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RADIOMETER SYSTEMS FOR OBSERVATIONS OF LUNAR OCCULTATIONS

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GENERAL

The occultation radiometers utilize three low frequency parametric amplifier systems, operating simultaneously on the 85-2 telescope. Each system is independent of the other, with exception of the common feed system. The front-end housings are weather proof and temperature controlled. Heating and cooling are provided by automatically-controlled solid-state thermoelectric heat pumps. Data is taken on magnetic tape and a six-channel Sanborn recorder.

FEED SYSTEM

The occultation systems use a model 297 Jasik Laboratories primary feed system. It consists of a 60-inch diameter ground plane with two sets of radiating elements orthogonally polarized to each other. Each set of radiating elements consists of two dipoles spaced in the H-plane. The phase center is at the face of the ground plane. The 405 MHz system uses one set of dipoles while the 234 MHz and 256 MHz systems share the other set. A diplexing filter with transmission loss of less than 0.5 dB is used to obtain separate outputs.

Jasik Laboratories Model 297 primary feed system specifications are:

H-Plane			
	405 MHz	14 1/2 dB	Taper ± 60°
	256 MHz	18 3/4 dB	Taper ± 60°
	234 MHz	17 dB	Taper ± 60°
E-Plane			
	405 MHz	12 dB	Taper ± 60°
	256 MHz	14 3/4 dB	Taper ± 60°
	234 MHz	14 3/4 dB	Taper ± 60°

f MHz	VSWR
232	1.15
234	1.09
236	1.15
254	1.16
256	1.06
258	1.19
395	1.25
398	1.25
405	1.15
412	1.09
415	1.20

FEED CABLES

The original feed cables were RG 9/U and were replaced by 1/2 inch Spiroline low loss cable about September 1, 1964. The following measurements were taken on September 10:

Frequency	Type Cable	Measured Length	Measured Insertion Loss
234 MHz	RG 9/U	2.56 m	0.29 dB
234 MHz	Spiroline	1.55 m	0.08 dB
256 MHz	RG 9/U	2.34 m	0.27 dB
256 MHz	Spiroline	2.29 m	0.12 dB
405 MHz	RG 9/U	2.24 m	0.35 dB
405 MHz	Spiroline	2.34 m	0.18 dB

FRONT-END HOUSING

The front end housings are 60" long, 16" wide and 10" deep and are constructed of aluminum. Three brackets are attached to the 10" dimension for mounting on the focal point support legs. The 405 MHz system is mounted on the East leg, the 234 MHz system on the North leg, and the 256 MHz system on the West leg. Each housing, with equipment, weighs approximately 150 pounds. When one system is removed from the telescope, a dummy weight is installed to maintain the same load on that leg.

The inside of the housings are insulated with 3/4" polyfoam. The cover is also insulated and equipped with DZUS fasteners for quick access to the equipment. The solid-state thermoelectric heaters are mounted in the same cover.

The housings were constructed with baffled input and output vents for temperature control with a cone heater in the input vent and a rotron fan at the exhaust vent. This system proved unsatisfactory and the vents were closed and sealed when the thermoelectric heaters were installed.

PARAMETRIC AMPLIFIERS

The parametric amplifiers used with these systems were manufactured by Airborne Instruments Laboratory. Models 3657A and 3657B (234 MHz and 256 MHz) are mounted on flat plates 12" x 14". Model 3657C (405 MHz) is mounted on a flat plate 12" x 18". All are non-degenerate, one-port amplifiers using the difference frequency mode.

The klystron power supplies are similar to others supplied by AIL. Meters are provided to monitor beam voltage, beam current and reflector voltage. The varactor bias supply is contained in this power supply unit but is not used. A mercury battery bias supply has been installed in each amplifier, thereby reducing the possibility of ground loops affecting the operation of the amplifier. The klystron filament transformer was replaced with a SOLA voltage regulated transformer for better stability. The klystron power supplies are designed for mounting in a standard 19" rack. Alignment and maintenance instructions are covered in the Handbook of Instructions provided by the manufacturer.

EQUIPMENT

The front-end equipment is mounted on three sections of 3/4" plywood which are shock mounted to the housing. The cable connectors are mounted on a BAKELITE plate and isolated from the housing.

234 MHz System

Equipment	Manufacturer and Serial Number
Parametric amplifier -------	AIL Model 3657A, Serial No. 001
Directional coupler ---------	Narda Model 3000-20, Serial No. 781
Diode switch ---------------	AEL (NRAO No. 2744)
Mixer preamp --------------	LEL Model UAC-3, Serial No. 11818
150 V DC supply ------------	ACDC Electronics, Serial No. 4125
DC filament supply ---------	Valor Instruments, Serial No. 128
Noise tube firing box --------	NRAO
Coaxial argon noise tube -----	AIL
50 Ω termination ------------	Microlab
DC block (2) ----------------	Microlab
10 dB Attenuator ------------	Microlab
Image rejection filter --------	NRAO
50 Ω load in thermos --------	Comparison channel
50 Ω load in thermos---------	Antenna substitution
Coaxial relay (2) ------------	FXR
Rotron fan -----------------	NRAO, No. 3100
Circulator -----------------	Sperry Company

256 MHz System

Parametric amplifier --------	AIL Model 2657B, Serial No. 001
Directional coupler ---------	Narda Model 3000-20, Serial No. 782
Diode switch ---------------	AEL SNB 682A, Serial No. 101
Mixer preamp --------------	LEL (NRAO No. 3035)
150 V DC supply ------------	ACDC Electronics, Serial No. 4101
DC filament supply ---------	Valor Instruments, Serial No. 116
Noise tube firing box -------	NRAO

Continued --

234 MHz System (continued)

Equipment	Manufacturer and Serial Number
Coaxial argon noise tube ----	AIL
50 Ω termination -----------	Microlab
DC block (2) --------------	Microlab
10 dB Attenuator -----------	Microlab
Image rejection filter ------	NRAO
50 Ω load in thermos -------	Comparison channel
50 Ω load in thermos -------	Antenna subsitution
Coaxial relay (2) -----------	FXR
Rotron fan ----------------	NRAO 3102
Circulator ----------------	Sperry Company

405 MHz System

Parametric amplifier -------	AIL Model 3657C, Serial No. 001
Directional coupler ---------	Narda Model 3000-20, Serial No. 490
Diode switch --------------	AEL Model SNB 683A, Serial No. 101
Mixer preamp -------------	LEL Model UBC-3, Serial No. 11816
150 V DC supply -----------	ACDC Electronics, Serial No. 4115
DC filament supply ---------	Valor Instrument Co., Serial No. 127
Noise tube firing box -------	NRAO
Coaxial argon noise tube ----	AIL
50 Ω termination -----------	Microlab
DC block (2) --------------	Microlab
10 dB Attenuator -----------	Microlab
Image rejection filter -------	NRAO
50 Ω load in thermos -------	Comparison channel
50 Ω load in thermos -------	Antenna substitution
Coaxial relay (2) ----------	FXR
Rotron fan ----------------	NRAO No. 3161
Circulator ----------------	Sperry Company

CABLING

AC Cable (11 Conductor No. 12)

Connector pin at focal point	Terminal No. in equipment room	Color code	Use
A	1	Shield	Shield
B	2	Green	Temp. control
C	3	Blue	Temp. control
G	4	Orange	Preamp filament
H	5	Red	Unreg. AC (fan)
J	6	White	Preamp filament
K	7	Blue/Black	Unreg. AC (fan)
L	8	White/Black	Noise tube
M	9	Black	Noise tube
N	10	Orange/Black	Noise tube
R	11	Green/Black	Reg. AC
S	12	Red/Black	Reg. AC

DC Cable (11 Conductor No. 18)

A	1	Shield	Shield
B	2	Shield	Ref. Gnd.
C	3	Shield	Bias Gnd.
F	4	White/Black	Beam
G	5	White RG 58	Ref.
H	6	Black RG 58	Bias (not used)
J	7	Orange/Black	Common
K	8	Red	Therm.
L	9	Red/Black	Therm.
M	10	Blue/Black	Xtal 1
N	11	Blue	Xtal 2
P	12	Green/Black	Xtal common

Continued --

DC Cable (11 Conductor No. 18)
(continued)

Connector pin at focal point	Terminal No. in equipment room	Color code	Use
R	13	Orange	+ 150 DC
S	14	Green	150 DC common

Antenna change-over relays and calibration relays use RG 58/U. Switch drive, LO and IF use RG 9/U.

PARAMETRIC AMPLIFIERS -- MEASUREMENT OF GAIN-BANDPASS CHARACTERISTICS

The parametric amplifiers were aligned using the test equipment arrangement shown in Figure 2. Scope sensitivity was 200 μV/cm and the input level was adjusted as low as possible to avoid saturation.

Model 3657A (234 MHz)

Gain: 20 dB

BW (1 dB points): 232.5 MHz - 235.5 MHz = 3 MHz

BW (3 dB points): 231 MHz - 237 MHz = 6 MHz

Center frequency: 234 MHz

Model 3657B (256 MHz)

Gain: 20 dB

BW (1 dB points): 254.5 MHz - 257.5 MHz = 3 MHz

BW (3 dB points): 253 MHz - 259 MHz = 6 MHz

Center frequency: 256 MHz

Model 3657C (405 MHz)

Gain: 20 DB

BW (1 dB points): 399 MHz - 411 MHz = 12 MHz

BW (3 dB points): 392 MHz - 415 MHz = 23 MHz

Center frequency: 405 MHz

PARAMETRIC AMPLIFIERS -- NOISE FIGURE MEASUREMENTS

The noise figure measurements were made using the Y-factor method. Both hot-cold and argon measurements were taken. The argon measurements should be disregarded.

Hot-Cold Method

Frequency	Y_{dB}	T_s	T_2	T_R
234 MHz ----	3.47	160 °K	20 °K	140 °K
256 MHz ----	3.60	150 °K	21 °K	129 °K
405 MHz ----	3.39	168 °K	22 °K	146 °K

Argon Method (with 9.9 dB attenuator)

Frequency	Y_{dB}	T_s	T_2	T_R
234 MHz ----	5.6	75 °K	20 °K	55 °K
256 MHz ----	5.3	101 °K	21 °K	80 °K
405 MHz ----	5.1	125 °K	22 °K	103 °K

Argon Mount Measurements

Frequency	Cold insertion loss	Hot insertion loss	Cold VSWR	Hot VSWR	Argon correction
234 MHz ----	0.20	13.15	1.05	1.13	0.3 dB
405 MHz ----	0.35	13.20	1.10	1.14	0.3 dB

Weinschel 10 dB attenuator measured 9.9 dB at 234 MHz, 256 MHz and 405 MHz.

SYSTEM BANDPASS MEASUREMENTS

Bandpass measurements were made from the antenna input connector to the IF output connector on the front-end housing and from the antenna input connector to the detector out jack on the standard receiver.

Frequency	Bandwidth antenna input to IF out	Bandwidth antenna input to detector out
234 MHz ---	4 MHz	4 MHz
256 MHz ---	4 MHz	4 MHz
405 MHz ---	9 MHz	8 MHz

Measurements were also made with 30 MHz Filtech filters at input to standard receiver. The 2 MHz and 4 MHz bandwidth filters gave system bandwidths of 2 MHz and 4 MHz. The 8 MHz filter gave a system bandwidth of 6 MHz on the 405 MHz system.

SYSTEM NOISE FIGURE MEASUREMENTS

System noise figure measurements were made using the Y-factor method. Both hot-cold and argon measurements were taken. Measurements do not include feed cable.

