

NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, WVMEMORANDUM

October 14, 1991

To: G. Seielstad
From: G. Behrens
Subj: Proposed Plan to Implementing Prime Focus Receiver Requirements for the GBT

This memo addresses a proposed plan for implementing the prime focus, broadband, single-feed receiver requirements for the GBT. Questions regarding multiple frequency/simultaneous operation-type receivers are not considered here.

The objective of the plan is to meet the following requirements:

1. Provide continuous frequency coverage in the 290-1230 MHz frequency band.
2. Provide a choice of either dual-linear or dual-circular polarization.
3. Minimize receiver noise temperatures.
4. Maximize efficiency/system noise temperature.
5. Minimize receiver changes and make such changes as quick and as simple as possible.
6. Minimize system complexity and cost.

Receiver Bandwidths

To cover the 290-1230 MHz frequency range, the frequency range of the individual receivers Pf-1 thru Pf-5 are as shown in Table 1. These frequency bands are defined by the maximum B.W. ratio we can expect from the dual-polarized, waveguide/coax assembly we propose to use as an OMT for Pf-3 through Pf-5. Trying to cover the remaining two bands (290-520 MHz, B.W. ratio = 1.79) with one receiver would not be possible because the bandwidth ratio of high performance HEMT amplifiers does not exceed 1.5:1.¹ Similarly, expected feed performance over such a wide range would be poor.

¹EDIR No. 286, "Design and Performance of Cryogenically-Coolable, Ultra Low-Noise, L-Band Amplifier", J. D. Gallego and M. Pospieszalski.

Feeds

As shown in Table 1, single-mode, corrugated horns are proposed for receivers Pf-3 thru 5. For high G/T performance over our bandwidth ratio of 1.35, single-mode corrugated horns are superior to other known feeds because of their circularly symmetrical radiation patterns, low cross polarization and sidelobe levels. Other horns such as the Trimode feed and dual hybrid mode feed have even better performance but are limited to B.W. ratios of 1.07:1.

Receiver packaging:

In this plan it is proposed that one standard NRAO front-end box with interchangeable feeds and dewar packages be used to cover the entire 290-1230 MHz range.

The interchangeable dewar packages will mount in the front-end box by passing it through the feed end of the box with the feed removed. To facilitate installation and accurate positioning, linear ball bushings on the dewar package will mate with a pair of precision shafts mounted inside the front-end box as shown in Figure 10.

At frequencies below 510 MHz, efficient corrugated horns are physically too large to fit in the space allocated. Therefore, for the two lower bands, cavity-backed, crossed-dipole feeds, backfire² antenna feeds and quadridge horn³ feeds are under consideration.

The dimensions of the horns proposed are as shown in Figure 1. These dimensions were determined by calculating the E/T for 800 MHz horns with various flare angles and a constant aperture diameter of 57.6 inches for various values of T' , where $T' = T_{RX} + T_{SKY}$. These values were plotted in Figure 2 and show that the optimum E/T occurs when the semi-flare angle equals 30 degrees. This corresponds to an edge taper of 22 dB at 39 degrees. The other two horns were then designed using this edge taper, but having maximum aperture diameters limited by the allotted space as defined by the feed envelope shown in Figure 1.

To reduce the weight of the feeds, light weight construction techniques using electroless copper-plated foam is being considered. See Figure 3.

Polarizers

Because of size constraints, the use of broadband orthmode transducers (OMT) such as the quadridge OMT or sloping septum polarizers normally used at higher frequencies are too large to be usable at frequencies below 1 GHz. For example, both the quadridge OMT and the sloping septum polarizer would be almost four feet long at 1 GHz, leaving little room for anything else in our front-end box.

²Handbook of Antenna Design, A.W. Rudge, et al.

³Seavey Engineering Associates, Cohasset, MA.

By foregoing the 1.6:1 B.W. ratio that a quadridge OMT operates over and instead accepting a 1.35:1 B.W. ratio, we feel we can get reasonable isolation over most of the band. This seems to be confirmed by some preliminary measurements on a circular waveguide 5 GHz prototype tunable OMT. The device (Figure 5) is limited at the low end of the band by return loss of -15 dB (Figure 6) and at the upper end of the band by the generation of the $TM_{0,1}$ mode which degrades polarization purity to -15 dB (Figure 7). However, over most of the band the return loss is better than -25 dB and cross-polarization level below -30 dB. Unfortunately, the B.W. ratio is only 1.3:1 which happens to be the ratio of cut-off frequencies for the $TE_{1,1}$ and the unwanted $TM_{0,1}$ mode. We are next going to try a square waveguide device whose dominant mode to first higher order mode cut-off frequency ratio is 1.41:1, and we feel this will give us the 1.35:1 B.W. ratio we need.

In an attempt to minimize losses between the feed and the low-noise amplifier, the OMT probes will be made an integral part of the dewar input lines, thereby eliminating input connectors and their associated noise contributions.

Low-Noise Amplifiers

HEMT amplifiers cooled to 12 K will provide the low-noise amplification with an expected noise temperature of 5 K. Since current HEMT amplifiers have an optimum performance B.W. ratio of 1.5:1, they will more than cover the required 1.35:1 ratio.

Integration of noise calibration couplers into the amplifiers will, hopefully, reduce the losses normally associated with commercial couplers and their connectors.

Front-End Block Diagrams

Dewars:

The proposed block diagram is as shown in Figure 8. To cover the required frequency range, it is proposed that four interchangeable dewar packages be built. The first dewar package will contain the HEMT amplifiers for receivers Pf-1 and 2, and the remaining three dewar packages containing the amplifiers for Pf-3, 4 and 5.

Polarization selection:

Either dual-circular or dual-linear polarization will be remotely selectable from the monitor and control operating station which will operate RF switches at the polarization network. This network will synthesize circular polarization from the dual-linear polarizations supplied by the feeds and OMT's. Bandwidth of the circular polarization mode as defined by isolation between RHC and LHC will be limited by the phase and amplitude match of the HEMT amplifiers.

