

**NATIONAL RADIO ASTRONOMY OBSERVATORY  
Green Bank, West Virginia**

**ELECTRONICS DIVISION INTERNAL REPORT  
NO. 294**

# **HAWAII S AND X RECEIVER SYSTEM**

**S. D. WHITE**

**April 1993**

## TABLE OF CONTENTS

1.0	General.....	3
2.0	S and X Receiver Package.....	3
2.1	S and X Feed.....	3
2.2	Dewar Assembly.....	3
2.3	Phase Locked Oscillator Box.....	4
2.3.1.	Phase Detector Module.....	4
2.4	Analog Optical Fiber Optic Link.....	4
2.5	Phase Calibration.....	5
2.6	Receiver Control and Monitor .....	5
2.7	System Noise Temperatures .....	5
3.0	VLBA Interface .....	5
4.0	Acknowledgements.....	6
5.0	References.....	6
<b>TABLES</b>		
1	Worst Case Axial Ratio Measurements .....	7
2	Feed Performance .....	7
3	System Noise Temperature.....	7
4	Navnet VLBI.....	8
5	USNO VLBA.....	8
<b>FIGURE</b>		
1	Control Room Display.....	9
<b>DRAWINGS</b>		
	A17222D001 .....	10
	A17222B001 .....	12
<b>BLOCK DIAGRAMS</b>		
	Hawaii Receiver.....	13
	Composite .....	15
<b>APPENDICES</b>		
A	S/X Feed, A17222B010	
B	IF Amplifier Detector, A17222B004	
C	Phase Locked Oscillator, A17222B007	
D	Analog Optic Box, A17222B005	
E	500 MHz Divider, A17222B003	
F	MCB Interface	
G	Receiver Card Box	
H	VLBA Interface	

## 1.0 General

This report documents the receiver system of the USNO 20 meter antenna located in Hawaii. The design is the same as the receiver systems used on the 85 foot antennas of the interferometer, with an increased bandwidth and other improvements. An electronics division internal report 287<sup>1</sup> documents the 85 foot receivers, and a paper<sup>2</sup> submitted to JPL gives a detail description of the components of the receiver.

The S/X band system receives the 2210 to 2345 and 8210 to 8932 MHz frequency bands and downconverts them to baseband. The receiver consists of a dual-band feed, which is a single corrugated horn with two circular waveguide concentric openings at the throat; a S/X four channel cryogenic dewar package<sup>3</sup>; front-end amplifiers, mixers and filters; an IF amplifier and detector module; a phase locked oscillator module, which generates all the front-end LO's; an analog optic module, which receives the 500 MHz reference and modulates the IF, along with the returned 500 MHz reference signal on to an optic fiber. The IF system is designed to accommodate a Mark III VLBI recorder, a VLBA DAR recorder, or the existing CDP receiver with either of the recorders. A list of drawing numbers is given in document A17222D001.

## 2.0 S and X Receiver Package

The receiver is mounted in a standard NRAO Green Bank front end box, 60" by 28" by 28", supported in the focus and polarization mount by a 45" diameter circular flange. The receiver box is kept at a temperature of 25 C + or -3 C, with thermoelectric heat pumps and a proportional controller. The block diagram and parts list of the receiver are given in documents B17222K001 and A17222B001, respectively. As shown on the block diagram, both the right and left-hand circularly polarized signals are received. The two polarizations at each frequency are designated X-R, X-L and S-R, S-L. The signal flow is from the feed through the low noise amplifier. After amplification in the low noise amplifier, the signals are limited in frequency by the band pass filters. The RF amplifiers increase the signal level ahead of the mixer to minimize the mixer contribution to the overall noise temperature. The Intermediate Frequency signals from the mixer are amplified and detected to get the total power for monitoring receiver performance. The X-R and S-R IF signals, along with the 500 MHz Local Oscillator reference signal, are combined in the IF triplexer.

### 2.1 S and X Feed

A dual-frequency dual-polarized feed was designed for this receiver. It illuminates the reflector antenna with an  $f/d$  of .43, with minimum spillover. From feed patterns obtained on the test range, the computed aperture efficiency was 65% at S-Band, and the spillover and scattered noise was less than 3.5 degree Kelvin. At X-band feed patterns predicted 60% aperture efficiency and less than 0.9 degree Kelvin spillover. The worst case axial ratio measurements and the feed performance is given in Table 1 and 2, respectively. An outline drawing of the feed and the parts list is given in documents D17222M005 and A17222B010, respectively.<sup>2</sup>

### 2.2 Dewar Assembly

The receiver uses low noise HEMT amplifiers cooled to 15 Kelvin, with a closed-cycle helium refrigerator system. The S-band inputs to the dewar are through rectangular waveguide. The X-band input is a circular waveguide, with the polarizer inside the dewar. Typical gain and noise temperatures for the S-band channels are 33 dB and 12 Kelvin. The X-band noise temperatures at the dewar flange are 14 Kelvin, with a gain of 35 dB.<sup>3</sup>

## **2.3 Phase Locked Oscillator Box**

The local oscillator system generates the X-band and S-band LO signals by phase locking a 7600 MHz and 2000 MHz oscillator to a 100 MHz VCO. The fifth harmonic of the 100 MHz VCO, which is derived from a step recovery diode comb generator, is compared to a 500 MHz reference from the hydrogen maser, and the error signal is used to lock the VCO.

The local oscillators can be switched on and off from the control computer. This allows one to determine if offsets exist in the total power monitors used for system temperature measurements.

### **2.3.1 Phase Detector Module**

A phase detector, loop amplifier and lock indicator module are used in the phase lock loop in the receiver front end. The schematic and parts list are given in B17222S002 and A17222B009, respectively. Signal and reference input levels are 0 dBm. The mixers M1 and M2 perform as phase detectors. The signal input to the lock detector mixer M2 is shifted 90 degrees by the lumped constant quarter wave transmission line so its output is maximum when the oscillator and reference are locked. If the lock indicator level drops below -.5 volt level set by pot K1, power is applied to the 555 timer to generate a square wave. This signal is injected into the loop amplifier to sweep the oscillator frequency to aid in attaining lock. The phase lock loop natural frequency and damping are set by R14, C15 and R13.

## **2.4 Analog Optical Fiber Optic Link**

The fiber optic link consists of the analog optic box located in the front-end box, the fiber optic cable connecting the front-end box with the control room electronic, and the optical receiver located in the VLBA interface. The analog optical box (A17222B005) houses the optical transmitter, an IF triplexer, two RF switches, and the optical receiver. One RF switch selects either the X-R or the X-L for input to the triplexer. The other RF switch selects either the S-R or the S-L input to the triplexer. The triplexer combines the selected X-band IF and the selected S-band IF with the returned 500 MHz reference. The transmitter and receiver operate at optical wavelength of 1300 nanometer. The laser diode transmitter is amplitude modulated by the radio frequency signals with a maximum frequency range of 10 to 1500 MHz. Single mode fibers are used to carry these broadband signals. To minimize the noise from the optical transmitters, the reflections in the fiber must be low. Low reflection optical connectors were installed on the transmitters and receivers. Fusion splices are used to interconnect all optical fibers. The fiber optic cable contains four single mode fibers for use with the analog links and four multimode fibers for digital links.

The rf transmission loss with the transmitter connected directly to the receiver is about 15 dB. The maximum input power level is +10 dBm, and with narrow band signals the S/N at the receiver is 120 dB/Hz. When broadband signals are transmitted through the link, the noise level increases due to intermodulation. With the 230 MHz wide S-Band IF and the 866 MHz X-Band IF signals transmitted on the same link, the S/N at the control room is calculated to be 24 dB.

## **2.5 Phase Calibration**

The phase calibration system uses the Mark III VLBI Phase and Group delay calibrator to generate the 1 MHz comb of frequencies. These signals are combined with the noise calibration signals through a 6 dB directional coupler, as shown in document B17222K001, and injected into the cal port on the dewar for each of the four channels. The input 5 MHz to the delay calibrator antenna unit is produced by dividing the 500 MHz local oscillator reference signal by 100.

## 2.6 Receiver Control and Monitor

The receiver has six power supply voltages and other analog signals which are monitored and displayed at the Control Building. There are also separate on/off controls for each of the local oscillators and the noise calibration signals. The control and monitor is implemented using a VLBA standard interface board mounted in an RFI tight enclosure in the receiver box. This board contains a microprocessor, an A-D Converter and multiplexer, as well as digital I/O. The MCB Interface Box contains the standard interface card, the receiver control card (A17222S007), the analog multiplexer card (A17222S008), and the fiber optic interface board (A17222S009). The analog multiplexer card scales all the detected signals by a resistive divider and multiplexes them to the four A-D converters. The relative address RA3 through RA7 enables the four analog multiplexers via logic located on the receiver control card, while RA0 through RA2 determines which signals are output. The receiver control card multiplexes the digital command and monitor signals onto the sixteen I/O bits of the standard interface card. All functions are read once every two seconds. Once the data is converted to a serial data stream, the data is modulated onto the multimode fiber on the fiber interface board. A receiver on the board converts the optical signal to a serial data stream input to the standard interface card.

The output from the computer is through the serial port, which is operated at 56 kilobaud. The computer interface box (A17222S010) receives and transmits the serial data from the computer. The computer program provides a real time display receiver status as shown in Figure 1. The lock status of the S-Band, X-Band and 100 MHz VCO are displayed. The on/off state of the noise source, LO, and the type of polarization are displayed along with the LO level and HEMT LED voltage. The refrigerator second stage temperature and the receiver box temperature are shown along with the cryogenic compressor supply and return pressures. A total power reading from a square law detector for each channel is displayed as a voltage, along with a more precise reading used for pointing measurements. The transmitter and receiver status are shown, as well as the MCB status registers.

## 2.7 System Noise Temperatures

The system noise temperatures were measured in the receiver test building. For these measurements, the hot load was a microwave absorber at ambient temperature placed just in front of the feed. The cold load was the sky, assumed to have a temperature of 5K. Measurements were wide band, using the total power detector monitors located in the front-end box. System temperature for the S/X band and right and left hand polarization were determined using the hot and cold loads. In addition, the noise cals were fired and the cal values were determined from the system temperatures<sup>4</sup>. The results are given in Table 3.

## 3.0 VLBA Interface

The function of this equipment is to receive the S-Band, X-Band, and returned 500 MHz from the optical fiber, and convert the IF to the frequencies needed by the backends. The VLBA interface also contains a 500 MHz VCO which is locked to the 5 MHz reference from the Hydrogen Maser. The 500 MHz signal is used as an LO for all downconversion, transmitted to the frontend over the fiber optic link and used as a reference for all LO's. The 500 MHz is also the reference signal for the round trip phase measurement system. A listing of the S-Band and X-Band IF converter frequencies for VLBI and VLBA are tabulated in Table 4 and Table 5, respectively. The composite bandpass, which includes the S-Band IF, the X-Band IF, and the 500 MHz reference frequency, is separated by the triplexer. The X and S bands are then filtered and downconverted to baseband. The IF amplifier/detector module provides a total power monitor, which are displayed on the front panel, of the X and S bands.

The interface is designed to accommodate a Mark III backend, a VLBA DAR backend, or the existing CDP receiver with either of the backends. In order to use the CDP receiver, the CDP X input must be connected to item 8, and the CDP S input to item 20 as shown in the block diagram. Items 10 and 13 should be interchanged in the CDP X-A DAR signal path. A block diagram and parts list are given in documents A17222K002 and A17222B002, respectively.

#### **4.0 Acknowledgements**

Funding for the construction of the receiver was provided by the U.S. Naval Observatory for operation with the 20 meter Kokee Park antenna located in Hawaii.

The receiver was constructed from the design of the late J.R. Coe, under the direction of B.J. Levin. B. Shank and J. Oliver did the majority of the construction and testing of the receiver system.

G. Behrens designed the S/X feed, which was fabricated by the Green Bank Machine Shop. R. Norrod designed the dewar assembly.

