PROPOSED RECEIVER FOR THE VLBI ARRAY

Options

The proposed receiving system covers all of the suggested VLB observing frequencies. A cost breakdown will give some idea of the savings resulting from the reduction in the number of frequencies.

Discussions within NRAO came up with three possible options for the receiver configurations. These are summarized in the following table.

OPTION	PRIME FOCUS	CASSEGRAIN FOCUS	SUBREFLECTOR SIZE	RECEIVERS		FEEDS		ADVANTAGES	DISADVANTAGES
				PRIME	CASSEGRAIN	PRIME	CASSEGRAIN		
A	<4.5 GHz	>4.5 GHz	1 METER	COOLED 20K	COOLED 20K AND 4K	4	6	SUBREFLECTOR EASILY REMOVED FOR PRIME FOCUS OBSERVATIONS.	UNABLE TO USE SHAPED REFLECTOR BECAUSE OF EFFICIENCY LOSS OF 50% AT 1.4 GHz.
B	<1.4 GHz	>1.4 GHz	3.65 METER	UNCOOLED	COOLED 20K AND 4K	2	8	CAN USE SHAPED REFLECTOR FOR IMPROVED EFFICIENCY.	SUBREFLECTOR LARGE AND WOULD TAKE SEVERAL HOURS TO REMOVE FOR PRIME FOCUS WORK.
C	<22 GHz	>22 GHz	50 CM	COOLED 20K	COOLED 20K AND 4K	8	2	PRIME FOCUS RECEIVER BOX COULD BE ROTATED TO BRING FEEDS ON AXIS. SUBREFLECTOR COULD ALSO BE MOUNTED ON BOX AND ROTATED INTO POSITION FOR 22/43 GHz OPERATION.	UNABLE TO USE SHAPED REFLECTOR. PRIME FOCUS RECEIVER WOULD BE DIFFICULT TO PACKAGE. HIGHER SPILLOVER GIVING GREATER T_S.

Although options A and C have several good features, the major problem results from the desirability of using a shaped antenna for improved antenna efficiency in the cassegrain mode. When the shaped antenna is used at prime focus, there is a loss of performance. In option A, for example, the overall antenna efficiency would be about 25% at 1.4 GHz where the deviation due to shaping from the ideal paraboloid is about $\frac{\lambda}{16}$.

Option B would appear to be the most attractive. The proposed subreflector size of 3.3 meters is larger than the VLA subreflector (2.36 meters), consequently the 1.4 - 1.7 GHz prime focus feed can be a conventional horn antenna.

The major disadvantage of option B is the inconvenience of removing the large subreflector for prime focus operation at 327 and 610 MHz. Operationally, this may not be too much of a problem if the low frequency work occurs relatively infrequently. Alternatively, the 327 MHz could be left off as an observing frequency and the 610 MHz could be implemented at the cassegrain focus with somewhat limited performance.

The following table compares the performance of cooled GASFET amplifiers with that obtainable from upconverter/masers up to 15.4 GHz and then masers alone at higher frequencies. These figures are about the best noise temperatures available with significant frequency coverage and are based on measurements made on the 5 - 26 GHz receiver on the 140' telescope.

RECEIVER NOISE TEMPERATURES FOR VARIOUS TYPES OF FRONT-ENDS AS A FUNCTION OF FREQUENCY (VALUES IN PARENTHESIS ARE 1986 ESTIMATES)

FREQUENCY	RECEIVER NOISE TEMPERATURE GASFET @ 300K	GASFET @ 20K	UP-CONV -MASER @ 4K	ADDITIONAL NOISE *
0.33	40 (30)	10 (7)	-	35
0.61	45 (30)	10 (7)	-	31
1.4 - 1.7	50 (40)	12 (9)	5	22
2.2	60 (50)	15 (11)	10	22
5	90 (70)	20 (14)	10	22
8.85	130 (110)	30 (20)	10	20
10.7	170 (140)	40 (25)	10	25
15.4	280 (170)	70 (40)	15	32
22	470 (200)	130 (60)	10	40
43	- (800)	- (200)	(30)	45

* ADDITIONAL NOISE DUE TO TRANSMISSION LINES, ANTENNA LOSSES, AND ATMOSPHERE.

Front Ends

Recent work at NRAO and Berkeley developing cooled GASFET amplifiers for 1.4 - 1.7 GHz and 4.5 - 5.0 GHz has shown that these amplifiers are capable of good low-noise performance and high reliability. About 25 of the 4.5 - 5.0 GHz amplifiers have replaced parametric amplifiers in the VLA front ends and they have been operating for many months without a single failure.

