PERFORMANCE OF S-BAND AND L-BAND SURVEILLANCE RADARS DURING RAIN AND CLOUD CONDITIONS

By

A W Randall, C C Trout,

J. E Herrmann and Paul H Leake

Technical Development Report No 92

CIVIL AERONAUTICS ADMINISTRATION

TECHNICAL DEVELOPMENT

INDIANAPOLIS, INDIANA

April 1949

TABLE OF CONTENTS

TABLE INDEX

Manuscript received, October 1948

PERFORMANCE OF S-BAND AND L-BAND SURVEILLANCE RADARS DURING RAIN AND CLOUD CONDITIONS

SUMMARY

This report describes the results of comparison tests on the performance of S-band (3000 Mc) and L-band (1300 Mc) radar equipments used to detect the presence of aircraft flying through rain or various cloud formations. The tests were conducted to determine quantitatively the ratio of the received signals from aircraft to those from clouds or rain for each of the two frequencies. Tabulation of these data show that a practical improvement in performance of 11.7 db may be expected by using 1300 Mc for airport surveillance functions.

INTRODUCTION

It has long been known that detection of aircraft by means of search type radars is frequently very difficult if not impossible when the target aircraft is flying through rain, snow, or moisture-laden cloud formations. Under certain conditions, when the aircraft is small and is flying near the maximum range of the radar, the signal is normally very weak and may become undetectable if the path of transmission and reception is intercepted by rain. A similar condition can exist to make detection of the aircraft impossible when the aircraft is flying through rain at approximately the maximum range of detection. In this latter case, the signal from the cloud may greatly exceed the amplitude of the signal from the aircraft.

Theoretical consideration of these factors indicates that both the space attenuation and reflection of radio waves from rain, snow, and clouds decrease with frequency. The improvement in performance to be expected by using L-band (1300 Mc) instead of S-band (3000 Mc) equipment may be calculated with only a fair degree of accuracy because of a number of variables and conditions whose effects can not be determined. An improvement of approximately 12 db was calculated from information contained in a report, dated April 17, 1947, by W. D. White of Airborne Instruments Laboratory. Direct measurement of the improvement in performance would provide a more significant figure of merit if the measurements were made on a practical installation. This report describes the work done in making actual performance comparisons.

EQUIPMENT CONSIDERATIONS

In order to compare two radar systems it is essential that they have identical operating characteristics, at least in so far as those characteristics may have a bearing on the end results.

Because of the difficulty in procuring two radars having the same characteristics and differing only in the transmitted radio frequency, it was necessary to modify available equipment. The AN/CPS-5 was selected for the 1300 Mc radar and the AN/GPN-2 was chosen for the 3000 Mc equipment. Modifications were made to each set to obtain the following characteristics

	AN/CPS-5	AN/GPN-2
Frequency	1290 Mc	2990 Mc
PRF	2000 pps	2000 pps
Pulse width	0.5 μ sec	0.5 μ sec

A block diagram of the equipment used is shown in Fig. 1. The AN/GPN-2 radar required relatively few changes. Terminal connections for a remote gain control are provided in the receiver. These connections were terminated at a remote gain control mounted on the comparison indicator. Other changes made to the AN/GPN-2 radar involved the replacement of the antenna rotational drive motor with a dc motor to provide slow speed reversible operation. Controls for the antenna servo-system were located at the AN/GPN-2 monitor scope position.

The modifications to the AN/CPS-5 radar were quite extensive. Replacement of the rotary spark gap modulator was necessary to obtain the correct PRF and pulse width. A hard tube modulator from an SCR-584 radar was used after being modified to provide the 0.5 μ sec pulse. This modulator was housed on the AN/CPS-5 antenna tower, and the modulator power supply was installed in the operations hut. A spare 30 Mc receiver from the AN/GPN-2 radar was used in place of the AN/CPS-5 receiver to provide additional band width, and to duplicate the receiving systems. The use of two identical receivers (one for each radar) made it possible for the operator of each radar to track the target aircraft accurately servoed to the target being used. Signaling systems and interphone connections were provided for each operator to facilitate coordination of activities. Fig. 2 shows the installation of the AN/GPN-2 and AN/CPS-5 radar equipments. Fig. 3 shows the radar indicator and control positions in the operations hut.

