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Technical Memorandum

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SCTM- 196-53-52

A PULSED FREQUENCY-MODULATION TRANSMISSION SYSTEM

R. E. Glass

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SANDIA SYSTEMATIC DECLASSIFICATION REVIEW
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ABSTRACT

This report describes a system for transmitting and receiving information in the frequency range from 0 to 25 megacycles or an equivalent pulse risetime in the order of 0.01 microsecond.

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INTRODUCTION:

One method of transmitting high frequency type information either in the form of fast risetime pulses or continuous frequency phenomena is to utilize the inherent electrical capabilities of a reflex-klystron[1]. The information signal is applied to the high input impedance reflector element of a reflex-klystron to obtain frequency modulation of carrier frequency.

The receiving system utilizes the advantages to be obtained in a balanced Magic "T" type crystal mixer[2], namely; suppression of local oscillator noise, over-all noise figure improvement, small local oscillator power required, and local oscillator power radiation reduced. A wide-band intermediate frequency amplifier capable of passing the information frequency is used to raise the level of the intermediate frequency to a value such that a wide band frequency demodulator will detect the information pulse or frequency. Further amplification of the information pulse is accomplished by use of a high frequency response video amplifier in the associated cathode-ray oscilloscope.

MODULATION TEST SETUP:

In order to ascertain the modulation capabilities of some of the more recently manufactured types of reflex klystrons the test setup shown in Figures 1 and 2 was made.

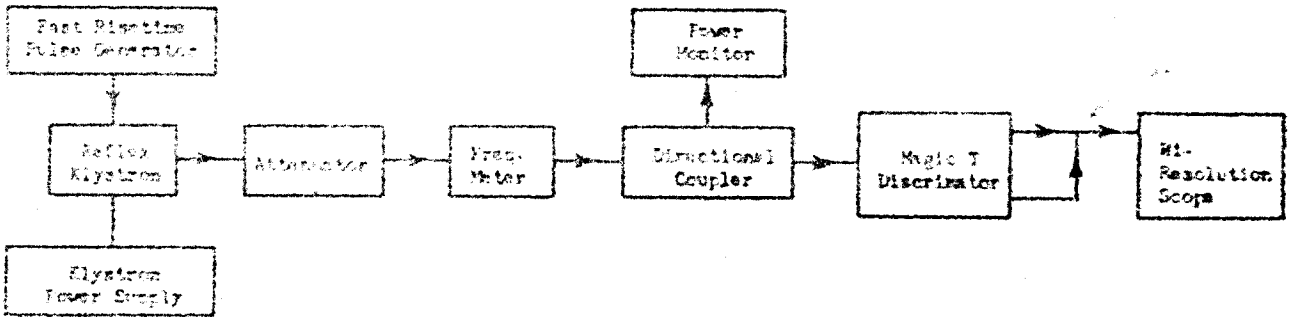

FIG. 1

The bandwidth between half-power points for two or three modes of operation of various reflex-klystrons were obtained by the conventional method. Results are tabulated in Table I along with maximum power output. Figure 3 is a picture of the Varian-type V-55 klystron.

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1 "Klystron and Microwave Triodes" MIT Rad. Lab. Series, Vol. 7 pp. 441-469.
2 "Microwave Mixers" MIT Rad. Lab. Series, Vol. 16, pp. 257-289.

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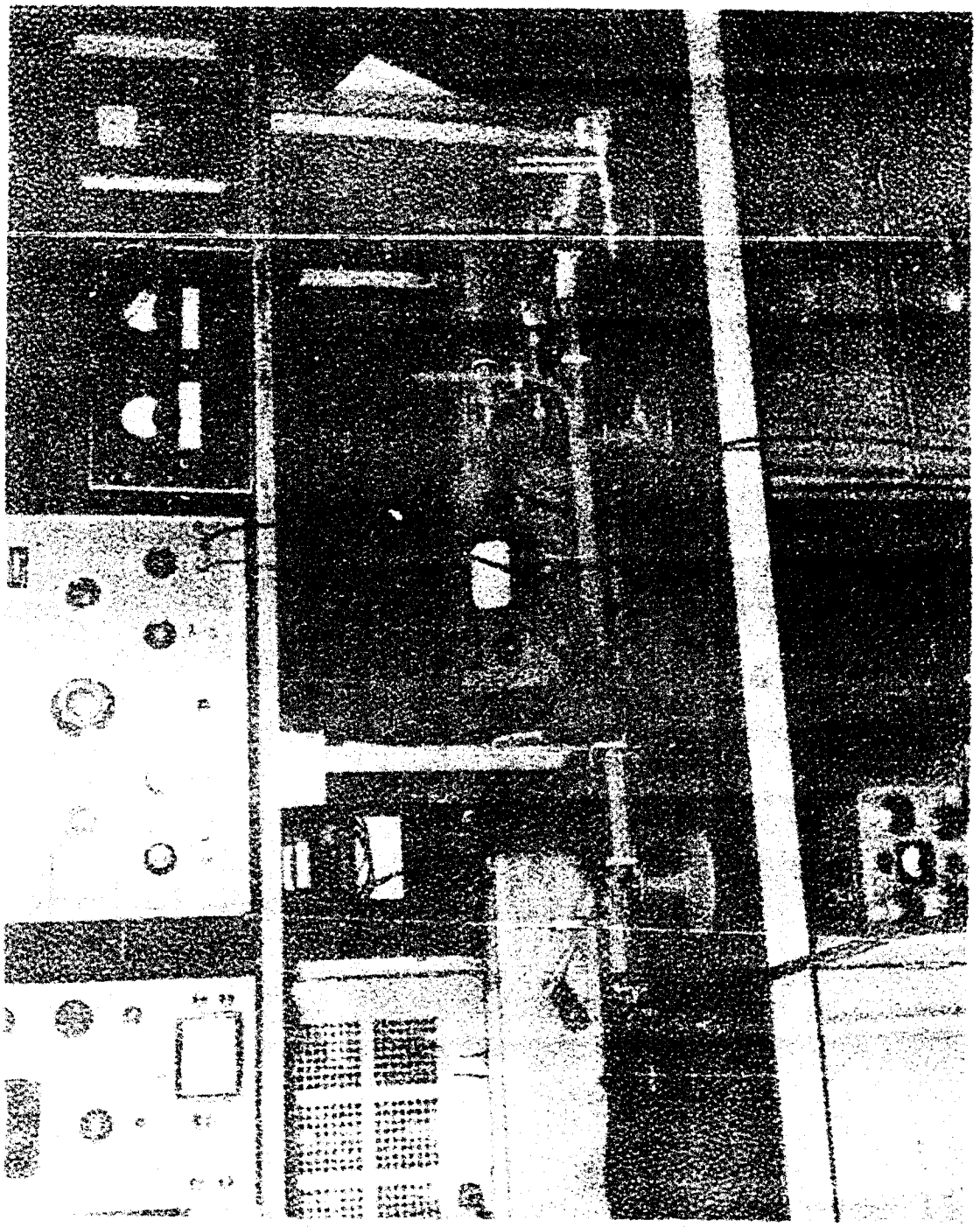

