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Hendry, A.

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Report (National Research Council of Canada. Radio and Electrical Engineering Division : ERB), 1958-03

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NATIONAL RESEARCH COUNCIL OF CANADA
RADIO AND ELECTRICAL ENGINEERING DIVISION

FIELD MEASUREMENTS ON FIRST PRODUCTION MODEL OF AN/MPQ-501 COUNTER MORTAR RADAR, AT CAMP SHILO, MANITOBA, 25-28 MARCH, 1958

A. HENDRY

Declassified to:
ORIGINAL SIGNED BY
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Authority: S. A. MAYMAN
Date: NOV 26 1992

OTTAWA

MARCH 1958 NRC # 35586

ABSTRACT

An investigation of deficiencies in the receiving system of the AN/MPQ-501 Counter Mortar Radar was carried out. Field reports of poor video amplifier rise time and high scanner VSWR were confirmed, while AFC circuit operation which had been reported as poor, was observed to be satisfactory. An overall check of the transmitter and receiver indicates that system performance is generally satisfactory, although improvements in the video amplifier circuitry are necessary in order to obtain an acceptable rise time. A table of recent equipment faults is included, together with recommendations which, if implemented, should improve system reliability considerably.

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Restricted

FIELD MEASUREMENTS ON FIRST PRODUCTION MODEL OF AN/MPQ-501 COUNTER MORTAR RADAR, AT CAMP SHILO, MANITOBA, 25-28 MARCH, 1958

- A. Hendry -

INTRODUCTION

The measurements described in this report were made in order to determine desirable changes in the receiving system of future production models of the AN/MPQ-501 radar, to assess the importance of known deficiencies in the first production model, and in particular, to determine if immediate remedial work was necessary.

The known deficiencies included high scanner VSWR and poor receiver rise time. Prior to the measurements reported here, little quantitative information was available to indicate the degree of impairment of radar performance caused by these deficiencies.

In order to determine the source of poor rise time for pulsed signals passing through the receiver, the bandwidth of the i-f amplifier was determined, and direct observation of the video amplifier rise time was made using rectangular pulses from a video pulse generator.

Two logarithmic i-f amplifiers built at the National Research Council were checked in the radar set in preparation for evaluation trials on this type of amplifier.

The overall radar performance was checked using the NRC Ku-band radar test set.

In addition to results of measurements on the receiving system, a few miscellaneous observations on the remainder of the radar equipment are included, and a list of recent equipment faults appears in Table I.

1. RECEIVER BANDWIDTH AND RISE TIME MEASUREMENTS

a) I-F Amplifier Bandwidth

The passbands of the receiver preamplifier and main amplifier were determined separately and are plotted in Fig. 1. The overall bandpass curve (Fig. 2) was then computed from the separate curves. An attempt was made to determine the overall bandpass curve directly; however, it was not successful because it