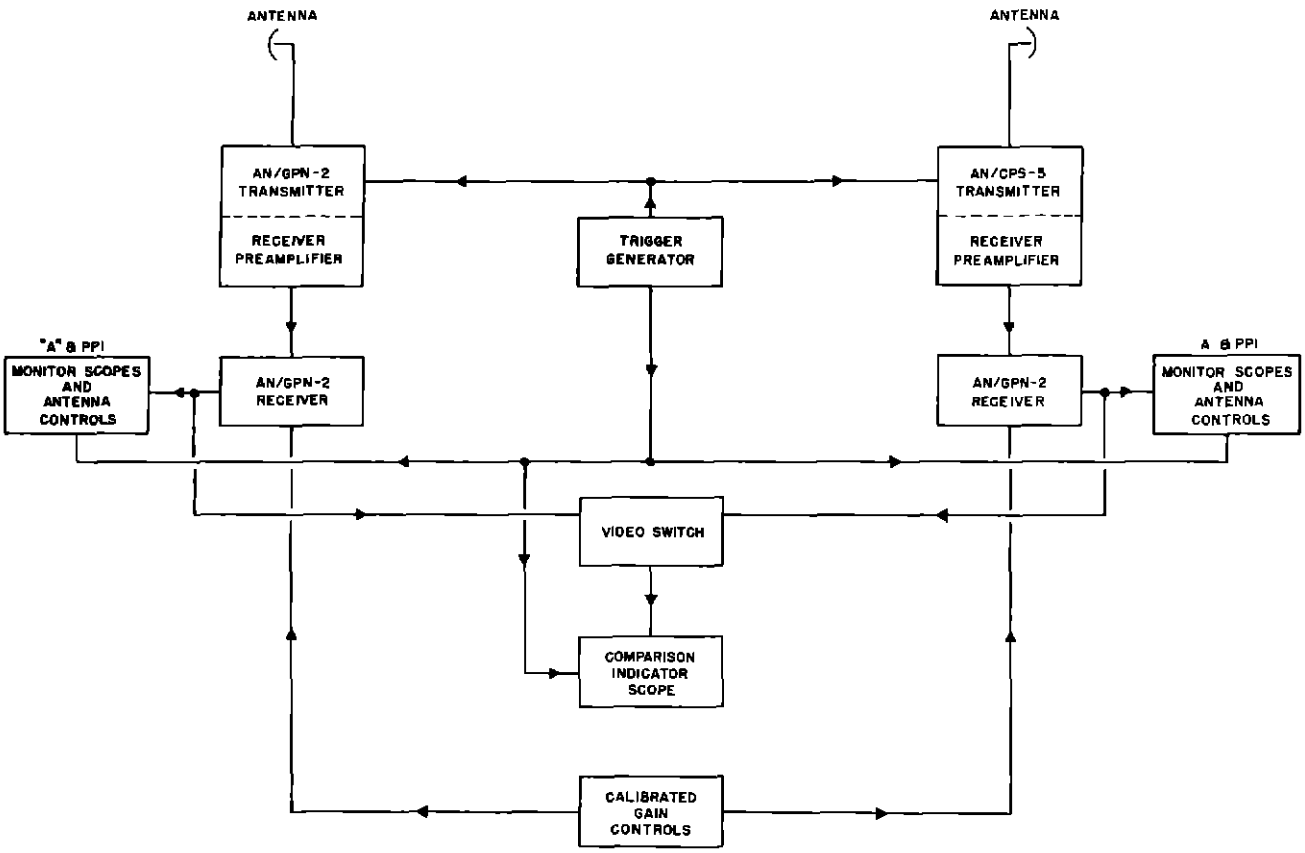


Fig. 1 Functional Block Diagram of the Radar Equipments

continuously. The receiver used with the AN/CPS-5 radar was connected to a remote calibrated gain control as was done with the AN/GPN-2 receiver.

The trigger generator used to trigger all indicators as well as the modulators was a Measurements Corporation model 79-B pulse generator

The video output from each receiver was fed to the comparison indicator through a coaxial relay type switch. The operator recording the comparison data could thus select either L-band or S-band video signals rapidly after having been advised by the operator of each radar that the antennas were

An AN/CPS-4 radar was operated for the purpose of obtaining information on the altitude of the target aircraft and clouds.

