrections of the report draft of the Phase I Data Package have been completed and the report has been reproduced and will be distributed in the near future. Data packages on the Phase II results have been previously distributed, thus completing the data requirements on the contract.

Plans for the next reporting period include submission of a final letter report documenting the accomplishments under the contract. Expenditures as of 1 March 1977 were approximately $98,000 of which $40,000 were for personal services. Thus all funds on the contract have been expended.

Sincerely,

Nicholas C. Currie
Project Director

NNC:mme

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

12 May 1977

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Monthly Progress Letter No. 14
1 April 1977 to 30 April 1977

Gentlemen:

The results and current status of work performed under the referenced contract during the reporting period are summarized below.

This progress report will serve as the final report on the contract. Services performed on the contract can be summarized as follows: AN/APS-127 shore evaluation tests were performed at Boca Raton, Florida from May 1976 through August 1976; a report summarizing the results (Phase I Final Data Package) was submitted after completion of the tests. Support was given in November 1976 and January 1977 to the AN/APS-127 airborne tests, and two letter reports summarizing the support measurements (Phase II Final Data Package) were submitted after the completion of the tests.

The Phase I Final Data Package report has been approved for publication by NADC and has been distributed according to instructions received from NADC.

All contractual requirements have been completed by our records and all remaining funds have been expended.

Sincerely,

Nicholas C. Currie

NCC/sb

Approved:

James A. Scheer, Chief
Experimental Branch

ENGINEERING EXPERIMENT STATION
Georgia Institute of Technology
Atlanta, Georgia 30332

SHORE TESTS ON THE AN/APS-127 AIRBORNE RADAR SYSTEM

Final Test Data Package - Phase I
EES/GIT Project A-1820

by

N. C. Currie, M. M. Horst, and J. C. Butterworth

Prepared for

Department of the Navy
Naval Air Development Center
Warminster, Pennsylvania 18974

under

Contract N62269-76-C-0232

February 1977

Contract N62269-76-C-0232
Department of the Navy
Naval Air Development Center
Warminster, Pennsylvania 18974

A-1820 Phase I Final Data Package
Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia 30332

SHORE TESTS ON THE AN/APS-127 AIRBORNE RADAR SYSTEM

by

N. C. Currie, M. M. Horst, and J. C. Butterworth

ABSTRACT

A series of shore based performance tests on the AN/APS-127 radar system are described, and the preliminary results are summarized. The results consist of radar cross section plots, empirically measured receiver operating curves, decorrelation times, blip-scan ratios, and minimum detectable signal measurements on small- and medium-sized boats. Predictions are included for the expected performance during the upcoming flight tests and recommendations are made as to the scope and procedure for the flight tests.

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I. INTRODUCTION

This report summarizes the results of the performance evaluation of the AN/APS-127 airborne radar system performed during the period May to August 1976 at Boca Raton, Florida. Reliability and maintenance data will not be discussed here, but instead the emphasis will be placed on the ability of the radar system to detect boats and other targets of interest in the hostile radar environment provided by the sea.

A. Background

The U. S. Coast Guard over the last several years has undertaken to develop a new generation of airborne radars designed to meet modern operational requirements. The Engineering Experiment Station was involved in the test and evaluation of a previous system developed under this program, the AN/APS-119 radar. [1] The AN/APS-127 radar system is designed primarily for use in the new Medium Range Aircraft (MRA) although a wider range of deployment may eventually take place. The radar was developed by Texas Instruments, Inc. and is to a certain extent based on existing Navy airborne radars so as to take advantage of the Navy development experience and supply system.

The Aero Electronic Technology Department (AETD), Naval Air Development Center was tasked by the U. S. Coast Guard with the roles of technical development and technical evaluation of the radar system. In turn the Engineering Experiment Station at Georgia Institute of Technology (EES/GIT) was contracted by NADC to assist in the test and evaluation of the radar system during the shore-based tests and to provide ground support during the airborne measurements. EES was given specific tasks to perform during the ground tests including: (1) operation of the Georgia Tech/U. S. Navy field site at Boca Raton, Florida, (2) participation in the gathering of data on the performance of the radar, (3) computer analysis of the data using the Georgia Tech Mobile Data Reduction Facility, and (4) presentation of preliminary results and conclusions to NADC for inclusion in the test results to be reported to the U. S. Coast Guard. This report will summarize how these tasks were carried out during the test program.

B. Description of Tests

Data characterizing the performance capabilities of the radar were gathered at the Georgia Tech Field Site in Boca Raton, Florida, during the period May to August, 1976. The shore-based tests were designed to provide a quick look at the radar performance to aid in determining its potential for airborne usage. The acceptance tests performed earlier at Texas Instruments, Inc. served as a baseline for the shore verification tests, which assumed the radar was working properly prior to any data gathering runs. Statistical data were collected in order to verify proper operation and to provide a measure of performance at different ranges and under varying environmental conditions.

1. Test Site

The Georgia Tech/U. S. Navy Field Site, which is described more fully in Reference 2, is located on the eastern coast of Florida within the city of Boca Raton which has a population of about forty thousand. Boca Raton is located forty miles north of Miami and twenty-five miles south of West Palm Beach. The precise geographical location of the radar test site is latitude 26° 22' 12" North, longitude 80° 40' 07" West.

The Gulf Stream passes unusually close to shore along this section of coast, the near edge being typically between a few hundred yards and a few miles off-shore. Most ocean vessels can maneuver in relative safety as little as 3,000 yards from shore. This fortuitous occurrence of the deep water of the Gulf Stream so near to shore means that the surface of the ocean retains many of the characteristics of the open sea, and this is the prime reason for choosing this particular area for the field site.

The topography of the area is dominated by the elevated coastal ridge which begins at West Palm Beach and continues to the Miami area, where it becomes partially submerged and forms the backbone of the Florida Keys. On the beach side of the coastal ridge, a dune has formed which varies in height and width with location. It is on this dune that the tower for the Georgia Tech/U. S. Navy Field Site (shown in Figure 1) is located. Several radars are permanently installed on this tower, including the Georgia Tech GT-X experimental radar. At the base of the tower, approximately 100 feet from the mean surf line, the dune is 28 feet above the mean water level. The 53-foot height of the tower gives a total antenna height of 81 feet above the water. The AN/APS-127 antenna was mounted on an existing pedestal atop the radar tower, 75 feet above mean sea level. Protection from the weather was provided by

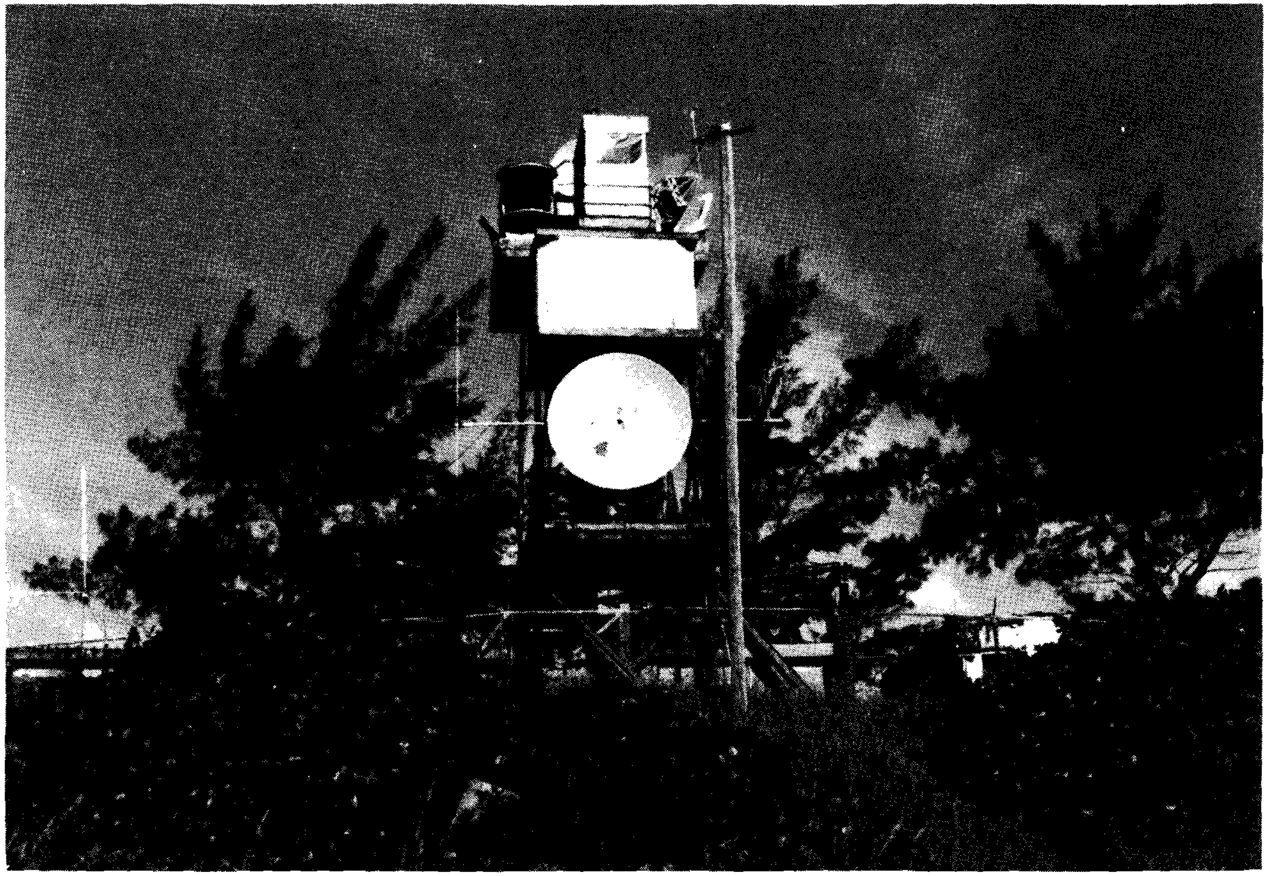

Figure 1. Radar tower located at the Georgia Tech/U. S. Navy field site, as viewed from the beach.

a temporary plywood enclosure with 0.005" mylar window for a radome. The GT-X antenna can be seen behind the AN/APS-127 housing in Figure 1.

The test site is comprised of a large parking area and a fenced compound approximately 85 feet by 60 feet which contains two concrete block buildings, each 27 by 20 feet in size, connected by a breezeway. The van containing the GT-X radar electronics is located at the north end of the compound. (See Figure 2). The north building is completely air conditioned and contains two equipment rooms, a work shop and bathroom. The recording and data reduction equipment as well as the plan position indicator, pilots indicator and test stand containing the radar set controls were located in the north building for these tests. The south building was used primarily for storage.

Wind speed and direction at the field site were measured by instrumentation located inside the compound. Remote readouts were provided in the X-band radar van. A wavegauge normally utilized for testing was not available because of storm damage.

2. AN/APS-127 Radar

The AN/APS-127 radar, described in Reference 3, was modified by Texas Instruments from the standard AN/APS-115 in an attempt to solve the problems associated with detection of small targets in a sea clutter environment. Several features are incorporated into the AN/APS-127 in order to improve detection of small surface targets over the AN/APS-115. These include a relatively fast scan antenna system (2 scans/second), an adjustable clutter envelope processor (CEP) and scan-to-scan integrating direct view storage tube (DVST) indicators. For long range mapping, a secondary operational mode is implemented by means of a slower antenna scan rate and wider transmit pulse-width. Selectable Iso-echo contouring also increases the utility of this mode of operation for weather avoidance or penetration. Figure 3 shows exterior views of the individual units which comprise the AN/APS-127.

The top two units shown by Figure 3 are the displays for the AN/APS-127: the main display, a plan position indicator (PPI), shown in (a), and the pilot's indicator, shown in (b). The main PPI processes radar Identification-Friend-from-Foe (IFF) video for display in PPI format and provides target range and bearing information to the navigation system, while monitoring its own operation with the built-in-test (BIT) system. The pilot's indicator displays radar

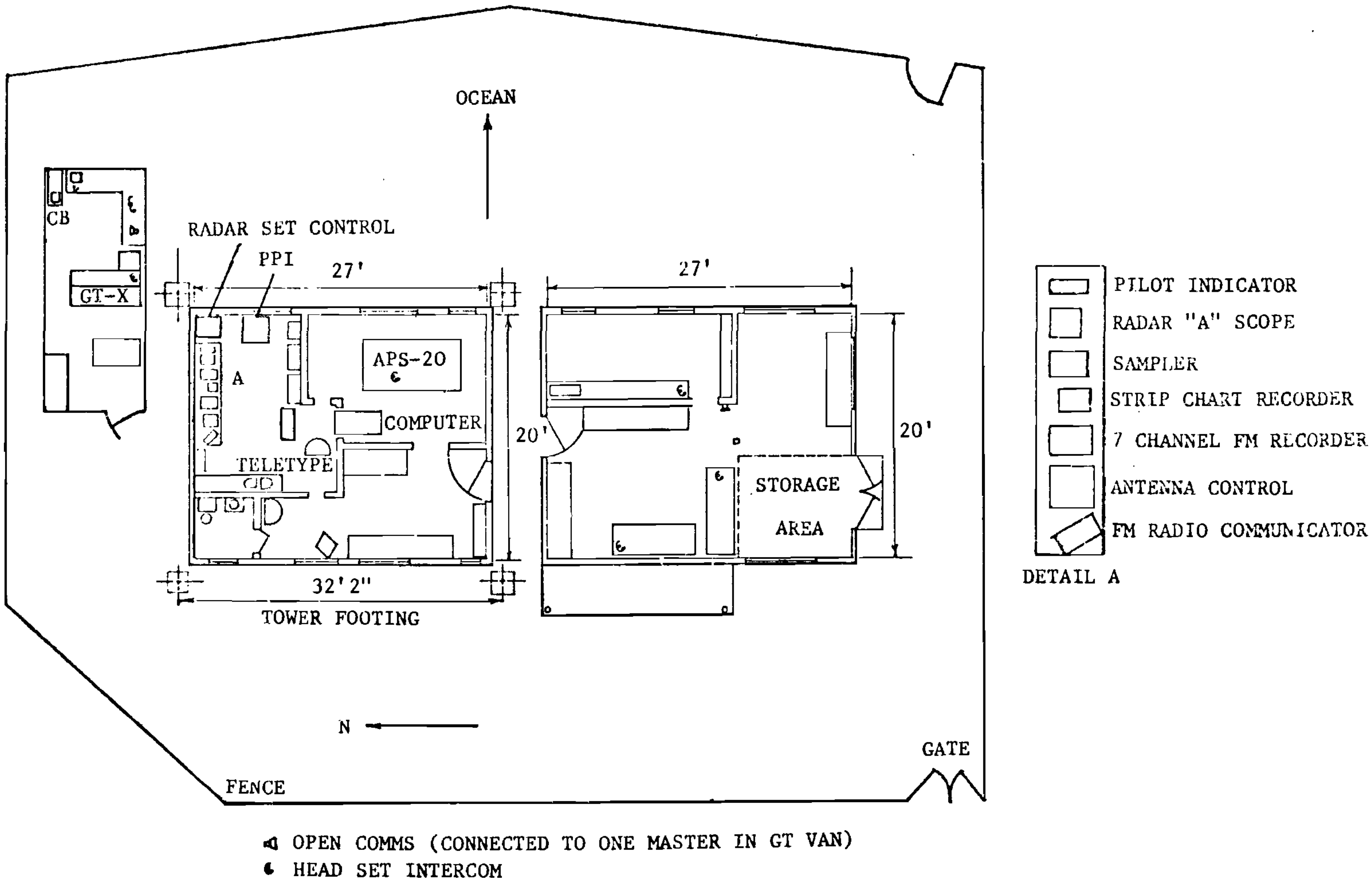

Figure 2. Layout of the Georgia Tech field site.

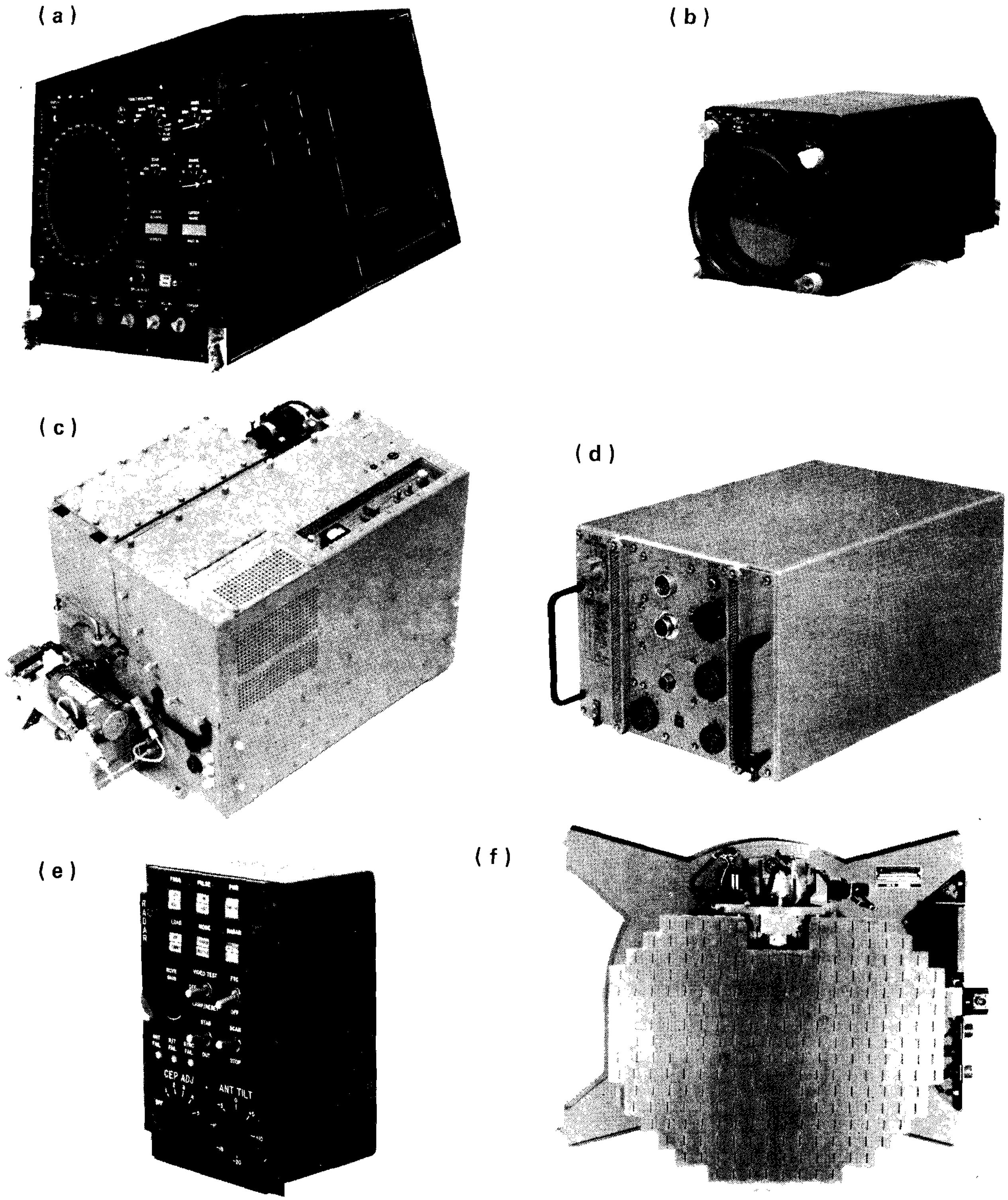

Figure 3. Major components of the AN/APS-127 radar. (a) PPI, (b) Pilot's indicator, (c) Receiver/Transmitter unit, (d) Synchronizer, (e) Set control, (f) Antenna.

video in PPI format independently of the main PPI controls and also provides quantitative indications of weather cell intensity in the weather mode of operation (Iso-echo control).

Figure 3(c) shows the Receiver/Transmitter unit which generates RF pulses for radiation by the antenna and processes the X-band energy received by the antenna into radar video. The R/T also monitors its own operation with BIT. The Synchronizer unit, shown in Figure 3(d), generates the primary timing signals for the radar and PPI, generates control signals for stabilizing and scanning the antenna, and also generates the sweep and unblanking signals for the pilot's indicator. Radar video is processed by the Synchronizer to minimize the effects of clutter. The Synchronizer monitors its own operation and that of the antenna, and uses the fail signal from the R/T to control fail indicators for these three units on the Set Control, shown in Figure 3(e). This unit controls the radar status (warmup/standby/operate) and the primary power relays in the Synchronizer and R/T. Control knobs on the set select RF pulse width (long/short), operating mode (search/weather), transmitter frequency mode (fixed/agile), transmitter load (antenna/dummy). Controls are also present for receiver gain and STC, antenna scan, stabilization and tilt, and for the clutter envelope processor (CEP) in the Synchronizer.

The slotted array antenna for the AN/APS-127 radar is illustrated in Figure 3(f). The antenna transmits and receives both the X-band energy generated by the R/T and reflected by targets, and L-band energy for the IFF system. It utilizes aircraft gyro inputs to maintain both arrays in pitch and roll stabilized position and can tilt the X-band array in response to manual input from the Set Control.

The basic parameters of the AN/APS-127 are listed in Table I and a block diagram showing the interconnection of data acquisition equipment is given in Figure 4. Figure 5 shows the antenna mounted to the steerable pedestal at the Boca Raton Field Site. Note the closed circuit television camera mounted on the antenna test stand and the calibration signal generator and receiver/transmitter test set which can be seen in the foreground. Photographs of the PPI direct view storage tube (DVST) and radar set control as installed at the Boca Raton shore test site are shown in Figures 6 and 7. The statistical data gathering instrumentation is illustrated in Figure 8.

TABLE I

NORMAL PARAMETERS OF AN/APS-127 RADAR

Modes

- Search/detection of sea surface targets
- Navigation
- Weather avoidance

Transmitter

Frequency	9.05 GHz
Frequency Agility	40-80 MHz at 75 ± 5 Hz swept rate
Peak Power (kW)	143 kW
Average Power (Watts)	190 Watts
Pulse Width/PRF	2.5 μsec/400 Hz
	0.5 μsec/1600 Hz

Receiver

System Noise Figure	9.5 dB at 9.05 GHz
Bandwidth	2.5 MHz/0.5 MHz
Pulse Width	0.5 μsec/2.5 μsec
Type	log
Display	7 inch DVST

Design Considerations

Prime Power	1.6 KVA
Weight	240 lbs.
200 Hrs. MTBF	
BIT (Built-in-Test) to WRA level	
0.6 hrs. MTTR	

Antenna

Gain	30.5 dB
Beamwidth (3 dB)	
Azimuth	5°
Elevation	6.5°
Scan Rate	12 rpm/120 rpm

Displays

	Observer	Pilot (Cockpit)
Display type	Direct view storage tube	Direct view storage tube
Display diameter	7 inches	5 inches
Resolution	75 lines/inch	85 lines/inch
Persistence (adjustable)	0.5 to 10.0 seconds	0.25 to 9.0 seconds
Shades of gray	5	5
Cursor Accuracy		
Range	± 2 percent of selected range	
Azimuth	± 2 degrees	

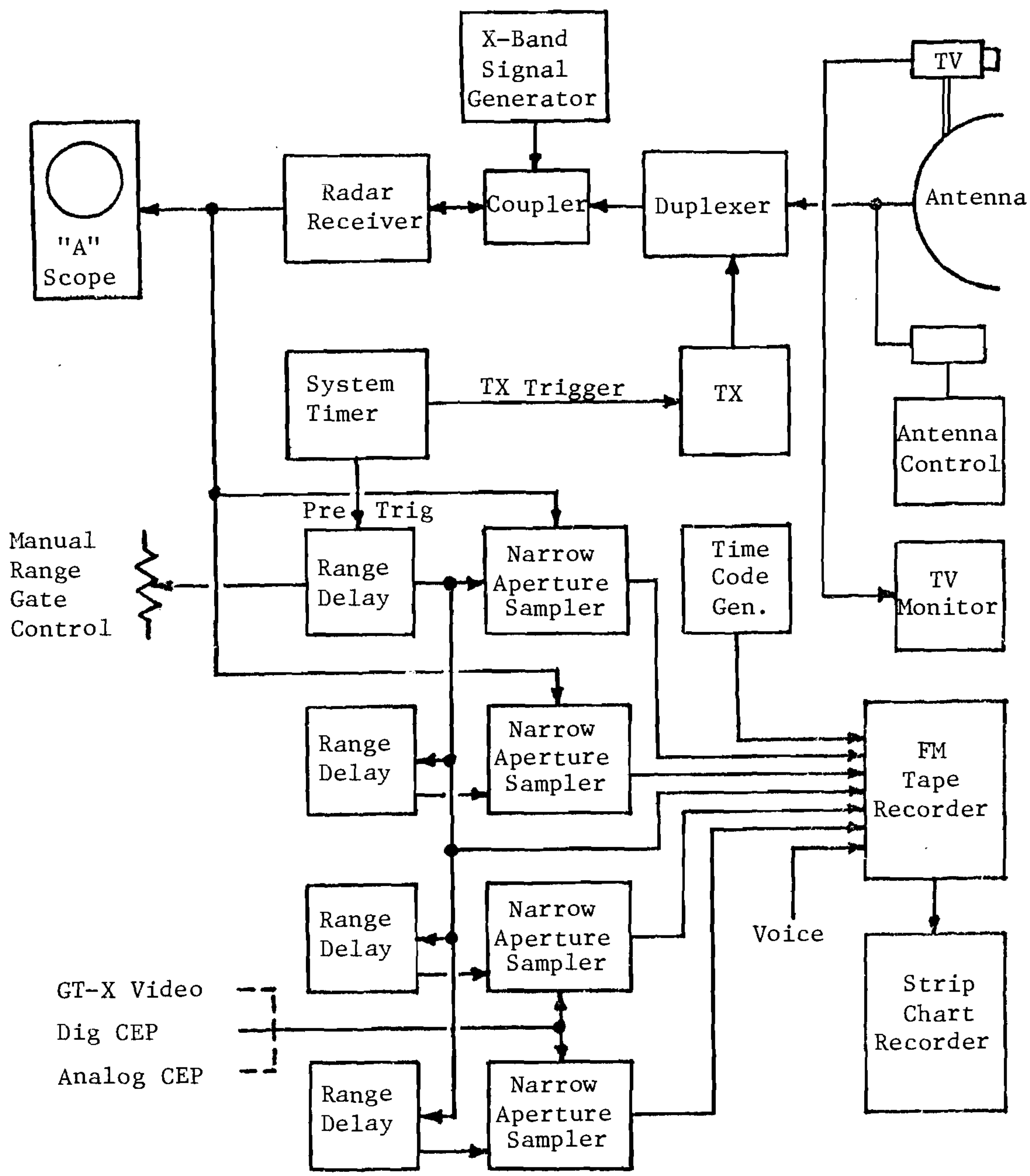

Figure 4. Block diagram of Statistical Data Acquisition System.

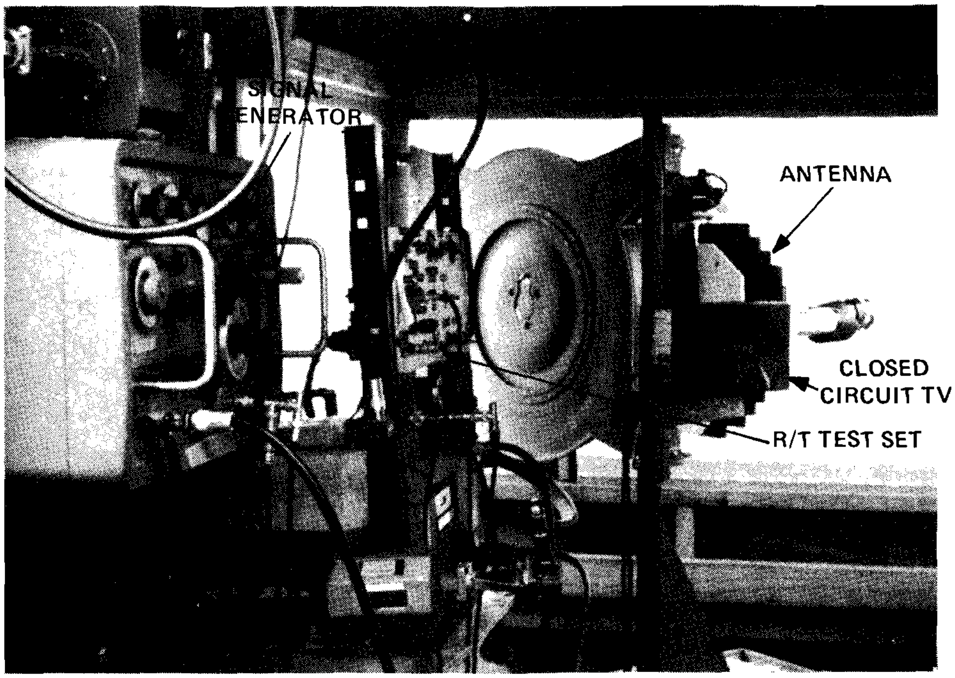

Figure 5. Interior of antenna enclosure showing signal generator, antenna, closed circuit television, and the R/T test set.

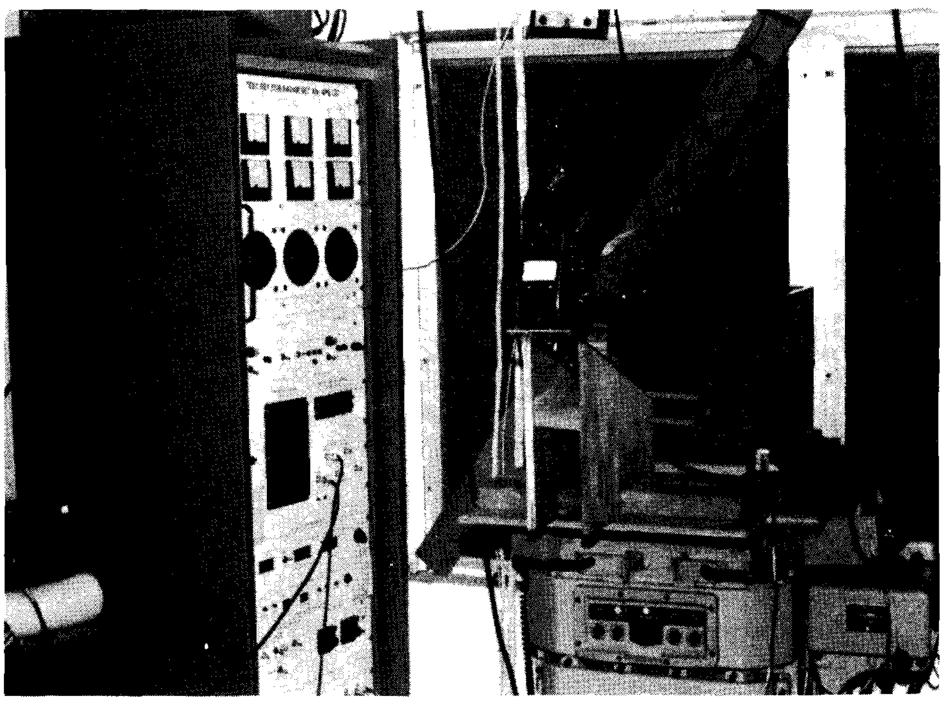

Figure 6. View of AN/APS-127 radar controls and main PPI display at the field site.