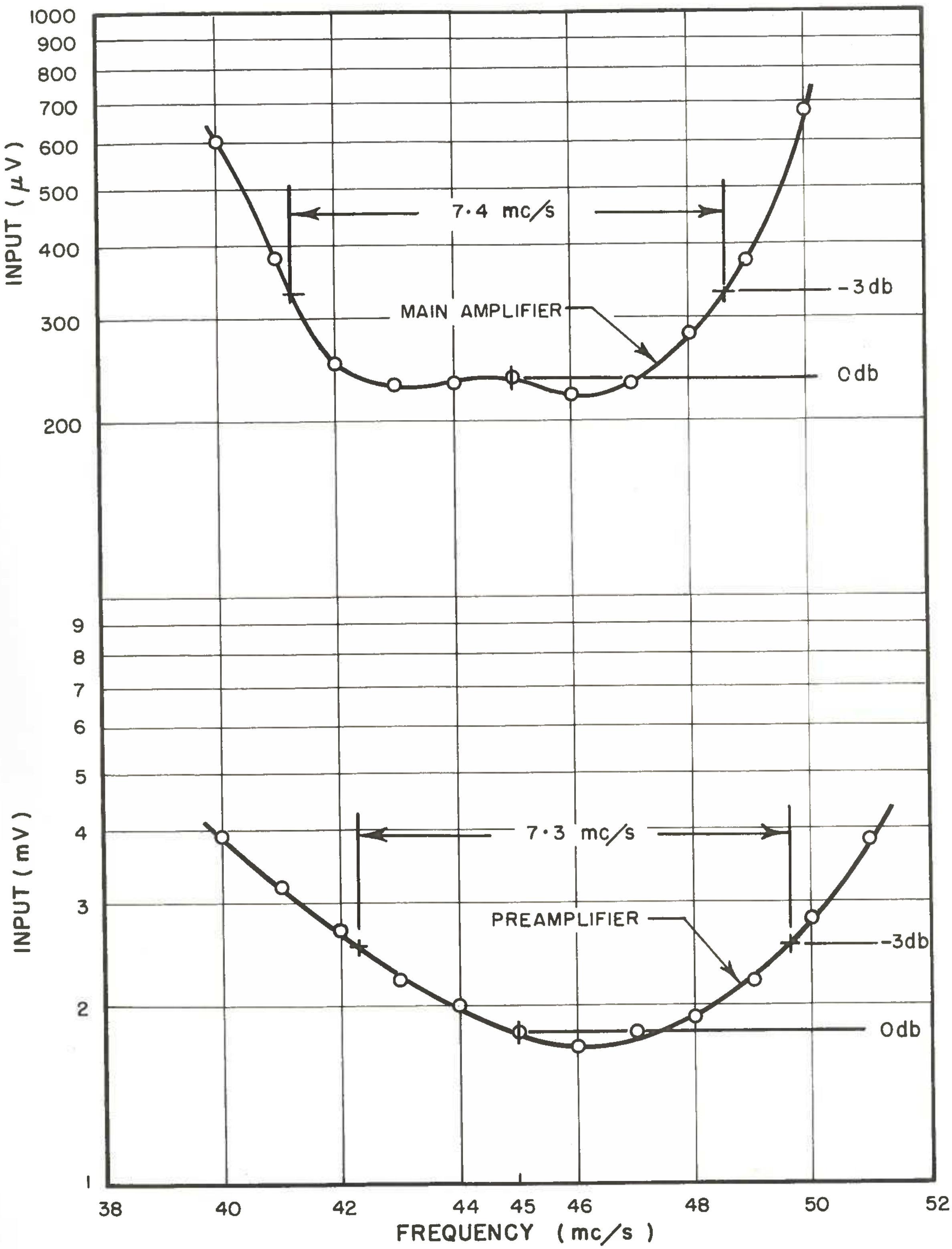

FIG. 1. FREQUENCY RESPONSE CURVES OF I-F AMPLIFIERS

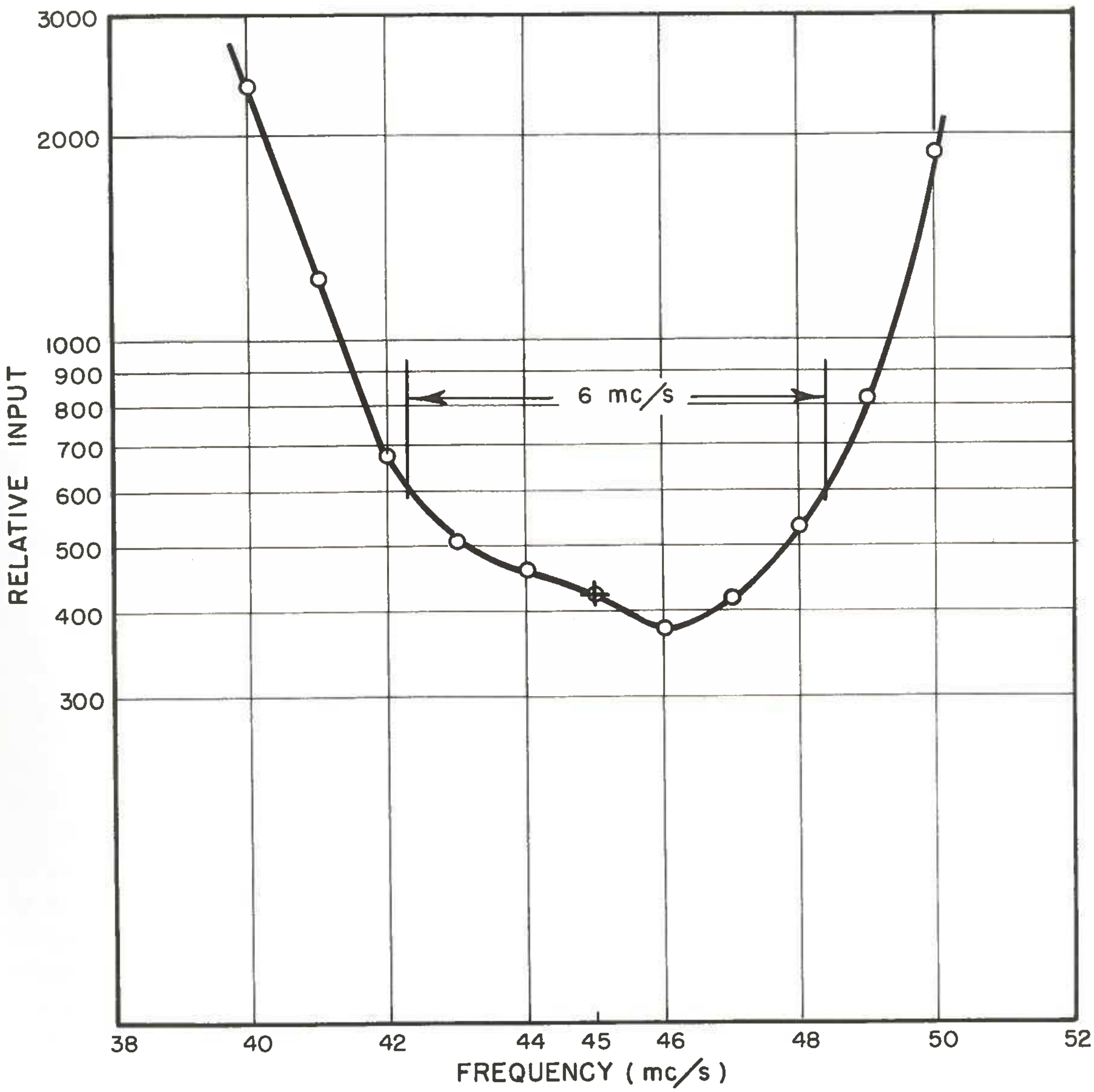

FIG. 2. COMPUTED OVERALL I-F RESPONSE CURVE

was impossible to obtain signals well above the noise level when the output cable from the i-f amplifier was matched with a 50-ohm resistive load. (It was necessary to match the cable so that the additional capacitance of the measuring apparatus would not influence the shape of the passband.) Because of the low sensitivity of the oscilloscope used, there was only a narrow range between noise level and saturation level; thus the readings obtained were not indicative of the regular performance of the receiver, and were discarded.

The response curve for the preamplifier indicates that it is slightly mistuned; however, the effect of this is probably barely noticeable. The computed overall bandpass curve, obtained by multiplication of the ordinates of the two individual bandpass curves indicates that the overall i-f bandwidth is approximately 6 mc/s, with some asymmetry introduced by the preamplifier. This asymmetry, however, is not serious, but should be corrected in future production. The bandwidth is less than the 7 mc/s design figure, but this will probably be corrected if the preamplifier curve is made symmetrical about 45 mc/s.

b) Video Amplifier Rise Time

i) "A-Scope" Amplifier

The output pulse from a Hewlett-Packard 212A pulse generator was applied to the input of the video amplifier, using a 50-ohm termination at the point of entry of the signal to the video chassis. The pulse was then observed on the radar cathode-ray tube using the type-A display (see Plates I and II). The sweep length displayed in all plates is 2000 meters. The rise time from the 0 to 90% points was estimated to be 0.25 μsec. This was confirmed by using the range marker to determine the range interval between these points, range readings of 32 to 40 meters being obtained. ($C/2 = 150$ meters/μsec, where C = velocity of light; thus 0.25 μsec corresponds to $37\frac{1}{2}$ meters.) Plates III and IV show the shape of the transmitter pulse on the "A-scope" display, while Plate V shows the shape of signals obtained from stable permanent echoes. The poor video amplifier rise time is evident from these plates.

ii) "B-Scope" Amplifier

The output of the B amplifier (J18) was applied to the A-scope plates (J12), the A-B changeover relay actuated by an external jumper and video pulses applied as in (i) above from the pulse generator. (Jack numbers refer to Canadian Arsenals Limited video amplifier schematic drawing.) It was then observed that the rise time of signals from the B amplifier depended on the signal level. For signals above limit level, the rise time was approximately 25 meters (0.17 μsec) (see Plate VI). For signals below limit level, the rise time was reduced to perhaps 15 meters (0.1 μsec) (see Plate VII).

In order to determine in what stages of the video amplifier the pulse shape deteriorated, the pulse signal was applied in turn to the following points:

i) directly to cathode-ray tube plates;
ii) into marker channel, jack J7;
iii) into J14, which bypasses the first video stage.

