Research and Development Technical Report
ECOM-00390

FINAL REPORT

RADAR SET AN/PPS-6(XE-6)

11 OCTOBER 1964 to 24 JUNE 1966

JUNE 1967

DISTRIBUTION STATEMENT

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UNITED STATES ARMY ELECTRONICS COMMAND · FORT MONMOUTH, N.J.

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Hicksville, LI, New York 11802

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Personal Author(s) : Smirlock, Marc

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Abstract : This report summarizes the development of a lightweight, man-portable battlefield surveillance radar set. It gives a description of the radar set, and a comparison of its parameters with those specified. The report describes the steps in the development and the modifications required to solve operational problems discovered during the service tests. A reliability prediction is then followed by recommendations for future work. The radar set was to operate in the frequency range of 9.0 to 9.6 KMc. It was to be capable of detecting and identifying personnel and vehicular targets by means of the doppler principle.

Descriptors : *COMBAT SURVEILLANCE), (*SEARCH RADAR, (*DOPPLER RADAR, COMBAT SURVEILLANCE), NOISE(RADAR), AUDIO AMPLIFIERS, PORTABLE EQUIPMENT, X BAND, ENEMY PERSONNEL, VEHICLES, RELIABILITY(ELECTRONICS), MATHEMATICAL MODELS, MATHEMATICAL PREDICTION, RADIOFREQUENCY INTERFERENCE, RADAR TRANSMITTERS, RADAR RECEIVERS, POWER AMPLIFIERS, RADAR ANTENNAS, TELESCOPES, CONTROL SYSTEMS, STORAGE BATTERIES, SPECIFICATIONS, FAILURE(ELECTRONICS), TABLES(DATA), WEIGHT.

Subject Categories : ACTIVE AND PASSIVE RADAR DETECTION & EQUIPMENT

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RESEARCH AND DEVELOPMENT TECHNICAL REPORT

ECOM-00390-F

FINAL REPORT

RADAR SET AN/PPS-6(XE-6)

11 OCTOBER 1964 to 24 JUNE 1966

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JUNE 1967

PREPARED BY

MARC SMIRLOCK

GENERAL INSTRUMENT CORPORATION
HICKSVILLE, LI, NEW YORK 11802

Radio Receptor Division - 813-101

FOR

US ARMY ELECTRONICS COMMAND, FORT MONMOUTH, NJ

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Frontispiece Radar Set AN/PPS-6(XE-6), Tactical Employment

1.0 PURPOSE

The purpose of this contract was to develop a compact, lightweight, man-portable battlefield surveillance radar set.

The radar set was to operate in the frequency range of 9.0 to 9.6 KMc. It was to be capable of detecting and identifying personnel and vehicular targets by means of the doppler principle.

3.0 RELATED PUBLICATIONS

3.1 Design Plan for Radar Set AN/PPS-6(XE-6)

General Instrument Corporation, Radio Receptor Division, 4 May 1965.

3.2 Test Plan for Radar Set AN/PPS-6(XE-6)

General Instrument Corporation, Radio Receptor Division, 7 October 1965.

3.3 Compliance Test Report for Radar Set AN/PPS-6(XE-6)

General Instrument Corporation, Radio Receptor Division, 21 February 1966.

3.4 (U) Radar Set AN/PPS-6(XE-6) Service Test, Final Report of Project No. 20-65-07, 26 April 1966 (CONFIDENTIAL)

Marine Corps Landing Force Development Center.

4.0 FACTUAL DATA

This contract was for the development of ten radar sets to meet the requirements of SCL-8005 dated 18 December 1963 and Amendment No. 3 dated 3 September 1965. Designation of the radar as AN/PPS-6(XE-6) distinguishes this model from the AN/PPS-6(XE-5) built by USAECOM, Fort Monmouth, New Jersey. An additional lot of four radars was ordered on 10 November 1965.

4.1 Description of Equipment

The radar set (figure 4-1) consists of the two major operating units, the receiver-transmitter and the angular control, which are supported during field operation by the tripod unit. A detailed description of these units isgiven below. Accessories are described in paragraph 4.1.4. Table 4-1 gives a summary of the mechanical parameters.

4.1.1 Receiver-Transmitter

All electrical components of the receiver-transmitter (figure 4-2) are housed in an aluminum case with overall dimensions of 11 x 11 x 8 inches. The case is divided into two sections: an rf and a main section. Each section contains modules which can be easily removed and replaced during maintenance.

The rf section is secured to one side of the case and can be detached to provide access to its interior by unlocking four camlock screws. A parabolic reflector forms the outside surface of

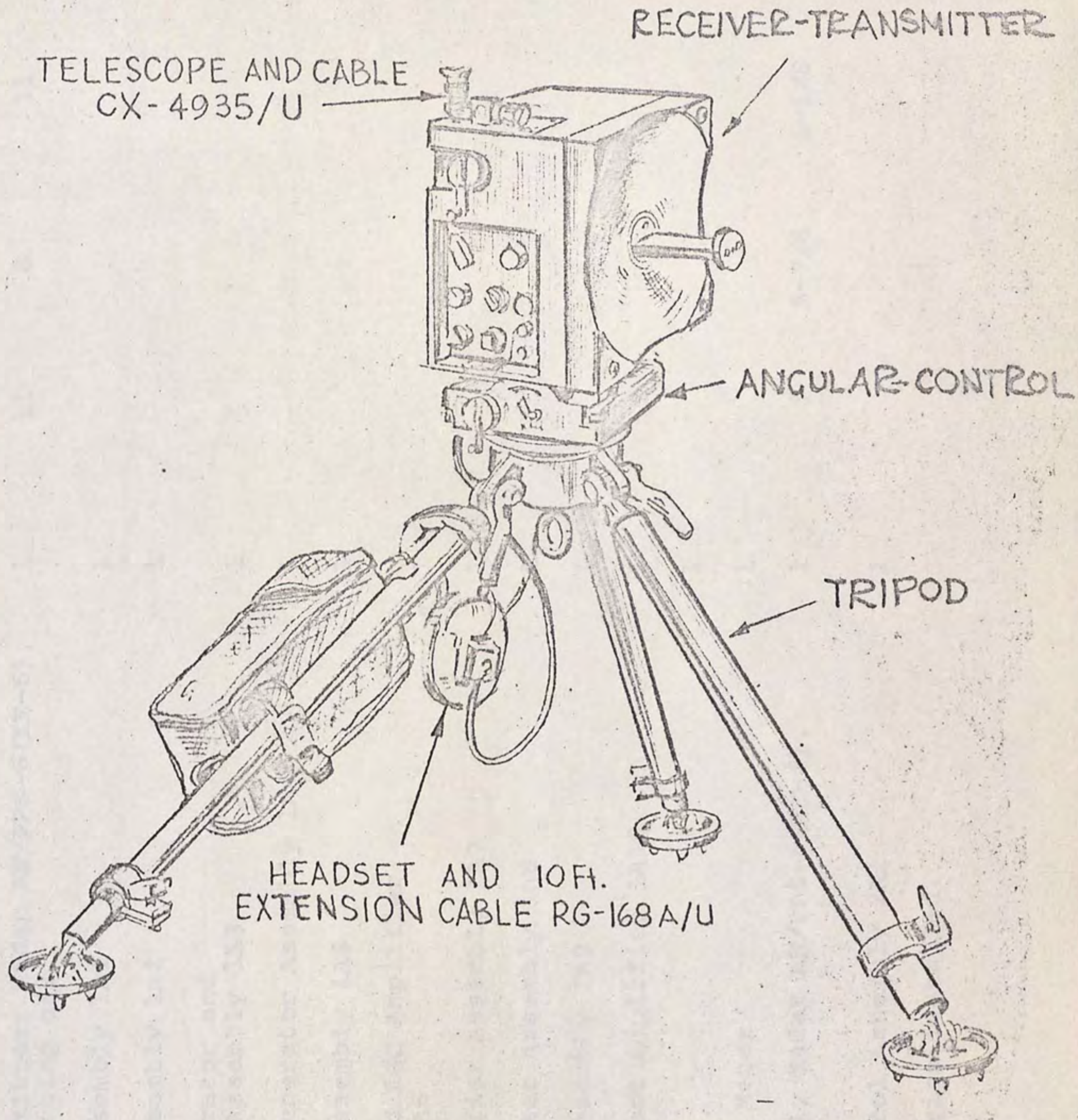


Figure 4-1 Radar Set AN/PPS-6(XE-6), Major Components

Table 4-1 Equipment Components

Components	Quantity	Height (in.)	Depth (in.)	Width (in.)	Unit Wt. (lb-oz.)
Receiver-Transmitter, Radar AN/PPS-6(XE-6), Unit 1 consisting of:	1	11	8	11	*22-13
RF Module Assembly 1A1	1				
Modulator Assembly 1A2	1				
Trigger Generator and AFC Video Assembly 1A3	1				
Range Gate Generator Assembly 1A4	1				
Video Mode Assembly 1A5	1				
IF Video, and AGC Amplifier Assembly 1A6	1				
AFC IF Amplifier Assembly 1A7	1				
Power Converter Assembly 1A8	1				
Delay Line Assembly 1A9	1				
Crystal Current Amplifier 1A10	1				
Battery 1BT1	1				
Elapsed Time Meter	1				
Angular Control, Radar AN/PPS-6(XE-6), Unit 2	1	3	5-7/8	6-1/8	5-8
Angular Control Assembly 2A1	1				

* With batteries installed.