234 MHz System

	Hot-Cold	Argon
Paramp --------------------	140 °K	55 °K
Switch and directional coupler--	50 °K	50 °K
Second stage contribution -----	20 °K	20 °K
Complete system ------------	210 °K	125 °K

256 MHz System

	Hot-Cold	Argon
Paramp --------------------	130 °K	80 °K
Switch and directional coupler--	80 °K	69 °K
Second stage contribution -----	21 °K	21 °K
Complete system ------------	231 °K	170 °K

Continued --

405 MHz System

	Hot-Cold	Argon
Paramp --------------------	146 °K	103 °K
Switch and directional coupler--	82 °K	65 °K
Second stage contribution ------	22 °K	22 °K
Complete system -------------	250 °K	190 °K

THERMAL CALIBRATIONS

Each system uses an argon calibration with directional coupler and 10 dB attenuator. See system block diagram. Thermal calibrations were made at the input connections to the front-end box and do not include feed cable or losses of the diplexer at 234 MHz and 256 MHz. No diplexer is used at 405 MHz.

Frequency	Date	Calibration by	Calibrated argon
234 MHz --	2-29-64	Pasternak	10.5 °K
256 MHz --	3-5-64	Pensinger	12.18 °K
405 MHz --	2-29-64	Pasternak	12.88 °K
234 MHz --	10-16-64	Pasternak	9.16 °K
256 MHz --	8-27-64	Pasternak	11.31 °K
405 MHz --	9-25-64	Pasternak	14.03 °K

The following thermal calibrations were made on the telescope and include the RG/9 U feed cable. The 234 MHz and 256 MHz calibrations do not include the diplexer loss.

Frequency	Date	Calibration by	Calibrated argon
234 MHz --	7-15-64	Perry	10.74 °K
256 MHz --	7-15-64	Perry	14.03 °K
405 MHz --	7-15-64	Perry	17.97 °K

SYSTEM TESTING PROCEDURE ON TELESCOPE

The feed system for occultation is usually installed on the same day as the occultation to minimize lost telescope time. To permit testing of the occultation systems, without feed, a DC coaxial relay and a 50 ohm termination were installed at the system input to allow tests with switched ambient loads. This arrangement has proved very satisfactory. Troubles in phase detectors, receiver power supplies, local oscillators and the Sanborn recorder were detected and repaired prior to observation time. This method helps determine the telescope testing time required when troubles are indicated in the front-end equipment.

EQUIPMENT CHANGES AFTER INITIAL INSTALLATION

1. The +150 V DC power supplies and the DC filament power supplies for the preamps were removed from the front-end housings and installed in the control room to reduce the heat dissapation.

2. Thermoelectric heat pumps were installed in the front-end housing covers.

3. The argon calibration systems were modified by adding a coaxial relay. Noise generated by the noise tube firing box interfered with all systems. During observations the noise tube remains fired and the calibration is injected by operation of the DC relay.

4. Three-port circulators were installed between the paramp and mixer on the 234 MHz and 405 MHz systems. A three-port circulator was installed between the diode switch and paramp on the 256 MHz system.

5. The RG 9/U feed cables were replaced with low loss Spiroline.

6. Spare RG 9/U feed thru connector installed near antenna input connector.

DISCUSSION

Prior to installation, all the equipment to be used at the telescope was connected in the lab and stability tests were made with the systems operating on switched ambient loads. After installation, the 256 MHz system would not operate on antenna, but operated satisfactorily on switched loads. This led to extensive testing of the 256 MHz system. See test report "Special Test on 256 MHz Occultation Front End" by Pasternak, filed under project 621. As a result of these tests all paramp circulators were found to be defective and were returned to the manufacturer for repair. Additional circulators were purchased from Sperry Company. These circulators are used to isolate the second stage in the 234 MHz and 405 MHz systems. The 256 MHz system required a circulator at the paramp input for best stability.

Extensive lab tests were made to determine the cause of total power instability on all systems. See Figures 11-14. Sudden gain changes in the order of 0.1 dB to 0.75 dB were traced to beam voltage changes. This effect was minimized by careful adjustment of the beam feedback and beam output controls and proper adjustment of the klystron reflector voltage.

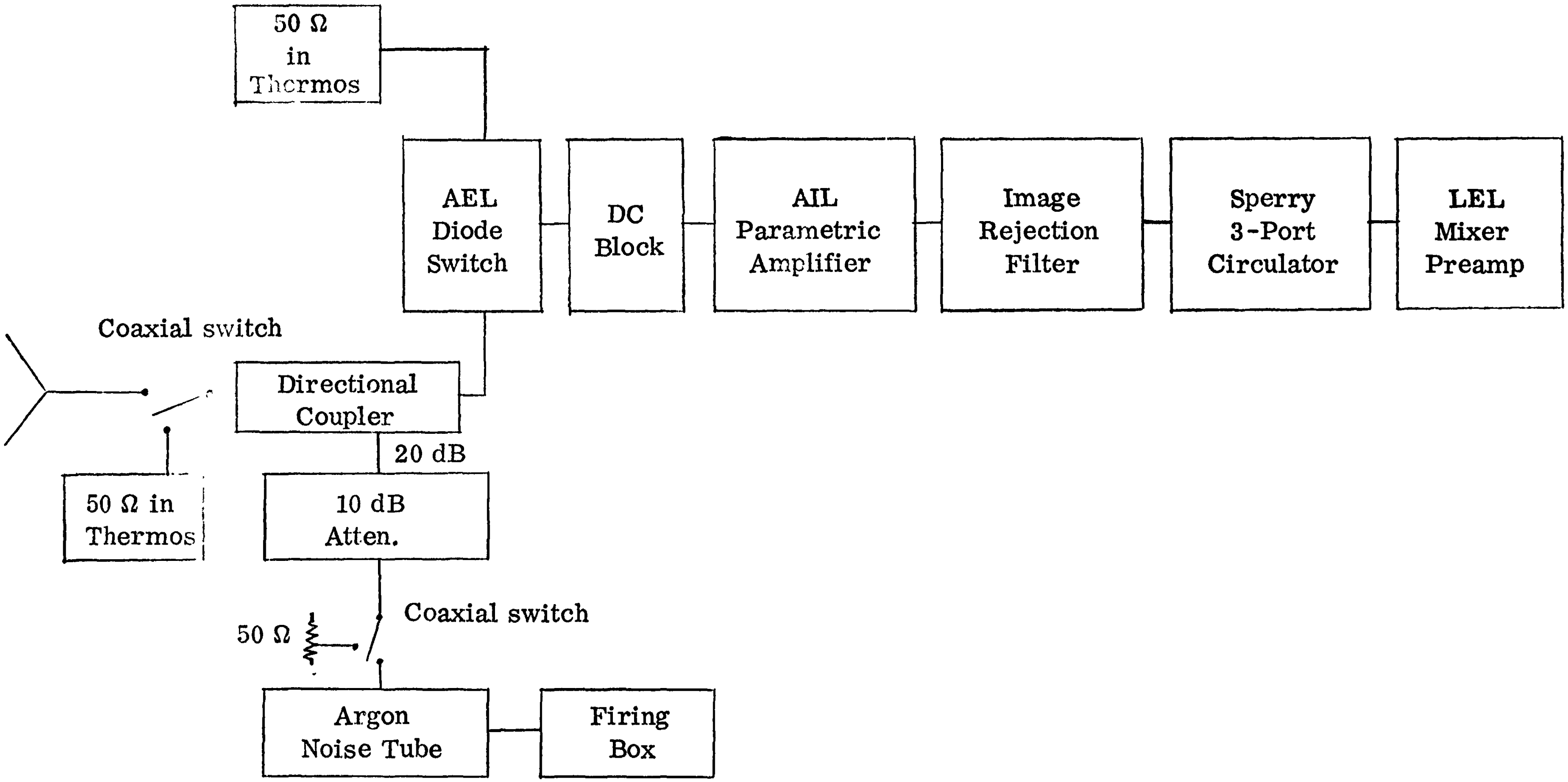


Figure 1. Block diagram of front-end equipment for 234 MHz and 405 MHz systems. The 256 MHz system has the 3-port circulator directly in front of the parametric amplifier.

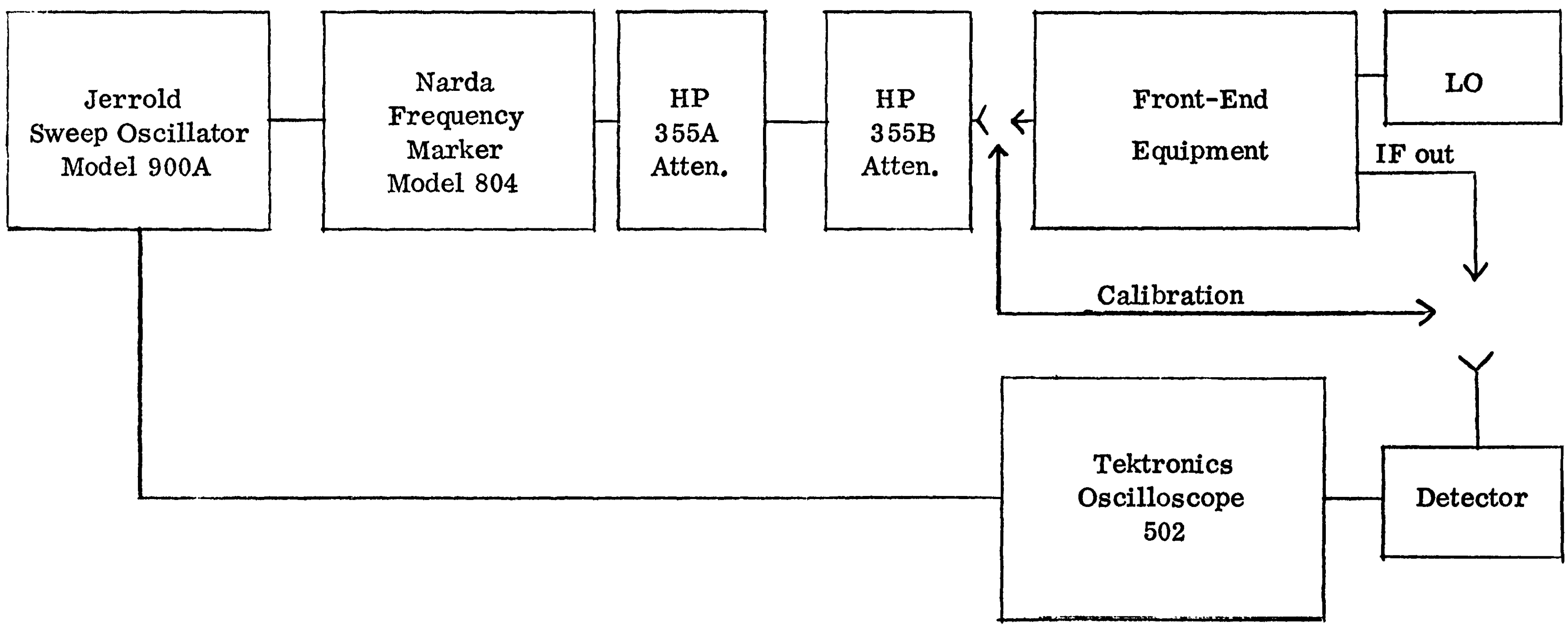


Figure 2. Test equipment arrangement used to observe gain-bandpass characteristics. Scope sensitivity was 200 $\mu V/cm$ and input level was adjusted for minimum to avoid saturation of the parametric amplifier.

