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SUBJECT

A Pulse "Phantom" Target For Use

With Radar IFF Equipment

NAVAL RESEARCH LABORATORY

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NAVY DEPARTMENT

A Pulse "Phantom" Target for Use with Radar and IFF Equipment.

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WASHINGTON, D. C.

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ABSTRACT

Theoretical considerations are given to show the possibility of using an oscillator with high R.C. combination in the grid circuit, which will block with a Radar pulse, as an overall test unit to produce artificial pulses for alignment of Radar in the absence of regular echoes. The use of the equipment to determine relative transmitter power and receiver sensitivity is also shown. Experimental results are given for various types of Radar and IFF Equipments.

TABLE OF CONTENTS

APPENDICES

AUTHORIZATION

1. This problem was authorized by BuShips letter S67/36 (485J) serial C-485-799 of 30 January 1942.

REFERENCES

2. (a) NRL Report R-1862 of 17 April 1942

(b) Radiation Laboratory (MIT) Report on 10 cm. Echo box of 31 March 1942.

(c) Radiation Laboratory (MIT) Report 55-1 on Resonant Echo Box of 4 September 1942.

Problem

3. The purpose of the problem was to develop a "Phantom" Target for use with Radar. A solution of this has already been developed, reference (a), and is now in production for the SC type of equipment. The Radiation Laboratory (MIT) has carried the laboratories solution into the ultra high frequency field, reference (b) and (c). The high "Q" type of "Phantom" Target does not give a true return pulse to the Radar receiver, but a decaying CW signal that shows on the indicator scope immediately after the transmitter pulse and remaining for a length of time dependent on the Q and other factors. The desirable "Phantom" Target is one in which a pulse, similar to an echo, appears on the indicator scope at a delayed time that can be fixed or varied.

THEORETICAL CONSIDERATIONS:

4. The output of an oscillator, whose grid RC circuit is a large value, is a series of oscillations (motorboating) which can be made similar to echoes. If the oscillatory circuit of this oscillator is the resonant circuit of a high Q type "Phantom" Target or other resonator, the voltage built up by the Radar pulse will produce a negative bias across the grid resistor due to the rectifying action of the grid. If this bias is large enough the tube will stop oscillating for a length of time depending on the RC combination and the value of bias at which the tube will oscillate. Plate 1.

5. The addition of other RC circuits can be used in combination with the fundamental circuit. The voltage produced by a separate diode, as in the present High Q "Phantom" Target indicator, can be used in series with or as part of the grid circuit of the oscillator. An RC combination in the plate circuit of the oscillator can be used to create a single, several, or a series of pulses after the initial delay time. Plate 2.

6. The use of an attenuator in the input circuit from antenna to resonator can be used to change the delay time but more important is its use to attenuate the oscillator pulses to determine the receiver sensitivity. It is also convenient to vary the plate supply voltage in

addition to the attenuator to get the proper oscillator pulse voltage in different equipment.

7. It would appear that high "Q" resonators are not important for this type of "Phantom" pulse, however for stability, for accuracy of tuning as for a wavemeter, and for large values of induced resonant voltage from the transmitter, it would seem that a fair value should be maintained. The resonator used in the tests had, before the addition of the oscillator, a Q of about two thousand (2000). Probably a resonant line tuned by a variable condenser would be satisfactory.

8. Several methods of tuning indication on the "Phantom" target are possible.

(a) The use of a separate diode and vacuum tube voltmeter may be used as in the High Q type, this method is not too satisfactory as simultaneous determination of Pulse voltage and oscillator voltage is not possible.

(b) A cathode ray oscillograph indicates very well both oscillator operation and tuning to transmitter pulse. In this case the voltages measured can be, if desired, taken from across the grid bias and thus eliminate the diode rectifier tube. It is not necessary to use a sweep circuit, since the pulsing oscillator of low voltage is operating at a faster rate than the Radar pulse at higher voltage. The result shows up as a short bright line for the oscillator and a long dim line for the Radar pulse.

