Experimental MXPI Equipment
National Research Council of Canada. Radio Branch

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https://doi.org/10.4224/21274024
PRA; no. PRA-115, 1944-06

SECRET

PRA-115

COPY NO. 54

NATIONAL RESEARCH COUNCIL OF CANADA
RADIO BRANCH

EXPERIMENTAL MZPI EQUIPMENT

OTTAWA

JUNE, 1944

CONFIDENTIAL

NATIONAL RESEARCH COUNCIL OF CANADA
RADIO BRANCH

SECRET PRA-115

EXPERIMENTAL MZPI EQUIPMENT ANALYZED

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SUMMARY

The following report describes an experimental model of a Microwave (S-Band) Zone Position Indicator. The operational requirements leading up to the design of this equipment are considered and the evolution of a particular set to meet these requirements is discussed. There is a brief description of the antennas and of the transmitter and receiver circuits. The problems involved in operation in conjunction with an APF unit are discussed. The results are given of flight trials, both at Ottawa under clutter-free conditions, and on sites around Vancouver under very bad clutter conditions. These show that the equipment meets the range specifications and that it is capable of tracking aircraft through very bad clutter.

It is emphasized that this report describes an experimental model, which in many respects differs considerably from the proposed production model. The report ends with a brief tentative description of the latter.

NATIONAL RESEARCH COUNCIL OF CANADA
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S E C R E T   EXPERIMENTAL MZPI EQUIPMENT   PRA-115

CHAPTER I -- GENERAL DESCRIPTION

Requirements:

It has been known for some time that under some conditions the Zone Position Indicator (ZPI) of the GL Mk. III-C does not perform its function satisfactorily. The main drawback is the dependence of ZPI performance on siting conditions; specifically, the wide beam, combined with appreciable side and back lobes, results in an excessive amount of interference from permanent echoes. In mountainous country, this might mean that the minimum usable range of the ZPI could be greater than the maximum range of the APF so that no transfer to the APF could be effected. Moreover, even on sites relatively free of permanent echoes, the wide antenna beam ~~results~~ in inadequate resolution although adequate azimuthal accuracy can be obtained on a single echo. Another effect of the site is to influence the pattern of the antenna in the vertical plane. Although a gap-free pattern is obtained when the beam is projected over water, serious gaps appear when the beam is over land and these become quite distorted over rough terrain. (See N.R.C. Report PRA-73). The large beam width in the horizontal plane and the operating frequency of 150 mc. render the set susceptible to jamming.

In addition to these difficulties, there are several technical limitations to the ZPI equipment. Our knowledge of radar circuits and service requirements has increased considerably since the time that the ZPI was designed. Thus in designing equipment which will overcome the limitations of the ZPI, full advantage has been taken of this recently augmented knowledge to produce a more satisfactory piece of equipment.

The following specifications were laid down for MZPI (Microwave Zone Position Indicator):

Wavelength: S-band

Range: 60,000 yards on a Hudson aircraft up to an altitude of 45,000 feet.

Range Accuracy: ± 1000 yards

Azimuthal Accuracy: ± 2° or better

Vertical Coverage: As complete as possible from the horizon up to 70°

Rotational Speed: 10 - 15 r.p.m.

In addition to these, it was decided that a complete picture of the area covered by MZPI should be maintained at all times on the display which should be of the PPI type, and that the equipment should be mobile.

It will be seen that a microwave set eliminates most of the major limitations of the ZPI. The antenna pattern is substantially independent of the site since there is little evidence to indicate that the reflected wave from the average terrain contributes appreciably to the antenna pattern. Consequently gap-free coverage is obtained to a much lower angle than with the ZPI. An extremely narrow beam can be used in the horizontal plane with negligible side lobes and back radiation. This results in greatly improved resolution and much less clutter. Thus many sites in mountainous country are quite practicable, which with the ZPI, were unusable. The use of a very narrow beam in the horizontal plane renders jamming of such equipment very difficult.

Design Problems:

The first problem encountered was to determine the amount of power required to produce the required range and vertical coverage. In view of the fact that a complete picture of the required area should be maintained, the use of a pencil type antenna beam with a spiral scan is undesirable as it involves an excessive amount of time to scan the entire area or else the scan is so rapid that the possibility of an incoming plane not registering for several complete scans is greatly increased. For these reasons, it was decided to use a fan shaped beam, narrow in the horizontal plane and broad in the vertical. An antenna beam width[(1)] of 2° in the horizontal plane was decided upon as giving the best balance between angular resolution, antenna gain, antenna size and spot size on the PPI display tube. This factor having been fixed, the vertical plane coverage requirements then determined the antenna gain, and the maximum range to be expected could be calculated from available formulae[(2)] tempered by the results obtained with existing equipment. This was done and it was found that to provide a complete continuous coverage as laid down in

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(1) All antenna beam widths are quoted as the full beam width at one-half peak voltage.

(2) Report No. ORG-E-9-1 "The translation of the Military Requirements of Range into the Technical Specifications for a Radar Set".

the specification, with existing production magnetrons (Type 3BX) and present receiver sensitivities, three complete radar sets would be required. This appeared too complex both from the design and maintenance standpoints so it was decided to compromise on a two-transmitter, two-receiver system. One antenna has a vertical plane pattern as shown in Fig. 2A and has its own transmitter and receiver. This is a fat beam which should give complete coverage out to about 25,000 yards. A second antenna, with its own transmitter and receiver has a long narrow beam in the vertical plane (Fig. 2C) with an estimated maximum range of 60,000 yards. However, its vertical beam width is 15° and this is not sufficient to provide adequate high and low angle coverage beyond 25,000 yards so it was decided to give this beam an 8° beam split. This beam shifts from one position to the other once per rotation of the antenna. To summarize, there is a short range beam which is on all the time and provides complete coverage out to 25,000 yards and a long range beam which swings up and down alternately with rotation of the arrays and which provides the requisite coverage from 25,000 yards to 60,000 yards. In this set, the coverage out to 25,000 yards was important since transfers to the APF were to be made at 17,000 yards or less.

<u>Layout</u>:

The layout of the MZPI is shown in Fig. (1). The two arrays are mounted on the side of a cab which is built on a standard GCI turntable and APF trailer. The turntable is rotated at 10 r.p.m. by a 3 h.p. induction repulsion motor. The rotation is continuous and no attempt is made to reverse or to maximize on an echo. The rotating trailer contains the complete transmitter unit and a receiver rack. The latter rack contains two receiver units, each consisting of mixer, local oscillator and automatic frequency control, and I.F. amplifier. In addition, there is a video, an "A" scope and a sweep to supply monitoring while lining up. During the first 25,000 yards of the sweep the short range receiver only is turned on. From 25,000 yards to 80,000 yards the long range receiver only is turned on. This is accomplished by a suitable strobe circuit which permits the outputs of the two receivers to be presented on a single c.r. tube without doubling up the noise level or presenting phasing difficulties.

The I.F. output from the two receivers is brought out through slip rings and goes through cable to the display rack which is mounted in a standard GMC 6 x 6 truck. This rack is not mounted in the trailer since it was found to be impractical to rotate the operator at 10 r.p.m. for any considerable period of time. The display rack contains three more I.F. stages, detector and video, a 9-inch PPI tube with selsyn sweep, range calibrator and an interference suppressor circuit which is designed to blank out all interference above a certain preset level. Remote control of the modulator voltage together with remote metering of transmitter and receiver operation is available on the display rack.

CHAPTER II -- SPECIFIC DESCRIPTION

Antennas:

The antennas used in MZPI are stacked waveguide arrays. The long range array consists of six waveguides 13.5 feet long stacked vertically with the wide side of the guides in the vertical plane. Each waveguide has fifty slots cut in its wide side which form the radiating elements. The waveguides are centre-fed by a vertical feeder waveguide which is slot coupled to the individual radiating waveguides. By means of a ring switch in the feeder guide (Fig. 3) the waveguides can be fed either from the top or the bottom. The positions of the coupling slots are so adjusted that this either raises or depresses the beam by 4° thus producing an 8° beam split. The short range array is constructed similarly except that it consists of only two stacked waveguides and is always fed from above as no beam split is required. To obtain the required coverage the long range array is tilted at an angle of 11° to the vertical and the short range array is tilted at 20°.

To prevent precipitation from entering the waveguides through the radiating slots, they are covered by a special type of waterproof cellulose tape, which appears to resist weathering quite effectively. The use of such tape alters the resonant length of the radiating slots slightly and this is taken into account when the slots are made. No observable adverse effects have been detected when the tape over the slots is covered with rain drops.

It was decided to use this type of array rather than a single linear array feeding a cylindrical parabloid reflector (see N.R.C. Report PRA-92) for the following reasons:-

1. It would appear very difficult to swing the beam up and down with a paraboloid reflector except by swinging the entire reflector mechanically. It seemed desirable to do this in about 0.1 second so as to minimize the switching time. It would be virtually impossible to meet this requirement; and, in any case, the mechanical tilting mechanism would be undesirable. However, the beam switching requirement is easily met with the stacked waveguide array and waveguide switch as described.

2. It is difficult to obtain a very broad beam as required for the short range beam (beam width approximately 54°) with a small parabolic reflector since the feeder waveguide obscures a large proportion of the total aperture.

3. It is desirable to reduce the depth of the arrays to a minimum since they are mounted on the side of a rotating cab. The stacked waveguide array is only as deep as the narrow dimension of a waveguide plus the necessary supports. However, the reflector type array is as deep as the focal length of the parabola plus the supporting members. Thus the reduction in depth is appreciable.

The beam width (full width at half voltage) of the long range array is 2° in the horizontal plane and 15° in the vertical plane. The corresponding beam widths for the short range array are 2° and 54° respectively. One problem in the use of such arrays is the bandwidth of the array; i.e., the range of magnetron frequencies which can be used. The bandwidth is limited by two factors: the input impedance of the array and the pattern. Usually either one or the other of these is the limiting factor; in the present case it is the input impedance. The standing wave ratio as seen by the magnetron does not exceed 1.5 over a wavelength change of ± 0.5 mm. This is sufficient for experimental purposes but would be inadequate for field operations. New arrays are now being designed which will have a considerably greater bandwidth.

It would not be appropriate in this report to give a detailed account of the theory of slot radiators or the technique of designing slot arrays. For further information the reader is referred to N.R.C. reports PRA-80, 84, 88, 96, 102, 108 and 109. A detailed report of the MZPI arrays will be published shortly.

<u>Transmitter:</u>

A simplified circuit diagram of the transmitter is shown in Fig. 4. This shows only the essential parts, omitting overload and control relays, metering circuits, etc. The high voltage is supplied by a high voltage transformer, a bridge rectifier and a brute force filter. This is followed by the charging inductance and spark gap short circuit to ground. Up to this point, all components are common to the two magnetrons. The ungrounded spark wheel contact is connected to two "Blumlein" pulse forming lines, each of which is terminated by a Type 3BX strapped magnetron. Each line forms a one microsecond pulse and the spark gap operates at a recurrence frequency of 692 cycles/second. Separate pulse forming lines were used to reduce the heat dissipation per unit and to prevent interaction between the magnetrons. At the recurrence frequency employed, the usable peak power is limited not by voltage arc-over but by the average power dissipation in the magnetrons. It is estimated that in normal operation, each magnetron delivers about 300 KW peak RF power.

<u>Receiver:</u>

Each of the two receiver units consists of a T/R switch, crystal mixer, local oscillator with automatic frequency control, and a three-stage I.F. preamplifier followed by a five-stage I.F. amplifier. See Fig. 1.

The T/R switch is a gas filled cavity resonator which breaks down forming a short across the mixer input on application of high RF power. It provides adequate crystal protection for any received RF power provided a keep-alive is used to supply a continual source of ions. The T-R cavity is window coupled into the main waveguide. No R-T switch is used since over the frequency range of magnetrons allowed by the antenna, the electrical distance between the magnetron and the T-R switch does not change by more than plus or minus twelve electrical degrees. At worst, this means less than 8% power loss on reception which produces a negligible effect on range. The non-oscillating impedance of the magnetron is sufficiently different from its impedance while oscillating to prevent all but a very small percentage of the received energy from being absorbed by the magnetron.

