GBT Memo No. 49

NATIONAL RADIO ASTRONOMY OBSERVATORY
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AXIAL FOCUSING

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In order to achieve precise axial focusing in practice, the prime focus feed or the subreflector is moved axially from its nominal position in either direction until the gain of the telescope has dropped by a certain amount, say 3 dB. The feed or the subreflector is then moved to a location precisely halfway between the above extremities for achieving axial focusing. An assumption made here is that the drop in gain with distance moved is the same in either direction. In the case of the GBT, the axis along which the subreflectors are to be moved (without the telescope beam shifting in the sky) for axial focusing and the amount of movement required had to be determined. This memorandum presents results of a study carried out to determine the above.

For the big subreflector M1 (7.55m x 7.95m), the axis of focusing is 36.73° from the axis of the parent paraboloid (the main reflector) or 24.4° from the secondary focus feed axis as in Figure 1. Table 1 gives the amount of axial movements required for approximately 3 dB gain loss at 1.42 and 8 GHz. This is 2.46 wavelengths for movement towards (positive) the main reflector at both frequencies and 1.6 wavelengths at 1.42 GHz and 1.47 wavelengths at 8 GHz for movement away (negative). In each of the above cases, the pointing error is less than 1/20 of the half-power beamwidth (HPBW). Also given in the table are results for the axis of focusing tilted by ± 0.5° from 36.73°. The positive/negative signs on the pointing error values indicate the beam shift on either side of the telescope axis.

In the case of the small subreflector M2 (4.07m x 4.35m), the axis of focusing is 38.79° from the paraboloid axis. Results for this case at 5 and 100 GHz are presented in Table 2. The amount of movement required for a 3 dB gain loss is different from Table 1 because of the different magnifications for the two cases. In both of the above cases, the axes are picked so that the pointing error is zero at the higher frequency.

It is mechanically simpler to have a common axis for axial focusing for the two subreflectors. The results for the case of M1 when the 38.79° axis (the axis for M2) is used is presented in Table 3. The axial movement for a 3 dB gain loss is about the same as in Table 1, but the pointing errors are much larger and have exceeded the $\frac{1}{20}$ HPBW values. However, by translating M1 in the elevation plane, the pointing errors can be minimized to those values in Table 1.

The gain loss as a function of movement of the subreflector away from its nominal position has been calculated. Figures 2 and 3 are for M1 along the 36.73° and 38.79° axes, respectively, at 1.42 GHz. Figure 4 shows gain loss curve for M2 at 5 GHz. As is obvious from the figures, the gain loss drops off faster for movement away from the main reflector than for movement towards the main reflector. The forward spillover (spillover past the subreflector) increases when the subreflector is moved away, while decreasing when moved towards the main reflector, and possibly this is the reason for the asymmetry in the gain loss curve. At 1 GHz, the amount of travel required for a 3 dB gain loss for M1 may be too large from a mechanical point of view. Hence, any suitable value less than 3 dB may be used. For example, for 1 dB gain loss in Figure 3, the amounts of travel required are +1.65 and -0.8 wavelengths, and at 1 GHz this would necessitate a total travel of 29 inches.

Figures 2 and 3 seem to indicate that the wrong nominal position has been picked for the subreflector. However, the cross-polarization level is the lowest at zero displacement and, hence, is the optimum position for the subreflector M1.

TABLE 1. Subreflector - M1 (7.55m x 7.95m) on 36.73° Axis.

Freq. (GHz)	Angle Between Focus Axis and Paraboloid Axis (degrees)	Axial Movement		Gain Loss (dB)	Pointing Error (arcsecs)	Axial Movement		Gain Loss (dB)	Pointing Error (arcsecs)
		d_1(ins.)	d_1/λ			d_2(ins.)	d_2/λ		
1.42	θ_1	20.5	2.46	-2.98	25.2	-13.310	-1.6	-2.99	10.8
	θ_1 - 0.5	20.5	2.46	-2.97	41.0	-13.310	-1.6	-2.98	0
	θ_1 + 0.5	20.5	2.46	-2.98	9.7	-13.310	-1.6	-2.99	21.9
8.00	θ_1	3.638	2.46	-3.08	0	- 2.170	-1.47	-3.02	1.1
	θ_1 - 0.5	3.638	2.46	-3.07	2.2	- 2.170	-1.47	-3.00	-1.0
	θ_1 + 0.5	3.638	2.46	-3.08	-3.6	- 2.170	-1.47	-3.01	2.9

Note: $\theta_1 = 36.73°$

$\frac{1}{20}$ HPBW at 1.42 GHz = 26.3"

$\frac{1}{20}$ HPBW at 8 GHz = 4.6"

TABLE 2. Subreflector - M2 (4.07m x 4.33m) on 38.79° Axis.