Fig. 2 Bench Setup - Modulation Test

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Fig. 2 Type V-55 Klystron

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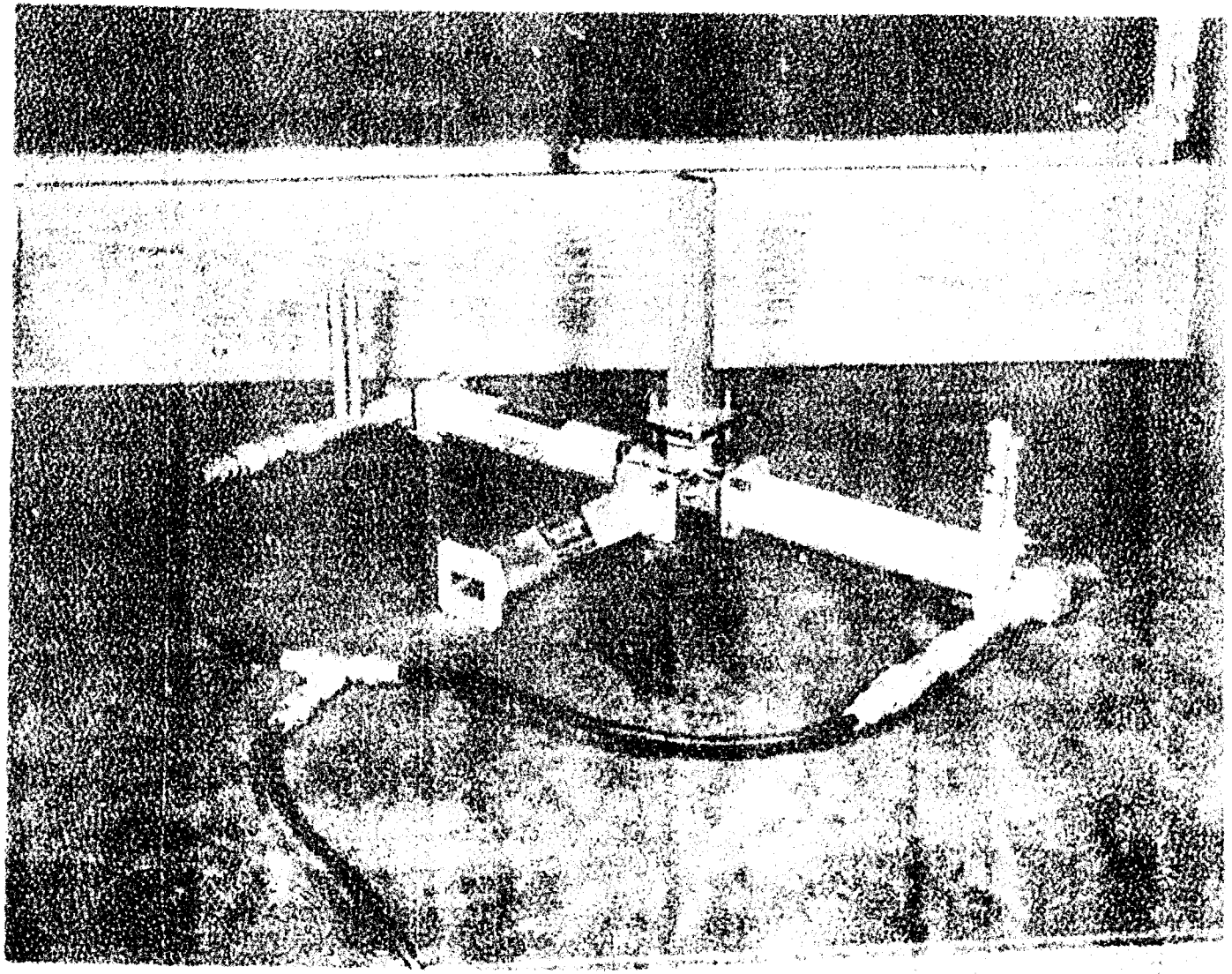

Fig. 4 Waveguide Magic "T" Discriminator

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Another report will describe the theory, operation and setup procedure for use of the Magic "T" discriminator. The Magic "T" discriminator, shown in Fig. 4, is used in this setup only as a part of the test equipment in order to reproduce the extremely fast rise time pulse. Ordinarily it will not be used in the transmitting and receiving system other than its use as a means for setting up and checking out the transmitter. The Magic "T" discriminator has a fairly linear output of increasing or decreasing voltage versus frequency change over bandwidths from 10 to 30 megacycles depending upon the method of adjustment.