Essentially zero rise time was observed under condition (i) (see Plate VIII). When the signal was applied to the marker channel, the rise time observed on the cathode-ray tube was approximately 0.1 μsec. There was no change in rise time when the pulse was applied to J14 as compared with input to the normal video input jack. From this evidence it may be concluded that the first stage of the video amplifier does not contribute appreciably to the pulse distortion, and that the bandwidth following the marker input is fair. The deterioration of the pulse, therefore, occurs in the intervening two stages.

It should be noted that the marker itself appears to have a rise time of approximately 0.15 μsec, considerably in excess of the desirable upper limit of 0.05 μsec, making precise measurement of range difficult.

2. AFC OPERATION

Although it was stated by several persons connected with the radar trials that the AFC rarely operated satisfactorily, or at best operated very poorly, observation of its performance in the field does not bear out these statements.

According to the RCEME Radar Mechanic assigned to the set, the AFC was in operation all day on Thursday, 27 March, 1958, when particularly good results were obtained. The author observed AFC operation for a period of approximately 2½ hours on 28 March, during which period operation was completely stable. There was, however, a barely detectable loss of sensitivity on AFC as compared with manual tuning. This is explainable by reference to the i-f preamplifier response curve in Section 1. above, which shows that a slight mis-tuning of the preamplifier exists. In any case, the slight reduction in sensitivity can probably be removed by a slight adjustment of the discrimination "cross-over" frequency in the AFC chassis.

It appears, however, that occasionally the AFC has dropped out of tune, and further observation of the performance of this circuit is desirable. Also, a positive, prominent indicator should be provided to advise the operator when the AFC fails to operate satisfactorily. (Such an indicator is presently in use on the M33 Radar, where a neon lamp indicates whenever the AFC drops out of lock.) The relative tuning indicator apparently is not used by the operators, and the time constant of the crystal current meter is such that the crystal current does not appear to fluctuate when the search circuit is sweeping the local oscillator frequency.

3. SCANNER VSWR MEASUREMENTS

Measurements of the input VSWR of the scanner plus rotary joint were made and are given in Fig. 3. Initially, the measured VSWR varied between 1.14 and 1.30 over the useful portions of scanner rotation, with higher VSWR at the "cross-over" points. At one cross-over, the VSWR reached 1.8, but high reflections were obtained only over a very narrow sector. A large number of less important peaks were observed as the scanner was rotated. It was evident that the results were somewhat erratic, as difficulty was experienced in obtaining the same readings when the scanner was re-set to a given reading after rotation. (Note in Fig. 3 that the reading at 360° is not equal to the reading at 0°.)

The rotary joint was taken apart, and inspected at this time. No physical damage was evident, but some minute specks of dust were blown out. Upon re-assembly, the entire VSWR versus rotation curve was changed. Further improvement was obtained when compressed air was blown through the waveguide leading to the scanner (see Fig. 3). Subsequent measurements indicated that the VSWR changed after each air blast, indicating that loose particles were present in the scanner. No further measurements were made, because they would be meaningless; however, the air blast resulted in a definite improvement. Subsequent investigation indicated that metallic dust and chips had entered the scanner through inspection holes at the small end. These particles had probably been formed when the pulley on the scanner motor drive shaft shifted so as to rub on the casting supporting the motor. Considerable wear is evident at that point, and various mechanical failures had occurred in that region (see Table I). All loose dust was cleaned out of the scanner drive pulley region, and the pulleys are now being inspected regularly to prevent a recurrence of this condition.

The ferrite isolator used in the radar was checked, and found to be undamaged. (It had been thought that large reflections of transmitter power into the isolator might have damaged it.) Thus the VSWR of the scanner is sufficiently low that the isolator affords adequate protection, and no harm should be caused to the magnetron by continued operation of the scanner in its present condition.

4. LOGARITHMIC I-F AMPLIFIER OPERATION

Two NRC-built logarithmic i-f amplifiers were tested for proper operation in the radar. Each amplifier could be switched from logarithmic to linear operation when desired. One amplifier has a gain of 80 db, and the other 90 db gain. The bandwidth is approximately $7\frac{1}{2}$ mc/s in both cases.

