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March 7, 1970

MEMORANDUM

to: NRAO Counsil
from: S. von Hoerner

A Spillover Shield for the 140-ft Focus

1) General Outline

The main reason for planning a Cassegrain system for the 140-ft seems to be the reduction of spillover, for beam-switching with low-noise receivers. A simple horn feed gives too large a spillover, picking up about 20 - 30 °K additional noise from the ground. A good scalar feed may reduce this to about 10 °K, but two good scalar feeds for beam - switching would be too large for the prime focus because of coma. In Report 3 (1965) I suggested a spillover shield around the prime focus, and this was rediscussed recently. The following is a suggestion for a test of this method on the 140-ft.

Fig. 1 shows the general outline, and Fig. 2 the suggested size. The shield is a truncated cone, fitted inside and along the feed legs, reaching from the doughnut to the line of sight (focus - dish edge). The spillover radiation from the feed then is reflected by the shield into the dish and from there into the sky. The feed legs just happen to have the proper angle ($\alpha = 54.2^\circ$, with the condition that $\alpha \leq 60^\circ$). If made from sheet aluminum of 1 mm wall thickness, for example, the shield has a weight of about 100 lb.

The central radiation from the feed to the neighborhood of the vertex would be reflected from the dish into the shield and then to the ground. In addition, any prime focus feed yields a standing wave between feed and vertex. Both can easily be avoided by a vertex cone as shown in Fig. 1 and 2. For reflecting a feed-vertex ray just outside the focus shield of diameter a, the height H of the vertex cone must be

$$H \geq \frac{a^2}{8F}. \qquad (1)$$

2) Diffuse Edge of Shadow

The task of the shield is to produce a sharp edge of the illumination at the rim of the dish. There are three effects which make this edge diffuse.

a) The limited aperture, a, of the shield. Calling this diffusion width

$$\Delta_a = \frac{1}{2}\beta = 0.6\ \lambda/a\ , \tag{2}$$

we have

$$\Delta_a = \begin{cases} 1.70^\circ & \text{for} \quad \lambda = 21\ \text{cm}, \\ 0.49^\circ & \text{for} \quad \lambda = 6\ \text{cm}. \end{cases} \tag{3}$$

b) The feed size, d, with an illumination angle of 60°, gives

$$\Delta_b = \frac{1}{2}\ \frac{d \sin 30^\circ}{\ell} \tag{4}$$

and if the feed illuminates the dish with 3 db down at D/4 off-axis, we have

$$d = 1.15\ \lambda\ , \tag{5}$$

and

$$\Delta_b = \begin{cases} 1.42^\circ & \text{for} \quad \lambda = 21\ \text{cm}, \\ 0.41^\circ & \text{for} \quad \lambda = 6\ \text{cm}. \end{cases} \tag{6}$$

c) Diffraction at the edge of the shield. The diffraction pattern at a straight edge is shown in Fig.3. The distance from the geometrical shadow to the first maximum is

$$\Delta_c = 0.84\sqrt{\lambda/L} = \begin{cases} 4.66^\circ & \text{for} \quad \lambda = 21\ \text{cm}, \\ 2.49^\circ & \text{for} \quad \lambda = 6\ \text{cm}. \end{cases} \tag{7}$$

In summary, the diffraction is by far the largest of the three effects, and the two other ones will mainly result in just smearing out the finer wiggles of the diffraction pattern. Diffraction is more serious then (a) because the edge of the dish is in the near-field of the shield aperture. Effect (b) is only a small one because the shield edge is in the far-field of the feed horn.

3) Results and Discussion

Three illumination patterns are shown in Fig.4. The simple horn feed plus shield yields a very sharp cut-off, considerably better than that of the scalar feed; in fact it yields exactly the same cut-off as a Cassegrain of same aperture, a, would give. A still better cut-off (if ever necessary) could be achieved with a Cassegrain having a specially shaped edge (correcting collar), but this works only for a limited bandwidth and must be changed for different wavelengths. In case of beam-switching, a one-sided spillover occurs, which again is the same for the shield and a Cassegrain. It thus seems that the focus shield is a good and inexpensive solution.

Since the shield is not much larger than the doughnut, the increase of blocking and sidelobes is only small. With a blocking of

$$B = 4\,(a/D)^2 \qquad (8)$$

for a tapered illumination, and a sidelobe level γ as given by Baars (NRAO Report 1964), we find

	blocking, B	first sidelobe, γ
without shield	2.25% = 0.10 db	22.3 db
with shield	3.87% = 0.16 db	21.5 db

(9)

Since the focus shield yields a sharp cut-off at the dish edge, we might consider using a feed with a somewhat wider illumination angle. With increasing illumination angle, the gain reaches a maximum and then drops again, while the sidelobe still increases. It might be worthwhile to derive a best illumination angle (depending on receiver noise); S. Weinreb has a computer program which could be used for this purpose.

