GBT Memo No. 29

NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, WV

MEMORANDUM

January 24, 1990

To: GBT Optics Group

From: J. R. Coe

Subj: **Multibeam Receivers for the GBT**

Several multibeam receivers will eventually be developed for use on the GBT. This report considers a seven-feed/6.25 cm receiver in a Gregorian configuration. Optimum feed positions for each of the offset feeds were determined. The gains of the offset beams were computed.

The half-power beamwidth of the 100 meter aperture at 6.25 cm wavelength is 0.0394 degrees. The beam separation for the offset beams is 2.8 HPBW's. To determine the best focus positions for the offset feeds using the program CLCGG the beam offsets in elevation and azimuth are needed.[1] With the feeds oriented in a tight cluster as shown in Figure 1, the offset in azimuth for Beam 2 is -2.8 * 0.0394 or -0.11 degrees with 0.0 elevation offset. The offsets for the other beams are listed on Figure 1. The Gregorian configuration considered uses the subreflector designated M1 with the parameters $\beta = 5.57°$, $E_{CC} = 0.528$, $Y_C = 54$ meters, C = 11 meters, and D = 14.2285. The subreflector size for a single on-axis beam is 7.553 by 7.948 meters. By trying different values of Z_F and using the programs multe and patt.e, the maximum gain for all offset beams appears to be at $Z_F = 10.95$ meters.[2] However, for larger offsets the best focal position is further from the subreflector for a Gregorian system. For a 0.55 degree beam offset the off-axis feed location for maximum gain is at a Z_F of 11.15 meters. The location of the phase center for each of the offset feeds X_F, Y_F, and Z_F is shown in Table 1. The coordinate system origin is at the primary reflector focus with Z positive toward the primary reflector vertex and with the Y axis in the elevation plane. This table also lists the 100 meter aperture rim pattern projected on the subreflector. X_1, Y_1, and Z_1 list the dimensions of this pattern with respect to the primary reflector focus for the ϕ cut of 0, 30, 60 ... 330 degrees.

---

[1] Reflector and Lens Antennas: Analysis and Design using Personal Computers, C. J. Sletten (editor), M. Calvo, Y. C. Chang, F. S. Holt, W. P. Schillue (Aertech House, Norwood, MA, 1988).

[2] Ibid.

To aid in visualizing the projected aperture rim pattern on the subreflector, the X_1 and Y_1 coordinates were used to draw the Figures 1, 2 and 3. Figure 1 shows the projected aperture rim patterns for all of the beams. Figure 2 compares the on-axis Beam 1 and off-axis Beam 2 patterns, and Figure 3 shows Beam 7 and Beam 1 patterns on the subreflector. To obtain the maximum gain for the offset beams the subreflector would have to be extended to intercept these projected rim patterns. The dimensions of the subreflector would have to be increased about .30 meters. If this is done, the gain for the six offset beams would be within 0.03 dB of the on-axis beam gain. However, increasing the size of the subreflector will increase the amount of spillover past the main reflector which reduces the sensitivity of all of the single beam observations. Consider the effect on the gain of the offset beams if the subreflector is not expanded. A portion of the main reflector would not be illuminated properly. The area that is not illuminated would be near the edge of the main reflector. With the tapered illumination it is estimated the effect on the offset beams of not extending the subreflector would be a gain reduction of less than .01 dB. The conclusion is the subreflector need not be extended for use with this multibeam receiver. The offset feeds should be tilted 2.1 degrees toward the on-axis feed to position the patterns properly on the subreflector and the phase centers for these feeds should be located as listed in Table 1.