The mixer is loop coupled into the T-R switch cavity. Small 3-cm. chokes are included to attenuate third harmonics from the magnetron which are thought to have a bad effect on the crystal in some cases. The mixer output is connected by three inches of AS 8 coaxial cable to a three-stage 30 megacycle I.F. preamplifier which is mounted directly on the waveguide. The preamplifier is used to minimize multiple ground currents in the I.F. input stage which affect the I.F. noise level. Its bandwidth is about 2 megacycles at full width to half down in voltage. The preamplifier feeds a five stage negative feedback 30 megacycle amplifier mounted in the rack with a bandwidth of 5 megacycles, (see Fig. 5).

The local oscillator is a McNally Type 707B reflex klystron. This is a low voltage tube with removable cavity which is frequency sensitive to reflector voltage. By changing this voltage the frequency may be swung through about 15 megacycles. This property permits the use of AFC (automatic frequency control).

A separate mixer for AFC[1] is mounted directly on the waveguide and coupled to it through a piston attenuator which produces about 60 db attenuation between the waveguide and the crystal. It is fed by the same local oscillator as the main mixer. As shown in Fig. 6, the I.F. output from the AFC mixer goes through two I.F. amplifier stages which feed a discriminator circuit of the general type described by Travis.[2] The discriminator circuits are tuned to 28.5 and 31.5 megacycles so that the discriminator detectors give a resultant d.c. output voltage which is positive or negative if the difference between magnetron and local oscillator frequencies is respectively greater or less than 30 megacycles. This d.c. voltage is amplified and used to control the reflector voltage of the McNally local oscillator, thus automatically bringing it back to the correct frequency. Manual tuning control is available for checking AFC action. The AFC circuit has operated very satisfactorily and has proved essential with such comparatively narrow band I.F. amplifiers.

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(1) N.R.C. Report PRA-103

(2) Charles Travis P.I.R.E. 23, 1125, 1935

It is evident that with two local oscillators in the same rack, the possibility arises of interaction between them. To reduce this, both McNally tubes were mounted in specially designed shields equipped with 10 cm. chokes on all power leads. Although this reduced the direct intercoupling to a negligible amount, there was sufficient mutual coupling between the antennas to provide a strong blocking CW signal on both receivers if the McNally tubes were anywhere between 26 megacycles and 34 megacycles apart in frequency. However, since the McNally frequency can be 30 megacycles above or below its magnetron frequency, the local oscillators could always be tuned up so as to eliminate such interference for any given pair of magnetrons. This proved to be the only complication encountered in the operation of this two-receiver system.

The receiver components described above are duplicated for the two receivers. However, the I.F. outputs are mixed following the main I.F. amplifier so that the remainder of the components to be described are common to both receiver systems.

The receiver rack also contains a 5-inch c.r. tube with type A display for use as a monitor, (Fig. 7), with accompanying detector, video and sweep circuit. Also included in this rack is a simple strobe circuit which turns off the long range receiver every sweep from 0 to 25,000 yards and then turns it on and turns the short range receiver off. Thus the two receivers are never on at the same time. See Fig. 5.

The common I.F. output is taken out through slip rings and piped through 100 feet of coaxial cable to the display rack which is mounted in a standard GMC 6 x 6 truck. The signal passes through three more I.F. stages, detector and video to the grid of a 9-inch PPI c.r. tube (Fig. 8). The video has a band pass from 50 kc. to 3 mc. The low frequencies are suppressed to prevent blocking by clouds and extensive ground clutter. Video amplitude limiting is adjustable to obtain optimum contrast conditions on the display tube for weak signal detection.

For the interference suppressor some of the I.F. output from the trailer goes through a separate 7 megacycle bandwidth I.F. amplifier in the display rack, and is detected and passed through a pulse forming video. Fig. 8. The output pulse is applied to the main video amplifier as a blanking pulse. A limit setting circuit ensures that only pulses above a certain preset level are applied as blanking pulses. In practice, this level is set a little higher than the strongest aircraft signal to be received. Hence all signals below this level are unaffected. However, if an interfering signal comes through which is above this level, the blanking pulse is passed and blanks one of the main video tubes. Thus all strong interfering signals appear on the PPI tube, not as bright spots, but as black holes, which in the the case of 1 microsecond pulses are not observable. By a careful choice of time constants in the suppressor I.F. and video, no delay line is necessary in the main I.F. channel. This interference suppressor is very effective in wiping out all observable interference from nearby spark gap modulators.

Sweep System:

The MZPI uses a selsyn sweep for the PPI tube; that is, the deflection coil on the PPI tube is stationary and the magnetic field, which it generates, rotates. A positive sawtooth followed by a rectangular negative pulse centering is generated by a Millar feed-back sweep circuit and is fed from a constant current source into the rotor of a selsyn which is geared to the rotating trailer in a 1:1 ratio, (Fig. 10). The stator of this selsyn is connected to a similar stator, which is mounted on the PPI tube as the deflection coil. This system provides a good linear sweep and avoids the hunting, backlash and complicated mechanical assemblies usually associated with the rotating coil type systems. Sweep speeds of 40,000 and 80,000 yards are provided. For further details concerning the selsyn sweep see N.R.C. Reports PRA-47 and 92.

Range calibration is provided from a negative resistance tube LC oscillator (Fig. 9). The sine wave output is squared up through a push pull amplifier and differentiated to provide 10,000 yard calibration pips which are inserted into the main video circuit.

Power Supplies:

All power supplies in both racks, except those supplying the high voltage for the c.r. tubes and +600 volts for the sweep amplifier, are electronically regulated. The low current supplies use VR tubes and the high current supplies use type 2A3's in a feedback circuit. The set is designed to use 220 volts a.c. at 60 cycles and can be operated from the diesel supply used in the GL III-C.

Transmission of Information:

The azimuth readings are taken from the PPI tube by means of a mechanical cursor geared to a magslip which transmits the azimuth setting to the APF. The range is estimated by interpolation between the 10,000 yard calibration rings on the tube and also transmitted to the APF by a manually set magslip. The system used here is the same as in the old ZPI.

Operation with APF:

Some consideration has been given to the problem of operating the MZPI in close proximity to the APF of the GL III-C or GL III*-C. Since both sets operate in the same frequency band, it is evident that unless some precautions are taken, the crystals of both sets will burn out when the sets are pointing at each other. A series of experiments were made which showed that the use of a T-R switch prevents this. When a T-R switch is used with a "keep-alive", it will be fired by any received power which is sufficiently great to burn out a crystal. Since the APF in GL III-C is not equipped with a T-R switch at present, one would be installed when operating with an MZPI.

Another problem is that of interference on the displays. If the two sets are sufficiently close together, the interference suppressor described above will effectively remove the effect of interference from the APF transmitter. The converse problem, i.e. interference on the APF due to the MZPI, probably will not require such treatment since the APF receiver is in operation during its strobing period only. Thus the probability that an MZPI transmitter pulse will occur during the strobing period of the APF is small. If necessary some of the APF strobing pulse could be piped over to the MZPI to delay the striking of the MZPI spark gap until the end of the strobing pulse.

It may be wondered why the two transmitters are not simply synchtronized. However, both MZPI and the GL III*C APF use rotating spark gap modulators and operate at considerably different recurrence frequencies. This latter objection also applies in the case of the GL III-C APF.

No consideration has been given to the problem of interference caused by a beating of the MZPI local oscillators with that of the APF. This will occur if the two local oscillators are 30 megacycles apart. However, the production model of the MZPI will use only one local oscillator so that if such a situation arose, it could be easily remedied by changing the local oscillator frequency over to the other side of the magnetron frequency.

CHAPTER III - FLIGHT TRIALS

Ideal Site Trials:

Flight trials have been conducted with the experimental model in both Ottawa and Vancouver. The purpose of the Ottawa trials was to check the performance of the set on an ideal flat site and to determine that it meets the specifications. The purpose of the Vancouver trials was to study the performance of the set on a typical mountainous site where the old two-metre ZPI had proved most unsatisfactory.

The Ottawa trials were designed to check the following:-

1. The maximum range of the set on a given type of aircraft.

2. The vertical coverage actually realized with the three antenna beams; namely, the long range beam in the lower position, the long range beam in the upper position and the short range beam.

This data was obtained by plotting the coverage diagram for each individual beam separately. In each case a Hudson aircraft was brought in over the same radial path at a number of suitably chosen altitudes. The estimated echo strength was recorded as a function of range and plotted on a range height diagram. In these tests, standard Sylvania crystals were used whose characteristics were average. 3BX magnetrons were used which had been selected for frequency and voltage breakdown but not for efficiency. They were normally run with an applied peak voltage of about 22 KV.

Fig. 2 shows the coverage diagrams obtained with the three beams. No flights were made above an altitude of 23,000 feet since this was the ceiling height of the Hudson aircraft used for these tests. It can be seen that the maximum range on the Hudson is 60,000 yards on the peak of the long range beam for almost solid coverage and 75,000 yards for broken coverage. The agreement with the predicted ranges is obvious. By extrapolation, it is estimated that the maximum range on a B-17 should be about 100,000 yards. The vertical coverage checks well with the predicted patterns except that the long range beam is about 2° lower than expected. This was not considered serious and was not corrected before proceeding to Vancouver.

Mountainous Site Trials:

The Vancouver trials were held for the following reasons:-

1. To compare the clutter diagram of the microwave set with the clutter diagram on the 2-metre ZPI, both operating on the same site.

2. To study the tracking of the aircraft through bad clutter conditions with the MZPI.

3. To study the modifications in the vertical coverage pattern introduced by mountains within 10,000 or 15,000 yards of the set.

In each of these trials it was necessary to establish that the overall performance of the set was normal; otherwise the clutter diagrams obtained would not have been representative. This was done by tracking an aircraft over a clutter-free run (in this case over the sea) at a known altitude and checking the maximum range obtained with that obtained previously at Ottawa at the same altitude. Test runs were made at an altitude of 10,000 feet as this altitude ensures a fairly definite maximum range point. Moreover, if any anomalous propagation were present, the maximum observed range would be, if anything, slightly decreased. In this manner, it was found that the performance of the set was slightly reduced for the first two tests (about -10% in range) and somewhat improved for the last test (about +5% in range). This was considered to be sufficiently normal performance to yield representative results.

The three chief weaknesses of the coverage of the 2-metre ZPI are:-

1. Low resolution in azimuth due to the great width of its main beam.

2. Spurious returns from permanent echoes due to its minor lobes spaced at widely separated angles.

3. A dependence of the vertical pattern on the surrounding site. A poor site may produce bad nulls and also reduce the maximum range.

These weaknesses are unfortunately inherent in any antenna of reasonable size at this wavelength. On the other hand, the microwave set has a very narrow beam in the horizontal plane in contrast to the 2-metre ZPI, namely 2° against 24°, giving it a marked increase in resolution. Moreover, its minor lobes lie close to the side of the main beam completely eliminating spurious returns. Also there is no indication that the vertical pattern is in any way dependent on the surrounding site, except, of course, where actual shielding occurs.

These points are well illustrated in the photographs shown in Fig. 12 taken of the PPI display tubes of the two sets. Data from two different sites are presented. In each case the ZPI and MZPI were within 100 yards of each other so that there is complete correspondence of the pictures from the two sets.

Fig 12 A and B give the ZPI picture at Little Mountain showing the effect of the beam width and minor lobe radiation. In many cases this is so pronounced that a single large echo produces a complete circle on the tube. These photographs were taken with a 7 microsecond time constant differentiating circuit in the ZPI video. With good low frequency response in the video, the picture appears much worse as it is not broken up radially to the same extent. Fig. 12 C, D, E show the corresponding photographs on the MZPI. A 2 microsecond time constant differentiating circuit was used in the video. This caused some overshoot which made the mountains stand out as on a relief map. This can be greatly reduced if necessary. However, it should be pointed out that the space taken up on the tube by overshoot was not lost as in most cases an aircraft could be seen in the dark space left by the overshoot. This is largely because most of the observable overshoot occurred at relatively short ranges where the aircraft echo would be fairly strong. Swinging the beam up removed a considerable amount of detail in the valleys between the mountain ranges thus providing better tracking in those areas. Fig. 12 E shows the effect of heavy rain clouds when using a good low frequency response in the video; i.e. with the differentiating circuit removed. It will be seen that the valleys have been completely filled in by the clouds. Under similar conditions, no echoes were observed from rain clouds when using the differentiating circuit in the video.