As soon as possible, an experiment should be made at the 140-ft for measuring the performance of the focus shield, using a low-noise receiver with a normal feed horn, measuring gain and spillover noise, both with and without shield and vertex cone as given in Fig.2.

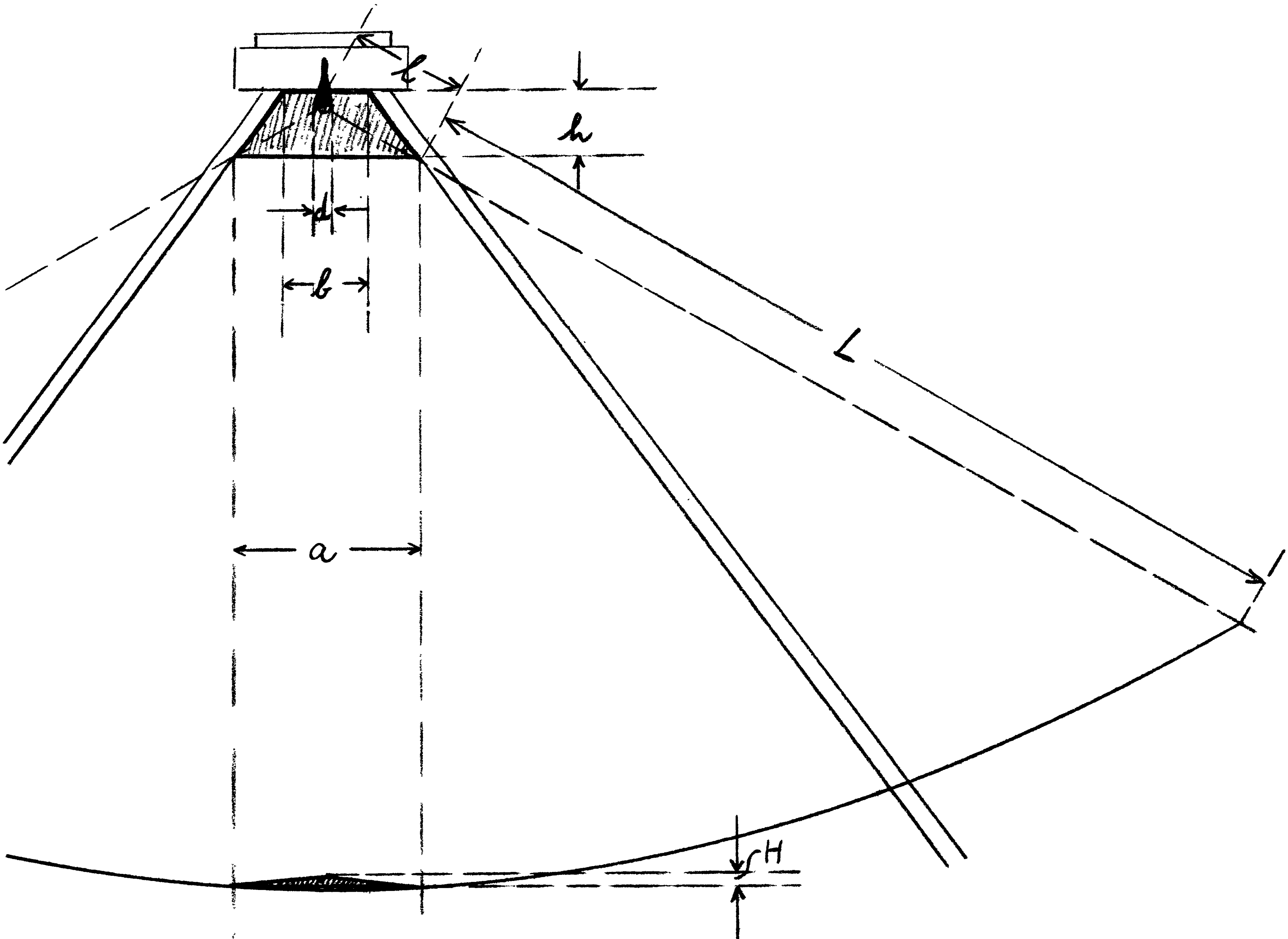

Fig. 1.
Focus shield and vertex cone.