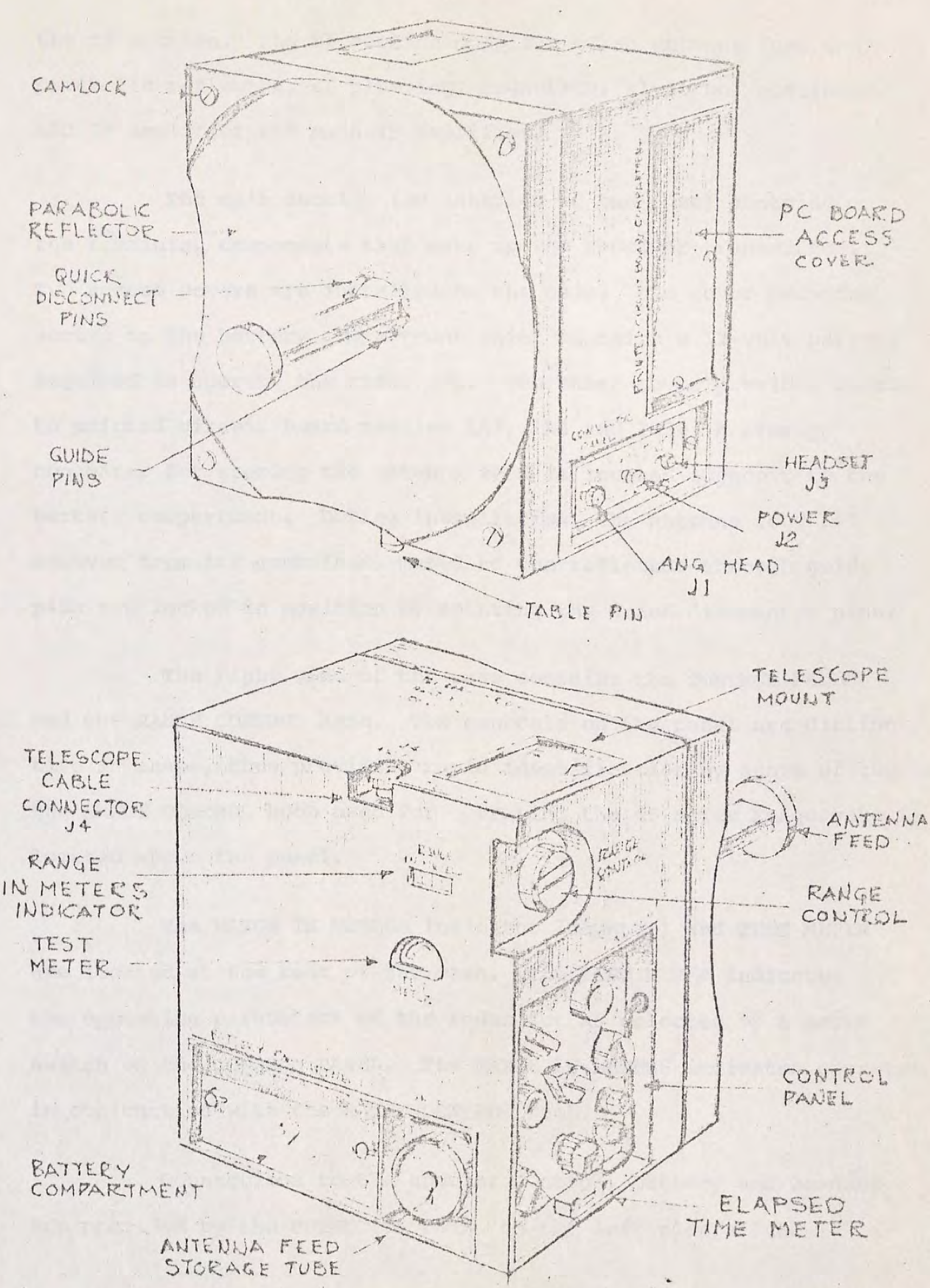


Figure 4-2 Receiver-Transmitter

the rf section. The rf section consists of an antenna feed and parabolic reflector, rf plumbing, magnetron, klystron, modulator, AFC IF amplifier and main IF amplifier.

The main section (or interior of the case) contains the remaining components that make up the receiver-transmitter. Two access covers are installed on the case. One cover provides access to the battery compartment which contains a 12-volt battery required to operate the radar set. The other cover provides access to printed circuit board modules 1A3, 1A4 and 1A5. A storage container for storing the antenna feed is located adjacent to the battery compartment. During installation, the antenna feed is removed from its container, mated to the reflector through guide pins and locked in position by rotating the quick-disconnect pins.

The right side of the case contains the CONTROL PANEL and the RANGE CONTROL knob. The controls on the panel are distinctive in shape, thus providing rapid identification by sense of touch. The RANGE CONTROL knob used for operating the 45 meter range gate is located above the panel.

The RANGE IN METERS indicator (counter) and TEST METER are located at the rear of the case. The TEST METER indicates the operating parameters of the radar set as selected by a meter switch on the CONTROL PANEL. The RANGE IN METERS indicator operates in conjunction with the RANGE CONTROL knob.

Connections to the angular control, battery and headset are provided by the CONNECTOR PANEL on the left side of the receiver-transmitter unit. Power to the angular control is applied through cable W1 to ANG HEAD jack J1. The POWER CONNECTOR J2 cap, in position, permits use of the internal battery power. An external dc voltage source may be used by disconnecting the cap and connecting the remote power cable W2 to connector J2. The headset is plugged into HEADSET jack J3.

A telescope used for antenna boresighting is mounted on top of the case. It is secured to the case by two camlock screws. A connecting telescope cable supplies power to the telescope for graticule illumination and is connected to jack J4 on the receiver-transmitter. Illumination is also provided for the RANGE IN METERS indicator and TEST METER. A table pin for locking the receiver-transmitter to the angular control is located at the bottom of the unit. Two guide pins are also provided to prevent the unit from pivoting in its locked position.

An elapsed time meter, clipped on to the lower rim of the CONTROL PANEL, is used to record the operating time of the radar set during test. The meter consists of a capillary tube filled with two columns of mercury separated by an indicating gap of electrolyte. When power is applied, the resulting current flow causes electroplating of the mercury from one column to the other at an exact rate. The meter has a 100-hour full scale and must be reset after reaching full scale.

4.1.2 Angular Control

The angular control (figure 4-3) consists of an enclosed housing whose overall dimensions are approximately 5-3/4 inches wide by 7 inches long by 5-1/2 inches high. An elevation table located

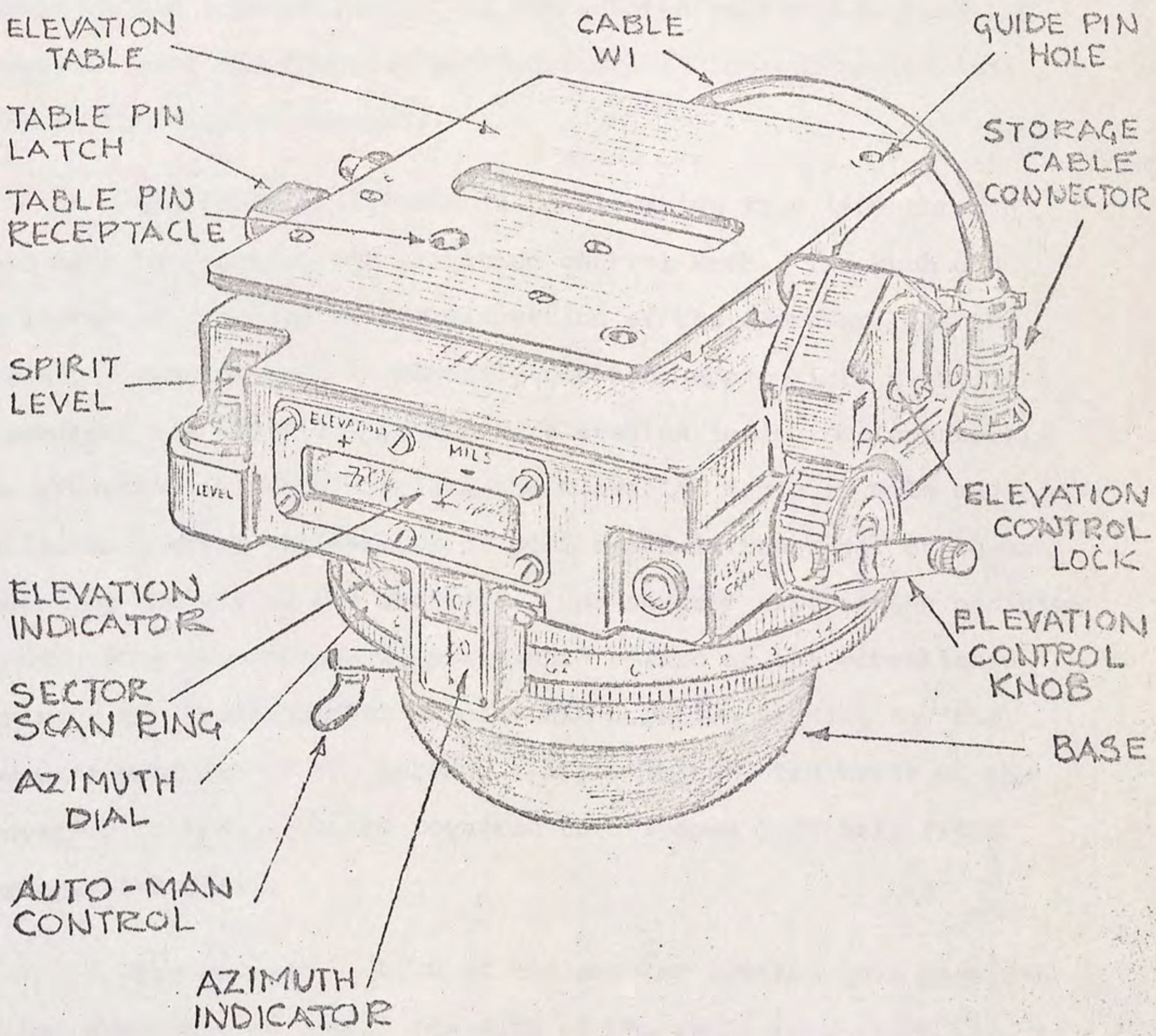


Figure 4-3 Angular Control

on the upper portion of the angular control supports the receiver-transmitter. A latch located beneath the table is used to lock the two units together. The base of the angular control mates with tripod, unit 3. A leveling clamp is used to secure the base to the tripod. The main(or mid-section) of the unit provides elevation and azimuth control of the mounted receiver-transmitter. A spirit level for leveling the radar set is located on the left side of the angular control.

The table is adjustable in elevation from +400 through -600 mils by rotating the elevation control knob. The knob can be locked in position at the discretion of the operator. As the elevation control knob is manually rotated, appropriate gears drive both the elevation table and elevation indicator (counter). The elevation indicator displays the elevation angle in mils and also indicates whether the antenna is positioned in the upper or lower sector by the use of two shutters. One shutter exposes the positive reading when the antenna is positioned upward of the established horizon; the other shutter exposes the negative reading for the downward position of the antenna. Approximately ten turns of the elevation control knob are required to traverse 1000 mils (+400 through -600 mils).

The azimuth section of the angular control unit provides either automatic or manual scanning of the radar set. With the receiver-transmitter set to either MODE 1 or MODE 2 and the angular control AUTO-MAN control set to AUTO, the radar set will automatically scan 600 mils in azimuth at the rate of 36 mils per second. A marker on the sector scan ring provides a center position for the 600 mil azimuth scan sector. The driving mechanism for automatic scanning consists of a motor and gear assembly which operates in conjunction with two microswitches, a latching relay and a cam. The mechanism provides reversal of the motor at the end of each scan and a linear rate during the scan cycle. When the receiver-transmitter is set to MODE 3, the motor is turned off. When the AUTO-MAN control is set to MAN, the motor is disengaged from its driving mechanism, permitting manual scanning by the operator over a range from 0 through 6400 mils in azimuth. In any event, the motor drives the angular head through a slip clutch so that the drive mechanism can be manually overridden at any time.

The azimuth indicator is used to read the azimuth-mils dial. The dial is graduated from 0 through 64, representing 0 through 6400 mils (or 360 degrees). The minor graduations represent 10 mils; the intermediate graduations, 50 mils; and the major graduations, 100 mils. Each 200-mil graduation is numbered. For example: the interval between numbers 44 to 46 represents 200 mils.

A circular spirit level, with a pentaprism, for ease of viewing, is mounted to the left of the elevation indicator. This facilitates the proper leveling of the angular control when mounted on the tripod wye. When the elevation indicator reads zero, the antenna is horizontal and the radar set will scan in a horizontal plane.

Three lamps provide illumination within the angular control unit. One lamp is used to illuminate the circular level, the other two lamps illuminate the elevation indicator and azimuth indicator dial.

4.1.3 Tripod

The tripod (figure 4-4) is constructed of lightweight rigid materials. The apex or "wye" portion of the tripod forms part of the leveling mechanism. The spherical contour mates with the leveling head and provides $\pm$15 degrees displacement about the horizontal and forms the center portion of the wye. Three ears with serrated locks and locking levers allow the legs to be quickly placed in an erected position. The telescoping legs provide maximum holding strength without danger of collapsing. The end of each leg is terminated in a pad adaptable to the various ground conditions encountered in operational service of the radar set. This pad is joined to the telescoped leg by means of a swiveling ball joint to allow for ground contour variations. In its transport condition, the tripod can be telescoped to a length of 30 inches and diameter of 6 inches. In addition, the tripod assembly contains a captive cable, and an accessory bag.