Figure 5 illustrates the manner in which a negative voltage pulse is applied to the reflector element of the reflex klystron to obtain an rf carrier that is pulse-frequency modulated.

TABLE I

BANDWIDTH TESTS ON REFLEX KLYSTRONS
TYPE V-55

TUBE NO.	E_o VOLTS	E_R-MODE CENTER VOLTS	ΔE_R VOLTS	B.W. Δf MC.	SENSITIVITY MC/VOLT	P_o MAX WATTS
1774	470	290	65	41	.63	.52
	470	130	38	97	2.5	.415
	500	255		47		.75
	500	95		108		.52
	600	220	55	54	.98	1.00
	700	180	50	54	1.08	1.14
1775	470	325	65	52	.8	.53
	470	145	40	106	2.6	.40
	500	325		58		.775
	500	145		124		.50
	600	255	70	65	.93	1.10
	650	230	70	91	1.3	1.14
1493	470	265	50	53	1.06	.58
	470	120	35	124	3.5	.37
	500			67		.70
	500			133		.46
	600	215	60	76	1.26	1.008
			TYPE V-51			
1236	350	165	40	119	3.0	.[illegible]
	350	76	25	147	5.9	.097
	350	20	13	135	7.5	.029
1235	350	168	40	119	2.95	.240
	350	72	30	164	5.5	.108
	350	40	20	162	8.1	.023
1265	350	170	40	141	3.5	.225
	350	35	23	155	6.7	.089
	350	32	15	140	9.9	.021

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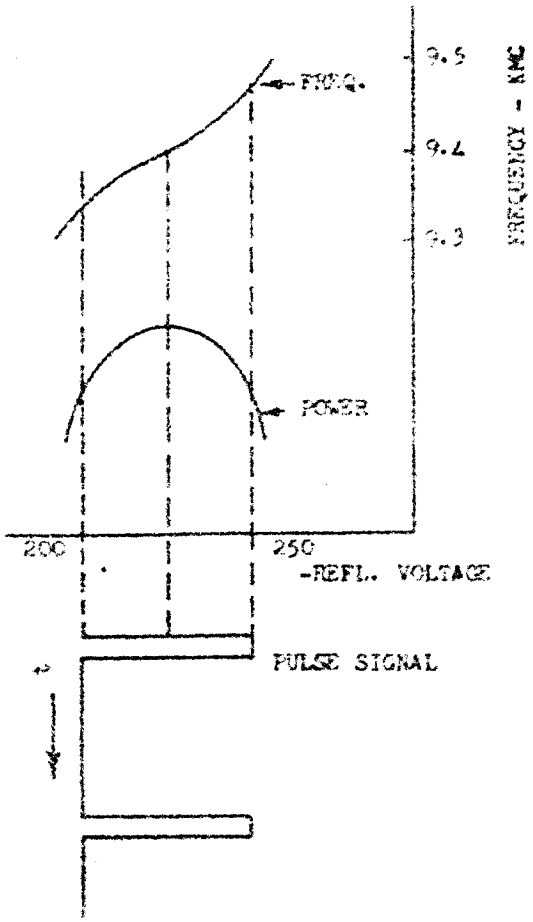

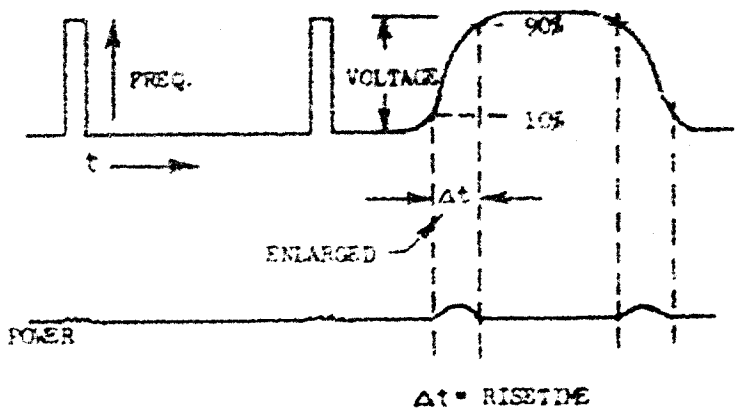

From Figure 5 it can be seen that the rf carrier contains very little amplitude modulation and the information is transmitted by frequency modulation. The polarity of the output pulse is dependent upon the discriminator characteristic.

Figure 6 shows a circuit diagram and the manner in which the pulse is applied to the reflector element of the reflex klystron.