Each amplifier was operated in the radar. However, because of higher fila-

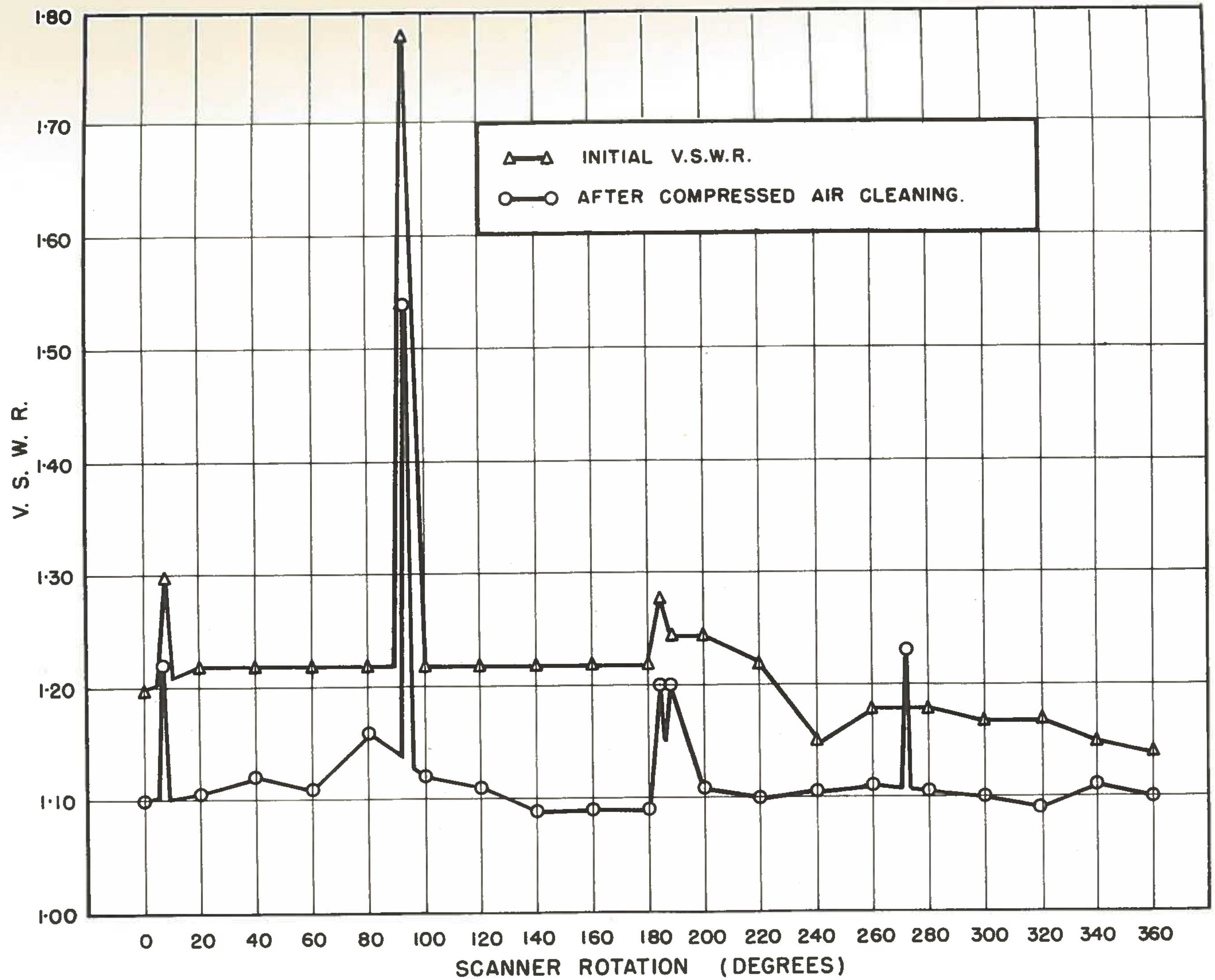

FIG. 3. SCANNER VSWR AT 16,000 MC/S

ment current requirements, the higher-gain amplifier caused burnout of a fuse in the primary circuit of the filament transformer after approximately 15 minutes of operation. Hence all tests were conducted with the lower-gain amplifier. It has, however, adequate gain for the application.

The radar was sited in an area where ground clutter was moderately heavy. With the anti-clutter circuit in operation, there appeared to be little difference in the display between linear and logarithmic operation. Logarithmic operation was judged to be slightly better. No attempt was made to detect moving targets in the clutter. The results should be regarded as inconclusive, and a full evaluation of the logarithmic i-f amplifier should be made under conditions of heavy ground clutter and rain clutter.

It was noted that with the NRC i-f amplifier installed, the display appeared to be better than with the radar i-f amplifier, and the improvement was evident in both the linear and logarithmic modes of operation. Echoes appeared to be clearer with better defined edges when the NRC amplifier was used. No investigation was made into this apparent improved operation.

5. RADAR PERFORMANCE CHECKS USING NRC TEST SET

The transmitter power, frequency, and receiver sensitivity were checked with the NRC test set. The results were:

Transmitter frequency	16,057 mc/s
Transmitter average power	97 watts
Tangential signal at duplexer	-118 dbw
	(= -88 dbm)

Comparison with expected values:

a) Receiver Sensitivity

With receiver noise factor of 13 db, bandwidth 7 mc/s, a tangential signal should be -118.5 dbw.

b) Transmitter Power

i) Calculated Power Output

PRF = 8335 pulses/sec
Pulse length = 0.25 μsec
Magnetron power input = 20 ma at 23 kv
Magnetron efficiency = 25% (assumed)
Calculated power output = 115 watts

ii) Relative Power Indicator Reading

Indicated peak power output, <u>if the relative power meter cali-</u>

bration is linear was 57 kw. (Relative power meter calibration was known only at full power setting of 75 kw.) Indicated average power, using relative power meter as above, = 119 watts.

Thus the measured output power is approximately 0.7 db below the output power calculated above. However, the following losses were not included in the test set calibration:

Ferrite Isolator	0.5 db
Duplexer	0.3 db
3 feet of waveguide not accounted for in test set calibration	0.6 db
Total	1.4 db

When these losses are included, the calculated power level at the test set is approximately 0.7 db below the measured power level.

6. MISCELLANEOUS OBSERVATIONS

1. RCEME personnel on the trials offered the opinion that some motors may not be powerful enough; in particular, the azimuth drive motor, which is $\frac{1}{4}$ hp, cannot slew the antenna at temperatures much below 0°F.

2. Radar cab heating is reported to be insufficient in cold weather.

3. The anti-clutter circuit does not pass 0.2-μsec pulses with undiminished amplitude. A somewhat longer time constant may be desirable.

4. Because drift in the line structure of echoes (due to non-synchronization of the azimuth and range sweep circuits) is somewhat bothersome, the operators defocus the cathode-ray tube slightly. This may lead to somewhat poorer accuracy than would be obtained with the cathode-ray tube sharply focussed.

5. The wireless set in use at the present time is the No. 510, which operates in the band 38-55 mc/s. Whenever the wireless transmitter is turned on, the noise level on the cathode-ray tube decreases somewhat, probably owing to carrier power leaking into the radar i-f amplifier. A different communication set or better shielding would be desirable. The interference is not serious at present.

6. The No. 19 wireless set in the radar is useful for short ranges only, because of interference from the radar transmitter. Usually a land line to a remote wireless set is necessary in order to get reliable communication. Better shielding or improved equipment is desirable.

7. The magnetron in use until recently operated for 102 hours, and still operates satisfactorily. (It was replaced at the time that the pulse transformer failed.)

8. Brushes on the main generator appear to be inaccessible.

7. RECOMMENDATIONS

1. Steel pins rather than setscrews should be used wherever possible to eliminate mechanical failures such as have occurred in the scanner drive system.

2. The small end of the scanner should be tightly sealed against the entry of dust, oil, and metal particles, since there is a pressure differential along the axis of the scanner under operating conditions which tends to draw foreign material into the scanner through holes now open in the end casting.

3. The scanner rotor should be removed at a suitable date, and all foreign material removed from the interior of the scanner.

4. The video amplifier bandwidth should be increased as soon as possible to decrease the pulse rise time.

8. SUMMARY

The overall bandwidth of the i-f amplifiers, as determined from the individual passbands of the preamplifier and main i-f amplifier, is 6 mc/s, with slight asymmetry. This bandwidth is slightly less than the design figure of 7 mc/s, but is not expected to cause appreciable trouble.

The "A" video amplifier rise time is 0.25 to 0.3 μsec and the "B" video amplifier rise time is approximately 0.17 μsec. This makes precise determination of the range of an echo difficult. The stages causing this pulse distortion have been isolated.

The AFC circuit appears to operate satisfactorily, but because there is no positive indication given to the operator should it fail to function properly, manual tuning has usually been used.

Metallic dust particles, which have entered the small end of the scanner through holes in the end casting behind the drive pulley, are causing higher than normal VSWR in the scanner. The particles probably were introduced while the pulley on the scanner drive motor was rubbing on the end of the scanner casting. The presence of the metallic particles in such critical locations as the chokes, rotary joint, and waveguide radiator probably accounts for arcing in the scanner and subsequent failure of the pressurizing windows which had been observed previously.

