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INTERIM REPORT ON SEARCH RADAR PLAN POSITION INDICATOR TESTING

Technical Memorandum No. 49

Electronic Defense Group
Department of Electrical Engineering

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This is not a final report. Further investigation may make it desirable to have this report revised, superseded or withdrawn.

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ABSTRACT

A study of search radar jamming techniques has been instituted in the Electronic Defense Group for the evaluation and comparison of various jamming signals. This report presents a full description of equipment and experimental procedures. Schematics and receiver curves are included.

INTERIM REPORT ON SEARCH RADAR PLAN POSITION INDICATOR TESTING

I. INTRODUCTION

In an attempt to verify and complement the studies of search radar jamming techniques which have been conducted in the past few years by various laboratories, the Electronics Defense Group has organized a series of experiments to study and compare various jamming signals and to determine optimum modulation parameters. This report will be concerned only with the plan position indicator, but provisions have been made for a study of "A" scope effects at a later date. As the first complete publication[1] relating to these studies, it is intended only to furnish a description of the equipment and procedures employed. Test results will be published in the future.

2. EXPERIMENTAL PROCEDURES

The two major criteria of studies of this nature are that the experiment yields results applicable to actual field conditions and that potential variables are held to a strict minimum if any type of result approaching universality is to be gained. Obviously, in search radar study, these two criteria are incompatible; however, in this case, incompatibility must not result in divorce if meaningful results are to occur, thereby forcing a compromise solution. Depending on the type of jamming encountered, field

1. Resumes of this program may be found in Electronic Defense Group Quarterly Progress Reports Nos. 5,6,8,9, and 11, and in Electronic Defense Group Task Order No. EDG-7, Progress Reports Nos. 1 through 9.

operators are completely justified in varying such receiver characteristics as gain, indicator intensity, scan rate, etc. Naturally these liberties cannot be granted the laboratory observers if consistent data for a close comparison of effectiveness of different jamming signals are to be obtained. Therefore, in the course of all search radar experiments, the procedure has been to keep all variables under the control of a technician monitor, thus insuring a consistent basis for the analysis of data and the comparisons of observer performances. Recognition should be made that visual reception of observers differs, placing an unavoidable variable into the data. Effects of receiver characteristics will be studied at a future date.

2.1 Observer Procedures

The observers employed in these studies are all non-technical personnel, students and/or students' wives at the University of Michigan whose services are restricted to experimental observations on the search radar program and other such statistical studies. Before any attempt is made to utilize his or her data, the observer is subjected to a thorough training period which lasts until performance with normal target presentations indicates that "learning effects" are negligible. Normally this takes about two weeks of half-day sessions.

The usual operating procedure is to use the observers in pairs for no more than one four-hour session per day. Each observer makes two consecutive runs, consisting of one hundred presentations each, with a parameter change in between. Then the observer is off duty until the other observer has made his two runs. The alternation of observers in this manner and the limitation of four hours per day has resulted in improved data due to minimizing of visual fatigue and of the monotony which the work involves due to its nature.

As mentioned earlier, all changes in jamming parameters as well as operating characteristics are accomplished by the monitor. He performs the necessary checks, changes, and measurements (see Table I in Appendix I) before each run and records them in a permanent log book together with the results of the previous run (See Appendix I).

As another means of stabilizing the results, a bonus system has been instituted which rewards the observer monetarily for maximum target detection. This has proven to be very satisfactory on all counts.

2.2 Target Presentation and Answering

The indicator presentation is designed to simulate the acquisition of a target, such as a bomber, which is approaching the radar site within a radius of twenty miles. The bomber is acquired on any one of four possible azimuth lines approaching the site, and its echo will appear at any one of four possible range positions. Figure 1 shows the range and azimuth lines marked on the indicator screen. The intersections of these lines offer sixteen possible target positions, each being used in a random manner. The indicator is divided into three main sections, the target area (90 degrees), the answering area (180 degrees), and a blank area in which the new target is introduced to the system while the observer is preparing himself for the next tour through the target area.

After the trace has cleared the last azimuth line, a white light on the observer's answer box is energized, indicating the beginning of the answer cycle; this remains on during the entire answering period. The observer pushes those buttons which correspond to the target position. For an answer which is correct in azimuth and/or range, one or both of two yellow lights on the answer box will be energized indicating the correct choice. This is for the benefit of the observer only, as the number of correct

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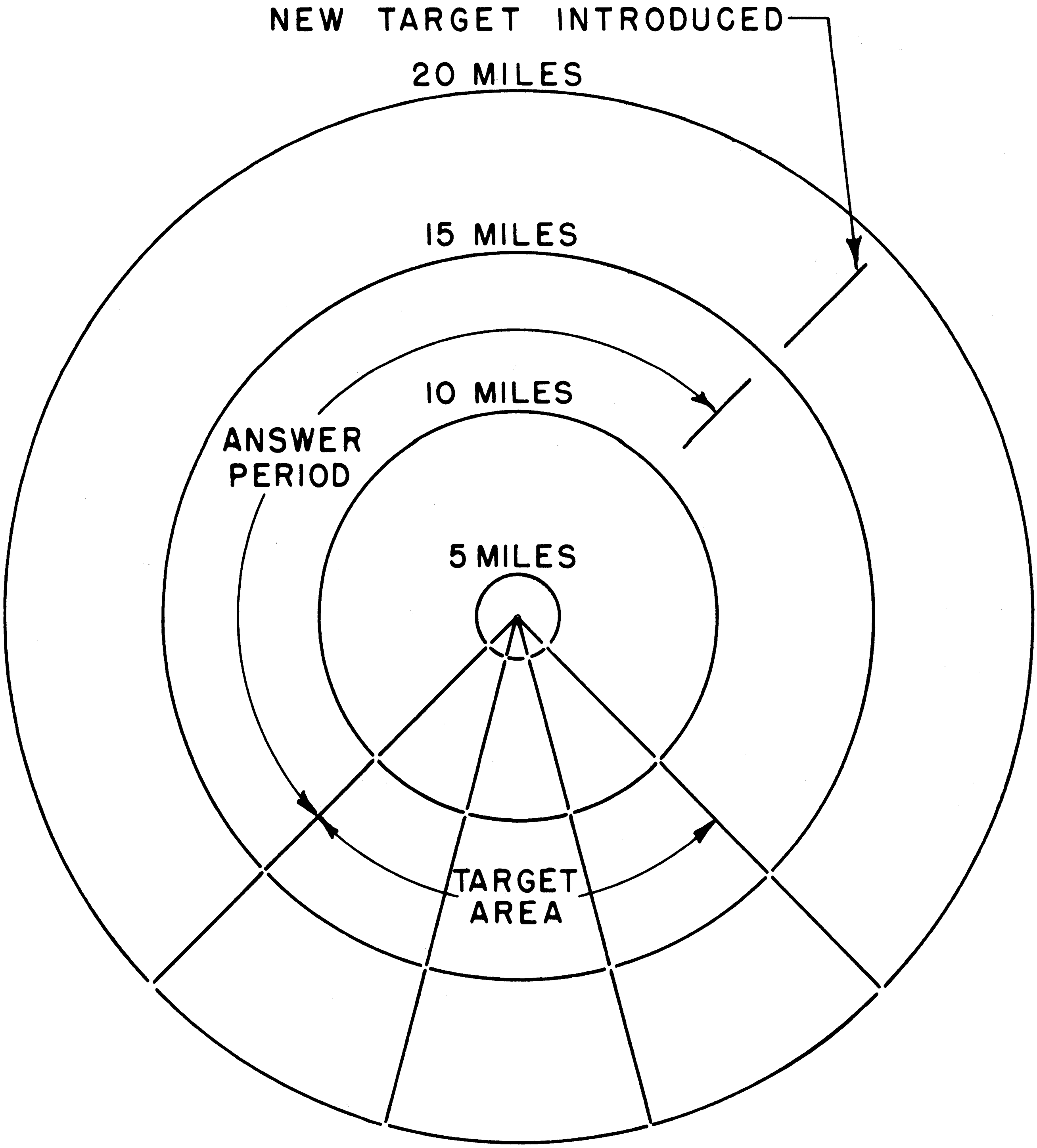


PLAN POSITION INDICATOR

FIG. 1

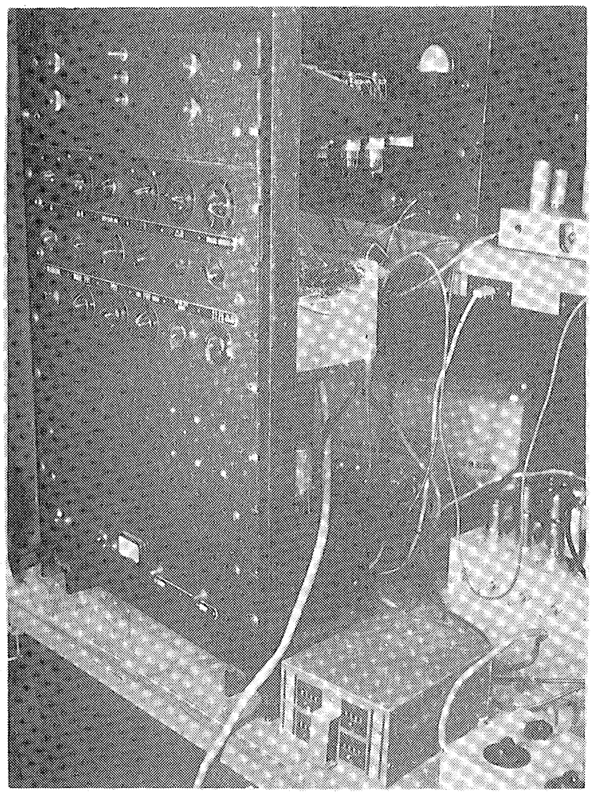
answers, range and azimuth individually as well as both, are automatically tallied on counters together with the total number of trials. The answering circuitry is such that only one answer is accepted for each trial, making second-guessing impossible.

At the end of the answering period, the white light is extinguished and a red light, also on the answer box, will flash to indicate that the new target has entered the system successfully and will be presented. The observer is again prepared as the trace approaches the target area. The circuitry is such that the red light will indicate malfunction by either remaining lighted or by not lighting at all.