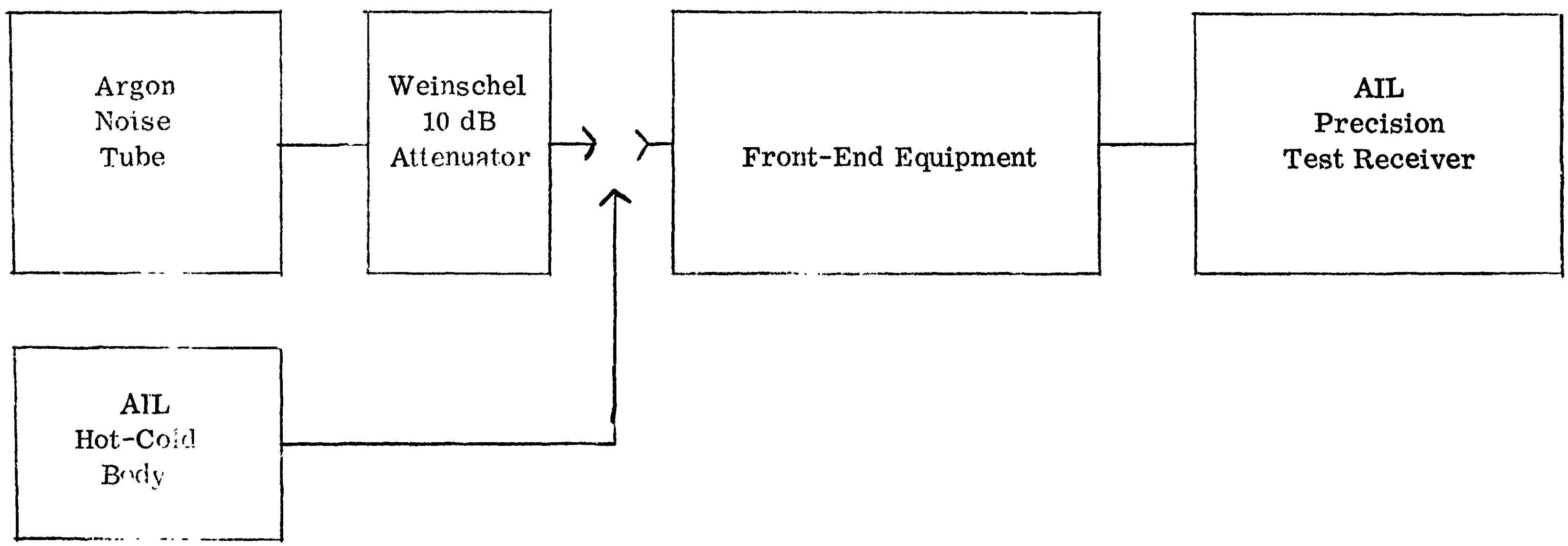


Figure 3. Methods used for making system noise figure measurements.

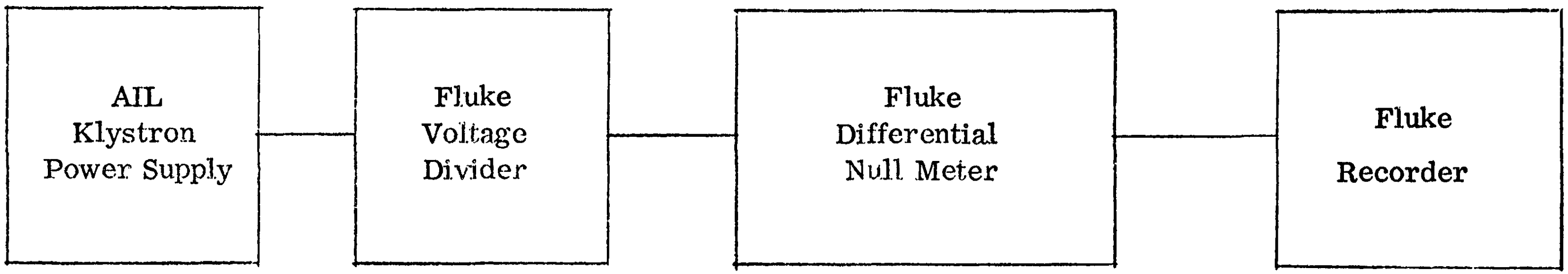


Figure 4. Method used to monitor beam voltage.

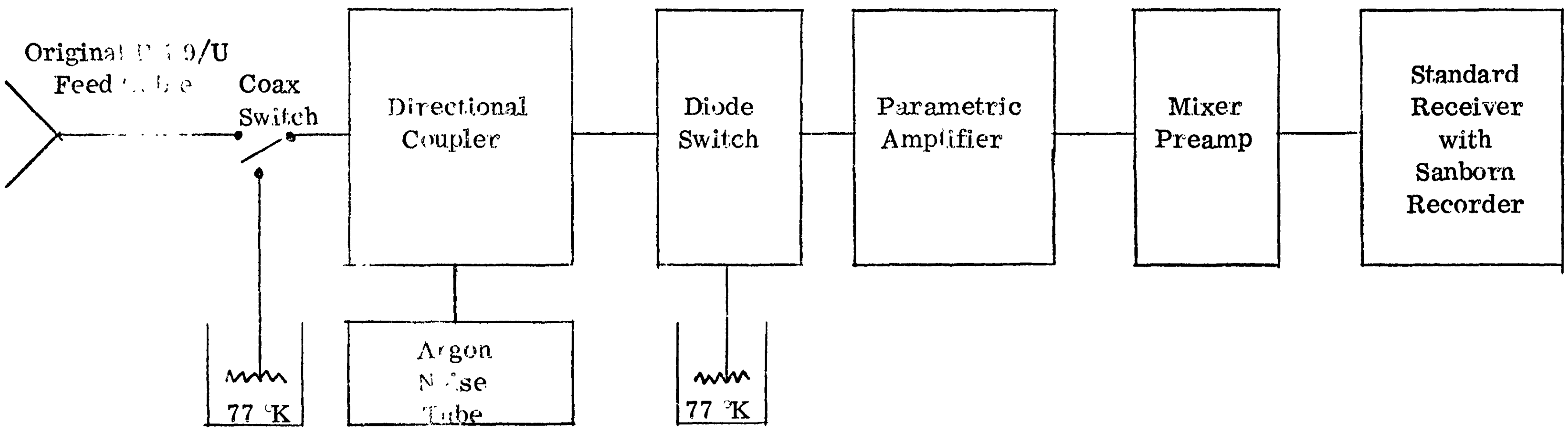


Figure 5. Simplified block diagram showing method used to determine approximate antenna temperature at 2[illegible]6 MHz. The receiver was balanced on switched 77 °K loads and argon calibrations of approximately 63°, 80° and 100 °K were injected. The coaxial switch was then operated to the antenna position for comparison. See test record for results.

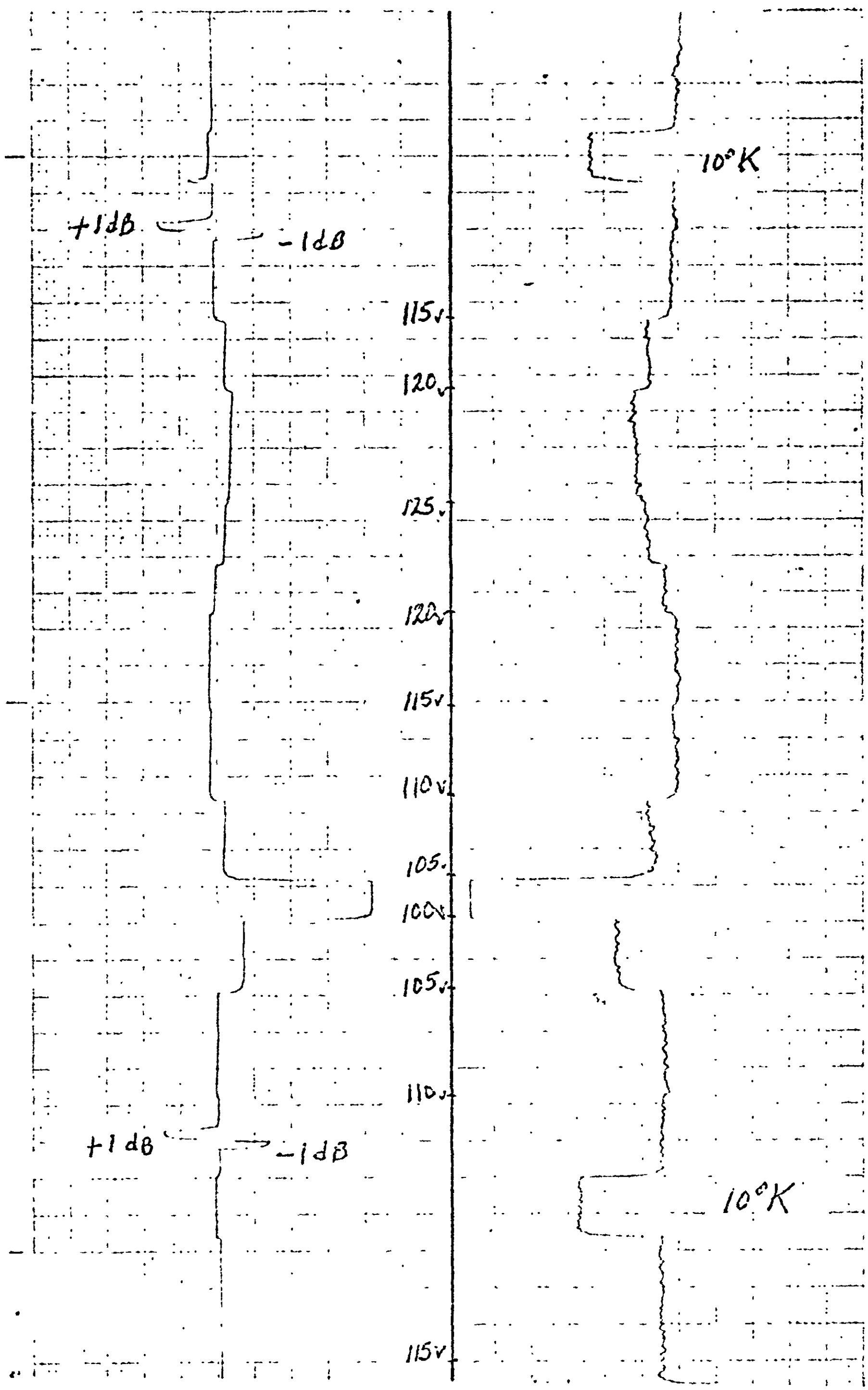


Figure 6

234 MHz Paramp

AC Line Voltage vs. Output

Receiver switching between 77° and 300 °K.

Chart speed 5 mm/min. Time constant 2 sec. Receiver balanced at 115 V AC and temperature approximately 25 °C.

