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EXPERIMENTAL JAMMING TRANSMITTER USING A 200-WATT CW X-BAND DEVELOPMENTAL MAGNETRON

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ABSTRACT

This report describes X-band jamming equipment developed for experimental use in determining requirements for jamming in this range. Samples of the RCA X-band magnetrons, Types A-131 and A-136, have been utilized in this equipment as they were made available by the contractor. A modulator supplying random-noise modulation for use with the equipment has been developed for determining jamming characteristics. Tests indicate that the maximum r-f power output is of the order of 200 watts at an efficiency of 30 to 45 percent. The frequencies of the samples varied, but the proposed final center frequency will be 9400 Mc and the tuning range will be of the order of 15 percent overall. The equipment was used in making trial jamming measurements against the Model SU-2 radar at CBA but variation in propagation conditions have made further tests necessary before any conclusions may be reached. These will be made and reported upon as additional tubes become available.

PROBLEM STATUS

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

AUTHORIZATION

NRL Problem R06-33D (BuAer Prob. EL-9A-334).

EXPERIMENTAL JAMMING TRANSMITTER USING A 200-WATT CW X-BAND DEVELOPMENTAL MAGNETRON

INTRODUCTION

The investigation of jamming techniques in X-band has been limited by the lack of vacuum tubes having adequate c-w output. One tube development which is being conducted by RCA has as its objective a magnetron with a nominal output of 200 watts c-w tunable over as wide a range as possible centered around 9400 Mc. This tube, having an internal tuning structure, was originally designated as Type A-131, but this designation was changed to A-136 when it became necessary to adopt an external tuning cavity coupled to the anode of the tube to obtain greater tuning range. As the development has progressed, RCA has supplied NRL with operating sample tubes in various experimental stages. The characteristics of these sample tubes have been measured in an experimental apparatus and recommendations have been made for improved performance. A complete transmitter--including an r-f unit, a modulator capable of supplying wide-band random noise of adequate power to modulate the magnetron, the power supply, and antennas of suitable directivity and circular polarization--has been built around the modified tubes. This transmitter has been used in making surface-jamming measurements against the SU-2 radar at CBA. These tests will be the subject of a subsequent report; this report deals only with equipment and tube developments. The magnetrons which have been made available so far have required a separate electromagnet, which is large and heavy, but the final tubes are expected to incorporate a permanent magnet as part of the tube structure. It is planned to incorporate these tubes in equipment of smaller size and weight, suitable for airborne installations. The latter can be used for taking additional jamming measurements. This work is being done as part of the Integrated Jamming System project,[1] but an additional application for the Automatic Search and Jam System project,[2] will be made as advances warrant it.

TEST OF THE TYPES A-131 AND A-136 MAGNETRONS

A total of six tubes have been made available to NRL. The first two were designated as type A-131.[3] Subsequent tubes have the type number A-136.[4] Table I includes the

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[1] BuShip Conf. Ltr. Sect 920, Ser. C-920-7549 of 20 Nov. 1945 to NRL

[2] BuAer Conf. Ltr. Aer-EL-91, Ser. 08563 of 2 Dec. 1947 to NRL

[3] RCA Report No. 1043-6, "The A-131, A Tunable X-band CW Magnetron."

[4] RCA monthly progress reports under Navy Contract No. Nobsr 29037.

important characteristics of these tubes; their operational use is summarized in the next seven paragraphs.

TABLE I

Characteristic	A-131-12.1	A-131-7.1	A-136-C2	A-136-J2	A-136-M2
Av Pwr Output (Watts)	60	50	160	150	140
Max Pwr Output (Watts)	84		200	192	
Plate Voltage (Volts)	1500	1500	2100	2200	2500
Av Plate Current (ma)	150	150	200	200	200
Max Plate Current (ma)	150	150	250	250	250
Dynamic Impedance	1500	1500	300	300	300
Starting Filament Current (Amps)	25	25	30	30	30
Operating Filament Current (Amps)	10	10	0	0	0
High Frequency Limit (Mc)	9410		9200	9300	10000
Low Frequency Limit (Mc)	8670		7800	8400	9000
Total hours in use	70	5	50	40	20

The A-131-12.1 and A-131-7.1 were early models in which the tuning was accomplished in the resonant structure of the cavity within the tube. The A-131-7.1 became inoperative after five hours of use due to an open filament. The A-131-12.1 operated for 70 hours. A complete transmitter, designed around this tube, was used to make X-band jamming tests against SU radar equipment. This tube, as well as the later A-136 models, could be amplitude modulated without severe frequency modulation. No mode jumping was found to exist except when over modulated at low plate currents. The chief shortcomings were the relatively low power output and a tendency toward instability of plate current with an accompanying frequency shift. This latter difficulty was overcome by using modulating tubes in series with the magnetron. The tube ultimately failed because of an open filament.