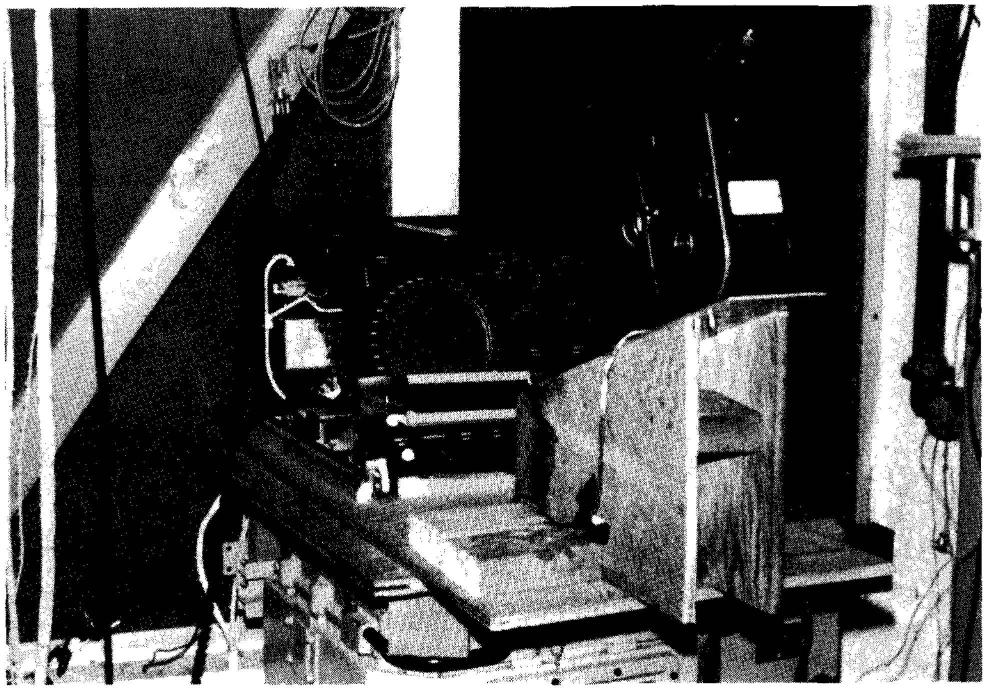

Figure 7. View of main PPI display showing 16 mm photographic instrumentation.

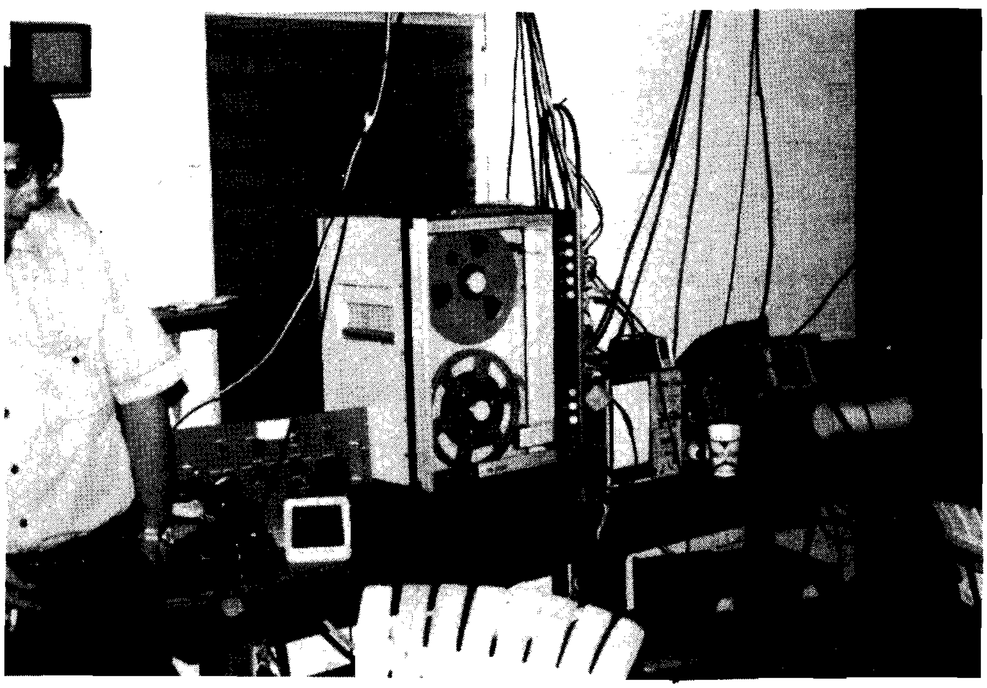

Figure 8. Statistical data recording instrumentation including an FM tape recorder, a range-gated sampler, a strip-chart recorder and an oscilloscope.

3. GT-X Radar

The radar consists of three major subsystems--the operating van assembly, the rapid-scan antenna assembly, and the slow-scan antenna assembly. The van is a modified piggy-back freight container without wheels or running gear. It houses the operator console, the system power supplies, and communication equipment while the transmitter, the waveguide system, the two receiver mixer-preamplifiers, and the rapid-scan antenna are mounted on the rapid-scan antenna pedestal. Figure 1 shows the experimental radar installed at the field site at Boca Raton, Florida. The rapid-scan antenna assembly is mounted on top of the tower, and the van is at the base of the tower in the right foreground. The slow-scan antenna is not shown in Figure 1 in its normal position, but has been removed from its pedestal in order to accommodate the AN/APS-127.

The transmitter is comprised of a master-oscillator, power-amplifier (MOPA) chain consisting of a magnetron and two crossed-field amplifiers (CFA's). The MOPA transmitter operates at approximately 9.4 GHz with either 5 kW, 10 kW, or 250 kW peak power. The transmitted pulse width is approximately 400 ns at 5 kW, 250 ns at 10 kW or 150 ns at 250 kW and occurs at a repetition rate which is variable between 50-4000 pulses per second.

The receiver consists of two identical channels each operating from an antenna system equipped with a dual polarization feed. The antenna is capable of transmitting either horizontal, vertical, right or left circular polarization while receiving return which is the same polarization as that transmitted (parallel) or its orthogonal (cross) polarization signal simultaneously. Each receiver channel contains three intermediate frequency (IF) amplifiers, a mixer/preamp, gain control IF followed by step attenuators (0-120 dB in 1 dB steps), and an 80 dB logarithmic amplifier and detector. Video line drivers are provided for both the parallel and cross receiver outputs.

Signal processors such as fast time constant (FTC), polarization ratio discrimination (PRD), threshold discrimination, scan conversion integration, and direct view storage tube integration are incorporated. Sample and hold circuits for statistical data collection for computer analysis are available which allow radar return to be recorded either at the prf rate or the scan rate (10 scans/sec).

Nominal values of some parameters of the experimental X-band radar are listed in Table II. Many of the parameters are adjustable over a wide range to provide flexibility in the experimental procedures.

4. Measurement Procedure

Basic measurements were performed with the AN/APS-127 radar not only to verify design characteristics but also to identify any problem areas which might occur during future flight tests.

a. Radar Verification

After allowing sufficient time for warm-up, the following tests were performed on a daily basis. The prime power (3ϕ, 400 Hz) was monitored and adjusted for 115 ± 1 VAC. The transmitter frequency was measured using a high Q frequency meter; if found to be other than 9.05 GHz, the magnetron was tuned to correct for error. The pulse repetition frequency (PRF) and pulse width were verified to be 400 ± 20 Hz and 2.5 ± 0.15 μsec for the long pulse mode and 1600 ± 80 Hz and 0.5 ± .05 μsec for the short pulse mode. The transmitted power was measured using two methods: (a) a direct measurement of average power, and (b) use of a notch wattmeter NAVAIRDEVCN RF test set. Receiver sensitivity tests in the form of a step calibration were performed each time statistical measurements were recorded. The calibrated signal generator was set at maximum output and data were recorded for 20 to 30 seconds at this level and at 10 dB decremented levels until only noise was apparent at the receiver output. Built-In-Test (BIT) lamps were observed periodically on both PPI and Set Control as well as individual units exercised during performance verification. Wave guide losses were measured at the initial setup of the AN/APS-127 radar and after any change in waveguide configurations. The loss measurements were recorded in the daily log along with the measurement procedures.

b. Radar Calibration

In order to properly evaluate any radar system a standard target calibration, such as that described in Reference 4, must be performed. By injecting calibrated standard RF signals into the input of the receiver the video output signals can be characterized. The receiver input power is then related to target backscatter cross-section by the radar range equation:

TABLE II

PARAMETERS OF GEORGIA TECH GT-X EXPERIMENTAL RADAR

Paramater	Description
Frequency	9.3 - 9.5 GHz
Peak Power	5 kW/10 kW/250 kW
Pulse Width	400 ns/250 ns/150 ns
PRF	50 -4000 pps
Antenna Type	Four Paraboloids (Rapid Scan) Cut Paraboloid (Slow Scan)
Scan Rate	
360°	15 rpm
Sector	15 rpm or 600 rpm
Searchlight	Yes
Azimuth Beamwidth	1.5° (Rapid) 1° (Slow)
Elevation Beamwidth	1.5° (Rapid) 3° (Slow)
Polarization	H, V, RC, Slant Transmitted, Orthogonal components received simultaneously
Antenna Gain (Effective)	37 dB Rapid Scan 38 dB Slow Scan
IF Center Frequency	60 MHz
IF Bandwidth	5 MHz
IF Response	Logarithmic (linear available)
Noise Figure	10 dB
Dynamic Range	80 dB
Display Type	A-Scope, B-Scope
Antenna Height	81 ft. (MSL) Rapid Scan 75 ft. (MSL) Slow Scan

$$P_r = \frac{P_T \, G^2 \, \lambda^2 \, \sigma_T}{(4\pi)^3 \, R^4 \, L} \qquad (1)$$

where P_r is power at the receiver input,

P_T is transmitter power,

G is gain of antenna,

λ is wavelength,

σ_T is target cross section,

R is range, and

L is fixed system loss.

The parameters P_T, G, λ, R and L are known or measured quantities. When a standard target (corner reflector) is employed, system parameters and propagation conditions can be determined. As a standard procedure, two corner reflectors, 12 dBsm and 18 dBsm, were used in connection with statistical data runs on small boats and sea clutter. Backscatter multipath curves were calculated to determine the proper height at which corner reflectors should be placed above the reflecting plane of the water surface for a given range. Corners were hand-held and aimed using a boresight tube mounted on the side of each reflector. Exact height above mean sea level could only be approximated by a person standing in a small boat.

c. STC Calibration

The sensitivity time control (STC) modifies the receiver gain as a function of range according to a predetermined profile. Calibration of this function was accomplished by injecting a calibrated pulsed RF signal into the receiver input at ranges of 1, 2, 4 and 8 nmi. The level of the generator was then adjusted at each individual range to produce a given video standardized signal. The difference in attenuation levels was then recorded to characterize the STC. A family of such curves was plotted versus Receiver Gain STC wiper voltage and is shown in Figure 9. An STC calibration curve was generated for each set of statistical data.

d. Statistical Target Measurements

Measurements were made on selected surface targets to evaluate radar detection performance as a function of range for various sea conditions. Three separate small boats were used as targets during the course of the

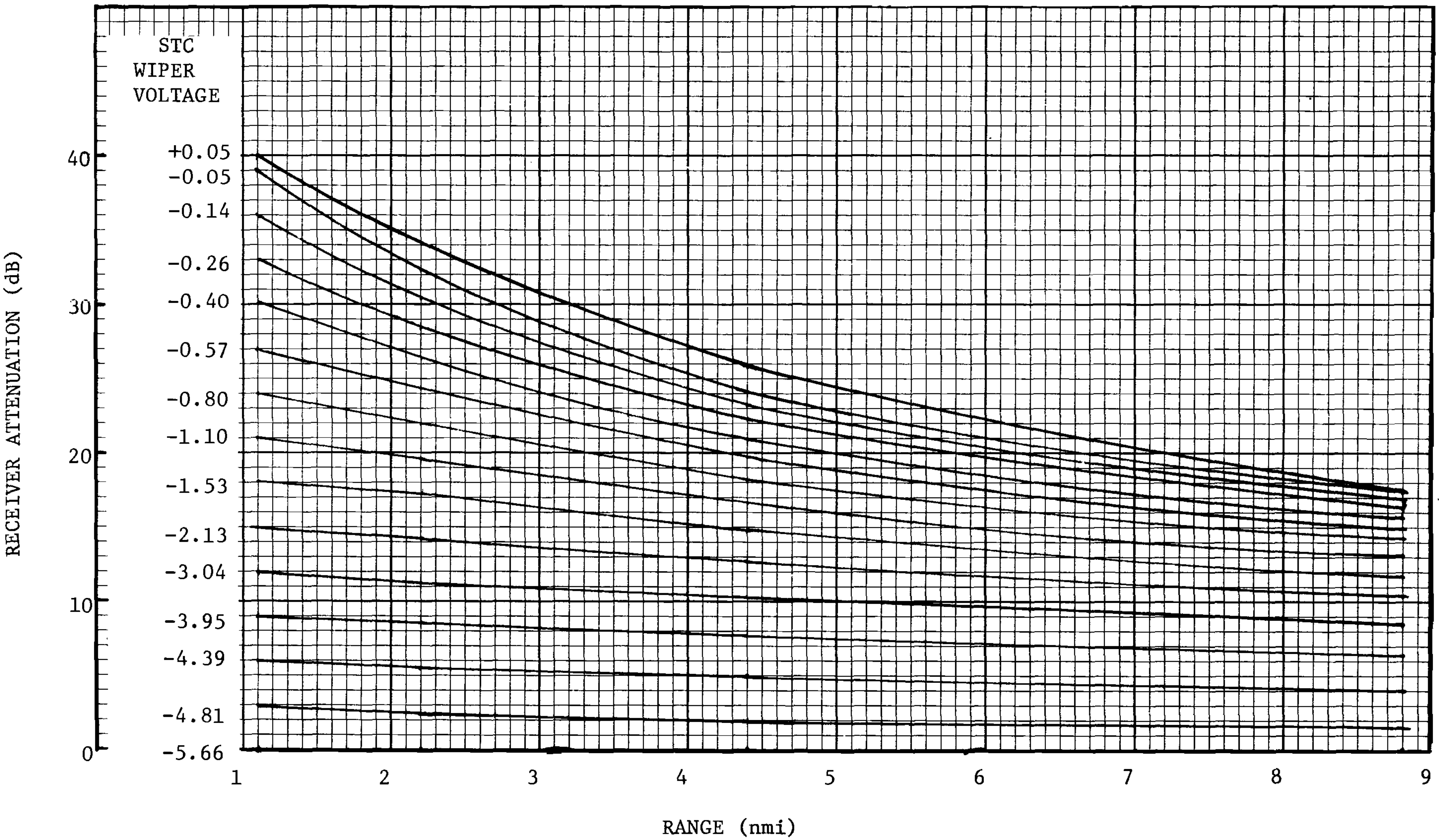

Figure 9. AN/APS-127 receiver calibration curves as functions of STC wiper voltage.

operation and can be described as follows: (1) The "Foxy Lady" was an 18-foot tri-hull runabout, with an outboard motor and approximately 1.5' freeboard. (2) A 22' deep-V hull boat was rented from the Florida Oceanographic Science Institute (FOSI). It had an outboard motor, 3' freeboard and a canopy with aluminum struts extending approximately another 3' above the cockpit. (3) The final small boat used for the tests was an 18' SF-190 deep V-hull, inboard/outboard boat provided by the Coast Guard, with 2-3' freeboard and a 1' windshield. The majority of the small boat data were taken on these three boats. In addition, limited data were collected on a 4-man Winslow life raft, 7.5' in diameter and approximately 2' high, and on a fiberglas dinghy, 5.5' x 3'. To provide measurements on a wider variety of targets, the Coast Guard Auxiliary Flotilla 310 of Boca Raton arranged for ten of its boats, ranging in length from 25' to 45', to be used as targets. Measurements were made while these boats (charter type fishing boats and cabin type pleasure boats) were operated on radial paths intersecting the site position at speeds from 5 to 10 knots. Data were also collected at bow, stern, and broadside aspects of craft dead in the water.

Statistical data were gathered using a Georgia Tech narrow aperture (25ns) sample and hold, and recorded on a seven channel frequency modulation tape recorder. (See Figure 8.) Two variable range gates were employed: one at the target range, and the second approximately 2 μsec nearer in range than the target gate, for a sea clutter sample. An "A" scope radar display was used to monitor the return video and to position the range gate properly on the target to be sampled. The radar antenna was searchlighted on the target (Figure 5) using the GT-X slow scan pedestal and control, a closed circuit television camera mounted on the antenna frame with the monitor at operator position. In addition to the above two channels of "boxcar" data from the AN/APS-127, two similar channels of data from the GT-X radar, time code and voice log were recorded on the other channels. Processed video digital clutter envelope processor (CEP), analog clutter envelope processor or other boxcar data were sometimes substituted for the GT-X data. A two channel paper strip chart recorder was provided as monitor for the FM tape recorder.

e. Blip/Scan

Using targets of known radar cross-section, blip/scan data can be accumulated to characterize the detection capability of a given radar system and display.

An electronic counter accumulates pulses in two channels: a preset channel to count each scan of the antenna, and a channel to count each antenna scan if an observer has closed a hand held switch. For the tests the preset counter was set to count 100 antenna revolutions while a given operator would hold the switch closed when the target was visible on display, open when target was not visible. Operational runs were made on small boats as a function of range from the radar. Blip/scan data were taken from close in-range (where the target was obscured by sea clutter) to maximum range (where the target was lost in noise).

f. Minimum Detectable Signal

Evaluation of the AN/APS-127's direct view storage tube (DVST) integrating display was accomplished by determining the minimum detectable signal (MDS) an operator was able to identify. A calibrated RF test signal was injected into the receiver. The test signal was gated to have an azimuth extent equal to one antenna beamwidth and located randomly at one of nine points in range and azimuth. The level at which an operator could first positively identify the artificial target (approximately a 0.5 blip/scan ratio) was defined as MDS. The signal generator was set below the level of the noise or clutter background and stepped up in 1 dB increments at 30 second intervals until the observer verified the range and bearing to the artificial target.

g. 16 mm Film

Qualitative assessment of the radar performance was also made using a 16 mm movie camera which photographed the main PPI. The experimental set-up including a data clock on lower face of the DVST is shown in Figure 7. Timing of the shutter was synchronized by a signal from the Synchronizer Unit which opened and closed the shutter for every other scan.

II. DATA ANALYSIS

A. Data Analysis Techniques

The availability of an on-site computer facility at the Boca Raton Field Site during the shore tests on the AN/APS-127 radar system proved to be of considerable value. The ability to provide prediction curves for specific environmental and meteorological conditions aided in the design of experiments while on-line data acquisition and real-time data reduction helped to keep a check on the quality of data being recorded. Immediate data analysis served to direct the course of the field operation and allowed for more flexible test planning.

The major part of the data analysis performed under this contract consisted of both real-time and after-the-fact reduction of the data recorded on magnetic tapes. Data from other sources, such as the blip/scan ratio measurements and minimum detectable signal measurements described in Chapter I, completed the analysis efforts on the radar. Auxiliary data (i.e., video recordings and strip chart records) were used to provide background information but were not analyzed directly.

1. Mobile Data Reduction Facility

The PDP-8/F based mobile data-reduction facility of the Systems and Techniques Laboratory of EES was used to process all the data taken during the shore tests on the AN/APS-127. Figure 10 illustrates the basic computer components in block diagram form. These include: (1) An analog signal-conditioner unit which provides variable gain and offset to allow the interface of varied types of signals to the data-reduction facility, (2) A Fabritek Series 1072 instrument computer, which serves as an A/D and D/A interface and also computes real-time pulse-height distributions. The D/A output from the Fabritek computer can be displayed on a CRT display or be plotted on an x-y plotter, (3) A 16K PDP-8/F mini-computer which can exchange information directly with the Fabritek computer, (4) A teletype, and (5) A Digital Equipment Corporation Decassette unit for program development and storage.

An extended version of $FOCAL_{TM}$ has been developed for use with the PDP-8/F and is designated FOCL/F [5]. This language is interactive and greatly facilitates program correction and modification. Also available is a machine

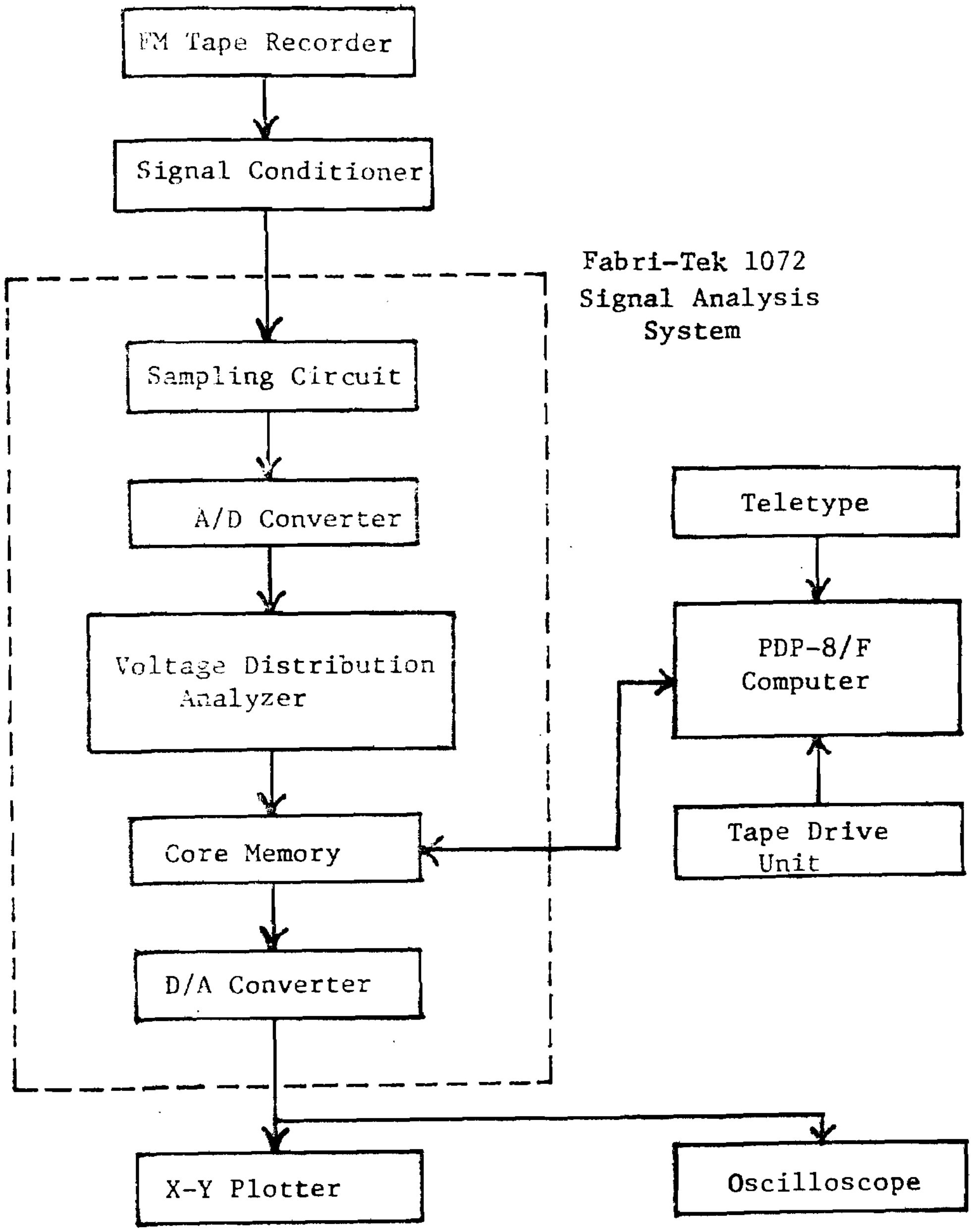

Figure 10. Block diagram of the Data Reduction Facility.

language software package for calculating fast Fourier transforms (FFT), and a set of software commands for Fabritek control. These two machine language software packages along with the extended $FOCAL_{TM}$ software make this system a very powerful and flexible data-reduction tool.

2. Data Analysis Procedures

The types of results which can be obtained from the data facility include pulse-height amplitude distributions, receiver operating curves, and auto-correlation functions. The methods for obtaining these three classes of results are sufficiently different as to require entirely different $FOCAL_{TM}$ programs for their calculation.

In addition, blip/scan ratio and minimum detectable signal (MDS) measurements were made to characterize the various available displays. These results, in conjunction with the results from the recorded data, are considered to provide an evaluation of the AN/APS-127 radar.

a. Pulse-Height Amplitude Distributions

Pulse-height amplitude distributions calculated by the data facility are displayed in two forms: as probability density plots and as probability distribution functions. The probability density plots are generated from data time histories using a Fabritek Type SW-75 PHA plug-in as a preprocessor. This plug-in samples the input analog time history, A/D converts the samples, determines into which of 1024 amplitude bins the sample belongs, and increments a stored variable corresponding to the number of samples which have fallen in that amplitude window. When repeated a large number of times, this process generates an unnormalized density, which is then divided by the total number of samples to achieve a normalized probability density function.

The voltage amplitudes are calibrated by a stepped calibration signal injected into the receiver input. The peak of the distribution for each 10 dB step in the calibration is assigned the dB value corresponding to that step and the program then generates a table relating dB value to amplitude bin number. The cubic fit program was developed to "linearize" nonuniform calibration steps to allow the output density functions to be plotted on a linear scale.

The probability distributions are calculated by a point-by-point numerical integration of the probability density functions. The functional values of these distributions are then multiplied by a nonlinear transfer function and plotted on log-normal probability paper.

The resultant probability distributions are useful in determining the median values of the distributions and also their shapes.

b. Receiver Operating Curves

Receiver operating curves (ROC) are important in the analysis of radar systems because they provide a measure of the quality of the receiver that is independent of any radar parameters, such as power, wavelength, antenna gain, etc. The ROC is actually a family of curves of the probability of detection (PD) versus the probability of false alarm (PFA) for various signal-to-background ratios.

To compute one curve in the family, pulse height analyses are done on the target return signal (target plus clutter plus noise) and on the background (clutter plus noise). Note that the "signal-to-background" ratios obtained from the ratios of the median values of these distributions are actually (signal plus background)-to-background ratios. The two probability densities are constructed and calibrated to the same scale. An initial value is chosen for probability of false alarm (PFA) and numerical integration performed on the background probability density to determine the threshold for that PFA. Then, using that threshold, the probability of detection (PD) is computed by numerical integration of the target probability density above the threshold. This procedure is repeated for different values of PFA and the results plotted on the ROC.

It is important to understand exactly what is represented by the distributions used as input for the ROC. Theoretical ROC's are often computed by taking the target plus background and background distributions at the antenna and then using some signal processor model to describe the transfer function of the receiver. The ROC's are then constructed for the distributions at the receiver. In contrast, the distributions used as input for the ROC here represent the actual signal after processing, due to the method of recording the raw video data leaving the receiver. Therefore these ROC's reflect the actual PD versus PFA at the receiver, not an approximation based upon an assumed signal distribution or an assumed signal processor model.

c. Auto-Correlation Functions

The auto-correlation functions are determined from data time histories, which are input to the Fabritek via the Type SW-71 plug-in. The fast Fourier transform package in the PDP-8/F takes the data into frequency domain and the auto-correlation function is the inverse transform of the magnitude of the frequency spectrum squared. This method of calculating auto-correlation has one inherent limitation, however. Due to the limited memory available in the Fabritek, the lowest frequency that can be accurately measured is approximately one-tenth the total sampling period. Thus to measure the auto-correlation function of a signal with 800 Hz bandwidth, the sample rate would be 1600 Hz and the lowest frequency would be

$$F_{low} = \frac{\text{sample rate}}{\text{total memory}} = \frac{1600 \text{ Hz}}{1024 \text{ memory bits}} = 1.56 \text{ Hz} \qquad (2)$$

A partial solution to this problem is to calculate the auto-correlation function using a lower sample rate to pick up lower frequencies at the expense of higher frequencies. A family of curves can thus be generated at different sampling rates which describe the auto-correlation function over any desired band of frequencies.

B. Summary of Results

The results of the shore tests on the AN/APS-127 radar consisted of recordings of the received power from small and medium size boats for wave-heights of 1 to 6 feet, blip scan measurements, minimum detectable signal tests for noise and clutter, and movies of PPI display. These results will be discussed in the following sections.

1. Interpretation of the Data

The AN/APS-127 radar system is designed as an airborne surface search system and this factor must be taken into account during the analysis of data taken during ground tests. Furthermore, since the system was not designed as an instrumentation radar, obtaining calibrated data on system performance is more difficult than would be the case for an instrumentation radar. A number of problems were encountered during the tests which increased the difficulty of evaluation of the radar performance. These included: (1) The sensitivity time control (STC) could not be disabled making it difficult to determine the received power as a function of range. Basically, a calibration of the STC attenuation was made each morning and the circuit was then assumed to be stable for the rest of the day. (2) In addition to changing the receiver response as a function of range, the STC circuit quite often clipped the baseline making it difficult to determine the noise and clutter levels. (3) Evaluation of the PPI performance was hindered by its non-uniformity and the almost impossible task of determining the integration time which gave optimum results. (The integration control was not calibrated.) (4) The evaluation of the performance of the system with and without frequency agility was hindered by the fact that the AFC was often unstable introducing extraneous modulations onto the returns from targets and clutter and making the determination of the decorrelation properties with and without frequency agility very difficult. (5) In addition, the normally encountered difficulties due to environment such as rapidly changing sea state and propagation conditions added to the problems. Estimating sea state was particularly a problem since a wave gauge was not available and wave height had to be estimated from visual observations.

With these limitations in mind the data were analyzed to obtain the following results: (1) A measure of the cross-section of a number of different types and sizes of boats obtained using the AN/APS-127 radar. (2) A measure of the signal-to-clutter ratios that can be expected for the AN/APS-127 for various targets and sea states. (3) Estimates of the display performance for various sea conditions. (4) Determination of the effects of frequency agility on target/clutter decorrelation. (5) Using prediction techniques to estimate the performance of the radar for the airborne scenario. The results obtained are approximate due to the aforementioned problems and in many cases due to limited data samples, but should give "ballpark" estimates of the expected radar performance.

2. Test Results

The results of the data analysis efforts on the AN/APS-127 airborne radar system are presented in this section. In most cases, only selected plots or summary tables are shown here. Other supplementary data may be found in the Appendices.

a. Pulse Height Analyses

Pulse height amplitude distributions were computed for over 1200 separate data runs by the Mobile Data Reduction Facility. Approximately two-thirds of these analyses were done real-time. Probability distributions were calculated for small and medium size boats in motion and dead in the water, at ranges from 0.5 to 7.0 nmi, for sea states 0 to 3. Calibration runs were made on two corner reflectors, and an associated clutter run was recorded for every target run. Returns from the AN/APS-127, with and without the clutter envelope processor, and from the GT-X radar were analyzed. The GT-X data are presented here since it is anticipated that GT-X will be employed to provide ground truth data during the flight tests. Probability distributions selected from all the runs analyzed may be found in Appendix A.

The distributions of the return from a target and its associated clutter yield (among other things) the target cross-section and the signal-to-clutter ratio. Table III lists the cross-sections measured and the range of signal-to-clutter ratios which were observed for several classes of boats by the AN/APS-127 and GT-X. Note that while the cross-sections measured by the AN/APS-127 are very close to those measured by GT-X, the signal-to-clutter ratios of the AN/APS-127 are 5 to 10 dB lower than those of GT-X. This is due to the fact that the GT-X is "optimized" for detection of small targets on the sea surface by possessing a narrow antenna beam and short pulse length. Figures 11, 12, and 13 are pictures of the three larger boats included in the table. These boats are members of the Coast Guard Auxiliary Flotilla 310 of Boca Raton, which provided the majority of the medium sized boats used as targets. Appendix B contains a summary of the data gathered on the flotilla on 26 June 1976.

b. Receiver Operating Curves

An evaluation of the receiver of the AN/APS-127 airborne radar system is provided by receiver operating curves. The ROC's presented here are families of PD versus PFA curves, as functions of (Signal plus Background)/Background, for the AN/APS-127 and GT-X, for various sea states and radar operating modes. Due to the method of recording raw video, these measured ROC's are computed from the actual target-plus-background and background distributions at the receiver. When the probability density functions of these signals are examined, those from GT-X show the expected log-normal shape. However, some of the clutter densities for the AN/APS-127 exhibit bottom-clipping, due to the action of the STC. Figures 14 and 15 illustrate the effect of the STC on the probability density function of the background signal. (Signal plus Background)/Background ratios are computed as the ratios of the median power levels of the two densities; for a clipped density, this ratio will tend to be high. Since the STC clipping is a real phenomenon affecting the signals input to the receiver, the use of the actual clipped densities as input to the ROC program means that these ROC's accurately reflect the quality of the receiver.

