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REPORT ON THE DEVELOPMENT OF THE AN/UPT-T3 TRAINING EQUIPMENT

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NRL Problem S550R-S

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ABSTRACT

The AN/UPT-T3 is a training jammer designed to simulate electronic jamming on S-band radars. The equipment delivers an RF signal to a small antenna which is placed in the beam of and pointed at the radar antenna. It should be used only in the immediate vicinity of the victim radar. Modulation by several sine wave frequencies or by noise may be applied to the tunable RF oscillator to simulate the various types of countermeasures. The device may be used in the study of the effect of electronic jamming on contemporary S-band radars, such as the SG and the Mark 8. It may also be employed to acquaint radar operators with these countermeasures and to train them in the technique of minimizing the effects of such jamming. This report describes the design, operation, and performance of this equipment.

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TABLES AND PLATES

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5	BuShips, 938
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1	ORI
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INTRODUCTION

1. The subject problem, requests development of a low power S-band training jammer, consisting of an S-band oscillator, a modulator, an RF attenuator, and several antennas. It requests that the equipment be made sufficiently powerful to operate at a moderate distance from the victim radar, such as from ship to ship, as well as at close range, as in training schools or aboard ship. A modification of the problem, written when it became apparent that additional work would be necessary to provide an equipment with sufficient power to work at a distance, requires operation only at close range. The requirements for pulse and frequency modulations are also waived. Overmodulation with sine waves is requested as a substitute for pulse, to simulate railings.

2. The function of the equipment is to produce an effect on an S-band radar similar to that which would be caused by tactical electronic jamming by the enemy. The purposes are to facilitate study of the effect of electronic jamming on such radars, to accustom operators to these countermeasures, and to train them in the technique of operating in the presence of such difficulties.

PRELIMINARY INVESTIGATIONS

3. A water cooled lighthouse tube oscillator with a power output of about 1/2 watt was available at the time the problem was written. As it was known that this triode can be amplitude modulated, it was used in the first work on S-band jamming at NRL. Provision was made for operating CW, and for modulating 100% with noise or sine wave (10 Kc. to 350 kc.).

4. The first tests were run against an ASG radar, with antenna separations of about 200 yards. Although they were successful, these tests and information extrapolated from data taken at lower frequencies indicated that more power would be necessary for self screening even small ships at ranges less than 12,000 yards.

5. A push-pull lighthouse tube oscillator having twice the power of the circuit used in the above mentioned tests was proposed for use with a higher gain antenna. However, since several phases of the push-pull circuit development were not completed at that time, it was decided to expedite delivery of a training jammer by waiving the requirement for ship to ship operation.

[redacted]

6. Design of a low power triode oscillator for this application and development of the modulator circuits around an existing oscillator were begun. A pilot model was constructed at NRL with its modulator giving 60 cycle, 10 kc., 50 kc., 200 kc., or 350 kc, sine wave, or noise, at 50 percent or 100 percent modulation. Provision was also made for running CW, overmodulating with the sine waves, and for superimposing 60 cycles on the sine wave and noise modulations. It was demonstrated that the pilot model could be operated successfully against contemporary S-band radars.

GENERAL DESCRIPTION OF THE AN/UPT-T3

7. A pre-production model of the AN/UPT-T3, using the oscillator designed expressly for service in this equipment was manufactured by Harvey Radio Laboratories, Inc., from the pilot model described above. It consists of the generator unit, an antenna, 25 feet of RG-8/U cable, ten feet of line cord, and carrying cases for the above. The equipment, less carrying cases, is shown as connected for use in Plate 1. (The head set shown in this plate will not be furnished with the equipment.) The generator unit alone, with dust cover removed, is shown in Plate 2.

8. The equipment operates from the 110 volt, 60 cycle line and consumes 150 watts. The size of the generator unit is 12" x 12" x 18", and its weight 67 pounds. The characteristics and performance of the pre-production model closely approximate those of the final production model.

9. The main controls are: (See Plates 1 and 5)

(a) (S-2) The four position modulation selecting switch by which CW, noise, sine wave, or overmodulated sine wave operation may be selected.

(b) (S-5) The 60 cycle modulation switch.

(c) (S-1) The four position sine wave frequency switch, for selecting frequencies of 10 kc., 50 kc., 200 kc., or 350 kc.

(d) (S-3) The two position percentage modulation switch for choosing between 50 percent and 100 percent modulation.

(e) (S-4) The oscillator meter circuit switch, through which the meter may be caused to read grid current, plate current, or plate voltage.

(f) (S-6 and S-7) The two power circuit switches.

(g) (A) The oscillator tuning control.

[redacted]

(h) (B) The attenuator and output connector.

(i) (R-34 and J-1) The listen through device gain control and headset jack. A name plate will be furnished on the final production model, showing the function of each control.