Figs. 12 G to L show the ZPI pictures obtained at Ambleside Site and the corresponding pictures of the MZPI. A comparison of Figs. 12 I and 12 J showsthe advantage of decentering the start of the sweep when the clutter is very bad near the centre of the tube. The first 10,000 yards has been greatly expanded in azimuth and the details become much clearer. This, of course, has the disadvantage of distorting the map of the area as the operator sees it.

It is evident from these photographs that large areas of the PPI tube are left clear for tracking aircraft in the MZPI while the same areas are completely blanked out with clutter in the ZPI.

The second test was designed to study the tracking of aircraft through the clutter which still remained on the PPI tube of the MZPI. This was done by deliberately sending an aircraft over the mountains giving the worst clutter. It was found that the aircraft would flash up here and there as it passed through dark spots within the mass of clutter. In most cases it was possible to track the aircraft so that a transfer to the APF could have been made at any time. It should be noted that an aircraft is represented by a single round point on the PPI tube; in many cases this enables it to be distinguished from masses of clutter which appear as irregular outlines. This degree of contrast between the shape of echoes from aircraft and mountains does not exist on the old ZPI.

It was found in the final tests that the effect of the mountains on the vertical coverage diagram is simply to blank out that portion of the normal diagram which falls beneath the line of sight.

CHAPTER IV -- PROPOSED PRODUCTION MODEL

It has been emphasized in this report that the set described is an experimental model, built to test the following points:-

1. The feasibility of using stacked waveguide arrays to form a complete antenna.

2. Whether or not a practical set could be constructed which would fulfill all of the tentative specifications laid down for MZPI.

3. The practicability of a two-transmitter, two-receiver system.

4. The advantage of an MZPI over a 2-metre ZPI in bad clutter conditions where the ZPI has proved quite unsatisfactory.

The results of the flight tests have shown that the set meets the specifications and can be of great use even in bad clutter conditions. The experimental antenna patterns checked the theoretical patterns very closely and no difficulty was experienced in operating the two-transmitter, two-receiver system simultaneously. The results have been sufficiently satisfactory to indicate a real and pressing need for such a set in the field and it is desirable to put it into production as sooh as possible. However, some features of the present equipment were constructed as they were because it was expedient to do so. These are not all desirable features for a production model for field use and several alterations will be necessary. A description of the proposed production model is given below. It must be emphasized that this can be only tentative since the production model has not yet been frozen and additional changes will undoubtedly be made before it makes its appearance.

The production model will be completely self-contained in a single GMC 6 x 6 truck except for the power supply, (Fig. 13). This eliminates the rotating trailer and will increase the mobility of the set. A single transmitter and receiver will be used. The antenna beams will remain approximately as described above but the "short range" beam will be switched on, say, every sixth revolution. The "long range" beams will operate unchanged. The "short range" beam will be sharpened up slightly by adding one more waveguide and its sole purpose will be to cover high flying aircraft at short range. When the experimental set was designed, transfers to the APF were made at 17,000 yards or less so that it was necessary to maintain continuous complete coverage at short range. However, it now appears desirable to make transfers at ranges up to 30,000 yards so that the short range beam thus loses some of its importance. Moreover, a single radar system will greatly facilitate maintenance in the field. Manual control of beam switching will also be available for tracking a particular target.

The antennas will be mounted on the roof of the truck and they alone will rotate. They will be folded down on the roof during transit to provide adequate overall road clearance. This eliminates the large GL type slip rings which were previously necessary and which gave considerable trouble due to excessive wear caused by the relatively high rotational speed. It also eliminates all the remote control relays and remote metering necessary in the experimental model.

The receiver and display units will be mounted in a single rack with an I.F. preamplifier mounted on the waveguide as before. Narrow band I.F. amplifiers will be used for anti-jamming and to reduce interference. The only major change will be that the I.F. amplifiers will not be split up as previously and, of course, no range strobing will be used. Mk. III IFF equipment will be installed, the 5-inch A scope serving the dual purpose of monitor and IFF display.

It is intended that the primary function of this set will be to replace the present ZPI in the GL convoy. Under these circumstances, the power for the set will be supplied by the diesel generator used in the GL convoy. However, it will also be possible to use the set independently as a microwave medium range air warning set. For this purpose a separate power supply will be supplied.

DATA COMPILED
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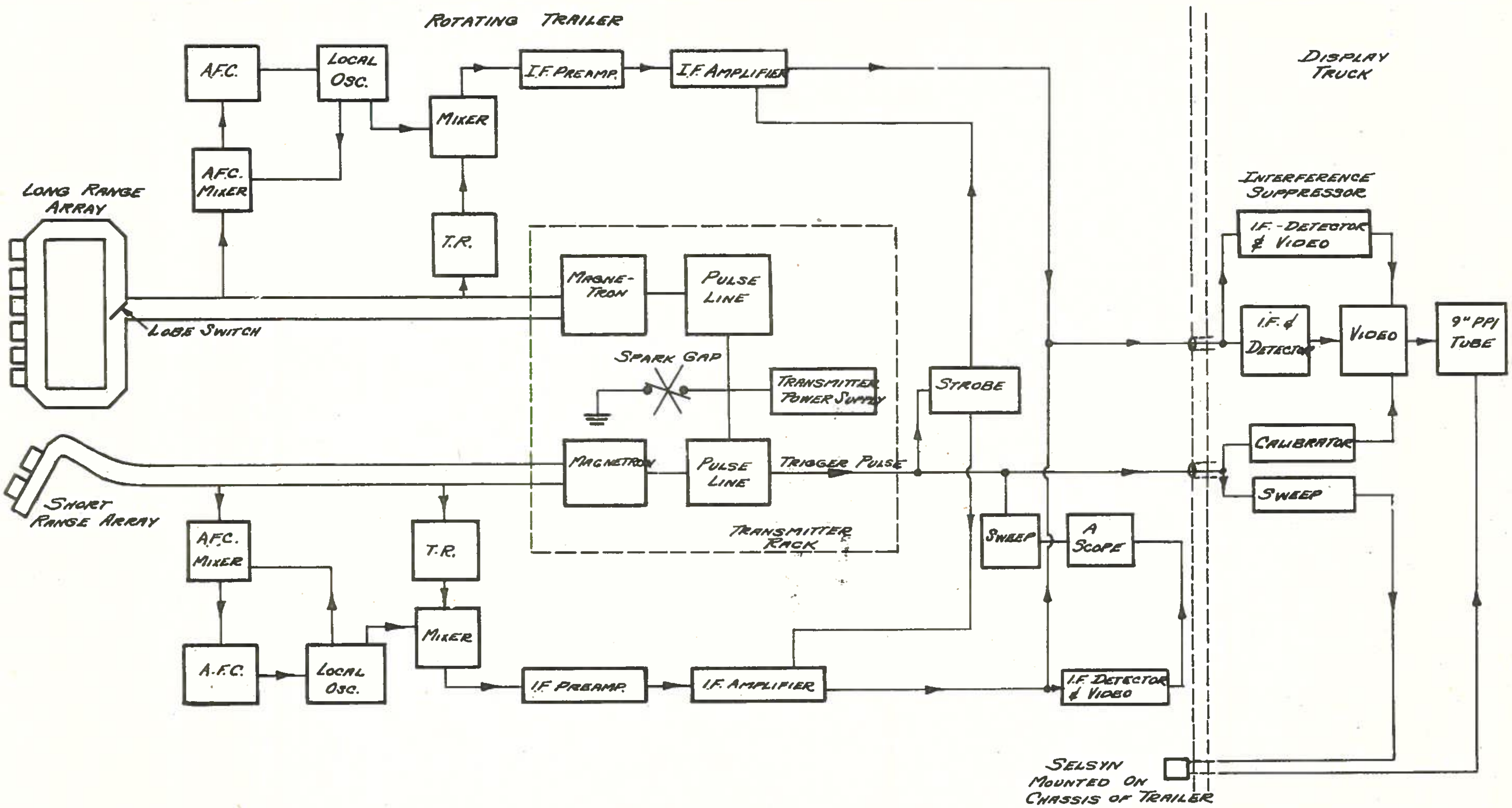
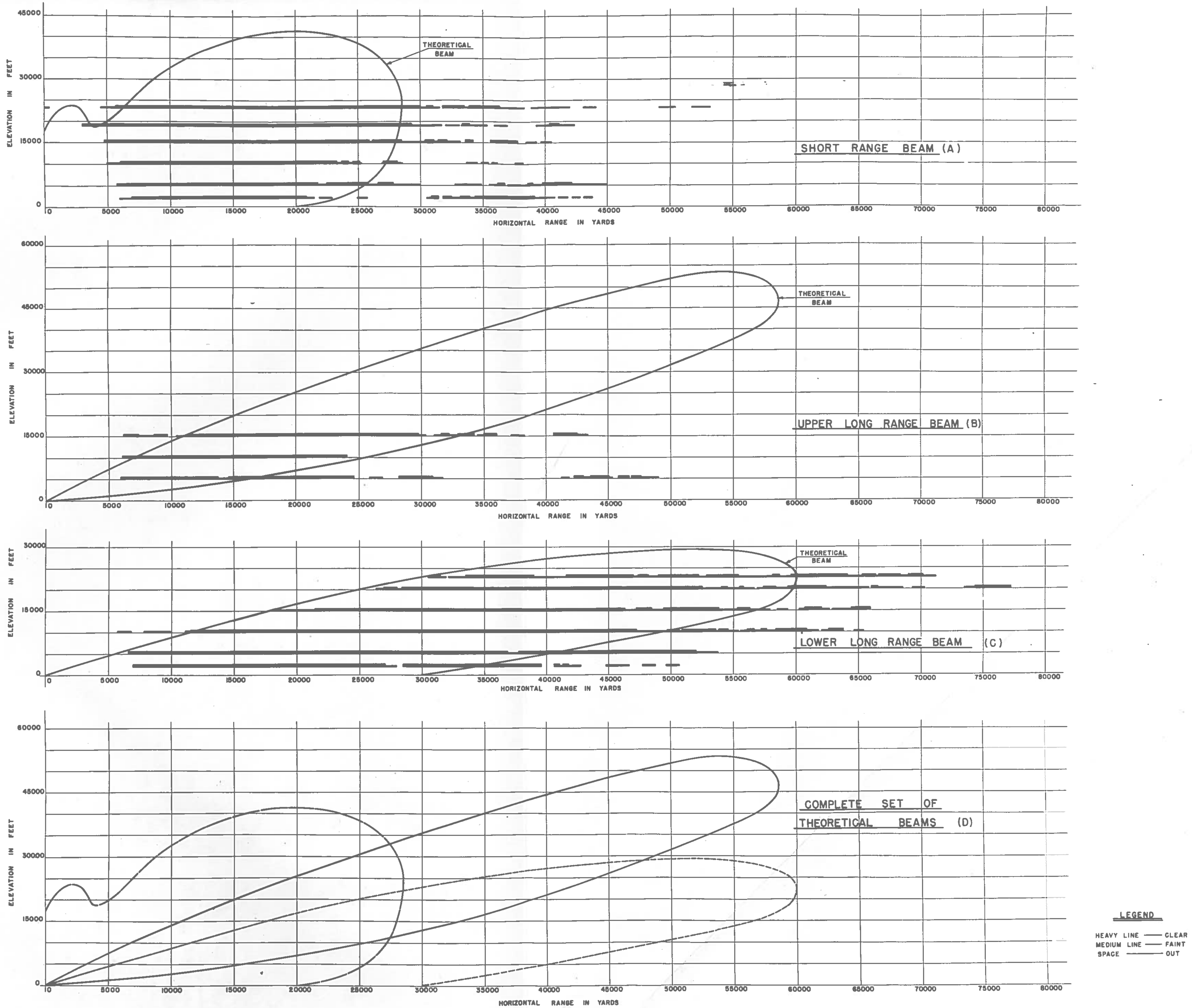


ITEM	PART NO.	QUAN.	MAT'L	DESCRIPTION
DRAWN BY E.H.B.	DATE May 1, 1944	SUPERSEDES		
CHECKED	DATE	SCALE		
ENG. APPROV. K.G.M	DATE	FINISH.		

