TECHNICAL REPORT NO. LWL 74-73

EVALUATION OF THE MULTIPURPOSE FOLIAGE PENETRATION RADAR (M-FOPEN) IN HAWAII

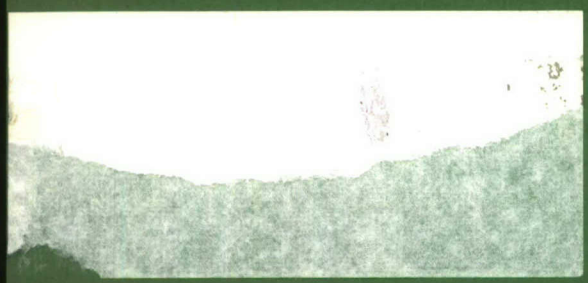
Task 05-P-70

by

Louis V. Surgent, Jr.

May 1974

Final Report



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Aberdeen Proving Ground, Maryland 21005

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This report describes the implementation, procedure, and results of the M-FOPEN Radar conducted by the 25th Infantry Division. The Evaluation (MASSTER Test No. 77) was observed by a representative of MASSTER, Ft.Hood, TX.

Maximum ranges of detection were determined for the M-FOPEN operating in various types of terrain and foliage and probability of detection calculated for each range, target, and foliage combination. These tests demonstrated

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BLOCK 20. ABSTRACT CON'T

the capability of the M-FOPEN to penetrate up to 700 meters of foliage and detect moving targets, with a negligible false alarm rate. A tactical exercise was conducted during which the M-FOPEN and the standard AN/PPS-5 Ground Surveillance Radars were deployed and the detection performance and false alarm rates of each compared. Detection experiments were performed with the M-FOPEN using a helicopter (AH-1G) as the target to determine the doppler signature of the aircraft. These demonstrated that a unique doppler signature does exist for helicopters and that helicopters are detectable using the M-FOPEN even though the path between the radar and the aircraft is blocked by foliage.

As an adjunct to the tactical exercise, the M-FOPEN was deployed in a local town and the radar used to track personnel and vehicles obscured by buildings, power lines, etc.

Appendix B is the 25th Division After Action Report on the evaluation and Appendix C is the Observer Report in the evaluation by MASSTER.

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SUMMARY

This report describes the implementation, procedure, and results of the Multipurpose Foliage Penetration Radar (M-FOPEN) conducted by the 25th Infantry Division. The Evaluation (MASSTER Test No. 77) was observed by a representative of MASSTER, Ft. Hood, TX.

Maximum ranges of detection were determined for the M-FOPEN operating in various types of terrain and foliage, and probability of detection calculated for each range, target, and foliage combination. These tests demonstrated the capability of the M-FOPEN to penetrate up to 700 meters of foliage and detect moving targets, with a negligible false alarm rate. A tactical exercise was conducted during which the M-FOPEN and the standard AN/PPS-5 Ground Surveillance Radars were deployed and the detection performance and false alarm rates of each compared. Detection experiments were performed with the M-FOPEN using a helicopter (AH-1G) as the target to determine the doppler signature of the aircraft. These demonstrated that a unique doppler signature does exist for helicopters and the helicopters are detectable using the M-FOPEN even though the path between the radar and the aircraft is blocked by foliage.

As an adjunct to the tactical exercise, the M-FOPEN was deployed in a local town and the radar used to track personnel and vehicles obscured by buildings, power lines, etc.

To conclude the report, Appendix B is the 25th division After Action Report on the evaluation and Appendix C is the Observer Report in the evaluation by MASSTER.

PREFACE

The User Evaluation of the LWL Foliage Penetration Radar was conducted by the 1st Battalion, 5th Infantry Division, 1st Brigade, 25th Infantry Division, Hawaii, during the period 23 March to 25 April 1973. The success of the evaluation was to a great extent a result of the excellent cooperation of commander of the 1st Battalion, LTC James Thompson, and his staff, including MAJ S. F. Scott Johnson, CPT Richard White, and CPT Wayland Smith.

Testing was observed by MAJ Paul LaBay, MASSTER, Ft. Hood, TX who prepared the observer report included as Appendix C. His assistance from the preliminary test plan preparation through the actual field testing and editing of this report is greatly appreciated. The assistance and hard work of both Mr. Frank Perusich, the contractor's technical representative from Aerospace Research, Inc. and Sergeant Thomas Loughran from the LWL Military Operations Division contributed greatly to the success of the test.

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LWL Hawaii Evaluation Report:
User Evaluation of the Multipurpose Foliage
Penetration Radar (M-FOPEN), MASSTER Test No. 77

1. Introduction:

This report presents the results of the User Evaluation of the LWL Multipurpose Foliage Penetration (M-FOPEN) radar system by the 25th Infantry Division in Hawaii. A copy of the 25th Division After Action Report is included as Appendix B. A representative of MASSTER, Ft. Hood, TX observed the tests and prepared an Observer Report included as Appendix C.

2. General:

a. The 1st Battalion, 5th Infantry, 25th Infantry Division, LTC James L. Thompson commanding, was tasked to accomplish the M-FOPEN user evaluation. The troop element actually performing the evaluation was the Ground Surveillance Section of the Combat Support Company, 1/5th Infantry. The entire assets of the section were committed to this evaluation.

b. The developer, US Army Land Warfare Laboratory (LWL) was represented by Louis V. Surgent, the LWL Project Officer, and SFC Thomas Loughran, Military Operations Division. The civilian contractor, Aerospace Research Incorporated (ARI), Boston, MA was represented by Mr. Frank Perusich. The designated MASSTER observer was MAJ Paul LaBay III.

c. Messrs Surgent, Perusich and SFC Loughran arrived in Hawaii on Thursday, 22 March 1973. The M-FOPEN's and ancillary equipment arrived on Friday, 23 March 1973. The MASSTER Observer arrived in Hawaii on Monday, 26 March 1973. The evaluation began Monday, 26 March, with the Inspection and Inventory Phase and was concluded 30 April with the debriefing of test personnel.

3. Background:

a. With the advent of accelerated US combat activity in RVN, the defense of large logistical installations and remote base camps surrounded by varying degrees of vegetation became a critical operational problem. In September 1966, the US Army Land Warfare Laboratory (LWL) started a program to develop a lightweight, man-portable radar which could detect and locate moving targets obscured by foliage. Emphasis was placed on detection over irregular and densely foliated terrain which precluded the use of conventional micro-wave radar systems. This program resulted in the fabrication of several man-portable VHF radar systems which could detect moving targets in vegetation and automatically provide the operator with the target's range and general direction with respect to the radar. A larger base station radar system was also built which incorporated a high-power amplifier, narrow-beam antenna and "A" scope into the basic man-portable version to increase the system's ranging capability.

b. In December 1969, a feasibility evaluation of a modified man-portable radar was conducted by the POTLID Task Group at the Tropic Test Center, Panama. The system demonstrated a potential as a radar sensor for use in the IGLOO WHITE/DUFFLE BAG program.

c. The Army Concept Team in Vietnam (ACTIV) operationally evaluated the man-portable and base station configurations designated CRCRIST during FY 70. The ACTLV reports, references 1 and 2, concluded that, although both configurations performed as designed in a surveillance role, they were not suitable for operational deployment. Both reports specified the need for an azimuth capability with fairly narrow resolution to provide for target location. Environmental hardening and numerous human engineering changes were also recommended.

d. LWL initiated the current program to correct the shortcomings noted in the ACTIV reports. This has resulted in the development of a basic radar system called the Multipurpose Foliage Penetration Radar (M-FOPEN). The M-FOPEN has three specific implementations: the Man-portable Radar (MPR), the Intermediate Range Radar (IRR), and the Base Station Radar (BSR).

e. Although the eveluation of this radar was originally scheduled for MASSTER at Ft. Hood, TX, a delay in equipment availability and a lack of personnel and suitable test areas at Ft. Hood, Ref 3, prevented MASSTER from testing the FOPEN Radar. On 1 Sep 72, Ref 4, it was proposed to the Commander-in-Chief, US Army Pacific, that a User Evaluation be conducted by the 25th Inf Division, and a proposed evaluation plan was provided. By Ref 5, the 25th Inf Division agreed to perform this evaluation and requested that test area criteria be provided to assist in site selection. These criteria were forwarded in Ref 3, and it was proposed that the LWL Task Officer visit Hawaii to assist in site selection and discuss the conduct of the evaluation. During Feb 73, Mr. L. Surgent of the USA Land Warfare Laboratory visited the 25th Div in Hawaii, assisted in selecting suitable test sites, and revised the proposed evaluation plan to reflect comments received from MASSTER, Ref 7, and support available within the 25th Div. A copy of the revised plan was discussed with MAJ Paul LaBay, MASSTER, at APG during early March and a finalized copy completed.

4. Equipment Description:

a. General Description: The M-FOPEN is a low frequency (VHF) ground-to-ground radar designed to provide the user a foliage independent, all-weather battlefield surveillance capability. It is a coherent, pulse doppler, moving target indicator (MTI) radar, which processes doppler returns with or without fixed returns as a reference. The set incorporates a 60^{o} field-of-view that can be rotated 360^{o} manually or remotely, and a multiple target detection capability.

(1) The M-FOPEN system consists of a basic, low-power, man-portable radar, (Figure 1), with add-on modules which enable it to be used as either an IRR or BSR (Figure 2) in a wide variety of ground surveillance applications. Due to the low operating frequency of the radar, the system is capable of effective performance in any type of vegetation. However, in order to direct the antenna energy near the ground (where the target is), it is necessary to elevate the antenna. Antenna height capability from 30 to 50 feet is provided with each system.

(2) The M-FOPEN system was designed to be issued to the Ground Surveillance Section of the Infantry Battalion. The systems would then be used by regular or unconventional army units in conjunction with other battlefield surveillance and target acquisition equipment in areas where conventional systems are limited by vegetation, weather, terrain, detection range or portability.

b. Major System Components: Appendix A describes the major components of the M-FOPEN Radar.

c. For this evaluation, the IRR was not considered. However, the MPR was used with the AB-577/GRC antenna mast (Figure 3) to extend the range of detection and provided data at different antenna heights.

d. Support Equipment: Test data was automatically recorded on a two-channel Gould Brush 280 chart recorder with manual inputs being directly recorded on the chart as they occur. The data recorded automatically were the output voltages (volts DC) of the inner and outer low velocity range gate integrators. Selected correlated data manually recorded on the chart were controller determined location of the target, operator-determined target location to include azimuth readings as well as selected automatic frequency control (AFC) and automatic gain control (AGC) readings to provide an indication of system sensitivity. Two other devices were used concomitantly to monitor the internal electronic operation of the radar sets (Fig.4). The first was Type 422 TEKTRONIX Oscilloscope used to monitor target video and radar transmitter/receiver (T/R) signals. The other was a test monitor designed by Aerospace Research, Inc and called "FOPEN TEST MONITOR, Model TMI". It provides direct meter readings of the AFC, AGC, as well as the low and high speed integrator voltages for both the inner and outer range gates. This device permits direct monitoring of set sensitivity, internal electronic conditions of the radar, and external environmental conditions of the test area.