F. Ghigo wrote the software for monitoring the receiver and provided scientific input.

#### **5.0 References**

1. EDIR NO. 287, "85-3 S and X Receiver System," J. R. Coe (April 1990)
2. NRAO paper submitted to JPL, "Design and Implementation of a Low-noise Prime Focus S/X Receiver System for Radio Astronomy," R.D. Norrod, G.H. Behrens, F.D. Ghigo, and B.J. Levin (December 11, 1992)
3. EDIR No. 283, "A S/X Four Channel, Cryogenic Dewar Package," R.D. Norrod (April 1989)
4. Memo "System Temperature of USNO/KPGO Receiver," B.J. Levin

**TABLE 1**  
**Worst Case Axial Ratio Measurements**

<u>Radiation Angle From Borsight</u>	<u>S-Band Maximum Axial Ratio</u>	<u>X-Band Maximum Axial Ratio</u>
0	1.1 dB	3.0 dB
20	1.6 dB	4.0 dB
40	1.9 dB	6.0 dB
60	2.6 dB	32.0 dB

**TABLE 2**  
**Feed Performance**

	<u>Avg Edge Taper E-Plane</u>	<u>H-Plane</u>	<u>Calculated Efficiency</u>	<u>Calculated Spillover</u>
<b>S-Band</b> 2.35 GHz	16.94 dB	19.14 dB	0.65	3.0 K
<b>X-Band</b> 8.6 GHz	17.05	27.88	0.62	0.88 K

**TABLE 3**  
**System Noise Temperature**

<u>Band</u>	<u>Tsys [K]</u>	<u>Tcal[K]</u>
X-R	29.6	5.5
X-L	32.6	6.5
S-R	27.0	7.2
S-L	24.7	6.8

**TABLE 4**  
**NAVNET VLBI**

<u>Sky Frequencies [MHz]</u>		<u>BBC Frequency [MHz]</u>
1	8210.99	610.99
2	8220.99	620.00
3	8250.99	650.99
4	8310.99	710.99
5	8420.99	820.99
6	8500.99	900.99
7	8550.99	950.99
8	8570.99	970.99
9	2217.99	717.99
10	2222.99	722.99
11	2237.99	737.99
12	2267.99	767.99
13	2292.99	792.99
14	2302.99	802.99

**TABLE 5**  
**USNO VLBA**

<u>Sky Frequencies [MHz]</u>		<u>BBC Frequency [MHz]</u>
1	8212.99	612.99
2	8252.99	652.99
3	8352.99	752.99
4	8512.99	952.99
5	8732.99	632.99
6	8852.99	752.99
7	8912.99	812.99
8	8932.99	832.99
9	2220.99	720.99
10	2230.99	730.99
11	2250.99	750.99
12	2305.99	805.99
13	2340.99	840.99
14	2345.99	845.99

Receiver Status 1992-276 18:27:05 UT

Lock	CAL	LO	LOlevel	HENT	LED	Pol:	RCP
Sband :locked	off	on	3.66	4.69		BoxTemp	25.97 C
Xband :locked	off	on	4.53	7.03		Pcal T:	48.45 C
100MHz:locked							

	Power	Exten. Pwr	Gate_Mon	Dewar	Compressor
SR:	0.46	-10.00	-0.54	15K 302.88	Supply(psi): 6.35
SL:	0.47	-10.00	-0.78	50K 297.51	Return(psi): 1.46
XR:	2.25	10.00	-0.29	Vac 10.00	Ref. Dr(amp): 0.01
XL:	2.12	10.00	-0.34		

Power Supplies	Fiber RCVR	MCB Status Registers		
32V: 31.84	15V: 14.98	laser: norm	adr_pe: 0	bad SYN: 0
24V: 23.82	-15V: -14.90	recvr: low	blk_pe: 65413	good ctl: 4243
12V: 12.05	+5V: 4.97		ctl_pe: 0	good dat: 896
	-5V: -5.01			

CONTROL ROOM DISPLAY

FIGURE 1

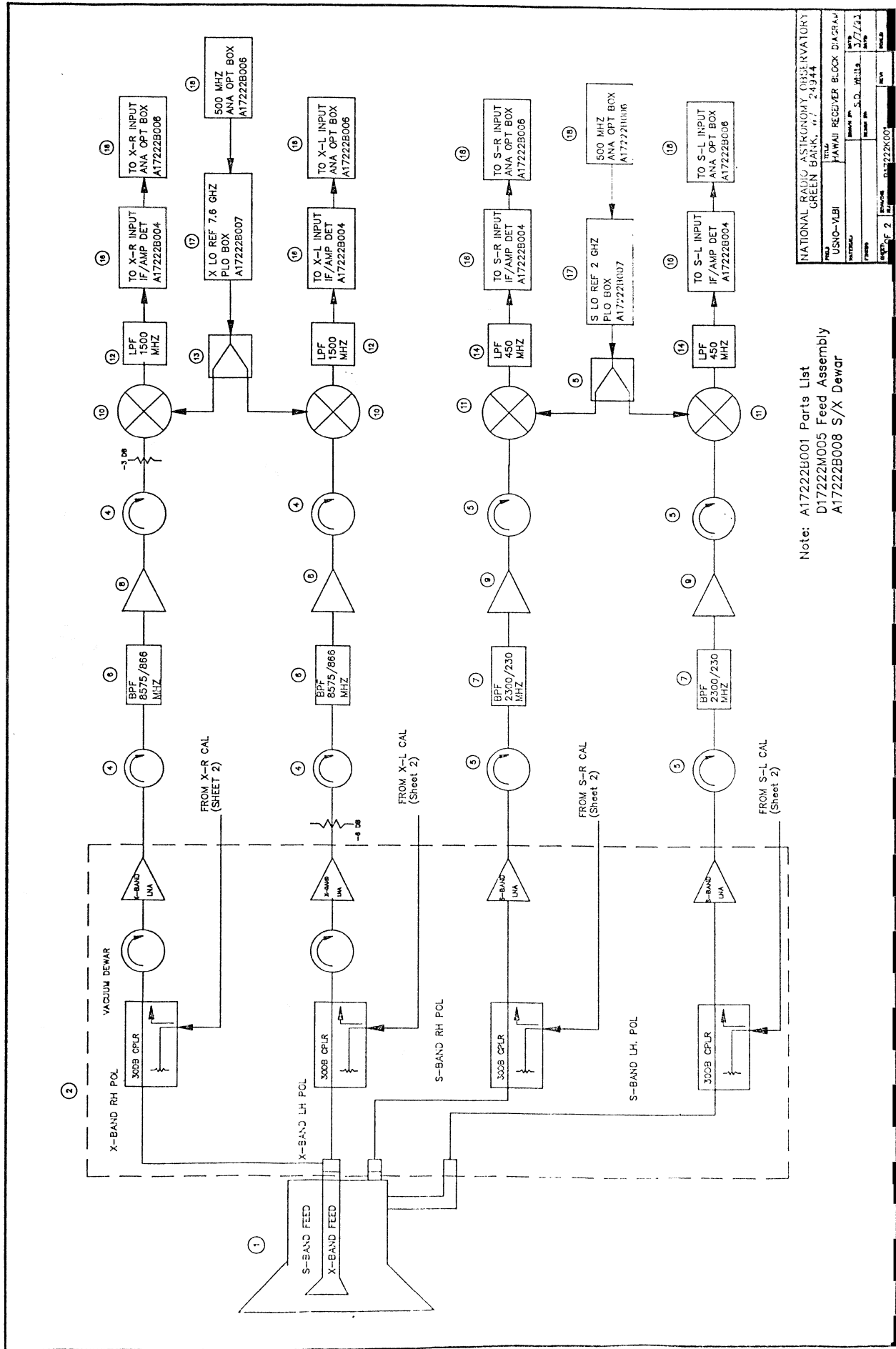
Drawing List: A17222D001		Date: 4/26/1993			
Drawing Title	Drawing Number	Date	Format	Pages	
Receiver Control Assembly	A17222A008	4/23/93	ACAD	1	
Analog Multiplex Assembly	A17222A009	4/23/93	ACAD	1	
Hawii RCVR Front End Box	A17222B001	3/16/93	QPRO	1	
VLBA Interface Drawer	A17222B002	3/16/93	QPRO	1	
500 Mhz Divider	A17222B003	3/16/93	QPRO	1	
IF Amplifier Detector	A17222B004	3/16/93	QPRO	1	
Analog Optic Box	A17222B005	3/16/93	QPRO	1	
IF Triplexer	A17222B006	3/18/93	QPRO	1	
Phase Locked Oscillator Box	A17222B007	3/16/93	QPRO	1	
S/X Dewar	A17222B008		QPRO	1	
500 Mhz Phase Detector	A17222B009	3/17/93	QPRO	1	
S/X Feed	A17222B010	3/29/93	QPRO	1	
Receiver Card Box	A17222B011	4/26/93	QPRO	1	
MCB Box	A17222B012	4/28/93	QPRO	1	
Hawaii Receiver Blk Dia	B17222K001	3/7/93	ACAD	2	
VLBA Interface Drawer	B17222K002	3/4/93	ACAD	1	
Analog Optic Box	B17222K003	3/9/93	ACAD	1	
Phase Locked Oscillator Box	B17222K004	3/9/93	ACAD	1	
Hawii Composite Blk Dia	B17222K005	3/2/93	ACAD	1	
500 Mhz Divider Box	A12222M001		ACAD	1	
Phase Locked Oscillator Box	B17222M002		ACAD	1	
IF Amplifier Detector	B17222M003		ACAD	1	
500 Mhz Phase Detector	B17222M004		ACAD	1	
S/X Feed Assembly	D17222M005	3/26/93	ACAD	2	
IF Triplexer Box	B17222M006		ACAD	1	
Analog Optic Box	B17222M007		ACAD	1	
Front End Cabling Dia	D17222M008	8/28/91	ACAD	1	
S/X Feed Large Section	D17222M009	3/29/93	ACAD	1	
S/X Feed Small Section	D17222M010	3/29/93	ACAD	1	
S/X Feed Tuning Section	D17222M011	3/29/93	ACAD	1	
S/X Feed Polarizer	D17222M012	3/29/93	ACAD	1	
S/X Feed Dielectric Polarizer	D17222M013	3/29/93	ACAD	1	
S/X Orthromode Transducer	D17222M014	7/29/91	ACAD	1	
S/X Back Short	D17222M015	2/28/90	ACAD	1	
S/X Feed Iris	D17222M016	3/29/93	ACAD	1	
S/X Waveguide Shim	D17222M017	3/29/93	ACAD	1	
X Band Waveguide Disconnect	D17222M018		ACAD	1	
X Band Circular Waveguide	D17222M019		ACAD	1	
S/X Dielectric Tuning Plug	D17222M020		ACAD	1	
X Band Dielectric Feed Cone	D17222M021		ACAD	1	
S/X Feed Septum	D17222M022		ACAD	1	
Receiver Card Box	D17222M023	4/26/93	ACAD	1	
500 Mhz Divider PC	A17222P001	3/29/93	ACAD	1	
IF Amplifier Detector PC	A17222P002		ACAD	1	
500 Mhz Phase Detector PC	A17222P003		ACAD	1	
IF Triplexer	A17222P004		ACAD	1	

500 Mhz Divider PC	A17222Q001		ACAD	1
IF Amplifier Detector PC	A17222Q002		ACAD	1
500 Mhz Phase Detector PC	A17222Q003		ACAD	1
IF Triplexer	A17222Q004		ACAD	1
IF Amplifier Detector	A17222S001	3/3/93	ACAD	1
500 Mhz Phase Detector	A17222S002	3/26/93	ACAD	1
500 Mhz Divider	A17222S003	3/9/93	ACAD	1
Control Interface Card	A17222S004	3/6/93	ACAD	2
Monitor Interface Card	A17222S005	4/1/93	ACAD	1
IF Triplexer	A17222S006	3/17/93	ACAD	1
Receiver Control	A17222S007	3/21/93	ORCAD	2
Analog Multiplex	A17222S008	4/22/93	ORCAD	2
Fiber Interface	A17222S009	4/22/93	ORCAD	1
Computer Interface	A17222S010	4/23/93	ORCAD	1
PLO Box Wiring List	A17222W001	3/30/93	QPRO	2
Analog Optic Box Wiring List	A17222W002	3/30/93	QPRO	1
IF Amp Det Wiring List	A17222W003	3/30/93	QPRO	1
Rec Card Box S3	A17222W004	3/30/93	QPRO	2
Receiver Card Box	A17222W005	3/30/93	QPRO	3
VLBA Interface Drawer	A17222W006	3/30/93	QPRO	1
VLBA Interface Power	A17222W007	3/30/93	QPRO	1
MCB Interface Box	A17222W008	3/30/93	QPRO	1

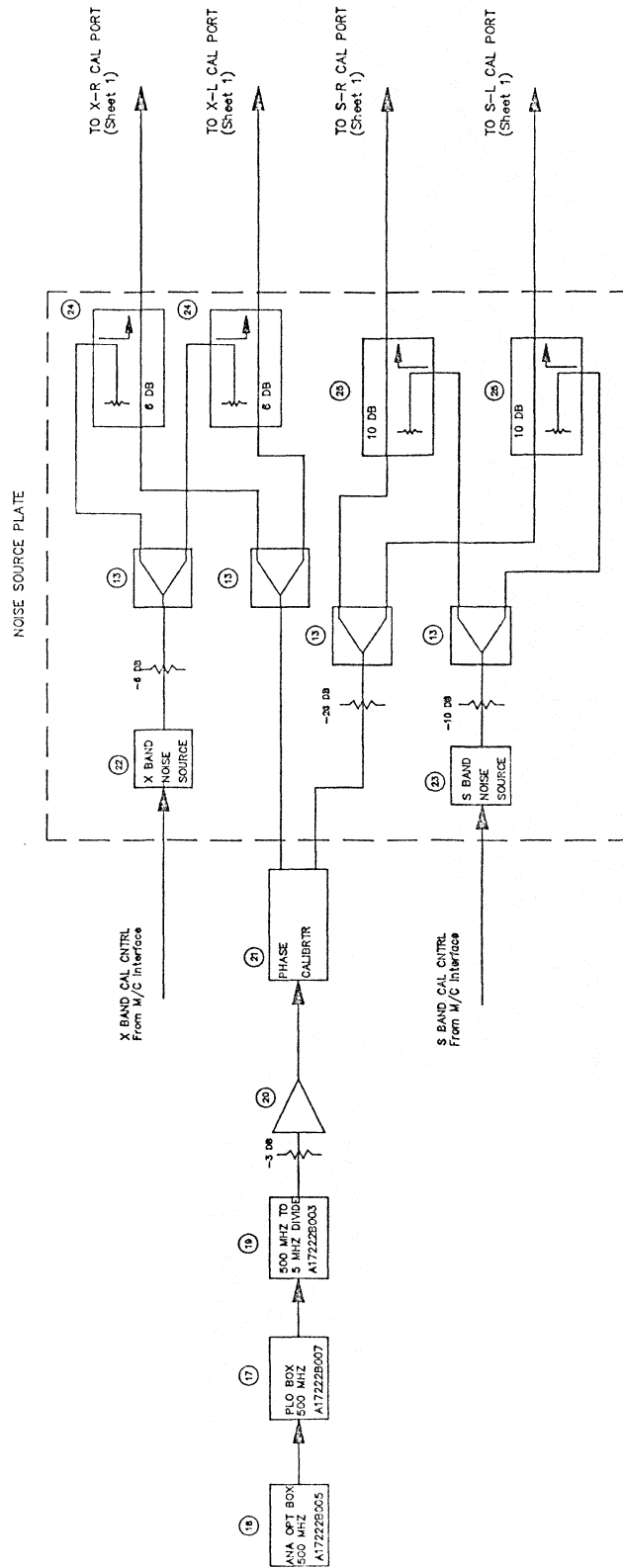
Drawing Number: A17222B001  
 Title: Hawaii Receiver

