NRL REPORT NO. R-3301

FR-3301

A PPI PARAMETER STUDY SYSTEM

★

NAVAL RESEARCH LABORATORY

WASHINGTON, D.C.

[redacted] CONFIDENTIAL UNCLASSIFIED

DECLASSIFIED

NRL REPORT NO. R-3301

UNCLASSIFIED

A PPI PARAMETER STUDY SYSTEM

T. B. Jackson

UNCLASSIFIED

June 17, 1948

UNCLASSIFIED

Approved by:

Mr. J. P. Hagen, Head, RF Research Section
Dr. J. M. Miller, Superintendent, Radio Division I

NAVAL RESEARCH LABORATORY
CAPTAIN H. A. SCHADE, USN, DIRECTOR
WASHINGTON, D.C.

DECLASSIFIED

DECLASSIFIED

CONFIDENTIAL [redacted]

DISTRIBUTION

ONR
Attn: Code N-427 (3)
Attn: Code N-482 (2)

BuShips
Attn: Code 910B for 915 (3)
Attn: Code 910B for 934 (2)

BuOrd
Attn: Code Re4 (3)

CNO
Attn: Code Op-413 (5)
Attn: Code Op-34H8 (1)

BuAer
Attn: Code EL (3)
Attn: Code TD-4 (1)

CO, ONR, Boston (1)

CO, ONR, London (1)

Dir., USNEL (2)

SNLO, USNELO (1)

CO, USNOTS
Attn: Reports Unit (2)

OCSigO
Attn: Ch. Eng. & Tech. Div., SIGTM-S (1)

CO, SCEL
Attn: Director of Engineering (2)

Dir., ESL (1)

CG, AMC, Wright-Patterson Air Force Base
Attn: Eng. Div., Electronics Subdiv., MCREEO-2 (1)
Attn: Aircraft Lab., MCREXA (1)

CO, 4151st Air Force Base Unit, Red Bank
Attn: Ch. Eng. Div., WLENG (1)

CO, 4153rd Air Force Base Unit, Cambridge
Attn: ERCAJ-2 (1)

DECLASSIFIED

CONTENTS

ABSTRACT

This report covers pertinent design details, operational information, and results of tests made to date with an equipment especially designed for the study of PPI parameters. The system includes three PPI repeater units for observation purposes, and was designed for long-term service. The design of the equipment is such that the method of "constant stimulus" may be used, in order to approach the study of radar parameters from a point of view different from that used by the majority of past investigators.

The parameters that can be studied in the present equipment are: antenna beam pattern, antenna rotational speed, azimuth position of signal, range position of signal, transmitted pulse width, receiver noise, signal amplitude, pulse repetition rate, writing speed, receiver gain, and video gain. A complete list of these variables is tabulated in Appendix I.

Tests are made by maintaining constant a given set of radar operating conditions and then making ninety-six observations on each of three PPI scopes as the signal is varied in range and in azimuth over sixteen fixed positions, which appear in a random order for a fixed period of time.

At present, tests are being run to determine the effects of antenna beam width and rotational speed on signal detectability in the presence of simulated sea return noise. The results are limited by the present approach to sea return simulation, but are intended as a starting point to be improved as more detailed information is made available as to the characteristics of sea return.

PROBLEM STATUS

This is an interim report; work on this problem is continuing.

AUTHORIZATION

NRL Problem No. R10-55R

[redacted]

A PPI PARAMETER STUDY SYSTEM

INTRODUCTION

Early in 1947, work was started on the design and construction of an equipment for determining the effects of radar PPI parameters on signal detectability. The purpose in designing such an equipment was twofold. It was concluded, after examining the available reports on PPI parameter studies, that none of the studies had been sufficiently complete or detailed to yield definite design information. A need had also developed for a more or less permanent, flexible system that could be used for specific studies such as the effect of sea return on signal detectability as a function of antenna rotational speed and beam width. The system described in this report was designed so that the operating characteristics of the equipment could be readily varied by an operator to simulate the working conditions of any PPI radar system. Provisions have been made for a parameter variation as large as practicable at this time. Stability of operation under continuous or intermittent operation has been considered of prime importance. Additions and improvements in the system have been provided for.

An attempt was made to monitor all the main units in the system with either an oscilloscope or a meter to aid in setting up and holding constant any set of radar operating conditions. A signal-presentation plan was developed and based on the method of constant stimulus, although the system is flexible enough to be used with the method of limits.

GENERAL DESCRIPTION OF EQUIPMENT

In general, the system is made up of three identical PPI units upon which the test signals are displayed. A fourth PPI and a 'A' scope are used for monitoring purposes. The antenna rotation simulation is provided by a d-c variable-speed motor, which is mechanically coupled to each PPI unit, and a beam simulator device described later, all of which are properly synchronized by geared drives. (Reference should be made to the block diagram, Figure 1, to aid in understanding the interconnections of the various units composing the system.) The antenna rotational speed is varied by regulating the drive-motor speed and selecting the proper drive gears, a number of which are used to cover the wide speed variation of the system.

The indicator scopes are triggered from the synchronizing unit, which supplies an isolated synchronizing pulse, variable in repetition rate, to each scope unit. The delay circuit supplies a variable pulse to the gated mixer unit. The variable pulse may be changed in width or time delay by the operator to simulate changes in the range of a signal or the transmitted pulse width.

 [redacted]

The gated mixer unit is fed from three sources, which include a 30-Mc variable-amplitude source for determining the signal strength; a delayed variable-width pulse, which determines the range position of the target; and an azimuth pulse, which determines the bearing of the target and the apparent beam width of the antenna. All of these factors are variable at the will of the operator. The output of the gated mixer is a 30-Mc signal, which represents the output of a conventional mixer in a pulse radar system. The output of the gated mixer is fed through a fixed attenuator so that the input level to the mixer may be relatively high. The 30-Mc signal is mixed with noise from a diode source before being injected into the 30-Mc amplifier, which, at present, is a conventional i-f amplifier with a 2-Mc band width. The signal is diode-detected and fed to a video amplifier, where it is inverted and used to drive five cathode follower circuits, one for each scope unit. Each display indicator unit has its own variable-gain video amplifier, which is set to give the same amplification for each test indicator.

OPERATION OF EQUIPMENT

The system is set up for operation by making the first adjustments under static or searchlight conditions whereby the system is stopped in its rotation on a signal maximum. The noise source is adjusted to a fixed output level as indicated by monitoring meters. The i-f gain control is then adjusted to give a predetermined output as indicated by a detector monitor and the "A"-scope presentation. The signal is adjusted to its approximate operating level by using the "A"-scope presentation. The rotating mechanism is then put into operation and the speed adjusted to the selected operating value. The signal is then observed on the monitoring PPI unit, and adjustments are made in signal strength according to the type of presentation desired.

The majority of test runs are made by choosing an appropriate signal level and holding that level constant for each day's test until a run has been completed against some parameter variation, such as rotational speed. After the proper signal level for the test has been set, the noise source monitors, the receiver monitors, the signal monitors, and the video monitors are each checked for proper operating level, and adjustments are made, if necessary, to correct for any deviation from standard conditions. A test is run by making ninety-six observations of the signal, which is displayed for an interval of one minute, or some other convenient measure such as a fixed number of trace revolutions. An observer is placed at each of three PPI indicators and asked to locate the signal position and relay his choice to the system operator by pushing an appropriate button on his answer board. His answer is registered on a master control board at the operator's position, where it is recorded, even if incorrect. If an observer has not registered an answer at the end of a set period he is asked to make a guess as to the signal position. The signal is not displayed beyond the selected time interval.

The signal is displayed ninety-six times for each test, so that a total of two hundred and eighty-eight observations are recorded for each parameter variation. Four range positions and four azimuth positions are available, making it possible to have the signal appear six times in each of sixteen positions for one test. The probability of an observer's having guessed a signal correctly and not having had any indication of its presence is taken into consideration in the final score, which is calculated from:

$$\text{"Detectability Factor" (F)} = \frac{\text{Correct Answers} - 6}{90}$$

The signals are displayed one after the other in groups of twelve or sixteen, with a rest interval of five minutes between groups.

This method requires considerable time to gather data, but each datum point is based on a large number of observations, which tends to balance out some irregularities that may occur in a system or in an operator. A number of tests have been repeated with different operators, and a good correlation has been found between the results.

CIRCUIT FUNCTIONS

Synchronizing Unit

Trigger Section - The synchronizing unit is divided into two main parts, the first of which is the trigger section. This section determines the repetition rate of the system and supplies isolated trigger pulses to each of the scopes as well as the delay circuit. The synchronizing rate or repetition rate of the system is determined by a master oscillator built around tube V1, which utilizes its first half as a Wein bridge oscillator and its second half as a feed-back amplifier. (Refer to circuits in Figure 2.) This stage has a sine-wave output that varies in frequency from 30 to 10,000 cycles in eleven steps with switch sections S1 and S2. The 6-w lamp used in the cathode circuit of V1 is used as a regulator.

