28

Final Engineering Report

Project A-579

VOLUME III

# *Modifications to Improve the Radiation Characteristics of the AN/SPS-10 Antenna*

Contract No. NObsr-85387

Project No. SF 010 204, TASK 5727

Placed by

Bureau of Ships
Department of the Navy
Washington, D. C.

15 September 1963

Engineering Experiment Station

GEORGIA INSTITUTE OF TECHNOLOGY

Atlanta, Georgia

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FINAL ENGINEERING REPORT

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VOLUME III

# MODIFICATIONS TO IMPROVE THE RADIATION CHARACTERISTICS OF THE AN/SPS-10 ANTENNA

By

R. C. Johnson

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DEPARTMENT OF THE NAVY
BUREAU OF SHIPS — ELECTRONICS DIVISION
WASHINGTON, D. C.

## PREFACE

This work was performed by the Engineering Experiment Station of the Georgia Institute of Technology under Contract No. NObsr-85387. The Final Engineering Report consists of three volumes. Volume I (Unclassified) summarizes statistical gain characteristics of four antennas and discusses mutual gain measurements and predictions for interfering search radar antennas. Volume II (Confidential) summarizes the statistical gain characteristics of the AN/SPS-29 antenna. Volume III (Unclassified), the present volume, discusses modifications of the AN/SPS-10 antenna to improve its radiation characteristics.

ABSTRACT

The susceptibility of radar search antennas to radio-frequency interference is determined to a great extent by the minor-lobe structure. Modifications of the AN/SPS-10 antenna have resulted in significant improvements of the radiation characteristics.

The modified SPS-10 antenna has three advantages over the original version. They are (1) a 20 db increase in isolation between two SPS-10 radars, (2) a removal of the side spill-over lobes which sometimes cause the appearance of false targets on the radar display, and (3) a 10 db increase in isolation from other equipments including jammers.

Field change kits were fabricated and installed aboard two destroyers. A brief evaluation at sea indicated that about a 20 db increase in isolation between the two SPS-10 radars was achieved, as expected.

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## I. PURPOSE

The purpose of this contract is to conduct studies on and obtain information on radar and other antennas designed for operation between 200 and 10,000 Mc in order to develop techniques for predicting mutual gain between two interfering antennas. The measurement program includes studies in the Fresnel zone as well as in the far zone, and it involves signals of both parallel and orthogonal polarization at both in-band and out-of-band frequencies. Additional work was undertaken to determine the feasibility of reducing the susceptibility of the AN/SPS-10 antenna to radio-frequency interference.

## II. DETAIL FACTUAL DATA

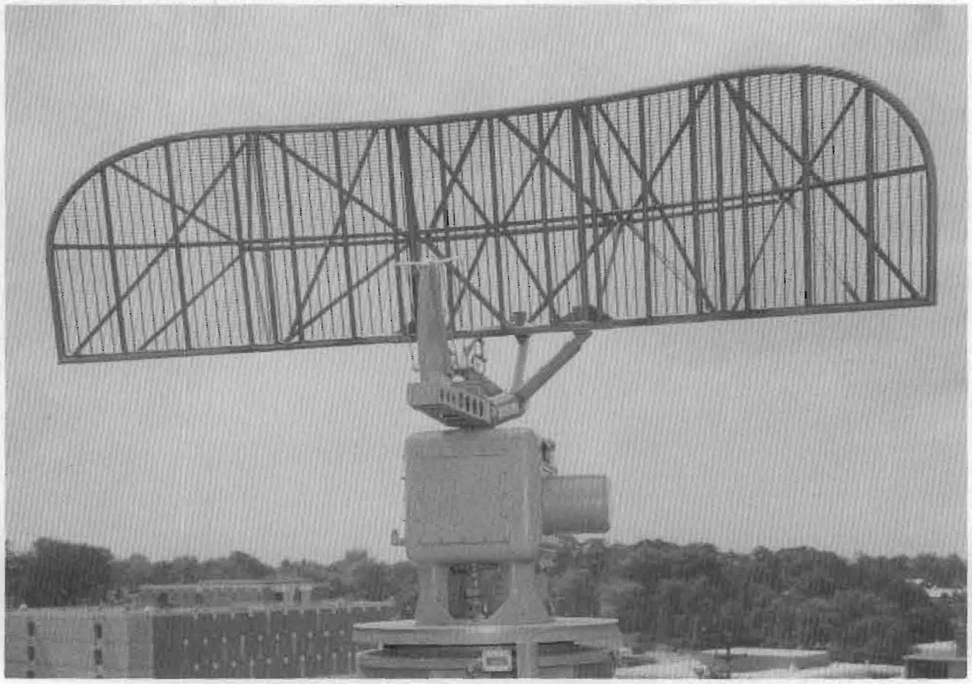
### A. Introduction

Radar search antennas are characterized by a narrow main lobe which continuously scans 360 degrees in azimuth. The susceptibility of these antennas to radio-frequency interference (RFI) is determined to a great extent by the minor-lobe structure since the main lobe is directed toward an interfering source only a small part of the time. Therefore, a reduction of gain in the minor-lobe structure will reduce the effects of RFI.