Date: 3/16/93  
 Rev: A

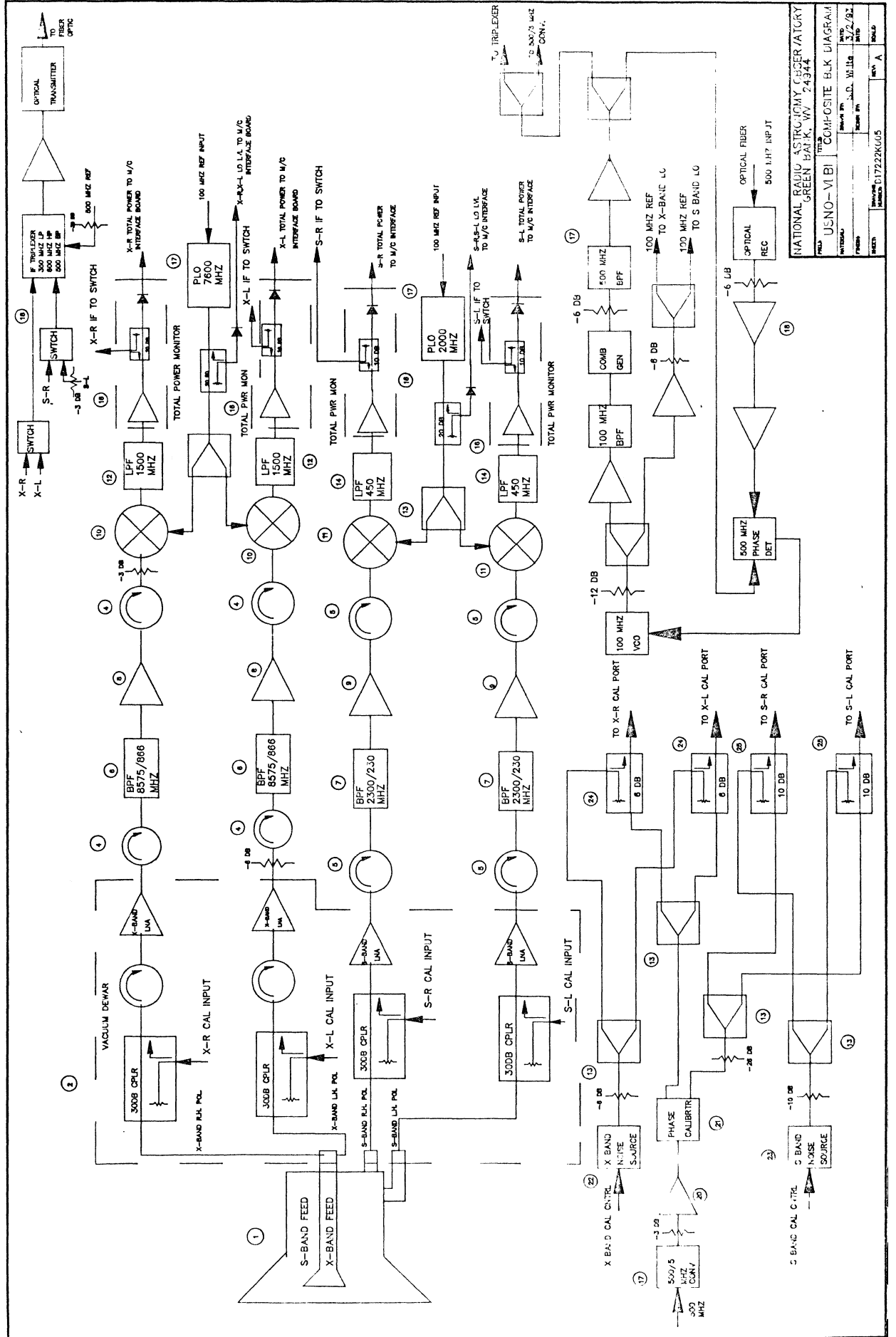
ITEM	QTY	DESCRIPTION	PART NUMBER	MANUFACTURE
1	1	S/X Feed Assembly	A17222B010	NRAO
2	1	S/X Dewar	A17222B008	NRAO
3	1	Receiver Block Diagram	B17222K001	NRAO
4	4	X Band Isolator	9-8012-11	Applied Eng
5	4	S Band Isolator	9-2040-11	Applied Eng
6	2	8575 Mhz BPF	3C2-8575-1000-S11	Reactel
7	2	2300 Mhz BPF	5B2-2300-230-S11	Reactel
8	2	X Band Amplifier	AMF-2B-8286-45	Miteq
9	2	S Band Amplifier	AMF-2B-2224-35	Miteq
10	2	X Band Mixer	FP50 MC2	Triangle Microwave
11	2	S Band Mixer	DM2-4A	RHG
12	2	1500 Mhz LPF	4L121-1500/U7400-0/0	K&L
13	3	X Band Splitter	2035-6365-0	Omni-Spectra
14	2	450 Mhz LPF	4L2-450-S11	Reactel
15	3	S Band Splitter	2035-6365-0	Omni-Spectra
16	1	IF Amp Detector	A17222B004	NRAO
17	1	PLO Box	A17222B007	NRAO
18	1	Analog Optic Box	A17222B006	NRAO
19	1	500 Mhz Divider	A17222B003	NRAO
20	2	100 Mhz Amplifier	QBH-9-160	Q-Bit
21	1	Phase Calibrator		Haystack Obs
22	1	X Band Noise Source	NC3206F	Noise/Com
23	1	S Band Noise Source	NC3204F	Noise/Com
24	2	6 Db Coupler(X band)	4015C-6	Narda
25	2	10 Db Coupler(S Band)	4013C-10	Narda



NATIONAL RADIO ASTRONOMY OBSERVATORY	
GREEN BANK, W. VA. 24944	
PROJECT	USNO-VLBI
TITLE	HAWAII RECEIVER BLOCK DIAGRAM
DATE	March 1978
DESIGNED BY	S.D. Willis
DRAWN BY	3/7/78
REVISION	REV. 2



NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944	
PROJECT	USNO-VLBI
INSTRUMENT	HAWAII RCVR BLK DIA
DATE	3/9/93
DESIGNED BY	S.C. WHITE
DESIGNED IN	
REVISED BY	
REVISED DATE	
FIGURE NO.	2 OF 2
FIGURE TITLE	NOISE SOURCE B17222K001
REV. A	



NATIONAL RADIO ASTRONOMY OBSERVATORY  
 GREEN BANK, WV 24944  
 PROJECT: USNO-VI BI  
 TITLE: COMPOSITE BLK DIAGRAM  
 DATE: 3/2/82  
 DRAWN BY: J.D. White  
 CHECKED BY: J.D. White  
 SCALE: 1:1  
 SHEET: 1 OF 1  
 DRAWING NO: D1722K005

**APPENDIX A**

**S/X FEED  
A17222B010**

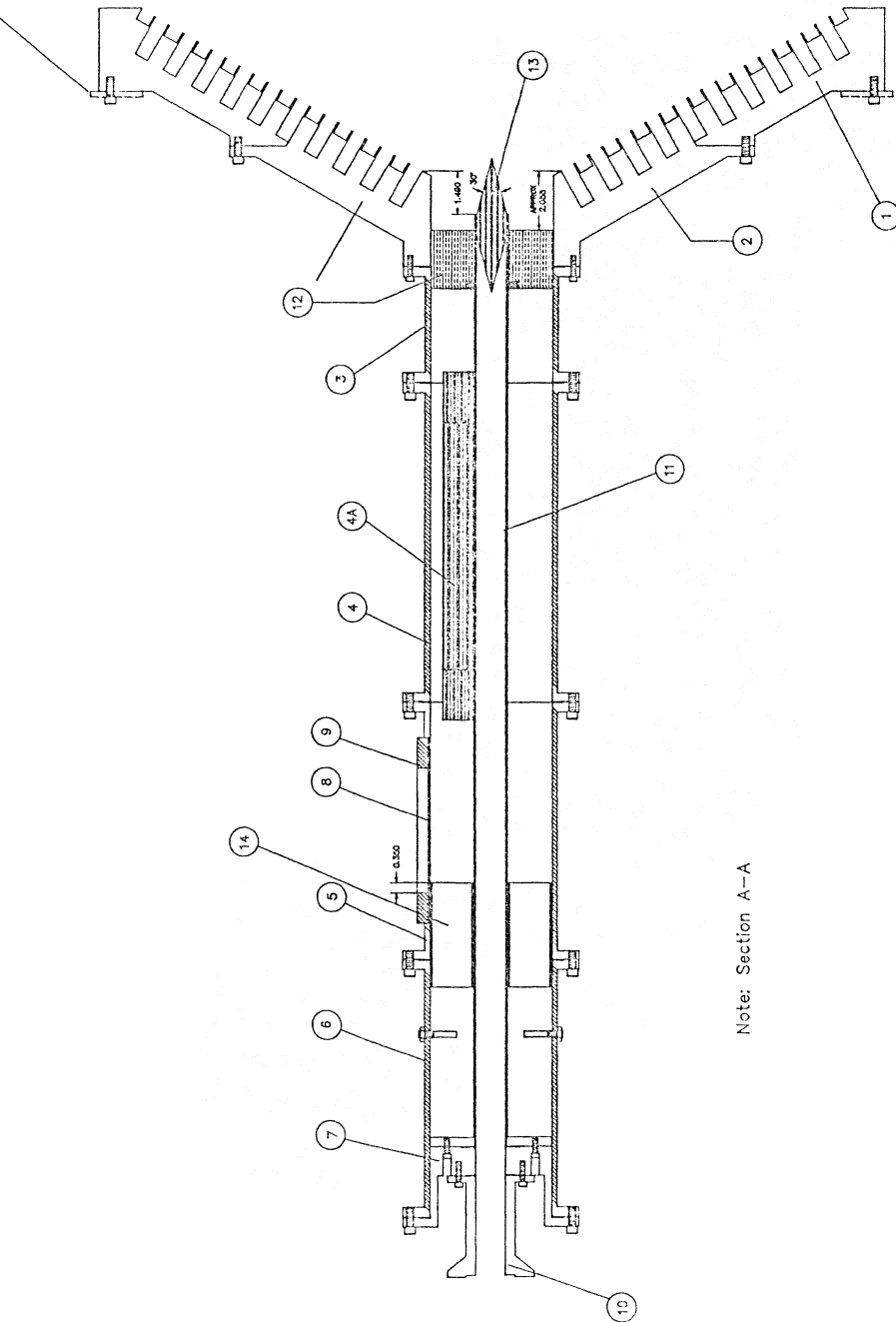
Drawing Number: A17222B010  
Title: S/X Feed

Date: 3/29/93  
Rev: A

ITEM	QT	DESCRIPTION	PART NUMBER	MANUFACTURE
0	1	S/X Feed Assembly	D17222M005	NRAO
1	1	Large Feed Section	D17222M009	NRAO
2	1	Small Feed Section	D17222M010	NRAO
3	1	Tuning Section	D17222M011	NRAO
4	1	Polarizer	D17222M012	NRAO
4A	1	Dielectric Polarizer	D17222M013	NRAO
5	1	Orthomode Transducer	D17222M014	NRAO
6	1	Orthomode Transducer	D17222M014	NRAO
7	1	Back Short	D17222M015	NRAO
8	1	Iris (no drawing)	D17222M016	NRAO
9	1	Waveguide Shim	D17222M017	NRAO
10	1	X-band WG Flange	D17222M018	NRAO
11	1	X-band Circular WG	D17222M019	NRAO
12	1	Dielectric Tuning Plug	D17222M020	NRAO
13	1	Dielectric Feed Cone	D17222M021	NRAO
14	1	Septum	B17222M022	NRAO
15	1	Front End Cabling Diagram	D17222M008	NRAO