The later (A-136) series of tubes feature tuning by means of an external cavity. These tubes provide considerably greater power output and do not exhibit the plate-current instability noticed in the A-131 models. Frequency drift on starting is of the order of several megacycles for the first two minutes after which no drift can be detected on the model TSX-4SE spectrum analyzer. The tuning mechanism is rather hard to turn, but is otherwise satisfactory. The reset accuracy of tuning is good. One criticism of the tube is the cumbersome starting procedure. Under operating conditions cathode heating is derived entirely from back bombardment, filament current being required only for starting. The operating instructions require that the filament current be reduced incrementally with increasing plate power. This procedure, if made automatic, would require a relatively complicated starting mechanism.

The A-136-C2 operated for 50 hours. Near the end of this period it exhibited manifestations of gassiness as indicated by excessive anode current at low voltage and soon thereafter the filament circuit opened, terminating its use. The major portion of this operating period was applied to overwater jamming tests during which time the tube functioned satisfactorily. The characteristics were measured after the tube indicated the presence of gas, and since the results were obviously quite different from that experienced previously, they are not included in the table. The values given for this tube are those determined by RCA. Otherwise, the data in the table are NRL test data.

The A-136-J2 has been in operation for 40 hours. Its use in test procedure has been satisfactory.

The A-136-M2 is characterized by an increase in the center frequency of its tuning range. This tube was found to have a tendency to jump to a mode of oscillation such that its frequency was approximately 7500 Mc. This condition was most serious when operating at maximum current, or when being heavily modulated. The condition became progressively worse until, when it was returned to RCA, it could not be operated at higher than 150-ma plate current. It was also found that the power output was considerably less than the accompanying data sheet indicated it should have been.

A sixth tube, A-136-S1, was received in a gassy condition and was returned to RCA for repairs.

EQUIPMENT

Tuning of the A-136-J2 magnetron is accomplished by turning the large knurled cylinder (Figure 1a), which works on a threaded part, to change the resonant structure in the tuning cavity. The calibration is of the micrometer variety. Extending vertically above and below the tube are fins through which air for cooling is forced at the rate of approximately 70 cfm. On the opposite side from the tuning knob is the output coupling structure which bolts onto an X-band waveguide. The heater and modulated high voltage supply are connected to the two metal rings shown on the end of the stem extending toward the lower left of Figure 1b. The two insulating discs, placed midway down the stem protect against arc-over--since all plate voltage exists between the body of the tube and the heater terminal. On either side of the body are trunions for mounting the tube on the magnetic structure.

