Interoffice

NATIONAL RADIO ASTRONOMY OBSERVATORY

TUCSON, ARIZONA

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12 METER MILLIMETER WAVE TELESCOPE

MEMO No. 73

To: H. Hvatum

From: M. A. Gordon

Subject: Aperture blockage of the 12-m telescope

I. Summary

I have calculated the aperture blockage of the proposed 12-m telescope by the subreflector support truss. Two cases were considered: Lee King's design of 810826 (see the attached figures), and a variation where the support struts were extended to the reflector rim.

For the general case, the blockage consists of 3 components: blockage by the Stirling mount assembly of an incoming plane wave front, blockage by the struts of an incoming plane wave front, and blockage by the struts of the spherical wave front reflected from the surface to the feed. A Cassegrain case (like ours) can be easily considered, because all members are in the far field of the feed. Because the strut width is 63.5 wavelengths at 150 GHz, the average scattering efficiency of each strut is nearly 1.00. I assumed an illumination taper of 11db.

These results are given below:

Table 1: Aperture Blockage by a Quadrupod Structure

Design	Field efficiency	Power efficiency	Power blockage
Strut-to-ring	0.959	0.919	8.1%
Strut-to-rim	0.967	0.934	6.6%

Table 2: Percentage Distribution of Power Blockage

Design	Stirling mount and hub	Strut (plane)	Strut (spherical)
Strut-to-ring	25.7%	44.4%	29.9%
Strut-to-rim	24.8%	75.2%	---

While a strut-to-rim design offers greater telescope efficiency by 1.5%, its most attractive feature may be to permit the use of a solid template for the surface setting rather than to increase the telescope sensitivity.

As can be seen in Table 2, 75% of the blockage is due to the struts. This power blockage can be reduced substantially if the 5-inch diameter of the struts can be made smaller.

II. Calculations

The general procedure has been described by Ruze (1968). Here is how I applied his technique.

The quadrupod blockage is divided into 3 components, which I've described in Section I above. (See the attached Figure 2 of Ruze.) The aperture field blockage of each component is calculated by

$$A = \int\int B(r,\phi) f(r) dr\, d\phi \qquad (1)$$

where

$B(r,\phi) \equiv$ the geometry of the blocking element,

$f(r) \equiv$ the illumination taper, and

r, ϕ are the polar coordinates of the telescope surface (z lies along the optical axis).

The illumination taper may be expressed as:

$$f(r) = 1 - ar. \qquad (2)$$

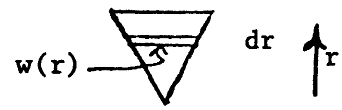
For a normalized radius ($r_{max} = 1$) and an 11db taper,

$$f^2(r) = \text{alog}\ (10/11\text{db}) = 0.0793,$$

giving the taper function

$$f(r) = 1 - 0.7182r. \qquad (3)$$

My approach was to express elements of King's design into (r, ϕ) coordinates. For example, the Stirling mount consists of 8 triangular sections arranged as an octagon. By using a function to express the width as a function of r (normalized), I transformed equation 1 into a one-dimensional integral.