TABLE 1

Computed Feed Phase Centers and Projected Aperture Pattern at the Subreflector for the 6.25 cm Multibeam Receiver

ϕ	X_1	Y_1	Z_1
BEAM #1, ON-AXIS, GAIN = 73.27 Db			
ELEVATION=0, AZIMUTH=0			
XF=0	YF=-1.067257	ZF=10.95	
0	-3.776319	-4.078425	-2.827205
30	-3.142237	-5.73278	-1.900038
60	-1.763581	-6.863941	-1.266094
90	1.526192E-07	-7.26236	-1.042807
120	1.763582	-6.86394	-1.266094
150	3.142236	-5.73278	-1.900038
180	3.776313	-4.078423	-2.82721
210	3.409436	-2.283392	-3.833214
240	2.031682	-0.8694557	-4.625636
270	1.911582E-06	-0.3289364	-4.928564
300	-2.031677	-0.8694539	-4.625637
330	-3.409439	-2.28339	-3.833213
BEAM #2, OFF-AXIS, GAIN = 73.26 dB			
ELEVATION=0	AZIMUTH=-.11		
XF=0.3649271	YF=1.071641	ZF=10.95	
0	-3.928772	-4.058858	-2.742575
30	-3.320515	-5.705444	-1.82125
60	-1.967784	-6.842211	-1.218378
90	-0.2157934	-7.259291	-1.042368
120	1.558029	-6.880079	-1.31276
150	2.961807	-5.75591	-1.977383
180	3.621669	-4.095442	-2.910003
210	3.272398	-2.290485	-3.898381
240	1.903813	-0.8707582	-4.659845
270	-0.1247992	-0.3288674	-4.927531
300	-2.158704	-0.867762	-4.58935
330	-3.544839	-2.275111	-3.766002

Continued --

TABLE 1 (continued):

BEAM #3, OFF-AXIS, GAIN = 73.24 dB
ELEVATION=-0.095 AZIMUTH=-0.055
XF=0.1813012 YF=-1.392197 ZF=10.95

0	-3.863906	-3.933782	-2.859708
30	-3.248926	-5.584542	-1.981122
60	-1.879396	-6.725815	-1.398939
90	-0.1078045	-7.137859	-1.213047
120	1.674683	-6.744756	-1.446063
150	3.069689	-5.6098	-2.059097
180	3.710422	-3.952122	-2.943352
210	3.344159	-2.161614	-3.900231
240	1.967252	-0.7568368	-4.651684
270	-6.239274E-02	-0.2209279	-4.928621
300	-2.094673	-0.7553069	-4.616447
330	-3.480332	-2.153872	-3.83408

BEAM #4, OFF-AXIS, GAIN = 73.24 dB
ELEVATION=-0.095 AZIMUTH=0.055
XF=-0.1813012 YF=-1.392197 ZF=10.95

0	-3.710428	-3.952128	-2.943345
30	-3.069689	-5.609799	-2.059097
60	-1.674682	-6.744756	-1.446063
90	0.1078048	-7.137859	-1.213047
120	1.879396	-6.725815	-1.398939
150	3.248926	-5.584542	-1.981122
180	3.8639	-3.93378	-2.859714
210	3.48034	-2.15388	-3.834074
240	2.094677	-0.7553085	-4.616446
270	6.239656E-02	-0.2209279	-4.928621
300	-1.967246	-0.7568346	-4.651685
330	-3.344151	-2.16161	-3.900235

Continued --

TABLE 1 (continued):

BEAM #5, OFF-AXIS, GAIN = 73.26 dB
ELEVATION=0 AZIMUTH=0.11
XF=-0.3649271 YF=-1.071641 ZF=10.95

0	-3.621676	-4.095445	-2.909998
30	-2.961807	-5.75591	-1.977383
60	-1.558029	-6.880079	-1.31276
90	0.2157937	-7.259291	-1.042368
120	1.967785	-6.842211	-1.821251
150	3.320508	-5.705446	-1.218378
180	3.928765	-4.058851	-2.742582
210	3.544843	-2.275115	-3.765998
240	2.158708	-0.8677646	-4.58935
270	0.124803	-0.3288674	-4.92753
300	-1.903812	-0.8707563	-4.659846
330	-3.272395	-2.290478	-3.898385

BEAM #6, OFF-AXIS - GAIN = 73.24 dB
ELEVATION=0.095 AZIMUTH=0.055
XF=0.1836472 YF=-0.7468906 ZF=10.95

0	-3.68635	-4.220627	-2.792935
30	-3.033151	-5.877003	-1.81749
60	-1.646171	-6.996703	-1.132028
90	0.1079891	-7.380964	-0.8713872
120	1.851211	-6.977786	-1.084757
150	3.212623	-5.851799	-1.739327
180	3.839975	-4.202387	-2.709144
210	3.473044	-2.404126	-3.76414
240	2.095245	-0.9817554	-4.597521
270	6.240829E-02	-0.436828	-4.926448
300	-1.967773	-0.9832198	-4.632777
330	-3.336774	-2.411757	-3.830372