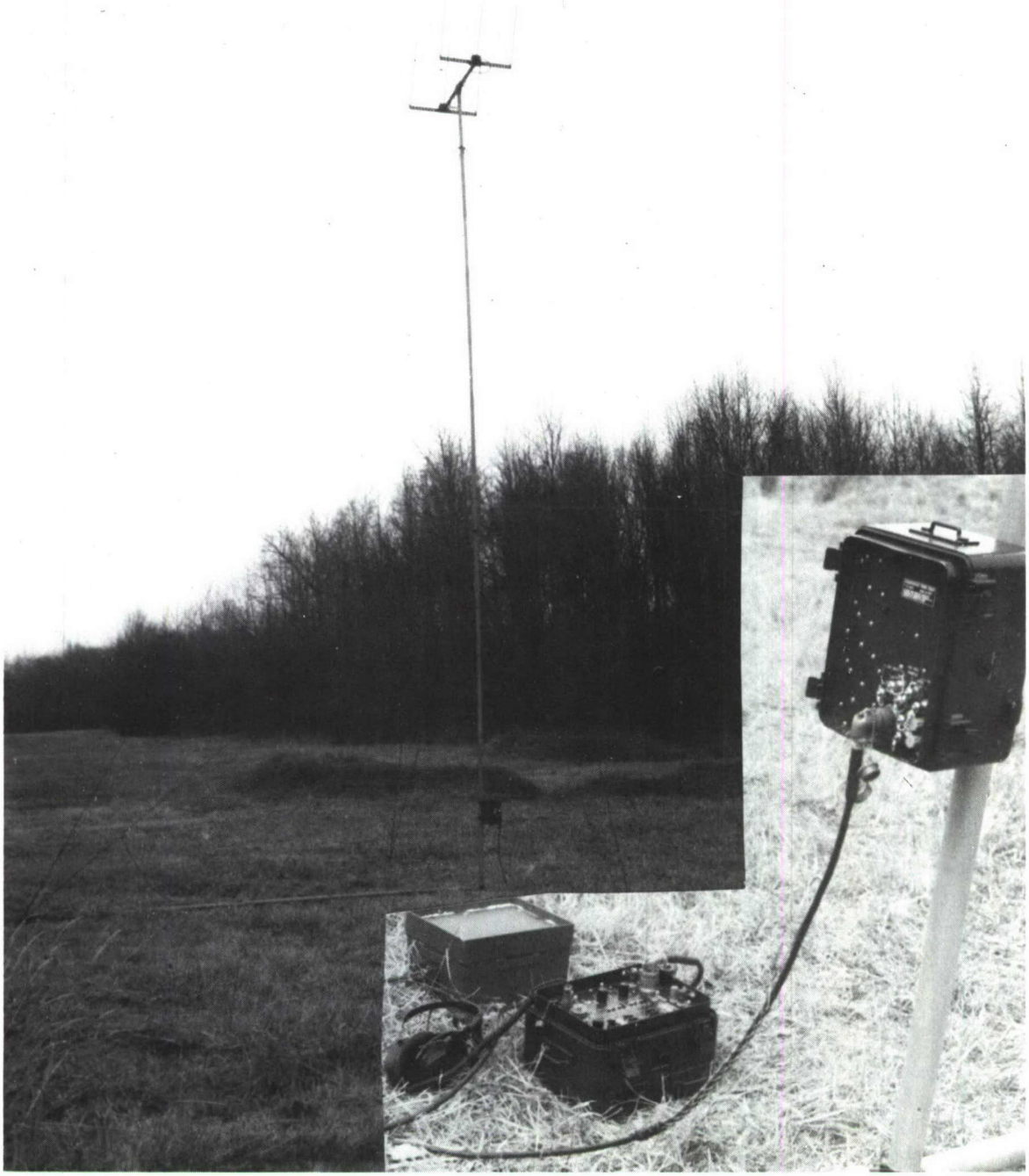

Figure 1. Man Portable Configuration of the M-FOPEN

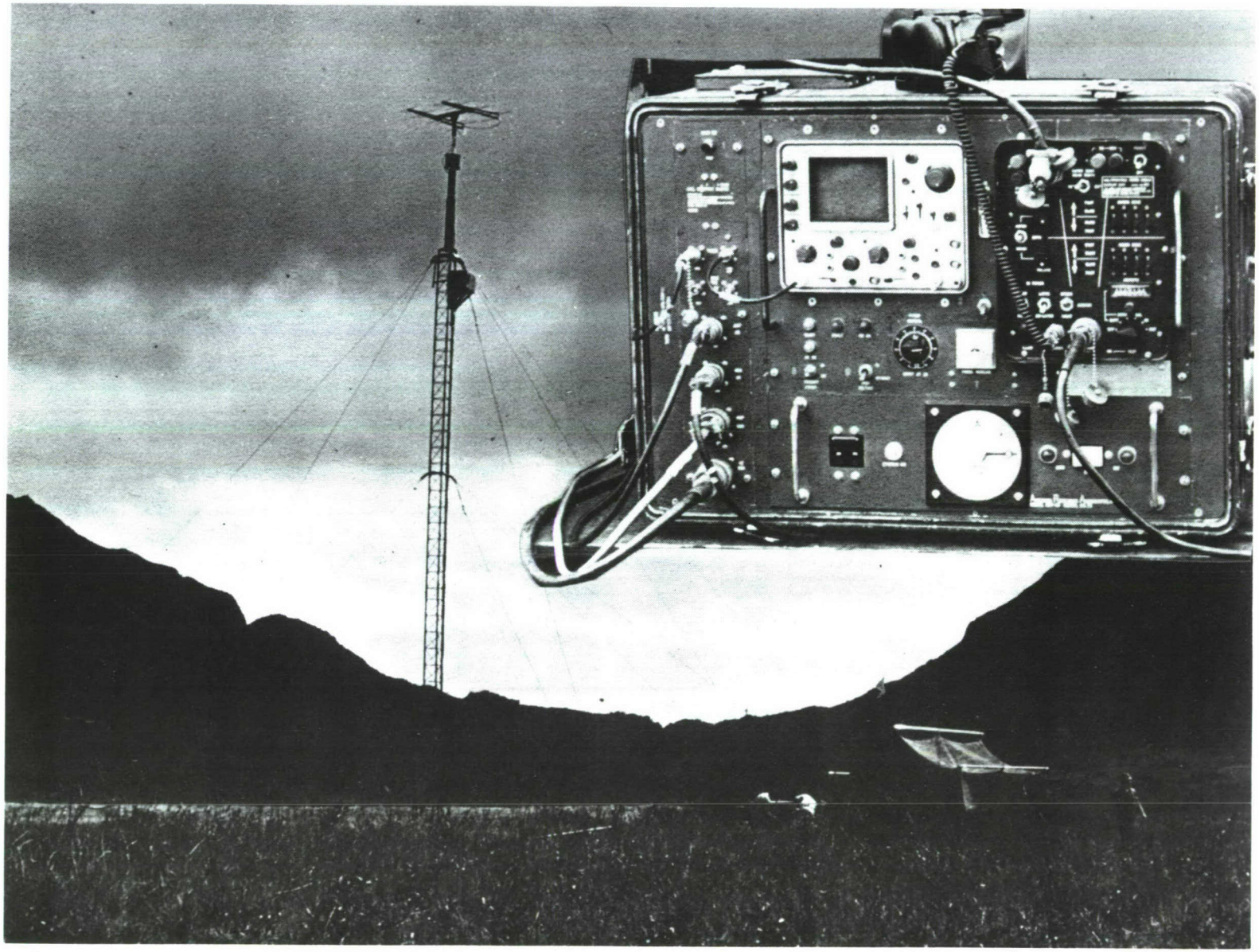

Figure 2. Base Station Configuration of the M-FOPEN

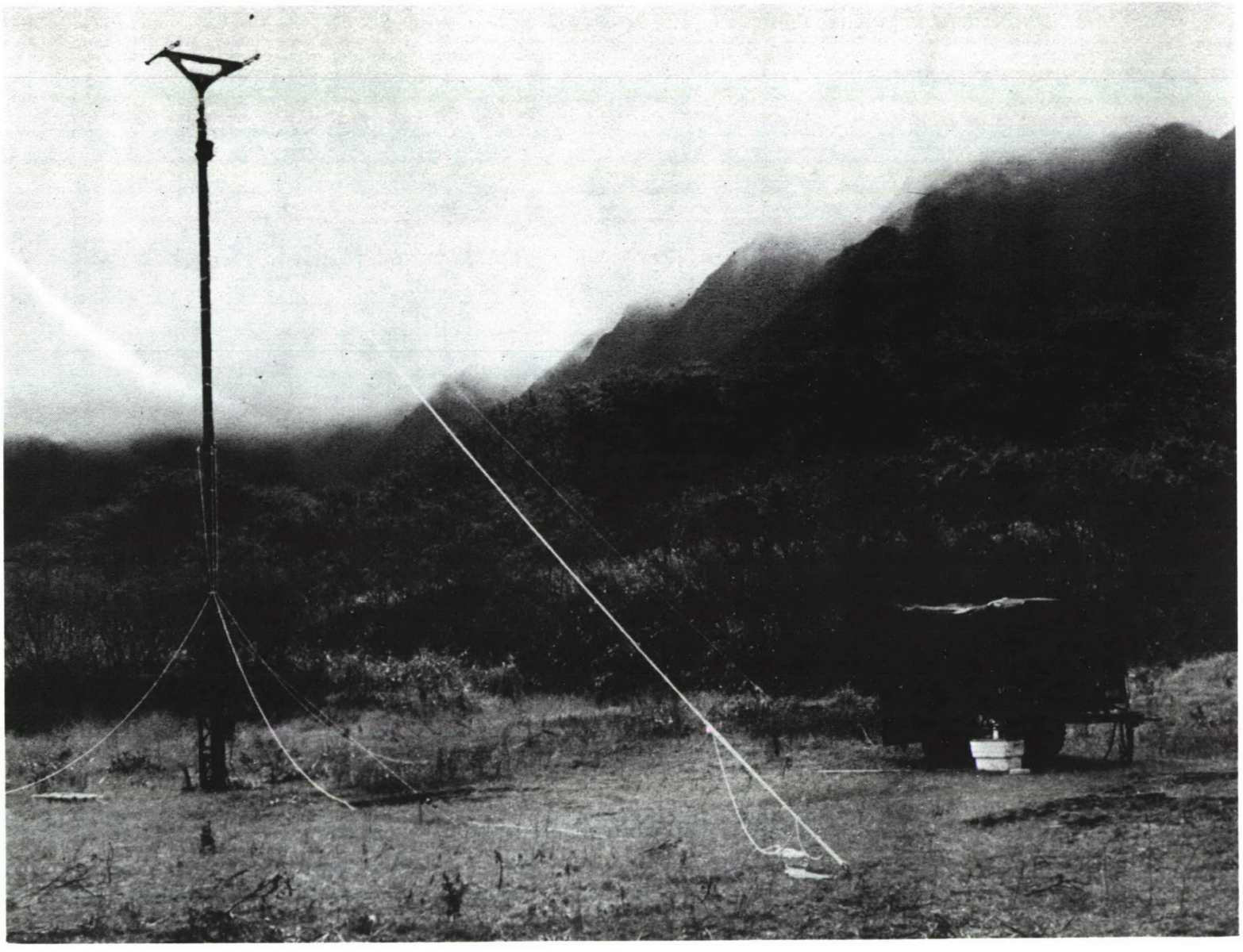

Figure 3. M-FOPEN with the AB-577/GRC Antenna Mast

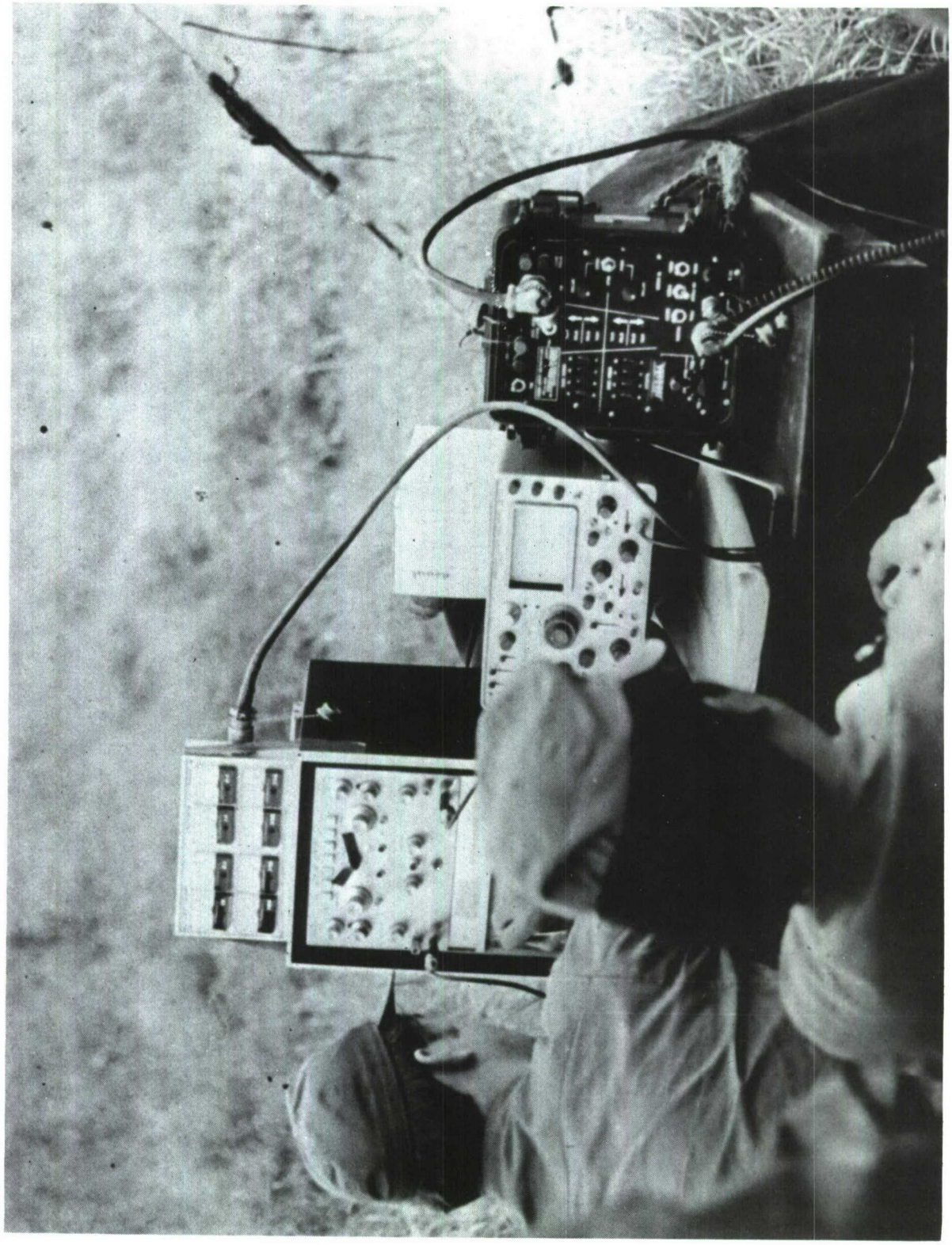

Figure 4. M-FOPEN Test Data Recording Equipment

5. Test Objectives:

a. Purpose of the Evaluation: The purpose of this user evaluation was to determine if this item is ready for production in operational quantities or, if not suitable, to specifically identify those shortcomings in design and performance which make it unsuitable.

CDC will utilize the results of this evaluation in the preparation of a ROC (Required Operational Characteristics) document for a foliage penetration system.

b. Specific Test Objectives:

(1) Objective 1 - To determine the performance characteristics of the M-FOPEN (MPR and BSR configurations):

(a) Ranges at which detection occurs (ROD) for various targets and at different antenna heights.

(b) False alarm rate (FAR).

(c) Estimated amount and type of foliage penetrated.

(d) Target recognition capability by the operator.

(e) System range and azimuthal resolution.

(f) Percentage of true targets detected and recognized.

(g) Susceptibility to simple countermeasures (ECM).

(2) Objective 2 - To investigate the utility of the remote capability.

(3) Objective 3 - To investigate the reliability characteristics of the M-FOPEN, the logistical support requirements to properly maintain the M-FOPEN, and to determine the human engineering deficiencies associated with the operation and employment of the M-FOPEN.

(4) Objective 4 - To determine the training requirements to properly operate the M-FOPEN.

6. Scope:

a. This user evaluation involved the utilization of the M-FOPEN radar in a variety of roles against various targets. Tests of the radar were conducted in areas ranging from flat, bare ground to very dense foliage. Targets considered included single and multiple personnel, vehicles, and helicopters.

b. At times during the conduct of the test, scheduling problems associated with the ranges used forced a delay in the evaluation. Although these delays cost approximately one week of test time, they were unavoidable due to the high degree of utilization of these limited training areas by the 25th Division.

c. Additional testing segments not originally planned for were added to the evaluation after additional capabilities of the M-FOPEN became apparent. These included a detection experiment of the M-FOPEN against helicopters concealed by foliage and an experiment in which the M-FOPEN was set up in a built up residential area and detected and tracked personnel and vehicles concealed by buildings, powerlines, and foliage.

7. Methodology: The user evaluation was designed to satisfy the four test objectives described in paragraph 5. In satisfying these objectives the following subtests were designed and conducted:

a. Subtest A: Inspection and Inventory (26 to 28 March 1973)

The purpose of this subtest was to determine if the M-FOPEN arrived in Hawaii complete and in an operational condition ready for testing. The items were unpacked, checked against the appropriate shipping documents, checked out, and electronically calibrated by the contractor's technical representative.

b. Subtest B. Operator Training (26 to 30 March 1973)

Operator training was conducted during the first week of the test. This included 3 hours of classroom instruction and 12 hours of practical experience in erecting the radar systems.

c. Subtest C: Base Line Testing and Additional Operator Training (28 March to 23 April 1973)

(1) The purpose of this subtest was to determine under controlled conditions the operational performance characteristics of the M-FOPEN against various targets and the maximum range of detection for targets in the open and in foliage. In addition, the base line testing was used to provide operators with practical training on the response of the radar to different type targets.