NATIONAL RESEARCH COUNCIL-RADIO SECTION - OTTAWA CANADA

NAME FIG. I BLOCK DIAGRAM OF MZPI

DWG. NO. MZPI 139 B



MZPI FLIGHT TESTS

N.R.C. FIELD STATION FEBRUARY 3, 1944

Fig 2

EHB	FEB 15 44	
NATIONAL RESEARCH COUNCIL-RADIO SECTION		
MZPI FLIGHT TESTS	MZPI-44[illegible]	

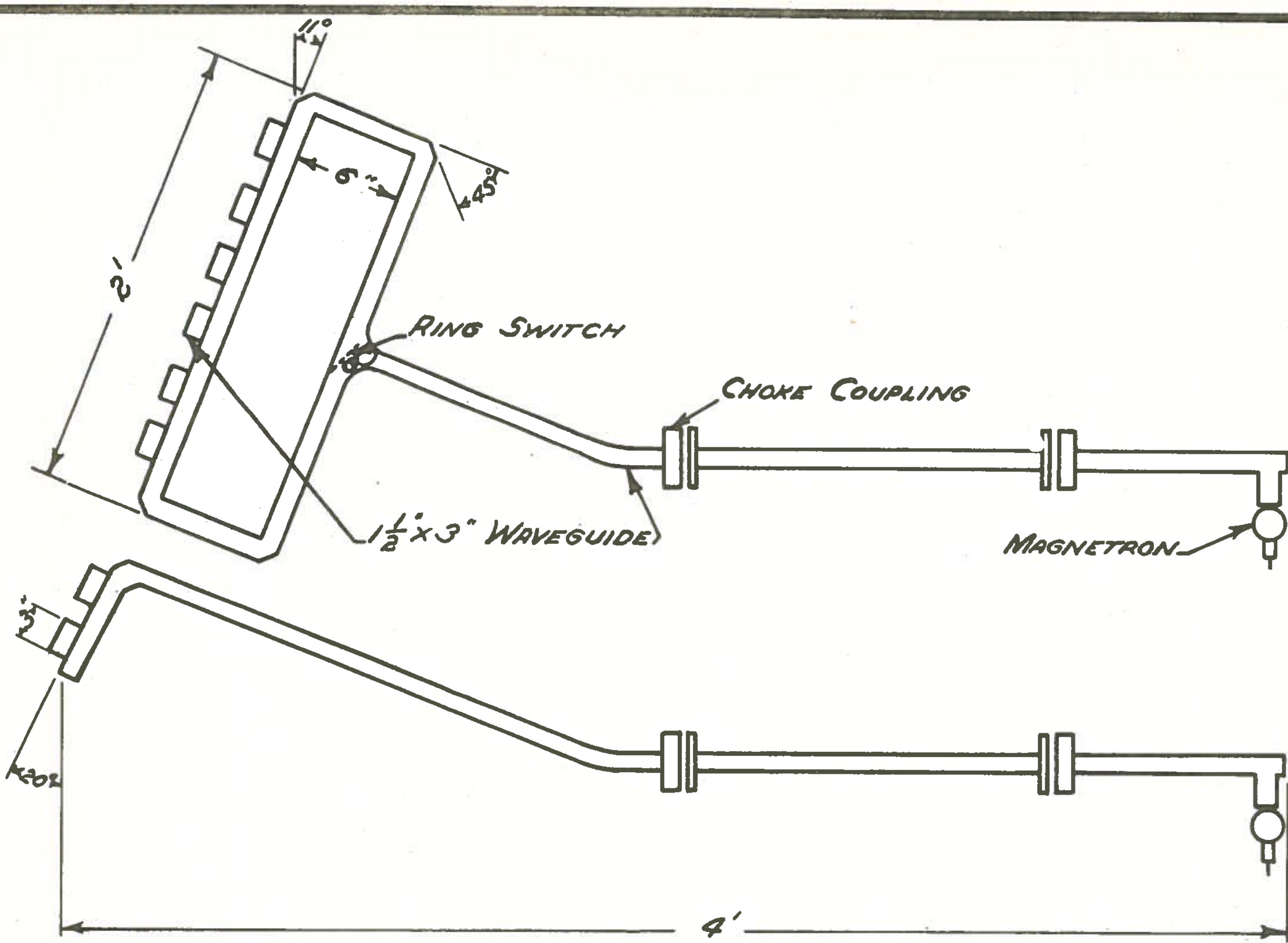


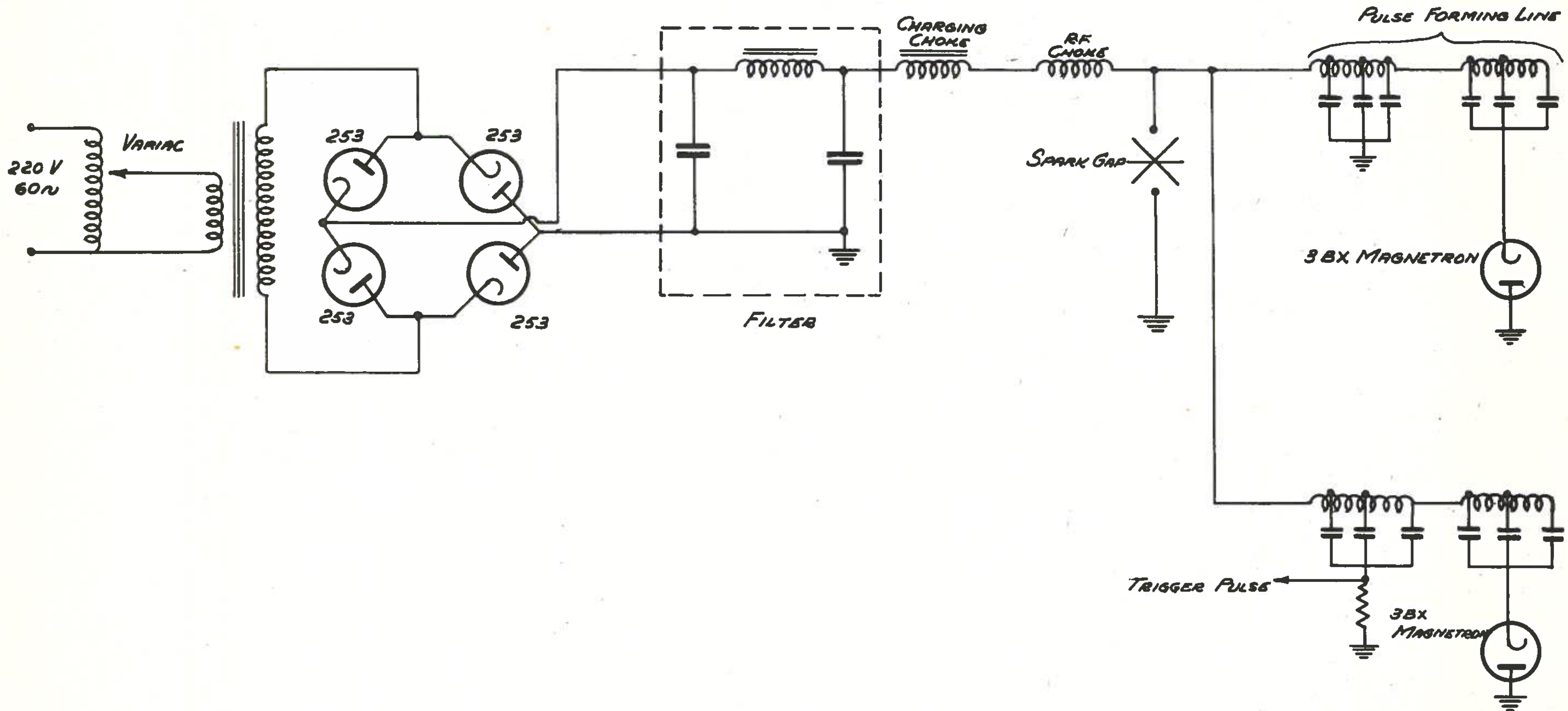
FIG. 3

ITEM	PART No.	QUAN.	MAT'L	DESCRIPTION

DRAWN BY	J. R. D.	DATE	16/5/44	SUPERSEDES	
CHECKED	NCB.	DATE		SCALE	—
ENG. APPROV.	NCB.	DATE		FINISH.	