Continued --

TABLE 1

Computed Feed Phase Centers and Projected Aperture Pattern at the Subreflector for the 6.25 cm Multibeam Receiver

ϕ	X_1	Y_1	Z_1
BEAM #1, ON-AXIS, GAIN = 73.27 Db			
ELEVATION=0, AZIMUTH=0			
XF=0	YF=-1.067257	ZF=10.95	
0	-3.776319	-4.078425	-2.827205
30	-3.142237	-5.73278	-1.900038
60	-1.763581	-6.863941	-1.266094
90	1.526192E-07	-7.26236	-1.042807
120	1.763582	-6.86394	-1.266094
150	3.142236	-5.73278	-1.900038
180	3.776313	-4.078423	-2.82721
210	3.409436	-2.283392	-3.833214
240	2.031682	-0.8694557	-4.625636
270	1.911582E-06	-0.3289364	-4.928564
300	-2.031677	-0.8694539	-4.625637
330	-3.409439	-2.28339	-3.833213
BEAM #2, OFF-AXIS, GAIN = 73.26 dB			
ELEVATION=0	AZIMUTH=-.11		
XF=0.3649271	YF=1.071641	ZF=10.95	
0	-3.928772	-4.058858	-2.742575
30	-3.320515	-5.705444	-1.82125
60	-1.967784	-6.842211	-1.218378
90	-0.2157934	-7.259291	-1.042368
120	1.558029	-6.880079	-1.31276
150	2.961807	-5.75591	-1.977383
180	3.621669	-4.095442	-2.910003
210	3.272398	-2.290485	-3.898381
240	1.903813	-0.8707582	-4.659845
270	-0.1247992	-0.3288674	-4.927531
300	-2.158704	-0.867762	-4.58935
330	-3.544839	-2.275111	-3.766002

Continued --

TABLE 1 (continued):

BEAM #3, OFF-AXIS, GAIN = 73.24 dB
ELEVATION=-0.095 AZIMUTH=-0.055
XF=0.1813012 YF=-1.392197 ZF=10.95

0	-3.863906	-3.933782	-2.859708
30	-3.248926	-5.584542	-1.981122
60	-1.879396	-6.725815	-1.398939
90	-0.1078045	-7.137859	-1.213047
120	1.674683	-6.744756	-1.446063
150	3.069689	-5.6098	-2.059097
180	3.710422	-3.952122	-2.943352
210	3.344159	-2.161614	-3.900231
240	1.967252	-0.7568368	-4.651684
270	-6.239274E-02	-0.2209279	-4.928621
300	-2.094673	-0.7553069	-4.616447
330	-3.480332	-2.153872	-3.83408

BEAM #4, OFF-AXIS, GAIN = 73.24 dB
ELEVATION=-0.095 AZIMUTH=0.055
XF=-0.1813012 YF=-1.392197 ZF=10.95

0	-3.710428	-3.952128	-2.943345
30	-3.069689	-5.609799	-2.059097
60	-1.674682	-6.744756	-1.446063
90	0.1078048	-7.137859	-1.213047
120	1.879396	-6.725815	-1.398939
150	3.248926	-5.584542	-1.981122
180	3.8639	-3.93378	-2.859714
210	3.48034	-2.15388	-3.834074
240	2.094677	-0.7553085	-4.616446
270	6.239656E-02	-0.2209279	-4.928621
300	-1.967246	-0.7568346	-4.651685
330	-3.344151	-2.16161	-3.900235

Continued --

TABLE 1 (continued):

