GBT Memo No. 66

NATIONAL RADIO ASTRONOMY OBSERVATORY
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M E M O R A N D U M

To: GBT Science Working Group

From: M. Balister/R. Norrod/S. Srikanth

Subject: Gregorian Receivers for the GBT

The following is a proposed plan for general purpose receivers at the Gregorian focus of the GBT. Prime focus receivers will cover lower frequencies and be covered in a separate memo.

We have decided that the objective should be to have complete frequency coverage from 1.15 GHz to 50 GHz. The plan (Table 1) has been optimized to give the highest sensitivity at minimum cost using close to current technology. The frequency range has been divided into 15 separate bands. There are ten different feeds covering this same frequency range.

The lowest five frequency bands in Table 1 will use quadridge polarizers with bandwidth ratios of 1.5. It is proposed that if circular polarization is desired, that it be generated following the cooled amplifiers using a 90° hybrid. This technique has been routinely used at the 140-foot telescope in the 1.3-1.8 GHz and 3.0-3.4 GHz receivers.

For higher frequencies, the quadridge polarizers become difficult to fabricate because of scaling problems and tight tolerances. Septum polarizers built by Atlantic Microwave have been used successfully in the VLBA, Voyager and other projects at NRAO. A recent unit to cover a bandwidth ratio of 1.25 has been incorporated into the 12.0-15.4 GHz VLBA receiver. It is proposed that these polarizers (or equivalent) be used in the 8.2-50 GHz frequency range.

The plan is to use HEMT amplifiers at a physical temperature of 12 K (or less). The expected amplifier noise temperature which we confidently expect to obtain using the best devices (0.1 μm) currently available (1991) is shown in the attached curve (see Figure 1). The future curve represents the performance which should be feasible after evaluation and selection of experimental devices whose 300 K performance has been already reported in the literature.

Consequently, above 8.2 GHz each feed band is divided into two receiver bands to optimize amplifier and polarizer performance. Each receiver band will have two closely spaced feed horns, followed by a polarizer and two low-noise amplifiers. The two antenna beams will be separated by 5-7 beamwidths in the sky. The reason for doing this is two-fold:

1) Double position switching is possible so that the source is always in one antenna beam or the other, leading to a $\sqrt{2}$ increase in sensitivity.

2) Beam switching at a faster rate by switching at RF <u>after</u> the low-noise amplifiers should give good continuum performance for pointing, etc. This assumes that the gain stability of the amplifiers will be very good.

Input noise calibration couplers will be integrated into all the amplifiers to 8.2 GHz. Above this frequency, waveguide couplers will be used. It is hoped that the restricted 1.25 bandwidth ratio will make possible an amplifier which is optimized to minimize return loss at the input which will remove the requirement for an isolator. The final decision regarding the use of isolators will be made during the design phase after a complete evaluation of the trade-offs has been made.

There are eight openings in the feed turret for receivers. The layout of these openings is shown in Figure 2. A proposed distribution of receivers in these openings is listed in Table 2. Figure 3 shows how feeds for frequencies above 8.2 GHz are arranged in the openings. Each feed pair is located so as to switch the beams in azimuth, but none of the feeds can be brought directly on axis. Based on previous work, the loss in efficiency because of this will be well within 1%, but there will be some degradation of the cross-polarization. Other layouts have been discussed that allow either of the feeds in each pair to be brought on axis, but none allows all 15 receiver bands to be simultaneously installed. We feel that this is an important advantage of the plan presented here, but quantitative analysis of the performance for the feed locations shown may lead us to make some revisions in the layouts.

An explanation of the columns in the attached Table 1 follows:

1) **Rx Number** - receiver identification number.

2) **Band** - conventional band designation.

3) **Feed, GHz Low/High** - lowest and highest operating design frequency for the feed. Operation outside this range possible (see later notes).

4) **Type** - describes type of feed horn. Profile horns preferred to linear taper (Lin. Taper) at lower frequencies because of their smaller size.

5) **BW Ratio** - ratio highest to lowest operating frequency for the feed.