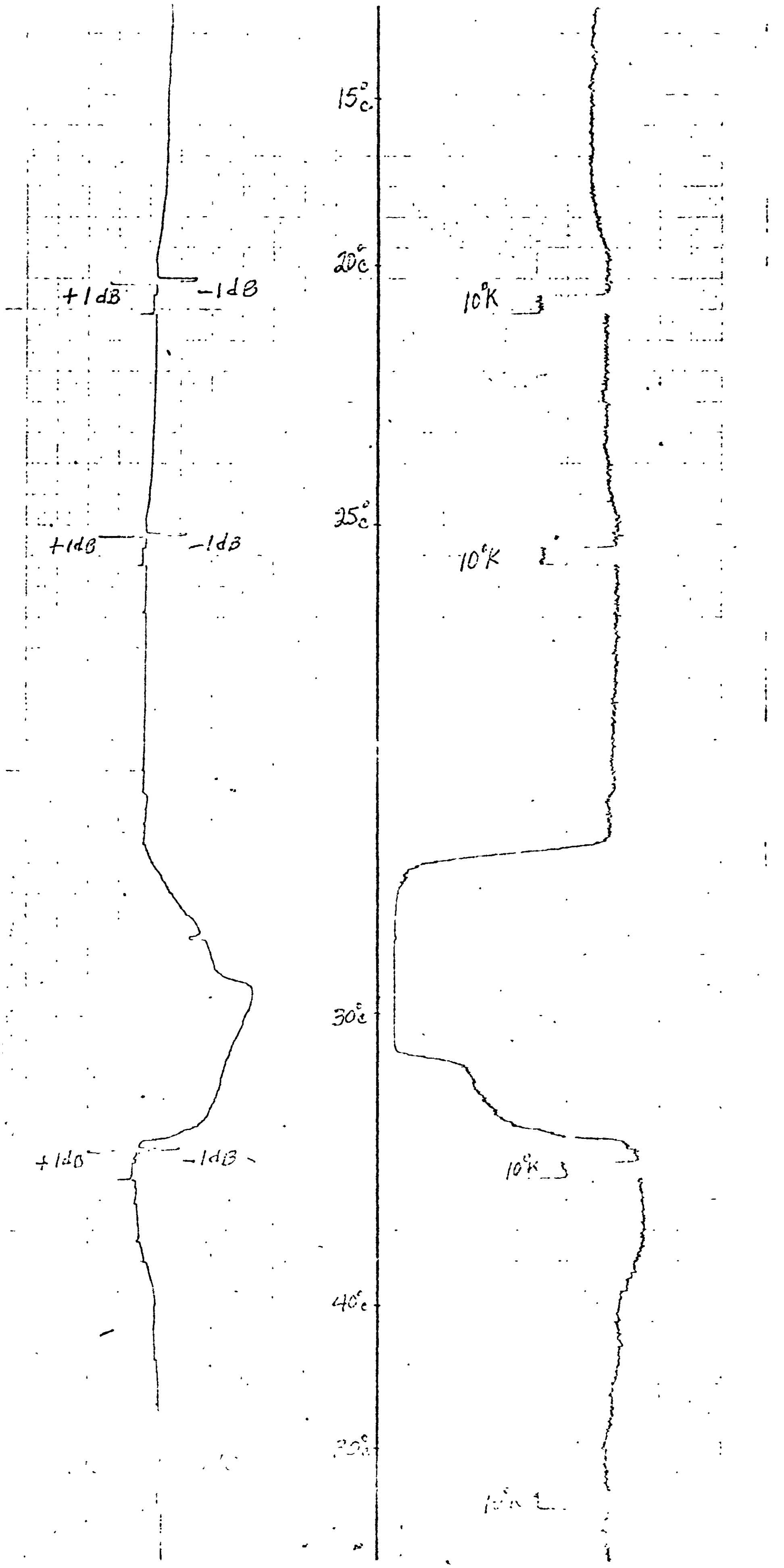


Figure 7

234 MHz Paramp

Ambient Temperature
vs. Output

Receiver switching
between 77° and 300 °K.
Chart speed 1 mm/min.
Time constant 2 sec.
Receiver balanced at
25 °C.

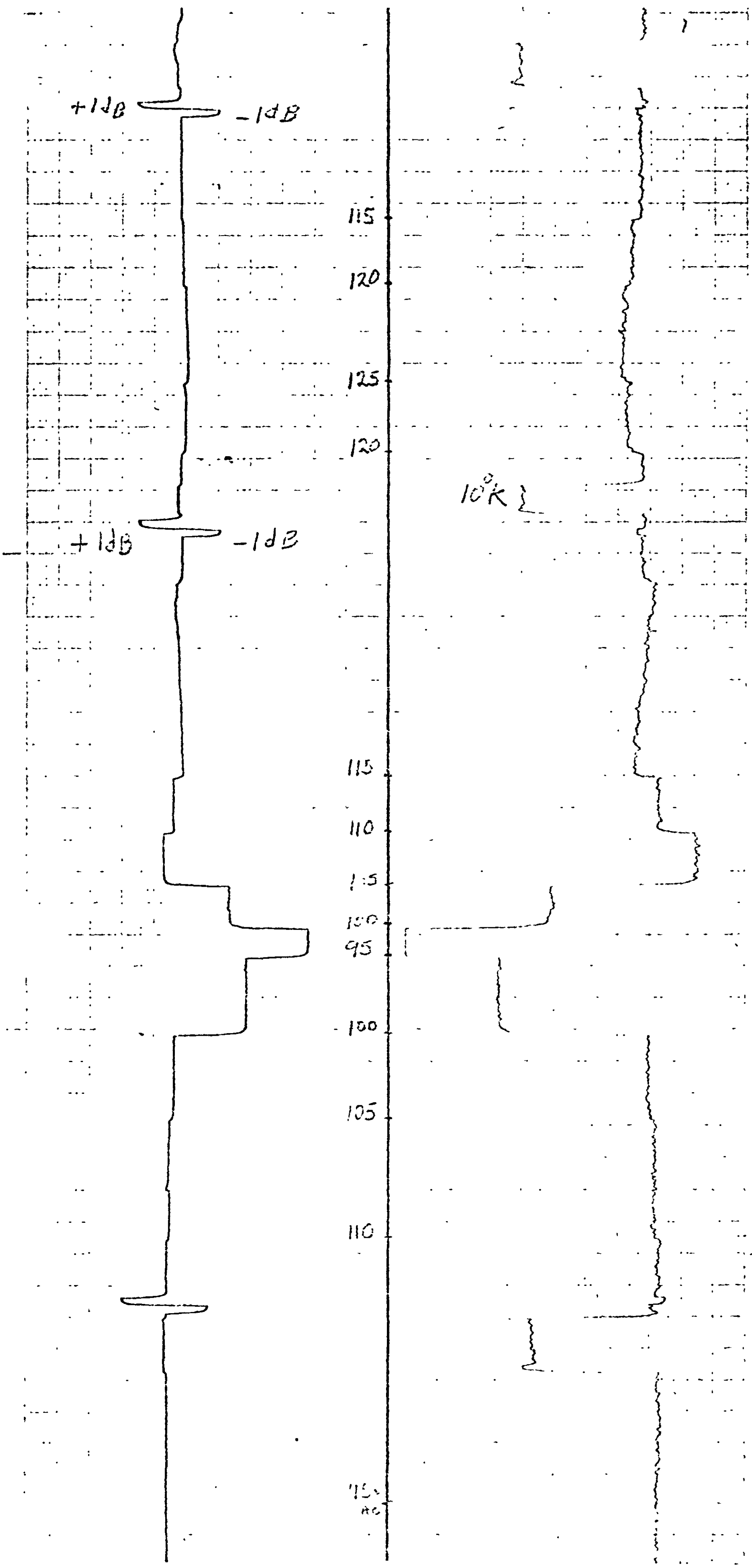


Figure 8

256 MHz Paramp

AC Line Voltage vs. Output

Receiver switching between 77° and 290 °K. Chart speed 5 mm/min. Time constant 2 sec. Receiver balanced at 115 V AC and temperature approximately 25 °C.

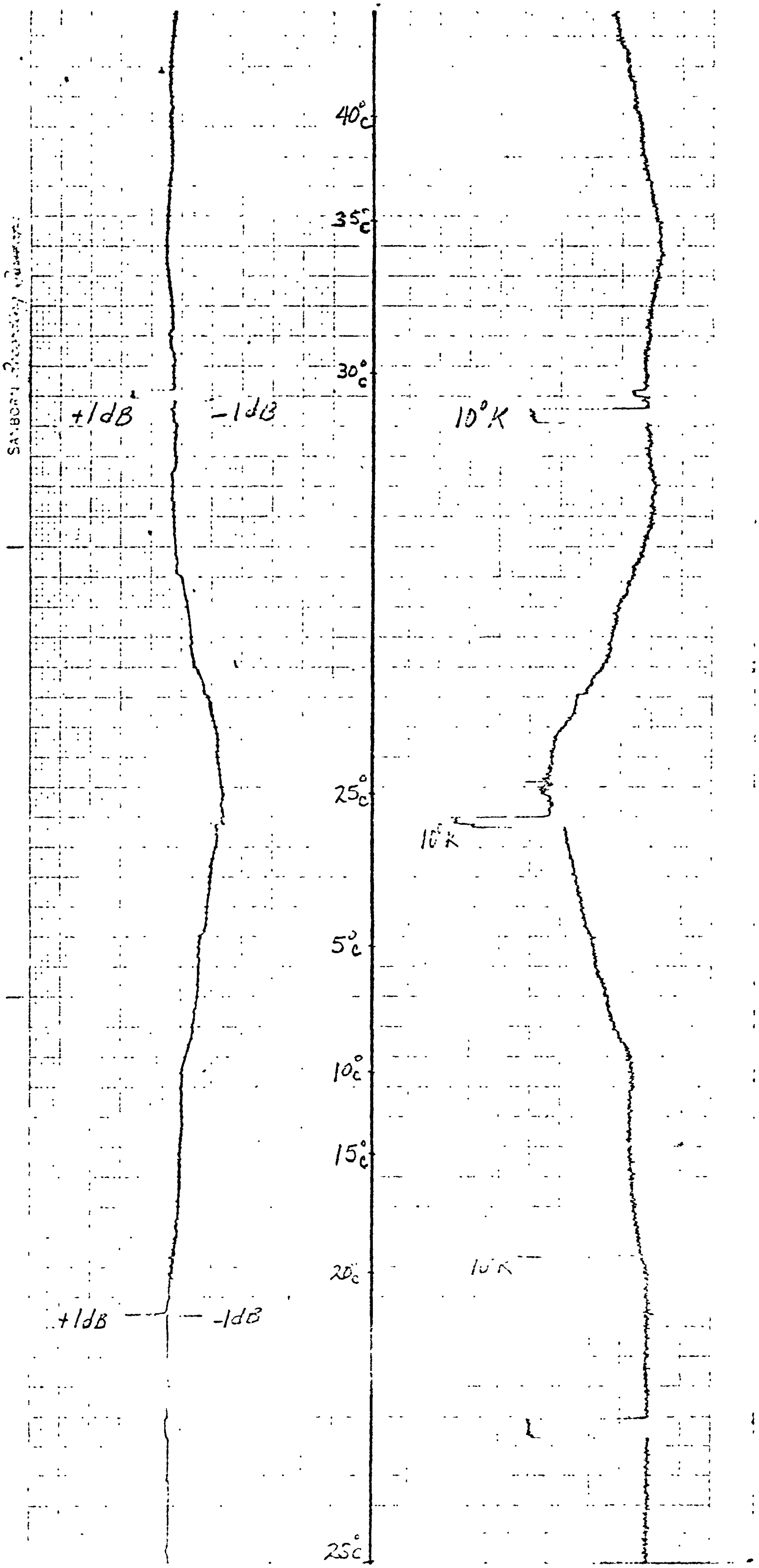


Figure 9

256 MHz Paramp

Ambient Temperature vs. Output

Receiver switching between 77° and 300 °K. Chart speed 1 mm/min. Time constant 2 sec. Receiver balanced at 115 V AC and temperature 25 °C.