OSCILLATOR

10. From the early investigations it was concluded that for antenna separations under 100 feet, powers of the order of 1/2 milliwatt at an LZ antenna (gain about 12 db.) are adequate. To deliver this power through seventy five feet of RG-8/U cable, the oscillator should have an output of about 50 milliwatts. It was recognized that the equipment should be sturdy, stable in power and frequency, simple to operate, small, and light. Since the characteristics of the two cavity triode circuit recommended it on all of these points, it was selected for use in this equipment.

11. The cathode-grid line is "folded back" over the plate-grid line, as may be seen in the enclosed drawing of the RF circuit (plate 3). Both cavities are tuned with pistons activated by a screw drive mechanism and the pitches of the drive screws are so related as to make the two pistons track over the tuning range of the circuit. A sliding clutch arrangment, released by pulling out the tuning knob, permits trimming the cathode piston adjustment with respect to that of the plate. A series of interlocking washers between the two movements limits the amount of possible reset displacement and thereby prevents the possibility of operator confusion as a result of inadvertently detuning the cathode circuit a considerable amount.

12. From the drawing of the RF circuit shown in Plate 3 it may be seen that the cathode piston is made up of two sections insulated from each other. Each section contacts one conductor of the coaxial line in which it appears. Capacity provides low RF impedance across the back of the piston, while permitting the DC insulation necessary for developing bias. The plate circuit is tuned by a plunger with broad band RF chokes at its inner circumference. The chokes serve the same purpose as the capacity in the cathode piston, and also permit operation of the piston in a region closer to the tube than would be possible with the capacity type. To prevent the cavity behind the plate piston from reflecting undesirable impedances through the chokes, a traveling baffle plate is provided. This plate divides the portion of the cavity behind the piston into two sections, and prevents unfavorable reflections which would otherwise result. Feedback coupling is effected by means of a loop coupled tightly to the plate cavity, and terminated in a capacity coupling to the cathode circuit. The degree of coupling thus introduced proves adequate for the type 2C40 tube, and does not require adjustment. The output probe, which extends into the plate cavity, is not shown in the enclosed drawing.

[redacted]

13. The output of an average tube in this circuit is about 50 milliwatts at 9 centimeters, increasing to 100-150 milliwatts at the lower frequencies. The output level for a fixed frequency varies with the input to the oscillator from the unregulated 300 volt power supply. These variations have not been noticeable in any of the operational tests to which the equipment has been subjected.

14. Frequently a new tube may be substituted in the circuit without requiring any adjustment. Occasionally some trimming of the semi-permanent adjustments, such as the input voltage and the piston positionings, is necessary when tubes are changed.

ATTENUATOR

15. Since the training jammer is tightly coupled to the radar in actual use, an attenuator is needed in the RF circuit to facilitate simulation of marginal jamming. It is not necessary that the attenuator be linear, or even that it be calibrated. However, it should provide continuous adjustment of attenuation, and have low minimum insertion loss.

16. A capacity type attenuator is used with this equipment. It consists of a fixed and a moveable section of the central conductor of a coaxial line. The one section is moved by means of a screw adjustment on the front panel, and may be adjusted to actually contact the fixed portion of the central conductor. The attenuation increases from a minimum value as the moveable probe is withdrawn from this position.

17. The discontinuity produced in the line when the moveable probe is withdrawn gives rise to reflections. A resistive disc, inserted in the line between the oscillator and the attenuator, damps undesirable reflections to the point where serious effect on the performance of the oscillator is avoided. This produces a minimum insertion loss for the attenuator of about 3 db.

18. The attenuator, as provided on the equipment, permits adjusting the output from about half the output power of the oscillator to a level which causes essentially no disturbance on the victim radar screen. At no adjustment of the attenuator is the oscillation of the RF generator seriously impaired.

ANTENNA

19. Waiving the requirement for remote operation made it possible to perform all necessary functions with one antenna. Since the available RF power is adequate, even with low gain antennas, an antenna beam sufficiently wide to allow inaccuracies in pointing is permissible. Thus a small, rugged, wide-band radiator with a wide beam width in both polarizations was needed for the equipment.

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20. To meet these requirements, an S-band horn, 7" x 8" x 10", is provided. A 1/8" polystyrene window is clamped across the aperture and sealed with a rubber gasket. A probe feed, operating into a type N fitting provides the necessary coax to wave guide transition. A block containing four tapped holes is secured to the waveguide to allow attachment of any mounting device which may be desired.

21. The standing wave ratio (voltage) of the antenna varies from 1.0 to 2.0 across the band from nine to eleven centimeters. The highest reflection encountered does not interfere with the operation of the oscillator, even when connected directly to it, and ordinarily at least four db. of cable will isolate the two components. The amount of power reflected is less than 15% in all cases.

