GBT Memo No. 26

NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, WV

MEMORANDUM November 28, 1989

To: GBT Optics Group

From: J. Coe

Subj: **Beam Switching using Tilting Mirrors in a Gregorian System**

Some observations require beam switching to cancel atmospheric and baseline effects. Beam switching can be done by nutating the subreflector, but the illumination pattern on the main reflector and associated spillover changes for the different subreflector positions.

In a Gregorian system a mirror can be positioned between the feed and subreflector so the beam can be switched by tilting the mirror. The practicality of such a system depends upon how large a mirror would be required. If the mirror size is smaller or equivalent to the subreflector size, then the tilting mirror should be used since it could also be used for receiver selection. The mirror must be large enough to intercept the feed power pattern down to the -30 dB level. The distance from feed to mirror plus the mirror to subreflector must be equal to the feed to subreflector distance with no mirror present. Also, if the beam is to be switched by tilting the mirror only, the mirror must be at a point between the feed and subreflector located at the intersection the positive beam scan angle ray and the negative beam equal scan angle central ray. To determine this point, a version of the program CLCGG was used. [1] This program allows one to determine the best secondary focal point for a given main beam scan angle. It also locates on the subreflector a circle of rays received from the main reflector at any user selected main aperture radius. This radius can be set to the main reflector aperture radius if the outline of the edge of the main reflector rays on the subreflector for a given scan angle is desired. To locate the central ray of the scanned beam on the subreflector, a small number is used for the radius.

Beam switching of + and - 5 half-power beamwidths will be studied. At 6 cm the half-power beamwidth is 0.038° and 5 HPBW is 0.19°.

The Gregorian system analyzed has the parameters of main aperture radius: R - 50 meters; main aperture offset, YC - 54 meters; focal length, F - 60 meters; Gregorian subreflector focal length, C - 5 meters; subreflector axis tilt, β - 2.5°; feed horn tilt, α - 11.5°. The horn semiflare angle subtended by the subreflector is 10.2° and the subreflector size is 2.1 x 2.3 meters.

The program CLCGG2 with these parameters was used with the inputs: Elevation = 0; azimuth = 0.19°, and Radius = 50 meters. From the outputs the best focal point for +0.19° azimuth scan is X_F = 0.958 meters, Y_F = -0.265 meters, and Z_F = 5.1 meters with the origin at the paraboloid focus and Z positive toward the paraboloid axis. The point on the subreflector where the center of the scanned beam is located at X_C = 0.244 meters, Y_C = -1.17 meters and Z_C = 1.035 meters. Running C2CGG2 again with azimuth scan of -0.19° results in X_F = 0.958 meters and X_C = -0.244 meters. Now in the azimuth plane we can locate the point where the mirror must be positioned as the intersection of the lines for X_F to X_C for positive and negative scan angles. The total distance in the Z direction from focus to subreflector is $Z_F - Z_C$ = 6.27 meters. The feed phase centers to mirror distance L_C can be computed:

$$X_F/L_C = X_C/(6.27 - L_C)$$

$$X_E/X_C = L_C/(6.27 - L_C) \text{ and } (X_F/X_C) = 0.958/0.244$$

$$L_C = 3.93\ (6.27 - L_C) = 4.99 \text{ meters}$$

The feed phase center to mirror distance L_C can then be used to determine the mirror size.

$$\text{Mirror Radius} = L_C * \tan(\theta_{30\ dB}) * \sec\psi$$

where

L_C is the feed phase center to mirror center distance.

$\theta_{30\ dB}$ is the feed pattern angle at -30 dB taper.

ψ is the feed axis to mirror surface angle.

Using 20° for $\theta_{30\ db}$ and ψ = 45°, the Mirror Radius = 4.99 * tan 20° * sec(45°) = 2.57 meters. A mirror over 5 meters in diameter would be needed to provide beam switching by tilting the mirror. This size mirror is much too large to be considered as a practical solution to the beam switching problem. It appears that nutating the subreflector is a better solution.

REFERENCE

[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).

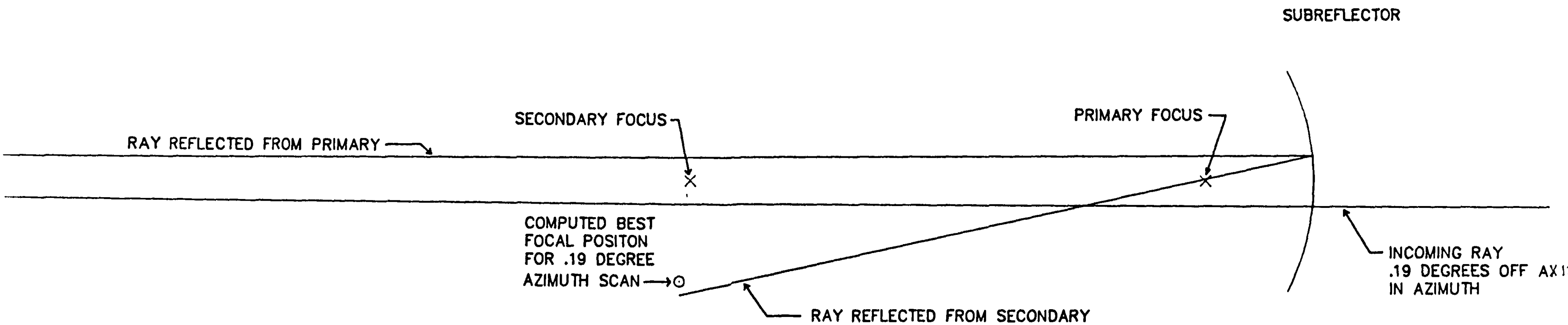

FIGURE 1

Azimuth Scan Ray Trace for a Gregorian System

APPENDIX A

As a check on the computations in the program CLCGG the central ray offset 0.19° in azimuth was plotted to the main reflector, reflected back to the subreflector and then to the secondary focal region as shown in Figure 1: Azimuth Scan Ray Trace for a Gregorian System. The computed best focal position using CLCGG of $X_F = -0.958$ meters and the point the ray strikes the subreflector $X_C = 0.244$ meters agrees well with the ray tracing as shown in Figure 1.