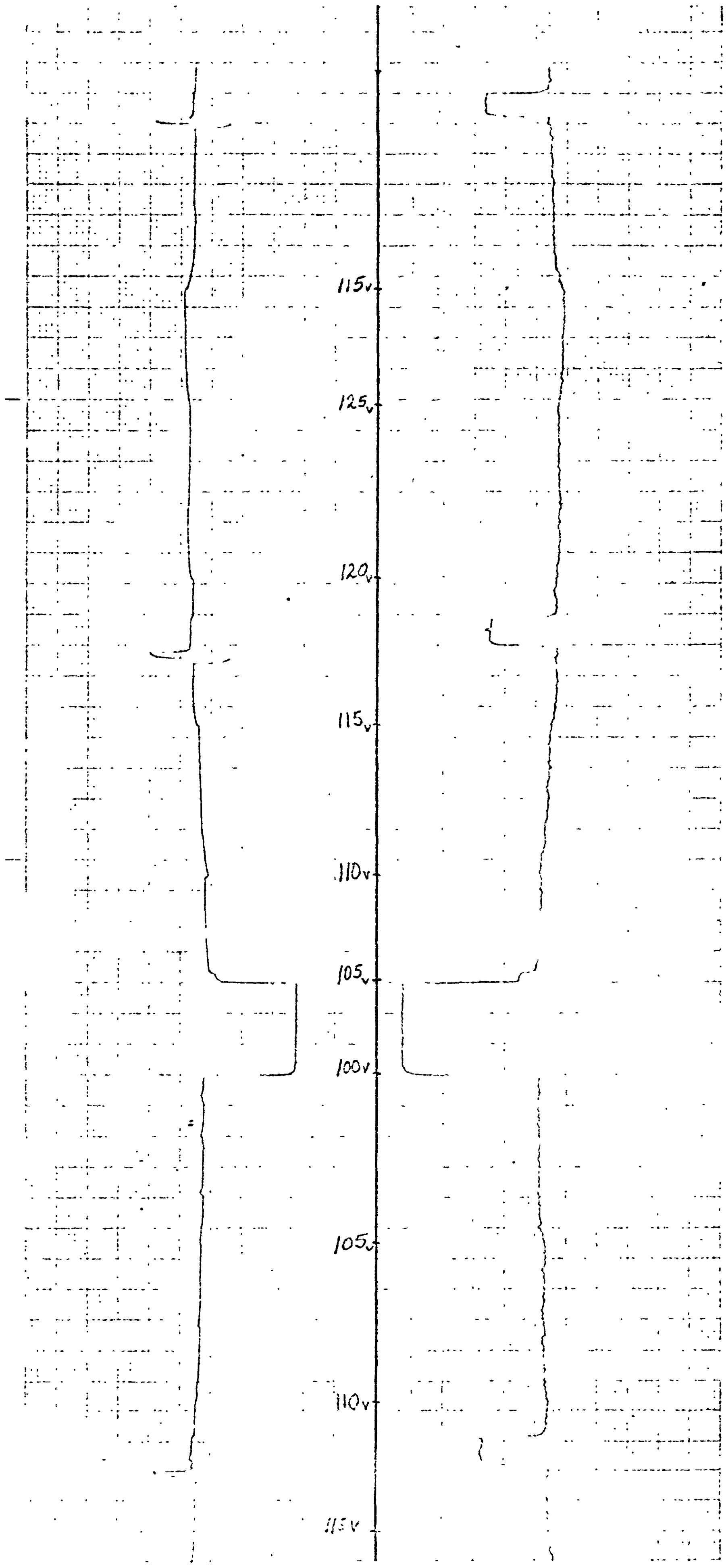


Figure 10

405 MHz Paramp

AC Line Voltage vs. Output

Receiver switching between 77° and 300 °K. Chart speed 5 mm/min. Time constant 2 sec. Receiver balanced at 115 V AC and temperature approximately 25 °C.

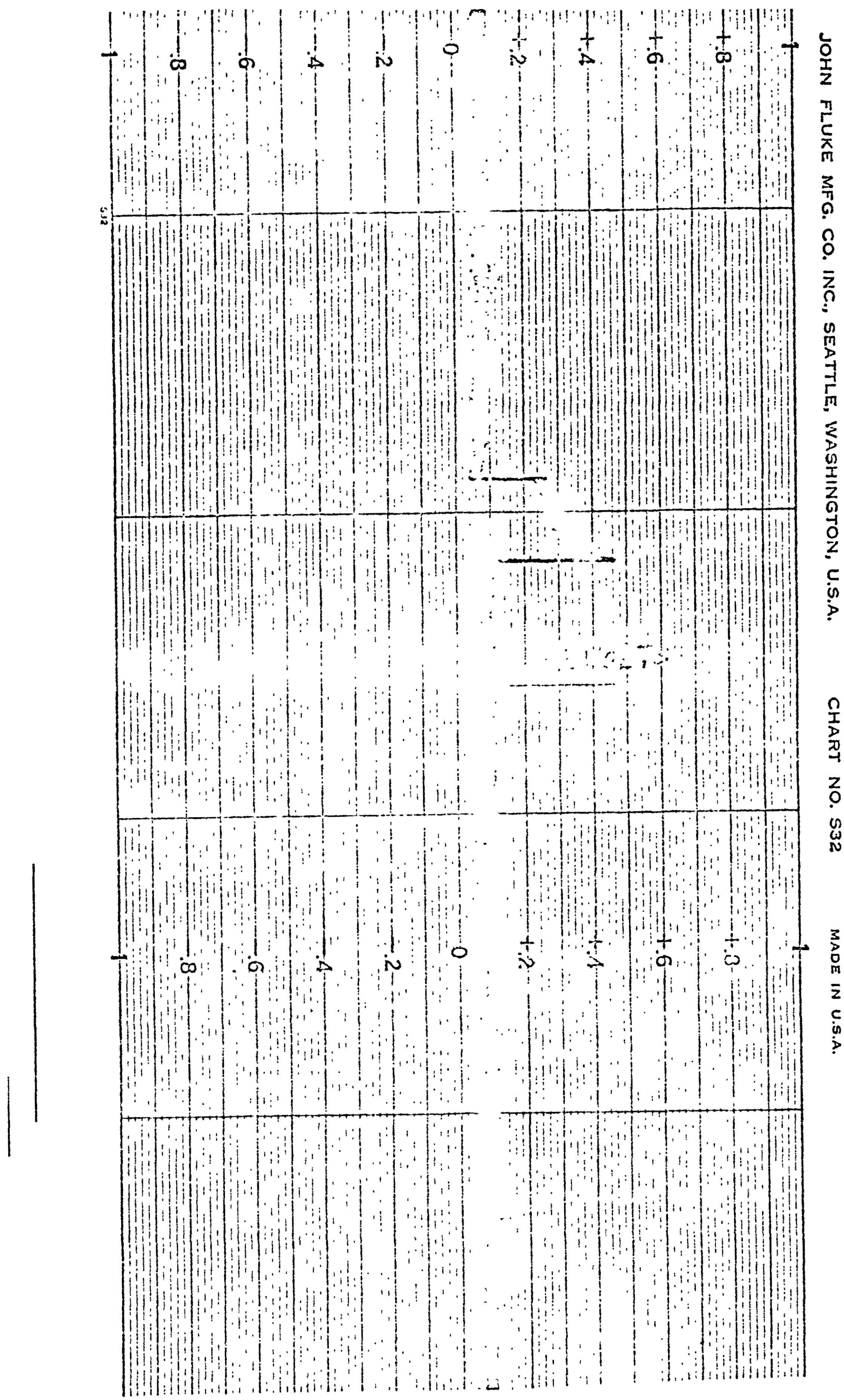


Figure 11. Portion of 234 MHz system record showing beam voltage change. See text for discussion and block diagram for equipment arrangement. Chart speed 3" per hour.

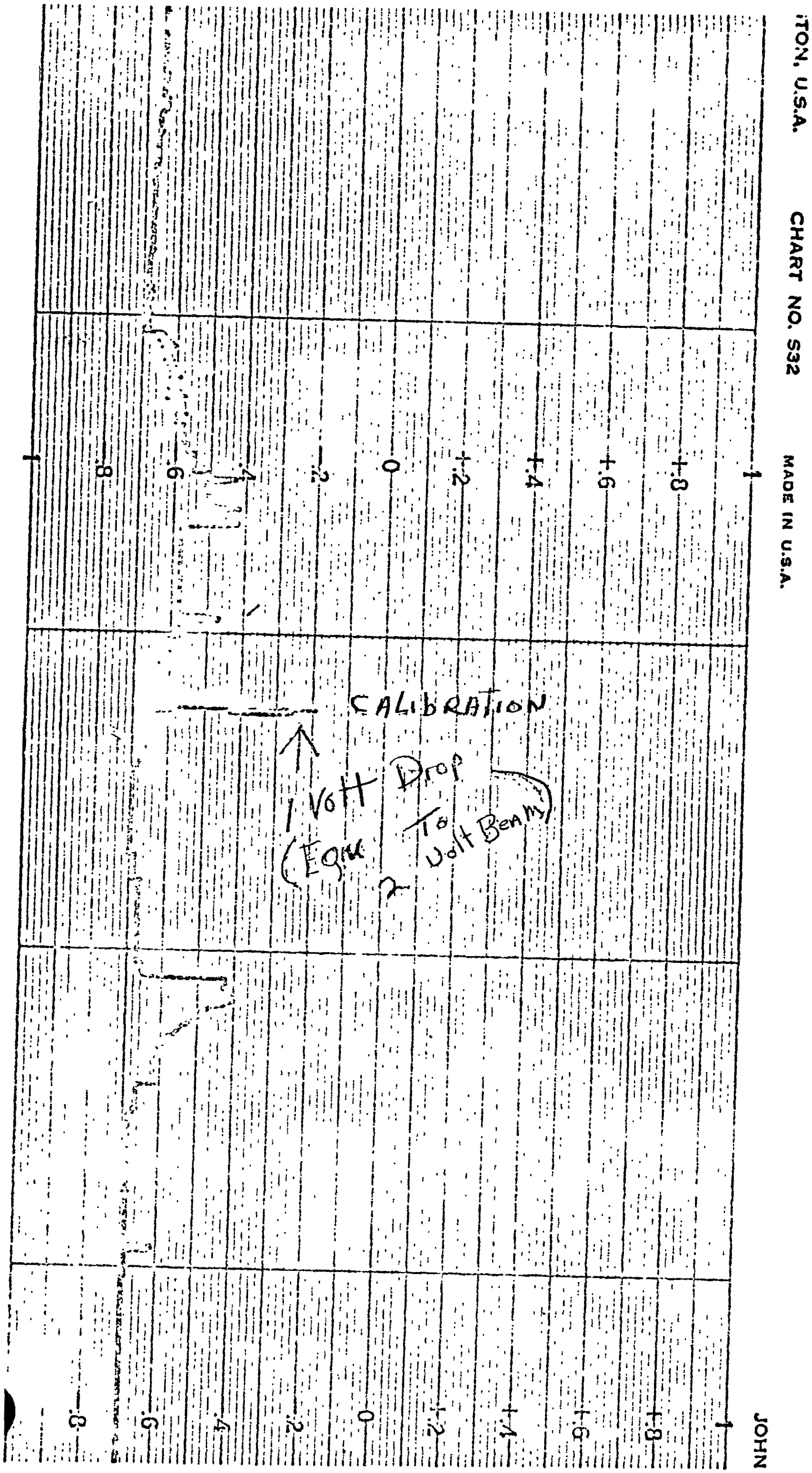


Figure 12

Portion of Record Showing Beam Voltage Change in 256 MHz System.

Chart speed 3" per hour. See text for discussion and block diagram for equipment arrangement.