6) **WG Dia.** - size of circular waveguide at output of feed.

7) $\mathbf{F_{co}}$ - cutoff frequency of dominant mode (TE_{11}) in circular waveguide of diameter given in previous column.

8) $\mathbf{F_{hom}}$ - frequency at which TE_{21} mode propagates. Operation above this frequency possible but danger of resonances causing problems.

9) **Receiver, GHz Low/High** - operating frequency range for polarizer and low-noise amplifier combination.

10) **BW Ratio** - ratio of highest to lowest operating frequency for the polarizer and low-noise amplifier combination.

11) **Polarization** - dual linear to 8.2 GHz. Dual circular for higher frequencies.

12) **T_R Projected** - The receiver noise temperature (including polarizer) that we expect to obtain using HEMT amplifiers operating at physical temperature of 12 K.

13) **VLBA** - receivers that cover VLBA frequencies are marked with an asterisk (*).

14) **Prio.** - priority of Gregorian receiver construction based on recommendations of GBT SWG (March 12, 1991). When prime focus and Gregorian receivers were rated together, #2 priority went to the 300-1000 MHz receiver.

Attachments

TABLE 1

GBTRX SEPT-91

GBT RECEIVER PLAN

BAND		FEED							RECEIVER			POLARIZATION	Tr		Prio.
RX NR.		GHz LOW	GHz HIGH	TYPE	BW RATIO	WG DIA Inches	Fco GHz	Fhom GHz	GHz LOW	GHz HIGH	BW RATIO		Proj. Kelvin	VLBA	
1	L	1.15	1.73	Profile	1.50	6.628	1.04	1.73	1.15	1.73	1.50	Dual Linear	5	*	1
2		1.73	2.60	Profile	1.50	4.406	1.57	2.60	1.73	2.60	1.50	Dual Linear	5	*	10
3	S	2.60	3.95	Profile	1.52	2.900	2.39	3.95	2.60	3.95	1.52	Dual Linear	6		9
4		3.95	5.85	Lin.Taper	1.48	1.930	3.59	5.94	3.95	5.85	1.48	Dual Linear	7	*	3
5	C	5.85	8.20	Lin.Taper	1.40	1.303	5.31	8.80	5.85	8.20	1.40	Dual Linear	8		8
6	X	8.20	12.40	Lin.Taper	1.51	0.938	7.38	12.23	8.20	10.00	1.22	Dual Circular	10	*	6
7						0.769	9.01	14.92	10.00	12.40	1.24	Dual Circular	11		
8	Ku	12.40	18.00	Lin.Taper	1.45	0.620	11.17	18.50	12.40	15.40	1.24	Dual Circular	12	*	5
9						0.499	13.87	22.97	15.40	18.00	1.17	Dual Circular	13		
10	K	18.00	26.50	Lin.Taper	1.47	0.427	16.21	26.85	18.00	22.00	1.22	Dual Circular	15		2
11						0.349	19.81	32.81	22.00	26.50	1.20	Dual Circular	20	*	
12	Ka	26.50	40.00	Lin.Taper	1.51	0.290	23.86	39.53	26.50	33.00	1.25	Dual Circular	25		7
13						0.233	29.72	49.22	33.00	40.00	1.21	Dual Circular	27		
14	Q	40.00	50.00	Lin.Taper	1.25	0.192	36.02	59.66	40.00	45.00	1.13	Dual Circular	30	*	4
15						0.171	40.52	67.12	45.00	50.00	1.11	Dual Circular	35		