TABLE III

TYPICAL CROSS-SECTIONS OF SOME CLASSES OF BOATS

FOR 1 - 3' WAVE HEIGHTS

		Average Cross-Section* (dBsm)							
		Boat in Motion		Dead in Water		$\sigma°$ (dB)		Signal-to-Clutter** (dB)	
	RANGE*** (nmi)	AN/APS-127	GT-X	AN/APS-127	GT-X	AN/APS-127	GT-X	AN/APS-127	GT-X
FOXY LADY (18' Tri-Hull Runabout)	2.8-4.4	-1.7	-1.1	-9.3	-11.0	-60.4 to -65.0	-59.8 to -65.3	6.4 to 17.7	12.0 to 24.7
Coast Guard 18' Boat	1.9-5.1	-0.7	-1.4	-4.1	-4.9	-55.8 to -65.6	-57.0 to -66.3	8.3 to 23.0	12.8 to 28.6
FOSI 22' Boat	2.3-4.3	9.0	--	8.6	--	-55.9 to -65.8	--	19.6 to 27.2	--
SKYLARK 30' Elco	2.1-3.9	6.1	6.8	2.1	4.9	-57.1 to -63.4	-64.0 to -64.8	18.4 to 24.9	29.2 to 35.4
JONA 43' Wheeler	2.2-5.4	10.9	10.8	9.6	10.7	-58.8 to -63.4	-62.4 to -64.6	23.6 to 28.1	34.5 to 37.6
SOUTHWARD 43' Pearson	3.7-4.5	14.7	14.3	11.3	12.8	-62.7 to -63.3	-63.6 to -63.8	27.1 to 32.4	35.1 to 39.4

*Cross-section numbers represent the average of the cross-sections measured for the given target at all ranges.

**Signal-to-clutter numbers represent the maximum and minimum values measured for the given target at all ranges.

***Range increments over which data were obtained.

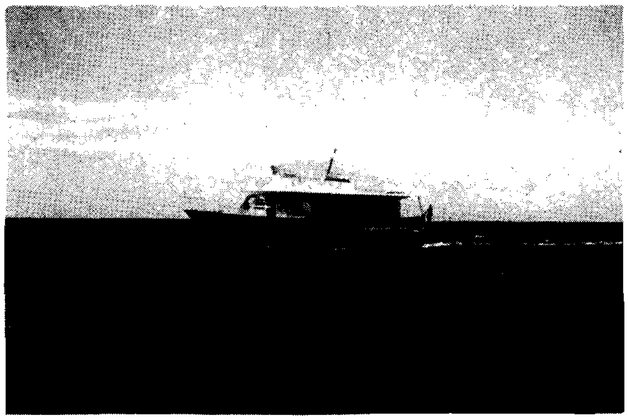

Figure 11. Broadside view of the "Southward", a 43 foot Pearson.

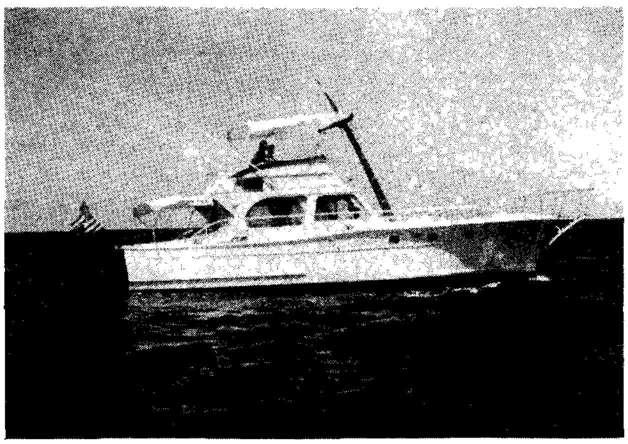

Figure 12. Broadside view of the "Jona", a 43 foot Wheeler.

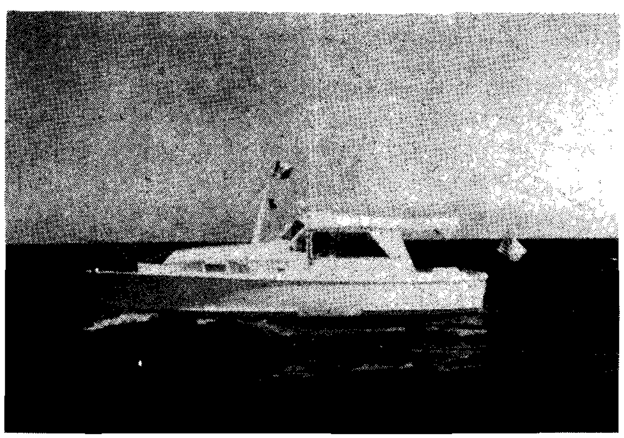

Figure 13. Broadside view of the "Skylark", a 30 foot Elco.

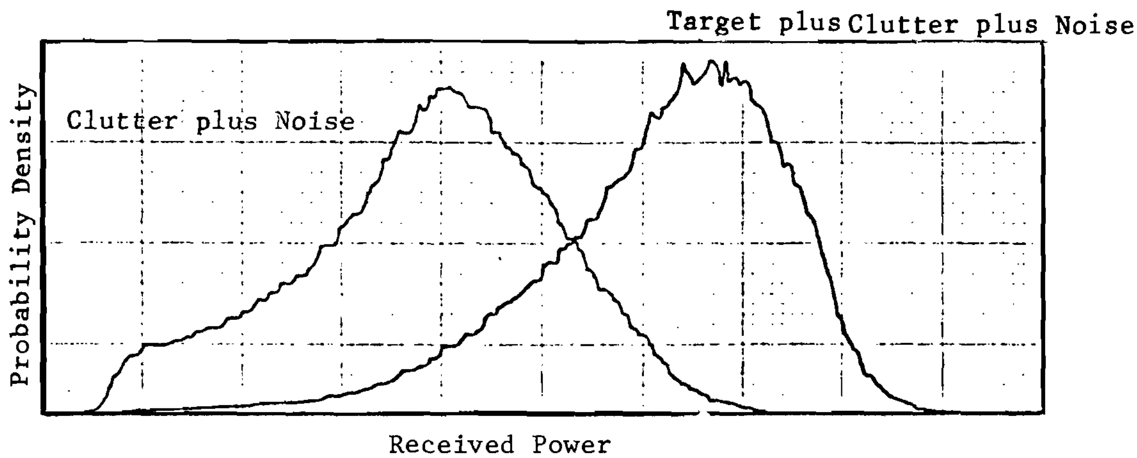

Figure 14. Uncalibrated ROC input density functions with STC clipping. (Signal plus Background)/Background ratio is 12 dB.

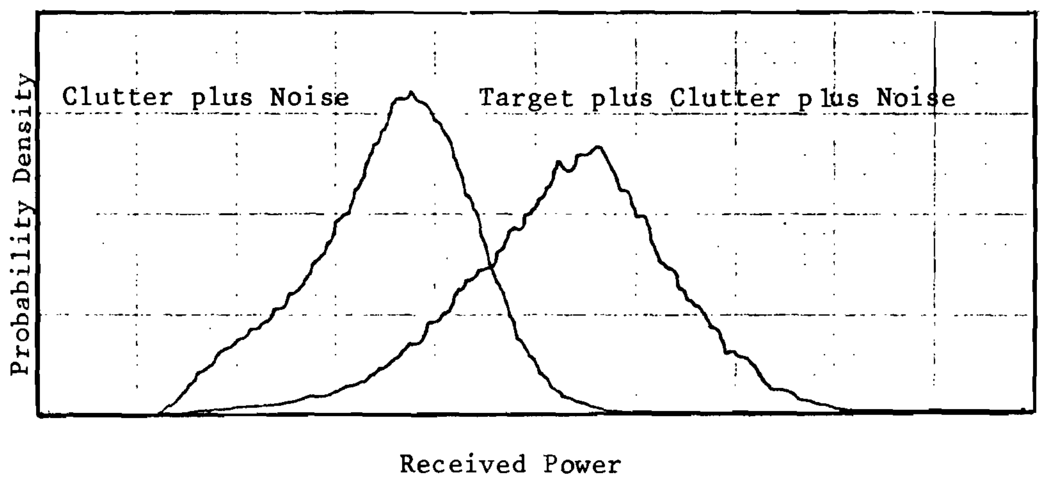

Figure 15. Uncalibrated ROC input density functions without STC clipping. (Signal plus Background)/Background ratio is 10.9 dB.

Figure 16 is an ROC for the AN/APS-127 in fixed frequency mode, for wave heights of 1-3 feet. The ROC's for the clipped and unclipped densities of Figures 14 and 15 are presented on this plot; note that the PD is higher for the unclipped densities with a 10.9 dB (Signal plus Background)/Background, than for the clipped densities with 12 dB (Signal plus Background)/Background, illustrating again that the apparently higher signal to background ratios actually result in poorer performance for the case of the clipped densities. The data for the 17.5 dB curve, which crosses the 10.9 dB curve, were taken on a different day with a slightly different sea state. The log book lists 1-3' wave heights for the former and 1-2' wave heights for the latter; thus the cross-over is probably due to this difference since the clutter signal was probably noise for the 1-2' wave height.

Figure 17 is an ROC for the GT-X radar with horizontal polarization and for wave heights of 1-3'. The shapes of the curves are very similar to those for the AN/APS-127 shown in Figure 16.

The ROC for the AN/APS-127 in fixed frequency mode, for wave heights 3-5', is shown in Figure 18. Again, the cross-over between the 7.1 dB and 11.4 dB curves is probably due to slightly different sea states (logged as 3-5' waves and 2-4' waves, respectively). Figure 19 is an ROC for the AN/APS-127 in the frequency agile mode for wave heights of 3-5'. There is some degradation of performance from the fixed frequency mode, but it appears slight.

Appendix C contains other selected ROC's, including ROC's for both the analog and digital CEP.

The probabilities computed from raw video data to form the ROC's presented here are, of course, single scan probabilities since the input data are gathered directly from the receiver output. The integrating capability of the display implies that the actual probabilities will show an improvement over the non-integrated case. Theoretical signal-to-background families of PD versus PFA may be constructed, assuming Gaussian input distributions, to illustrate the effect of integration. Figure 20 compares theoretical single scan PD versus PFA curves with the measured ROC's of Figure 18. The theoretical PD versus PFA curves are computed for Gaussian distributions with the same medians and standard deviations as the input distributions to the ROC's. It is tempting to assert that a good match between corresponding curves implies that the actual distributions used as ROC input are Gaussian or

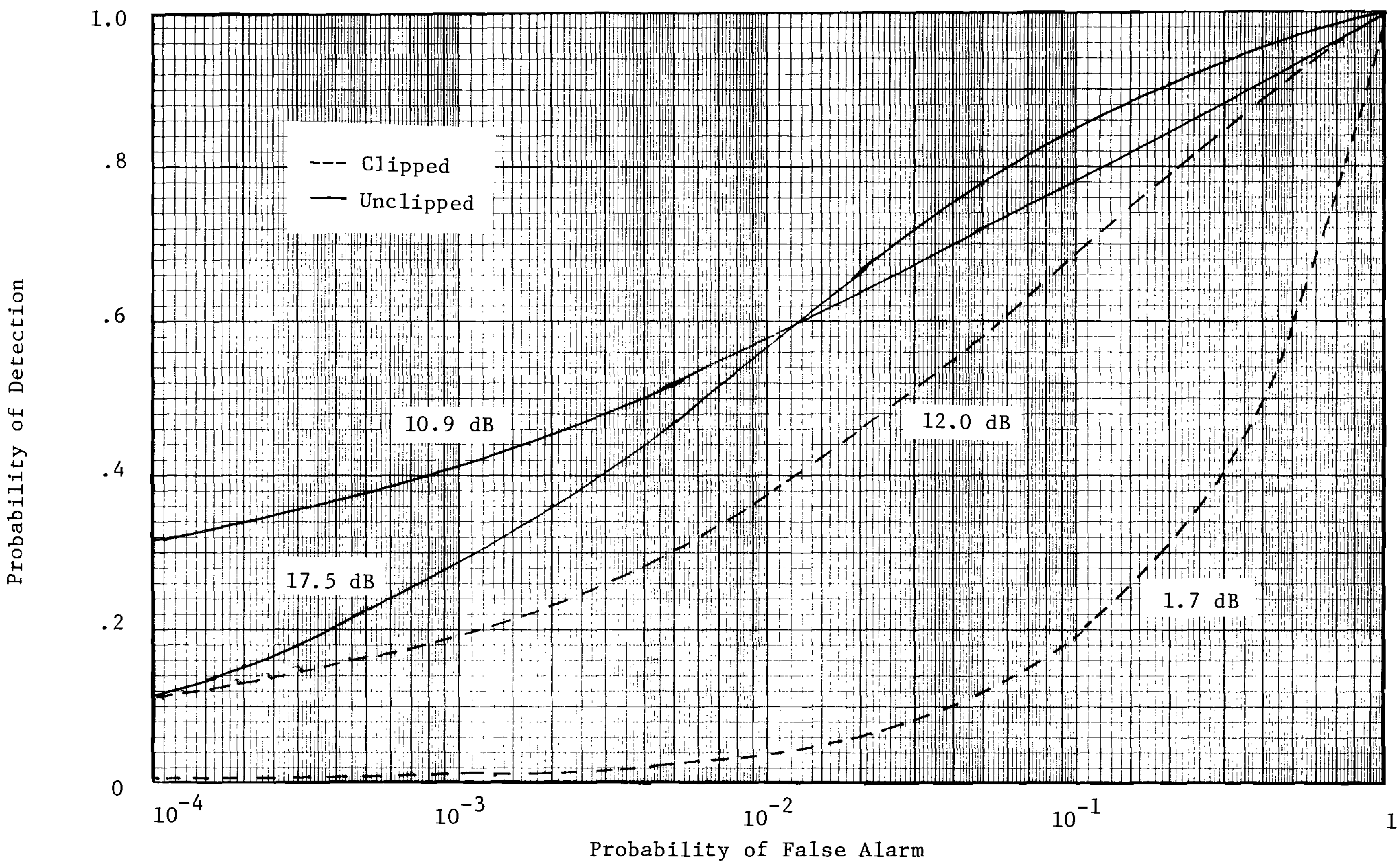

Figure 16. Receiver operating curves for AN/APS-127, fixed frequency mode, wave heights 1-3 feet; as functions of (Signal plus Background)/Background.

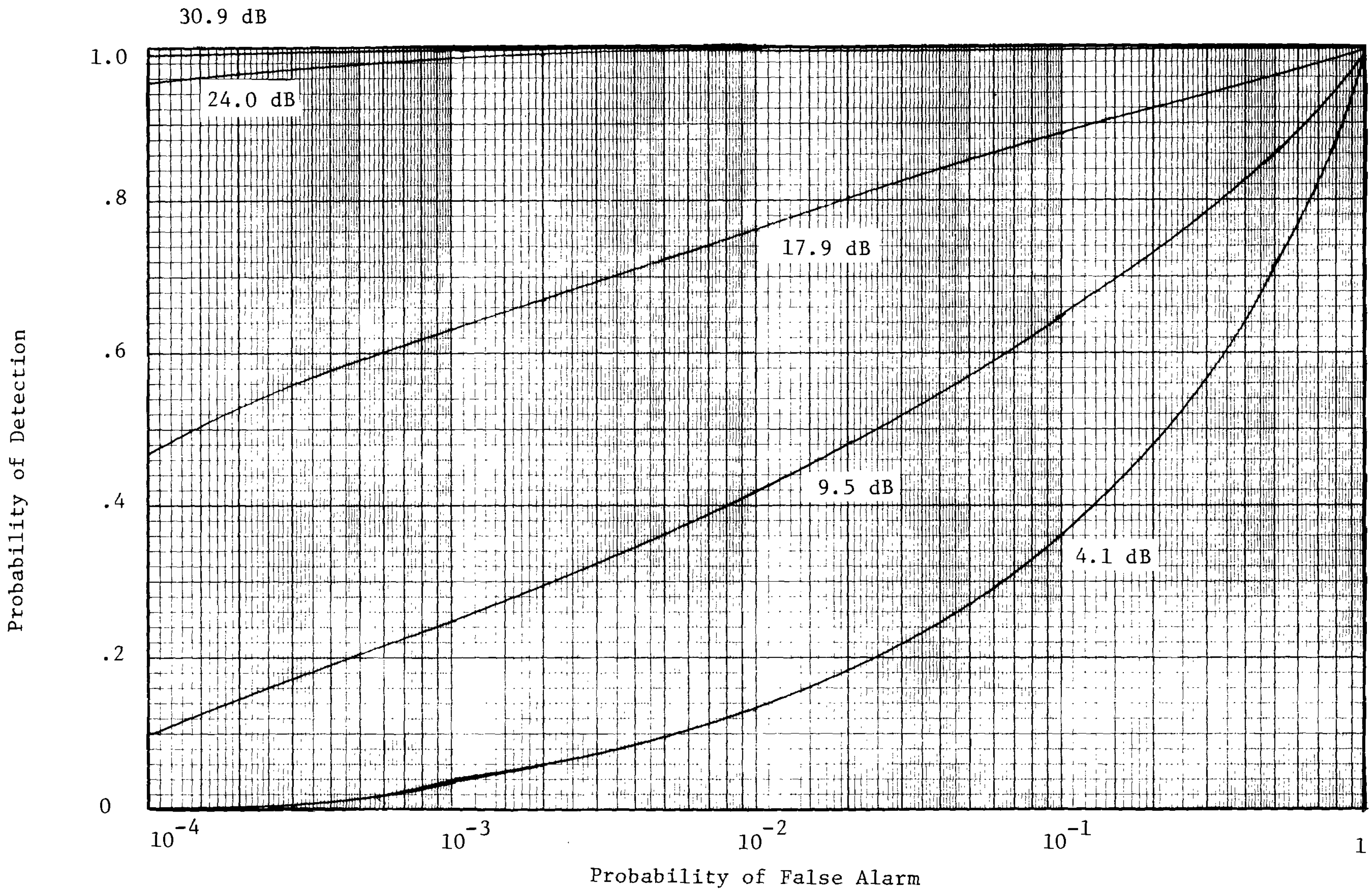

Figure 17. Receiver operating curves, for GT-X radar, horizontally polarized, wave heights 1-3 feet; as functions of (Signal plus Background)/Background.

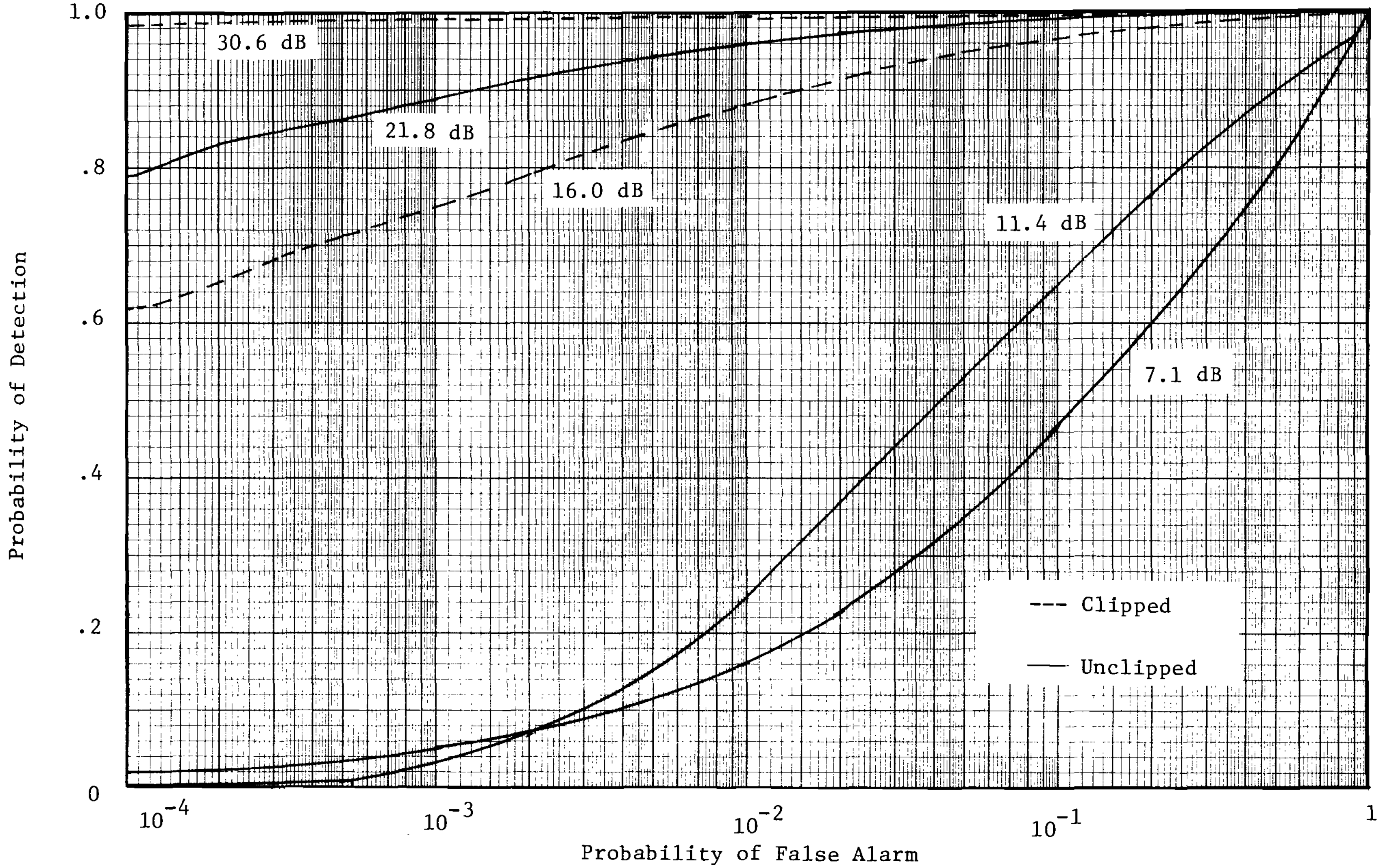

Figure 18. Receiver operating curves for AN/APS-127, fixed frequency mode, wave heights 3-5 feet; as functions of (Signal plus Background)/ Background.

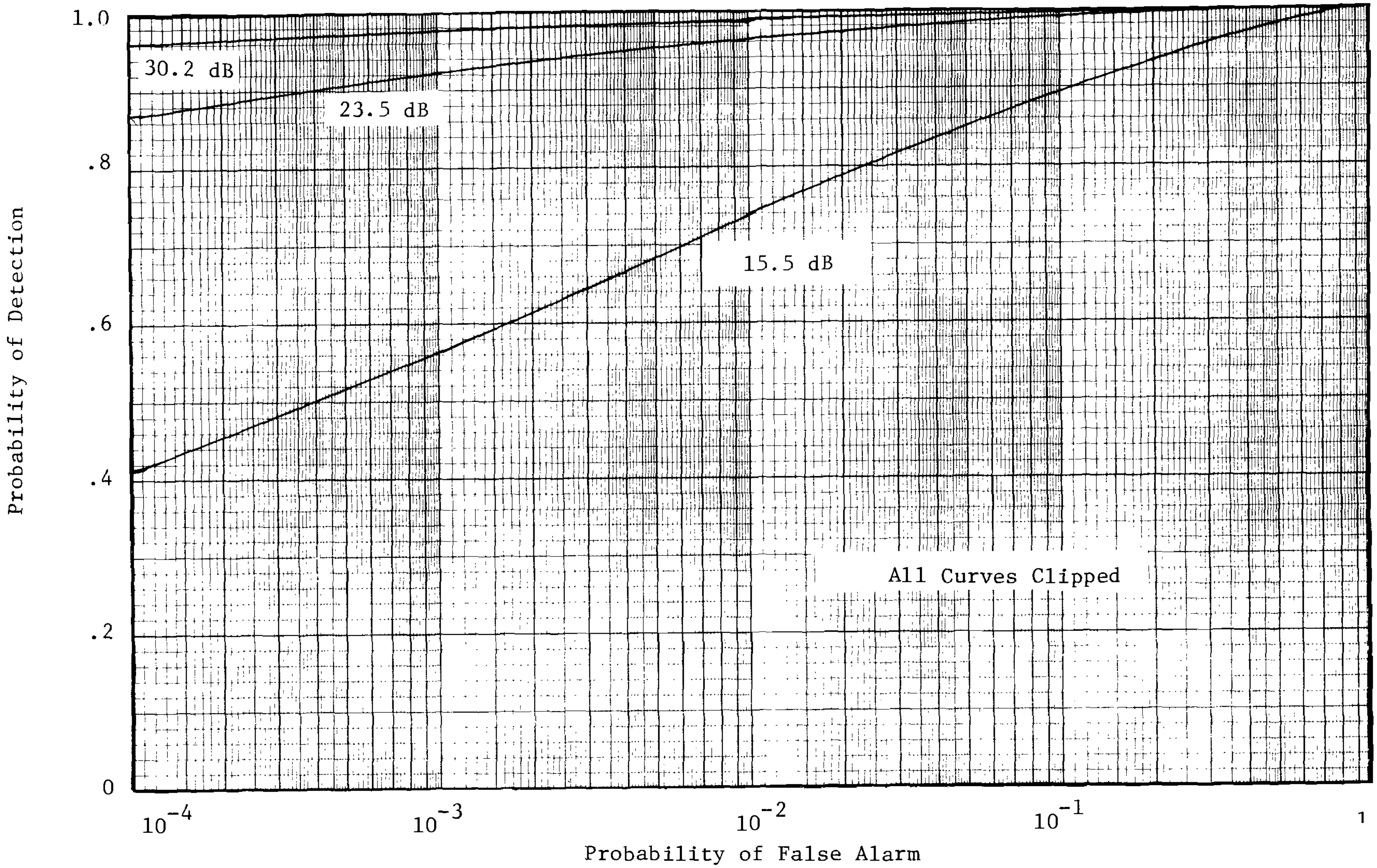

Figure 19. Receiver operating curves for AN/APS-127, frequency agile mode, wave heights 3-5 feet; as functions of (Signal plus Background)/ Background.

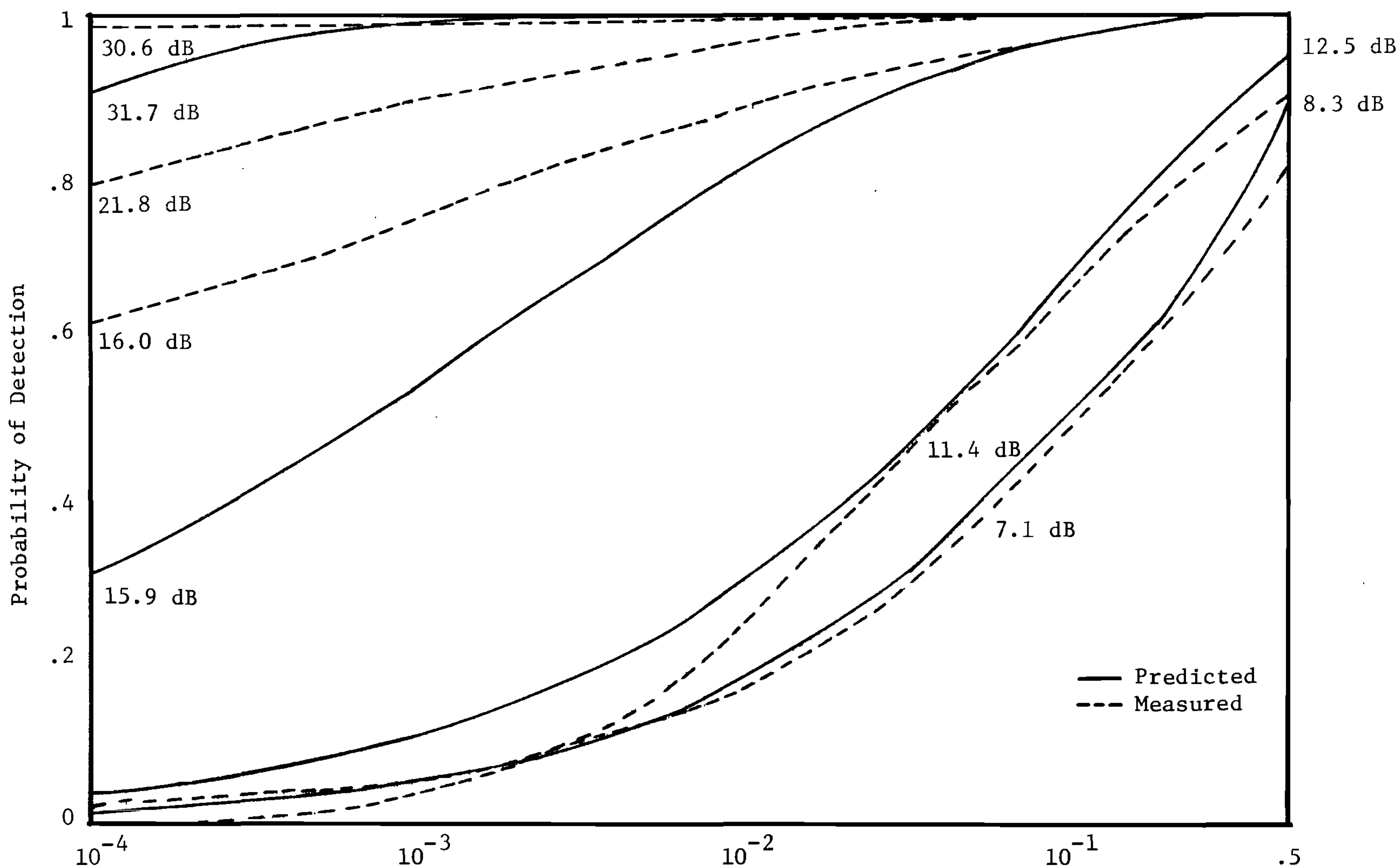

Figure 20. Comparison of measured ROC for the AN/APS-127 with predicted probability of detection vs. probability of false alarm as a function of signal/clutter.

nearly Gaussian. It appears, however, that this is not the case. Agreement between theoretical and measured PD versus PFA is excellent for the 7.1 dB curves, for example, but examination of the input distributions to the ROC reveals that the distributions (target plus background and background) are far from Gaussian-shaped. Their shapes are, however, similar to each other, and possibly this similarity contributes to the normal-appearing result.

Figure 20 indicates that the Gaussian distribution model does provide a reasonable approximation to measured ROC for the non-integrated PD versus PFA. The next question to be explored is the improvement which might be obtained from integration.

Figure 21 compares predicted integrated and non-integrated PD versus PFA curves for several values of signal-to-clutter. The parameters of the AN/APS-127 DVST display are used in the program, and an integration time of 5 seconds is assumed. The decorrelation properties of targets and clutter as measured by the AN/APS-127 shore tests are also used as inputs to the model. The improvement due to the integrating capability of the display is illustrated by this plot.

c. Auto-Correlation Functions

Figures 22 and 23 display normalized auto-correlation functions for sea clutter at 2.4 nmi measured by the AN/APS-127 radar in the fixed frequency and frequency agile modes respectively, on a 1.0 second time scale. The data were taken on 4 June 1976, when wave heights were reported at 3-5'. The narrow band (60 MHz) frequency agility is seen to aid the decorrelation slightly on this time scale. Figures 24 and 25 display the same data on a 150 msec time scale. The effects of frequency agility are more pronounced in these two figures. Along with a faster decorrelation time, the auto-correlation function in Figure 25 also shows more high frequency components due to the frequency agility.