(c) An electron-ray tube will operate in a manner similar to that of the cathode ray tube, except that quantitative measurements would be hard to make. The use of this tube has the advantage of saving equipment and space.

(d) Another method of tuning is possible using the Radar receiver for the indicator. This is not a direct method but it is accurate. It is based on the fact that the more nearly the resonator is tuned to the transmitter, the longer is the pulse delay. In operation the oscillator is tuned to the receiver, as indicated on the indicator unit, and then tuned further in the direction of more pulse delay. The receiver is retuned and the process repeated as many times as necessary to get the maximum delay.

9. Transmitter power can be indicated by one of two methods:

(a) A cathode ray tube or vacuum tube voltmeter may be used as in the High Q "Phantom" Target.

(b) The delay time, as indicated on the indicator unit, is a function of the transmitter power, consequently for any given standard conditions this delay time may be used for comparison. This delay time is not directly proportional to peak power but to the log of the square root of peak power. Pulse length is also a factor if the Q of the resonator is high. An idea of the relative transmitter power can, however, be obtained by this method. Further work is being done to determine how well the relative power can be determined. Appendix A.

EXPERIMENTAL RESULTS

10. This type of "Phantom" Target has been tried on several types of equipment.

(a) XAR and SC Equipment. In conjunction with the XAR and SC, the pulse "Phantom" Target could be used satisfactorily for an overall test, tuning of receiver to the transmitter frequency, to indicate roughly transmitter power and receiver sensitivity, and as a continuous monitor without interfering with the normal operation. For best operation it was essential that the oscillator output did not saturate the receiver. The shielding of the Phantom Target was not too good but with low plate voltage, the attenuator could be used fairly satisfactorily. For precise relative transmitter power, it is important that C in the grid time delay circuit be small. A check of the final power formulae in Appendix A was made experimentally. The power was changed approximately one half, R was two and one half (2.5) megohms and C was one hundred (100) micromicrofarads, which should give a difference of time delay of one hundred seventy-five (175) microseconds. The actual results were twelve (12) microseconds. With the value of C about three hundred (300) micromicrofarads, there was practically no change in delay time. Further work needs to be done to determine the best compromise value of C and the accuracy of relative power measurements and also to see if a separate diode rectifier as on Plate 2 would improve the results.

(b) British ASV Equipment. This equipment was set up in a shielded booth with a dummy load on the transmitter. The pulse "Phantom" Target operated fairly satisfactorily, though not as well as on the XAR, due to the instability of frequency and power of the Radar transmitter and a consequent instability of the pulses appearing on the indicator unit.

(c) F. C. Equipment. No pulse "Phantom" Target has been built for the FC, however, it is believed that the present LW equipment could be modified to operate on this same principle to give a continuous monitoring check of the Radar Equipment.

(d) S. G. Equipment. An oscillator using a GL446, built by the Centimeter Research Section, was tried on the SG Equipment. Some difficulty was encountered in reducing the oscillator power to a point where it would not saturate the receiver, however, enough results were obtained to show the feasibility of the method. Due to the ruggedness of the antenna system it would appear satisfactory to operate the "Phantom" Target out of the wave guide near the transmitter. If the overall system needs to be tested, a remote tuning control would have to be used to control the pulse oscillator. Further work is being carried on to improve this model.

(e) B. L. Equipment. The same unit used on the lower frequency Radar was used on this equipment. Due to the lower power, different values of RC time constant would be preferable, however, good results were obtained. The results obtained were similar to those obtained with the XAR and SC. In this case, because of the reliability of the antenna system, it may be preferable to operate the oscillator directly from the transmitter rather than from a "pick-up" antenna. The High Q "Phantom" Target will not operate with this equipment because of the low power.

CONCLUSIONS

11. From the tests made the following conclusions can be drawn:

(a) That the pulse type "Phantom" Target can be used satisfactorily to produce simulated echoes for overall test of Radar and IFF equipment.