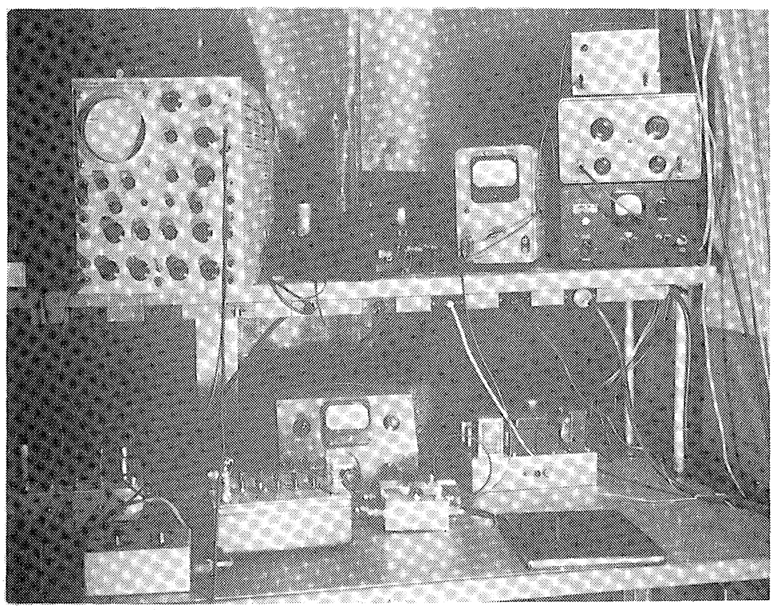
Each run consists of one hundred trials. At the end of each run, the monitor records the counter readings in a log book along with the parameters of that run. He then prepares the next run. For the most part, the experimental work has involved choice of sixteen possibilities. However, the circuitry allows switching to four-choice trials, employing either constant range with random azimuth or vice-versa.

2.3 Screen Room

The equipment is completely contained in a screen room (Figure 2) to avoid interference from external sources. The observer is seated in front of the console (Figure 3) in a relatively comfortable position and holds the answer box in whichever way is most convenient for him. During the experimental runs, all lights are extinguished. The screen room walls have been covered with opaque paper to eliminate distracting reflections on the indicator screen. Due to the large amount of heat generated within the screen room, forced-air ventilation has been provided for the comfort of the observers.



(a)



(b)

FIG. 2. PPI EXPERIMENTAL EQUIPMENT.

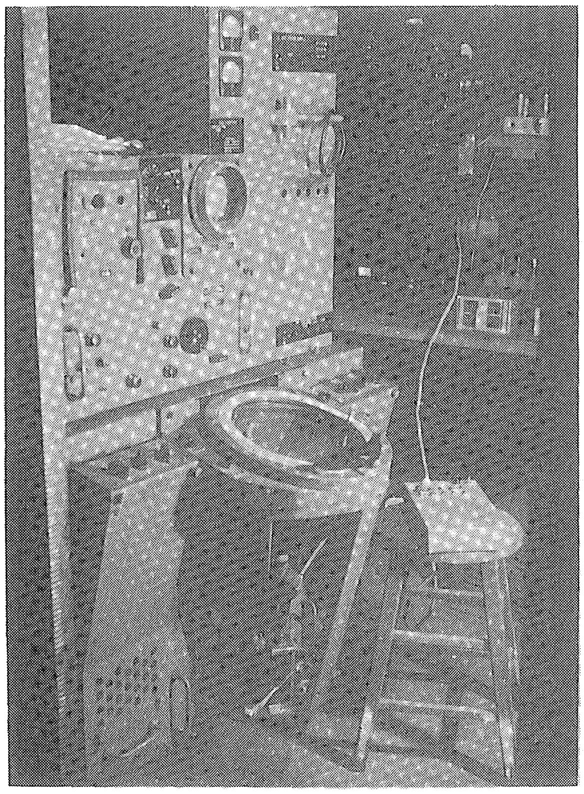


FIG. 3. PPI CONSOLE

3. RECEIVER AND INPUT COMPONENTS

The block diagram of Figure 4 presents the basic system being used in the search radar studies. A relatively brief explanation of the more important circuits follows in this section.

3.1 Programming

Programming is initiated by the random selector's choice of one of sixteen possible positions. The target generator, operating at video frequencies, receives the random selection via the relay system and generates a video pulse correctly timed with respect to the indicator presentation. The video pulse gates the (nominally) thirty megacycle pulsed oscillator (Figure 5), resulting in the actual target pulse being sent into the receiver after proper attenuation. In addition, the video target generator supplies a synchronizing pulse to the receiver sweep and blanking circuit every millisecond.

The timing of this cycle is controlled by a 360-degree single turn linear potentiometer which is geared to the deflection yoke motor, thereby developing a sawtooth voltage whose amplitude is proportional to the angular position of the indicator trace. At the start of a trial cycle, when the trace is at the two o'clock position on the indicator (Figure 1), the flyback of the sawtooth occurs; after differentiation, it is delivered to other circuits in the form of a reset trigger by the cycle timer. After the trace has swept through the target area, the cycle timer (Figure 6) energizes the observer-answering circuits. At the end of this answering period, the new cycle begins.