4.1.4 Description of Accessories

4.1.4.1 Telescope and Cable

Elbow telescope M-62A10, or equivalent (figure 4-5), mounts on top of the receiver-transmitter assembly by use of two camlock

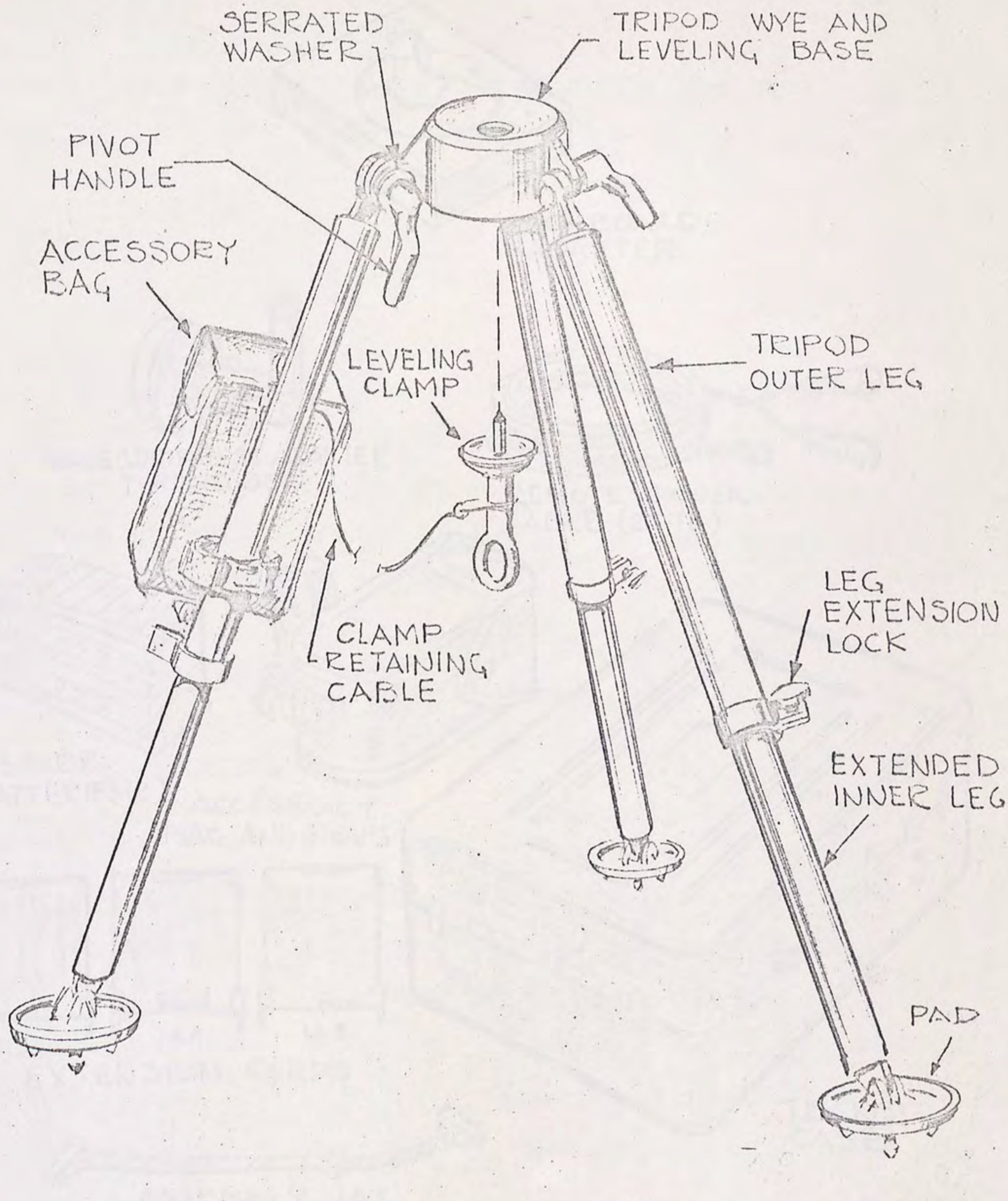


Figure 4-4 Tripod

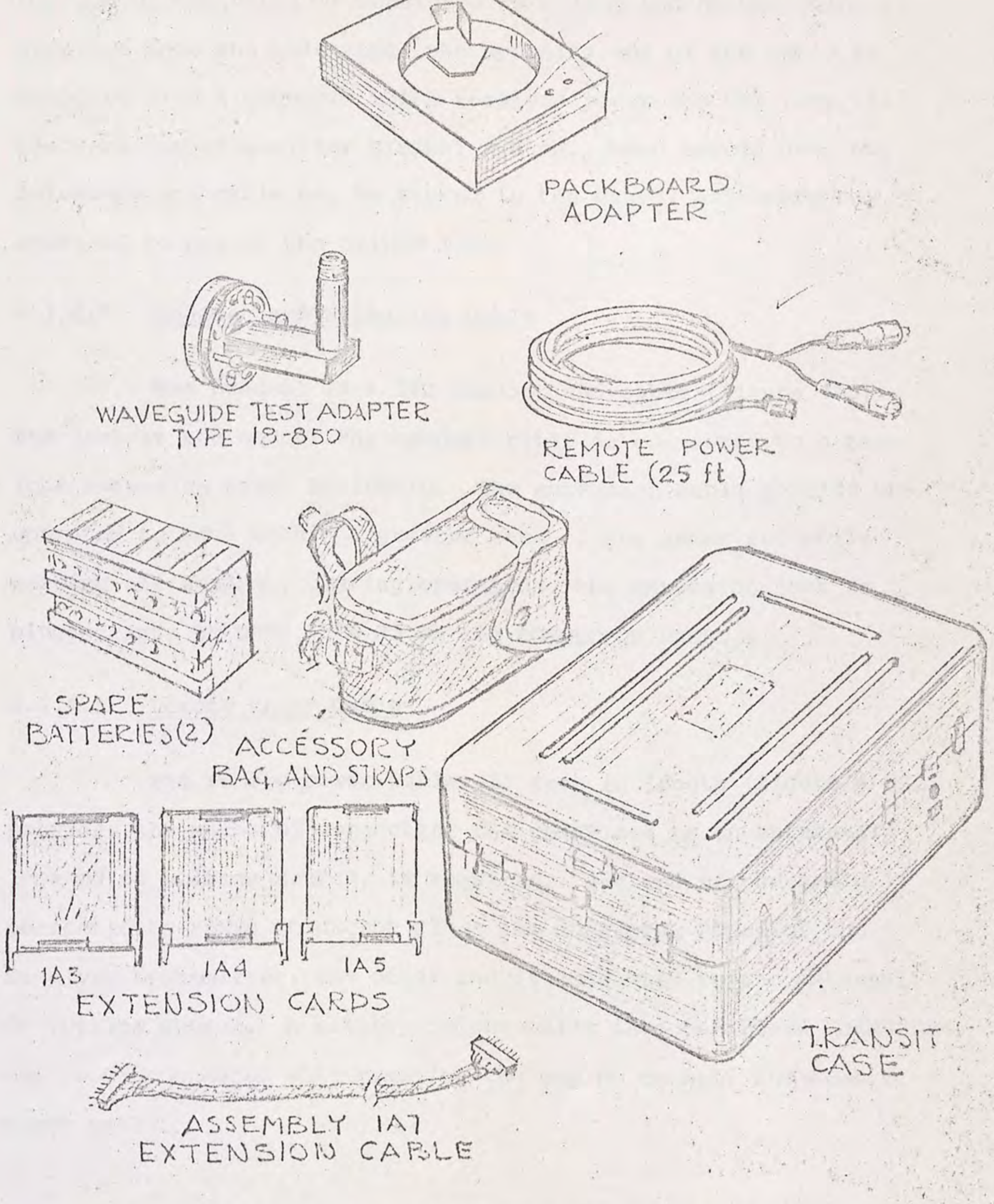


Figure 4-5 Radar Set AN/PPS-6(XE-6), Accessories

screws. The telescope is used for boresighting during initial setup. Attaching cable CX-4935/U is supplied with the telescope. One end of the cable is connected to a lamp and holder which is inserted into the telescope; the opposite end of the cable is supplied with a connector which receives power for the lamp via the receiver-transmitter DISPLAY switch. When not in use, the telescope and cable may be stored in the canvas accessory bag attached to one of the tripod legs.

4.1.4.2 Headset and Extension Cable

The headset is a 32Ω headset and cable (figure 4-5). The jack at the end of the headset cable is connected to a ten-foot extension cable RG-168A/U. The extension cable permits the operator to move within a greater area of the radar set while wearing the headset. During operation, the extension jack is plugged into HEADSET jack J3 on the CONNECTOR PANEL.

4.1.4.3 Remote Power Cable

The remote power cable, 25 feet in length (figure 4-5), provides the means of connecting the radar set to an externally located dc voltage source, if required. One end of the cable is connected to POWER CONNECTOR J2 on the CONNECTOR PANEL of the receiver-transmitter; the other end is connected to the external dc voltage source. A battery jumper built into the POWER CONNECTOR cap is disconnected when removing the cap to connect the remote power cable.

4.1.4.4 Waveguide Test Adapter

The waveguide test adapter, waveguide-to-coaxial adapter (figure 4-5), provides the means of coupling an external signal to the radar set for testing purposes. The adapter consists of a waveguide section terminated by a type N female connector. When in use, the radar set antenna feed is uncoupled from its reflector and the waveguide flange of the adapter substituted in its place. The opposite side of the adapter is connected to the test equipment coaxial cable.

4.1.4.5 Accessory Bag

A canvas accessory bag (figure 4-5) is used to store some of the minor components of the radar set such as the headset and its extension cable, and the telescope and cable. A fastening strap 1-inch wide and 24-inches long is attached to the bag. The strap is used to fasten the tripod legs together during transport.

4.1.4.6 Batteries

Three special silver cell batteries are provided with the radar set. One is installed in the BATTERY COMPARTMENT of the receiver-transmitter unit and two spares (figure 4-5) are stored in the transit case. Each battery is an assembly of eight series-connected cells, firmly joined by cement and fiberglas tape around the cell bodies. Two strips of an epoxy potting compound are molded over the cell terminals. When the battery is filled with electolyte, charged and ready for use, it is capable of providing 14 ampere hours of service. These batteries are rechargeable.

4.1.4.7 Transit Case

The transit case (figure 4-5) is a light, water and vapor proof container which is used to store all the major and minor components of the radar set. The case is divided into two sections which are secured to each other by the use of 14 spring-loaded latches. A two-way automatic relief (or breather) valve used to equalize air pressure before opening the transit case, is located on the lower right side of the transit case.

4.1.4.8 Extension Cards and Cables

Extension cards 1A3, 1A4, 1A5 and an extension cable for 1A7 (figure 4-5) are used for extending assemblies out of the case for maintenance. For example, assembly 1A3 may be removed from its position in the PRINTED CIRCUIT BOARD COMPARTMENT and plugged into its extension card. The card is then plugged into the compartment occupying the original position of the assembly.