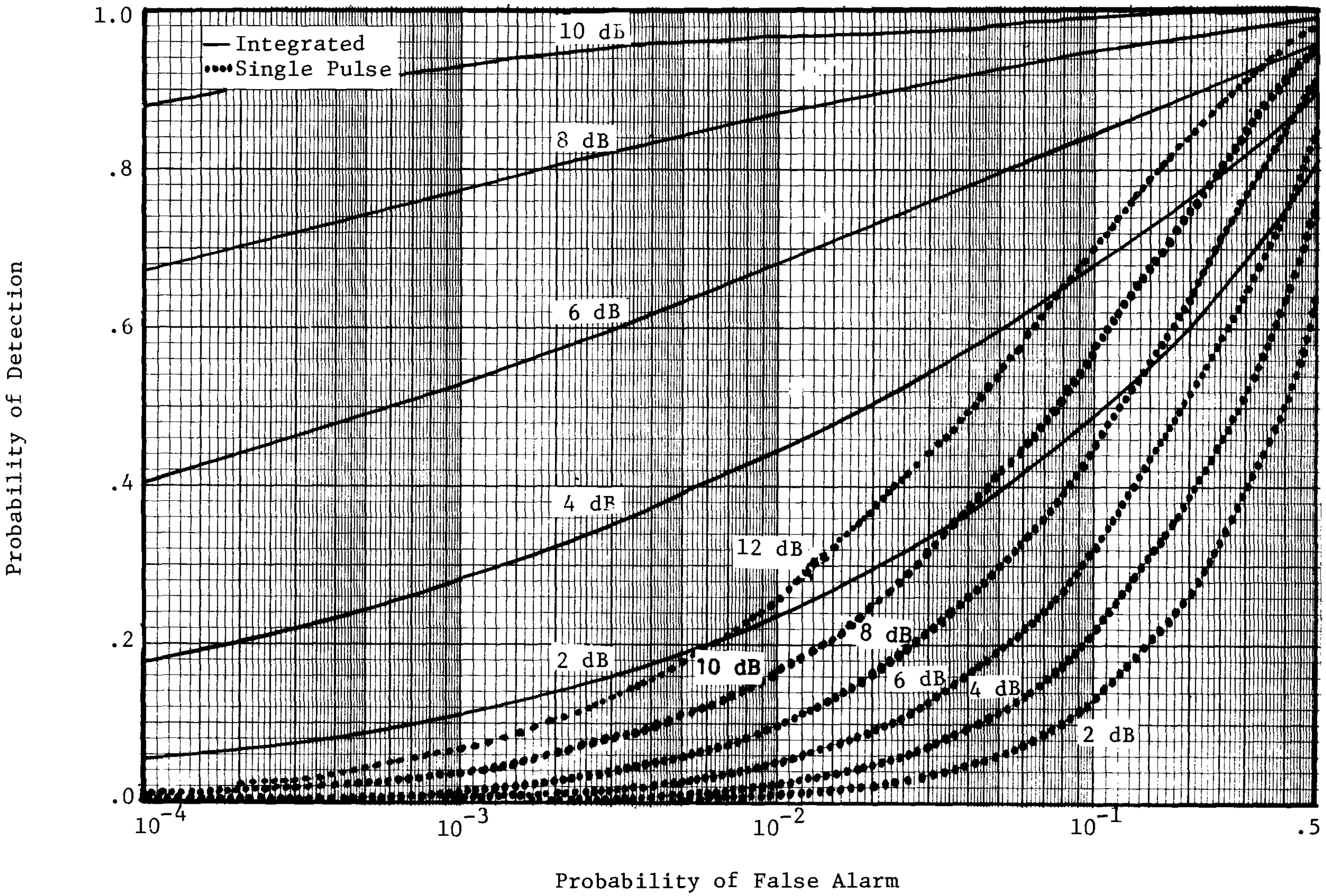

Figure 21. Comparison of integrated and single pulse probability of detection vs. probability of false alarm as a function of signal to background ratio.

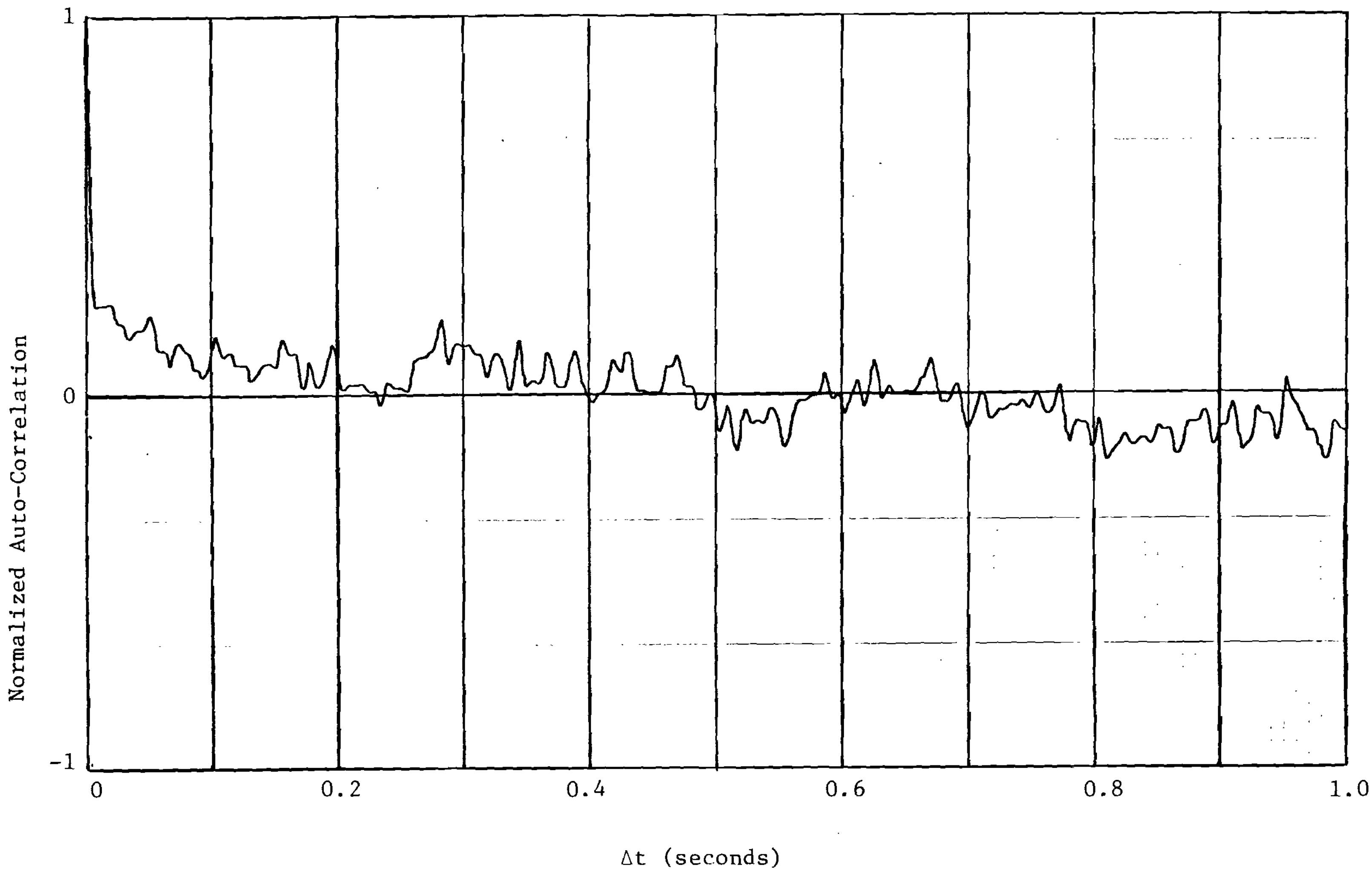

Figure 22. Normalized auto-correlation function for sea clutter at 2.4 nmi, AN/APS-127 in fixed frequency mode; 1.0 second time scale.

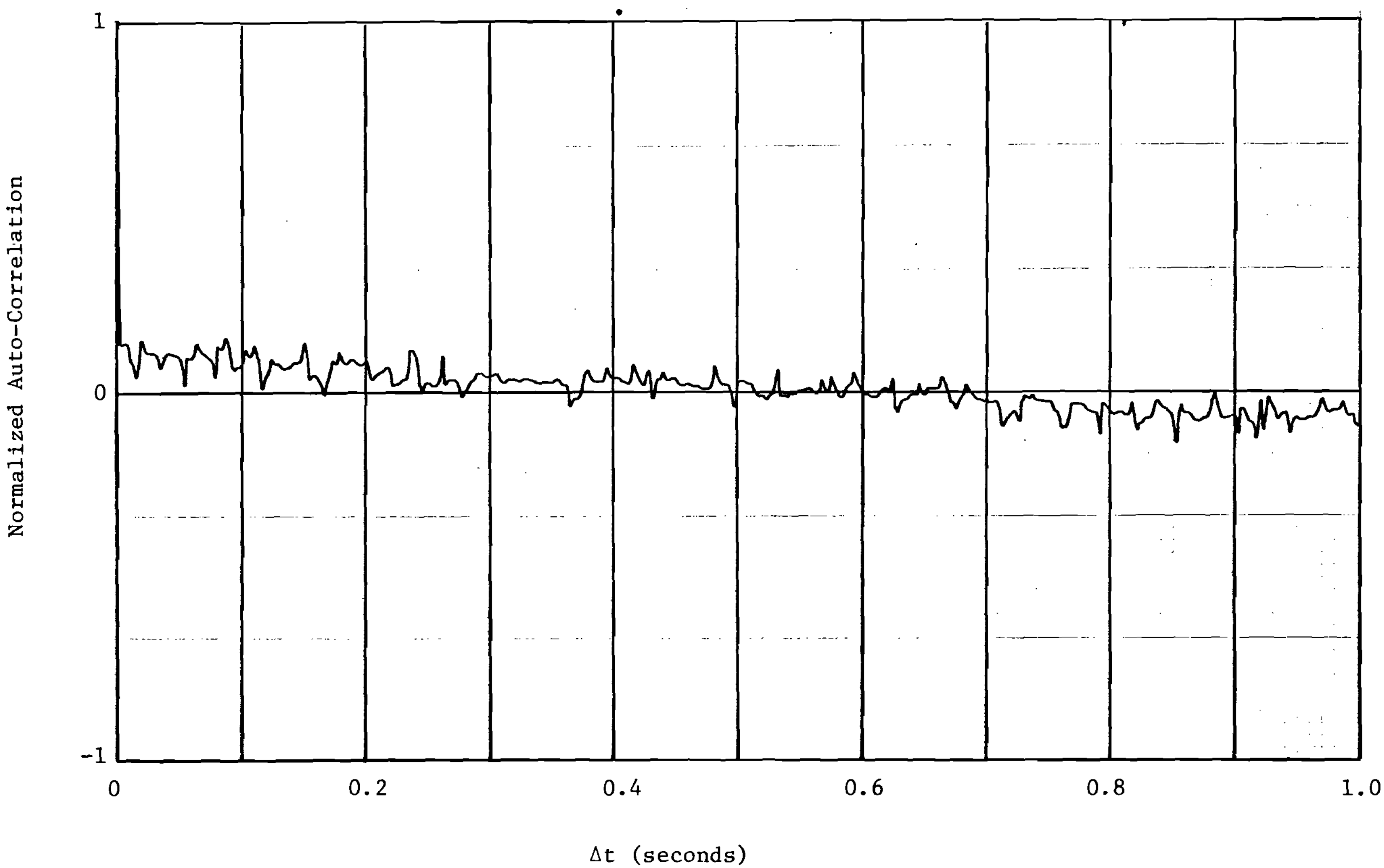

Figure 23. Normalized auto-correlation function for sea clutter at 2.4 nmi, AN/APS-127 in frequency agile mode; 1.0 second time scale.

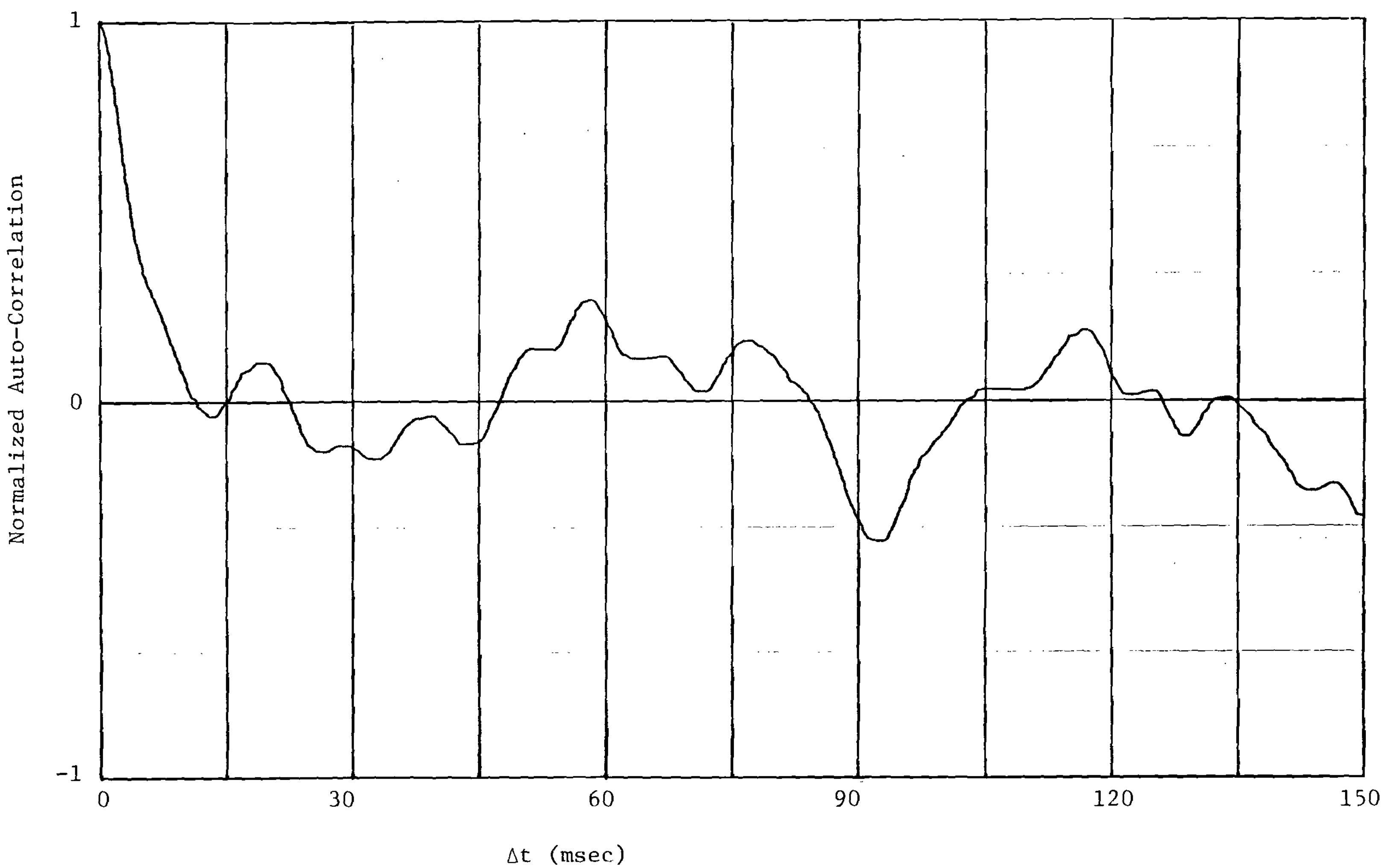

Figure 24. Normalized auto-correlation function for sea clutter at 2.4 nmi, AN/APS-127 in fixed frequency mode; 150 msec time scale.

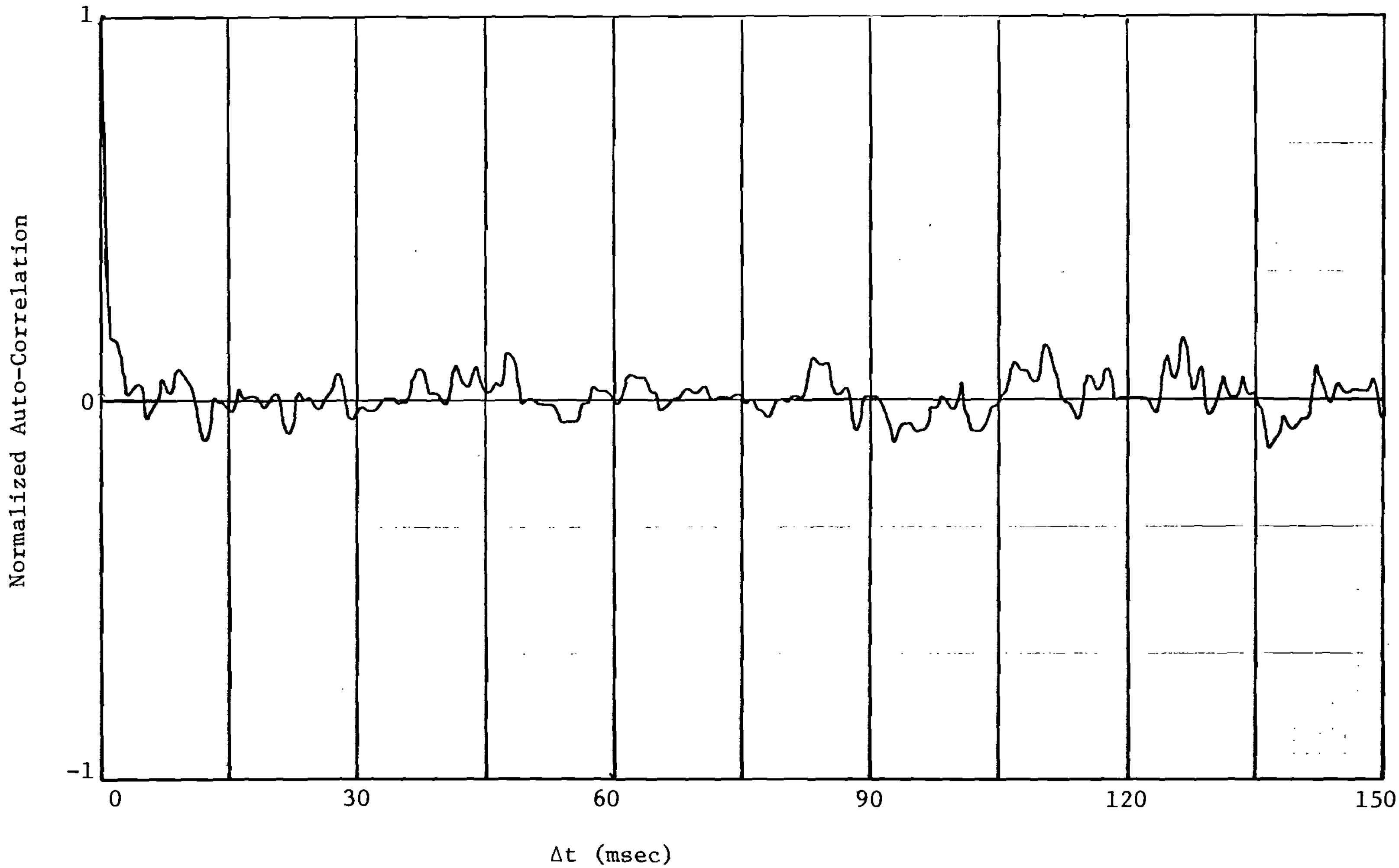

Figure 25. Normalized auto-correlation function for sea clutter at 2.4 nmi, AN/APS-127 in frequency agile mode; 150 msec time scale.

d. Minimum Detectable Signal

MDS measurements made on each of the two displays are summarized in Figures 26 and 27. Figure 26 is a plot of minimum detectable cross-section versus range in noise and in clutter for sea state 2+, for the main (PPI) display. Slopes from 5-10 nmi are parallel except for the data from June 14, which were taken with the CEP and no STC. As expected, minimum detectable cross-sections in noise alone are lower than those in clutter.

Figure 27 is a plot of minimum detectable cross-section versus range in clutter for sea state 2, for the pilot's display. Again, the slope between 5 and 10 nmi is steeper for the receiver with the STC on than for the CEP without STC.

e. Blip/Scan

Blip/Scan measurements were made on an 18 foot boat in 3-6' waves using the main display. Figure 28 shows blip/scan ratio versus range for this set of measurements. Inside 2.5 nmi, the display is clutter-limited and the blip/scan ratios are low. From approximately 3 to 5.5 nmi, ratios close to 1.0 are recorded. Moving out in range, the blip/scan ratio falls off as the target is lost in noise at about 5.8 nmi.

f. Airborne Performance Predictions

An important aspect of the short tests of the AN/APS-127 is the data base provided. Using the radar performance prediction computer programs developed at Georgia Tech over the years, a model of a small boat target may be constructed to fit the data obtained during the shore tests. [6] Figure 29 illustrates the match between the small boat cross-section versus range as predicted by the program and as measured on the 22' FOSI boat on 2 and 4 June 1976. With confidence in the ability of the program to predict cross-section for the shore geometry, the same model may now be applied for the airborne geometry.

Figures 30 through 32 show the predicted radar cross-section versus range of the FOSI boat (10 m^2 target) for various sea states and airplane altitudes. Also plotted on these graphs are the clutter cross-sections corresponding to the same sea states and airplane altitudes. Values are plotted for the upwind direction only, since this represents the worst case. Clutter cross-sections would be 4-5 dB lower for cross-wind and 8-10 dB lower for downwind. Figure 30 predicts the cross-sections measured at 500 feet, and indicates a detectability range of at least 15 nmi in sea states 1 and 2. Figure 31 presents

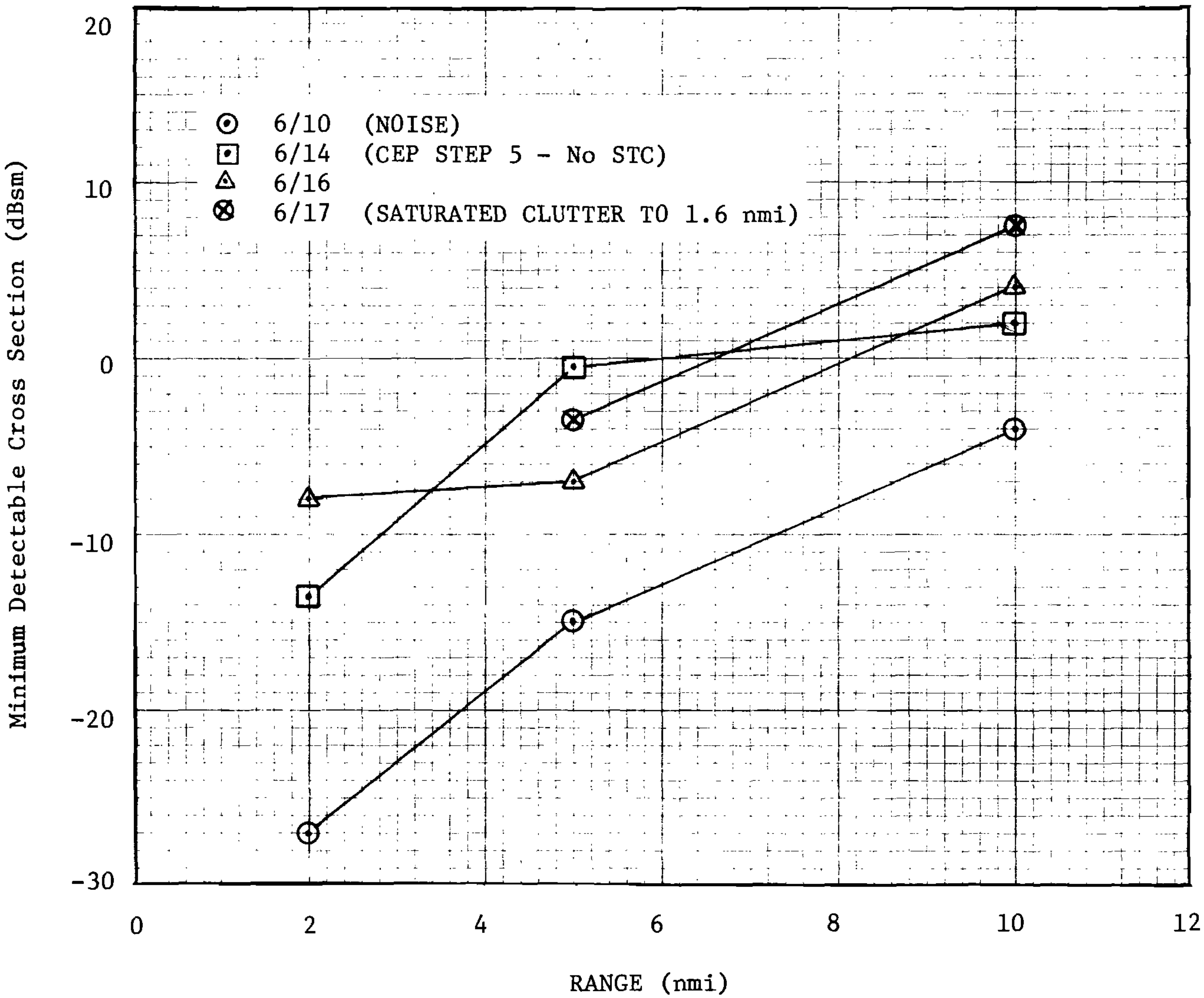

Figure 26. Minimum detectable cross-section measurements in noise and in clutter with Sea State 2+, for main display.

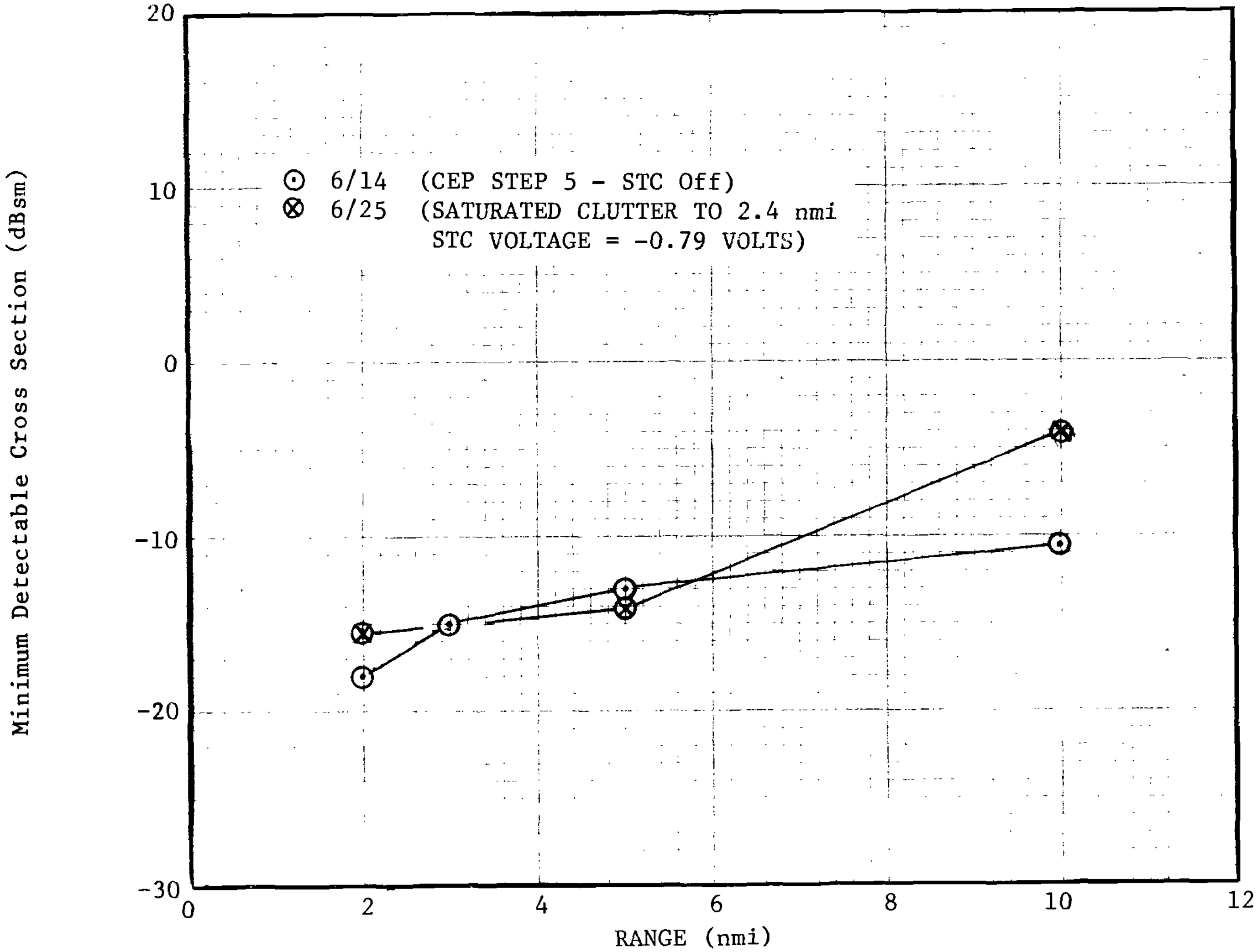

Figure 27. Minimum detectable cross-section measurements in clutter for sea state 2, for pilot's display.

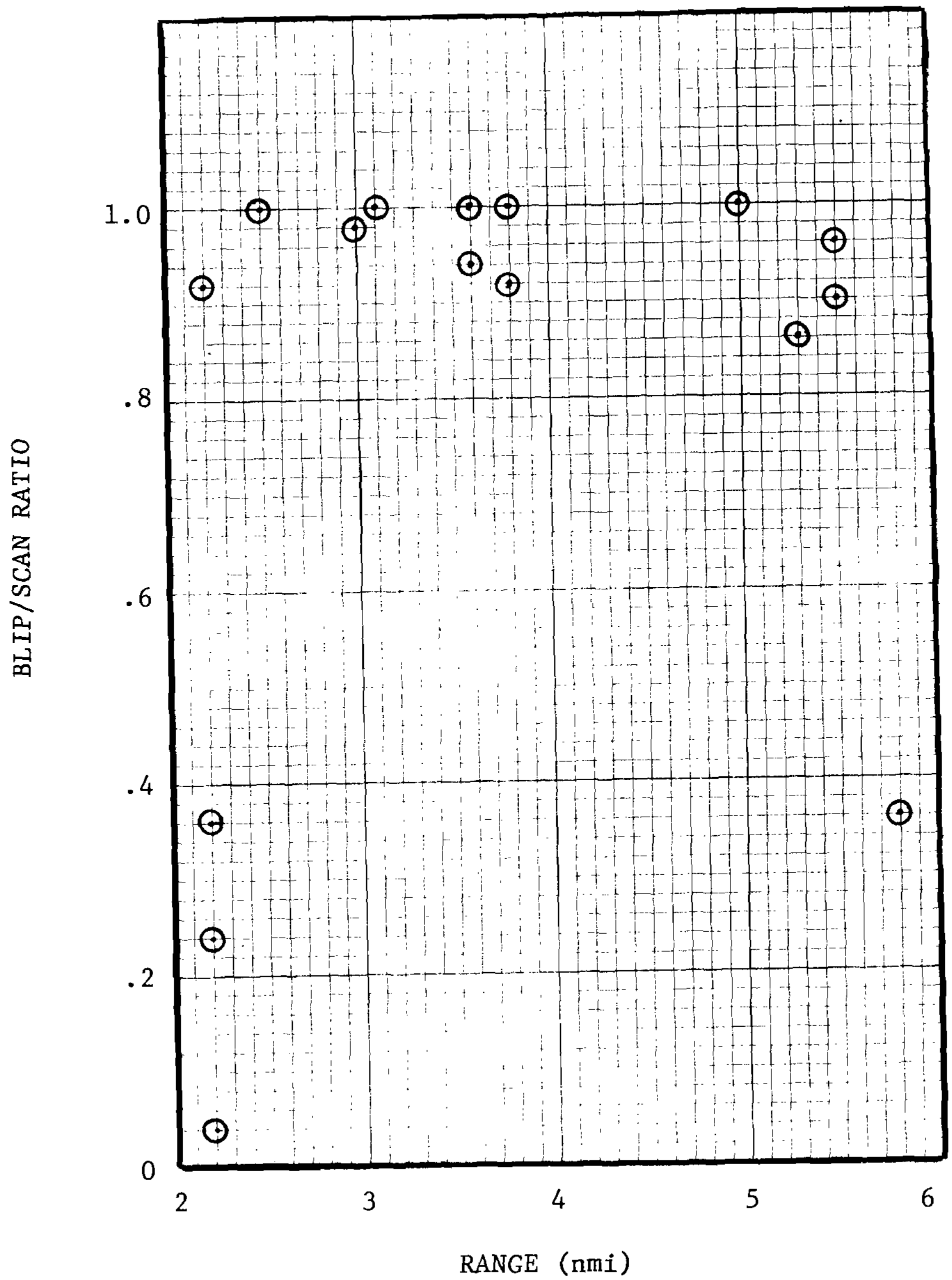

Figure 28. Main display blip/scan measurements on Coast Guard 18' boat in 3-6' waves

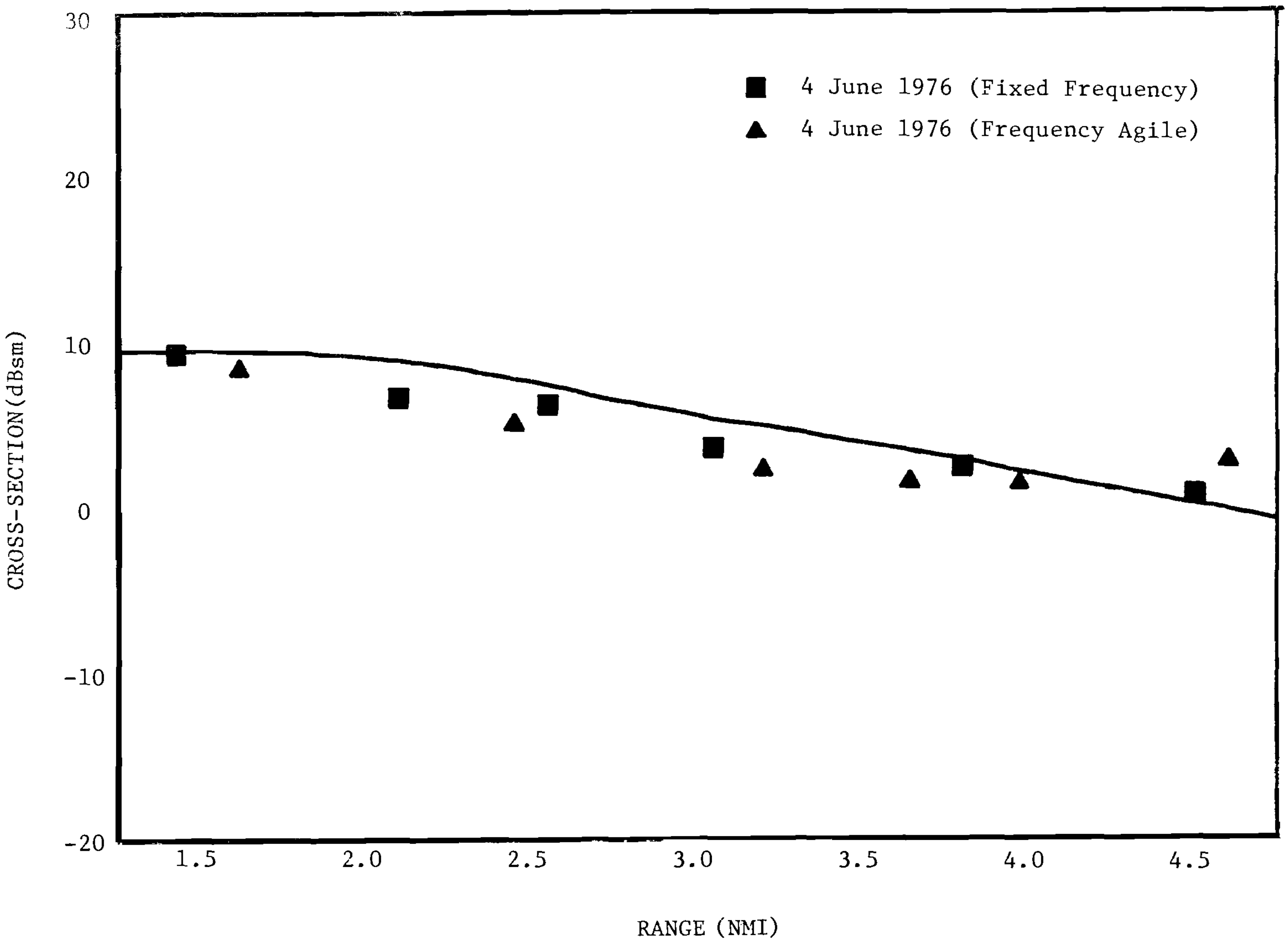

Figure 29. Predicted and measured radar cross-section for the AN/APS-127 radar of the 22 ft FOSI boat as a function of range; shore test geometry, sea state three.