Interference rejection:

A filter bank with variable bandwidths of 5, 10, 20 and 30% and remotely selectable will be used to provide interference rejection.

To minimize cost and equipment changes, all attempts will be made to utilize common components when frequency bands are changed.

LO/IF Block Diagram

The proposed block diagram for the LO and IF system is as shown in Figure 8. The RF output from the prime focus front-end box is routed to the secondary focus room via coax cable. The RF signal is upconverted by the first mixer to a frequency in the 1-2 GHz frequency range. The LO signal for the first mixer is derived from the remotely tunable frequency synthesizer in the receiver room. The IF signal is then sent to the control room via a fiber optic link and then down-converted to frequencies compatible with the IF spectrometer and the VLBI terminal. Selection of the exact IF frequencies to be used will be determined after a study is done to minimize possible intermodulation products.

Receiver Packaging

In this plan it is proposed that one standard NRAO front-end box with interchangeable feeds and dewar packages be used to cover the entire 290-1230 MHz range.

The interchangeable dewar packages will mount in the front-end box by passing it thru the feed end of the box with the feed removed. To facilitate installation and accurate positioning, linear ball bushings on the dewar package will mate with a pair of precision shafts mounted inside the front-end box as shown in Figure 10.

Standby Dewar Packages and Feeds

It is proposed that dewar packages not being used be kept cold and stored in close proximity to the prime focus service station along with the unused feeds. This means we should have cryogenic lines running to this dewar service lot that can handle at least three dewars. Structural details regarding storage area for feeds and dewars should be considered.

GHBjr/cjd

Enclosures

Figures 1-10

Table

GBT PRIME FOCUS RECEIVER
PLAN A

<u>Rx No.</u>	<u>Freq. Range</u> <u>(MHz)</u>	<u>B.W.</u> <u>Ratio</u>	<u>Feed Type</u>	<u>Polarization</u>	<u>Polarizer</u>
PF-1	290- 395	1.36	Coaxial Fed Cavity-Backed Dipoles or Backfire Antenna	Dual Linear	Crossed Dipoles
PF-2	385- 520	1.35	Coaxial Fed Cavity-Backed Dipoles or Backfire Antenna	Dual Linear	Crossed Dipoles
PF-3	510- 690	1.35	Waveguide Fed Corrugated Horn	Dual Linear	Crossed Tunable W/G Probe
PF-4	680- 920	1.35	Waveguide Fed Corrugated Horn	Dual Linear	Crossed Tunable W/G Probe
PF-5	910-1230	1.35	Waveguide Fed Corrugated Horn	Dual Linear	Crossed Tunable W/G Probe

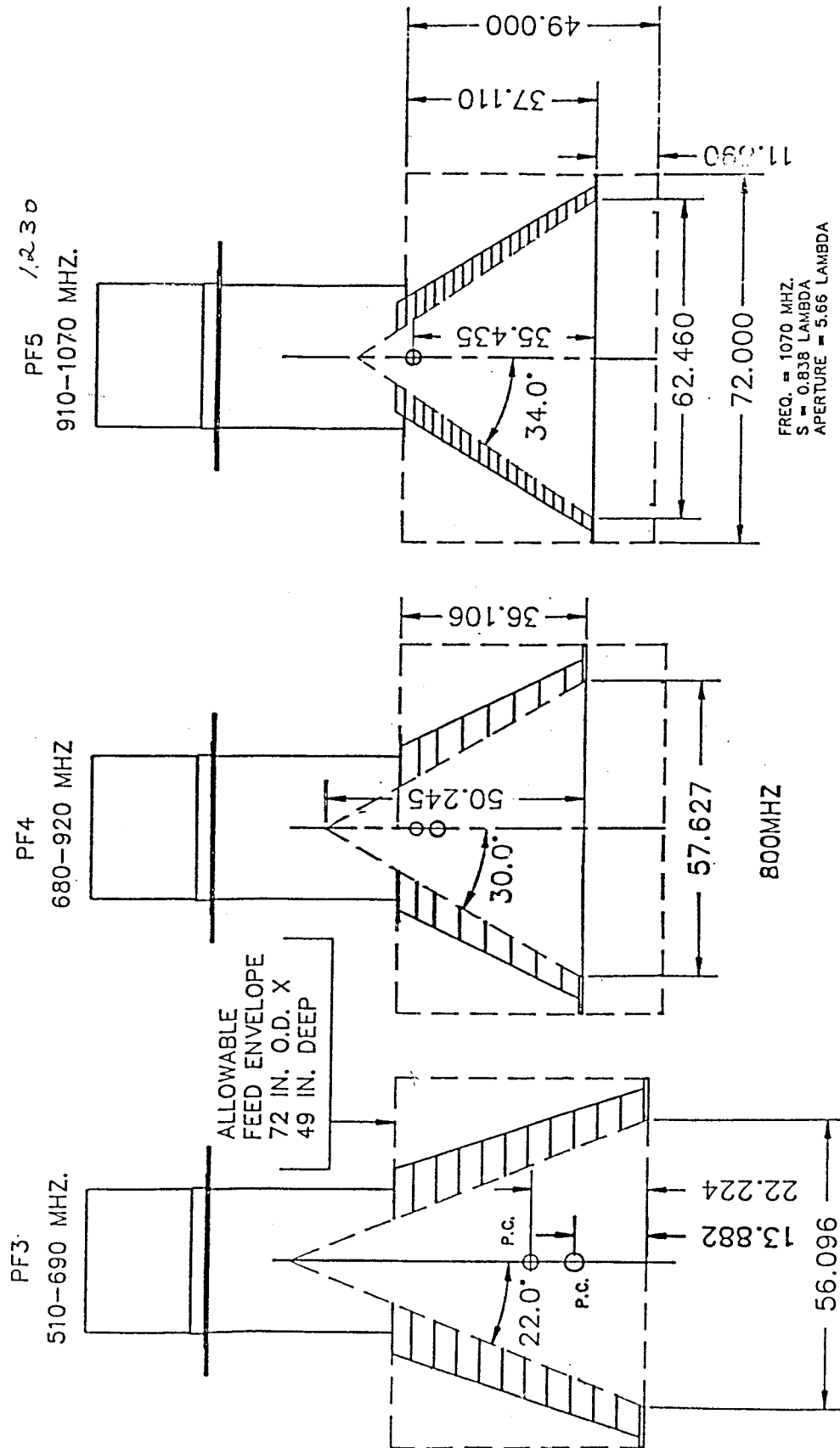


FIGURE 1

NATIONAL RADIO ASTRONOMY OBSERVATORY GREEN BANK, WV 24944			
DATE	1/26/71	BY	W. J. PETER
PROJECT	RF-100	REVISION	1
DESIGNED BY	W. J. PETER	CHECKED BY	W. J. PETER
APPROVED BY	W. J. PETER	DATE	1/26/71

