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4-FEED, 21-CM RECEIVER

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4-FEED, 21-cm RECEIVER

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Introduction

The original 4-feed, 21-cm receiver built in the late sixties is now replaced with a new receiver covering the 1.3-1.5 GHz range. Used mainly as a survey instrument, significant improvements in sensitivity, stability, bandwidth and reliability have been achieved with the new receiver. These improvements are mainly the result of (1) replacing inherently unstable paramps with gain stable GaAsFET amplifiers, (2) improving the temperature stability of other front-end components, (3) replacing the old internal LO with the more stable ULO system, and (4) rebuilding the original feeds which had mechanically unstable feed probe assemblies.

In October 1982 the new receiver was installed on the 300-ft telescope for its first observing run. Except for intermittent instabilities, due to the unstable feed probes (now corrected), the new receiver performed very well. The "on telescope" system noise temperature for all channels was measured at or less than 98°K as compared to the old receiver noise temperature of 150°K. Also, the measured peak-to-peak noise fluctuations are very close or equal to theoretical values for time constants less than 1 second. Because of interference considerations, an RF filtering feature has been added to allow the user to remotely narrow the front-end RF bandwidth to minimize interference effects. The user has a choice of four different filter bandwidths for

each channel. The noise cal system is arranged to allow the receiver to function as either a total power or as a noise adding radiometer.

General Description

The front-end portion of the receiver (Figure 1) is housed in a standard NRAO temperature-controlled front-end box and can be installed at either the 300-ft or 140-ft telescope. Control and monitoring of the front end is accomplished from the control rack (Figure 2). The relationship of the receiver with other components of the telescope system is shown in the block diagram of Figure 3. The RF block diagram and the monitor and control block diagram of the receiver are shown in Figures 4 and 5, respectively.

Front-End Description

The front-end can be divided into five subsystems: (1) the feed assembly, (2) the low-noise amplifier housing, (3) the noise source and RF sweeper system, (4) the bandpass filter assembly, and (5) the mixer and IF system.

1) Feed Assembly

The four standard pyramidal feed horns (Figure 6) used in the receiver are the same ones used in the old 4-feed receiver. The dimensional relationship between the horns, shown in Figure 7, is also identical to the old receiver. However, the feeds are now designated alphabetically rather than numerically as in the old receiver. The geometrical relationship of the radiation beams of the four feeds is shown in Figure 8.

During the initial observing run two of the receiver channels were intermittently unstable. This instability was traced to poor mechanically supported feed probes. The probe assemblies were rebuilt, the feeds were cleaned, electroplated with copper and passivated with Metcote 7P to prevent corrosion. After reassembly the feeds were tuned for best match. Measured values of return loss are shown in Figures 9A and 9B.

2) Low Noise Amplifier Housing

To insure maximum temperature stability of the low-noise RF amplifiers and noise cal coupers, they are heat sunk to heavy copper plates and then enclosed in a thermally insulated aluminum chassis.

a) Low noise GaAsFET amplifiers

The 3-stage GaAsFET amplifiers, designed and built at NRAO/Charlottesville, are identical to those described in EDIR #220 ("Ultra Low Noise 1.2-1.7 GHz Cooled GaAsFET Amplifiers") except that the amplifiers have been optimized to operate at room temperature rather than 15 K. Measured test data of the amplifiers used with the 4-feed, 21-cm receiver are shown in Figures 10A and 10B. Each amplifier is biased by its own constant current supply shown in Figure 11. Measured operating values of bias voltages and currents for the various channels and stages are given in Table 1.

TABLE 1

Operating Bias Voltages and Currents of FET Amplifiers
measured at Constant Current Power Supplies. 1/

Channel	Stage	Drain Voltage (Volts)	Drain Current (mA)	Gate Voltage <u>2/</u> (Volts)
A	1	5.50	20.0	-0.426
	2	5.50	20.0	-0.708
	3	4.00	10.0	-1.358
B	1	5.5	17.5	-1.057
	2	5.5	17.5	-0.691
	3	4.0	10.0	-1.168
C	1	5.5	17.15	-0.508
	2	5.5	13.75	-0.834
	3	4.0	10.0	-1.230
D	1	5.50	20.0	-0.483
	2	5.50	17.5	-1.020
	3	4.0	10.0	-1.609

Notes: 1/ Values measured 13 December 1983.

2/ Gate voltage read at DPM in control room is same as
measured at power supplies.

b) Bipolar transistor amplifiers

An additional 31 dB of RF gain to overcome the noise contribution of the mixer, RF filters, and power dividers is provided by Trontec, Inc., bipolar transistor amplifiers, model P2GC4.

3) Noise Add, Noise Cal and RF Sweeper System

As shown in the block diagram of Figure 12, there are two noise sources, NS-1 and NS-2. Both noise sources are Microwave Semiconductor Corporation solid state noise sources models MSC-1000, with NS-1 being used as the calibration noise source and NS-2 used during the noise adding radiometer mode.

Since the stability of solid state noise sources are dependent on both drive current stability and temperature stability, steps were taken to insure stability of these two parameters. The circuit shown in Figure 13 is used to provide constant current for the noise sources. The current stability of the circuit was tested by varying ambient temperature and supply voltage. Results of these tests indicate:

Temperature coefficient = 1.03 uA/°C

Supply voltage effects = 3.0 uA/volt

To minimize the effects of thermal drift, the noise sources and constant current circuit components were thermally bonded to a heavy copper block which was then mounted in the noise source assembly chassis (a thermally insulated aluminum chassis

which also houses the pin modulators, circulators, and hybrids associated with the cal system).

4) Bandpass Filter Assembly

Because recent EMI surveys in the 1.0-2.0 GHz range show considerable time varying interference in the passband of the GaAsFET amplifiers (1.2-1.7 GHz), it was decided that remotely switched RF bandpass filters were needed in the front end to allow the user to pick the optimum band depending upon existing interference conditions. This function is achieved through the use of the bandpass filter assembly shown in the block diagram (Figure 14) and schematically in Figures 15A and 15B. The table below shows what filter choices are available.

<u>Switch Position</u>	<u>Filter Passband (MHz)</u>	<u>Filter Bandwidth (MHz)</u>
1	1350-1427	77
2	1295-1427	132
3	1295-1500	205
4	No filter.	-

If experience shows other passbands are more desirable, it will be a simple matter to replace the existing filters with new filters.

5) Mixer and IF System

Mini-Circuits Model ZLW-11 double balanced mixers are used to provide RF to IF conversion. The mixers are driven at an LO level of +7 dBm (5 milliwatts) from the Universal LO system

(ULO) in the control room. Remote leveling of the LO is obtained from the ULO ALC circuit. The 5 volt input signal necessary to drive the ALC circuit at the ULO is derived from sampled LO at mixer A. The LO signal is sampled with a crystal detector, amplified in the front end by circuit CF-5 (Figure 16), buffered and level-adjusted in the control rack by CR-5 (Figure 17) and then sent to the ULO to drive the ALC circuit.

A Trontec Model W500F-4 amplifier (5-500 MHz) provides 44 dB of IF gain for each channel. The amplifiers have a 1 dB gain compression point at greater than +26 dBm. The four amplifiers are mounted to a heavy heat exchanger to minimize thermal effects on gain stability.

6) Monitor and Control Circuits

Several plug-in circuit cards are located in both the front-end box and the control rack. These circuits allow remote monitoring and control of various front-end functions from the control rack. The circuit cards for the front-end box and the control rack are located in card cages CC-F and CC-R, respectively. The function, location, and figure number of the various circuits are shown in Table 1.

TABLE 2

Plug-In Circuit Cards located in the Front-End and Control Rack

<u>Circuit</u>	<u>Function</u>	<u>Fig.</u>
CF-1	Gate voltage monitor driver/Channel A	18
CF-2	Gate voltage monitor driver/Channel B	18
CF-3	Gate voltage monitor driver/Channel C	18
CF-4	Gate voltage monitor driver/Channel D	18
CF-5	LO ALC and level monitor driver	16
CF-6	Sweeper ALC level monitor driver	20
CF-7	Bandpass monitor driver	22
CF-8	Noise cal and noise add PIN modulator driver	24
CF-9,10	Spare	
<u>Control Rack</u>		
CR-1	Gate voltage monitor driver/Channel A	19
CR-2	Gate voltage monitor driver/Channel B	19
CR-3	Gate voltage monitor driver/Channel C	19
CR-4	Gate voltage monitor driver/Channel D	19
CR-5	LO ALC and level monitor receiver	17
CR-6	Sweeper ALC level monitor receiver	21
CR-7	Bandpass monitor receiver	23
CR-8	Temperature monitor	25

7) Temperature Monitor and Control System

The temperature of the front-end box is stabilized in the usual fashion, i.e., a 4 K thermistor located at the output of the heating-cooling duct acts as the control sensor for the temperature control system in the control room.

The temperature of the front-end box or of the noise source assembly can be observed at a DPM on the monitor panel in the control rack. A selector switch at the DPM determines which temperature is monitored. The temperature monitor circuit is shown in Figure 25. The monitor sensor for the front-end box is located at the output of the heating-cooling duct. The sensor for monitoring the temperature of the noise source assembly is mounted on the copper block which houses the temperature sensitive components of that system.

8) Bias Controller

Remote on/off control of the FET and the RF transistor amplifiers is achieved through the use of the Bias Controller. The block diagram and schematic of the bias controller are shown in Figures 26 and 27, respectively.

9) Front-End DC Power Distribution

To minimize system instabilities due to ground loops, noise and hum picked up by long telescope cables, all DC voltages required for driving critical front-end components are derived from power supplies located in the front-end box. These power supplies are installed on the power supply chassis PSC-F. DC voltages for uncritical functions, e.g., lights and relays,

are obtained from the control rack via telescope cables. Distribution of the DC voltages is shown in Figure 28.

10) Front-End AC Power Distribution

The 115 V, 60 Hz, AC supply voltage for the front-end box is obtained from the control rack via a 4/C - #8 cable. The AC supply voltage enters the front-end box via connector JF-AC and is distributed to the various AC outlets in the front-end as shown in the wiring diagram of Figure 29.

11) Interconnecting Cables

Information regarding the various interconnecting cables between the front-end box and the equipment in the control room is shown in the following Table 3.

(Table 3 follows.)

TABLE 3

Telescope Interconnecting Cable and Connector Information

Cable Information

Cable	Function	Front End		Control Room Equipment		
		Connector	Terminal Board	Equipment	Terminal Board	Connector
15 Pair - #18	CH A & C Monitor & Control	JF-A	TBF-A	Control Rack	TB-A	JC-A
15 Pair - #18	CH B & D Monitor & Control	JF-B	TBF-B	Control Rack	TB-B	JC-B
15 Pair - #18	Common Functions Monitor & Control	JF-C	TBF-C	Control Rack	TB-C	JC-C
30/C - #16	Control	JD-D	TBF-D	Control Rack	TB-D	JC-D
30/C - #16	Control	JF-E	TBF-E	Control Rack	TB-E	JC-E
4/C - #8	115 V AC for F.E.	JF-AC	F.E. AC Dist. Box	Control Rack	Monitor Chassis Outlet	JC-AC
4/C - #8	D.C. for F.E. Heat/Cool	JF-DC	TBF-DC	Temp. Control Rack	-	-
7/8 Spiroline	LO	LO	-	ULO	-	ULO Output
Coax 7/8 or RG-9	IF CH A	IF-A	-	Digital Receiver	-	IF Input CH 0
Coax 7/8 or RG-9	IF CH B	IF-B	-	Digital Receiver	-	IF Input CH 1
Coax 7/8 or RG-9	IF CH C	IF-C	-	Digital Receiver	-	IF Input CH 2
Coax 7/8	IF CH D	IF-D	-	Digital Receiver	-	IF Input CH 3
Coax 7/8	RF Sweep	Sweep	-	Control Rack	-	Sweeper to F.E.

TABLE 3 (continued):

15 TWISTED PAIR - 18 GA: CONNECTOR JF-A/JC-A 7-21-82

LOCATION		FRONT END BOX/CONTROL RACK		Function
TBF-A/TB-A		Pin	Term.	
Tracer Color	Wire Color	Pin Letter	Term. No.	
Blue	Red	A	1	VG1 Monitor, CH A
	Yellow	B	2	Return
	Shield	E		Shield
Purple	Red	C	3	VG2 Monitor, CH A
	Yellow	D	4	Return
	Shield	J		Shield
Gray	Red	O	5	VG3 Monitor, CH A
	Yellow	P	6	Return
	Shield	H		Shield
Green	Red	F	7	LO Monitor, CH A
	Yellow	G	8	Return
	Shield	M		Shield
Yellow	Red	T	9	Bandpass, CH A
	Yellow	U	10	Return
	Shield	N		Shield
White	Gray	K	11	FET Amp ON-OFF Switch, CH A (+28 V = Off, 0 V = On)
	Yellow	L	12	FET Amp "ON" Indicator, CH A (28 V = On, 0 V = Off)
	Shield	R		
White	Blue	X	13	Transistor Amp ON-OFF Switch, CH A (28 V = Off, 0 V = On)
	Yellow	Y	14	Transistor Amp "ON" indicator CH A (28 V = On, 0 V = Off)
	Shield	Q		
White	Gray	Z	15	VG1 Monitor, CH C
	Red	a	16	Return
	Shield	S		
White	Red	V	17	VG2 Monitor, CH C
	Yellow	W	18	Return
	Shield	d		
Black	Red	m	19	VG3 Monitor, CH C
	Yellow	n	20	Return
	Shield	e		
Orange	Red	b	21	LO Monitor, CH C
	Yellow	c	22	Return
	Shield	k		
Red	Red	r	23	Bandpass, CH C
	Yellow	s	24	Return
	Shield	x		
Brown	Red	t	25	FET Amp ON-OFF Switch, CH C (+28 V = Off, 0 V = On)
	Yellow	u	26	FET Amp "ON" Indicator CH C (+28 V = On, 0 V = Off)
	Shield	y		
White	Blue	f	27	Transistor Amp On-OFF Switch, CH C (28 V = Off, 0 V = On)
	Gray	g	28	Transistor Amp "ON" Indicator CH C (+28 V = On, 0 V = Off)
	Shield	p		
White	Red	h	29	Spare
	Blue	j	30	Spare
	Shield	q		

C = 57.6 pF/ft wire-to-wire.

C = 97.4 pF/ft wire-to-shield.

TABLE 3 (continued):

15 TWISTED PAIR - 18 GA: CONNECTOR		JF-B/JC-B		
LOCATION		FRONT END BOX/CONTROL RACK		
		TBF-B/TB-B		
Tracer Color	Wire Color	Pin Letter	Term. No.	Function
Blue	Red	A	1	VG1 Monitor, CH B
	Yellow	B	2	Return
	Shield	E		
Purple	Red	C	3	VG2 Monitor, CH B
	Yellow	D	4	Return
	Shield	J		
Gray	Red	O	5	VG3 Monitor, CH B
	Yellow	P	6	Return
	Shield	H		
Green	Red	F	7	LO Monitor, CH B
	Yellow	G	8	Return
	Shield	M		
Yellow	Red	T	9	Bandpass, CH B
	Yellow	U	10	Return
	Shield	N		
White	Gray	K	11	FET Amp ON-OFF Switch, CH B (+28 V = Off, 0 V = On)
	Yellow	L	12	FET Amp "ON" Indicator, CH B (28 V = On, 0 V = Off)
	Shield	R		
White	Blue	X	13	Transistor Amp On-OFF Switch, CH B (28 V = Off, 0 V = On)
	Yellow	Y	14	Transistor Amp "ON" Indicator CH B (+28 V = On, 0 V = Off)
	Shield	Q		
White	Gray	Z	15	VG1 Monitor, CH D
	Red	a	16	Return
	Shield	S		
White	Red	V	17	VG2 Monitor, CH D
	Yellow	W	18	Return
	Shield	d		
Black	Red	m	19	VG3 Monitor, CH D
	Yellow	n	20	Return
	Shield	e		
Orange	Red	b	21	LO Monitor, CH D
	Yellow	c	22	Return
	Shield	k		
Red	Red	r	23	Bandpass, CH D
	Yellow	s	24	Return
	Shield	x		
Brown	Red	t	25	FET Amp ON-OFF Switch, CH D (+28 V = Off, 0 V = On)
	Yellow	u	26	FET Amp "ON" Indicator CH D (+28 V = On, 0 V = Off)
	Shield	y		
White	Blue	f	27	Transistor Amp ON-OFF Switch, CH D (28 V = Off, 0 V = On)
	Gray	g	28	Transistor Amp "ON" Indicator CH D (28 V = On, 0 V = Off)
	Shield	p		
White	Red	h	29	
	Blue	j	30	
	Shield	q		

C = 57.6 pF/ft wire-to-wire.

C = 97.4 pF/ft wire-to-shield.

TABLE 3 (continued):

15 TWISTED PAIR - 18 GA: CONNECTOR		JF-C/JC-C		
LOCATION		FRONT END BOX/CONTROL RACK		
		TBF-C/TB-C		
Tracer Color	Wire Color	Pin Letter	Term. No.	Function
Blue	Red	A	1	Sweeper ALC
	Yellow	B	2	Return
	Shield	E		
Purple	Red	C	3	Noise cal; 0 V = On, +5 V = Off
	Yellow	D	4	Return
	Shield	J		
Gray	Red	O	5	Noise add; 0 V = On, +5 V = Off
	Yellow	P	6	Return
	Shield	H		
Green	Red	F	7	Noise cal indicator; 0 V = cal on
	Yellow	G	8	+5 V = cal off
	Shield	M		Return
Yellow	Red	T	9	Noise add indicator; 0 V = noise on
	Yellow	U	10	+5 V = noise off
	Shield	N		Return
White	Gray	K	11	Spare
	Yellow	L	12	Spare
	Shield	R		
White	Blue	X	13	Spare
	Yellow	Y	14	Spare
	Shield	Q		
White	Gray	Z	15	F.E. Box Temperature Monitor
	Red	a	16	Return
	Shield	S		
White	Red	V	17	Noise Add Temperature Monitor
	Yellow	W	18	Return
	Shield	d		
Black	Red	m	19	F.E. Temperature Control } to BNC at
	Yellow	n	20	Return } top of rack.
	Shield	e		
Orange	Red	b	21	F.E. Temperature Monitor } to BNC at
	Yellow	c	22	Return } top of rack
	Shield	k		
Red	Red	r		
	Yellow	s		
	Shield	x		
Brown	Red	t		
	Yellow	u		
	Shield	y		
White	Blue	f		
	Gray	g		
	Shield	p		
White	Red	h		
	Blue	j		
	Shield	q		

C = 57.6 pF/ft wire-to-wire.

C = 97.4 pF/ft wire-to-shield.