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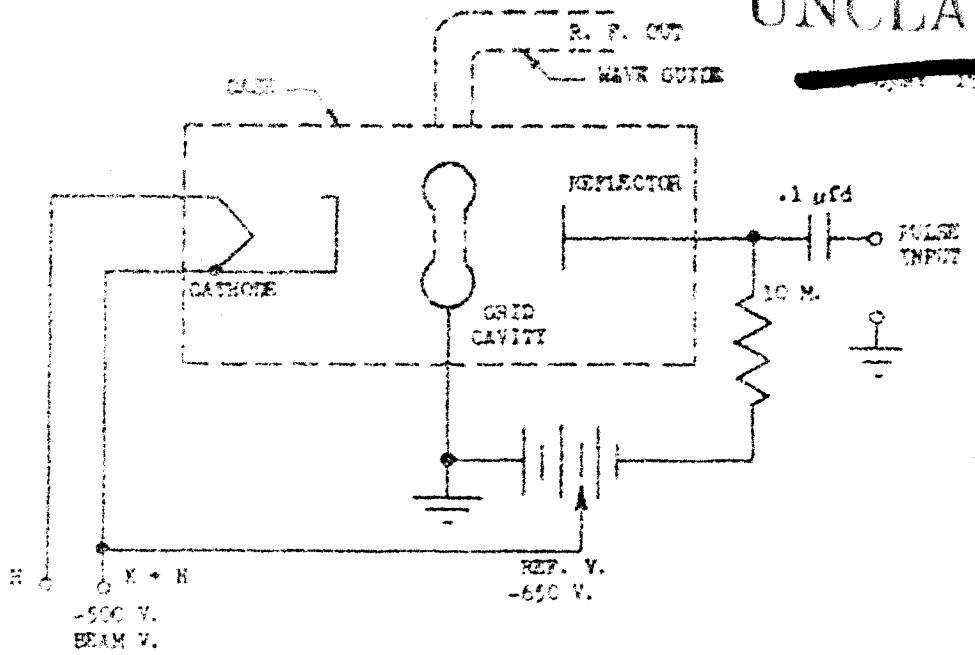

FIG. 6

The pulse input can be either positive or negative depending upon the setting of the reflector voltage in the power mode. Thus the frequency can be pulsed either in an increasing or decreasing direction. Since the internal impedance of the beam voltage power supply is usually quite low, the pulse is effectively applied between cathode and reflector. The reflector always operates at a high negative voltage with respect to the cathode in order to repel the electrons back through the grid cavity to sustain rf oscillation due to the bunching and debunching action in the grid cavity. Therefore, practically no reflector current flows and the input impedance to this element is quite high. However, the input capacity to ground is in the order of three to four micromicrofarads.

One factor of primary interest is the maximum rate of change in frequency that can be obtained by using this method of modulation. Stated in another way, we would like to know the minimum pulse risetime that can be obtained as illustrated in Figure 5, i.e., Δt between 10% and 90% voltage points when frequency change is converted to a voltage change.

In order to investigate this aspect of the system, the rf signal from the reflex klystron is attenuated considerably in order to not overload the crystals used in the Magic "T" discriminator in the test setup shown in Figure 1. Frequency and power are monitored by means of a reaction-type frequency meter, directional coupler, bolometer and power meter. The frequency change is detected in the Magic "T" discriminator and converted to a voltage change due to crystal current flow through the crystal load resistors. The output of the two crystals are combined since one crystal is a "backward" type. The combined pulse output is then applied to the input of an extremely fast sweep speed scope in order to examine the leading edge of the pulse.

Limiting factors of the measuring equipment should be pointed out at this time. The following three pulse generators are available at the present time:

1. Hewlett-Packard Model 212A
   <u>0.02 Microsecond Risetime</u>

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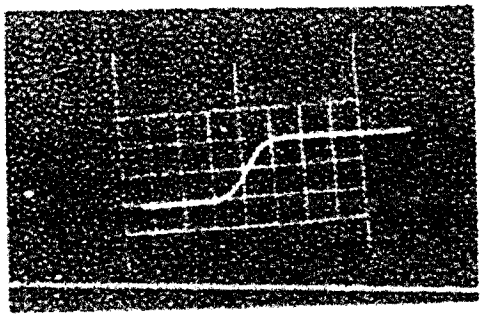