FRONT END  
FIELD PLATE

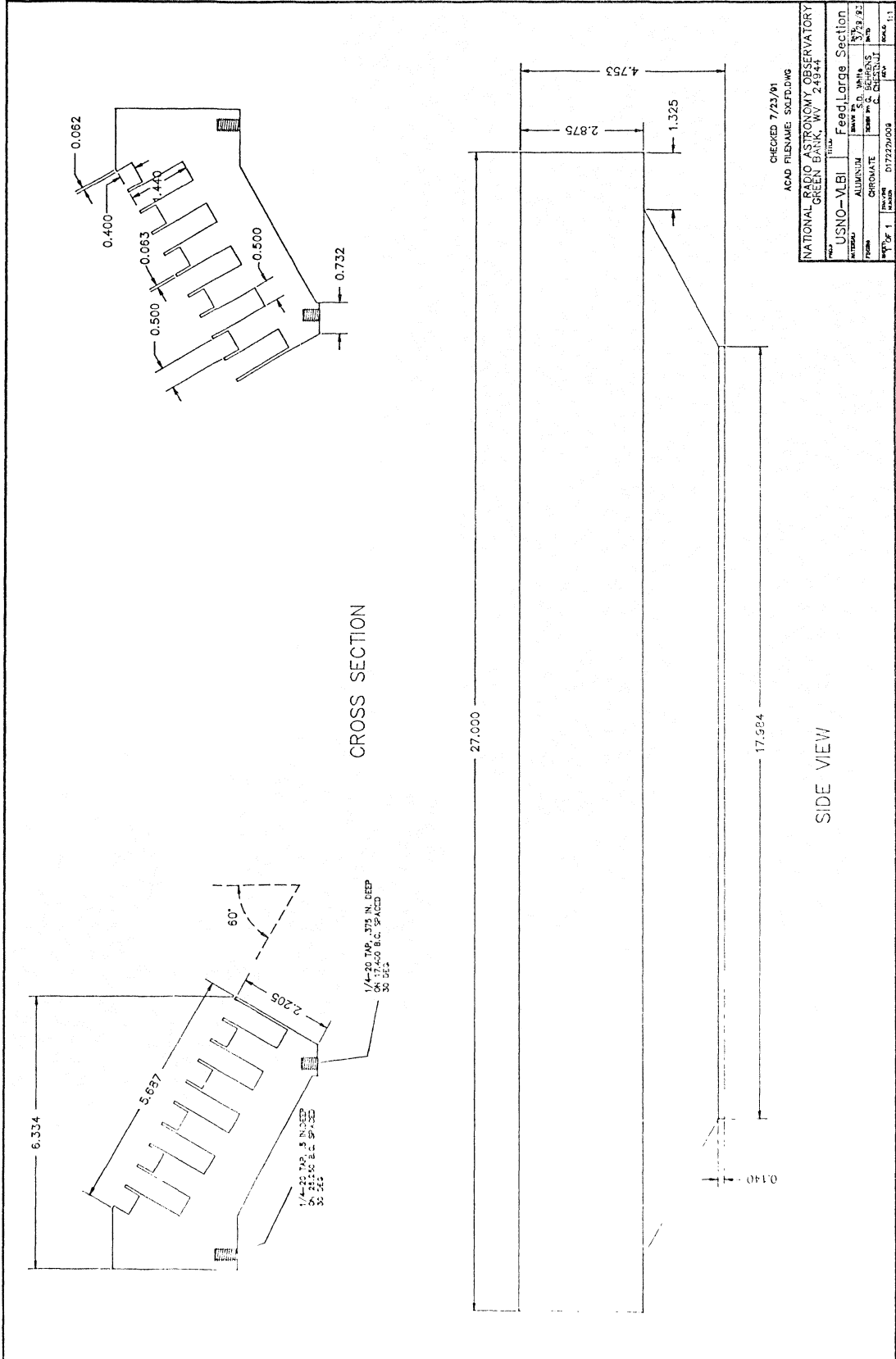


Note: Section A-A

CHECKED 7/22/74  
ACD FLD-JMS BPS:DWG

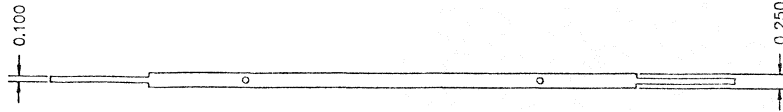
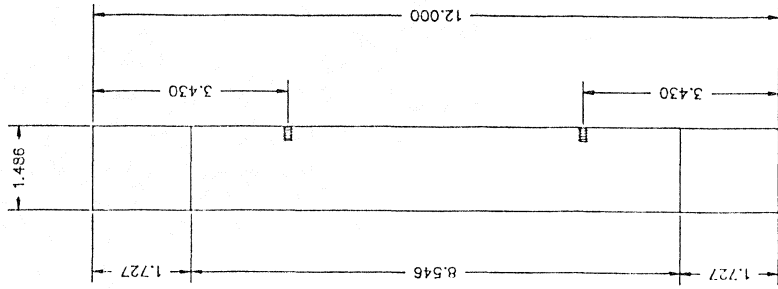
NATIONAL RADIO ASTRONOMY OBSERVATORY  
GREEN BANK, WV 25944

PROJECT	USNO-VLBI	TITLE	S/X FEED
DESIGNED BY	ALLUMBA	SCALE	3/29/74
DRAWN BY	CHROMATE	DATE	7/29/74
CHECKED BY	OF 2	DATE	8/2/74
PROJECT NO.	D17224005	REV.	2









RADIUS TO MATCH INNER RADIUS OF OUTER CONDUCTOR (2.363 IN.)

RADIUS TO MATCH RADIUS OF INNER CONDUCTOR (.680 IN.)

END VIEW ( x5 SCALE )

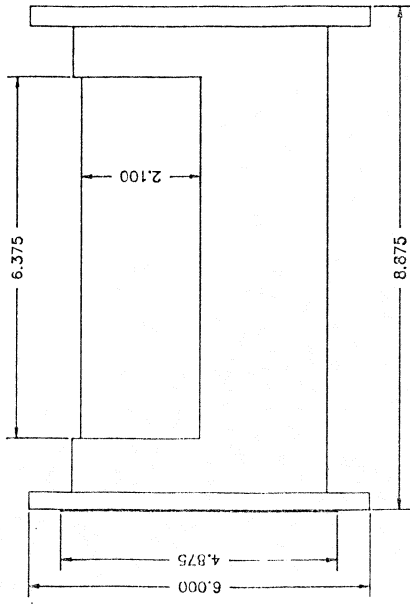
FRONT VIEW

SIDE VIEW

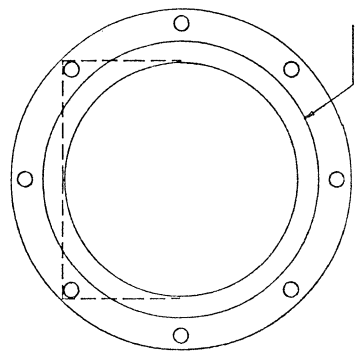
Scale: As Shown

NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 26034		DATE: 2/19/82	
PROJECT: USVO-1A2B	TITLE: DIELECTRIC POLARIZER	DESIGNER: J.C. BERNIS	SCALE: 1:1
MATERIAL: ALUMINUM	FINISH: POL. WHITE	DATE: 2/19/82	
QUANTITY: 1	REVISION: 1		
DRW: 1	REV: 1	DWG NO: D17226G13	

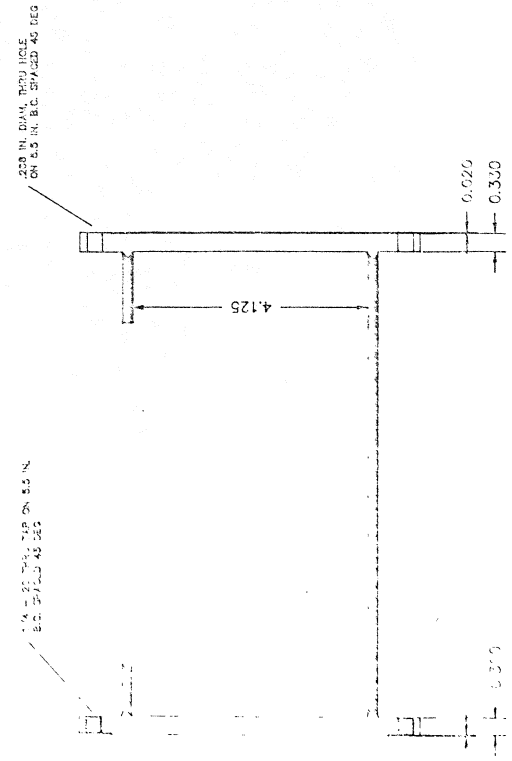




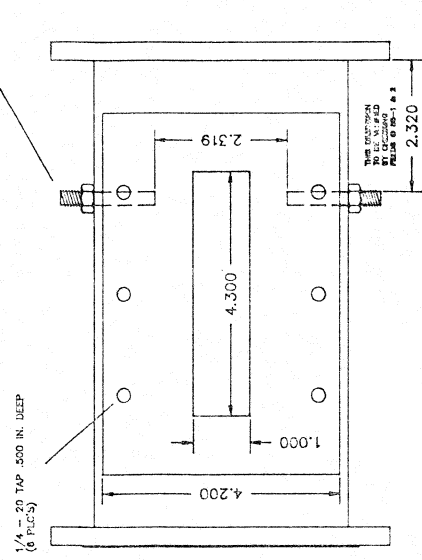
SIDE VIEW



FRONT VIEW



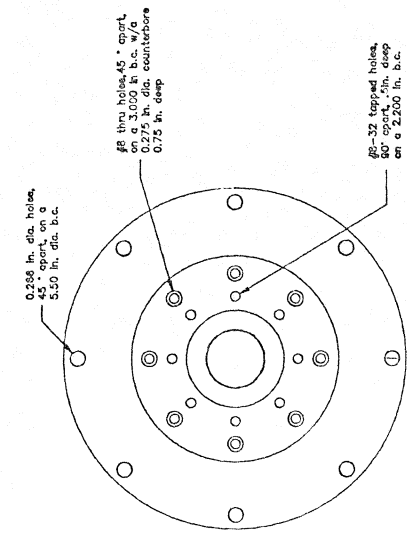
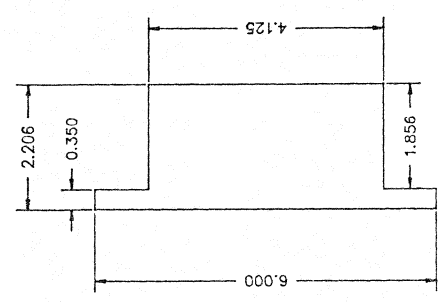
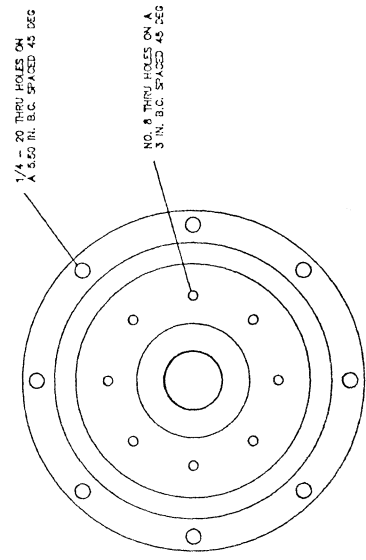
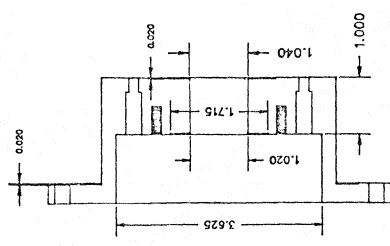
CROSS SECTION



TOP VIEW

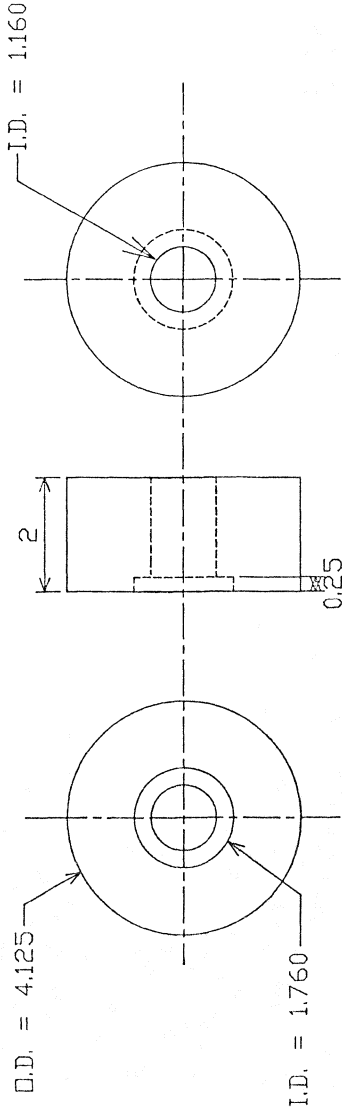
CHECKED 7/23/91  
SHEET 14 D1722A014

NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WY 24344	
PROJECT	USNO-VBI
MATERIAL	ALUMINUM
FINISH	CHROMIATE
DATE	7/23/91
DESIGNER	W. B. BIRNBAUM
DRWING NO.	D1722A014
SHEET	14



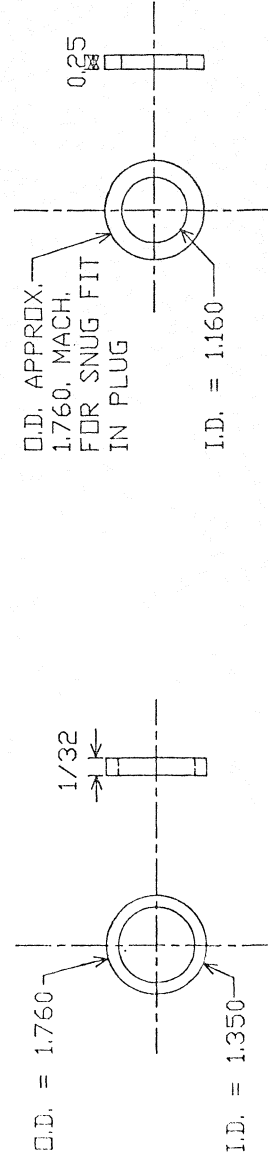
CHECKED 7/22/91  
Samps A-2-D17212M010

NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24344	
USNO-VLBI	S/X Feed BACKSHORT
ALUMINUM	ALUMINUM
CHROMATE	CHROMATE
Dr. 1	Dr. 1
D17212M015	D17212M015
DATE	DATE
BY	BY
REV.	REV.