MEASUREMENT PROCEDURES

In order to collect the data tabulated herein, the receiver gain controls of both the S-band and L-band radars were calibrated by the introduction of test signals into the receiver system. No attempt was made to calibrate absolute signal levels but, rather, comparative amplitudes. The controls were calibrated in steps of 3 db, which was the amount of gain control adjustment required to bring the video

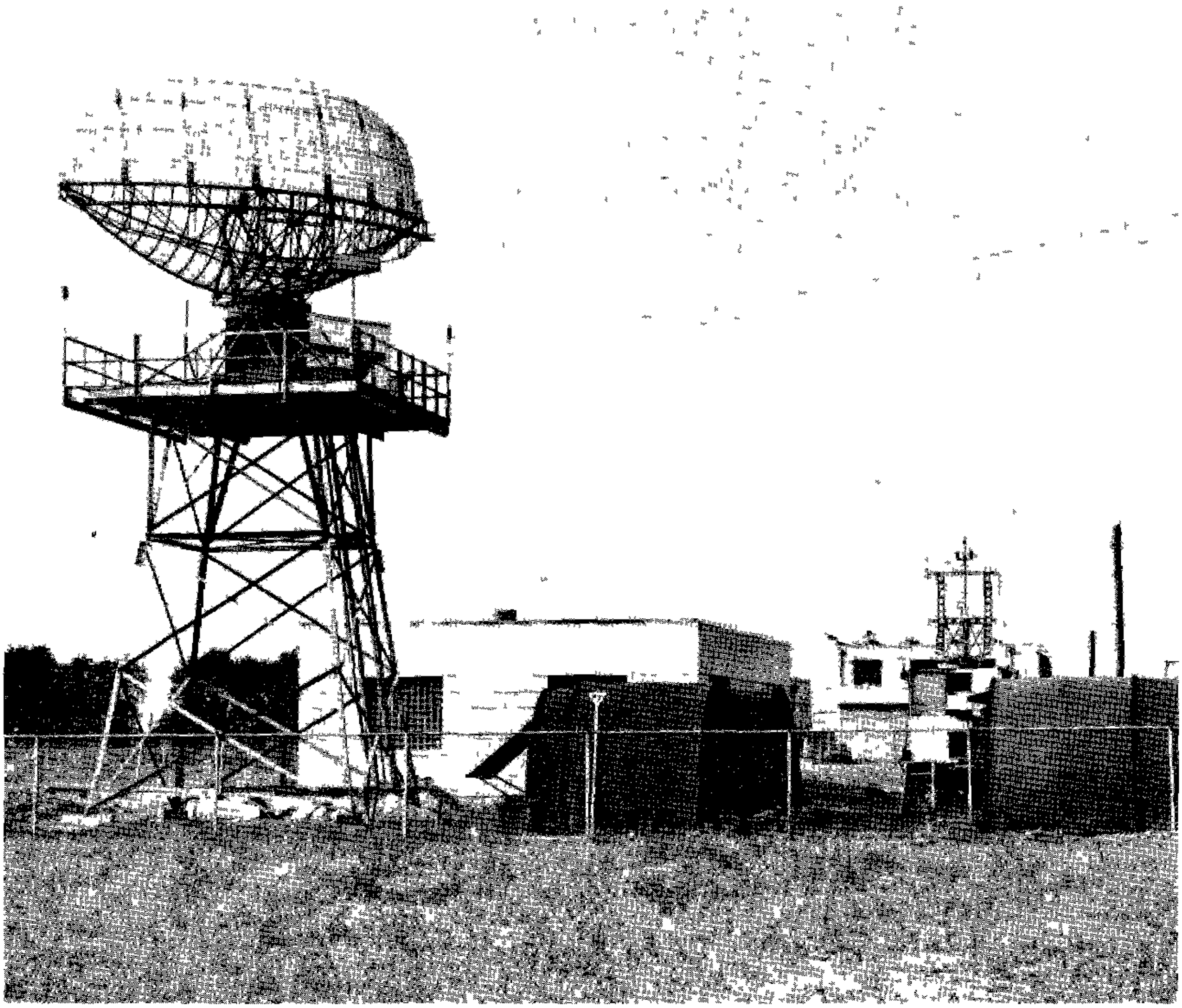


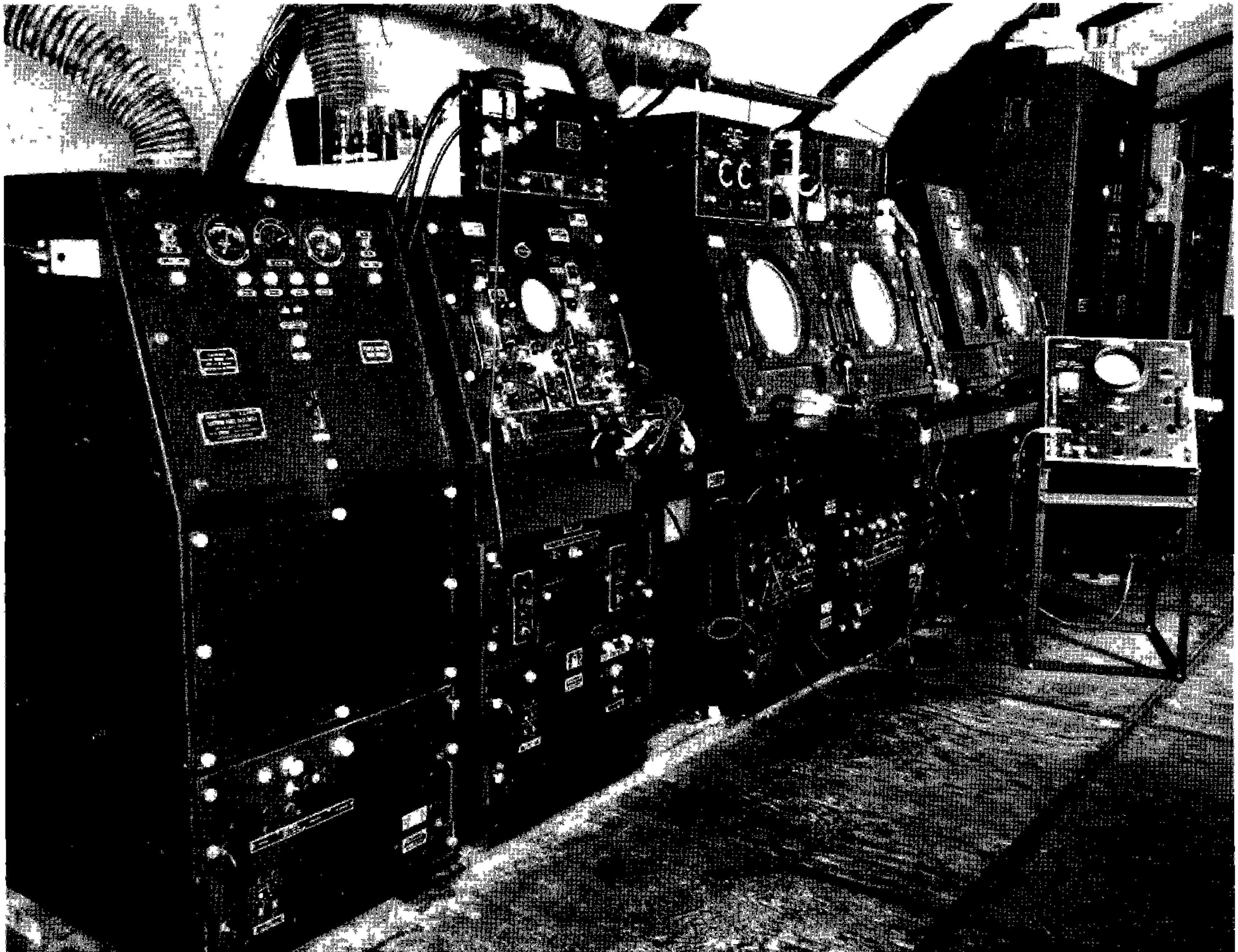
Fig 2 AN/CPS-5 and AN/GPN-2 Radar Installations

signal back to a reference level after an input signal change of 3 db The receivers were operated well below the saturation level at all times

The method of using the calibrated gain controls was to adjust the gain control for a given video level on the comparison A-scope for the cloud or rain return, then to readjust the controls for the same video level for the target aircraft signal, and record the difference between these two readings. This difference was taken as an indication of target aircraft signal to cloud signal ratio expressed in decibels The comparison indicator and calibrated gain controls are shown in Fig 4.