Fig. 7a HP 212A Output Pulse to Input of Klystron

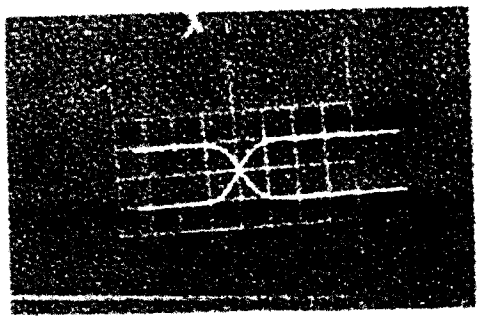

Fig. 7b Input and System Output Pulse

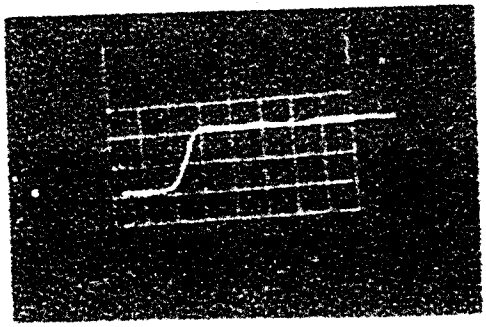

Fig. 7c EPIC Mod 200 Output Pulse

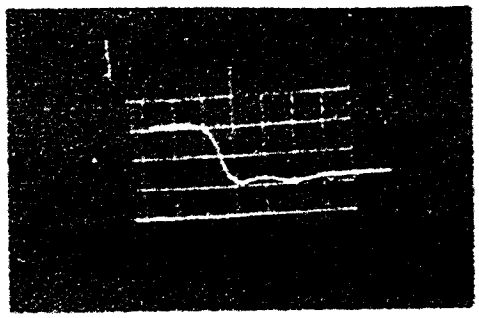

Fig. 7d System Output Pulse using EPIC

Fig. 7 Pulse Test Results Sweep Speed - 0.01 μsec/cm

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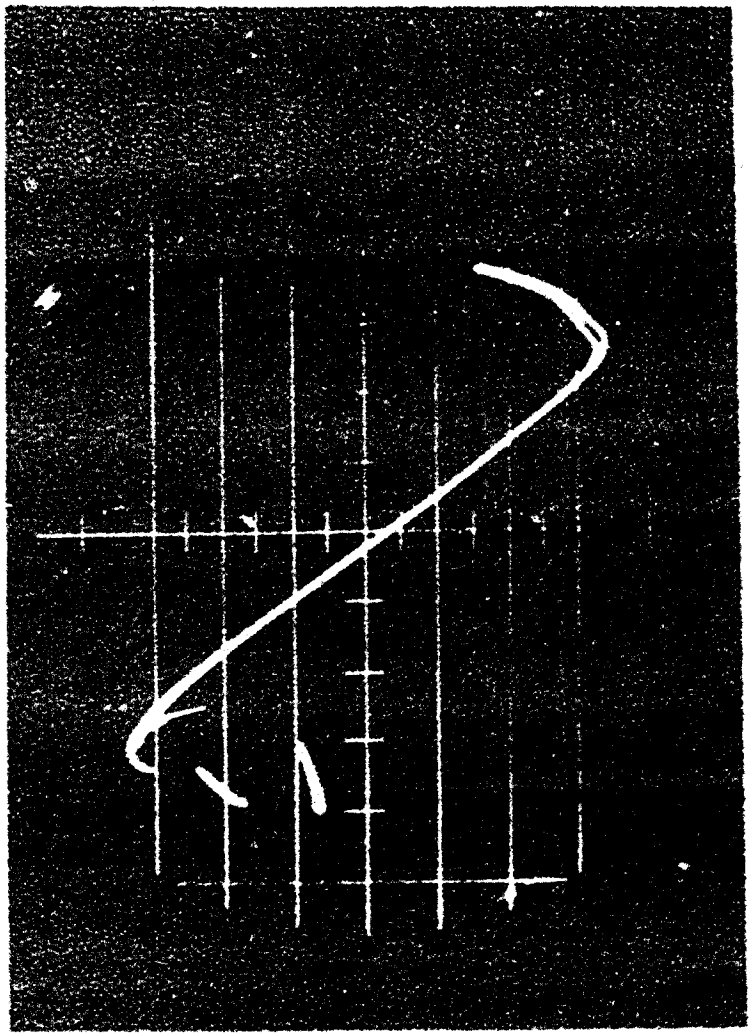

Fig. 2 Magic "T" Discriminator Curve

50-5000 pps, pulse length 0.07 to 10 microseconds. Maximum output: 50 volts to a 50-ohm load.

2. Rutherford Model B-2
   0.02 Microsecond Risetime
   10 cps - 100 kcps, pulse length 0.1 to 1000 microseconds, maximum output open circuit 100 volts across a 93-ohm plate or cathode resistor.

3. Electrical and Physical Instrument Corporation, Model 200
   0.001 Microsecond Risetime
   Pulse lengths: 1, 2, 5, 7.5, 10, 25, 50, and 100 millimicroseconds.
   60 pps only.
   Maximum output 100 volts to a 50-ohm load.

Risetime ratings are those given by the manufacturer.

A Tektronix-Type 517 oscilloscope has a rated vertical amplifier transient response of not greater than 0.007 microsecond which should be free of ringing and overshoot. Test equipment, impedance matching, interconnecting cables and connectors therefore limit the accuracy to which true risetime can be measured.

Figure 7 shows the results of two tests performed by modulating the reflex klystron with different pulses. Figure 7A is the positive input pulse to the klystron from the HP Mod 212A recorded on the Tektronix-Type 517 oscilloscope at a sweep speed of 0.01 microsecond per centimeter. The risetime is in the order of 0.012 microsecond. The output negative going pulse from the discriminator is shown in Figure 7B superimposed upon the input positive pulse. Close examination shows no perceptible difference in the risetime of the two pulses. Figure 7C is the positive input pulse to the Klystron from the EPIC Mod 200. Although the risetime on this pulse should be 0.001 microsecond, the actual risetime recorded on the scope is in the order of 0.005 to 0.006 microsecond due to the limitation on transient response of the Tektronix-Type 517 oscilloscope. The output negative going pulse from the Magic "T" discriminator is shown in Figure 7D. Its risetime is in the order of 0.007 to 0.008 microsecond. This last result shows that we are closely approaching the minimum risetime obtainable using this modulation method. In both cases, Figure 7B and Figure 7D, the klystron was pulsed over a bandwidth of 40 megacycles which is the linear region of the output discriminator curve shown in Figure 6 for this particular setup.

Another factor of interest is the pulse delay time through the klystron using pulse frequency modulation. This delay was measured by using two equal lengths of cable between the outputs of the pulse generator and the X-band discriminator to the input of the Tektronix 517 scope. The delay through the klystron, waveguide and crystal detector measured 0.0095 microsecond. The delay measured separately through the crystal detector was 0.004 microsecond. Therefore the delay through the klystron is in the order of 0.005 to 0.006 microsecond. Since X-band waveguide has a delay time of 0.01 microsecond per 7 ft. at 9400 megacycles the delay in the amount of waveguide used in the setup was negligible.

RECEIVING SYSTEM TEST SETUP:

A functional diagram of the receiving system test setup is shown in Figure 9. The bench test setup is shown in Figure 10.