MATERIAL = ECCOFDAM PS 1.04

DIELECTRIC PLUG



MATERIAL: 1/32 AL.

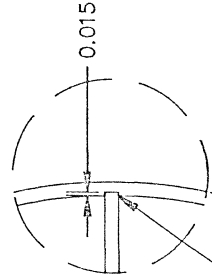
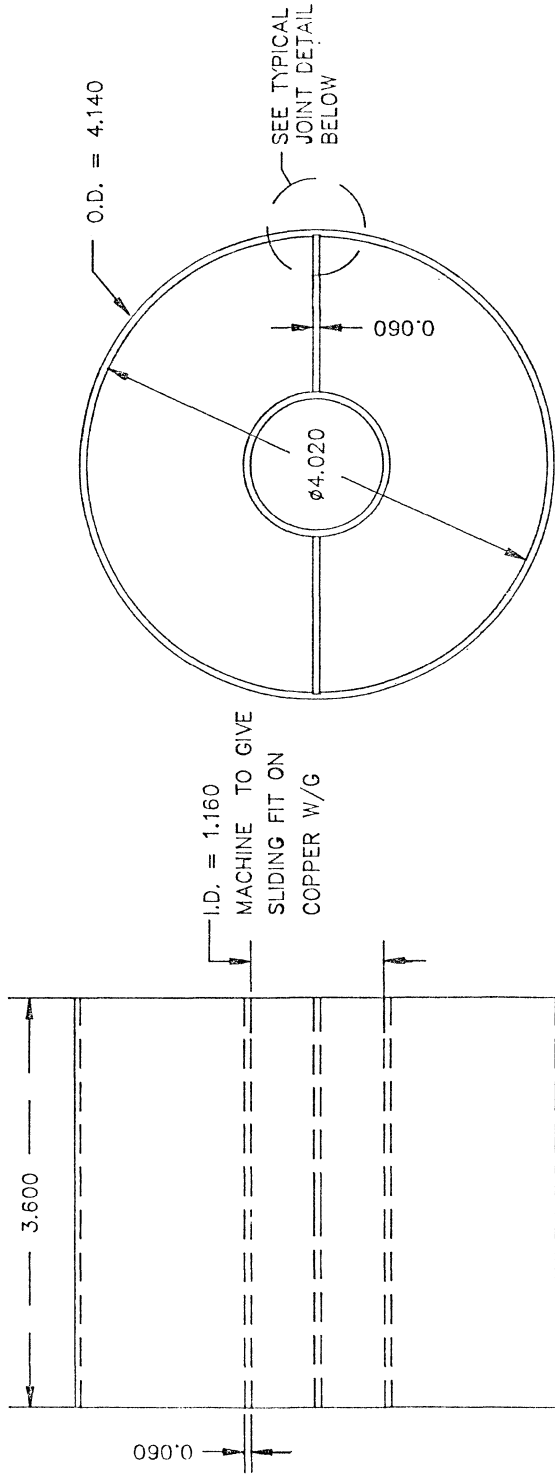
MATERIAL: ECCOFDAM PS 1.04

TUNING RING

RETAINING RING

Checked 7/22/91  
 Same As DI7212M015

NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944	
PROJECT	USNO-VLBI
DATE	3/29/91
DESIGNED BY	S. D. White
DRAWN BY	L. Behrman
CHECKED BY	DI7212M015



SOLDER ALL JOINTS  
SCALE : X2

CHECKED 7/22/91  
Same As B17212M017

NATIONAL RADIO ASTRONOMY OBSERVATORY  
GREEN BANK, WV 24944

FILE	USNO-VLBI	TITLE	SEPTUM
DATE	2/7/89	BY	SD White
DESIGN	GOLD PLATE	REVISION	G. BEHRENS
SHEET	OF 1	REV	0
			PULL

TYPICAL JOINT DETAIL

**APPENDIX B**

**IF Amplifier Detector  
A17222B004**

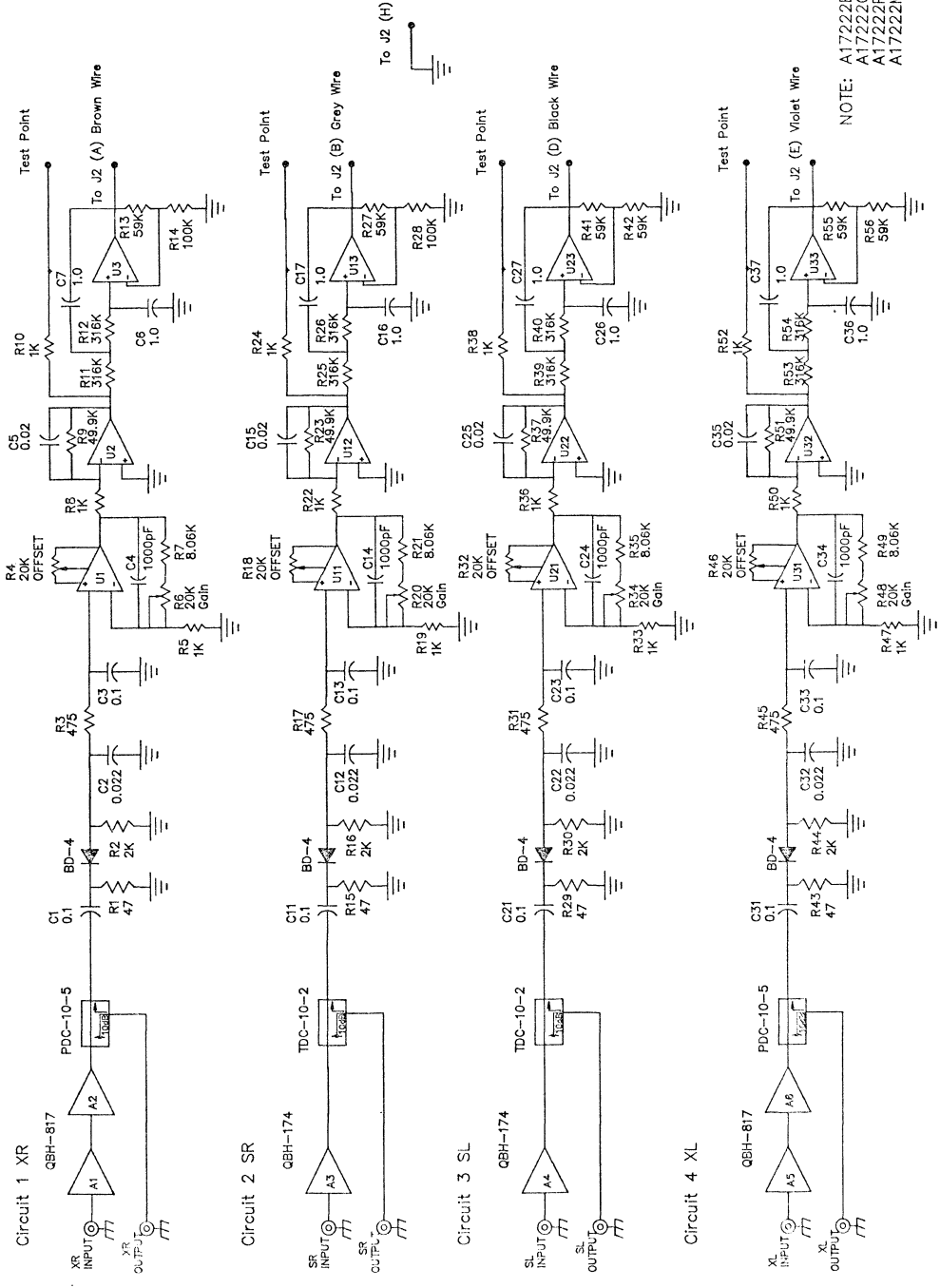
Drawing Number: A17222B004  
 Title: IF AMP-Detector

Date: 3/16/93  
 Rev: A

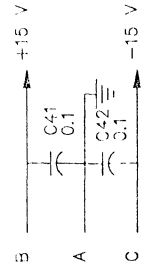
ITM	QTY	DESIGNATION	DESCRIPTION	PART NUMBER	MANUFACTURE
1	1		Assembly	A17222A002	NRAO
2	1		Mechanical Box	A17222M003	NRAO
3	1		PC Board	A17222P002	NRAO
4	1		PC Artwork	A17222Q002	NRAO
5	1		Schematic	A17222S001	NRAO
6	4	A1,A2,A5,A6	IF Amplifier	QBH-817	Q-Bit
7	2	A3,A4	IF Amplifier	QBH-174	Q-Bit
8	2		10 dB Coupler	PDC-10-5	Mini-Circuits
9	2		10 dB Coupler	TDC-10-2	Mini-Circuits
10	4	R1,R15,R29,R43	Res 5% 1/4w 47 Ohm		
11	4	R2,R16,R30,R44	Res 5% 1/4w 2K Ohm		
12	4	R3,R17,R31,R45	Res 5% 1/4w 475 Ohm		
13	12	R5,R8,R10,R19,R22,R24,R33,R36,R38,R47,R50,R52	Res 5% 1/4w 1K Ohm		
14	8	R4,R6,R18,R20,R32,R34,R46,R48	Pot 10T 1/4w 20K Ohm		
15	4	R7,R21,R35,R49	Res 1% 1/4w 8.06K Ohm		
16	8	R9,R23,R37,R51,R11,R12,R25,R26	Res 1% 1/4w 49.9K Ohm		
17	4	R39,R40,R53,R54	Res 5% 1/4w 314K Ohm		
18	4	R13,R27,R41,R55	Res 5% 1/4w 59K Ohm		
19	4	R14,R28,R42,R56	Res 5% 1/4w 100K Ohm		
20	10	C1,C3,C11,C13,C21,C23,C31,C33,C41,C42	Cap 0.1 uF ceramic		
21	4	C2,C12,C22,C32	Cap 0.022 uF ceramic		
22	4	C4,C14,C24,C34	Cap 1000pF ceramic		
23	4	C7,C17,C27,C37	Cap 1.0 uF ceramic		
24	4	D1 thru D4	Back Diodes	BD-4	HP
25	8	U1,U2,U11,U12,U21,U22,U31,U33	Op Amps	OP-27GN	
26	4	U3,U13,U23,U33	Op Amps	OP-07CN	



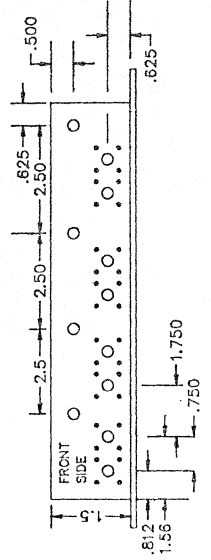
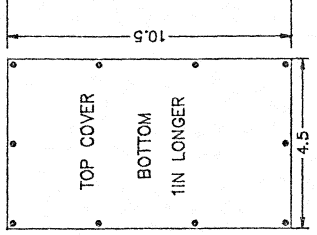
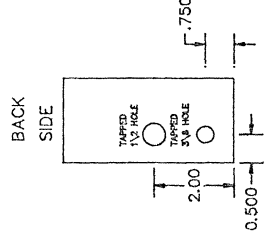
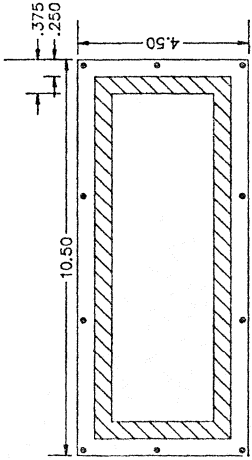
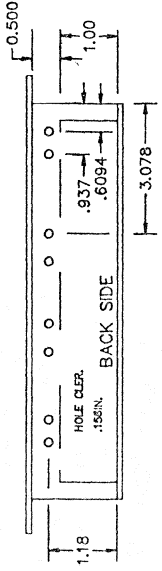
U1,U2,U11,U12,U21,U22,U31,U32 OP27GN  
 U3,U13,U23,U33 GP07CN



NOTE: A17222B004 PARTS LIST  
 A17222G002 ART WORK  
 A17222P002 PC BOARD  
 A17222M003 MECHANICAL



NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944	
PROJECT	TR-3
MATERIALS	IF AMP-DETECTOR
DATE	10/13/83
DESIGNED BY	WHL
TESTED BY	
REVISED BY	
REVISED DATE	
WORK ORDER	A17222S001
SHEET	1 OF 1



NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944	
PROJECT	USNO-VLBI
PI	F. AMP. DET.
DESIGNED BY	J. OLIVER
DATE	4/20/83
REVISED	B17222M003

NOTE: A17222B004 ASSEMBLY

NOTE:  
ON FRONT SIDE TOP HOLES 12-32TAPPED  
BOTTOM HOLES .156IN.CLER.