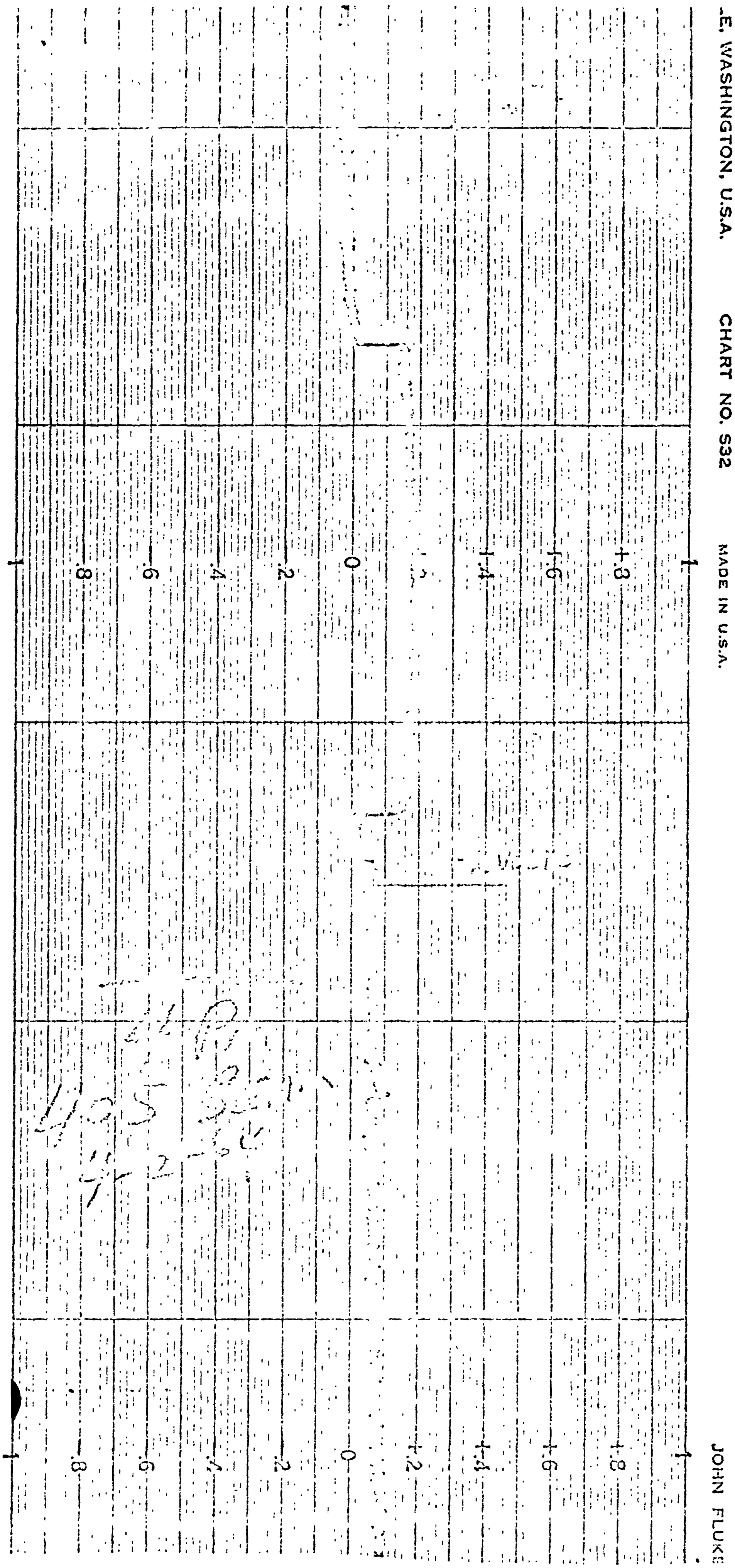


Figure 13

Portion of Record Showing Beam Voltage Change in 405 MHz System.

Chart speed 3" per hour. See text for discussion and block diagram for equipment arrangement.

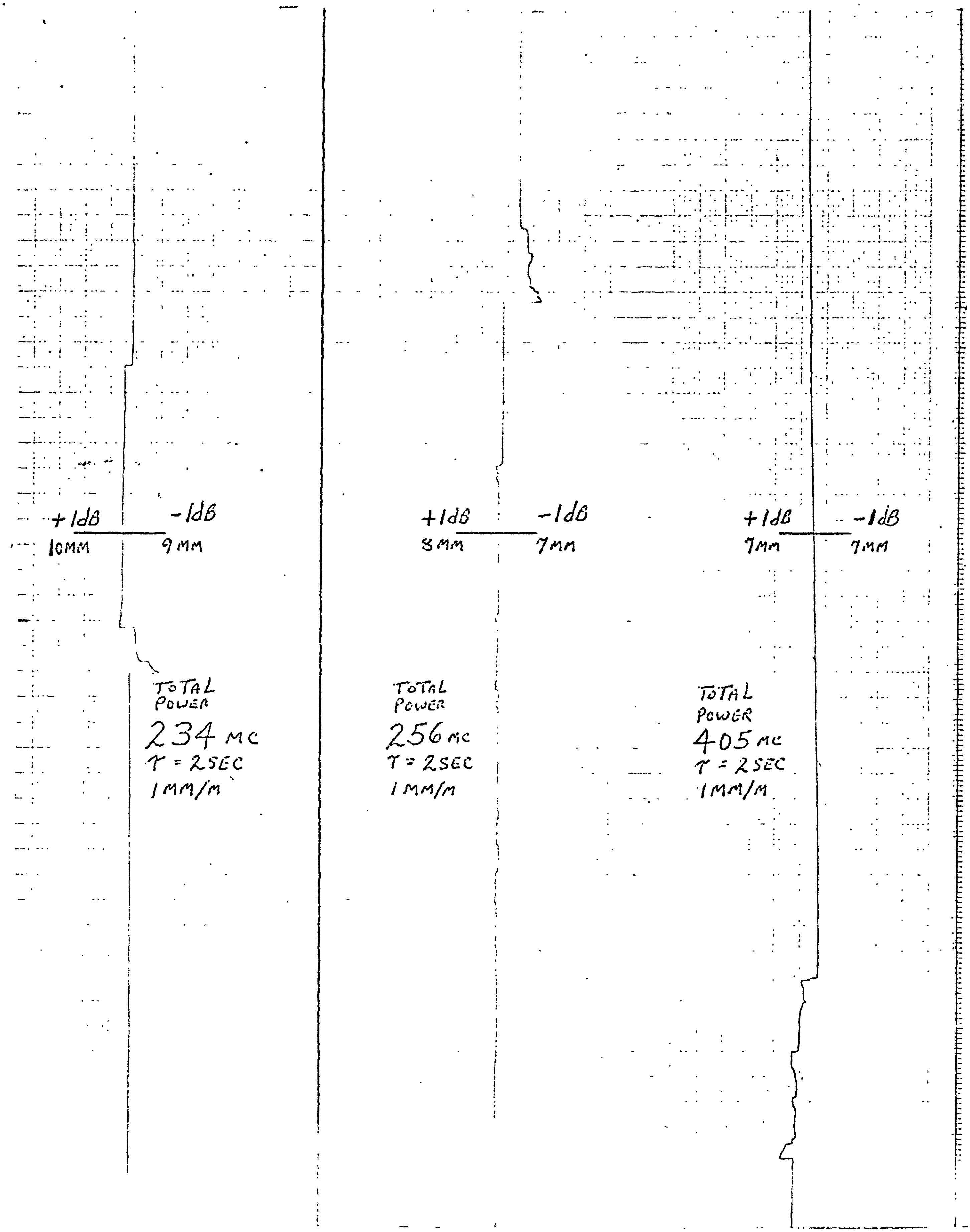


Figure 14. Portion of overnight record showing total power instability due to beam voltage changes. This portion selected to show instability existed in all systems and does not agree with examples of beam voltage changes in this report.

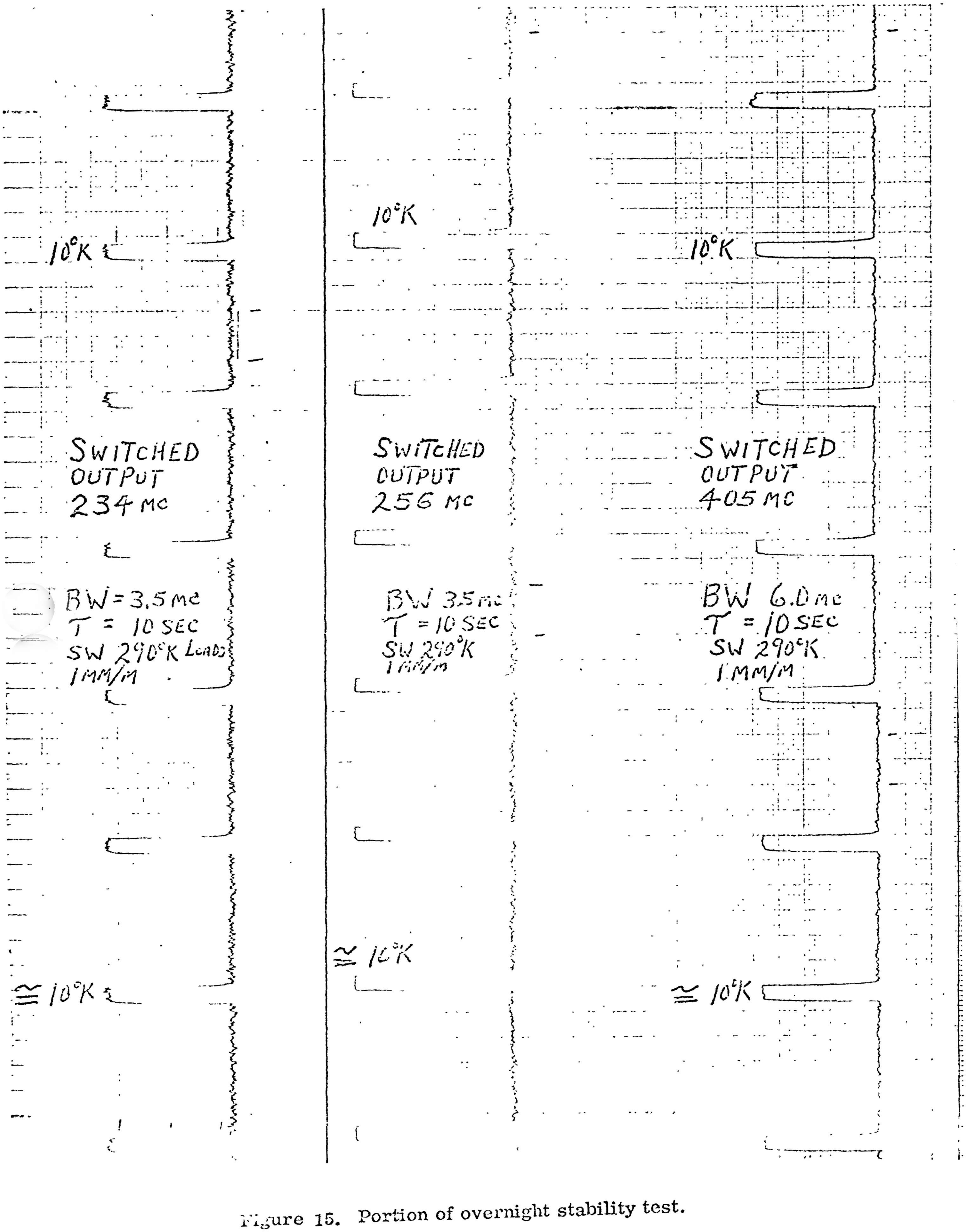


Figure 15. Portion of overnight stability test.

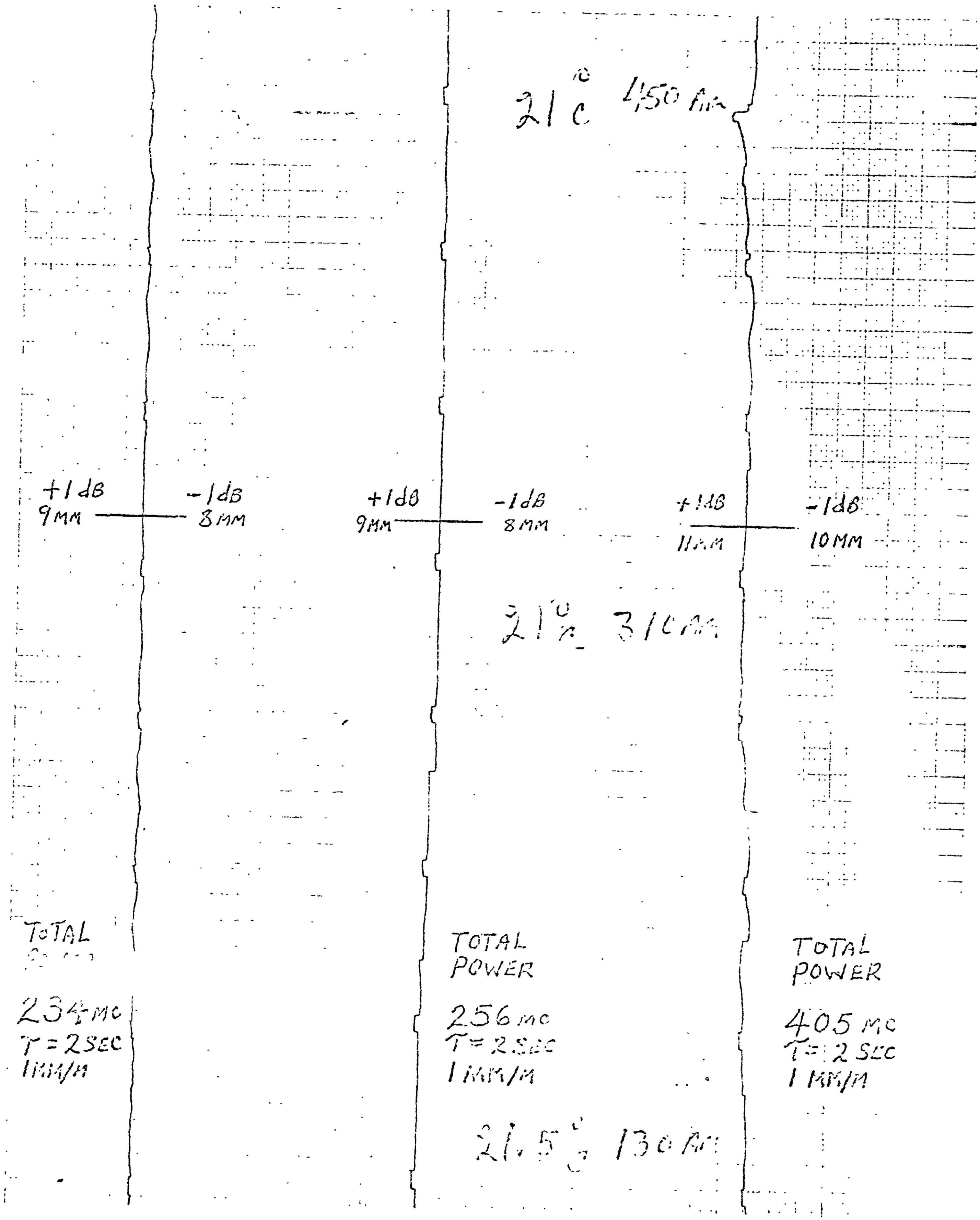


Figure 16. Portion of overnight stability test.