(2) The MPR on the AB-577/GRC antenna mast (this mast was used to facilitate maximum range of detection (ROD) experiments to be performed at different antenna heights) and the BSR were set up on one end of the range. Range markers were placed at 50-meter intervals from the radar location out to the maximum range available. Targets moved under the direction of the target controller along selected portions of this path to determine for each target type the maximum range of detection. The range accuracy of the radar was determined by correlating peak target readings on the chart recorder with the time the target crossed the range marker. The angle accuracy of the radar was measured by moving targets over known paths several times and determining the variations in operator

readings. The antenna was then rotated a known amount and the previous target iterations repeated.

(3) To enable baseline testing to be accomplished under as wide a variety of terrain and foliage conditions as practical, three major test areas were utilized.

(a) Open area baseline tests were conducted 28 March - 13 April 1973 in an area called "McCarthy Flats," an M-60 machinegun range. A maximum straight-line path of 1400 meters was available. Beyond the maximum point the impact area for artillery and mortar firing began. Topographically the ground was characterized by relatively flat open ground with a gentle slope of 5^{o} or less. Tropical grass and brush, 1' to 3' tall, covers the area. The only man-made obstructions were metal silhouette machinegun targets and 3' x 6' wooden lane markers spread throughout the area to separate and control machinegun firing. The area from 420 to 550 meters was found to contain several mounds of dirt, 12 to 24 inches in height, running tangentially to the radar line-of-sight.

(b) Densely foliated baseline experiments were conducted on 12 April to 14 April 1973 at the South Range Test Area on the edge of the Schofield Barracks Forest Reserve. A schematic of this test site is shown in Fig 5. The area is slightly elevated from the surrounding terrain and exposed to all prevailing winds. The tops of the trees are normally moving in the trade winds which pervade the area. During gusts or high winds, significant tree motion was induced in the top portions of the trees. Extensive limb motion was induced on the ground and intermediate levels. At this site, two locations were used; one with the antenna immersed in the trees, the other with the radar removed 30 meters from the edge of the trees.

(c) Medium to light foliage and open mixed terrain baseline tests were conducted 16 to 24 April 1973 at Makua Gulch (Figure 6). There is a slight terrain mask directly in front of the radar. The area has a gentle upward slope of 3^{o} going away from the radar position. Terrain limitations prevented detection experiments at ranges beyond 750 meters for light foliage, 450 meters for medium/dense foliage, and 1100 meters on the open road. The M-FOPEN was deployed on the Farrington Highway side of the Gulch with a 38' high hillock between the M-FOPEN radar and the highway. The AN/PPS-5 radar, used for the comparison phase, was deployed on the top of the hillock with the antenna approximately 10' above the M-FOPEN antenna. Operators familiarized themselves with the area and performed target experiments during the baseline tests of the M-FOPEN.

d. Subtest D: Tactical Exercise and AN/PPS-5 Comparison (24-27 Apr 73)

(1) The M-FOPEN and AN/PPS-5 radars were collocated at one end of the Makua Gulch test site, both scanning essentially the same presentation of terrain and foliage. The heights of both antennas were approximately the same height above ground, i.e., 30 feet (Figure 7). The area of surveillance was a 60^{o} fan centered on an avenue of approach into the area. Operators were separated so they could not observe or hear each other's activities. This portion of the evaluation was conducted by the 25th Division Project Officer.