The comparison of the performance of the two radars was made by directing the antennas of both equipments at the same target aircraft simultaneously. The tilt control of the AN/GPN-2 radar was manipulated for maximum signal from the aircraft. The skill of the operator of each radar set was relied upon in pointing the antenna of his particular radar exactly "on target."

The observations from both radars were made on one A-scope comparison indicator by rapidly switching from one radar to the other. Care was taken to avoid taking readings with the target in or near antenna pattern nulls, which were determined prior to the tests and are plotted in Fig 5. At the beginning of the tests, it was visualized that dif-



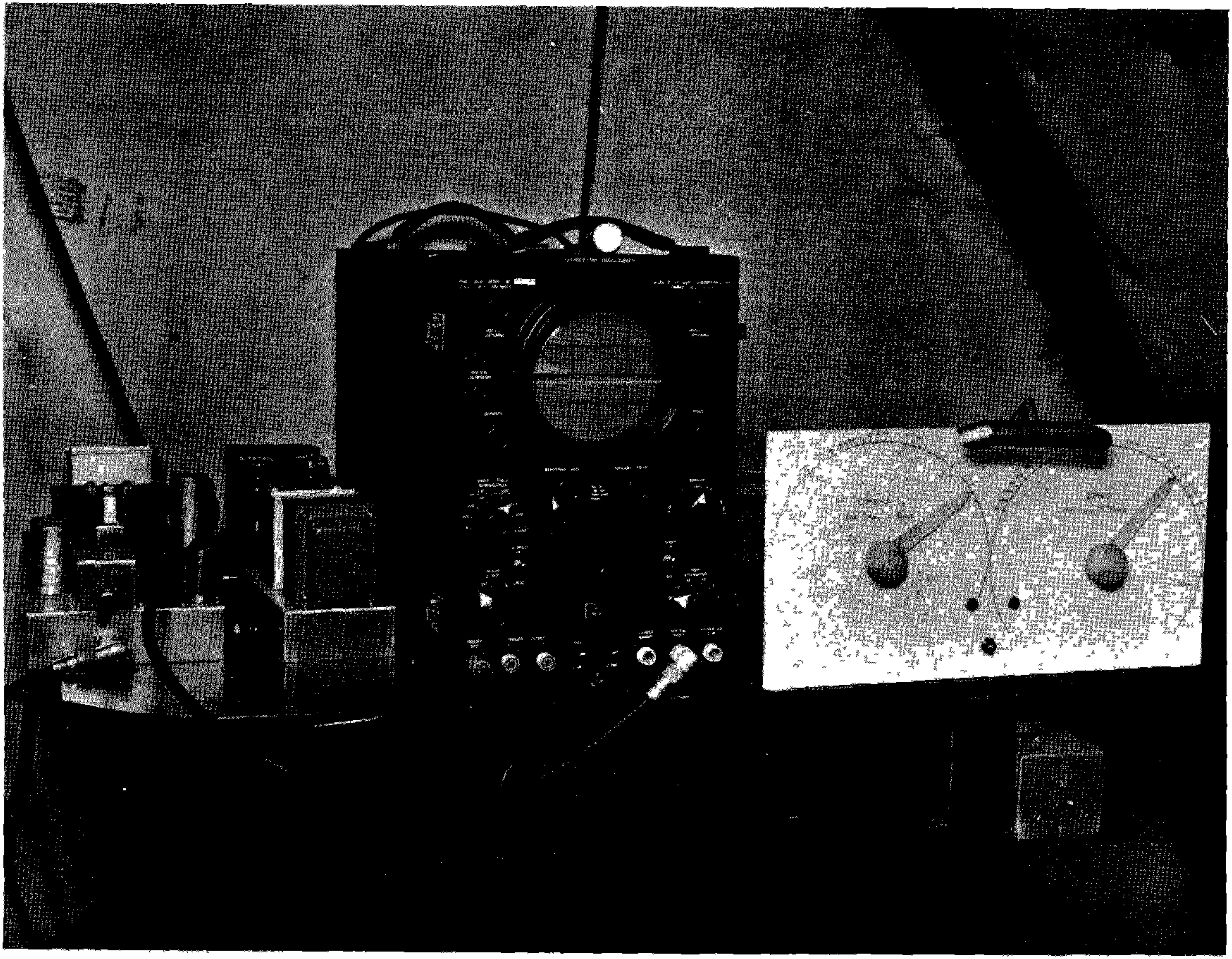


Fig. 4 Comparison Indicator and Calibrated Gain Controls

ferences in the two radars due to different antenna patterns, in the vertical plane, would present some problem Designing and building antennas for both L-band and S-band having identical patterns would have delayed