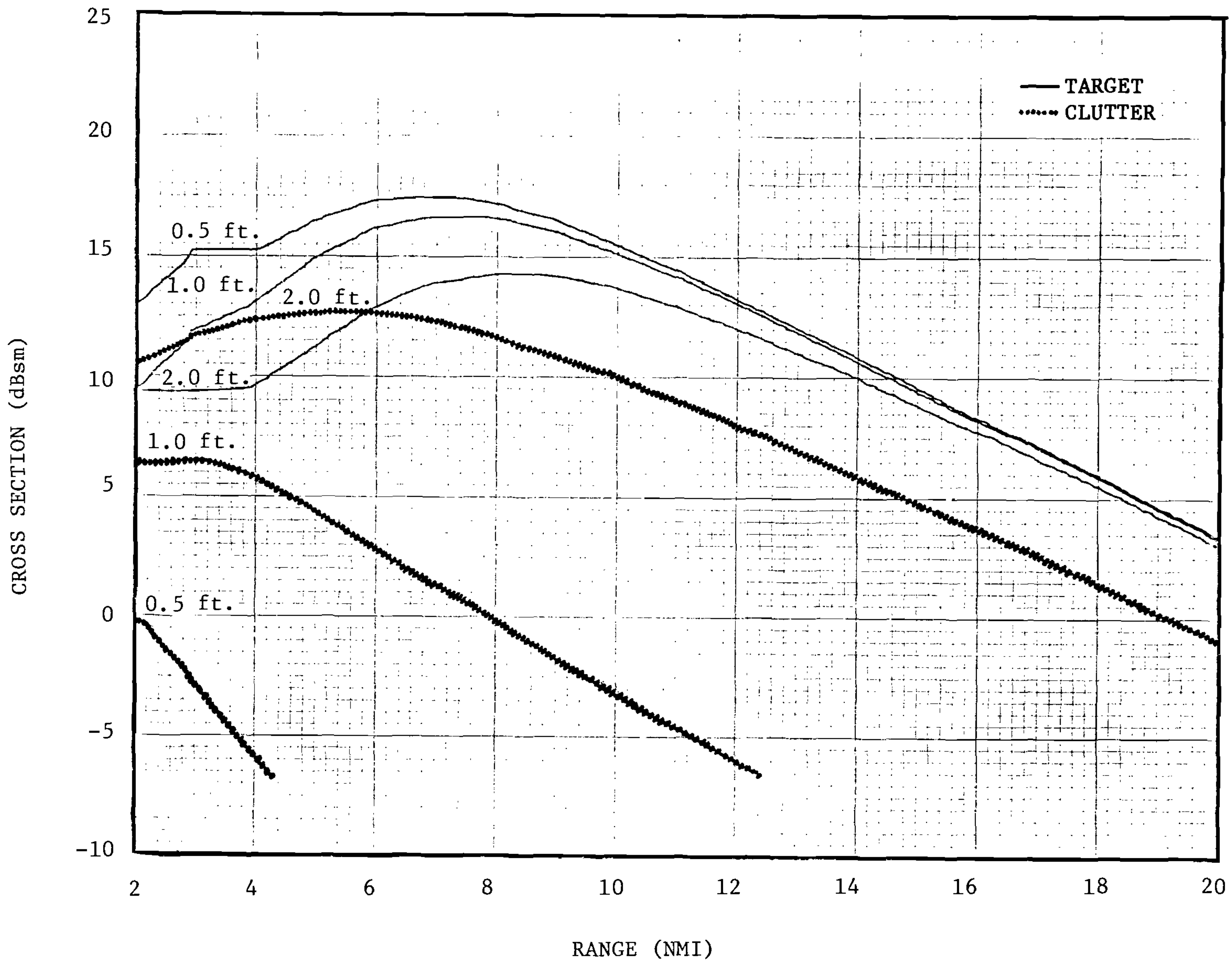

Figure 30. Predicted radar cross section for the AN/APS-127 radar of a small boat and sea clutter as a function of range for average wave height; 500 feet altitude and upwind direction.

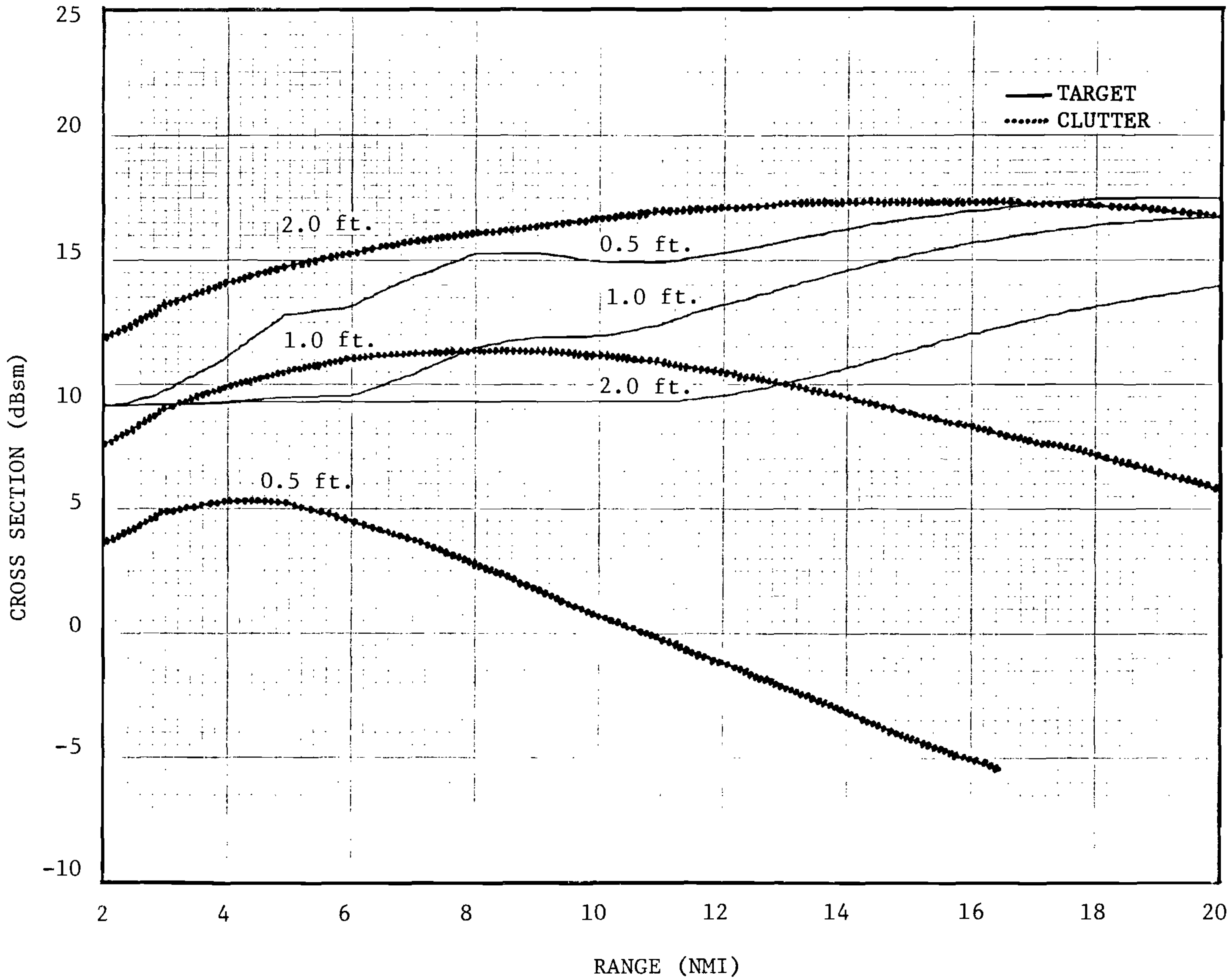

Figure 31. Predicted radar cross section for the AN/APS-127 radar of a small boat and sea clutter as a function of range and average wave height; 1500 feet altitude and upwind direction.

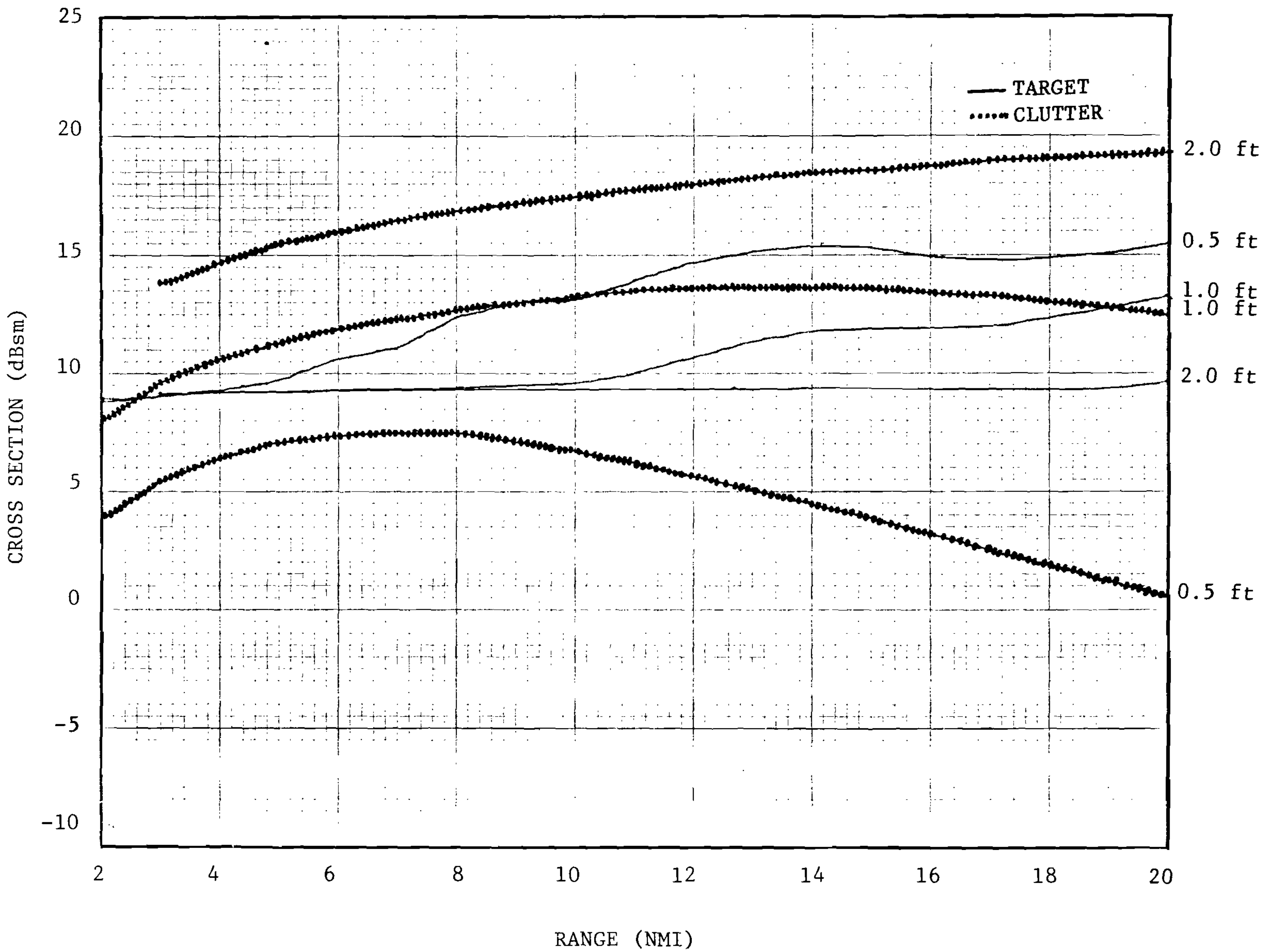

Figure 32. Predicted radar cross-section for the AN/APS-127 radar of a small boat and sea clutter as a function of range and average wave height; 2500 feet altitude and upwind direction.

the predictions for 1500 feet, which show only marginal detectability at the higher sea states. Figure 32 predicts values measured at 2500 feet, and for this altitude, detection appears likely only at the lowest sea state.

A clearer picture of detectability ranges is given by Figures 33 through 35, which plot the predicted signal-to-background ratio versus range for the geometries of Figures 30-32. The single pulse ROC's for the AN/APS-127 presented in this report indicate that approximately 15 dB signal-to-background is required for 50% probability of detection with 0.1% probability of false alarm. Assuming a 7 dB improvement due to integration, Figure 33 implies a range of about 17 nmi at an altitude of 500 feet for sea states 1 and 2. Figure 34, for 1500 feet, shows that a small boat is detectable at ranges from 5 to better than 20 nmi in sea state 1, and from 17 past 20 nmi in sea state 2, but not at all in sea state 3. Figure 35 implies that the radar will be able to see small craft from an altitude of 2500 feet only in sea state 1 at ranges greater than 11 nmi.

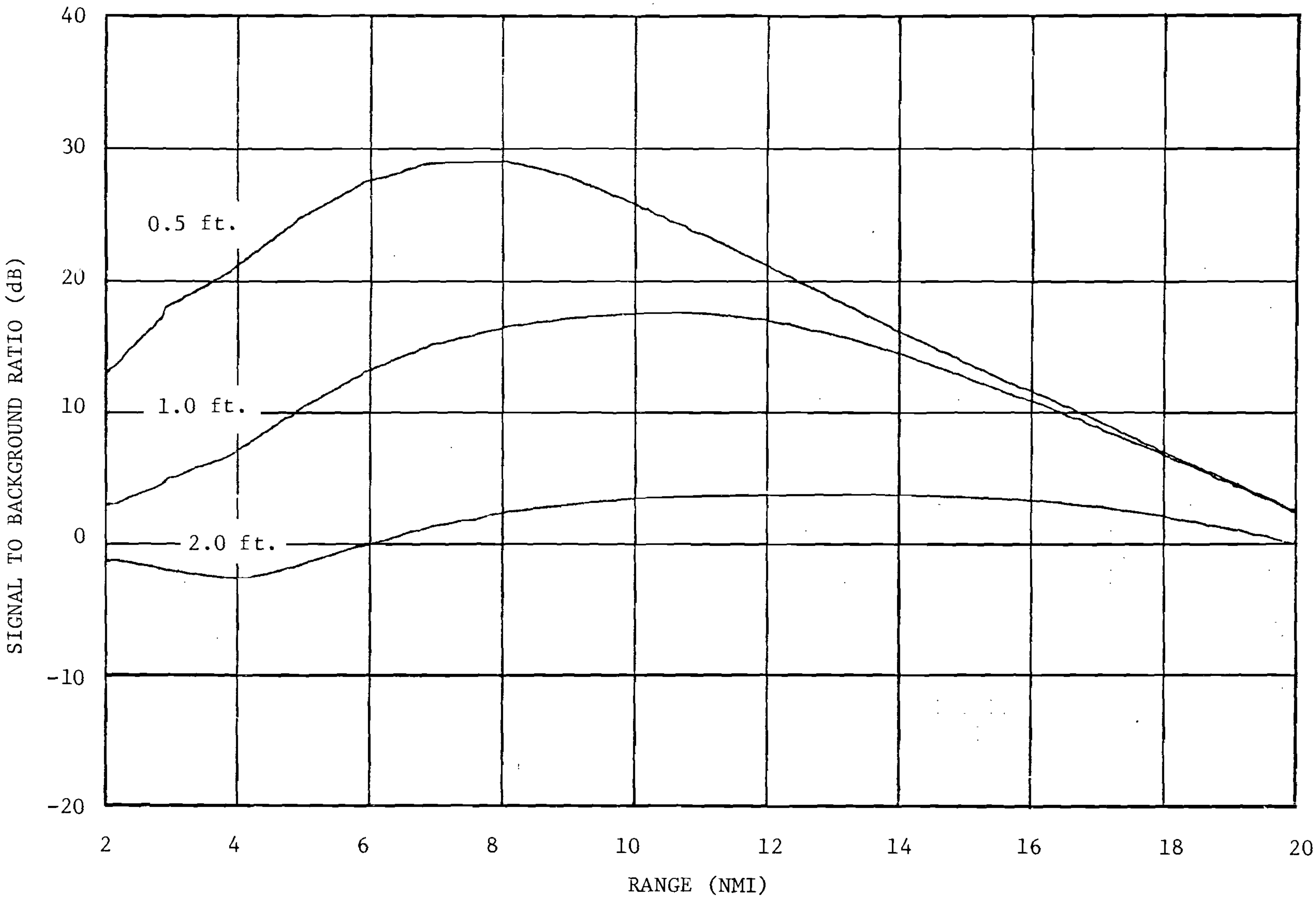

Figure 33. Predicted signal to background ratio for the AN/APS-127 radar of a small boat as a function of range and average wave height; 500 feet altitude and upwind direction.

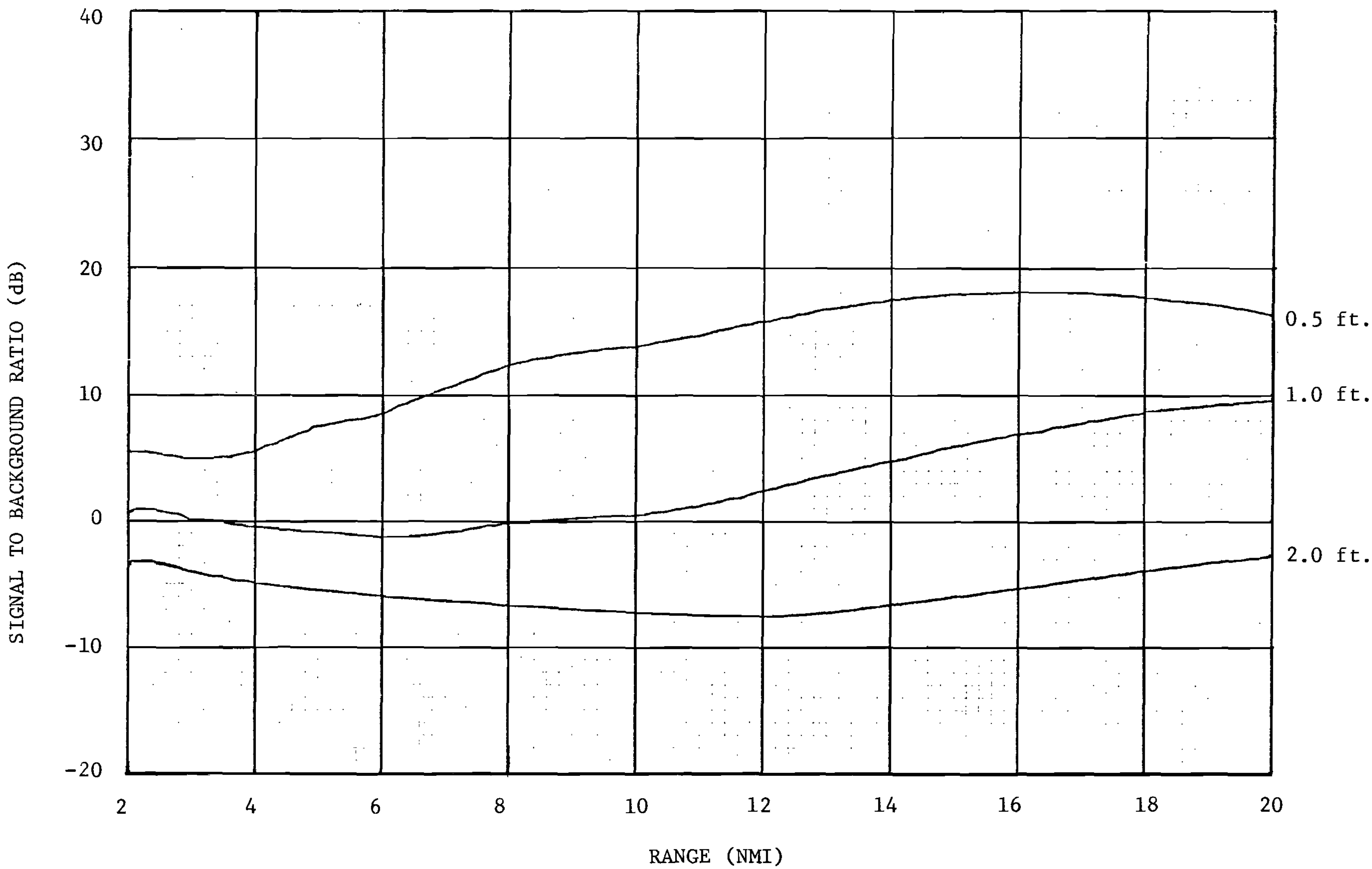

Figure 34. Predicted signal to background ratio for the AN/APS-127 radar of a small boat as a function of range and average wave height; 1500 feet altitude and upwind direction.

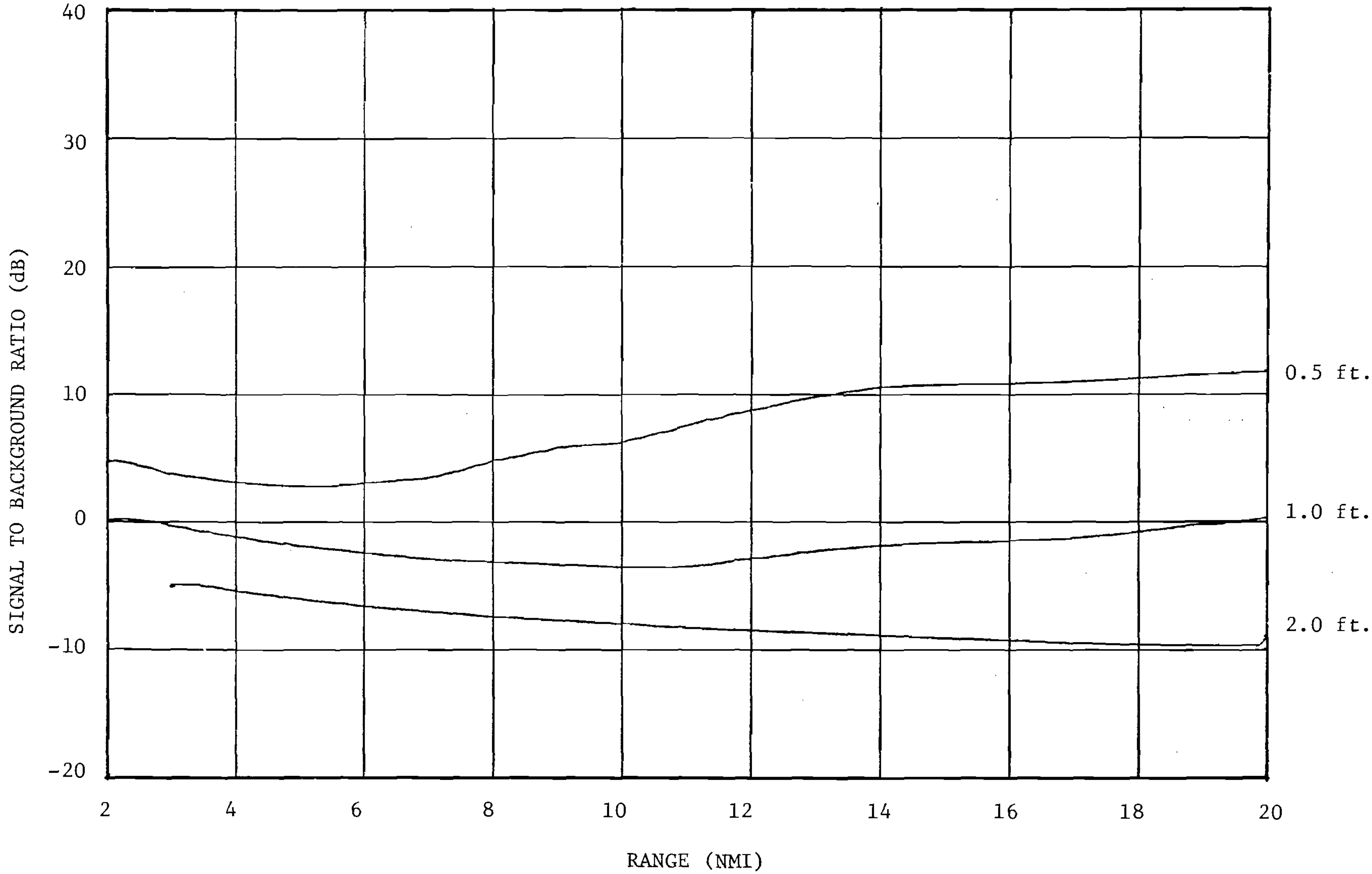

Figure 35. Predicted signal to background ratio for the AN/APS-127 radar of a small boat as a function of range and average wave height; 2500 feet altitude and upwind direction.

III. CONCLUSIONS AND RECOMMENDATIONS

The results presented in this report of the expected performance of the AN/APS-127 radar system are based on the data obtained during the ground based tests, and the use of predictive programs to extrapolate the ground results to the airborne case. Therefore, any conclusions as to the expected performance for the airborne scenario should be considered as preliminary only and of use primarily as guidelines for the upcoming airborne tests. However, based on the results of the ground tests, several preliminary conclusions as to the performance of the system can be deduced. These include the following:

(1) For the classes of boats studied during these tests (18' to 50') the radar cross-sections measured by the AN/APS-127 varied from -10 dBsm to +15 dBsm.

(2) Typical signal-to-clutter ratios averaged 5 dB to 10 dB lower for the AN/APS-127 radar than for the GT-X radar (which has a narrower beam antenna and shorter pulse length).

(3) Measured receiver operating curves for the AN/APS-127 indicate that the "bottom clipping" action of the STC circuit may reduce the effective signal-to-clutter ratio thus retarding the detection performance.

(4) The auto-correlation analysis indicated that the use of the narrow band (60 MHz) frequency agility in the AN/APS-127 does have a slight effect on the decorrelation times of sea clutter.

(5) Blip-scan measurements on an 18' boat indicate that the boat was reliably detected on the main PPI display from a range of 2.5 nmi to 5.5 nmi in 3-5' waves.

(6) Predictions of airborne performance indicate that a 10 m^2 target should be reliably detected (8 dB signal-to-clutter ratio and upwind direction) at 500' aircraft height from 2 nmi to 17 nmi for 0.5' average wave height, from 4 nmi to 18 nmi for 1.5'; at 1500' aircraft height, from 5 nmi to 20 nmi for 0.5' wave height, from 17 nmi to 2 nmi at 1.0' wave height, not detected at 1.5' average wave height; at 2500' aircraft height, from 11 nmi to 20 nmi at 0.5' wave height, not detected at 1.0' or 1.5' wave heights.

(7) Larger boats which were determined to be up to 25 dB higher in cross-section than the 18' boats should be detectable out to 20 nmi even at 2500' aircraft altitude and 1.5' wave heights.

The following specific recommendations are made as to the procedures for the upcoming flight tests in order to characterize as completely as possible the system performance.

(1) At least two different sized boats should be used as targets during the tests including an 18' boat and a 40' to 50' boat.

(2) Flights should be scheduled to include both calm seas and rough seas, if possible, to characterize the degradation in performance as the sea clutter increases.

(3) Upwind, downwind, and cross wind runs should be made to determine detection performance differences.

(4) The tests should include radial runs to and from the test targets so that both minimum and maximum detection ranges are determined for given sea conditions.

(5) Shore data should be obtained using the GT-X radar during the tests for correlation with the airborne results on the AN/APS-127 performance.

IV. REFERENCES

1. N. C. Currie and F. B. Dyer, "Performance Tests on the AN/APS-119 Radar System," Final Report on Contract DOT-CG-04132-A-1, 15 February 1974.

2. F. B. Dyer and M. J. Gary, "Clutter Reduction Radar," Final Report on Contract N00024-68-C-1125, 31 July 1973.

3. W. K. Rivers and F. B. Dyer, "An Investigation of the Effects of Frequency Agility on Radar Backscatter from the Sea," Part I, Technical Report No. 1 on Contract N00024-68-C-1125, January 1969.

4. N. C. Currie, F. B. Dyer, and R. D. Hayes, "Radar Land Clutter Measurements at Frequencies of 9.5, 16, 35, and 95 GHz," Technical Report No. 3 on Contract DAAA-25-73-C-0256, 2 April 1975.

5. D. E. Wrege and D. S. Harmer, "FOCAL/F, An Extended Version of 8K FOCAL 69TM," School of Nuclear Engineering, Georgia Institute of Technology, 1 June 1972.

6. M. T. Tuley, F. B. Dyer, and J. E. Rhodes, "High Resolution Radar Detectability Studies," Phase One Final Report on Subcontract No. 600128 on Contract N00017-72-C-4401, July 1975.

V. APPENDICES

APPENDIX A

Selected Pulse Height Amplitude Distributions

This appendix presents cumulative probability distributions of the cross-sections of selected targets at various aspects and ranges, for the AN/APS-127 radar operating in both fixed frequency and frequency agile modes, for various sea states. Several points may be illustrated by these plots. Figures A-1 through A-5 are sample distributions of data used to compile Table III. Note that the distributions for the larger boats exhibit a 6-7 dBsm standard deviation. Figure A-6 for the dinghy shows a median cross-section of -4 dBsm. Figure A-7 and A-8 on the FOSI boat and Figures A-9 and A-10 on the Coast Guard boat in sea states 2 and 3 indicate that median and peak cross-sections are not appreciably affected by the higher wave heights; however, the differences in cross-section are pronounced for the lower probabilities. Figures A-10 and A-11 demonstrate that frequency agility has little or no effect on target cross-sections. Figure A-12 is an example of a corner reflector (calibration) run with its high cross-section and small standard deviation. Finally, Figure A-13 shows a probability distribution for the digital CEP with its "step" characteristics.