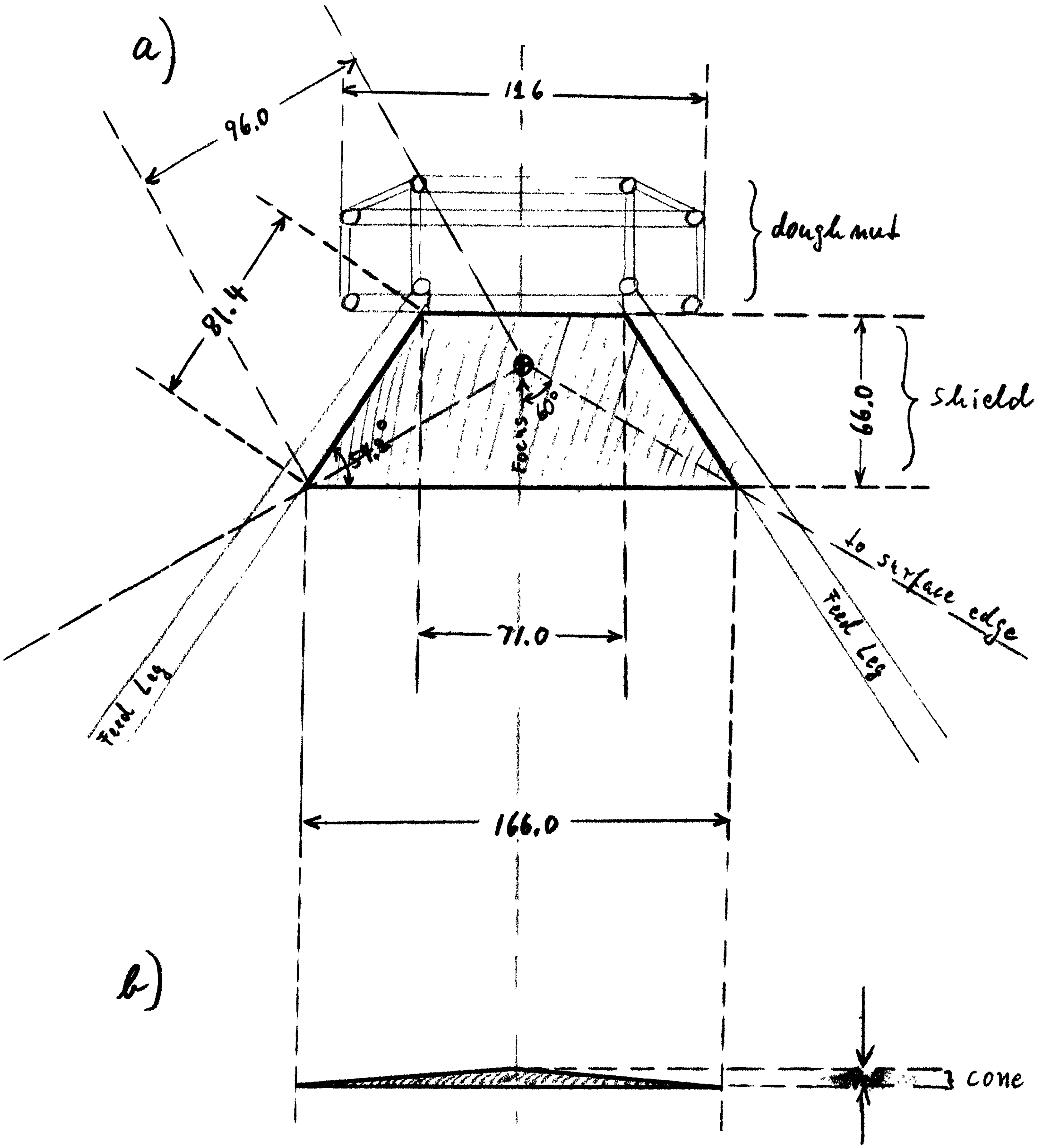

Fig. 2.
Suggested sizes for the 140-ft; (inch)
a) focus shield,
b) vertex cone.