The VSWR, at present, is low enough that the ferrite isolator built into the radar gives adequate protection to the magnetron.

The logarithmic i-f amplifiers built at the National Research Council were operated in the radar set in preparation for evaluation trials on this type of amplifier. No conclusive results were obtained during these measurements.

The radar performance was checked using the NRC Ku-band radar test set, and was found to be satisfactory, with the exception of transmitter power. The transmitter is being deliberately operated at lower than the 75 kw peak power rating owing to higher than normal scanner VSWR.

9. ACKNOWLEDGMENT

The author wishes to thank all the Army personnel whose assistance made completion of these measurements possible in the period allotted.

TABLE I

SUMMARY OF FAULTS ON AN/MPQ-501

(21 January to 28 March 1958)

DATE	FAULT	LOST TIME	REMARKS
21 Jan.	Δt dial creeping-bad clutch	none	Replacement clutch arrived 5 Feb. and was installed without lost time.
31 Jan.	Azimuth slew unreliable	none	Ground return for relay was cold-soldered and came loose
5 Feb.	Scanner motor noisy	none	Setscrew holding pulley on scanner motor shaft worked loose. Motor replaced, and two setscrews installed, one to hold key and second to bear on motor shaft. Replacement motor had bad bearings.
5 Feb.	Transverse plane bearing pin loose (in levelling mechanism)	none (on maintenance day)	Antenna jacked up and pin replaced. Setscrew helicoil thread replaced and additional setscrew added.
11 Feb.	Azimuth counter revolving continuously	10 min.	Azimuth servo amplifier was not tightly plugged in.
12 Feb.	Magnetron current half proper value at high prf.	$2\frac{1}{2}$ hrs.	Prf. generator required re-adjustment. (Time required was longer than necessary because repairs to the test oscilloscope were necessary before repair could be made.)
14 Feb.	Longitudinal leveller driving wrong way	none	Actuator which had been installed in January had leads reversed inside. This was first opportunity to correct condition.
25 Feb.	Routine tube check on maintenance day — no faults	none	Replaced 6 tubes
27 Feb.	Waveguide air pressure interlock switch open	5 min., but see remarks	Drain plug in copper air line developed leak. Interlock by-passed and set operated at half power, 8 psi pressure for remainder of day. Plug replaced later.

DATE	FAULT	LOST TIME	REMARKS
28 Feb.	Angle of sight drive motor failed	see remarks	No spare. Set now operating without motor. Angle of sight adjusted manually.
4 Mar.	Scanner drive belt broken	½ hr.	
11 Mar.	Scanner motor shaft broken	4 days	Motor previously removed (see 5 Feb. above) was re-installed with bad bearings.
11 Mar.	No video signals		Replaced magnetron, without removing fault. Pulse transformer removed and found defective. Spare transformer defective. Replacement transformer from CAL arrived 14 Mar. and was installed same day. Terminals reversed on this transformer. (No firing until 17 Mar.)
18 Mar.	Scanner drive belt broken. Motor pulley worn	one day	Bearings in motor replaced (spare bearings had just arrived). Pulley re-bored and bushed.
24 Mar.	Willys motor mis-firing	—	One spark plug lead loose, carburetor leaking. M33 generator being used until carburetor repaired.
25 Mar.	Poor azimuth accuracy at 17,000 meters range	—	Computer had not been set up for this range, resulting in 85 meter errors.