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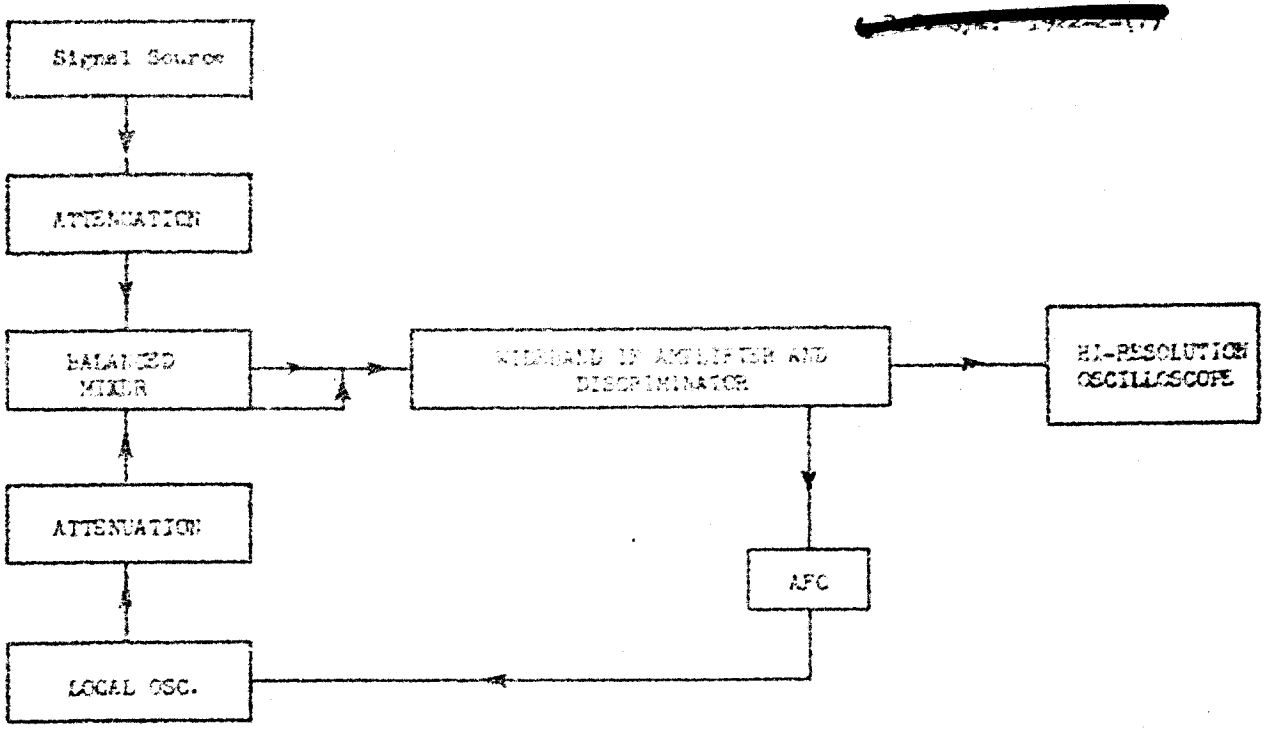

FIG. 9

This test setup essentially simulates an actual receiving system. The signal source is a reflex klystron of the type previously described under "Modulation Test Setup", and its power level is attenuated to about minus 60 to 70 DBM. A balanced mixer[1], shown in Figure 11, receives the low level signal and the local oscillator signal through the E and H arms of a Magic "T" waveguide structure. The difference or intermediate frequency of the local oscillator frequency and the signal frequency is held essentially constant by means of automatic frequency control. The intermediate frequency is detected and appears in the combined output of the two crystals located in the two side arms of the Magic "T" structure. The intermediate frequency is amplified in the IF amplifier. The information pulse, being transmitted by frequency modulation, is detected by means of a wide-band type discriminator circuit. The recovered information pulse is then displayed on a high-resolution oscilloscope for analysis and study.

Three output pulses shown in Figure 12 were obtained through this receiving system which used a Motorola type R-[illegible]-D IF amplifier. These output pulses have approximately a 0.07 microsecond risetime since the oscilloscope horizontal sweep speed is 0.05 microsecond per centimeter. Figure 12A is the resultant output pulse with a 0.001 microsecond risetime input pulse on the reflector element of the signal source klystron. Figure 12B is the resultant output pulse when using a 0.012

1 "Microwave Mixers" MIT Rad. Lab. Series, Vol. 15, pp 257-259.