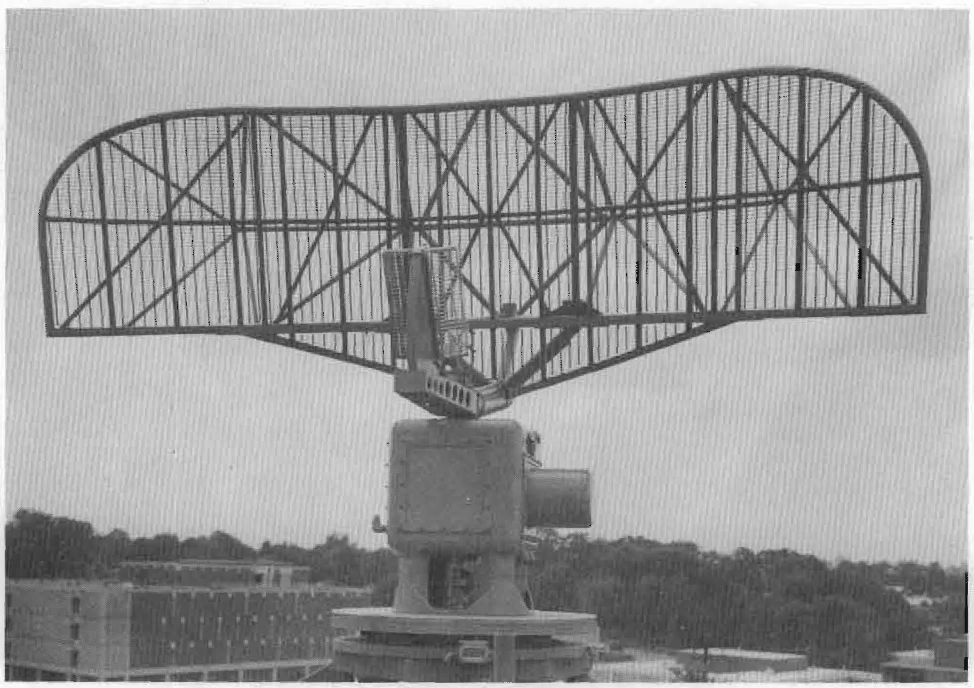
Previous studies (see Volume I of this report) have shown that the statistical gain characteristics of individual antennas, and the mutual gain characteristics of two interfering antennas, can be described with Gaussian curves. A good description of the gain characteristics of an antenna can be specified by two numbers--the median gain and the standard deviation. This description is independent of in-band frequency variations and range changes (including Fresnel zone), and it is not sensitive to site modifications. With the additional knowledge of transmitted power, operating wavelength, and distance between antennas, the power distribution of received pulses can easily be determined for two interfering radars.

### B. Original AN/SPS-10 antenna

The AN/SPS-10 antenna has a parabolic-cylinder reflector with a hoghorn feed as shown in Figure 1(a); it is usually installed aboard ships for the function of surface search. The nominal characteristics are the following:



(a) ORIGINAL ANTENNA



(b) MODIFIED ANTENNA

Figure 1. Photographs of the original and modified AN/SPS-10 antennas.

| | |
|---|---|
| frequency | C-band |
| gain | 30 db |
| half-power beamwidth | |
| vertical | 17° |
| horizontal | 1.8° |
| beam type | cosecant-squared |
| polarization | horizontal. |

Typical vertical and horizontal patterns are illustrated in Figures 2(a) and 3(a), and the statistical gain distribution is shown in Figure 4. Although the peak gain of the antenna is about 30 db, the median gain (the gain for which the ordinate of the cumulative gain distribution curve is equal to 0.5) is only -13 db.

The horizontal pattern, illustrated in Figure 3(a), shows an aperture diffraction pattern out to about 60° on each side of the main lobe. The broad lobes at 90° on each side of the main lobe are caused by spill-over at the sides of the reflector, and most of the back radiation is due to spill-over under the reflector. Note that the spill-over regions are more significant in determining the median gain than the aperture diffraction region around the main lobe. Also, the high spill-over lobes at 90° sometimes cause the appearance of false targets on the radar scope.