(b) That a rough determination of relative transmitter power can be made.

(c) That a somewhat more than rough determination of receiver sensitivity can be made.

(d) That continuous monitoring of Radar operation can be had without interfering with the normal operation.

(e) That the equipment can be used as an accurate frequency meter as in the High Q type.

(f) That the equipment, though slightly more complicated, is more positive in results than the High Q type of "Phantom" Target.

(g) That Radar equipments, in conjunction with a dummy antenna and this equipment, could be kept in secret operation until its use was needed.

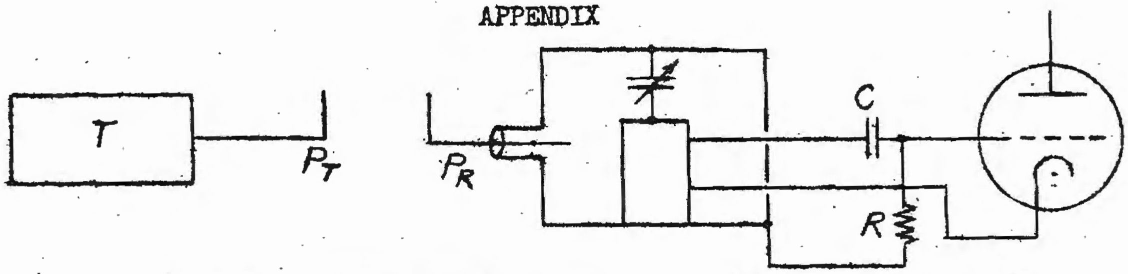
RECOMMENDATIONS

12. It is recommended that:

(a) This pulse type "Phantom" Target be furnished the fleet for all Radar and IFF equipment except where the model OAA and Model LW are used.

(b) Test be made to determine the feasibility of converting the model LW to this type of operation.

APPENDIX



Let v = Maximum negative grid bias voltage at which oscillator will oscillate

V = DC voltage of rectified pulse

E_1 = Pulse voltage at grid

t = delay time due to RC

$v = Ve^{-t/RC}$ or $V/v = e^{t/RC}$

then $\log_e V/v = t/RC$ or $t = RC \log_e V/v$

$V = kE_1$ where k = constant of rectification

then $t = RC \log_e kE_1/v$

The value of E_1 is dependent on the Q of the resonator circuit, t_p or pulse length, and E_o or rf voltage that would be built up if t_p was long.

The build up of rf in a resonant circuit is

$$E_o/E_1 = 1-e^{-W_o t_p/2Q} \quad \text{or} \quad E_1 = \frac{E_o}{1-e^{-W_o t_p/2Q}}$$

$$\text{then } t = RC \log_e \frac{\dfrac{kE_o}{1-e^{-W_o t_p/2Q}}}{v}$$

but $E_o^2 = k_1 P_R = k_1 a P_T$ where a = attenuation between antennas and k_1 = constant depending on coupling to oscillator etc.

$$\text{so } t = RC \log_e \frac{k' \sqrt{P_T}}{1-e^{-W_o t_p/2Q}}$$

where $K' = k\sqrt{k_1 a/v}$

if Q and frequency constant, let $k'' = W_o/2Q$

so $t/RC = \log_e \dfrac{k'\sqrt{P_T}}{1-e^{-k''t_p}}$

and $e^{t/RC} = \dfrac{k'\sqrt{P_T}}{1-e^{-k''t_p}}$

For relative power

$$e^{(t_1 - t_2)/RC} = \sqrt{\frac{P_{T_1}}{P_{T_2}}} \times \frac{1-e^{-k''t_{p2}}}{1-e^{-k''t_{p1}}}$$

If pulse length does not change greatly, the second part of the right hand side is approximately one. It is equal to one if k" is large, which is true if Q is not great.