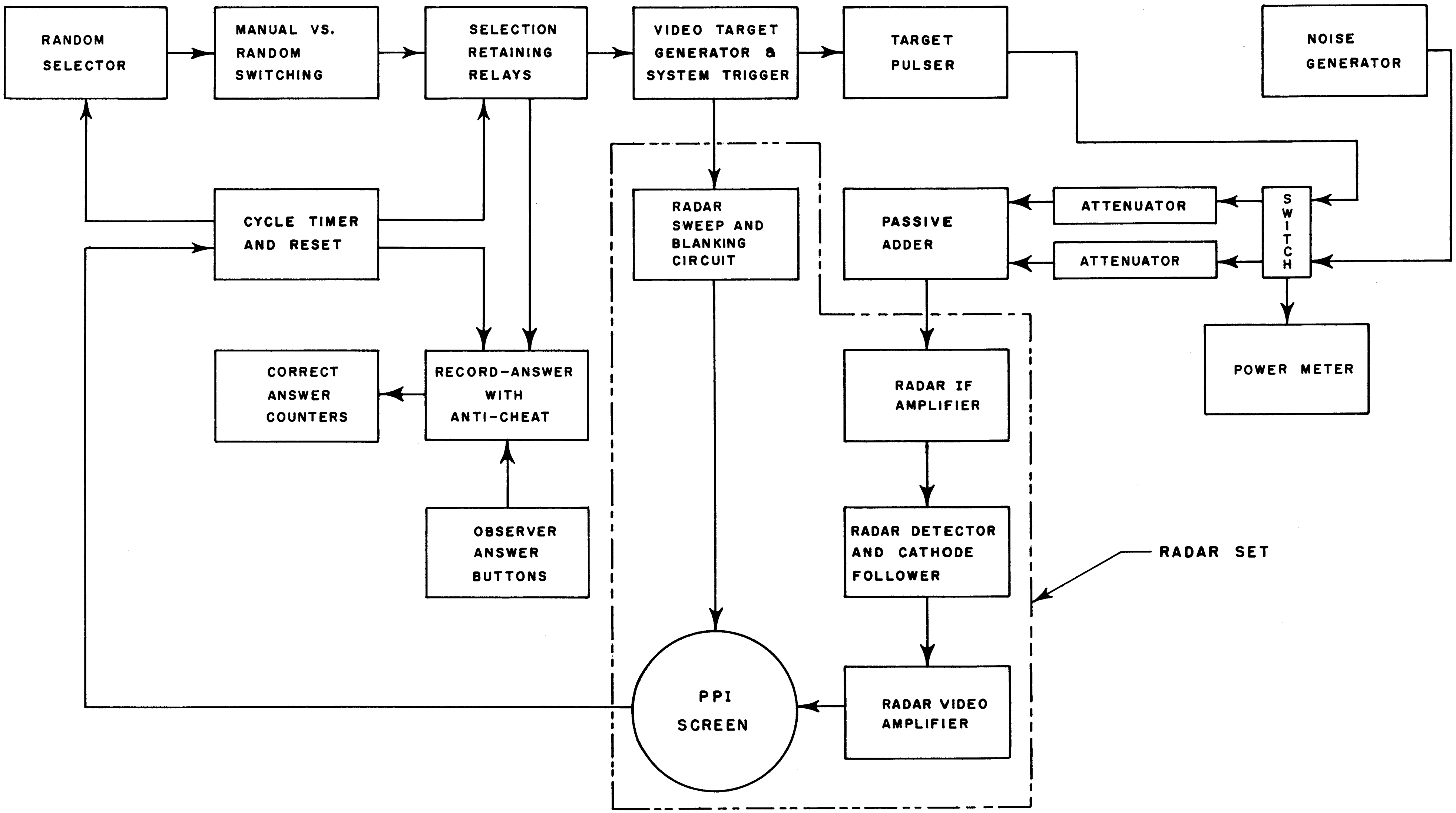


FIG. 4. BLOCK DIAGRAM OF PPI TEST EQUIPMENT

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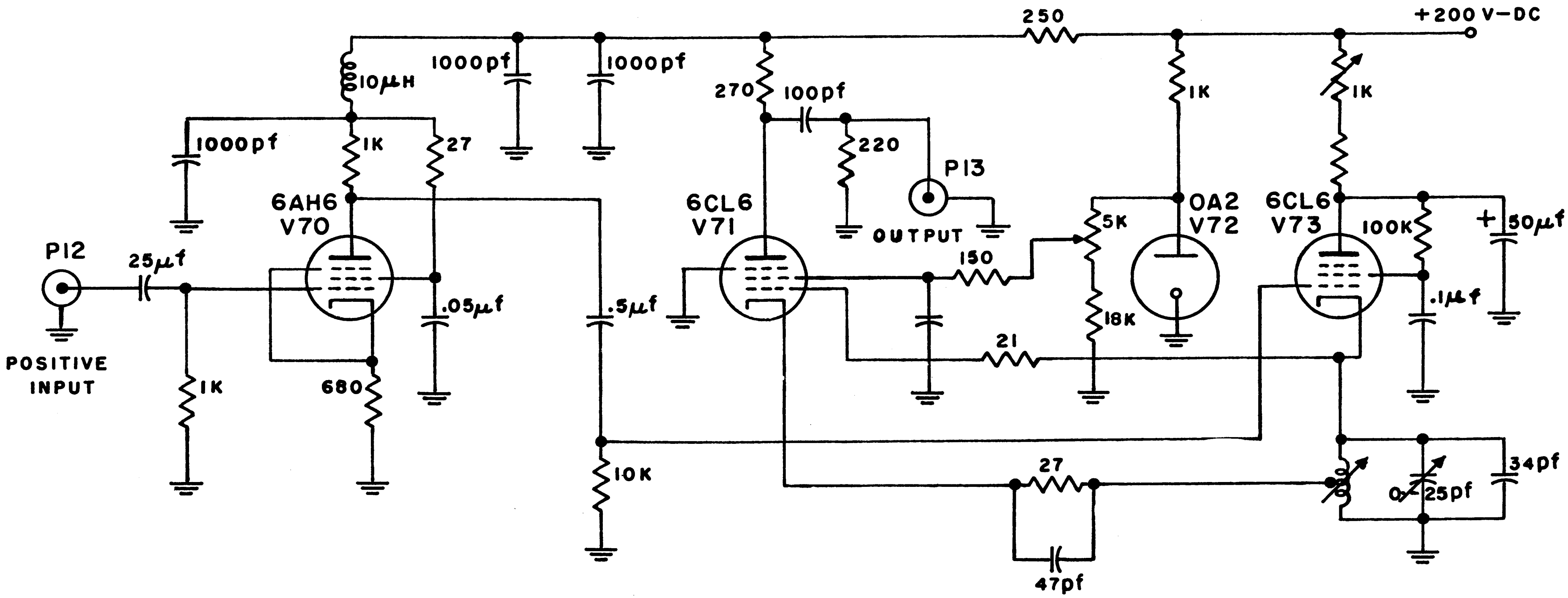

FIG. 5,

TARGET PULSER

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S1 – ON-OFF SWITCH
S2 – TWO CYCLE – ONE CYCLE SWITCHING
(ONE CYCLE AS SHOWN)
L4 – ANSWER CYCLE LIGHT
C4 – TOTAL TRIALS COUNTER
R20 – ANSWER CYCLE SET

ALL RELAYS ARE SHOWN IN UNENERGIZED POSITION

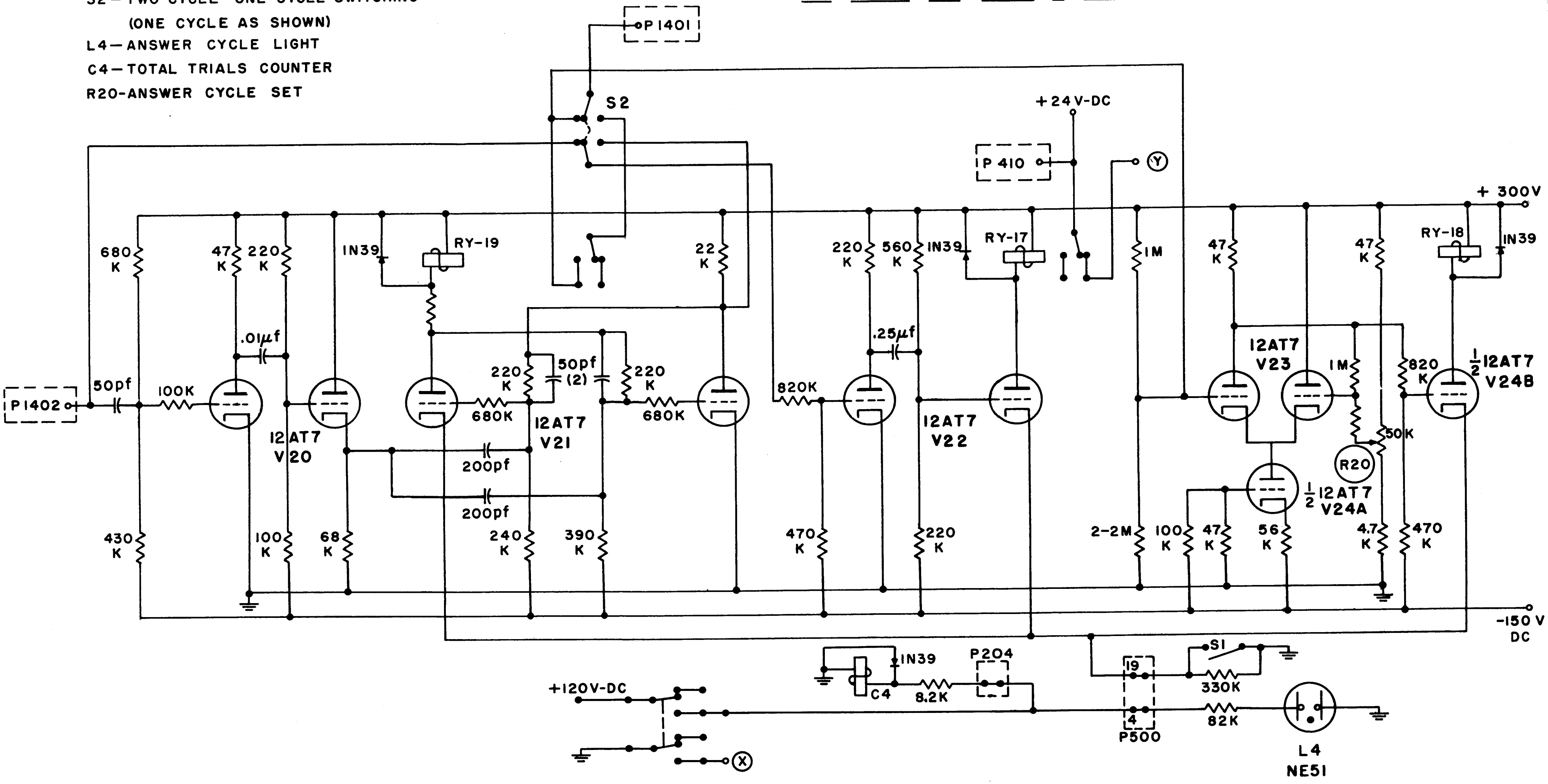

FIG. 6. CYCLE TIMER

3.2 Random Selector (Figure 7)

The four-by-four matrix of the PPI presentation is provided by two complete ring-of-four counter circuits, each composed of four bistable multivibrators and each controlled by an independent random pulse generator. A single-shot multivibrator, triggered by the random peaks of a Gaussian noise source, is employed as the random pulse generator. At any instant when no pulse is received by the counters, three of the multivibrators are in one stable state, and the fourth is in the opposite stable state. At the beginning of a trial cycle, the pulse input to the counter is stopped, and the counters are interrogated by means of relays connected to each of eight thyratron outputs, one thyratron in each counter transmitting its selection by firing and energizing its corresponding relay. These selections are retained by the relays, which are then disconnected from the random selector, allowing the counters to resume circulation until the next cycle.

3.3 Selection Retaining Relays (Figure 8)

The random selections are retained in the relay section for the duration of the cycle. The necessary control voltage for determination of range and azimuth coordinates is provided to the target generator by the two energized relays at the same time that they send target information to the answering circuit (Figure 9). As shown in Figure 8, the reset pulse disconnects the 24-volt supply from the entire switching system by means of Relay 18, thus de-energizing all relays and stopping circulation of the random selector counters. One-half second later, the 24-volt supply is again introduced, causing relays Ry-9 and Ry-11 to be energized. Relays Ry-1 through Ry-8 are then connected to their respective thyratron outputs of the random selector. As the selector energizes its two relays, relays Ry-10 and Ry-12 are activated, relays Ry-9 and Ry-11 are de-energized, and the