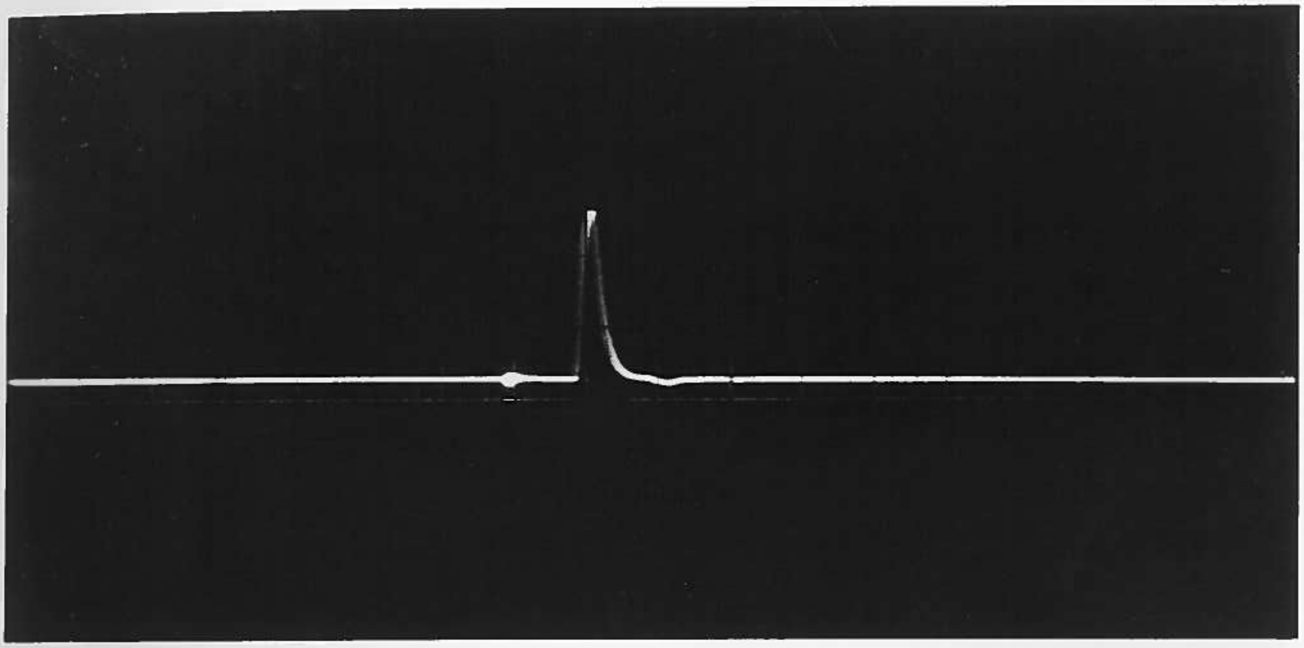

PLATE I OUTPUT OF "A" VIDEO AMPLIFIER
WITH 0.2 μsec PULSE INPUT

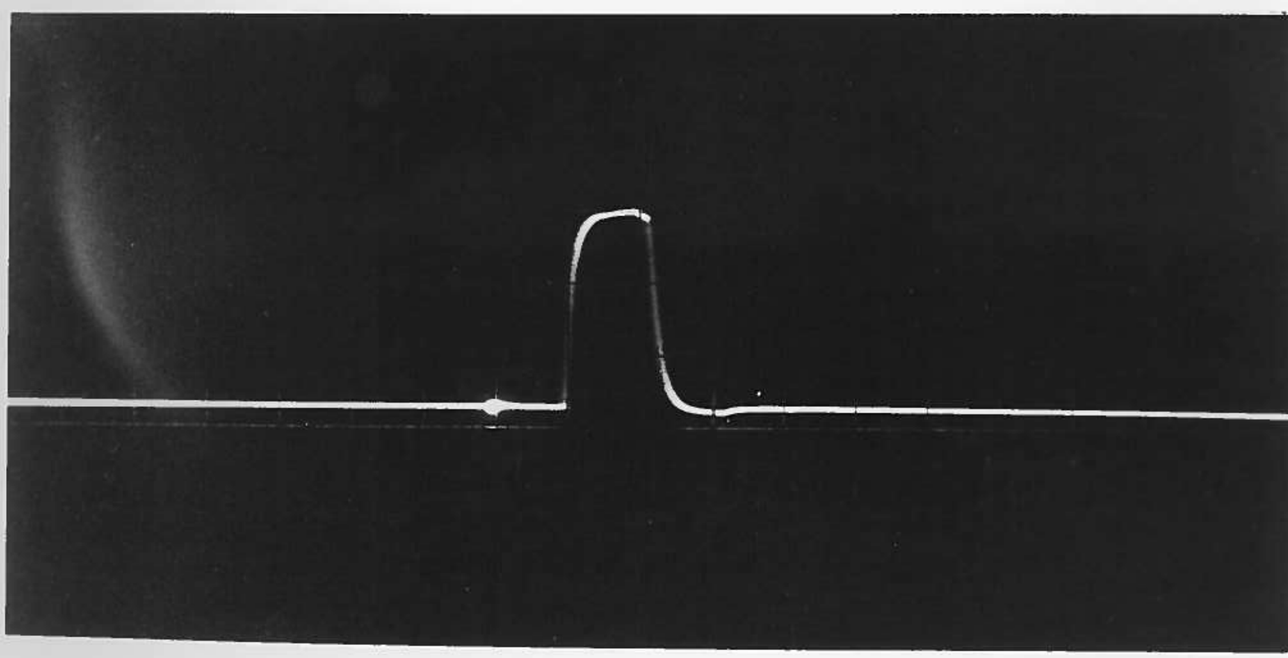

PLATE II OUTPUT OF "A" VIDEO AMPLIFIER
WITH 1.0 μsec PULSE INPUT

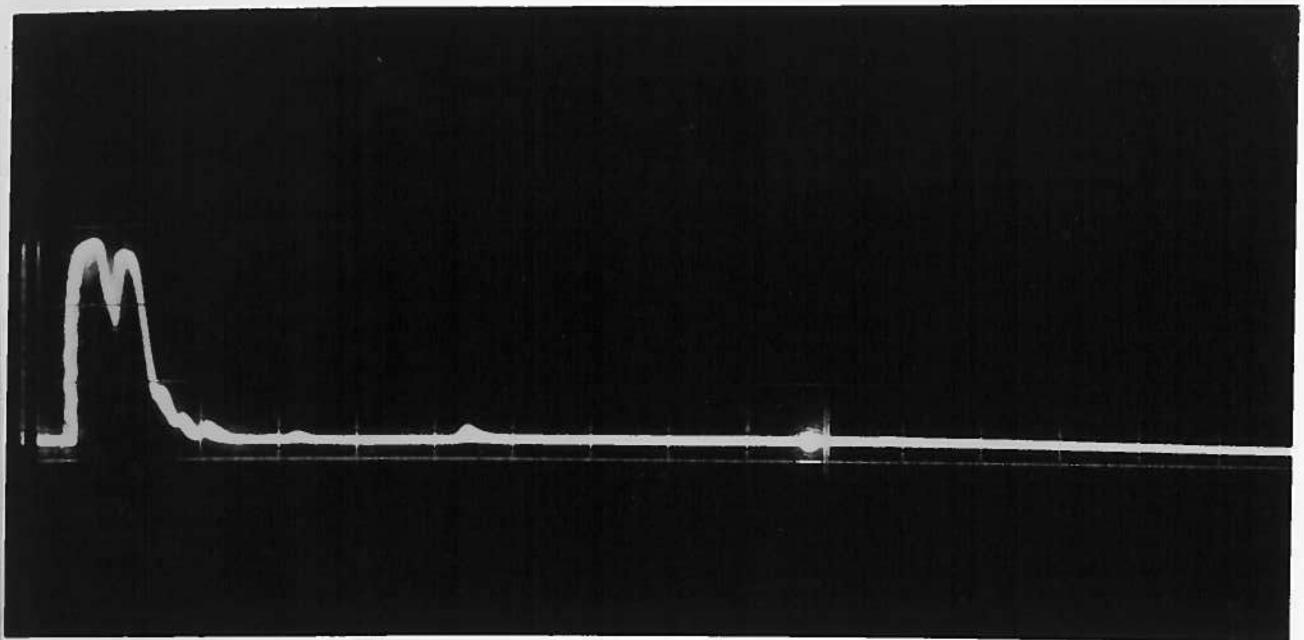

PLATE III OUTPUT OF "A" VIDEO AMPLIFIER
SHOWING TRANSMITTER PULSE AT LOW GAIN SETTING

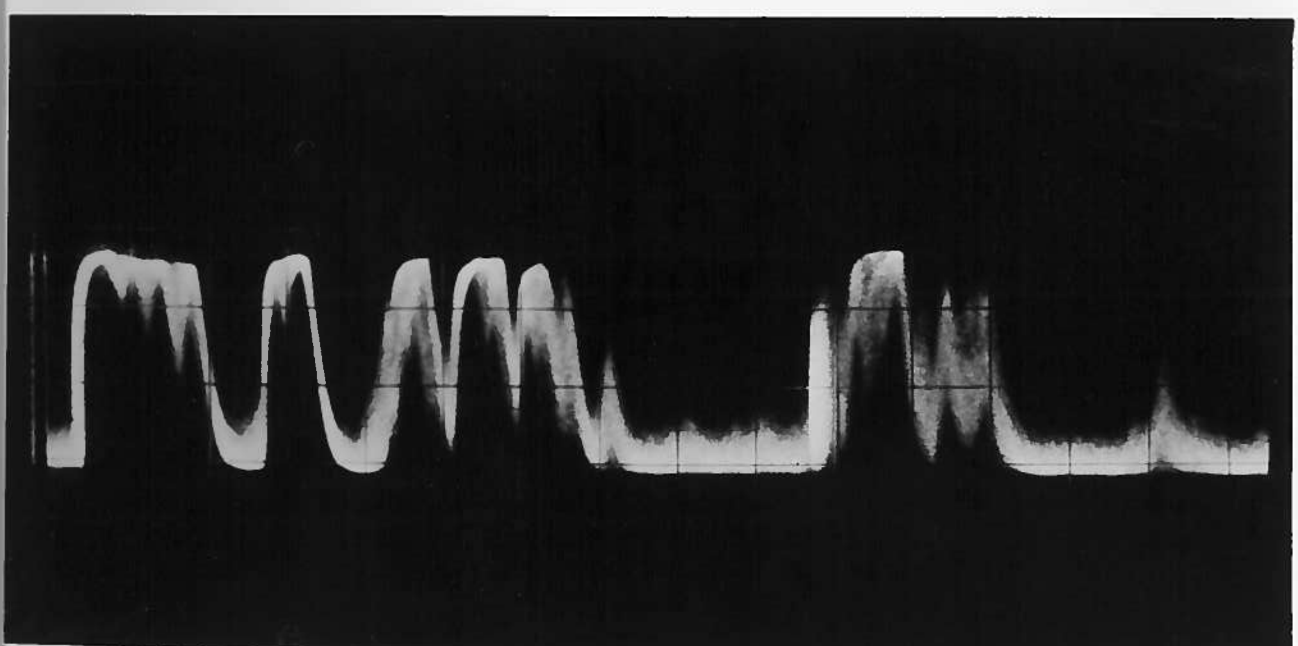