BEAM #5, OFF-AXIS, GAIN = 73.26 dB
ELEVATION=0 AZIMUTH=0.11
XF=-0.3649271 YF=-1.071641 ZF=10.95

0	-3.621676	-4.095445	-2.909998
30	-2.961807	-5.75591	-1.977383
60	-1.558029	-6.880079	-1.31276
90	0.2157937	-7.259291	-1.042368
120	1.967785	-6.842211	-1.821251
150	3.320508	-5.705446	-1.218378
180	3.928765	-4.058851	-2.742582
210	3.544843	-2.275115	-3.765998
240	2.158708	-0.8677646	-4.58935
270	0.124803	-0.3288674	-4.92753
300	-1.903812	-0.8707563	-4.659846
330	-3.272395	-2.290478	-3.898385

BEAM #6, OFF-AXIS - GAIN = 73.24 dB
ELEVATION=0.095 AZIMUTH=0.055
XF=0.1836472 YF=-0.7468906 ZF=10.95

0	-3.68635	-4.220627	-2.792935
30	-3.033151	-5.877003	-1.81749
60	-1.646171	-6.996703	-1.132028
90	0.1079891	-7.380964	-0.8713872
120	1.851211	-6.977786	-1.084757
150	3.212623	-5.851799	-1.739327
180	3.839975	-4.202387	-2.709144
210	3.473044	-2.404126	-3.76414
240	2.095245	-0.9817554	-4.597521
270	6.240829E-02	-0.436828	-4.926448
300	-1.967773	-0.9832198	-4.632777
330	-3.336774	-2.411757	-3.830372

Continued --

TABLE 1 (continued):

BEAM #7, OFF-AXIS, GAIN = 73.24 dB
ELEVATION=0.095 AZIMUTH=-0.055
XF=0.1836472 YF=-0.7468906 ZF=10.95

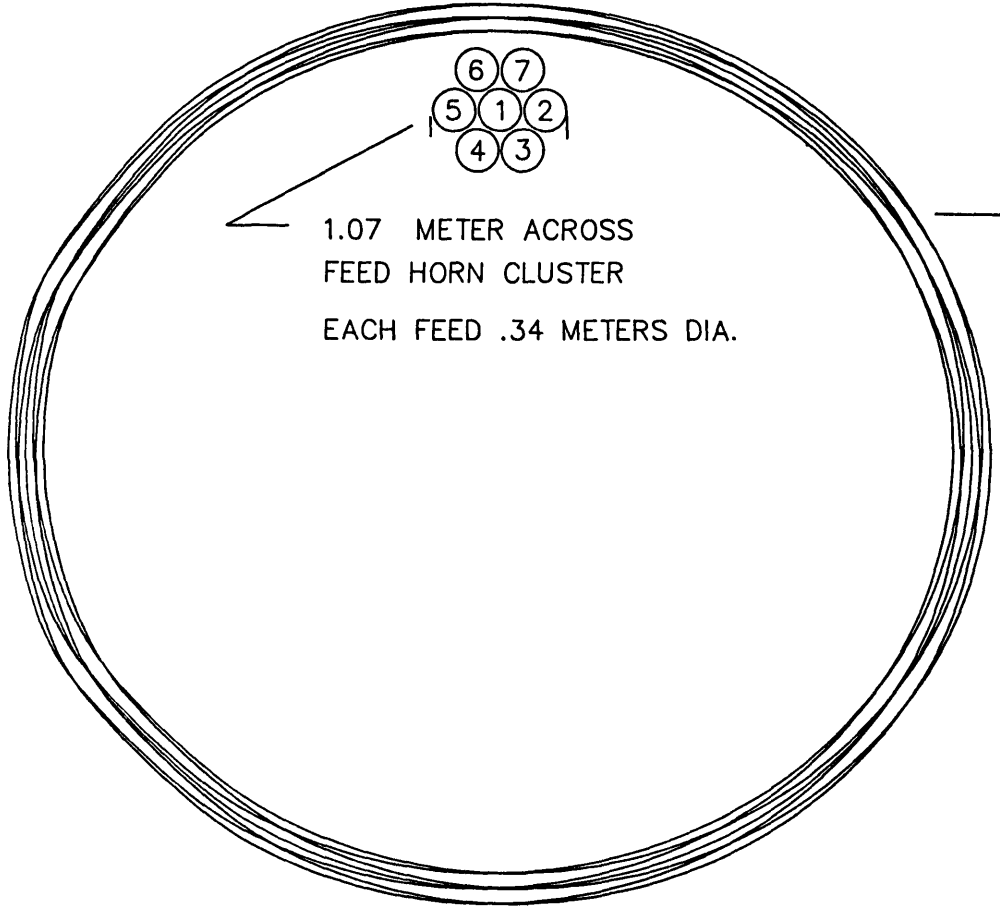
0	-3.839975	-4.202395	-2.709139
30	-3.212619	-5.8518	-1.739327
60	-1.851215	-6.977786	-1.084757
90	-0.1079888	-7.380964	-0.8713872
120	1.646169	-6.996703	-1.132028
150	3.033154	-5.877002	-1.817489
180	3.686344	-4.220625	-2.792941
210	3.336776	-2.411758	-3.83037
240	1.967778	-0.9832227	-4.632777
270	-6.240446E-02	-0.436828	-4.926448
300	-2.095243	-0.981754	-4.597522
330	-3.473041	-2.404125	-3.764142