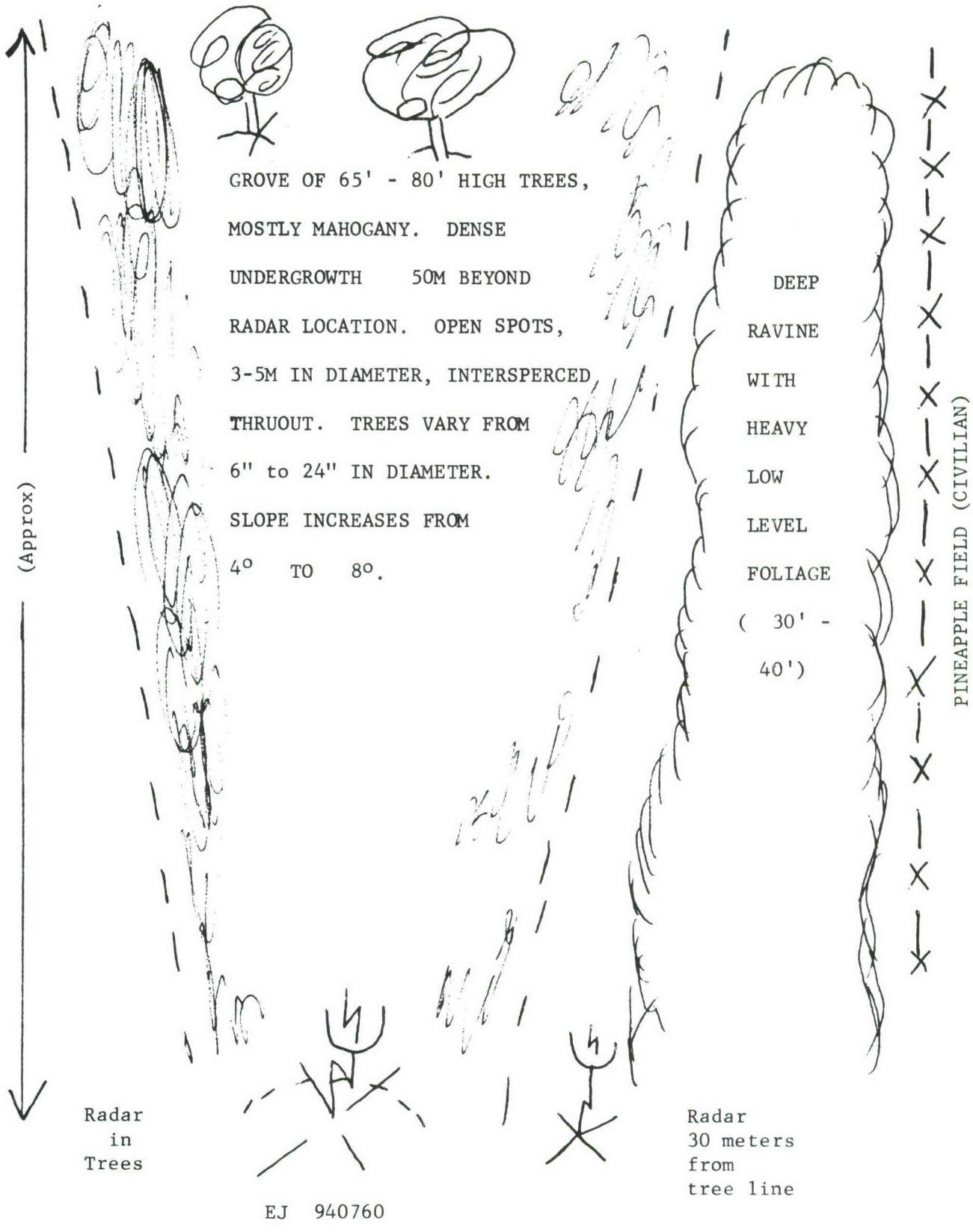

Figure 5. South Range Test Area

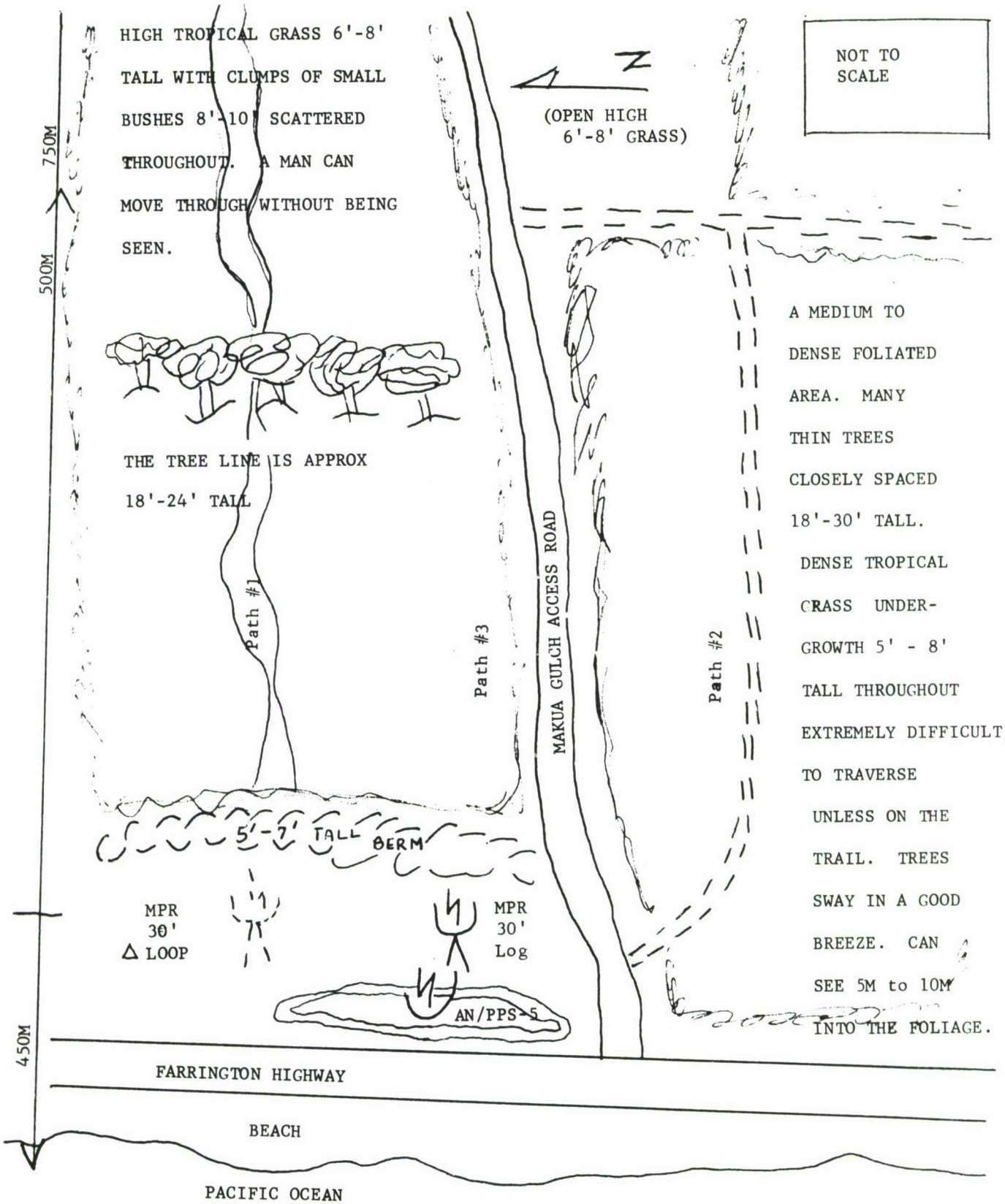

Figure 6. Makua Valley Test Area

Figure 7. Makua Valley Test Area. Location of M-FOPEN and PPS-5 Radar Antenna

(2) The range gates were deployed according to varying simulated tactical situations in which both radars were confronted; variations of terrain, foliage, and target avenues of approach. Random single and multiple targets were injected separately and simultaneously into both radars area of surveillance with tactical dispersion distances used for multiple personnel targets. When a target was detected, the radar operator immediately notified the test controller of a target detection(s), the range and azimuth to the detected target, and an estimate of the number and type targets. The operators had no knowledge of the sequence of events, target insertion time, target paths, or target composition. One day and two night exercises were conducted. The time to assemble the M-FOPEN under conditions of total darkness was determined on the second night.

e. Subtest E: Helicopter Detection Experiment performed 20 Apr 73 at Makua Valley. One of the three M-FOPEN radars was modified so helicopters could be tracked and their doppler spectra measured. UH-1 and AH-1G helicopters participating in a live fire demonstration down range were used as targets.

f. Subtest F: Field Countermeasures Test Conducted 27 April 1973 at Makua Valley

During this test, which was completed at the end of the tactical exercise, the effects of simple field expedient countermeasures and the electronic vulnerability to other radiating sources, and the effect of standard military FM equipment on the M-FOPEN radar were investigated. Two types of passive, field expedient target imitators were used against the M-FOPEN. Random motion of the targets was induced by test personnel shaking the targets. During this countermeasure exercise, targets were inserted along pretested paths and the difference in detection capability recorded.

g. Subtest G: In-Town Experiment (26 April 1973)

As an adjunct to the tactical exercise the M-FOPEN was disassembled and reassembled in a built-up residential neighborhood in the town of Makaha (Fig 8) in the back yard of a friendly resident. A total range of 700 meters was available along Makaha Valley Road which ended at Farrington Highway and the Pacific Ocean.

h. Subtest H: Operator Debriefing (30 April 1973)

The debriefing of the M-FOPEN operators was completed at the Ground Surveillance Section TO&E Room, A Company, 1st Bn, 5th Inf, 25th Division. Operators completed a questionnaire and were interviewed by the LWL and the 25th Div Project Officer.

8. Results:

a. Subtest A. Inspection and Inventory: All systems arrived complete, operational and were certified ready for testing on 3 Apr 73. The only shipping dammage noted was a defective antenna terminal on the Delta Loop Antenna which was repaired in approximately 1 hour by the

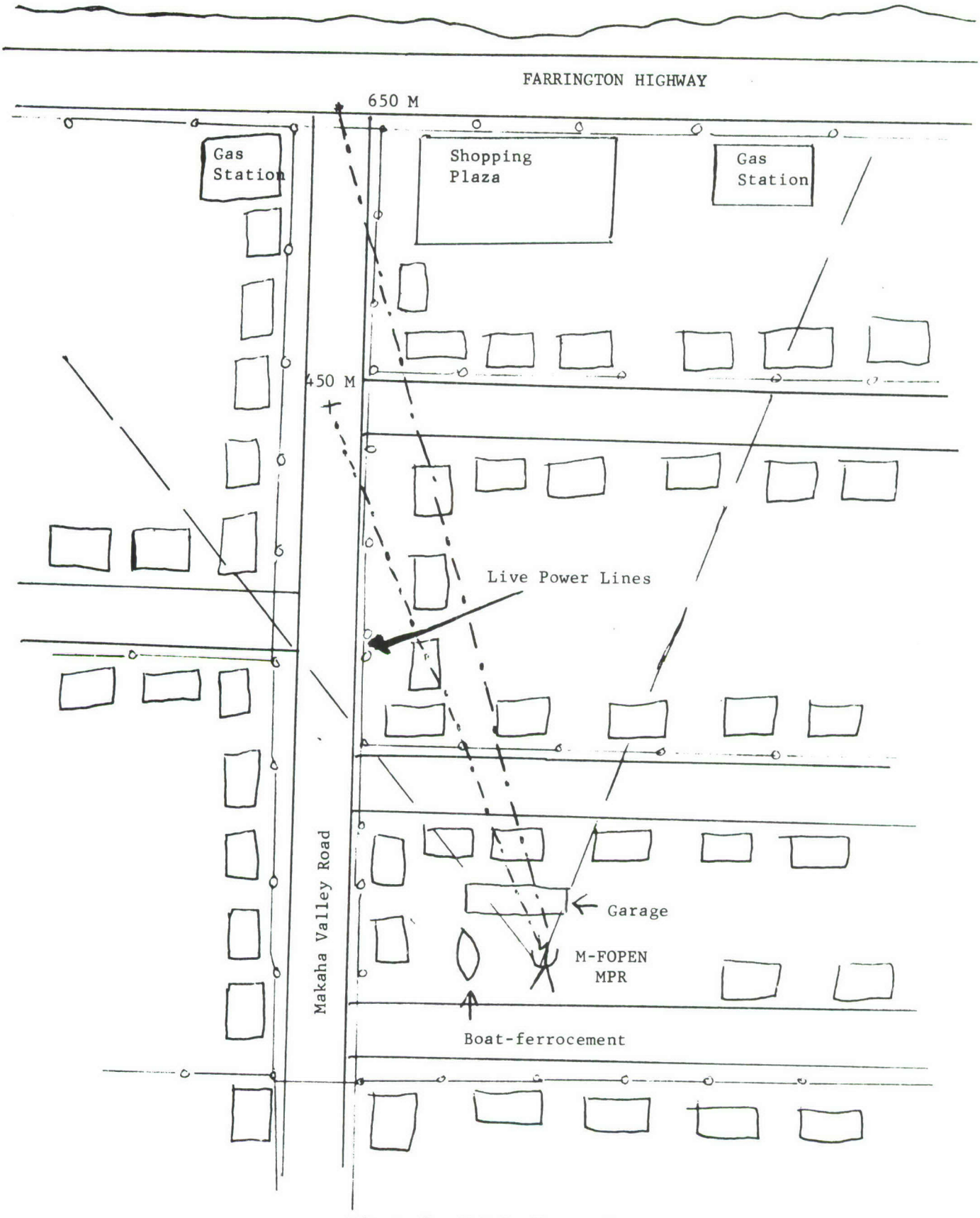

Figure 8. Makaha Intown Test

Contractor's technical representative.

b. Subtest B. Operator Training:

(1) Operator training was conducted during the 1st week of the evaluation. During this period 9 operators received 3 hours of classroom instruction and 12 hours of practical application in the assembly and operation of the MPR with both antenna masts and assembly of the BSR configuration. Subsequent training was provided during the second week of test on the BSR.

(2) The time to assemble and make ready the MPR on either the fiberglass mast or AB-577/GRC antenna mast during daylight was found to be 20 minutes. The second (and last) time the BSR was assembled it took 4-1/2 hrs.

c. Subtest C. Baseline Testing and Additional Operator Training:

(1) Open Baseline Testing - McCarthy Flats

(a) The results of open baseline testing are shown in Table 1. There were no false alarms for either the MPR or BSR in this phase of testing during which 594 separate targets were presented to the radars. However, during the beginning of the bare ground baseline tests at McCarthy Flats unusually high AGC/AFC (Automatic Gain Control/Automatic Frequency Control) levels were noted in the MPR. It was felt that these were due to movement of the RF cables next to the metal AB-577/GRC antenna mast or wind motion of the metal machine gun targets on the range. After eliminating both of these possibilities, the high levels were traced to spurious (RFI) radio frequency interference. Although these high levels resulted in some desensitization of the radar the system experienced NO false alarms and targets could still be detected at reduced ranges. Attempts to locate this source took approximately 5 days and resulted in a subsequent delay in the start of testing. To locate the source signal, elements at Schofield Barracks were contacted with negative results. Experiments were then performed with the police, fire department, local cab company, and samples of most RF emitters available to the Army. Finally, one radar was used to direction-find (DF) on the source. The system was set up at several locations on Schofield Barracks and direction finding cuts were taken. The culprit, located at range control less than 1,000 meters from the radar antenna, was a commercial AM radio of several hundred watts operating at 139.095 MHz and 143.085 MHz. Arrangements were made to minimize use of this radio set for the duration of our baseline tests at McCarthy Flats.

(b) Operators were able to identify single and multiple personnel and vehicular targets presented by their distinctive audio presentation, and relative speed as they traversed through a range gate, and the duration and intensity of the signal indicated on the FOPEN Test monitor.

(c) The system range accuracy was determined to be within $\pm$ 5 meters of the actual range as determined by the target controller using range markers.