4.1.5 Manpack Transit

To provide manpack transit, the radar set units are removed from the transit case and mounted on a standard Army packboard. The packboard dimensions are approximately 15-inches wide by 24-inches high and 2-1/2-inches deep (figure 4-6). One side of the packboard consists of a canvas cover tightly laced across its concave side. Shoulder straps are pulled through the packboard openings at the top and buckled at the bottom. The other side of

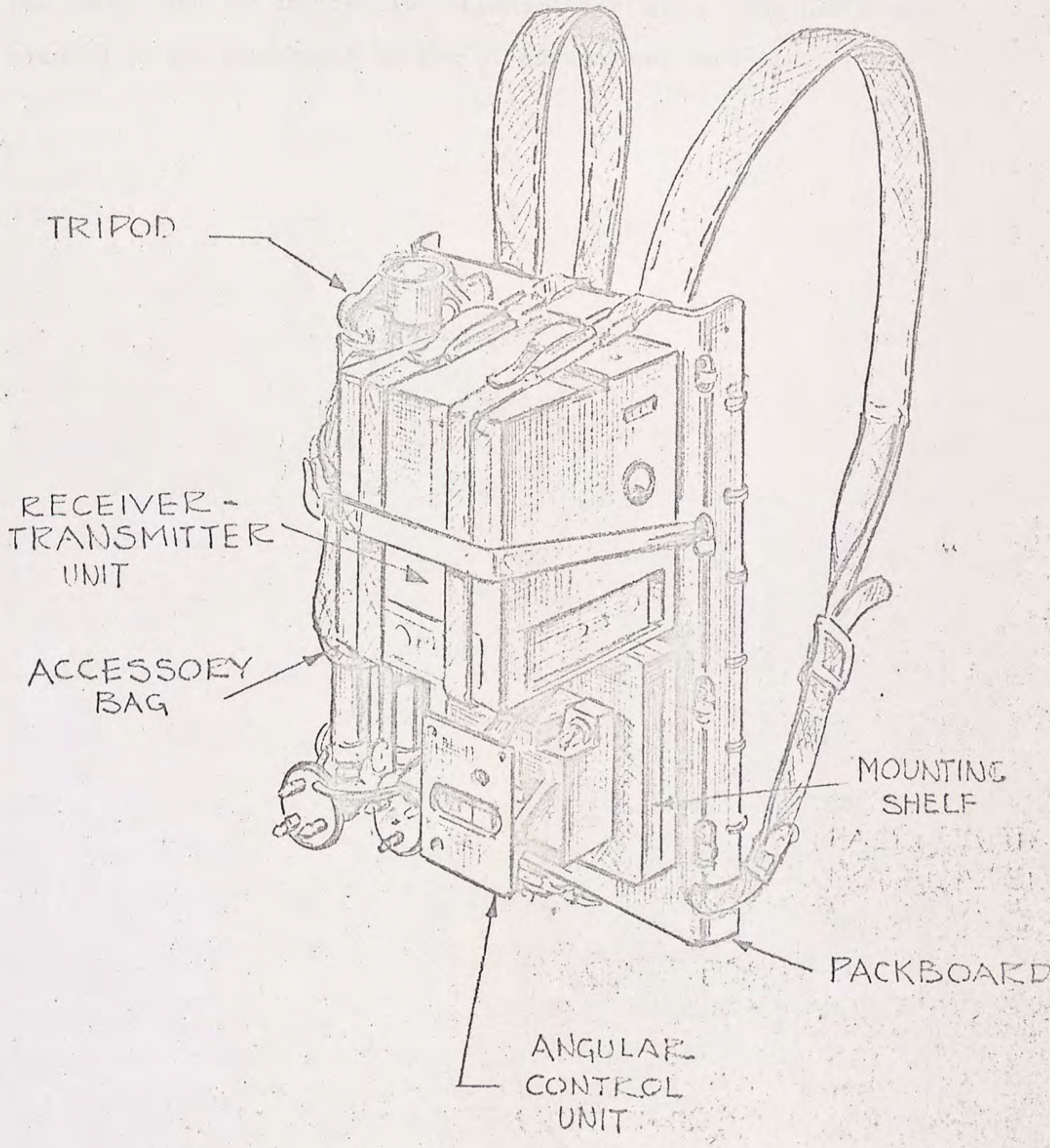


Figure 4-6 Radar Set AN/PPS-6(XE-6), Manpack Transit

the board is used for mounting of the units. Prior to installing the units on the packboard, a mounting shelf is attached to the board in order to position the angular control unit and support the lower edge of the receiver-transmitter unit. The units are secured to the packboard by use of straps and cords.

4.2 System Parameters

Table 4-2 gives a summary of the salient parameters of the radar as specified in SCL-8005 and as present in the final delivered equipment. The following is a discussion of those areas where the system differs from the original specification, or where clarification is necessary.

4.2.1 Frequency Range

The frequency range specified was from 9.0 to 9.6 KMc. The transmitter tube was specified as either a Type 7503 or BL-M003 Magnetron. Neither of these tubes were tunable through the above specified range. The Type 7503 is tunable from 9.3 to 9.6 KMc, and the Type BL-M003 is tunable from 9.0 to 9.5 KMc. The latter tube was chosen for use in the AN/PPS-(XE-6) because of its broader tuning range and higher efficiency.

4.2.2 Pulse Repetition Rate

The specified prf was 2000 cps ± 100 cps. At $-25^{\circ}F$, however, the prf of an actual equipment was reduced to 1840 cps. The cause of this problem was found to be an increase in saturation flux of the Permalloy core used in the power converter transformer. (The power converter oscillation frequency determines the prf of the radar.) This problem could be corrected by either changing the core material or deriving the radar prf from a more stable oscillator.

Table 4-2

Radar Set Characteristics

Parameter	SCL-8005	Actual
Frequency Range	9.0 - 9.6 KMc	9.0 - 9.5 KMc
Prf	2000 cps ± 100 cps	2000 cps ± 150 cps
Pulse Width	.3 μS + 0.00 μS, -.05 μS	.24 to .28 μS
Peak Power	100 watts min	150 watts min
Average Power	60 mW min	90 mW min
Intermediate Freq.	30 Mc ± 2 Mc	30 Mc ± .5 Mc
IF Bandwidth	6.3 Mc ± .3 Mc	6.3 Mc ± .3 Mc
Min discernible signal (video basis)	-95 dbm	-95 dbm min
Min discernible signal (audio basis)	not specified	-103 db min
Noise Figure	not specified	12.8 db
Dynamic Range (less AGC)	30 dbm min	30 dbm min
Dynamic Range (with AGC)	60 dbm min	80 dbm min
IF Gain	80 db min	80 db min
IF Man Gain Control	40 db	40 db
Video Bandwidth	4 Mc - .3 Mc + 1.0 Mc	4 Mc - .3 Mc + 1.0 Mc
Video Gain	30 db min	30 db min
Audio Bandwidth	26 cps to 1000 cps	*
† Detection Range .5 sq meter target (personnel)	50 m to 1500 m	50 m to 1800 m
10 sq meter target (vehicles)	50 m to 3000 m	50 m to 3000 m
Range Gate Width	45 meters max	45 meters max

Table 4-2 (Cont'd)

Parameter	SCL-8005	Actual
Antenna		
Elevation Manual Tilt	-600 mils to +400 mils	-600 mils to +400 mils
Azimuth Manual Rotation	0 - 6400 mils	0 - 6400 mils
Beamwidth (3 db points)		
E plane:	1) 7° average none greater than 7.5°	7.15° average, none greater than 7.5°
	2) Side lobe suppressions -17 db average, none greater than -14 db; shoulder suppression of at least -13 db shall be maintained	-19.5 db average, none greater than -17.4 db
H plane:	1) 8° average, none greater than 8.5°	-7.78° average, none greater than 8.0°
	2) Side lobe suppressions -20 db; shoulder suppression at least -13 db	-20.5 db average, none greater than -19.2
Gain	24.5 db min	24.65 db min
Resolution		
Range	50 meters	45 meters
Azimuth	150 mils	142 mils
Primary Power	Self-contained Silver-Zinc battery and plug for external 12 volt source	12 volts
Power Consumption	12 watts max	12.7 watts
Automatic Area Search	A 315 or 630 meter range depth scanned in azimuth ± 300 mils	A 315 or 630 meter range depth scanned in azimuth ± 300 mils
Scan Speed	36 mils/sec	50 mils/sec
Sub-Clutter Visibility	40 db	40 db

Table 4-2 (Cont'd)

Data Display

Panel Meter - Visual indicators

Counter - Reading range in meters

Dial - Reading azimuth in mils (0 - 6400)

Headphones - Aural detection and identification

Counter - Reading elevation angle in mils

* See paragraph 4.2.5.

The first solution would lead to increased power drain, due to the fact that more stable core materials have core losses an order of magnitude higher than the selected Permalloy core. The second solution would have the power supply frequency and radar prf asynchronous. This would lead to additional requirements for power supply filtering with their attendant increase in size and weight.

The only effect of the lowered prf is a decrease of the velocity ambiguity from 35 mph to 32 mph. Since the purpose of the radar is detection and not to accurately measure target velocity, it is not recommended that any change be made to further stabilize the prf.

4.2.3 Transmitter Pulse Width

The minimum width of the transmitter pulse on some units was found to be less than the specified 0.25 μS (.24 μS). However, system performance in terms of range resolution and minimum range operation is enhanced due to the narrower pulse with virtually no degradation in any other system parameters.

4.2.4 Video Gain

The video gain requirement of 30 db minimum coupled with the requirement of 30 db dynamic range would lead to excessively large amplitude video signals if a linear video amplifier were utilized in the radar. Therefore, a logarithmic characteristic was employed to reduce the large video signals without compromising the gain required to amplify small signals.