NRAO AMPLIFIERS AND DEVICE LIMITS

AT 12.5 K

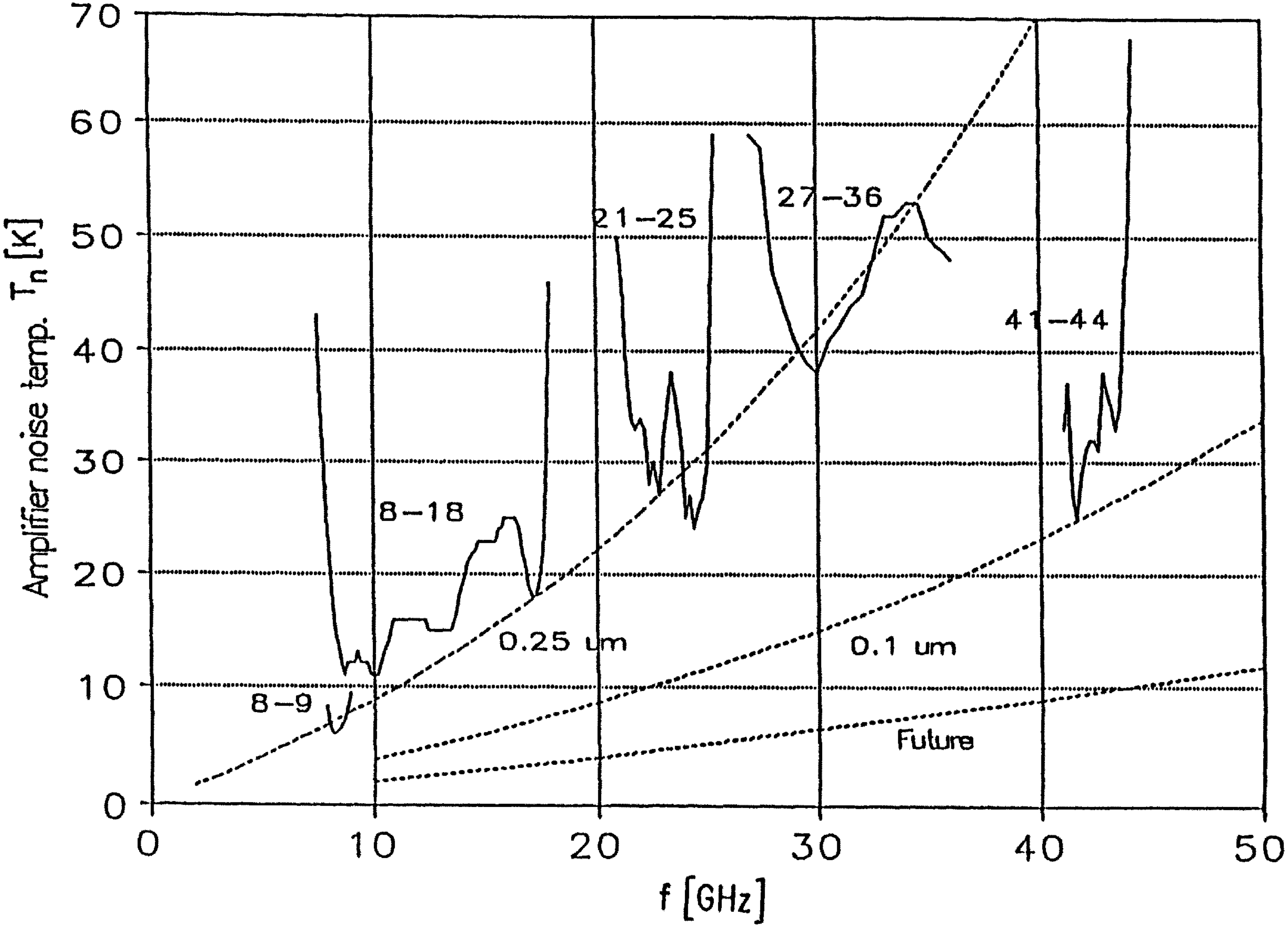


Figure 1

POSITION	DIA	B.C.
1	48	TBD
3,5,7	36	TBD
2,4,6,8	24	TBD

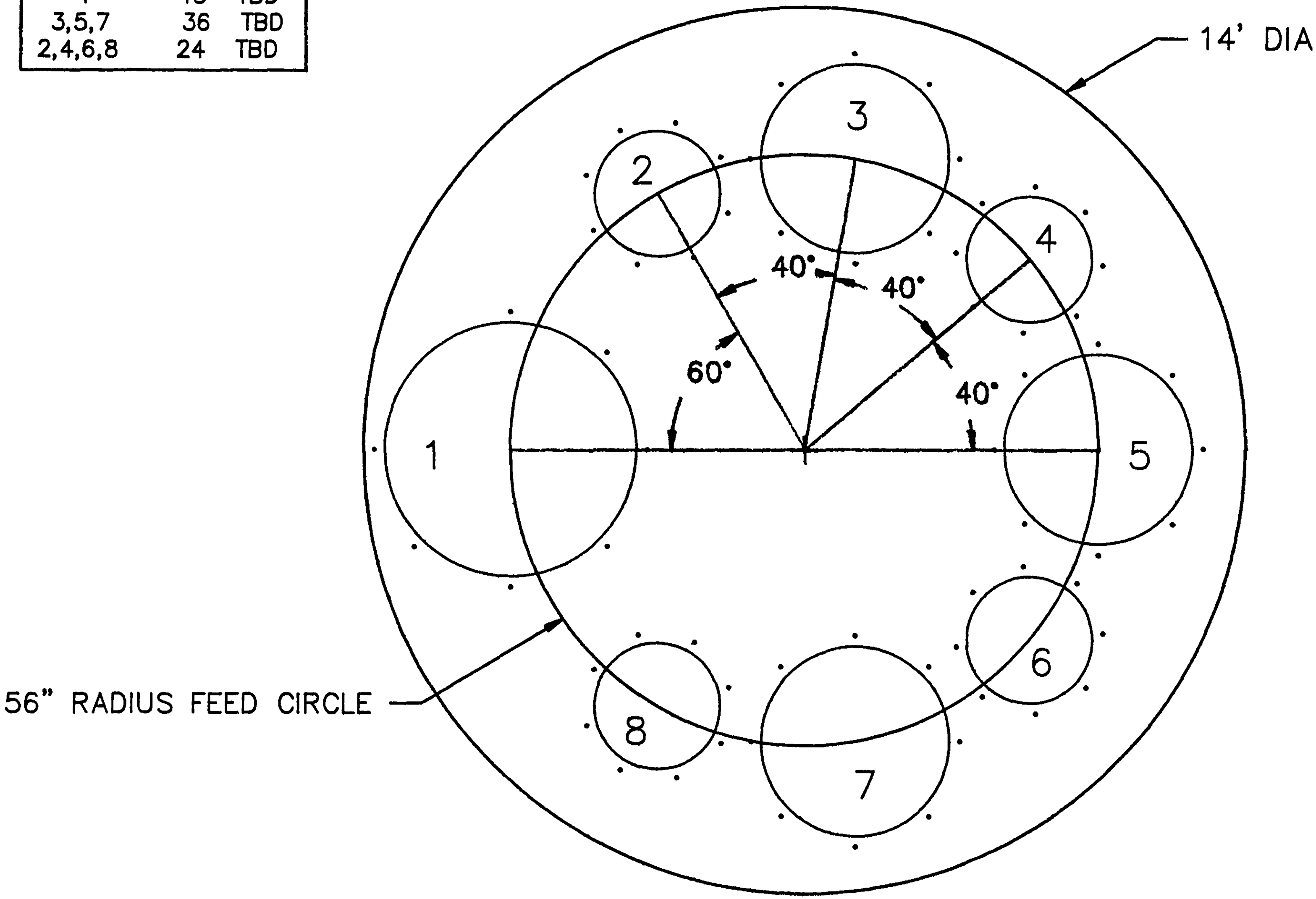