22. The orientation of the antenna is changed to effect different polarizations. Its beam width is approximately 30 degrees for both polarizations, and its gain about 10 db.

MODULATOR

23. The types of modulation requested are noise and high frequency sine wave, with provision for superimposing 60 cycle sine wave on either. It should be possible to operate at 50 percent or 100 percent modulation with any combination. The problem (as modified) also requests overmodulation with the high frequency sine waves.

24. A Hartley oscillator is used as a sine wave generator. A four position switch (S-1) selects the proper resonant circuit for 10 kc., 50 kc., 200 kc., or 350 kc. oscillation. With a VR-150 tube used to regulate the plate and screen voltages, the output remains essentially constant for these frequencies. The oscillator operates into a 6V6 cathode follower. A semi-permanent adjustment of the percentage sine wave modulation is provided in the potentiometer appearing as a portion of the output circuit of this cathode follower.

25. Noise is generated by an 884 gas tube, and amplified by a 6V6. The coils, L-4 and L-3, in the plate circuits of the 884 and 6V6 respectively are used to increase the high frequency output of the circuit by tending to neutralize the shunt capacity in the tubes and other parts of the circuit. The band width of this noise generator is about 1.5 megacycles. Percentage modulation is adjusted by means of a potentiometer in the plate circuit of the 6V6 amplifier.

26. The RF oscillator is plate modulated by two parallel 6V6 tubes. A switch (S-2) selects excitation for the modulator from one of the two generators mentioned, or removes all excitation, permitting the RF oscillator to operate CW. Over modulation with sine waves is effected by driving the modulator with the full sine wave output of the cathode follower mentioned in paragraph 24.

[redacted]

27. The secondary of the 60 cycle modulation transformer is connected in series with the DC plate voltage circuit of the RF oscillator. Excitation of the primary of this transformer from the power source thus introduces the required 60 cycle modulation. A variable resistor in the primary of this transformer provides adjustment of the percentage 60 cycle modulation, and a switch (S-5) in the same circuit is used to turn it on or off.

28. Sine wave and noise excitations for the modulator appear across a tapped resistor. The percentage modulation switch (S-3) in the 100 percent position connects the grids of the modulator across the complete resistance, and in the 50 percent position across just half of it. Another section of the same switch changes the voltage across the primary of the 60 cycle modulation transformer.

29. Signals from the victim radar picked up in the AN/UPT-T3 antenna appear in the plate-grid cavity of the RF oscillator. The feed back circuit couples these signals to the cathode-grid cavity of the oscillator, and the pulses of the radar appear as detected signals on the grid of the oscillator tube. The amplitude of these signals increases as the oscillator is tuned to the frequency of the victim radar. The grid circuit of this oscillator is used to excite a two stage audio amplifier operating into a headset. It is possible to set the jammer frequency to approximately that of the radar by tuning for maximum strength signal in the phones, since the tuning circuit for this listen through receiver is the plate circuit of the oscillator itself.

30. With the four controls it is possible to apply 50 percent, 100 percent or about 500 percent modulation by 10 kc., 50 kc., 200 kc., or 350 kc. sine wave, 50 percent or 100 percent noise modulation, or 60 cycle modulation combined with any of the other types mentioned except overmodulation. It is also possible, by means of the setting-on device, to adjust the frequency of the jammer to approximately that of the victim radar. A complete circuit diagram of the modulator, power supplies, and listen through device is shown in Plate 5.

OPERATION

31. The AN/UPT-T3 equipment is connected for use as shown in Plate 1. The antenna should be mounted in the beam of the victim radar antenna, and pointed at the latter. The transmitter operates satisfactorily if less than seventy five feet of RG-8/U cable is used to connect to its antenna, and the separation between antennas is less than 100 feet. The effects of the equipment on the A scope of an SF radar are shown in figures 1, 2, and 3 of Plate 4. The modulations used are 100 percent noise, 100 percent 350 kc. sine wave, and overmodulated 350 kc. sine wave respectively. Figure four shows the trace in the absence of jamming. The radar gain control was left in the same position for all of these photographs.

[redacted]

When it is desired to remove the jamming effect, it has been found advisable to detune the jamming oscillator or disconnect it from the antenna, rather than shut down the power supply. The slight drift in frequency immediately following the application of plate voltage is thus avoided.

33. The pre-production model has been used under field conditions at NRL against the SE, SG, and Mark 8 radars. In all tests over fifty feet of cable was used between the transmitter and the antenna of the AN/UPT-T3, and its antenna was mounted 100 feet from that of the victim radar. All except the strongest signals were obscured in all cases.

CONCLUSIONS

34. The AN/UPT-T3 adequately meets the requirements of the subject problem as modified, in respect to modulation, tuning range, power output, ease of operation, size, and overall performance.

