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FINAL REPORT
EVALUATION OF RADAR SET AN/TPQ-8 AS A JAMMER OF GROUND-BASED RADAR (U)

(Project 33-56-0033)

April 1957

Electronic Warfare Department
U. S. ARMY ELECTRONIC PROVING GROUND
Fort Huachuca, Arizona

- - -

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FOREWORD

This report evaluates the AN/TPQ-8 as a jammer of ground-based radar, and has been prepared by the Electronic Warfare Department as part of Project 33-56-0033 (USAEPG-3 EW Systems Test) of the U.S. Army Electronic Proving Ground Technical Program. The report is based on field tests conducted at Fort Huachuca, Arizona, during November and December 1956.

Aircraft support for the tests was provided by the Aviation Department of USAEPG. Personnel of the 1st Signal Group, Fort Huachuca, participated in operating and maintaining the various equipment utilized in the tests.

H. McD. BROWN
Col SigC
Chief, Electronic Warfare Department

ABSTRACT

This is a report of a series of tests conducted to evaluate the effectiveness of the AN/TPQ-8 as a jammer of ground-based radars and to determine under what conditions the AN/TPQ-8 could introduce interference into target radars and the effects on friendly radar. These tests were conducted under line-of-sight conditions and also with the target radar located in defilade.

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Section I. Summary

Tests to evaluate the effect of the AN/TPQ-8 on ground-based radar and tests to determine ways to reduce effects of jamming of ground-based radar by ground-based jamming equipment are summarized as follows:

The AN/TPQ-8 is of limited use in determining the operating characteristics of a radar; only the operating frequency was obtained with consistent accuracy. At ranges of 5,000 and 30,000 yards and 0 degrees antenna elevation the AN/TPQ-8 caused serious interference on the scope of the tracking portion of the M-33 radar. Other antenna elevations of the AN/TPQ-8 caused interference which varied from serious to slight. To cause interference of any degree the AN/TPQ-8 had to be on the same frequency as the M-33. Off-frequency jamming was ineffective, as was jamming of a radar employing variable frequency operation. The AN/TPQ-8 was able to cause the M-33 to break track on a target the size of an L-20 for target ranges greater than 14,000 yards when the jammer-to-radar distances were 8,000 yards and 20 miles.

Operating against the T-9 radar of the T-38 AA gun directing system the AN/TPQ-8 caused serious interference to the T-9 at all antenna elevations of the AN/TPQ-8 and ranges of 5,000 and 10,000 yards. Interference was serious through a range of frequencies from as low as 30 Mc/s below to as high as 95 Mc/s above the operating frequency of the T-9. The AN/TPQ-8 was able to cause the T-9 to break track consistently on a target the size of an L-20 at a distance from 1,000 yards to 40,000 yards at jammer-to-radar ranges of 5,000 and 15,000 yards. The AN/TPQ-8 was also effective at these same ranges in preventing the T-9 from establishing an initial track. The results of these tests prove conclusively that the AN/TPQ-8 is completely effective against the T-9 at the test ranges.

The AN/TPQ-8 caused serious interference with a GCA radar at 3,500 yards range and jammer antenna elevations up to 400 mils. Complete jamming of the GCA radar was effected at jammer-to-radar ranges up to 20,000 yards.

Further test results indicate that the AN/TPQ-8 was not able to detect a signal from or jam an M-33 radar located in defilade. It was deduced, therefore, that line-of-sight conditions between jammer and radar must exist for effective jamming of the radar.

The M-33 was able to determine accurately the azimuth of the AN/TPQ-8 within plus or minus 4 mils regardless of the antenna

orientation of the jammer. It would be possible to locate the jammer by means of triangulation using several M-33 radars. The accuracy with which the AN/TPQ-8 can determine the azimuth of target tracking radar varies from 21 mils to 179 mils depending on the characteristics of the signal source. This accuracy is marginal, when the jammer beam width is considered. The accuracy with which the AN/TPQ-8 can determine the azimuth of a radar is a function of operator skill.

Section II. Introduction

1. BACKGROUND

Radar Set AN/TPQ-8 is a countermeasures device primarily designed to interfere with and deny the enemy use of airborne radar. The AN/TPQ-8 is slaved to a tracking radar, usually the AN/MPQ-16, when utilized against airborne targets.

Extensive tests have been conducted by the U. S. Army Signal Engineering Laboratories (USASEL) and the Electronic Warfare Department (EWD) at Fort Huachuca, Arizona, on the AN/TPQ-8 as a jammer of airborne radar. Little testing had been performed to evaluate the effectiveness of the AN/TPQ-8 against ground-based radar. For this reason the AN/TPQ-8 was included on the test schedule of the U. S. Army Electronic Proving Ground (USAEPG) at Fort Huachuca, Arizona, for testing against ground-based radars.

Tests 9, 10, and 11 were conducted at the request of U. S. Army Air Defense Board Number 4 (7104), Continental Army Command, Fort Bliss, Texas, and were concerned primarily with determining ways of reducing the effects of jamming of ground-based radar by ground-based jamming equipment.

2. PURPOSE

The purpose of these tests was to determine the effectiveness of the AN/TPQ-8 in jamming ground-based radar and to determine the interference from the AN/TPQ-8 encountered by various friendly ground-based radars.

Section III. Description of Radar Set AN/TPQ-8

3. GENERAL

Radar Set AN/TPQ-8 is a transportable countermeasures set designed to counter radar signals in a frequency range from 9,075 to 9,675 Mc/s.

4. FUNCTIONAL DESCRIPTION OF RADAR SET AN/TPQ-8

Radar Set AN/TPQ-8 is a countermeasure device designed to produce noise-modulated X-band energy concentrated in a relatively narrow beam. The source of the radio frequency (rf) power is a tunable continuous wave (cw) magnetron. The rf power is radiated by a servo-operated antenna system which can be positioned in azimuth and elevation either automatically or manually.

The AN/TPQ-8 receiving system provides a panoramic display of the signals received indicating signal strength, frequency, and modulation.

The antenna system consists of receiving and transmitting antennas mounted on the same pedestal and aligned so that their axes are parallel. The polarization of both antennas can be varied in four steps: 0 degrees, 45 degrees, 90 degrees, or 135 degrees. The polarization rotators are synchronized so that the transmitting channel transmits energy of equal polarization to that which the receiving antenna is accepting.

5. PHYSICAL CHARACTERISTICS

Radar Set AN/TPQ-8 consists of a pair of parabolic reflectors (one transmitting and one receiving), a transmitter, a receiver, and controls all mounted on a searchlight type trailer. An additional trailer is required to carry the power source. Figures 1 and 2 present a front view of the AN/TPQ-8 and a view of the equipment in operating position.

6. TECHNICAL CHARACTERISTICS

The AN/TPQ-8 has the following technical characteristics:

Transmitter frequency . . . . . 9,075 to 9,675 Mc/s
Transmitter power output . . . 1 kw (600 to 750 watts normal)

Transmitting antenna without auxiliary reflector:	
Beam width, horizontal . .	4 deg
Beam width, vertical . . .	2½ deg
Gain (calculated)	2600
Transmitting antenna with auxiliary reflector:	
Beam width, horizontal . .	7 deg
Beam width, vertical . . .	2½ deg
Gain (calculated)	1200
Modulator, noise	6D4 noise source, 3 stages of video amplification, and a 4-1000A modulator driving the cw magnetron
Magnetron	Litton type 560 cw magnetron. Normal operating conditions are: plate 5000 v, 300 ma; fil 5-29 va at 0 plate volts.

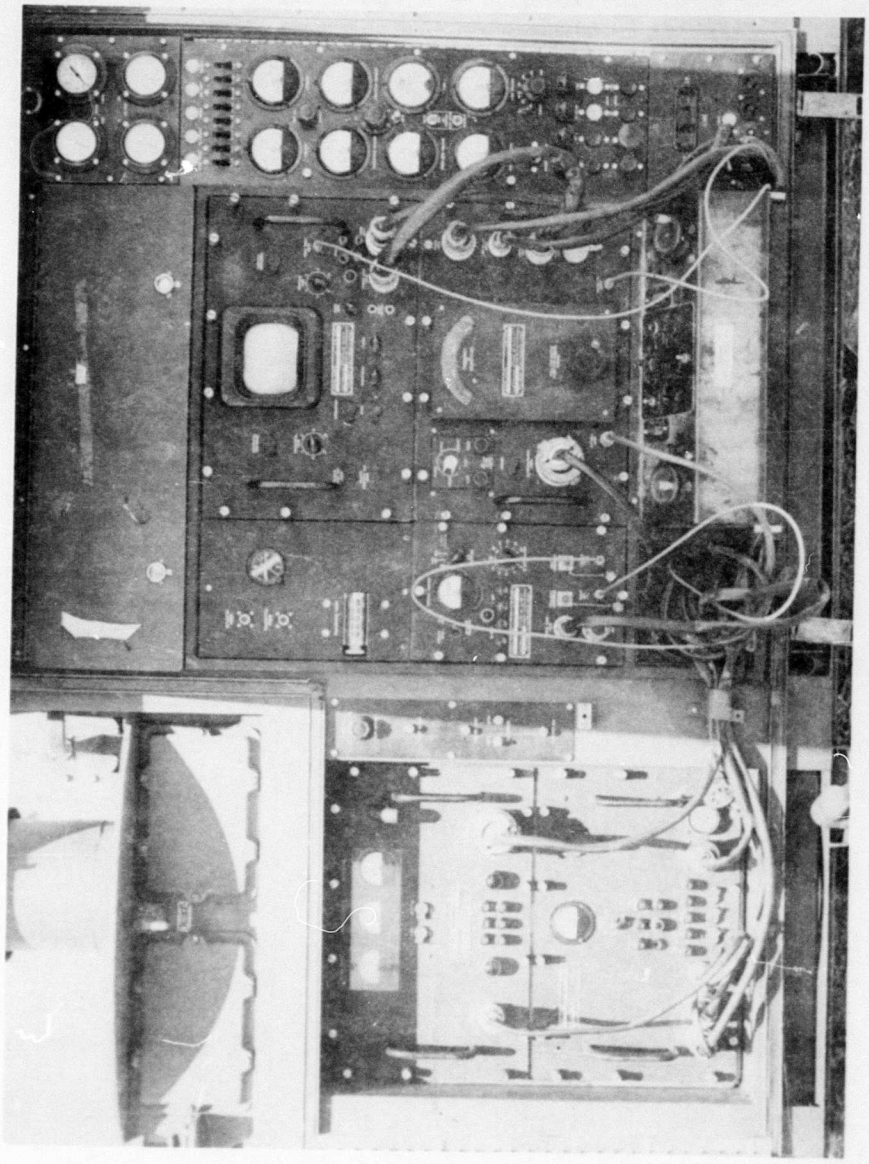

Figure 1. Front View of AN/TPQ-8

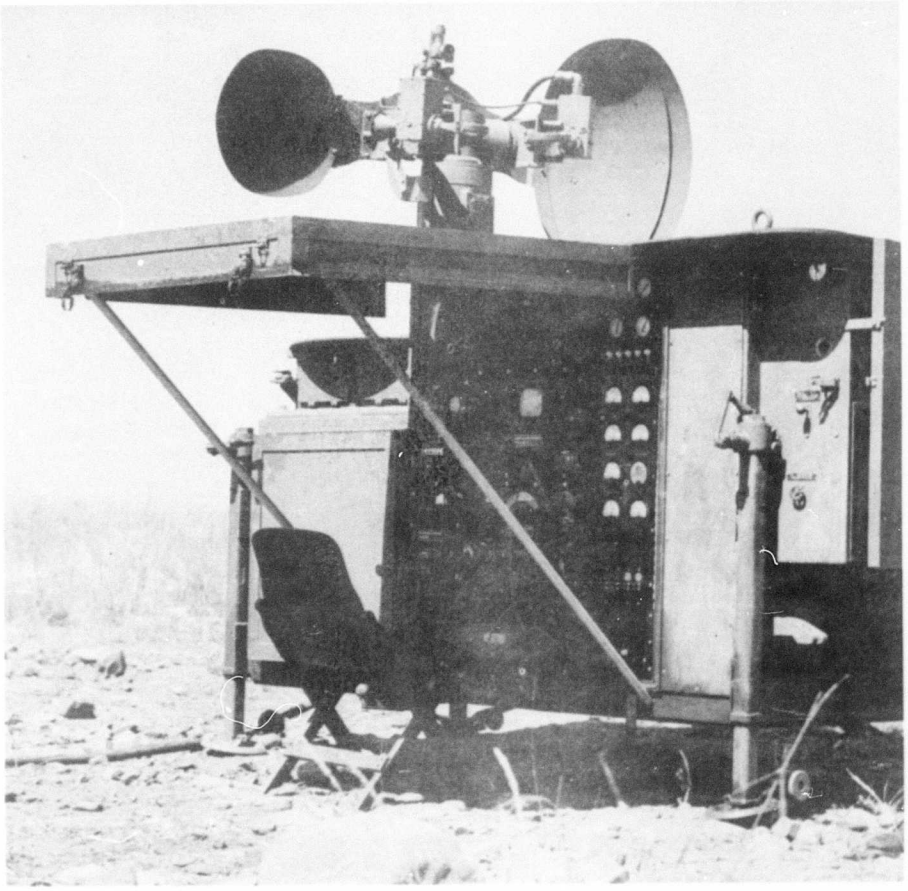

Figure 2. AN/TPQ-8 in Operating Position

Section IV. Test Procedures and Results

7. TEST 1: EFFECTIVENESS OF AN/TPQ-8 AS A DETECTING DEVICE

This test was conducted to find out to what extent the AN/TPQ-8 could determine the technical operating characteristics of a tracking radar operating in the X-band.

Equipments used for the test were the Radar Set AN/TPQ-8 and the Target Tracking Radar (TTR) component of the M-33 Fire Control System.

Locations of the equipment are illustrated in figure 3. The M-33 was located at coordinates 625966. The AN/TPQ-8 was set up at two separate locations: 5,000 yards from the M-33 at coordinates 608925 and 8,000 yards from the M-33 at a position 3.6 miles north of the north gate of Fort Huachuca.

The test procedure was as follows: The TTR antenna was elevated 800 mils. The M-33 was operated with the TTR antenna in three positions. The first position was with the antenna aimed directly toward the AN/TPQ-8, the second with the antenna rotated 90 degrees clockwise from the first, and the third with the antenna rotated 90 degrees counterclockwise from the first. The M-33 operating frequency, type of polarization, and pulse repetition frequency were logged for each position. Corresponding data detected by the AN/TPQ-8 was reported for each position. An analysis of data indicated that the AN/TPQ-8 detected operating frequencies of the M-33 with an average error of 34 Mc/s for 18 measurements. The AN/TPQ-8 was unable to detect the type of polarization or the pulse repetition frequency of the M-33.

The M-33 in this case was circularly polarized. The scanner motor was on and the tracker scanner was activated. When the scanner motor is off and the polarization is not circular, the AN/TPQ-8 can detect the M-33 polarization. Normal X-band tracking operation requires the scanner motor to be on. Without external equipment, there is no way to determine M-33 polarization at the M-33 site when the scanner motor is off.

Operating frequencies of the M-33 ranged from 9,100 to 9,600 Mc/s; and pulse repetition frequencies were 1,000 pulses per second for each position of the TTR antenna.

Test data are tabulated in Annex A.