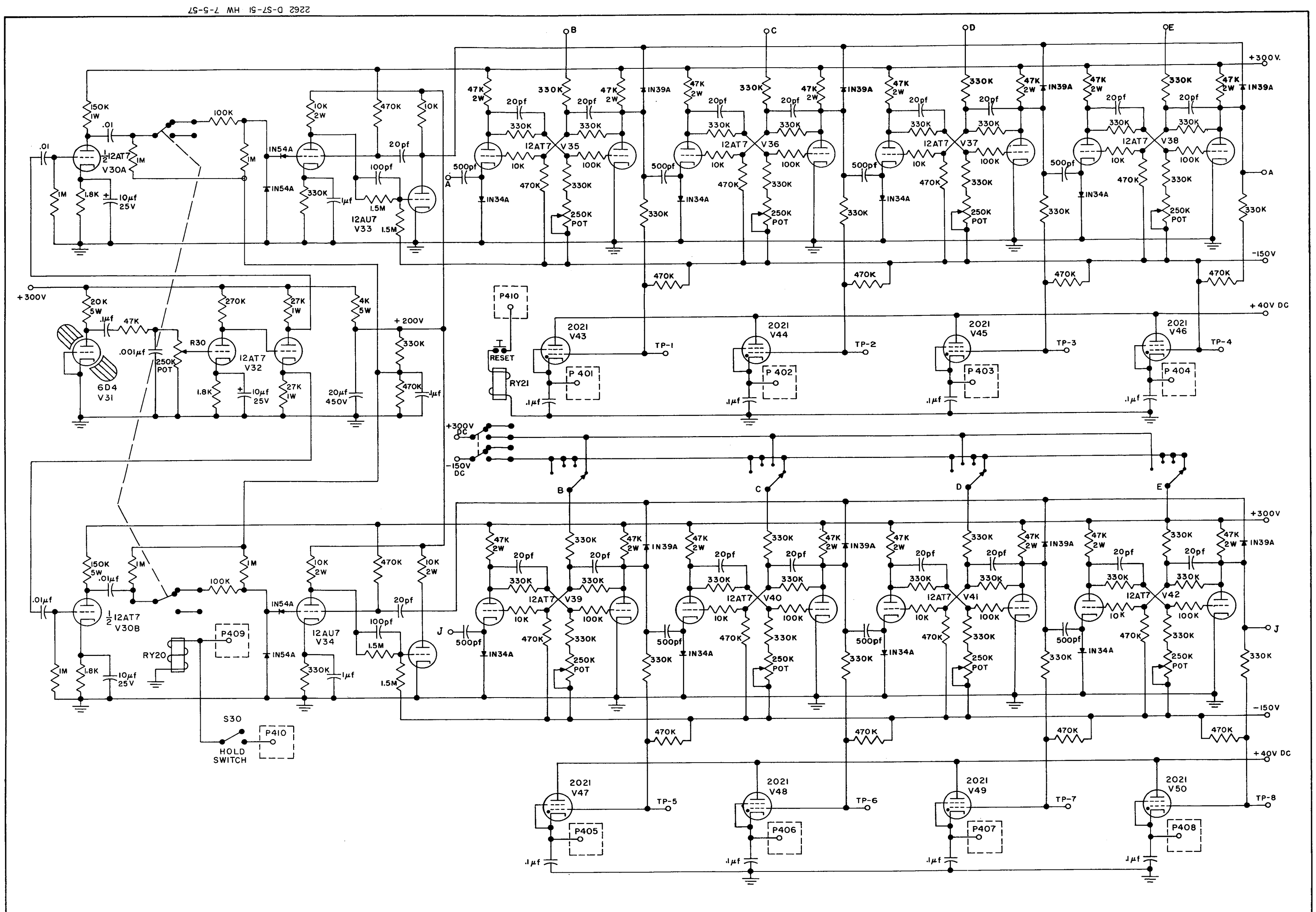

FIG 7 RANDOM SELECTOR

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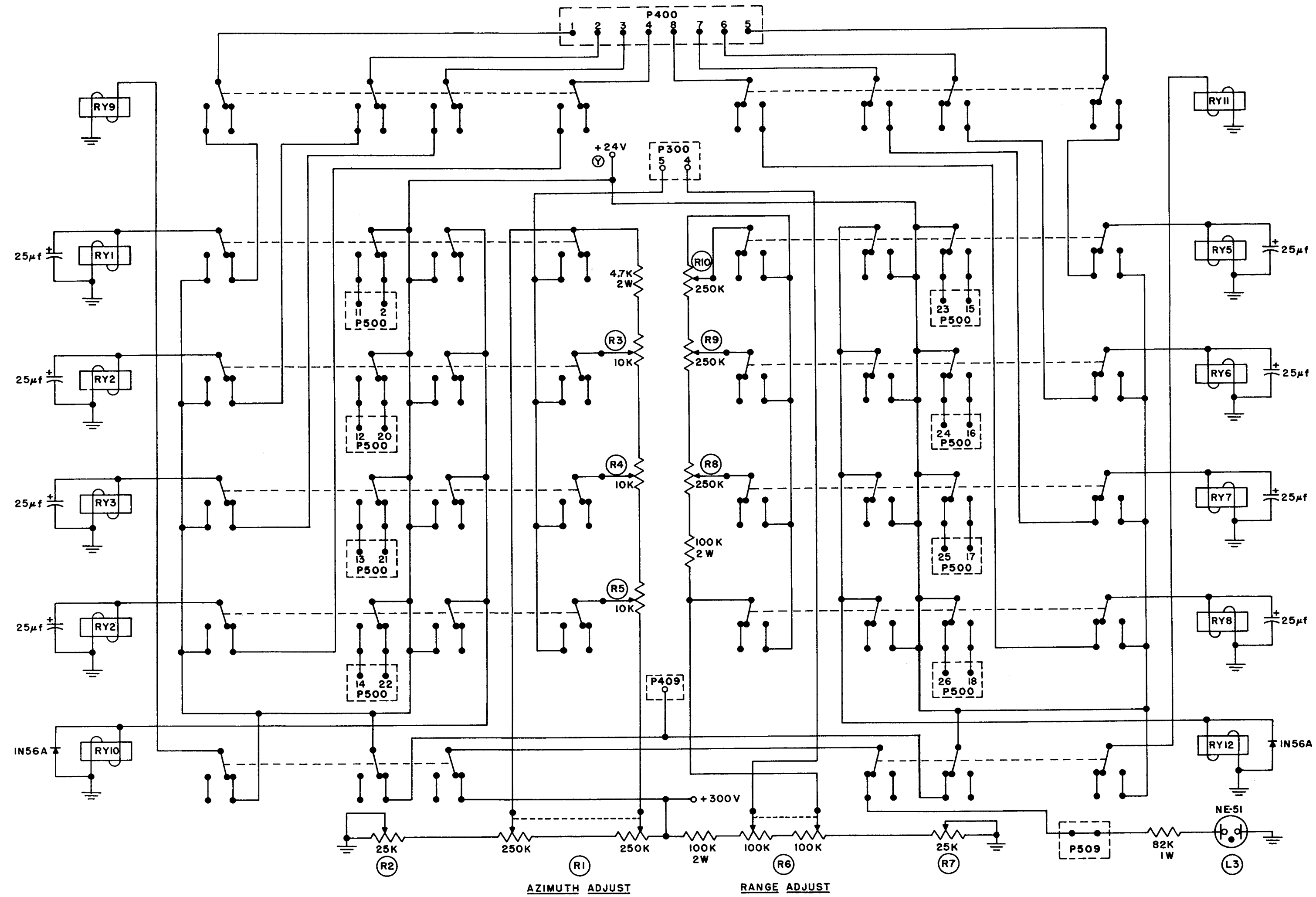

ALL RELAYS SHOWN IN
UNENERGIZED POSITION
L3-NEW CYCLE WARNING LIGHT
R1 THRU R5-AZIMUTH POSITIONING
R6 THRU R10-RANGE POSITIONING

FIG. 8

SELECTION RETAINING RELAYS

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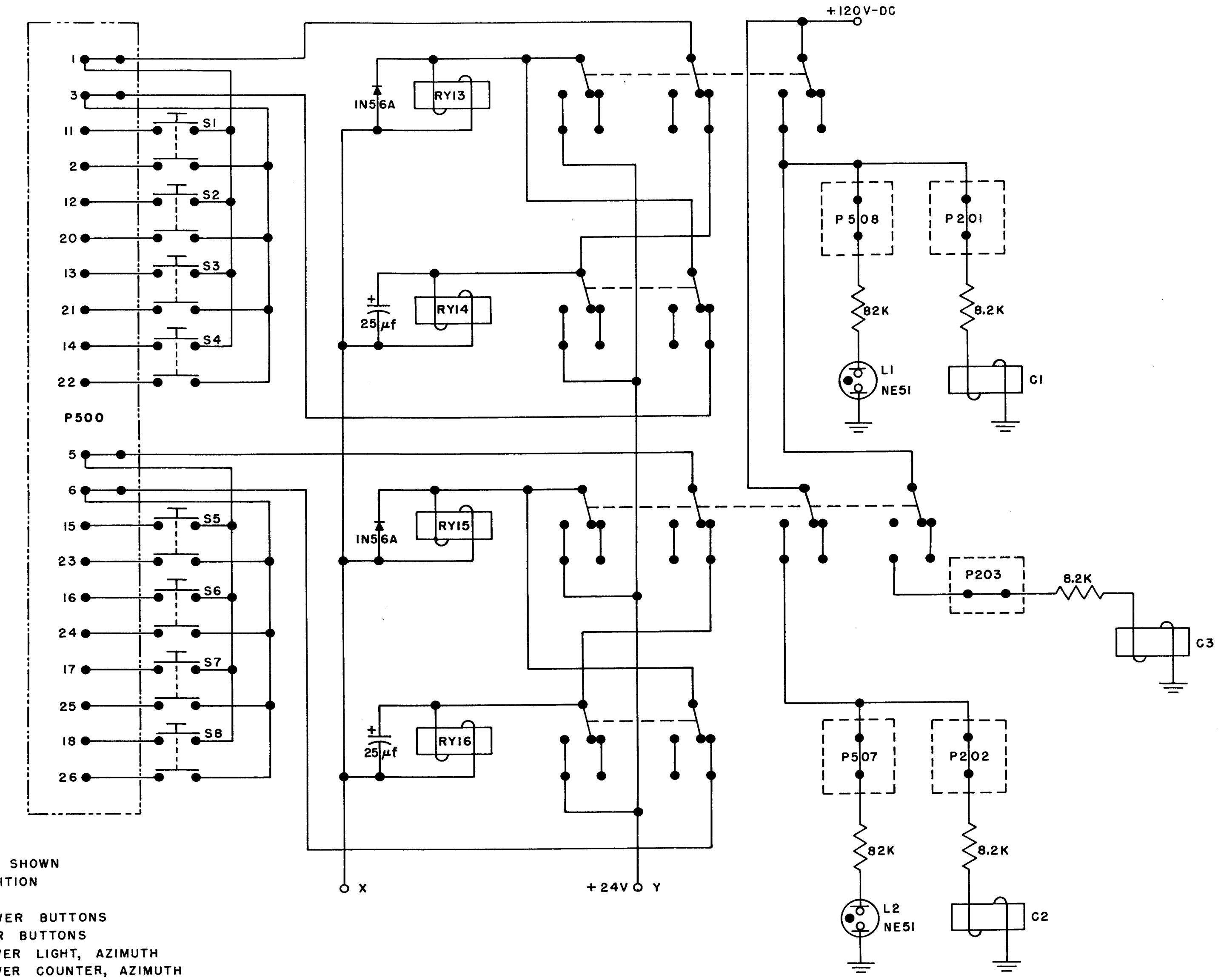
2262 D-S7-52 HW 7-5-57

2262 C-S8-50 HW 7-5-57



ALL SWITCHES AND RELAYS SHOWN
IN THE UNENERGIZED POSITION

S1 TO S4—AZIMUTH ANSWER BUTTONS
S5 TO S8—RANGE ANSWER BUTTONS
L1———CORRECT ANSWER LIGHT, AZIMUTH
C1———CORRECT ANSWER COUNTER, AZIMUTH
L2———CORRECT ANSWER LIGHT, RANGE
C2———CORRECT ANSWER COUNTER, RANGE
C3———CORRECT ANSWER COUNTER, BOTH RANGE AND AZIMUTH

FIG. 9
RECORD-ANSWER CIRCUIT
(WITH ANTI-CHEAT)

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random selector is again disconnected. L-3, the observer red warning light, is on at the beginning of this switching cycle and goes out when the switching sequence is completed.