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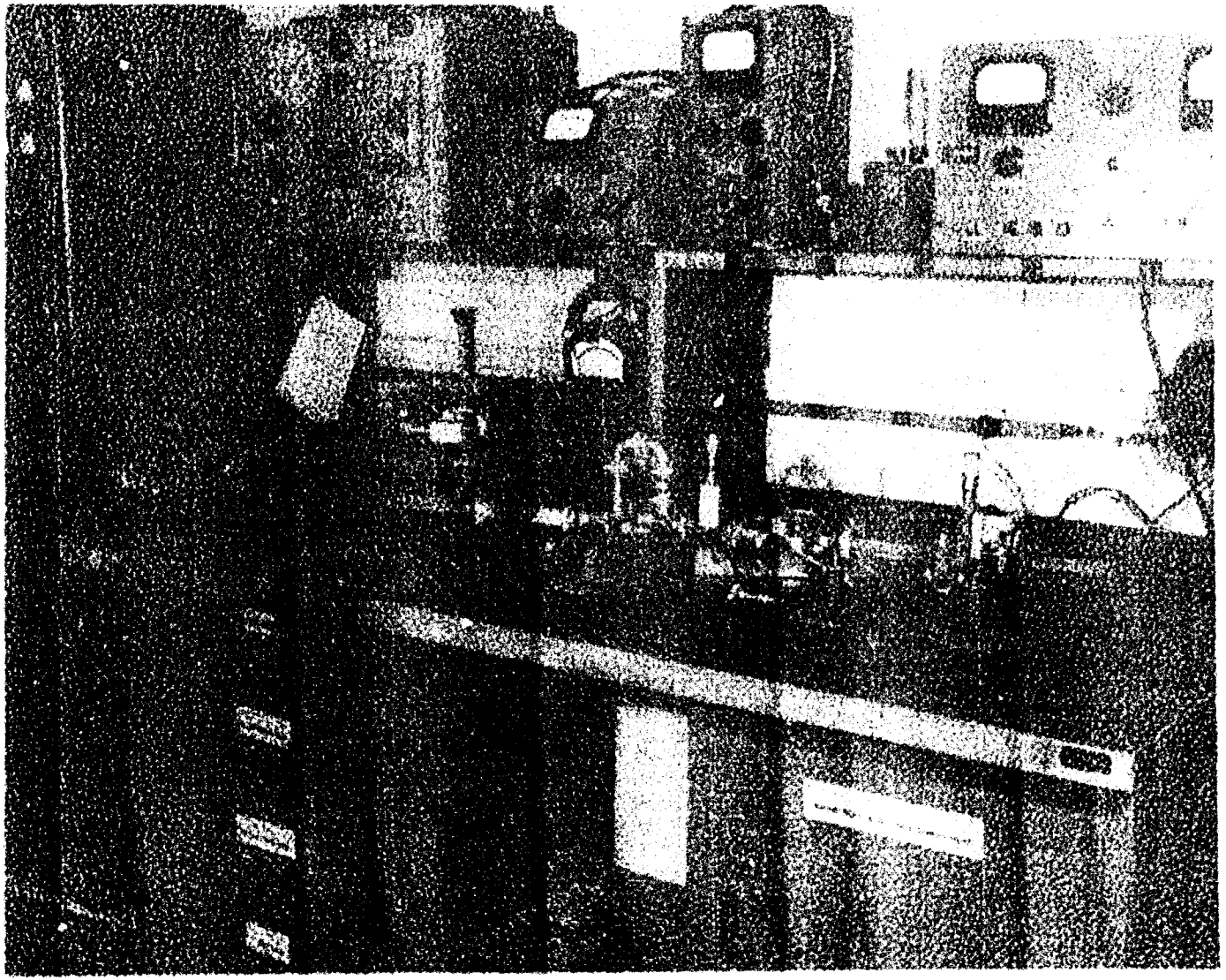

Fig. 10 Receiving System Bench Test Setup

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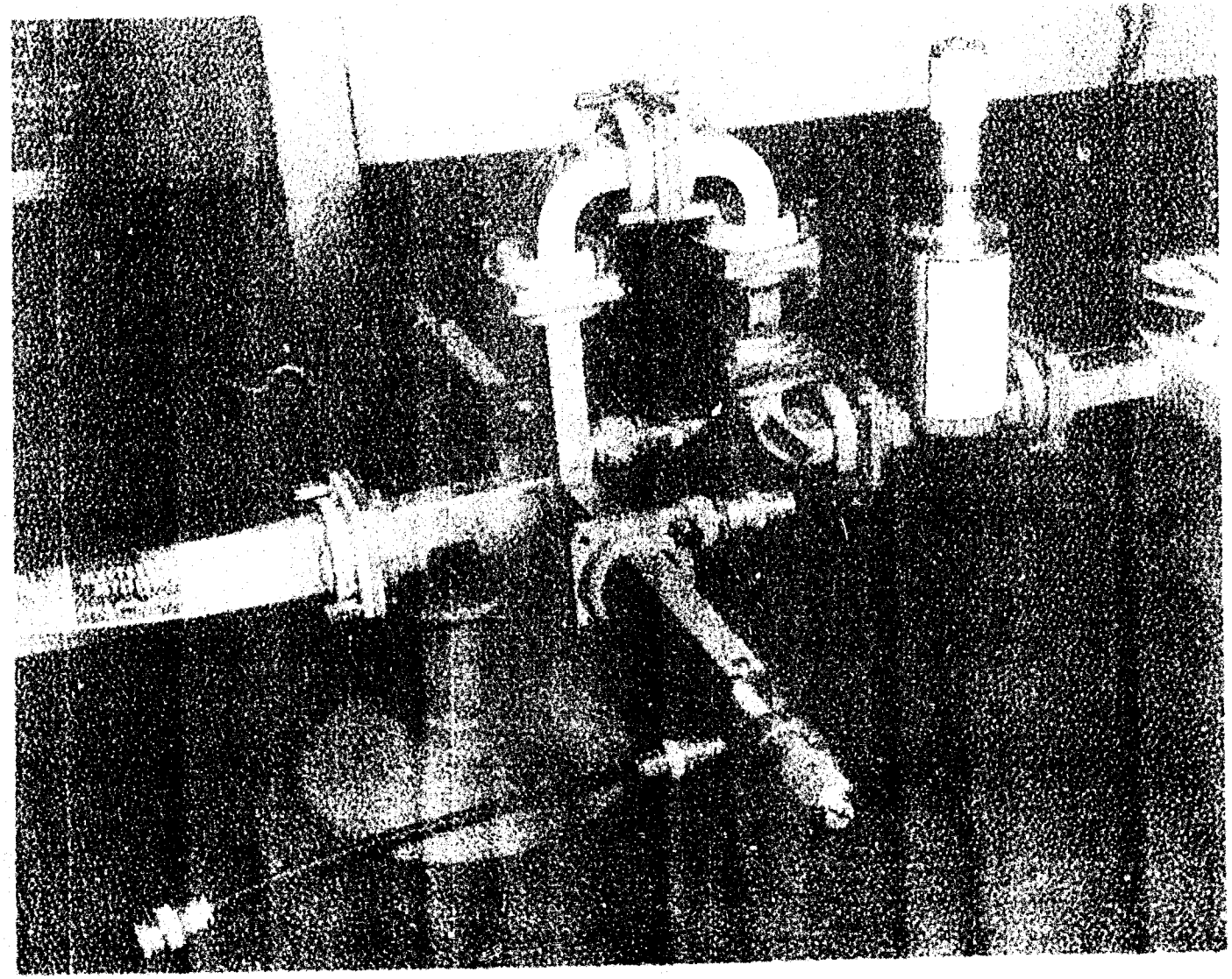