TABLE 3 (continued):

30 CONDUCTOR - 16 GA: CONNECTOR JF-E/JC-E

Wire Color	Pin Letter	FRONT END BOX/CONTROL RACK		Function
		TBF-E/TB-E	Term. No.	
Orange Purple	A	1		BP Filter Sw., CH B, Pos. 1, Coil, +28 V
Orange Blue	B	2		" " " " " " 2 " "
Yellow White	C	3		" " " " " " 3 " "
Yellow	D	4		" " " " " " 4 " "
Red Purple	E	5		" " " " " " 1 Indicator, Return
Red Blue	F	6		" " " " " " 1 " +5 V
Orange Green	G	7		" " " " " " 2 " Return
Yellow Black	H	8		" " " " " " 2 " +5 V
Yellow Brown	J	9		" " " " " " 3 " Return
Black	K	10		" " " " " " 3 " +5 V
White Yellow	L	11		" " " " " " 4 " Return
Red Green	M	12		" " " " " " 4 " +5 V
Orange Yellow	N	13		" " " CH D " 1 Coil, +28 V
Orange	P	14		" " " " " " 2 " "
Brown	R	15		" " " " " " 3 " "
Red	S	16		" " " " " " 4 " "
Red Black	T	17		" " " " " " 1 Indicator, Return
Red Yellow	U	18		" " " " " " 1 " +5 V
Red Brown	V	19		" " " " " " 2 " Return
Orange Brown	W	20		" " " " " " 2 " +5 V
Green	X	21		" " " " " " 3 " Return
Orange White	Y	22		" " " " " " 3 " +5 V
Orange Black	Z	23		" " " " " " 4 " Return
Blue	a	24		" " " " " " 4 " +5 V
Purple	b	25		+5 V for F.E. Box
Purple White	c	26		+5 V Return for F.E. Box
Green White	d			
Green Black	e			
Green Brown	f			
Red White	g			
Shield	1	Shield		

TABLE 3 (continued):

30 CONDUCTOR - 16 GA: CONNECTOR			JF-D/JC-D	7/20/82	
LOCATION			FRONT END BOX/CONTROL RACK		
			TBF-D/TB-D		
Wire Color	Pin Letter	Term. No.	Function		
Orange Purple	A	1	BP Filter Sw., CH A, Pos. 1, Coil, +28 V		
Orange Blue	B	2	" " " " " " 2 " "		
Yellow White	C	3	" " " " " " 3 " "		
Yellow	D	4	" " " " " " 4 " "		
Red Purple	E	5	" " " " " " 1 Indicator Return		
Red Blue	F	6	" " " " " " 1 " +5 V		
Orange Green	G	7	" " " " " " 2 " Return		
Yellow Black	H	8	" " " " " " 2 " +5 V		
Yellow Brown	J	9	" " " " " " 3 " Return		
Black	K	10	" " " " " " 3 " +5 V		
White Yellow	L	11	" " " " " " 4 " Return		
Red Green	M	12	" " " " " " 4 " +5 V		
Orange Yellow	N	13	" " " CH C " 1 Coil, +28 V		
Orange	P	14	" " " " " " 2 " "		
Brown	R	15	" " " " " " 3 " "		
Red	S	16	" " " " " " 4 " "		
Red Black	T	17	" " " " " " 1 Indicator Return		
Red Yellow	U	18	" " " " " " 1 " +5 V		
Red Brown	V	19	" " " " " " 2 " Return		
Orange Brown	W	20	" " " " " " 2 " +5 V		
Green	X	21	" " " " " " 3 " Return		
Orange White	Y	22	" " " " " " 3 " +5 V		
Orange Black	Z	23	" " " " " " 4 " Return		
Blue	a	24	" " " " " " 4 " +5 V		
Purple	b	25	+28 V for F.E. Box		
Purple White	c	26	+28 V Return for F.E. Box		
Green White	d	27	+15 V for F.E. Box		
Green Black	e	28	-15 V for F.E. Box		
Green Brown	f	29	+ 15 Return		
Red White	g	30	F.E. AC on Indicator, +28 V from Relay		
Shield	l	Shield			

TABLE 3 (continued):

4-CONDUCTOR - 8 GA: CONNECTOR JF-AC/JC-AC and JF-DCLOCATION FRONT END BOX/CONTROL RACK

<u>Wire Color</u>	<u>Pin Letter</u>	<u>Term. No.</u>	<u>Function</u>
<u>AC STANDARD*</u>			
Black	A		{Tied together in } Hot for F.E.
Red	B		{AC Distribution Box } AC Outlets
Shield	C		Gnd
White	D		{Tied together in } Neutral for F.E.
Green	E		{AC Distribution Box } AC outlets
<u>DC STANDARD*</u>			
		JF-DC	
Black	A	1	+DC Source to Heat Pumps
Red	B	2	-DC Source to Heat Pumps
Shield	C	3	Shield
White	D	4	+DC Source to Heat Pumps
Green	E	5	-DC Source to Heat Pumps
<u>NON-STANDARD</u>			
Black	A	_____	_____
Red	B	_____	_____
Shield	C	_____	_____
White	D	_____	_____
Green	E	_____	_____

* Note: +DC pins A and D are tied together in rack and front-end box (as are -DC pins B and E) in order to protect heat pumps by blowing the AC breaker if DC cable is accidentally connected to the AC source.

Control Rack Description

The control rack (Figure 2) consists of four subassemblies: (1) the monitor chassis, (2) the control panel, (3) the RF bandpass test assembly, and (4) the power supply chassis.

1) Monitor Chassis

On the front panel of the monitor chassis are five DPMS used for monitoring the following front-end functions: (1) the gate voltage of each FET amplifier stage, (2) the LO input to each of the four mixers, and (3) the ambient temperatures of the front-end box and the noise source assembly. Adjacent to the selector switch of each DPM is a BNC jack which can be used for driving a chart recorder for stability tests. Also on the front panel are breaker switches, and associated indicators, for controlling the AC supply voltage to the control rack and the front-end box.

Inside the monitor chassis is mounted the card cage CC-C which contains the circuit cards for various monitor and control functions mentioned above. Also contained within the unit are two +5 V DC modular power supplies used for powering the DPMS.

2) Control Panel

Mounted on the front of the control panels are several switches which enable the user to do the following:

- 1) Choose one of four possible bandwidths for each channel.
- 2) Select either manual or computer operation of the noise cal and noise add systems.
- 3) Turn the FET amplifiers and bipolar transistor amplifiers on and off from the control room as required for certain maintenance and troubleshooting procedures.

Also on the panel are several LED indicators indicating the status of the front-end equipment with regard to the three statements listed above.

3) RF bandpass Test Assembly

This assembly consists of the RF bandpass panel and an oscilloscope (HP 130C) and is used to check the RF bandpass of the front-end including the RF filter assembly.

An external sweeper is connected to the RF input connector of the panel. With the sweeper set in the external ALC mode, and the ALC input of the sweeper connected to the ALC connector on the panel, the RF level is adjusted to cause the sweep level meter to read mid-scale. At this RF sweep level, the response of each channel can be observed on the oscilloscope and should be approximately 0.5-1.0 volts.

4) Power Supply Chassis

The power supply chassis contains several regulated power supplies and is mounted at the bottom of the control rack. The table below gives information regarding this subassembly.

TABLE 4
Power Supply Data for Control Rack

Power	Manufacturer		
PSC-1	AD922	+5 V	PIN modulator driver for noise add and noise cal system. LEDs on monitor panel. CKT CR-8.
PSC-2A	Lambda LM C15	+15 V	Circuits CR-1 thru CR-8.
PSC-2B	Lambda LM C15	-15 V	Circuits CR-1 thru CR-7.
PSC-3	Lambda LM D28	28 V	BPF assembly coax switches. F.E. "AC on" indicator.

TABLE 5

Microwave Component List

Code	Device	Specifications	Manufacturer and Model No.
A1 thru A4	Room temperature, low noise, GaAsFET amplifiers	1.3-1.5 GHz N.F. = 60°K maximum Gain = 24 dB minimum	NRAO
A5 thru A8	RF bipolar trans- istor amplifiers	1.2-1.6 GHz N.F. = 3 dB maximum Nominal gain = 31 dB	Trontec, Inc. Model P2GC-4
A9	RF amplifier	1-2 GHz N.F. = 3.7 dB maximum Gain = 30 dB	Trontec, Inc. Model W2GA-3
AI-1 thru AI-4	IF amplifier	5-500 MHz N.F. = 2.5 dB maximum Gain = 46 dB minimum	Trontec, Inc. Model W500F-4
C1 thru C14	Ferrite circulator	1-2 GHz I.L. = 0.5 dB maximum 150 L. = 20 dB minimum VSWR = 1.25 maximum	UTE Microwave Model CT-2102- OT
CS1 thru CS8	Coaxial switch	DC-18 GHz 1 pole - 4 throw	DB Products 4S0211
D1 thru D4	Directional coupler	1-2 GHz Coupling = -30 dB Flatness = \pm 0.75 dB I.L. = 0.1 dB maximum VSWR = 1.10 maximum	MAC Technology Model 3203-30
DT1 thru DT4 & DT9	Point contact detector	0.01-12.4 GHz T _{SS} = -43 dBm K = 300 mV/mW (O.C.) Polarity - Negative	Omni-Spectra Model 20090
DT5 thru DT8	Schottky detector	1.0-2.0 GHz T _{SS} = -54 dBm K = 2500 mV/mW typical	Aertec, Inc. Model DOM102BR
F1 thru F4	Feed horn	Pyramidal horn Linear polarized Optimized tuning at 1.4 GHz Return loss = -20 dB maximum IN 1.35-1.45 GHz range	NRAO
FL1 thru FL4	RF bandpass filter	1 dB B.W. = 1350-1427 MHz I.L. = 0.7 dB maximum at f ₀ VSWR = 1.5 maximum in P.B. Rejection: 5 pole response	Reactel Model 5B2-1388- 85S11

TABLE 5 (continued):

Microwave Component List

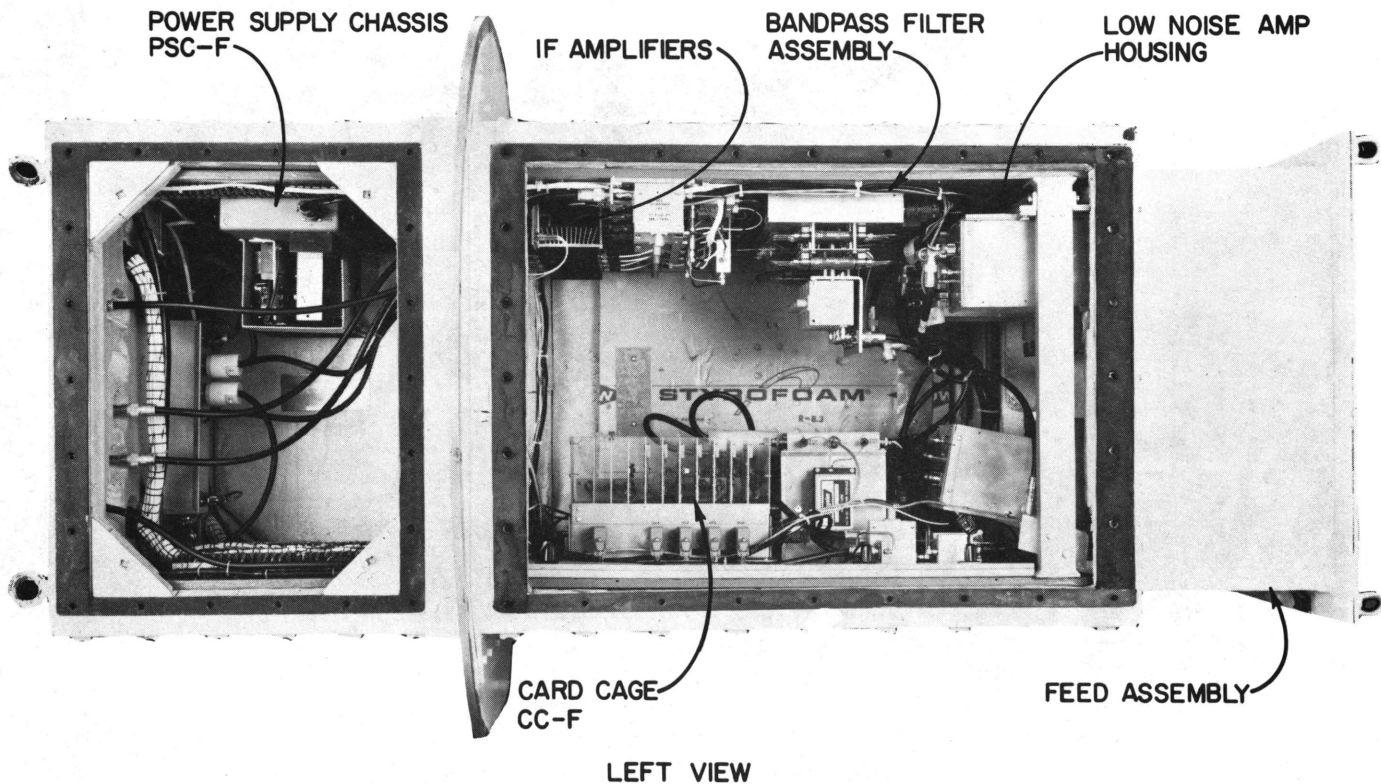
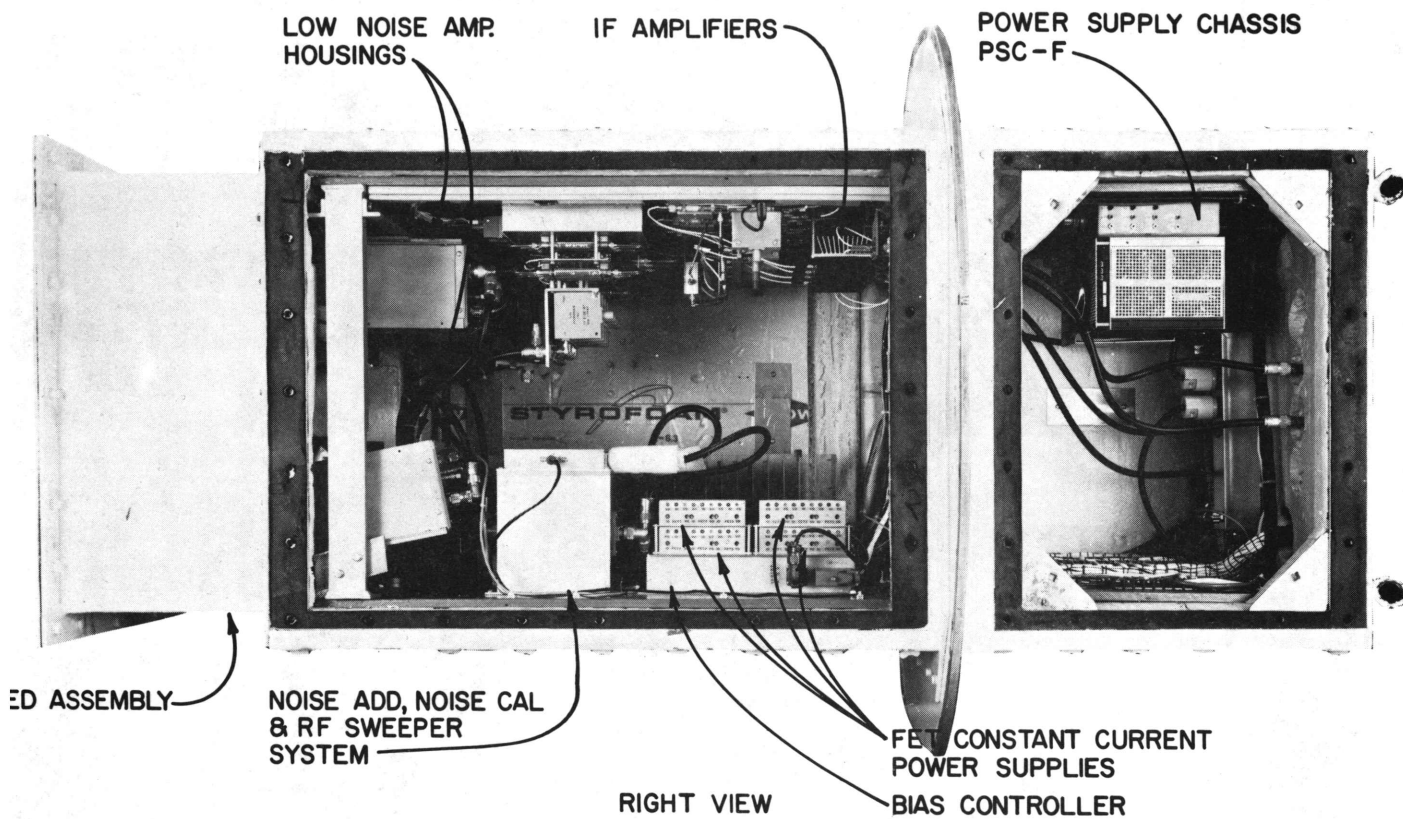
Code	Device	Specifications	Manufacturer and Model No.
FL5 thru FL8	RF bandpass filter	1 dB B.W. = 1295-1427 MHz I.L. = 0.7 dB maximum at f_o VSWR = 1.5 maximum in P.B. Rejection = 5 pole response	Reactel Model 5B2-1361- 137S11
FL9 thru FL12	RF bandpass filter	1 dB B.W. = 1295-1500 MHz I.L. = 0.4 dB maximum at f_o VSWR = 1.5 maximum in P.B. Rejection = 5 pole response	Reactel Model 5B2-1397- 210S11
FL13 thru FL16	IF low pass filter	3 dB B.W. = 0-500 MHz I.L. = 0.5 dB maximum at $f_o/2$ VSWR = 1.5 maximum in P.B. Rejection = 5 section response	Reactel Model 5L2-500- S11
H1 thru H3	3 dB 90° hybrid	1-2 GHz	Norsal Model 4501-3
MX1 thru MX4	Frequency mixer	RF response = 5-2000 MHz IF response = 10-600 MHz Conversion loss = 6.5 dB typical LO-IF isolation = 30 dB typical	Mini-Circuits, Inc. Model ZLW-11
NS1	Solid State Noise Source	ENR = 35 dB I = 7.35 mA	Microwave Semi- conductor Corporation Model MSC-1000
NS2		ENR = 35 dB I = 4.7 mA	
PD1 thru PD10	2-Way power divider	1-2 GHz Phase difference = 2° typical VSWR = 1.2 typical I.L. = 0.25 dB typical Isolation = 25 dB typical	Mini-Circuits, Inc. Model ZAPD-2
PD11	4-Way power divider	1-2 GHz Phase difference = 6° typical I.L. = 0.3 dB typical Isolation = 25 dB	Mini-Circuits, Inc. Model ZA4PD-2
PM1 and PM2	Pin modulator	I.L. = 1.0 dB maximum Isolation = 35 dB minimum VSWR = 1.7 maximum I = -100 mA for maximum isolation	Hewlett-Packard Model HP33102A

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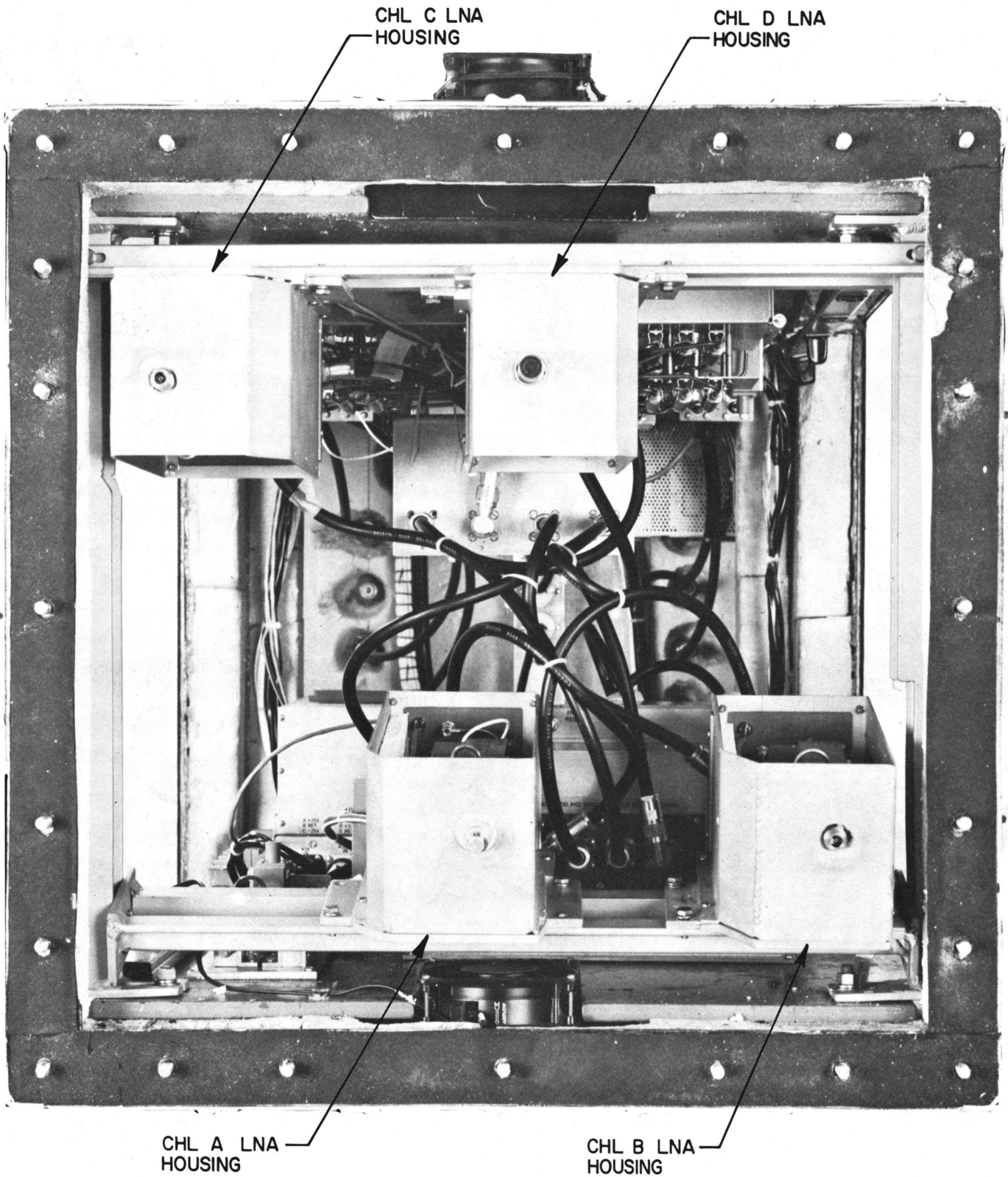
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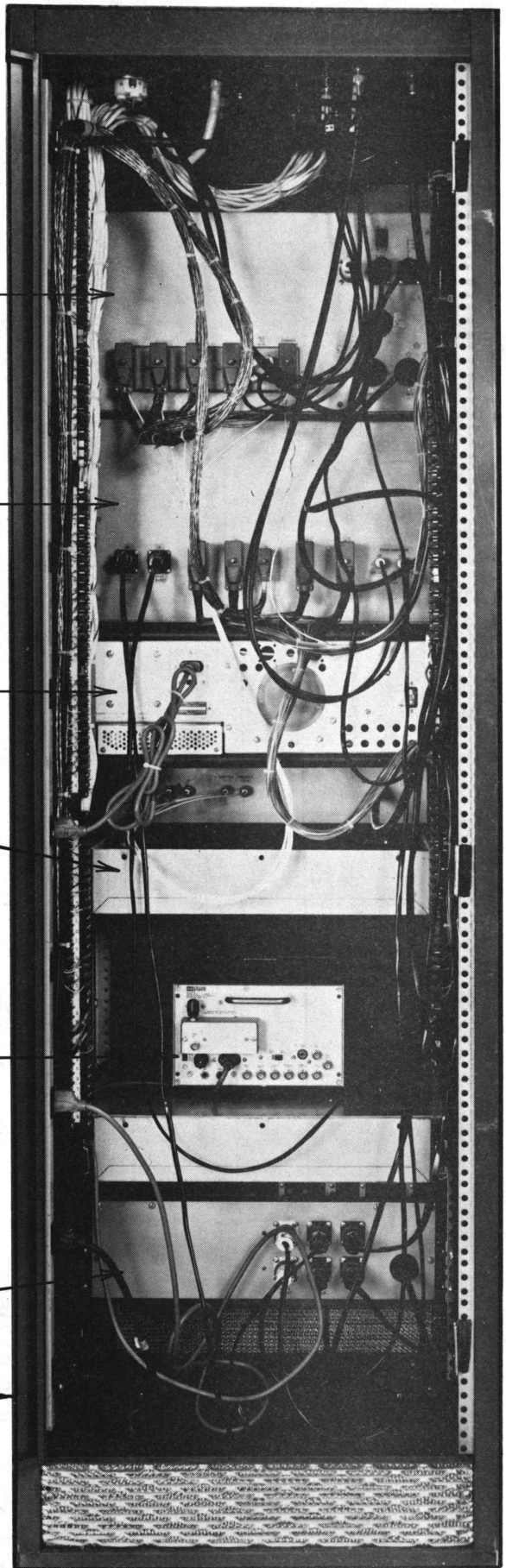
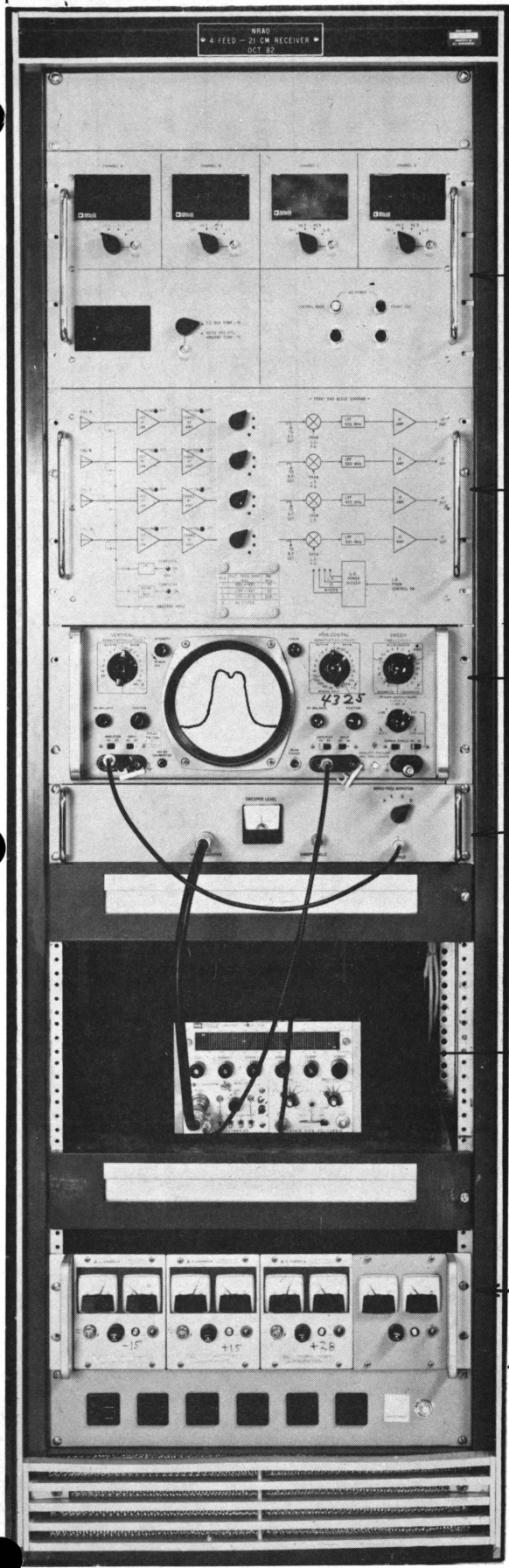
FRONT END BOX, 4-FEED, 21-CM RECEIVER