******

FIGURE 1

6.25 CM MULTIBEAM RECEIVER FOR THE GBT

ALL BEAMS



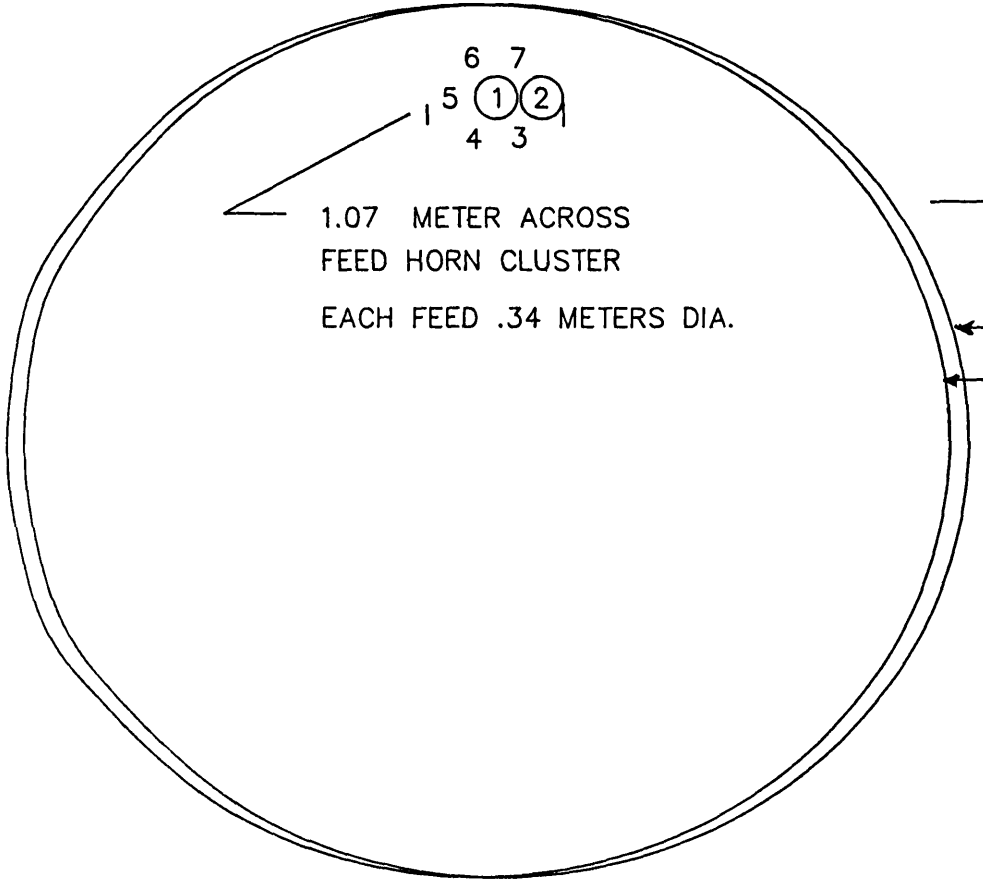
APERTURE RIM PATTERN
ON SUBREFLECTOR FOR
EACH BEAM