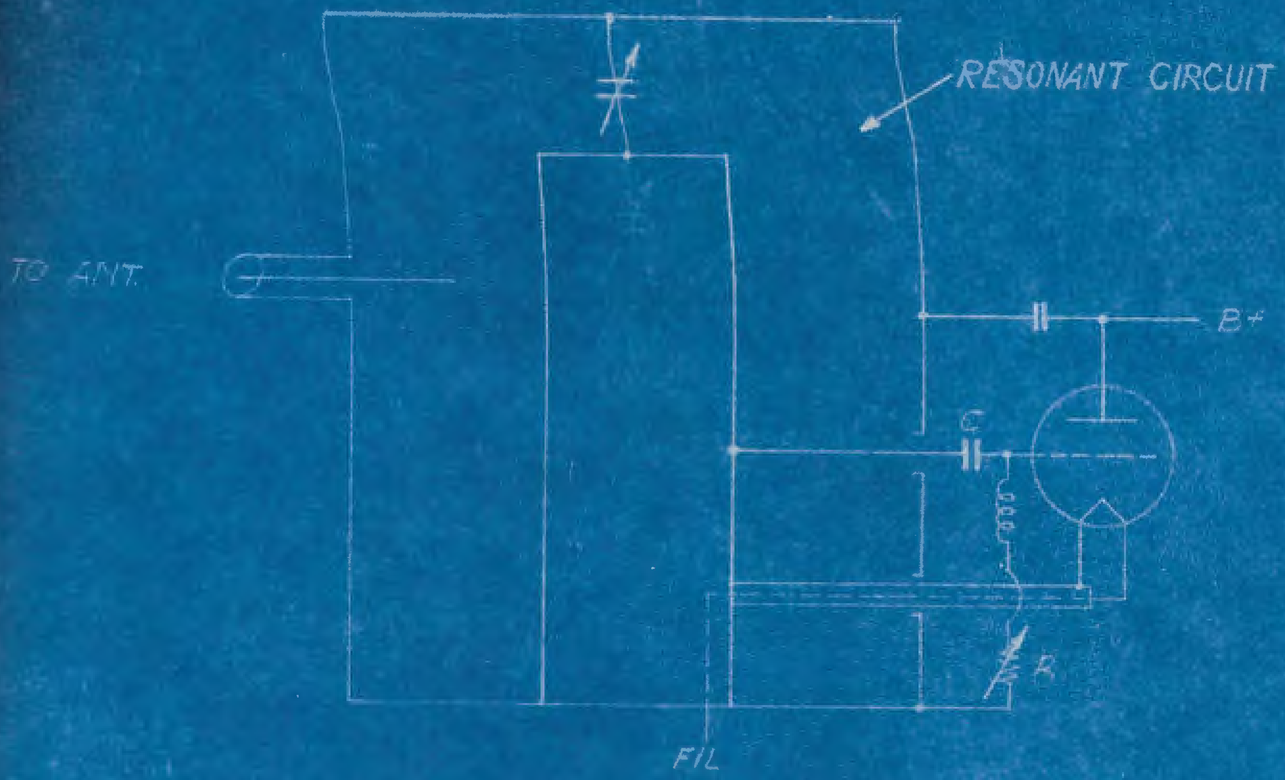
so $e^{(t_1 - t_2)/RC} = \sqrt{\dfrac{P_{T_1}}{P_{T_2}}}$

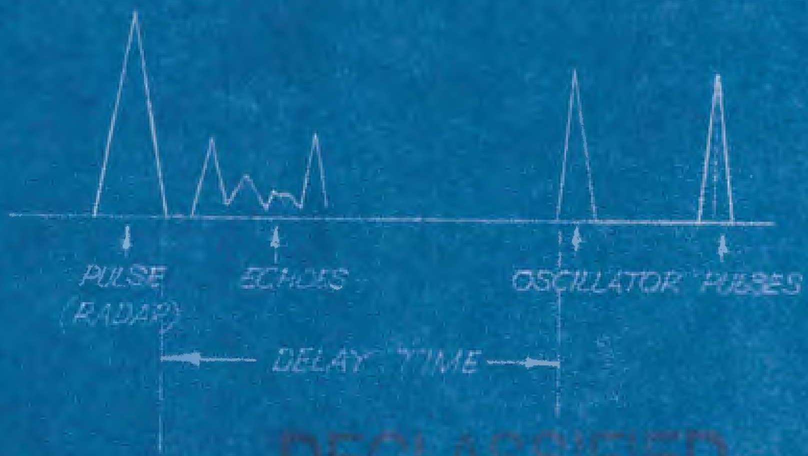
or $P_{T_2} = \left(\dfrac{e^{(t_1 - t_2)/RC}}{P_{T_1}}\right)^2$