C. Modified AN/SPS-10 antenna

Techniques for reducing spill-over in the SPS-10 antenna were studied. The most practical antenna modifications consist of an extension under the existing reflector and a pair of "blinders" for the hoghorn feed. The reflector extension reduces spill-over under the reflector, and the blinders reduce spill-over

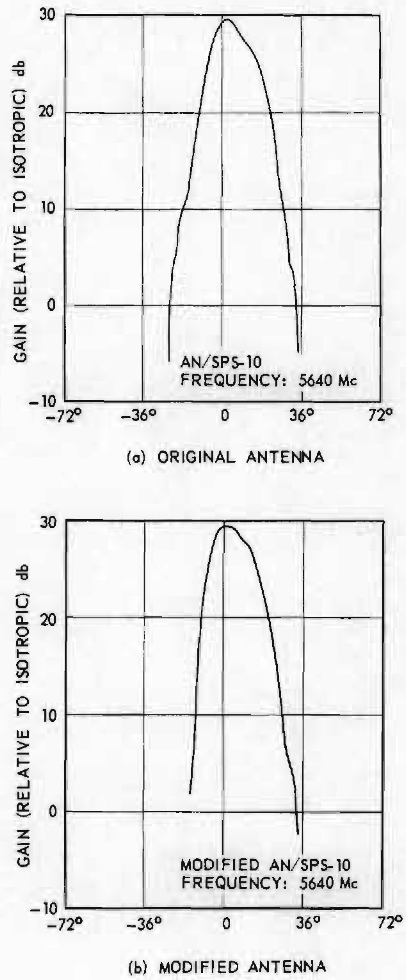



Figure 2. Vertical cuts through the main lobes of the original and modified AN/SPS-10 antennas.

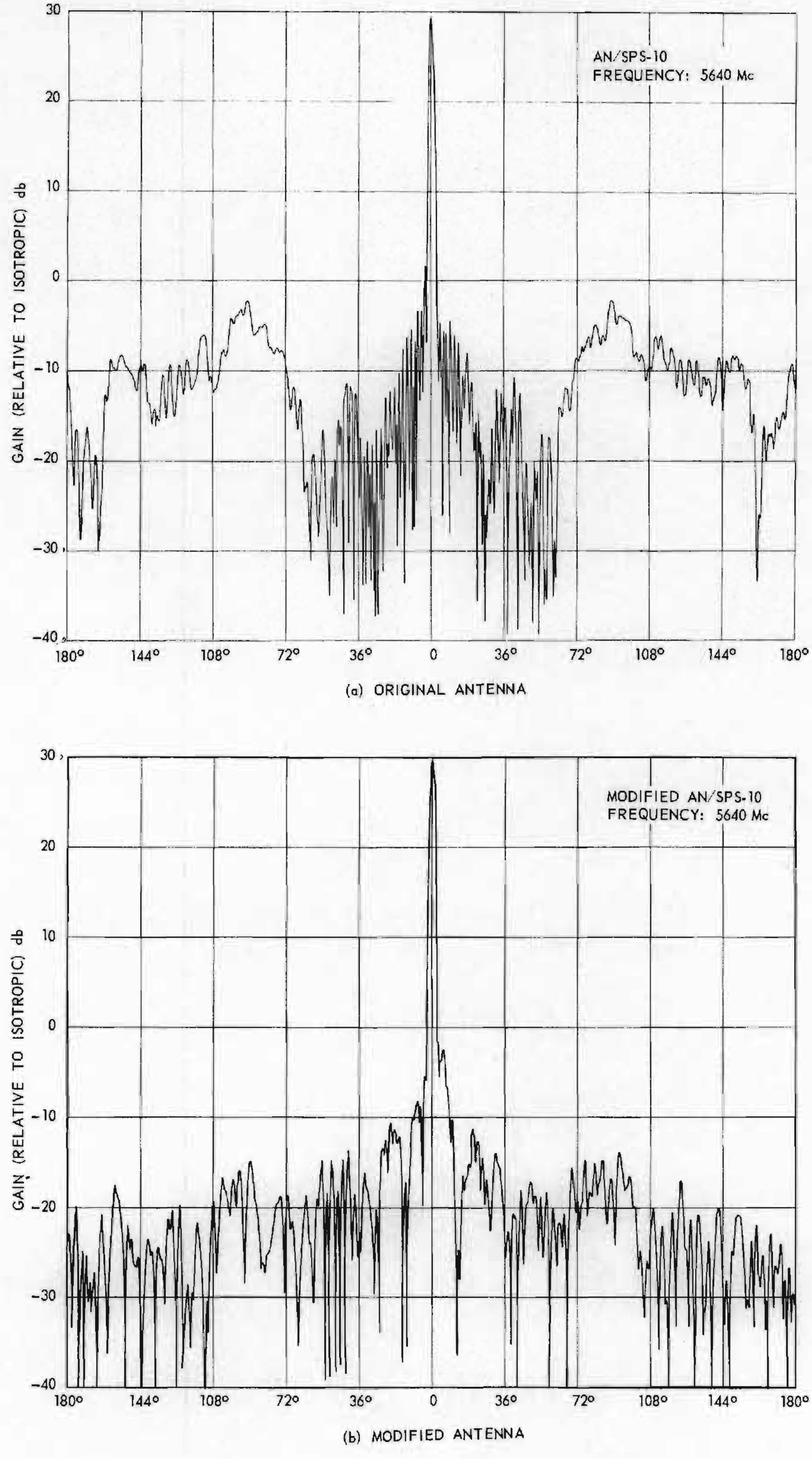



Figure 3. Horizontal patterns of the original and modified AN/SPS-10 antennas.