Freq. (GHz)	Angle Between Focus Axis and Paraboloid Axis (degrees)	Axial Movement		Gain Loss (dB)	Pointing Error (arcsecs)	Axial Movement		Gain Loss (dB)	Pointing Error (arcsecs)
		d_1(ins.)	d_1/λ			d_2(ins.)	d_2/λ		
5	θ_2	5.315	2.25	-3.01	3.6	-4.630	-1.95	-3.00	2.9
	θ_2 - 0.5	5.315	2.25	-3.00	7.2	-4.630	-1.95	-3.00	-0.4
	θ_2 + 0.5	5.315	2.25	-3.01	0	-4.630	-1.95	-3.00	6.1
100	θ_2	0.272	2.30	-3.06	0	- 0.215	-1.82	-3.00	0
	θ_2 - 0.5	0.272	2.30	-3.06	0.2	- 0.215	-1.82	-2.99	0
	θ_2 + 0.5	0.272	2.30	-3.07	-0.2	- 0.215	-1.82	-3.01	0

Note: $\theta_2 = 38.79°$

$\frac{1}{20}$ HPBW at 5 GHz = 7.2"

$\frac{1}{20}$ HPBW at 100 GHz = 0.3"

TABLE 3. Subreflector - M1 (7.55m x 7.95m) on 38.79° Axis.

Freq. (GHz)	Angle Between Focus Axis and Paraboloid Axis (degrees)	Axial Movement		Gain Loss (dB)	Pointing Error (arcsecs)	Axial Movement		Gain Loss (dB)	Pointing Error (arcsecs)
		d_1(ins.)	d_1/λ			d_2(ins.)	d_2/λ		
1.42	θ_2	20.5	2.46	-2.99	-39.6	-13.310	-1.6	-3.01	57.6
	θ_2 - 0.5	20.5	2.46	-2.99	-21.6	-13.310	-1.6	-3.00	45.4
	θ_2 + 0.5	20.5	2.46	-2.99	-54.0	-13.310	-1.6	-3.01	67.0
8.00	θ_2	3.602	2.44	-3.00	-13.0	- 2.156	-1.46	-2.98	8.6
	θ_2 - 0.5	3.602	2.44	-3.00	- 9.7	- 2.156	-1.46	-2.98	6.8
	θ_2 + 0.5	3.602	2.44	-3.01	-13.3	- 2.156	-1.46	-2.98	10.1

Note: $\theta_2 = 38.79°$

$\frac{1}{20}$ HPBW at 1.42 GHz = 26.3"

$\frac{1}{20}$ HPBW at 8 GHz = 4.6"