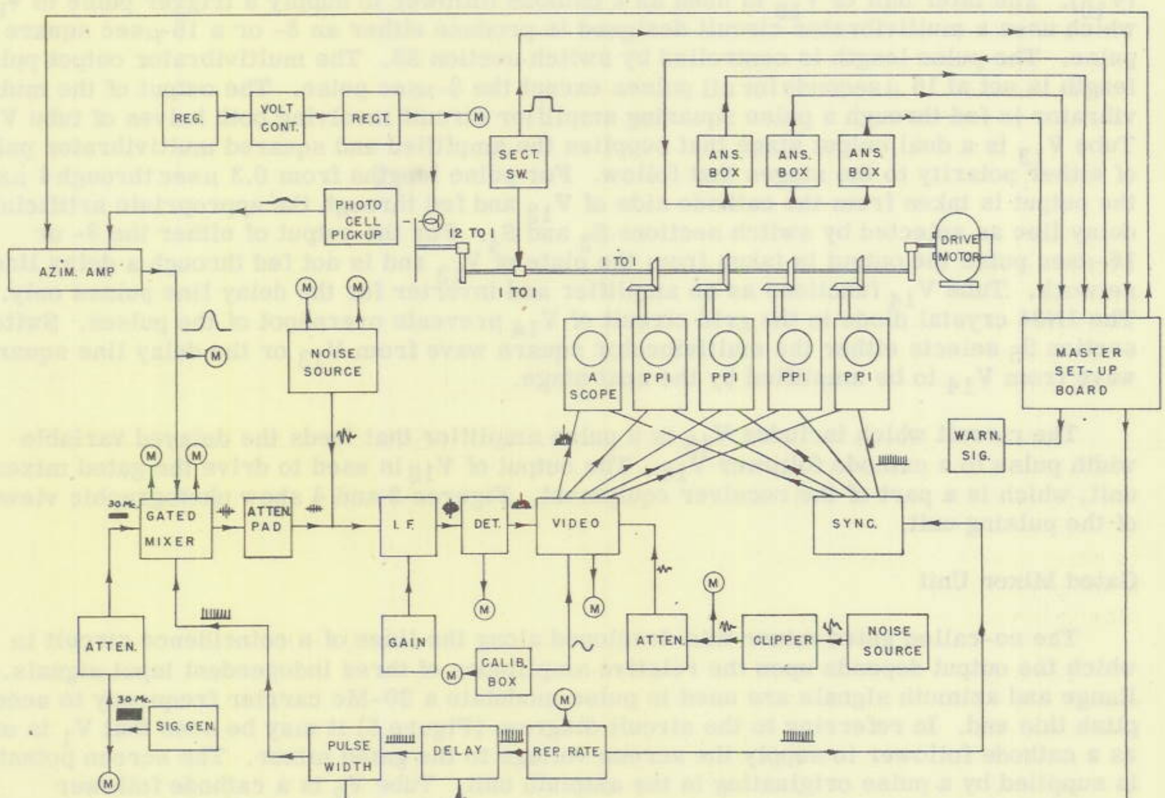


Fig. 1 - Block Diagram of PPI Parameter System

A two-stage squaring amplifier is built around the dual-triode tube V2. The output of the squaring amplifier is a good square wave that retains a sharp rise-time over its entire range of operation. The square wave is utilized as a trigger for the blocking-grid oscillator, which uses the first half of V3. This is a biased blocking-grid oscillator circuit that may be readily synchronized at any rate from 30 to 10,000 cycles. The second half of V3 is used as a cathode follower to transfer the oscillator pulse to the six identical cathode-follower circuits built around V4, V5 and V6. These cathode-follower sections are used to supply a synchronizing pulse to each of the four PPI units, the A scope, and the delay circuit.

Delayed Pulse Section - The second section of the synchronizing unit was designed to supply a variable-width pulse which might be delayed from the trigger pulse any predetermined value from 6 to 4250 μsec. This delayed pulse is used to simulate range variations in a signal. Tube V7 is a pulse amplifier and is utilized to supply a high-amplitude synchronizing pulse to the delay circuit built around both halves of tube V8. Relays A1, A2, A3, and A4 are energized one at a time by pressing the proper range button on the master control panel. The relay contacts select the proper time constants to give the desired delay for the pulse. Switch sections 7, 8, 9, and 10 are used to select the proper delay group to correspond with the sweep range in use on the VE indicators. Delay groups for 4-, 20-, 80-, and 400-mile sweeps are available.

The delayed pulse is fed to a pulse amplifier (V_9) and then to a blocking-grid oscillator (V_{10}). The later half of V_{10} is used as a cathode follower to supply a trigger pulse to V_{11} which uses a multivibrator circuit designed to produce either an 8- or a 16-μsec square pulse. The pulse length is controlled by switch section S6. The multivibrator output pulse length is set at 16 μseconds for all pulses except the 8-μsec pulse. The output of the multivibrator is fed through a pulse squaring amplifier circuit involving both halves of tube V_{12}. Tube V_{13} is a dual output stage that supplies the amplified and squared multivibrator pulse of either polarity to the stages that follow. For pulse lengths from 0.3 μsec through 4 μsec, the output is taken from the cathode side of V_{13} and fed through the appropriate artificial-delay line as selected by switch sections S_3 and S_4. For the output of either the 8- or 16-μsec pulse the output is taken from the plate of V_{13} and is not fed through a delay line network. Tube V_{14} functions as an amplifier and inverter for the delay line pulses only. The 1N34 crystal diode in the grid circuit of V_{14} prevents overshoot of the pulses. Switch section S_5 selects either the multivibrator square wave from V_{13} or the delay line square wave from V_{14} to be amplified by the next stage.

The circuit which includes V_{15} is a pulse amplifier that feeds the delayed variable width pulse to a cathode follower V_{16}. The output of V_{16} is used to drive the gated mixer unit, which is a part of the receiver equipment. Figures 3 and 4 show photographic views of the pulsing unit.

Gated Mixer Unit

The so-called gated mixer was developed along the lines of a coincidence circuit in which the output depends upon the relative amplitudes of three independent input signals. Range and azimuth signals are used to pulse modulate a 30-Mc carrier frequency to accomplish this end. In referring to the circuit diagram (Figure 5) it may be seen that V_1 is used as a cathode follower to supply the screen voltage to the gated mixer. The screen potential is supplied by a pulse originating in the azimuth unit. Tube V_2 is a cathode follower supplying the range pulse to the control grid of the gated tube V_3. A 30-Mc tuned circuit is located in the cathode side of the gated tube and is used as the gated mixer output. V3 is normally biased to cut-off by means of a regulated negative voltage, the amplitude of which is controlled by a potentiometer labeled "Bias Set". The screen of V_3 is normally held slightly negative by bleeding a portion of the regulated negative voltage to the screen so as to overcome the residual positive voltage on the cathode of V_1, which is tied through a resistance to the gated mixer screen. The bleeder is proportioned so that a negative two volts appears at grid number two when no azimuth pulse is present.

[redacted]

DECLASSIFIED

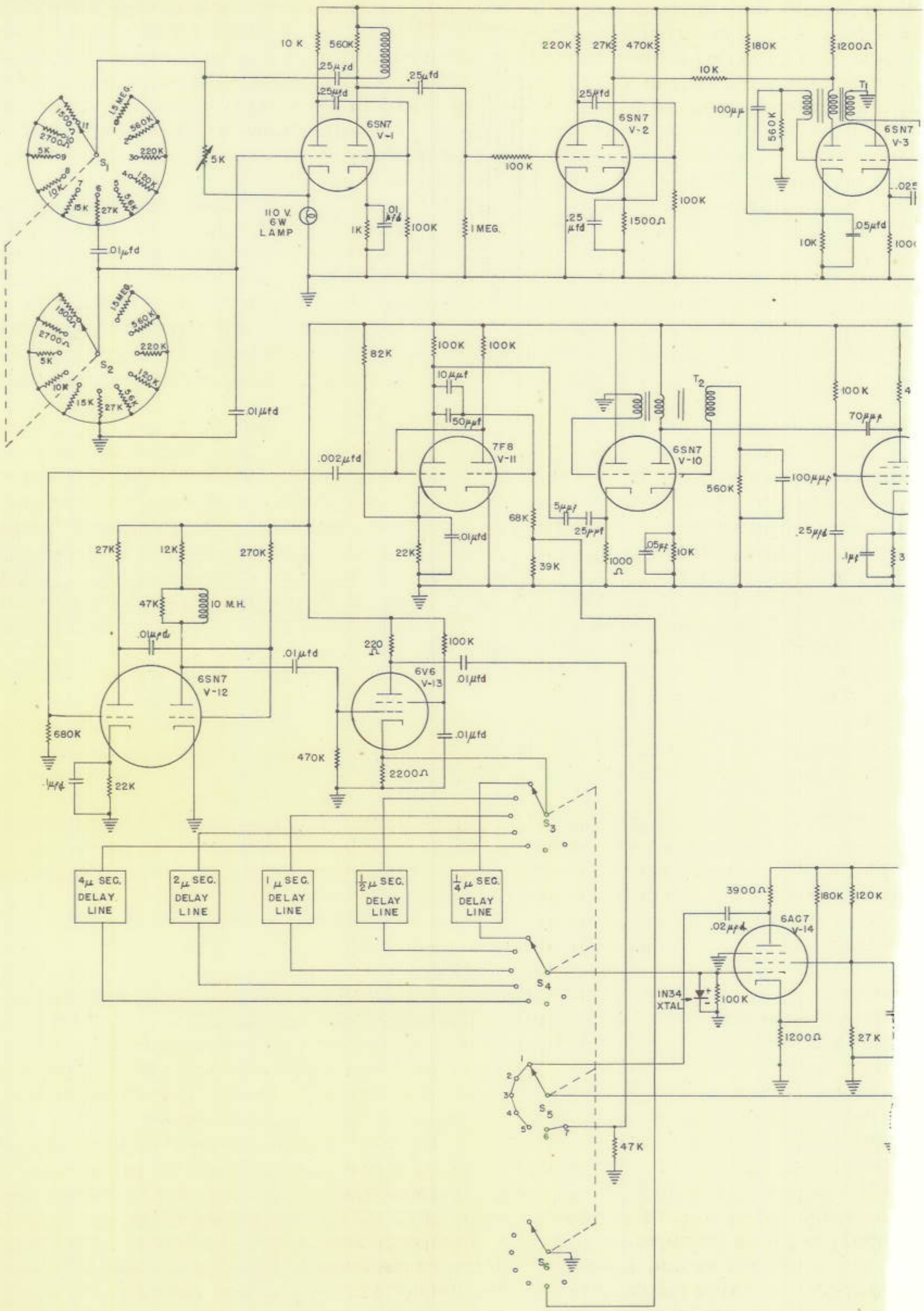
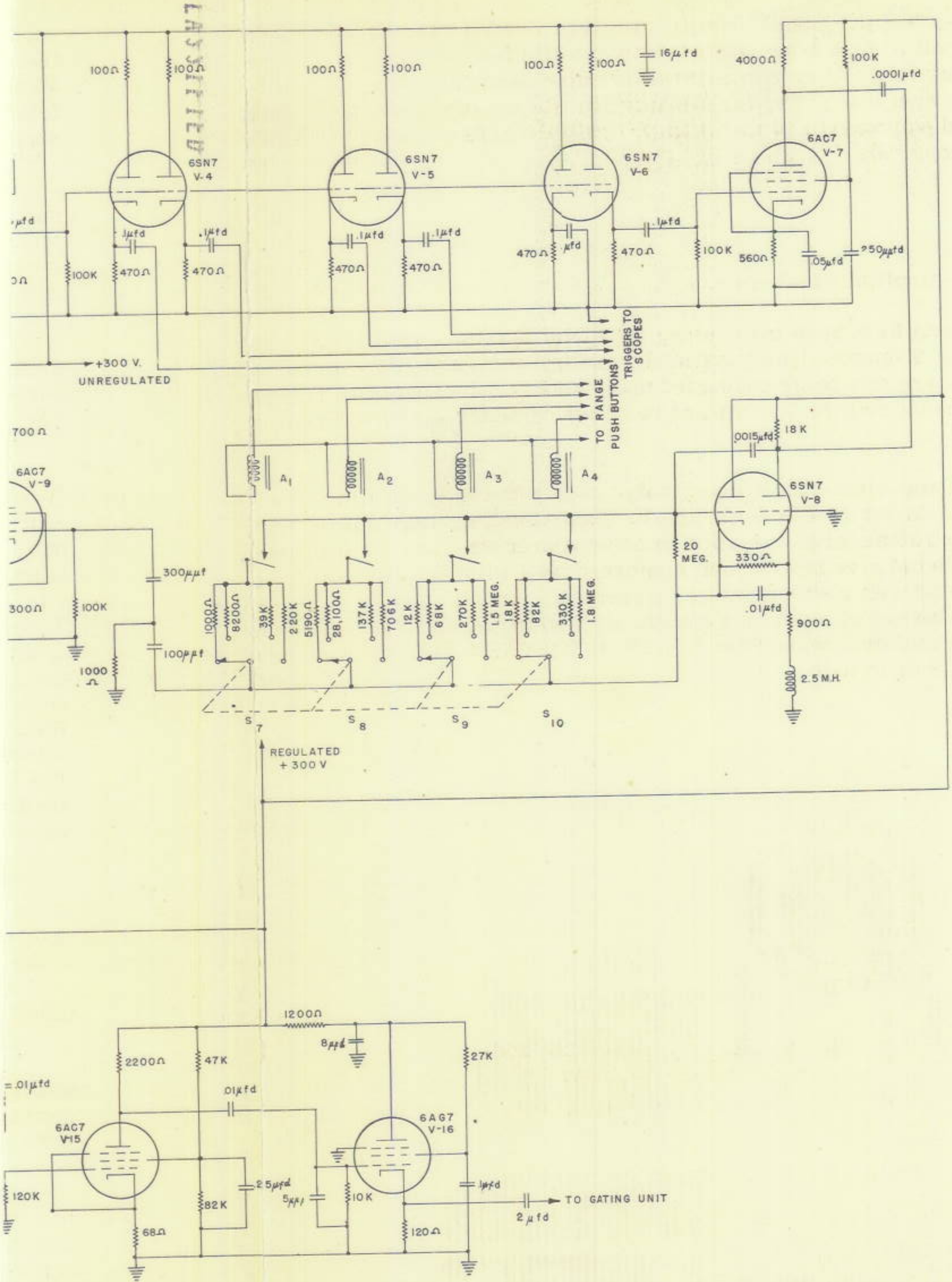