7/21/91

FEED FIG. OF MERIT FOR VARIOUS S.F.A. &
T' @ 800 MHZ. FEED ENV. 72" DIA. X 49" L

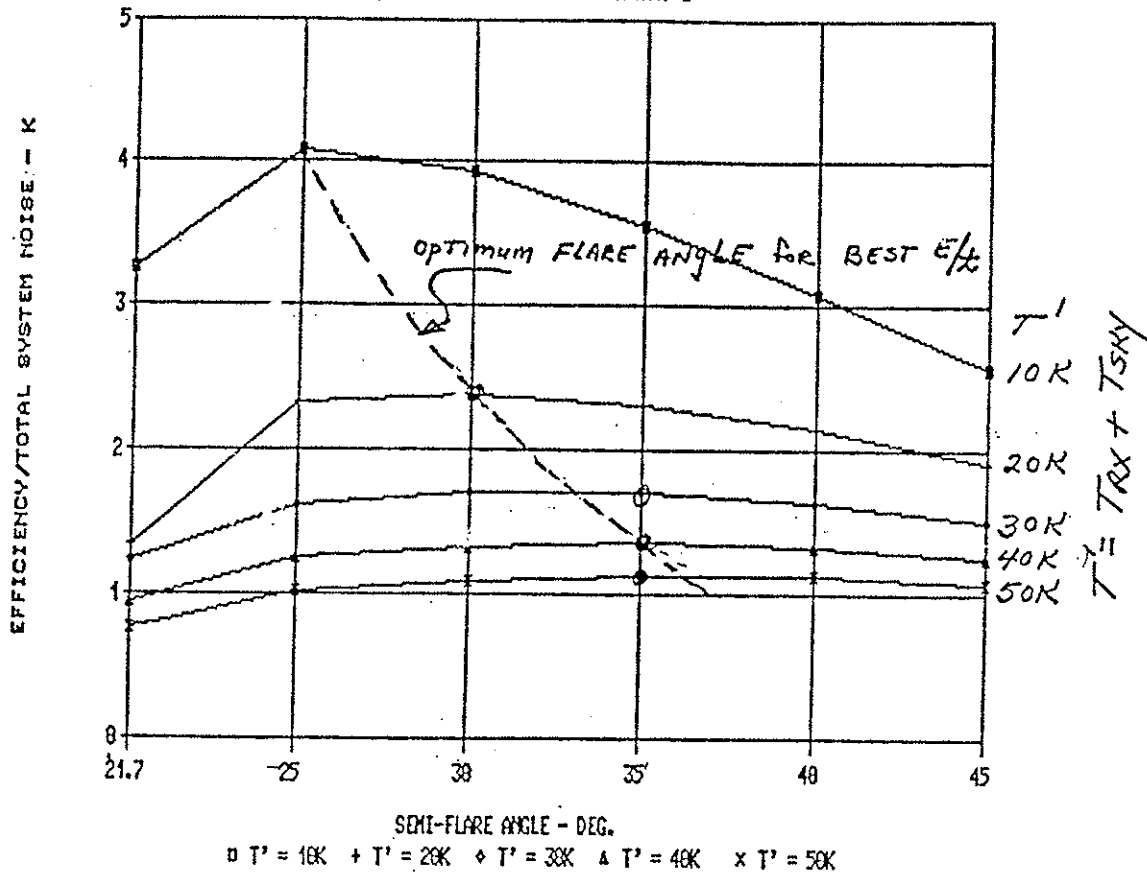
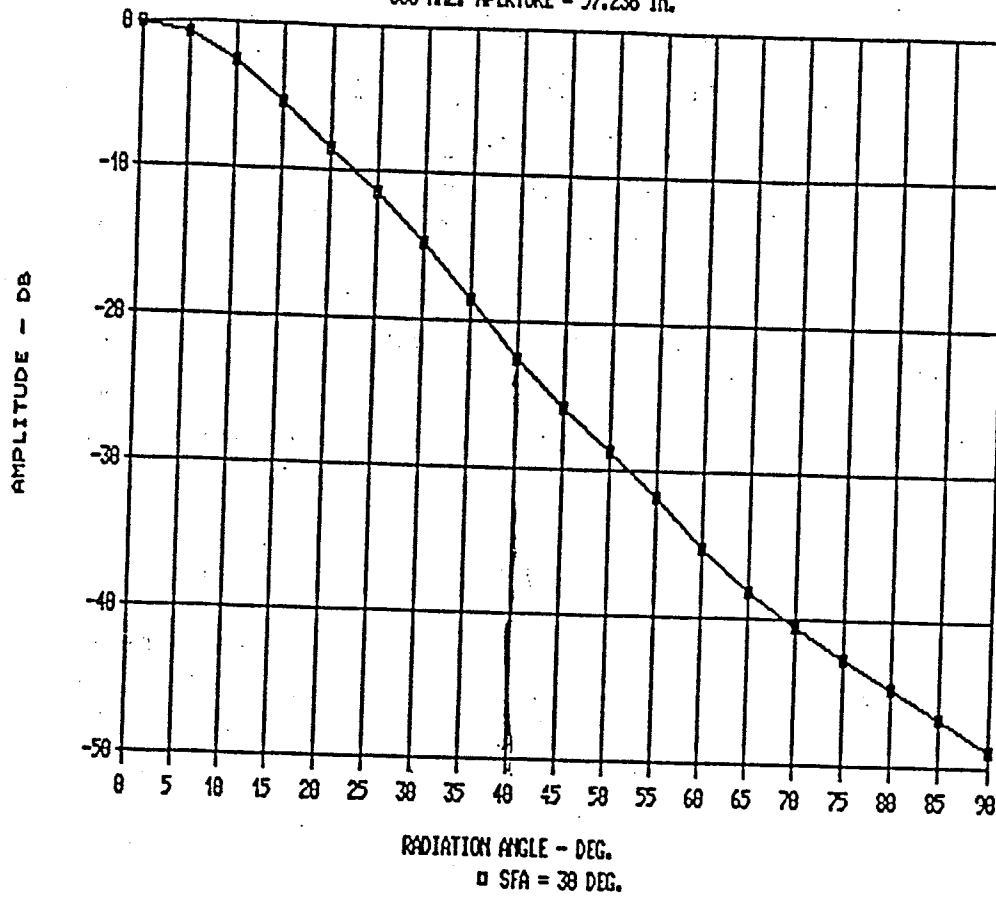


