GBT Memo No. 17

NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, WV

MEMORANDUM

October 4, 1989

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Subj: **Spillover Effects**

The attached document discusses the tradeoffs involved when considering the question of placing the feed support arm above or below an offset main reflector. Together with the document being distributed by Srikanth, presenting the results of his numerical calculations, it hopefully will prove useful when deciding the optical configuration of the GBT.

Since we could use either cassegrain or gregorian subreflectors, there are four possible configurations: arm below with gregorian or cassegrain, and arm above with gregorian or cassegrain. As is shown in the two supporting documents, the preferred configurations, from the standpoint of spillover noise, are arm below with cassegrain or arm above with gregorian. Of these two, the former is better by 2-3K over most of the antenna's elevation range, not an insignificant amount with today's receivers.

This is, of course, a multifaceted problem, and there are some aspects of the gregorian arrangement that makes it attractive. However, in my view, the 2-3K noise penalty mentioned above (which will be 10-20% of the total system temperature in the 1-10 GHz range) is serious enough that we should be absolutely sure that there is not some way to put the arm on the bottom at a reasonable cost.

RDN/cjd

Enclosure
"An Analysis of Spillover for
a Clear Aperture Antenna"

AN ANALYSIS OF SPILLOVER FOR A
CLEAR APERTURE ANTENNA

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October 4, 1989

1) Effects of Feed Support Arm Above/Below Main Reflector

Spillover noise can be split into two components:

a) "Forward Spillover": This is due to feed spillover and diffraction around the rim of the subreflector. This energy is in a cone (like an ice-cream cone because energy in the center is mostly blocked by the subreflector), the cone axis tilted at angle $\alpha - \beta$ from the main beam direction. β is tilt of the axis of the subreflector with respect to the paraboloid axis; α is tilt of the feed axis with respect to subreflector axis. (See Figure 1.) Let us use the convention that α is positive when the feed is tilted toward the main reflector side of the paraboloid axis, and negative otherwise. Hence, α is positive for cassegrain and negative for gregorian; β is always negative, and for the cases we are considering, $|\alpha| > |\beta|$. Therefore, the forward spillover cone is on opposite sides of the main beam for cassegrain and gregorian arrangements. (See Figures 2 and 3.) Approximate values for this cone tilt is +10° to +25° for cassegrain geometry, and -10° to -15° for gregorian. The angular radius of the cone is θ_H, θ_H being the half beam angle of the feed illumination pattern, and ranges from about 9° to 15°. θ_H, α, and β are interrelated so that the forward spillover cone is approximately tangent to the main beam (within a few degrees). The magnitude of the spillover cone can be controlled somewhat with subreflector illumination taper and/or flanges, but we should arrange the geometry to keep this cone out of the ground. The noise penalty is greater than 10 K at elevations below 30°, if the forward spillover cone is on the wrong side of the main beam. This means:

If the arm is on top ...... use gregorian;
If the arm is on bottom ... use cassegrain.

b) "Rear Spillover": This is energy, coming from the subreflector or prime focus feed, diffracting around or spilling past the rim of the primary reflector. This, too, is an ice-cream cone, axis tilted at an angle of $180° - \theta_0$ from the main beam (θ_0 is about 45° for geometries we are considering), and with angular radius of θ^* ($\theta^* \approx 38°$). (See Figure 4.) There is no major difference between gregorian and cassegrain; θ_0 is about 5° less for the gregorian case.

Let us now consider the difference in rear spillover when the arm is above or below the main reflector. When the main beam is pointed at the zenith, rear spillover in the two cases is exactly the same; one edge of the rear spillover cone is $180 - \theta_o + \theta^* \simeq 180°$ from the main beam. The other is at $180 - \theta_o - \theta^* \simeq 90°$ or pointed about at the horizon. With the arm below, the cone rotates into the sky as the main beam rotates down toward the horizon; with the arm above, the cone rotates in the opposite direction and stays in the earth. Therefore, the rear spillover noise contribution is <u>worse</u> for the arm above than for the arm below, at main beam elevations away from the zenith. However, the magnitude of the penalty is less than for the forward spillover, 1.5K at 60 degrees elevation, 2K at 30 degrees, and 2.9K at 10 degrees. This is because the edges of the rear spillover cone are less "fuzzy" than the forward cone, especially when the primary reflector is being illuminated by a subreflector or dual-mode primary feed.