System: Hawaii S/X Receiver  
Ass'Y: IF Amp/Det Box  
Type:  
Func: Interconnecting  
Dwg: A17222W003

Date: 3/30/93  
By: S.D. White  
Sheet: 1 OF 1  
Designation: J1,J2

Pin#	Function	To
J1-A	Return	Term Board
J1-B	+15V	Term Board
J1-C	-15V	Term Board
J1-D		
J2-A	X-R Total Power	J2-M (Rec Card)
J2-B	S-R Total Power	J2-N (Rec Card)
J2-D	S-L Total Power	J2-P (Rec Card)
J2-E	X-L Total Power	J2-R (Rec Card)
J2-H	Total Power Return	J2-S (Rec Card)

**Phase Locked Oscillator  
A17222B007**

Drawing Number: A17222B007  
Title: PLO Box

Date: 3/16/93  
Rev: A

ITEM	QT	DESCRIPTION	PART NUMBER	MANUFACTURE
1	1	PLO Assembly	A17222A003	NRAO
2	1	Mechanical Box	B17222M002	NRAO
3	1	PLO Block Diagram	B17222K004	NRAO
4	1	100 Mhz VCO	CO233-9516	Vectron
5	4	5-500 Mhz Splitter	ZFSC-2-1	Mini-Circuits
6	2	100 Mhz Amplifier	QBH-9-176	Q-Bit
7	1	7600 Mhz PLO	PLM-074-076-A-0-20P	Miteq
8	1	20 Db Coupler(S Band)	10616-20	Anaren
9	1	2000 Mhz PLO	PLC-019-021-A-0-20P	Miteq
10	1	Power Amplifier	ZHL-1-2W	Mini-Circuits
11	1	100 Mhz BPF	6B2-100-18S11	Reatel
12	1	Comb Generator	33002A	HP
13	1	500 Mhz BPF	3B120-500-U50/0/0	K&L
14	1	500 Mhz Amplifier	UTO-1003	Avantek
15	1	500 Mhz Amp(30 dB)	ZFL-2000	Mini-Circuits
16	1	500 Mhz Phase Detector	A17222B009	NRAO
17	2	6 Db Coupler(X band)	4015C-6	Narda

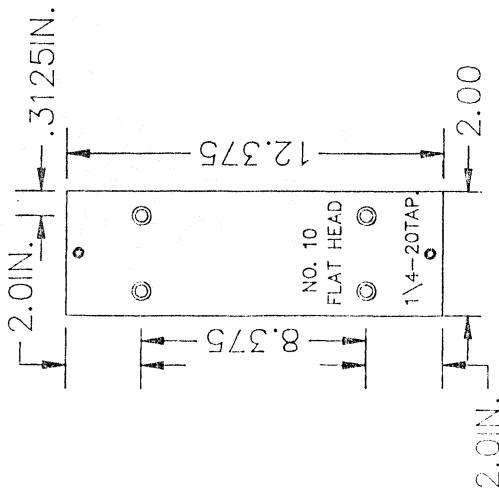
Drawing Number: A17222B009  
 Title: 500 Mhz Phase Detector

Date: 3/17/93  
 Rev: A

ITM	QTY	DESIGNATION	DESCRIPTION	PART NUMBER	MANUFACTURE
1	1		Assembly	A17222A004	NRAO
2	1		Mechanical Box	A17222M004	NRAO
3	1		PC Board	A17222P003	NRAO
4	1		PC Artwork	A17222Q003	NRAO
5	1		Schematic	A17222S002	NRAO
6	4	A1,A2,A3,A4	RF Amplifier	MSA-304	Avantek
7	3	OA1,OA2,OA3	Op Amp	OP-07	Analog Devices
8	1	MV1	Timer	SN555	Signetics
9	2	M1,M2	Phase Det Mixer	MPD-2	Mini-Circuits
10	2	R1,R2,R3,R4	Res 5% 1/2w 300 Ohm		
11	6	R5 thru R10	Res Chip 5% 20 Ohm	CRCW1206	Dale
12	2	R11,R12	Res Chip 5% 51 Ohm	CRCW1206	Dale
13	1	R13	Res 1% 1/4W 1K Ohm		
14	1	R14	Res 1% 1/4W 9.76K Ohm		
15	1	R15	Res 5% 1/2W 1K		
16	1	R16	Res 1% 1/4W 511 Ohm		
17	8	R17,R18,R22,R23,R24,R25,R27,R29	Res 1% 1/4W 10K Ohm		
18	1	R19	Res 1% 1/4W 511K Ohm		
19	1	R20	Res 1% 1/4W 49.9K Ohm		
20	1	R21	Res 1% 1/4W 470 Ohm		
21	1	R26	Res 1% 1/4W 100K Ohm		
22	1	R28	Res 1% 1/4W 20K Ohm		
23	1	R30	Res 1% 1/4W 2.5M Ohm		
24	10	C1,C12,C14,C18,C19,C21,C22,C23,C24,C20	Cap Chip 0.1uF		
25	1	C13	Cap Chip 1000pF		
26	1	C15	Cap 0.047 uF		
27	1	C16	Cap 0.47 uF		
28	1	C17	Cap 1uF		
29	1	C25	Cap Chip 6.2pF		
30	1	K1	Pot Trim 1T 1K Ohm	3329H	Bourne Cermet
31	1	K2	Pot Trim 1T 20K Ohm	3329H	Bourne Cermet
32	4	L1,L2,L3,L4	Ind 4.7uH		
33	2	L5,L6	Ind 1.5uH		
34	2	L7,L8	Ind 16nH (3T 0.064" D)		
35	2	Q1,Q2	Transistor	2N3904	
36	1	Q3	Transistor	2N2219	
38	2	D1,D3,D4	Diode Silicon	1N456	
39	1	D2	Diode Zener 5V		

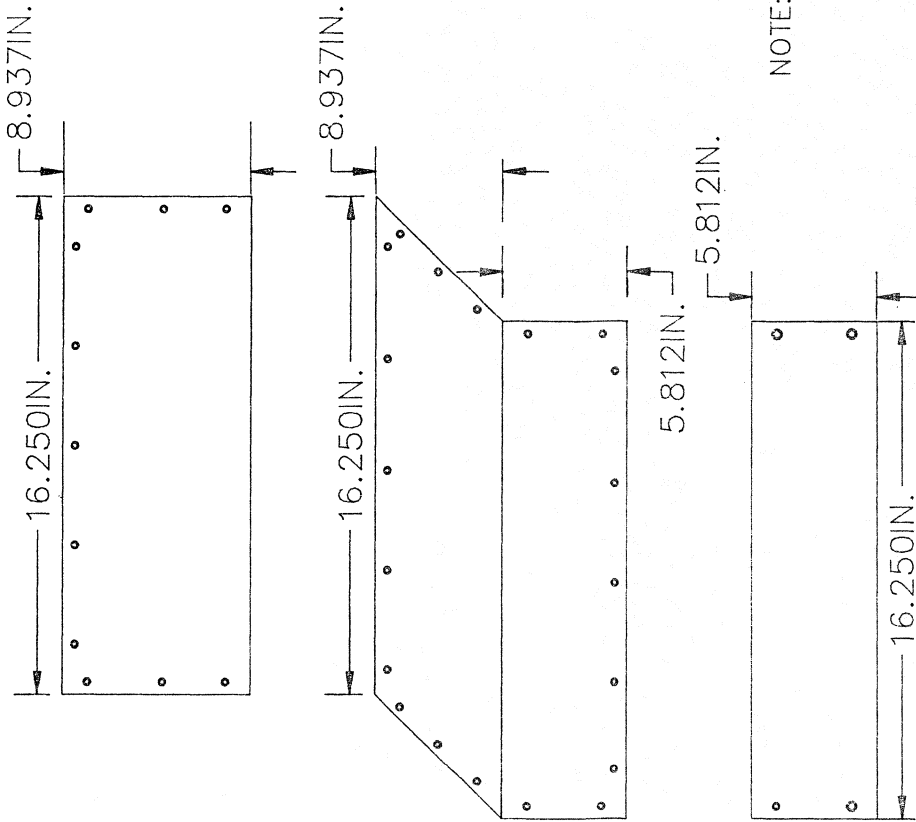
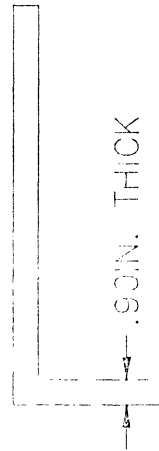


.250IN THICK



TWO EACH  
MOUNTING PLATE FOR PLO BOX

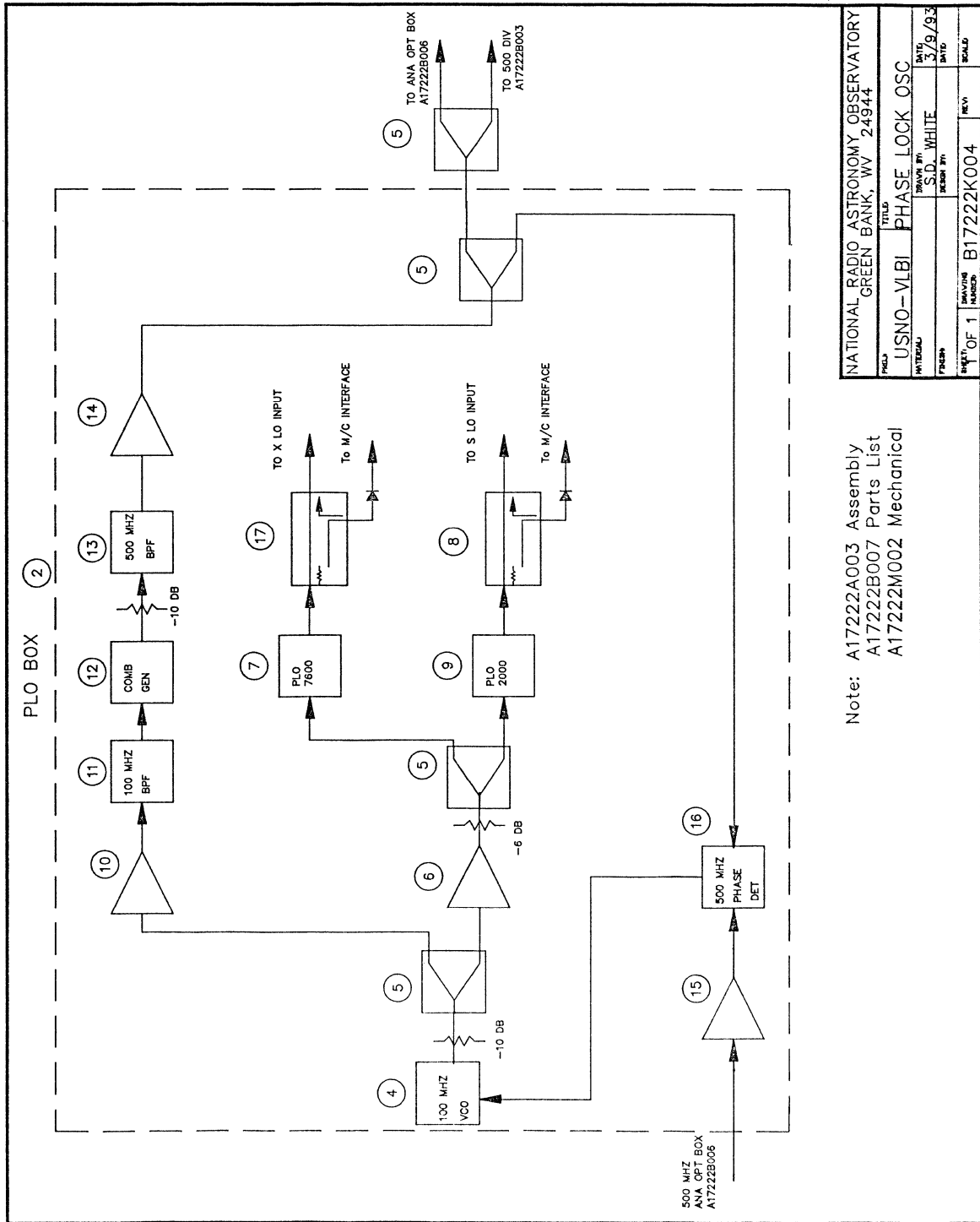
BEND TO 90 DEG.



NOTE: A17222A003  
A17222B007

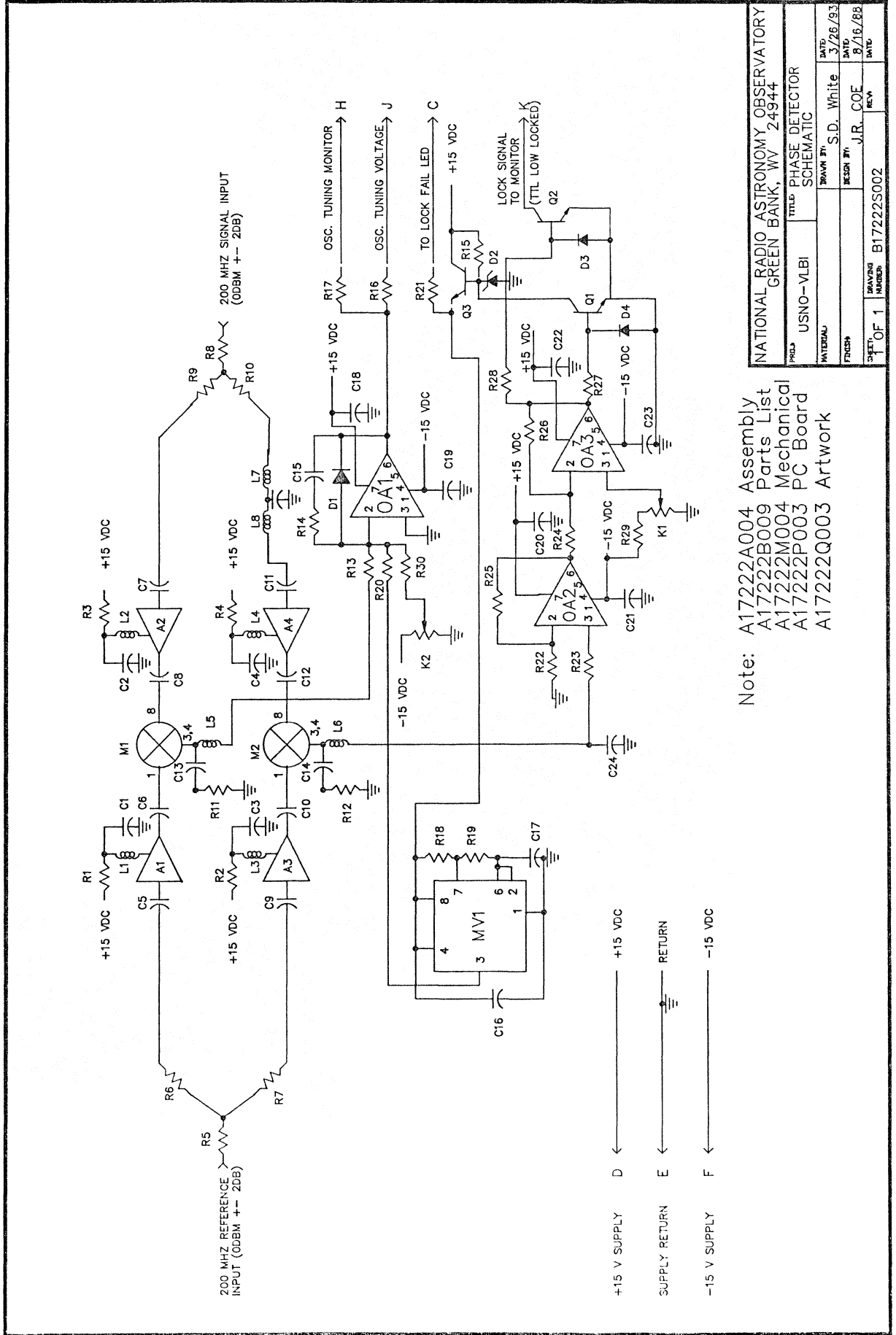
NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944	
FIELD	TITLE
USNO-VLBI	PLO BOX COVER
MATERIAL	DRAWN BY OLIVER
FINISH	DATE 4/23/93
SHEET NUMBER	DESIGN BY
B17222M002	20F2
	SCALE