FIGURE 2

AMP. PATTERNS OF A CORRUGATED HORN @
800 MHZ. APERTURE = 57.236 IN.



PHASE PATTERN OF A CORRUGATED HORN @
800 MHZ. APERTURE = 57.236 IN

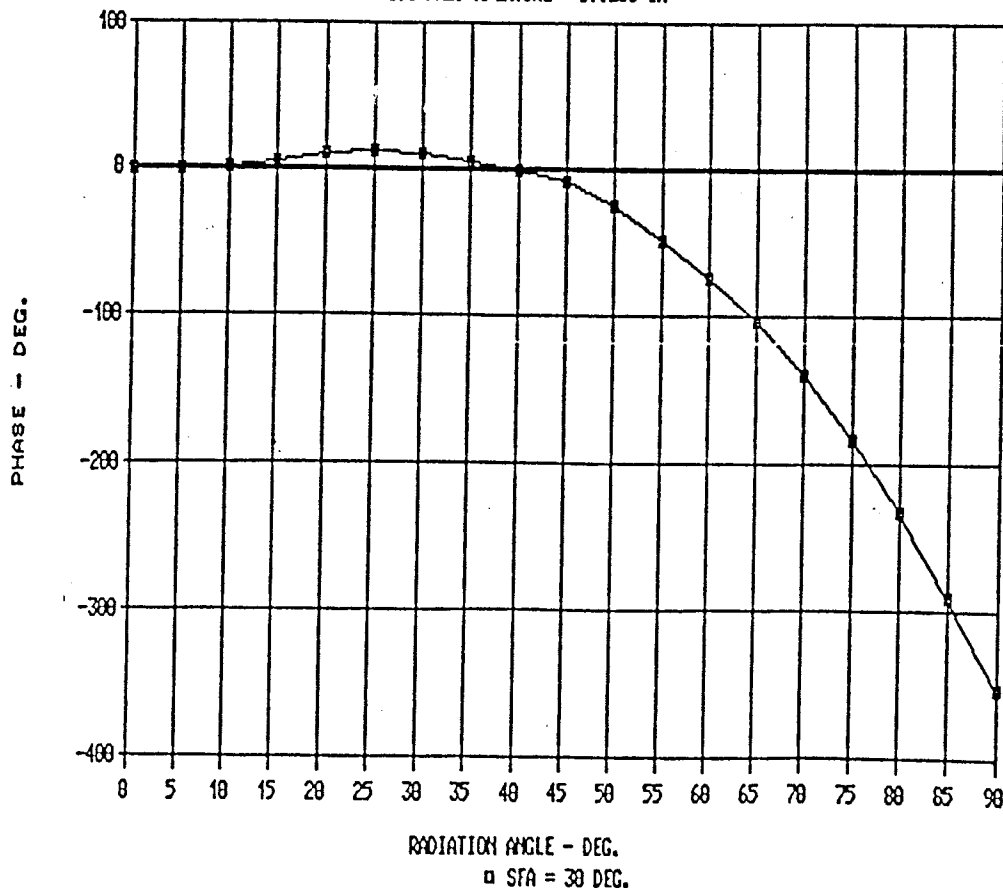
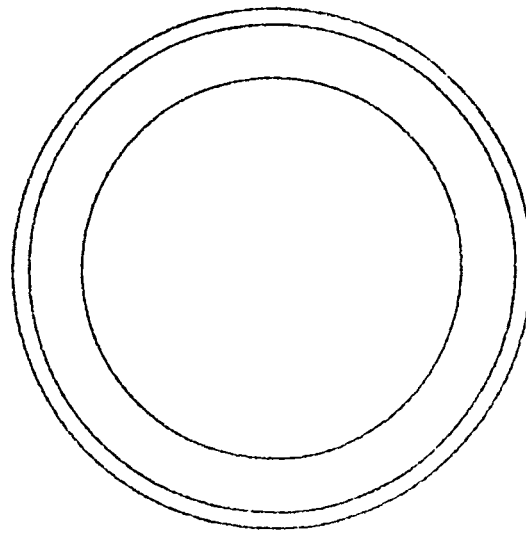
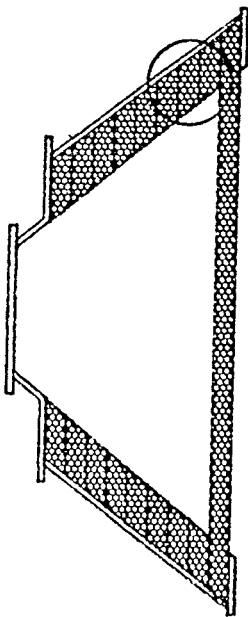