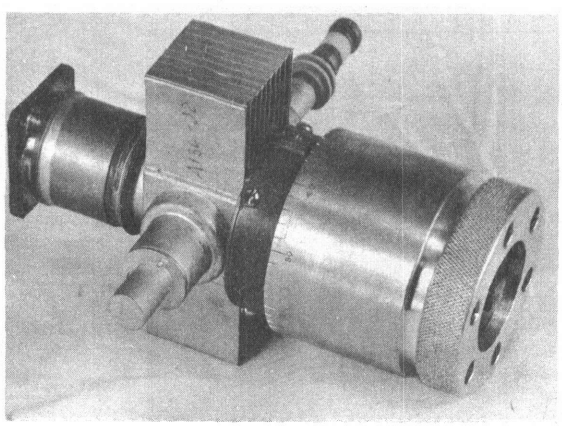

Fig. 1a - A-136-J2 Magnetron

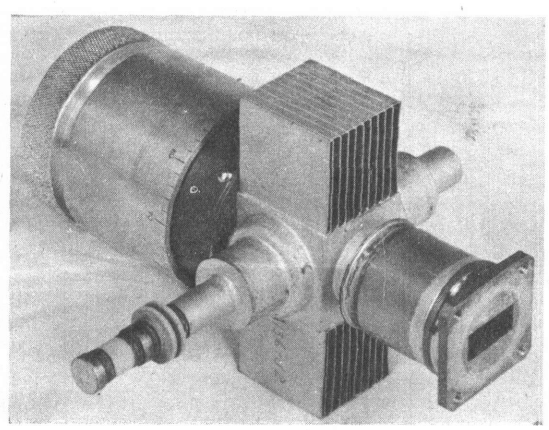

Fig. 1b - A-136-J2 Magnetron

Figure 2 shows the A-136-J2 mounted in the equipment. In the foreground is the power supply for the electromagnet. The electromagnet itself (Figure 3) is the mounting for the tube. A magnetic field of from 5000 to 6000 gauss is required. In its ultimate design, RCA will produce the tube as a "packaged" unit incorporating a permanent magnet as part of the tube structure. This will materially reduce the space, weight, and power requirements.