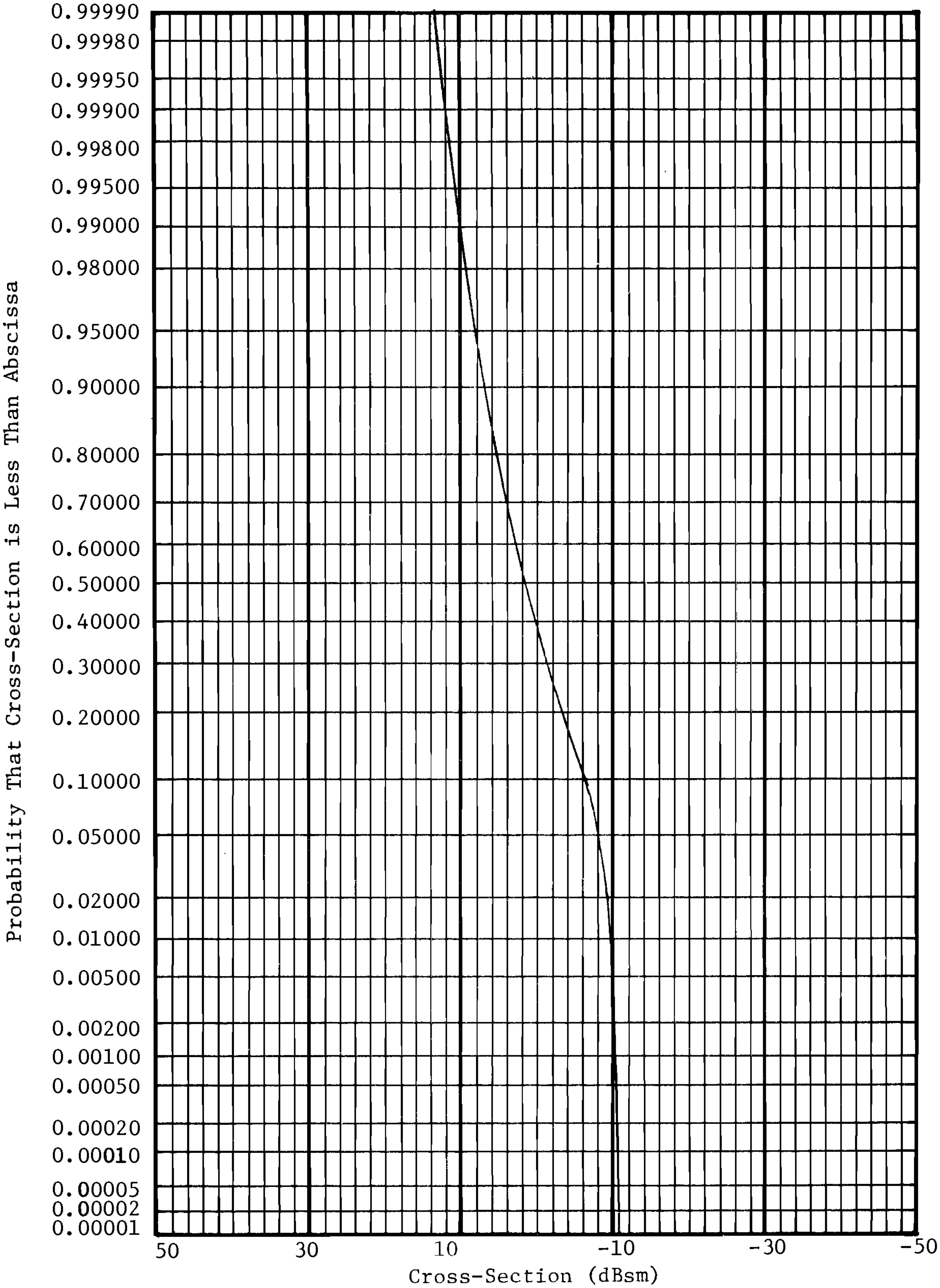

Figure A-1. Cumulative probability distribution of target cross-section for 18' "Foxy Lady" dead in the water with broadside aspect at 4.4 nmi; AN/APS-127 radar in fixed frequency mode; wave height 2-3 feet.

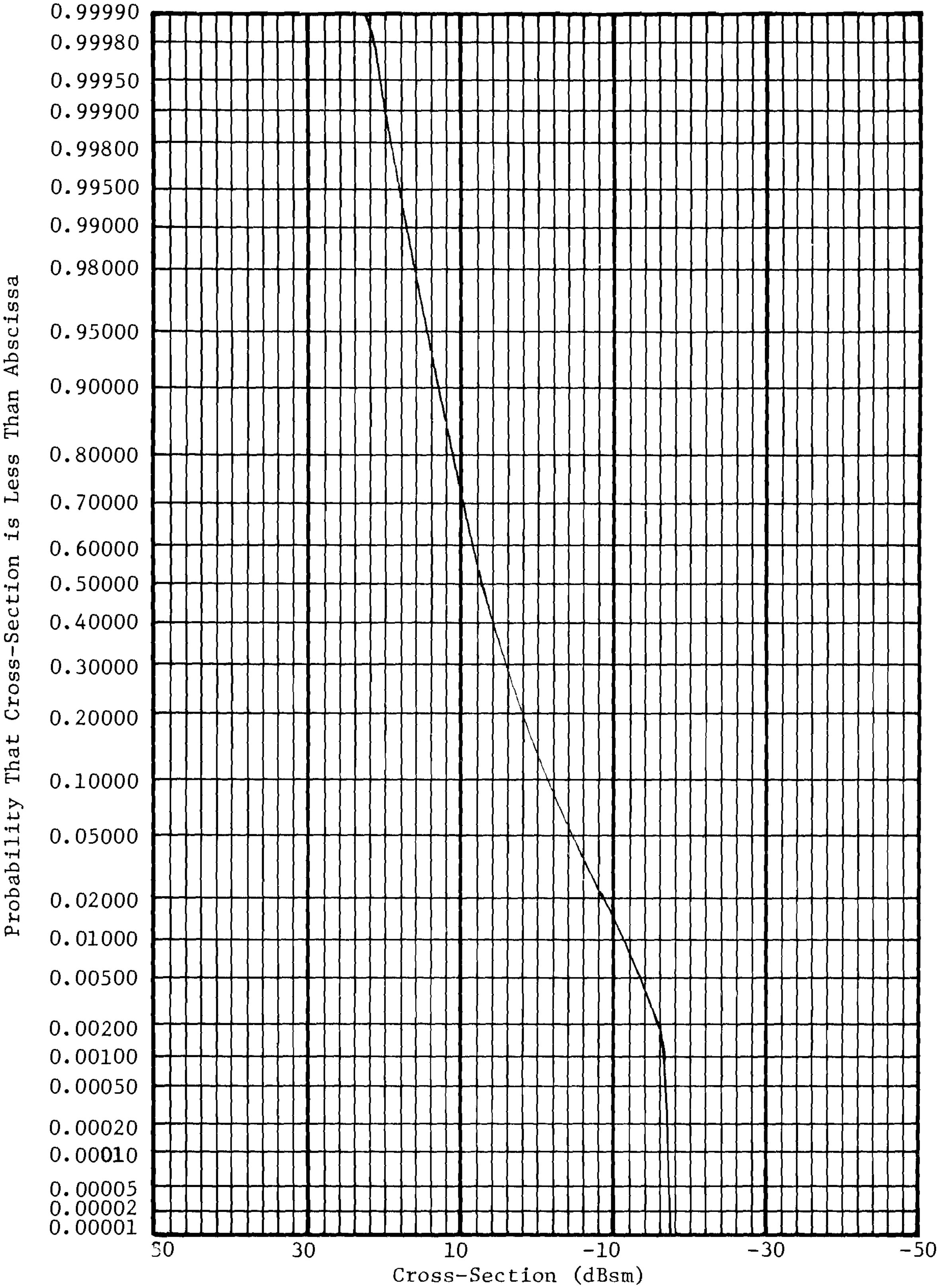

Figure A-2. Cumulative probability distribution of target cross-section for 18' "Foxy Lady" in motion at 2.75 nmi; AN/APS-127 radar in fixed frequency mode; wave heights 2-3 feet.

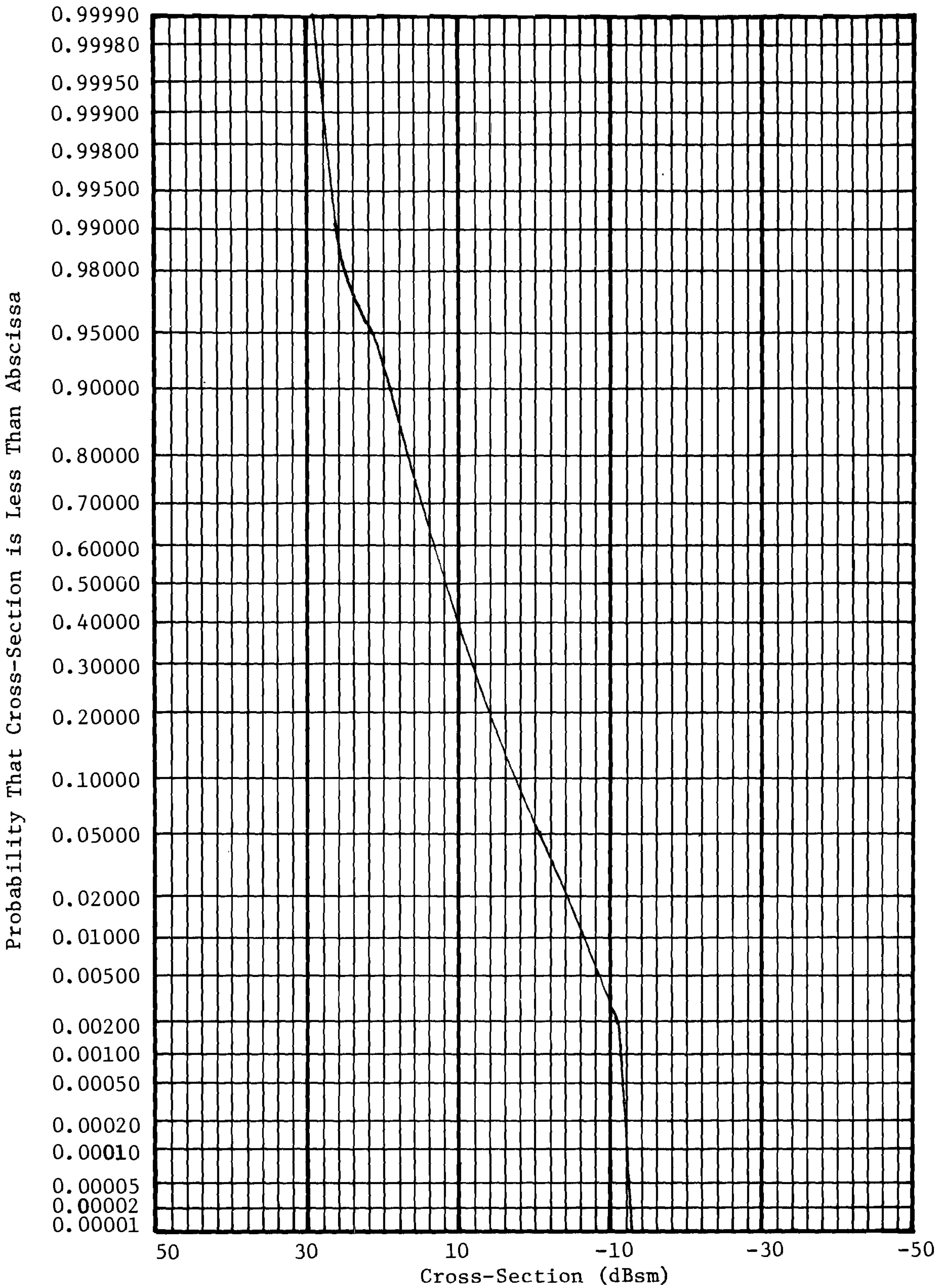

Figure A-3. Cumulative probability distribution of target cross-section for 30' "Skylark" dead in water at broadside aspect at 3.9 nmi; AN/APS-127 radar in fixed frequency mode; wave heights 2-3 feet.

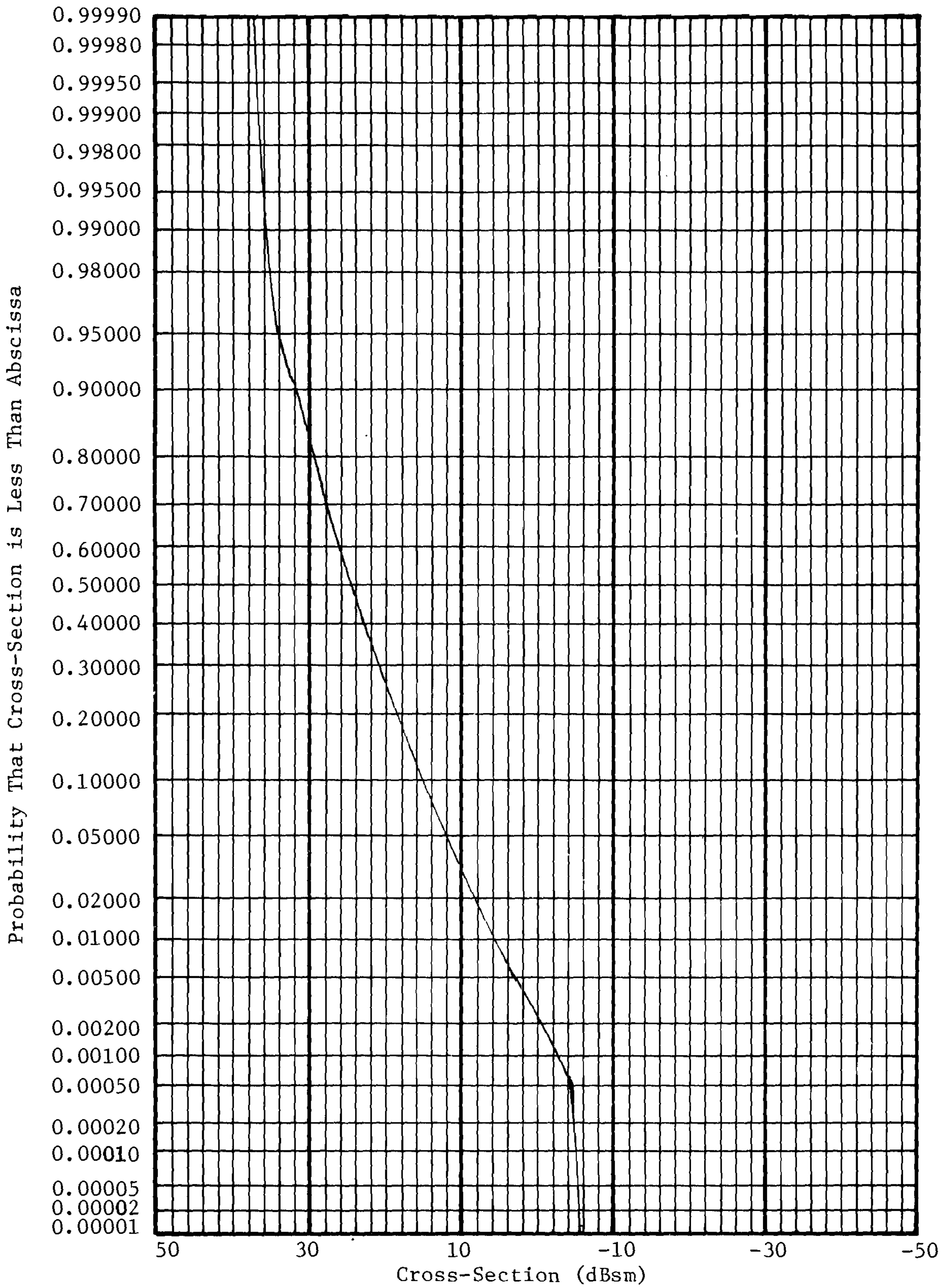

Figure A-4. Cumulative probability distribution of target cross-section for 43' "Jonah" dead in water at stern-on aspect at 5.4 nmi; AN/APS-127 radar in fixed frequency mode; wave height 2-3 feet.

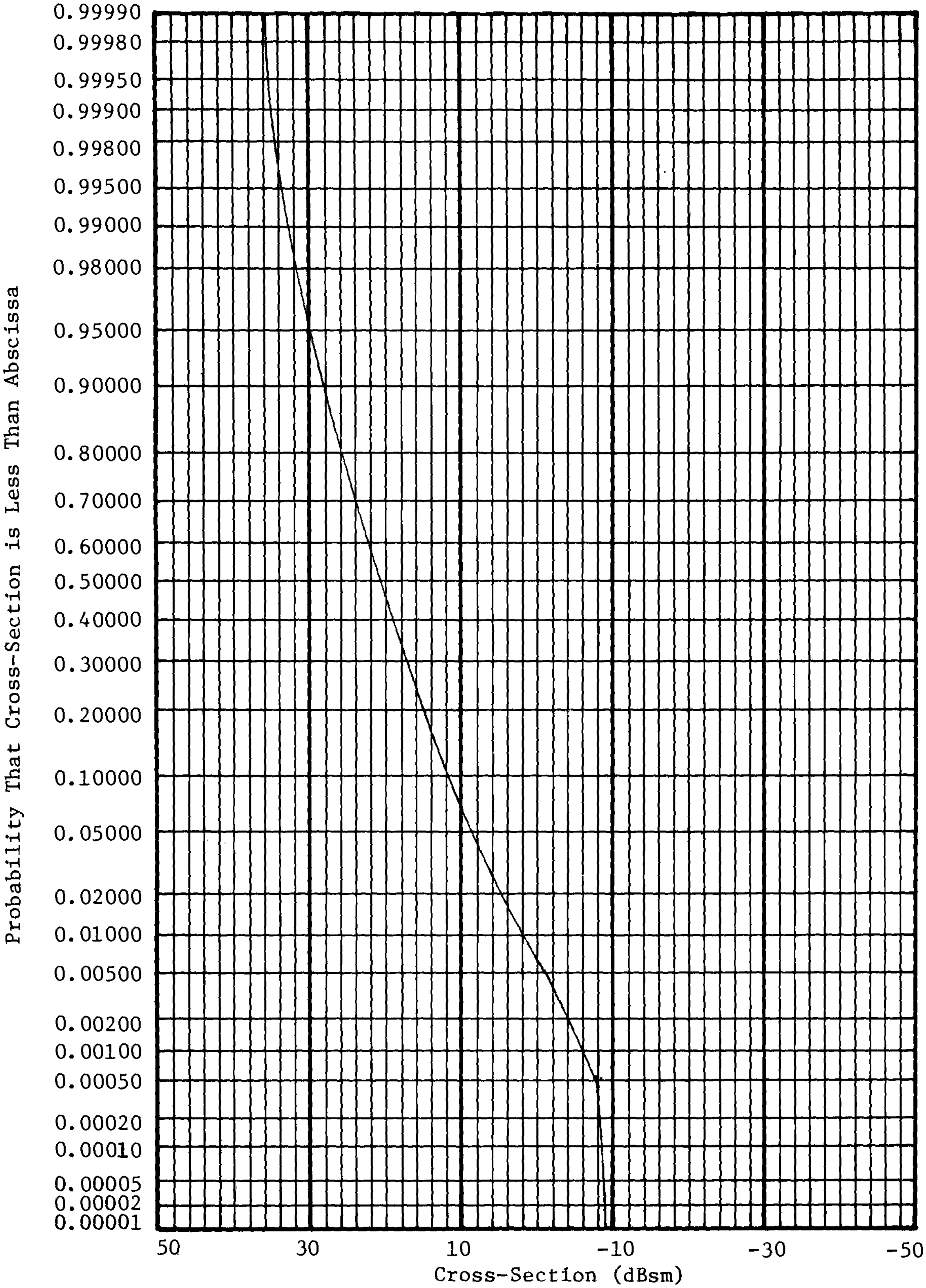

Figure A-5. Cumulative probability distribution of target cross-section for "Southward" dead in water at broadside aspect at 4.5 nmi; AN/APS-127 radar in fixed frequency mode; wave heights 2-3 feet.

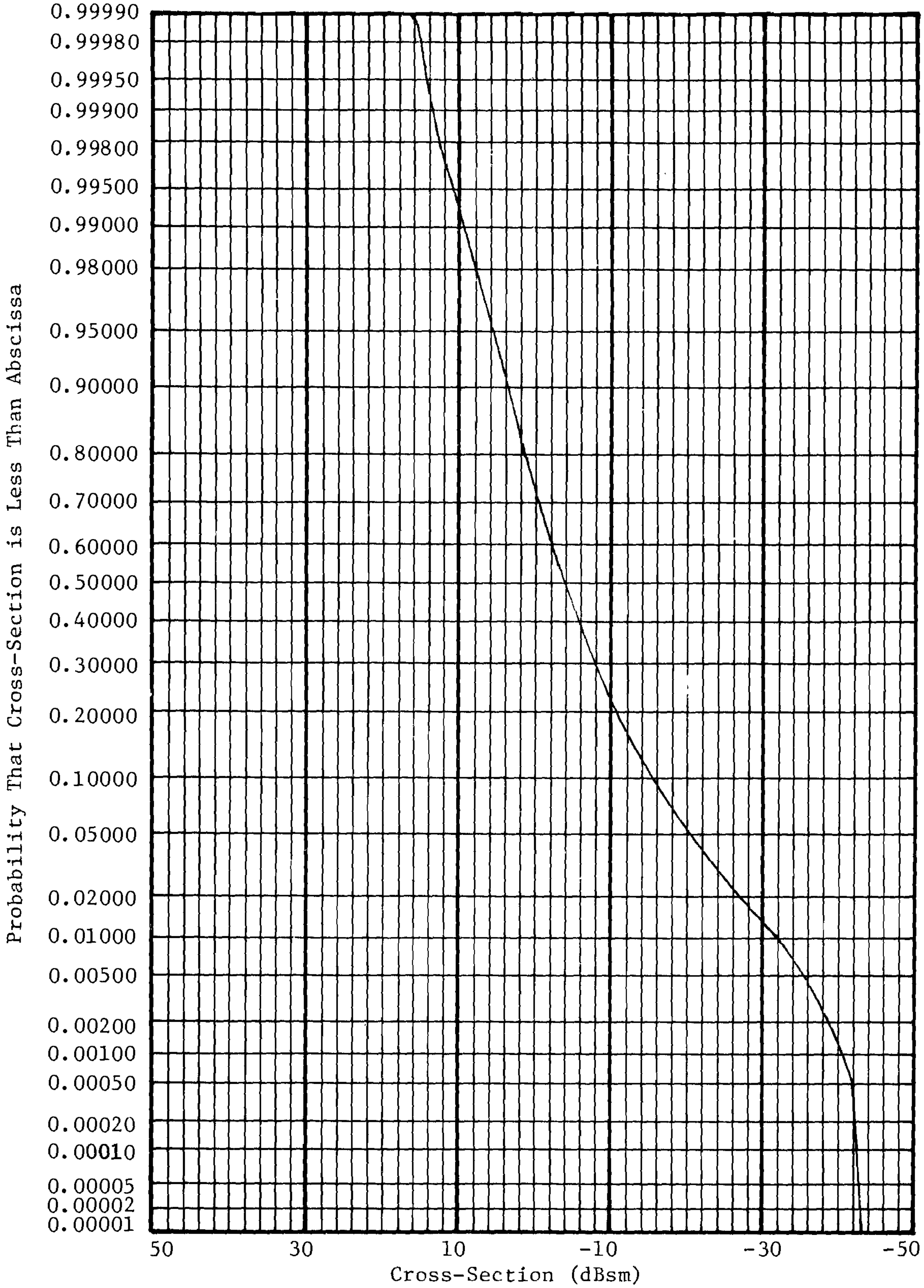

Figure A-6. Cumulative probability distribution of target cross-section for dinghy at broadside aspect at 1.4 nmi; AN/APS-127 radar in fixed frequency mode; wave height 2-3 feet.

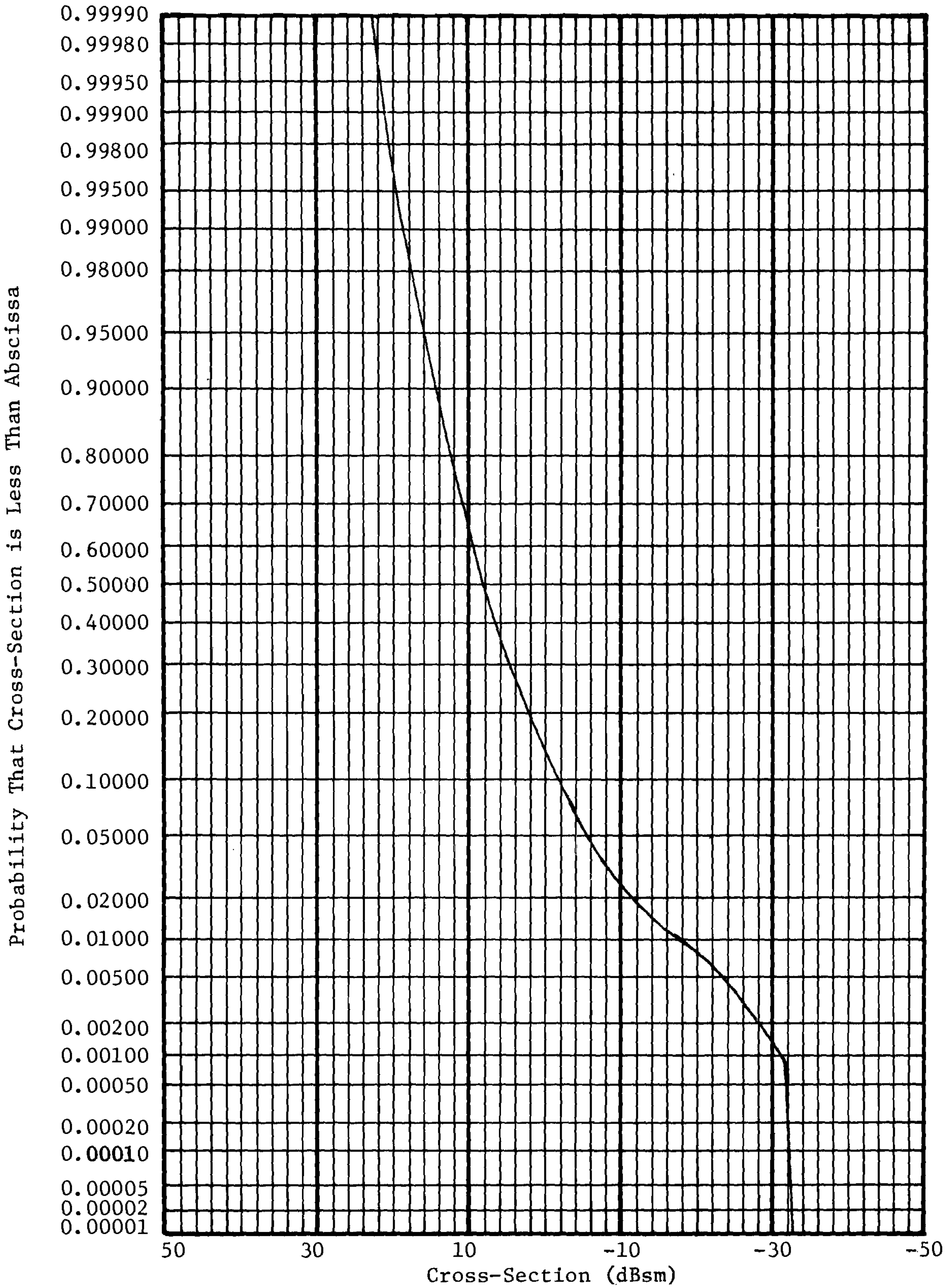

Figure A-7. Cumulative probability distribution of target cross-section for 22' FOSI boat at 2.6 nmi and broadside aspect; AN/APS-127 radar in fixed frequency mode; wave heights 2-3 feet.

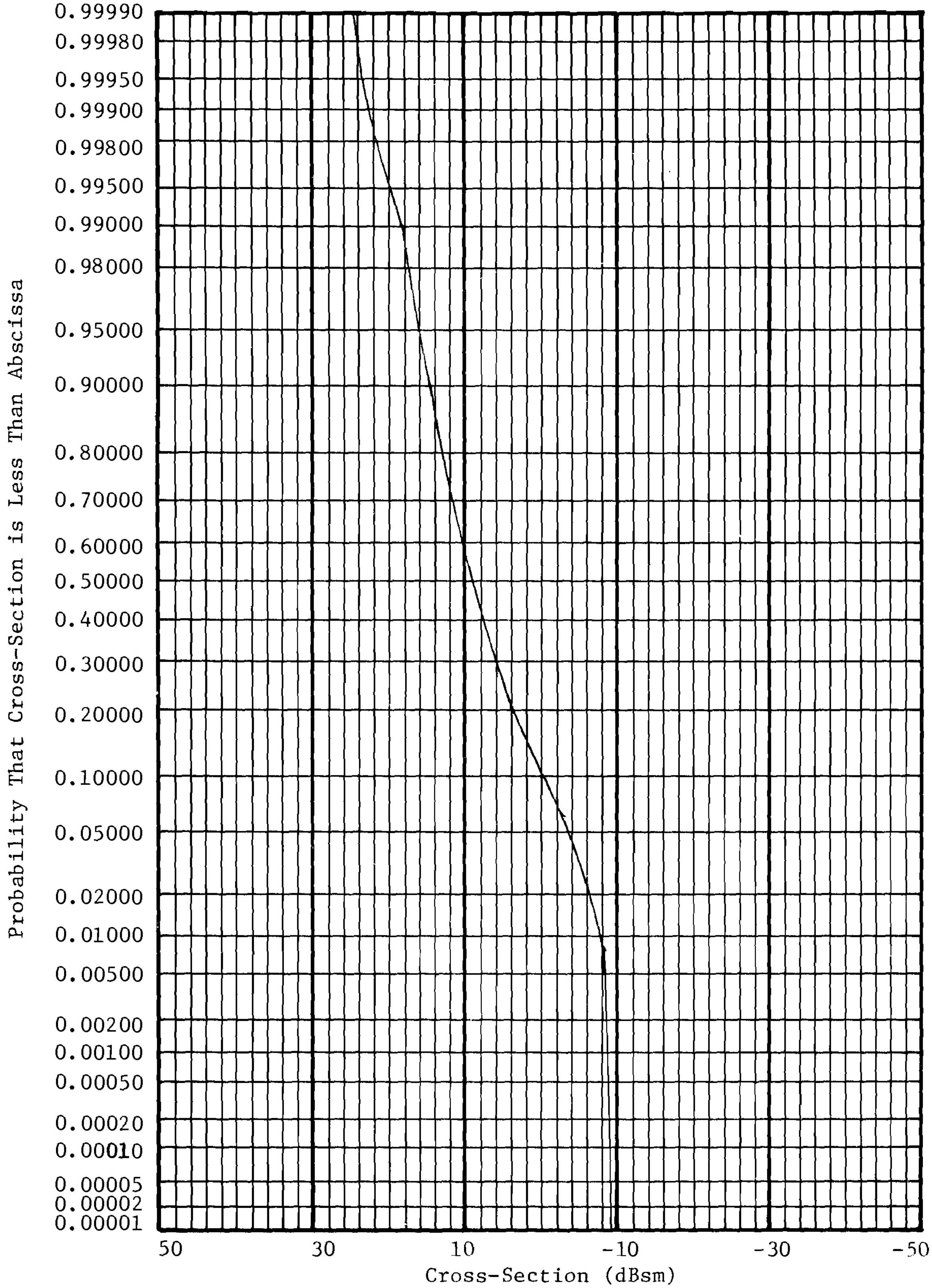

Figure A-8. Cumulative probability distribution of target cross-section for 22' FOSI boat at 3.1 nmi; AN/APS-127 radar in fixed frequency mode; wave heights 3-5 feet.