NATIONAL RESEARCH COUNCIL-RADIO SECTION - OTTAWA CANADA

NAME	DWG. NO.
ANTENNAS	MZPI - 149A

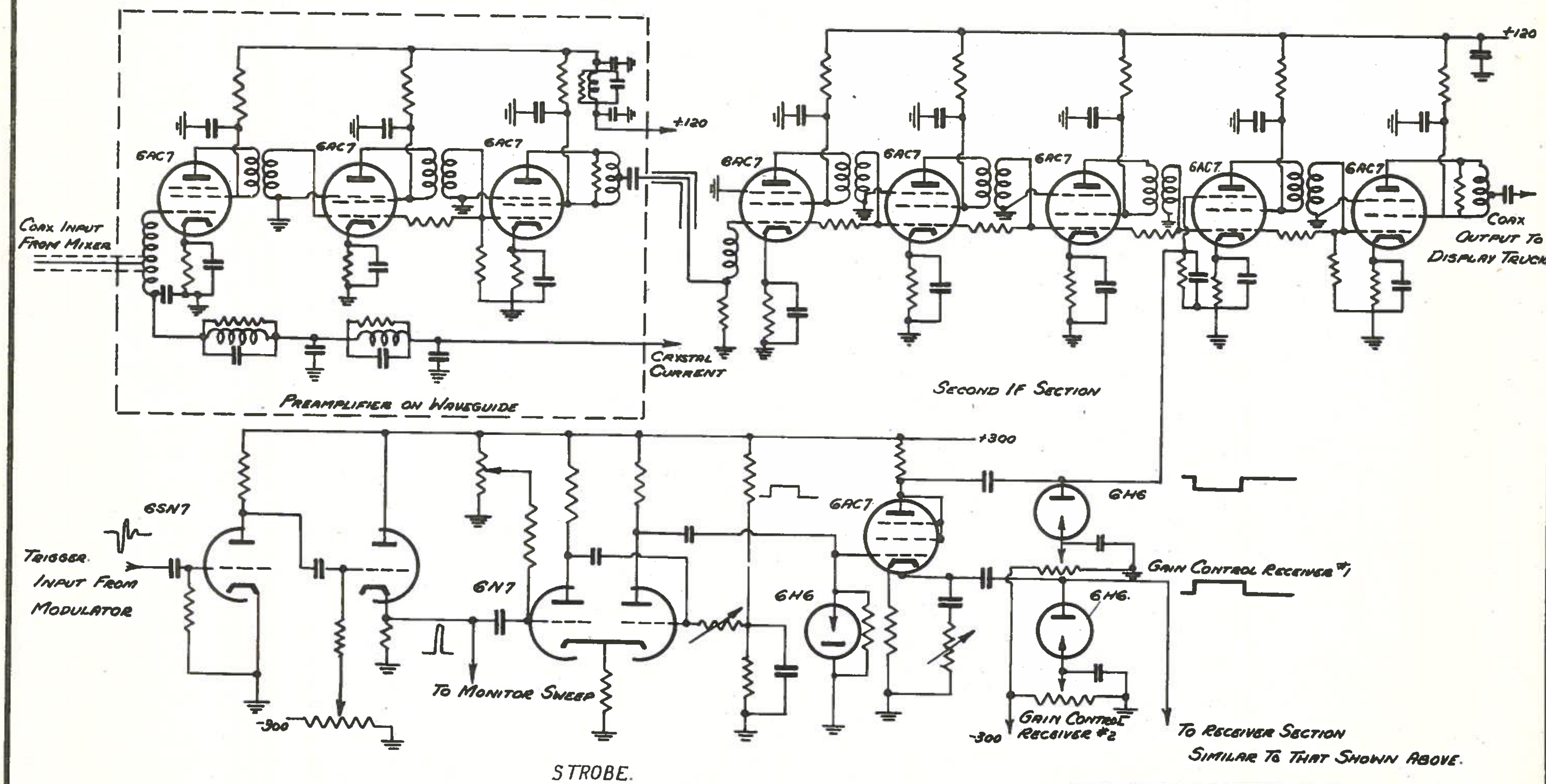


ITEM	PART NO.	QUAN	MAT'L	DESCRIPTION

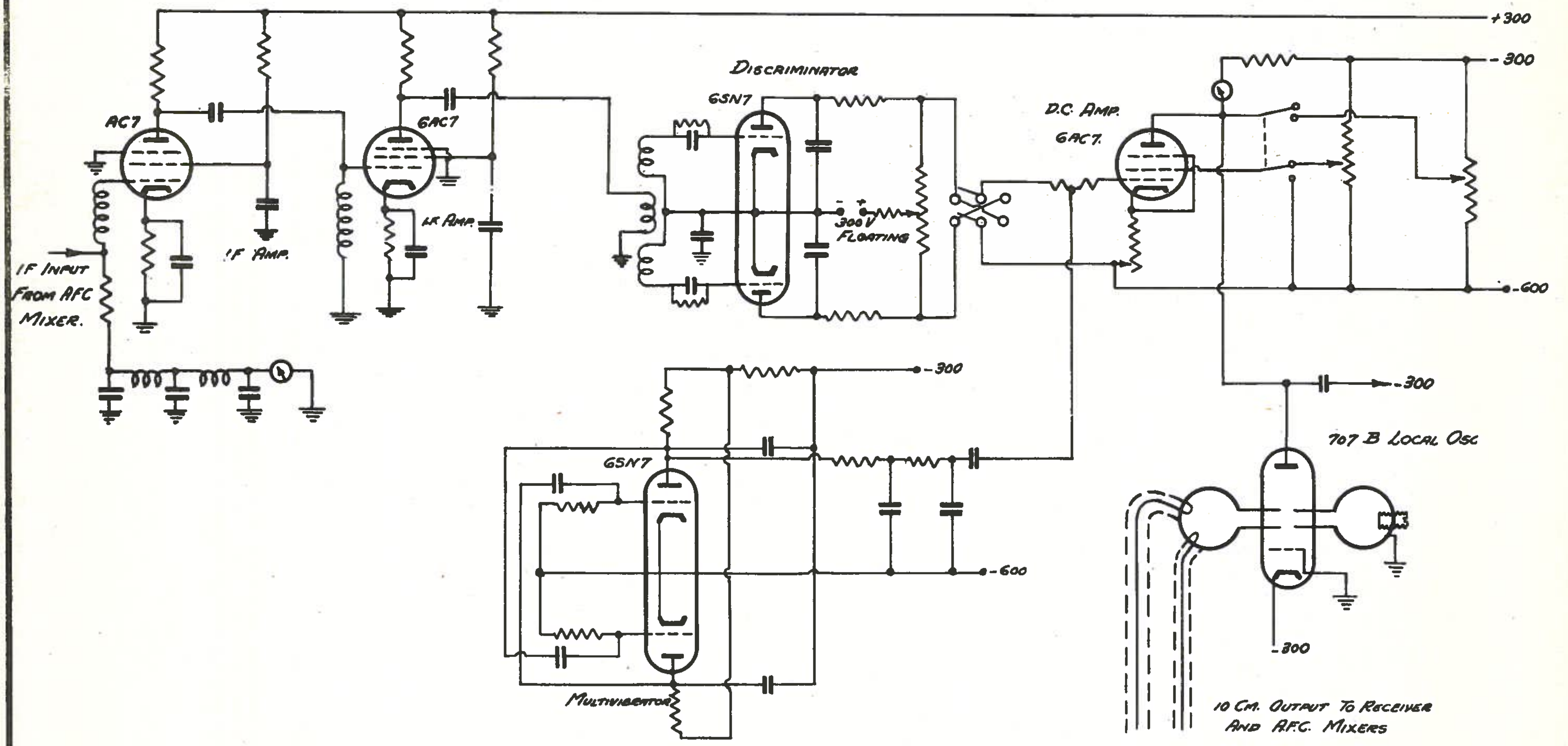
DRAWN BY DC.	DATE 1-5-44	SUPERSEDES	
CHECKED	DATE	SCALE	
ENG. APPROV. KGM	DATE	FINISH.	

NATIONAL RESEARCH COUNCIL-RADIO SECTION - OTTAWA CANADA

NAME	DWG. NO.
MZPI TRANSMITTER. FIG. 4.	MZPI 138B



ITEM	PART NO.	QUAN.	MAT'L	DESCRIPTION
DRAWN BY DC.	DATE 2-5-44.	SUPERSEDES		
CHECKED	DATE	SCALE —		
ENG. APPROV. KGM	DATE	FINISH.		
NATIONAL RESEARCH COUNCIL-RADIO SECTION - OTTAWA CANADA				
NAME RECEIVER I.F. AMPLIFIER and STROBE FIG. 5	DWG. NO. MZPI-140-B.			

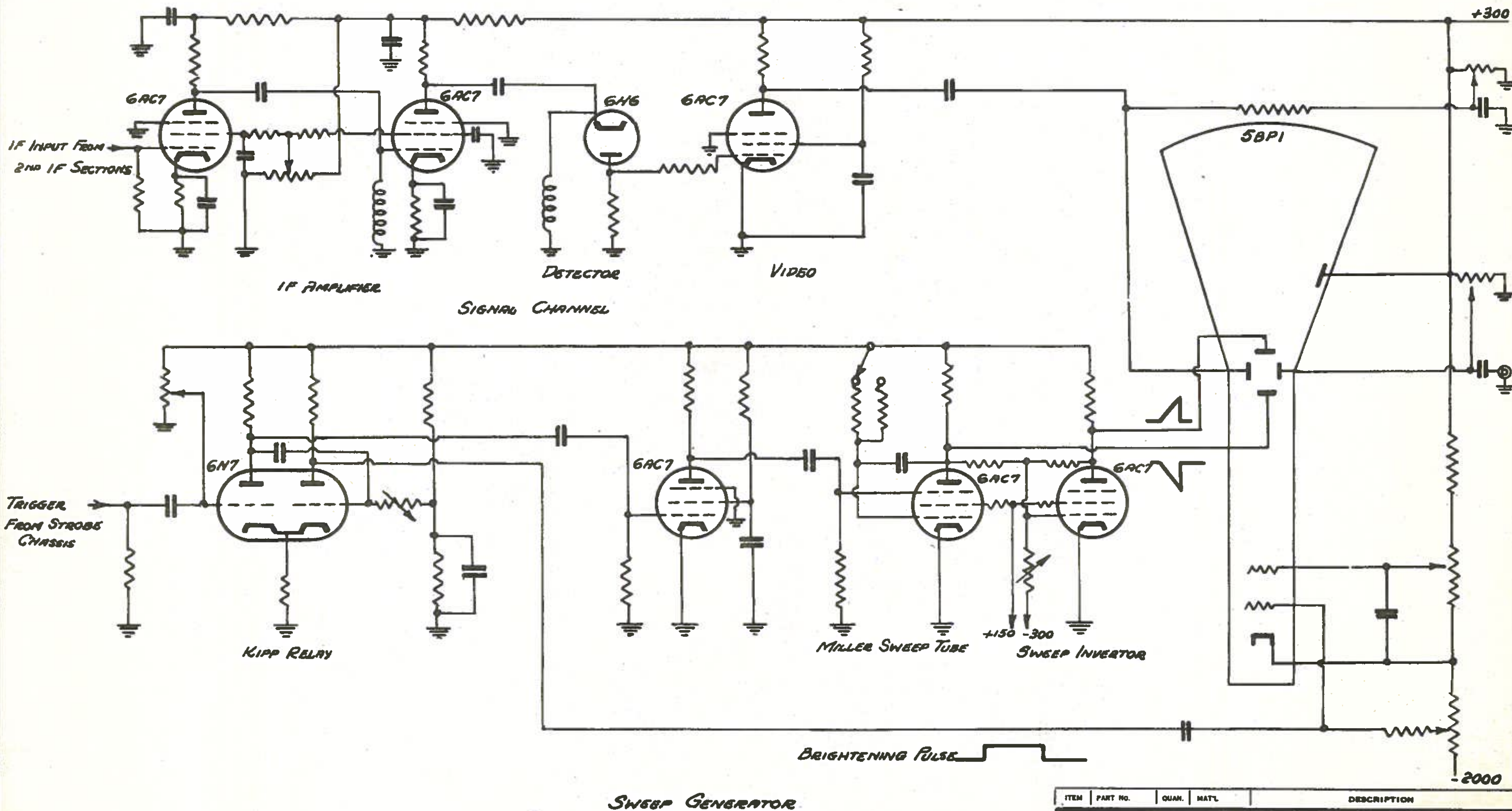


ITEM	PART NO.	QUAN.	MAT'L	DESCRIPTION

DRAWN BY D.C	DATE 8-5-44	SUPERSEDES	
CHECKED	DATE	SCALE —	
ENG. APPROV. K.G.M	DATE	FINISH.	