FIGURE 3



EMERSON-CUMMINGS ECCOBOND 45 EPOXY

ELECTROLESS COPPER PLATE

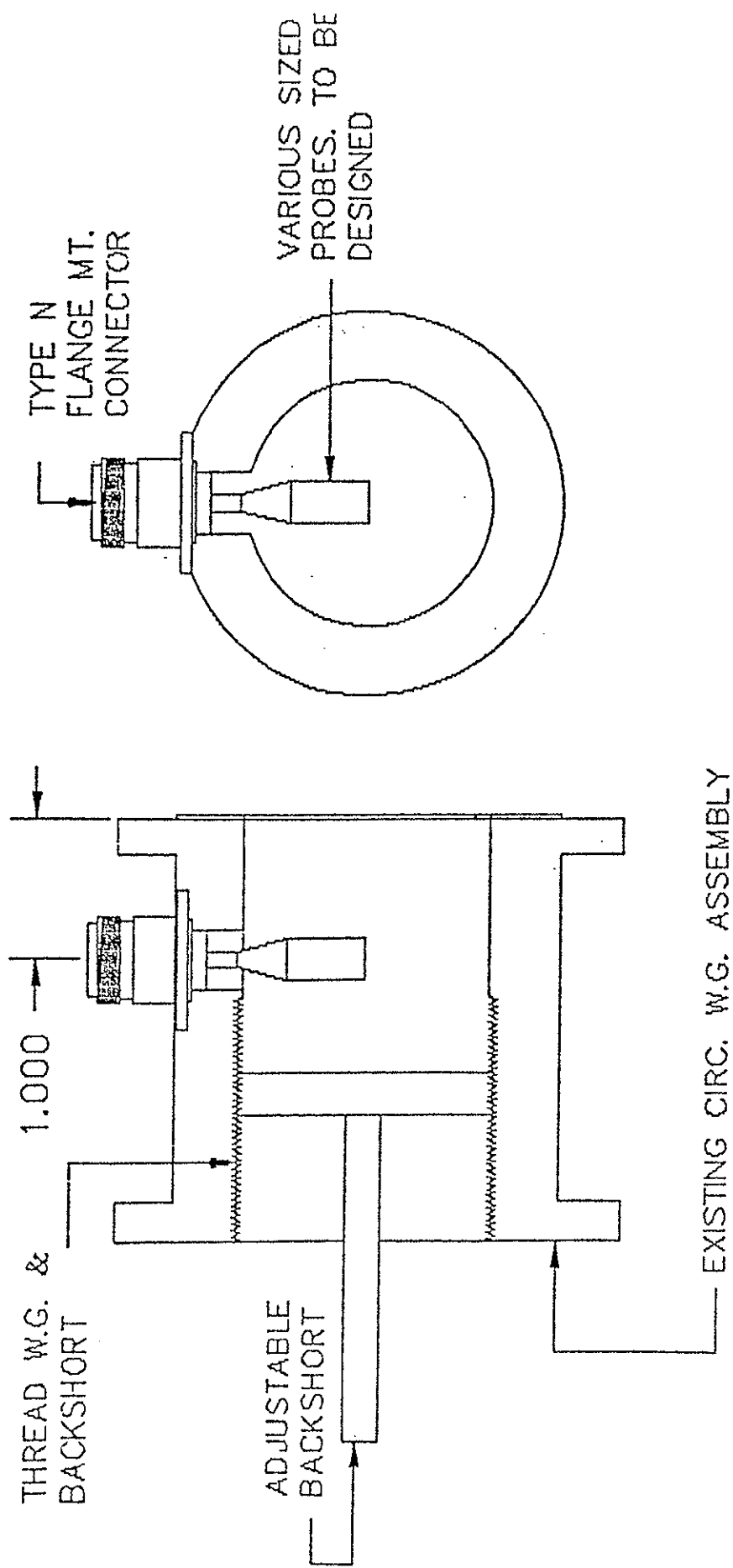
METAL EPOXY

CARBON FIBRE RE-INFORCING

SECTIONS SEPARATED TO SHOW CONSTRUCTION

NATIONAL RADIO ASTRONOMY OBSERVATORY			
GREEN BANK, WV 26031			
PROJECT	DATE	BY	REVIEWED
REF. PROJECT	1980-01-01	J. H. HARRIS	J. H. HARRIS
REVISION	1	J. H. HARRIS	J. H. HARRIS
DATE	1980-01-01	BY	REVIEWED
1980-01-01	J. H. HARRIS	J. H. HARRIS	J. H. HARRIS