35. Preliminary tests indicate that satisfactory performance against Navy S-band radars may be expected with a minimum of installation and operation difficulty.

RECOMMENDATIONS

36.

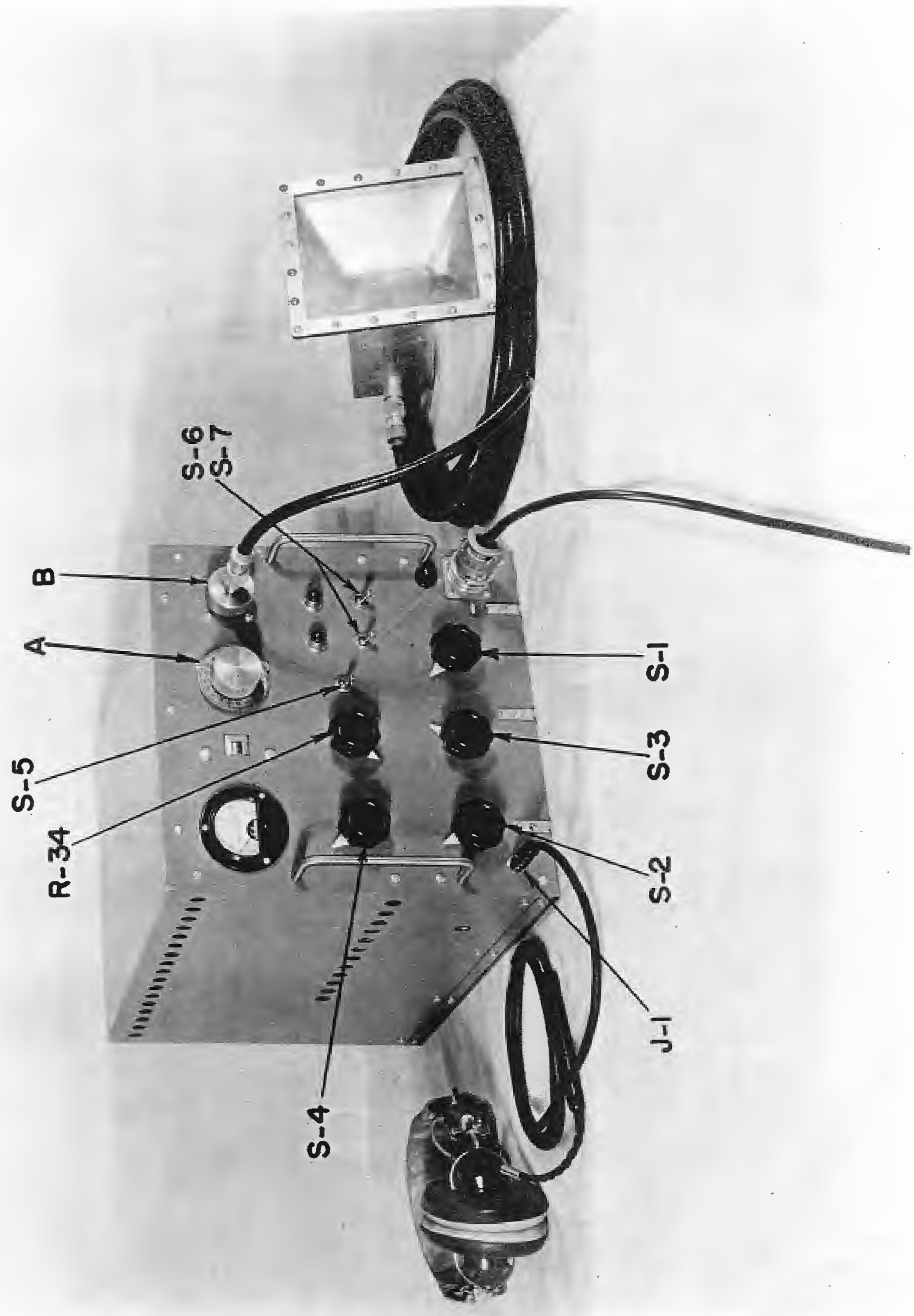
The AN/UPT-T3 is recommended for use in the immediate vicinity of the victim radar only. The RF power is not adequate for operation over long distances.