$$A = 8\int_o^r w(r).f(r)\ dr \qquad (4)$$

$$= 8k\left(\frac{r^2}{2} - \frac{ar^3}{3}\right) \qquad (5)$$

where the width function is

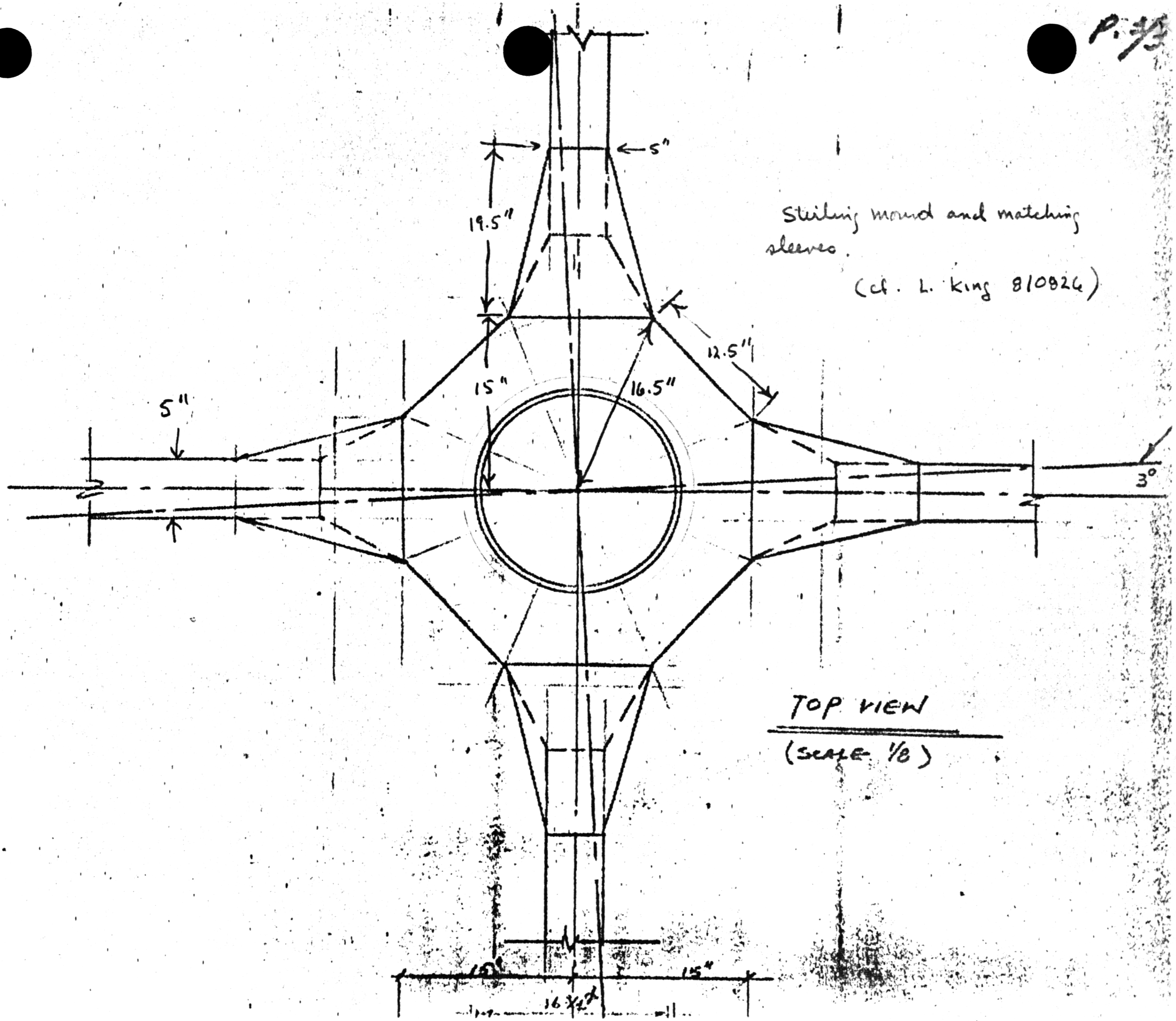
$$w(r) = kr \qquad (6)$$

This general approach was applied to both the hub and strut designs. The remaining blockage by the divergent wave was calculated by Ruze's equations with no modifications. The resulting blockages were normalized to the unblocked collecting area of the telescope, weighted by the illumination taper.

Reference: Ruze, J. 1968, Microwave Journal, December, pp. 76-80.

Stirling mound and matching sleeves.

(cf. L. King 810826)