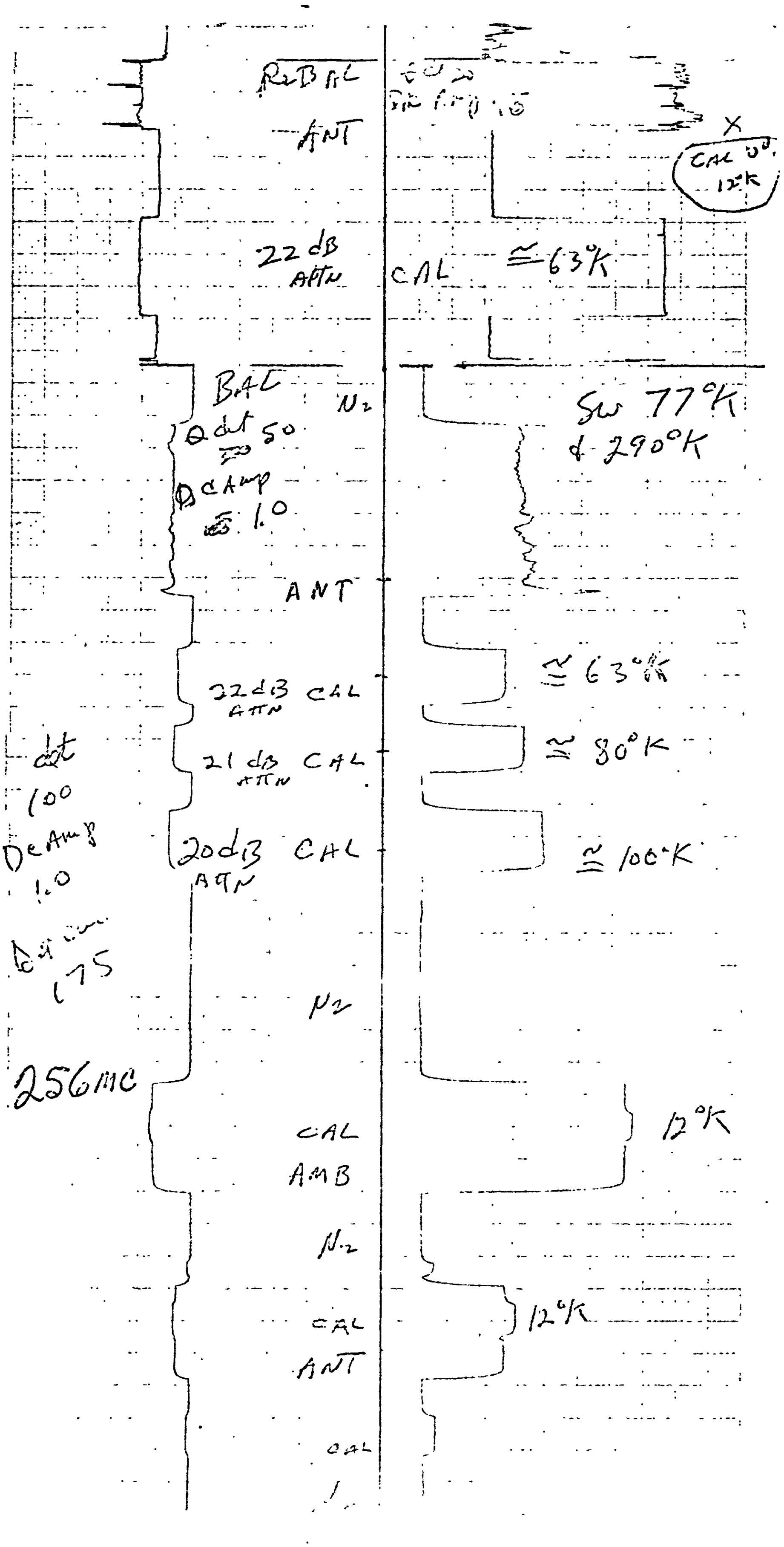


Figure 17

Test Record to Determine Approximate Antenna Temperature of Jasik Feed at 256 MHz.

Feed was placed at 45° L with ground, outside low noise lab window. Original RG 9/U feed cable was used. Receiver was balanced while switching between 77° loads at input to front-end box. Temperature of approximately 150 °K includes loss of feed cable and diplexer as well as spillover, ground effects, etc.

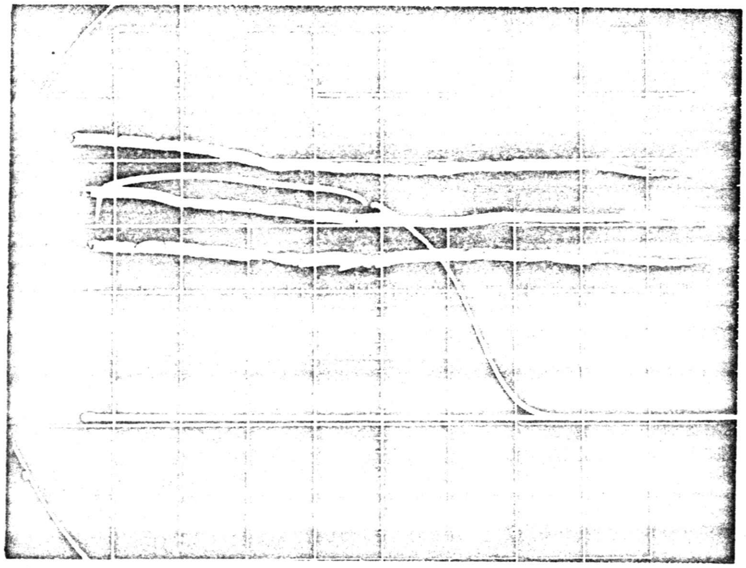


Figure 18. Frequency response of diplexer for 234 MHz system. Marker at 234 MHz. Response down 1 dB at 237 MHz and 2 dB at 240 MHz. 256 MHz port terminated with 50 ohms.

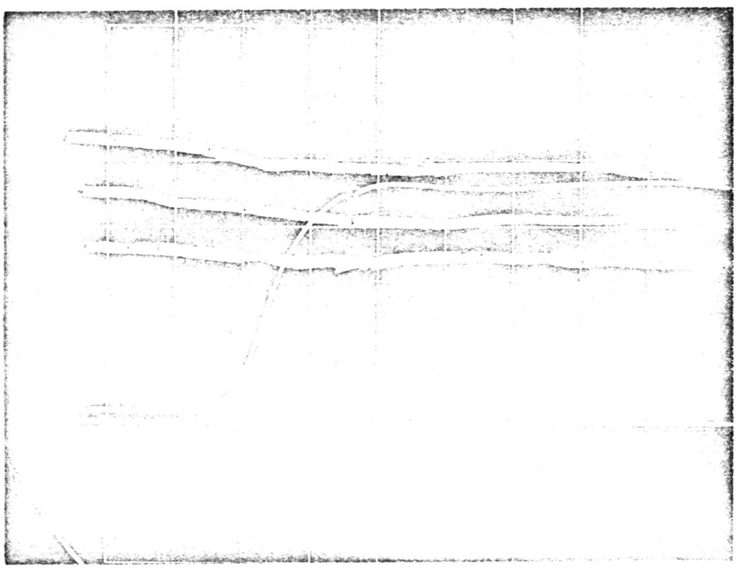


Figure 19. Frequency response of diplexer for 256 MHz system. Marker at 256 MHz. Response down 1 dB at 251 MHz and 2 dB at [illegible] MHz. 234 MHz port terminated with 50 ohms.

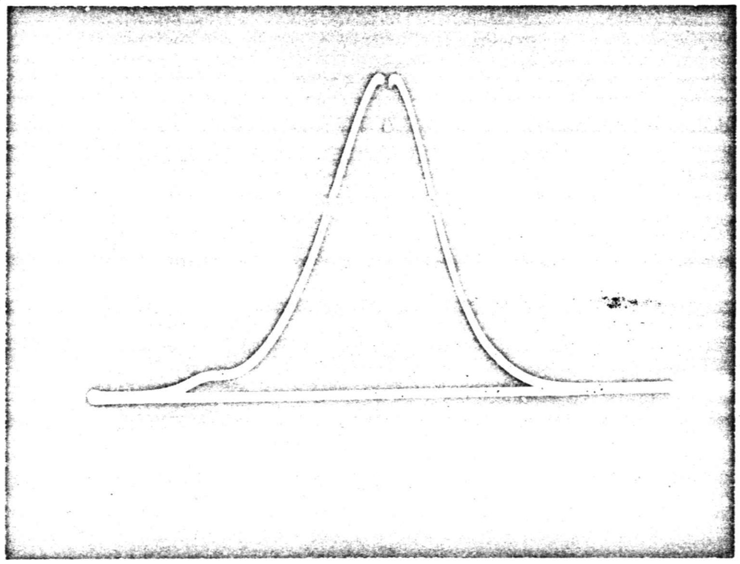


Figure 20. Typical frequency response of 234 MHz and 256 MHz systems. Bandwidth 4 MHz.