REFERENCE

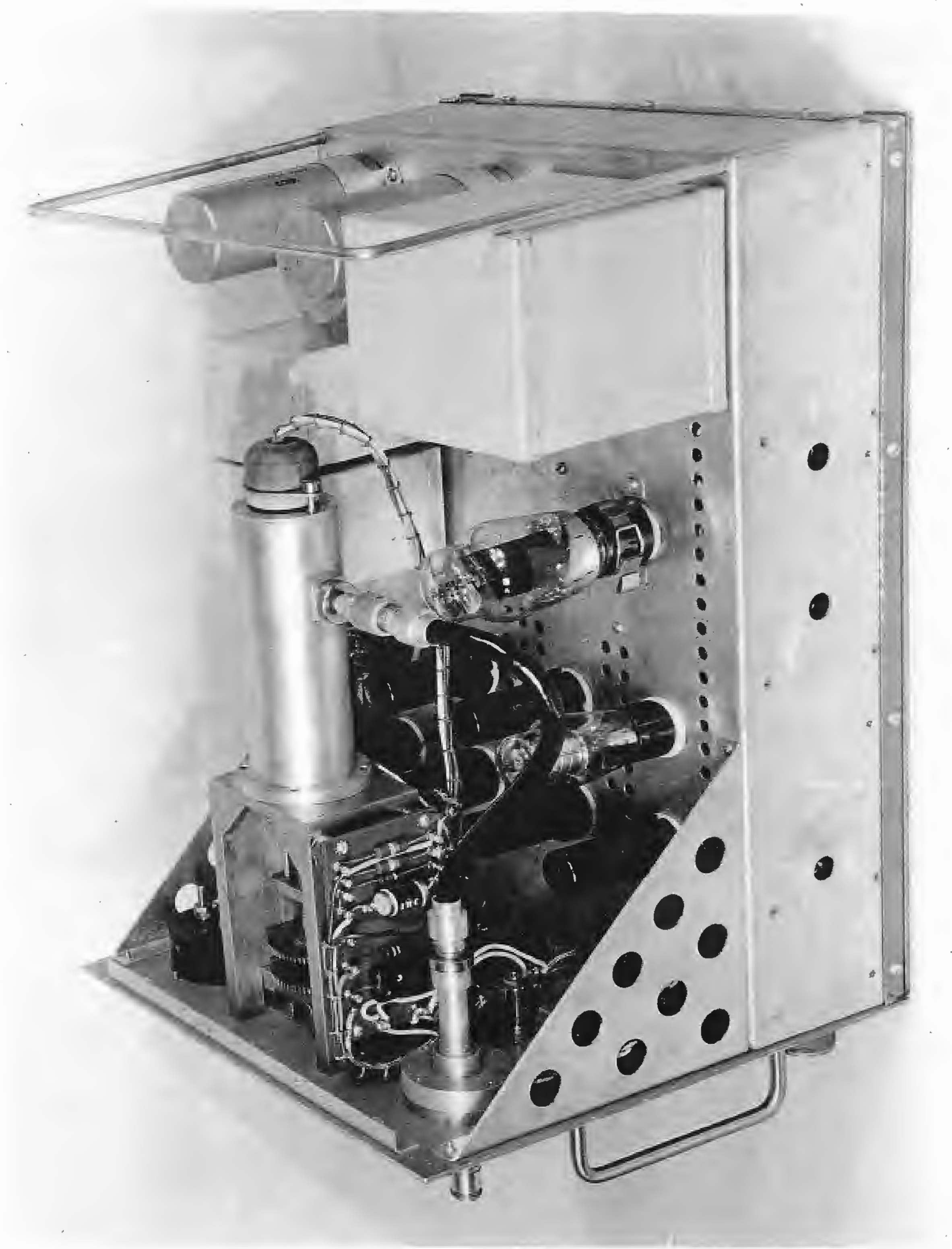
(a) BuShips ltr S-S67-5(920-Ds) Ser S-920-06623 of 6 Dec 1943 to Dir NRL (SRPPB)

(b) BuShips ltr S-S67-5(920Dr) S920-07708 of 3 Mar 1944 to NRL

[redacted]