NATIONAL RESEARCH COUNCIL-RADIO SECTION - OTTAWA CANADA

NAME	DWG. NO.
AFC CIRCUIT. FIG. 6.	HZPI - 141-B

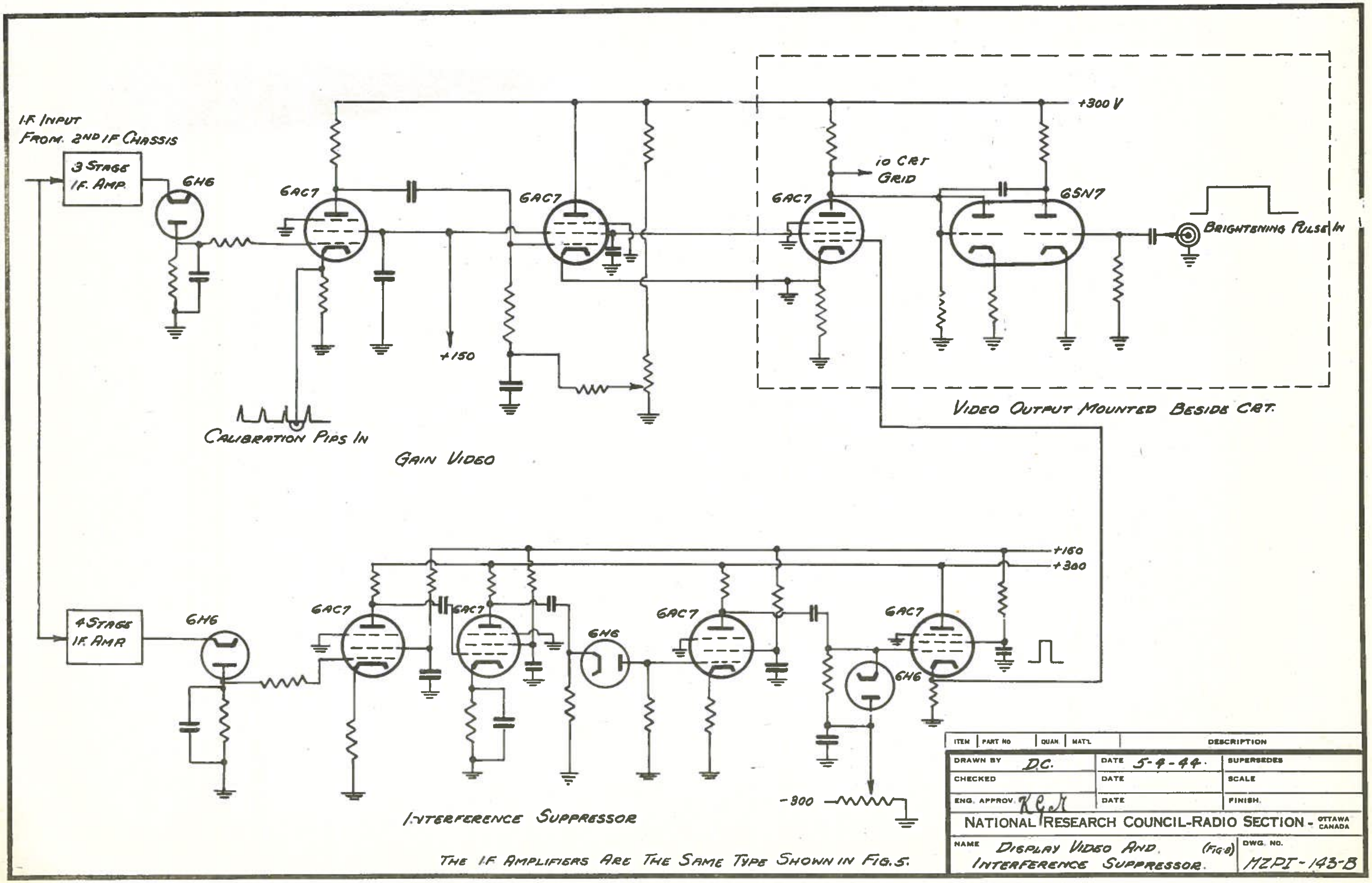


ITEM	PART NO.	QUAN.	MAT'L	DESCRIPTION

DRAWN BY D.C.	DATE 8-6-44.	SUPERSEDES	
CHECKED	DATE	SCALE	
ENG. APPROV. K.G.M.	DATE	FINISH.	

NATIONAL RESEARCH COUNCIL-RADIO SECTION - OTTAWA CANADA

NAME	DWG. NO.
MONITOR RECEIVER FIG. 7.	MZPI-142-B


I.F. INPUT
FROM 2ND I.F. CHASSIS
3 STAGE I.F. AMP.
6H6
6AC7
6AC7
+150
CALIBRATION PIPS IN
GAIN VIDEO
+300 V
TO CRT GRID
6AC7
6SN7
BRIGHTENING PULSE IN
VIDEO OUTPUT MOUNTED BESIDE CRT.
4 STAGE I.F. AMP.
6H6
6AC7
6AC7
6H6
6AC7
6AC7
6H6
+150
+300
-300
INTERFERENCE SUPPRESSOR
THE I.F. AMPLIFIERS ARE THE SAME TYPE SHOWN IN FIG. 5.
ITEM
PART NO
QUAN.
MAT'L
DESCRIPTION
DRAWN BY D.C.
DATE 5-4-44.
SUPERSEDES
CHECKED
DATE
SCALE
ENG. APPROV. K.G.M.
DATE
FINISH.
NATIONAL RESEARCH COUNCIL-RADIO SECTION - OTTAWA CANADA
NAME DISPLAY VIDEO AND INTERFERENCE SUPPRESSOR.
(FIG. 8)
DWG. NO. MZPI-143-B

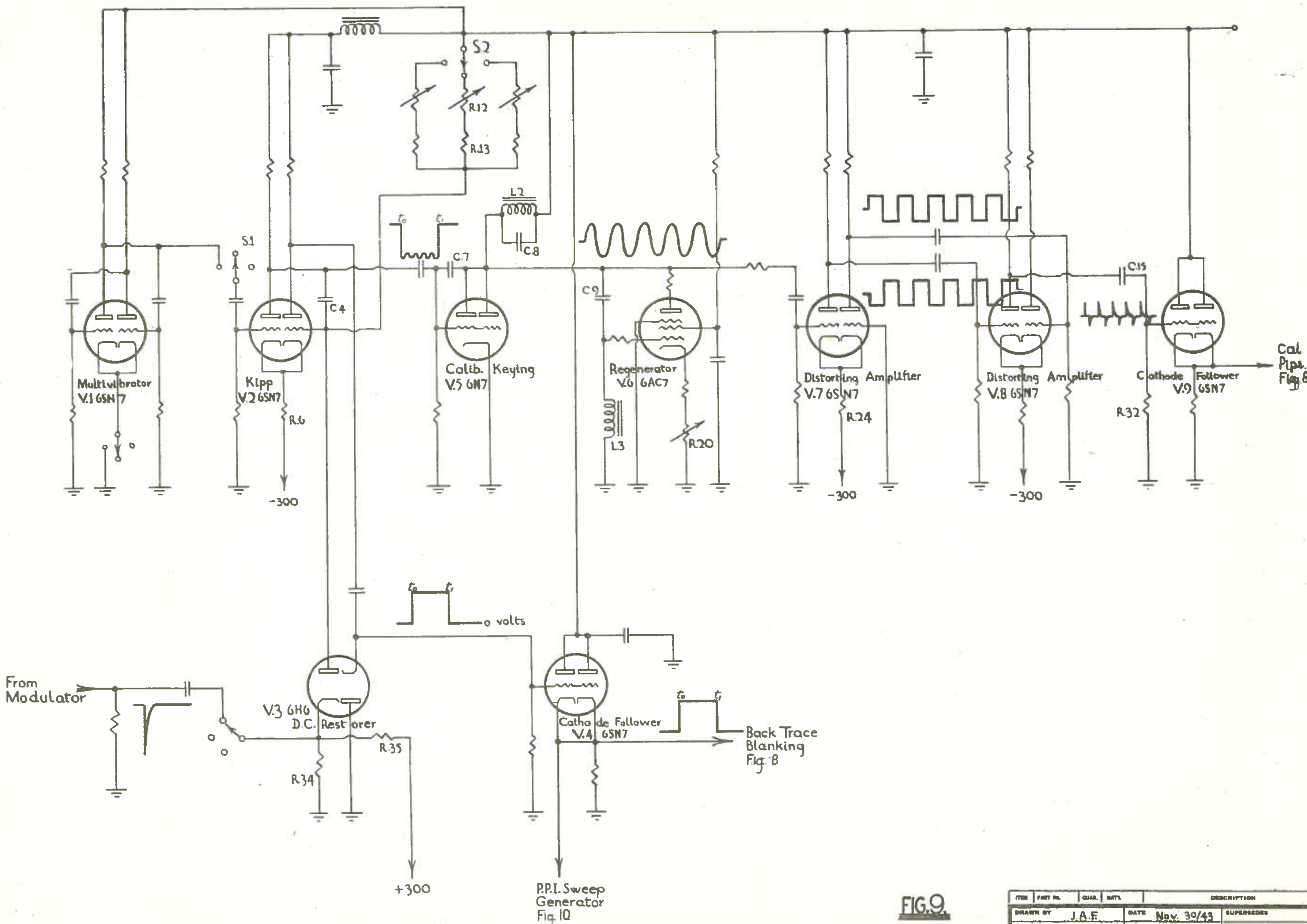


FIG.9.

ITEM | PART No. | QUAN. | MAT'L | DESCRIPTION

DRAWN BY J.A.F. | DATE Nov. 30/43 | SUPERSEDES

CHECKED | DATE | SCALE

ENG. APPROV. | DATE | FINISH.

NATIONAL RESEARCH COUNCIL-RADIO SECTION - OTTAWA CANADA

NAME Cal. Pips. + Back Trace Blanking | DWG. NO. RLX-194C

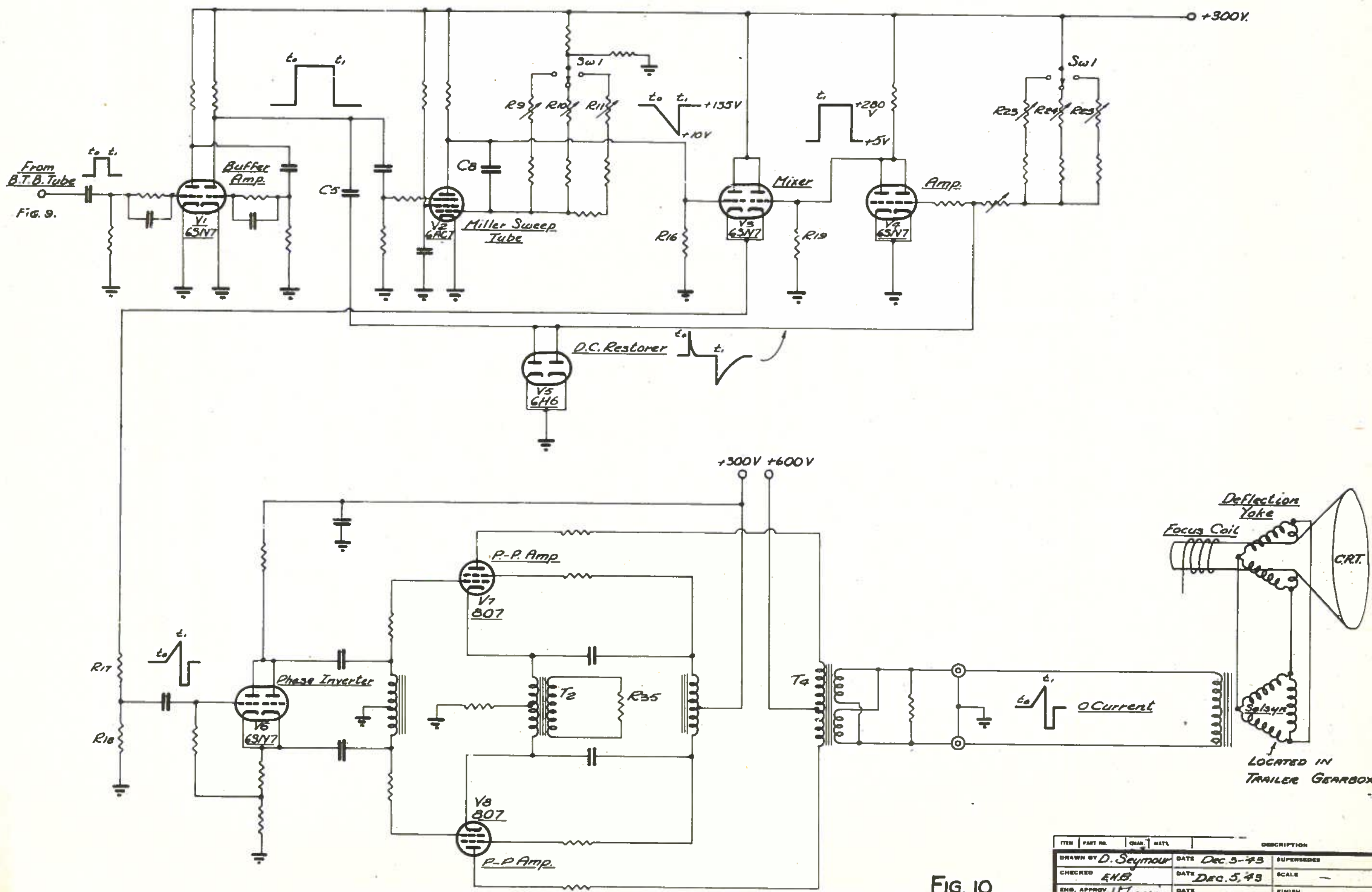
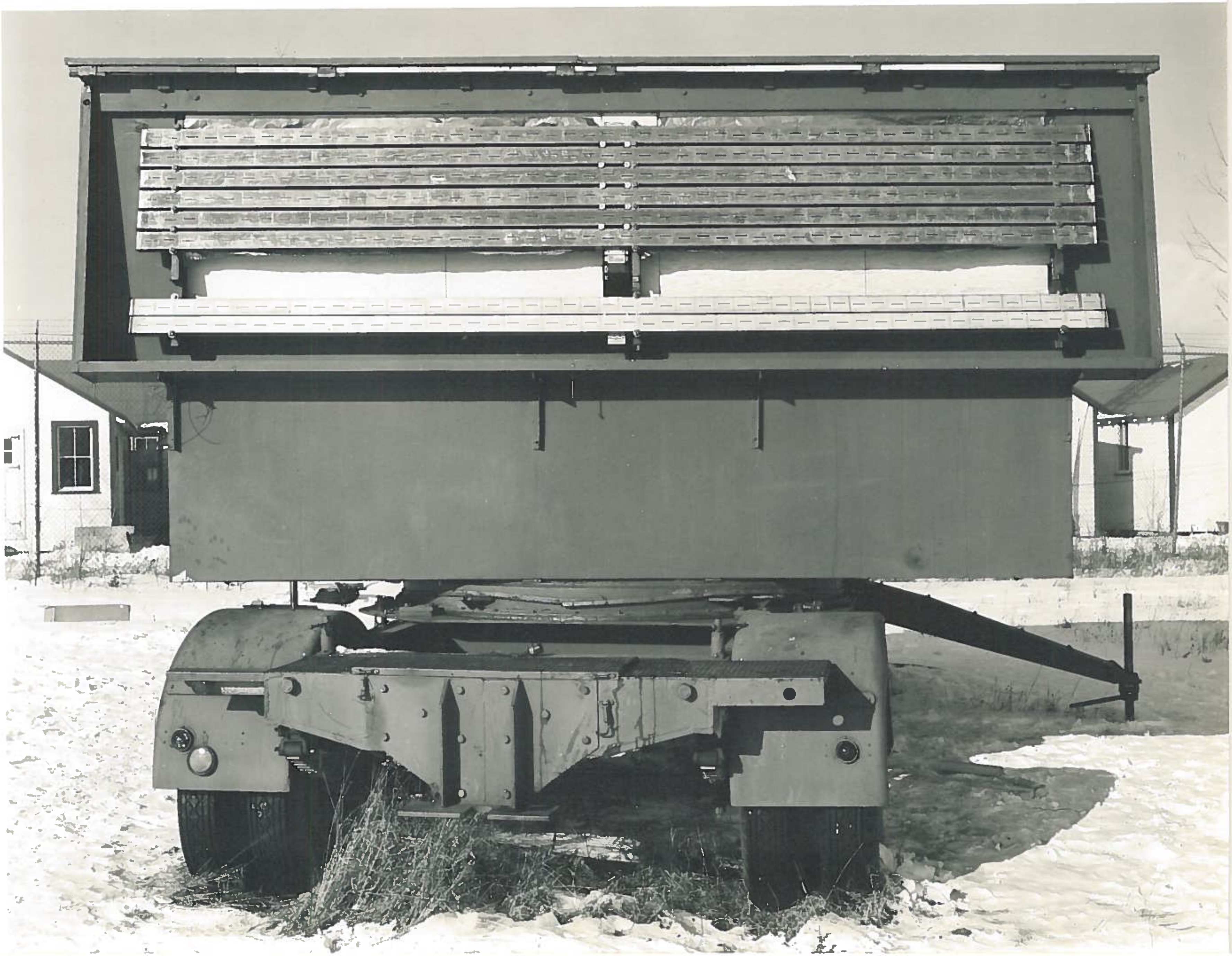