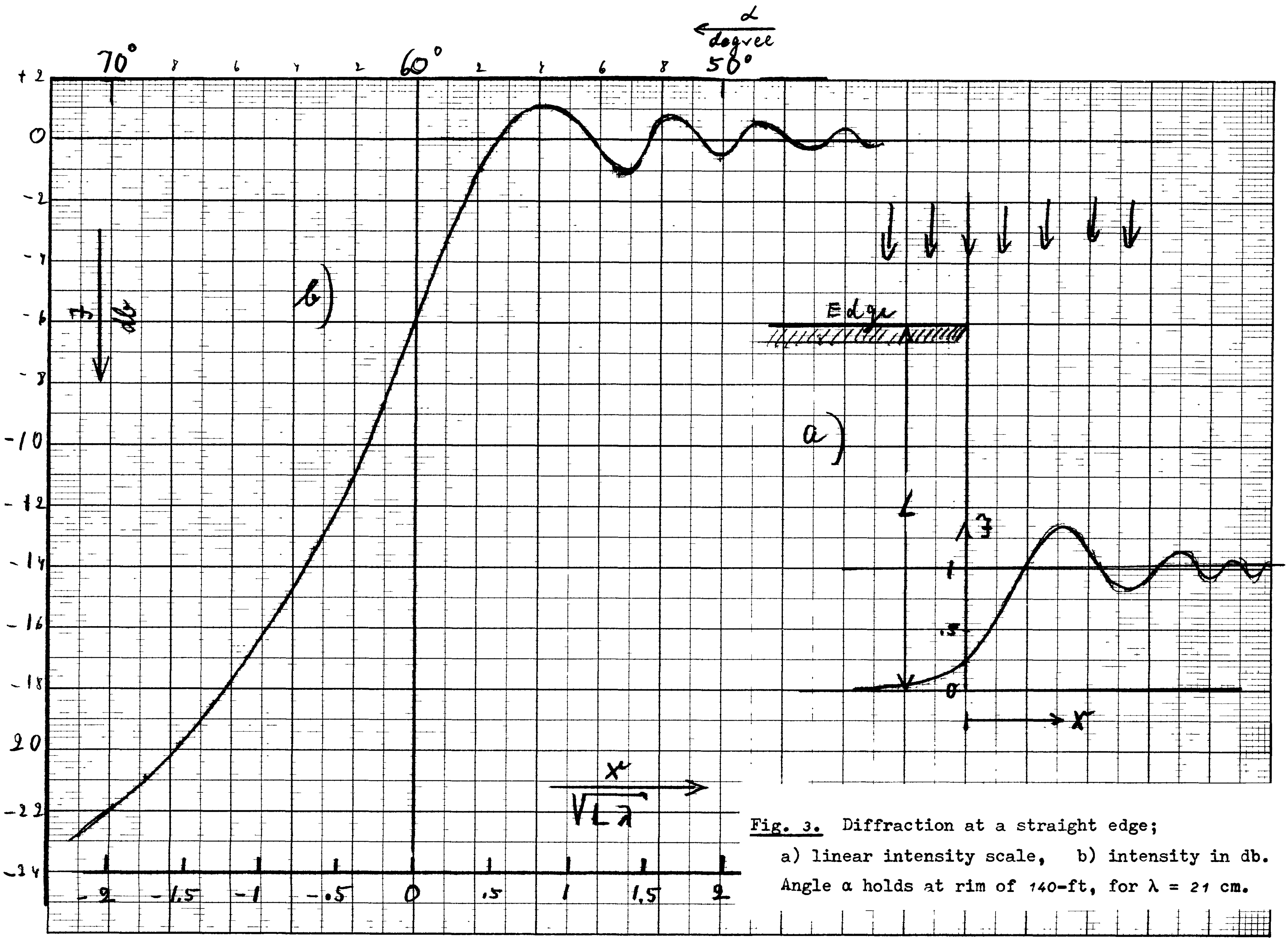

Fig. 3. Diffraction at a straight edge;
a) linear intensity scale, b) intensity in db.
Angle α holds at rim of 140-ft, for λ = 21 cm.