AN/UPT-T3



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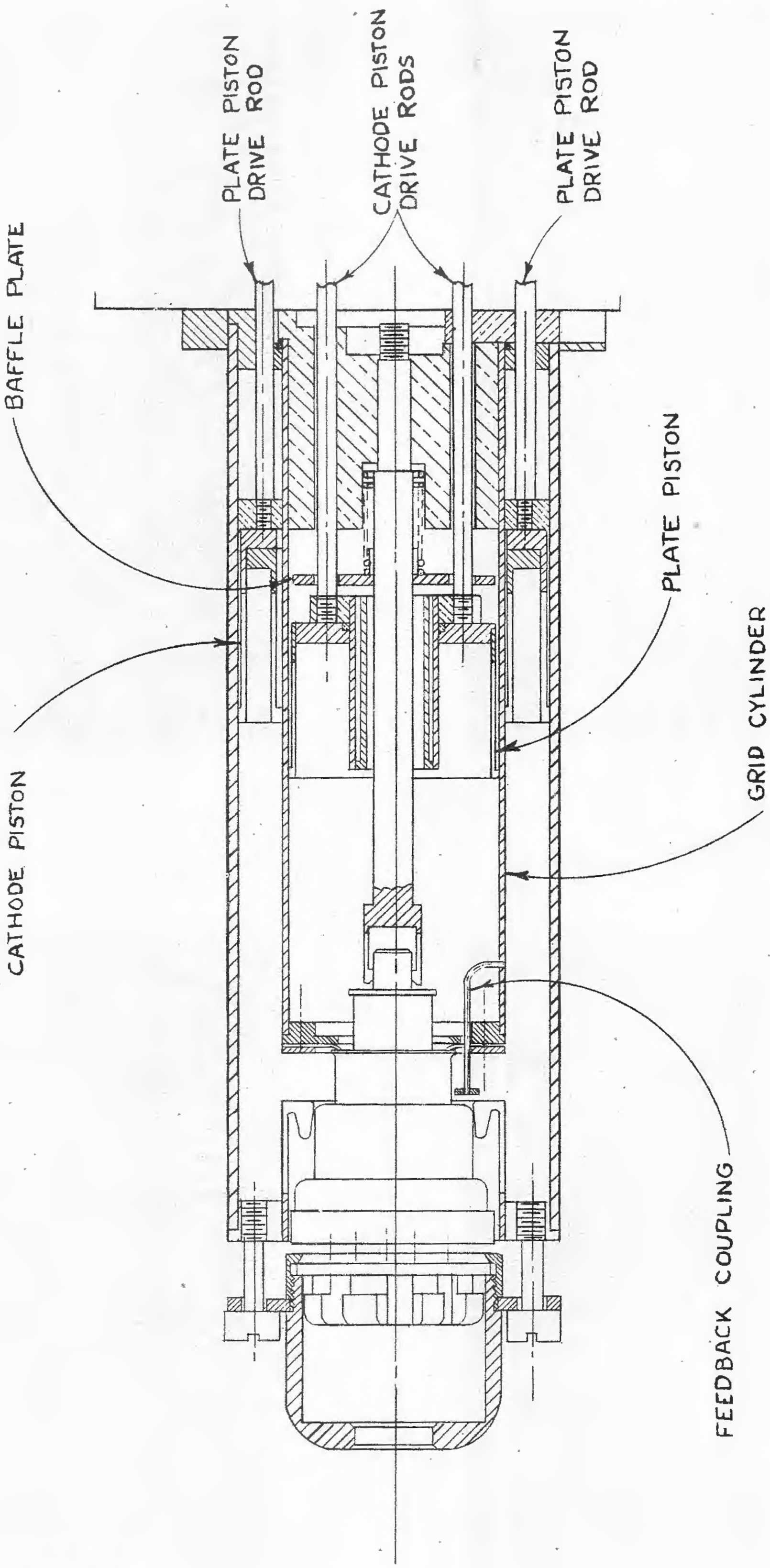

R.F. OSCILLATOR CIRCUIT

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PLATE 3

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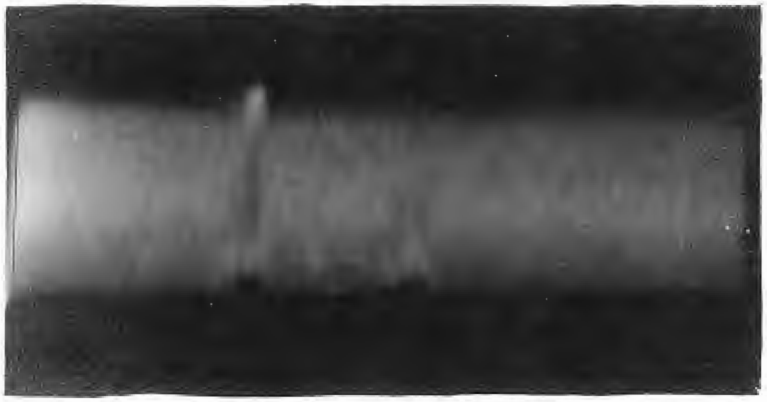