FIG. 10

DRAWN BY D. Seymour	DATE Dec. 3-43
CHECKED E.N.B.	DATE Dec. 5, 43
ENG. APPROV. H.Ferris	DATE

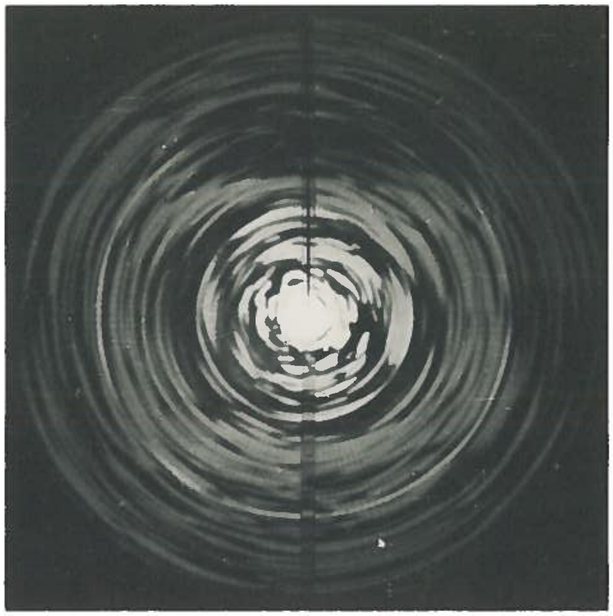
NATIONAL RESEARCH COUNCIL-RADIO SECTION - OTTAWA CANADA

NAME P.P.I. SWEEP SYSTEM — DWG. NO. RLX-196C

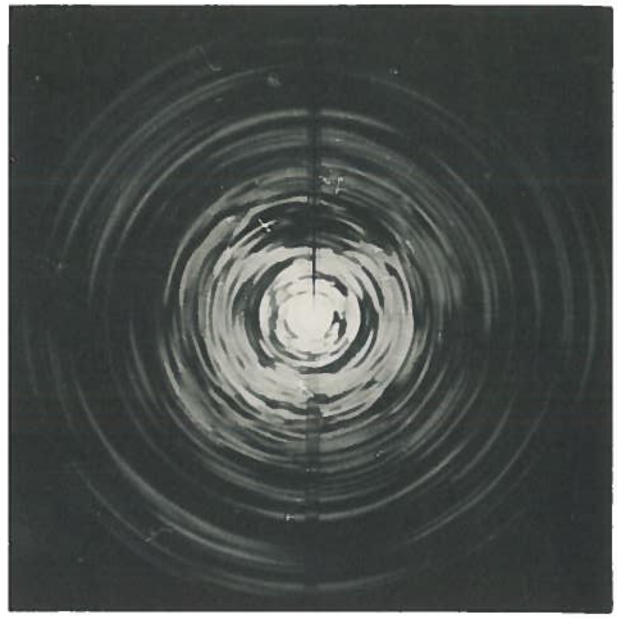


EXPERIMENTAL MZPI TRAILER

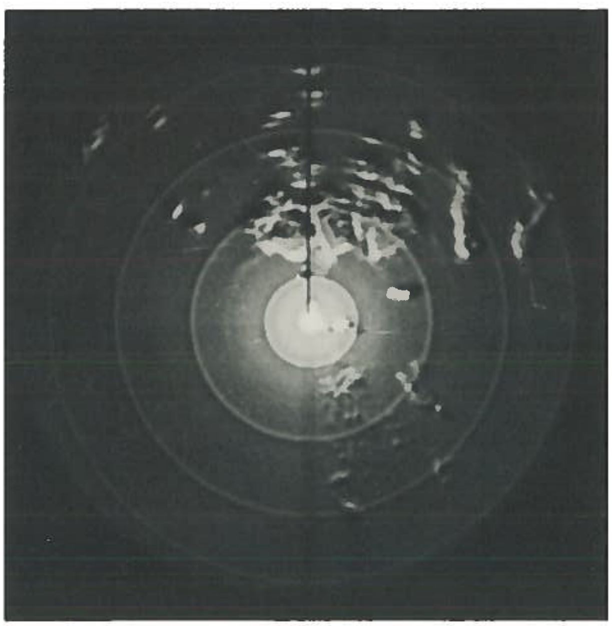
NRC Photo
Fig.11



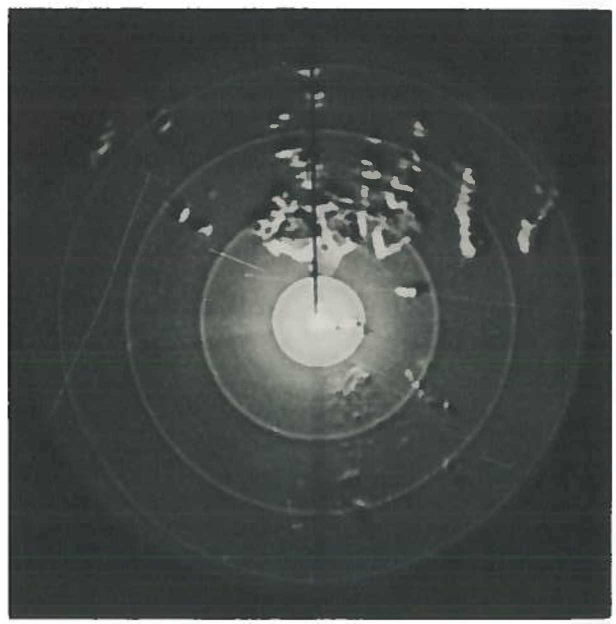
A ZPI AT LITTLE MOUNTAIN
RANGE 30,000 YARDS