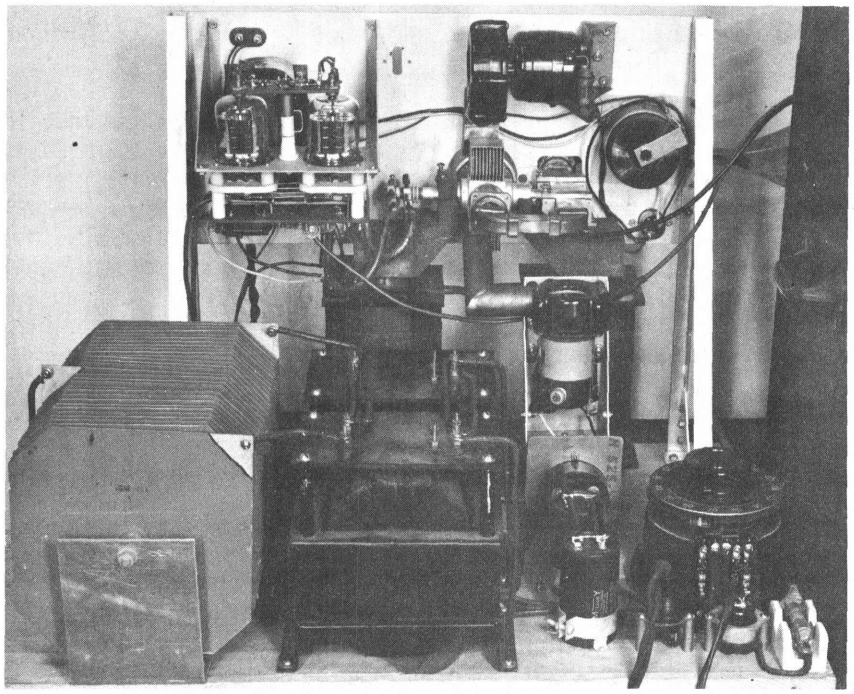

Fig. 2 - Rear View of Mounting Rack for
RCA A-136-J2 Magnetron

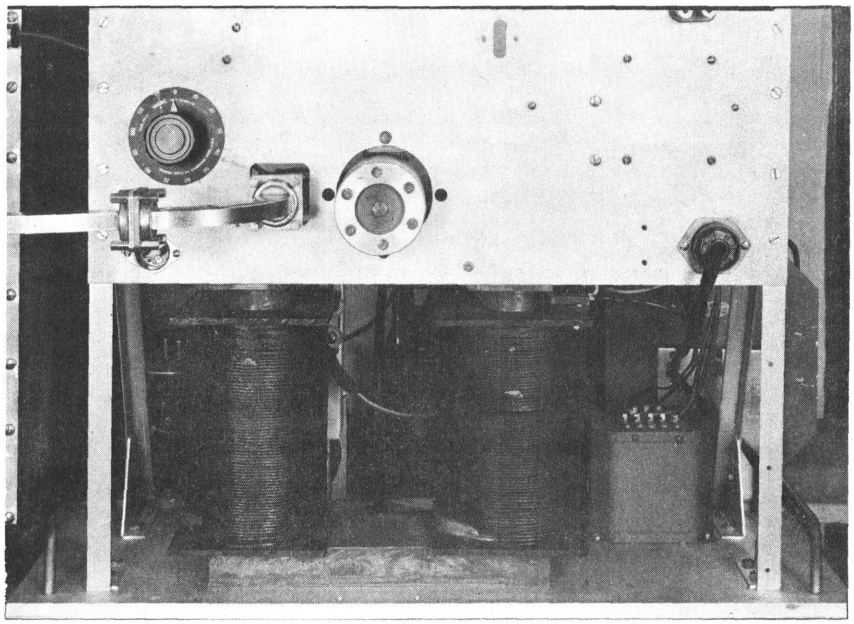

Fig. 3 - Front View of Mounting Rack for
RCA A-136-J2 Magnetron

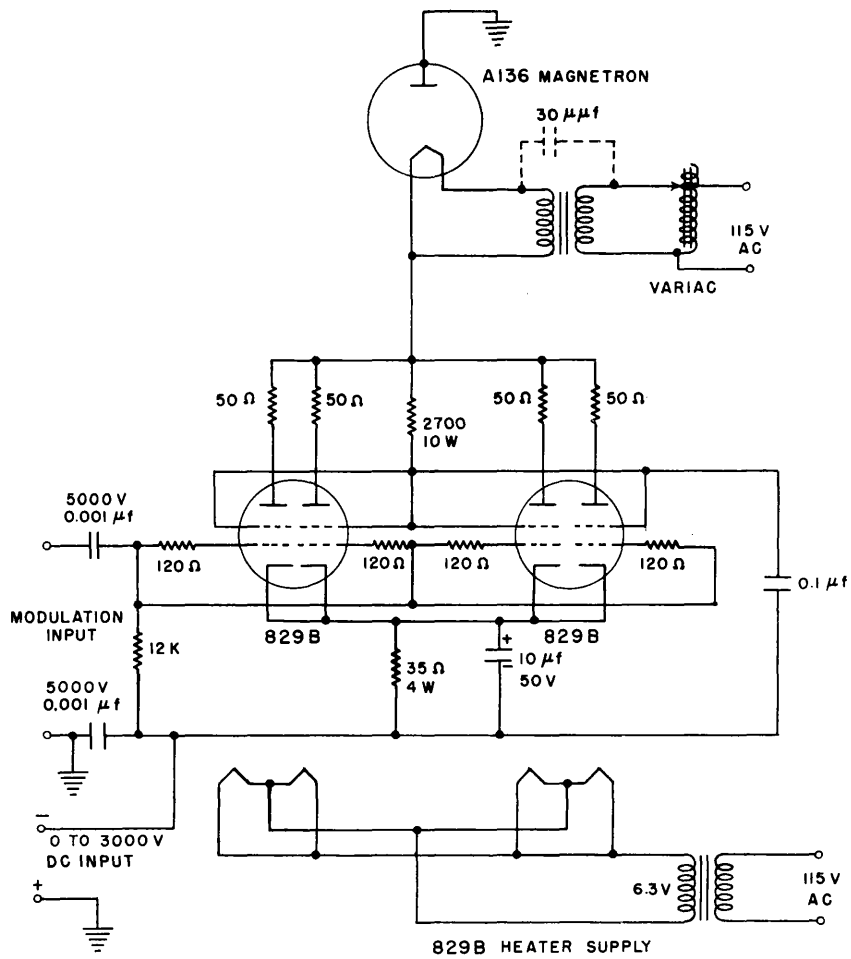

Fig. 4 - Schematic Arrangement of A-136 Magnetron and Modulator

Figure 4 is the schematic arrangement of the type-A-136 tube and modulator. Series modulation was first used with the early A-131 types to provide some current regulation. The later A-136 models do not require this feature but it has been retained as a safety factor and because the use of series modulation simplifies coupling between the modulator plates and the magnetron. The voltage dropping resistor between the screen by-pass condenser and the modulator plates prevents current cutoff on strong modulation peaks. The dynamic impedance of the magnetron to modulation is of the order of 300 ohms, which allows for low plate voltage on the modulator tubes. Thus the over-all supply-voltage requirements are not increased greatly by using series modulation. Because of the low dynamic impedance of the magnetron, no peaking circuits are required in the modulator-plate circuit and the response is essentially flat out to 5 megacycles. Isolating resistors are used in the plates and grids to prevent parasitic oscillation in the four paralleled sections of the 829B tubes. Since all the elements of the modulator are at high potential, the tubes are mounted so that they are well isolated from ground. Figure 5 shows the modulator mounted in the equipment.