FIG. 1

(OVER)



FRONT VIEW WITH FEED ASSEMBLY REMOVED



MONITOR
CHASSIS

CONTROL
PANEL

OSCILLOSCOPE

RF BANDPASS
TEST ASSEMBLY

RF SWEEPER

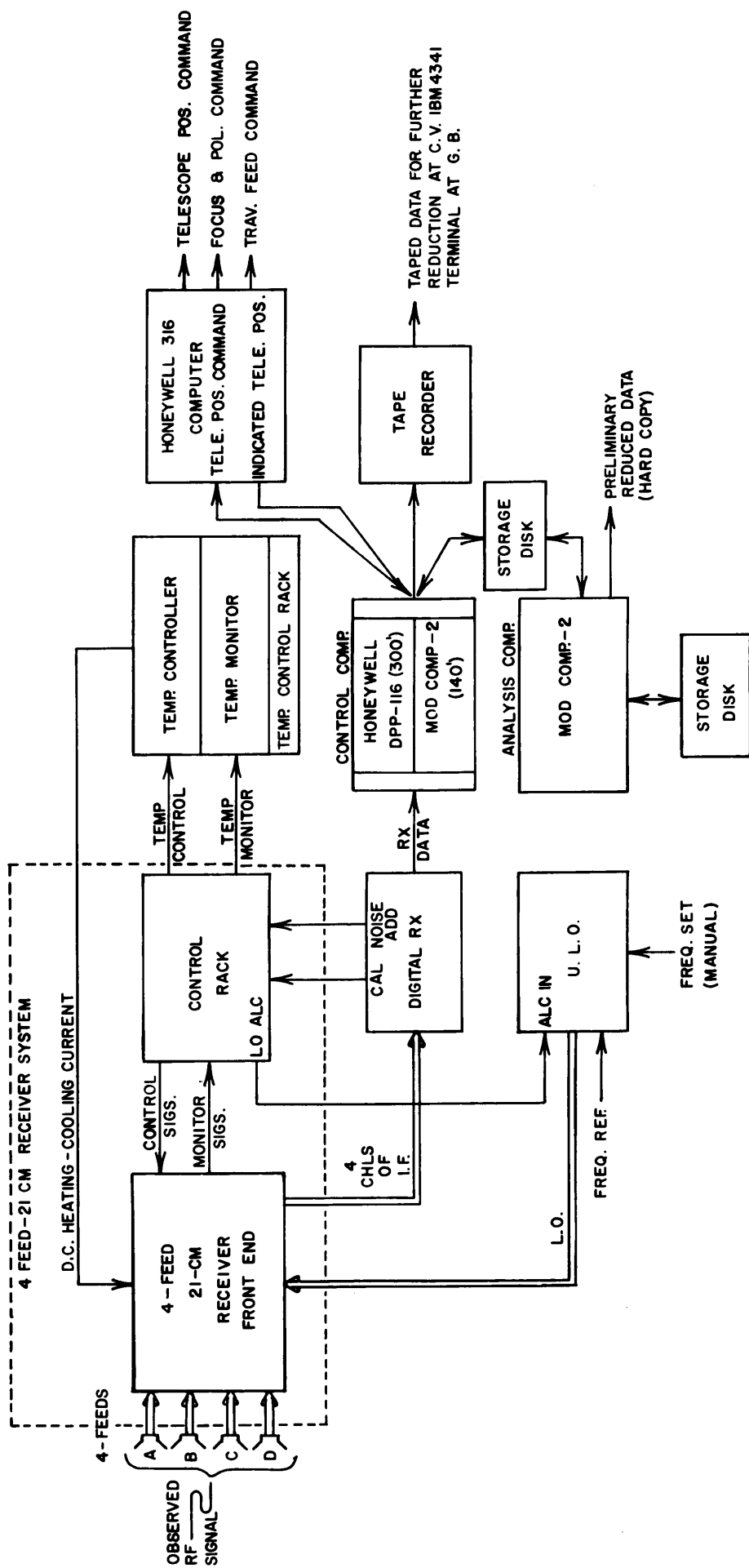
POWER SUPPLY
CHASSIS

← FRONT VIEW

REAR VIEW →

CONTROL RACK

FIG. 2



BLOCK DIAGRAM OF NRAO TELESCOPE SYSTEM USING 4-FEED, 21-CM RECEIVER SYSTEM

FIG. 3

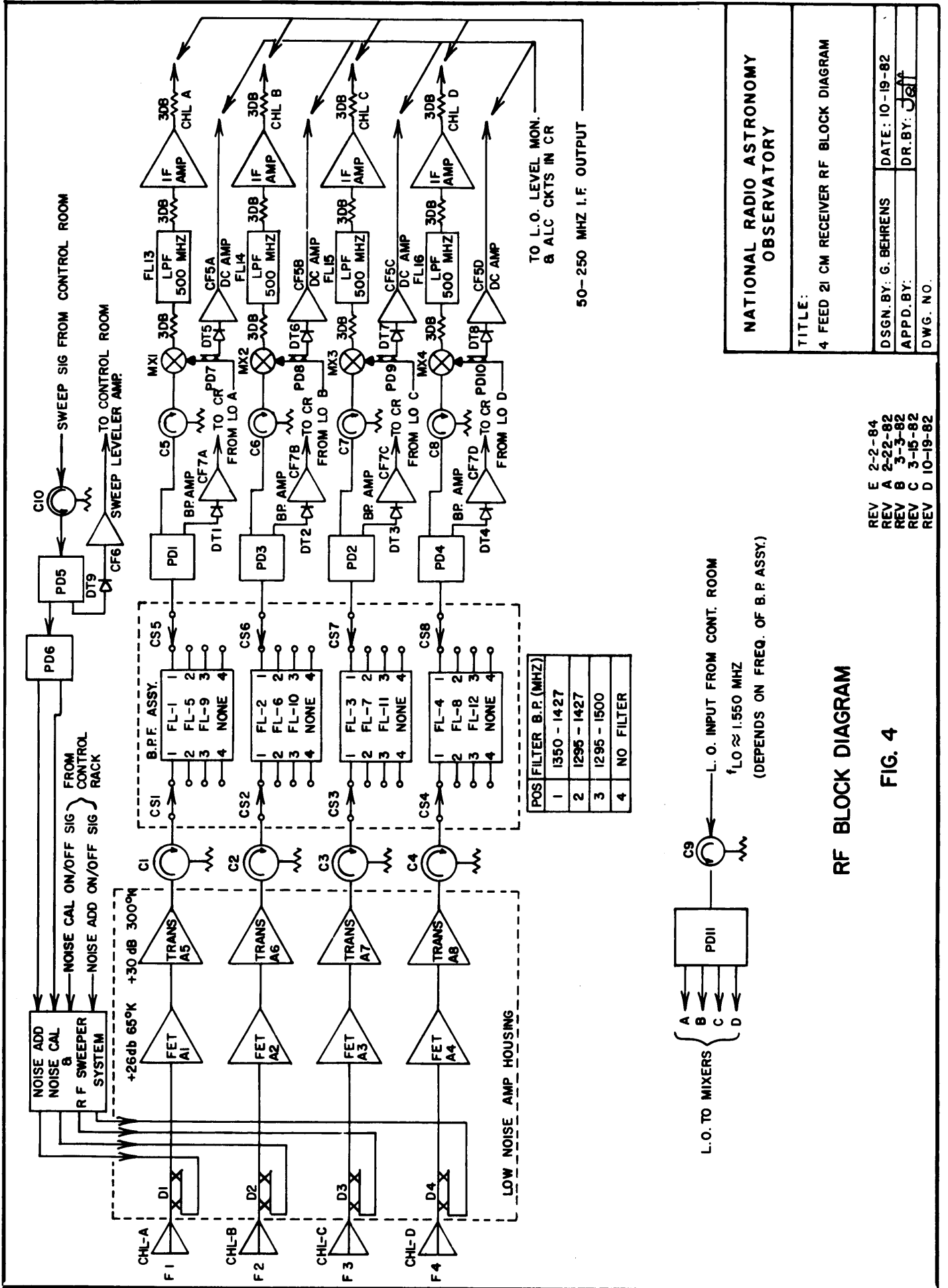
NATIONAL RADIO ASTRONOMY OBSERVATORY

TITLE: SIMPLIFIED BLOCK DIAGRAM OF TOTAL RADIO TELESCOPE SYSTEM USING THE 4 FEED - 21 CM RECEIVER SYSTEM

DSGN. BY: G. BEHRENS DATE: 1-4-84

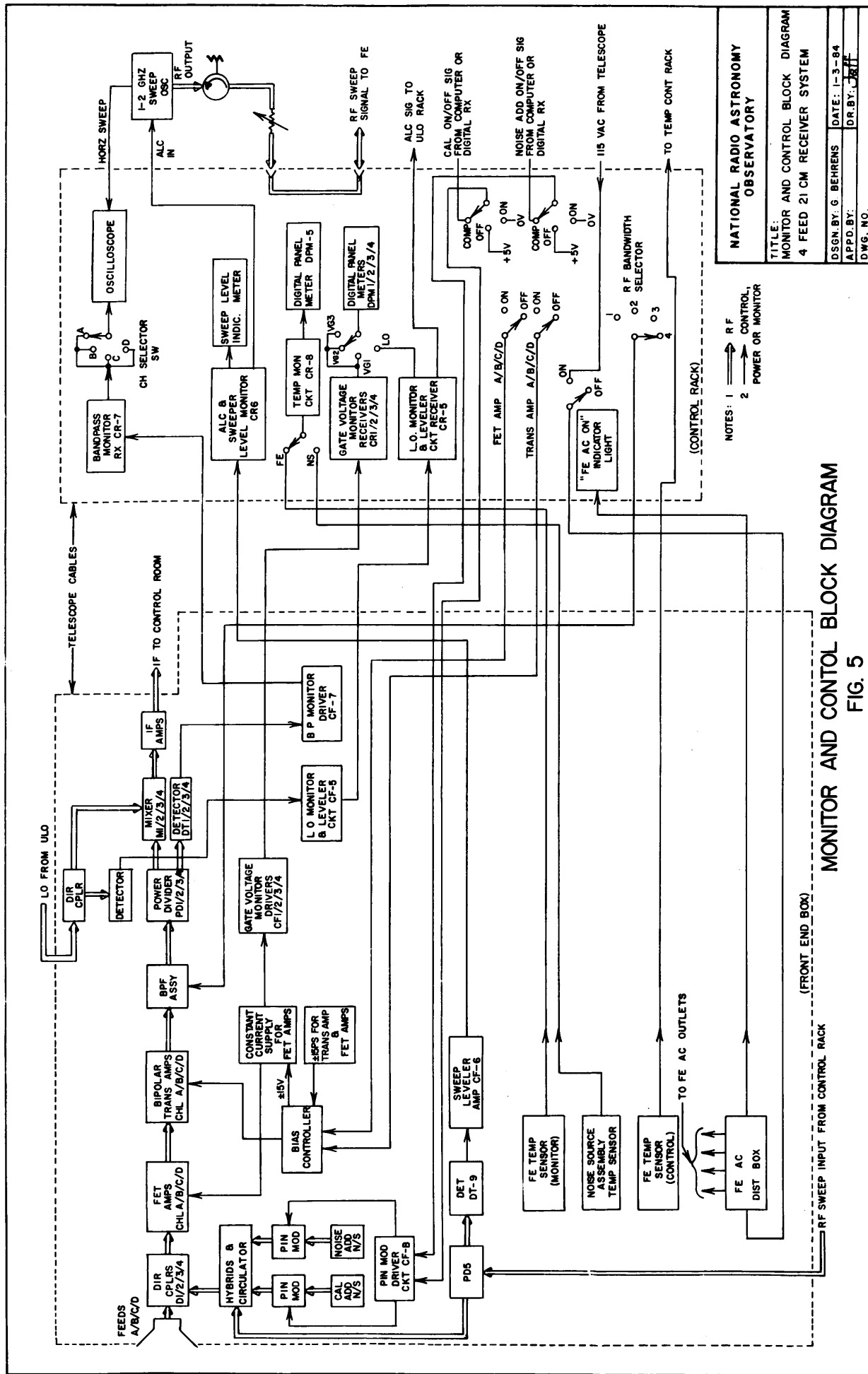
APPD. BY: J. G. J. DR. BY: J. G. J.

DWG. NO.



RF BLOCK DIAGRAM

FIG. 4



MONITOR AND CONTROL BLOCK DIAGRAM
FIG. 5

NATIONAL RADIO ASTRONOMY
OBSERVATORY

TITLE:
MONITOR AND CONTROL BLOCK DIAGRAM
4 FEED 21CM RECEIVER SYSTEM

DSGN BY: G. BEHRENS DATE: 1-3-84
APPD BY: J. B. DR. BY: J. B.
DWG. NO.

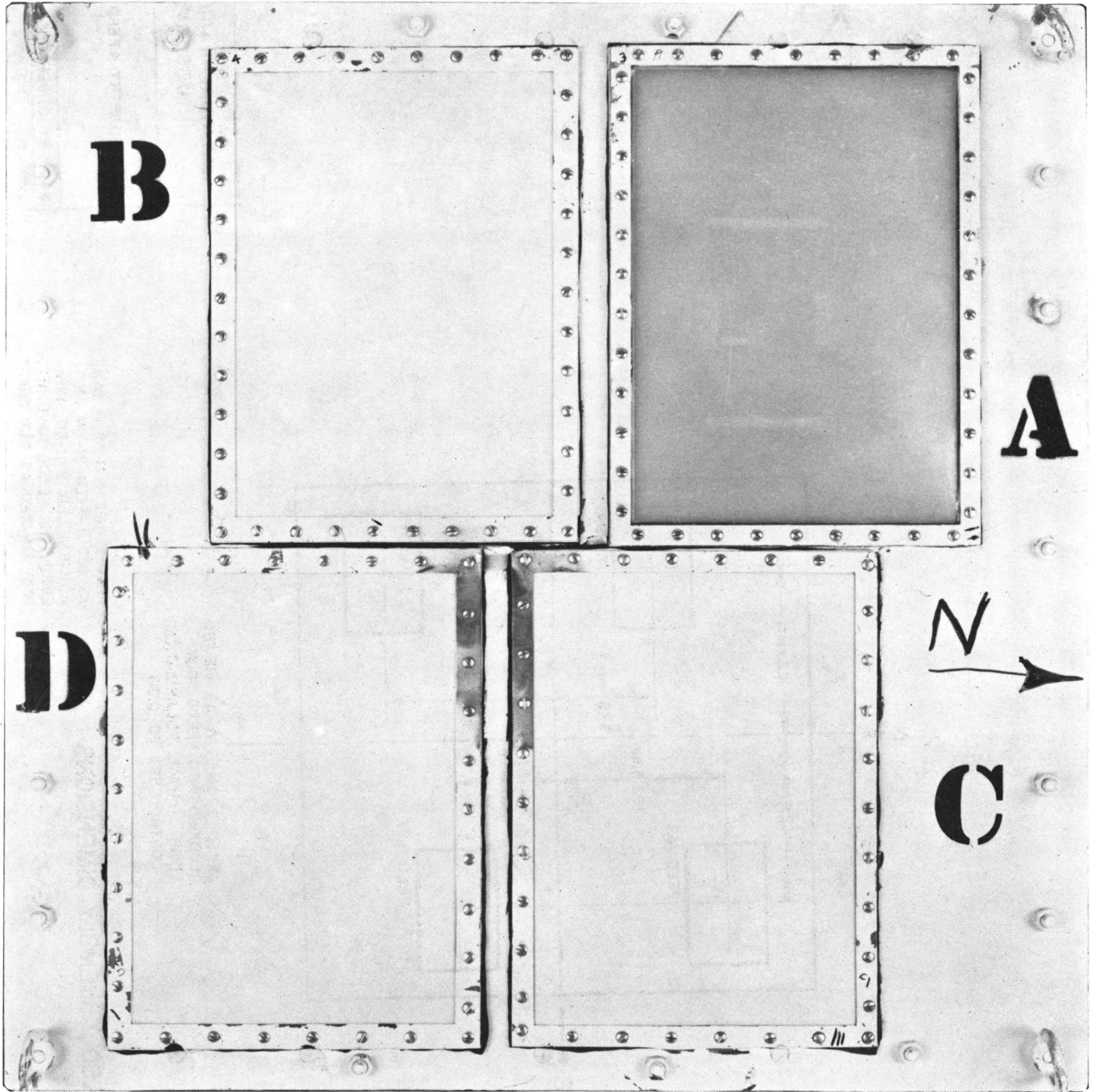
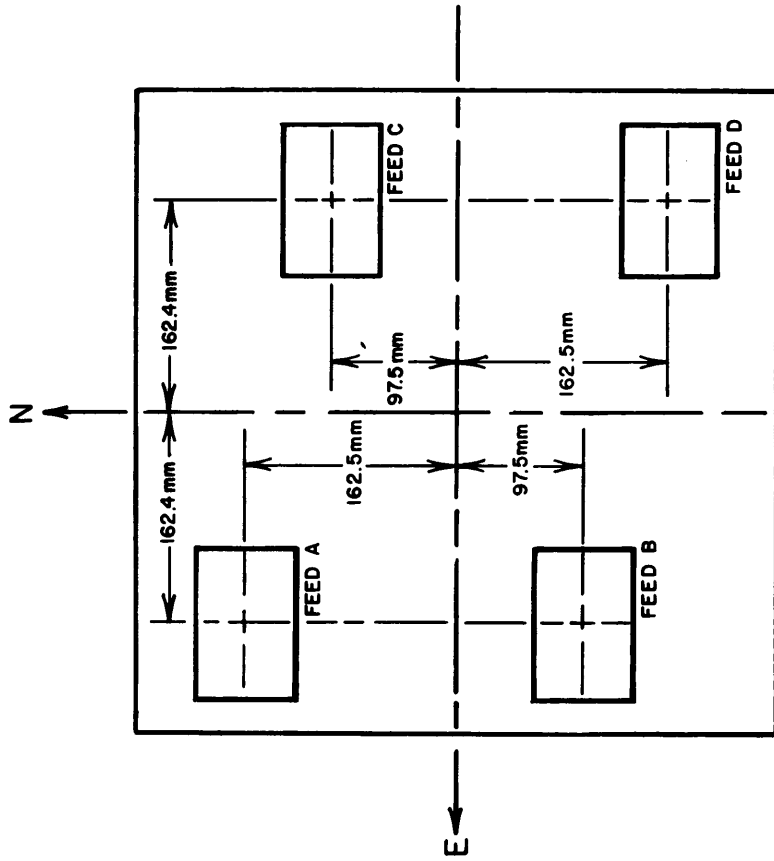


FIG. 6



FEED GEOMETRY AS VIEWED
LOOKING INTO FEEDS FROM
DISH SURFACE. POLARIZATION
CONTROL SET TO 0.00

NOTE: FEED CONFIGURATION IS SAME
AS OLD 4-FEED, 21-CM RX
AS INSTALLED 8-11-80. HOW-
EVER, THE FEEDS HAVE BEEN
REDESIGNATED AS PER CHART
AT RIGHT.