PLATE IV OUTPUT OF "A" VIDEO AMPLIFIER
SHOWING TRANSMITTER PULSE AT NORMAL GAIN SETTING

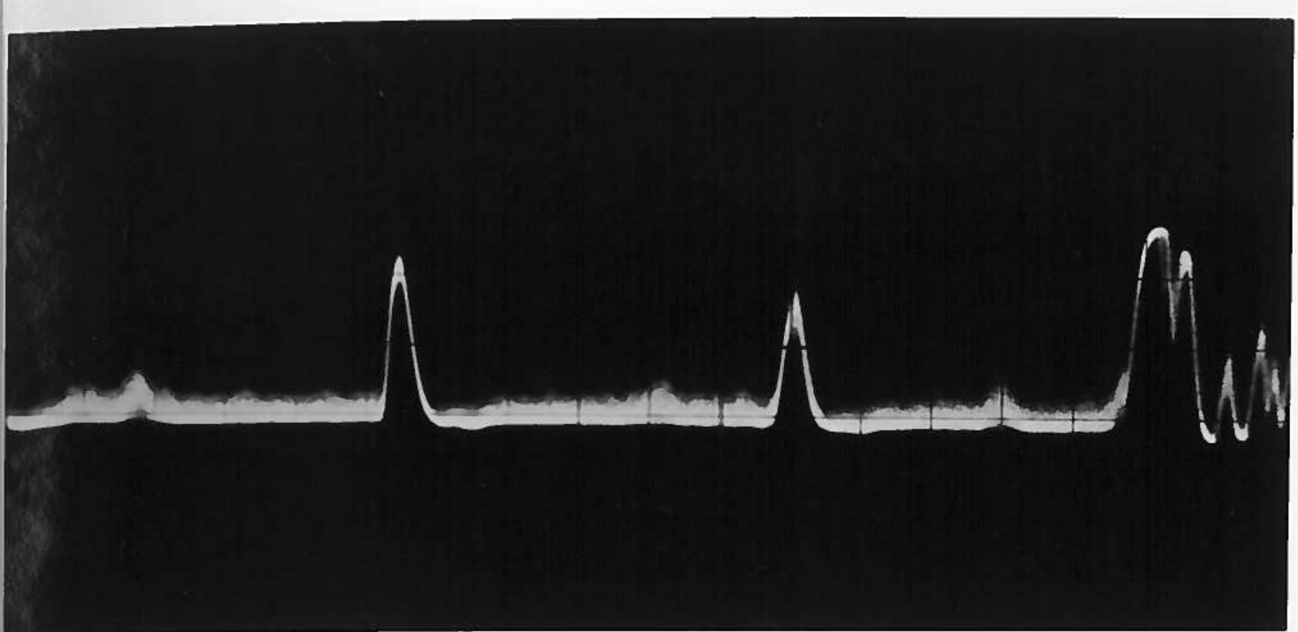

PLATE V OUTPUT OF "A" VIDEO AMPLIFIER
SHOWING STABLE PERMANENT ECHOES

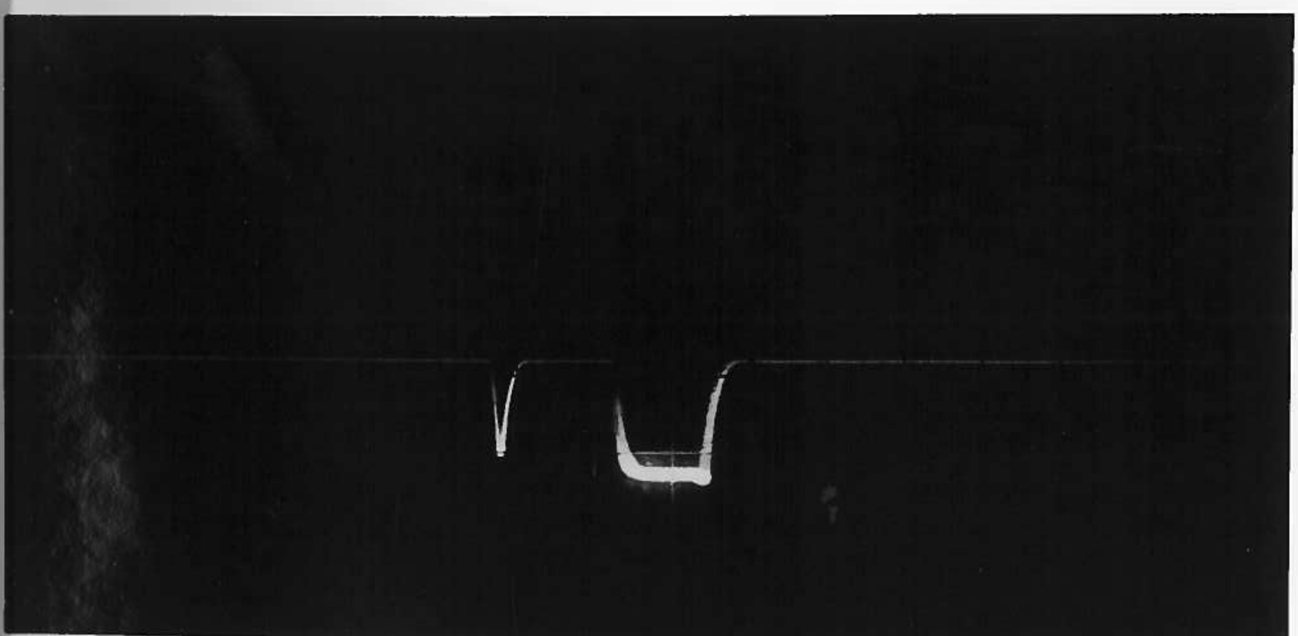

PLATE VI OUTPUT OF "B" VIDEO AMPLIFIER ABOVE LIMITING.
MARKER AND 1.0 μsec PULSE VISIBLE (NEGATIVE PULSES)