FIGURE 4



EXPERIMENTAL TUNABLE CIRCULAR W.G./COAX TRANSITION

FIGURE 5

8-26-91

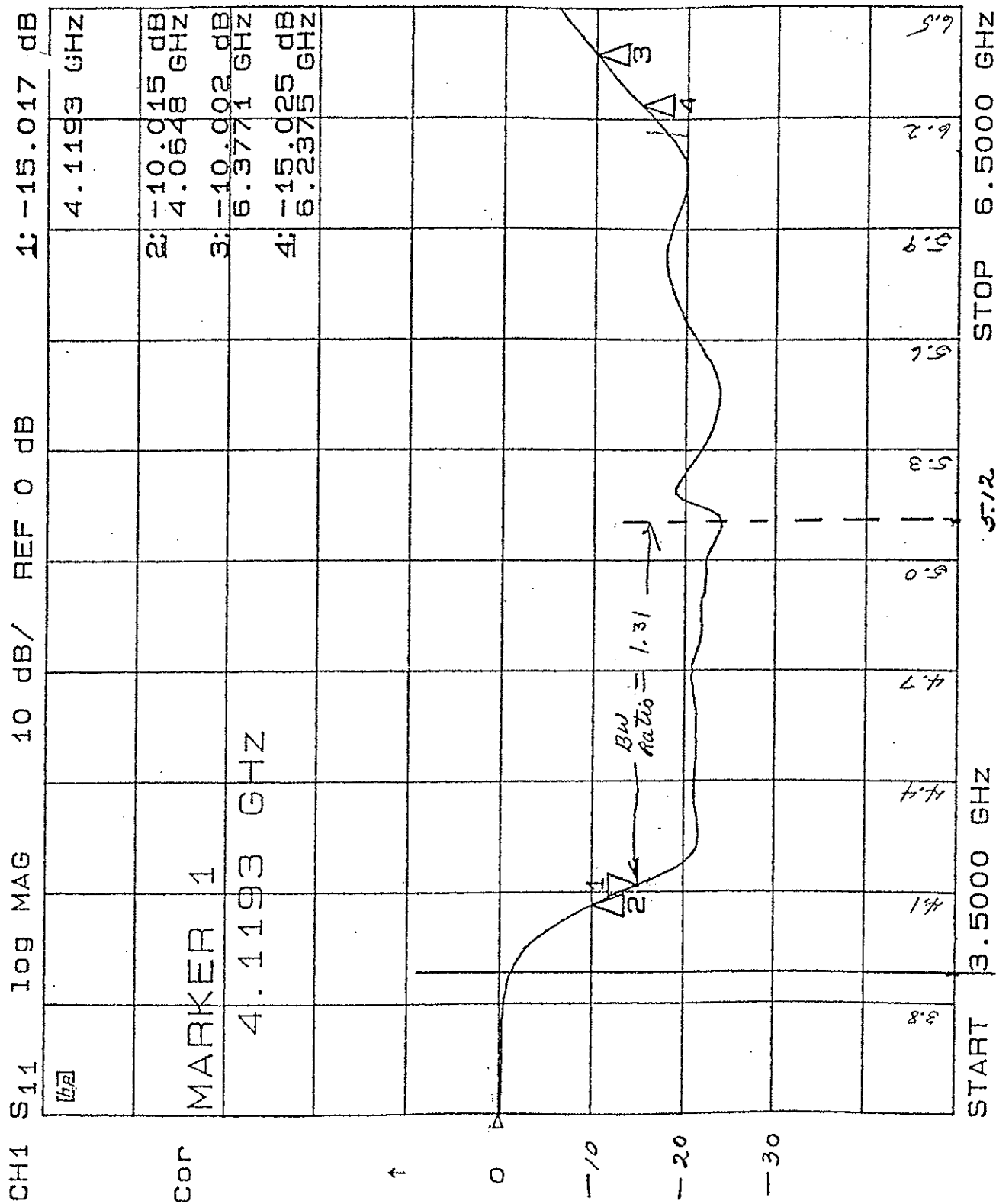
$$\text{Boyle's Law} = 0.764$$
$$\text{Prob } Z = 0.50$$
$$\text{Prob. Diam.} = 0.250$$
$$10Pb = 2.32 \text{ GHz}$$
$$155b = 2,12 \text{ GHz}$$


FIGURE 6

CH1 S21 10 dB/ REF 0 dB 1: -25.891 dB

8-29-91

Backshort = 0.1827

Probe L = 0.50

Probe diam = 0.250

LOAD Probe Backshort

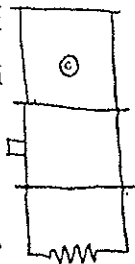
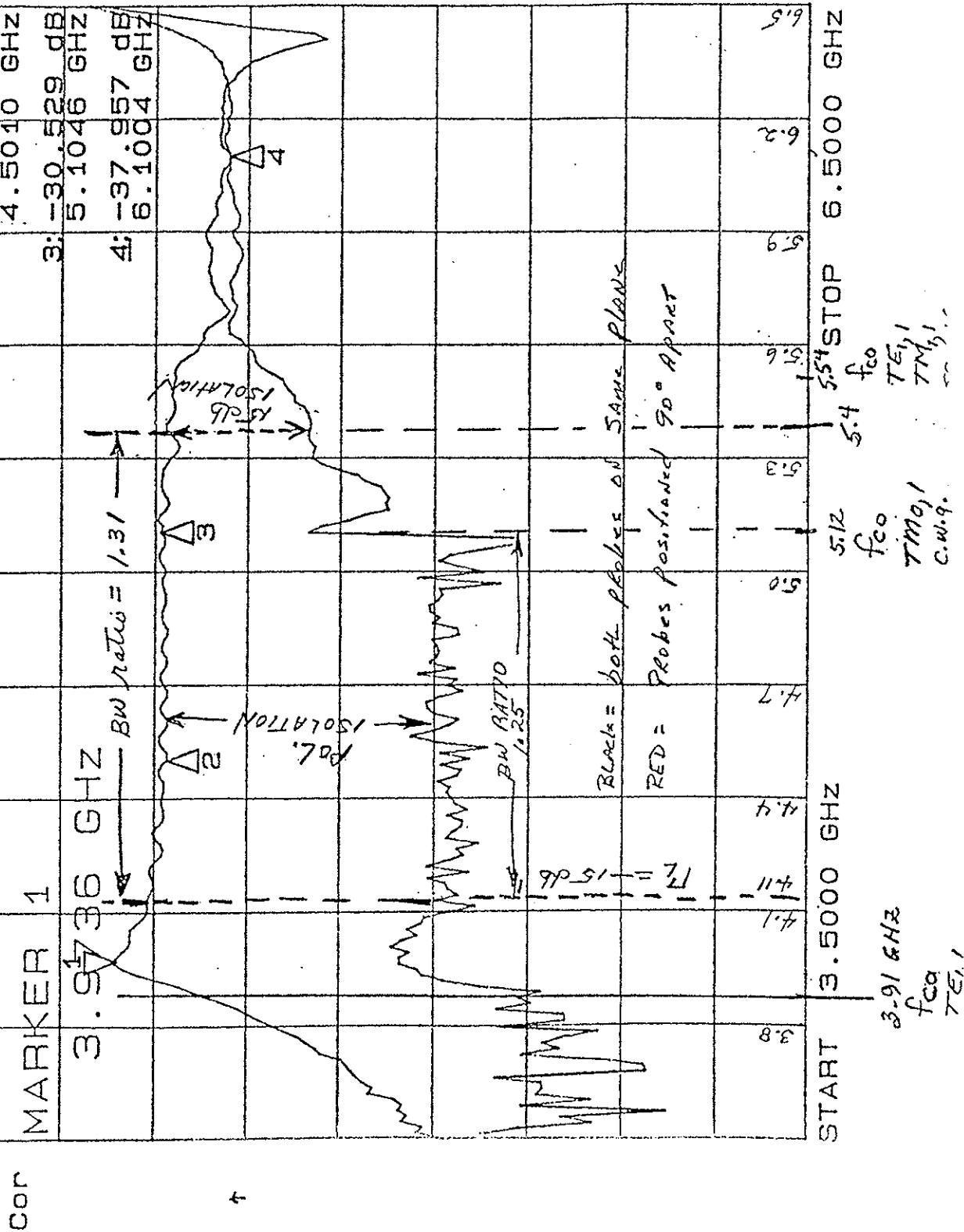