Figure 6 is the schematic of the preamplifier and noise source. The 6D4 thyratron, in a 370-gauss field, is used as the noise generator. The response-flattening network is

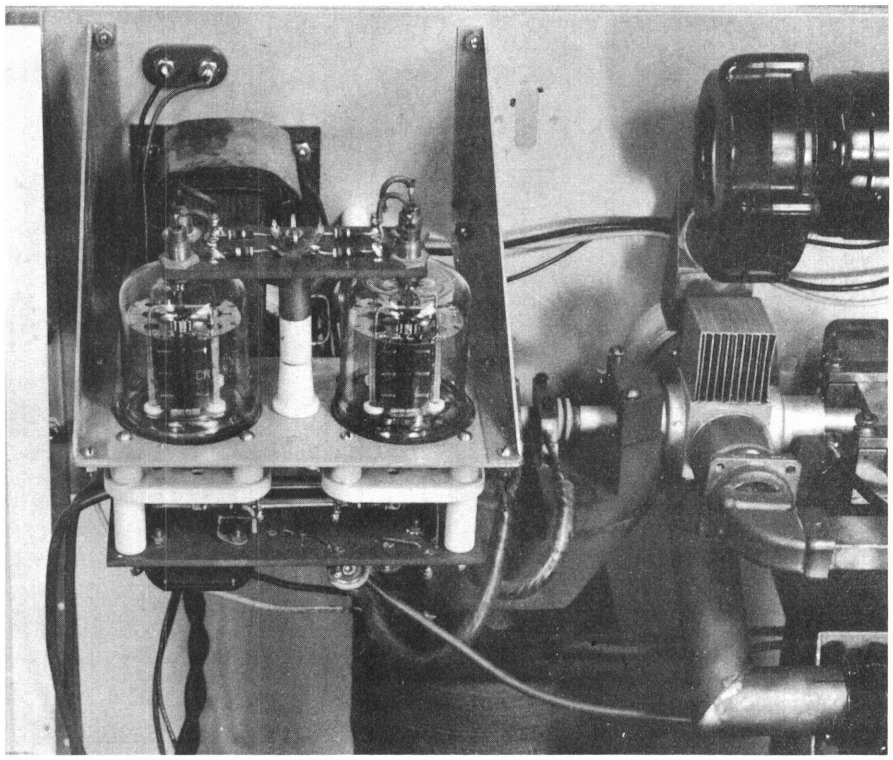

Fig. 5 - Modulator for the A-136-J2 Magnetron

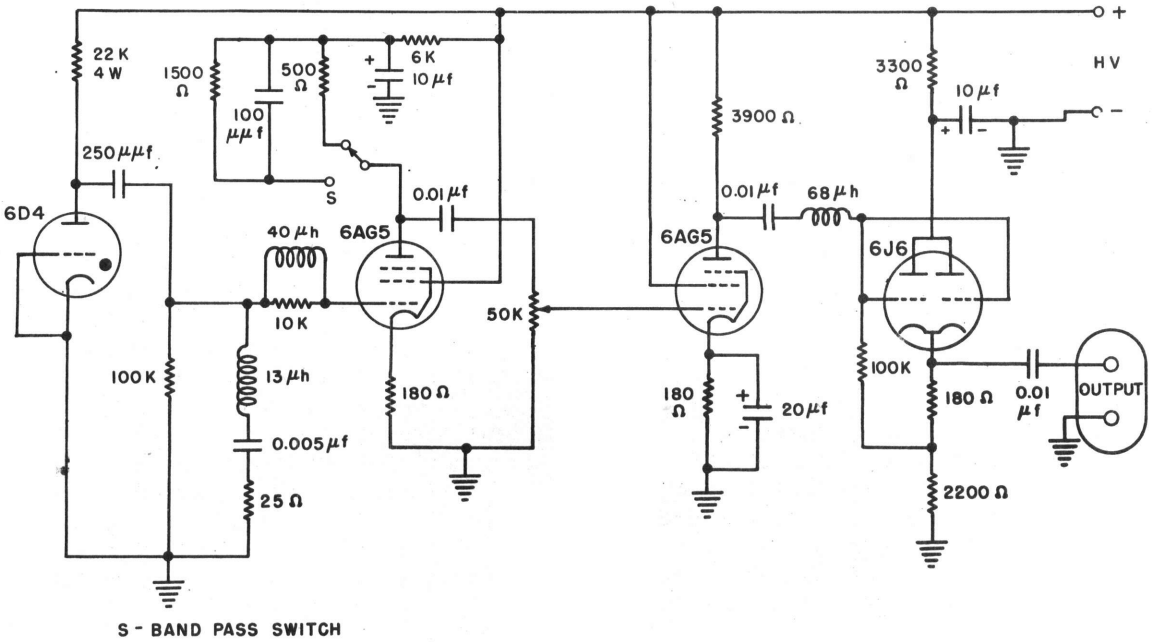

Fig. 6 - Schematic of Noise Source and Preamplifier

of interest in that it is accomplished completely in the output circuit of the 6D4. This is considered an advantage since the following stages may be designed for a flat response, making the preamplifier available for other types of modulation. For most purposes, however, the more general method of staggering the several compensating circuits throughout the amplifier is found to be less critical to tube replacement.

The band-pass switch, S (Figure 6), is used to change the width of the noise spectrum from 5 Mc to 1 Mc without changing the peak-to-peak swing. A second amplifier and cathode follower provide a low-impedance output with a maximum swing of approximately 40 volts peak-to-peak. The complete unit is shown to the right in Figure 7.