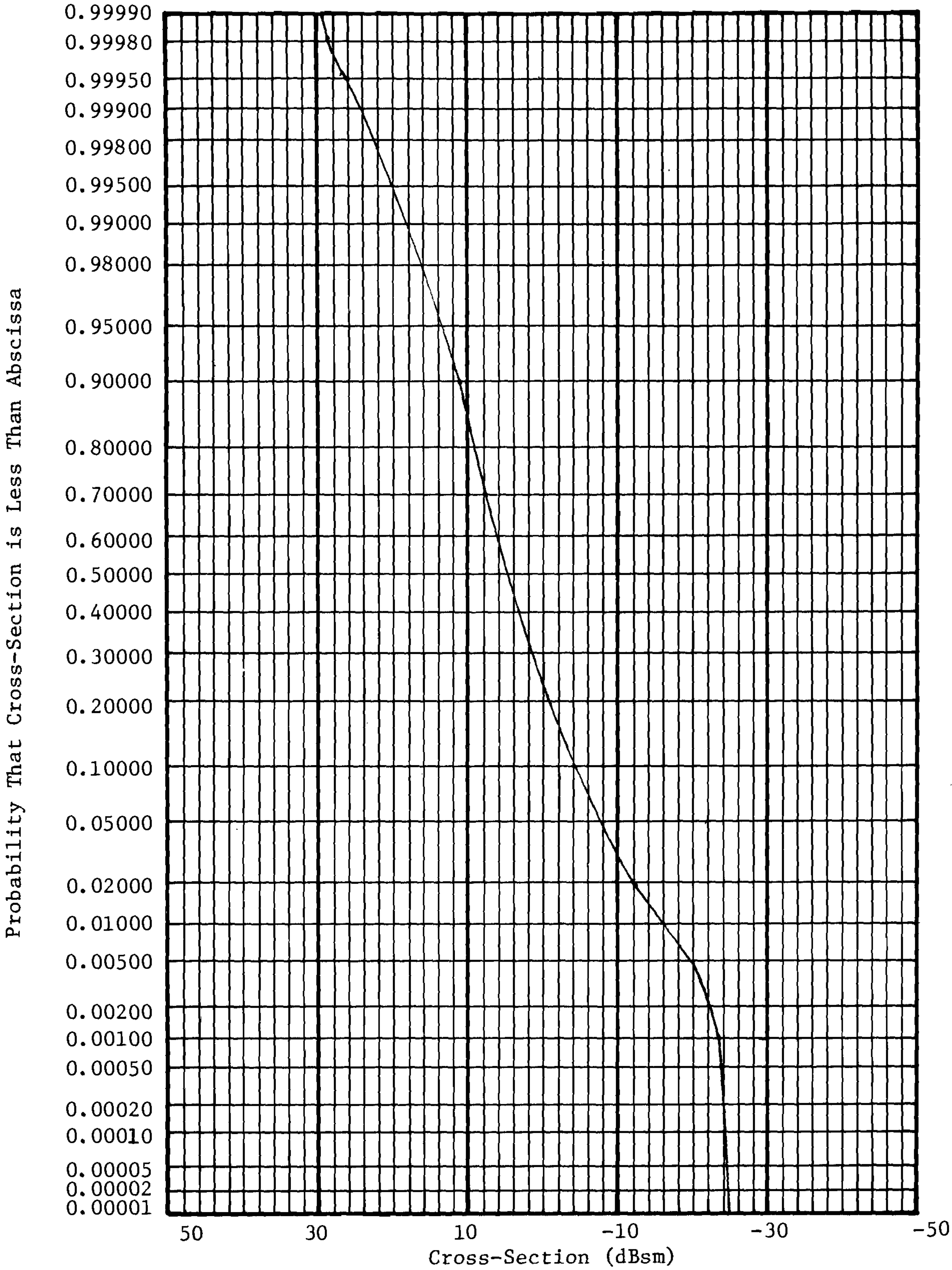

Figure A-9. Cumulative probability distribution of target cross-section for 18' Coast Guard boat at 1.8 nmi; AN/APS-127 radar in fixed frequency mode; wave heights 1-2 feet.

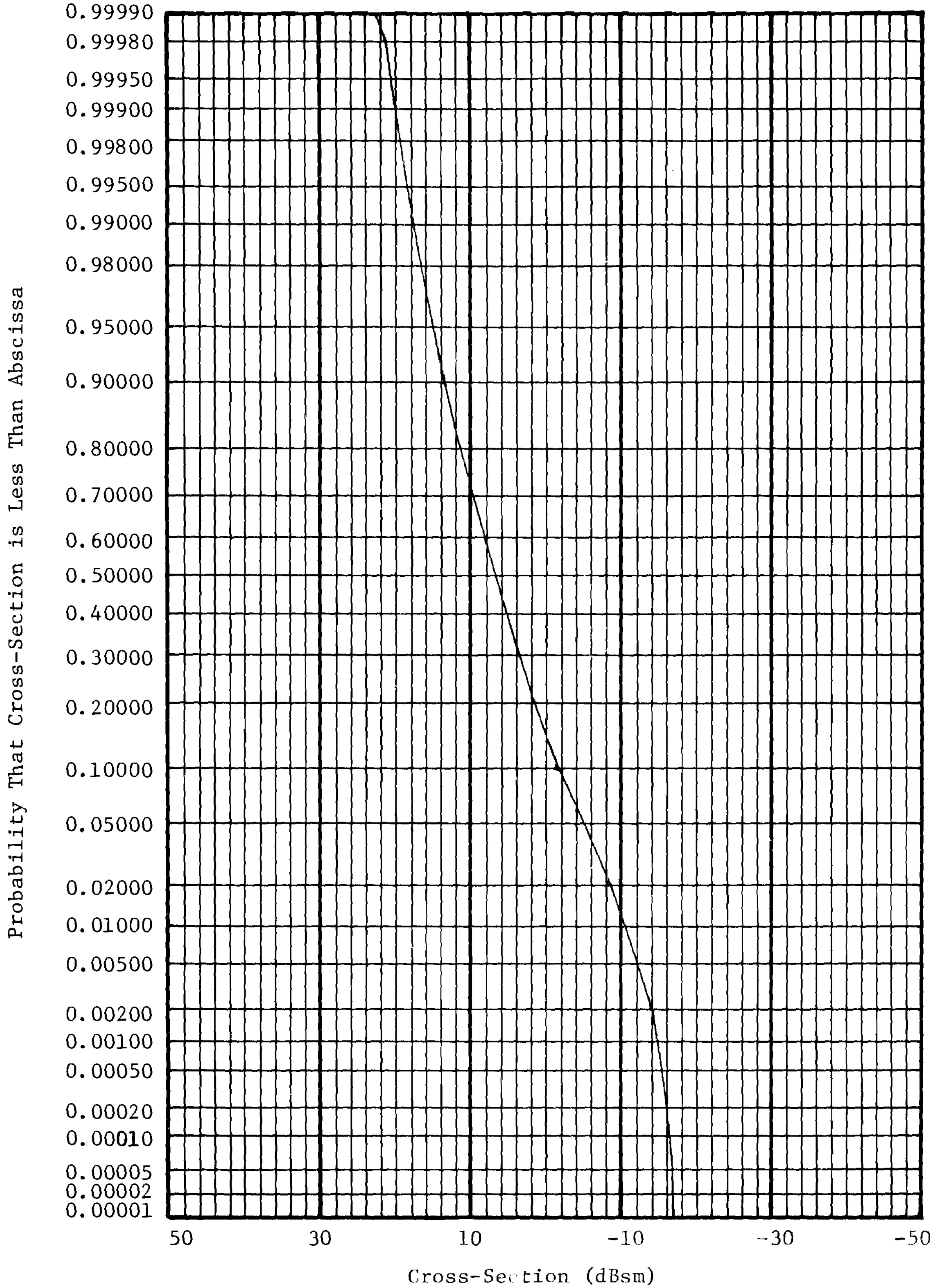

Figure A-10. Cumulative probability distribution of target cross-section for 18' Coast Guard boat at 2.1 nmi; AN/APS-127 radar in fixed frequency mode; wave heights 3-5 feet.

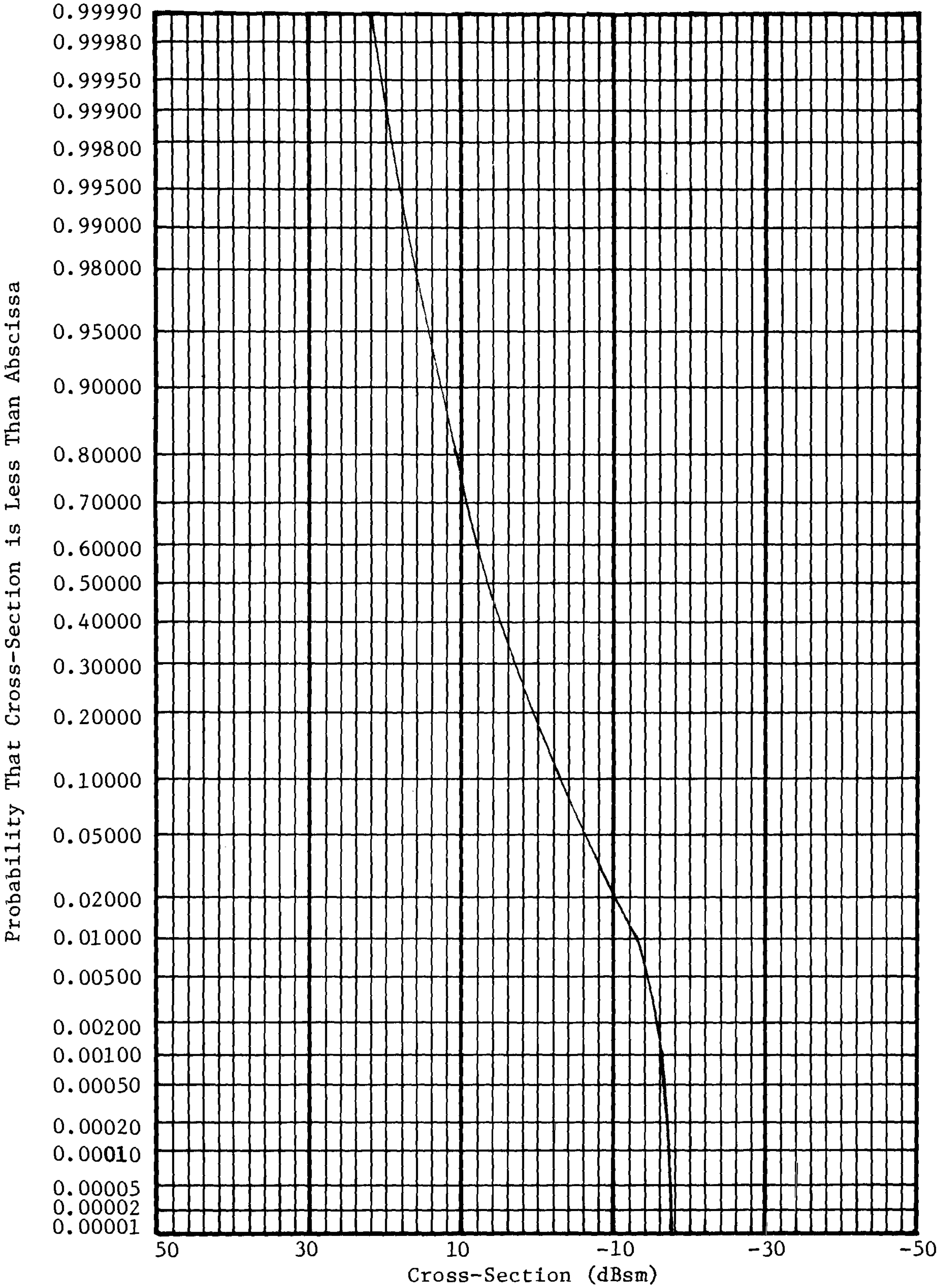

Figure A-11. Cumulative probability distribution of target cross-section for 18' Coast Guard boat at 2.0 nmi; AN/APS-127 radar in frequency agile mode; wave heights 3-5 feet.

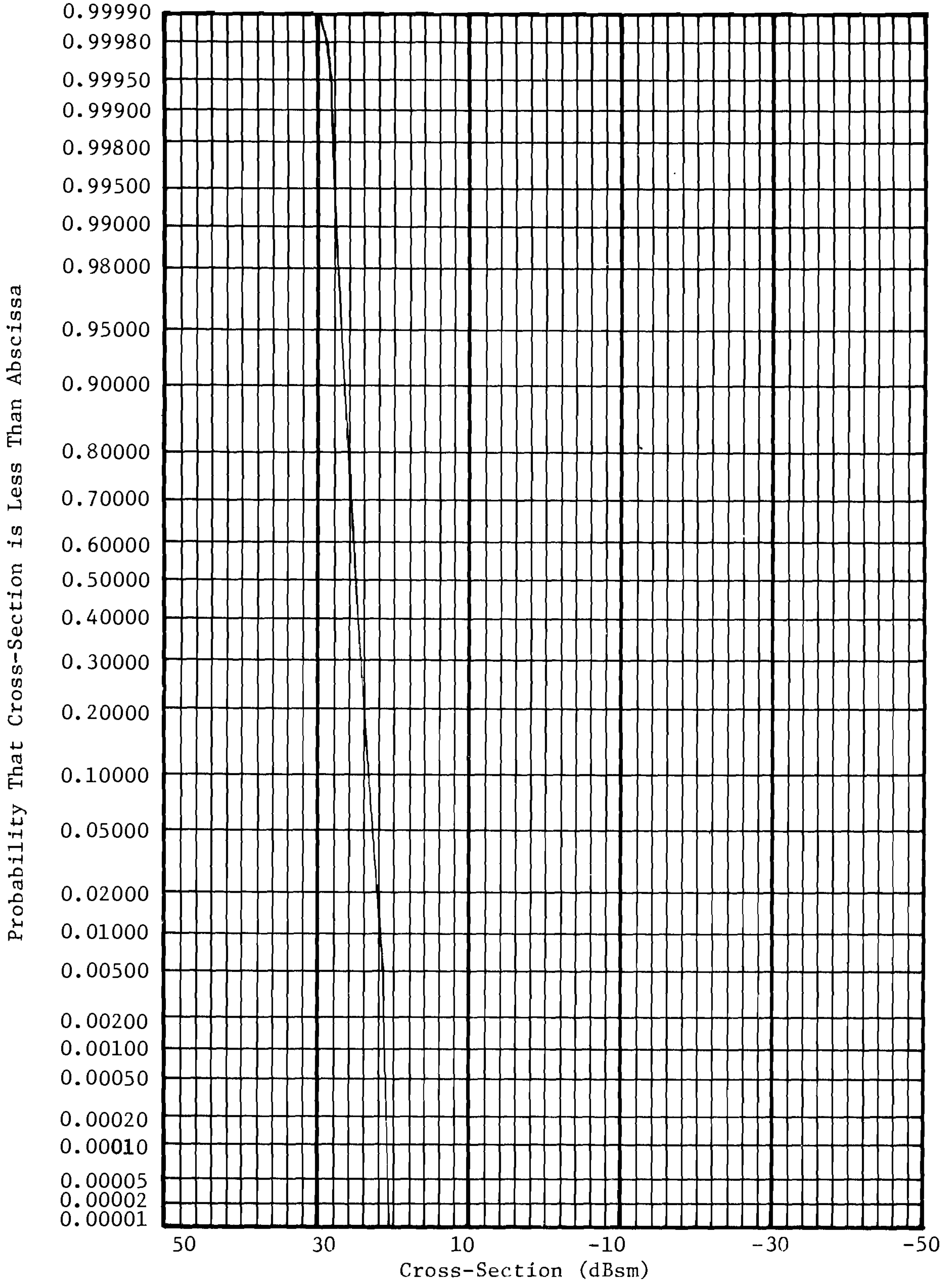

Figure A-12. Cumulative probability distribution of target cross-section for 18' Coast Guard boat with 14" corner reflector directed toward the radar; target at 1.8 nmi; AN/APS-127 radar in fixed frequency mode; wave height 1-2 feet.

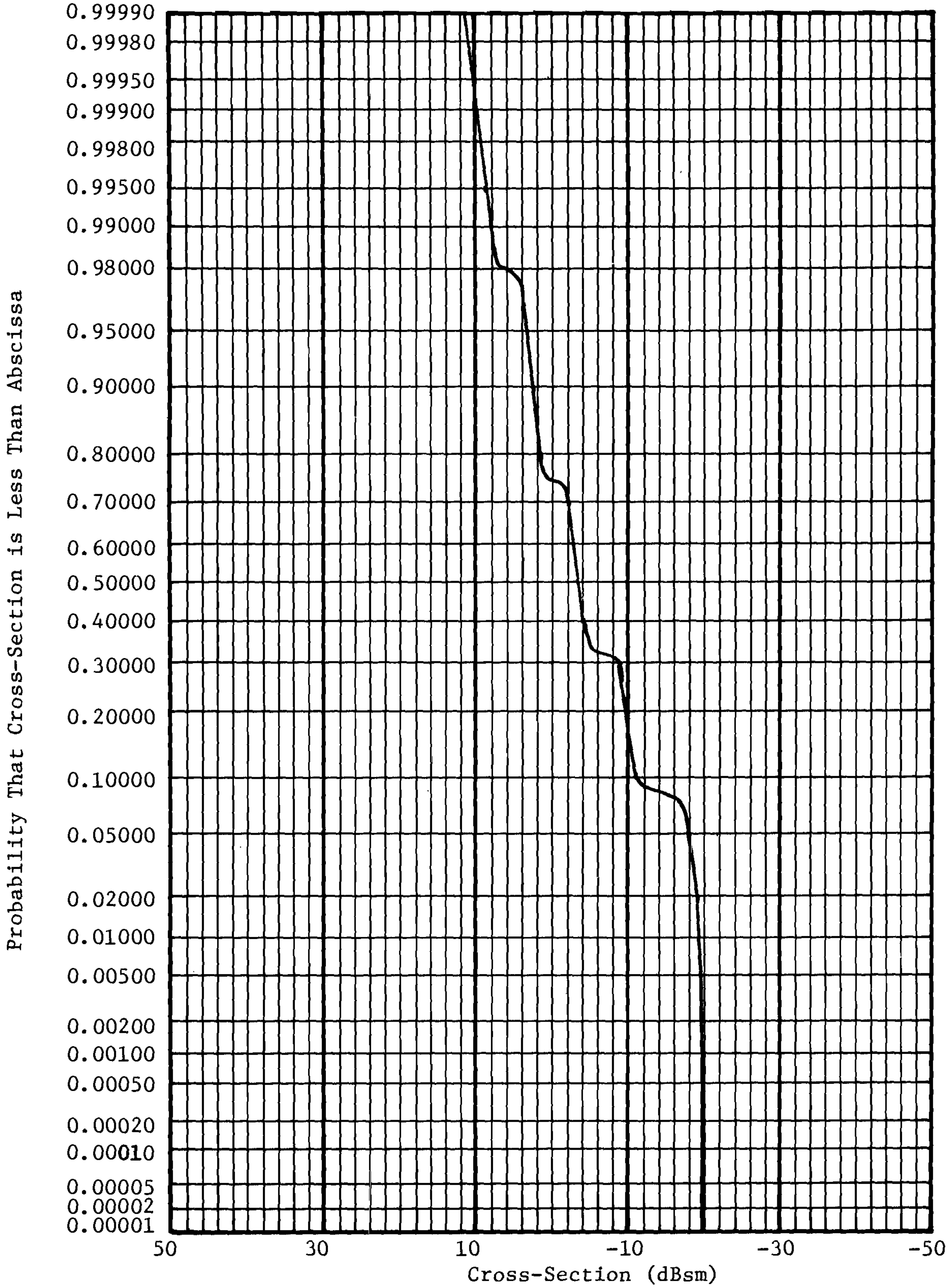

Figure A-13. Cumulative probability distribution of target cross-section for 22' FOSI boat inbound at 3.4 nmi; digital CEP; wave heights 3-5 feet.

APPENDIX B

Measured Radar Cross-Sections for a Number of Different Targets

This appendix presents in tabular form the results of measurements made on the Coast Guard Auxiliary Flotilla 310 of Boca Raton on 26 June 1976. The flotilla, consisting of ten craft from 25-45 feet in length, provided targets of different sizes, both in motion and dead in the water at various aspects. Also included for comparison are the results of the same measurements made on the three small boats used during the tests: the FOXY LADY, the FOSI boat and the Coast Guard boat. Target cross-section, clutter cross-section and $\sigma°$ as measured by the AN/APS-127 and GT-X radars are presented. These data support the conclusions mentioned previously: while the AN/APS-127 and GT-X measure comparable values for $\sigma°$ and target cross-section, the AN/APS-127 measures consistently 5-10 dB higher clutter cross-sections due to its wider antenna beam. Cross-sections for craft dead in the water are consistently below those for craft in motion.

MEASURED RADAR CROSS-SECTION FOR A NUMBER OF DIFFERENT TARGETS

BOAT	ASPECT	RANGE (nmi)	AN/APS-127 σ_T (dBsm)	AN/APS-127 σ_C (dBsm)	AN/APS-127 σ° (dB)	GT-X σ_T (dBsm)	GT-X σ_C (dBsm)	GT-X σ° (dB)	COMMENTS
FOXY LADY (18' tri-hull runabout)	stern	2.75	-0.1	-16.6	-60.4	2.3	-20.1	-59.8	E @ 10 kts; high spray
"	stern	3.3	-2.6	-20.3	-65.0	-2.1	-26.8	-65.3	E @ 8 kts; high spray
"	stern	3.8	-2.3	-18.2	-63.4	-3.5	-25.0	-64.0	E @ 10 kts; fair amount of spray
"	stern	4.3	-8.6	-17.1	-62.8	-10.3	-22.0	-63.4	Dead in water
"	broadside	4.4	-8.8	-16.8	-62.5	-10.4	-23.9	-63.4	Dead in water
"	bow on	4.3	-10.4	-16.8	-62.5	-12.3	-24.3	-63.8	Dead in water
EL MIPO (31' Trojan)	stern	2.4	7.0	-16.4	-59.6	7.3	-21.2	-58.1	E @ 10 kts; fair amount of wake
"	stern	3.4	5.4	-16.9	-61.5	8.0	-26.1	-64.3	E @ 10 kts
"	broadside	4.5	5.7	-16.7	-62.6	12.4	-23.6	-63.3	Dead in water
"	broadside	4.3	4.9	-17.5	-63.1	5.4	-23.9	-63.3	S @ 5 kts
"	bow on	4.6	0.7	-16.6	-62.5	4.3	-23.3	-63.0	Dead in water
LASSIE (25' Luhrs)	stern	2.2	7.4	-14.4	-57.2	10.9	-20.3	-56.9	E @ 10 kts
"	stern	3.2	4.2	-18.8	-63.2	4.6	-26.6	-64.5	E @ 8 kts; large amount of spray
"	stern	3.9	7.6	-18.4	-63.6	7.8	-25.4	-64.3	Dead in water
"	broadside	3.8	3.7	-18.5	-63.7	9.0	-25.3	-64.2	Dead in water
"	bow	3.9	8.4	-18.1	-63.3	10.4	-24.8	-63.8	Dead in water

BOAT	ASPECT	RANGE (nmi)	AN/APS-127 σ_T (dBsm)	AN/APS-127 σ_C (dBsm)	AN/APS-127 σ° (dB)	GT-X σ_T (dBsm)	GT-X σ_C (dBsm)	GT-X σ° (dB)	COMMENTS
SOUTHWARD (43' Pearson)	stern	3.7	14.1	-18.3	-63.3	14.3	-25.1	-63.8	E @ 10 kts
"	stern	4.2	12.4	-17.4	-63.0	14.4	-24.4	-63.8	Dead in water
"	broadside	4.5	10.2	-16.9	-62.7	11.1	-24.0	-63.6	Dead in water
PEGGY II (28' Seabird)	stern	2.7	6.8	-17.6	-61.3	7.4	-27.1	-64.3	E @ 8 kts; high spray
"	stern	3.9	1.6	-18.2	-63.5	3.7	-25.5	-64.4	E @ 10 kts; high spray
"	stern	4.5	-0.4	-16.9	-62.7	3.3	-24.3	-63.9	Dead in water
"	broadside	4.5	0.2	-16.9	-62.8	2.9	-24.3	-63.9	Dead in water
"	bow on	4.5	-1.1	-16.5	-62.4	1.0	-24.3	-64.0	Dead in water
LI'L DIPPER (45' Hatteras)	stern	2.6	9.5	-14.6	-58.1	10.4	-23.3	-60.4	E @ 10 kts; very little spray
"	stern	3.6	8.1	-18.8	-63.6	11.4	-25.8	-64.4	E @ 10 kts; little spray
"	stern	4.4	9.4	-16.8	-62.6	11.2	-24.0	-63.5	Dead in water
"	broadside	4.4	7.9	-16.9	-62.6	10.7	-24.1	-63.6	Dead in water
"	bow on	4.4	6.9	-16.7	-62.5	6.5	-24.1	-63.7	Dead in water
ME JANE (41' Hatteras)	stern	2.1	8.9	-9.7	-52.2	11.6	-19.7	-55.7	E @ 7 kts
"	stern	3.3	9.6	-14.2	-58.6	10.5	-22.8	-61.2	E @ 7 kts
"	stern	4.1	8.5	-16.4	-61.9	12.7	-23.2	-62.4	Dead in water
"	broadside	4.1	8.3	-16.7	-62.2	10.6	-23.3	-62.6	Dead in water
"	bow on	4.1	5.7	-16.3	-61.8	9.2	-24.0	-63.3	Dead in water

BOAT	ASPECT	RANGE (nmi)	AN/APS-127 σ_T (dBsm)	AN/APS-127 σ_C (dBsm)	AN/APS-127 σ° (dB)	GT-X σ_T (dBsm)	GT-X σ_C (dBsm)	GT-X σ° (dB)	COMMENTS
AVION II (36' Chris Craft)	stern	1.7	7.4	-12.8	-54.4	0.6	-18.2	-53.5	080° @ 7-8 kts
"	stern	2.7	7.4	-16.2	-59.8	7.2	-25.2	-62.4	090° @ 8-10 kts; medium spray
"	stern	3.2	6.6	-18.8	-63.1	9.4	-24.1	-62.6	E @ 9 kts; some spray
"	stern	3.5	4.9	-19.1	-63.9	9.2	-26.3	-64.8	Dead in water
"	broadside	3.5	5.6	-18.0	-62.9	6.8	-25.7	-64.3	Dead in water
"	bow	3.5	2.9	-18.3	-63.2	5.9	-25.3	-63.9	Dead in water
JONA (43' Wheeler)	stern	2.2	10.7	-16.0	-58.8	10.5	-25.7	-62.4	E @ 7 kts; small amount of spray
"	stern	3.4	11.1	-16.7	-61.3	11.1	-25.5	-63.7	E @ 8 kts; little spray
"	stern	5.4	13.3	-14.3	-60.9	10.1	-26.1	-64.6	Dead in water
"	broadside	3.7	10.2	-17.9	-62.9	12.8	-24.8	-63.6	Dead in water
"	bow	3.7	5.3	-18.3	-63.4	9.2	-25.3	-64.1	Dead in water
COLUMBIA		2.2	4.0	-16.7	-59.6	9.2	-20.0	-56.6	sailboat; target of opportunity
SKYLARK V (30' Elco)	stern	2.1	5.8	-14.5	-57.1	6.4	-23.7	-59.7	E @ 10 kts
"	stern	3.6	6.4	-18.5	-63.4	7.2	-26.4	-64.8	E @ 10 kts
"	stern	3.9	3.7	-17.3	-62.5	10.2	-25.2	-64.2	Dead in water
"	broadside	3.9	1.7	-17.7	-63.0	4.8	-25.0	-64.0	Dead in water
"	bow	3.9	0.8	-17.6	-62.9	4.9	-25.1	-64.1	Dead in water

BOAT	ASPECT	RANGE (nmi)	AN/APS-127 σ_T (dBsm)	σ_C (dBsm)	σ° (dB)	GT-X σ_T (dBsm)	σ_C (dBsm)	σ° (dB)	COMMENTS
OMEGA (27' Chris Craft)	stern	1.9	10.5	-9.4	-51.6	9.4	-19.5	-55.2	E @ 10 kts
"	stern	2.9	6.7	-16.4	-60.3	9.1	-24.6	-62.1	E @ 7 kts
"	stern	3.8	7.9	-18.1	-63.2	7.7	-24.4	-63.4	E @ 7 kts
"	starboard quarter	4.1	4.8	-17.1	-62.5	5.9	-25.2	-64.2	Dead in water
"	stern	4.1	4.6	-17.0	-62.5	6.9	-24.4	-63.6	Dead in water
"	broadside	4.2	2.7	-16.7	-62.3	5.3	-23.5	-62.8	Boat idling in water
"	bow	4.2	3.2	-16.5	-62.1	6.5	-23.6	-62.8	Boat idling in water
FOSI	stern	3.2	10.8	-15.7	-61.1	-	-	-	Radial out
(22' boat	stern	3.7	7.2	-14.2	-60.3	-	-	-	Radial out
with canopy)	broadside	2.3	12.2	-12.9	-55.9	-	-	-	Dead in water
"	broadside	2.6	6.4	-13.2	-56.8	-	-	-	Dead in water
"	broadside	4.3	7.1	-20.1	-65.8	-	-	-	Dead in water
Coast Guard	bow	3.4	2.1	-20.9	-65.6	0.7	-27.9	-66.3	In @ 30mph
(18' Boat)	stern	3.4	-3.5	-20.5	-65.2	-3.4	-26.8	-65.2	E @ 5kts
"	broadside	1.9	0.0	-13.8	-55.8	-0.6	-21.2	-57.0	Dead in water
"	broadside	5.1	-8.2	-16.5	-62.9	-9.1	-21.9	-62.0	Dead in water

APPENDIX C

Selected Receiver Operating Curves

Some ROC's not presented in the body of this report are included in this appendix. Figures C-1 and C-2 are ROC's for the GT-X radar, vertically polarized, in sea states 2 and 3 respectively. An ROC for the analog CEP is illustrated in Figure C-3 and an ROC for the digital CEP is given in Figure C-4.

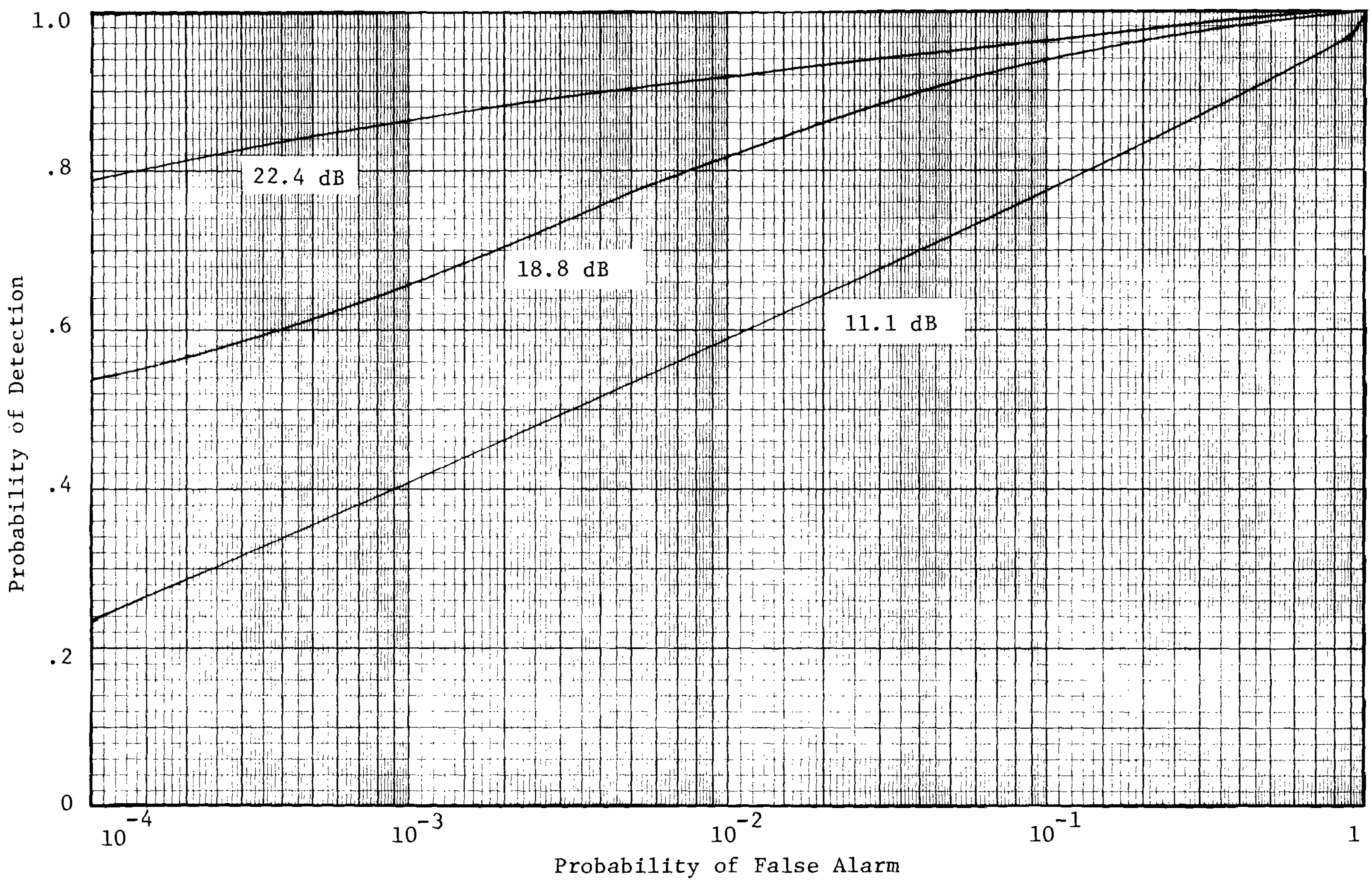

Figure C-1. Receiver operating curves for GT-X radar, vertically polarized, wave heights 1-3 feet; as functions of (Signal plus Background)/ Background.