BEAM #	ELEVATION	AZIMUTH
1	0 DEGS.	0 DEGS.
2	0.0	−0.11
3	−0.095	−0.055
4	−0.095	0.055
5	0.0	−0.11
6	0.095	0.055
7	0.095	−0.055

FIGURE 2

6.25 CM MULTIBEAM RECEIVER FOR THE GBT

BEAMS 1 and 2



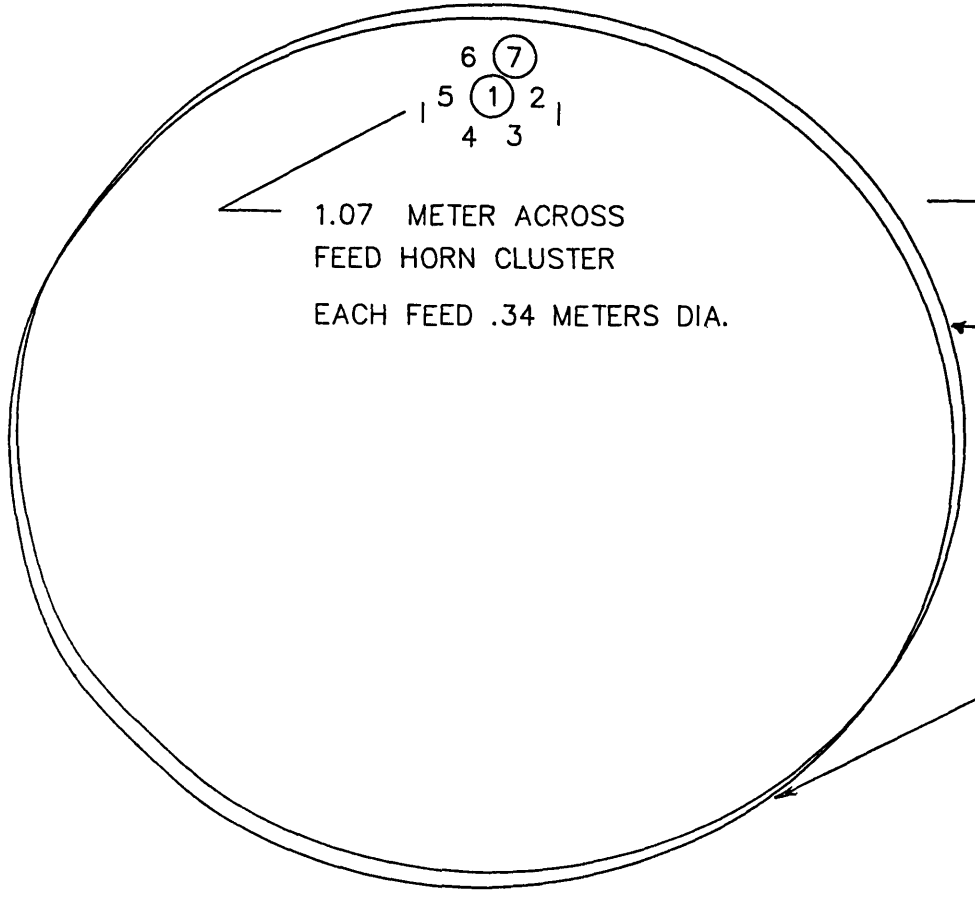
APERTURE RIM PATTERN
ON SUBREFLECTOR FOR
EACH BEAM

BEAM #	ELEVATION	AZIMUTH
1	0 DEGS.	0 DEGS.
2	0.0	−0.11
3	−0.095	−0.055
4	−0.095	0.055
5	0.0	−0.11
6	0.095	0.055
7	0.095	−0.055

FIGURE 3

6.25 CM MULTIBEAM RECEIVER FOR THE GBT

BEAMS 1 and 7



APERTURE RIM PATTERN
ON SUBREFLECTOR FOR
EACH BEAM

BEAM #	ELEVATION	AZIMUTH
1	0 DEGS.	0 DEGS.
2	0.0	−0.11
3	−0.095	−0.055
4	−0.095	0.055
5	0.0	−0.11
6	0.095	0.055
7	0.095	−0.055