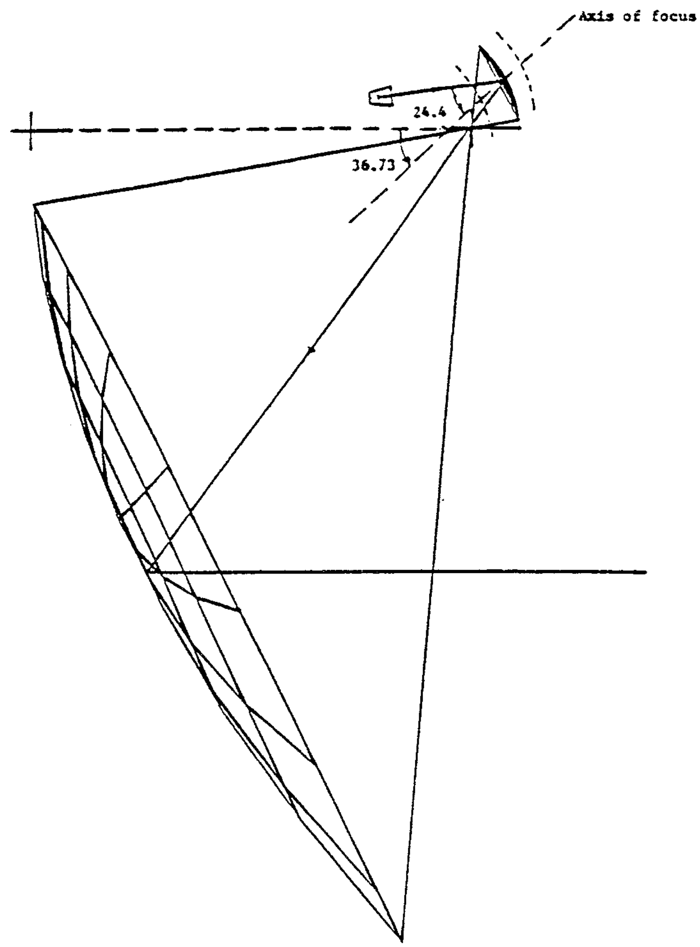

Fig. 1. Axis of focusing for subreflector M1.

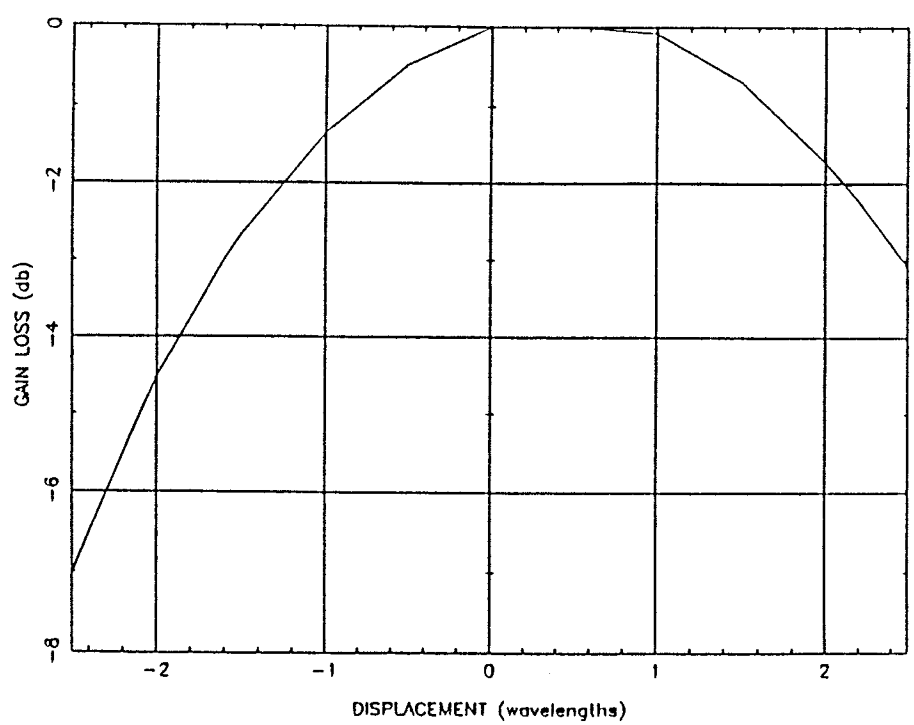

Fig. 2. Gain loss vs. displacement of M1 along 36.73° axis at 1.42 GHz.