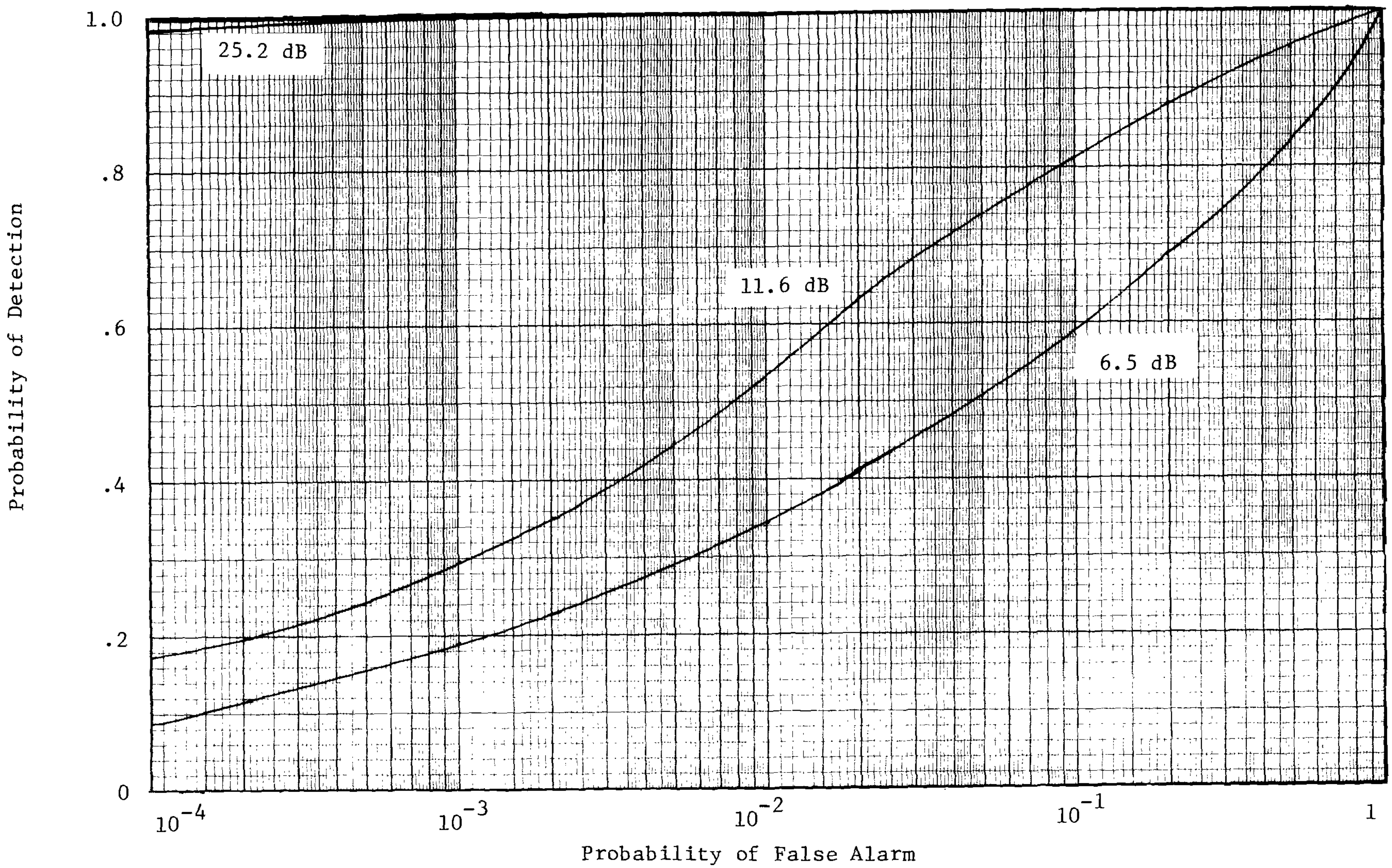

Figure C-2. Receiver operating curves for GT-X radar, vertically polarized, wave heights 3-5 feet; as functions of (Signal plus Background)/ Background.

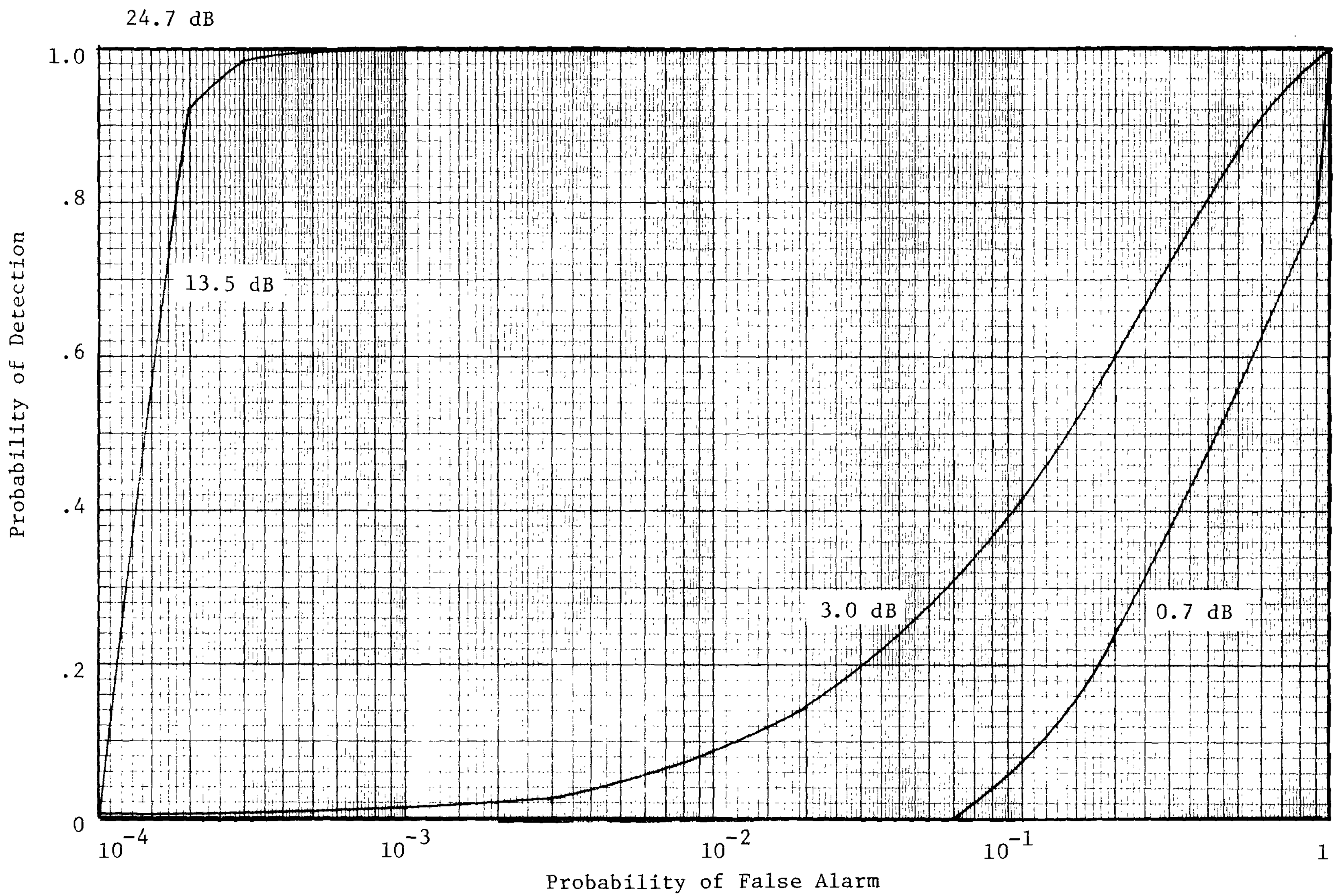

Figure C-3. Receiver operating curves for analog clutter envelope processor as functions of (Signal plus Background)/Background.

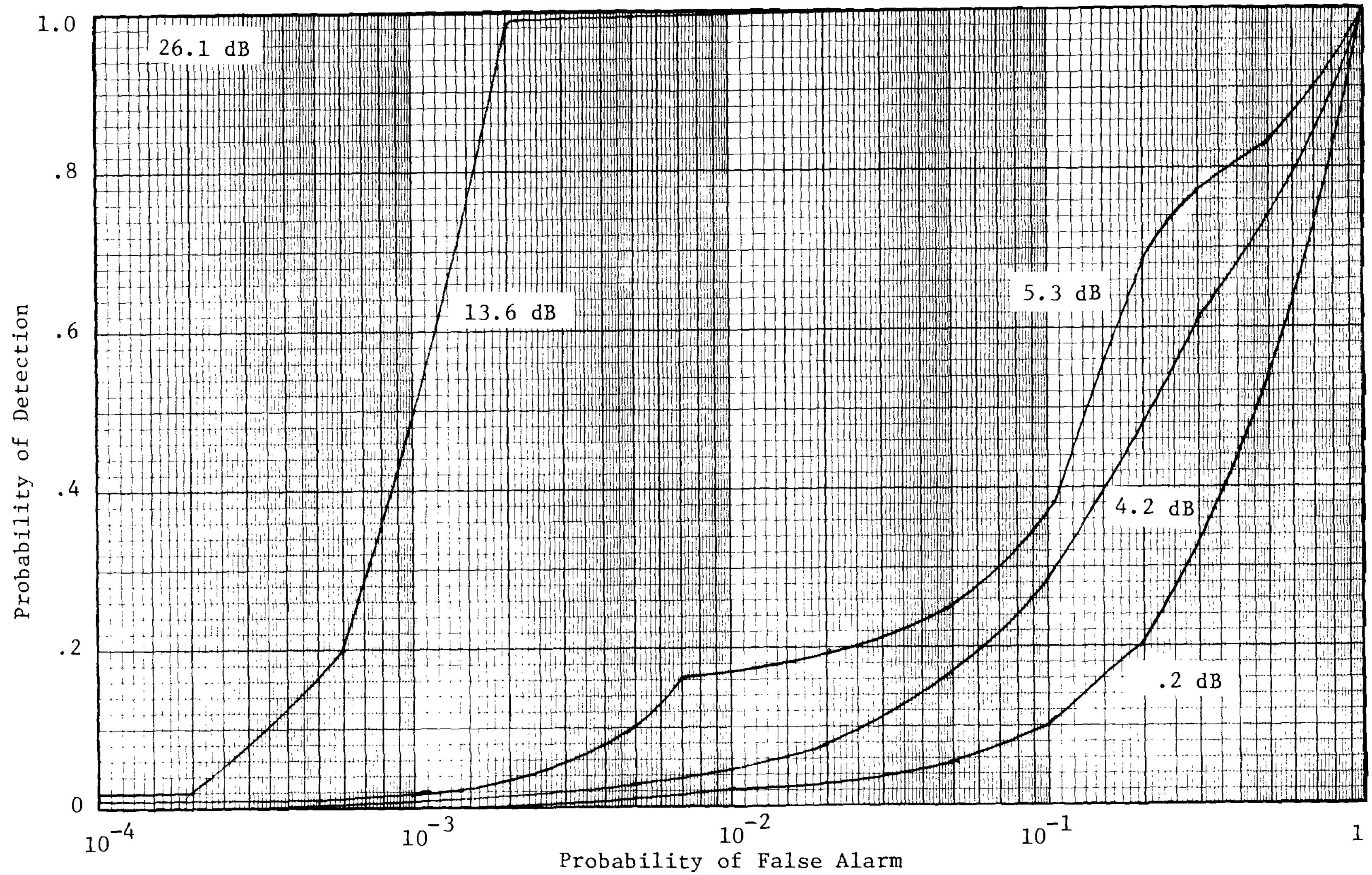

Figure C-4. Receiver operating curves for digital clutter envelope processor, as functions of (Signal plus Background)/Background.

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE *(and Subtitle)*

Shore Tests on the AN/APS-127 Airborne Radar System

5. TYPE OF REPORT & PERIOD COVERED

Final Test Data Package Phase I

6. PERFORMING ORG. REPORT NUMBER

EES/GIT-A-1820FI

7. AUTHOR*(s)*

N. C. Currie, M. M. Horst, and J. C. Butterworth

8. CONTRACT OR GRANT NUMBER*(s)*

N62269-76-C-0232

9. PERFORMING ORGANIZATION NAME AND ADDRESS

Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia 30332

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS

Department of the Navy
Naval Air Development Center
Warminster, Pennsylvania 18974

12. REPORT DATE

October 1976

13. NUMBER OF PAGES

xii + 83

14. MONITORING AGENCY NAME & ADDRESS*(if different from Controlling Office)*

15. SECURITY CLASS. *(of this report)*

Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

16. DISTRIBUTION STATEMENT *(of this Report)*

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Airborne Radar
Sea Return
Radar Tests

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A series of shore based performance tests on the AN/APS-127 radar system are described, and the preliminary results are summarized. The results consist of radar cross-section plots, empirically measured receiver operating curves, decorrelation times, blip-scan ratios, and minimum detectable signal measurements on small- and medium-sized boats. Predictions are included for the expected performance during the upcoming flight tests and recommendations are made as to the scope and procedure for the flight tests.

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A-1820

ENGINEERING EXPERIMENT STATION
GEORGIA INSTITUTE OF TECHNOLOGY • ATLANTA, GEORGIA 30332

16 May 1977

Commanding Officer
Naval Air Development Center (NADC)
Warminster, Pennsylvania 18974

Attention: Code 845

Reference: Contract N62269-76-C-0232

Subject: Phase II Test Data Package

Gentlemen:

Enclosed are tabulations of the median radar cross-sections of the target boats and normalized cross-section of the sea obtained with GT-X during the November and January flight tests of the APS-127. The target data is tabulated for each day with range and target aspect noted. In addition, remarks concerning the operation of the boat, speed and heading are noted in the comments.

The normalized cross-section of the sea is presented as a function of time and bearing from the Boca site. The sea data was obtained at shorter ranges than the target data since measurements of cross-section beyond approximately 3 miles were not practical due to power and sensitivity limitations. In addition, the wind speed, direction and sea state at the time of the measurements are noted in the comments.

The cross-section data obtained on the swimmer with the reflective parka indicated a radar cross-section of approximately -3.5 dBsm at 0.45 nautical miles. The parka was being held up by the swimmer toward GT-X rather than being worn during the measurement. This cross-section was 10 to 18 dB above the cross-section of the swimmer alone.

If there are any questions concerning the data, Mr. J. C. Butterworth, Mr. L. C. Bomar or I will be happy to answer them.

Sincerely,

Nicholas C. Currie
Project Director

NCC/sb

Enclosures

MEASURED RADAR CROSS-SECTION PER UNIT AREA OF SEA

DATE	TIME	RANGE(M)	BEARING	σ°dB	COMMENTS
1/13/77	9:17	8093	110°	-55.1	Winds NNE 25-30 mph; sea 4-6 ft.
	9:20	8111	110°	-55.0	" " "
	9:24	8167	110°	-57.7	" " "
	9:27	8296	110°	-54.7	" " "
	9:32	9260	110°	-53.6	" " "
	9:34	8334	110°	-54.1	" " "
	9:36	7408	110°	-51.2	" " "
	9:37	6482	110°	-50.5	" " "
	9:39	5556	110°	-47.7	" " "
	9:41	4630	110°	-45.3	" " "
	9:43	3704	110°	-45.3	" " "
	9:45	2778	110°	-44.0	" " "
	9:47	1852	110°	-44.3	" " "
	9:49	9260	110°	-54.7	" " "
	9:51	10186	110°	-57.8	" " "
	10:55	9260	135°	-56.6	Winds ENE 20-25 mph; sea 4-6 ft.
	10:58	8334	135°	-56.4	" " "
	11:00	7408	135°	-56.9	" " "
	11:02	6482	135°	-52.2	" " "
	11:03	5556	135°	-51.9	" " "
	11:06	4630	135°	-49.3	" " "
	11:07	3704	135°	-46.2	" " "
	11:09	2778	135°	-46.2	" " "
	11:12	1852	135°	-44.1	" " "
	11:16	10186	135°	-58.1	" " "
	11:35	9260	090°	-53.7	" " "
	11:37	8334	090°	-53.5	" " "
	11:43	7408	090°	-50.6	" " "
	11:44	6482	090°	-52.5	" " "
	11:46	5556	090°	-52.8	" " "
	11:48	4630	090°	-49.0	" " "

MEASURED RADAR CROSS-SECTION PER UNIT AREA OF SEA (continued)

DATE	TIME	RANGE(M)	BEARING	σ°dB	COMMENTS
1/13/77	11:49	3704	090°	-45.6	Winds ENE 20-25 mph; sea 4-6 ft.
	11:51	2778	090°	-43.0	" " "
	11:54	1852	090°	-45.3	" " "
	11:56	9260	090°	-55.7	" " "
	12:55	11112	135°	-59.6	" " "
	12:56	10186	135°	-59.3	" " "
	12:58	9260	135°	-62.5	" " "
	13:01	8334	135°	-57.3	" " "
	13:02	7408	135°	-56.5	" " "
	13:05	6482	135°	-51.6	" " "
	13:07	5556	135°	-54.1	" " "
	13:08	4630	135°	-48.3	" " "
	13:10	3704	135°	-46.9	" " "
	13:12	2778	135°	-47.6	" " "
	13:14	1852	135°	-46.8	" " "
	14:14	11112	090°	-60.9	" " "
	14:16	10186	090°	-60.2	" " "
	14:18	9260	090°	-58.7	" " "
	14:19	8334	090°	-58.4	" " "
	14:20	7408	090°	-57.7	" " "
	14:23	5556	090°	-53.4	" " "
	14:25	4630	090°	-49.1	" " "
	14:26	3704	090°	-45.4	" " "
	14:28	2778	090°	-53.1	" " "
	14:29	1852	090°	-43.9	" " "
1/14/77	8:32	648	090°	-55.3	Winds SE 25-30 mph; sea 3-5 ft.
	8:34	703	090°	-55.6	" " "
	8:35	703	090°	-55.9	" " "
	8:36	814	090°	-54.6	" " "
	8:38	851	090°	-54.9	" " "
	9:03	3778	110°	-49.7	" " "
	9:05	3852	110°	-50.6	" " "

MEASURED RADAR CROSS-SECTION PER UNIT AREA OF SEA (continued)

DATE	TIME	RANGE(M)	BEARING	σ°dB	COMMENTS		
1/14/77	9:18	5259	110°	-58.7	Winds SE 25-30 mph; sea 3-5 ft.		
	9:39	11112	120°	-59.5	"	"	"
	9:41	10186	120°	-56.4	"	"	"
	9:42	9260	120°	-56.1	"	"	"
	9:44	8334	120°	-52.0	"	"	"
	9:46	7408	120°	-53.5	"	"	"
	9:47	6482	120°	-54.9	"	"	"
	9:50	5556	120°	-49.9	"	"	"
	9:52	4630	120°	-53.8	"	"	"
	9:54	3704	120°	-44.5	"	"	"
	9:55	2778	120°	-41.3	"	"	"
	9:57	1852	120°	-42.3	"	"	"
	10:08	10186	120°	-60.4	"	"	"
	10:09	9260	120°	-59.0	"	"	"
	10:11	8334	120°	-53.7	"	"	"
	10:12	7408	120°	-60.5	"	"	"
	10:14	6482	120°	-55.0	"	"	"
	10:15	5556	120°	-55.3	"	"	"
	10:17	4630	120°	-52.9	"	"	"
	10:19	3704	120°	-51.9	"	"	"
	10:20	2778	120°	-45.9	"	"	"
	10:22	1852	120°	-46.9	"	"	"
	10:24	8334	120°	-62.3	"	"	"
1/17/77	10:34	1852	092°	-71.2	Winds WNW 15-20 mph; sea 5-6 ft.		
	10:36	2778	092°	-69.0	"	"	"
	10:37	3704	092°	-64.1	"	"	"
	10:38	4630	092°	-68.1	"	"	"
	10:40	5556	092°	-64.1	"	"	"
	10:42	6482	092°	-60.9	"	"	"
	10:43	7408	092°	-64.9	"	"	"
	10:45	8334	092°	-63.0	"	"	"
	10:47	9260	092°	-62.2	"	"	"

MEASURED RADAR CROSS-SECTION PER UNIT AREA OF SEA (continued)

DATE	TIME	RANGE(M)	BEARING	σ°dB	COMMENTS
1/18/77	11:00	1852	095°	-75.4	Winds WNW 5-10 mph; sea 2-3 ft.
	11:01	2778	095°	-71.5	" " "
	11:05	4603	095°	-72.4	" " "
1/19/77	9:31	7130	092°	-59.2	Winds NW 15-20 mph; sea 3-5 ft.
	9:35	7037	092°	-61.8	" " "
	9:37	7130	092°	-61.1	" " "
1/20/77	10:09	926	090°	-87.1	Winds W 1-5 mph; sea 2-3 ft.
	10:11	1389	090°	-82.0	" " "
	10:15	926	090°	-83.0	" " "
	10:16	1389	090°	-80.5	" " "
	10:18	1852	090°	-82.6	" " "
	10:19	2315	090°	-81.4	" " "
	10:27	926	045°	-82.9	Winds W 5-10 mph; sea 3-5 ft.
	10:29	1389	045°	-76.5	" " "
	10:30	1852	045°	-72.0	" " "
	10:32	2315	045°	-71.9	" " "
	10:33	2778	045°	-72.0	" " "
	10:35	3241	045°	-70.0	" " "
	10:36	3704	045°	-69.1	" " "
	10:39	4167	045°	-67.3	" " "
	11:09	920	090°	-65.3	Winds W 10-15 mph; sea 3-5 ft.
	11:10	1852	090°	-66.4	" " "
	11:12	2778	090°	-67.5	" " "
	11:13	3704	090°	-65.8	" " "
	11:15	4630	090°	-69.7	" " "
	11:16	5556	090°	-65.5	" " "
	11:21	920	045°	-67.6	" " "
	11:22	1852	045°	-59.7	" " "
	11:24	2778	045°	-56.3	" " "
	11:25	3704	045°	-62.6	" " "
	11:27	4630	045°	-65.5	" " "
	11:28	5556	045°	-66.6	" " "

MEASURED RADAR CROSS-SECTION PER UNIT AREA OF SEA (continued)

DATE	TIME	RANGE(M)	BEARING	$\sigma°$dB	COMMENTS
1/20/77	12:12	920	045°	-65.9	Winds W 10-15 mph; sea 3-5 ft.
	12:13	1852	045°	-63.7	" " "
	12:14	3704	045°	-62.2	" " "
	12:16	2778	045°	-63.4	" " "
	12:17	5556	045°	-63.6	" " "
	12:23	926	090°	-70.0	" " "
	12:24	1852	090°	-63.9	" " "
	12:26	2778	090°	-67.6	" " "
	12:27	3704	090°	-66.2	" " "
	12:29	5556	090°	-65.3	" " "
	12:38	926	135°	-69.8	" " "
	12:39	1852	135°	-66.7	" " "
	12:40	2778	135°	-72.3	" " "
	12:42	3704	135°	-69.1	" " "

MEASURED RADAR CROSS-SECTION OF 18-FOOT TARGET BOAT

DATE	TIME	RANGE(M)	ASPECT	σt (dBsm)	COMMENTS
1/12/77	11:32	2407	Broadside	-1.7	Idle speed
	11:43	3463	Broadside	-0.9	S at 5 knots
	11:50	4296	Stern Qtr.	+0.1	SE at 5 knots
	11:57	5333	Stern Qtr.	-1.9	SE at 5 knots
	14:06	6796	Stern Qtr.	-3.0	SE at 5 knots
	12:17	8389	Stern Qtr.	-9.9	SE at 5 knots

MEASURED RADAR CROSS-SECTION OF 18-FOOT TARGET BOAT

DATE	TIME	RANGE (M)	ASPECT	σt (dBsm)	COMMENTS
1/18/77	9:32	15371	Stern	+3.6	E at 2 knots
	9:34	15927	Broadside	+1.16	N at 2 knots
	9:40	15646	Bow	+8.5	W at 2 knots
	15:04	11112	Broadside	+8.9	N at 2 knots
	15:07	11038	Bow	+12.2	W at 2 knots
	15:10	11297	Stern	+12.3	E at 2 knots
	15:13	11389	Broadside	+16.9	S at 2 knots
	15:15	11260	Bow	+10.4	E at 2 knots
1/21/77	9:07	3389	Broadside	+19.1	N at Idle
	9:10	4037	Stern	+15.0	E at Idle
	9:12	4185	Starboard	+13.2	S at Idle
	9:15	4074	Bow	+4.8	E at Idle
	9:28	3370	Broadside	+16.5	N at Idle
	9:40	5889	Broadside	+16.3	N at Idle
	9:45	5926	Stern	+16.4	E at Idle
	9:50	6593	Broadside	+18.5	S at Idle
	9:52	6574	Bow	+11.9	E at Idle
	10:14	11852	Stern	+12.1	E at Idle

MEASURED RADAR CROSS-SECTION OF 18-FOOT TARGET BOAT

DATE	TIME	RANGE(M)	ASPECT	σt (dBsm)	COMMENTS
11/10/76	9:22	3519	Broadside	-1.45	Dead in water
	9:25	3519	Broadside	-0.7	Dead in water
	10:08	6593	Stern	-7.1	Idle speed
	10:31	6593	Broadside	0.3	Idle speed
	10:36	7408	Broadside	-5.0	Idle speed
	13:36	7408	Broadside	-7.9	Idle speed
	14:06	9093	Broadside	-7.8	Idle speed
	14:29	9593	Broadside	-10.8	Idle speed
	15:34	9519	Broadside	-10.7	Idle speed
	15:41	9371	Broadside	-6.1	Idle speed
	15:50	9427	Broadside	-12.7	Idle speed
	16:23	2185	Stern	0.3	Idle speed
	16:30	2593	Bow	2.5	W at 10 knots
	16:35	2407	Broadside	3.2	S at 10 knots
	16:39	2260	Bow	6.4	W at 10 knots
11/11/76	9:12	9316	Broadside	-5.4	Idle speed
	9:57	9278	Broadside	-8.5	Idle speed
	10:26	9538	Broadside	-9.2	Idle speed
	14:40	8797	Broadside	-2.0	Idle speed
	15:18	9167	Broadside	-2.6	Idle speed
	15:46	4223	Broadside	0.5	Idle speed
	15:55	2315	Broadside	-2.2	Idle speed
	16:03	2315	Broadside	-2.9	Idle speed
11/12/76	10:27	7630	Bow	-1.2	Idle speed
	10:44	3297	Bow	3.2	Idle speed
	12:33	9464	Broadside	-10.5	Idle speed
	13:49	9778	Broadside	-4.9	Idle speed
	14:29	9705	Broadside	-5.8	Idle speed
11/15/76	13:17	10995	Broadside	-13.0	Idle speed
	13:43	9816	Broadside	-10.73	Idle speed
11/16/76	13:55	7760	Broadside	-5.0	Idle speed
	15:15	7130	Broadside	-0.2	Idle speed
	15:17	7038	Broadside	-3.01	Idle speed
	15:19	7038	Broadside	-4.1	Idle speed

MEASURED RADAR CROSS-SECTION OF 50 FOOT TARGET BOAT

DATE	TIME	RANGE(M)	BEARING	σt (dBsm)	COMMENTS
11/9/76	13:31	5000	080°	13.1	Target boat #1
	13:41	4556	083°	3.8	Target boat #1
	14:00	6390	088°	10.9	Target boat #1
	14:21	6111	096°	10.1	Target boat #1
	15:19	4445	125°	7.4	Target boat #2
	15:39	2407	130°	4.7	Target boat #2

MEASURED RADAR CROSS-SECTION PER UNIT AREA OF SEA

DATE	TIME	RANGE(M)	BEARING	σ°dB	COMMENTS
11/9/76	13:31	5000	080°	-57.7	Winds ENE 15-20 mph; sea 4-6 ft.
	13:41	4630	082°	-65.4	" " "
	15:19	4630	125°	-62.3	" " "
	15:39	2063	130°	-50.5	" " "
	15:54	1482	135°	-50.0	" " (downwind)
		1852	135°	-51.1	" " "
		2778	135°	-51.5	Winds ENE 15-20 mph; sea 4-6 ft.
		3704	135°	-59.2	" " "
		4630	135°	-59.2	" " "
		5556	135°	-63.6	" " "
	16:00	1482	055°	-51.7	" " (upwind)
		1852	055°	-47.3	" " "
		3704	055°	-54.4	" " "
		5556	055°	-62.3	" " "
11/10/76	9:22	3519	090°	-65.6	Winds WNW 5-6 mph; sea 2-4 ft.
	9:28	3519	090°	-64.5	" " "
	16:23	2186	088°	-56.2	Winds ENE 10-12 mph; sea 2-4 ft.
	16:26	2186	088°	-58.0	" " "
	16:30	2186	088°	-57.9	" " "
	16:39	2186	088°	-59.5	" " "
11/11/76	15:40	4445	037°	-58.0	Winds ENE 10-12 mph; sea 3-5 ft.
	15:44	4260	037°	-58.9	" " "
	15:56	2315	035°	-49.4	" " "
	16:02	2408	035°	-49.8	" " "
11/12/76	10:44	3352	075°	-63.3	Winds WNW 1-3 mph; sea 1-3 ft.
	16:15	5500	092°	-56.0	" " "
11/15/76	14:34	1852	045°	-62.3	Winds S 17 mph; sea 2-3 ft.
		1852	090°	-53.7	" " "
		1852	135°	-52.7	" " "
		3704	045°	-65.7	" " "
		3704	090°	-58.4	" " "
		3704	135°	-56.7	" " "

MEASURED RADAR CROSS-SECTION PER UNIT AREA OF SEA (continued)

DATE	TIME	RANGE(M)	BEARING	σ°dB	COMMENTS		
11/16/76	11:11	4630	045°	-62.2	Winds NE 15-17 mph; sea 2-3 ft.		
		4630	090	-55.8	"	"	"
		4630	135°	-62.5	"	"	"
	11:45	3704	045	-63.6	"	"	"
		3704	090°	-59.9	"	"	"
		3704	135°	-65.5	"	"	"
	11:47	1852	045°	-65.6	"	"	"
		1852	090°	-71.4	"	"	"
		1852	135°	-72.9	"	"	"
	15:22	3704	045°	-61.8	"	"	"
		3704	090°	-57.3	"	"	"
		3704	135°	-63.4	"	"	"
	15:24	1852	045°	-55.6	"	"	"
		1852	090°	-60.9	"	"	"
		1852	135°	-71.2	"	"	"
11/17/76	10:35	1852	045°	-50.8	"	"	"
		1852	090°	-53.3	"	"	"
		1852	135°	-53.5	"	"	"
	10:40	3704	045°	-58.3	"	"	"
		3704	090°	-58.4	"	"	"
		3704	135°	-57.0	"	"	"