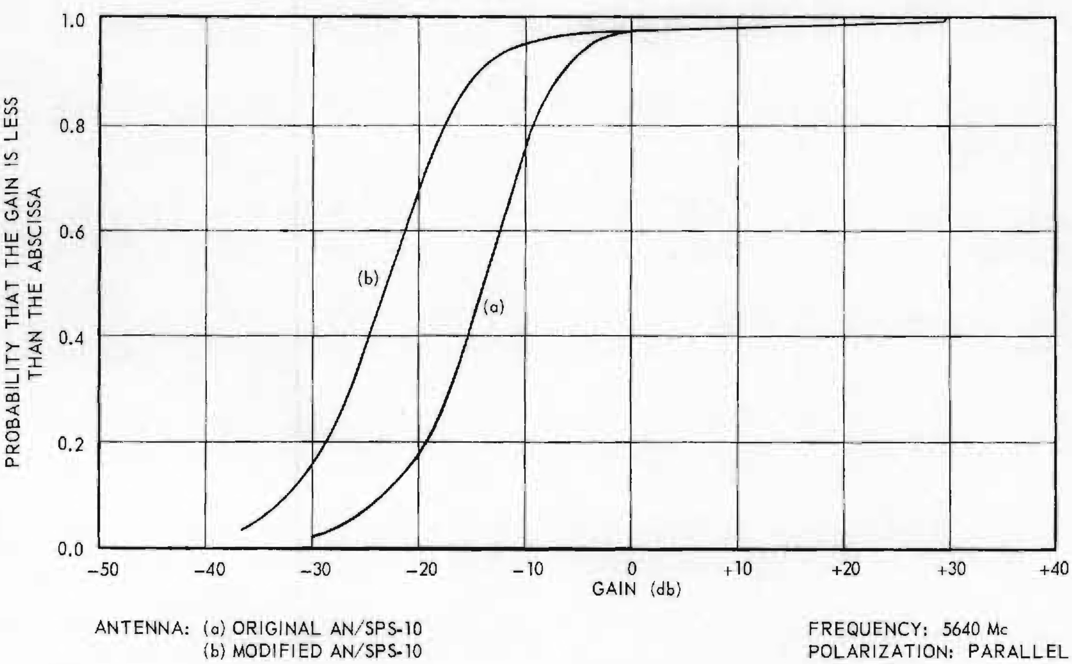



Figure 4. Cumulative gain distributions for the original and modified AN/SPS-10 antennas.

at the sides of the reflector. A modified SPS-10 antenna is shown in Figure 1(b). The reflector extension adds about 10 per cent in area to the original reflector, but it does not change the silhouette of the antenna.

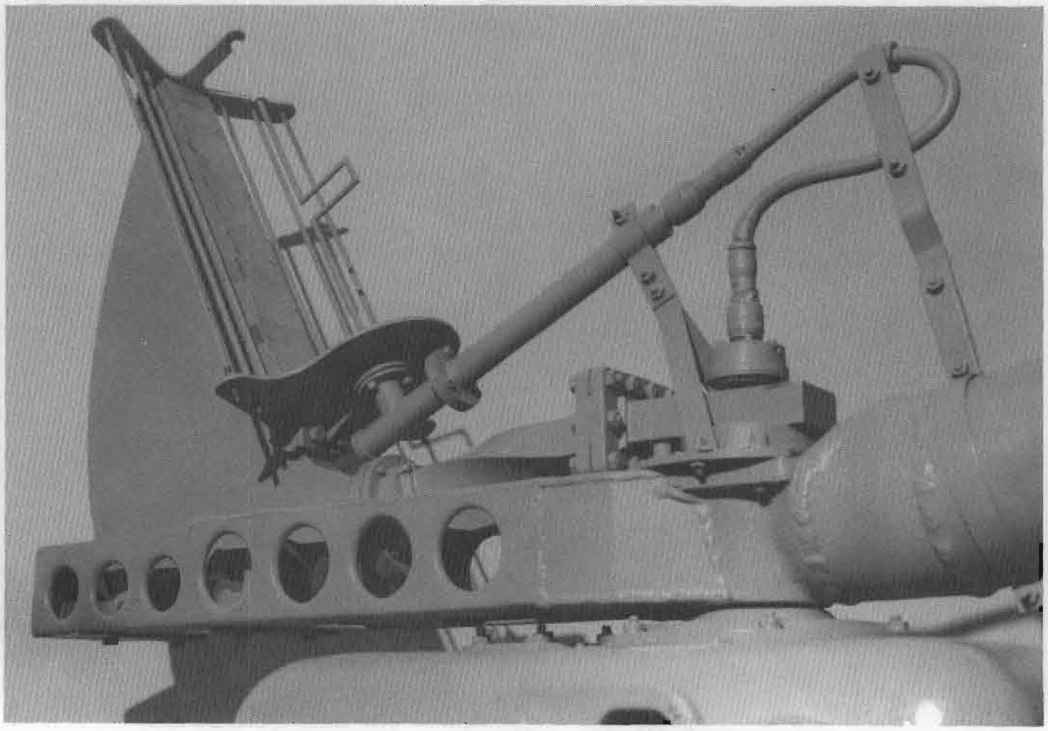
The feed of the original SPS-10 antenna has three vertical rods on each side of the hoghorn which form a corner reflector for the IFF radiating element as shown in Figure 5(a). In the modified SPS-10 antenna, the six vertical rods have been replaced by a pair of blinders as shown in Figure 5(b). The blinders modify the hoghorn radiation pattern to reduce the intensity at the sides of the reflector and also serve as a corner reflector for the IFF radiating element. Each blinder has a horizontal-slat structure with an array of choke slots to impede surface currents excited by the hoghorn feed. The horizontal slats are held in position by vertical spacers which serve as corner reflector elements for the IFF feed.