FIGURE 7



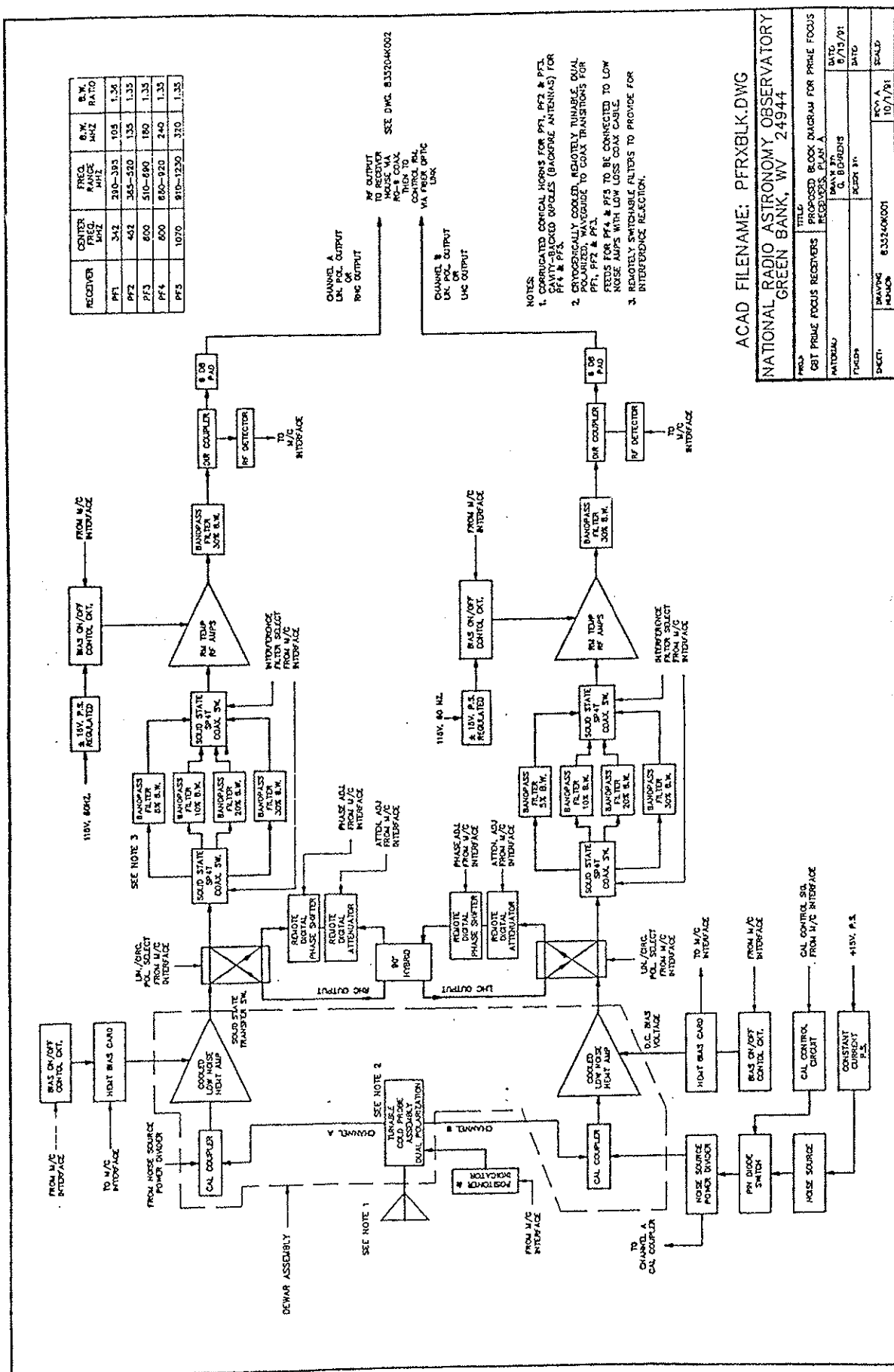


FIGURE 8

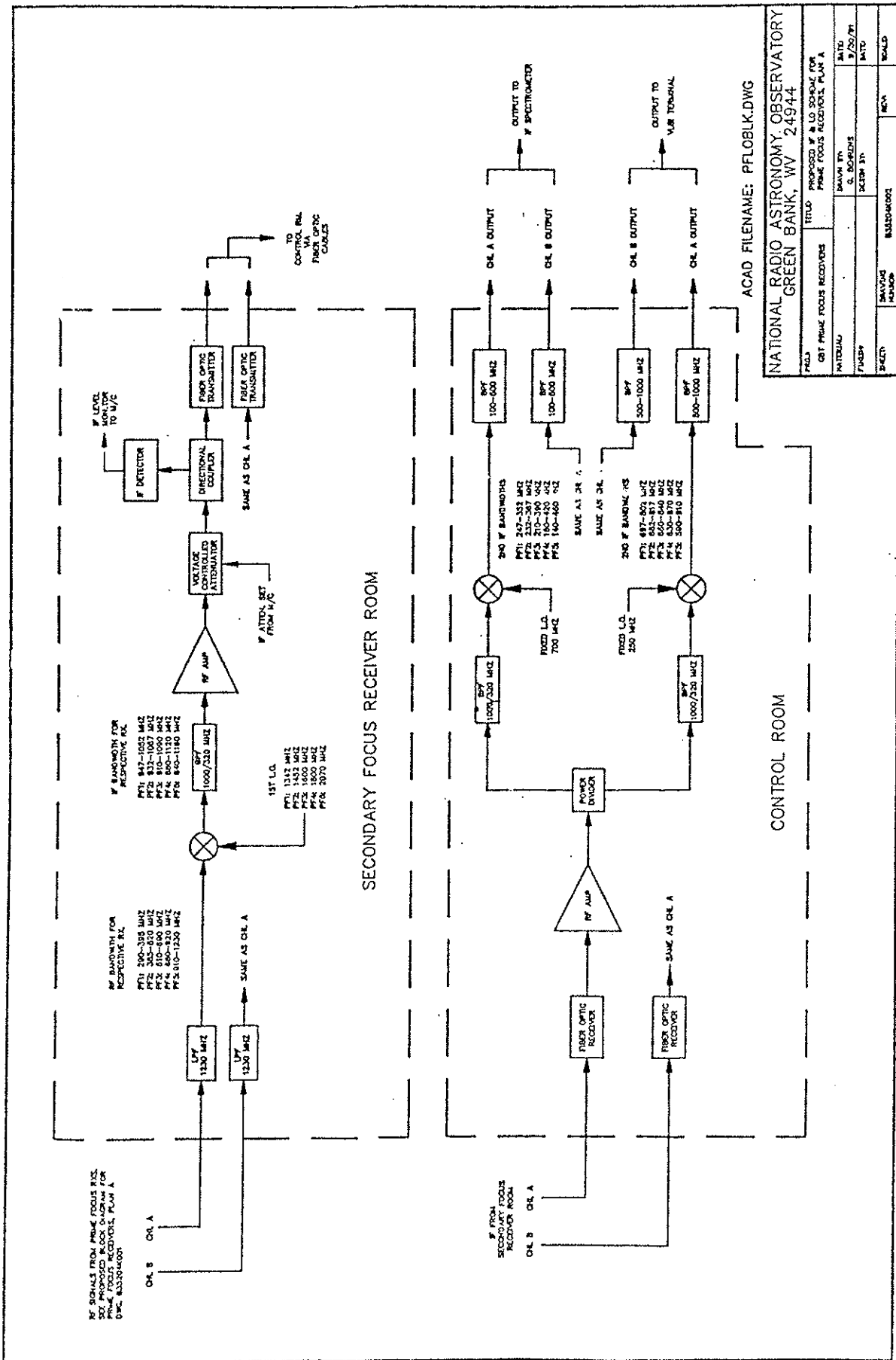


