NATIONAL RADIO ASTRONOMY OBSERVATORY

VLA ELECTRONICS MEMORANDUM NO. 101

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FRONT-END OPTIONS

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The memo describes various choices concerning VLA front-ends, feeds, and feed mounting arrangements. The examples described are not intended to cover all possibilities; the reader is urged to think of other configurations which may be more useful.

I. Front-Ends

Three possible front-ends are summarized here. A breakdown of the cost of each front-end is given in Tables A, B, and C.

Front-ends B and C require cryogenic refrigerators. NRAO now has 6 refrigerated systems and 5 years experience with one system. It is estimated that the 3 men will be required for refrigerator and vacuum maintenance and the operating cost of the VLA will be increased by $65K a year. It also can be expected that after an initial 6 month break-in period each system will be defective 1% of the time (i.e., a one-day failure every 3 months) and thus 24% of the time one of the 27 systems will be defective. The sensitivity advantage is probably worth this degree of unreliability.

Front-End A - 3/11 cm Degenerate Paramp

This is the front-end presently on the interferometer. Improvements would be made on the feed spillover and reliability of the pump multiplier package. The center frequencies are fixed, the allowed IF bandwidth is 40 MHz at 2.695 GHz and

100 MHz at 8.085 GHz, and SSB operation is not practical. Other characteristics are as follows:

FREQUENCY	SYSTEM TEMPERATURE
2.695 GHz	90°K
8.085 GHz	100°K

Production Cost per Antenna	88K
Development Cost	200K
NRAO Engineering Man-years	1

An uncooled 1.35-1.43 GHz front-end having 100°K system temperature could be added at a cost of 30K.

Front-End B - 3/11 cm Cooled Paramps

This is a replacement of the uncooled degenerate paramps of Front-End A with cooled non-degenerate paramps which are commercially available. The paramp bandwidths would be 200 MHz at 2.695 GHz and 500 MHz at 8.085 GHz. DSB or SSB operation is practical. Other characteristics are as follows:

FREQUENCY	SYSTEM TEMPERATURE
2.695 GHz	45°
8.085 GHz	55°

Production Cost per Antenna	$159K
Development Cost	300K
NRAO Engineering Man-years	3

Front-End C - Cooled Paramp-Mixer Combination

A multiple-frequency configuration utilizing a basic 4.5-5 GHz paramp in conjunction with an up-converter and two cooled mixers is shown in Figure 1. The technical factors which lead to the consideration of this system are:

1) Cooled paramps for the 4 GHz range are a highly developed art. Over 60 paramps having 500 MHz bandwidth and < 15°K noise temperature have been produced by a company.

2) The varactor up-converter is an inherently stable, easily tunable type of parametric amplifier. No circulator is required and it is easily cooled. The main disadvantage is low gain, but this is unimportant when it predes another low-noise amplifier.

3) Cooled mixers are also inherently stable and easily tunable. This is a new art which is being developed at NRAO. The mixers have loss (∿ 3 dB for SSB mixers in this frequency range) but contribute little noise of their own (T_D ∿ 50°K) and produce a fairly low system noise temperature.

4) All of the above devices are fairly small and it is reasonable to put a dual channel system on a single 10-watt 18°K refrigerator.

Characteristics of this option are as follows:

FREQUENCY RANGE	SYSTEM TEMPERATURE
1.35 - 1.72 GHz	55°K
4.5 - 5 GHz	40°K
14.0 - 15.5 GHz	130°K
20 - 25 GHz	150°K

Production Cost per Antenna	$180K
Development Cost	500K
Engineering Man-years	8

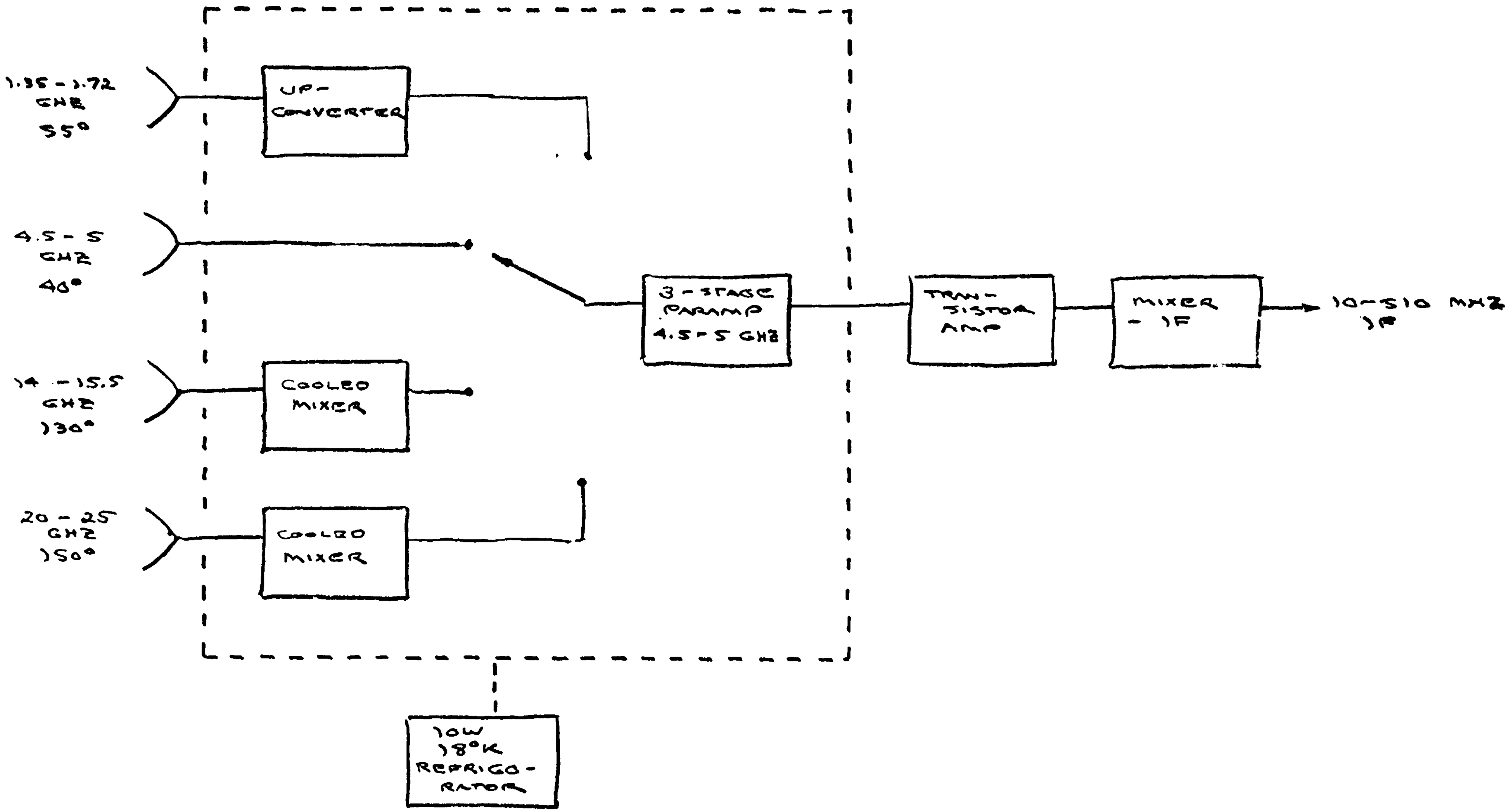

FIGURE 1 - Cooled paramp, up-converter, and mixer multiple frequency front-end.

A word should be stated about the risk in counting on a system such as this for the VLA. We have no experience with this type of system and cooled mixers are just now being developed. However, the risk is only that a portion of the system will not meet specifications. The 6 cm cooled paramp appears to be a solid item and the 18-21 cm up-converter has been designed in the past. Even if the cooled mixers are a total failure the remainder of the system is quite worthwhile.

II. Feeds

The following feed characteristics are desirable for the VLA:

1) Multiple-frequency Operation - It is desirable to operate the array with concentric beams at two frequencies which are in a ratio of 3:1.

2) Dual-circular Polarization - For linear polarization measurements it is desirable to have dual-circular polarized feeds with axial ratio < 1.04

3) Wide bandwidth - For simultaneous coverage of more than one spectral line it is desirable to have feeds with bandwidths in the 10 to 25% range. Examples: 1.35 - 1.72 GHz for H and OH, 4.66 - 4.83 GHz for OH and H_2CO and 22.2 - 23.8 GHz for H_2O and NH_3. Wide bandwidth feeds will also allow a change of frequency to avoid interference and allow an increased continuum sensitivity if a wide band IF transmission and delay system is developed. It is also desirable to be able to quickly (say < 1 day) change to operation at 2 or 3 more frequency bands.