3.4 Target Generator (Figure 10)

Synchronization of the radar blanking and sweep circuit to the target pulse time generation is governed by a one thousand pulses per second free-running blocking oscillator, each synchronizing pulse corresponding to one sweep of the indicator trace. The system time generation is complemented by the speed of rotation of the deflection yoke drive motor. The target generator fixes the position of the target, azimuth and range, by means of two voltage comparator circuits. Both comparator circuits are designed to have either of two constant outputs, depending on the input voltage's being greater or smaller than the reference voltage. At the instant when the input voltage is equal to the reference voltage, a step function results which can be differentiated to a pulse. The azimuth comparator refers the voltage representing the angular position of the trace to the azimuth control voltage of the selection retaining relays; the range comparator refers a sawtooth, whose slope is timed to the sweep, to a range control voltage. Although the range comparator is operative on each sweep, its output is utilized only when gated by a single-shot multivibrator, which is in turn controlled by the azimuth comparator. This type of circuitry dictates a constant sweep rotation of the trace, as the angular duration of the target is determined by time and not by space.

3.5 30-Megacycle Pulsed Oscillator (Figure 5)

The video pulse output of the target generator is used to gate the pulsed oscillator. The positive pulse is inverted in the first stage, and

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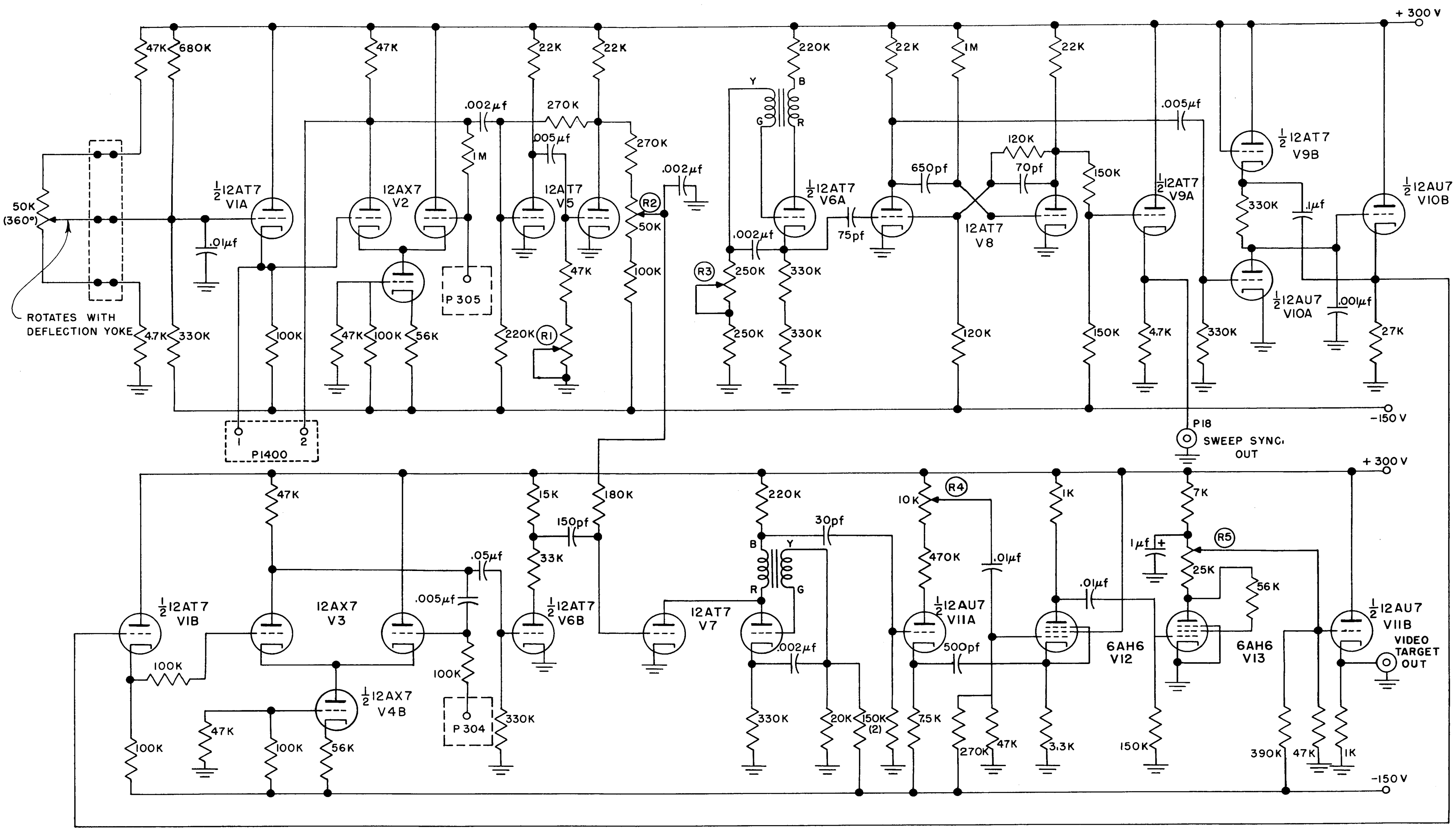

R1- Adjustment of number of pulse-bearing sweep presentations.

R2-Adjustment of gating bias.
R3-PRF Adjustment

R4-Adjustment of pulse width.
R5-Adjustment of pulse height.

FIG. 10.

VIDEO TARGET GENERATOR AND SYSTEM TRIGGER

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this inverted pulse initiates the thirty megacycle oscillation of a Hartley oscillator.[2] The amplitude of the pulsed oscillation is controlled by varying the regulated screen voltage of the output tube.

4. TESTING PROGRAM

At this time, the jamming program has been conducted with the philosophy of masking the target only. No attempts at deceptive jamming have been anticipated for the near future. Programming has been initiated using directly amplified RF noise and amplitude modulation by noise, the results of which will be released in a future publication. Other programs considered at the present include frequency modulation by noise, and combined amplitude and frequency modulation by noise.

The inherent noise of a commercial IF amplifier, Instruments for Industry Model No. 235, has been employed in the RF noise studies. This is a ten megacycle wide amplifier centered at thirty megacycles. In order to obtain amplitude and frequency modulations by noise, a thirty megacycle transmitter, capable of generating both types of signals, has been designed and constructed at the Electronic Defense Group (Figure 11). Available equipment permits modulating with noise bandwidths up to four megacycles.

Recognition should be given the fact that it is difficult to determine optimum jamming parameters on a universal basis. The receiver characteristics and the size of the target pulse can have a great effect on the jamming potential. Therefore current planning provides for a series of experiments studying the effects of varying receiver parameters. This program will await the conclusion of the jamming program. Parameters which have been

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2. Chance, Hughes, MacNichol, Sayre, and Williams, "Waveforms", Volume 19, M.I.T. Radiation Laboratory Series, McGraw-Hill, 1949.

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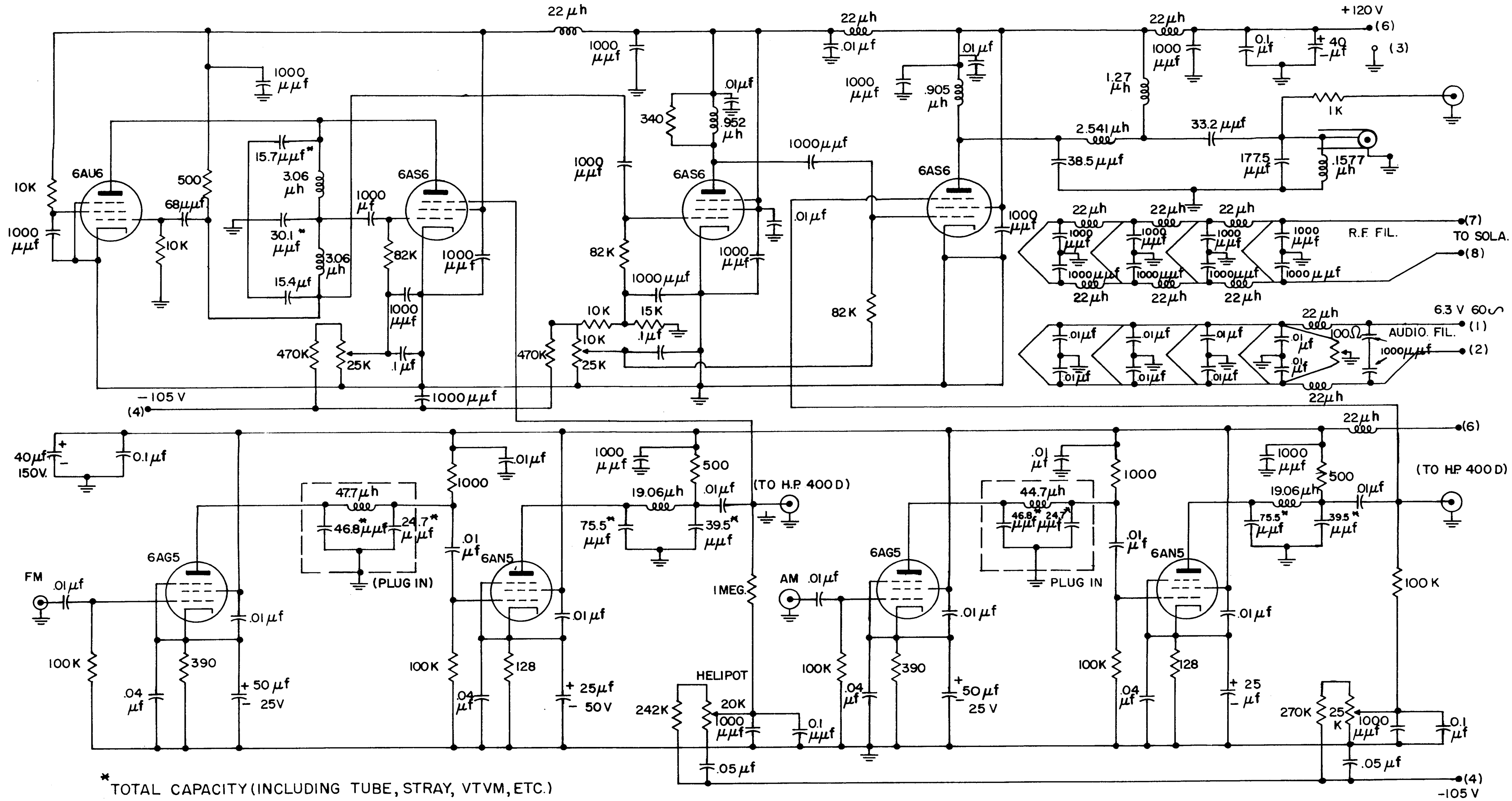

*TOTAL CAPACITY (INCLUDING TUBE, STRAY, VTVM, ETC.)