Fig. 2 - Trigger a

DECLASSIFIED



nd Delay-Pulse Unit

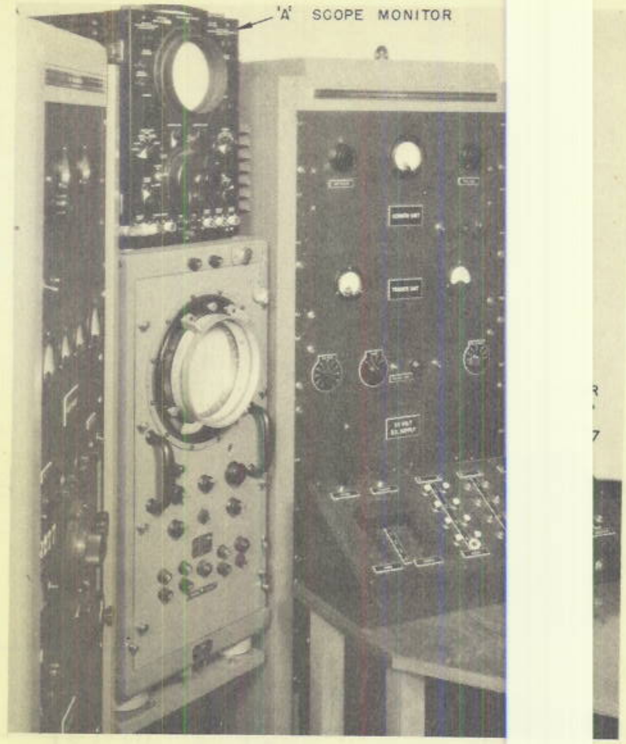


Fig. 3 - Front View of Operator's Equipment Showing Master Set-Up Board

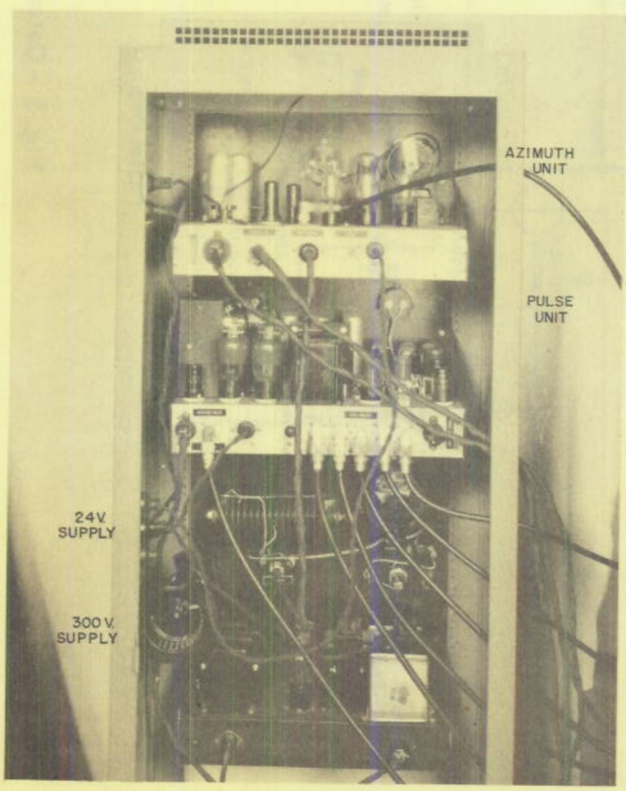


Fig. 4 - Rear View of Pulse Synchronizing Units

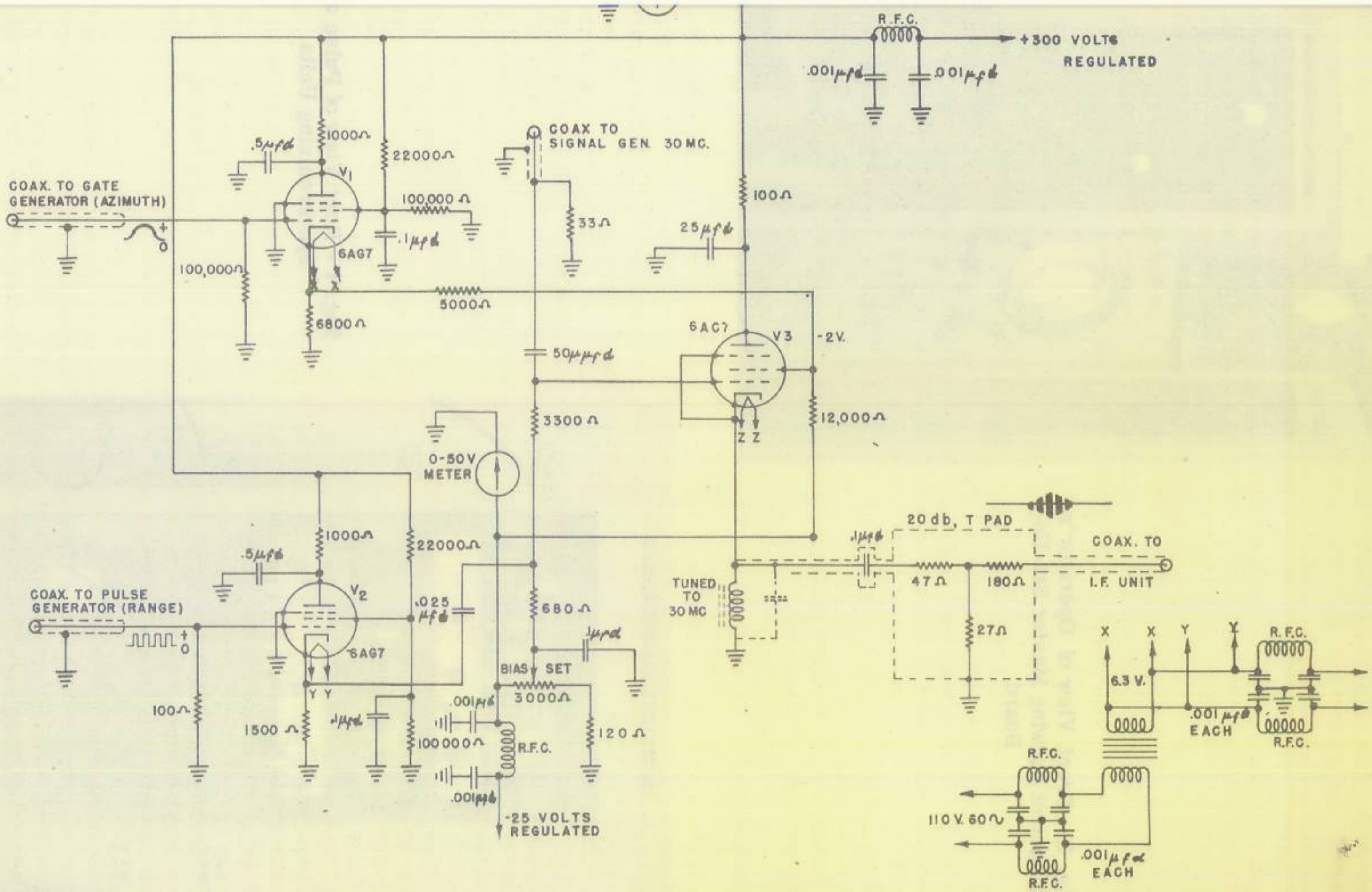


Fig. 5 - Gated Mixer Unit

due [redacted]

[redacted]

A 30-Mc c-w signal is fed to the control grid of V_3. As positive delayed pulse ge) are fed to the low end of the control grid circuit, they place the gated tube in a con condition in its linear region, providing a pulse (azimuth) is also applied to the scr Both pulses are required to have V_3 conduct. The output amplitude of the gated tul nds upon the amplitude of the delayed pulse, which remains a constant; the amplitude of azimuth pulse, the peak of which is kept constant; and the amplitude of the 30-Mc s source, which is variable. The attenuators in the 30-Mc generator are used as the amplitude control for the signal. The output of the mixer is attenuated 20 db befor applied to the i-f amplifier. This allows the mixer to be operated at relatively higl signal levels, thereby reducing the effects of r-f leakage from the 30-Mc source a r- ference from other sources.