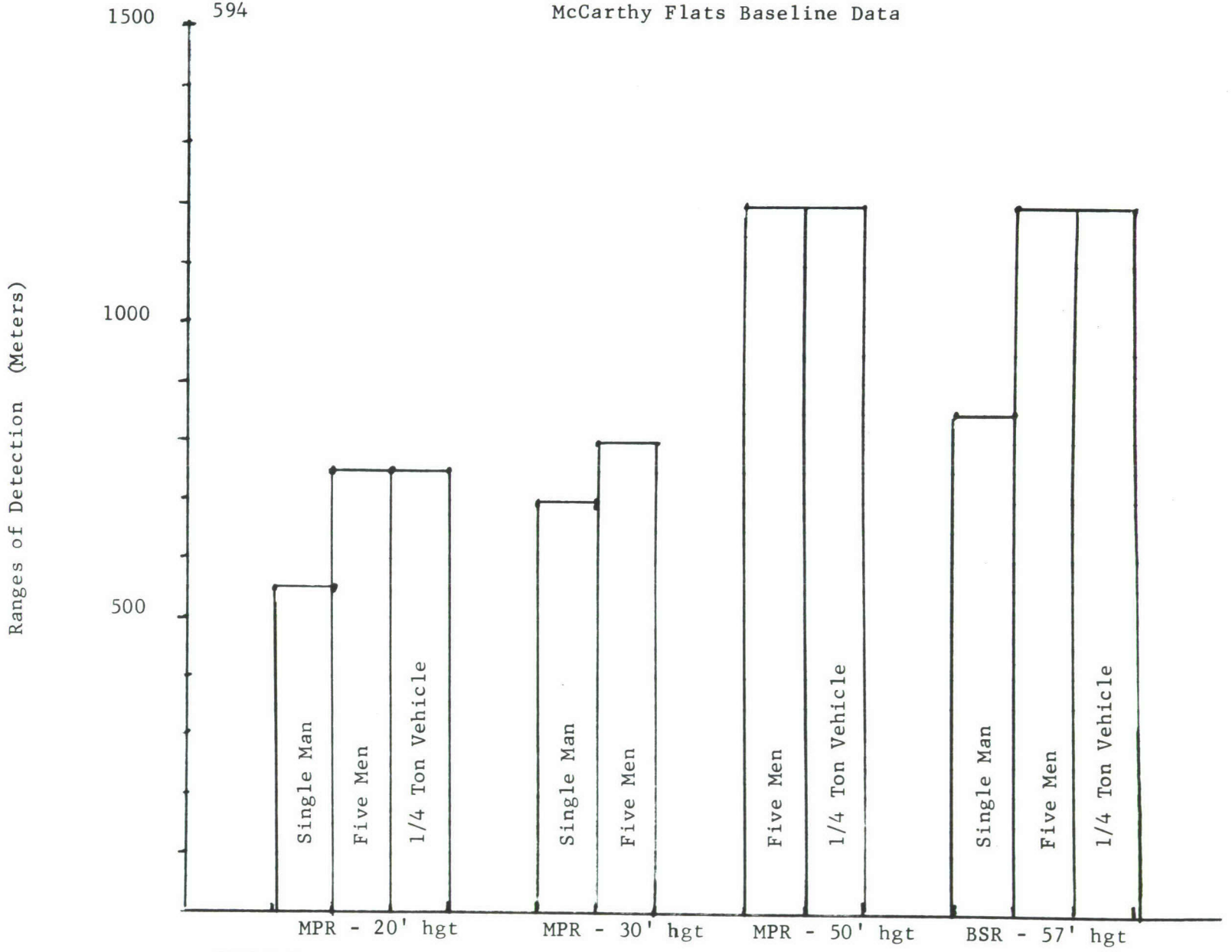

TABLE 1. Open baseline ranges of detection for type targets at tested antenna heights. Ranges given are for greater than 95% probability of detection.

South Range Foliage Baseline Data

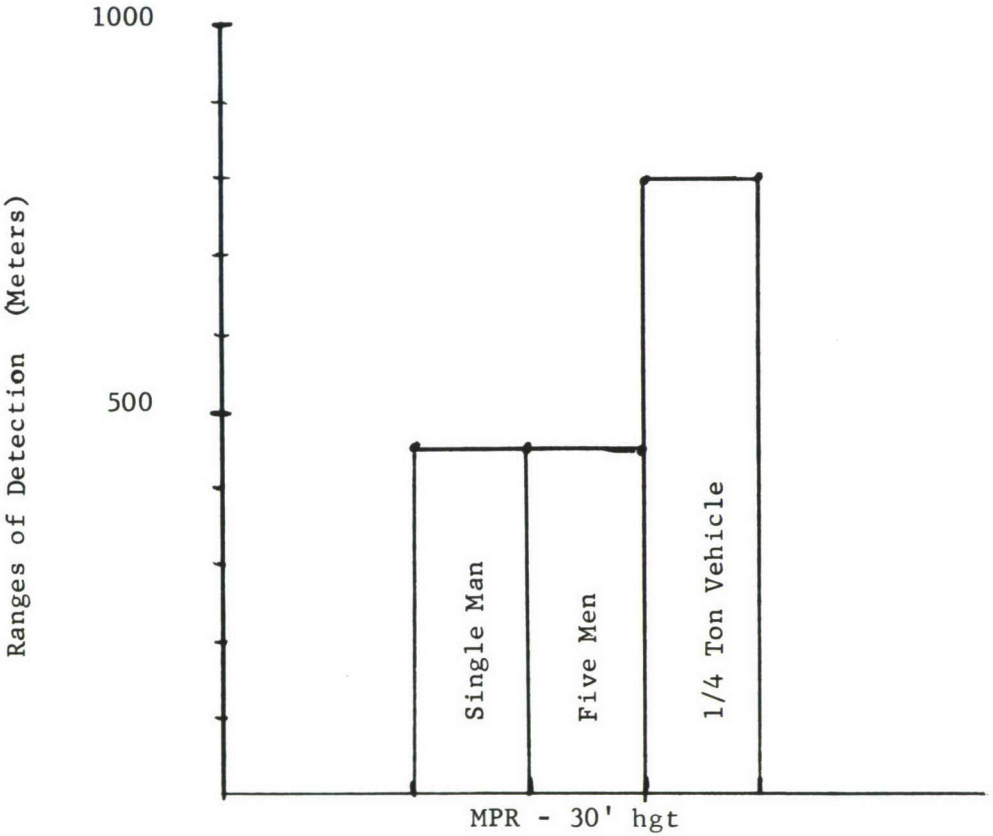

TABLE 2. Heavily foliated baseline ranges of detection for type targets. Ranges given are for greater than 95% probability of detection.

(d) The azimuthal resolution of the M-FOPEN for bare ground was better than ±3 degrees as compared with an advertised accuracy of ±5 degrees.

(e) The direction of target motion inbound or outbound was always (100%) accurate.

(f) The operators could determine when the radar was subjected to RFI (see preceding discussion) by listening to the audio. The extent to which the RFI affected the radar, i.e., reduced detection range could also be determined by the AGC/AFC readings in the test monitor box.

(g) On three occasions, light rain fell during testing with no apparent effect on radar performance.

(h) It was determined that the Base Station configuration (BSR) did not offer any significant advantage over the man-portable radar when the man-portable antenna was used at 50 feet in height using the AB-577/GRC antenna mast. Testing of the BSR was therefore terminated after completion of the Bare Ground Baseline Tests

(2) Dense Foliage Baseline Testing: South Range

(a) Experiments were performed with the MPR set up in the trees at both 30 and 50-foot antenna heights. The antenna was within 2 meters of major tree limbs. Under these conditions, high AFC readings were induced in the radar by tree motion close to the antenna. This extremely high AFC condition precluded the detection of personnel target beyond 150 meters because of the low frequency desensitization of the radar. This further confirmed empirically derived effects of operating a radar too close to the foliage.

(b) When the system was moved into an open area approximately 30 meters from the edge of the foliage, the detection ranges improved significantly as illustrated by Table 2. One hundred target iterations were performed at this location using the MPR with a 30' antenna height. Because of the prevailing winds at this location which moved the foliage continuously, some degree of AFC control (i.e., low frequency desensitization) was always present. However, although this limited the detection ranges to 450 meters for personnel, vehicles could still be detected through 800 meters of continuous foliage.

(3) Light Foliage/Mixed Terrain Baseline Testing - Makua Valley: A total of 448 target iterations were performed at this location.

(a) The results of the light foliage testing, limited to 750 meters by terrain, is shown as Table 3. Signal levels for group personnel and vehicular targets were often twice threshold. Figure 6 shows this path as #1.

(b) The results of the medium/dense foliage baseline tests are shown in Table 4. Figure 6 shows this path as #2. ROD* were limited by terrain to 450 meters. Signal levels for most targets were two to three times alarm threshold.

*ROD = Range of Detection

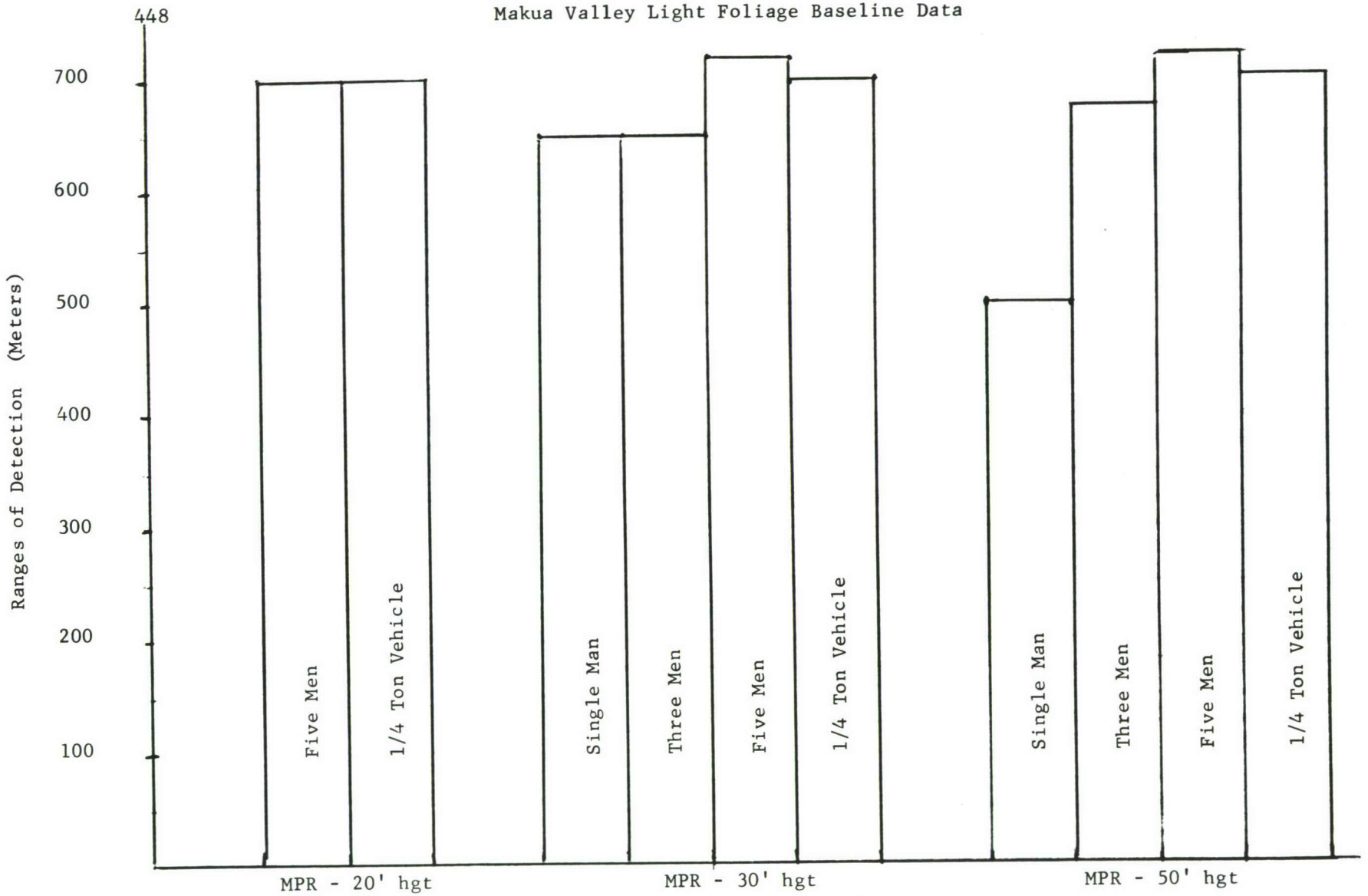

TABLE 3. Foliated baseline ranges of detection for type targets at tested antenna heights. Path limited to 750 M by terrain. Ranges given are for greater than 95% probability of detection.