2) <u>Comparison with Symmetric Antenna:</u>

For a symmetrical antenna, both spillover cones are concentric with the main beam ($\alpha = \beta = \theta_o = 0$). When a symmetric antenna is pointed at the horizon, one-half the forward and rear cones are in the sky and one-half in the ground. We can better the situation with the offset reflector, by placing most of the spillover cones in the sky at low elevations. This can be done by:

<u>Principle 1</u> - Control forward spillover cone by:

a) Use gregorian if arm is on top.

b) Use cassegrain if arm is on bottom.

<u>Principle 2</u> - Control rear spillover cone by:

Place arm on bottom.

Violating Principle 1 has a very large penalty: 10-30 K at elevations below 30°.

Violating Principle 2 has a smaller penalty, 1K-3K at elevations less than 60°.

3) <u>Gregorian or Cassegrain</u>

A gregorian arrangement has several features that makes it attractive:

1) The subreflector is less oblong. For example, one of the cassegrain arrangements considered yields a sub-reflector 7.2 x 9.8 m; a similar gregorian arrangement yields 7.4 x 7.8 m subreflector.

2) A large gregorian subreflector could stay in place while using a smaller gregorian or the prime focus.

3) The distance between the main reflector edge and paraboloid axis can be reduced from about 10 m to 3 or 4 m. This may reduce the structural cost some, and makes small improvements in the illumination efficiency and prime focus cross-polarization.

4) An image of the primary aperture plane is formed in the energy beam directed by the ellipsoid toward the feed. It might be advantageous to accomplish beam switching at short wavelengths by wobbling a mirror at this image.

<u>Some Disadvantages:</u>

1) If we use gregorian with the arm at the top, one forward spillover cone edge is a few degrees into the ground (about 3°) when the main beam is pointing at the horizon. If we use cassegrain with the arm at the bottom, the edge is still about 10° above the main beam. The combination of this effect and the increased rear spillover makes the gregorian with arm on the top worse than cassegrain with arm on bottom by the following approximate amounts: 1.6K at 60° elevation, 2K at 30°, and 3.6K at 10°.

2) The gregorian subreflector must be supported about 5-6 meters further from the main reflector.

3) NRAO has no practical experience with gregorian systems.