Receiver Noise Source

A separate noise source is included in the system to supplant the noise usually ginating in the mixer and first i-f stages. The noise is generated in a 708-A tube a diode. Special precautions have been taken to completely shield and isolate the n source. A multiple section filter is built into each supply lead for the diode, and th is enclosed in a grounded metal case. The diode is operated temperature limited, filament and plate supplies are regulated dc. The noise-source spectrum was chec against the noise of the i-f strip and found to be essentially the same, as determine noise analyzer. The noise source is operated at a fixed level for all except a few s tests for checking purposes.

Azimuth Unit

<u>Azimuth Selector</u> - The azimuth unit is composed of two main parts, the beam- n simulator and the azimuth selector. The latter is an electro-mechanical device th vs the operator to select one of four 20° sectors within which the signals may appear. sectors are 90° apart. The beam simulator is driven twelve times as fast as the se cam, and is so geared that the peak of any azimuth pulse will always appear at the of the selected 20° sector. The sector cam actuates four microswitches placed 90° in the plane of the cam rotation. The azimuth-selector switch closes the circuit fo one microswitch for a given setting and allows the azimuth pulse to be present for one azimuth position at a time.

<u>Beam Pattern Simulator</u> - The beam pattern simulator is composed essentially regulated variable light source, a disc-type light interrupter, a gated phototube and associated electronic circuits. The circuit diagram for the device is shown on Fig The exciter lamp is fed from a rectifier and filter unit to reduce the 120-cycle inte modulation to a negligible value. The light is concentrated on the phototube with a ser lens assembly and is passed through a slit-type aperture before being picked up by phototube. The light-interrupting disc is placed between the phototube and the slit e. The light is cut off except during the pulse time by the light-interrupter disc or pac which is slotted to pass light as a function of its angular position. It is so shaped tl phototube output varies in the same manner that radiation would vary with the angul i- tion of a conventional antenna system using a parabolic reflector. A separate disc quired for each beam pattern desired.

The phototube excitation voltage is supplied through V_2, which normally has its de negative with respect to ground. When the sector switch is closed, a positive volta placed on the grid of V_2, which pulls the cathode of V_2 and the phototube anode posi with respect to ground. This places the phototube in a conducting condition. The cu in the circuit will be a function of the amount of light reaching the phototube. The ou

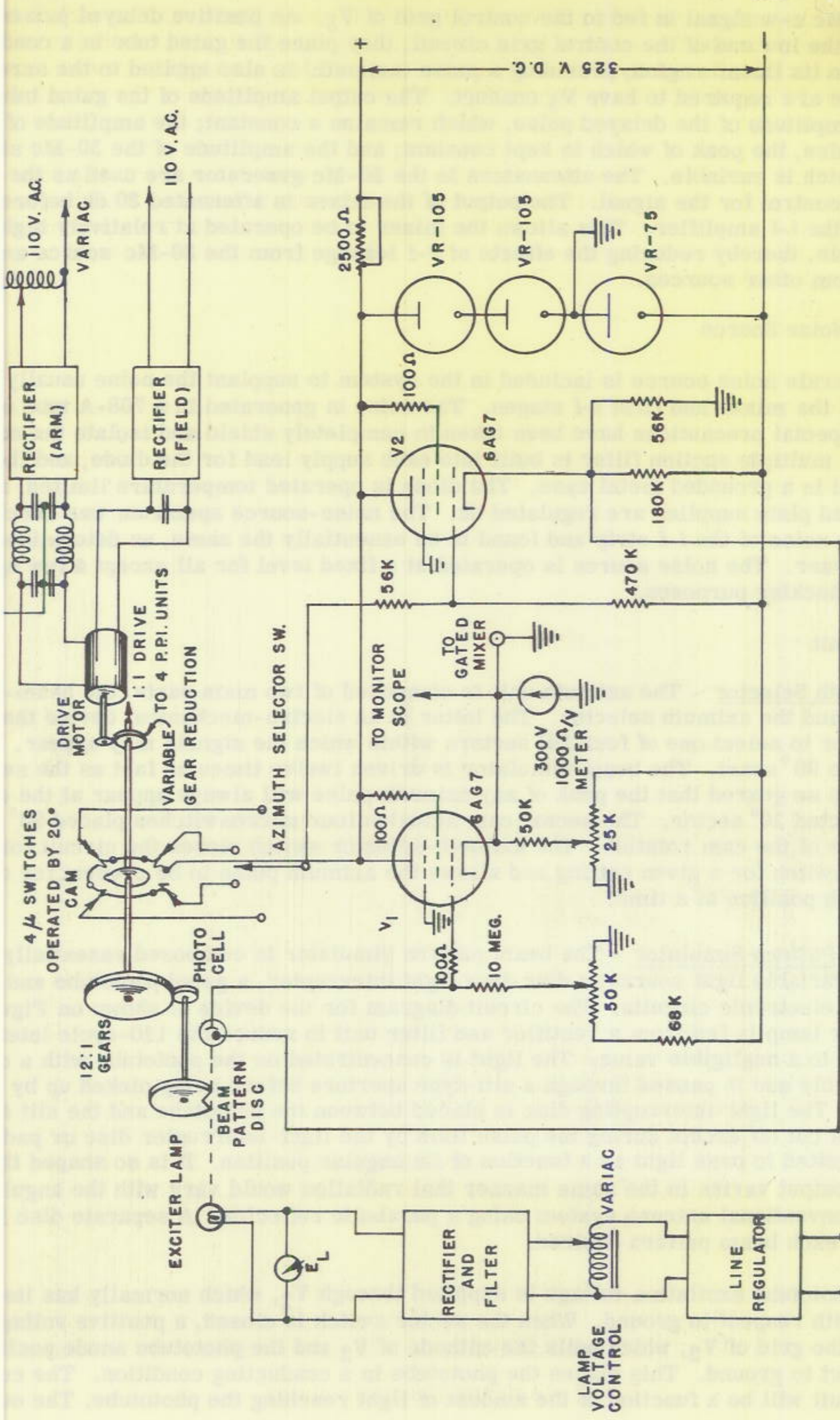


Fig. 6 - Azimuth Unit

of the phototube is fed to the grid of V_1, a cathode follower. The output as picked (
cathode of V_1 is directly coupled to the azimuth pulse cathode follower in the gated r
circuit. Direct coupling of the azimuth pulse is required throughout to prevent los e
low-frequency components of the pulse, especially under conditions of low rotation d
and wide beamwidths.

The entire system is driven by a variable-speed, geared d-c motor. The four
units and the azimuth unit are driven from five output shafts located on a large gea
All units are driven at the same speed. Rotational speeds from 1 to 200 rpm are a e
by changing the speed of the motor and selecting proper reduction gears which are
changed. Figure 7 presents a photographic view of the drive unit, azimuth selector
beam simulator.

Video Unit

The video unit was designed for use with either a positive or a negative input s
This feature was included so that a number of different i-f strips could be used wit
system if different amplifier characteristics were desired. The unit is composed (