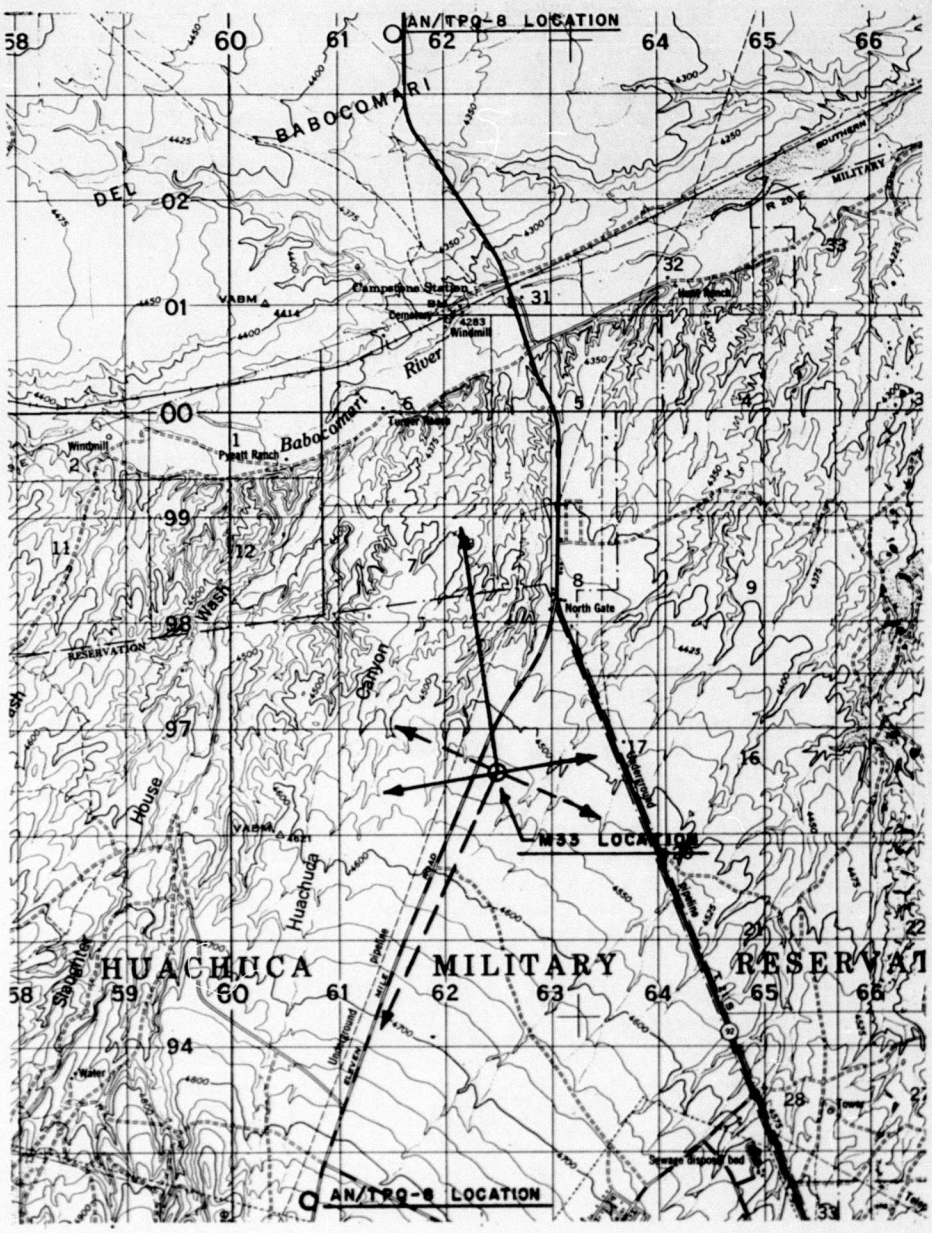

Figure 3. Equipment Locations for Test 1

8. TEST 2: EFFECTS OF AN/TPQ-8 INTERFERENCE WITH A TARGET TRACKING RADAR

This test was conducted to find out the conditions under which the AN/TPQ-8 could introduce interference into an X-band TTR.

Equipments used for the test were the Radar Set AN/TPQ-8 and the Target Tracking Radar (TTR) component of the M-33 Fire Control System.

Locations of the equipment are illustrated in figure 4. The M-33 was located at coordinates 625966. The AN/TPQ-8 was set up at two separate locations: 5,000 yards from the M-33 at coordinates 608925 and 30,000 yards from the M-33 at coordinates 856128.

The test procedure was as follows: The TTR antenna was elevated 800 mils at a constant azimuth toward the AN/TPQ-8. The AN/TPQ-8 antenna elevation was varied over its complete range (0, 400, 800, 1200, and 1600 mils) and the effects on the TTR were noted. The AN/TPQ-8 was operated at frequencies above, below, and on the same operating frequency as the TTR on azimuths directly toward the TTR and at azimuths 90 degrees clockwise and 90 degrees counterclockwise from that position.

At a range of 5,000 yards it was found that the AN/TPQ-8 caused severe TTR scope interference, when the AN/TPQ-8 was radiating at any frequency within the TTR range; but only when the AN/TPQ-8 antenna was at zero mils elevation and radiating directly at the TTR. Slight interference was noted when the AN/TPQ-8 antenna was at an elevation of 400 and 800 mils.

At a range of 30,000 yards it was found that the AN/TPQ-8 caused interference, when the AN/TPQ-8 was radiating at frequencies near the TTR operating frequency; but only when the AN/TPQ-8 antenna was at zero degrees elevation. Interference noted at other AN/TPQ-8 antenna elevations was negligible.

Test data are tabulated in Annex A. Scope presentations illustrating severe, moderate, slight, and no jamming conditions of interference are shown in figures 5 through 8.

9. TEST 3: EFFECTIVENESS OF JAMMING BY AN/TPQ-8 AGAINST TARGET TRACKING RADAR UNDER FIELD CONDITIONS

This test was conducted to determine if the AN/TPQ-8 could cause an X-band tracking radar to break track.

Equipments used for this test were the Radar Set AN/TPQ-8 and the Target Tracking Radar (TTR) component of the M-33 Fire Control

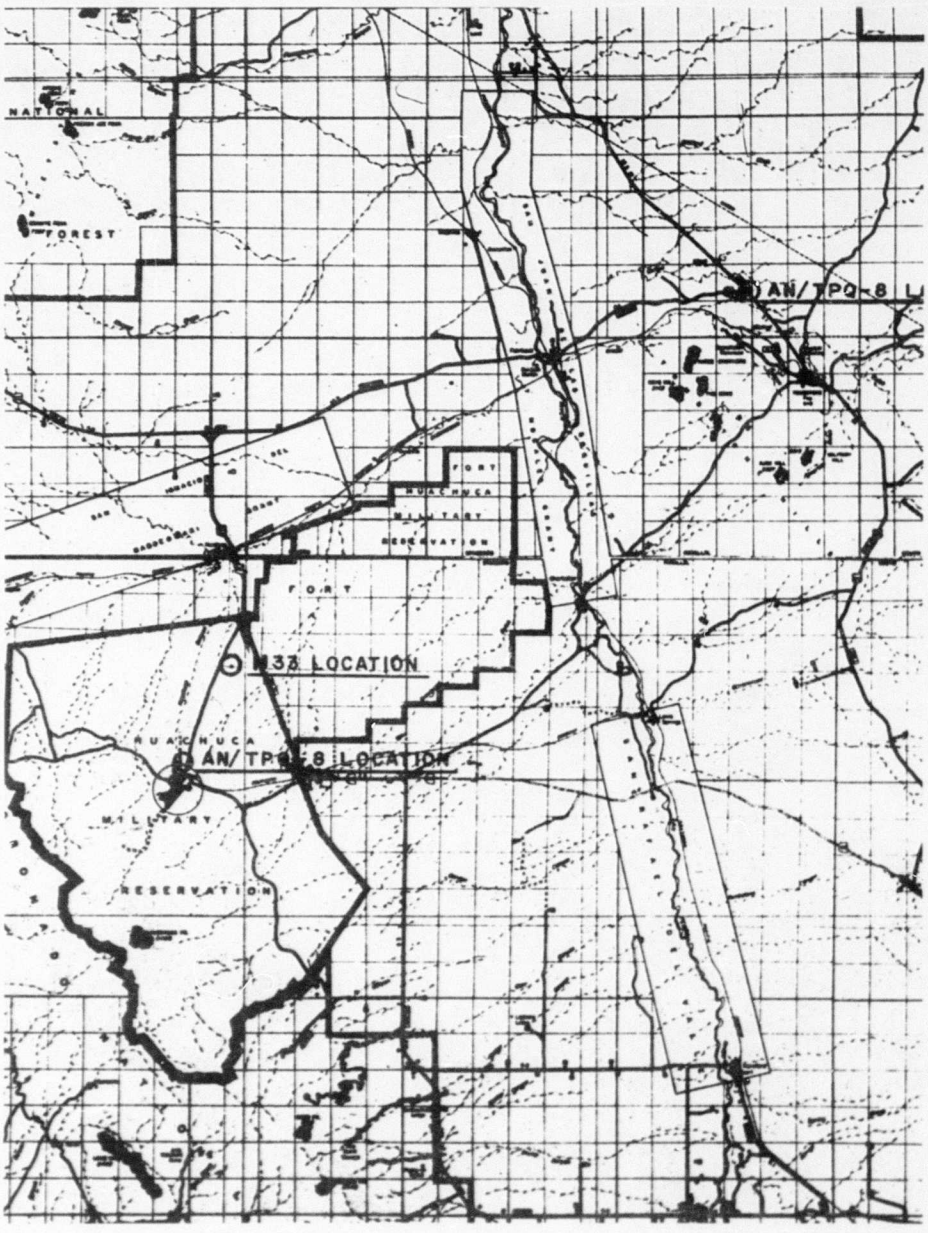

Figure 4. Equipment Locations for Test 2

System. An L-20 aircraft was used as the tracking target for the TTR.

Locations of the equipment are illustrated in figure 9. The M-33 was located at coordinates 625966. The AN/TPQ-8 was set up at two separate locations: 8,000 yards from the M-33 at a position 3.6 miles north of the north gate of Fort Huachuca and 20 miles from the M-33 at the junction of U. S. Highway 80 and Arizona State Highway 90. Four flight paths were used for the test and the aircraft was flown at an altitude of 9,000 feet.

The test procedure was as follows: In the first phase of the test the TTR was allowed to begin tracking the aircraft using a frequency known to the AN/TPQ-8 team. After the TTR had begun to track the aircraft, the AN/TPQ-8 team was notified and jamming started. The effects on the TTR were then recorded.

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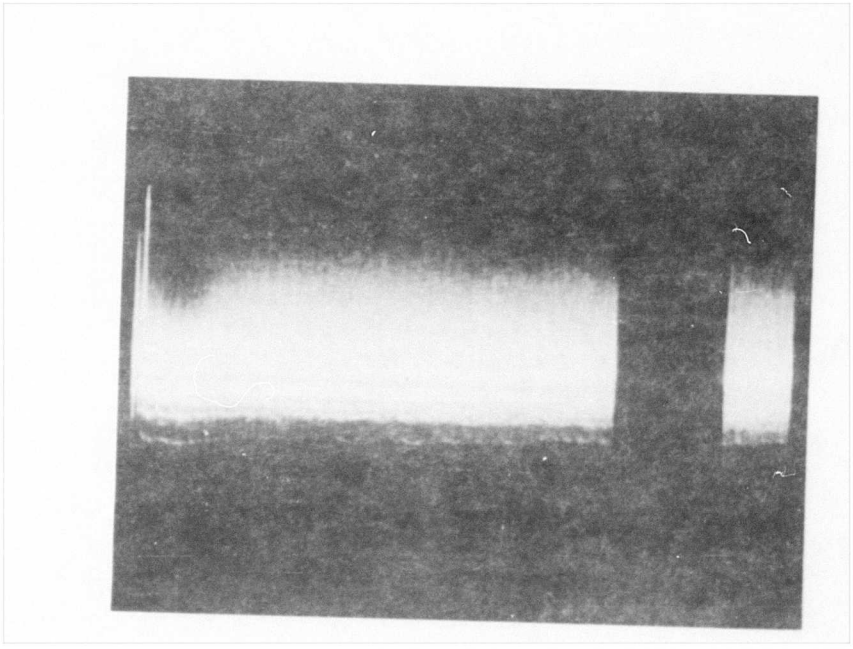

Figure 5. Scope Presentation of Severe Jamming, Test 2

In the second phase of the test the TTR was allowed to begin tracking the aircraft using a frequency known to the team. When jamming started, the operating frequency of the TTR was changed and the AN/TPQ-8 team was required to locate the new operating frequency and attempt jamming. The effects on the TTR were then recorded.

It was found that the AN/TPQ-8 is effective in causing the TTR to break track, when the TTR is at a range of more than 14,000 yards from the target and only when a constant operating frequency is used by the TTR. The TTR is capable of tracking through the jamming when TTR is at a range less than 14,000 yards from the target. Tracking ranges less than 14,000 yards from the target vary according to the size of the target being tracked. It was also found that the AN/TPQ-8 is ineffective when the operating frequency of the TTR is varied. This was true at all ranges of the TTR from the target tested.

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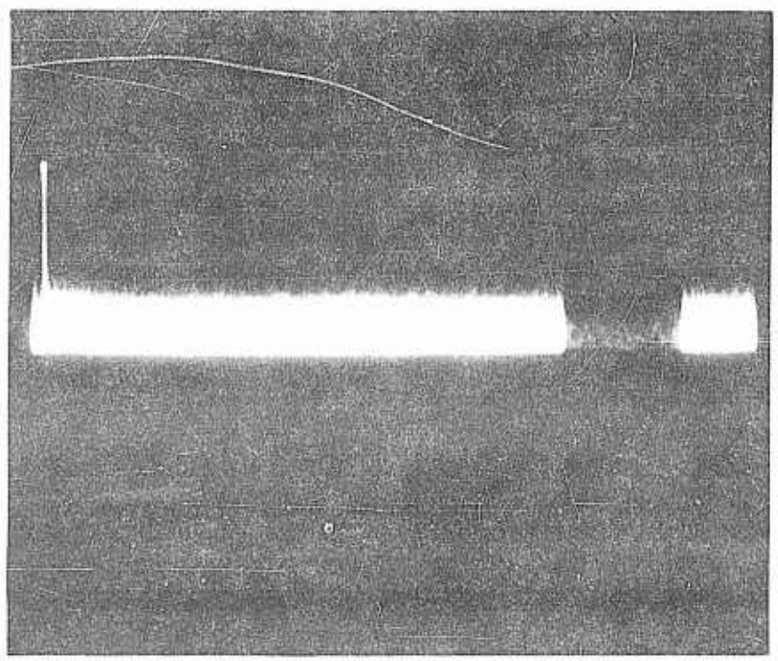

Figure 6. Scope Presentation of Moderate Jamming, Test 2

Test data are tabulated in Annex A. Scope presentations of jamming conditions are shown in figures 10 and 11.

10. TEST 4: EFFECTS OF AN/TPQ-8 INTERFERENCE MEASURED BY AA FIRE CONTROL RADAR

This test was conducted to determine the conditions under which the AN/TPQ-8 could introduce interference into an X-band AA fire control radar.

Equipments used for this test were the Radar Set AN/TPQ-8 and the T-9 radar component of the T-38 Fire Control System.

Locations of the equipment are illustrated in figure 12. The T-9 was located at coordinates 625966. The AN/TPQ-8 was set up at two separate locations: 5,000 yards from the T-9 at coordinates 608925 and 10,000 yards from the T-9 at the junction of the Tombstone and Nogales, Arizona, highways.

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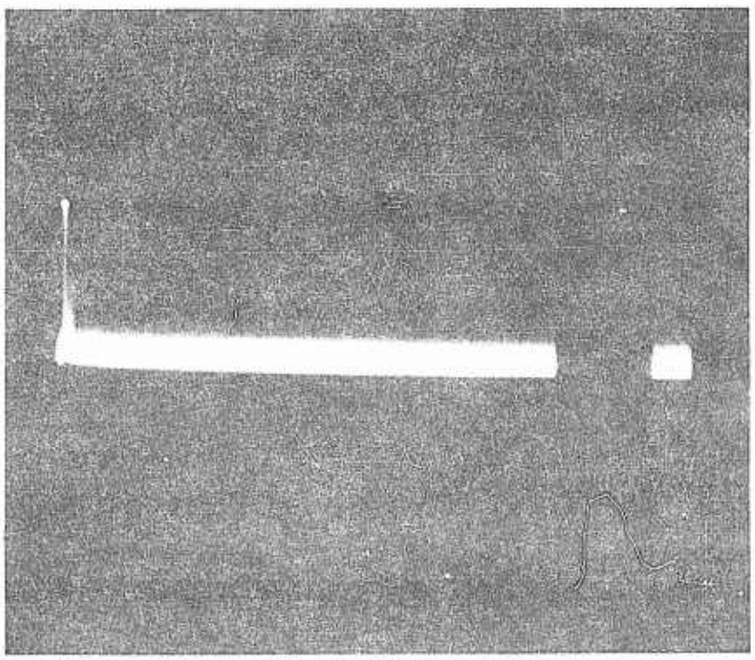

Figure 7. Scope Presentation of Slight Jamming, Test 2

The test procedure was as follows: The T-9 antenna was elevated 800 mils at a constant azimuth toward the AN/TPQ-8. The AN/TPQ-8 was tuned to the operating frequency of the T-9 and the antenna elevation of the AN/TPQ-8 was varied over its complete range in five steps (0, 400, 800, 1200, and 1600 mils). At each step in the antenna elevation the results on the T-9 scope were noted. The procedure was then repeated, varying the operating frequency of the AN/TPQ-8 to determine the upper and lower frequency limits at which jamming occurs.