NEW RX	OLD RX
CHL A =	CHL 2
CHL B =	CHL 3
CHL C =	CHL 1
CHL D =	CHL 4

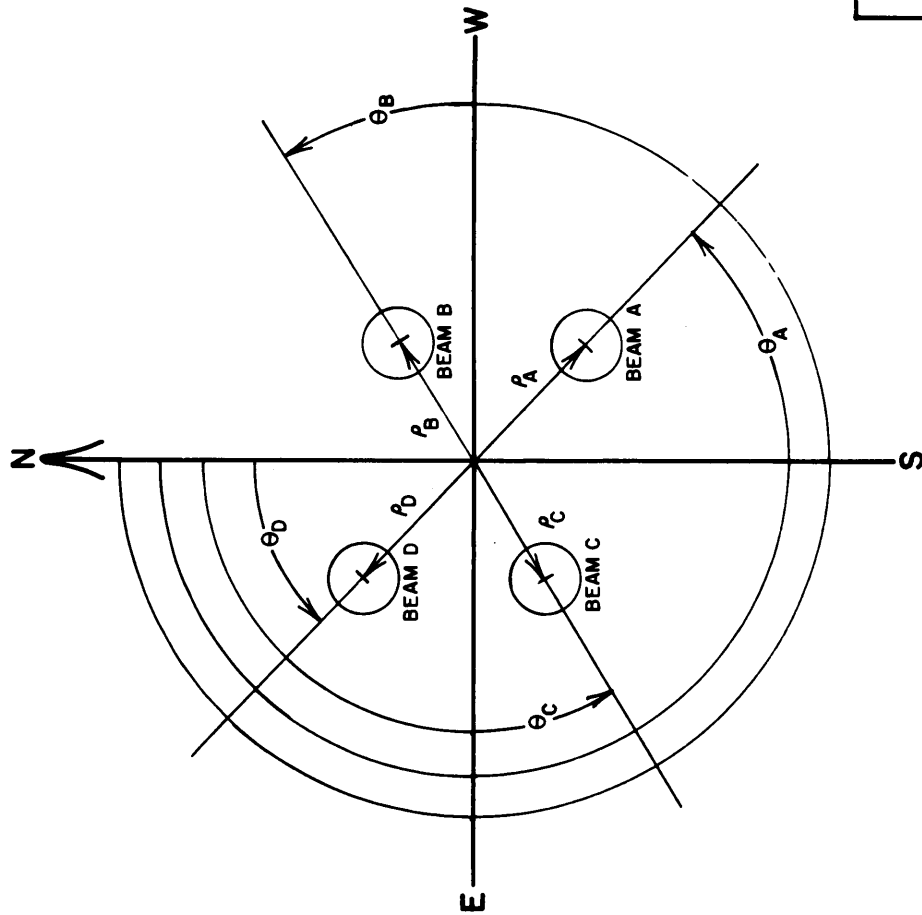
NATIONAL RADIO ASTRONOMY
OBSERVATORY

TITLE:
FEED GEOMETRY, 4 FEED 21 CM RECEIVER

DSGN. BY: G. BEHRENS DATE: 10-4-83
APPD. BY: J. R. JEFF DR. BY: J. R. JEFF
DWG. NO.

FEED ASSEMBLY DIMENSIONS

FIG. 7



BEAM	θ°	ρ
A	26.4	.2863
B	302.2	.2440
C	121.1	.2369
D	46.3	.2856

NOTE: VALUES OF θ AND ρ WERE OBTAINED FROM INSTALLATION SHEET OF 8-11-60. ACCURACY OF VALUES ARE UNCERTAIN & SHOULD BE REMEASURED IF ABSOLUTE ACCURACY IS REQUIRED.

NATIONAL RADIO ASTRONOMY OBSERVATORY

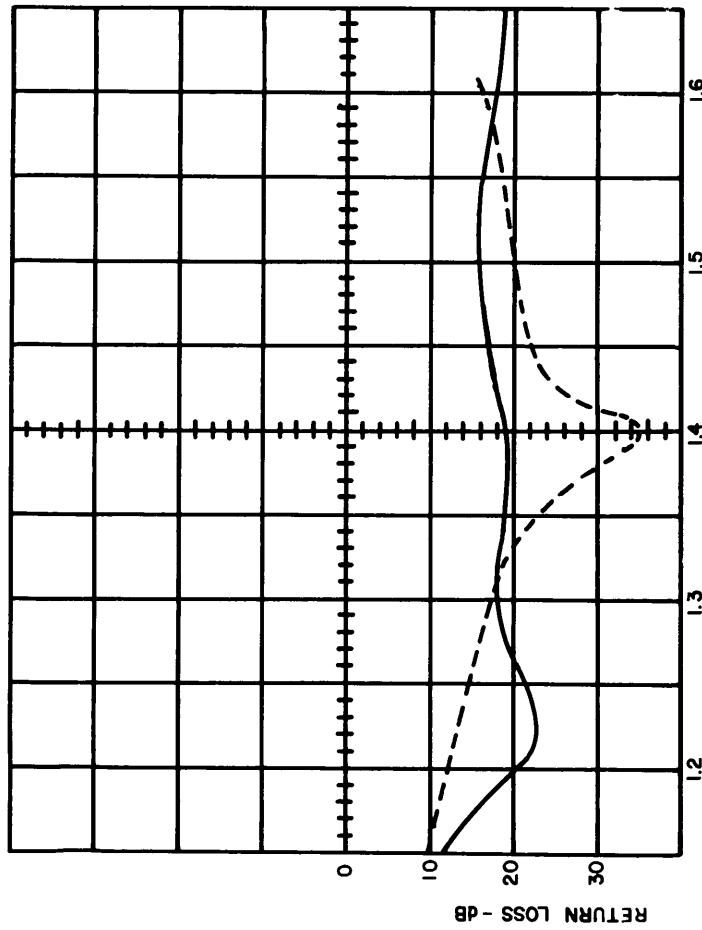
TITLE:
BEAM GEOMETRY AS PROJECTED ON THE SKY
POLARIZATION CONTROL SET TO 0.00

DSGN. BY: G. BEHRENS	DATE: 1-17-64
APPD. BY: J. J. J.	DR. BY: J. J. J.
DWG. NO.	

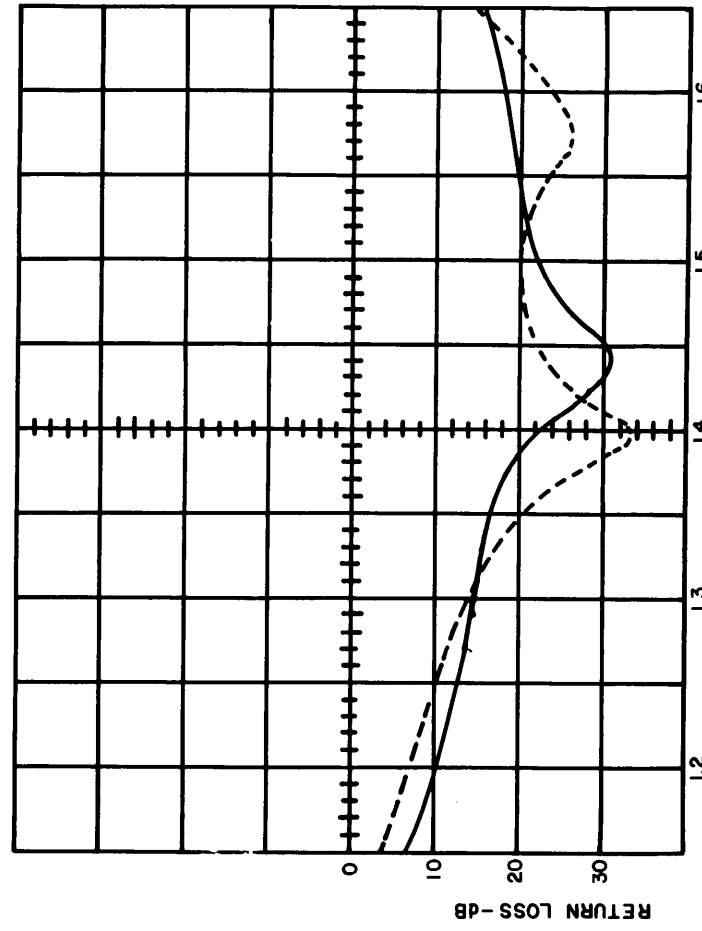
FEED ASSEMBLY BEAM GEOMETRY

FIG. 8

FEED "A"



FEED "B"



NOTE: — WITHOUT TUNING
----- WITH TUNING

NATIONAL RADIO ASTRONOMY
OBSERVATORY

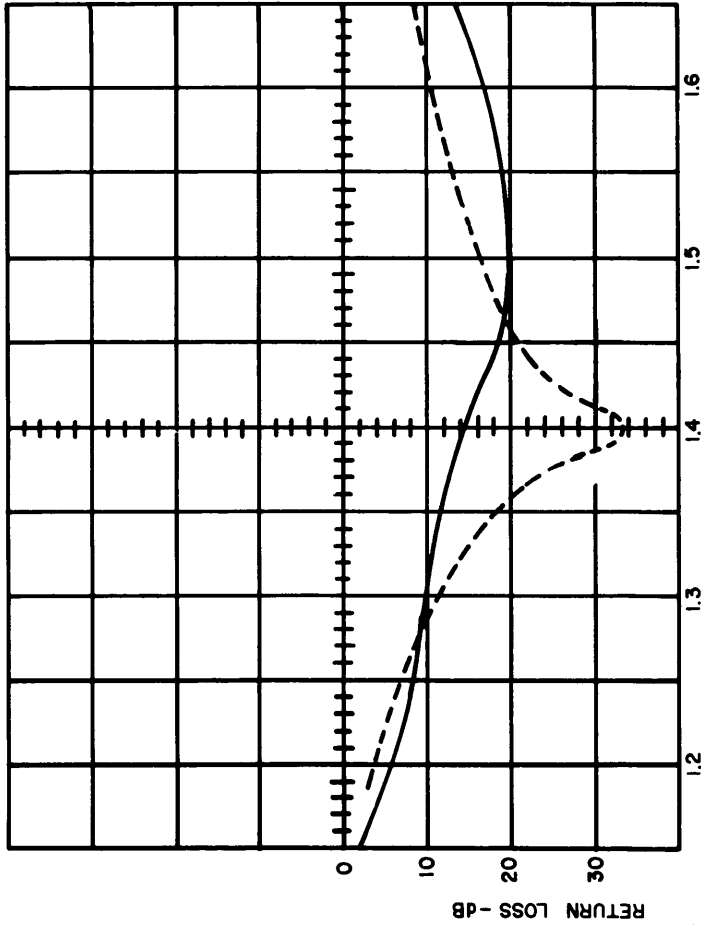
TITLE:
FEED
RETURN LOSS MEASUREMENTS 2-11-83

DSGN. BY: G. BEHERNS DATE: 1-16-84
APPD. BY: DR. BY: JGF
DWG. NO.:

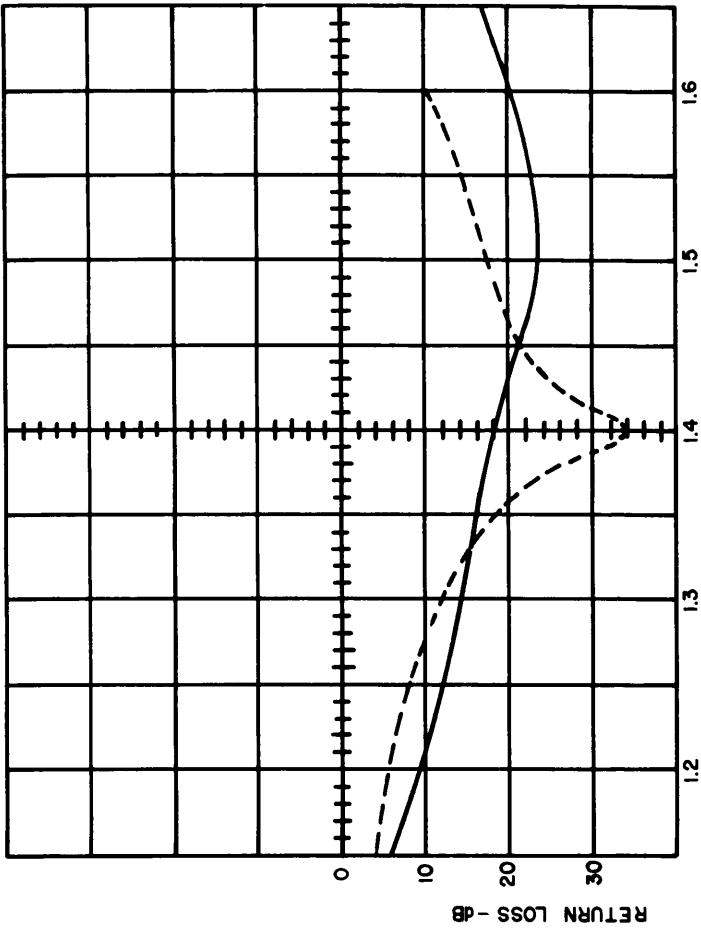
FEEDS A AND B RETURN LOSS MEASUREMENTS

FIG. 9A

FEED "C"



FEED "D"



NOTE: — WITHOUT TUNING
 - - - WITH TUNING

NATIONAL RADIO ASTRONOMY
 OBSERVATORY

TITLE:

FEED

RETURN LOSS MEASUREMENTS 2-11-83

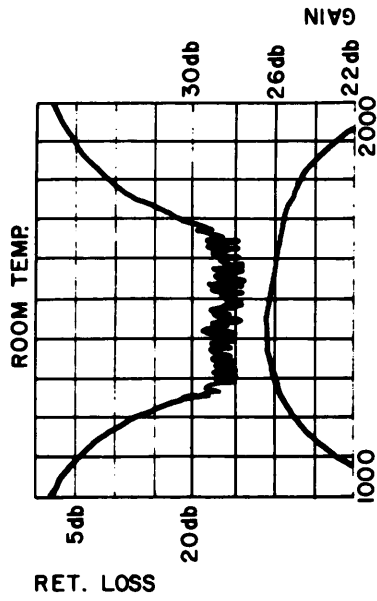
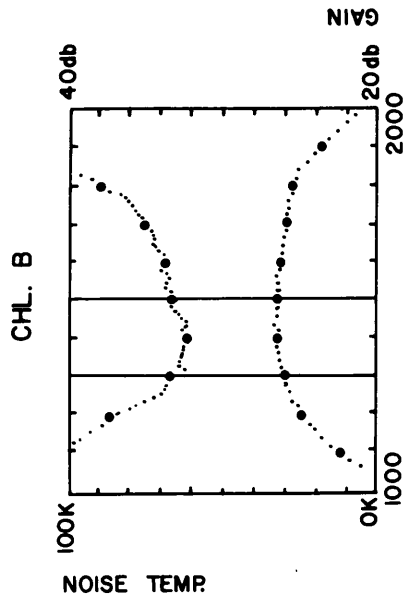
DSGN. BY: G. BEHERNS DATE: 1-16-84

APPD. BY: DR. BY: J. S. J. J.

DWG. NO.

FEEDS C AND D RETURN LOSS MEASUREMENTS

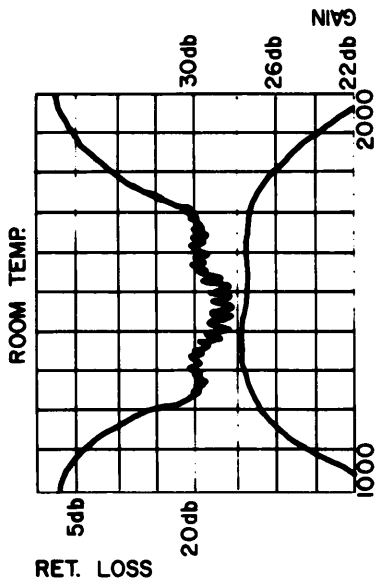
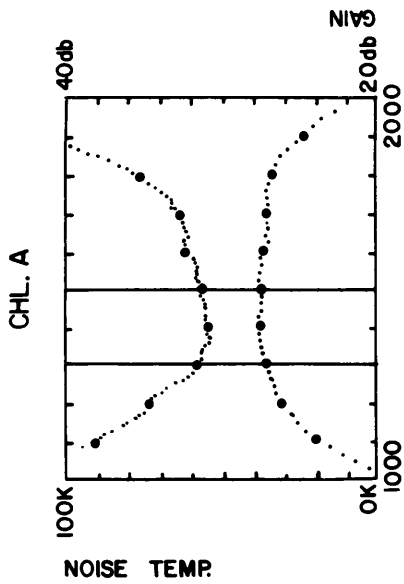
FIG. 9B



S/N 95 3-STAGE FET PS. - WITH THIRD

STAGE GATE CONTROL

	FET 1	FET2	FET 3
V_D	5.5	5.5	4.0
I_D (.1V/Ma)	17.50	17.50	10.0
V_G	-1.059	-.679	-1.170



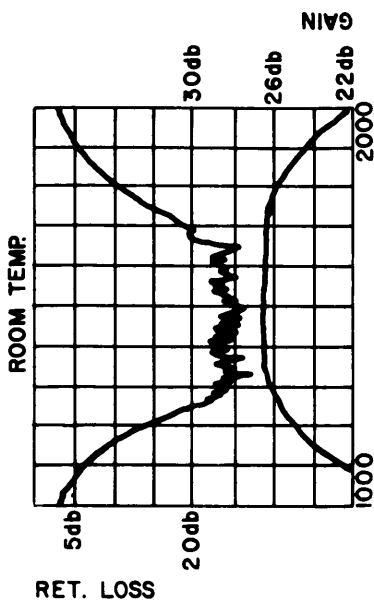
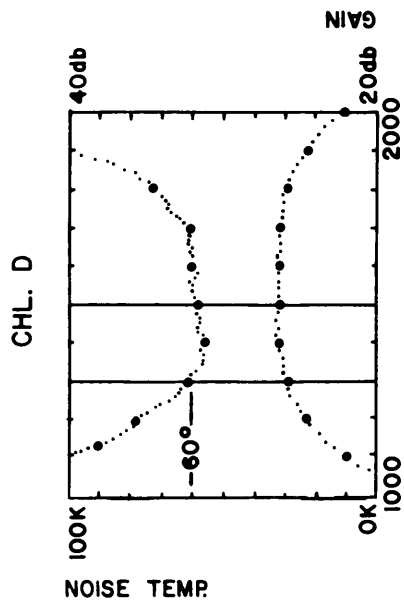
S/N 100 3-STAGE FET PS. - WITH THIRD