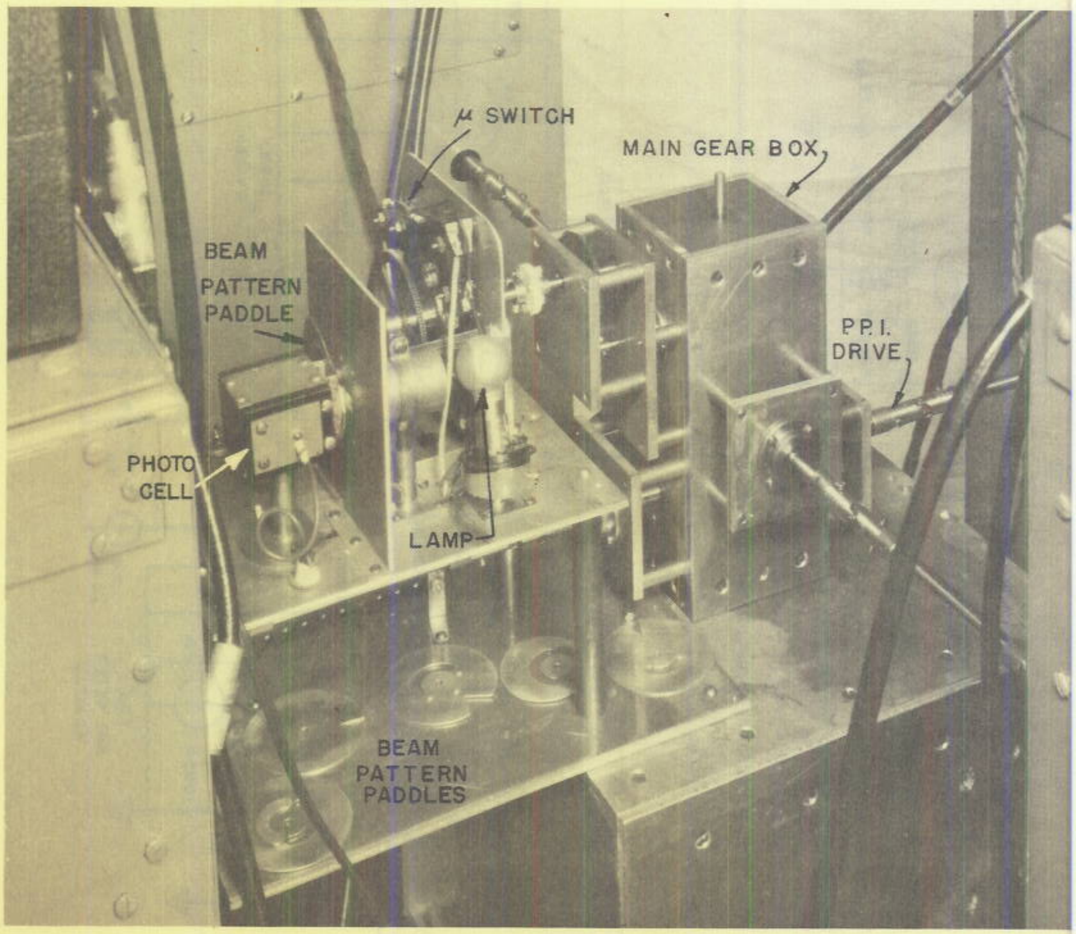


Fig. 7 - Antenna Beam Simulator

DECLASSIFIED

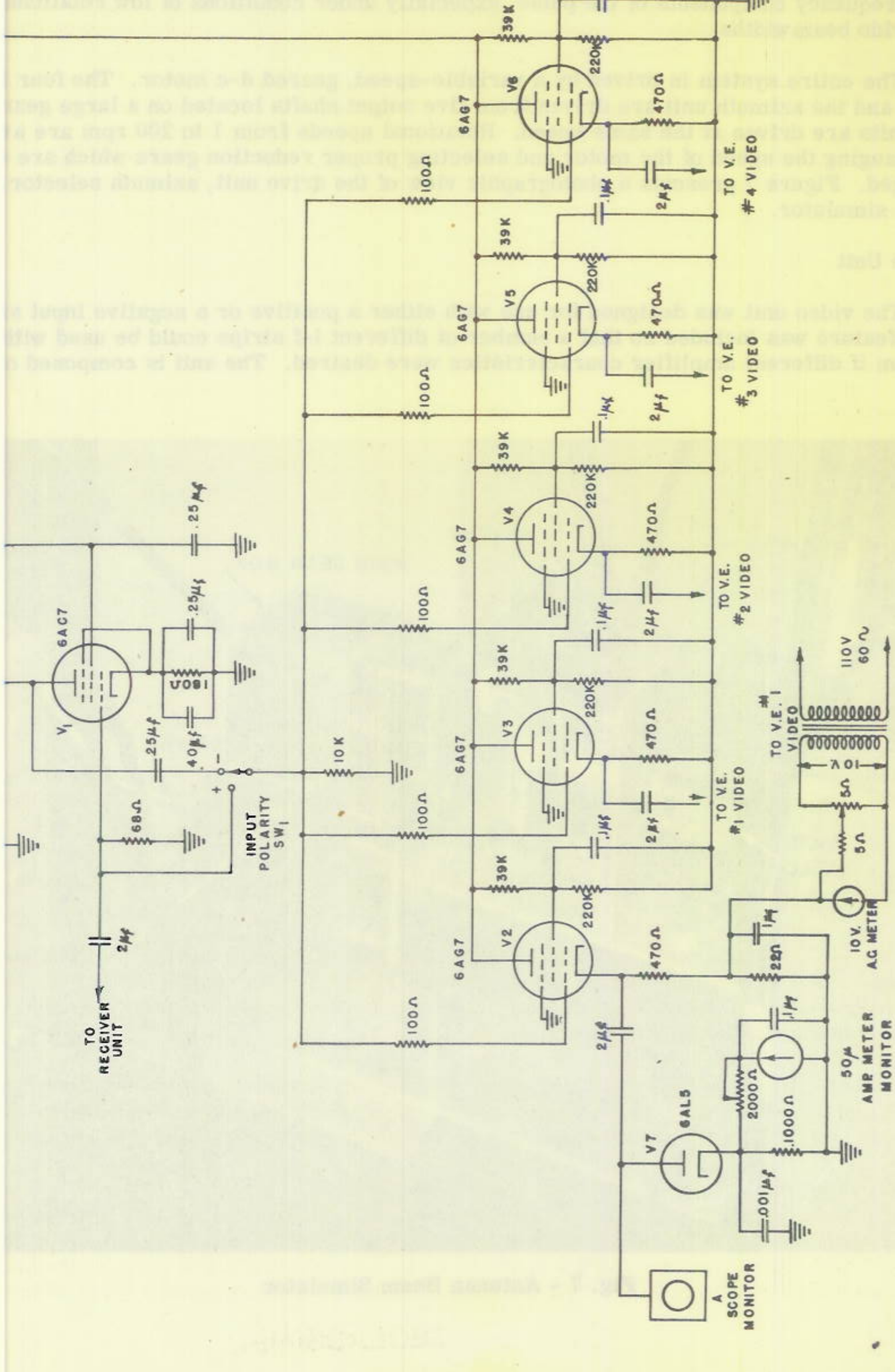


Fig. 8 - Video Unit

DECLASSIFIED

inverter stage V_1 and five cathode follower circuits built around tubes V_2 through V referring to the circuit diagram of the video unit (Figure 8) it will be noticed that th signal may be fed directly, or through the inverter stage, to the cathode followers s by switch S_1. The cathode-follower circuits use selected components and tubes, so the same output amplitude appears at each stage. Careful selection of components l make it possible to present identical information on all four PPI indicators. The ca follower V_2 is used for the "A" scope video and includes a circuit for calibrating th unit. A small 60-cycle voltage is injected in the cathode circuit of V_2 for calibratic purposes. The injection point is heavily by-passed for the higher frequency compor of the video signal. The calibrating signal is fed to both the "A" scope and video m circuits, and its amplitude is set by means of a separate meter. The scope deflecti the video meter reading are checked against one another and the calibrating meter aid in maintaining the proper gain of the "A" scope video and the system video. It i essential to keep the video gain of the system constant as some of the tests made wi equipment require injecting other signals at video level.

The video unit has a bandwidth of 2.25 Mc at the half-power point. Photographs the video unit are shown in Figures 9 and 10.

I-F Amplifier

The intermediate-frequency amplifier used at present is a standard strip utiliz six gain stages, a diode detector, and a cathode follower stage. The band pass of th is 1.8 Mc at the half-power point. The input impedance of the strip is 300 ohms. A ulated power supply is used in conjunction with the amplifier to aid in maintaining c gain. The system was designed to accommodate any standard 30-Mc i-f amplifier, makes it possible to change the i-f bandwidth if so desired.

Signal System

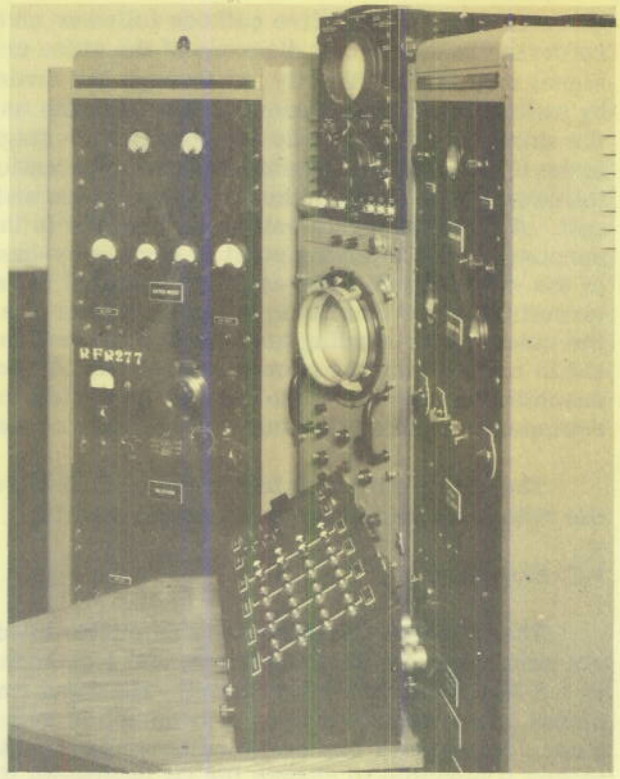
To aid the observers and the operator in registering and recording target posit a signal system has been included as a part of the equipment. The main unit in the nalling system is a "master control board", by means of which the operator control registers the azimuth and range position of a test signal. The range is selected by one of four range buttons, and the azimuth is selected by pushing one of four azimut buttons. The master set-up board also indicates the answers of each observer by n of lights. The information may be readily recorded by observing the position of the lights. Figures 3, 9 and 11 show the arrangement of both the master set-up board a observer answer boxes.

The answer boxes are identical and are so arranged that an answer button appe the same relative position as the signal. Hence as little effort as possible is requir for the observer to register his answer. This helps in reducing the errors made in istering an observed signal position.