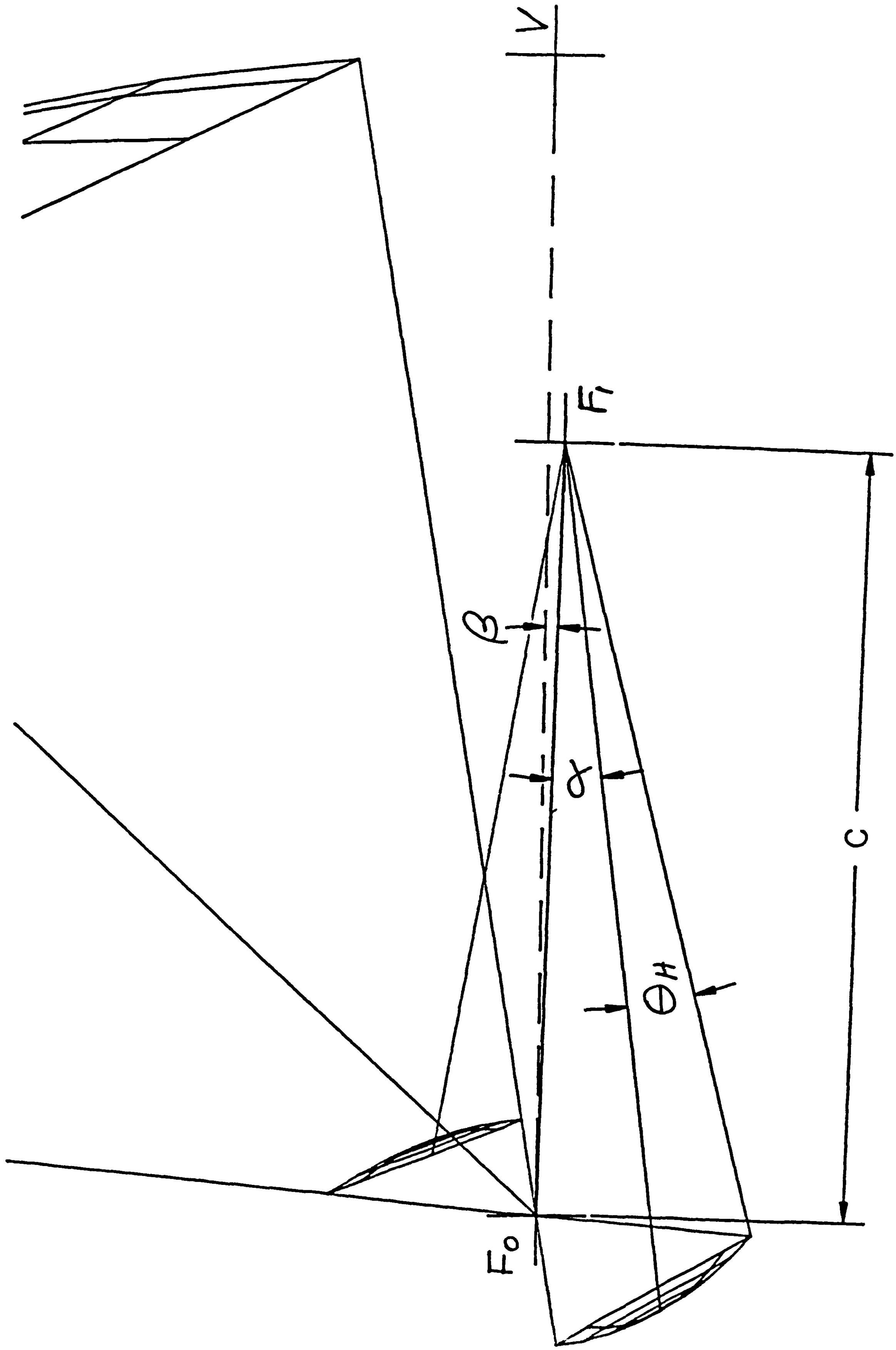

FIGURE 1

Gregorian and cassegrain arrangements.

α, β, and Θ_H are indicated for the gregorian. By convention, α is positive for cassegrain and negative for gregorian.