Makua Valley Heavily Foliated Area Baseline Data

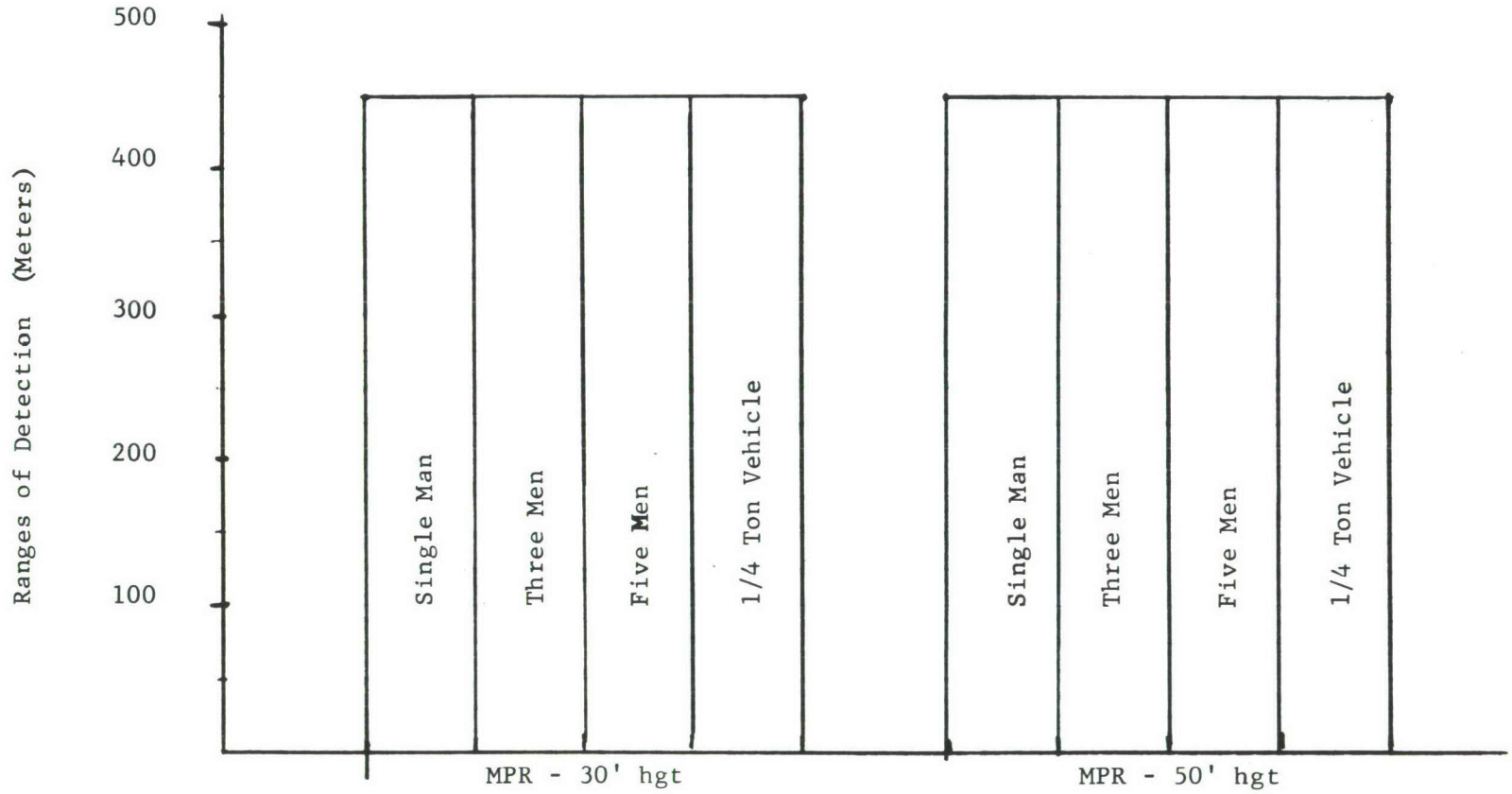

TABLE 4. Heavily foliated baseline ranges of detection for type targets at tested antenna heights. Path limited to 450 M by terrain. Ranges given are for greater than 95% probability of detection.

(c) Open baseline (with rising terrain) detection ranges are given in Table 5. This path is shown by Figure 6 as #3.

(d) During portions of the testing at 50' antenna height, sporadic AGC buildups were noted at ranges of 450 meters. This coincided in range to the beach to the rear of the test site, where high surf was present. When the antenna was lowered to 30' the hillock to the rear of the antenna used for the PPS-5 comparison blocked the antenna and prevented the AGC buildup. The meter box was again used to identify this phenomena. This result was observed previously at an abandoned airstrip next to the ocean where a preliminary test was performed.

(e) The resolution of the radar was found to fall within the ± 3 degree accuracy previously determined over bare ground.

d. Subtest D: Tactical Exercise and AN/PPS-5 Comparison

(1) A total of 34 separate target runs were presented to both radars during this phase of testing. A target run consisted of the movement of a target between two predetermined points using one or more of the paths 1 to 5 shown in Figure 6.

(2) The M-FOPEN (MPR at 30' antenna height) detected, tracked, and correctly identified 31 out of the 34 target runs presented. Of the three missed targets, one was a lateral target at the maximum range, 750 meters. The second occurred during a 5-minute period in which the batteries had dropped below the minimum operating voltage. The batteries had not been charged for 3 days contrary to operator training that each battery should be charged after 10 hours of use. The third miss occurred during the first evening of the exercise when a second group of targets was inserted after a previous group had proved out and stopped. The operators had tracked the first group of targets until they stopped, then placed the range gates (inner and outer) 59 meters either side of that location. The subsequent movement of the second group did not transverse either range gate. Subsequent discussion of the results of the first night's testing with both groups of operators resulted in the M-FOPEN operators deciding to keep 1 range gate at 150 meters as a guard ring and track with the outer gate only. A repeat of the multiple target experiment on the second evening resulted in both groups being detected and tracked. During the conduct of the tactical exercise only once was a target called in to test control by the M-FOPEN operators during a period in which there were no controlled targets in the area. The operators reported this as a grazed threshold which could not be tracked, in contrast with all other targets which could be tracked in range, identified by type, and located in azimuth. On the second evening of the practical exercise, the operators assembled the MPR on the AB-577/GRC mast in total darkness in one hour.

(3) The AN/PPS-5 radar which was performing surveillance on the same area, detected only 6 of the 34 targets presented. Of the 34 targets, 19 of the 34 targets crossed open areas visible to the PPS-5 and should have been detected. Four of the 6 detections were in daylight hours. One of the two evening target detections was a vehicle, the other, a group of 10 men on an open road. Neither was tracked for any significant

TABLE 5. Open baseline, rising terrain ranges of detection for type targets at tested antenna heights. Ranges given are for greater than 95% probability of detection.

distance, only the vehicular target could be identified as such, and the azimuth information provided was, for the most part, completely incorrect. The PPS-5 radar was operated from vehicular power with the inverter because the standard battery would not run the radar more than 20 minutes when the remote indicator was used. During both evening portions of the test, numerous false targets were called by the AN/PPS-5 operators to test control. Apparently these were caused by wind motion of the foliage within and at the edge of the field-of-view of the AN/PPS-5 radar. On the second evening the AN/PPS-5 was shut down due to wind motion of the foliage which rendered the set inoperative.

(4) Table 6 summarizes the results of the Tactical Exercise/PPS-5 comparison.

e. Subtest E. Helicopter Detection Experiment: Using the A scope and chart recorder with the modified MPR at 30' antenna height, helicopters were tracked to 2,990 meters, the maximum range of the FOPEN track capability. At the top of a hill, 1160 meters from the radar, two AH-1G Cobras landed and shut down their engines. The range gate was positioned over the aircraft and data recorded during approach, hover, and engine shutdown. A unique signature was recorded for each type of aircraft activity which clearly showed the rotation of the main rotor blade and doppler signal received from the moving aircraft fuselage. When the pilot shut down his engine the main rotor was observed to slow down and stop on the chart recorder. The energy received from the aircraft was 27 times the background noise at 1160 meters in range even though light foliage and a slight rise in the ground blocked the aircraft from the FOPEN radar.

f. Subtest F. Field-Expedient Countermeasures:

(1) Simple field expedient countermeasures which were installed in a heavily foliated area 400 meters from the radar consisted of aluminum foil targets and commo wire - WD-1. When suspended in the trees and shaken either manually or by the wind, they did not cause the M-FOPEN to alarm.

(2) Personnel were detected when they emplaced and activated the countermeasures.

(3) During the period the countermeasures were activated, 1-, 2- and 4-man targets were detected at 400 meters with only slight degradation due to a small AFC/AGC buildup caused by the countermeasures.

(4) The countermeasures could be located in range by moving out the range gate until a buildup in AGC/AFC was noted.

(5) Operation of standard FM radios, both man-pack and vehicular types, at subharmonics of the M-FOPEN frequency at distances of 10 feet from the radar had no measurable effect. FM radios were used for all phases of the evaluation with no measurable effect on system performance.

Radar	Total Targets Presented	# Detected During Day	# Detected During Night	Probability of Detection	# False Detection
M-FOPEN	34	11	20	91%	1
AN/PPS-5	34 (19 in field-of-view)	4	2	18%	Stopped recording after 30, too numerous to mention

TABLE 6. Tactical Exercises and AN/PPS-5 Comparison Test

g. Subtest G. In-town Experiment: As an adjunct to the tactical exercise, the MPR was disassembled and taken to the town of Makaha where it was assembled in 20 minutes in a back yard. Controlled personnel targets were tracked and identified out to 400 meters and vehicles out to 650 meters. Targets could not go beyond 650 meters on the road because of highway traffic. This was accomplished in spite of much uncontrolled personnel and vehicular activity in the area. To make these detections the M-FOPEN penetrated numerous houses, trees, powerlines, and telephone poles, as shown in Figure 8.

h. Subtest H. Operator Debriefing:

(1) At the conclusion of the evaluation, all operators completed questionnaires and were interviewed. One questionnaire of the nine operators reporting was not included because the operator responded to questions involving conditions which he had not experienced; therefore, his answers were invalid. The following is a general grouping of responses:

(a) Operator Training (objective 4): Table 7 lists operator responses to yes/no questions about the training phase.

(b) Operator Maintenance (objective 3) Table 8 lists responses to questions relating to operator-performed maintenance.

(c) Human Factors (objectives 2 & 3): Tables 9 and 10 list the operator responses to the operation of the M-FOPEN in general and the human factors aspects of the system.

(2) During the final exit interview, all operators indicated that they greatly preferred the automatic alarm features of the M-FOPEN to the method of target indication used with any other radar. The capability of remoting both the display box and automatic wrist alarm were considered by all operators to be very beneficial to the operation of the radar. Several operators indicated that they learned more about the operation of the radar during the 2 nights of the tactical exercise than during all previous training. Without exception, every operator stated they would want the M-FOPEN (MPR configuration with the AB-577 mast) if they were ever in combat. Five of the eight operators stated they prefer the M-FOPEN over the PPS-5.

(3) The following changes to the M-FOPEN (MPR configuration) were recommended by the operators:

(a) Modify the fold-up log periodic antenna to facilitate more rapid assembly/disassembly.

(b) Replace the battery cable, radar end with a connector.

(c) Replace the push-to-illuminate switch with a toggle switch.

(d) Replace range control switch with one capable of stepping the range gate both in and out. The current switch steps the range gate out, requiring operators to make complete cycle to step the gate in.