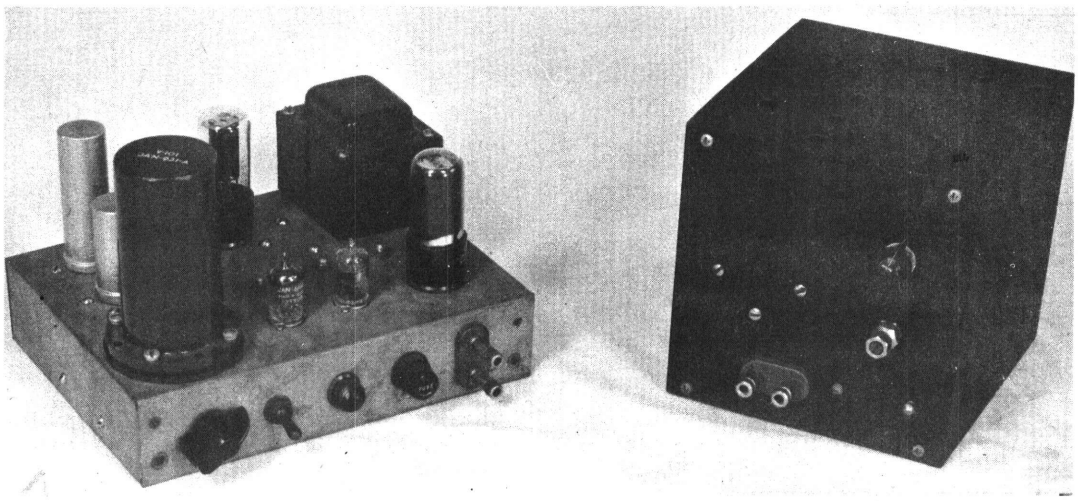

Fig. 7 - View of 6D4 and the 931A Noise Sources

A second noise source and preamplifier was designed using the 931A photo tube. This unit, shown to the left of Figure 7, has the advantage of having a very flat frequency spectrum out to 5 Mc. It requires more amplification, however, and is very sensitive to supply-voltage changes. Furthermore it requires a 1000-volt d-c power supply. For these reasons the gas tube is favored for practical applications. For laboratory use, however, the photo tube, because of its flat frequency spectrum, is preferred.

The power supply, shown in Figure 8, is generally conventional, having a maximum output of 3000 volts d.c. at 300 ma. Since the dynamic impedance of the magnetron is quite low it is sensitive to modulation from ripple in the power supply. Accordingly, the power-supply filter is designed such that the ripple voltage is less than 0.02 percent of the d-c output voltage.