Fig. 11 Mavic "T" Balanced Mixer

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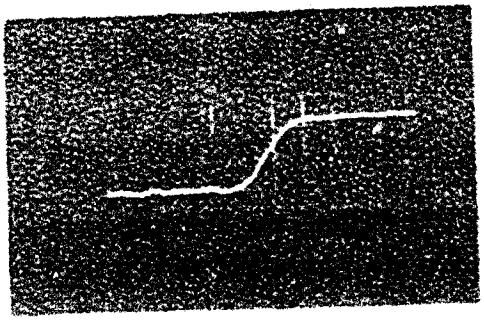

Fig. 12a Using EPIC

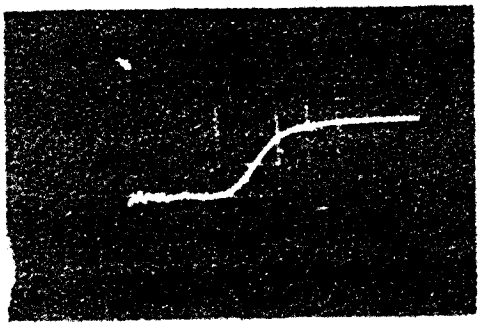

Fig. 12b Using HP 212A

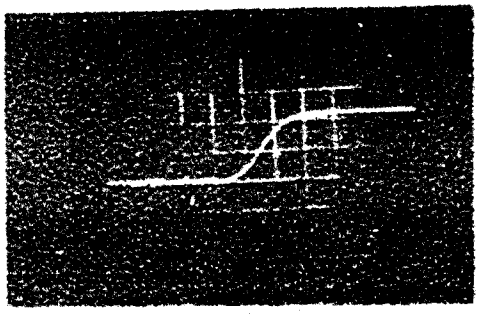

Fig. 12c Pulses Superimposed

Fig. 12 Receiver Test Output Pulses Sweep Speed - 0.05 μsec/cm

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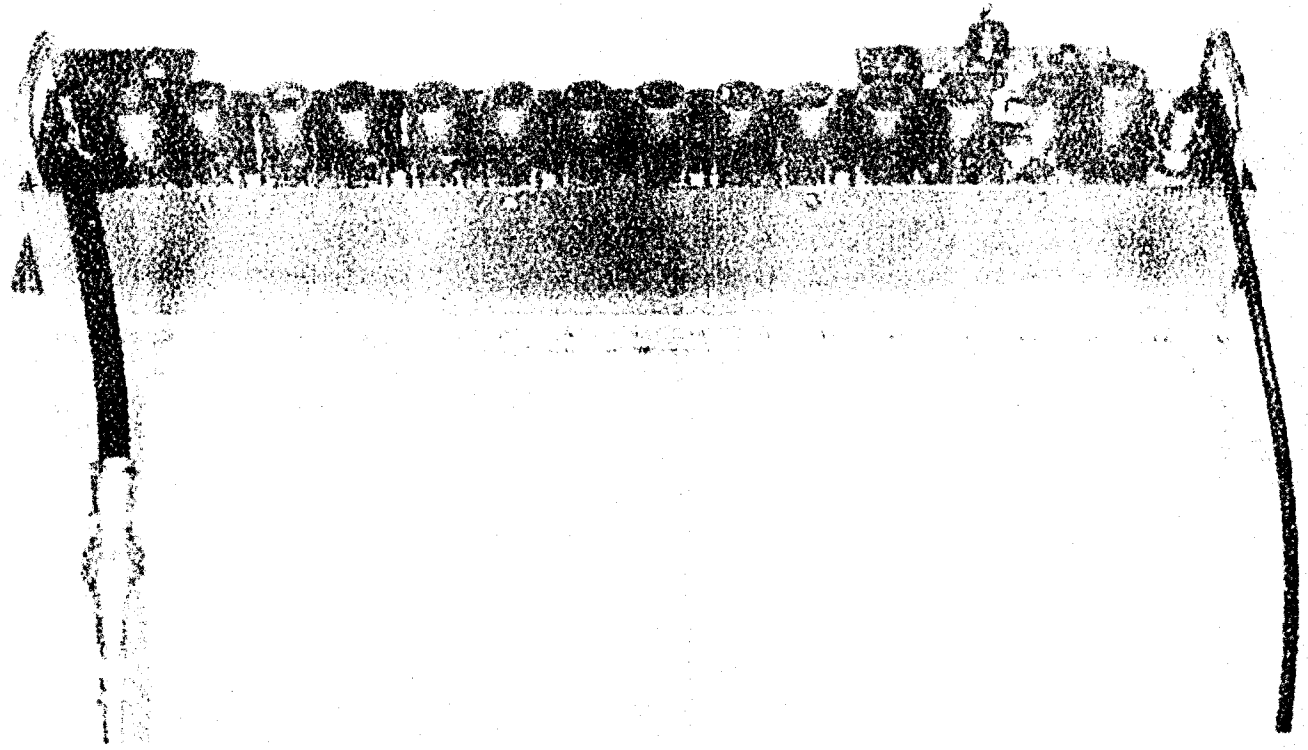

Fig. 13 Motorola Type F-2719-D IF Amplifier

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