TABLE 7. Responses of Operators to Questions on Questionnaire and Debriefing Concerning Training.

Operator Response to:	Yes	No	Comments
Enough Time	6	2	
Necessary Subjects Covered	4	4	
Quality of Training	6	2	
Maintenance Training	7	1	
Calibration Training	7	1	
Need for Practical Exercises	2	6	One felt wider variety of sites should be tested
Training on Equipment Setup	6	2	More training in deploying the setup needed

TABLE 8. Questionnaire and Debriefing Concerning Maintenance

Problem	Easy	Difficult	Comments
General Maintenance	8	0	No difficulties experienced in operator maintenance
Radar Cleaning	7	1	Cable connections hard to keep clean

TABLE 9. Response of Operators to Questions on Questionnaire and Debriefing Concerning General Evaluation

Response	Yes	No	Comments
Adverse Physical Effects	0	8	One bothered somewhat by the audio
Confidence in Unit	8	0	Confidence generally acquired quickly. One lacked confidence in detecting small targets.
Physical Security of Unit	8	0	One felt anyone having knowledge of radar could avoid it, felt high antenna would reveal position.
Acceptability in Combat Situation	6	2	More effective penetration required at lower antenna heights.

TABLE 10. Responses of Operators to Questions on Questionnaire and Debriefing Concerning Human Factors

Responses	Very Easy	Easy	Borderline	Difficult	Very Difficult	Comments
General Operation	7	1	0	0	0	Difficulty with antenna assembly and mast
MPR Assembly	0	5	3	0	0	Bulky, but portable
BSR Assembly	0	0	0	8	0	Too heavy and time consuming for extra range
External Power Source	2	6	0	0	0	
Cable Connections	3	5	0	0	0	Replace bare wires with plugs. Spread out connections on TR box.
Control Switches	0	8	0	0	0	Need two-way range control. Toggle switch for lights.
Alarm Indicators	3	5	0	0	0	One had difficulties with range counter, two with azimuthal indicator
Control Display & Power Supply Setup	6	2	0	0	0	Toggle light switch needed
Audio Alarm loudness	0	8	0	0	0	All found alarm loud enough to alert them
Range gate position	0	7	0	1	0	Some difficulty in tracking incoming targets.
Use of headset	0	7	0	1	0	One operator found the sound irritating
BSR antenna assembly	0	3	3	0	2	Too bulky and time consuming

(e) Spread out the coax connectors on T/R box to facilitate making connections.

i. Subtest I. Maintenance of M-FOPEN: There were no electronics, cable, or battery failures during the six weeks of this evaluation. No maintenance was performed on the M-FOPEN systems other than operator maintenance consisting of cleaning and charging batteries. Two mechanical field modifications to the AB-577/GRC antenna mast and antenna bracket were done by the Ground Surveillance Section during the test. These consisted of making nylon guylines to replace the metallic cable guylines used with the AB-577/GRC and fabricating a plywood antenna mount to raise the antenna above the metallic support. These mods were necessary to reduce the movement of metal items in the near field of the antenna.

9. Conclusions: It is concluded that:

a. The M-FOPEN has demonstrated a capability to detect military targets over bare ground and through foliage with greater than 95% probability of detection as shown by Tables 11 and 12.

b. The M-FOPEN has demonstrated an extremely low false alarm rate, i.e., 1 false alarm in 3 days of tactical testing.

c. The M-FOPEN (MPR) has demonstrated a capability of penetrating foliage not possible with conventional ground surveillance radars such as the AN/PPS-5.

d. The MPR has demonstrated a capability of penetrating the following amounts and types of vegetation to detect targets:

(1) 450 meters of dense foliage 65' - 80' Mahogany trees to detect personnel, 800 meters to detect vehicles.

(2) 750 meters of light foliage to detect both personnel and vehicles.

e. Operators were able to identify targets by their distinctive doppler audio presentation, relative speed through the range gate, and amplitude of the signal as displayed on the test monitor box.

f. The tactical utility of the MPR configuration was demonstrated during the tactical exercise in which 91% of the targets were detected, tracked, and identified with sufficient information to enable the targets to be engaged and neutralized.

g. The standard Army ground surveillance radar, the AN/PPS-5 was not capable of detecting or locating targets when any portion of the intervening field-of-view of the radar contained foliage.

h. The M-FOPEN was not significantly affected by or caused to false alarm by wind at any test location.

i. The M-FOPEN was not false alarmed or significantly affected by simple field expedient countermeasures although the system is slightly desensitized.

Ranges of Detection for Type Target vs Terrain. First range given is for > 95% probability of detection, second is for maximum detection range.

Targets	Open Baseline Ranges						
	Flatland (McCarthy Flats)				Rising Terrain (Makua Valley)		
	MPR 20'	MPR 30'	MPR 50'	BSR 57'	MPR 20'	MPR 30'	MPR 50'
Single Man	550 / 650	700 / 800	-	850 / 900	-	-	900 / 900
Three Men	-	-	-	-	-	-	900 / 900
Five Men	750 / 750	800 / 1100	1200 / 1300	1200 / 1250	-	1000 / 1050	-
1/4 Ton Vehicle	750 / 850	-	1200 / 1200	1200 / 1200	1000 / 1100	900 / 1250	1100 / 1100

TABLE 11. Summary of Bareground Baseline Data

Ranges of Detection for Type Target vs Terrain. First range given is for > 95% probability of detection; Second range given is maximum range of target detection.

Targets	Foliated Baseline Ranges					
	Light (Makua Valley)			Dense * (Makua Valley)		Very Dense (South Range)
	MPR 20'	MPR 30'	MPR 50'	MPR 30'	MPR 50'	MPR 30'
Single Man	-	650 / 750	500 / 750	450 / 450	450 / 450	450 / 450
Three Men	-	650 / 750	670 / 750	450 / 450	450 / 450	-
Five Men	700 / 750	710 / 750	710 / 750	450 / 450	450 / 450	450 / 450
1/4 Ton Vehicle	700 / 750	700 / 750	700 / 750	450 / 450	450 / 450	800 / 850

TABLE 12. Summary of Foliated Baseline Data

* Maximum Range Available is 450 Meters

Targets were detected prior to and during the emplacement of the countermeasures.

j. The tower and related assemblies of the M-FOPEN BSR were determined to be too mechanically complicated for installation under tactical conditions and offered only a slight advantage in detection range.

k. The M-FOPEN (MPR) when used with the AB-577/GRC mast provides a capability to detect targets similar to that of the BSR at a significant savings in size, weight, and complexity.

l. It was observed during tests at McCarthy Flats that target height is an important factor in the detection of the target. (This was observed when the target walked in a depression which reduced the return from the target at that range. Increasing the antenna height from 30 to 50 feet reduced this effect.)

m. The detection and tracking of rotary wing aircraft, even those concealed by foliage has been demonstrated and shown to be practical using the M-FOPEN radar. (Subsequent investigation has established that the signatures are unique and a simple discrimination system could be added to the M-FOPEN to enable discrimination between helicopters and other types of targets.)

n. The feasibility of using a M-FOPEN (MPR) radar in built-up residential areas to see through buildings, power lines, etc., to detect moving targets, has been demonstrated.

o. The fiberglass antenna mast used with the MPR configuration shows general military potential and application. It appears superior, particularly more durable, than the standard RC-292 antenna masts currently in Army-wide use. It was easier to assemble and disassemble, stronger, more flexible and capable of providing greater mast height than the RC-292.

p. The maintenance requirements of the M-FOPEN radar were found to be minimal. Normal operator maintenance consisting of cleaning was sufficient to maintain the radar for extended periods.

q. The test monitor box was determined by operators to be an invaluable adjunct to the operation of the radar. It provided the operators with additional information with which to determine target characteristics and the detection sensitivity of the radar.

r. The AB-577/GRC antenna mast is preferred over the fiberglass antenna mast.

s. The M-FOPEN alarm indicators (audio, lights, beeper and wrist alarm) are nonfatiguing and more than adequate to alert the operator under all conditions.

t. The remote capability of the M-FOPEN display box and the wrist alarm are very desirable features.

u. One week of training is sufficient to train most operators; however, two weeks with emphasis on tactical experience is preferred.

10. Recommendations: The following recommendations are presented by the developer, the USALWL:

a. The M-FOPEN be considered for world-wide use in light of its demonstrated capability to detect targets in built-up residential areas, in addition to its ability to penetrate foliage.

b. The M-FOPEN radar should be considered for service test after modification to the antenna, separation of the connectors on the T/R unit, and changing the range control and illumination switches.

c. The M-FOPEN be considered as a device to detect and identify helicopters and other aircraft.

d. The high level of FOPEN technology demonstrated by this system be incorporated in future ground surveillance radar systems.

e. The M-FOPEN Test Monitor be incorporated into the set and used in conjunction with the existing alarm indicators.

f. The batteries and fiberglass antenna mast used in the MPR configuration be examined for application to other US Army systems.

g. The Base Station (BSR) radar not be considered for further development in its current configuration.

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APPENDIX A

Description of M-FOPEN

1. General

a. The M-FOPEN is a low frequency 140 MHz (VHF) ground-to-ground radar designed to provide the user a foliage independent, all-weather battlefield surveillance capability. It is a coherent, pulse doppler, moving target indicator (MTI) radar, which processes doppler returns with or without fixed returns as a reference. The set incorporates a 60° electronic scan that can be rotated 360° manually or remotely, and a multiple target detection capability. Two operators are required for the man-portable system (MPR), and base station (BSR) configuration. Six personnel are required to assemble and erect the BSR telescoping antenna tower. Major components of the two radar configurations are as follows:

(1) Man-portable Radar:

(a) Display Box (Operator controls, azimuth readout, etc)	16 lbs
(b) Transmitter/Receiver Box (Contains all RF circuitry)	16 lbs
(c) Antenna (Two required for azimuth readout)	20 lbs
(d) Fiberglass Antenna Mast 30 Feet w/Hardware	60 lbs
(e) Control Cable (provides for operation up to 75' from antenna base); Antenna Cables and batteries	30 lbs

(2) Base Station Radar: The electronics portion of the radar is incorporated into a display console, and a 20 kw power amplifier is used with the transmitter. The electronics portion is identical to the man-portable and intermediate range configurations.

(a) Display Console (Control box, A-scope display, power amplifier controls, antenna rotator, speaker, power supplies, and cable connections)	100 lbs
(b) Power Amplifier (Connected to the output of the transmitter/receiver unit)	100 lbs
(c) 100-foot Cable (Remotes display console from power amplifier)	60 lbs
(d) 2 Antennas and 50-foot Tower	400 lbs
(e) Generator, 2-1/2 kw, 60-cycle, 110 VAC, 1 phase	Standard Military System

b. Technical Characteristics:

(1)	Operating Frequency	140 MHz
(2)	Pulse Width (meters)	20
(3)	Peak Output Power	
	(a) Man-Portable Radar	1 kW
	(b) Base Station Radar	5.0 kW
(4)	Average Power Output	
	(a) Man-Portable Radar	8 watts
	(b) Base Station Radar	40 watts
(5)	Target Velocity Limits	0.7 to 25 mph (40 mph with reduced sensitivity)
(6)	Maximum Range	200 to 1500 meters, depending on geometry, foliage, and wind conditions.
(7)	Minimum Range	75 meters
(8)	Antenna	
	(a) Man-Portable Radar	Array of two log periodic antennas, horizontally polarized
	(b) Base-Station Radar	Array of two log-periodic antennas, horizontally polarized
(9)	Mast Height	
	(a) Man-Portable Radar	30-75 feet depending on type of mast
	(b) Base Station Radar	50 feet
(10)	Range Gates	Two, independently selectable, 20 meters wide
(11)	Azimuth Coverage	60^{o} for both inner and outer gates; 40^{o} available for outer gate only
(12)	Target Angle Azimuth Readout	Angle Meter Readout on inner gate only
(13)	Azimuth Readout Accuracy	Better than $\pm 5^{o}$

(14) Supply Power

(a) Man-Portable Radar 22 to 30 V unregulated dc, 36 watts

(b) Base Station Radar 120 V, 60 Hz, ac power, 1.5 kW

2. Control/Display Console. The display box of the man-portable radar contains all operator controls, azimuth readout, target detection alarms, and headset capability. The operator sets each of two range gates, individually adjustable at ranges from 75 meters (150 meters for Base Station) to the maximum range of the radar for that location, typically 300 to 1500 meters depending on the antenna configuration, and environment. The range gates are 20 meters deep in a fixed 60^{o} horizontal azimuth beam width which can be rotated 360^{o} manually or remotely (for the BSR). The inner gate is equipped with an azimuth angle computer which provides the operator with the angle in mils left or right of the antenna direction to the target. The automatic visual and audio alarms are supplemented by the operator's headset which can monitor either or both range gates. Moving targets are presented by their characteristic doppler sounds in the headphones corresponding to the number, size and relative radial velocity of the target. The display box is incorporated into the display console of the base station system which also contains the "A" scope display, power amplifier controls, antenna rotator, speaker, power supplies and cable connections. The "A" scope can be used for range gate positioning, target identification, determining additional information on target motion, RFI jamming analysis, and trouble-shooting the radar.