The antennas used for jamming tests of the equipment are shown in Figure 9. To the left is a conventional high-gain horn polarized in a single plane. The other is a circularly-polarized horn which is equally effective against either horizontally- or vertically-polarized receiving equipment, though the power gain is 3 db below the equivalent plane polarized antenna.[5]

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[5] NRL Report No. R-3173, "X-Band Antenna for AN/APQ-33 (XB) Jam System."

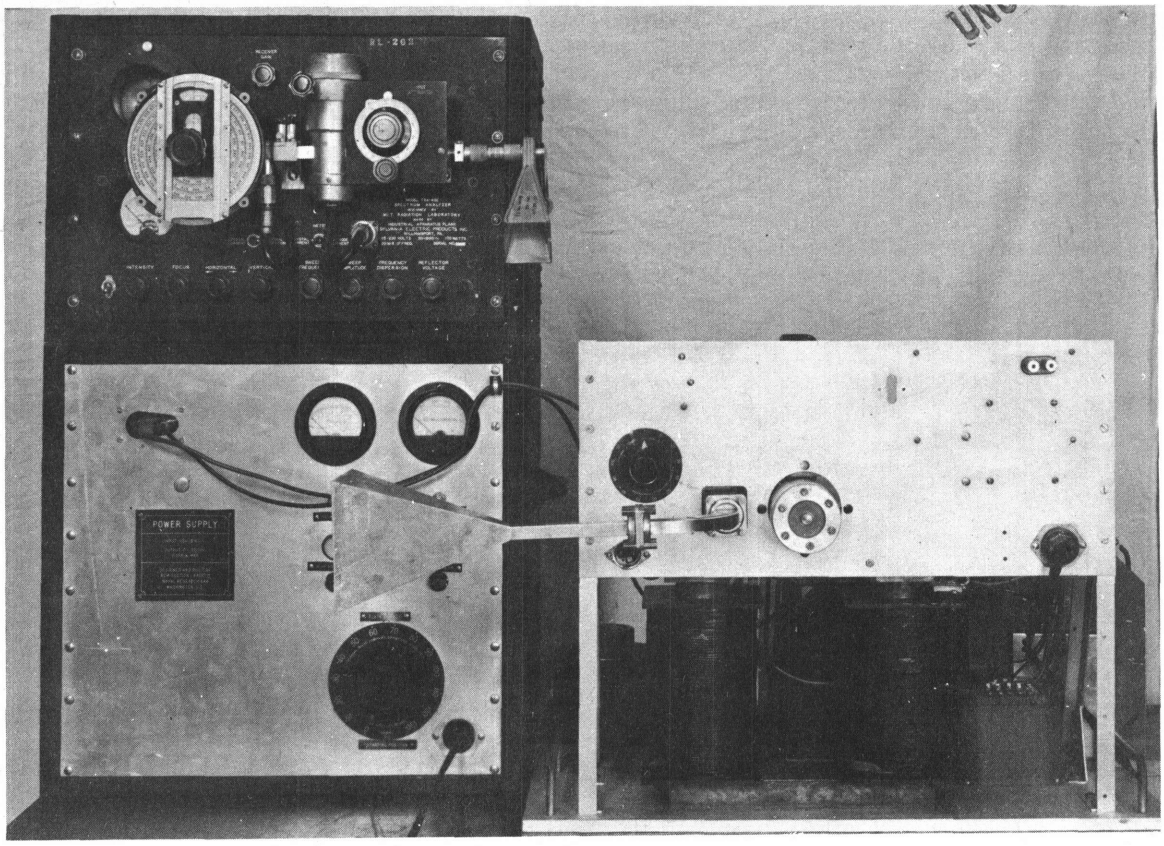

Fig. 8 - Transmitter Rack, Power Supply, and Receiving Analyzer

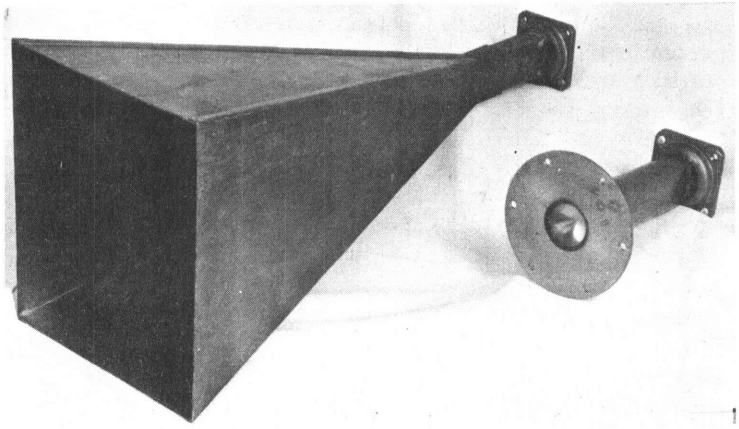

Fig. 9 - Antennas Used for Jamming Tests

The power-measuring equipment, shown in Figure 10, is a constant-flow water load in an X-band waveguide with thermistor beads at the input and output. The differential change in the resistance of the thermistors with temperature is indicated on the bridge-type vacuum-tube voltmeter shown at the lower left. This reading is calibrated in terms of the power absorbed in the liquid. The calibrating wattmeter is shown in the center of the view.

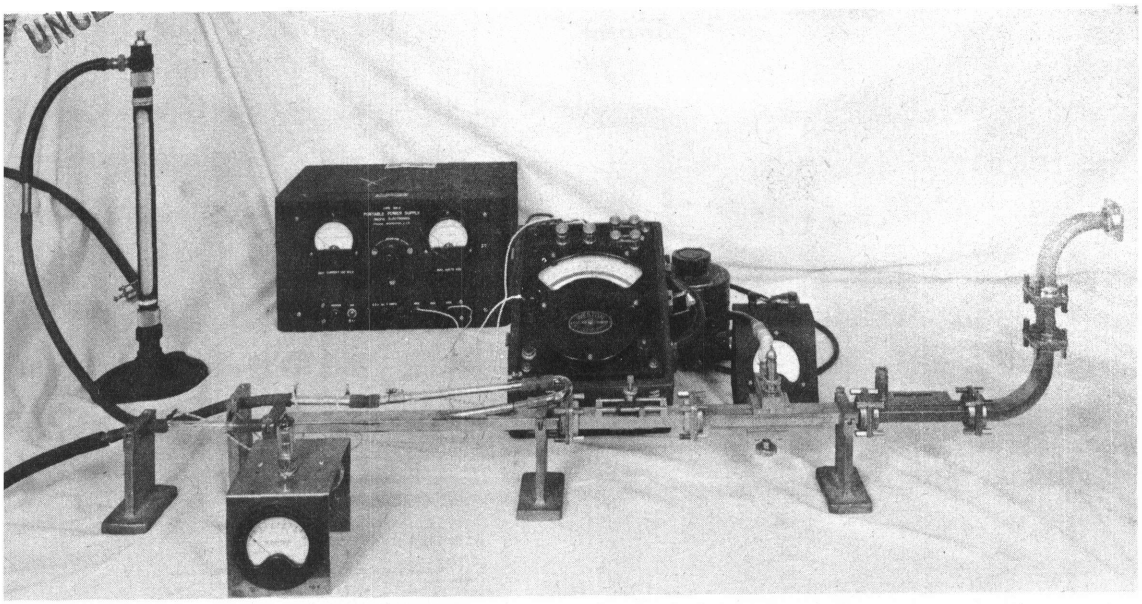

Fig. 10 - X-Band Power Measuring Equipment

CONCLUSIONS

It should be recognized that the tubes described in this report were experimental samples and had been subjected to design and test operation by the manufacturer before being received by NRL. Consequently, early tube failure was not too surprising. It is to be noted that the chief cause of failure was the opening up of the heater circuit. It is anticipated that the manufacturer will be able to rectify this difficulty.

Electrically the tubes were generally satisfactory. All but one were capable of being modulated by a random-noise spectrum flat out to 5 Mc. The one exception could be made to jump mode under heavy modulation. The modulation equipment and power supply requirements are relatively simple.

The starting procedure, requiring an incremental decrease in heater current with increasing plate current, is considered awkward. The tube manufacturer has been requested to make recommendations on heater voltages in relation to anode voltage in order that a fairly simple starting control, possibly of a step switch nature, can be designed.

* * *

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