B ZPI AT LITTLE MOUNTAIN
RANGE 60,000 YARDS

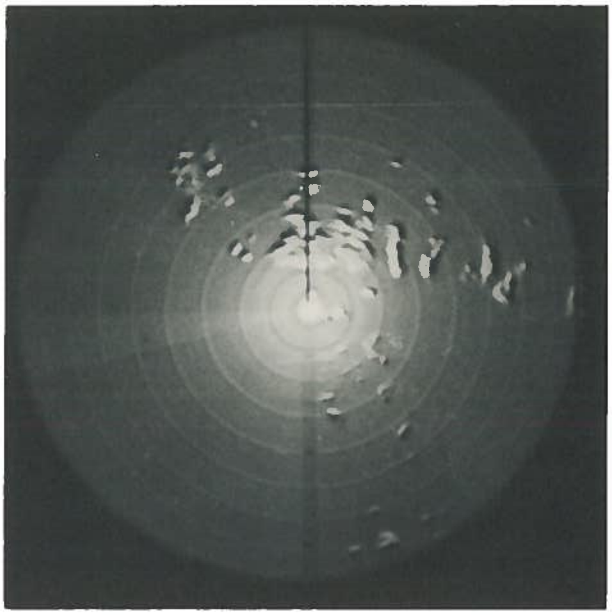


C MZPI AT LITTLE MOUNTAIN
RANGE 40,000 YARDS
LONG RANGE BEAM DOWN

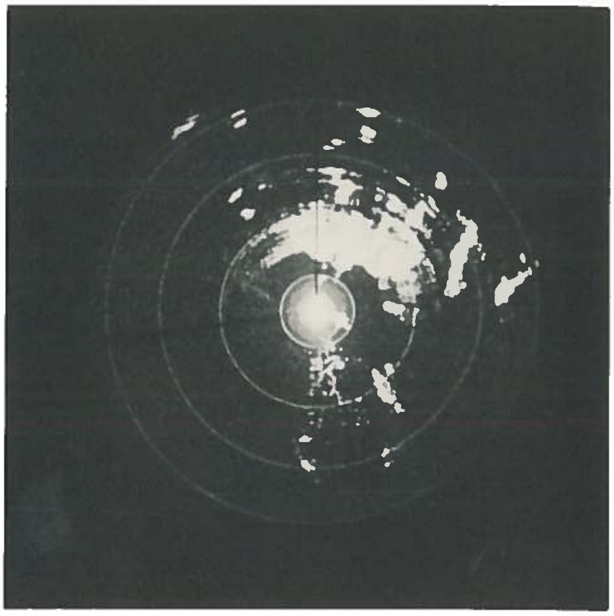


D MZPI AT LITTLE MOUNTAIN
RANGE 40,000 YARDS
LONG RANGE BEAM UP

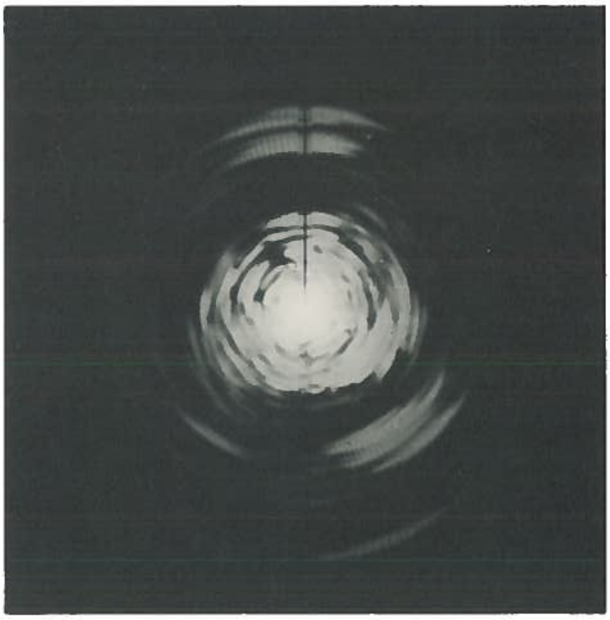
N.R.C. PHOTO
FIG. 12



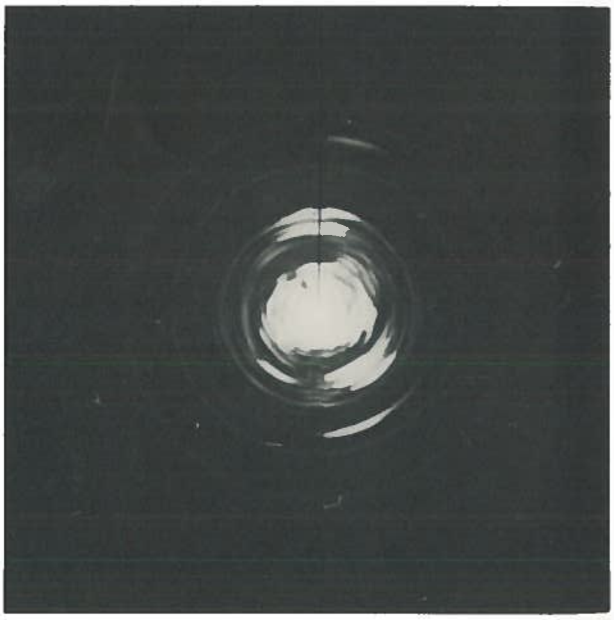
E M Z P I AT LITTLE MOUNTAIN
RANGE 80,000 YARDS
LONG RANGE BEAM DOWN



F M Z P I AT LITTLE MOUNTAIN
RANGE 40,000 YARDS
LONG RANGE BEAM DOWN
RAIN CLOUDS PRESENT AND NO
DIFFERENTIATION IN THE VIDEO

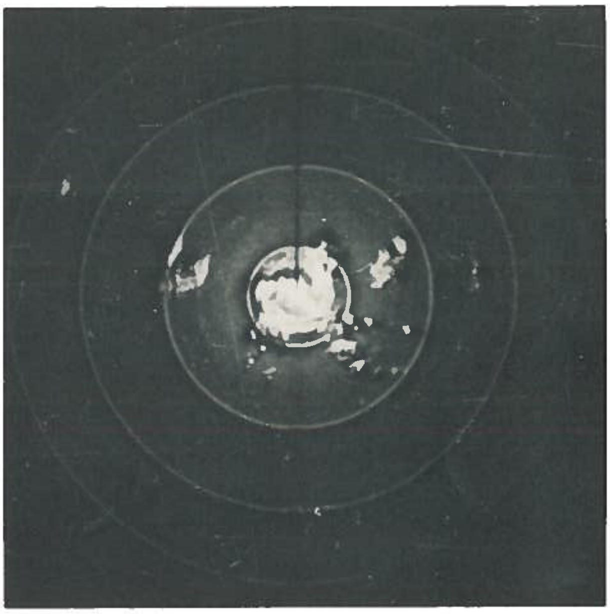


G Z P I AT AMBLESIDE
RANGE 30,000 YARDS
CURSOR BEARING - 293°

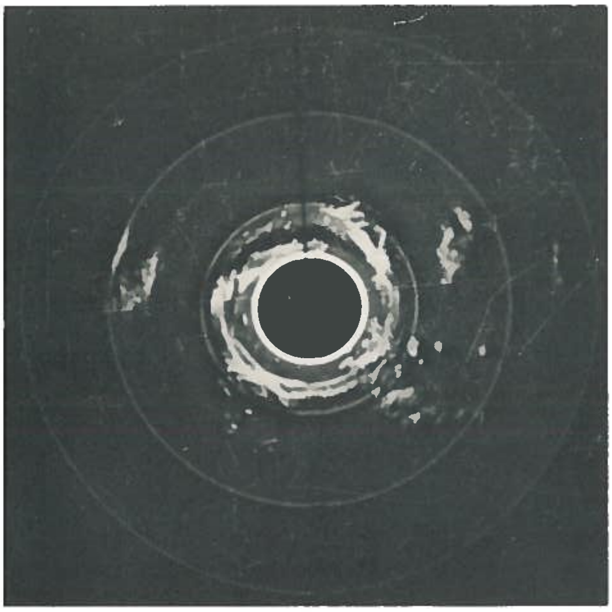


H Z P I AT AMBLESIDE
RANGE 60,000 YARDS
CURSOR BEARING - 293°

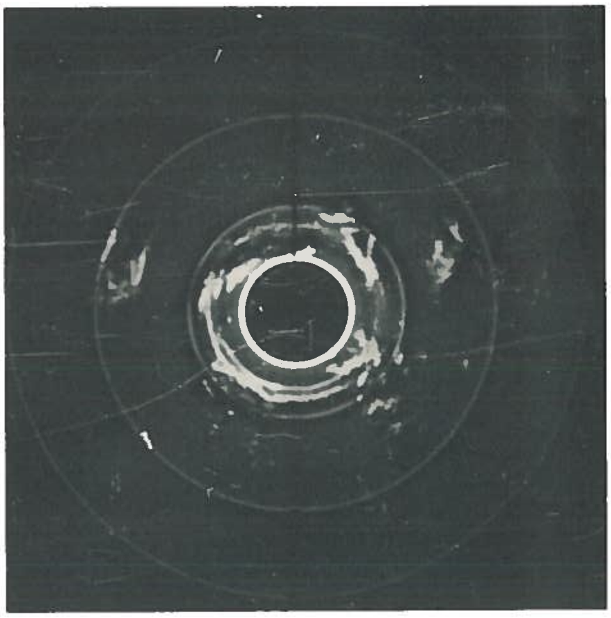
N.R.C. PHOTO
FIG. 12



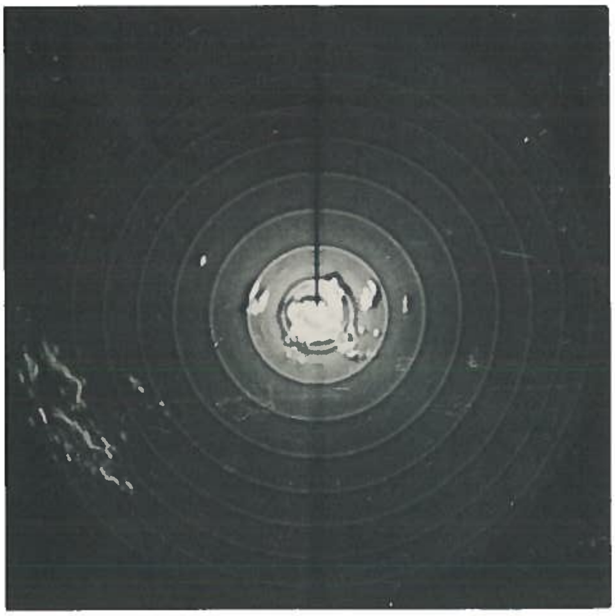
I M Z P I AT AMBLESIDE
RANGE 40,000 YARDS
LONG RANGE BEAM DOWN



J M Z P I AT AMBLESIDE
RANGE 30,000 YARDS
LONG RANGE BEAM DOWN
BEGINNING OF SWEEP DECENTERED

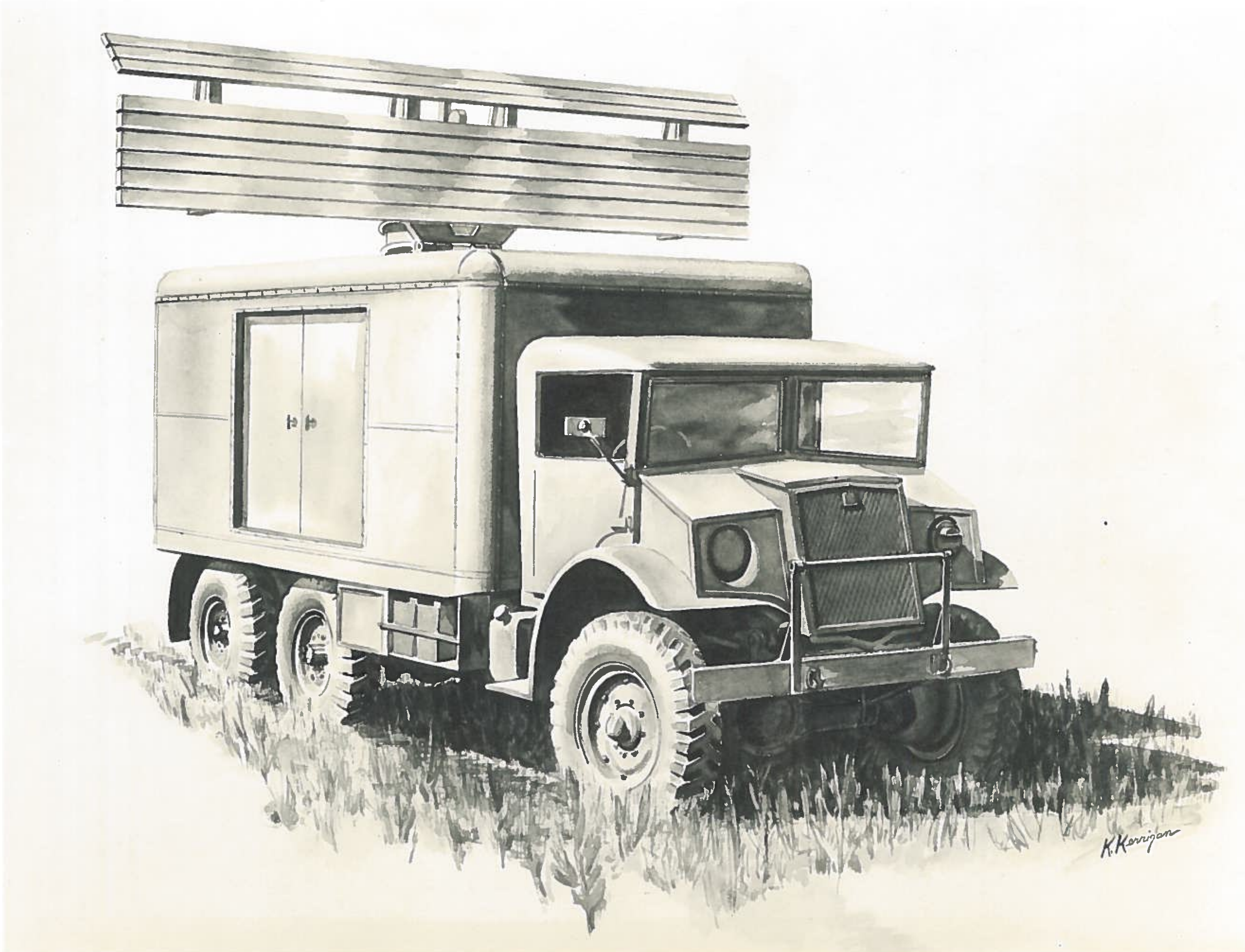


K M Z P I AT AMBLESIDE
RANGE 30,000 YARDS
LONG RANGE BEAM UP
BEGINNING OF SWEEP DECENTERED



L M Z P I AT AMBLESIDE
RANGE 80,000 YARDS
LONG RANGE BEAM DOWN

N.R.C. PHOTO
FIG. 12



GENERAL APPEARANCE
OF PROPOSED MZPI

NRC Photo
Fig.13