FIGURE 1

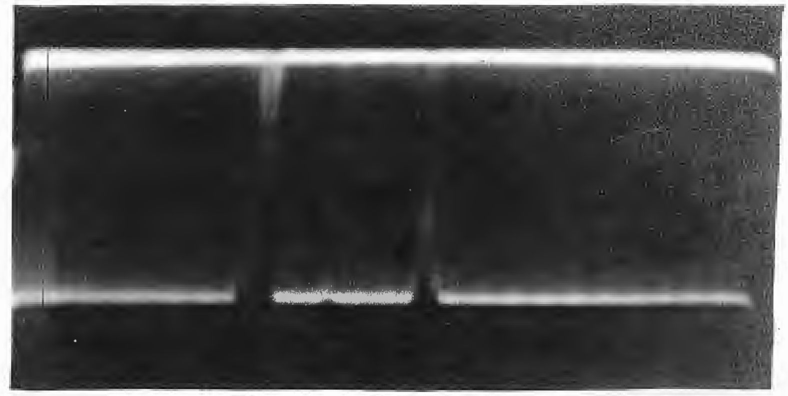


FIGURE 2

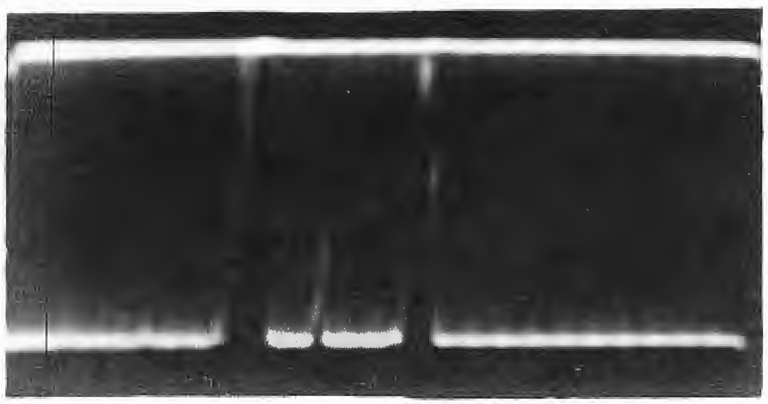


FIGURE 3

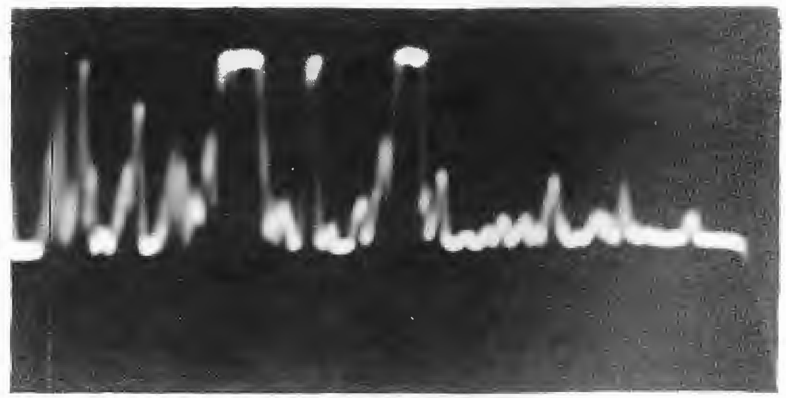
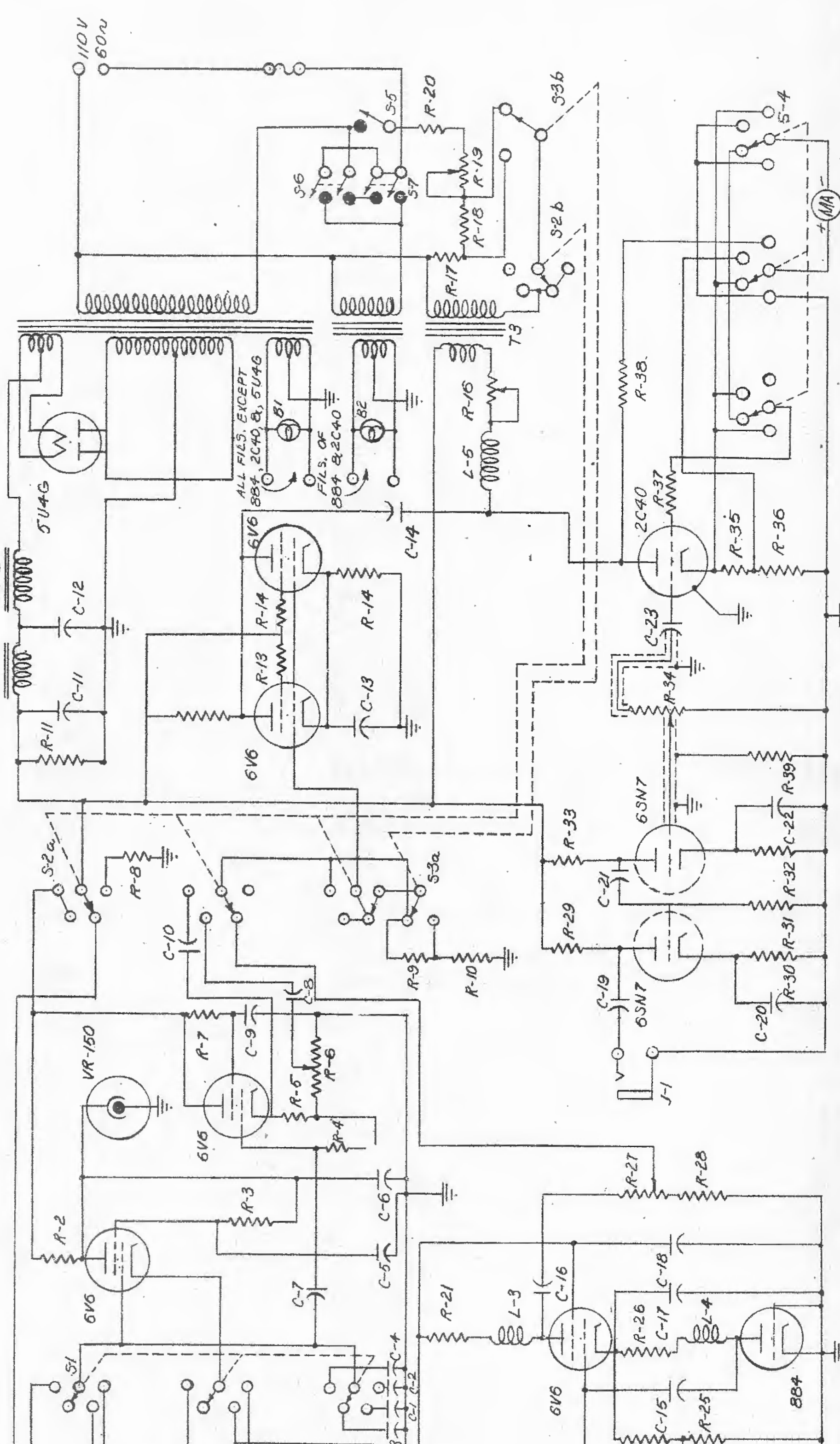