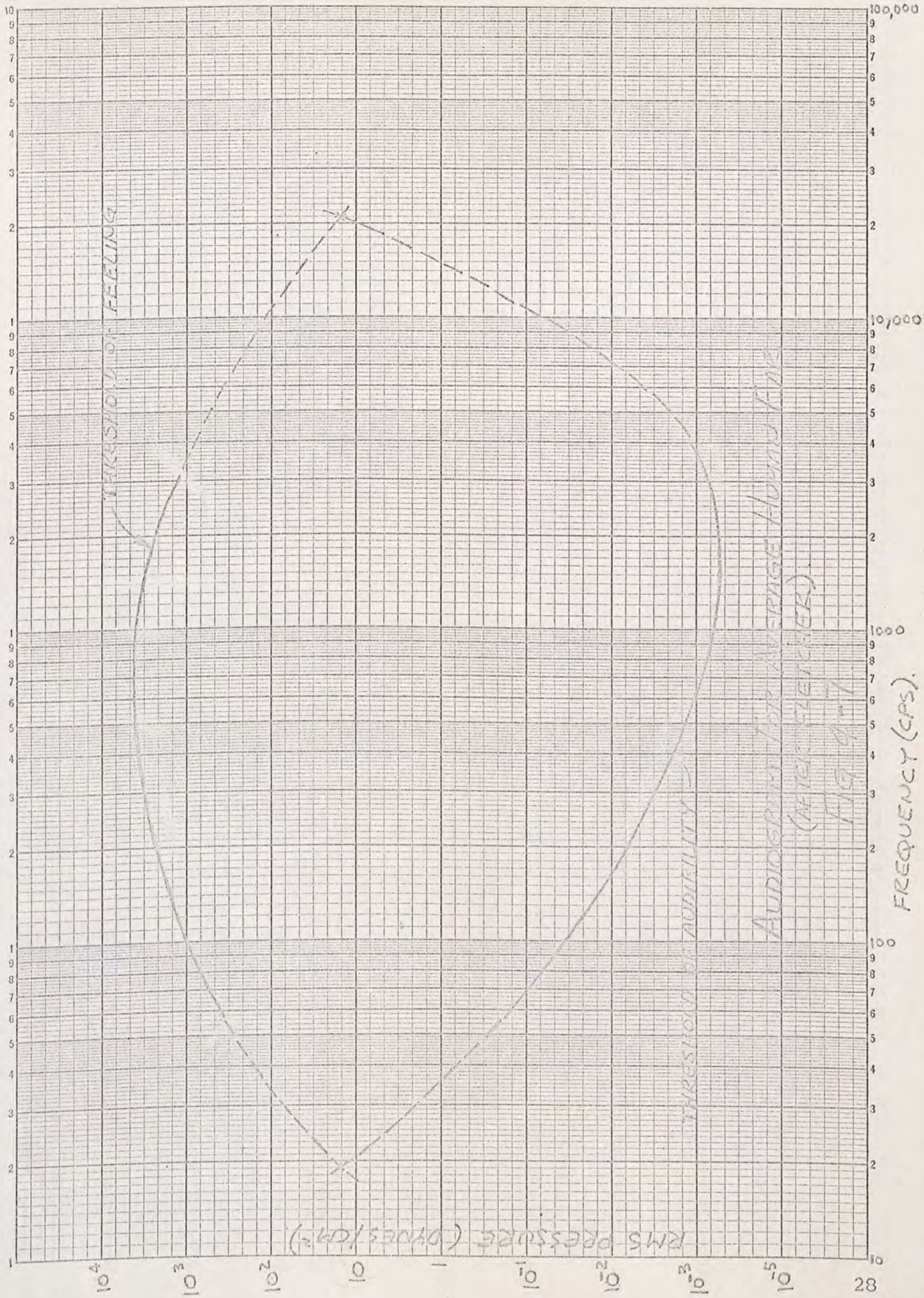
4.2.5 Audio Bandwidth

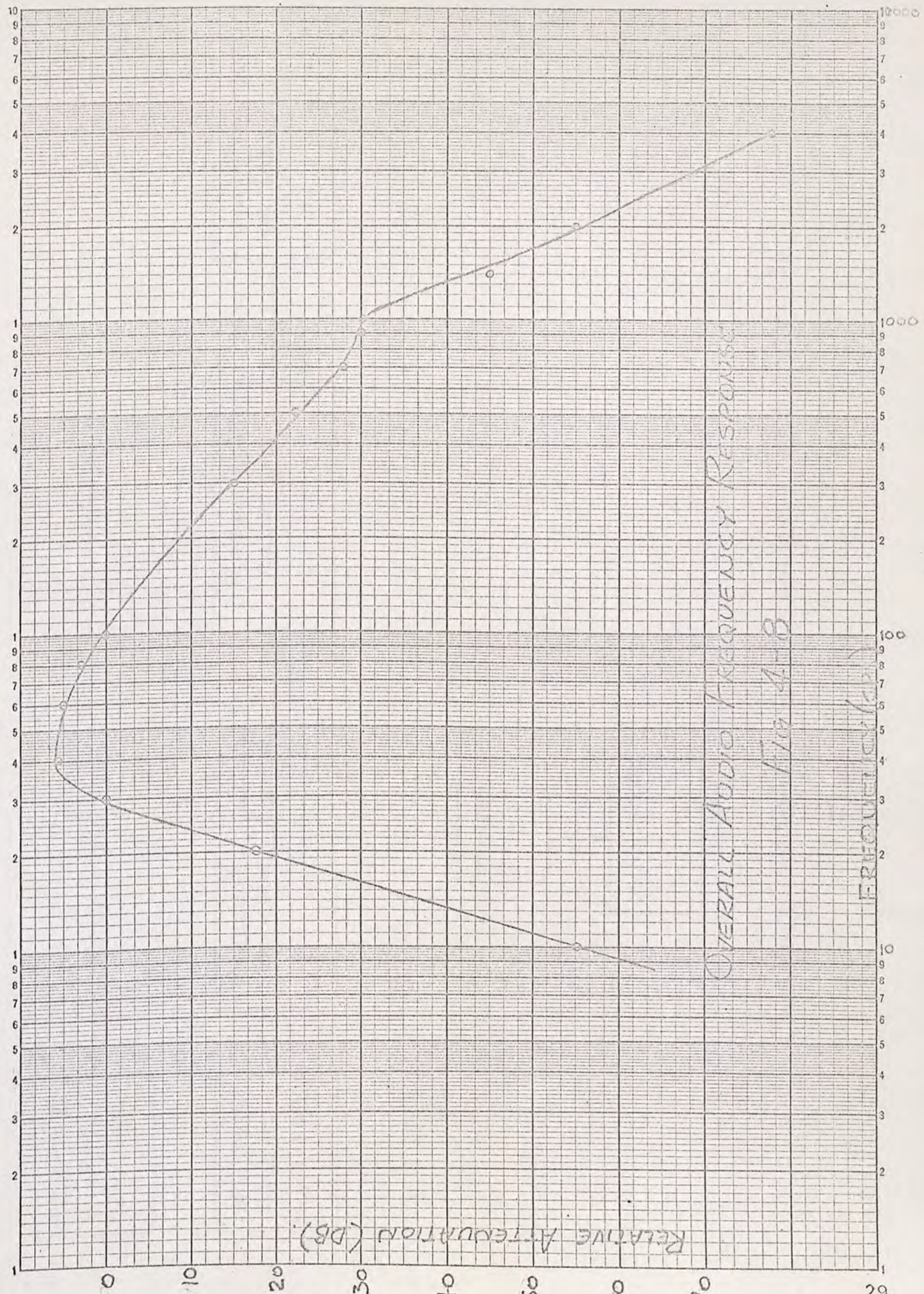
The specified audio bandwidth was 26 to 1000 cps. Normally, this requirement leads to the concept of a flat band-pass with the gain 3 db down at 26 and 1000 cps. However, due to the characteristics of the human ear, this is not desirable. Figure 4-7 gives an audiogram of the average human ear. It is noted that approximately 35 db of "bass boost" is required to compensate for the threshold of audibility. The audio frequency response of the AN/PPS-6(XE-6) is shown in figure 4-8. The block diagram of the test setup used to make this test is shown in figure 4-9. The frequency response measured includes the effects of the boxcar detector as well as the audio amplifier itself. This was accomplished by maintaining a constant level of approximately 10% of audio modulation versus frequency and using a wave analyzer to measure the output voltage at the headset in order to reject spurious frequencies generated by the boxcar detector.

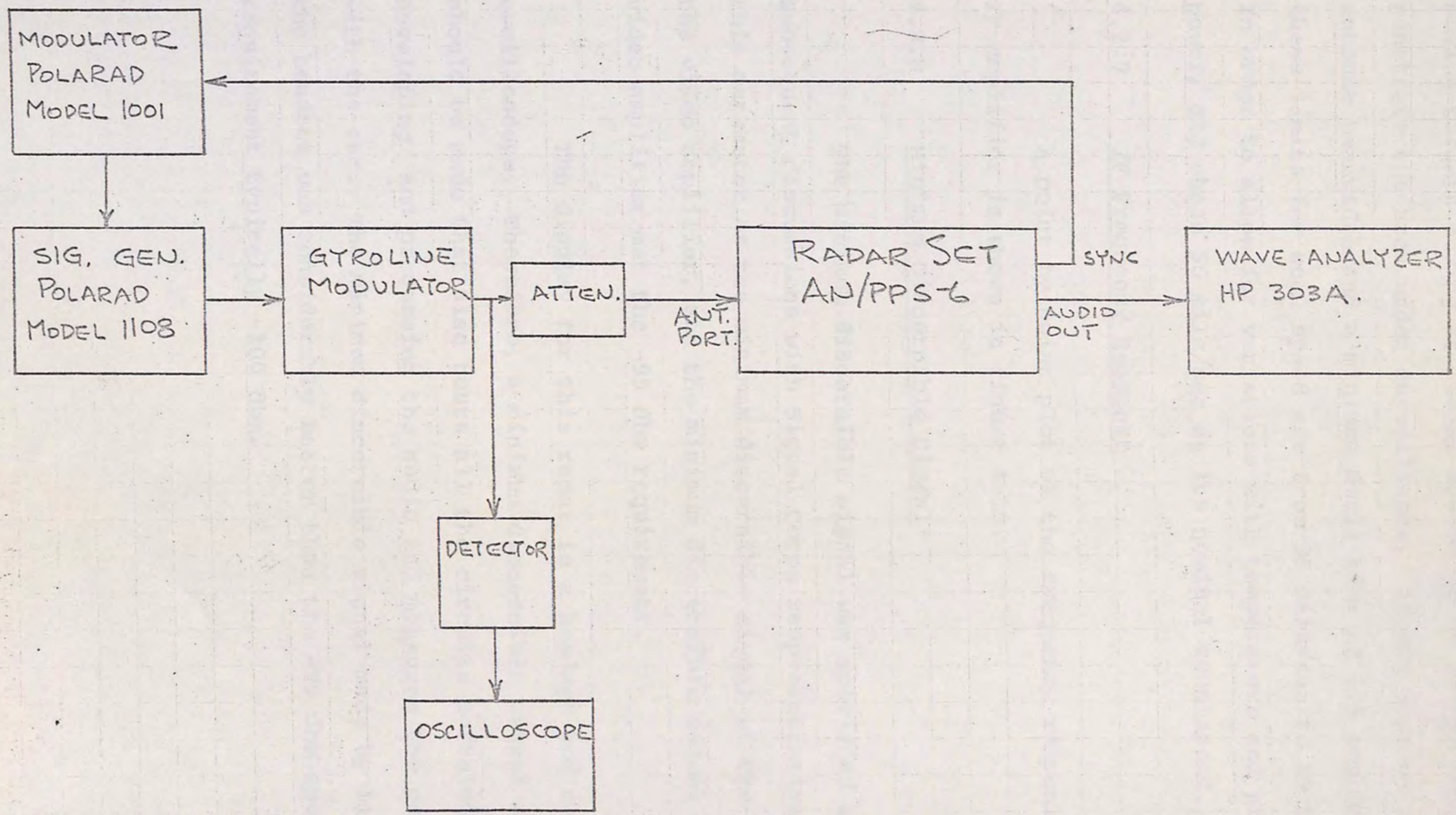
The resulting frequency response shows 36 db of "bass boost" necessary to compensate for the human ear, as well as a 36 db/octave roll-off below 26 cps and a 12 db/octave roll-off above 1000 cps introduced by the clutter filters in the audio amplifier.

4.2.6 Scan Speed

There are two factors that determine the speed of scan of the radar in Modes 1 and 2. They are dwell time on target, which fixes the maximum scan speed, and the desirability of detecting fast


THRESHOLD OF FEELING
THRESHOLD OF AUDIBILITY
AUDIOGRAM FOR AVERAGE HUMAN EAR
(AFTER FLETCHER)
FIG 4-7
FREQUENCY (CPS)
RMS PRESSURE (DYNES/CM²)
100,000
10,000
1000
100
10


OVERALL AUDIO FREQUENCY RESPONSE
FIG 4-8
FREQUENCY (CPS)
RELATIVE ATTENUATION (DB)
0
10
20
30
40
50
60
70
10
100
1000
10000
4 CYCLES X 60 DIVISIONS
MADE IN U.S.A.