STAGE GATE CONTROL

	FET 1	FET2	FET3
V_D	5.5	5.5	4.0
I_D (.1V/Ma)	20.0	20.0	10.0
V_G	-.403	-.692	-1.364

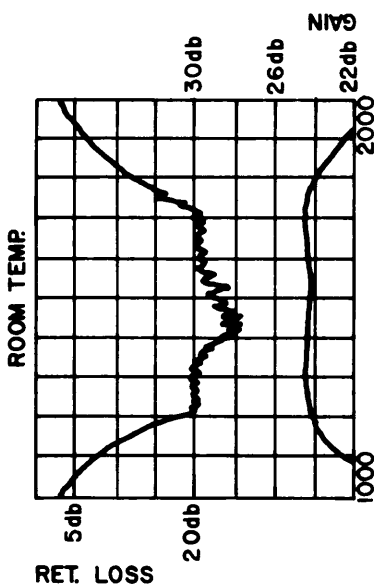
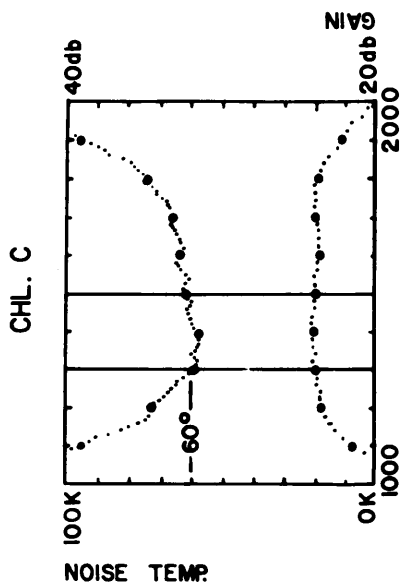
GAIN AND NOISE TEMPERATURE MEASUREMENTS OF CHANNELS A & B FET AMPLIFIERS

FIG. 10A



S/N 101 3-STAGE FET P.S. - WITH THIRD STAGE GATE CONTROL

	FET 1	FET2	FET3
V_D	5.5	5.5	4.0
I_D (1V/Ma)	20.0	17.5	10.0
V_G	-459	-1.023	-1.628



S/N 102 3-STAGE FET P.S. - WITH THIRD STAGE GATE CONTROL

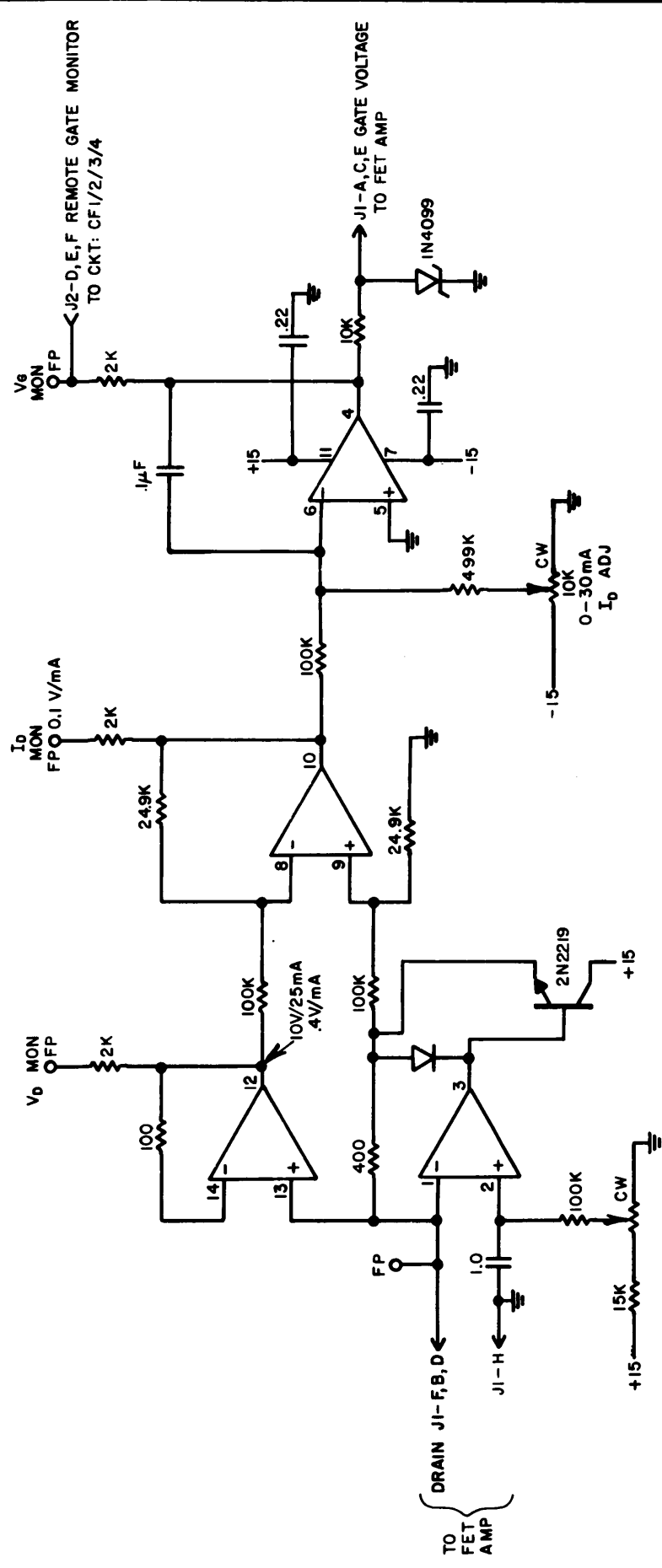
	FET 1	FET2	FET3
V_D	5.5	5.5	4.0
I_D (1V/Ma)	17.15	13.75	10.00
V_G	-486	-811	-1.240

GAIN AND NOISE TEMPERATURE MEASUREMENTS OF CHANNELS C & D FET AMPLIFIERS

FIG. 10B

- J1-7PIN TO FET**
 A VG1
 B VD2
 C VG2
 D VD3
 E VG3
 F VDI
 H GND
- J2-9PIN MONITOR**
 A N/C
 B GND
 C N/C
 D VG1 MON
 E VG2 MON
 F VG3 MON
 H +15
 J ARM TRIM POT (NOT USED)
 K -15
- J3-5PIN POWER**
 A +15
 B N/C
 C N/C
 D -15
 E GND
 F N/C

- ±15V FROM BIAS CONTROLLER**
 J3-A +15 (72 mA)
 J3-E GND
 J3-D -15 (30 mA)



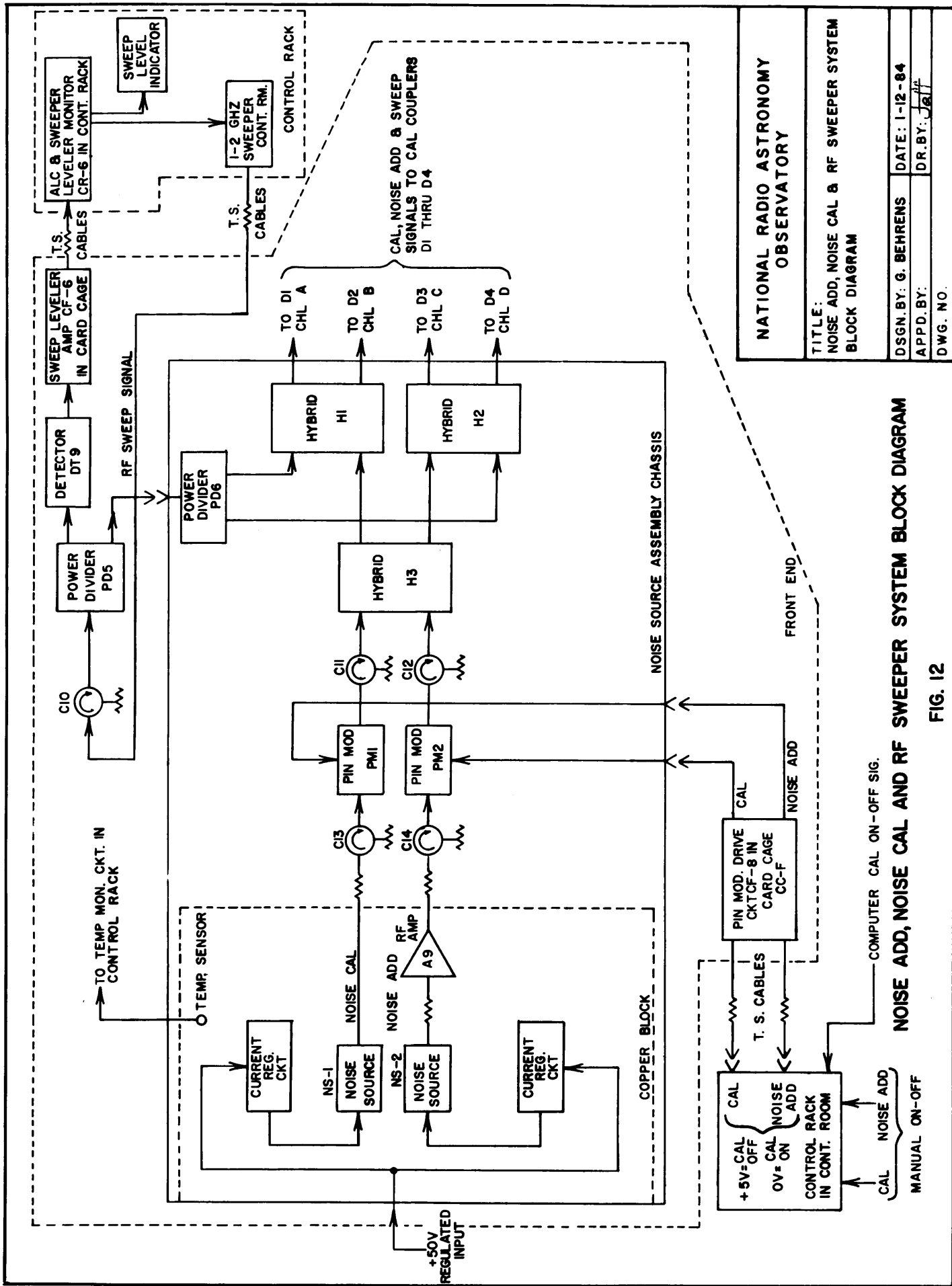
NOTES: 1 SAME CIRCUIT AS DESIGNED BY S. WEINREB 6-3-81 EXCEPT J3 ADDED TO SEPARATE ±15V INPUT FROM MONITOR CONNECTOR J2
 2 MEASURED POWER REQUIREMENT +15V AT 72 mA AND -15V AT 30 mA
 3 ALL OP AMPS 1/4 TI 07480CM

CONSTANT CURRENT SUPPLY FOR FET AMPLIFIERS

FIG. 11

NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, W. VA. 24944	
PROJ. TITLE	CONSTANT CURRENT FET SUPPLY
4 FEED 21 CM RX	
MATERIAL: N/A	DRAWN BY: JEFF
FINISH: N/A	DESIGNED BY: G. BEHRENS
	APPROVED BY:
	DATE: 1/23/82
	DATE: 8-21-82
	DATE:

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ANGLES 3 PLACE DEC.(xxx) #



NATIONAL RADIO ASTRONOMY OBSERVATORY

TITLE:
NOISE ADD, NOISE CAL & RF SWEEPER SYSTEM
BLOCK DIAGRAM

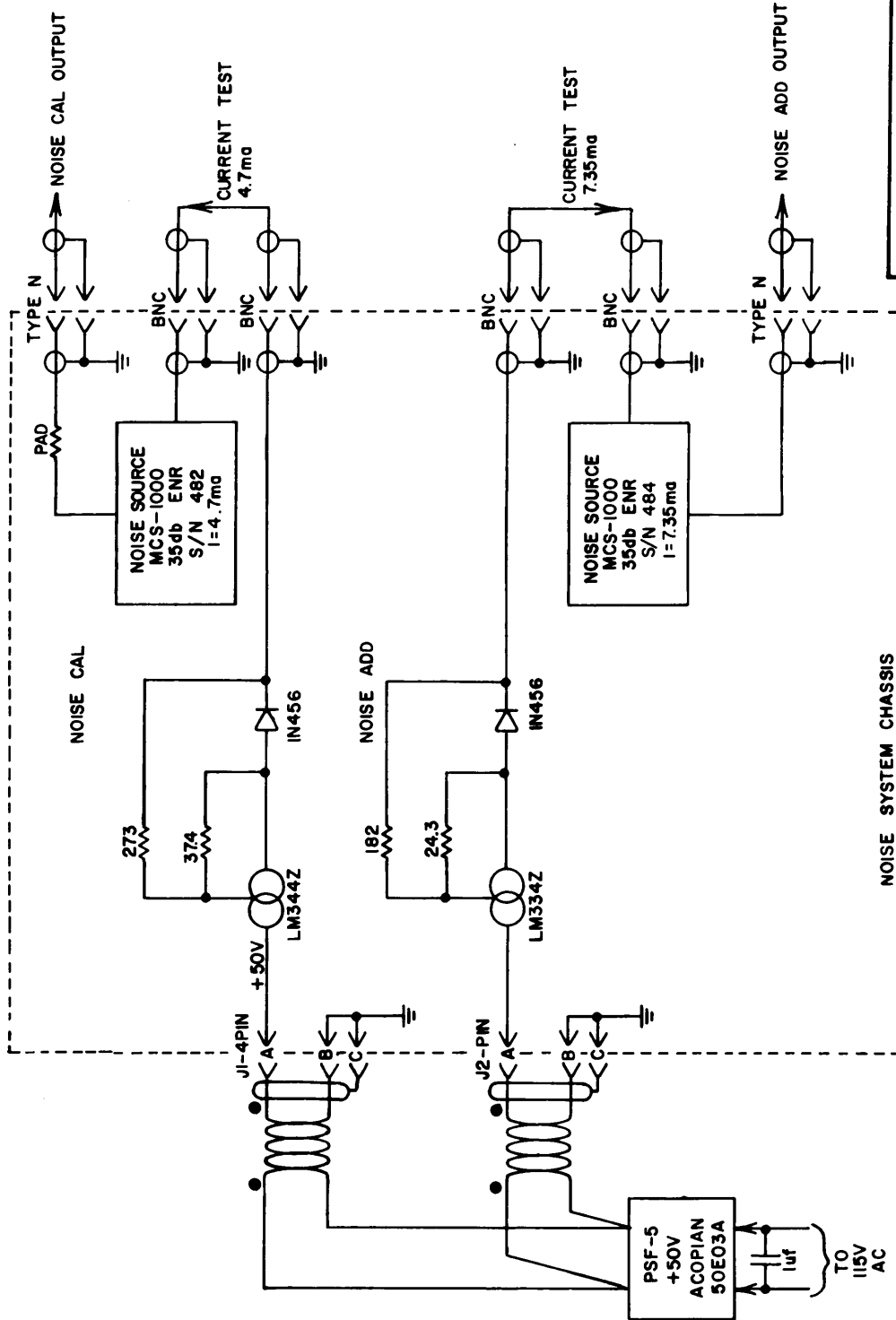
DSGN. BY: G. BEHRENS DATE: 1-12-64

APPD. BY: J. G. DR. BY: J. G.

DWG. NO.

NOISE ADD, NOISE CAL AND RF SWEEPER SYSTEM BLOCK DIAGRAM

FIG. 12



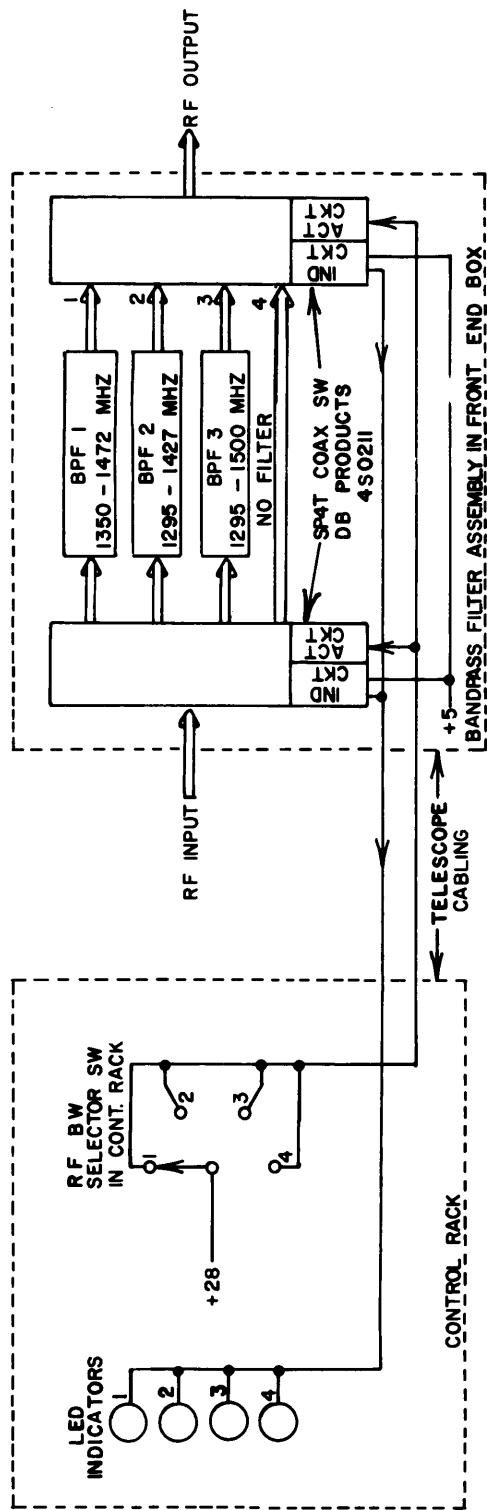
NATIONAL RADIO ASTRONOMY
OBSERVATORY

TITLE: CURRENT REG. CKT FOR
NOISE ADD. & NOISE CALIBRATION SIGNAL SYSTEM

DSGN. BY: G. BEHRENS DATE: 1-11-84
APPD. BY: Jeff DR. BY: Jeff
DWG. NO.

CURRENT REGULATOR CIRCUIT FOR NOISE SOURCES

FIG. 13



NOTE: ONE EACH PER CHANNEL

NATIONAL RADIO ASTRONOMY
OBSERVATORY

TITLE:
BLOCK DIAGRAM OF BANDPASS FILTER ASSEMBLY

DSGN. BY: G. BEHRENS

DATE: 1-5-84

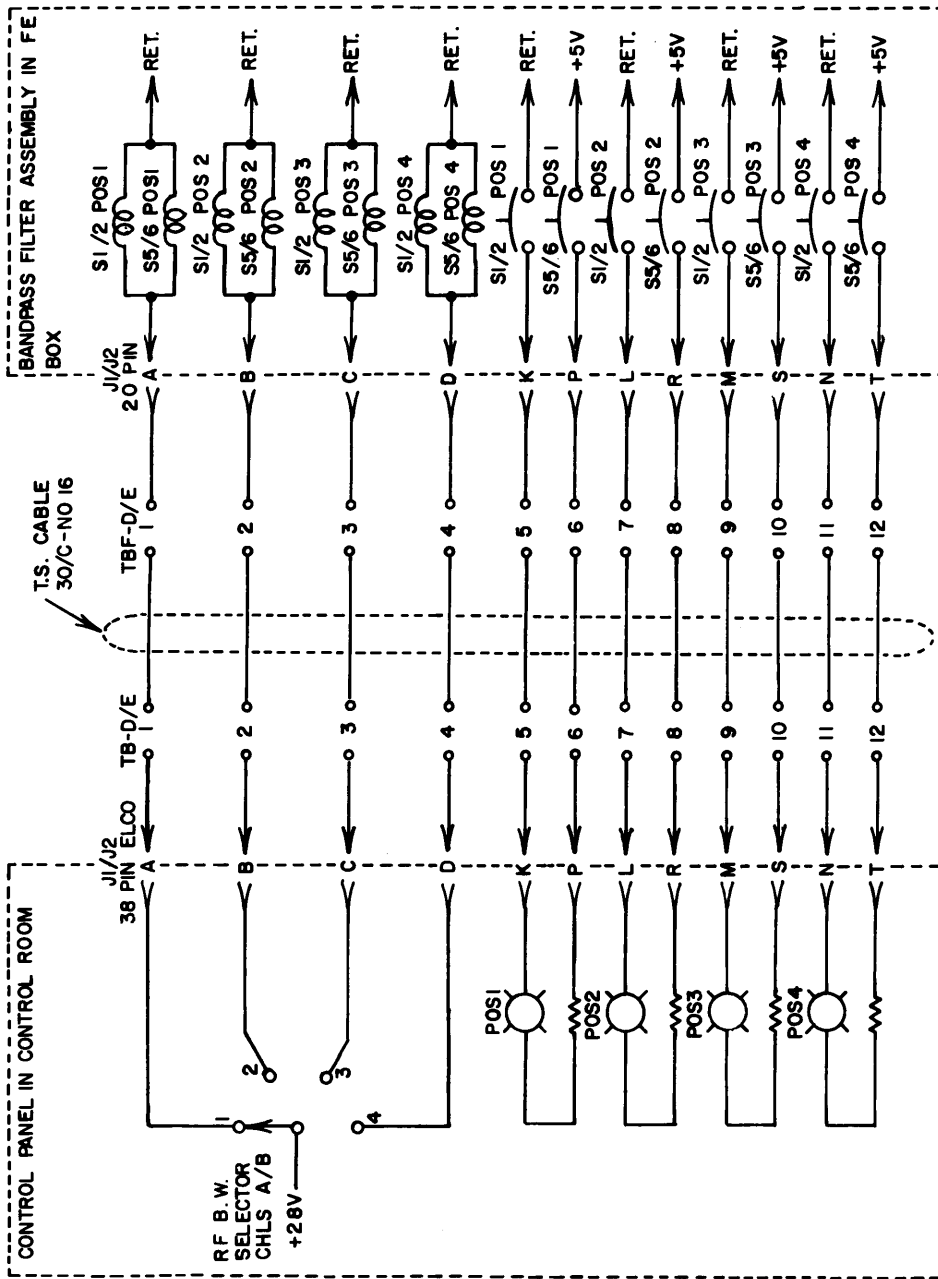
APPD. BY:

DR. BY: Jeff

DWG. NO.