Typical vertical and horizontal patterns for the modified SPS-10 antenna are illustrated in Figures 2(b) and 3(b), and the statistical gain distribution is shown in Figure 4. Note by comparing the patterns in Figure 3 that radiation in all spill-over regions has been greatly reduced. Measurements showed that the modifications reduced the median gain from -13 db to -23 db without degrading the gain and shape of the main lobe.

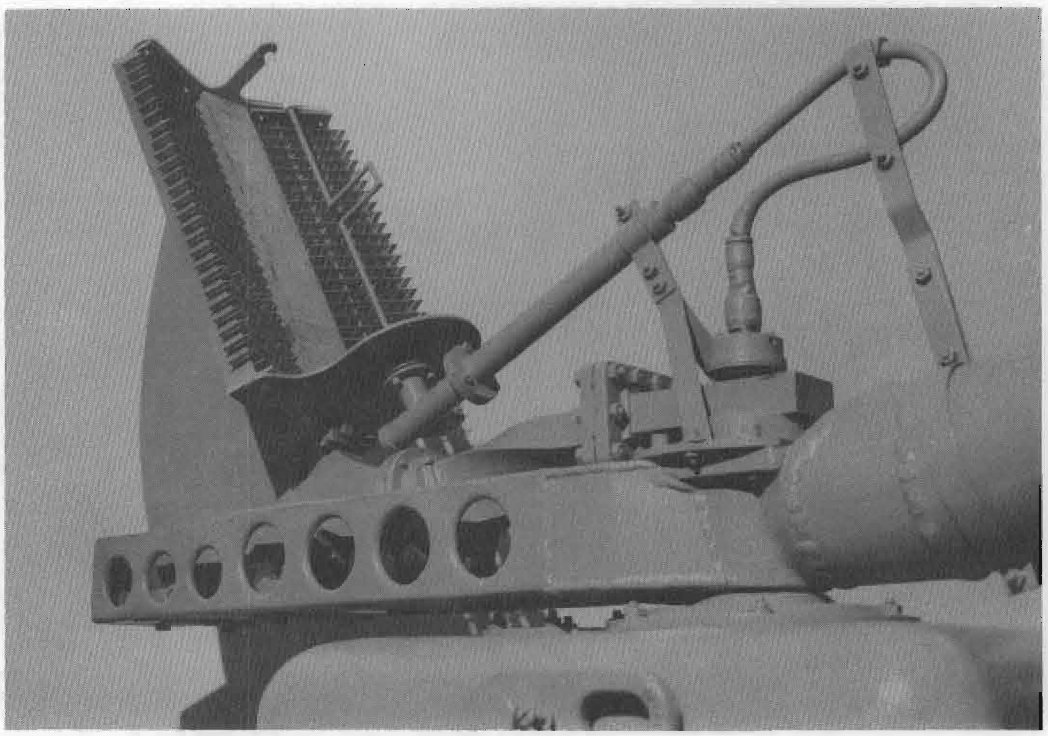
D. Evaluation of modified antennas

A brief evaluation (28-30 July 1963) of two modified SPS-10 antennas was conducted aboard the USS Eaton (DD 510) and the USS Bache (DD 470) operating out of Norfolk, Virginia.

On the evening of 28 July, both radars were observed in operation while the ships were moored at the Destroyer-Submarine Piers. Several other SPS-10



(a) ORIGINAL ANTENNA



(b) MODIFIED ANTENNA

Figure 5. Reflector feeds for the original and modified AN/SPS-10 antennas.

radars were also operating in the area. With sweep lengths of 5 to 10 miles, interference was not excessive; however, with sweep lengths of about 100 miles, much interference was observed on the PPI displays.