OVERALL FREQUENCY RESPONSE TEST SET-UP

FIG 4-9

moving targets moving at radial speeds up to 35 mph before they penetrate the area under surveillance. If one assumes a 7.5° antenna beamwidth and a minimum dwell time of 1.5 seconds, these limits for scan speed are from 35 mils/sec to 89 mils/sec. In order to allow for variations with temperature and primary power, GIC chose 50 mils/sec as its nominal scan speed.

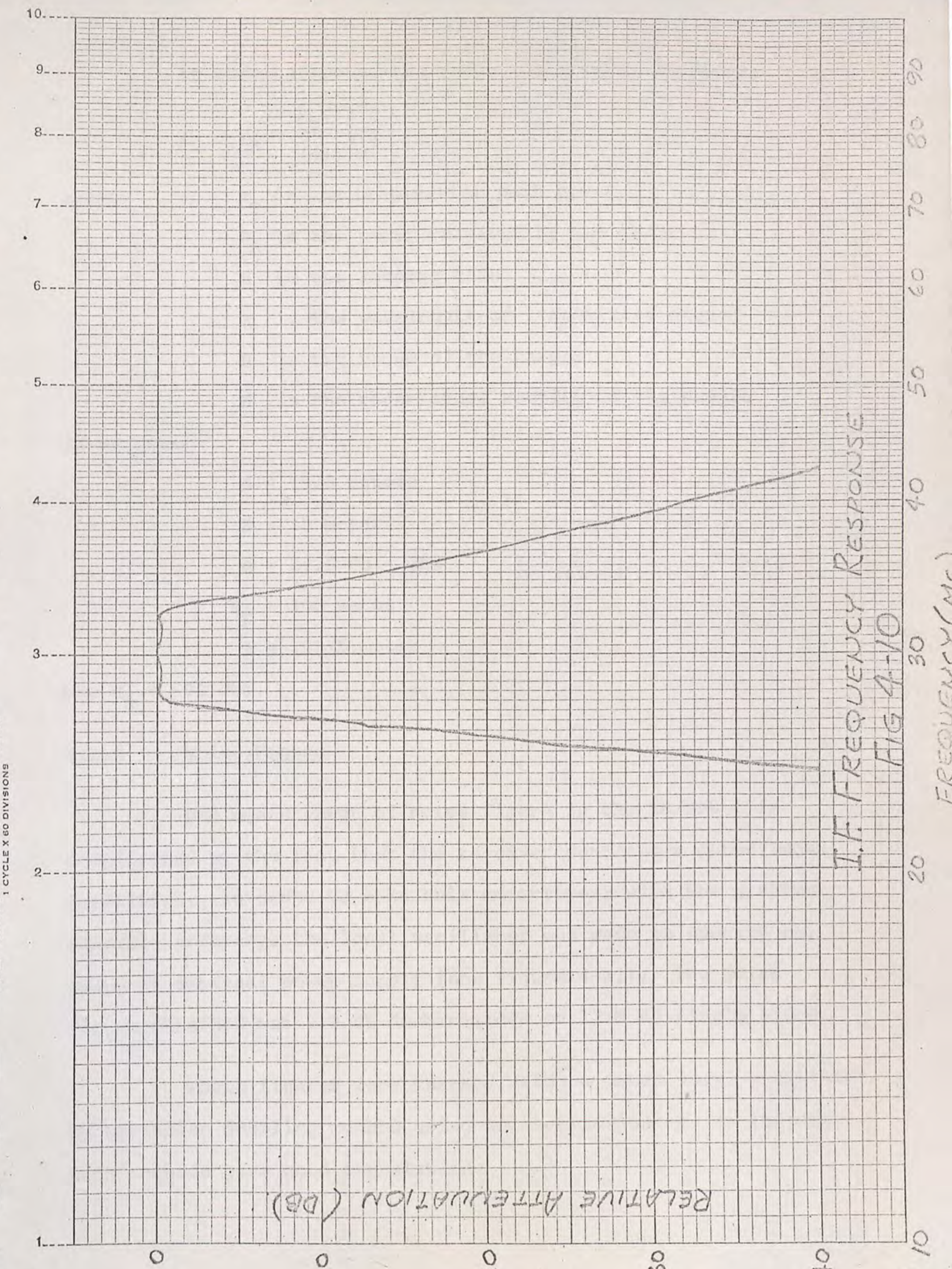
4.2.7 IF Frequency Response

A point by point plot of the frequency response of the IF amplifier is shown in figure 4-10.

4.2.8 Minimum Discernible Signal

The minimum discernible signal was specified as -95 dbm. Subsequent discussions with Signal Corps respresentatives defined this parameter as the minimum discernible signal at the output of the video amplifier, and the minimum discernible signal at the video amplifier met the -95 dbm requirement.

The display for this radar is a headset and not an oscilloscope. Therefore, a minimum discernible signal measurement should be made that also tests all the circuits pertaining to developing and processing the audio and measures the performance with the ear. The minimum discernible signal made by listening to the headset was considerably better than the -95 dbm specification requirement typically -100 dbm.


I.F. FREQUENCY RESPONSE
FIG 4-10
FREQUENCY (MC)
RELATIVE ATTENUATION (DB)
0
10
20
30
40
10
20
30
40
50
60
70
80
90
KEUFFEL & ESSER CO.
1 CYCLE X 60 DIVISIONS
MADE IN U.S.A.

An examination of the radar range equation shows:

$$P_R = \frac{P_T G^2 \lambda^2 S}{(4\pi)^3 d^4}$$

where:

P_T is the transmitter peak power

P_R is the power received by the radar

G is the antenna gain

λ is the wavelength of transmitted signal

d is the range of the target

S is the radar cross section of the target

If we take:

$d = 1500$ meters

$S = .5$ meter^2

$G = 24.5$ db $= 282$

$P_T = 100$ watts

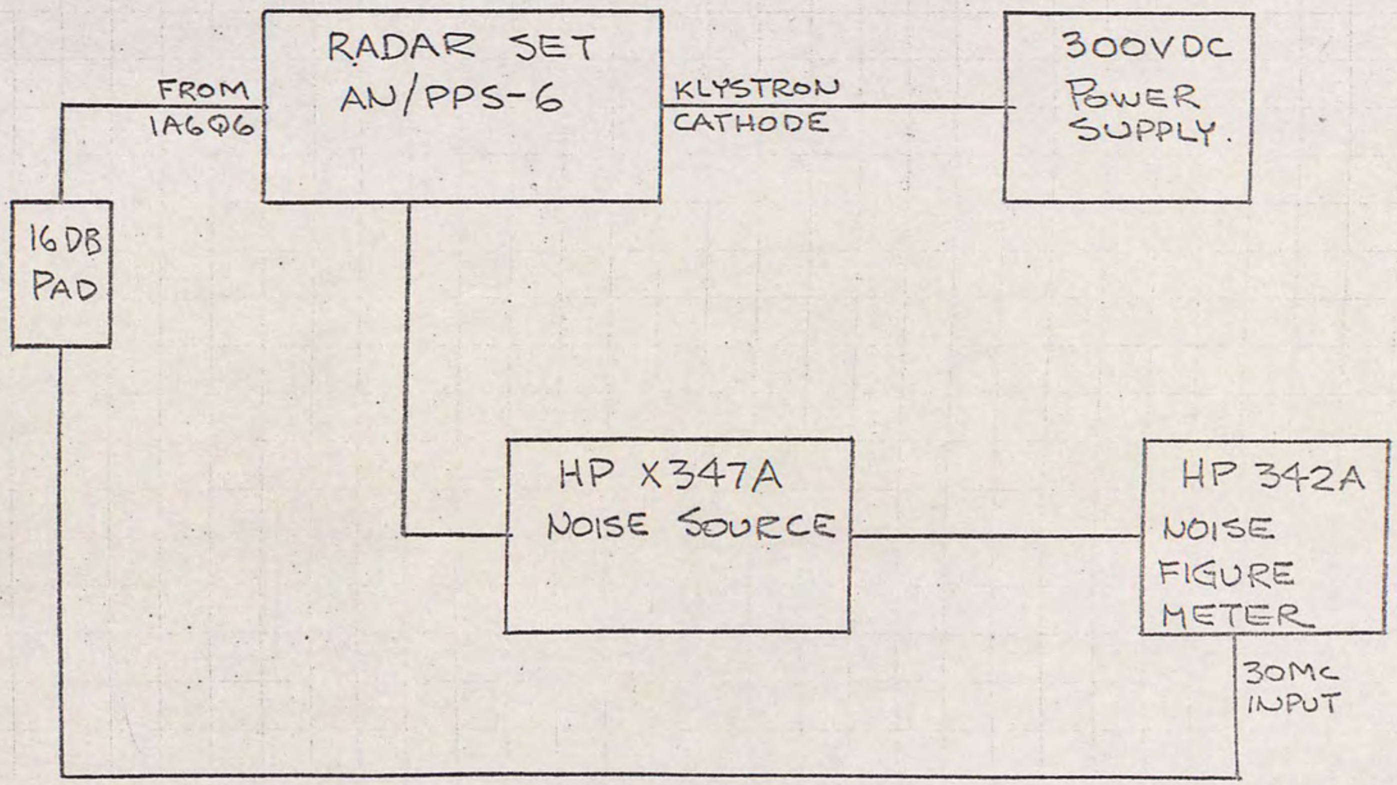
$\lambda = .0316$ meter

the $P_R = -94$ dbm.

4.2.9 Noise Figure

The measurement of noise figure in the AN/PPS-6 is complicated by the fact that the receiver contains a gated local oscillator. In order to make this measurement with the greatest possible accuracy, the local oscillator was made to operate cw, using an external power supply (see figure 4-11). The noise figure obtained was 9.8 db double-sided or 12.8 db single sided.

These figures were checked using a gated local oscillator by the noise doubling method using an oscilloscope as an indicator. Both methods gave good correlation.



NOISE FIGURE MEASUREMENT

FIG 4-11

4.2.10 Magnetron Spectrum

Figure 4-12 shows the magnetron spectrum as measured by a Polarad SA84 spectrum analyzer.

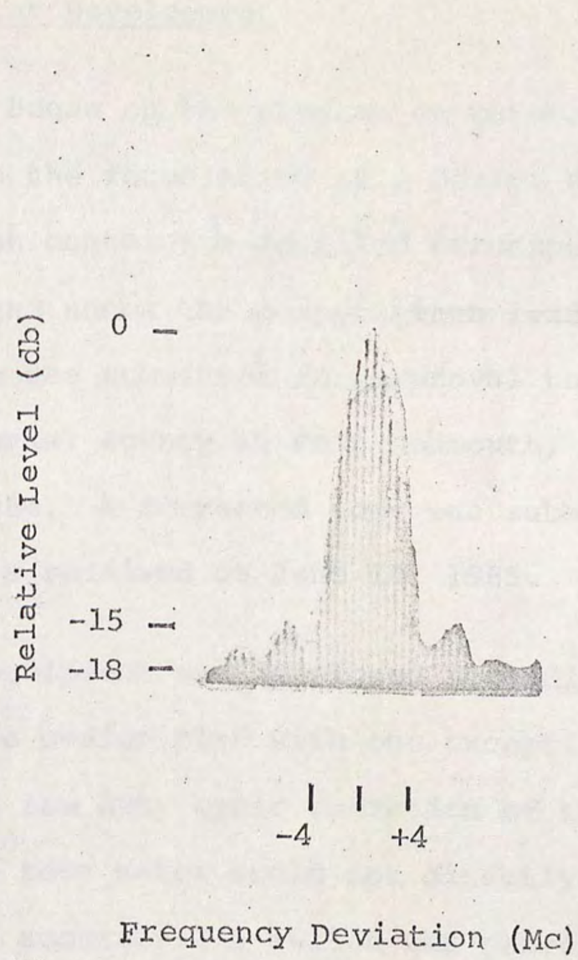


Figure 4-12 Magnetron Spectrum

4.3 Program Development

Work began on the program on October 19, 1964. The first phase was the formulation of a Design Plan for the radar. This Design Plan contains a detailed description of the components of the radar, and shows the computations leading to their design. The Design Plan was submitted for approval to the U. S. Army Electronic Material Agency at Fort Monmouth, New Jersey on December 23, 1964. A corrected copy was submitted on May 4, 1965 and approval was received on June 10, 1965.