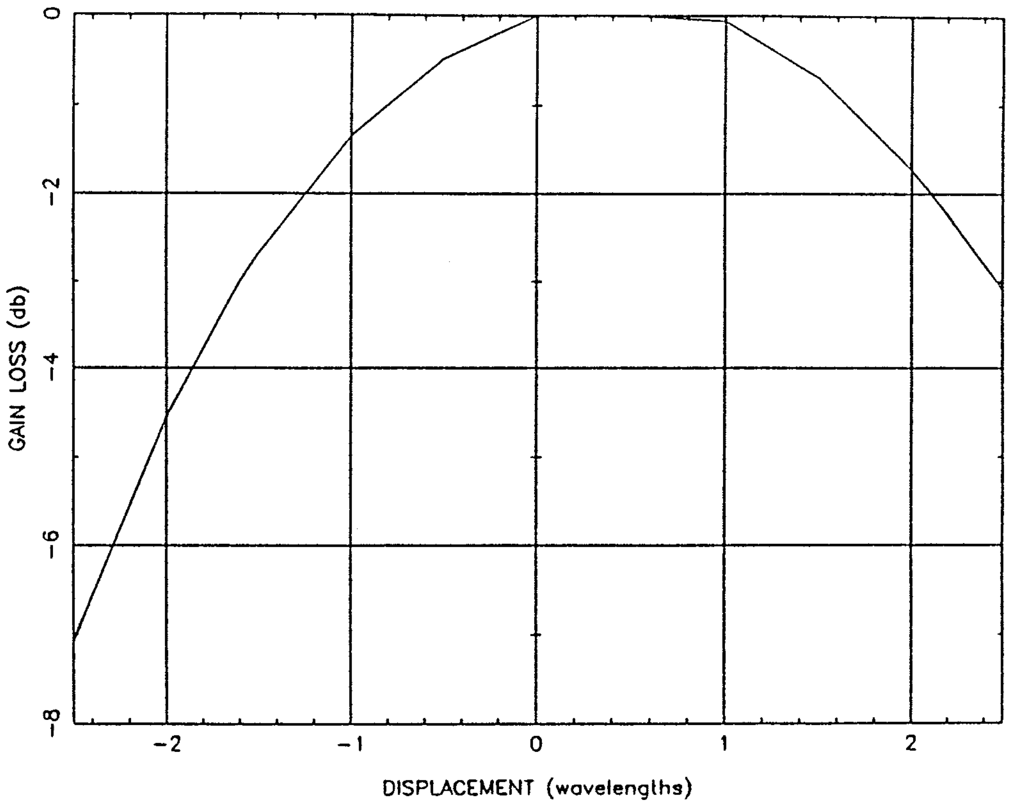

Fig. 3. Gain loss vs. displacement of M1 along 38.79° axis at 1.42 GHz.

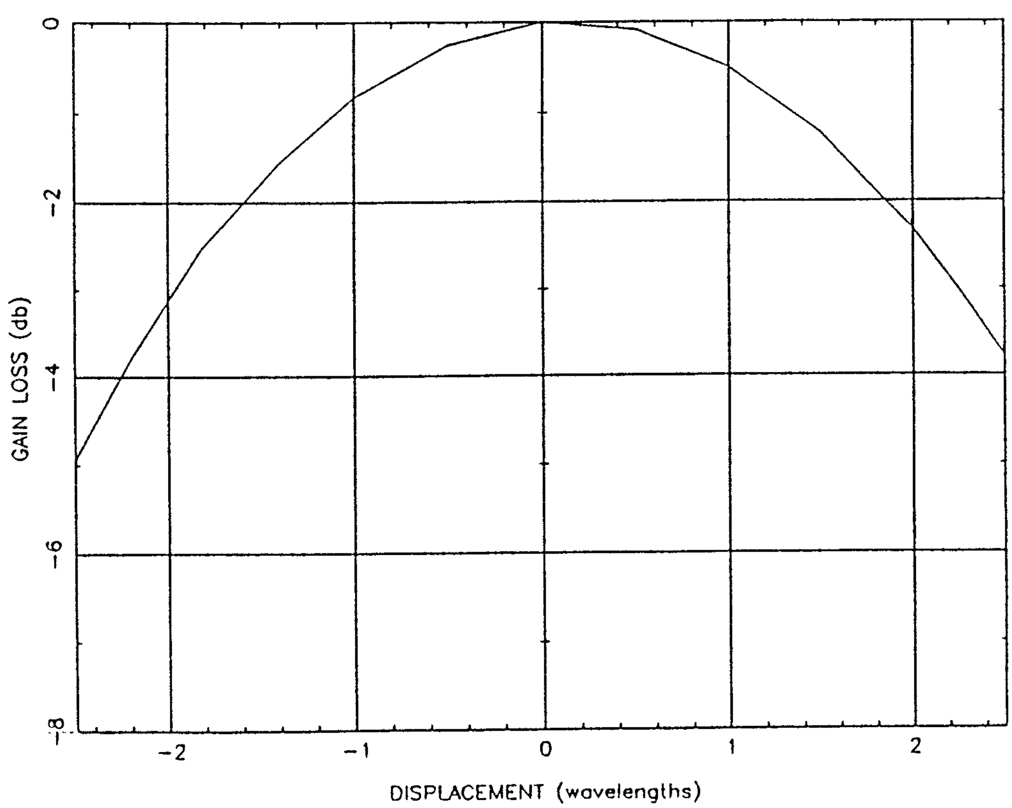

Fig. 4. Gain loss vs. displacement of M2 along 38.79° axis at 5 GHz.