It is proposed that room temperature GASFETs be used at 327 and 610 MHz, since it is assumed that high sensitivity is not critically important at these frequencies.

At 22 GHz and 43 GHz there is a significant improvement in going to masers; a 4K maser system based on the NRAO masers covering 22 GHz and 43 GHz is proposed. The GASFET alternative would result in system temperatures of at least twice that obtainable with a maser system. All the intermediate frequencies would be covered by 20K GASFET amplifiers. The expected system performance is tabulated as follows:

	FRONT END TYPE			T_R		T_{INPUT}	$T_{ANTENNA}$	$T_S = T_R + T_L + T_A$		
	GASFET		MASER							
FREQUENCY	300K	20K	4K	1980	1986	LINE LOSS		1980	1986	NOTES
0.33	X			40	(30)	5	30	75	(65)	Prime
0.61	X			45	(30)	6	25	76	(61)	Prime or Cass
1.4-1.7		X		12	(9)	7	15	34	(31)	Cassegrain
2.2		X		15	(11)	7	15	37	(33)	Cassegrain
5		X		20	(14)	7	15	42	(36)	Cassegrain
8.85		X		30	(20)	5	15	50	(40)	Cassegrain
10.7		X		40	(25)	5	20	65	(50)	Cassegrain
15.4		X		70	(40)	7	25	102	(72)	Cassegrain
22			X	10		10	30	50		Cassegrain
43			X	50	(30)	20	25	95	(75)	Cassegrain

Cryogenics

In the receiver developed by NRAO for the VLA the front end components for the four frequencies were installed in a large dewar and cooled to 20K with a 10W refrigerator. This has presented one problem which could be serious for a VLBI antenna. Failure of the refrigerator or cryogenic components generally means a loss of all four observing frequencies. Since skilled personnel are on call at the VLA site, this is not operationally a serious problem. If we attempt to put all VLB front ends in the same dewar, we are in danger of losing an entire antenna for significant periods of time if skilled personnel are unavailable at the antenna and have to come from a central location.

In the VLBI receiver we propose that the cooled FET amplifiers be mounted in small dewars on small refrigerators run off a large common compressor. The dewars can be mounted on the dual polarization transistions on the feeds and line losses can be kept to an absolute minimum.

At the moment it's not clear what would be the best type of refrigerator ~~to use~~. The CTI Model 20 has a 1 watt capability at 20K, but there is insufficient data on long term reliability. Six of these units could be run from one 1020 type compressor. A spare compressor with automatic changeover, if a failure occurred, would help decrease down time for maintenance and increase reliability.

A breakdown of the approximate VLBI receiver costs follows:

20K Cryogenics Costs

Refrigerators - Model 21	6 x $2,200	$ 13,200
or Model 350	3 x $5,000	15,000
Compressors	2 x $6,000	12,000

4K Cryogenics Costs

Refrigerator and Compressor		$ 50,000

4K and 20K Helium Lines

6 lines (one spare)		$ 12,000
	TOTAL	$ 89,000

300K Front-End Costs	Material $K	Labor Man Months
GASFET Amplifiers 327 and 610 MHz 2 Frequencies x 2 polarizations	4 x 1	2
Mixer/IF Amplifier	4 x 0.25	2 (assy)
Local Oscillator	2 x 0.5	
Totals	6	4
Total Labor cost	11	
Total material and labor	$17	

20K Front End Costs	Material $K	Labor Man Months
Dewar, input lines, etc.	10	6 (assy)
Cooled GASFET Amplifiers 1.4-1.7, 2.2, 5, 8.85, 10.7, 15.4 GHz 6 Frequencies x 2 Polarizations	12 x 1	6
Mixer/IF Amplifiers	12 x 1	
Local oscillator to cover all above frequencies	15	6
Totals	49	18
Total Labor cost	51	
Total material and labor	$100	

4K Front End Costs	Material $K	Labor Man Months
Dewar, input lines, etc	20	6 (assy)
Dual channel masers 22, 43 GHz	20	12
Solid State Pumps	20	
Local oscillator for both frequencies	20	6
Mixer/IF Amplifiers 4 x $2,500	10	
Totals	90	24
Total labor cost	68	
Total material and labor	$158	

Total receiver cost	$
20K Cryogenics	33,000
4K Cryogenics	56,000
300K Front Ends	17,000
20K Front Ends	100,000
4K Front Ends	158,000
Miscellaneous	
Calibration (System noise)	15,000
Calibration (Phase)	15,000
Power Supplies, etc.	10,000
Total receiver cost	$404,000