3. Power Supply.

a. The man-portable radar system which requires an external 22 to 30 VDC power source comes equipped with two 24-volt battery packs. These consist of commercial Gel-Cel batteries manufactured by Globe Union, both mounted in a welded aluminum case designed and fabricated by the LWL Shop. The 16-pound battery will power the manpack radar for 6-8 hours. The 32-pound battery for 10-12 hours. A 24-volt vehicle battery will power the M-FOPEN for up to 24 hours.

b. The base station system requires 110-120 VAC, 60 cycle, 1 phase (1.5 kW required) which is supplied by the 2.5 kW generator accompanying this system. The power amplifier (20 kW pulse) of the base station system is connected to the output of the multipurpose radar transmitter/receiver unit, mounted at the base of the 50-foot tower providing the voltages necessary to operate the electronic and electrical/mechanical elements of the set.

4. Transport/Antenna Tower Assembly. Transport of the man-portable system and assembly of the system including the 30-foot tower can be accomplished by two men. The base station system requires transportation by 2-1/2 ton truck and five personnel for setting up the system. The telescoping tower is erected manually and incorporates the two antennas from the other systems. The power amplifer and trnasmitter/receiver unit are mounted near the base

of the 50-foot tower. An AB-577 antenna mast used with the CORPS level TRC-110 radio equipment may be used instead of the 50-foot tower for a base station or fixed installation. This mast can be erected up to 75 feet and extend the range of either the Man-portable or Base Station systems.

APPENDIX B

DEPARTMENT OF THE ARMY
HEADQUARTERS 1ST BATTALION 5TH INFANTRY
1ST BRIGADE 25TH INFANTRY DIVISION
APO San Francisco 96557

TLTA-IN 24 May 1973

SUBJECT: After Action Report - Multi-Purpose Foliage Penetration Radar System (M-FOPEN)

THRU: Commander
1st Brigade 25th Infantry Division
APO San Francisco 96557

Commander
25th Infantry Division
APO San Francisco 96557

Commander
United States Army Pacific
ATTN: GPOP-FD
APO San Francisco 96558

TO: Headquarters, Department of the Army
Assistant Chief of Staff for Force Development
ATTN: DAFD-ZA
Washington, D.C. 20310

1. The 1st Battalion 5th Infantry was tasked to conduct the user evaluation of the Multi-Purpose Foliage Penetration Radar System (M-FOPEN). The purpose of the evaluation was to determine if the M-FOPEN is ready for production in quantity or, if not suitable, to specifically identify those shortcomings in design and performance which make it unsuitable. The M-FOPEN is designed to complement the AN/PPS-5 radar, not replace it. The United States Land Warfare Laboratory (LWL) is the developing agency for the M-FOPEN radar system. The troop element which performed the evaluation was the Ground Surveillance Section Combat Support Company, 1st Battalion 5th Infantry. The entire assets of the Section were committed to this evaluation.

2. The unit received the M-FOPEN on 23 March 73. The radar was inspected on 26 March 73 by Mr. Lou Surgent, LWL Task Officer, and Mr. Frank Perusich, Aerospace Research Incorporated representative, for any damage that might have occurred during shipment. Classes on orientation, theory of operation, check-out procedures and installation were conducted by SFC Thomas Longhran (LWL) beginning 26 March 73. Field testing began on 28 March 73 with the following two configurations of the M-FOPEN tested:

a. The Man-Portable Radar with the Man-Portable Mast system. This radar consists of a pair of antennas, a 30-foot fiberglass antenna mast, a transmit-receive unit, an operator's control and display unit, separate batteries, and connecting cables.

b. The Base Station System. This radar consists of a 30-foot fiberglass antenna mast, batteries, cables, electronics applicable to the system antenna rotator, and a higher power radio frequency amplifier.

3. The user evaluation test was conducted in the following two phases:

a. Phase I (Base line testing).

(1) The open area portion of the base line testing was conducted in the vicinity of Schofield Barracks (McCarthy Flats). The base line tests were used to obtain the maximum efficient range of the radar under ideal conditions and to determine the radars maximum capabilities under varying conditions. During the base line test period, an AB-577/GRC antenna mast was used instead of the regular base station tower. This was done to facilitate changing the antenna height to desired levels with a minimum expenditure of time and effort.

(2) The base line testing began with Man-Portable radar being deployed using the AB-577/GRC antenna mast raised to 20 feet. It was found that the wind caused the cables between the transmitter/receiver (TR) box and the antenn to move into and out of contact with the metalic mast, causing the automatic frequency control (AFC) and automatic gain control (AGC) to build in both the inner and outer range gates. This problem was corrected by firmly taping the cable to the mast. Mr. Surgent explained that the effects of the flapping antenna cable has been seen before in previous testing and present no new problems to this evaluation. Unknown radio frequency interference (RFI) created some problems during the base line testing. The radar was still detecting targets, but at a reduced range because of the radio frequency interference (RFI). The RFI was found to be coming from a citizens band radio of several hundred watts. The radio is a part of a damage control net established by United States Army Support Command Hawaii (USASCH). Arrangements were made with the station operators to minimize traffic until testing was completed.

(3) It was noted during the base line testing that radar determined range coincided very closely with the controller determined range using 1 to 5 men walking targets. Operators were getting target alarms and target personnel were calling off range markers within three seconds or less of each other. Jeep (M151) targets were detected out to 900 meters with good signal return.

(4) Initial foliated testing conducted vicinity of Schofield Barracks (South Range area) proved to be a poor field location due to radio interference Therefore, the decision was made by testing personnel to move to the Makua Valley training area. Testing began at Makua Valley on 18 April 73. Controlled targets, consisting of personnel and vehicles, were used to further test the M-FOPEN capabilities to penetrate moderate to dense foliage. A ¼ ton vehicle was tracked out to a range of 1100 meters, the first 600 meters being dense foliage. Five man targets were tracked out to 500 meters in dense foliage with the antenna raised to a height of 30 feet. An AN/PPS-5 radar was deployed behind the M-FOPEN and on top of a small 30 foot mound. Both radars were looking essentially at the same presentation of terrain and foliage. The AN/PPS-5 attempted to detect all targets presented. However, its capabilities were limited to detecting vehicles and personnel in open spots in the test area. The M-FOPEN did pick up surf movement (Makua Valley is in immediate vicinity of the ocean) in the antenna back lobes when raised to a height of 50 feet. The detection of the surf in the radar back lobes indicates that a more detailed analysis of antenna/set sensitivity characteristics is needed and that antenna patterns must be more closely defined. Base line testing was completed on 23 April 73.

b. Phase II (Tactical testing). The tactical exercise began on 25 April 73 and terminated on 27 April 73. Additional equipment was set up and selected target paths marked. Target personnel familiarized themselves with the tactical scenario, target paths, and control and communications procedures. During the tactical exercise, 33 tactical targets were presented consisting of two to twenty personnel moving along controlled paths at a controlled rate of speed. The M-FOPEN detected 31 of 33 tactical targets presented. The AN/PPS-5 detected only five of the 33 tactical targets presented and these were line of sight targets on the Makua Valley access road. The M-FOPEN detected personnel targets out to a range of 700 meters through dense foliage and vehicles out to a range of 1100 meters.

4. CONCLUSIONS: The M-FOPEN radar readily adapts to its environment. The Battalion's Ground Surveillance Section was well pleased with the performance and overall efficiency of the M-FOPEN. However, all operators agreed that the M-FOPEN antenna system needs additional development and testing. All operators expressed the desire to have the M-FOPEN on a pormanent basis for use during tactical

TLTA-IN 24 May 1973
SUBJECT: After Action Report - Multi-Purpose Foliage Penetration Radar System (M-FOPEN) (Cont)

training and operations. The fiberglass antenna mast used with the Man-Portable configuration shows general military potential and application. It appears superior, particularly more durable, than the standard RC-292 antenna masts currently in Army-wide use. It is easier to assemble and disassemble, stronger, more flexible and capable of providing greater mast height for the same amount of weight. The AB-577/GRC antenna is considered to be a better masting for the radar than that currently used in base station radar. It is lighter, takes up less space and is quicker and easier to assemble/disassemble. Rain has no apparent effect on the radar. It was noted that strong winds do have some effect on present antennas being used. The wind causes a build-up in automatic frequency control thereby decreasing the detection range of the radar. However, the detection of vehicles through foliage is possible despite high AFC levels. FM tactical radios operating in immediate vicinity have a negligible effect on the M-FOPEN. The maintenance requirements of the M-FOPEN during the test period were minimal. There were no electronic failures.

5. The user evaluation testing was concluded 27 April 73.

JAMES E. THOMPSON
LTC, Infantry
Commanding

CF:
Commanding Officer
US Army Land Warfare Laboratory
Aberdeen Proving Grounds, Md.

APPENDIX C

AFMAS-CSS-L 13 DEC 1973

SUBJECT: LWL Hawaii Evaluation Report: User Evaluation of the Multipurpose Foliage Penetration

Commander
US Army Land Warfare Laboratory
ATTN: AMXLW-ADP (Mr. Louis V. Surgent, Jr.)
Aberdeen Proving Ground, Maryland 21005

1. Reference letter, AMXLW-ADP, dated 25 Sep 73, subject as above.

2. The MASSTER observer to the test conducted in Hawaii worked closely with the LWL Test Officer in the formulation of the LWL test report. This included a period of direct involvement at Aberdeen Proving Ground as well as an informal review of the draft test report. MASSTER has reviewed the final report of evaluation and makes the following comments:

a. The M-FOPEN operated well in a built-up area. However, conclusions should be modified to indicate more precisely the characteristics of the particular built-up area, i.e., detached and semi-detached one and two story frame buildings.

b. While the ranges of detection under conditions experienced were very good, the detection ranges were not within what may be considered maximum ranges in a mid-intensity environment in Europe. Historically, during World War II contending forces were often separated in heavily wooded areas by several kilometers or more. It can be expected that on much of the terrain in Western Europe, there exists a requirement to be able to detect targets through foliage at ranges of 1,000 meters and greater. It would appear appropriate that a recommendation be included which expresses the need for continued development to achieve these ranges.

c. There were numerous occasions of high build-up of automatic frequency control (AFC) and automatic gain control (AGC) levels due to wind induced foliage movement, observation of surf across a beach, and various man-made objects in some test areas. The high AFC and AGC levels desensitized the M-FOPEN with a resulting decrease in range capability. This phenomenon apparently places the M-FOPEN very close to indicating false alarms. If these high AFC and AGC levels affect the military potential of the M-FOPEN, then development should be continued in order to minimize such effects.

AFMAS-CSS-L
SUBJECT: LWL Hawaii Evaluation Report: User Evaluation of the Multipurpose Foliage Penetration

3. Based on the above discussion, MASSTER does not agree that this User Evaluation is sufficient basis to recommend world-wide use of the M-FOPEN. The present recommendation 10a should be modified to indicate the need for further development of the range capability and further development and testing in a European-style residential environment, i.e., city blocks of apartments and other buildings constructed of concrete, steel, brick, etc. The latter is particularly critical in view of the advancing degree of urbanization of Europe.

4. Other than as noted above, MASSTER concurs in the LWL Evaluation Report.

FOR THE ~~DEPUTY~~ COMMANDER:

WILLIAM C. HARTED, JR.
CPT, AGC
Asst Adj.

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