CLEARANCE HOLES IN COVER FOR 4-40



Note: A17222A003 Assembly  
A17222B007 Parts List  
A17222M002 Mechanical

NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944	
PROJECT	USNO-VLBI
INTEGRAL	PHASE LOCK OSC
DATE	3/9/93
DESIGN BY	S.D. WHITE
REVISION BY	
SHEET	OF 1
REVISION NUMBER	B17222K004
SCALE	



Note: A17222A004 Assembly  
 A17222B009 Parts List  
 A17222M004 Mechanical  
 A17222P003 PC Board  
 A17222Q003 Artwork

NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944		TITLE: PHASE DETECTOR SCHEMATIC	
PROJ: USNO-VLBI	DRAWN BY: S.D. White	DATE: 3/26/93	
MATERIAL: FRESH	DESIGN BY: J.R. COE	DATE: 8/16/88	
SHEET: 1 OF 1	DRAWING NUMBER: B17222S002	REV: REV	DATE

System: Hawaii S/X Receiver  
Ass'Y: LO Box  
Type: 37 Pin D (P)  
Func: LO Internal Wiring  
Dwg: A17222W001

Date: 3/30/93  
By: S.D. White  
Sheet: 1 of 2  
Designation: J1

Pin#	Function	Color
1	24 V (ZHL-1-2W)	WH/BK
2	100 MHZ OSC Tuning Voltage	Y
3	2 GHZ OSC Tuning Volt Monitor	WH/BK/BK/R
4	7.6 GHZ OSC Tuning Volt Monitor	WH/BK/BK/Y
5	Signal Return	BH/BK/BK/GN
6	20 V Return (OSC Power)	WH/BN
7	+/- 15V Return(Phase Det)	BK
8	+15V (Phase Det)	R
9	24V Return (ZHL-1-2W)	WH/R
10	100 MHZ OSC Lock	W
11	7.6 GHZ OSC Lock	WH/Dark BN
12	2 GHZ OSC Lock	WH/LT BN
13	+20V (2 GHZ OSC)	WH/OR
14	+20V (7.6 GHZ OSC)	WH/Y
15	-15V (Phase Det)	OR
16	+15V (Out-Of-Lock CKT)	R
17	+15V (QBH-9-176)	WH/BL
18	+15V (100 MHZ OSC)	WH/V
19	+15V (UTO 1003)	WH/GY
20	7.6 GHZ OSC LVL DET SIG	Coax
21	7.6 GHZ OSC LVL DET Return	Coax Shield
22	2 GHZ OSC LVL DET SIG	Coax
23	2 GHZ OSC LVL DET Return	Coax Shield
24	+15V (ZFL-2000)	WH/BK/R
25	+15V Return (ZFL-2000)	WH/BK/OR
26	+15V Return (UTO-1003)	WH/BK/Y
27	+15V Retrun (100 MHZ OSC)	WH/BK/BL
28	7.6 GHZ OSC Lock	WH/BK/V
29	2 GHZ OSC Lock	WH/BK/GY
30	100 MZH OSC Lock	BN
31	Out-Of-Lock Return	WH/BK/BN
32	+15V Return (QBH-9-176)	BK
33	+15V Return (Out-of-Lock Ckt)	BK
34	Spare	
35	Spare	
36	Spare	
37	Spare	

System: Hawaii S/X Receiver  
 Ass'Y: LO Box Cable  
 Type: 37 Pin D (S)  
 Func: LO Box Interconnect  
 Dwg: A17222W001

Date: 3/30/93  
 By: S.D. White  
 Sheet: 2 of 2  
 Designation: J1

Pin#	Function	To
1	24 V (ZHL-1-2W)	Term Board
2	100 MHZ OSC Tuning Voltage	J2-CC (Rec Card)
3	2 GHZ OSC Tuning Volt Monitor	J2-DD (Rec Card)
4	7.6 GHZ OSC Tuning Volt Monitor	J2-EE (Rec Card)
5	Signal Return	J2-FF (Rec Card)
6	20 V Return (OSC Power)	J2-HH (Rec Card)
7	+/- 15V Return(Phase Det)	Term Board
8	+15V (Phase Det)	Term Board
9	24V Return (ZHL-1-2W)	Term Board
10	100 MHZ OSC Lock	J2-MM (Rec Card)
11	7.6 GHZ OSC Lock	J2-NN (Rec Card)
12	2 GHZ OSC Lock	J2-PP (Rec Card)
13	+20V (2 GHZ OSC)	J2-RR (Rec Card)
14	+20V (7.6 GHZ OSC)	J2-SS (Rec Card)
15	-15V (Phase Det)	Term Board
16	+15V (Out-Of-Lock CKT)	Term Board
17	+15V (QBH-9-176)	Term Board
18	+15V (100 MHZ OSC)	Term Board
19	+15V (UTO 1003)	Term Board
20	7.6 GHZ OSC LVL DET SIG	J2-C (Rec Card)
21	7.6 GHZ OSC LVL DET Return	
22	2 GHZ OSC LVL DET SIG	J2-E (Rec Card)
23	2 GHZ OSC LVL DET Return	
24	+15V (ZFL-2000)	Term Board
25	+15V Return (ZFL-2000)	Term Board
26	+15V Return (UTO-1003)	Term Board
27	+15V Return (100 MHZ OSC)	Term Board
28	7.6 GHZ OSC Lock	Light On LO Box
29	2 GHZ OSC Lock	Light On LO Box
30	100 MZH OSC Lock	Light On LO Box
31	Out-Of-Lock Return	
32	+15V Return (QBH-9-176)	Term Board
33	+15V Return (Out-of-Lock Ckt)	Term Board
34	Spare	
35	Spare	
36	Spare	
37	Spare	