also $(t_1 - t_2)/RC = \log_e \sqrt{\dfrac{P_{T_1}}{P_{T_2}}}$

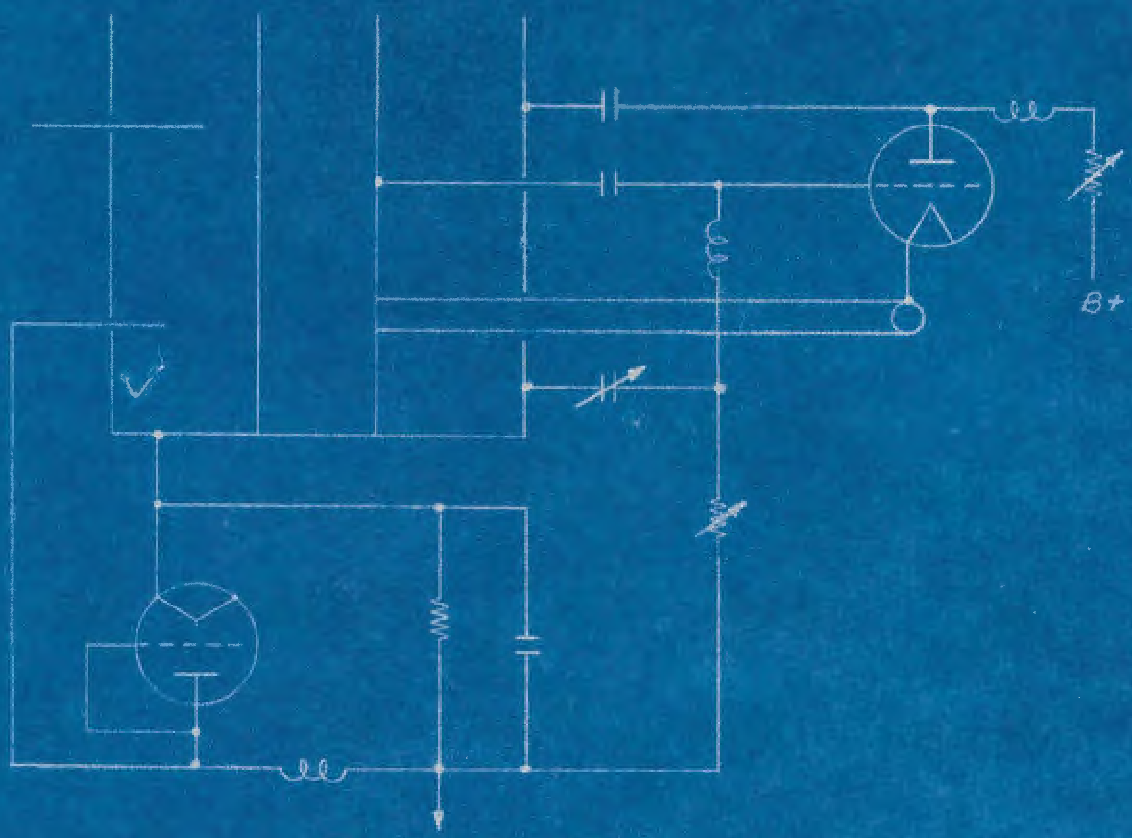
Note: This is true provided C is sufficiently small.