It was found that the AN/TPQ-8 can effectively interfere with the T-9 radar at ranges of 5,000 and 10,000 yards. At 5,000 yards the AN/TPQ-8 caused interference at all AN/TPQ-8 antenna elevations tested but the amount of interference decreased from full jamming at 0 mils antenna elevation to slight jamming at 1,600 mils antenna elevation. When the operating frequency of the AN/TPQ-8 was varied, interference was noted on the T-9 scope but full jamming was never accomplished. Operation of the AN/TPQ-8 at frequencies ranging from

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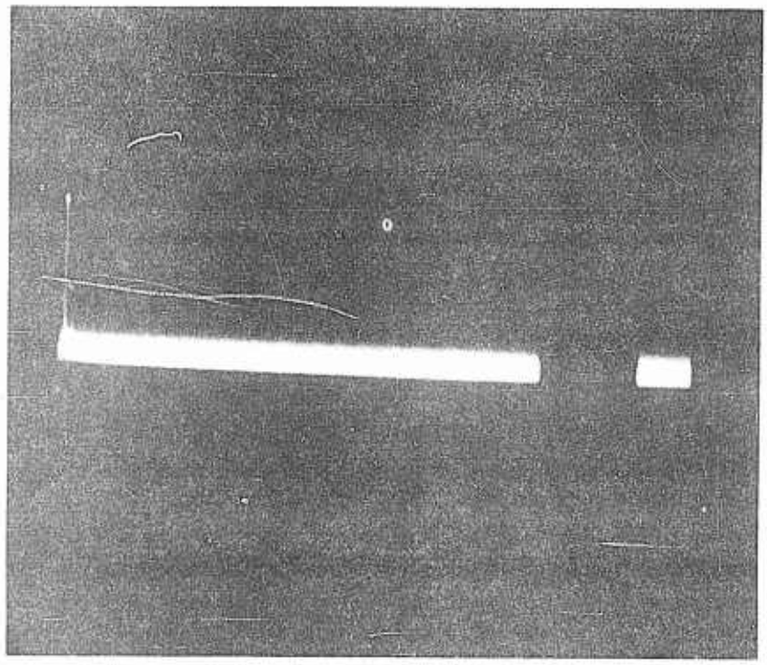

Figure 8. Scope Presentation of No Jamming, Test 2

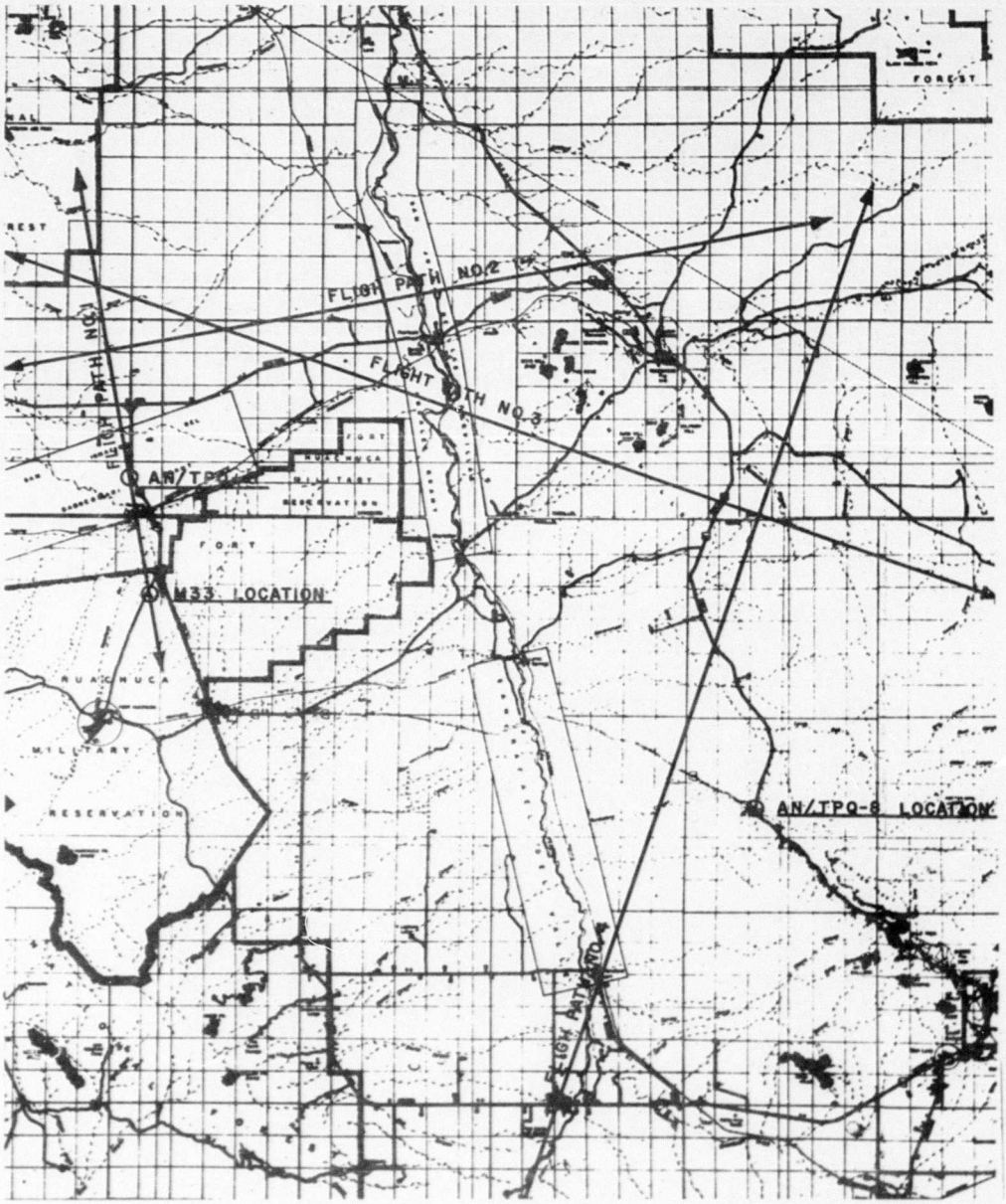

Figure 9. Flight Paths and Equipment Locations for Test 3

30 Mc/s below the T-9 frequency to 80 Mc/s above the T-9 frequency resulted in the introduction of interference.

Severe jamming was accomplished at a range of 10,000 yards at all AN/TPQ-8 antenna elevations tested, when the operating frequencies of both radars were the same. When the operating frequency of the AN/TPQ-8 was varied, interference was introduced from 20 Mc/s below the T-9 frequency to 95 Mc/s above the T-9 frequency.

Results indicate that the AN/TPQ-8 is capable of jamming the T-9 more effectively at long ranges than at short ranges. The results obtained at 10,000 yards range (severe jamming with the AN/TPQ-8 antenna elevated at 1,600 mils) could have been caused by the following conditions:

a. Reflections from a minor lobe of the AN/TPQ-8.

b. Jamming through a minor lobe of the T-9.

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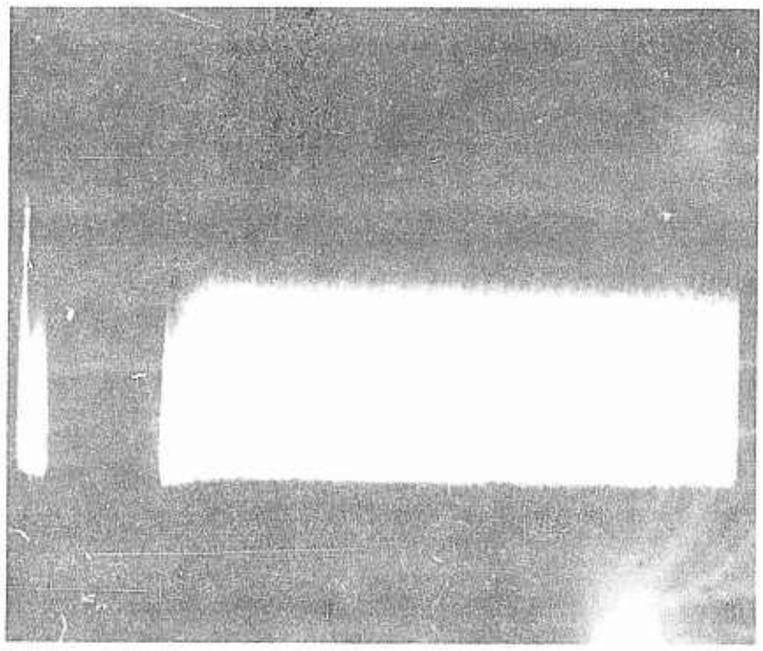

Figure 10. Scope Presentation Showing Jamming Condition, Target Lost for Test 3

Preliminary testing resulted in full jamming of the T-9, even when its antenna was oriented 3,200 mils from the AN/TPQ-8. These results indicate that very little power introduced into the antenna of the T-9 causes jamming. Thus a small signal, such as would be introduced through a minor lobe, could conceivably cause jamming, and the amount of jamming introduced would be dependent upon the size of the lobe. Therefore, the lobe distribution of the antennas involved would determine the range at which jamming occurred and the amount of jamming. It may be that at 10,000 yards range, jamming was accomplished through a larger minor lobe than at 5,000 yards.

Under normal operating conditions the AN/TPQ-8 antenna would be oriented on an azimuth directly toward the target radar and the conditions used in this test would not exist. These results are important, when consideration is given to the possibility of interference with friendly fire control radars.

Test data are tabulated in Annex A. Scope presentations, illustrate severe, moderate, and slight jamming conditions which

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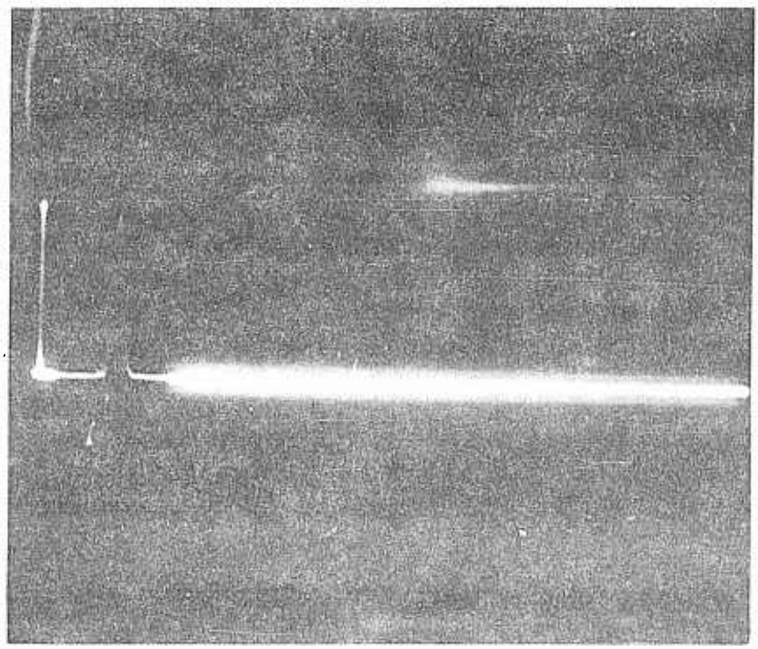

Figure 11. Scope Presentation Showing No Jamming, Tracking Target for Test 3

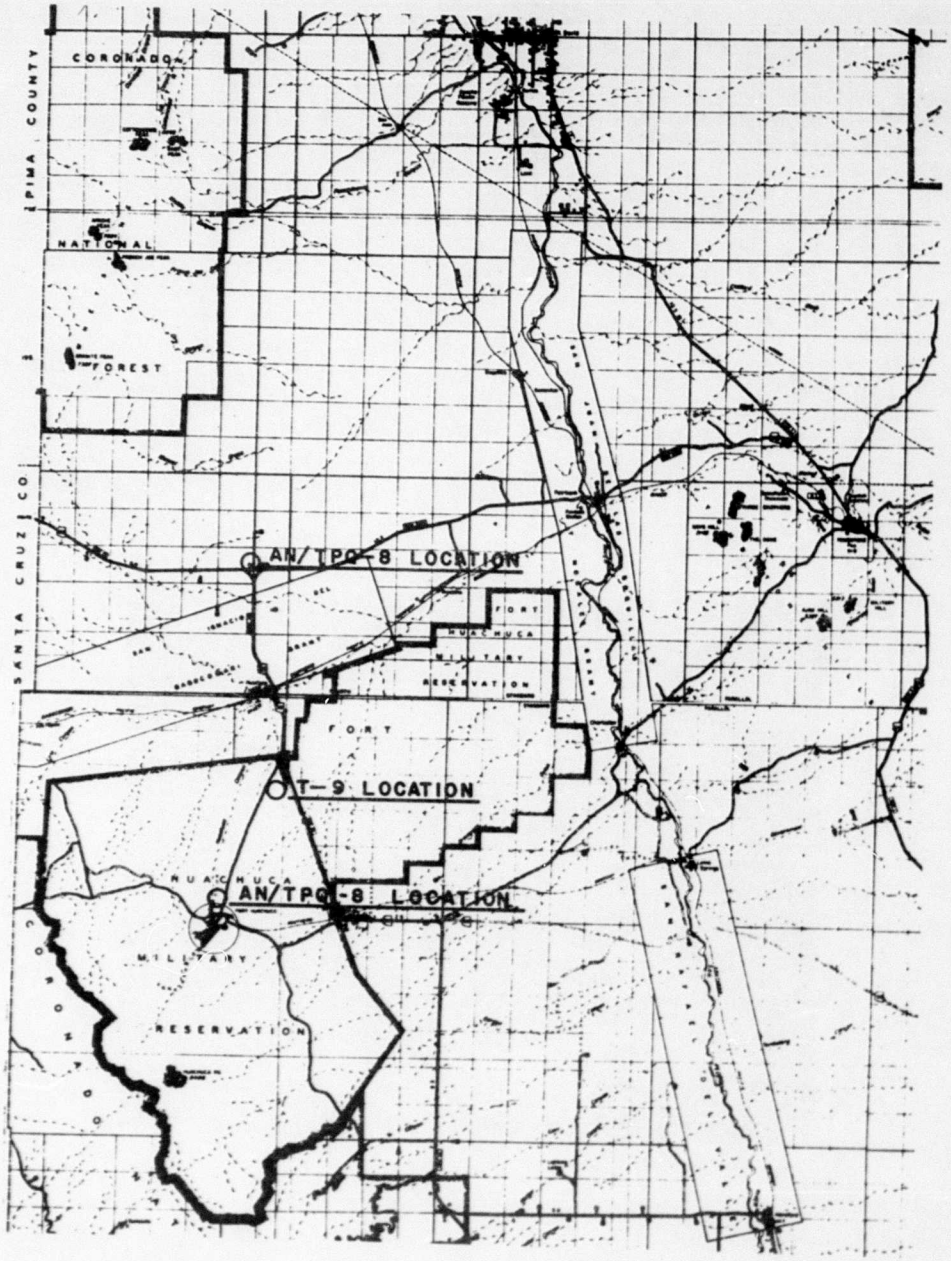

Figure 12. Equipment Locations for Test 4

are shown in figures 13 through 15.

11. TEST 5: JAMMING EFFECTIVENESS OF AN/TPQ-8 AGAINST AA FIRE CONTROL RADAR UNDER FIELD CONDITIONS

This test was conducted to determine if the AN/TPQ-8 could effectively jam a fire control type of radar and prevent it from acquiring and tracking a target.

Equipments used for this test were the Radar Set AN/TPQ-8 and the T-9 radar component of the T-38 Fire Control System.

Locations of the equipment and flight paths are illustrated in figure 16. The T-9 was located in relatively flat terrain at coordinates 625966 in line-of-sight with the AN/TPQ-8. The AN/TPQ-8 was set up at two separate locations: 5,000 yards from the T-9 at coordinates 608925 and at 15,000 yards at a point 5.8 miles east of the junction of the Tombstone and Nogales, Arizona, highways. An L-20 aircraft was used as the target for the T-9.

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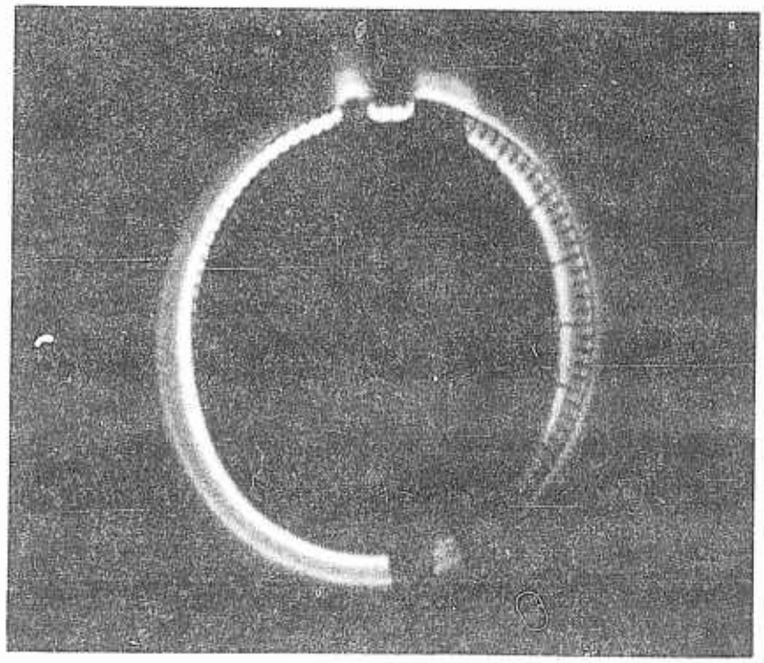

Figure 13. Scope Presentation of Severe Interference, Test 4

The test procedure was as follows: The operating frequency of the AN/TPQ-8 was 9,340 Mc/s and its antenna elevation was 0 mils. Altitude of the aircraft was 9,000 feet.