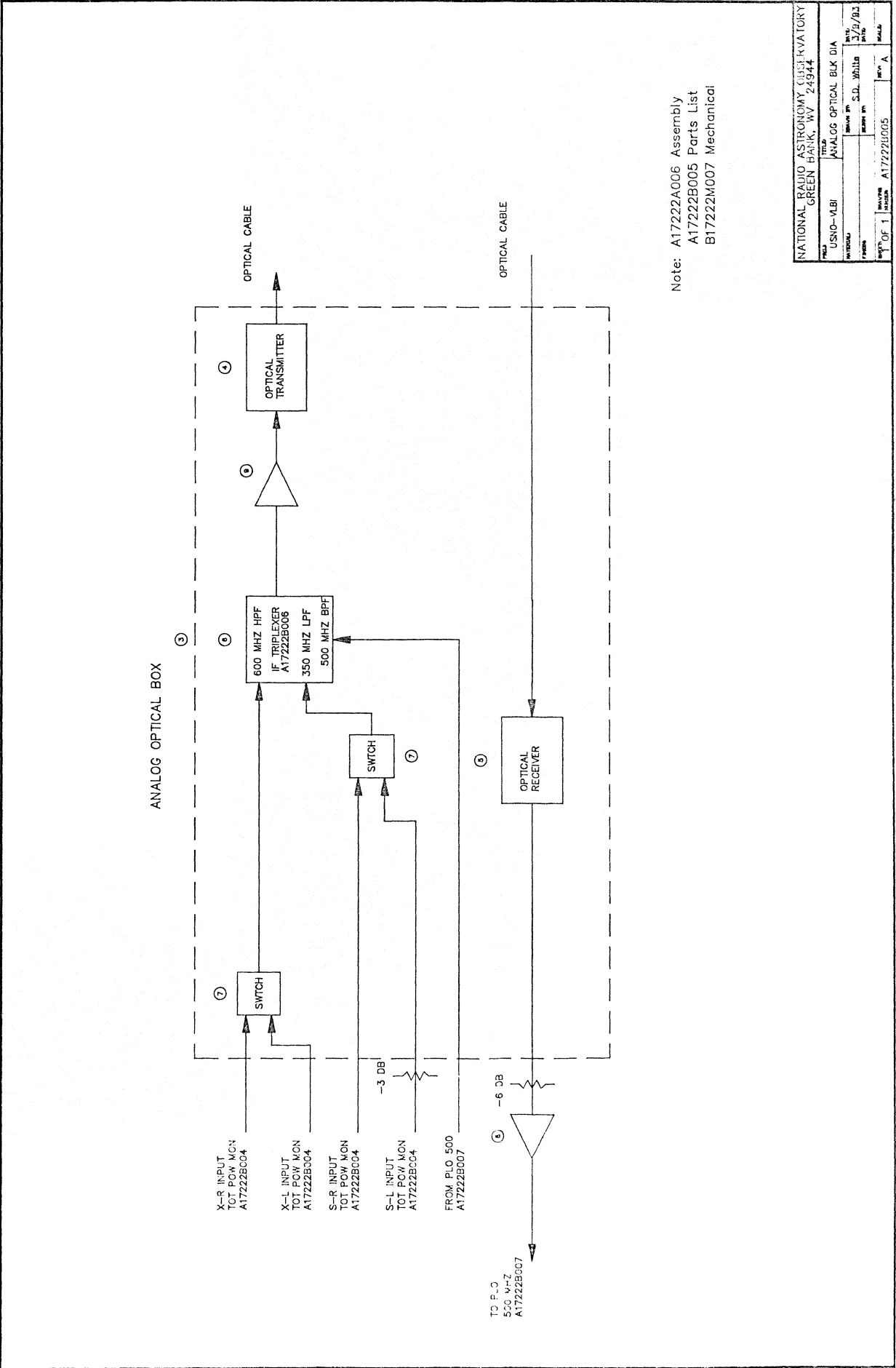
## APPENDIX D

**Analog Optic Box  
A17222B005**





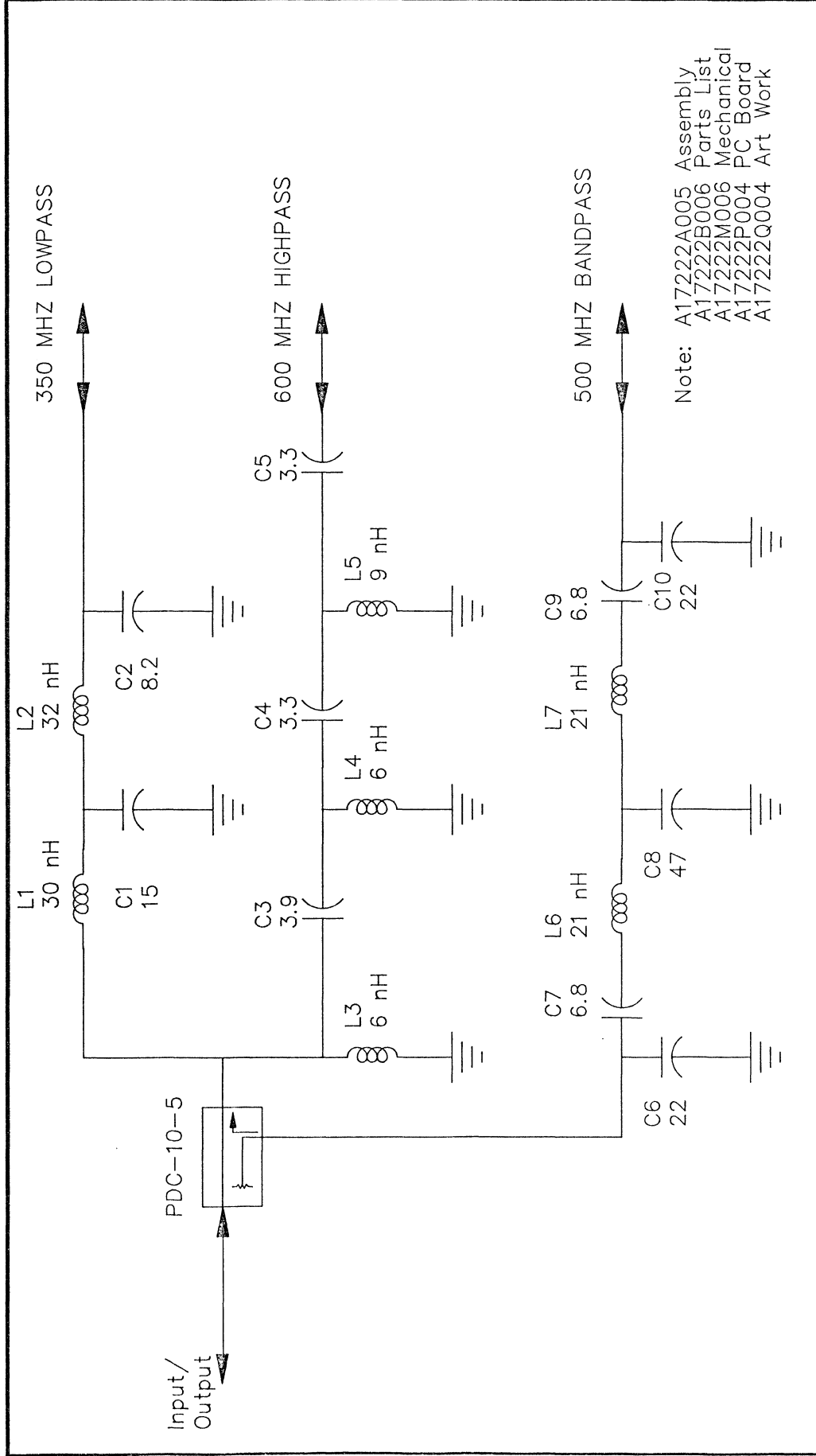




Note: A17222A006 Assembly  
 A17222B005 Parts List  
 B17222M007 Mechanical

PARTS		TITLE		DATE	
USNO-VLBI		ANALOG OPTICAL BLK DIA		3/29/82	
DESIGNED BY	DATE	DESIGNED BY	DATE	DESIGNED BY	DATE
		S.D. White			
PAGE 1 OF 1			REV. A		

NATIONAL RADIO ASTRONOMY OBSERVATORY  
 GREEN BANK, WV 24944



Note: A17222A005 Assembly  
 A17222B006 Parts List  
 A17222M006 Mechanical  
 A17222P004 PC Board  
 A17222Q004 Art Work

NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944			
PROJ.	TITLE	DRWN BY	DATE
USNO-VLBI	IF TRILEXER	S.D. WHITE	3/17/93
DWG#	DESIGN BY	J.R. COE	
SHEET	DRAWING NUMBER	REV#	SCALE
OF 1	A17222S006	A	

System:	Hawaii S/X Receiver	Date:	3/30/93
Ass'Y:	Analog Optic Box	By:	S.D. White
Type:	Amp 9 Pin, Amp 5 Pin,SMA	Sheet:	1 OF 1
Func:	Interconnecting	Designation:	J1-J8
Dwg:	A17222W002		

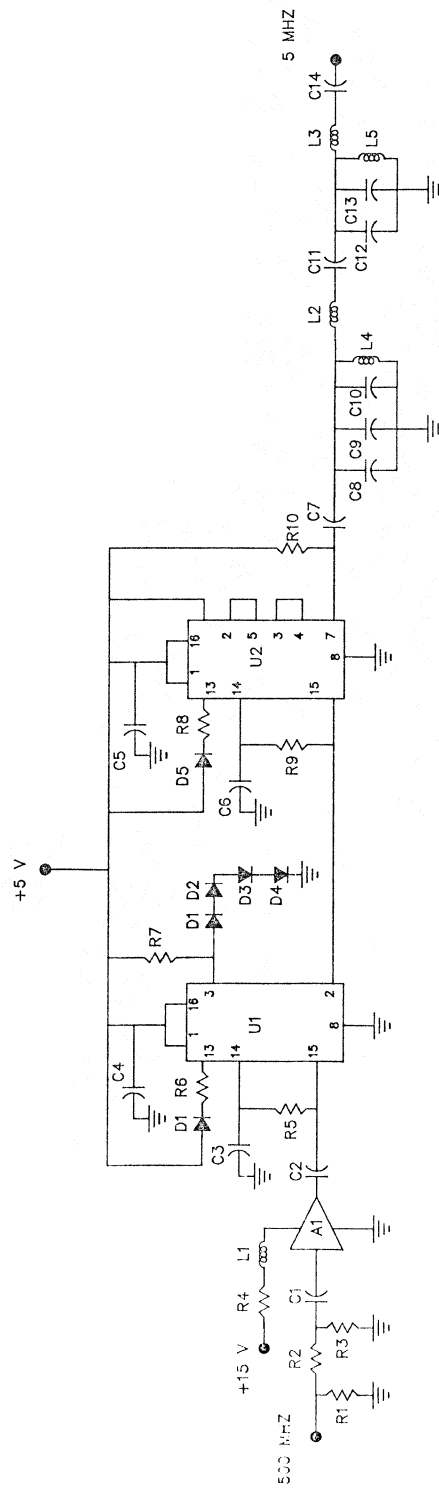
Pin#	Function	To	Color
J1-A	+15V	Term Board	
J1-B	Return	Term Board	
J1-C	-15V	Term Board	
J1-D	+5V	Term Board	
J1-E	Return	Term Board	
J1-F	-5V	Term Board	
J1-H	OPT Tx Alarm	J2-H (Rec Card) Box	
J1-J	OPT Rx Alarm	J2-J (Rec Card) Box	
J2-A	TTL/IF Switch	J2-X (Rec Card) Box X-R or X-L	
J2-B	TTL/IF Switch	J2-Y (Rec Card) Box S-R or S-L	
J2-D	+5V	Term Board	
J2-E	Return	Term Board	
J2-H	TTL Return	Term Board	
J3	X-R IF Input	SMA/LO box	
J4	S-R IF Input	SMA/LO Box	
J5	X-L IF Input	SMA/LO Box	
J6	S-L IF Input	SMA/LO Box	
J7	500 MHZ Input	SMA/LO Box	
J8	500 MHZ Output	SMA/LO Box	

Note: IF Switches: RF-1 = S+R - X-R | RF-2 = S-L - X-L



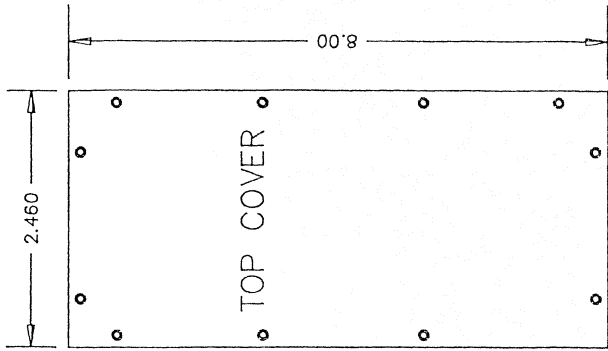
## **APPENDIX E**

**500 MHz Divider  
A17222B003**



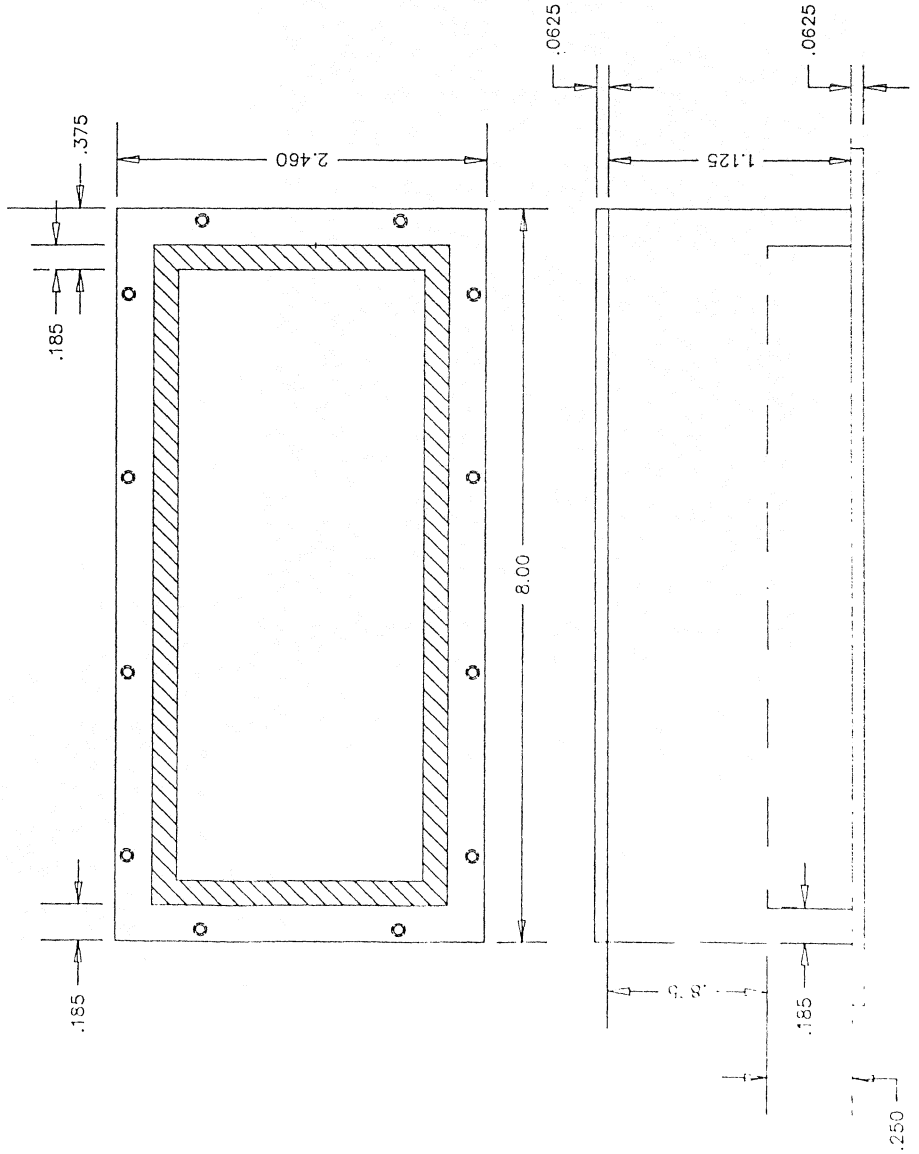
Note: A17222B003 Parts List  
 A17222A001 Assembly  
 A17222M001 Mechanical  
 A17222P001 PC Board

PARTS		TITLE	
NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944		500 MHz DIVIDER	
DESIGNED BY	S.D. WHITE	DATE	7/2/83
DRAWN BY	S.D. WHITE	DATE	7/9/83
CHECKED BY		APPROVED BY	
PROJECT	A17222S003	REV	Per A



BOTTOM COVER  
HALF INCH LONGER

NOTE: A17222A004 ASSEMBLY  
A17222B003 BILL OF MATE.



NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944	
PROJECT	TITLE
MATERIAL	DESIGN BY
FINISH	DATE
SHEET	REV.
DRAWING NUMBER	
SCALE	
USNO-VLB 500 DIVIDE BOX	
DRAWN BY: OLIVER	
DATE: 3/11/93	
DRAWING NUMBER: B17222M001	
SCALE:	

## APPENDIX F

### MCB INTERFACE

Drawing Number: A17222B003      Date: 3/16/93  
 Title: 500 Mhz Divider

ITM	QTY	DESIGNATION	DESCRIPTION	PART NUMBER	MANUFACTURE
1	1		Assembly	A17222A001	NRAO
2	1		Mechanical Box	A17222M001	NRAO
3	1		PC Board	A17222P001	NRAO
4	1		PC Artwork	A17222Q001	NRAO
5	1		Schematic	A17222S003	NRAO
6	2	R1,R3	Res 5% 1/4W 110 Ohm		
7	1	R2	Res 5% 1/4W 36 Ohm		
8	1	R4	Res 5% 1/2w 267 Ohm		
9	4	R5,R7,R9,R10	Res 5% 1/4w 1K Ohm		
10	2	R6,R8	Res 5% 1/4w 100 Ohm		
11	7	C1 thru C7	Cap 0.1 UF chip 50V	AVX 1205C104MAT050M	AVX
12	1	C8	Cap 3300 pF ceramic		
13	2	C9,C13	Cap 100 pF ceramic		
14	1	C10	Cap 120 pF ceramic		
15	1	C11	Cap 220 pF ceramic		
16	1	C12	Cap 4700 pF ceramic		
17	1	C14	Cap 300 pF ceramic		
18	1	L1	Ind 2.2 uH		
19	1	L2	Ind 4.4 uH		
20	1	L3	Ind 3.3 uH		
21	1	L4	Ind 0.3 uH		
22	1	L5	Ind 0.22 uH		
23	1	A1	Amp RF	MSA 0304	Avantek
24	2	U1,U2	Two Modulus Prescaler	MC12013L	Motorola
25	5	D1 thru D5	Diodes, Silicon	HP 5082-2835	HP

Drawing Number: A17222B012

Title: MCB Box

Date: 4/28/93

Rev: A

ITM	QTY	DESCRIPTION	PART NUMBER	MANUFACTURE
1	1	Mechanical Box	D17222M024	NRAO
2	1	Analog Multiplex Card	A17222A009	NRAO
3	1	Receiver Control Card	A17222A008	NRAO
4	1	Fiber Interface Board	A17222S009	NRAO
5	1	Interconnecting Wire List	A17222W008	NRAO