The equipment was developed according to the concepts set forth in the Design Plan with one exception. It was found that due to the low duty cycle operation of the klystron local oscillator, the test meter could not directly read crystal current with sufficient accuracy. A switch was provided so that the klystron could be operated continuously while crystal current was being read. It was felt however, that the extra power expended was not desirable. For these reasons, an amplifier was inserted between the crystal current sampling resistors and the meter.

The first three units were assembled and used for compliance testing which began on October 22, 1965 and ended on December 1, 1965. The results of the tests are summarized in the Compliance Test Report submitted on March 3, 1966.

The equipment passed the compliance tests except for two areas. One area of failure was the illumination test.

SCL-8005 requires that all indicators be illuminated to be visible from two feet, but there shall be no light sources visible from a distance of 25 meters from the equipment. Test showed that reflected light from the test meter face was indeed visible at a distance of 25 meters. This problem was solved by painting the white meter faces red.

The other problem area was the Radio Frequency Interference Tests. Preliminary testing indicated that in order to meet the specification the equipment would have to be modified mechanically. In order not to delay the program it was agreed that one of the three initial radars would be modified. These modifications would be incorporated in all subsequent units and the other two initial units would be modified at a later date. The results of these modifications are given later in this report.

During the moisture resistance test there were two component failures. One component--the transmitter magnetron--failed on the fourth cycle of the test. The unit was returned to the manufacturer who found the failure to be of a random nature not related to humidity.

The second component--the magnetostrictive delay line--failed after the fifth cycle. A failure analysis was performed and it was determined that a lead in the pickup coil broke due to improper assembly techniques in the manufacture of the delay line. The lead was not properly sealed with a lacquer coating. This allowed moisture to accumulate in the vicinity of this very thin wire and the repeated cycling eventually broke the wire. The condition was corrected and two delay lines were subjected to five humidity cycles with no deleterious effects.

Other minor problems such as the rusting of steel screws on the angular head, the pins on the tripod clamp, and the accessory bag fasteners were corrected by replacing those items with rust resistant material.

4.4. Service Tests

Two of the three units used for compliance tests were delivered to the Marine Corps Landing Force Development Center (MCLFDC) at Quantico, Virginia, on December 1, 1965, for field tests. The results of these tests are given in "(U) Radar Set AN/PPS-6(XE-6) Service Test, Final Report of, Project No. 20-65-07, 22 April 1966" (CONFIDENTIAL), which is not quoted herein.

Certain functional problems were made evident by Major George Clark of the USMC, who conducted the above tests. It was noticed that the radar performed differently at different locations having essentially the same type of terrain. The differences were mainly in the number of false alarms obtained. It was also noticed that there was a wide variation of performance with different operators. The Marine Corps personnel also noted a certain amount of "jitter" of the local oscillator frequency.

A closer examination showed that the false alarms occurred mainly when the radar was trained on large objects such as groves of trees, tanks, etc.

As a result of these findings a study program was initiated under Department of Navy Contract No. NOm-73475. The results of this study program are described in paragraph 4.5.

4.5 Results of Study Program

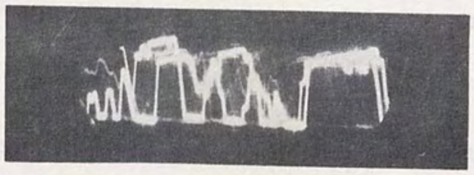
4.5.1 Audio Amplifier

Tapes were made of the output of the radar set in a high clutter environment (knee high grass and weeds, trees, etc.). Upon analysis, it was noticed that the "noise" from these areas seemed "choppy" and short periods of "hesitations" in audio output were noticed. An operator after some time of concentration and without an actual moving target for comparison would begin to regard these noise fluctuations as the normal audio signal from a real moving target.

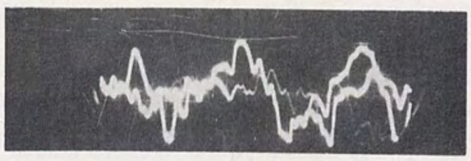
A high fidelity power amplifier was substituted for the audio power amplifier in the radar set. Tests when this amplifier was substituted proved that this "choppy" effect on clutter noise could be eliminated (except in high winds where there is still choppiness caused by the violent movement of vegetation) by increasing the dynamic range of the audio amplifier. It was experimentally determined that 18 db of audio dynamic range was necessary in this equipment. It was also demonstrated that the audio amplifier needed a quick recovery from saturation to eliminate the "hesitation" problem. Figure 4-13 shows the effect of dynamic range on a noise-like signal. Note that limiting causes the higher noise peaks to be eliminated--producing a hesitation effect.

In order to accommodate the increased dynamic range of the audio amplifier, a shunt regulator was installed in the audio amplifier dc power supply.

(a) Audio output of PPS-6(XE-6) for a noise-like signal



(b) Audio output of PPS-6(XE-6) with a load regulated power supply and limiting removed



(c) Modified PPS-6 audio amplifier (Increased dynamic range and no limiting)

Figure 4-13 Audio Amplifier Limiting

It was also determined experimentally that a roll off of 36 db/octave was necessary on the low frequency (below 26 cps) end of the clutter filters, for optimum separation between target and clutter.

This was done by actually increasing the low frequency roll off in 6 db increments, with the radar operating in an area of high clutter environment, until no improvement was noticed.

The results of this test show that it is not sufficient to define "subclutter" visibility as the maximum ratio of fixed to moving targets, but it is also necessary to consider the effects of randomly moving "clutter" such as vegetation.

It is also seen that the considerations for optimum detection of personnel are somewhat at odds with the detection of slowly moving vehicles. This becomes evident when one considers that the audio spectrum of a walking man has a significantly wide bandwidth with a large concentration of energy in the region of from 50 to 100 cps.

A vehicle moving at the same radial velocity would have a narrow spectrum centered around the doppler frequency corresponding to its radial velocity. Figure 4-14 shows the audio spectrum, as obtained on a General Radio Vibralyzer, of a walking man as detected by the PPS-6 Radar. This spectrum was obtained by Mr. Harold Tate of USAECOM, Fort Monmouth, New Jersey. Figure 4-7 shows that in the region of 26 cps the threshold of hearing approaches that of feeling. In order to hear frequencies in this

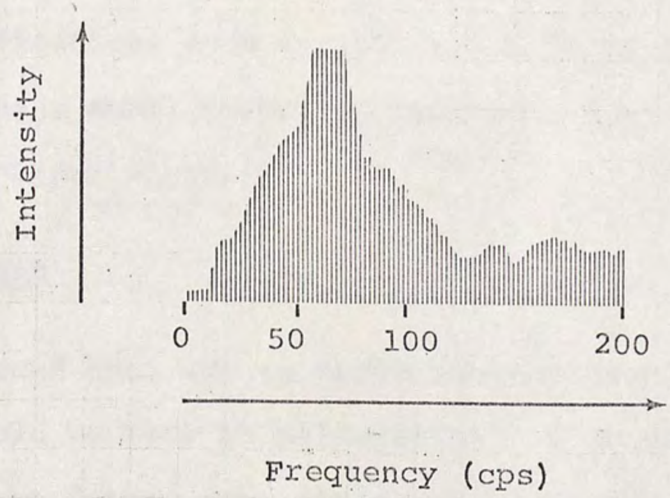


Figure 4-14

Audio Spectrum of a Walking Man
as Detected by the PPS-6(XE-6)
Radar--Courtesy of H. Tate, USAECOM

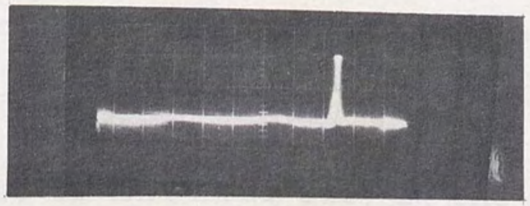
region distortion would have to be introduced (through limiting) as it was in the PPS-6(XE-6), so that higher frequency harmonics are generated. However, this distortion causes non-stationary noise-like signals such as those obtained from vegetation to sound similar to signals obtained from a walking man.

The modifications made to the system achieved a compromise by inserting a small amount of crossover distortion from the class B audio output stage.

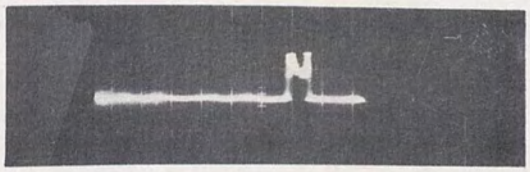
4.5.2 AFC Circuit

It was found that due to spike leakage from the TR tube the AFC circuit could be made to malfunction. This malfunction was found to take two forms. The first was the klystron locking at the wrong frequency, causing a loss in sensitivity. The second was that under certain conditions the klystron frequency varied in a random fashion (jittered). This FM signal, when applied to a receiver passband which was not perfectly flat, could cause an amplitude modulation leading to additional noise in the headset.

This problem was most expeditiously solved (at the suggestion of Mr. Frank Messina, USAECOM) by replacing the TR tube with a solid-state limiter. This has only a fraction of the spike leakage of the TR tube and also is free of the 2 db amplitude modulation and spike width variation of the gas tube. Figure 4-15 illustrates the reduction of spike leakage (approximately 11 db) provided by the solid-state limiter.



(a) Leakage from a T/R tube output detected through a 14 db attenuator



(b) Leakage from a solid-state limiter detected through a 3 db pad

Figure 4-15 Spike Leakage from T/R Switch

It should also be noted that part of the spike leakage problem was due to the fact that the video frequency components of spike fall into the 30 Mc IF frequency passband. The problem would be greatly eased if a high IF frequency could be used.

4.5.3 Miscellaneous

In addition to the above mentioned major areas, two second order effects were found which could also affect target detection.

The first of these was tilt in the video amplifier of the order of 5% on 5 μS pulses. This tilt could cause moving target information to be "stored" in the video amplifier causing the addition of clutter noise from range slot-to-range slot. This effect has been greatly reduced by increasing time constants in the video amplifier reducing the tilt to the order of 0.5%.

The second effect was a droop on the boxcar detector bias which under certain conditions could cause large video signals to break through the boxcar detector. This situation was completely corrected by increasing the boxcar detector bias time constant.

As a result of this study one of the radars was modified and re-submitted to the MCLFDC for service test on February 14, 1966. The results of this service test showed that the modifications corrected the aforementioned operational deficiencies.