At ranges of both 5,000 and 15,000 yards the T-9 attempted to acquire and track the aircraft using a frequency known to the AN/TPQ-8 team. The AN/TPQ-8 attempted to jam the T-9 before and after target acquisition over two different flight paths.

In the second phase of the test the T-9 was permitted to acquire the target and begin tracking. The AN/TPQ-8 then attempted to cause the T-9 to break track.

The AN/TPQ-8 was very effective against the T-9. At jammer-to-radar ranges of both 5,000 and 15,000 yards the T-9 could acquire and track the target aircraft only during a very short portion of the flight. The AN/TPQ-8 caused the T-9 to break track established prior to jamming and prevented track being regained.

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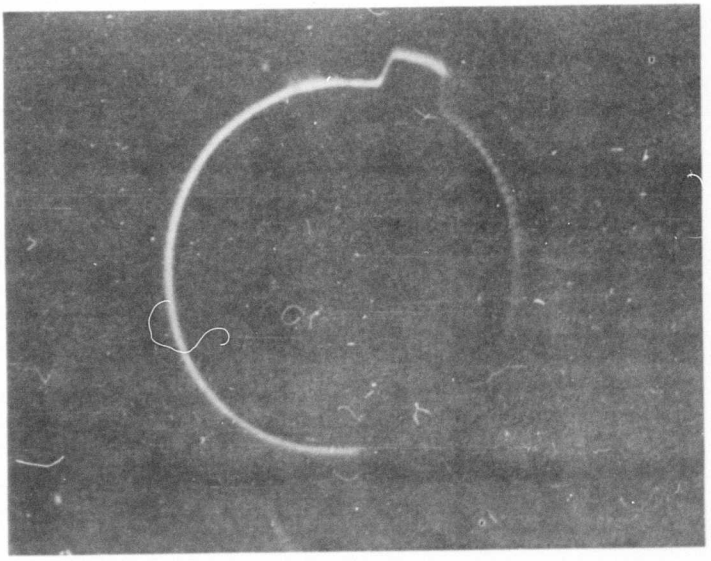

Figure 14. Scope Presentation of Moderate Interference, Test 4

It was observed that for 15,000 yards jammer-to-radar range the amount of jamming experienced, although great enough to cause breaking track, was considerably less than that experienced at a range of 5,000 yards. The maximum effective range of the AN/TPQ-8 to the target radar is 15,000 yards, when the target radar is tracking an aircraft the size of an L-20.

Test data are tabulated in Annex A.

12. TEST 6: EFFECTS OF AN/TPQ-8 INTERFERENCE MEASURED BY GCA RADAR

This test was conducted to determine the conditions under which interference could be introduced into an X-band GCA radar by the AN/TPQ-8.

Equipments used for this test were the Radar Set AN/TPQ-8 and the Gilfillan GCA Quadradar, Model MK IV.

Locations of the equipment are illustrated in figure 17.

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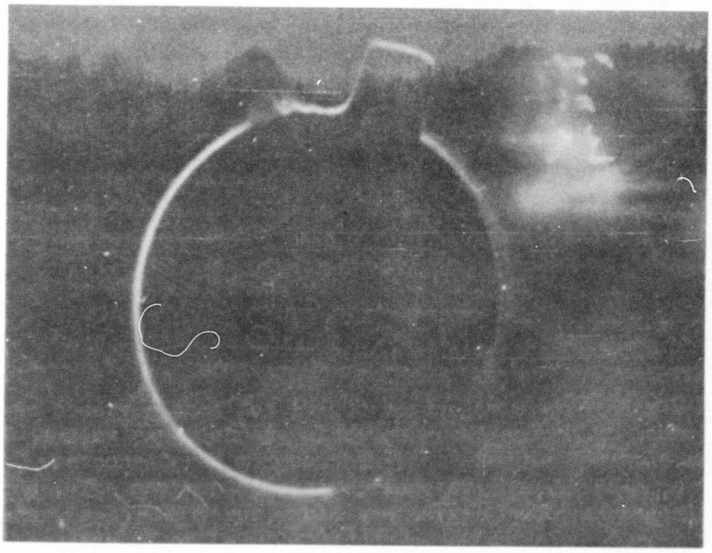


Figure 15. Scope Presentation of Slight Interference, Test 4

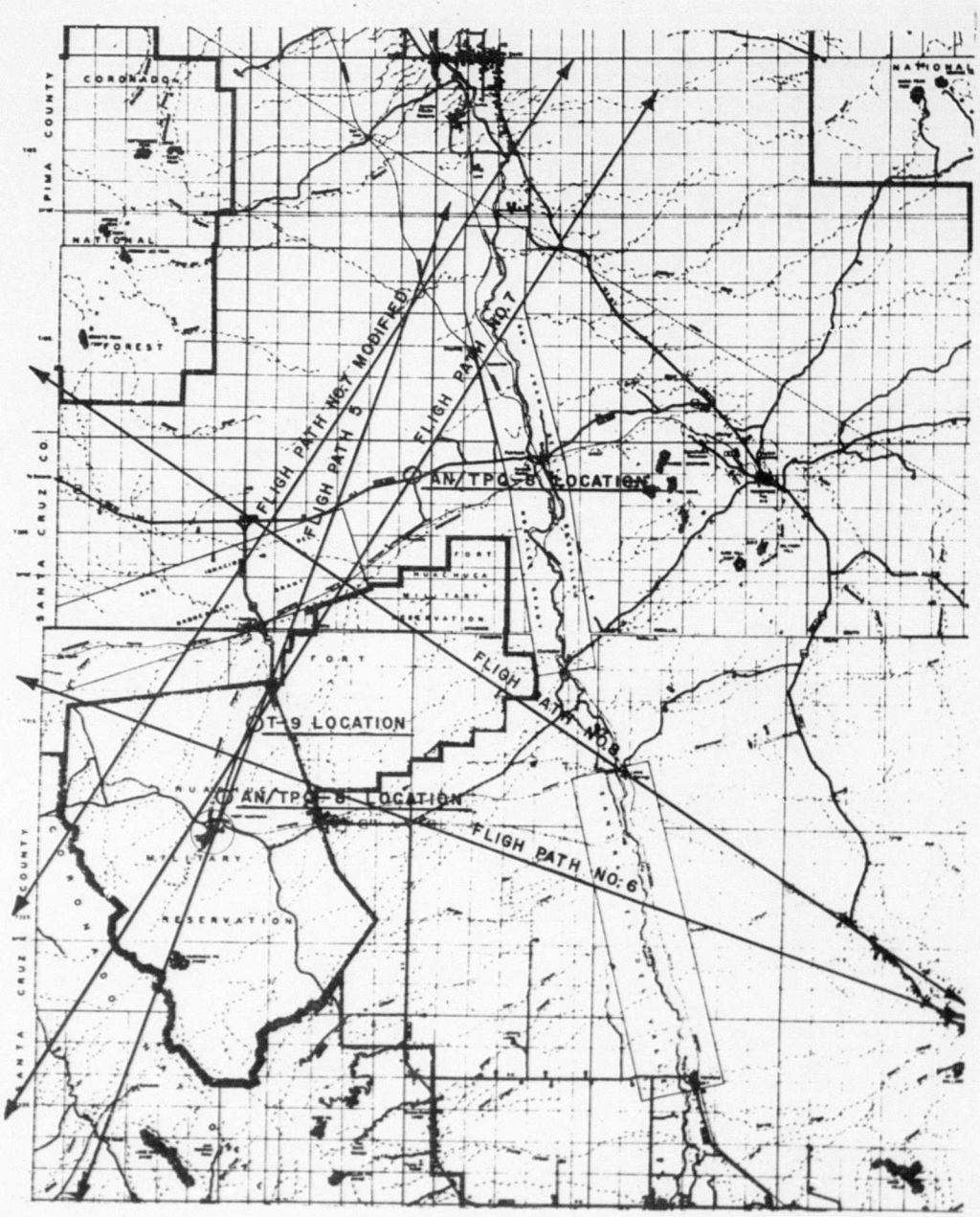


Figure 16. Flight Paths and Equipment Locations for Test 5

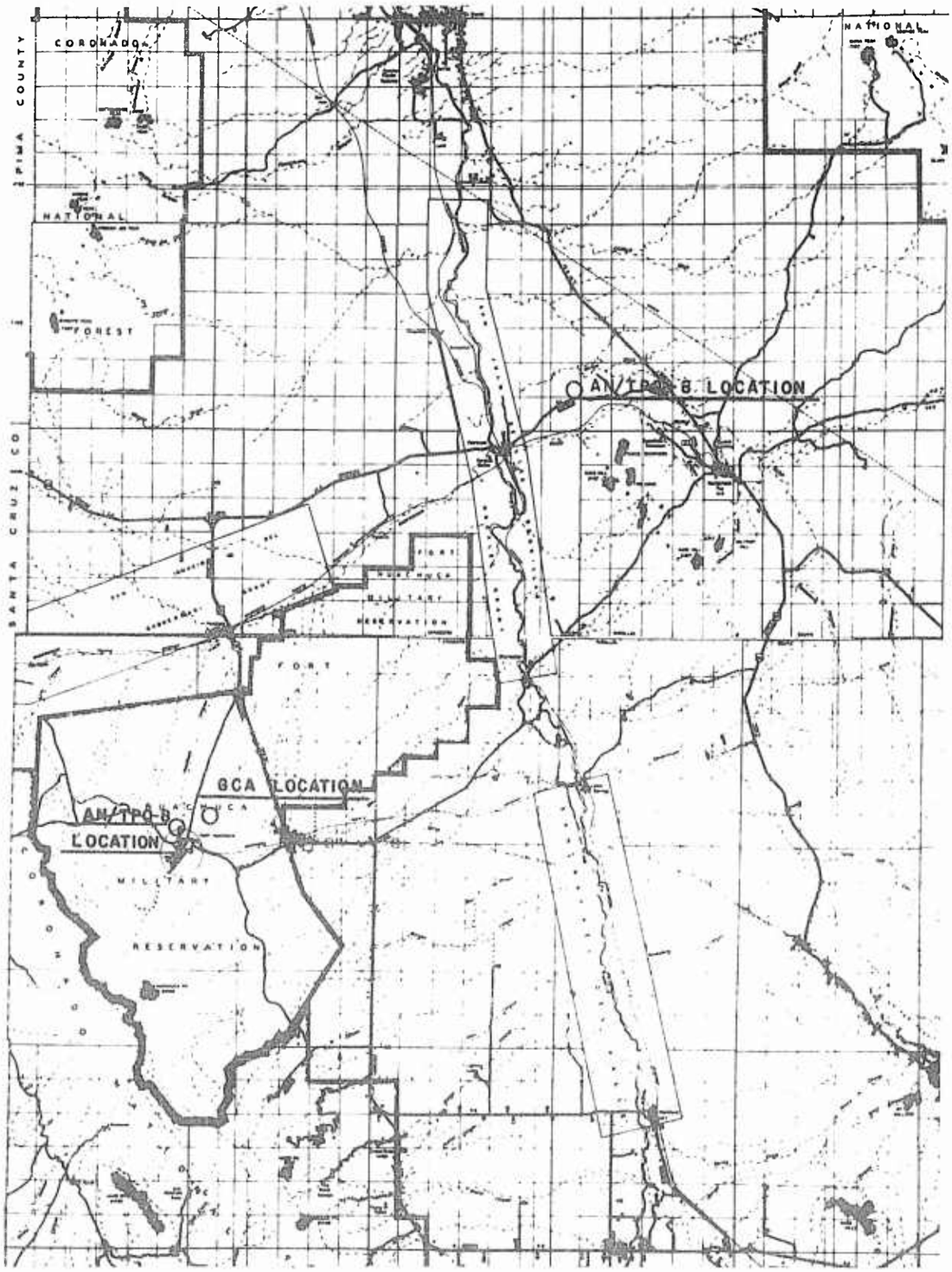


Figure 17. Equipment Locations for Test 6

The GCA radar was located in relatively flat terrain in the vicinity of Libby Army Airfield at coordinates 625943 in line-of-sight with the AN/TPQ-8. The AN/TPQ-8 was set up at two separate locations: 3,500 yards from the GCA radar at coordinates 608925 and at a range of 15 miles at a point 2.6 miles west of the junction of the Tombstone and Benson, Arizona, highways.

The test procedure was as follows: The GCA radar was allowed to operate on a frequency known to the AN/TPQ-8 team. The antenna polarization of the GCA radar was varied and the AN/TPQ-8 team attempted to determine the antenna polarization being used in each case.

In the second phase of the test the AN/TPQ-8 radiated directly toward the GCA radar, which was using horizontal antenna polarization. The antenna elevation of the AN/TPQ-8 was varied in five steps over its complete range and photographs of the GCA radar scope were taken at each step. The procedure was then repeated with the GCA radar using circular antenna polarization.

In the third phase of the test the operating frequency of the AN/TPQ-8 was varied above and below the operating frequency of the GCA radar. An appraisal of the GCA radar scope was made at each frequency step.

The entire procedure of test phases 1, 2, and 3 was repeated with the distance between the AN/TPQ-8 and the GCA radar increased to 15 miles.

It was determined that the AN/TPQ-8 can detect radiation from the GCA radar, but that it is not extremely accurate in determining antenna polarization. Accuracy would increase with operator training and experience. Radiation from the GCA radar could be detected only at less than two degrees (approximately 35 mils) GCA radar elevations.

At 3,500 yards range the AN/TPQ-8 caused severe interference to the GCA radar, when AN/TPQ-8 antenna elevations of 0 mils and 400 mils were used. No interference was experienced when AN/TPQ-8 antenna elevations higher than 400 mils were used. When the GCA radar antenna was circularly polarized, the AN/TPQ-8 caused interference at zero mils jammer antenna elevation only.

Severe scope interference was observed at an AN/TPQ-8 operating frequency from 50 Mc/s below (the minimum obtainable with the AN/TPQ-8) to 15 Mc/s above the GCA frequency. Moderate scope interference was encountered up to 35 Mc/s above the GCA frequency.

Test data are tabulated in Annex A, and scope presentations of the various conditions of interference are shown in figures 18 through 22.

13. TEST 7: JAMMING EFFECTIVENESS OF AN/TPQ-8 ON GCA RADAR UNDER FIELD CONDITIONS

This test was conducted to determine if the AN/TPQ-8 could prevent GCA radar from effectively controlling air traffic by introduction of interference into the GCA system.

Equipments used for this test were the Radar Set AN/TPQ-8 and the Gilfillan GCA Quadradar, Model MK IV.

UNCLASSIFIED Photograph

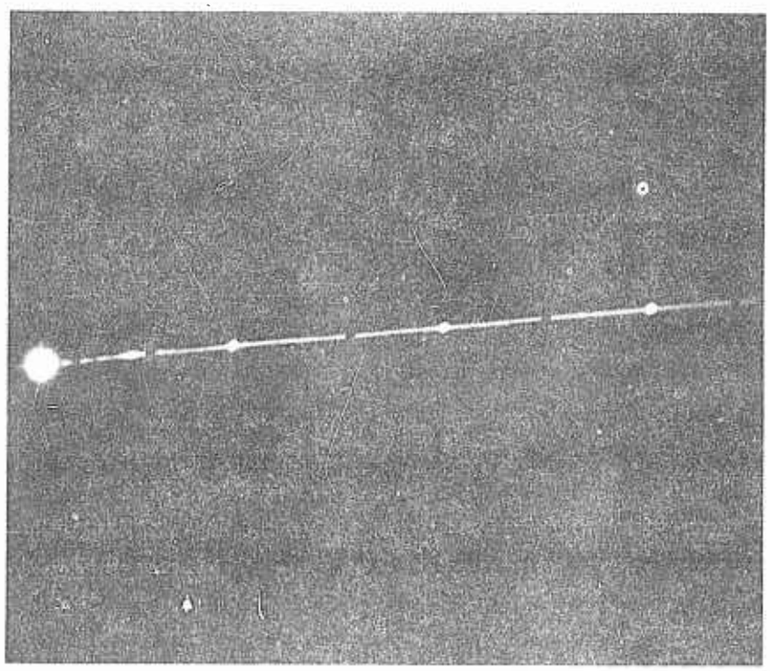


Figure 18. Beta Scan Normal Presentation of No Jamming (5-Mile Range Markers), Test 6

Locations of the equipment are illustrated in figure 23. The GCA radar was located in relatively flat terrain in the vicinity of Libby Army Airfield at coordinates 625943 and the AN/TPQ-8 was located at a range of 30,000 yards from the GCA radar at a point 5.8 miles east of the junction of the Tombstone and Nogales, Arizona, highways. An L-20 aircraft was used as a tracking target.

The test procedure was as follows: The L-20 aircraft flew a circular pattern at a radius of 15 miles from the GCA radar. The aircraft circled until directed by the GCA radar to do otherwise.