The types of interference which were of interest during these tests are illustrated in the photographs of Figures 6 and 7. Figure 6 illustrates minor-lobe interference which is characterized by a "spiral" appearance on the display. When this photograph was made, only partial (about 50 per cent) minor-lobe interference was occurring, and the PRF of the interfering radar was such that the spirals almost have a spoke-like appearance. Since the range sweep was only about 25 miles, the complete spirals are not displayed. Figure 7 illustrates main-lobe interference which is characterized by a "swirl" such as that appearing at an azimuth of about 245°. When this photograph was taken, the interference signals were not strong enough to be received on the minor lobes; however, they were received by the main-lobe. Other "bits" of interference can be seen in Figure 7, particularly at an azimuth of about 285°.

Soon after leaving the Cape Henry area on 29 July, an attempt was made to observe mutual interference between the Eaton and the Bache; however, many other ships in the area equipped with SPS-10 radars made it difficult to determine the amount of mutual interference. Therefore, the evaluation was postponed until late afternoon when the ships were further out to sea.

During the afternoon observations, mutual interference (with original antennas) was observed between the Eaton and the Bache. The two ships started with a separation of about 1000 yards and opened to a separation of 15,000 yards. Aboard the Eaton, continual (100 per cent) minor-lobe interference was observed until the separation was almost 4000 yards. The interference then decreased

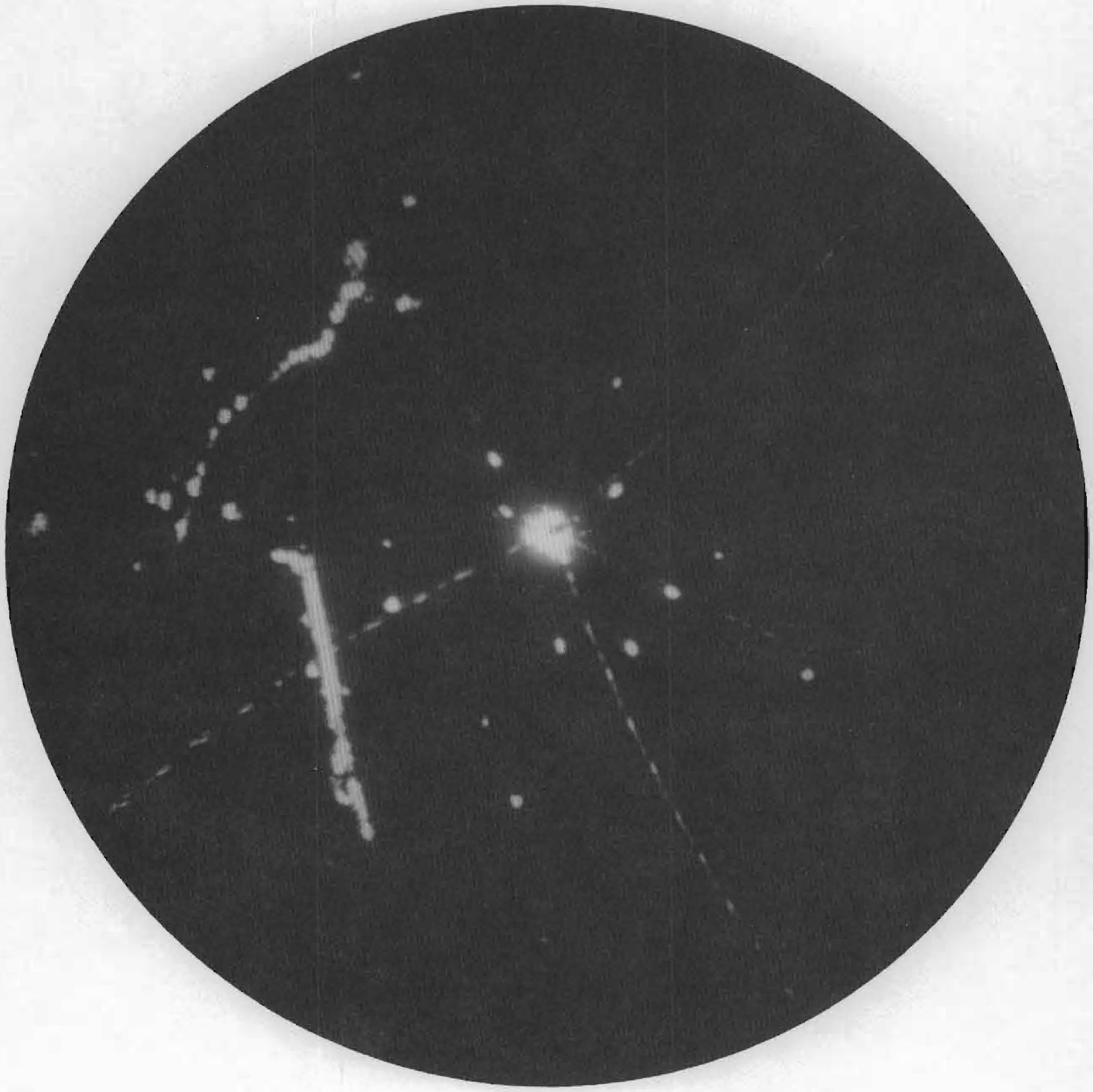


Figure 6. Radar display illustrating partial (about 50 per cent) minor-lobe interference. The range sweep is about 25 miles.