FIGURE 9

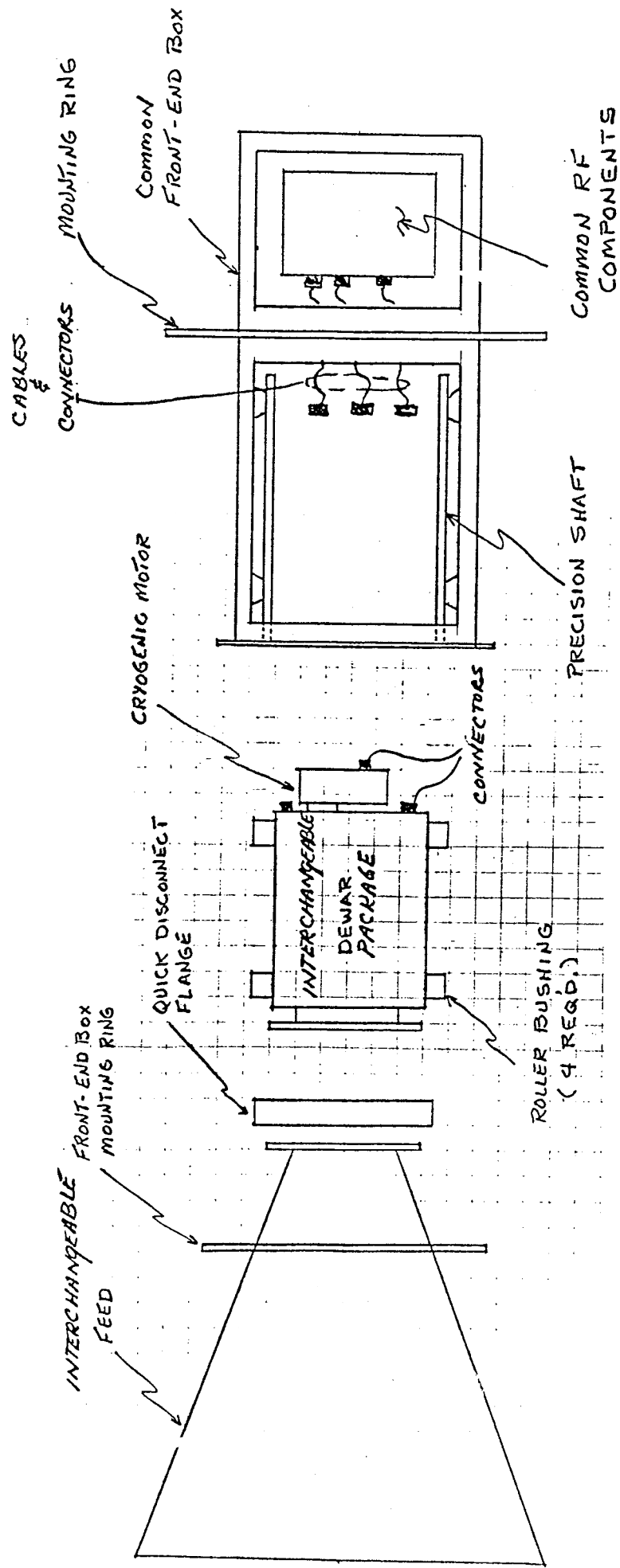


FIGURE 10
RECEIVER PACKAGING DETAILS