BANDPASS FILTER ASSEMBLY BLOCK DIAGRAM

FIG. 14



REV A 7-22-82 SHEET 2 OF 2

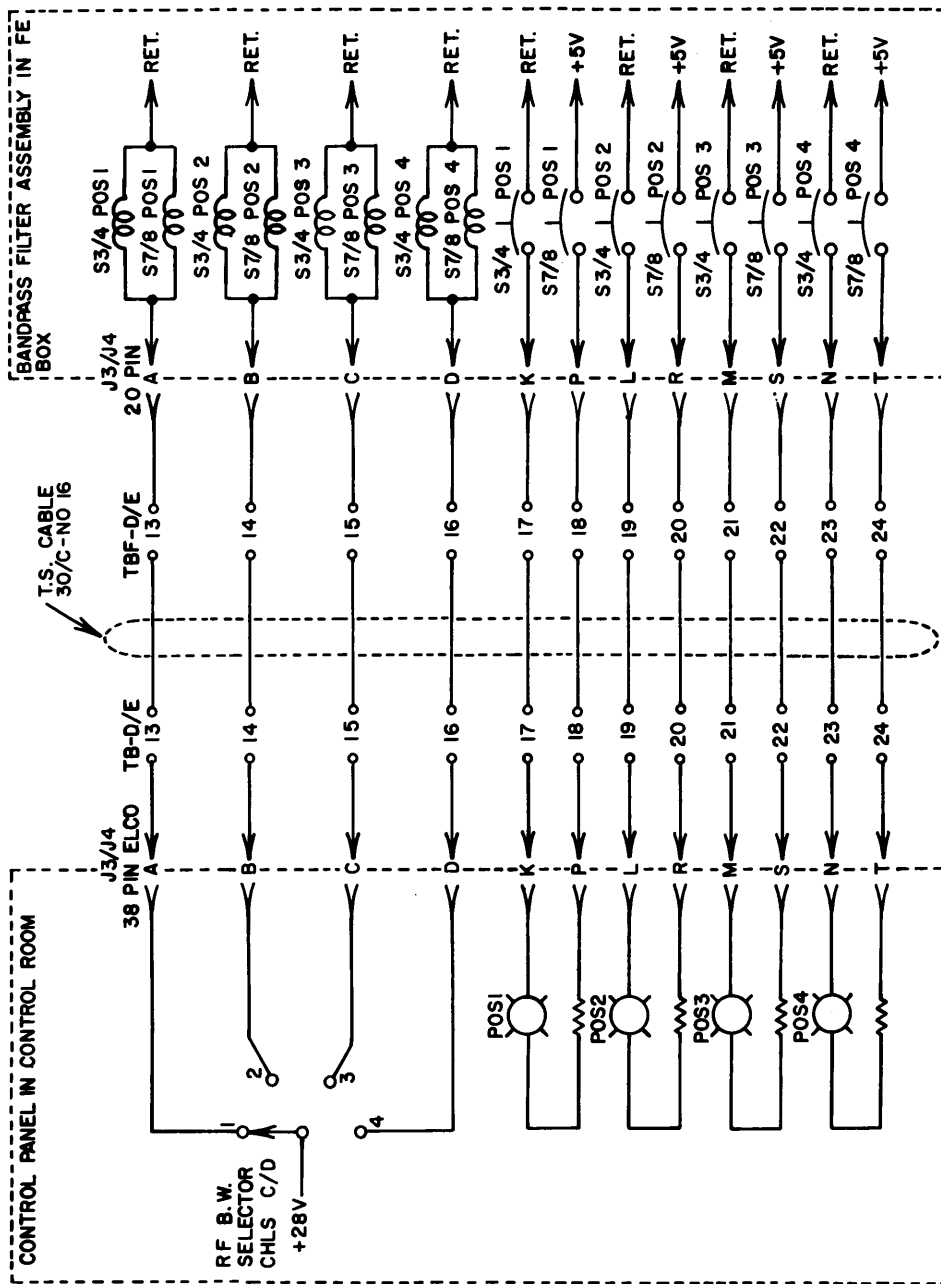
NATIONAL RADIO ASTRONOMY OBSERVATORY

TITLE: CHANNELS A/B
 BANDPASS FILTER ASSEMBLY ACTUATOR AND INDICATOR CIRCUIT

DSGN. BY: G. BEHRENS DATE: 7-20-82
 APPD. BY: DR. BY: Jett
 DWG. NO.

BANDPASS FILTER ASSEMBLY ACTUATOR AND INDICATOR CIRCUIT, CHANNELS A AND B

FIG. 15A



REV A 7-22-82 SHEET 1 OF 2

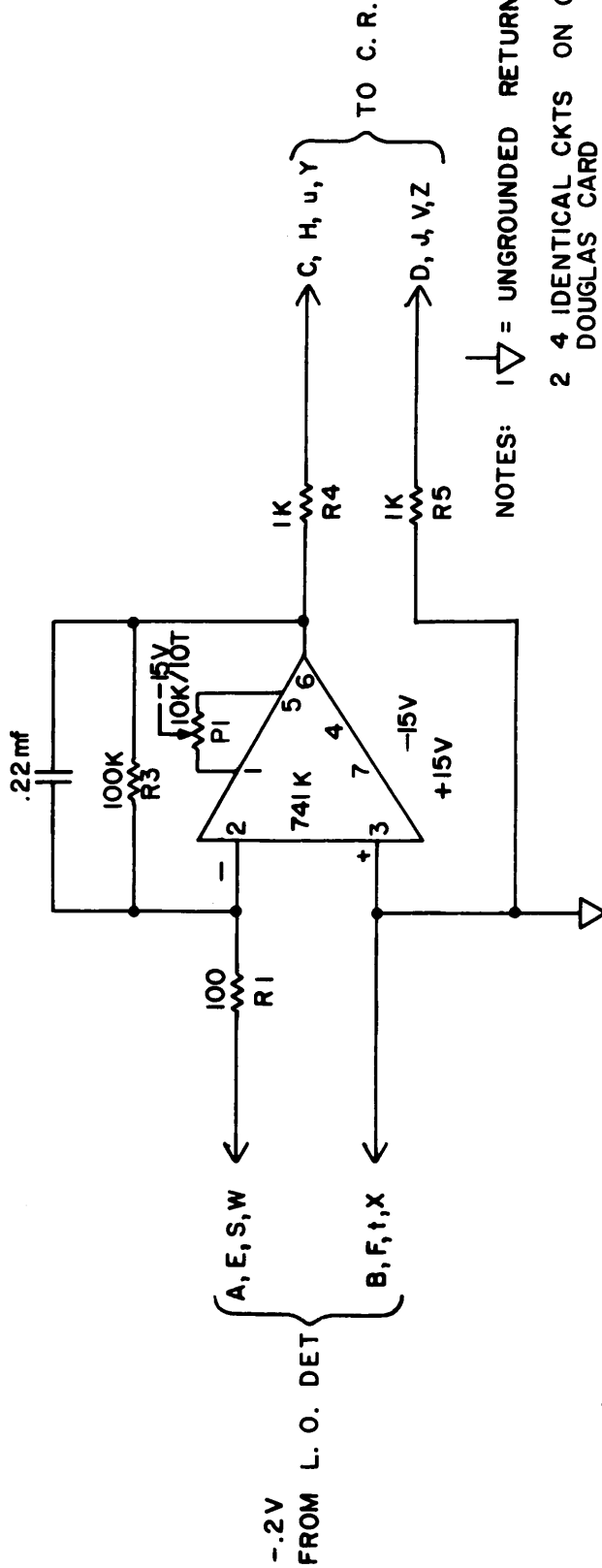
NATIONAL RADIO ASTRONOMY OBSERVATORY

TITLE: CHANNELS C/D
 BANDPASS FILTER ASSEMBLY ACTUATOR AND INDICATOR CIRCUIT

DSGN. BY: G. BEHRENS DATE: 7-20-82
 APPD. BY: J. Jeff DR. BY: J. Jeff
 DWG. NO.

BANDPASS FILTER ASSEMBLY ACTUATOR AND INDICATOR CIRCUIT, CHANNELS C AND D

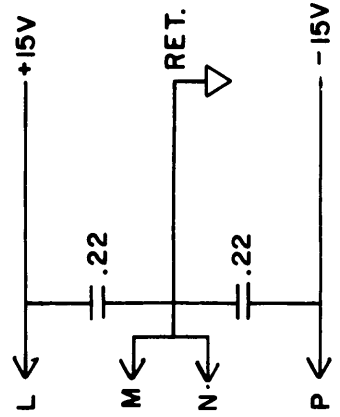
FIG. 15B



NOTES: ∇ = UNGROUNDED RETURN

2 4 IDENTICAL CKTS ON ONE DOUGLAS CARD

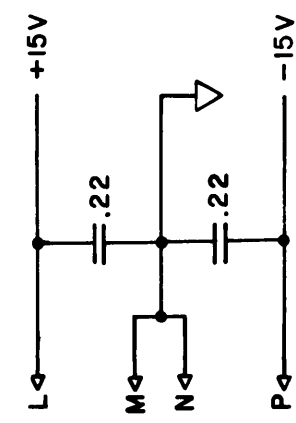
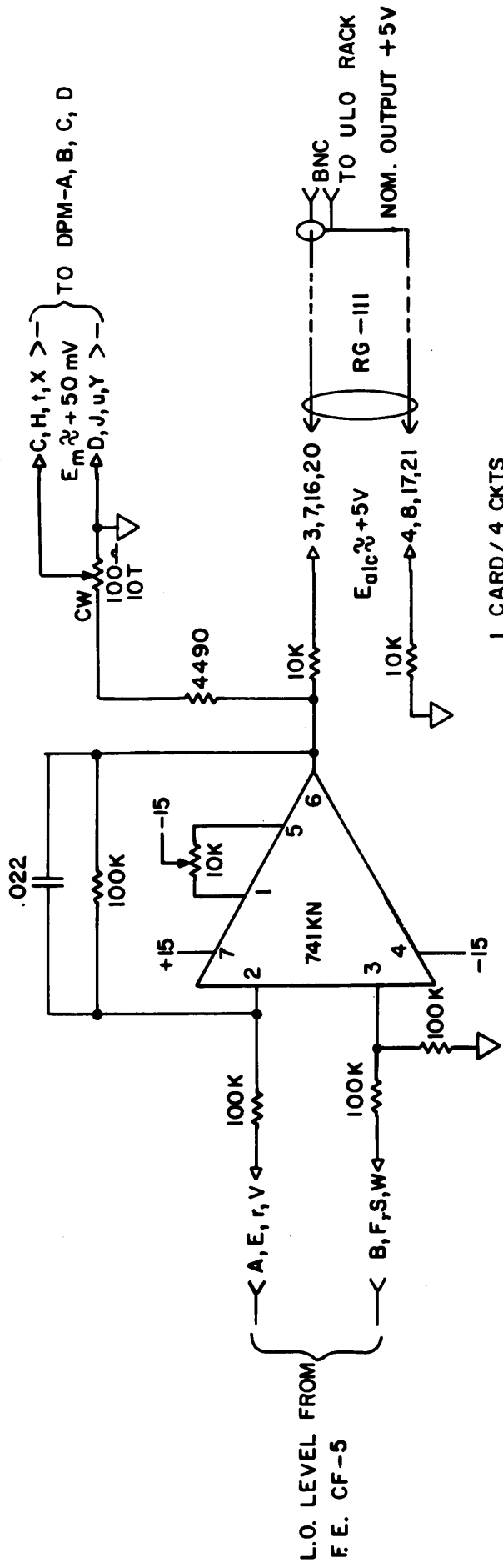
3 LABEL POTS ZERO A, B, C, & D



LO ALC AND LEVEL MONITOR DRIVER
CIRCUIT: CF-5

NATIONAL RADIO ASTRONOMY OBSERVATORY	
TITLE: L.O. MONITOR & LEVEL CKT AT F. E. BOX 4 CHLS. CKT: CF-5	
DSGN. BY: G. BEHRENS	DATE: 1/7/82
APPD. BY: <i>Jeff</i>	DR. BY: <i>Jeff</i>
DWG. NO. CF-5	

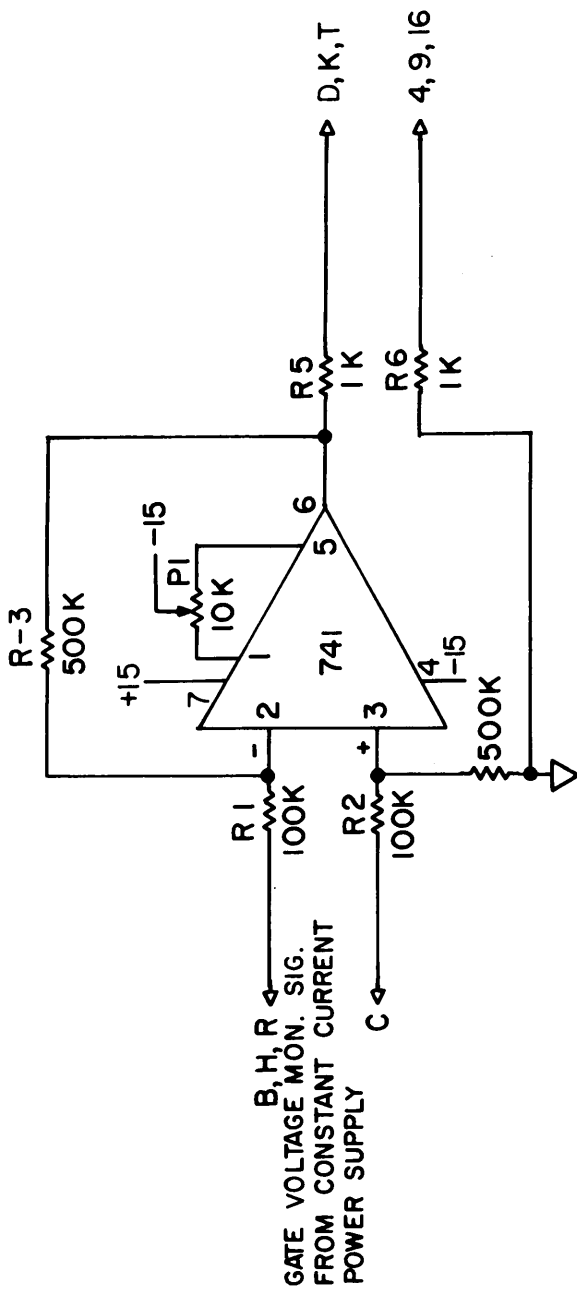
FIG. 16



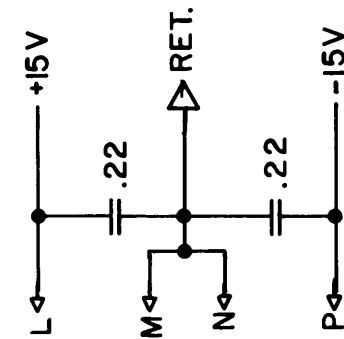
LO ALC AND LEVEL MONITOR RECEIVER
CIRCUIT: CR-5

NATIONAL RADIO ASTRONOMY OBSERVATORY	
TITLE: 4 FEED 21 CM RX L.O. LEVEL MONITOR & ALC RX CKT: CR-5	
DSGN. BY: G. BEHRENS	DATE: 9/28/82
APPD. BY: Jeff	DR. BY: Jeff
DWG. NO. CR-5	

FIG. 17



B, H, R
GATE VOLTAGE MON. SIG.
FROM CONSTANT CURRENT
POWER SUPPLY
C



- 3 CKTS/CARD
- 4 CARDS
- 1 STAGE B, D, 4
- 2 ND STAGE H, K, 9
- 3 RD STAGE R, T, 16

GATE VOLTAGE MONITOR DRIVER CIRCUIT:
CF-1, 2, 3, 4

NATIONAL RADIO ASTRONOMY
OBSERVATORY

TITLE: 4 FEED 21 CM RX

CK: CF-1, CF-2, CF-3, CF-4

FET GATE VOLTAGE MON. CKT. (DRIVER)

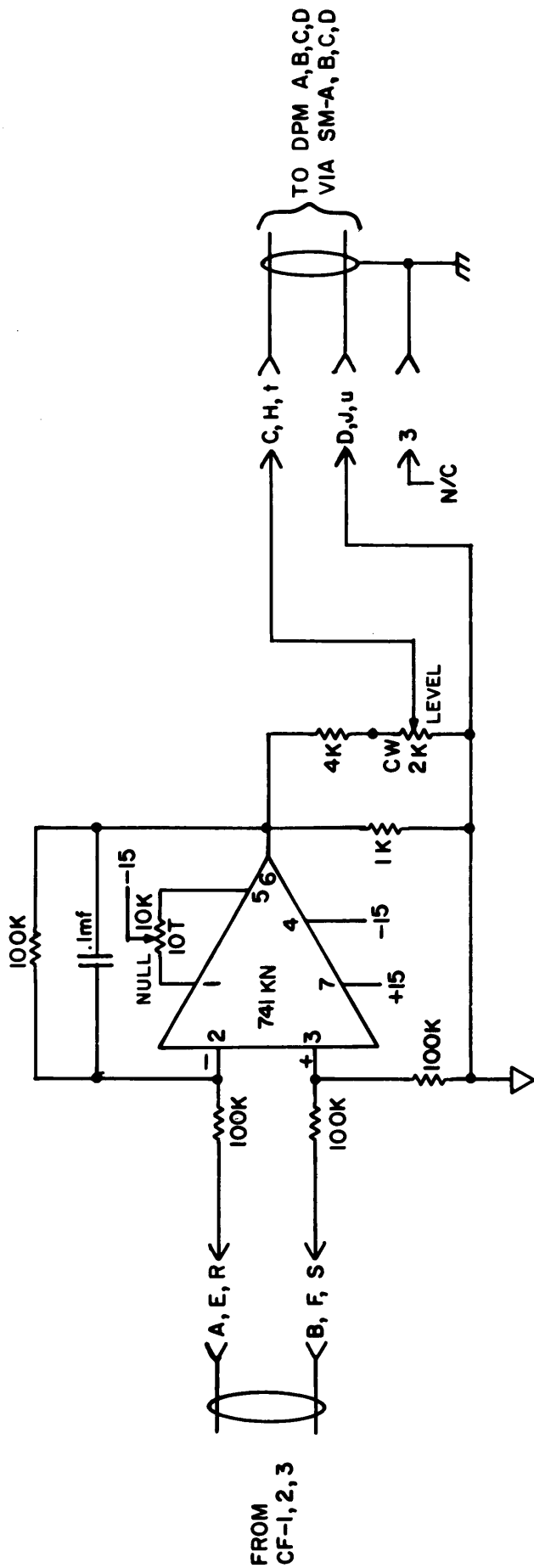
DSGN. BY: G. BEHRENS DATE: 1/22/82

APPD. BY:

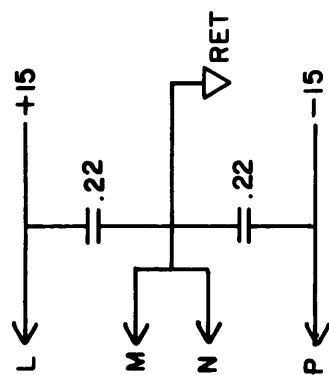
DR. BY: Jeff

DWG. NO.