On March 30, 1966, a Change Order to Contract No. DA-28-043-AMC-00390(E) was awarded for the purposes of modifying all fourteen (14) units, as dictated by the results of the study program.

4.6 Radio Frequency Interference

As indicated in paragraph 4.3 preliminary tests indicated that the equipment would not meet the RFI tests as specified in SCL-8005. The primary areas of leakage were through the face of the antenna, around the antenna gasket; and from the angular head cable, the external power cable, and the headset cable.

It was found during service test at MCLFDC that in spite of these conditions the equipment did not interfere with any of the Marine Corps communications equipment. It was also stated that conducted RFI was not a problem since it was not contemplated that any other equipment would be operating from the power source for the radar set.

However, appropriate steps were taken to improve the problem. The antenna gasketing was improved. The back of the antenna was silver plated. The angular head cable was shielded and the dc supply for the scan motor was filtered.

Subsequent tests showed that the equipment was within the specification for conducted and radiated susceptibility. The radar was within the specification for radiated interference when operated on its internal battery except when the microswitches were activated. The radar was above the specification for conducted and radiated interference when used with an external power supply. An RFI filter would have to be put in the line to insure compliance with the specification.

On March 30, 1966, a Change Order was issued accepting the RFI performance of the radar at that time and waiving any further requirements.

4.7 Mechanical Problems

4.7.1 Weight

The specified weight of the equipment was 23 lbs. The actual weight of the delivered equipment was 32 lbs. 6 oz.

Several reasons exist for the excess weight. Many of the sub-contracted items, such as the rf plumbing assembly, the antenna, and the batteries were delivered overweight and insufficient time was available to rework these parts. In addition, many additional parts were added as a result of the performance improvement study program, which further increased the weight. Another factor that led to the increased weight was the small quantities of equipments and short delivery schedule that negated the use of special tooling or components and necessitated the use of commercially available hardware where possible.

However, the equipment in its final configuration did not present any difficulties in handling or maintenance as evidenced by the Marine Corps Service Testing. In fact, the equipment is still one-man portable and one-man operable.

Significant weight reduction will not be achieved without a considerable redesign effort which, in the opinion of the contractor, is not warranted at this time. As a result, no further work is recommended in this area at this time..

4.7.2 Elevation Control Instability

The increased weight, particularly in the R/T Assembly, has resulted in excessive stress in some of the supporting members of the elevation control and angular head assemblies. While adequate performance has been achieved with the equipment in its present form, it is felt that equipment simpler to operate will result from a rather simple redesign effort of the elevation control and angular control assemblies. This is recommended for further work.

4.7.3 Clutch Mechanism

The clutch mechanism has not performed reliably and it is recommended that the clutch to be redesigned for future procurement.

4.8 Reliability Prediction

A mathematical model has been established for the AN/PPS-6(XE-6) Radar Set which relates the reliability of the equipment to the functional design configuration.

Figure 4-16 presents the reliability model in a functional block diagram. Failure rates are indicated in the functional paths by alphabetical designators. Table 4-3 is a summary of modular failure rates, and is keyed to the alphabetical designators of figure 4-16.

The reliability prediction is also expressed in table 4-4 where failure rates are summarized by the functional paths which exist in the radar equipment.

Failure effects are not analyzed herein, but few circuits exist in this equipment whose failures will not give rise to total equipment failure. (Total failure is defined as any operation of the radar outside of its specified tolerances.)

Analysis of the design configuration reveals that failure rates in the electronic portion of the radar set will change negligibly for the different modes of operation. Therefore, the mathematical model has not been unnecessarily complicated by adding small differentials of failure rate to account for mode differences. In the manual slewing mode, however, the failure rate of the angular head should be ignored since it is motor-driven only in the area search mode.

The transmit and receive modes of operation are time-shared, but there is no resultant gain to reliability because proper reception and processing is dependent serially upon proper transmission of the radar pulse.

The failure rates listed in table 4-5 reflect the actual electrical stress and duty cycle imposed upon the components of the system. Table 4-6 is a list of these components and their failure rates taken from MIL-HDBK-217 at 65°C, a 50% electrical stress and 90% confidence level.

The summation of all module failure rates yields an equipment MTBF of 2100 hours, as shown in table 4-3.

Table 4-3

Modular Failure Rate Summary

Module	Failure Rate Designator	Total Module Failure Rate (%/10^3 Hrs.)	Module MTBF (Hrs.)
1A1	A	2.000	
	B	10.000	
	C	1.590	
	Z	10.000	
	K	.057	
	L	1.485	
	M	.228	
	N	+ 4.000	
		29.360	3400
1A2	Y	.463	216000
1A3	P	1.088	
	Trigger Gen.	+ 1.838	
		2.926	34200
1A4	U	.945	
	F	.172	
	H	.139	
	G	+ 1.756	
		3.012	33200
1A5	E	.851	117500
1A6	D	3.317	
	I	+ .479	
		3.796	26400
1A7	R	1.477	67700
1A8		2.650	37800
1A9	T	.924	108000
1A10	Q	.430	233000
2A1 (Unit 2)		1.747	57200
TOTAL FAILURE RATE		47.636	2100 Hrs.

Table 4-4

Signal & Control Path Summary

Functional Path	Function	Path Failure Rate (% per 10^3 Hrs.)		Path MTBF (Hrs.)
A-B-C-D-E-F-G	Receive	A	2.000	
		B	10.000	
		C	1.590	
		D	3.317	
		E	.851	
		F	.172	
		G	1.756	
			19.686	5100
H-I	Automatic Gain Control	H	.139	
		I	.479	
			.618	162000
W	IF Gain Reduction (During Transmit)	W	1.239	81000
T-U		T	.924	
		U	.945	
			1.869	53500
L-R-P-N-M, K, V	Automatic Frequency Control	L	1.485	
		R	1.477	
		P	1.088	
		N	4.000	
		M	.228	
		K	.057	
		V	1.073	
			9.408	10600
Q	Crystal Current Test	Q	.430	230000
X-Y-Z-A	Transmit	X	.746	
		Y	.463	
		Z	10.000	
		A	2.000	
			13.209	7550
	Power Converter		2.650	37800
	Angular Head (Scan)		1.747	57200

Table 4-5

Failure Rates by Alphabetical Designation

Designator	Component Name	Component No. (N)	Failure Rate % Per 10^3 Hrs.	N
A	Microwave Circulator	1	2.000	2.000
B	T/R Limiter*	1	10.000	10.000
C	Crystal Diode	1	1.380	1.590
	Resistor	2	.004	
	Inductor	2	.100	
	Capacitor	2	.001	
D	Transistor	15	.088	3.317
	Resistor	78	.004	
	Capacitor	69	.001	
	Diode	12	.043	
	Inductor	11	.100	
E	Transistor	6	.088	.851
	Resistor	26	.004	
	Capacitor	5	.001	
	Diode	4	.043	
	Delay Line	1	.006	
	Delay Line (Tapped 6 Pcs.)	1	.036	
F	Diode	4	.043	.172
G	Transistor	14	.088	1.756
	Resistor	44	.004	
	Capacitor	33	.001	
	Diode	5	.043	
	Inductor	1	.100	
H	Resistor	2	.004	.139
	Transistor	1	.088	
	Diode	1	.043	
I	Resistor	10	.004	.479
	Transistor	2	.088	
	Diode	6	.043	
	Capacitor	5	.001	
K	Attenuator	1	.057	.057

*The failure rate shown is for a gas tube limiter, since figures for a solid state limiter are not now available.

Table 4-5
(Continued)

Failure Rates by Alphabetical Designation

Designator	Component Name	Component No. (N)	Failure Rate % Per 10^3 Hrs.	N
L	Crystal Diode	1	1.380	1.485
	Resistor	1	.004	
	Inductor	1	.100	
	Capacitor	1	.001	
M	Attenuator	4	.057	.228
N	Klystron	1	4.000	4.000
P	Transistor	7	.088	1.088
	Resistor	30	.004	
	Capacitor	8	.001	
	Diode	8	.043	
Q	Transistor	4	.088	.430
	Resistor	18	.004	
	Capacitor	6	.001	
R	Transistor	6	.088	1.477
	Resistor	36	.004	
	Capacitor	33	.001	
	Diode	4	.043	
	Inductor	6	.100	
T	Transistor	7	.088	.924
	Resistor	25	.004	
	Capacitor	16	.001	
	Diode	2	.043	
	Inductor	1	.100	
	Delay Line	1	.006	
U	Transistor	5	.088	.945
	Resistor	17	.004	
	Capacitor	7	.001	
	Diode	6	.043	
	Transformer	2	.080	
	Delay Line	2	.006	
V	Resistor	18	.004	1.073
	Transistor	5	.088	
	Diode	11	.043	
	Capacitor	8	.001	
	Transformer	1	.080	

Table 4-5
(Concluded)

Failure Rates by Alphabetical Designation

Designator	Component Name	Component No. (N)	Failure Rate % Per 10^3 Hrs.	N
W	Resistor	19	.004	1.239
	Transistor	5	.088	
	Diode	11	.043	
	Capacitor	10	.001	
	Transformer	3	.080	
X	Resistor	13	.004	.746
	Transistor	3	.088	
	Diode	8	.043	
	Capacitor	6	.001	
	Transformer	1	.080	
Y	Transformer	1	.080	.463
	Resistor	5	.004	
	Diode	4	.043	
	SCR	1	.088	
	Inductor	1	.100	
	Capacitor	3	.001	
Z	Magnetron	1	10.000	10.000
Power Converter	Transistor	6	.088	2.650
	Resistor	14	.004	
	Inductor	9	.100	
	Diode	25	.043	
	Capacitor	11	.001	
	Transformer	1	.080	
Angular Head	Relay	1	.722	1.747
	Motor	1	.970	
	Limit Switch	2	.025	
	Connector	1	.005	

Table 4-6

Failure Rates Taken from MIL-HDBK-217

Component	% Per 1000 Hrs. Failure Rate	MIL-HDBK-217
Resistor	.004	Figure 20
Capacitor	.001	Figure 36
Inductor	.100	Figure 43
Transistor	.088	Figure 14
Diode	.043	Figure 13
Microwave Diode — Detector	4.32	Figure 15F
Microwave Diode — Mixer	1.38	Figure 15B
Delay Line	.006	(Similar to RF Coil)
SCR	.088	(Similar to Transistor)
Transformer	.080	Figure 43
T/R Crystal Protector	10.000	(Similar to Microwave Switching Tube)
Klystron	4.000	Table IV
Magnetron	10.000	Table IV
RF Attenuator	.057	Table XXIV
Circulator	2.00	Table XXIV
Relay	.722	Figures 46,47
Motor	.970	Figures 44A, 43A
Limit Switch	.025	Figure 46
Connector	.005	Figure 45A

5.0 CONCLUSIONS

It is be concluded from this report that the radar set met the operational requirements set forth in SCL-8005 except in the areas of Radio Frequency Interference and weight. It may also be stated that the deficiencies in these areas did not impede the radar from fulfilling its function as a Man-pack Battlefield Surveillance Radar. It is also evident that additional specifications should be provided to insure proper operation of the radar.

The end product, through Marine Corps Service Testing, was proven to be an excellent and reliable tool for detecting and identifying moving targets in a battlefield environment.

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13. ABSTRACT

The subject report covers a summary of the engineering design effort in producing an AD model of the CSTA Laboratory developed model. Also included is a general and technical summary of the system's electrical and mechanical test procedures and test results.

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