FIG. 11.
30 MC FM-AM TRANSMITTER
(WITH SEPARATE POWER SUPPLY AS SHOWN)

considered include the target size, the pulse repetition rate, antenna scan rate, intensity, IF gain, video level, and video bandwidth.

Although this report deals specifically with the plan position indicator of the search radar, it should be noted that experimentation can also be conducted to study the effects of these same programs on the "A" scope. The existing equipment can serve this purpose as well as the present.

APPENDIX I

MEASUREMENTS

1. Signal Power

Signal power is measured prior to IF input, a type 650 Daven attenuator being between the measurement point and the IF amplifier of the search radar in order to adjust pulse size as desired. The target pulse is turned on continuously, and a reading is obtained from a Hewlett-Packard 430B Microwave Power Meter. In the computation of the jam-to-signal power ratio, this power reading is corrected for the duty cycle to give peak power.

2. Jamming Power

Jamming power is measured in a similar method as the signal power. The reading is made with the Hewlett-Packard Microwave Power Meter at a comparable point in the block diagram. The attenuated jamming and target signals are mixed in a passive adder at the outputs of their respective attenuators, and the total is fed into the receiver system.

3. Pulse Repetition Frequency

The pulse repetition frequency is measured and adjusted by means of viewing on a Tektronix 514 calibrated oscilloscope.

4. Alignment of Jamming Frequency to Target Frequency

The target pulse is turned on continuously and viewed on a Polarad Model TSA Spectrum Analyzer simultaneously with the jamming spectrum. The center frequencies are adjusted if a difference exists. Frequencies are checked at relatively frequent intervals during the course of experimental runs to assure proper alignment.

TABLE I

PARAMETERS

Description	Where Measured	Measurement Method	Reading	Units
SIGNAL CHARACTERISTICS				
Pulse Power	Input to receiver	HP 430B		db
Pulse Length	Input to indicator	Tektronix 514	1	μsec
Pulse repetition frequency	Indicator input	Tektronix 514	1000	pps
Scan rate	Indicator		10	rpm
Peak pulse voltage	Indicator input	Tektronix 514	3	volts
RECEIVER CHARACTERISTICS				
IF center frequency			28.8	megacycles
IF bandpass			2.1	megacycles
Video bandpass			280 cps to 2 mc.	
Video saturation			26.5 v peak output	
IF saturation			8.2 v rms output	
INDICATOR CHARACTERISTICS				
Scan Rate	Indicator		10	rpm
Intensity of trace	Indicator	visually	barely visible in dark room	

APPENDIX II

RECEIVER CHARACTERISTICS

The basis of the search radar testing equipment is Plan Position Indicator CG-55AEW unit of a World War II Model SK-1M Radar Equipment. For practical purposes, all original equipment has been removed with the exception of the sweep and blanking circuit and the indicator sections, with their corresponding power supplies. The receiver employs a commercial IF amplifier, Instruments for Industry Model No. 235, with gain of 38 db at the center frequency of 28.8 megacycles and three db bandwidth of 2.1 megacycles (Figures 12 and 13). The detector consists of a 1N64 diode with cathode follower output (Figures 14 and 16). The video amplifier (Figures 15, 17 and 18) is a two-stage shunt-peaked amplifier with a gain of 40 db and a three db bandwidth of about two megacycles. The overall receiver gain is about 46 db (Figure 19); the receiver gain does not reflect IF and video gains due to attenuation in the detector section and low gain in the detector cathode follower output.