An observer may change his answer any time during the observation period by gently on the answer button, which will release it from a contact position without dis any other circuit. A 24-v d-c supply was included for operating all relays and soler

VE PPI Repeater Units

The PPI scopes were changed over for direct mechanical drive by removing the drive motor and replacing it with a geared shaft which was extended through the bac equipment case and mounted on ball bearings. The sweep circuits were altered to g



g. 9 - Front View of Equipment, Operator's Position

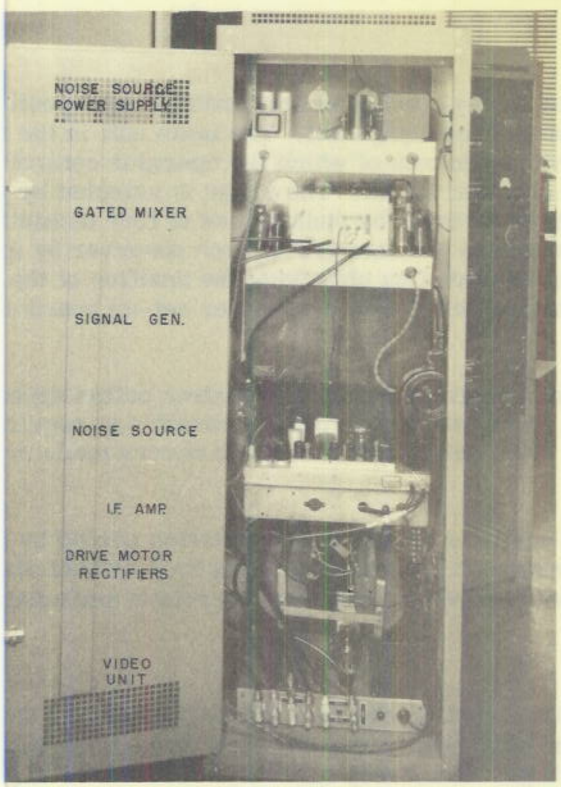


Fig. 10 - Rear View of Receiver and Video Units

400-mile sweep in addition to the original 4-, 20-, 80-, and 200-mile sweeps. T re-
peater uses a 7BP7 cathode-ray tube for signal presentation and includes circuit
supplying range rings as a part of the presentation. These range rings are displ n
the scope as a barely visible trace to aid the operator in judging the approximate
position of a signal. The VE has as standard equipment red and orange Wratten ,
which are removable from the face of the scope tube.

EXPERIMENTAL RESULTS

Simulation of Sea Return and Effect of Noise Amplitude on Detectability

Up to the present time the majority of tests have been made using a simulate
return noise background for all observations. This was done because a problem ng
sea return was of immediate interest. Tests are now being conducted using only er
noise for comparison with previous results using both sea return and receiver nc a
signal background.

The sea return noise was simulated by using a gas-tube clipped-noise sourc ed
a variable-step filter, the attenuation of which is variable in eight steps. This ar nent,
along with variable noise clipping, provides a rather large variation in noise cha
istics. The character of the noise was adjusted to give results that compared we
actual observed sea return on a PPI system and with photographs of sea return o I
system operating under approximately the same set of conditions chosen as "stan
for this system. The characteristics of the simulated-sea-return noise have bee
as nearly constant as possible during all the tests to date.

The effect of sea return amplitude was investigated for signal detectability as a function of both antenna beam width and rotational speed. The results are shown in Figures 12 and 13. These results do not take into account any change in the character of sea return noise as a function of sea return amplitude.

Signal Detectability vs Antenna Rotational Speed

The effect of antenna rotational speed on signal detectability was determined experimentally for three different beam widths. The results of these tests are shown in Figure 14. Each point is based on ninety-six observations by each of three observers. An observation time of one minute was used for each signal. Two values of input signal level were used for each beam width. It was originally intended to use the lower signal amplitude from 1 to 15 rpm and the higher signal amplitude from 15 to 150 rpm, which

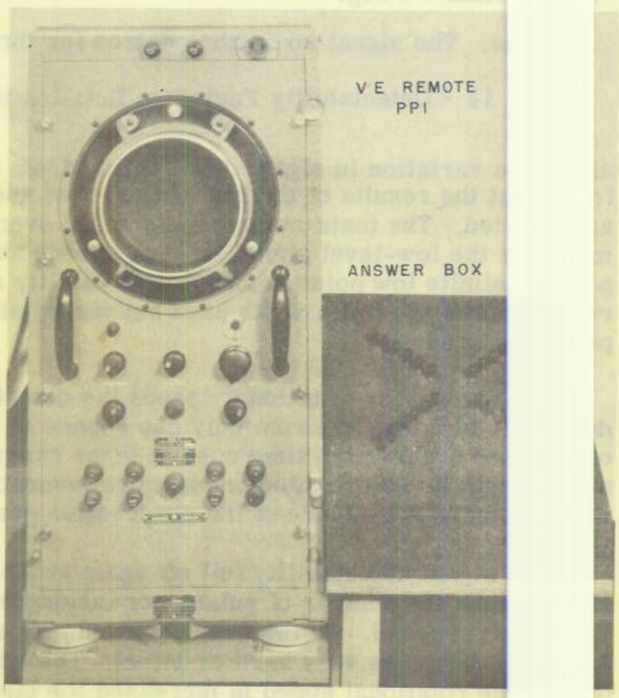
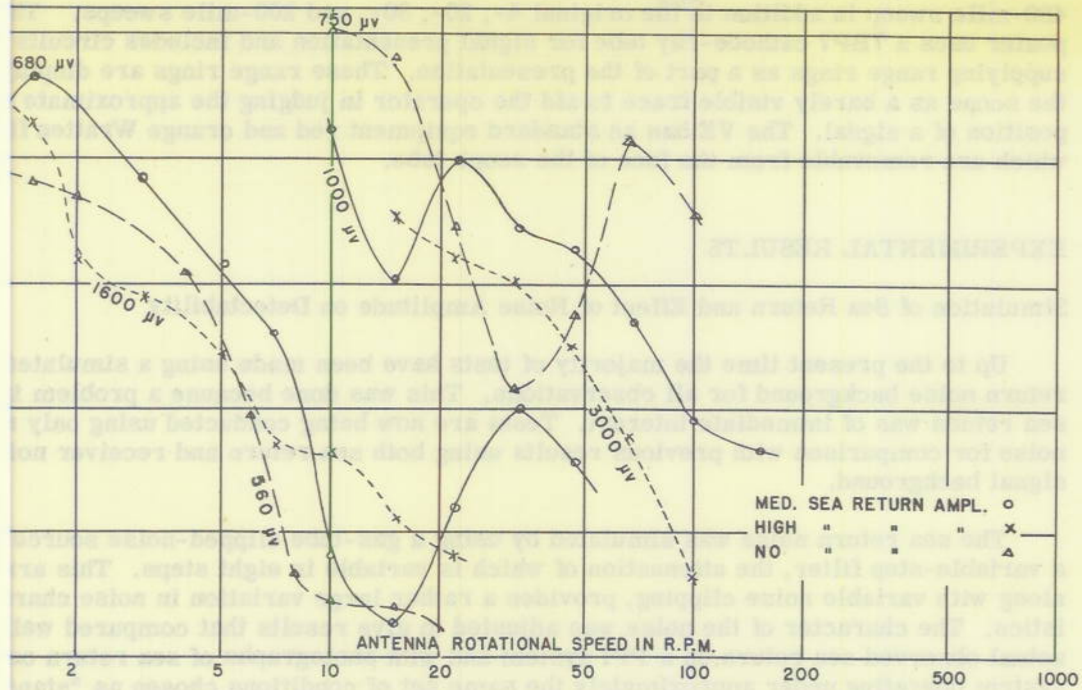


Fig. 11 - Front View of Observer's Equipment



tion Rate - 620 p.p.s.
Width - .8 μsec.
Range - 20 mi.
Width - 4 deg.

High Sea Return Noise - 6 x Receiver Noise
Med. Sea Return Noise - 1.5 x Receiver Noise
No Sea Return Noise - Receiver Noise Only

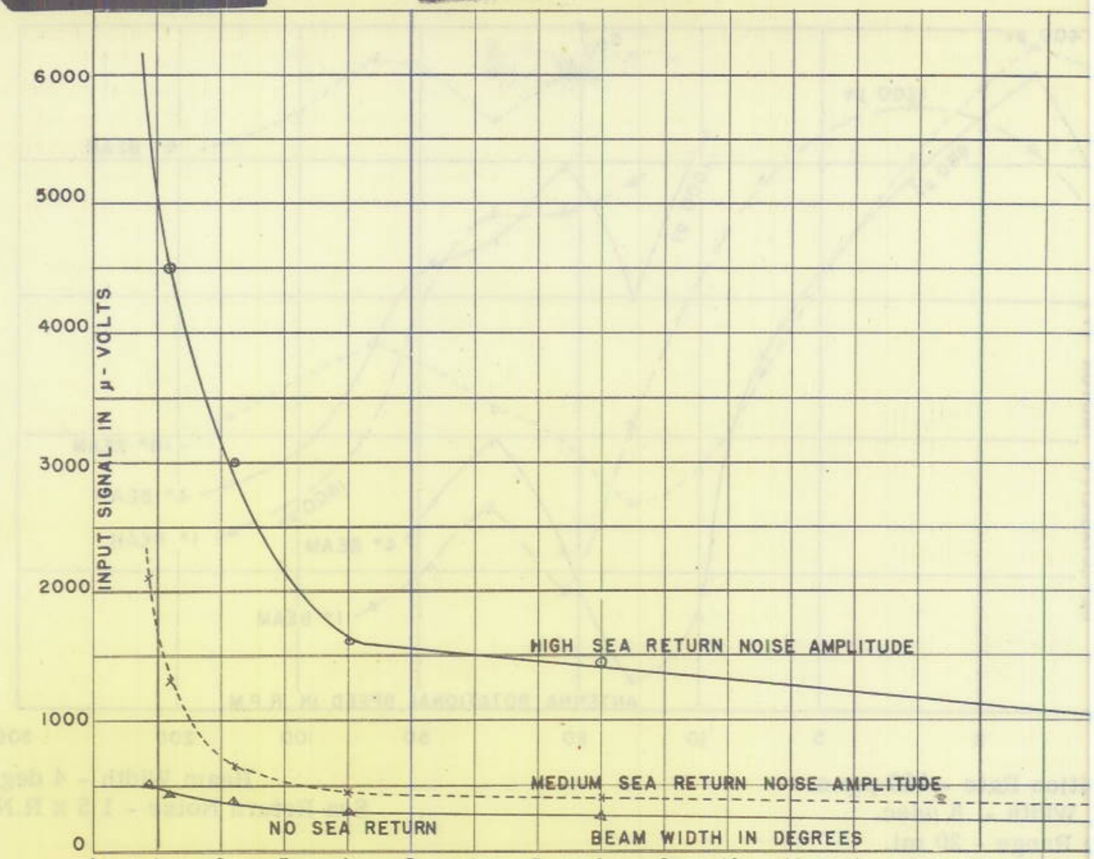
te: The signal strength required for threshold signals is noted on each curve.