UNCLASSIFIED Photograph

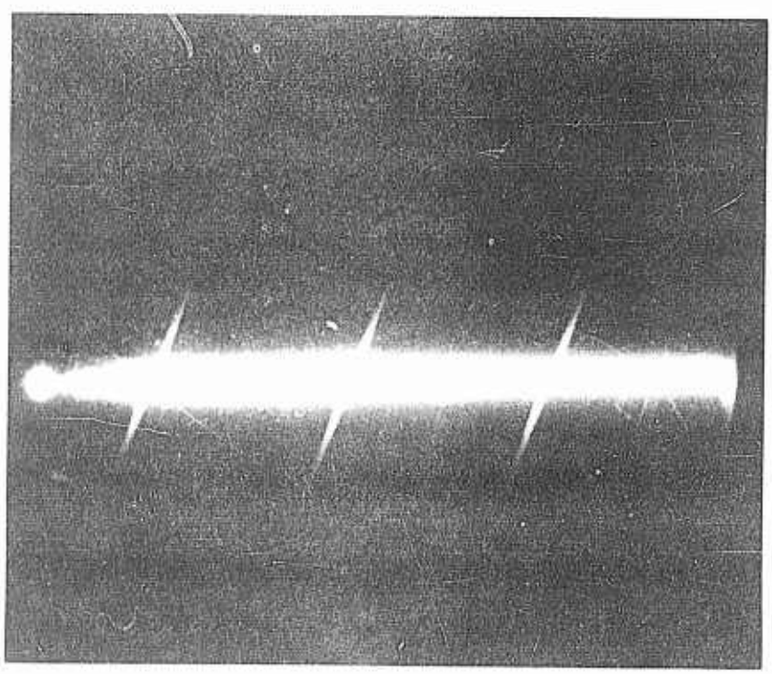


Figure 19. Beta Scan Presentation of Severe Jamming, Test 6

In the first phase of the test the GCA radar acquired the target and notified the AN/TPQ-8 team. The jamming was then started and the GCA attempted to maintain contact with the aircraft through 360 degrees of the circular flight pattern. Height finder readings were taken during this procedure and photographs of the GCA scope were made.

At the completion of the flight described in the first phase the aircraft began a landing approach under the direction of the GCA radar.

UNCLASSIFIED Photograph

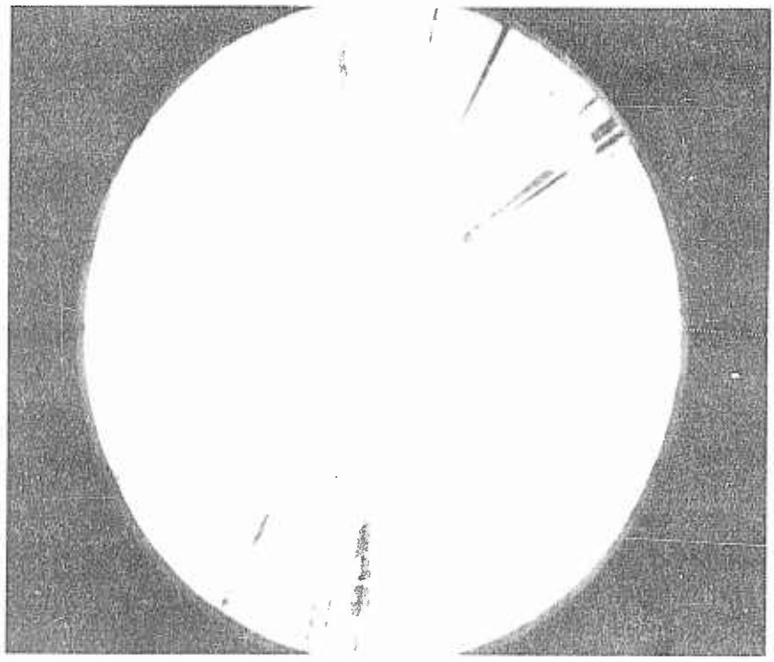


Figure 20. PPI Presentation of Severe Jamming, Test 6

The test results show that the AN/TPQ-8 is effective in jamming GCA radar. In the first phase reasonably accurate altitude information was obtained from the GCA radar, but only when the azimuth was made known. A second quadradar was used to provide this azimuth information. It was impossible for the jammed GCA to track the aircraft without using the azimuth information furnished by the second, unjammed radar to obtain altitude information. The GCA radar was denied all azimuth information as a result of the jamming.

UNCLASSIFIED Photograph

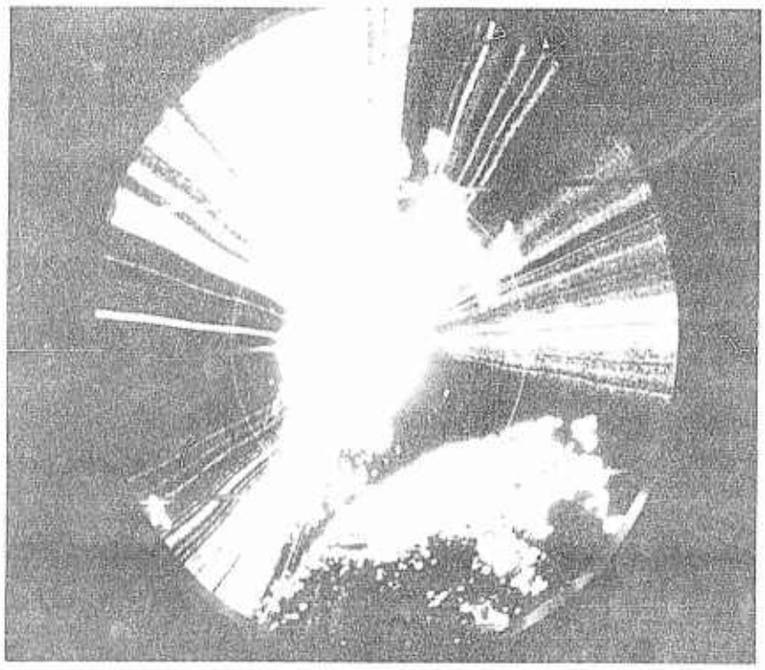


Figure 21. PPI Presentation of Moderate Jamming, Test 6

During the second phase it was found that the jammed GCA radar could not control the aircraft at ranges beyond six miles, but could with difficulty control the aircraft from a distance of six miles to point of landing. The second, unjammed radar was used to establish control from a distance of 15 miles to 6 miles; and the jammed GCA radar was used to establish control from a distance of 6 miles to point of landing.

Test data are tabulated in Annex A, and scope presentations of various conditions of interference are shown in figures 24 and 25. Horizontal and vertical scope presentations of final approach information are shown in figures 26, 27, 28, and 29.

UNCLASSIFIED Photograph

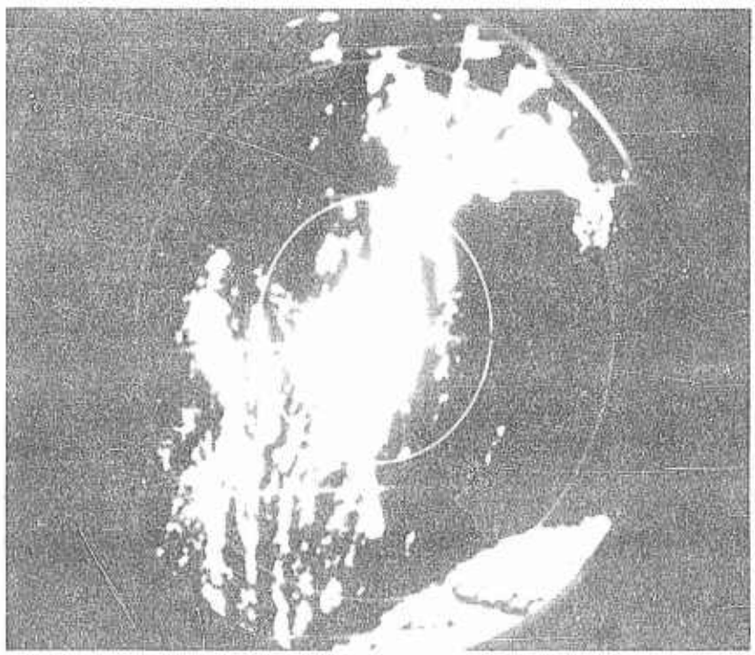


Figure 22. PPI Normal Presentation of No Jamming, Test 6

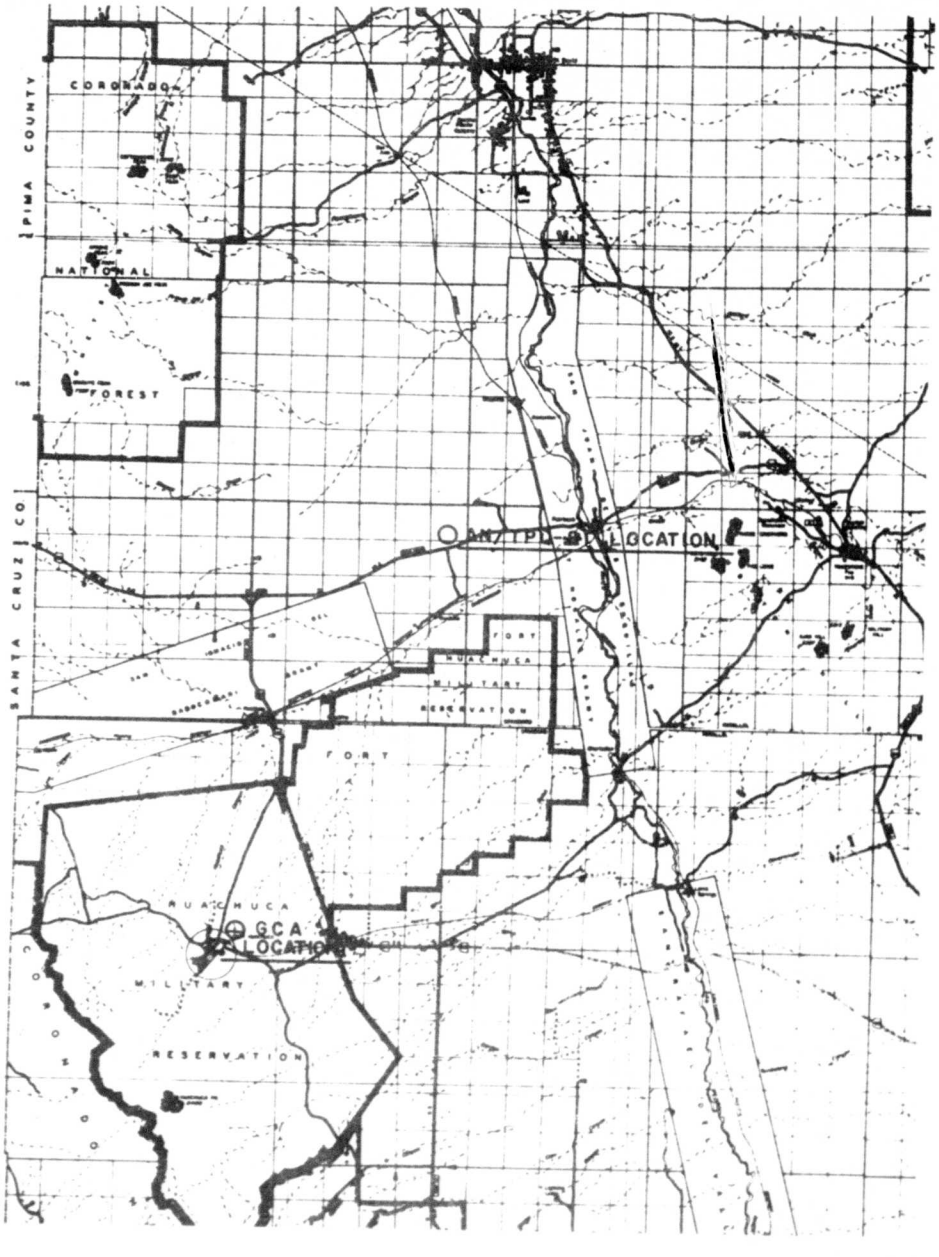


Figure 23. Equipment Locations for Test 7

14. TEST 8: JAMMING EFFECTS OF AN/TPQ-8 ON COMBAT SURVEILLANCE RADAR

This test was conducted to determine the effectiveness of the AN/TPQ-8 as a jammer of X-band combat surveillance radar.

Equipments used for this test were the Radar Set AN/TPQ-8 and the Radar Set AN/TPS-21. A unique, moving target-detection system was used in which audible amplitude modulations located in the receiver component were used as detection signals.

UNCLASSIFIED Photograph

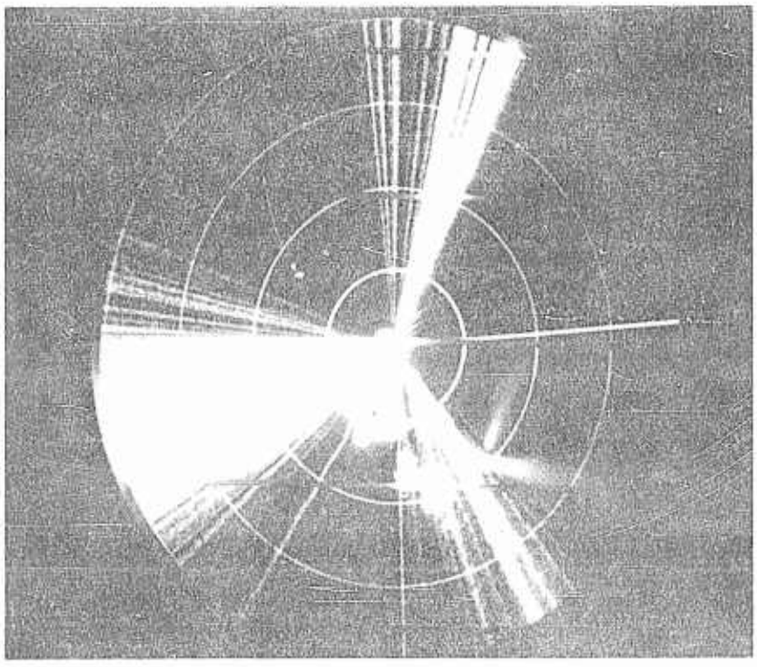


Figure 24. PPI Presentation of Moderate Overall Jamming and Severe Sectional Jamming, Test 7

Locations of the equipment are illustrated in figure 30. The AN/TPS-21 was located at coordinates 606924. The AN/TPQ-8 was set up in two separate locations: 8,000 yards from the AN/TPS-21 and 15,000 yards from the AN/TPS-21 at a point 5.8 miles east of the junction of the Tombstone and Nogales, Arizona, highways.

UNCLASSIFIED Photograph

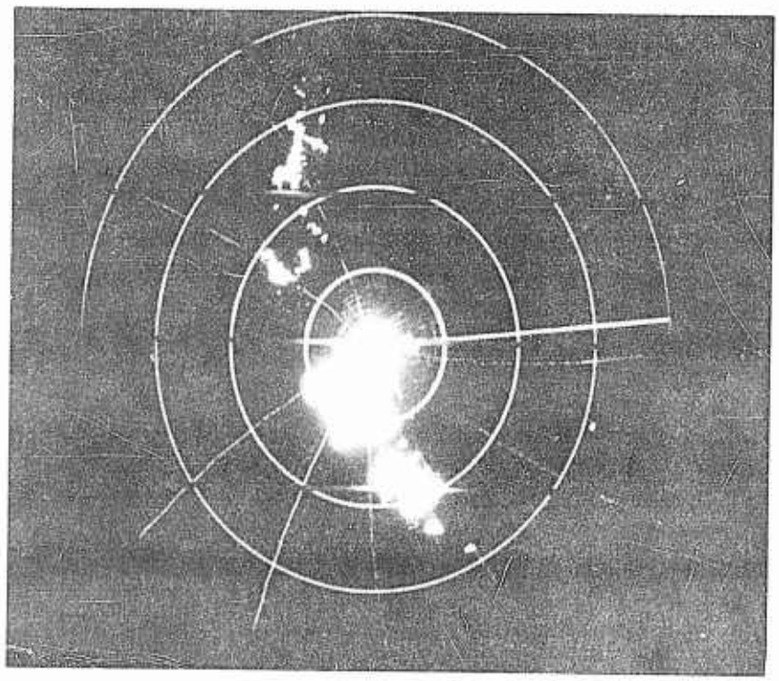
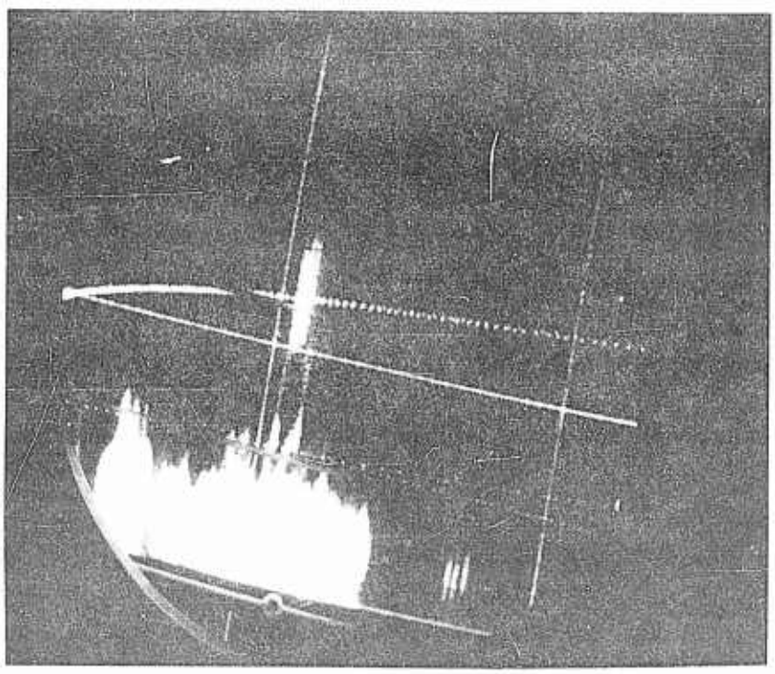