FIG. 18



NOTE: 3 CKTS/CARD



GATE VOLTAGE MONITOR RECEIVER
CIRCUIT: CR-1, 2, 3, 4

NATIONAL RADIO ASTRONOMY
OBSERVATORY

TITLE: 4 FEED 21 CM RX

FET GATE VOLTAGE MONITOR RX IN
CONTROL ROOM

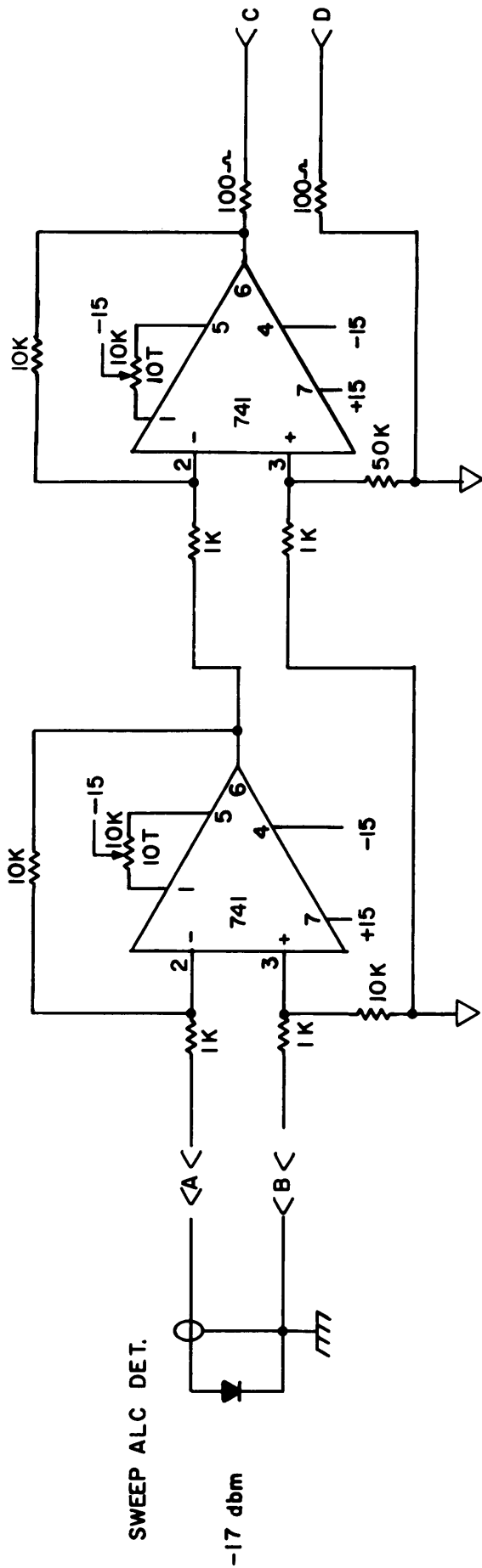
DSGN. BY: G. BEHRENS DATE: 1/13/82

APPD. BY: J. S. J. J.

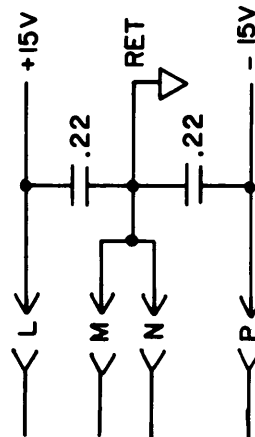
DWG. NO. CR-1, CR-2, CR-3, CR-4

CKTS: CR - 1 FOR CHL A
CR - 2 FOR CHL B
CR - 3 FOR CHL C
CR - 4 FOR CHL D

FIG. 19



NOTES:
 1 ONE CIRCUIT ON DOUGLAS CARD
 2 USE PREC. RESISTORS



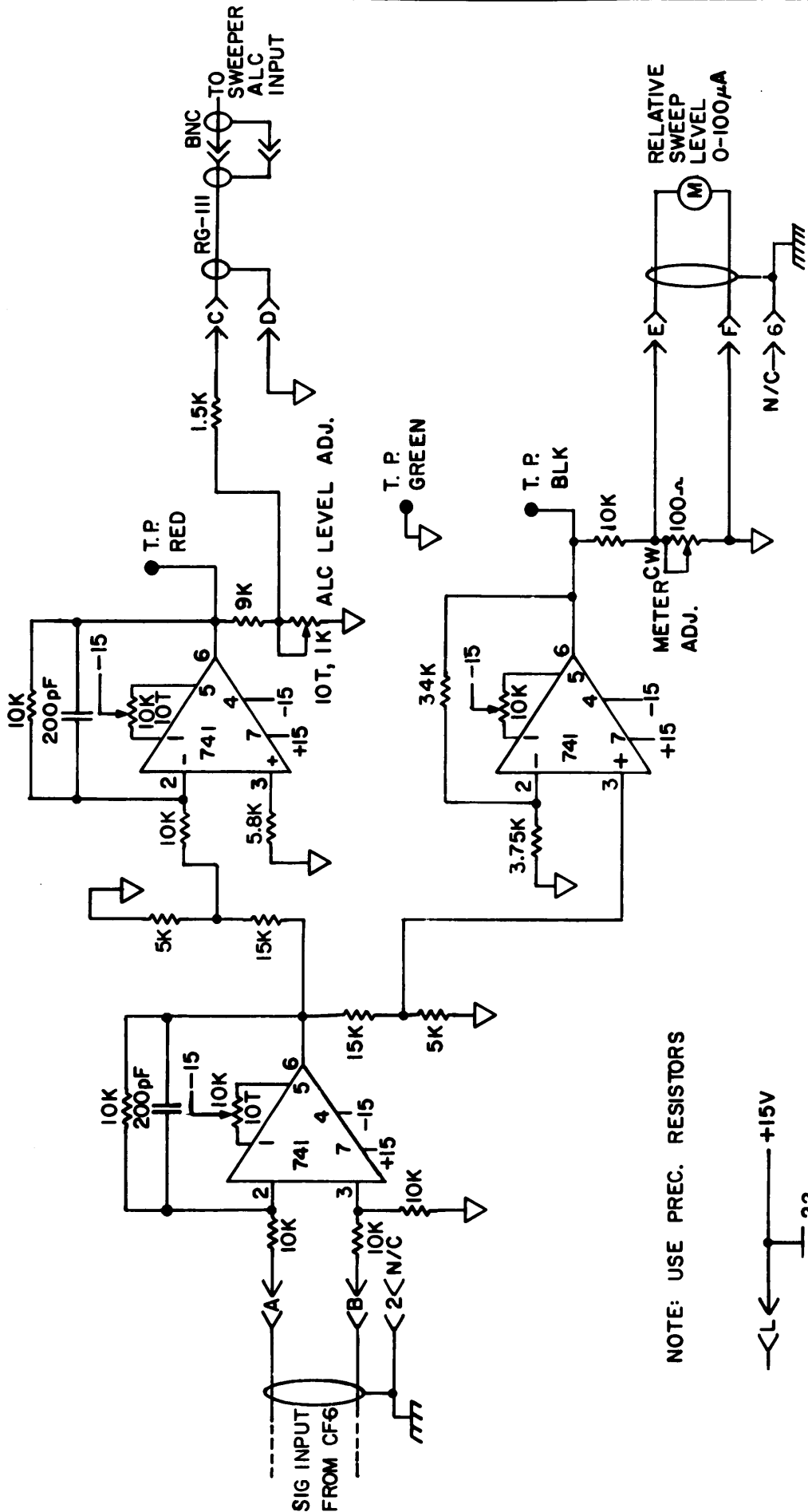
SWEEPER ALC AND LEVEL MONITOR
 DRIVER CIRCUIT: CF-6

NATIONAL RADIO ASTRONOMY
 OBSERVATORY

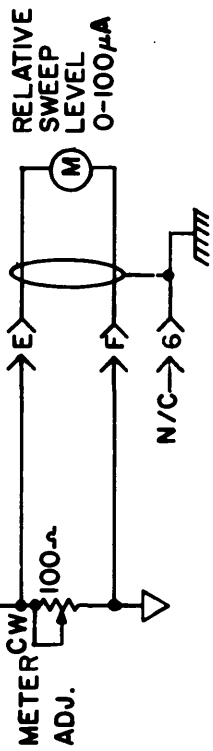
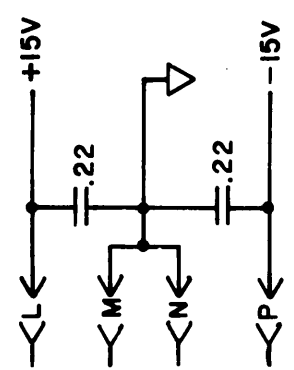
TITLE: 4 FEED - 21 CM RX, SWEEPER
 ALC LEVEL DRIVER IN F. E. BOX
 CKT: CF-6

DSGN. BY: G. BEHRENS DATE: 1-18-82
 APPD. BY: J. E. J. DR. BY: J. E. J.
 DWG. NO. CF-6

FIG. 20



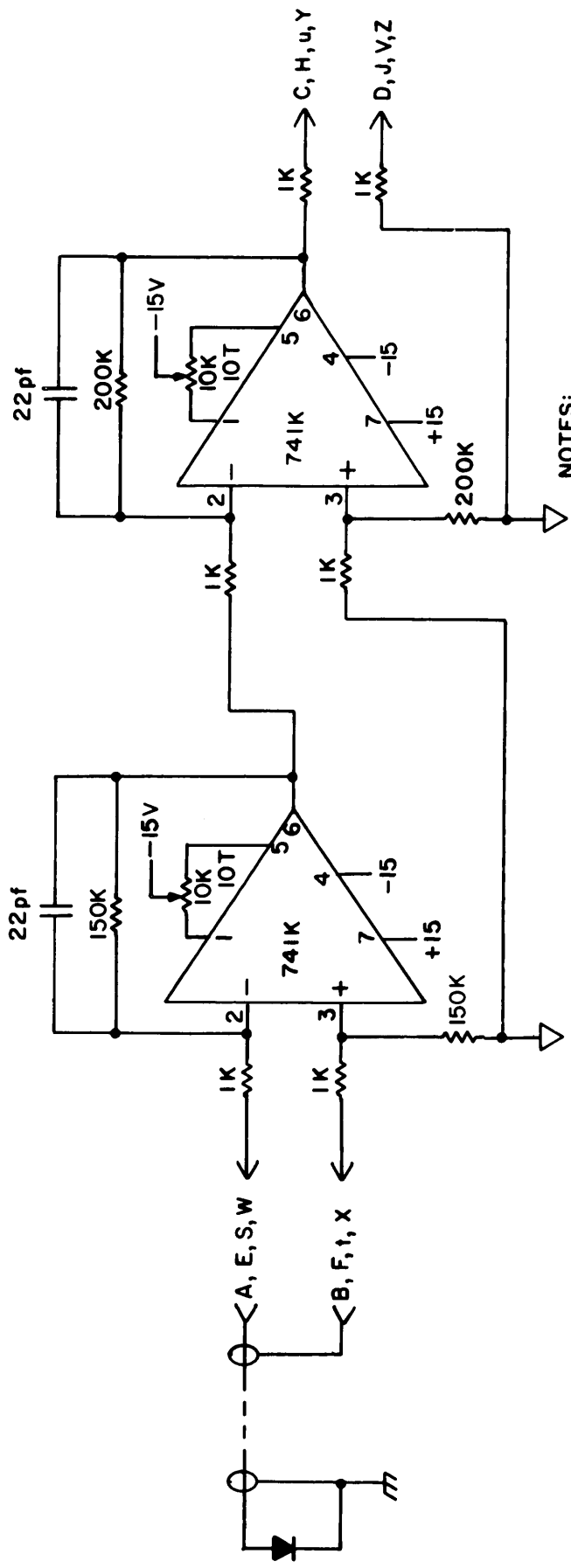
NOTE: USE PREC. RESISTORS



NATIONAL RADIO ASTRONOMY OBSERVATORY	
TITLE: ALC & SWEEPER LEVEL MONITOR RECEIVER	
CKT: CR-6	
DSGN. BY: G. BEHRENS	DATE: 1/18/82
APPD. BY: <i>deff</i>	DR. BY: <i>deff</i>
DWG. NO. CR-6	

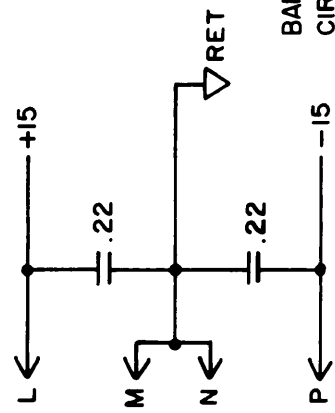
SWEEPER ALC AND LEVEL MONITOR RECEIVER CIRCUIT: CR-6

FIG. 21



NOTES:

1. USE PREC. RESISTORS
2. 4 CKTS ON ONE CARD



BANDPASS MONITOR DRIVER
CIRCUIT: CF-7

NATIONAL RADIO ASTRONOMY
OBSERVATORY

TITLE: 4FEED 21 CM RX

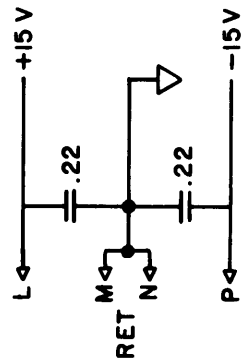
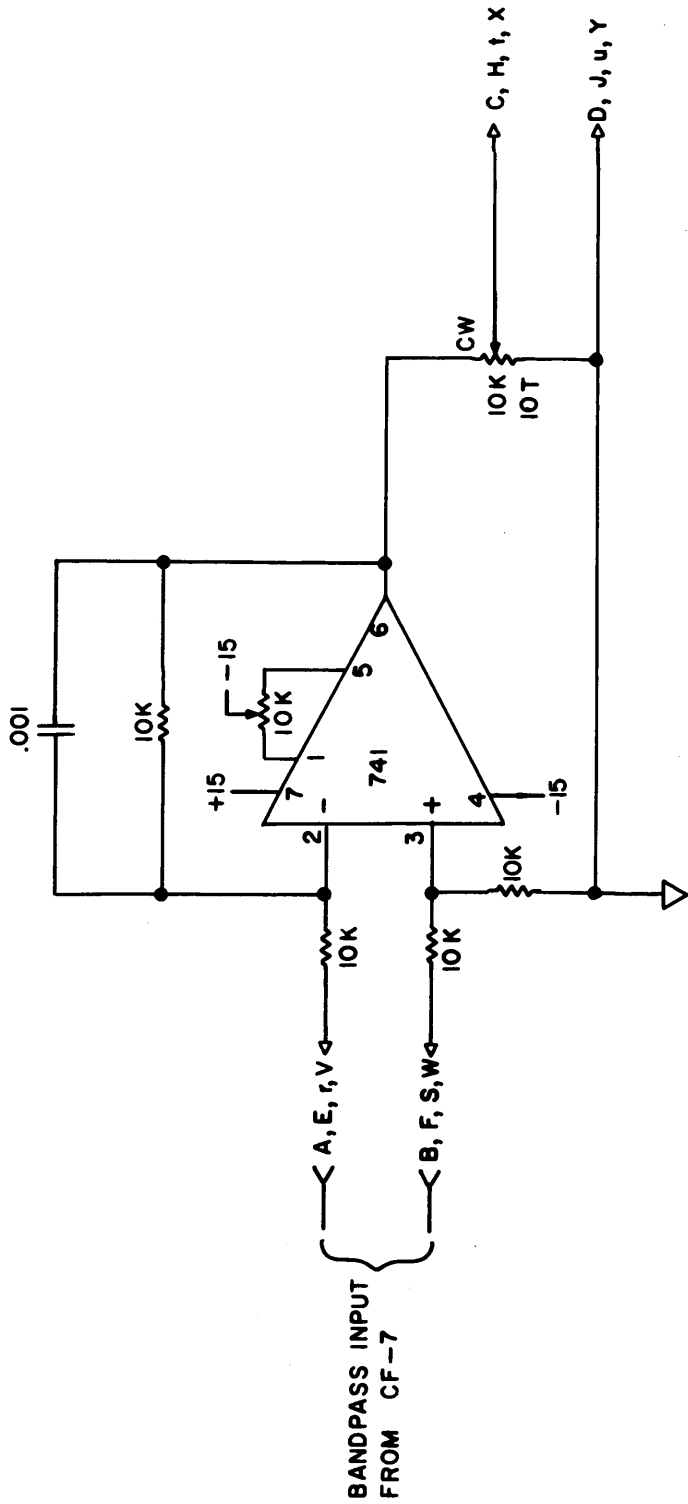
BANDPASS MONITOR DRIVER

DSGN. BY: G. BEHRENS DATE: 9/30/82

APPD. BY: *Jeff* DR. BY: *Jeff*

DWG. NO. CF-7

FIG. 22



BANDPASS MONITOR RECEIVER

FIG. 23

NATIONAL RADIO ASTRONOMY
OBSERVATORY

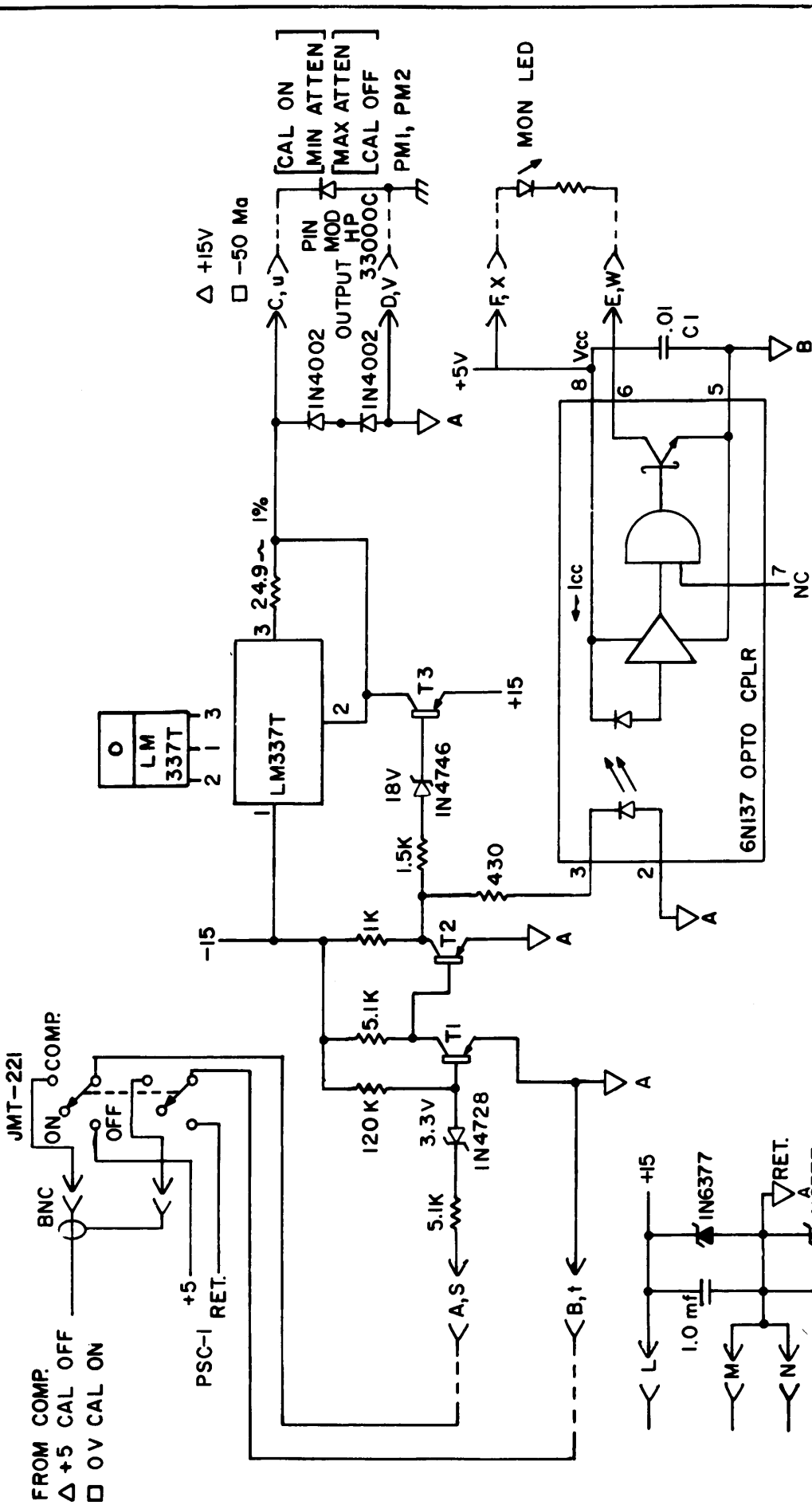
TITLE: 4 FEED 21 CM RX

BANDPASS MONITOR RECEIVER
CK: CR-7

DSGN. BY: G. BEHRENS DATE: 1/18/82

APPD. BY: Jett

DWG. NO. CR-7



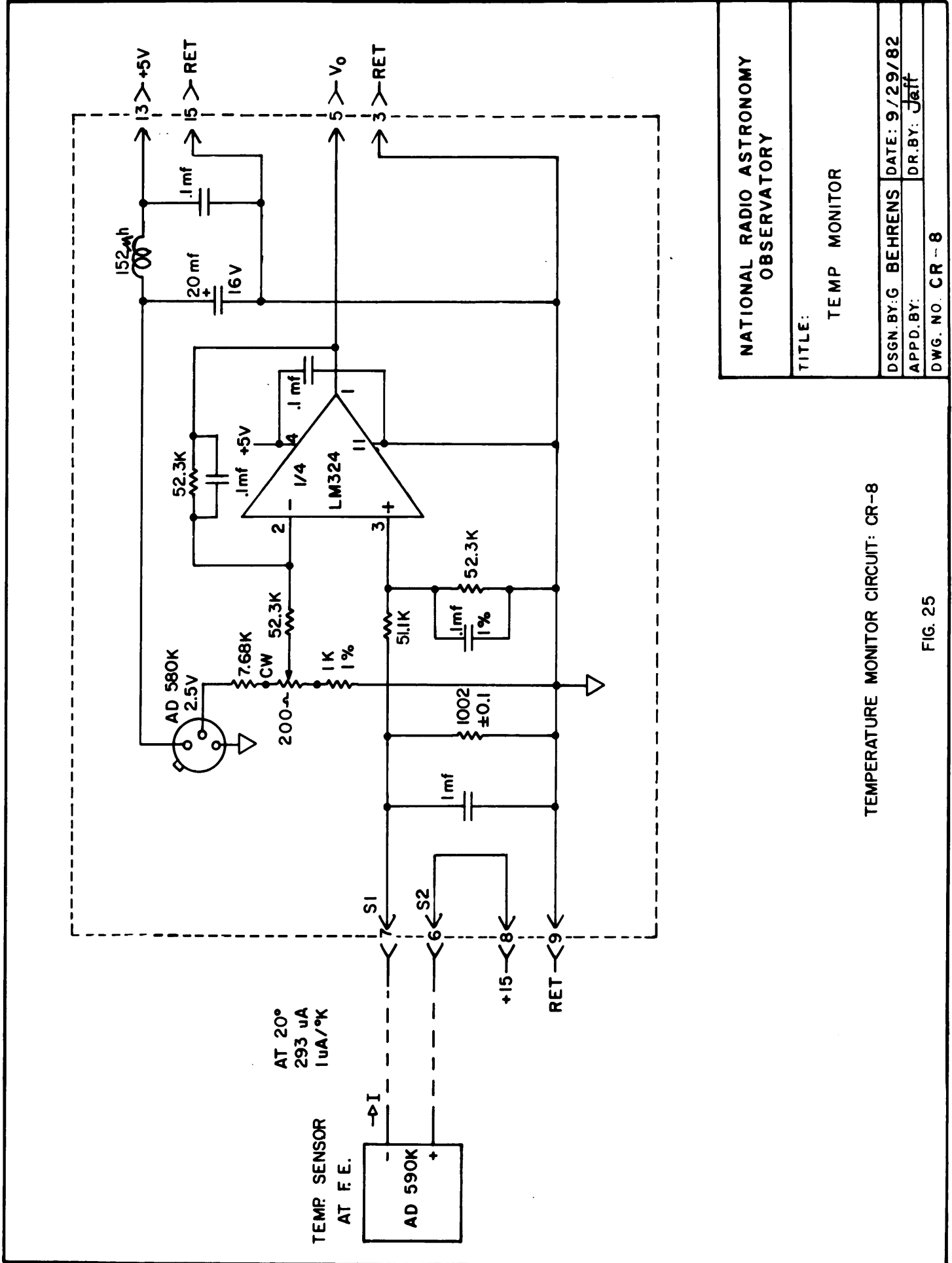
NOTES:

1. I CARD, 2 CKTS
2. MT. C1 ACROSS PIN 8 & PIN 5 OF 6N137
3. ∇ A ISOLATED FROM ∇ B
4. T1, 2, 3 - 2N3906

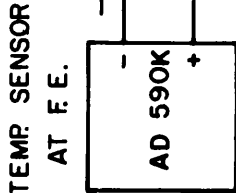
NOISE CAL AND NOISE ADD PIN
MODULATOR DRIVER CIRCUIT:
CF-8

NATIONAL RADIO ASTRONOMY OBSERVATORY	
TITLE: 4 FEED 21CM RX PIN MODULATOR DRIVERS FOR NOISE CAL & NOISE ADD SYSTEM	
DSGN. BY: G. BEHRENS	DATE: 9/3/82
APPD. BY: [Signature]	DR. BY: [Signature]
DWG. NO. CF-8	

FIG. 24



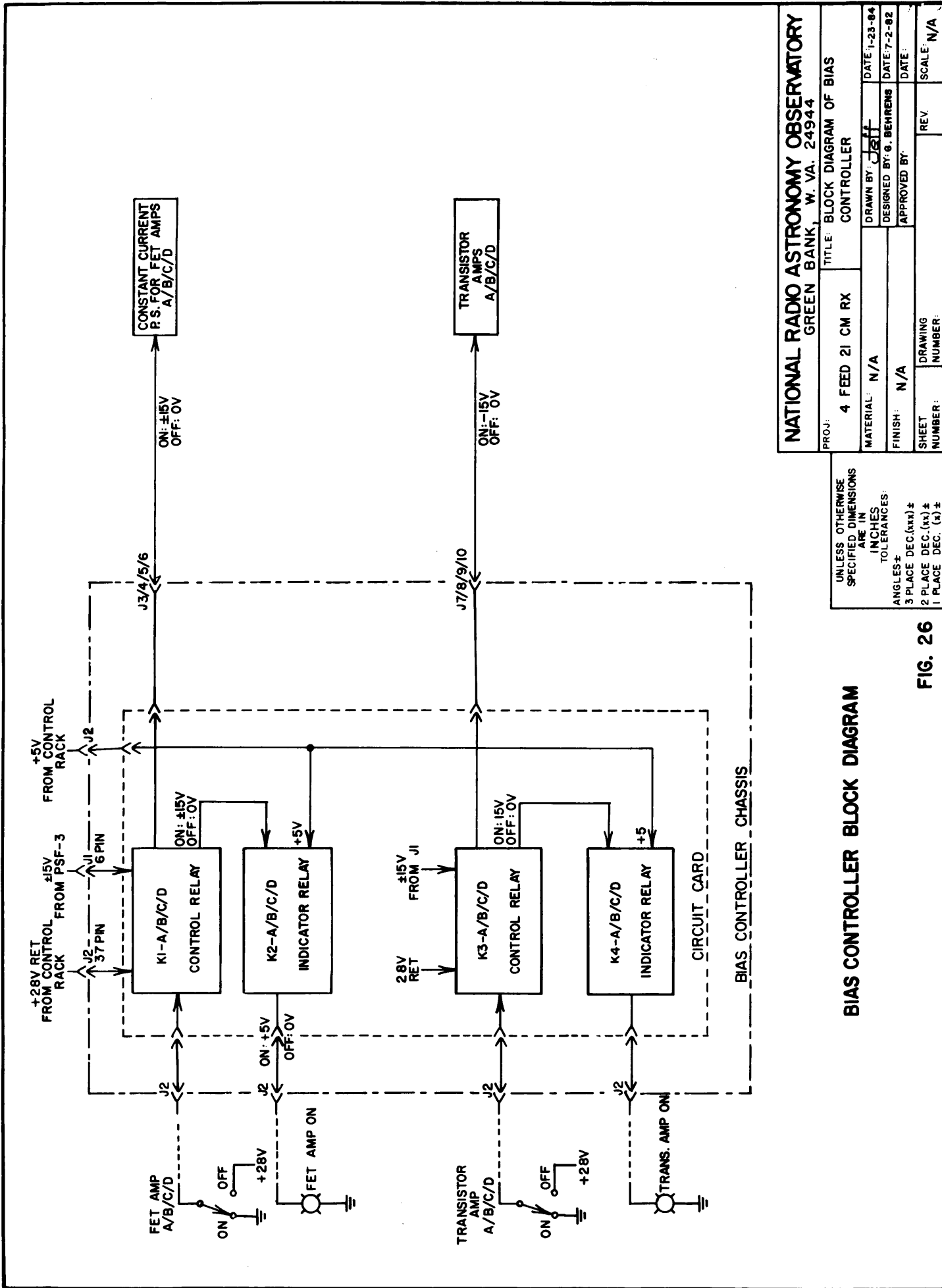
AT 20°
293 μ A
1 μ A/°K



NATIONAL RADIO ASTRONOMY OBSERVATORY	
TITLE: TEMP MONITOR	
DSGN. BY: G. BEHRENS	DATE: 9/29/82
APPD. BY: Jaff	DR. BY: Jaff
DWG. NO. CR-8	

TEMPERATURE MONITOR CIRCUIT: CR-8

FIG. 25

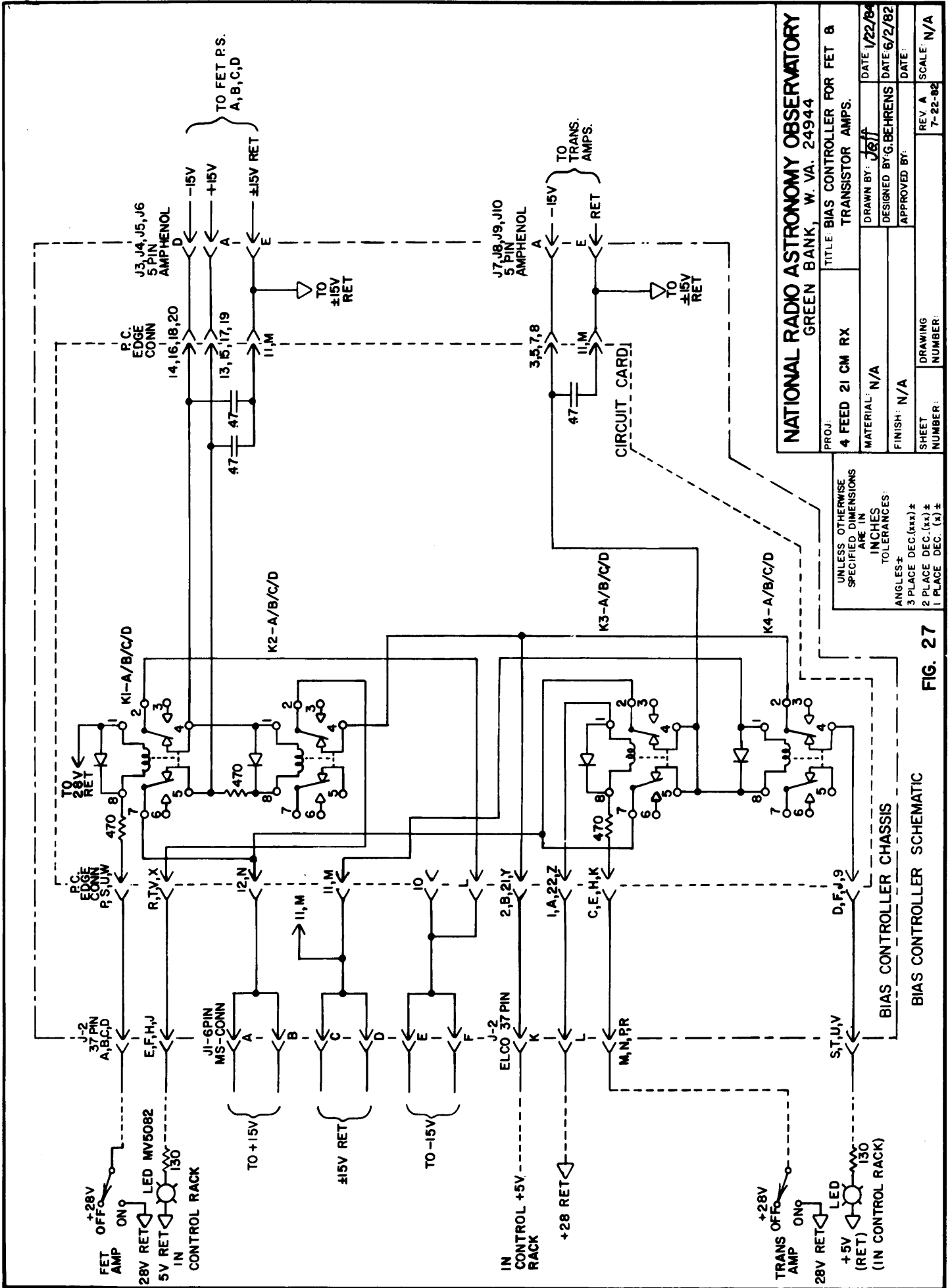


UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES: ANGLES ± 3 PLACE DEC.(xxx) ± 2 PLACE DEC.(xx) ± 1 PLACE DEC.(x) ±

FIG. 26

NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, W. VA. 24944		TITLE: BLOCK DIAGRAM OF BIAS CONTROLLER	
PROJ: 4 FEED 21 CM RX	MATERIAL: N/A	DRAWN BY: JEFF	DATE: 1-23-84
FINISH: N/A	APPROVED BY:	DESIGNED BY: G. BEHRENS	DATE: 7-2-82
SHEET NUMBER:	DRAWING NUMBER:	REV:	SCALE: N/A

BIAS CONTROLLER BLOCK DIAGRAM

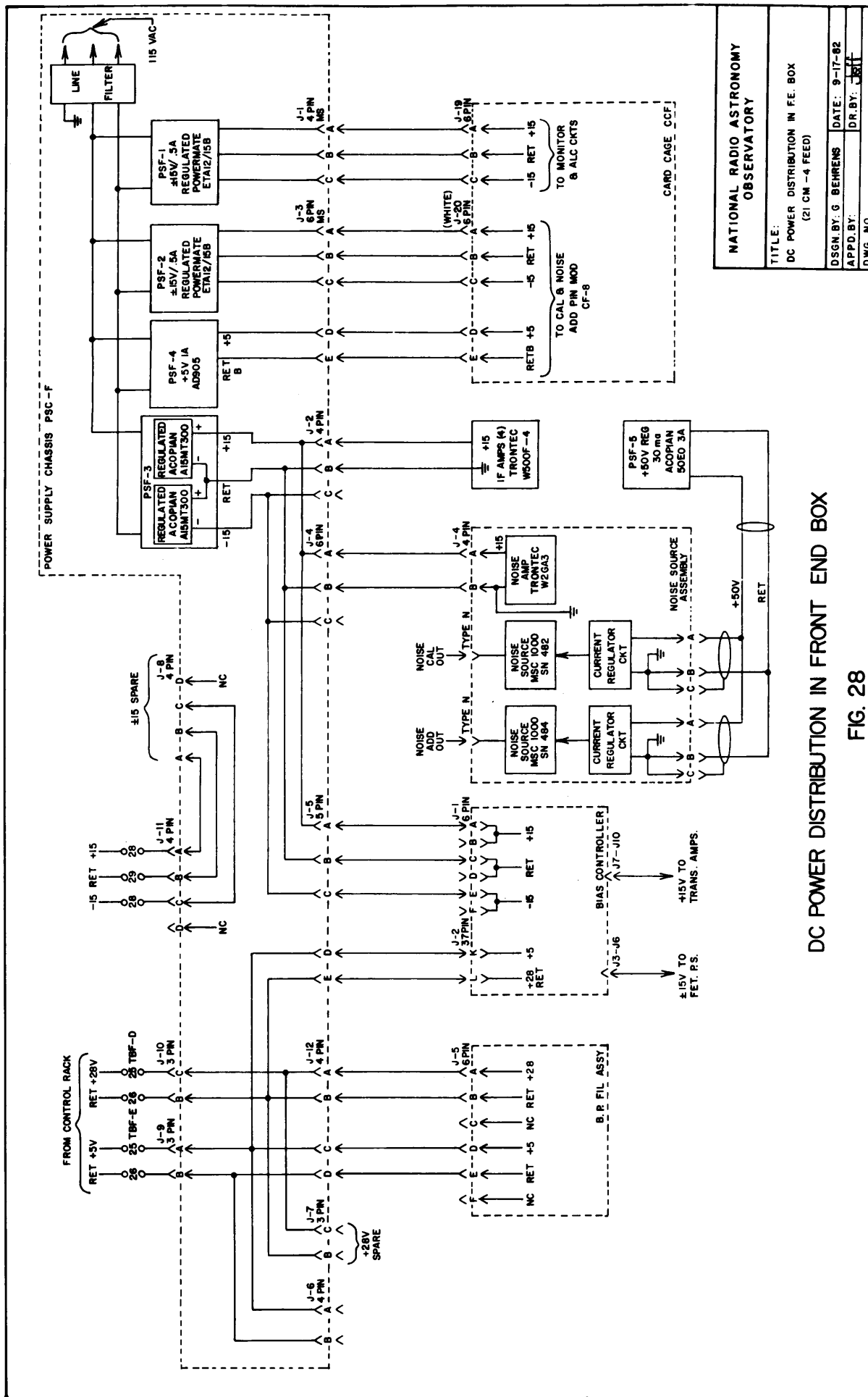


NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, W. VA. 24944	
PROJ: 4 FEED 21 CM RX	TITLE: BIAS CONTROLLER FOR FET TRANSISTOR AMPS.
MATERIAL: N/A	DRAWN BY: J. Jeff
FINISH: N/A	DESIGNED BY: G. BEHRENS
SHEET NUMBER:	DATE: 1/22/84
DRAWING NUMBER:	DATE: 6/2/82
REV. A	DATE:
SCALE: N/A	DATE:
7-22-82	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
 TOLERANCES:
 ANGLES ±
 3 PLACE DEC. (xxx) ±
 2 PLACE DEC. (xx) ±
 1 PLACE DEC. (x) ±

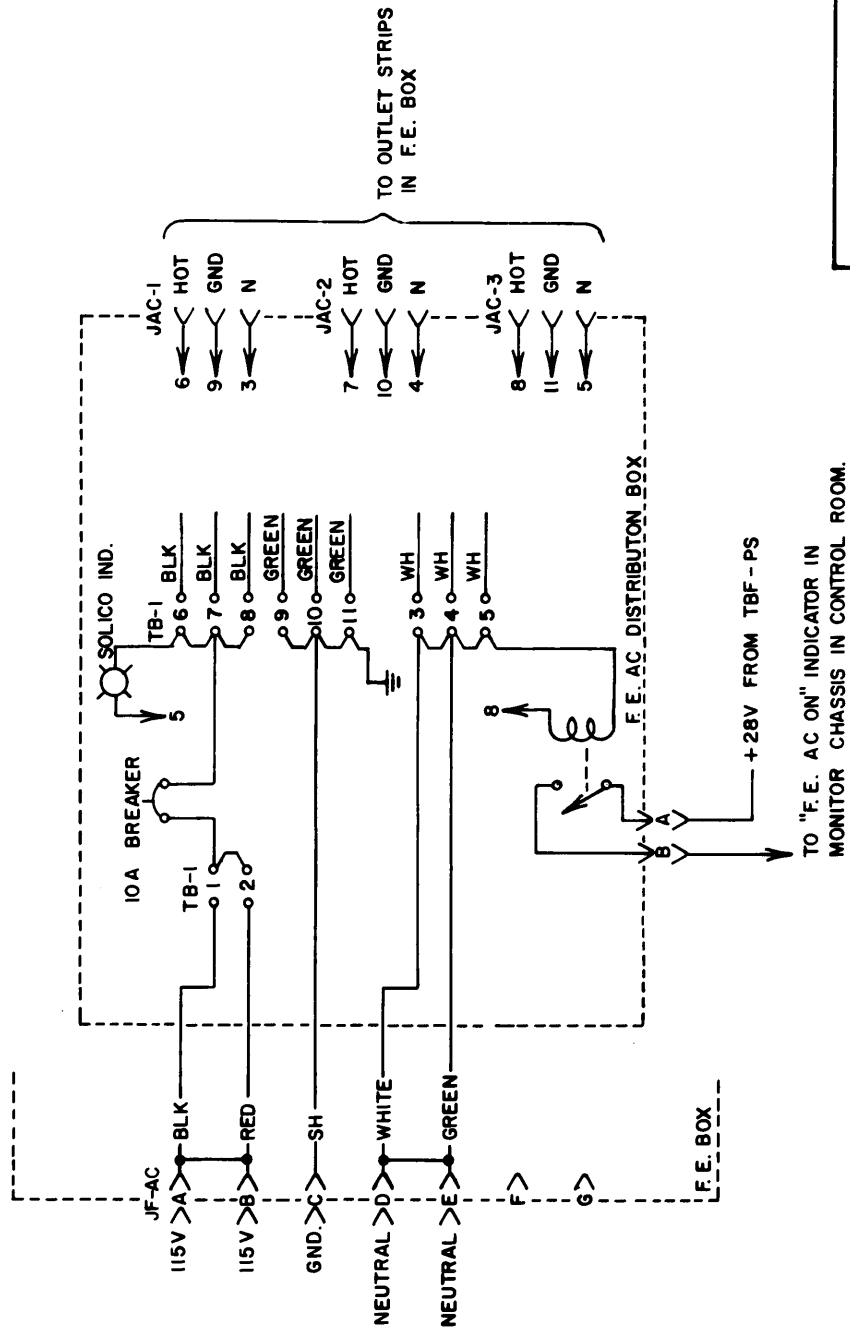
FIG. 27

BIAS CONTROLLER SCHEMATIC



NATIONAL RADIO ASTRONOMY OBSERVATORY	
TITLE:	DC POWER DISTRIBUTION IN FE. BOX (21 CM -4 FEED)
DSGN. BY: G. BEHRENS	DATE: 9-17-62
APPD. BY: JMT	DR. BY: JMT
DWG. NO.	

DC POWER DISTRIBUTION IN FRONT END BOX
FIG. 28



NATIONAL RADIO ASTRONOMY
OBSERVATORY

TITLE:
4 FEED 21CM FE. AC DISTRIBUTION BOX

DSGN. BY: G. BEHRENS DATE: 4-15-82

APPD. BY: J. J. JAFFE

DWG. NO.

AC POWER DISTRIBUTION IN FRONT END BOX

FIG. 29