Any one of the above requirements can be met in a conventional manner. Any two can be met with some difficulty and perhaps a compromise in performance. All three requirements are probably unfeasible in one feed. It will be necessary to have three feeds with changeover accomplished by one of the methods presented in the next section. Some examples are as follows:

Feed System A

Feed	Frequency	Bandwidth	Polarization
1	4.7 - 5.0 GHz	6%	Dual-circular
	14.4 -15.4 GHz	7%	Dual-circular
2	1.35- 1.72 GHz	25%	Dual-linear
3	20 - 25 GHz	22%	Dual-linear

Feeds 2 and 3 could be circularly polarized over a smaller bandwidth or over the larger bandwidth with 20°K loss in system temperature. Alternatively circular polarization could be formed at the front-end outputs with some loss in stability.

Feed System B

Feed	Frequency	Bandwidth	Polarization
1	1.35 - 1.43 GHz	6%	Circular
	4.7 - 5.0 GHz	6%	Circular
2	1.60 - 1.73 GHz	7%	Circular
	14.4 -15.4 GHz	7%	Circular
3	20 - 25 GHz	22%	Linear

III. Methods of Changing Feeds

At the secondary focus sufficient space for several front-ends exists and a change of front-end requires only that the feed be changed. Four options are available.

Option A - Physically Change the Feed

This is just the straight-forward-unbolt one feed and install another. However the feeds are likely to be large (i.e., 3' diameter and 12' long) and will have four waveguide flanges to be mated. Even with proper equipment this is likely to require 3 hours for 2 men on each antenna.

Option B - Install Secondary Reflector

It would be possible to switch from a prime focus to a secondary focus front-end by installing the subreflector. This would not be possible with the Option C multiple-frequency front end. One (expensive) possibility would be to have an Option A 3/11 cm front-end at prime focus and an Option C 1.25/2/6/20 cm front-end at secondary focus. Another possibility would be to have an 18/21/75 cm front-end at prime focus and a 1.25/2/6 cm front-end at secondary focus.

Option C - Pivot or Turret Secondary Focus

A pivot arrangement of secondary feeds and front-ends is shown in Figure 2. Three feeds and front-ends are pivoted thru an angle of $\sim 11°$ to put any feed on-axis. Change-over could be in a few seconds from the control room or by two men going to each antenna for 15 minutes. It may be possible to replace the large 21 cm horn with a short lens-corrected horn to reduce the torque load.

Option D - Off-axis Feeds

Three feeds could be permanently mounted with two of the feeds off-axis as shown in Figure 3. In this example, Feed Option A is shown. The 2/6 cm feed