Figure 25. PPI Presentation of No Jamming, Test 7

UNCLASSIFIED Photograph

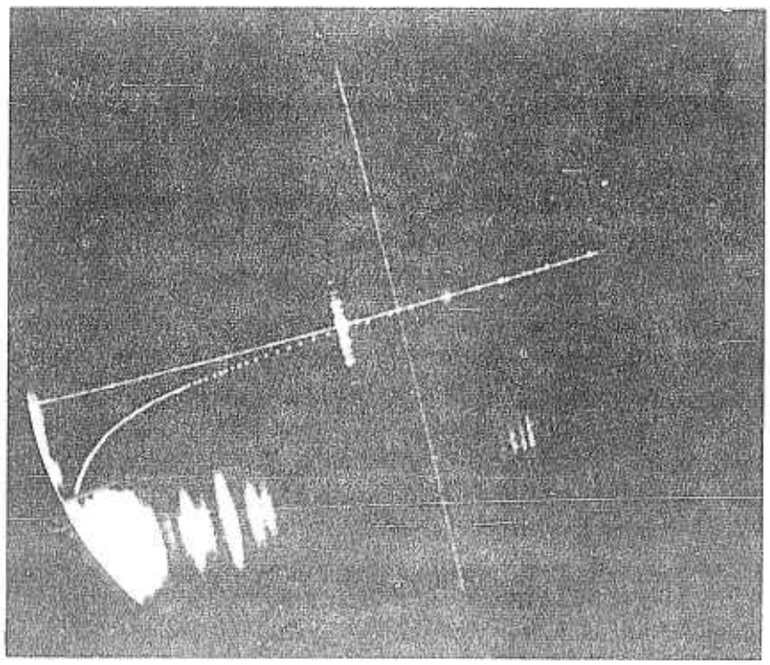


Legend:

Curved line indicates on-course path
Pips on curved line indicate aircraft
Vertical line indicates 2-mile range markers

Figure 26. Vertical Scope Presentation of Final Approach Information, Test 7

UNCLASSIFIED Photograph

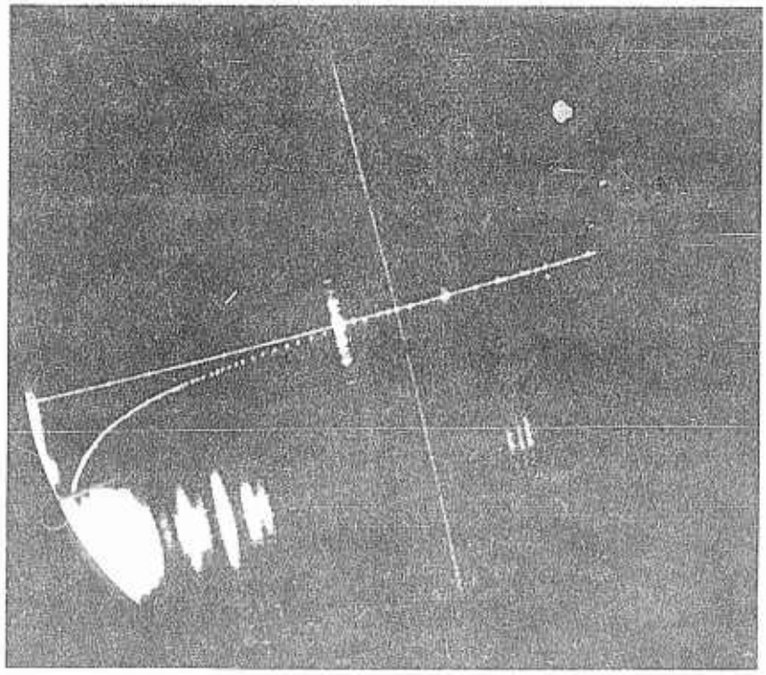


Legend:

Curved line indicates on-course path
Pips on curved line indicate aircraft
Vertical line indicates 2-mile range markers

Figure 27. Horizontal Scope Presentation of Final Approach Information, Test 7

UNCLASSIFIED Photograph

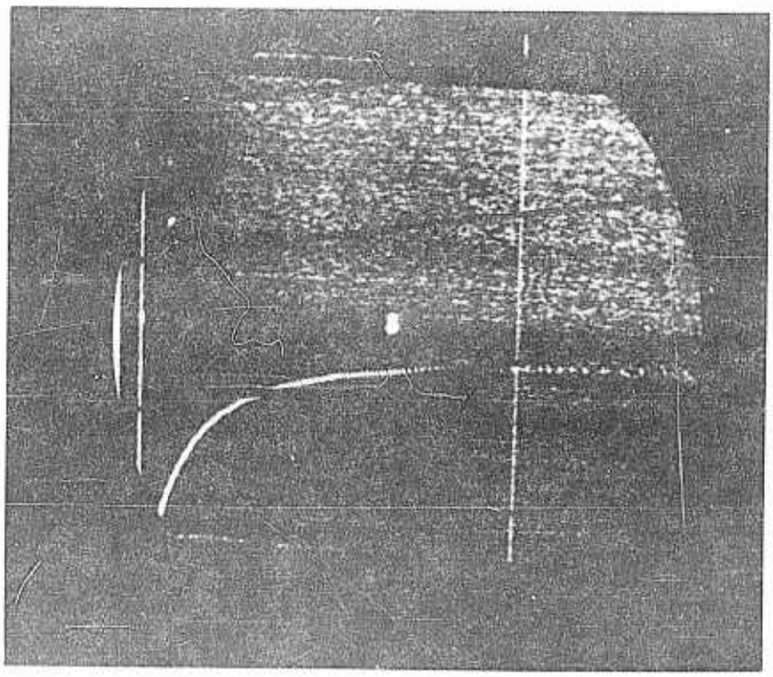


Legend:

Curved line indicates on-course path
Pips on curved line indicate aircraft
Vertical line indicates 2-mile range markers

Figure 28. Vertical Scope Presentation of Final Approach Information, Test 7

UNCLASSIFIED Photograph



Legend:

Curved line indicates on-course path
Pips on curved line indicate aircraft
Vertical line indicates 2-mile range markers

Figure 29. Horizontal Scope Presentation of Final Approach Information, Test 7

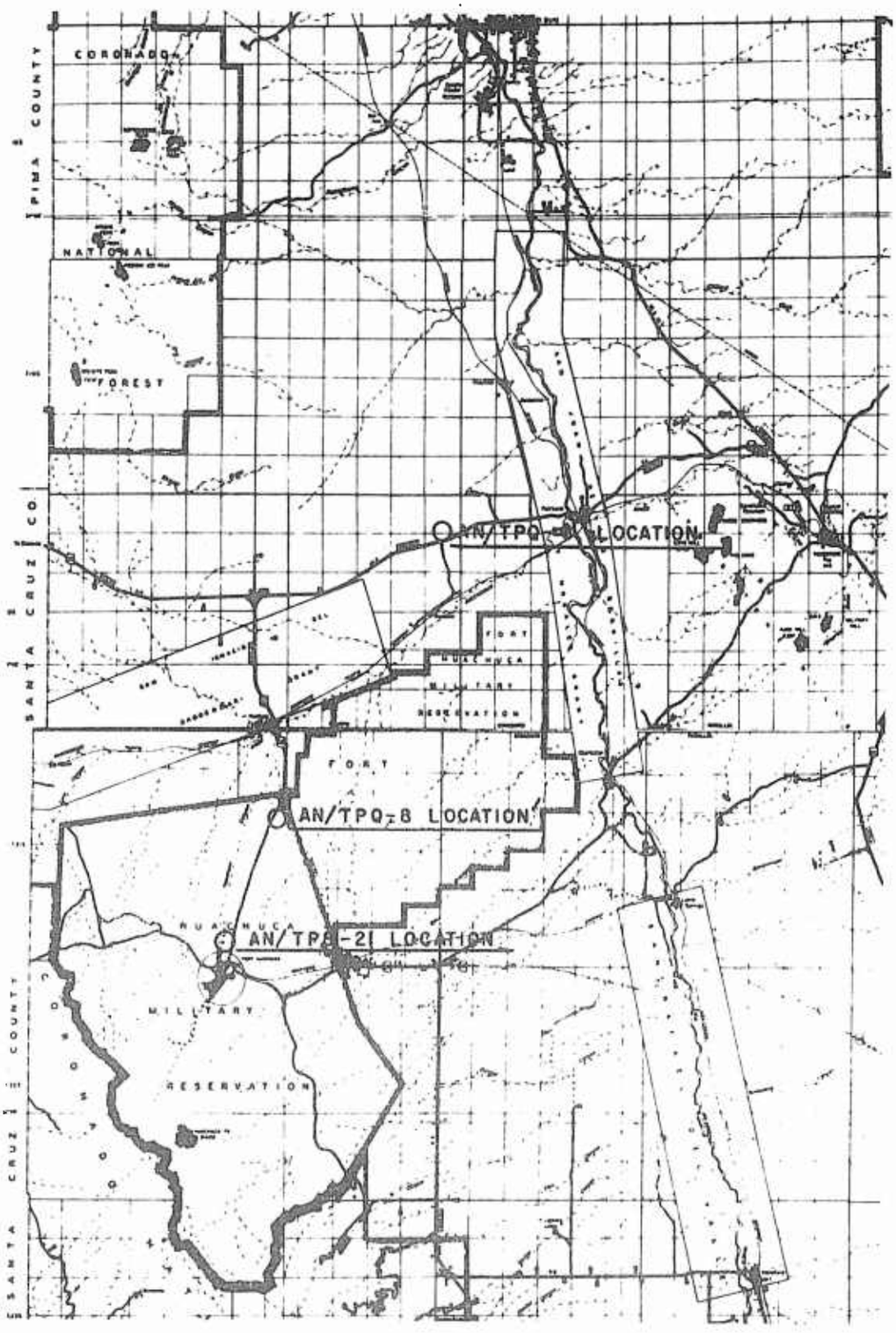


Figure 30. Equipment Locations for Test 8

The test procedure was as follows: Radar-to-target distance remained constant at 5,000 yards for all phases of the test. The jammer-to-radar distances were 8,000 and 15,000 yards.

The effectiveness of the AN/TPQ-8 in jamming the AN/TPS-21 is dependent upon the size and range of the target. At a jammer-to-radar distance of 8,000 yards only signals from targets closer than 1,000 yards were detected by the AN/TPS-21. When the jammer-to-radar distance was increased to 15,000 yards, the jamming completely eliminated the return for a two and one-half ton truck target at 5,000 yards. Targets of average automobile size were followed out to 2,000 yards at which point they were lost because of the jamming.

15. TEST 9: EFFECTS OF AN/TPQ-8 INTERFERENCE TO A TARGET TRACKING RADAR LOCATED IN DEFILADE

This test was conducted to find out the conditions under which the AN/TPQ-8 could introduce interference into a target tracking radar located in defilade.

Equipments used for the test were the Radar Set AN/TPQ-8 and the Target Tracking Radar (TTR) component of the M-33 Fire Control System.

Locations of the equipment are illustrated in figure 31. For part 1 of the test the M-33 was located at coordinates 813911 near Arizona State Highway 90. The AN/TPQ-8 was located at coordinates 741911 near Arizona State Highway 90. The equipments were 8,000 yards apart at approximately the same elevation with a low hill 100 feet high between the two locations. For part 2 of the test the M-33 was located at coordinates 823911 and the AN/TPQ-8 was located at coordinates 751911. The equipments were 8,000 yards apart at approximately the same elevation with a low hill 100 feet high between the two locations.

The test procedure was as follows: For part 1 of the test the M-33 was placed so that the angle between the line-of-sight of the TTR and top of the defilade was approximately 50 mils. The TTR was operating at 9,300 Mc/s with a high voltage of 7.8 kilovolts at 44 milliamperes and a magnetron current of 5.8 milliamperes. The magnetron voltage of the AN/TPQ-8 was five kilovolts at 300 milliamperes. The TTR azimuth was 4,600 mils and the AN/TPQ-8 azimuth was 1,400 mils. The AN/TPQ-8 attempted to detect the TTR signal under various elevations and azimuth settings of the TTR antenna. The AN/TPQ-8 failed to receive any signal from the TTR during this part of the test.

For part 2 of the test the entire procedure was repeated with the separation between the AN/TPQ-8 and TTR maintained at 8,000 yards and the angle of elevation between equipments set at less than 10 mils.

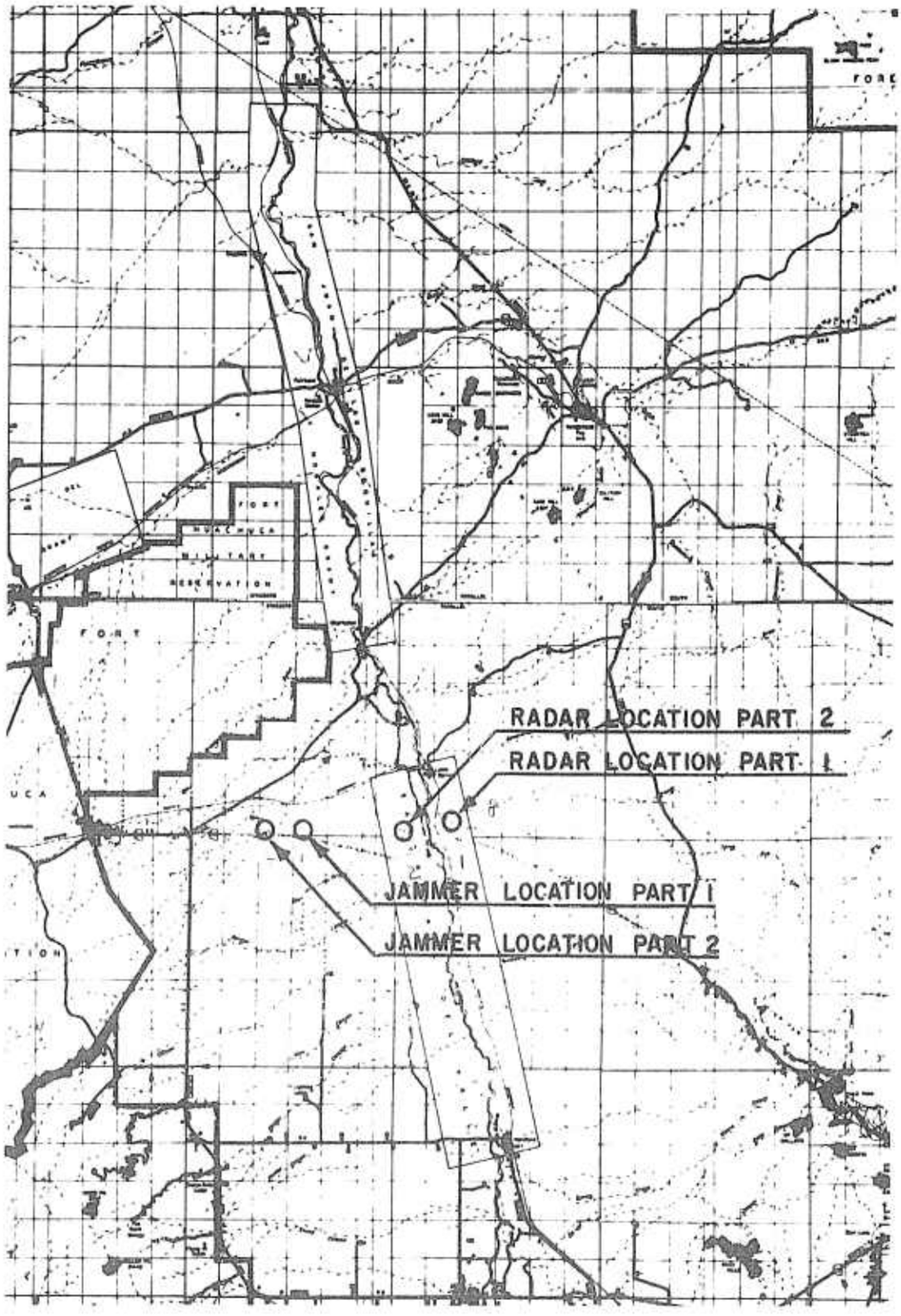


Figure 31. Equipment Locations for Test 9

The TTR azimuth and the AN/TPQ-8 azimuth were toward each other. The AN/TPQ-8 failed to detect any signal from the TTR, and the TTR failed to detect any signal from the AN/TPQ-8 during this part of the test. The AN/TPQ-8 was unable to cause any condition of jamming on the TTR scopes.