. 12 - Detectability Factor vs Rotation Rate for Three Levels of Sea Return

a variation in signal detectability from approximately .05 to .95. It was later at the results of the curve at 15 rpm and above for the high signal level were not cted. The tests were therefore run over again at 15 rpm and additional tests were r the low-level signal input at speeds above 15 rpm. The additional data indicated lefinite low point in signal detectability around 15 rpm. The effect showed up ess of the beam width used but varied slightly as to the speed at which the low peared.

the very low rotational speeds the detectability dropped slightly, which was probably he fact that at 1 rpm only one chance is given to observe a signal because of the ute observation time used in these experiments. The effects of low rotational night be investigated under more favorable conditions by using a set number of ons as a measure of the observation period.

signal detectability fell off again at the high rotational speeds, as might be ex- since the number of pulses per target per revolution decreases with the increase onal speed. As the number of pulses per target per revolution approaches one, al becomes very hard to detect. The effect is overcome somewhat by the fact the rotational speed is increased the target area is swept an increased number of an observation period.



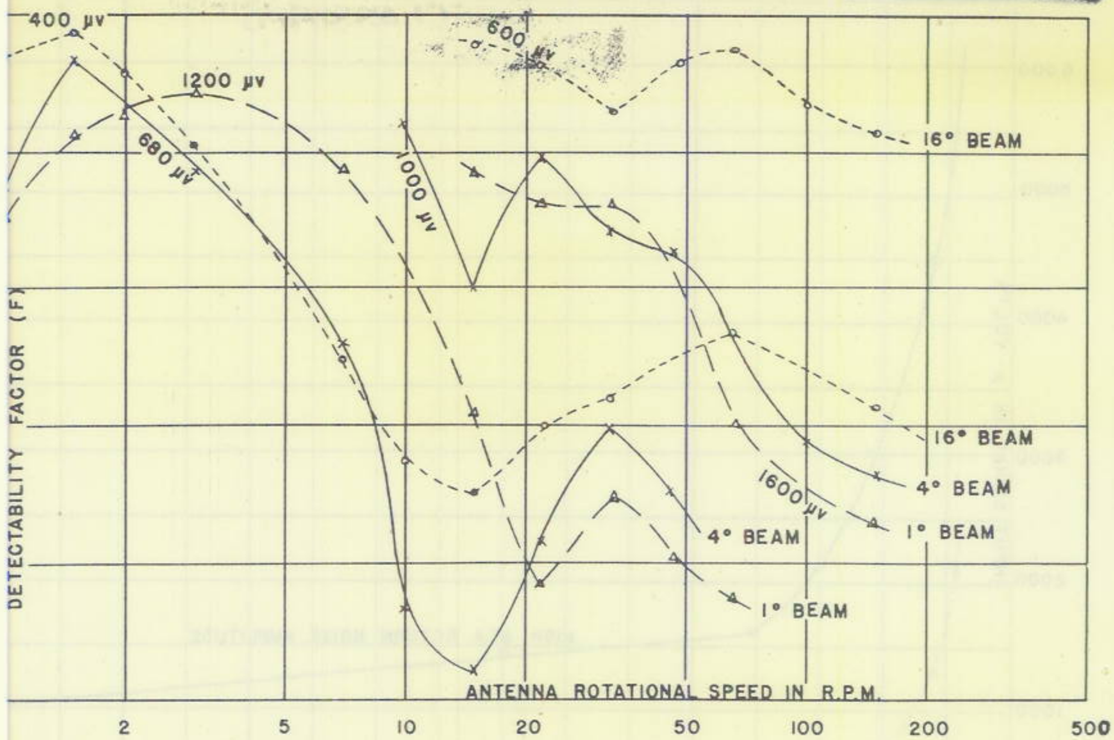
Repetition Rate - 620 p.p.s.
Pulse Width - 0.8 μsec.
Sweep Range - 20 mi.
Rotation Rate - 6 R.P.M.

High Sea Return Noise - 6 x Receiver N
Med. Sea Return Noise - 1.5 x Receiver
No Sea Return Noise - Receiver Noise (

Note: These are uncorrected data curves for which all parameters except signal strength and beam width were held constant.

Fig. 13 - Signal Strength vs Beam Width for 50% Detectability of Signals - Three I of Sea-Return Noise

The effect of keeping the number of pulses per target per revolution a constan variations in rotation rate was investigated in a separate experiment. The repetiti e was changed by the same factor as the rotation rate to keep the number of pulses p target per revolution independent of rotational speed. The results of this experim shown in Figure 15, which is a curve showing the relationship between signal detec y and rotational speed for a constant value of 25 pulses per target per revolution. T sults indicate improved detectability at the high rotational rates if the repetition r increased by the same factor as the rotation rate. However, later experiments sh the improved results gained by increasing both the repetition rate and the rotation was small compared to the improvement in signal detectability at the low rotation and with a repetition rate in the order of 600 p.p.s. This factor was demonst by an experiment in which the repetition rate was increased to 1850 p.p.s. an repeated to determine the effect of rotation rate on detectability (See Figure 1 The results showed an increase in detectability with a decrease in speed even thou



tition Rate - 620 p.p.s. Beam Width - 4 deg.
e Width - .8 µsec. Sea Return Noise - 1 5 x R.N.
p Range - 20 mi.

Note: The signal strength required for threshold signals is noted on each curve.

Fig. 14 - Detectability Factor vs Rotation Rate for Three Beam Widths

ition rate had been increased by a factor of 3 over that used in the first set of tests. re complete investigation is planned to determine what effect the number of pulses arget per revolution has on signal detectability.

l Amplitude Required for 50% Signal Detectability vs Antenna Beam Width

The effect of antenna beam on the signal amplitude required for 50% detectability was mined experimentally for three different rotational speeds. The results of these are shown in Figures 17 and 18. Each point is based on the average of ninety-six vations for each of three observers. An observation time of one minute was used ach signal.

The signal amplitude required for approximately 50% detectability was determined aking a test run giving something higher than 50% and a test run giving something than 50% of the signals visible. These two points were used to determine at what l level the third test should be run to result in very close to 50% of the signals being ectly observed. This procedure enabled determining the 50% detectability level nably accurately by graphical interpolation.

The experimental results in Figure 17 are based on maintaining all the system para- rs constant except the beam width for any particular antenna rotational speed. This

Repetition Rate - 55 to 1850 p.p.s.
Pulse Width - 0.8 μsec.
Sweep Range - 20 mi.
Beam Width - 4 deg.
Sea Return Noise - 1.5 x R.N.

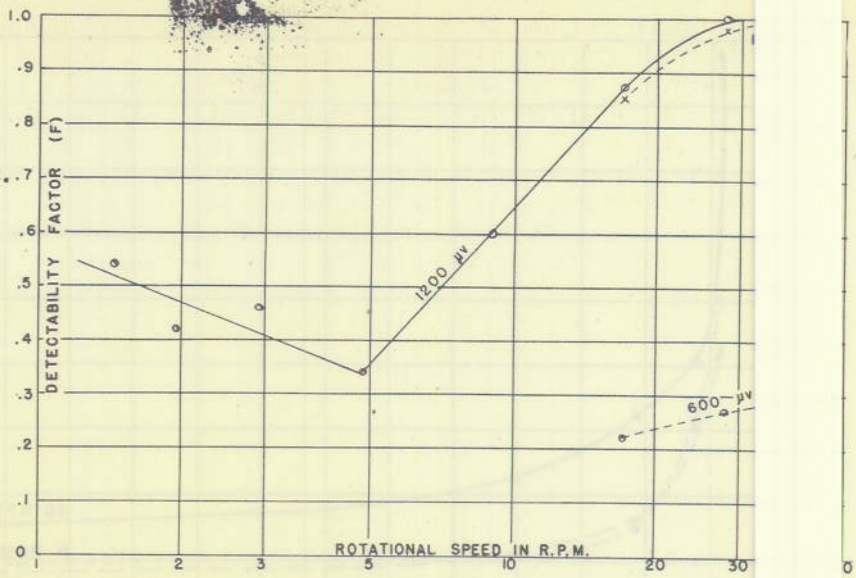
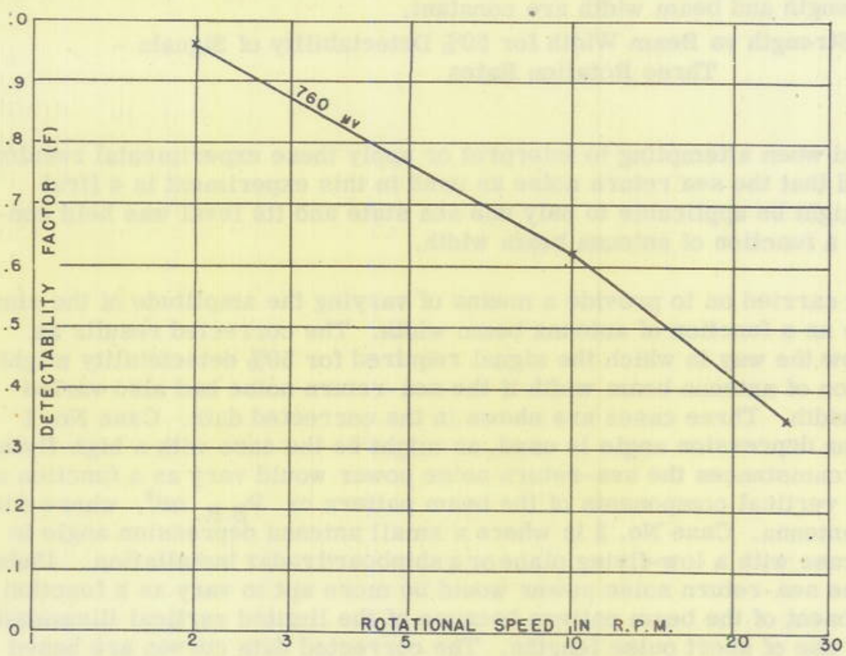


Fig. 15 - Detectability Factor vs Rotation Rate for Constant Number of Pulses per Target per Revolut

Note: The number of pulses per target per revolution was held constant at 2! increasing the repetition rate by the same factor that was used to incr the rotation rate. The signal strength required for threshold signals i noted on each curve.