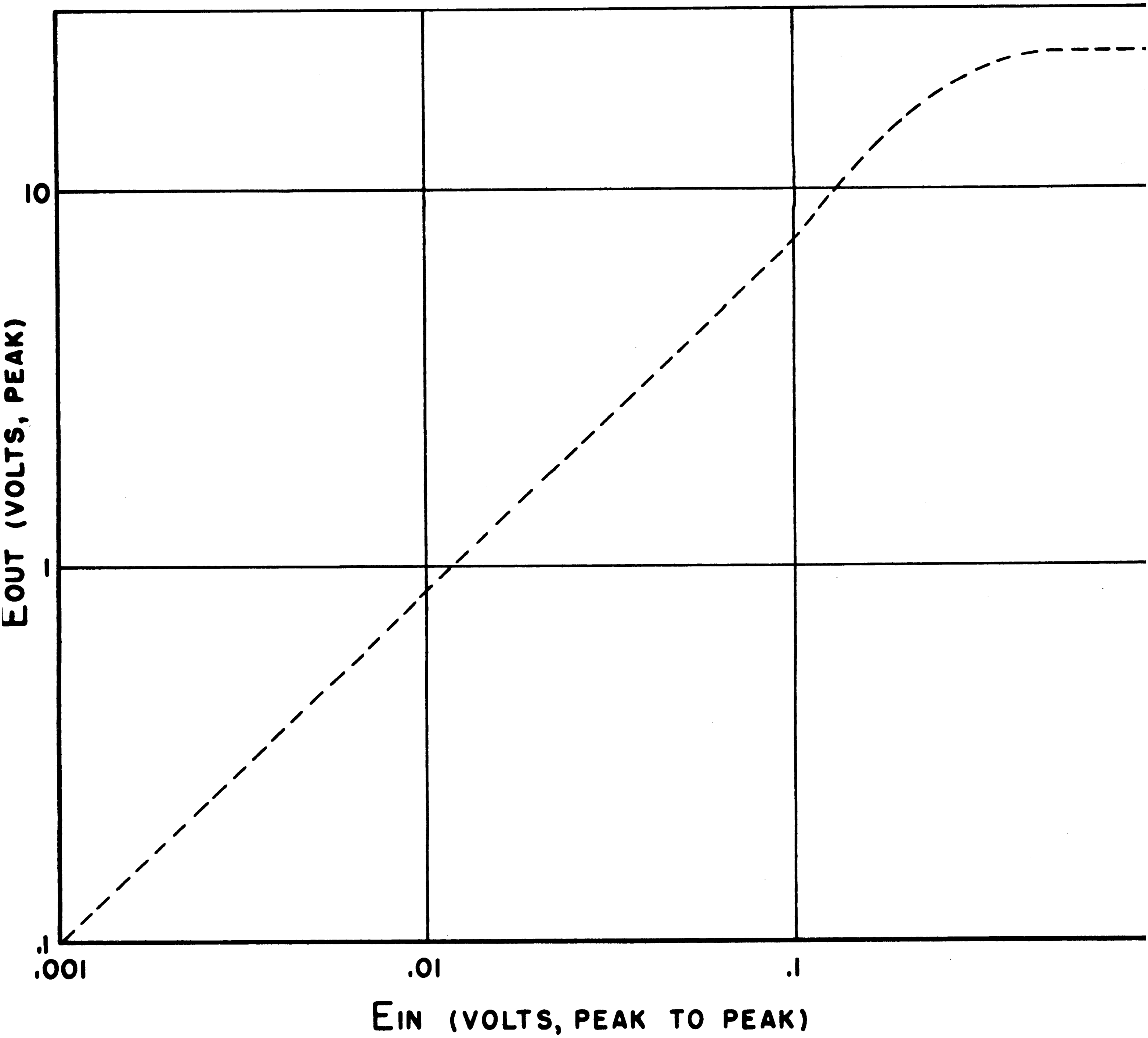

FIG. 12.
IF RESPONSE

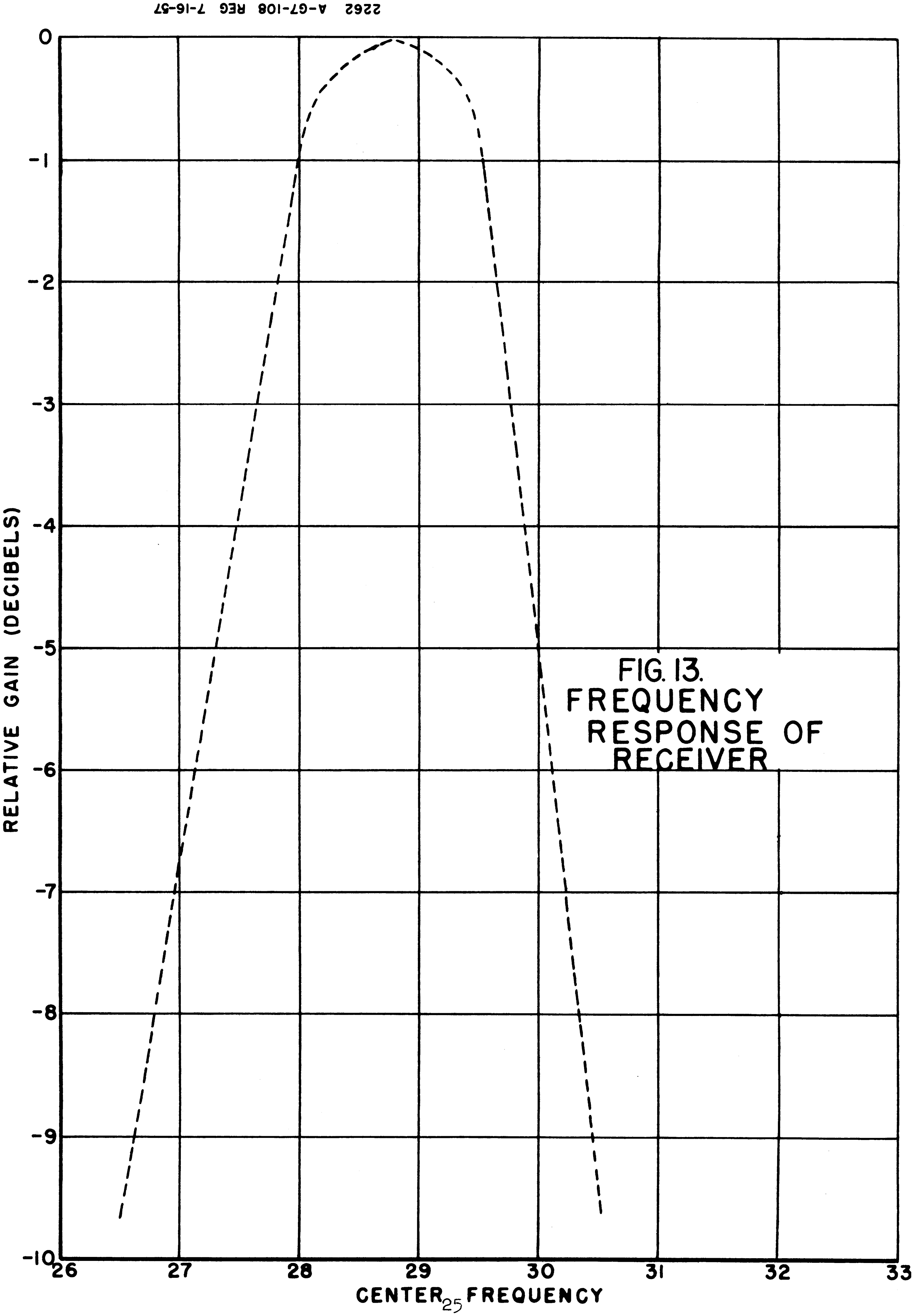

FIG. 13.
FREQUENCY RESPONSE OF RECEIVER

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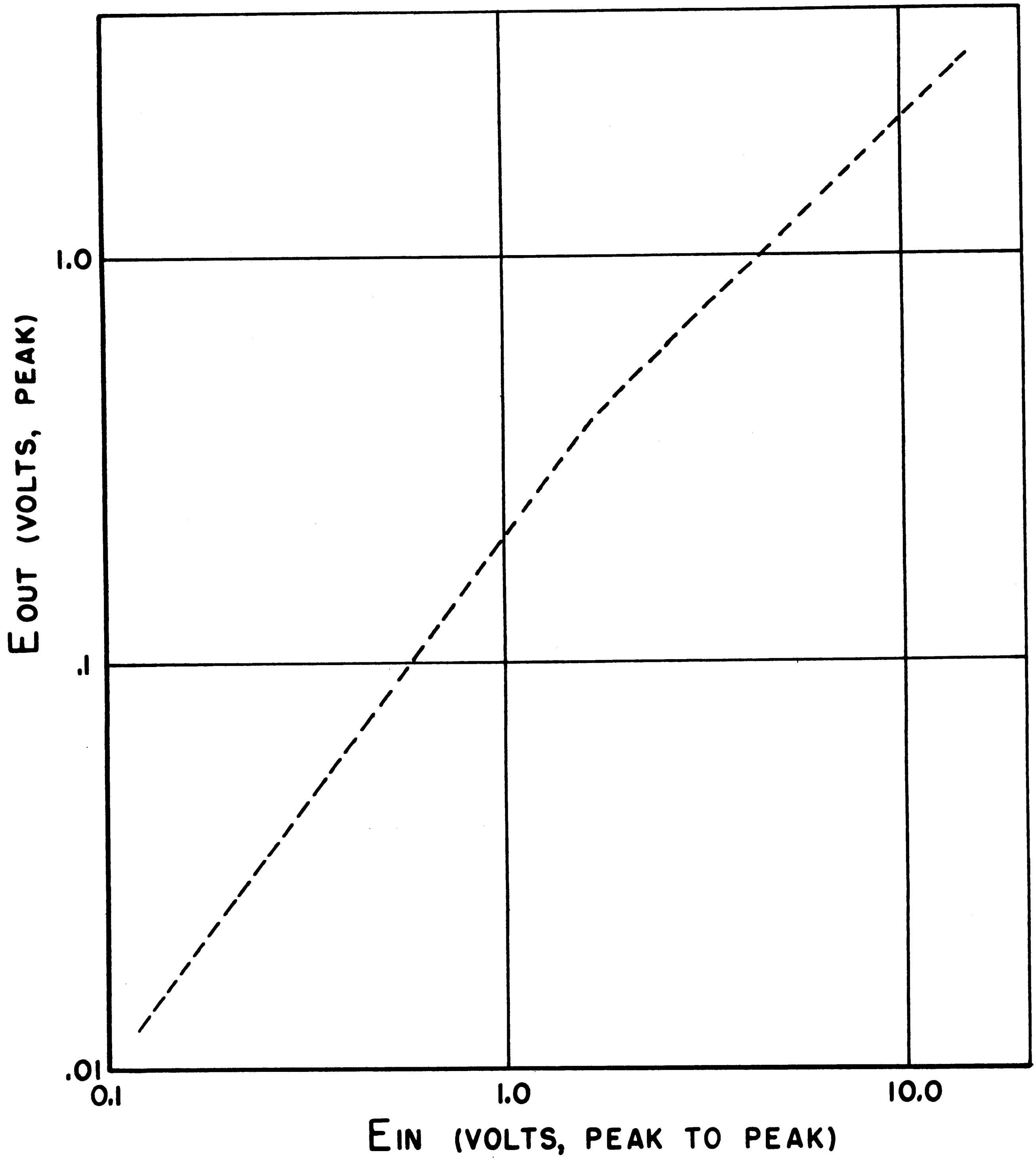

FIG. 14.
DETECTOR RESPONSE

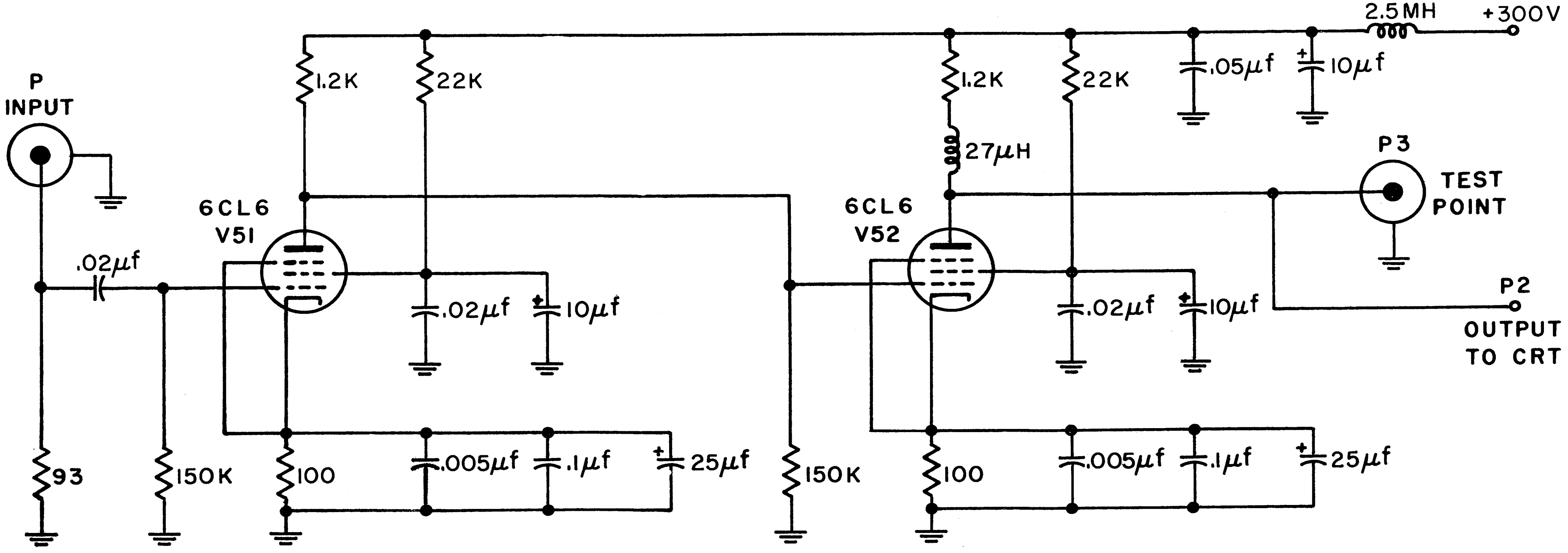

FIG. 15. VIDEO AMPLIFIER

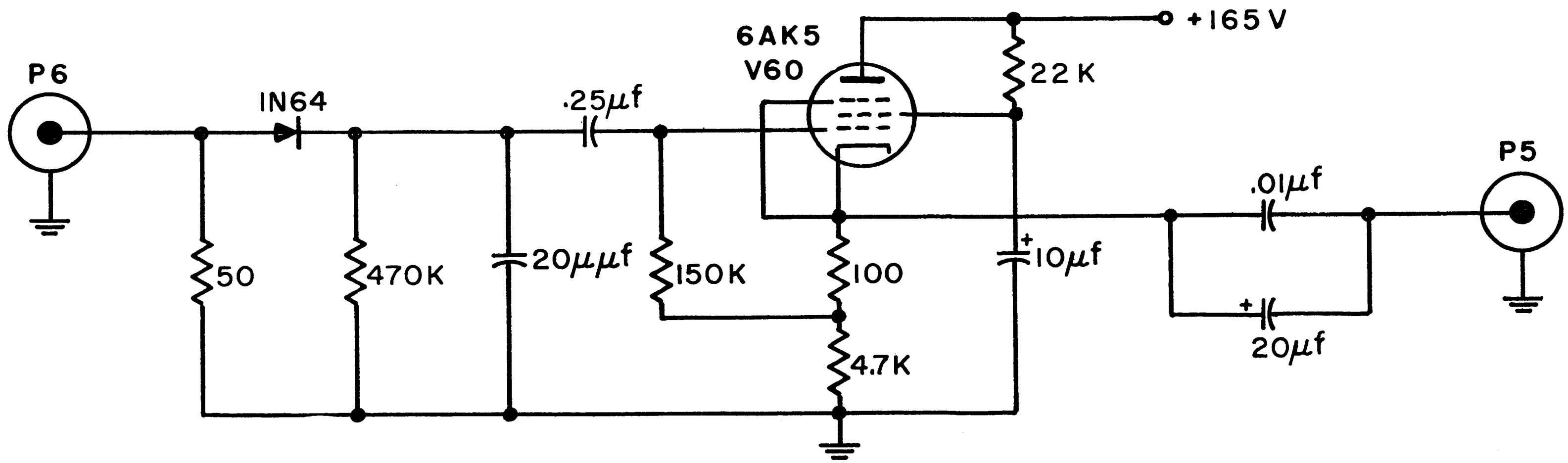

FIG. 16. VIDEO DETECTOR
(WITH CATHODE FOLLOWER OUTPUT)