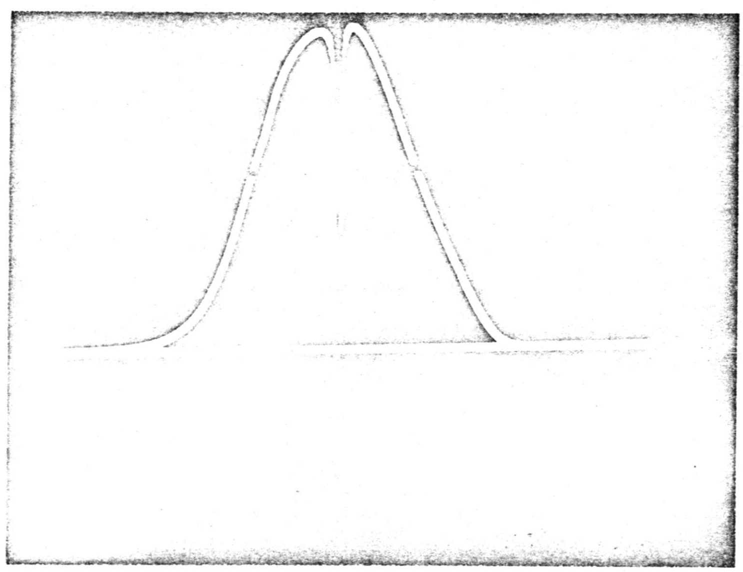
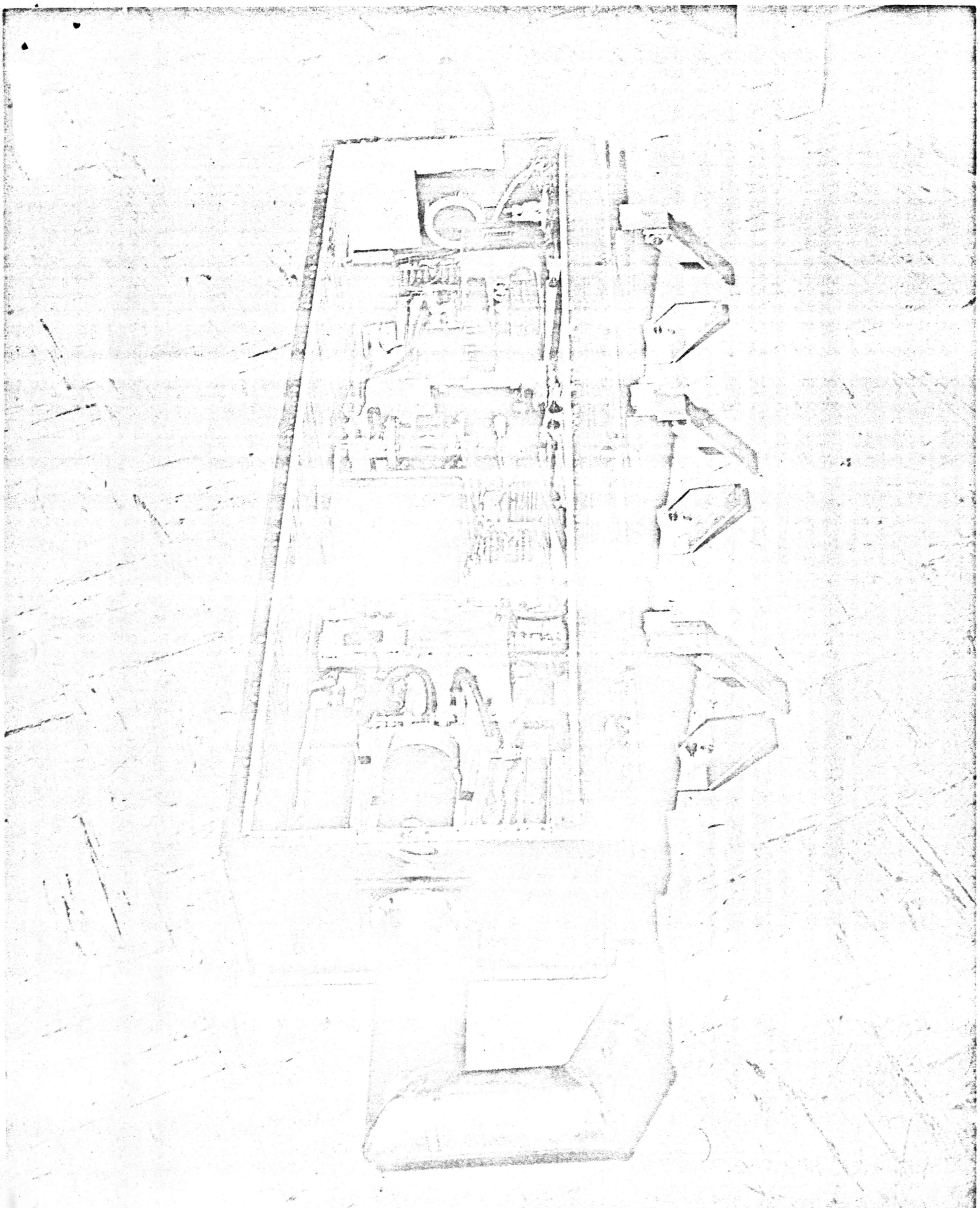


Figure 21. Frequency response of 405 MHz system. Bandwidth 8 MHz.



Fi[illegible] [illegible]Hz system. 256 MHz and 405 MHz are identical. See text for equipment [illegible] made after initial installation.

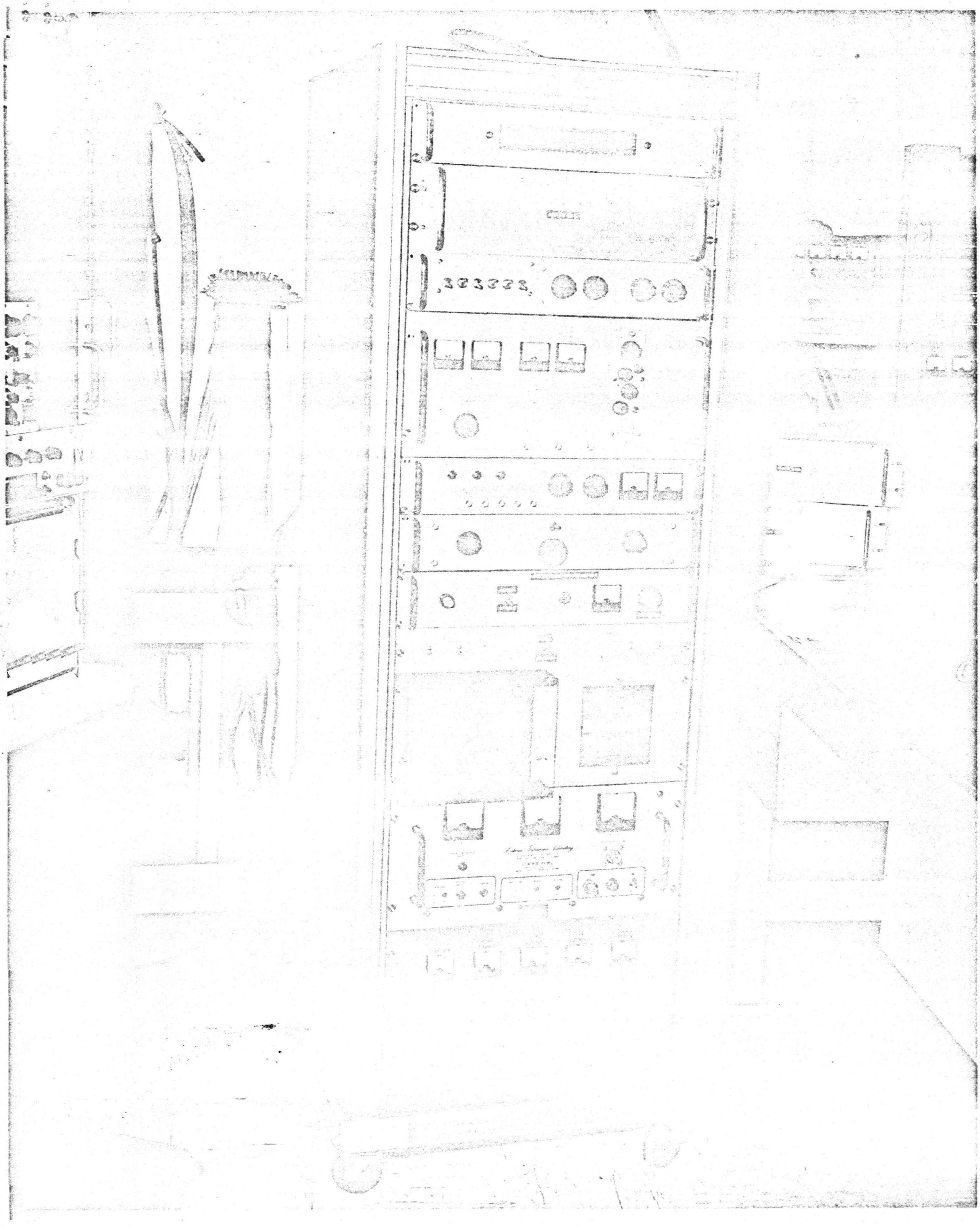


Figure 23. Photograph of standard receiver used with the 405 MHz systems. 234 MHz and 256 MHz are identical.

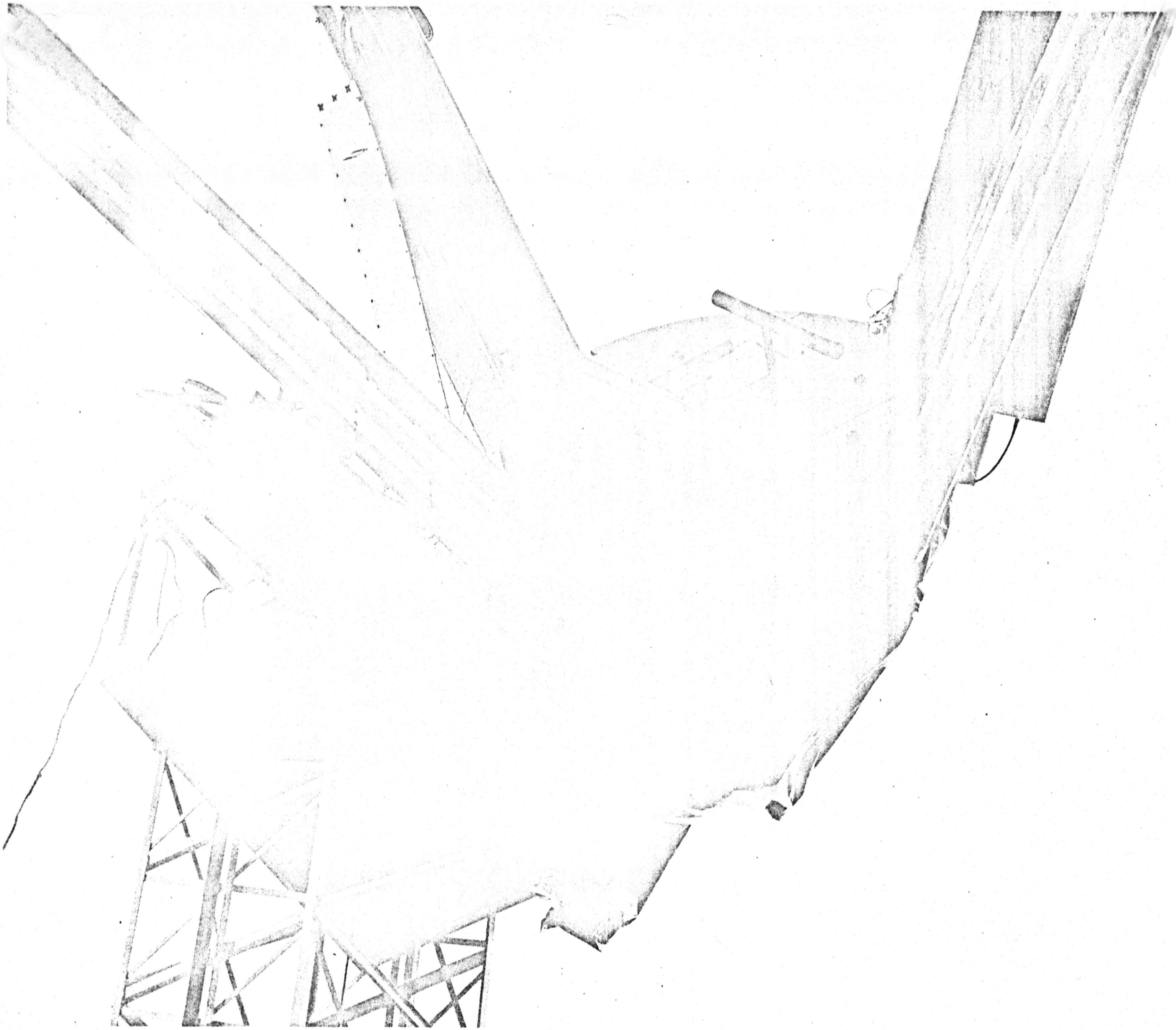


Figure 24. Photograph of Jasik feed mounted on telescope. Elevator is positioned for access to the 256 MHz front end which has cover partially removed.