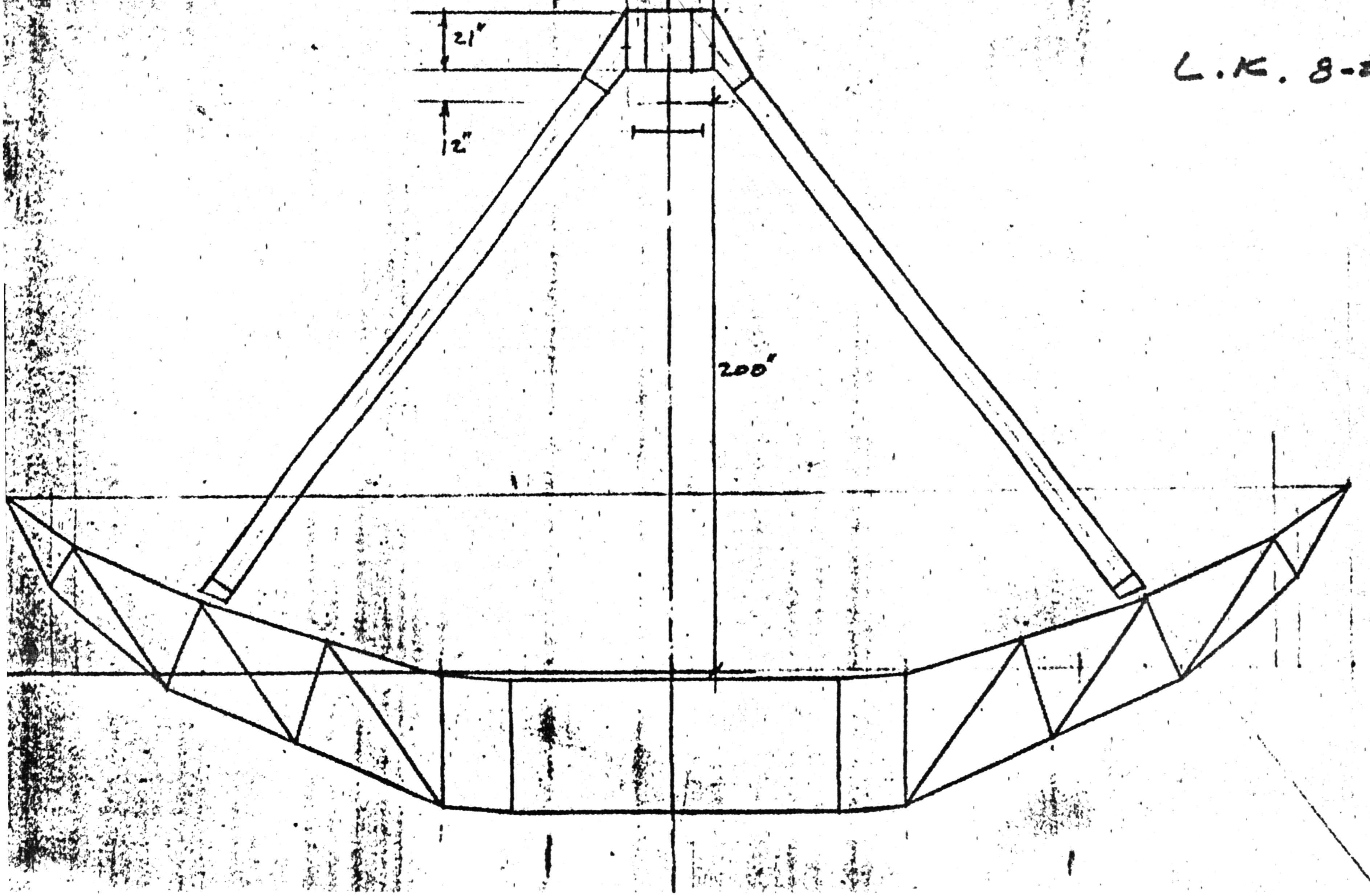


TOP VIEW

(SCALE 1/8)

JOHN PAYNE: THIS IS THE GEOMETRY FOR THE EXISTIN[G] STERLING MOUNT. PLEASE CALL ME WHAT WE SHOULD HAVE FOR THE 16¾ ϕ HOLE

L.K. 8-26-81



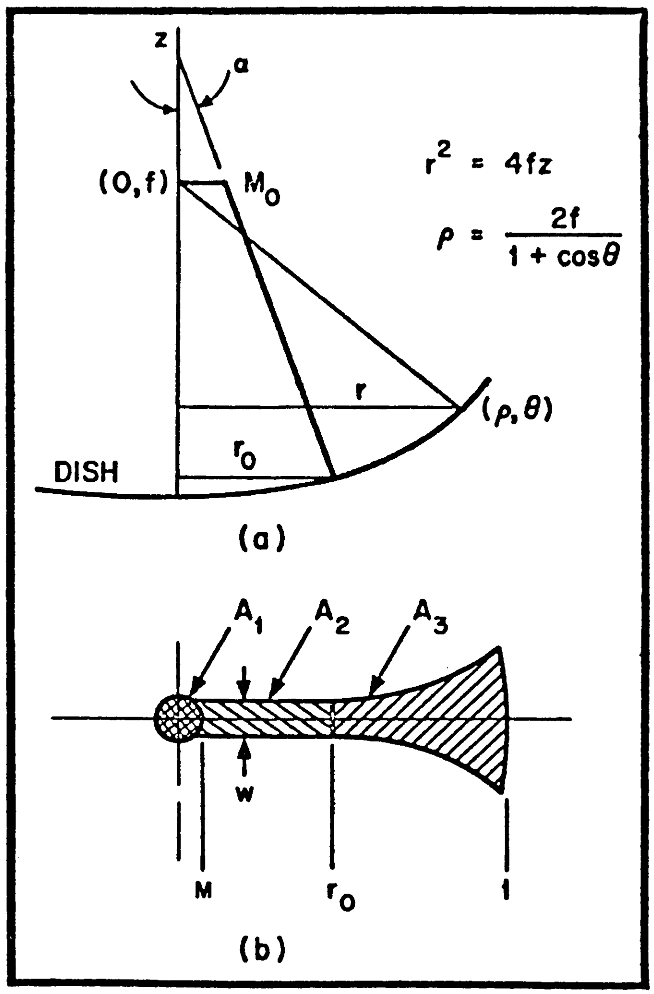


Fig. 2 — a) Geometry of feed supports; b) Projection of aperture plane.

From Ruze's paper:

$A_1 \equiv$ central hub shadow
$A_2 \equiv$ strut shadow
$A_3 \equiv$ divergent strut shadow