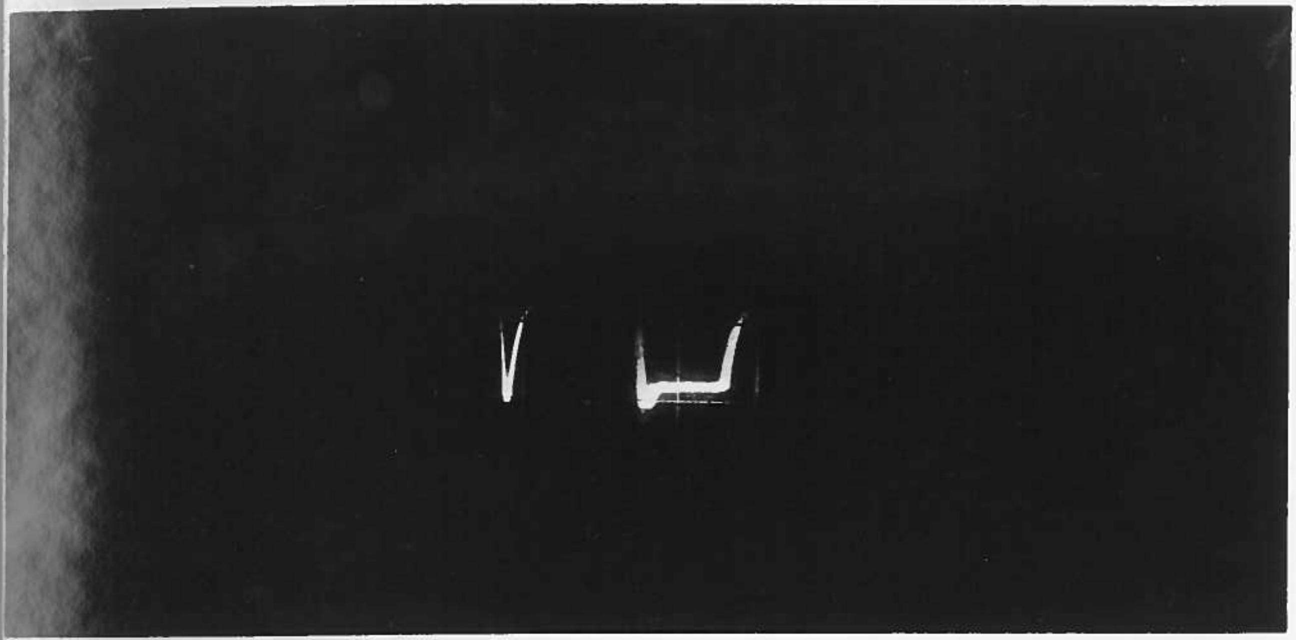

PLATE VII OUTPUT OF "B" VIDEO AMPLIFIER BELOW LIMITING. MARKER AND 1.0 μsec PULSE VISIBLE (NEGATIVE PULSES)

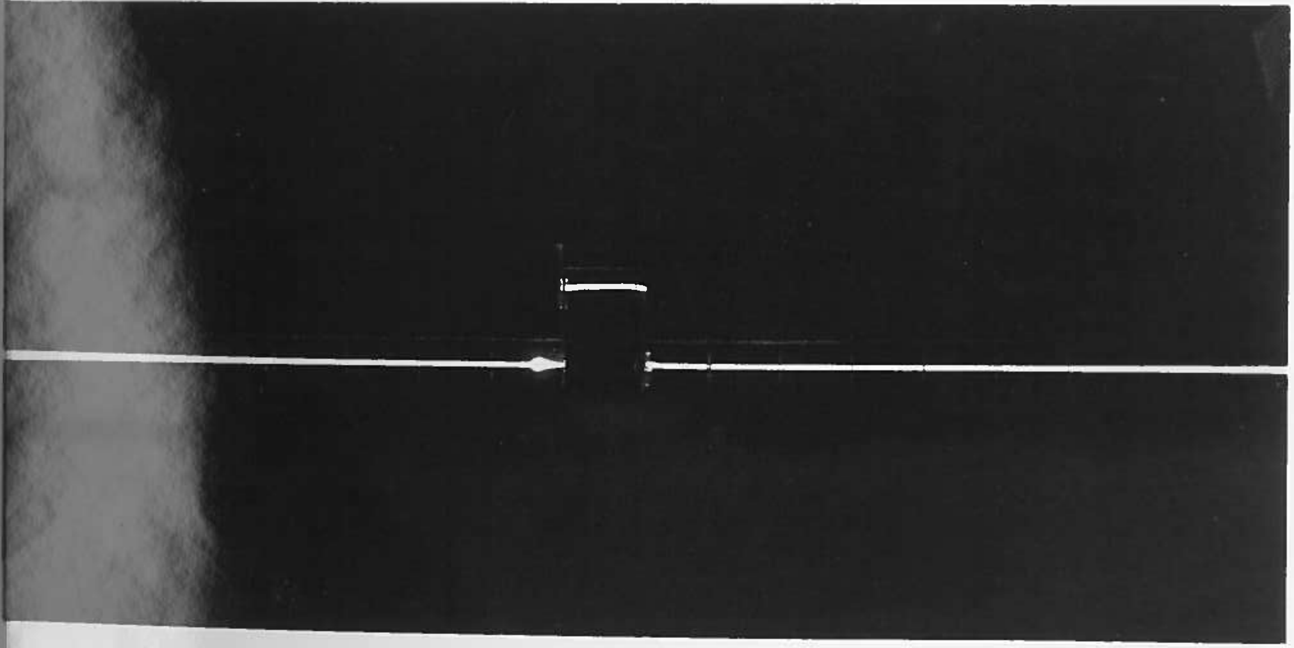

PLATE VIII OSCILLOGRAM OBTAINED WHEN 1.0 μsec PULSE IS APPLIED TO CRT PLATES