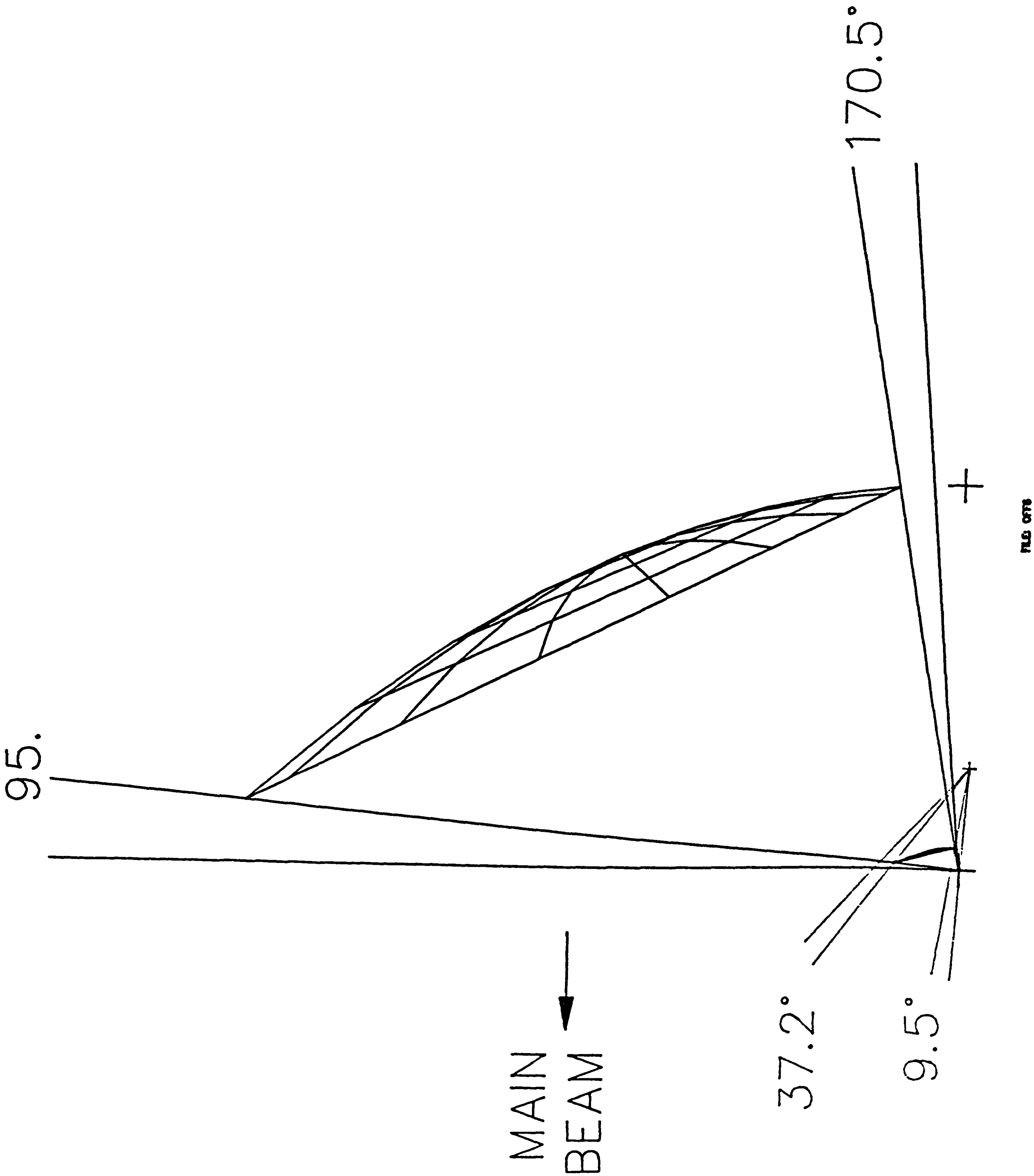

FIGURE 2

Forward and rear spillover cones indicated for a cassegrain design.

Angles indicated are at optical rims of reflectors, which correspond approximately to peaks of spillover patterns. "Edges" of spillover cones are, of course, not sharply defined due to diffraction and finite slope of feed patterns.

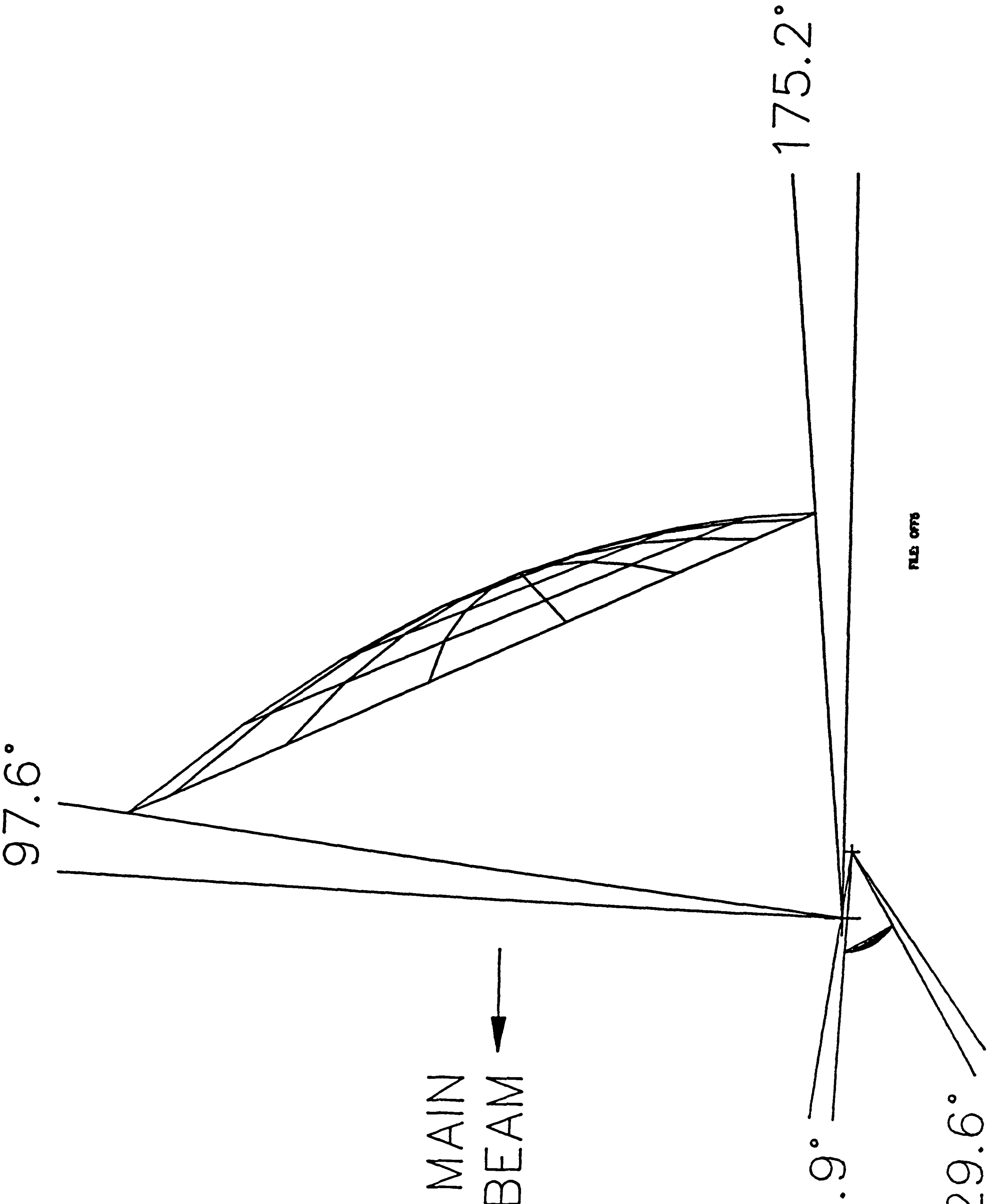

FIGURE 3

Forward and rear spillover cones indicated for a gregorian design.