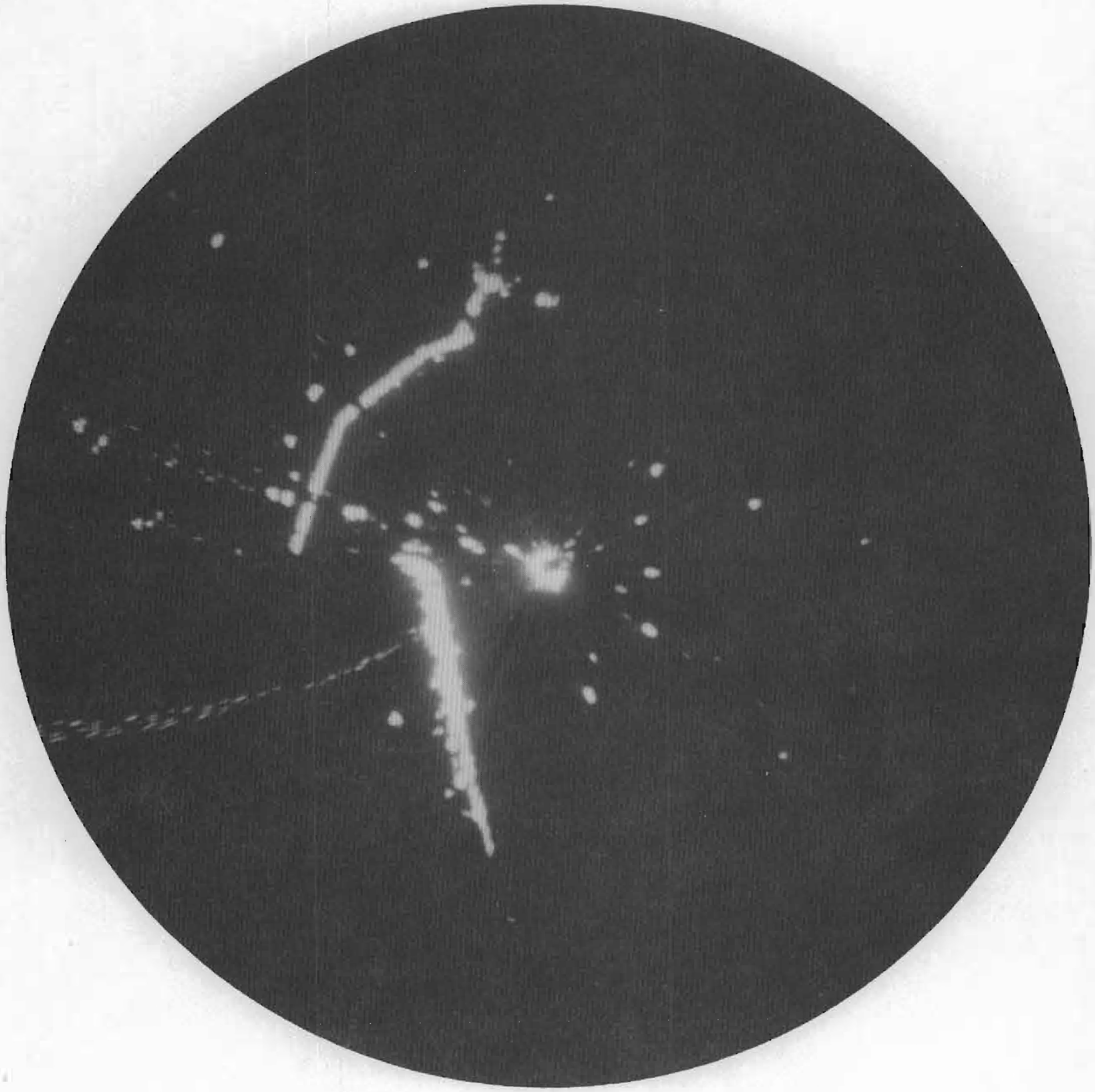


Figure 7. Radar display illustrating main-lobe interference. The range sweep is about 25 miles.

rapidly until the separation was about 6000 to 7000 yards; after that, only main-lobe interference was observed. The main-lobe interference was still observed with a separation of 15,000 yards. Similar observations were made aboard the Bache.