The tests illustrate that a ground-based jammer requires line-of-sight conditions to jam a ground-based radar.

16. TEST 10: USE OF TARGET TRACKING RADAR TO DETERMINE THE AZIMUTH OF THE AN/TPQ-8

This test was conducted to determine the direction-finding (D/F) effectiveness of a victim radar against the AN/TPQ-8.

Equipments used for the test were the Radar Set AN/TPQ-8 and the Target Tracking Radar (TTR) component of the M-33 Fire Control System for the first phase and the T-9 radar component of the T-38 Fire Control System for the second phase.

Locations of the equipment are illustrated in figure 32. The M-33 was located on relatively flat terrain at coordinates 625966 and the AN/TPQ-8 was located at a distance of 8,000 yards at coordinates 616037. In the second phase of the test the M-33 was replaced by the T-9, but the locations remained the same.

The test procedure was as follows: In phase one of the test the TTR operator was not advised of the location of the AN/TPQ-8, but was required to locate the AN/TPQ-8 by adjusting the TTR antenna until a maximum jamming signal was encountered. This procedure was repeated a total of ten times, after first determining the azimuth of the AN/TPQ-8 from the TTR by optical means.

The azimuth of the AN/TPQ-8 from the TTR, as determined by optical means, was found to be 6,054 mils. The average azimuth, as determined by the ten trials, was 6,058 mils. The variable average error was 4.6 mils (17.7 mils equal one degree).

The next procedure in the first phase of the test required the TTR and the AN/TPQ-8 antennas to be oriented directly toward each other. The AN/TPQ-8 operator then rotated his antenna in azimuth in small steps until jamming was no longer detected on the TTR tracking scope. The sector through which the TTR could detect the AN/TPQ-8 was then divided into five positions, and the previous procedure was repeated at each position. The azimuth from the TTR to the AN/TPQ-8 remained at 6,058 mils.

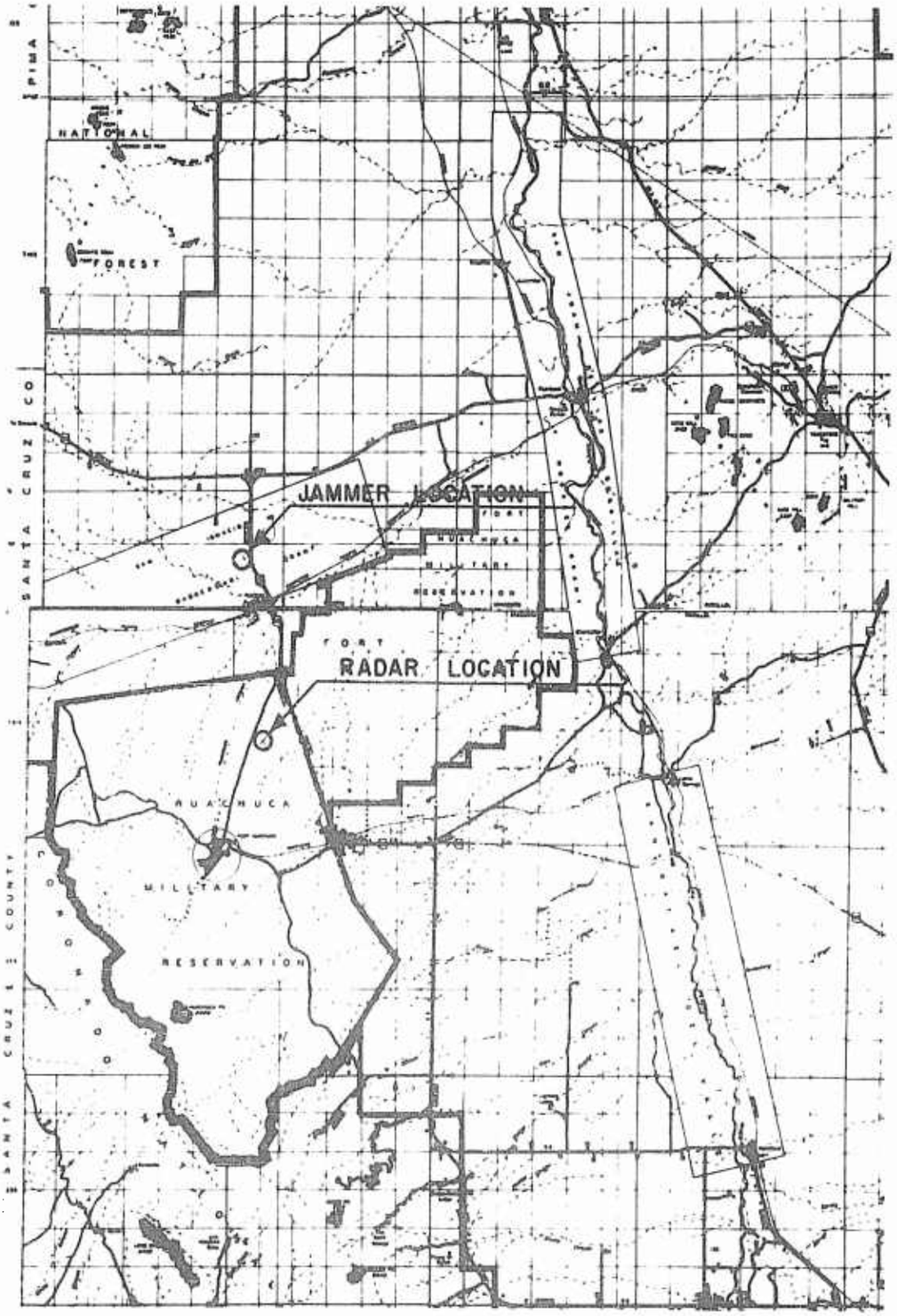


Figure 32. Equipment Locations for Tests 10 and 11

The jammer antenna was rotated to different azimuth positions from 6,054 mils to 3,654 mils in five steps. The azimuth readings obtained by the TTR for these five azimuth positions of the AN/TPQ-8 antenna had an average value of 6,048 mils. The azimuth of the AN/TPQ-8 was determined with equal accuracy regardless of the AN/TPQ-8 lobe detected.

In phase two of the test the M-33 was replaced by the T-9 radar. The T-9 was operated in PPI mode and the first part of the test procedure of phase one of the test was repeated. The azimuth from the T-9 to the AN/TPQ-8, as determined by optical means, was 6,054 mils. Ten azimuth readings were taken by the T-9. The average of these readings was 6,095 mils, an average error of 46 mils.

The capability of a TTR to determine the azimuth of an AN/TPQ-8 is dependent on the technical characteristics of the TTR. The results of the test show that the M-33 was able to determine the azimuth of the AN/TPQ-8 with an average error of 4 mils, but the T-9 radar recorded an average error of 46 mils. The AN/TPQ-8 antenna azimuth relative to the TTR did not affect the accuracy of the azimuth determination by the M-33. Accurate location of an AN/TPQ-8 position can be successfully obtained by a triangulation process involving two or more radars which were in line-of-sight to the AN/TPQ-8 position.

Test data are tabulated in Annex A.

17. TEST 11: D/F EFFECTIVENESS OF THE AN/TPQ-8 AGAINST AN X-BAND RADAR

This test was conducted to determine the effectiveness of the AN/TPQ-8 in detecting the azimuth of an X-band radar.

Equipments used for the test were the Radar Set AN/TPQ-8 and the M-33 Fire Control System for the first phase and the T-9 radar component on the T-38 Fire Control System for the second phase.

Locations of the equipment are illustrated in figure 32. The M-33 was located on relatively flat terrain at coordinates 625966 and the AN/TPQ-8 was located at a distance of 8,000 yards at coordinates 616037. In the second phase of the test the M-33 was replaced by the T-9, but the locations remained the same.

The test procedure was as follows: In phase one of the test the M-33 antenna was directed at the AN/TPQ-8 and was set at an elevation of approximately 300 mils. The AN/TPQ-8 was aligned with a compass so that azimuth readings of its antenna could be accurately compared with the true azimuth to the M-33.

The AN/TPQ-8 was first tuned to the frequency of the M-33. The AN/TPQ-8 operator attempted six trial azimuths, by observing the received signal to determine the azimuth. Two operators were used during the test, each operator attempting six azimuth determinations. The AN/TPQ-8 azimuth to the M-33, as measured by a compass, was determined to be 2,854 mils. The first operator determined the azimuth to be 2,841.6 mils, the result of averaging his six readings. The variation for these readings was plus 18.4 mils and minus 41.6 mils. The second operator determined the azimuth to be 2,824.1 mils, the result of averaging his six readings. The variation for these readings was plus 35.9 mils and minus 44.1 mils.

The second phase of the test repeated the procedure used for the first phase replacing the M-33 by the T-9. The azimuth from the AN/TPQ-8 to the T-9 remained at 2,854 mils. The average azimuth determined by the first operator was 3,074 mils with a variation of plus 82 mils and minus 174 mils. The average azimuth determined by the second operator was 2,992.5 mils with a variation of plus 107.5 mils and minus 92.5 mils. Variation is a result of operator skill and experience with target radar antenna characteristics.

The results of this test show that the AN/TPQ-8 was able to obtain azimuth information on the M-33 with an average error of 21 mils using two operators. This is considered to be good accuracy for ground-based D/F. The AN/TPQ-8 was able to obtain azimuth information on the T-9 with an average error of 179 mils using two operators. This error value is approximately 10 degrees.

The signal source radiated from the M-33 was a fixed signal source. The signal source radiated from the T-9 was not fixed, because the T-9 was operated in search mode and its antenna was simultaneously changing azimuth and elevation. This accounts for the lesser degree of accuracy obtained in attempting to determine the azimuth of the T-9 as compared to that determined for the M-33.

The accuracy depends on the skill of the AN/TPQ-8 operator. The operators used in this test were considered to be average, and the test results are considered to be typical for field operation.

Under the conditions of this test, an AN/TPQ-8 can determine the azimuth of a radar to within an average error of 10 degrees. This accuracy is marginal for the control of the jammer. This accuracy would not be sufficient to attempt D/F for artillery or other weapon use against the target radar, except possibly for a homing missile.

Test data are tabulated in Annex A.

Section V. Conclusions

18. The effectiveness of the AN/TPQ-8 against M-33 tracking radar was as follows:

a. TTR operating frequency but not polarization or PRF could be determined.

b. At distances of 5,000 and 30,000 yards the jamming caused severe scope interference when the AN/TPQ-8 antenna was at zero degrees elevation and orientated toward the M-33.

c. Interference resulting from AN/TPQ-8 radiations was significant only when the AN/TPQ-8 was operating on the M-33 frequency.

d. The AN/TPQ-8 was unable to effectively jam the M-33 when variable frequency operation was used by the M-33.

e. At jammer-to-radar ranges of 8,000 yards and 20 miles, with the M-33 operating on a constant frequency, it was found that the jamming prevented the M-33 from tracking an L-20 aircraft beyond 14,000 yards.

19. The effectiveness of the AN/TPQ-8 against the T-9 radar of the T-38 AA Fire Control System is as follows:

a. At jammer-to-radar ranges of 5,000 and 10,000 yards the AN/TPQ-8 caused serious interference to the T-9 at all antenna elevations of the AN/TPQ-8.

b. The AN/TPQ-8 caused serious interference when operating 30 Mc/s below to 95 Mc/s above the T-9 frequency.

c. The AN/TPQ-8 caused the T-9 to break track on the L-20 aircraft target varying in range from 1,000 to 15,000 yards, when the jammer-to-radar distance was 5,000 and 15,000 yards. Once track was broken the T-9 was unable to re-acquire the target because of the jamming.

20. The effectiveness of the AN/TPQ-8 against the Gilfillan GCA Quadradar, Model MK IV, was as follows:

a. At jammer-to-radar ranges up to 30,000 yards (the maximum tested) the AN/TPQ-8 was able to effectively prevent the GCA from controlling the L-20 aircraft target in a traffic pattern beyond a radius of six miles.

b. At a jammer-to-radar distance of 30,000 yards the AN/TPQ-8 was ineffective in preventing the Quadradar from controlling L-20 aircraft target within a radius of six miles of the radar, provided the target azimuth is known.

21. The AN/TPQ-8 was not capable of detecting or jamming a radar located in defilade, because line-of-sight conditions are necessary for effective jamming.

22. The AN/TPQ-8 can accurately determine the azimuth of a TTR. The accuracy depends on the skill of the AN/TPQ-8 operator and his knowledge of the technical characteristics of the TTR set.

23. The accuracy with which a radar can determine the azimuth of an AN/TPQ-8 is not affected by the orientation of the jammer antenna.

24. The average accuracy with which an AN/TPQ-8 can determine the azimuth of a TTR varies from an error of 21 mils for a signal of fixed intensity to an error of 179 mils for a signal of varying intensity.

25. The accuracy with which the AN/TPQ-8 can determine the azimuth of a radar is marginal to direct jamming by the AN/TPQ-8.

26. The accuracy of the AN/TPQ-8 in determining the azimuth of a radar is dependent upon the skill of the AN/TPQ-8 operator.

ANNEX A

Tabulation of Test Data

for

Radar Set AN/TPQ-8

I. Test 1 Test Data:

1. Range: 5,000 yards

M-33 Antenna Elevation: 800 mils

a. M-33 Azimuth Toward AN/TPQ-8

	Frequency	Polarization	PRF
M-33	9100 Mc/s	Circular	1000 pps
AN/TPQ-8 Report	9100 Mc/s	Undeter-minable	Undeterminable

b. M-33 Azimuth 90° Clockwise from AN/TPQ-8

	Frequency	Polarization	PRF
M-33	9300 Mc/s	Circular	1000 pps
AN/TPQ-8 Report	9350 Mc/s	Undeter-minable	Undeterminable

c. M-33 Azimuth 90° Counterclockwise from AN/TPQ-8

	Frequency	Polarization	PRF
M-33	9600 Mc/s	Circular	1000 pps
AN/TPQ-8 Report	9575 Mc/s	Undeter-minable	Undeterminable

2. Range: 8,000 yards

M-33 Antenna Elevation: 800 mils

a. M-33 Azimuth Toward AN/TPQ-8

	Frequency	Polarization	PRF
M-33	9100 Mc/s	Circular	1000 pps
AN/TPQ-8 Report	9125 Mc/s	Undeter-minable	Undeterminable

b. M-33 Azimuth 90° Clockwise from AN/TPQ-8

	Frequency	Polarization	PRF
M-33	9300 Mc/s	Circular	1000 pps
AN/TPQ-8 Report	9310 Mc/s	Undetermin-able	Undeterminable

c. M-33 Azimuth 90° Counterclockwise from AN/TPQ-8

	Frequency	Polarization	PRF
M-33	9600 Mc/s	Circular	1000 pps
AN/TPQ-8 Report	9510 Mc/s	Undetermin-able	Undeterminable

Test 2 Test data:

1. Range: 5,000 yards

TTR (M-33) Antenna Elevation: 800 mils

a. TTR (M-33) Azimuth toward AN/TPQ-8

Frequency (Mc/s)		AN/TPQ-8 Antenna Elevation (mils)					Remarks
TTR (M-33)	AN/TPQ-8	0	400	800	1200	1600	
9100	9100	Severe	Moder-ate	Moder-ate	Moder-ate	Moder-ate	Scanner on
9600	9600	Severe	Moder-ate	Moder-ate	Moder-ate	Moder-ate	Scanner on
9300	9300	Severe	Moder-ate	Moder-ate	Moder-ate	Moder-ate	Scanner on
9300	9302	Severe	Slight	Slight	Slight	Slight	Scanner off
9300	9304	Severe	Slight	Slight	Slight	Slight	Scanner off
9300	9315	Slight	Slight	Slight	Slight	Slight	Scanner on
9300	9310	Severe	Slight	Slight	Slight	Slight	Scanner on

Frequency (Mc/s)		AN/TPQ-8 Antenna Elevation (mils)					Remarks
TTR (M-33)	AN/TPQ-8	0	400	800	1200	1600	
9300	9290	Severe	Slight	Slight	Slight	Slight	
9300	9285	Slight	Slight	Slight	Slight	Slight	
9300	9288	Moder-ate	Moder-ate	Slight	Slight	Slight	
8500	9075	Slight	Slight	Slight	Slight	Slight	

b. TTR (M-33) Azimuth 90° Counterclockwise from AN/TPQ-8

Frequency (Mc/s)		AN/TPQ-8 Antenna Elevation (mils)					Remarks
TTR (M-33)	AN/TPQ-8	0	400	800	1200	1600	
9100	9100	Severe	Slight	Slight	Slight	Slight	None
9600	9600	Severe	Slight	Slight	Slight	Slight	
9300	9300	Severe	Slight	Slight	Slight	Slight	
9300	9310	Severe	Slight	Slight	Slight	Slight	
9300	9305	Slight	Slight	Slight	Slight	Slight	

c. TTR (M-33) Azimuth 90° Clockwise from AN/TPQ-8

Frequency (Mc/s)		AN/TPQ-8 Antenna Elevation (mils)					Remarks
TTR (M-33)	AN/TPQ-8	0	400	800	1200	1600	
9100	9100	Severe	Slight	Slight	Slight	Slight	None
9600	9600	Severe	Slight	Slight	Slight	Slight	
9300	9300	Severe	Slight	Slight	Slight	Slight	
9300	9304	Severe	Slight	Slight	Slight	Slight	
9300	9305	Slight	Slight	Slight	Slight	Slight	