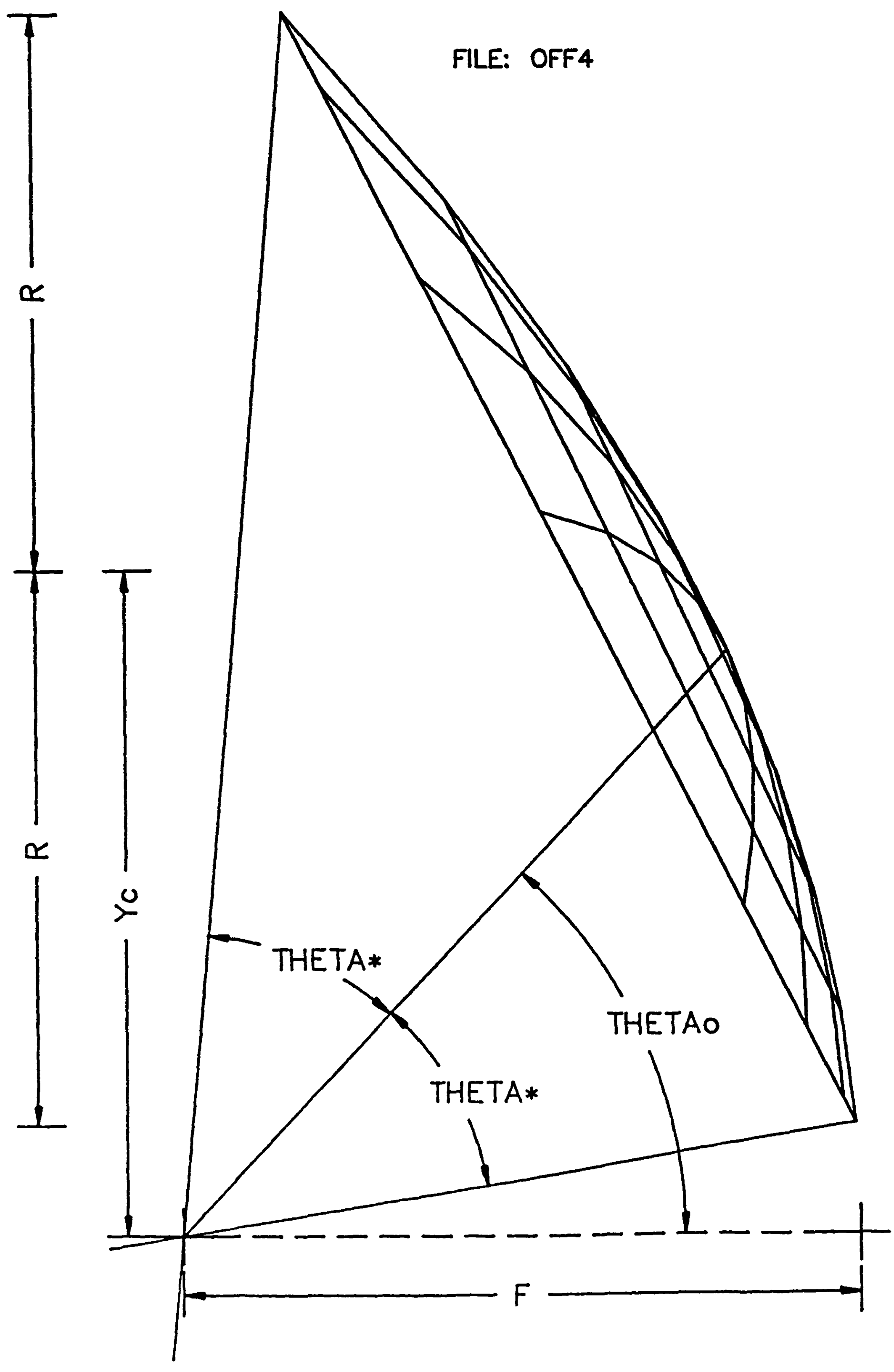

FIGURE 4

Angles Θ_o and Θ^* indicated for a clear aperture antenna.