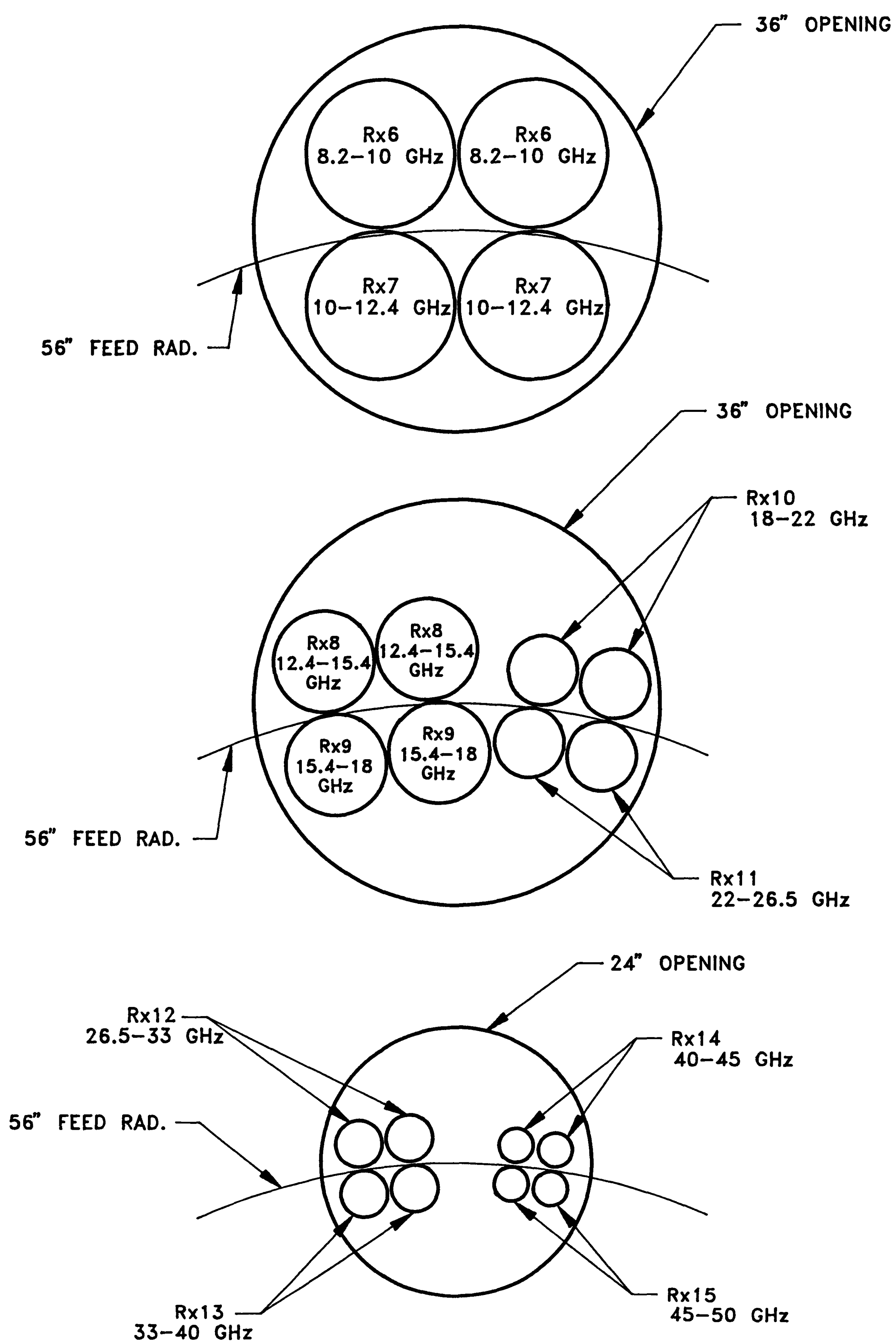


Fig. 2. Feed Openings in Turret

TABLE 2

RECEIVER ARRANGEMENT IN FEED TURRET			
Receiver No.	Turret Position No.	Opening Diameter *(Inches)*	Feed Diameter *(Inches)*
1	1	48	54
2	5	36	36
3	2	24	23.8
4	4	24	27.6
5	6	24	19.3
6, 7	3	36	13.2(x4)*
8, 9, 10, 11	7	36	9(x4)* 3.1(x4)*
12, 13, 14, 15	8	24	4.2(x4)* 6.2(x4)*

*(x4) indicates number of feeds.



FEED ARRANGEMENT IN OPENINGS

Fig. 3