PULSE "PHANTOM" TARGET





VARIATIONS IN PULSE "PHANTOM" TARGET



ATTENUATOR TO ANT.

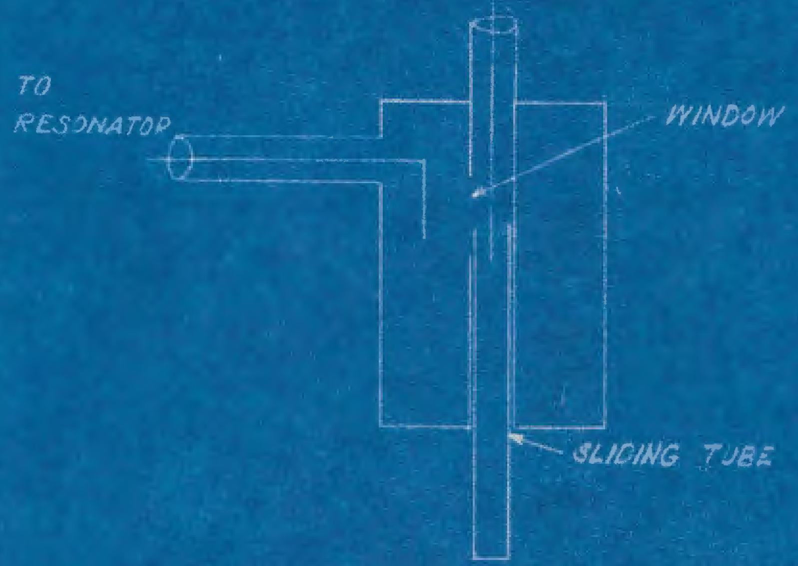


PLATE 2

150-240 MC PULSE "PHANTOM" TARGET

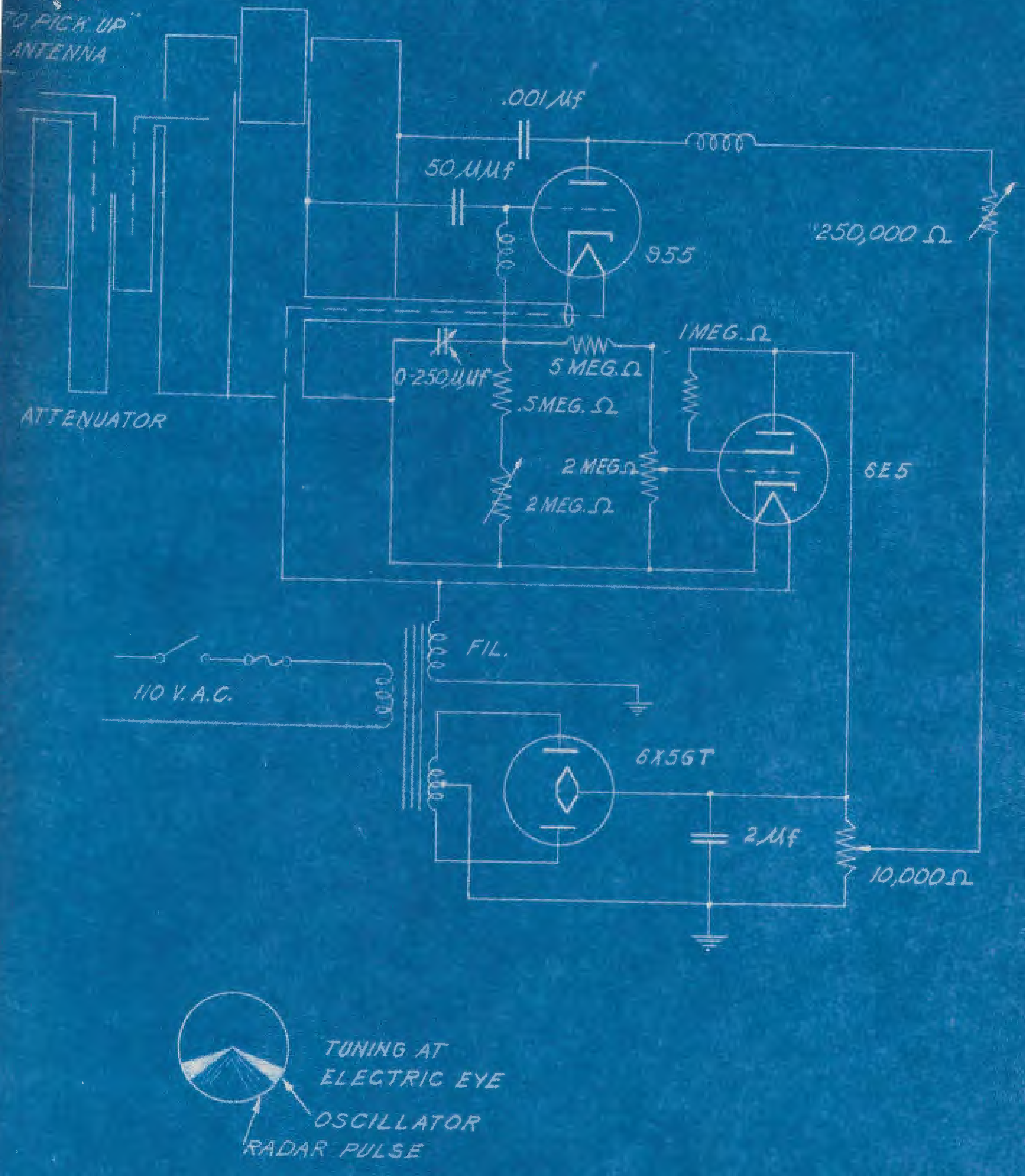