The modification kits were then installed on both ships. On the Bache, one technician made the modifications in 2 hours without problems. On the Eaton, difficulty was experienced while installing the reflector extension. Apparently, the bottom tubular member of the reflector frame does not have the same shape as those on the reflectors used for modeling the field change kits. The extension was temporarily attached to the reflector with two clamps and some safety wire. It is estimated that the two technicians could have installed the modifications in less than one hour if the bottom member of the reflector had conformed to the extension curvature. After returning to port, the technicians aboard the Eaton were able to pull the reflector extension to the reflector and accomplish a proper installation.

After the modifications were installed, an attempt was made to observe mutual interference between the Eaton and the Bache. Anomalous propagation was experienced giving land return at over 100 miles, and several main-lobe interference swirls from other ships were observed on the PPI displays. No minor-lobe interference was observed with the ships separated 1000 yards, and changes in the interference could not be detected on the Eaton when the Bache turned her radar off or on; therefore, evaluation of the modified antennas was postponed until the next day.

In the afternoon of 30 July, the evaluation of the modified antennas was continued. At a separation of 1000 yards, no minor-lobe interference was observed; however, main-lobe interference was present as expected. The ships closed to a separation of 500 yards, and about 50 per cent minor-lobe interference was observed.

To summarize, these limited data indicate that the minor-lobe interference was reduced by about 20 db or a factor of 10 in range. For example, a situation similar to that illustrated in Figure 6 (about 50 per cent minor-lobe interference) was observed at a range of about 5000 yards with the original antennas but was not observed with the modified antennas until the range was closed to about 500 yards. These results were predicted by the statistical analysis of the gain characteristics of the original and the modified SPS-10 antennas.

## III. CONCLUSIONS AND RECOMMENDATIONS

Modifications of the SPS-10 antenna, consisting of an extension under the existing reflector and a pair of special blinders for the hoghorn feed, can result in significant improvements of the radiation characteristics. Figure 3 shows the improvement in the antenna pattern, and Figure 4 shows the improvement in the statistical gain characteristics.

A modified SPS-10 antenna has three advantages over the original version. They are (1) a 20 db increase in isolation between two SPS-10 radars, (2) a removal of the side spill-over lobes which sometimes cause the appearance of false targets on the radar display, and (3) a 10 db increase in isolation from other equipments including enemy jammers. In the case of minor-lobe jamming, the enemy must increase their transmitted power by a factor of 10 in order to cause the same interference in a modified SPS-10 as they currently can cause in the original version. The improvements are quite impressive considering the small modifications required.

Field change kits were fabricated and installed aboard two destroyers. A brief evaluation at sea indicated that about a 20 db increase in isolation between the two SPS-10 radars was achieved, as expected.

The improved radiation characteristics of the SPS-10 antenna can be obtained for ships in the Fleet through the use of field change kits similar to those described in this report or by using redesigned reflectors along with the special blinders for the hoghorn feed. Either approach should be considered thoroughly from a mechanical viewpoint to determine the effects on wind loading.

The reflector extensions in the field change kits were designed to clamp to the lower tubular member of the parabolic-cylinder reflector. This method of attachment was used in order to enable the field change kits to be installed temporarily to an antenna, if desired. If production of a large number of field change kits is undertaken for the purpose of modifying additional antennas in the Fleet, other methods of attaching the extension to the reflector should be considered. In particular, the attachment method should allow adjustments to conform to the shape of the lower tubular member of any reflector, in order to avoid the difficulties encountered on the USS Eaton.

## IV. TECHNICAL PERSONNEL

The following is a list of some of the technical personnel who contributed to the success of this work.

| | |
|---|---|
| Allen, Grant E., Jr. | Assistant Research Engineer |
| Arnold, Maurice W. | Senior Research Technician |
| Bone, Elizabeth N. | Senior Electronics Technician |
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| Cerny, John C. | Research Engineer |
| Flynt, Edward R. | Special Research Engineer |
| Foster, Warren S. | Research Assistant |
| Goodman, Robert M., Jr. | Research Engineer |
| Hill, H. Charles, Jr. | Research Assistant |
| Ivey, C. Allen | Assistant Research Engineer |
| Johnson, Richard C. | Research Physicist |
| Long, Maurice W. | Special Research Engineer |
| Mosley, John T. | Student Assistant |
| Poinsett, Richard J. | Research Assistant |
| Rivers, Wayne K., Jr. | Research Physicist |
| Shackelford, Robert G. | Assistant Research Engineer |

## V. ACKNOWLEDGEMENTS

This work was possible only through the combined efforts of many persons at the Bureau of Ships and the Georgia Tech Engineering Experiment Station. Special thanks go to the Commander, Destroyer Division 282, and the Commanding Officers of the USS Eaton (DD 510) and the USS Bache (DD 470) for allowing us to conduct the brief evaluation of the modified SPS-10 antennas. We received splendid cooperation from the officers and men of both ships.

Respectfully submitted,

R. C. Johnson
Project Director
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Approved:

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