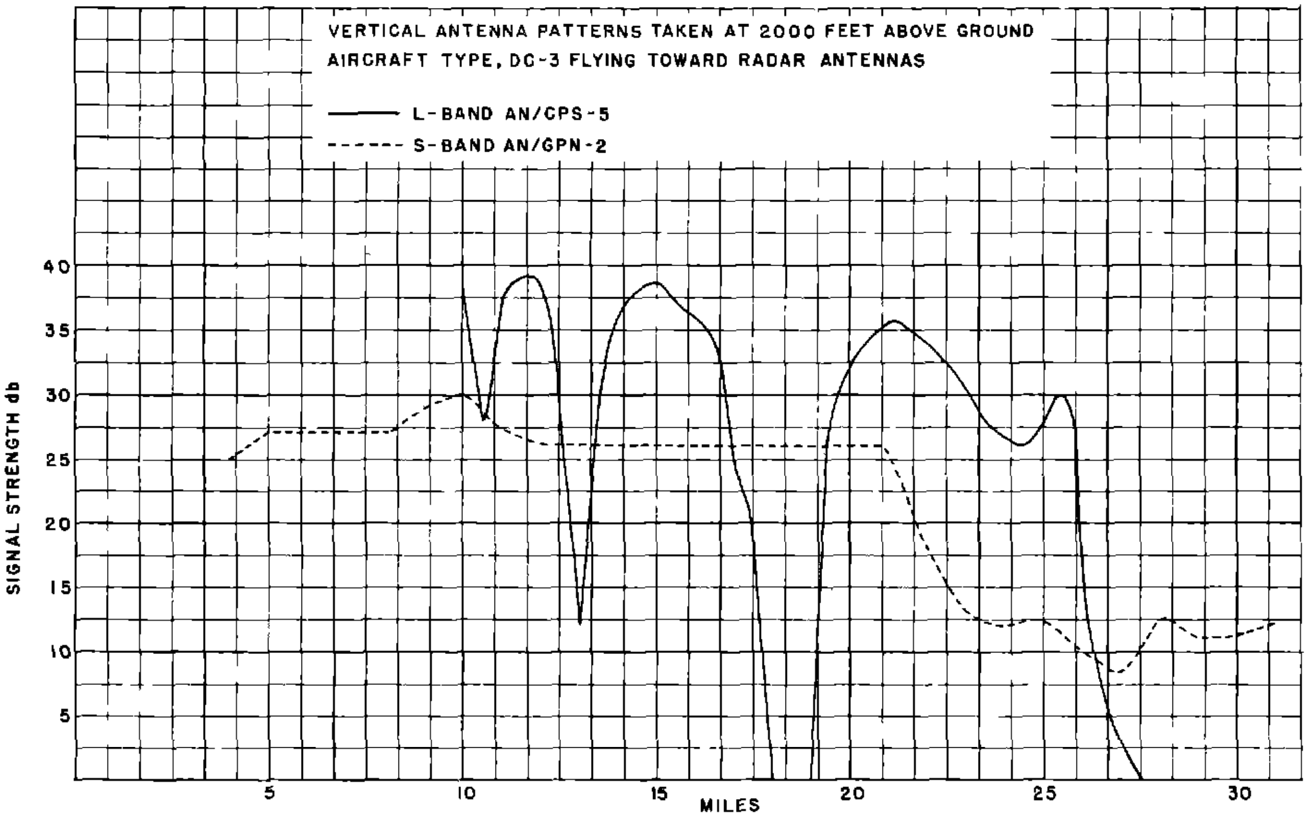


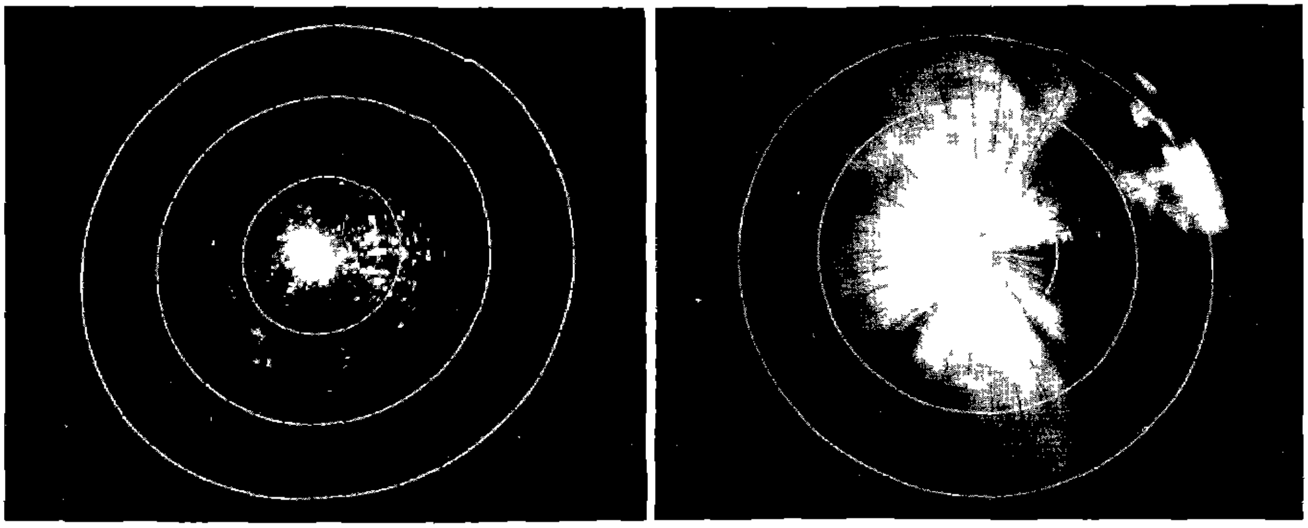
Fig. 5 Vertical Field Patterns for AN/GPN-2 and AN/CPS-5 Radar Antennas

the project. As an alternative, the target aircraft was flown into and around the cloud formation on each flight as carefully as possible to keep the aircraft well within the vertical patterns of the antennas.