FIGURE 4

EFFECT OF AN/UPT-T3 ON "A" SCOPE OF SF



CIRCUIT DIAGRAM OF AN/UPT - T3

[redacted]

PARTS LIST

R-2-2500 ohms, 10W
R-3-22K, 1W
R-4-10K, 1/2W
R-5-1200 ohms, 1/2W
R-6-750 ohms W.W. Pot.
R-7-4700 ohms, 1/2W
R-8-4200 ohms, 15W
R-9-2200 ohms, 1/2W
R-10-2200 ohms, 1/2W
R-11-33K, 2W
R-12-2000 ohms, 10W, N.I.
R-13-55 ohms, 1/2W
R-14-56 ohms, 1/2W
R-15-165 ohms, 2W
R-16-2500 ohms, 5W.Pot.
R-17-750 ohms, 1/2W
R-18-750 ohms, 1/2W
R-19-3000 ohms, 5W
R-20-500 ohms, 1W
R-21-560 ohms, 1W
R-22-15K, 5W
R-23-10K, 1/2W
R-24-8200 ohms, 1/2W
R-25-4700 ohms, 1/2W
R-26-150 ohms, 1/2W
R-27-750 ohms W.W.Pot.
R-28-1000 ohms, 1/2W
R-29-120K, 1/2W
R-30-1000 ohms, 1/2W
R-31-270K, 1/2W
R-32-1000 ohms, 1/2W
R-33-120K, 1/2W
R-34-50K Pot.
R-35-620 ohms, 1/2W
R-36-30MA. Shunt
R-37-10K, 1/2W
R-38-300 V. Multiplier
R-39-10K, 1/2W

C-1- .03 uf,
C-2- .0016 uf,
C-3- .0007 uf,
C-4- .0002 uf,
C-5- .1 uf, 400V Pap.
C-6- .1 uf, 400V Pap.
C-7- .01 uf,
C-8- .02 uf,
C-9- .1 uf, 400V P
C-10- .02 uf,
C-11- 8 uf, 600V, P.
C-12- 8 uf, 600V, P.
C-13- .5 uf,
C-14- .1 uf, 600V P.
C-15- .002 uf, MICA
C-16- .005 uf, MICA
C-17- .1 uf,
C-18- .1 uf, 400V P
C-19- .01 uf, 400V P
C-20- .01 uf,
C-21- .01 uf, 400V P
C-22- .01 uf,
C-23- .02 uf,

L-1- .66 Millihenry
L-2- 8.4 Millihenry
L-3- 150 uh @ 1MC
L-4- 60 uh @ 1MC
L-5- 80 mh

T-1- 800V C.T. @ 200 ma; 6.3V @ 3A;
5V @ 3A.
T-2- 6.3V @ 1.5A
T-3- Approx 30V

B-1- Red 6.3V Pilot Lite
B-2- Green 6.3V Pilot Lite
Ch-1,2-2.5 Henrys

[redacted]

Table 1.

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