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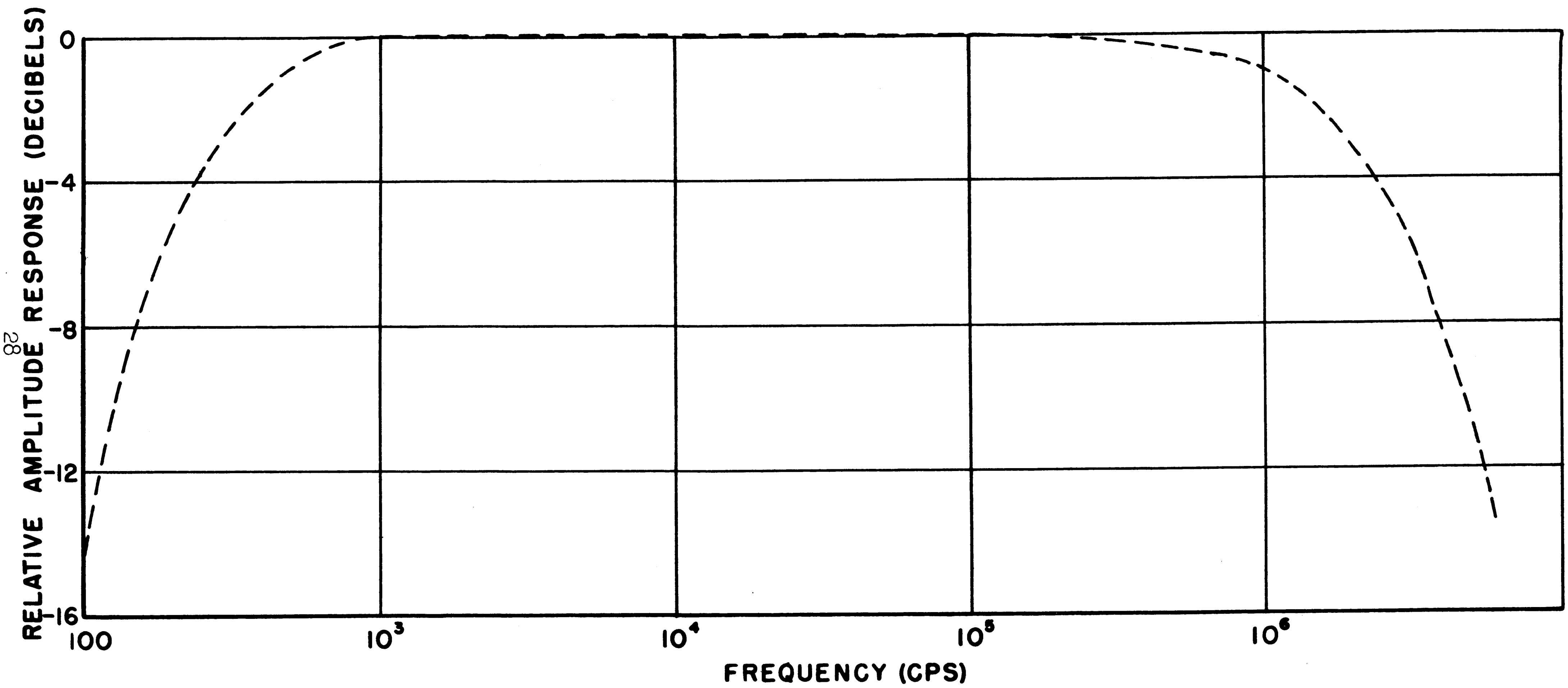

FIG. 17.
FREQUENCY RESPONSE OF VIDEO AMPLIFIER

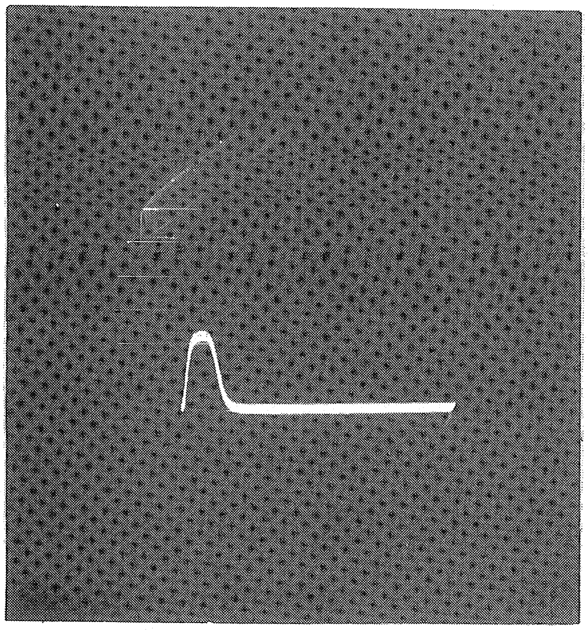

FIG. 18. VIDEO PULSE AT INDICATOR INPUT.

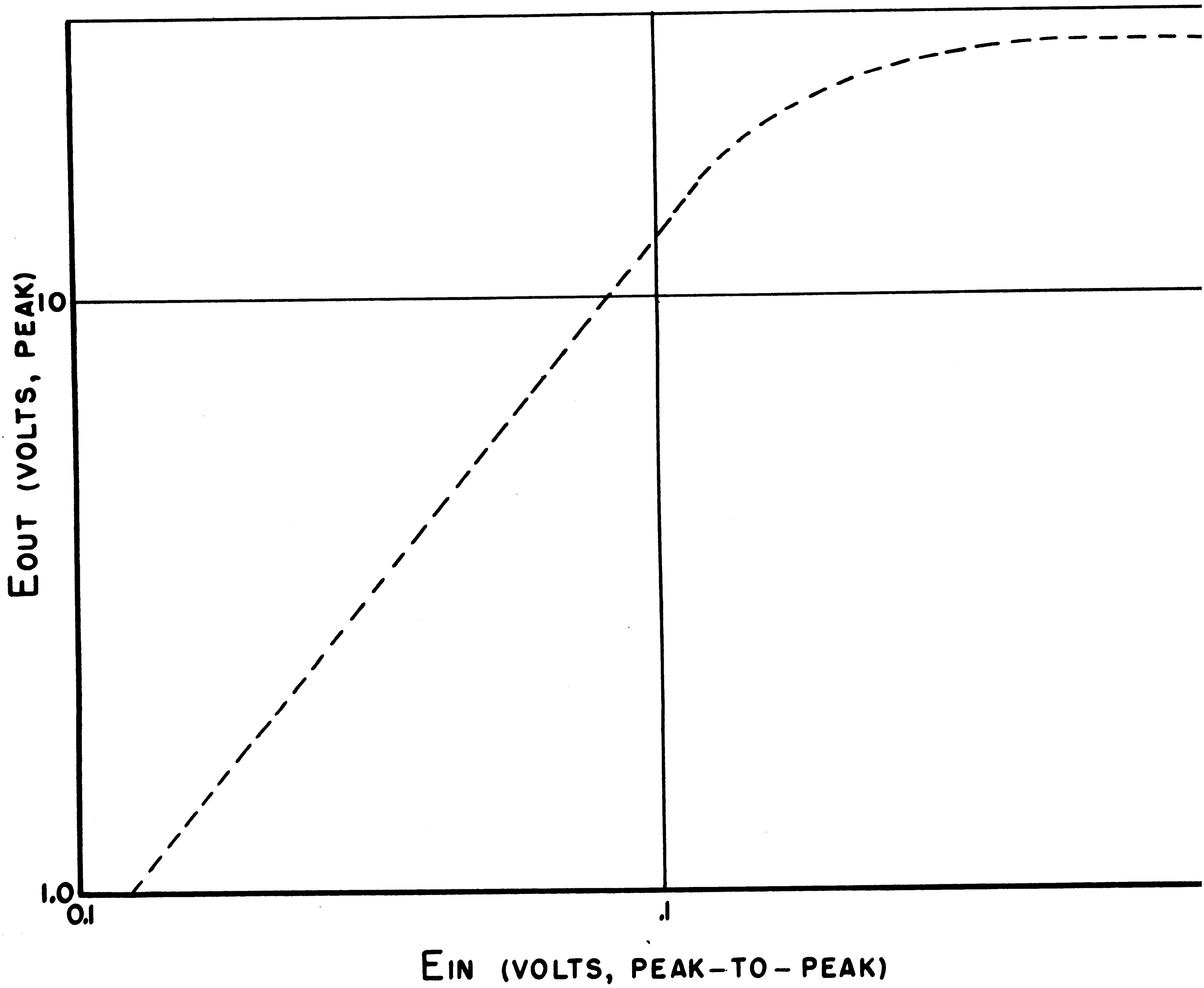

FIG. 19.
RECEIVER RESPONSE

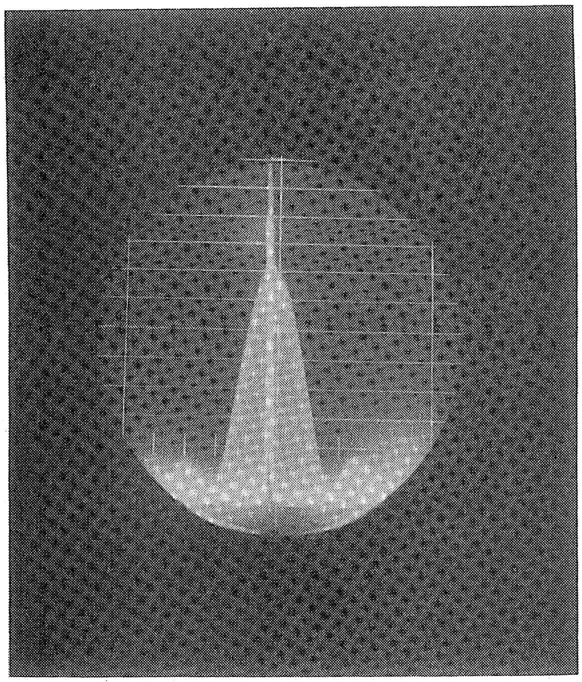

FIG. 20. SPECTRUM OF 30 MC PULSE, FREQUENCY MARKER AT CENTER.

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