RECORDED DATA

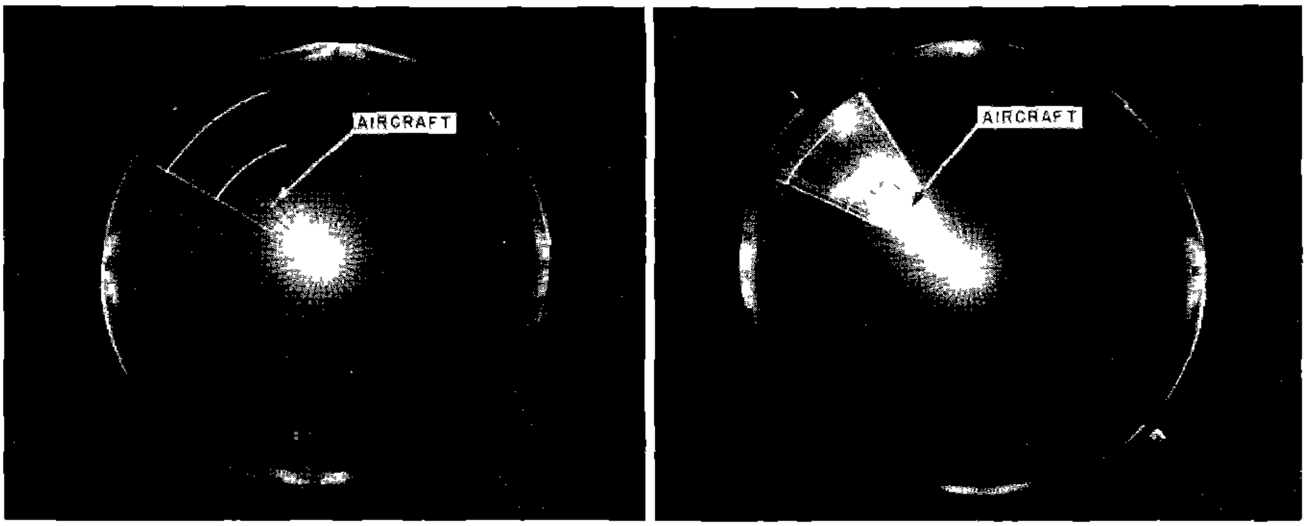
The recorded data in Table I show the target aircraft signal to cloud signal ratios for both the S-band and L-band systems measured during 15 separate flights All of the data were taken with a DC-3 type aircraft flown into rainstorms of moderate density. The average of the improvement figure is 11.7 db. It will be noted from the preceeding data that 11 of the 15 readings show an improvement of more than 10 db The four readings showing less than 10 db improvement are believed to be due to errors on the part of the operators of each radar, in training the antennas directly on target.

Photographs of the S-band and L-band radar plan position indicators taken simultaneously are reproduced in Fig. 6. These photographs were taken during a thunderstorm with moderately heavy rain Fig. 7 shows the freedom from rain clutter on L-band frequencies for an aircraft approximately 12 miles from the airport, headed away from the radar and in a heavy rain Severe rain clutter present on the S-band PPI for the same aircraft at the same instant is shown at the right in this Figure These pictures do not represent the most favorable or the most unfavorable conditions observed but are typical illustrations of the practical improvement to be expected by using L-band frequencies



L-band PPI — 30 Mile Range — S-band PPI

Fig. 6 PPI Presentation with Moderate Rain



L-band PPI — 30 Mile Range — S-band PPI

Fig. 7 Sector Sweep on Aircraft at 12 Miles Range

CONCLUSIONS

The data obtained in these tests confirm previous experience gained by a long period of operation, namely, that almost all cloud formations of sufficient density to be visible on the 1300 Mc radar scope will completely mask out all targets when viewed on the 3000 Mc radar scope. Extremely heavy rains have caused masking of the first 15 to 20 miles of range on the L-band PPI. The masking caused by rain was seldom of sufficient density to mask out aircraft or ground clutter targets, however. This condition of complete masking has been observed only three times in eight months of operation. In the tests described above, the 11 7 db improvement in performance was due entirely to the use of the L-band frequencies. Fast time constants were not used in the receiver circuits to differentiate the video signals to give an apparent increase in contrast. These tests have proved conclusively that the theoretical improvement in performance in rain of approximately 12 db can be closely approached and, further, that the utility and value of the entire radar system is greatly increased by taking advantage of this improvement.

TABLE I

TEST DATA

	Target Aircraft			Cloud Formation	Target Aircraft signal to cloud signal ratio in decibels		Improvement at L-band in decibels
Comparison No	Azimuth Degrees	Range Miles	Altitude in Feet AG	Range in Miles	L-band	S-band	
1	197	21	2000	21-35	0	-3	3
2	193	21	2000	21-35	-5	-19	14
3	187	21	2000	21-35	+12	-3	15
4	198	21	2000	27-32	-4	-15	11
5	191	21	2000	27-32	0	-10	10
6	198	27	2000	28-36	0	-15	15
7	322	24	2000	25-29	+1	-10	11
8	328	25	2000	25-29	-6	-12	6
9	322	22	2000	25-29	+6	-7	13
10	322	20.5	2000	25-30	-6	-12	6
11	330	20	2000	20-25	-7	-16	9
12	227	17	2000	19-24	+10	-4	14
13	341	17	2000	20-25	+6	-12	18
14	347	17	2000	18-25	+3	-11	14
15	347	17	2000	18-25	+1	-14	15

GPO CH FSO 6-4-49 2 000