PLATE 3

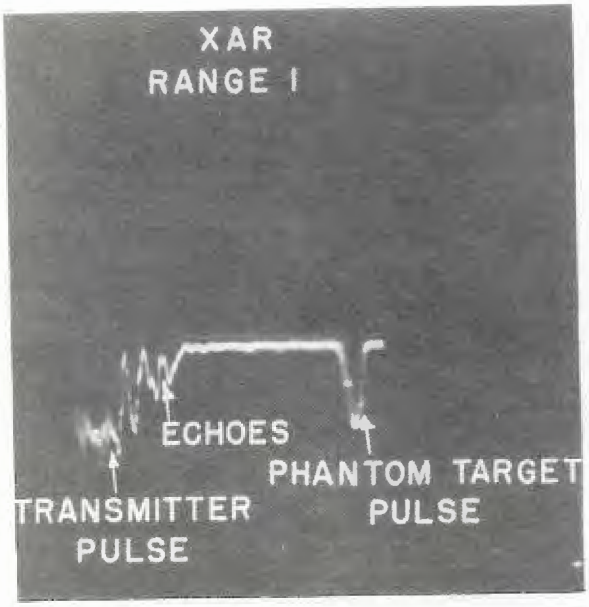


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PLATE 4

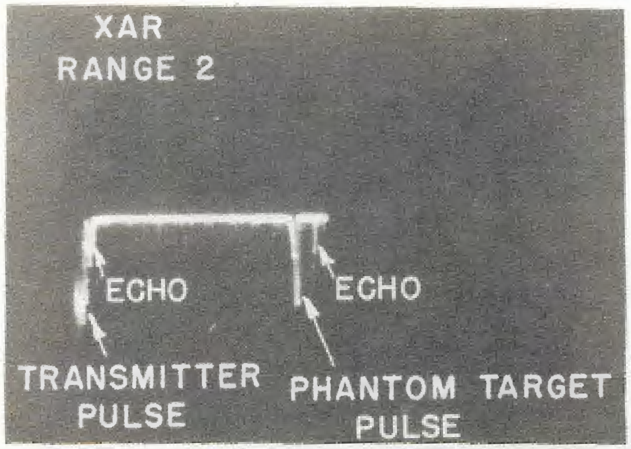

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PLATE 5