2. Range: 30,000 yards

TTR (M-33) Antenna Elevation: 800 mils

a. TTR (M-33) Azimuth Toward AN/TPQ-8

Frequency (Mc/s)		AN/TPQ-8 Antenna Elevation (mils)					Remarks
TTR (M-33)	AN/TPQ-8	0	400	800	1200	1600	
9100	9100	Slight	Slight	Slight	Slight	Slight	None
9600	9600	Slight	Slight	Slight	Slight	Slight	
9300	9300	Moderate	Moderate	Moderate	Moderate	Moderate	
9300	9305	Severe	Moderate	Moderate	Moderate	Moderate	
9300	9307	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate condition is marginal; almost severe.
9300	9308	Moderate	Moderate	Moderate	Moderate	Moderate	
9300	9295	Moderate	Slight	Slight	Slight	Slight	
9300	9285	Slight	Slight	Slight	Slight	Slight	
8500	9075	Slight	Slight	Slight	Slight	Slight	

b. TTR (M-33) Azimuth 90° Counterclockwise from AN/TPQ-8

Frequency (Mc/s)		AN/TPQ-8 Antenna Elevation (mils)					Remarks
TTR (M-33)	AN/TPQ-8	0	400	800	1200	1600	
9100	9100	Slight	Slight	Slight	Slight	Slight	None
9600	9600	Slight	Slight	Slight	Slight	Slight	
9300	9300	Slight	Slight	Slight	Slight	Slight	

Frequency (Mc/s)		AN/TPQ-8 Antenna Elevation (mils)					Remarks
TTR (M-33)	AN/TPQ-8	0	400	800	1200	1600	
9300	9305	Severe	Moder-ate	Moder-ate	Moder-ate	Moder-ate	
9300	9307	Moder-ate	Moder-ate	Moder-ate	Moder-ate	Moder-ate	
9300	9308	Moder-ate	Moder-ate	Moder-ate	Moder-ate	Moder-ate	

c. TTR (M-33) Azimuth 90° Clockwise from AN/TPQ-8

Frequency (Mc/s)		AN/TPQ-8 Antenna Elevation (mils)					Remarks
TTR (M-33)	AN/TPQ-8	0	400	800	1200	1600	
9100	9100	Slight	Slight	Slight	Slight	Slight	None
9600	9600	Slight	Slight	Slight	Slight	Slight	
9300	9300	Moder-ate	Slight	Slight	Slight	Slight	
9300	9305	Severe	Moder-ate	Moder-ate	Moder-ate	Moder-ate	
9300	9307	Severe	Severe	Moder-ate	Moder-ate	Moder-ate	
9300	9308	Moder-ate	Moder-ate	Moder-ate	Moder-ate	Moder-ate	

III. Test 3 Test Data:

1. Flight Path Nr 1

Range: 8,000 yards

Frequency: 9300 Mc/s

Flight	Time Track Established	Time Jamming Started	Time Track Lost	Time Track Regained
I	13:30	13:32	13:32	Not regained
II	13:35	13:36	Not Lost	

Note: Tracking at close range with no jamming.

Flight	Time Track Established	Time Jamming Started	Time Track Lost	Time Track Regained
III	13:49	13:50	13:50	13:52
IV	14:05	14:06	14:06	14:07
V	14:19	14:19 30/60	14:20 15/60	14:21 30/60

Note: Lost at 16,000 yards range, regained at 14,000 yards range and not lost again.

VI	14:34	14:35	14:35 30/60	

Note: In cases where track was regained the radar was put into manual control and kept in the optical track and then switched back to automatic.

Note: Jamming did not cause track loss at less than 14,000 yards range.

2. Flight Path Nr 1

Range: 8,000 yards

Frequencies: 9,100; 9,300; 9,600 Mc/s

Note: Three flights were made. Each time interference was indicated in the M-33 tracking scope the M-33 shifted frequency and, as a result, the track was never broken.

3. Flight Path Nr 2

Range: 8,000 yards

Frequency: 9,300 Mc/s for Flights I, II, and III

Frequencies: 9,100; 9,300; 9,600 Mc/s for Flights IV, V, and VI

Flight	Time Track Established	Time Jamming Started	Time Track Lost	Time Track Regained
I	10:25	10:26	10:26	No
II	10:36	10:37	10:37	No
III	10:46	10:49	10:49	No
IV	10:57	See Note		Yes
V	11:05	See Note		Yes
VI	11:16	See Note		Yes

Note: Frequency changed 10 to 12 times each flight for Flights IV, V, and VI and the target was lost 3 times each flight, but was regained shortly thereafter.

4. Flight Path Nr 3

Range: 20 miles

Flight	Time Track Established	Time Jamming Started	Time Track Lost	Regained
I	14:30	14:32 50/60	14:33 5/60	No
II	14:45	14:46	14:46 25/60	No
III	14:53	14:57 20/60	14:57 40/60	No

Note: First runs were at 9,300 Mc/s. After 60 seconds of trying to regain track, the frequency changed to 9,100 Mc/s and 9,600 Mc/s, and the AN/TPQ-8 failed to cause the M-33 to break track. There was a minimum of three frequency changes per run.

5. Flight Path Nr 4

Range: 20 miles

Flight	Time Track Established	Time Jamming Started	Time Track Lost	Regained
I	15:15	15:18 6/60	15:18 15/60	No
II	15:31	15:32 30/60	15:32 40/60	No
III	15:40	15:41 50/60	15:41 55/60	No

Note: First runs were made at 9,300 Mc/s. After 60 seconds of trying to regain track, the frequency changed to 9,600 Mc/s and 9,100 Mc/s and the AN/TPQ-8 failed to cause the M-33 to break track. There was a minimum of three frequency changes per run.

IV. Test 4 Test Data:

1. Range: 5,000 yards

T-9 Elevation: 800 mils

Frequency (Mc/s)		AN/TPQ-8 Antenna Elevation (mils)				
T-9	AN/TPQ-8	0	400	800	1200	1600
9339	9339	Severe	Moderate	Slight	Slight	Slight
9339	9349	Moderate	Slight	Slight	Slight	Slight
9339	9359	Moderate	Moderate	Slight	Slight	Slight

Note: Jamming ceases at 9419 Mc/s (upper) 9309 Mc/s (lower).

2. Range: 10,000 yards

T-9 Elevation: 800 mils

Frequency (Mc/s)		AN/TPQ-8 Antenna Elevation (mils)				
T-9	AN/TPQ-8	0	400	800	1200	1600
9340	9340	Severe	Severe	Severe	Severe	Severe
9340	9390	Severe	No Data	No Data	No Data	No Data
9340	9415	Severe	No Data	No Data	No Data	No Data
9340	9425	Severe	No Data	No Data	No Data	No Data

Note: Top limit of jamming was at 95 Mc/s above operating frequency, and bottom limit of jamming was at 20 Mc/s below operating frequency.

V. Test 5 Test Data:

1. Range: 5,000 yards

a. Flight Path Nr 5

Flight	Time Target Acquired	Time Jamming Started	Time Track Lost	Regained
I	13:53	13:55	13:15	No
II	13:58	14:00	14:00	No
III	14:05	14:06	14:06	No
IV	14:11	14:12	14:12	No
I	No	Continuous	AJ Switch off	
II	No	Continuous	AJ Switch off	
III	Tracked for 15 seconds	Continuous	AJ Switch on	
IV	Tracked for 15 seconds	Continuous	AJ Switch on	

b. Flight Path Nr 6

Flight	Time Target Acquired	Time Jamming Started	Time Track Lost	Regained
I	14:19	14:20	14:20	No
II	14:25	14:26	14:26	No
III	14:33	14:34	14:34	No
IV	14:40	14:41	14:41	No
I	No	Continuous		
II	No	Continuous		

2. Range: 15,000 yards

a. Flight Path Nr 7 (unmodified)

Flight

I Never able to track

II Tracked for 50 seconds when directly overhead

III Tracked for 55 seconds when directly overhead

b. Flight Path Nr 7 (modified)

Flight	Time Target Acquired	Time Jamming Started	Time Track Lost	Regained
I	10:38	10:39	10:39	No
II	10:43	10:44	10:44	No
III	No	Continuous		
IV	No	Continuous		

c. Flight Path Nr 8

Flight	Time Target Acquired	Time Jamming Started	Time Track Lost	Regained
I	10:10	10:11	10:11	No
II	10:14	10:15	10:15	No
III	No	Continuous		
IV	No	Continuous		

VI. Test 6 Test Data:

1. Range: 3,500 yards

a. GCA antenna elevation at 0°

GCA Antenna Polarization	AN/TPQ-8 Polarization Report (degrees)
Vertical	45
Circular	45
Vertical	90
Circular	135
Horizontal	0
Horizontal	0

Note: AN/TPQ-8 could not receive a signal at other than 0° GCA antenna elevation.

b. GCA horizontal antenna elevation 25° with horizontal polarization.

AN/TPQ-8 Antenna Elevation (mils)	Jamming Condition
0 to 400	Severe
800 to 1600	None

c. GCA horizontal antenna elevation 25° with circular polarization.

AN/TPQ-8 Antenna Elevation (mils)	Jamming Condition
0	Severe
400 to 1600	None

d. GCA Frequency: 9200 Mc/s

AN/TPQ-8 Frequency (0° elevation) (Mc/s)	Jamming Condition
9198	Moderate
9196	Severe
9194	Severe
9185	Moderate
9180	Moderate
9170	Severe
9160	Severe
9150	Severe
9205	Severe
9210	Severe
9215	Severe
9220	Moderate
9225	Moderate
9230	Moderate
9235	Moderate
9240	Slight
9245	Slight

2. Range: 15 miles

Frequency: 9,200 Mc/s

GCA antenna elevation 0° and 2°

GCA Antenna	Polarization	Elevation (degrees)	AN/TPQ-8 Polarization Report (degrees)
Vertical	Vertical	0	90
	Circular	0	45
	Vertical	0	90
Horizontal	Horizontal	2	90
	Circular	2	90
	Horizontal	2	0

Note: AN/TPQ-8 could not receive signals at other than listed elevations of the GCA.

VII. Test 7 Test Data:

1. Target aircraft circling at 15 miles radius from the GCA radar at 10,000 feet altitude.

Azimuth (degree)	Altimeter (feet)	GCA Report (feet)	Horizontal	Vertical
10	10,020	none	Severe	Moderate
80	9,980	none	Severe	Moderate
140	10,000	9,670	Severe	Slight
290	10,000	9,360	Moderate	Slight
320	10,120	9,720	Moderate	Slight

Note: 160° to 250° azimuth information is not available for observation of aircraft because it was behind some mountains.

A second quadradar operating on a different frequency was used to give azimuth information to the jammed quadradar. Without the unjammed radar no height readings would have been obtained.

Aircraft was observed for about 10 per cent of circular path by jammed radar.

2. Target Aircraft making ground controlled approaches.

a. East-west approaches

Note: Jammed GCA radar could not control aircraft from a radius of 6 to 15 miles, so this was done by the unjammed radar.

Jammed GCA radar had good control from a radius of 6 miles to the point of landing.

b. West-east approaches

Note: Jamming in this sector was much more effective than from the other direction, because it hit nearer one of the main lobes of jamming. Aircraft was still controlled but with much more difficulty than on the other run.

Aircraft pilot considered GCA control to be very good. Maximum jamming occurred at 0^{o}, 120^{o}, and 240^{o} with respect to the jammer and maximum jamming could be effected against this type of radar by using two AN/TPQ-8 radars at an angle separation of 60^{o} from the GCA radar.

VIII. Test 10 Test Data:

M-33: Frequency was 9,300 Mc/s; located at coordinates 625966 (weather station); optical determination yielded azimuth of 6054 mils from M-33 to AN/TPQ-8. Optically determined elevation was minus 6 mils. High voltage was 7.7 kv at 42 ma, magnetron current was 5.8 ma.

AN/TPQ-8: Frequency was 9,300 Mc/s; located at coordinates 616037; high voltage 5 kv at 300 ma.

Range: 8,000 yards constant

M-33 D/F Readings on AN/TPQ-8

Trial	D/F Azimuth (mils)	D/F Elevation (mils)	M-33 Polarization Relative to AN/TPQ-8 Polarization (degrees)	Gain*
1	6060	-10	90	Very low
2	6062	-15	90	Very low
3	6062	-13	90	Very low
4	6047	-10	0	Very low
5	6057	-12	Circular	Very low
6	6048	-8	Circular	Very low
7	6062	-6	90	Very low
8	6060	-10	90	Very low
9	6064	-8	90	Very low
10	6060	-14	0	Very low

* Gain control was set to almost minimum value, and the most easily identified D/F readings were made with M-33 polarization at 90 degrees from jammer polarization. A series of jamming peaks occurred on the scope when the M-33 antenna was rotated. The definite maximum peak occurred when antenna was oriented directly at jammer.

D/F READINGS ON AN/TPQ-8 WITH

M-33 (POLARIZATION AT 90° FROM JAMMER POLARIZATION)

	AN/TPQ-8 AZIMUTH 6,054 MILS		AN/TPQ-8 AZIMUTH 5,254 MILS		AN/TPQ-8 AZIMUTH 4,454 MILS		AN/TPQ-8 AZIMUTH 3,654 MILS	
TRIAL	D/F AZIMUTH (MILS)	D/F ELEVATION (MILS)	D/F AZIMUTH (MILS)	D/F ELEVATION (MILS)	D/F AZIMUTH (MILS)	D/F ELEVATION (MILS)	D/F AZIMUTH (MILS)	D/F ELEVATION (MILS)
1	6050	-5	6043	-12	6045	-10	6047	-15
2	6050	-3	6045	-13	6047	-10	6046	-15
3	6078	-40	6045	-18	6047	-10	6052	-5
4	6050	-10	6045	-20	6045	-10	6050	-10
5	6055	-10	6045	-20	6047	-15	6052	-14

T-9: Located at coordinates 625966 (weather station); azimuth to jammer was 6,054 mils; frequency was 9,390 Mc/s; magnetron voltage was 3.5 kv at 13 ma.

AN/TPQ-8: Located at coordinates 616037; frequency was 9,390 Mc/s; magnetron voltage was 5 kv at 300 ma; AN/TPQ-8 azimuth to M-33 was 2,854 mils.

T-9 D/F Readings on AN/TPQ-8

Trial	D/F Azimuth (mils)
1	6100
2	6070
3	6080
4	6120
5	6090
6	6100
7	6100
8	6110
9	6080
10	6100

Beam width was 50 mils of jamming sector. T-9 center of PPI sweep moved off center resulting in incorrect azimuth information.

IX. Test 11 Test Data:

M-33: Located at coordinates 625966 (weather station); high voltage was 7.4 kv at 42 ma; magnetron current was 5.8 ma; azimuth was 6,054 mils, elevation was 8,000 mils.

AN/TPQ-8: Located at coordinates 616037; not transmitting; AN/TPQ-8 azimuth to M-33 was 2,854 mils.

Range: 8,000 yards constant

AN/TPQ-8 D/F Readings on M-33

Trial	Operator 1 D/F Azimuth (mils)	Operator 1 D/F Elevation (mils)	Operator 2 D/F Azimuth (mils)	Operator 2 D/F Elevation (mils)
1	2,850	50	2,800	0
2	2,860	25	2,850	0
3	2,800	40	2,860	0
4	2,840	50	2,780	0
5	2,850	50	2,825	0
6	2,850	0	2,830	0

T-9: Located at coordinates 625966 (weather station); frequency was 9,390 Mc/s; azimuth to jammer was 6,054 mils; magnetron voltage was 3.5 kv at 13 ma.

AN/TPQ-8: Located at coordinates 616037; not transmitting; azimuth to radar was 2,854 mils.

Range: 8,000 yards constant

AN/TPQ-8 D/F Readings on T-9

Trial	Operator 1 D/F Azimuth (mils)	Operator 1 D/F Elevation (mils)	Operator 2 D/F Azimuth (mils)	Operator 2 D/F Elevation (mils)
1	3,140	0	3,100	0
2	3,156	0	3,050	0
3	2,900	0	2,955	0
4	*150	0	2,950	0
5	3,100	0	2,900	0
6	*2,100	0	3,000	0

*Trials 4 and 6 for Operator 1 were in error because the signal was received through minor lobes of the AN/TPQ-8 antenna. Signals received through main lobes were stronger than those received through minor lobes.