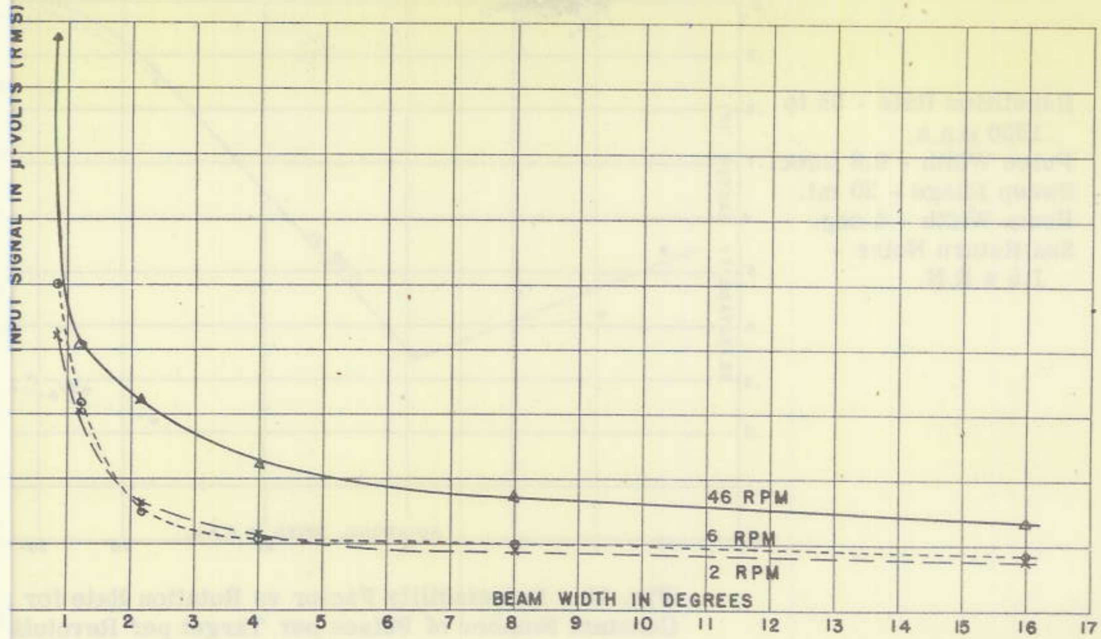


Repetition Rate
p.p.s.
Pulse Width - (
Sweep Range -
Beam Width - 4
Sea Return Nois
1.5 x R.N.

Fig. 16 - Detectability Factor vs Rotational Speed for a High Repetition Rate

Note: The signal strength required for threshold signals is noted on the curve

DECLASSIFIED



tion Rate - 620 p.p.s.
Width - 0.8 μ sec.

Sweep Range - 20 mi.
Sea Return Noise - 1.5 x R.N.

Note: The rotation rates are noted on each curve.

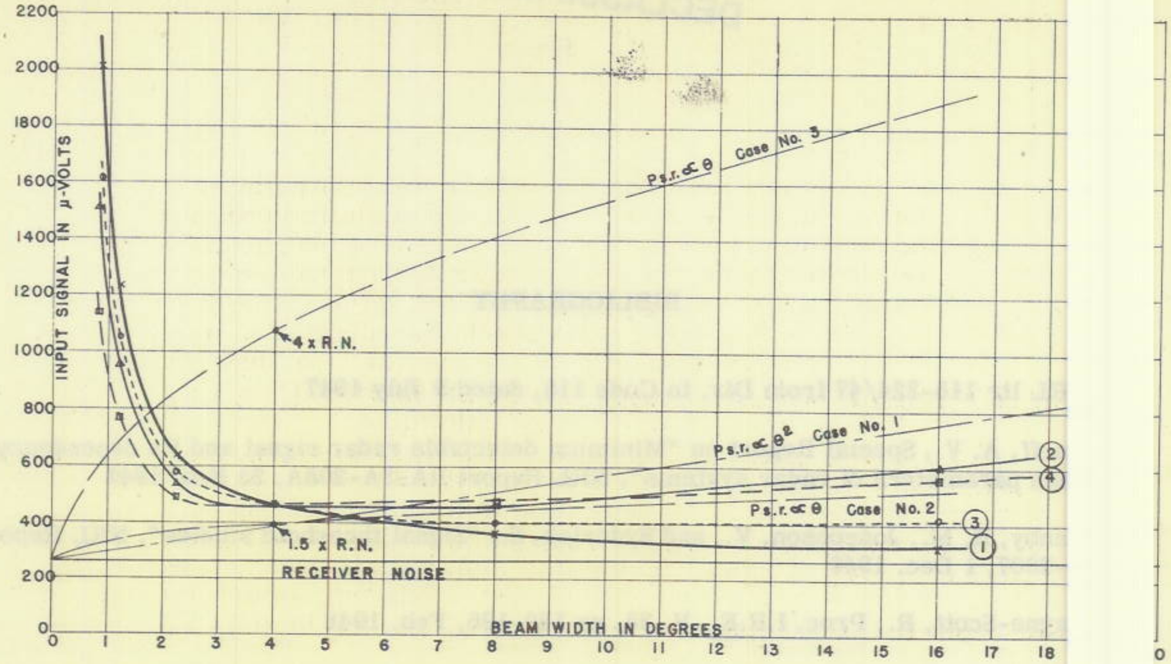
These are uncorrected data curves for which all parameters except signal strength and beam width are constant.

Fig. 17 - Signal Strength vs Beam Width for 50% Detectability of Signals - Three Rotation Rates

ust be considered when attempting to interpret or apply these experimental results. t be remembered that the sea return noise as used in this experiment is a first timation which might be applicable to only one sea state and its level was held con- nd not varied as a function of antenna beam width.

ork is now being carried on to provide a means of varying the amplitude of the sim- sea return noise as a function of antenna beam width. The corrected results as in Figure 18 show the way in which the signal required for 50% detectability might aried as a function of antenna beam width if the sea-return noise had also varied nction of beam width. Three cases are shown in the corrected data. Case No. 1 re a large antenna depression angle is used, as might be the case with a high-flying Under these circumstances the sea-return noise power would vary as a function of e horizontal and vertical components of the beam pattern or $P_{S.R.} \alpha \theta^2$, where θ is m width of the antenna. Case No. 2 is where a small antenna depression angle is s might be the case with a low-flying plane or a shipboard radar installation. Under ircumstances the sea-return noise power would be more apt to vary as a function horizontal component of the beam pattern because of the limited vertical illumination results from the use of short pulse lengths. The corrected data curves are based assumption that:

) The product P_T G_O of the transmitting antenna remains a constant.
) The receiver be a linear voltage device in its working range.



Repetition Rate - 620 p.p.s.
Pulse Width - 0.8 μsec.

Sweep Range - 2
Rotation Rate -

Curve No. 1 - Original Data Curve
Curve No. 2 - 1.5 x R.N.*- Corrected to Case #1, Large Antenna Depression Angle
Curve No. 3 - 1.5 x R.N. - Corrected to Case #2, Small Antenna Depression Angle
Curve No. 4 - 4.0 x R.N. - Corrected to Case #3, Small Antenna Depression Angle
R.N. - Receiver Noise

Fig. 18 - Signal Strength vs Beam Width for 50% Detectability of Signals - Corrected Data

(3) The sea return noise voltage $E_{SR}\alpha(\theta)$ for Case No. 1 or $E_{SR}\alpha\sqrt{\theta}$ for Ca 2, where θ is beam width.

It must also be remembered that the characteristics of sea return also vary w direction and amplitude, ground swell direction and amplitude, angle of illuminatio and many other variables that are not at present separable or controllable. As the of these variables become known in terms of noise pulse amplitude and frequency- bution characteristics, a more accurate simulation of sea return under various co will be possible.

The corrected experimental results show that an antenna beam width between four degrees appears to be best under the operating conditions specified in Case N A beam width between four and six degrees appears to be best under the operating ons specified in Case No. 2.

***

[redacted]

DECLASSIFIED

BIBLIOGRAPHY

NRL ltr 115-224/47 from Dir. to Code 115, dated 9 July 1947

Haeff, A. V., Special Report on "Minimum detectable radar signal and its dependency upon parameters of radar systems", NRL Report RA-3A-208A, 23 Feb. 1943

Ashby, R. M., Josephson, V., and Sydoriak, S., "Signal threshold studies", NRL Report R-3007, 1 Dec. 1946

Payne-Scott, R., Proc. I.R.E., V. 36, pp 180-196, Feb. 1948

DECLASSIFIED

APPENDIX I - LIST OF SYSTEM VARIABLES

Parameter	Range of variation	Control	Standa value
System Repetition Rate	30 to 10,000 p.p.s. in 11 steps	Repetition rate switch	620 p.p.s.
Signal Pulse Width	.3 to 16 μsec. in 7 steps	Pulse-width switch	.8 μsec.
Beam Width (signal arc length)	.8 to 16 deg. in 6 steps	Beam pattern paddle	4.0°
Rotational Speed	Continuously variable from 1 to 200 R.P.M.	Motor-speed and gear ratio	6 R.P.M.
Sweep Length (writing rate)	4 to 400 miles or 14 to 1400 μsec./in.	Range selector switch	20 miles or 70 μsec./in.
Input Signal	10 to 10,000 μ volts into 300 ohms	Continuous and step attenuators of signal generator	Varies with c parameters
Signal Position - Azimuth	4 positions 90° apart	Azimuth push-button switch	Appears an e number of ti each position
Signal Position - Range	4 equally spaced positions for each sweep length	Range switch and range push-button switch	Appears an e number of tin each position
Signal Display Time	Any number of revolutions or fixed length of time	Operator	1 min. or 6 r ons
Focus (trace width)	Normal range of VE	Focus control	0.5 to 0.8 mm diam.
Intensity	Normal range of VE	Intensity control	Visible backg with no noise nal
Display Filter	Red, orange, blue, or plain	Wratten filters	Orange