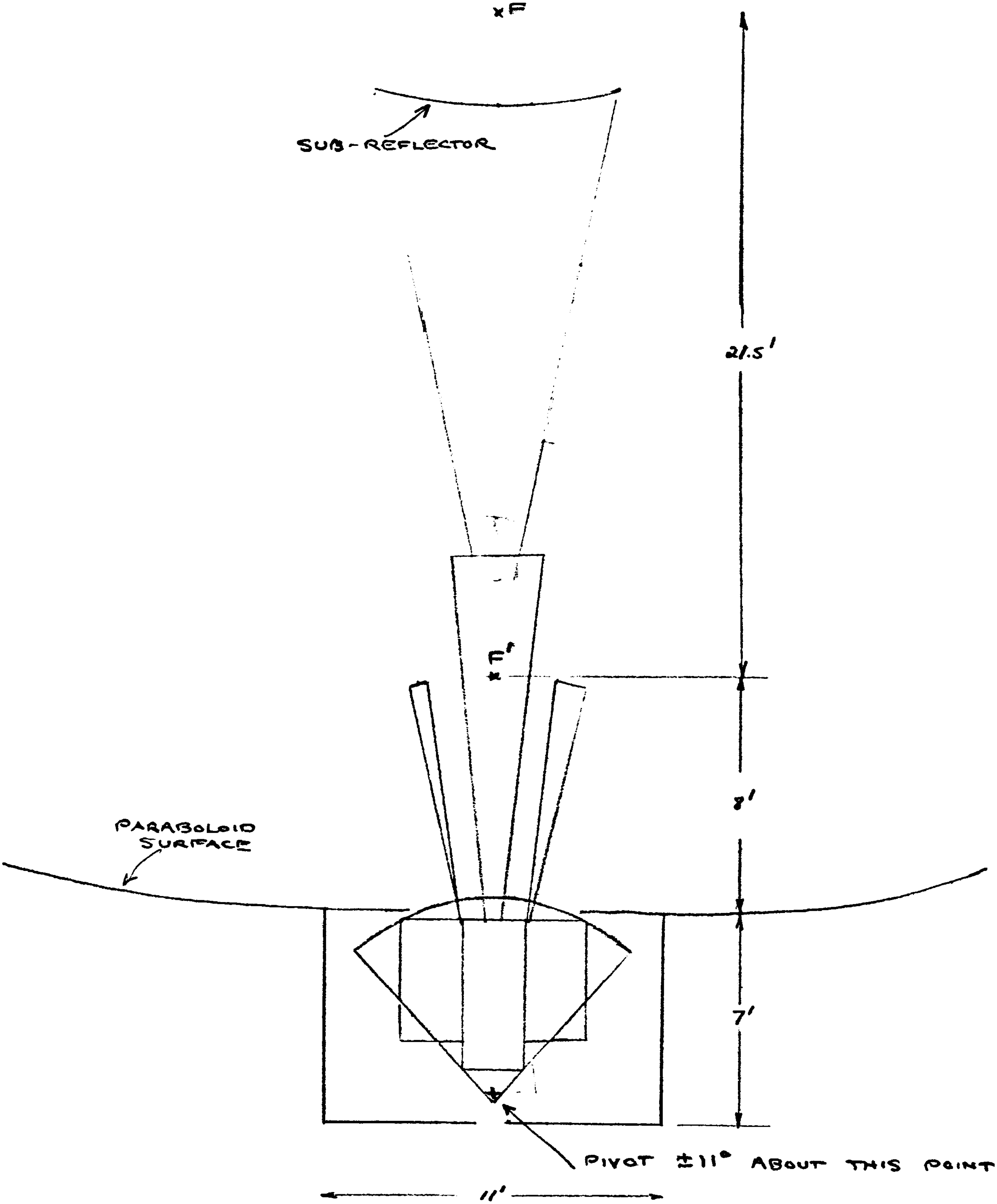

FIGURE 2 - Pivot arrangement to position any one of 3 feeds on axis.

is mounted on-axis and the 18-21 cm and 1.2-1.5 cm feeds are mounted off-axis in elevation. The 1.2-1.5 cm beam will be displaced by 4.8 beamwidths from the 2/6 cm beam; the gain loss and coma lobe are negligible at this displacement with a Cassegrain system with this magnification ($\sim$ 6.8). There may be some degradation in the instrumental polarization with off-axis feeds. This problem needs further investigation but is probably not serious and, of course, does not effect the on-axis feed.

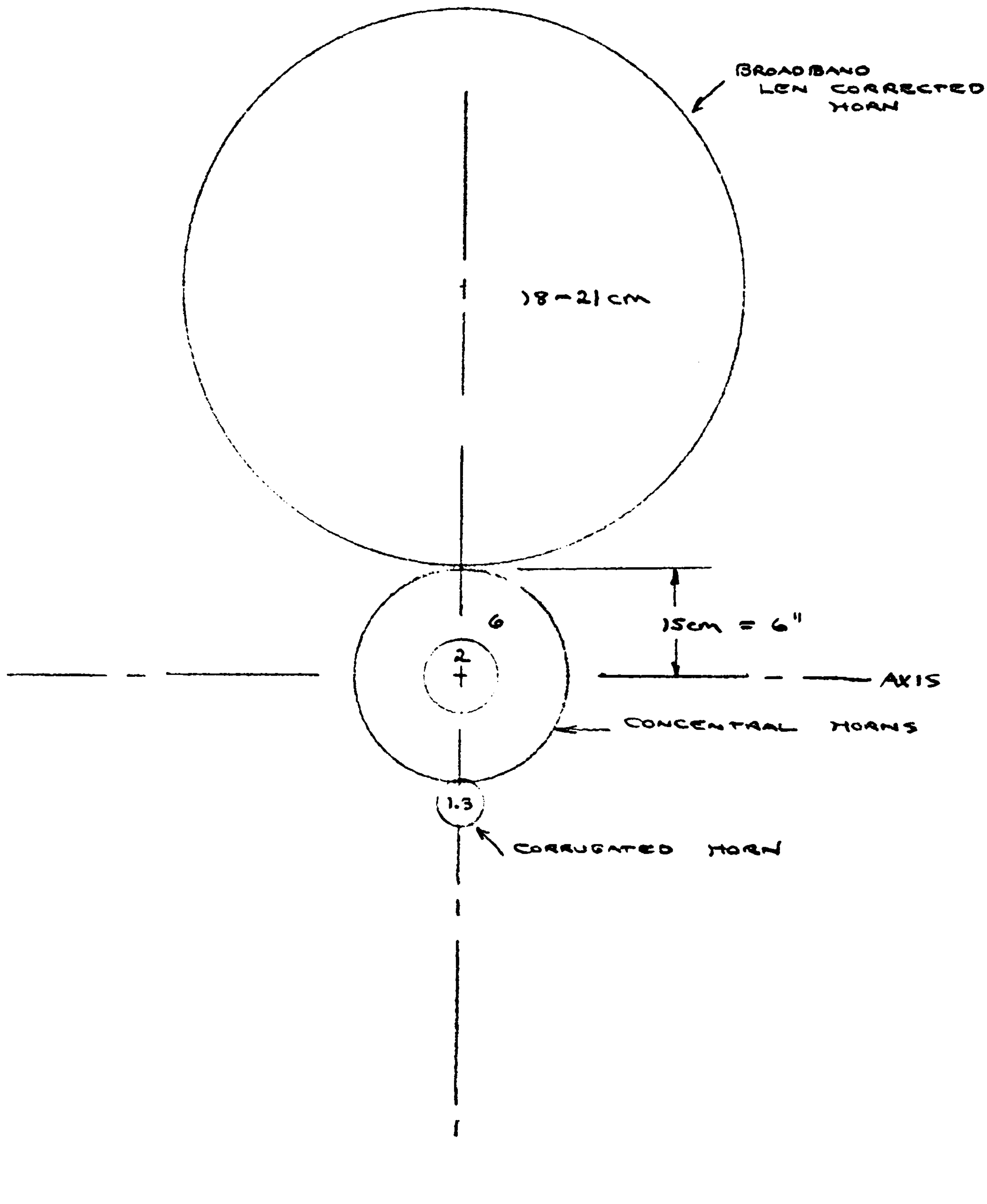

FIGURE 3 - View looking down at vertex with
Feed System A installed.

TABLE A

Cost Breakdown
(1973 Dollars)

Front-End A - 3/11 cm Degenerate Paramp

3/11 cm Dual-circular Feed	15K
2 - Single-stage 11 cm Paramps	6K
2 - Single-stage 3.6 cm Paramps	6K
Pump Multiplier Package	15K
4 - Mixer-preamps	4K
Pump Power and Phase Control	2K
Calibration Components	2K
Cables and Connectors	10K
Temperature Controlled Box	3K
Miscellaneous	5K
Assembly and Test	20K
TOTAL	$88K

Development Cost

Feed Development	100K
Prototype System	100K

+ One Man-year NRAO Engineering

TABLE B

Cost Breakdown
(1973 Dollars)

Front-End B - 3/11 cm Cooled Paramps

3/11 cm Dual-circular Feed	20K
2 - Three-stage 3 cm Paramps	18K
2 - Three-stage 11 cm Paramps	18K
Paramp Pumps	20K
Refrigerator + Compressor	20K
Vacuum Dewar	5K
Calibration Components	2K
Cables and Connectors	10K
4 - Mixer-preamps	3K
Local Oscillator Multipliers	5K
Miscellaneous	5K
Packaging	3K
Assembly and Test	30K
TOTAL	$159K

Development Cost

Feed Development	100K
Prototype System	200K

+ 3 Man-years of NRAO Engineering

TABLE C.

Cost Breakdown
(1973 Dollars)

Front-End C - 1.3/2/6/21 cm Cooled Front-End

2/6 cm Dual-circular Feed	20K
18-21 cm Dual-Linear Feed	15K
1.25 cm Dual-Linear Feed	5K
Refrigerator + Compressor	20K
Vacuum Dewar	5K
2 - Three-stage 6 cm Paramps	18K
Paramp Pump	10K
2 - Up-converters	6K
2 - 2 cm Cooled Mixers	4K
2 - 1.25 cm Cooled Mixers	4K
Calibration Components	3K
2 - Mixer-preamps	2K
Local Oscillator Multipliers	10K
Cables and Connectors	10K
Miscellaneous	5K
Packaging	3K
Assembly and Test	40K
TOTAL	$180K

TABLE C (cont.)

Development Cost

Feed Study	50K
Prototype Feeds	150K
Prototype Up-Converter	80K
Prototype Cooled-Mixers	120K
Prototype Other Components	100K
TOTAL	$500K

+ 6 Man-years NRAO Engineering