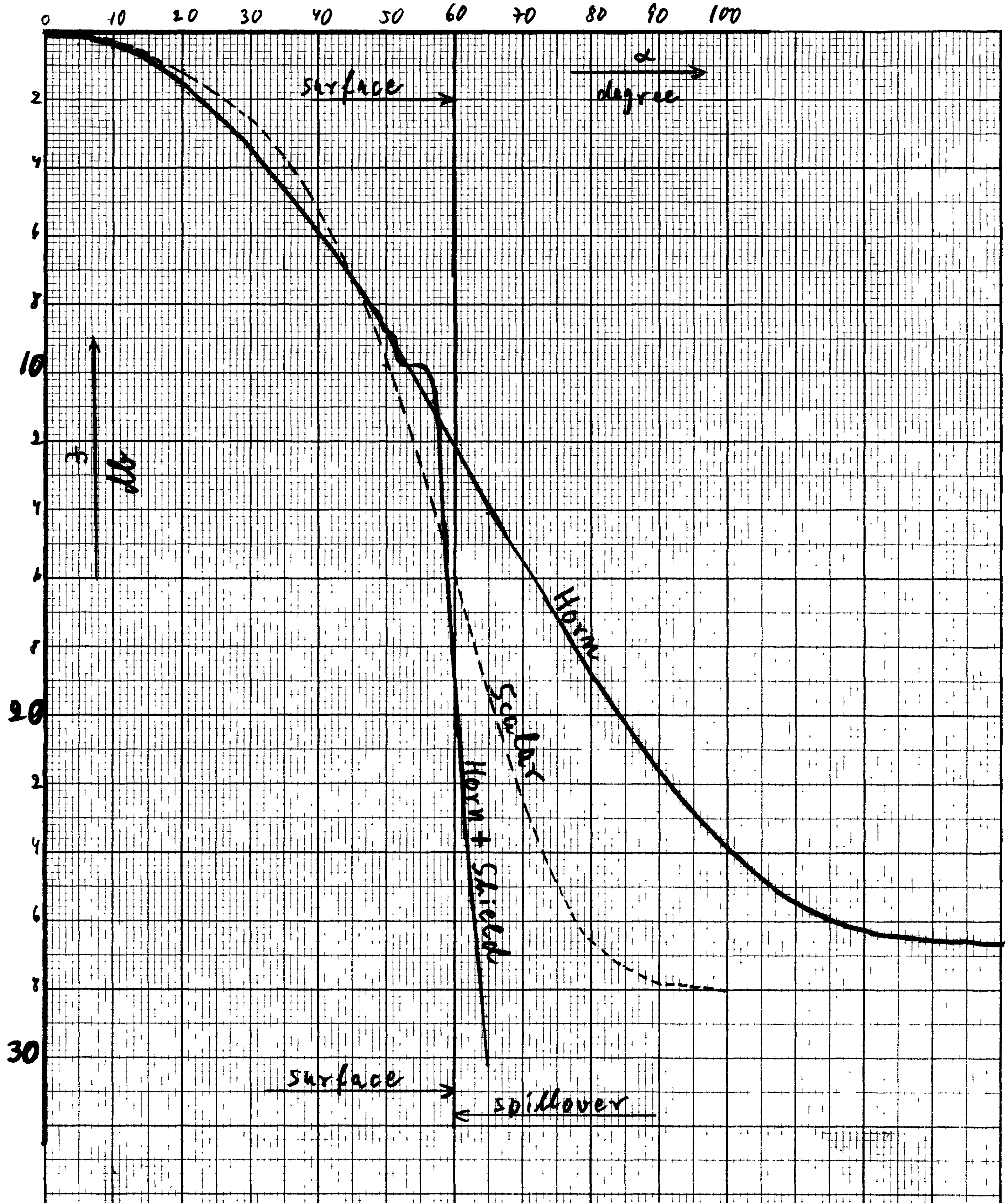

Fig. 4. Illumination pattern of 140-ft; with simple horn feed, scalar feed, and horn feed plus focus shield; λ = 21 cm.

National Radio Astronomy Observatory
Charlottesville, Virginia

April 8, 1970

M E M O R A N D U M

To: D. S. Heeschen ✓

From: S. von Hoerner

Subj: Present State of Homologous Telescope

I. Surface Plates

3000 long, trapezoidal plates of 15 ft^2 (75x28 in). All have exactly the same length; 17 groups of different width, 90 ... 260 identical plates in each group.

Each plate has 36 screws for internal adjustment; rms deviation is measured at 48 additional points, too. Estimated cost: 12$/$ft^2$ (based on 4.4$/$ft^2$ from ALCOA for simpler triangles without adjustments).

Performance: measured ± 0.0020 inch rms deviation.
(goal ± 0.0030 inch rms deviation)

II. Surface Panels

44 trapezoidal panels in 4 groups; with 4 ... 16 identical panels per group. Each panel consists of 180 pieces of pipe, giving 7900 pipes total (300-ft design = 88 panels, 1250 pipes each, 11,000 pipes total).

From the four groups, two are practically finished, giving 0.0032 and 0.0037 rms deviation in any telescope tilt (goal 0.0032). The other two will follow in about one month. Survival stability is ok for all.

III. Telescope Structure

A preliminary one is finished; without vertex cabin, only 1/3 of built-up members replaced by single pipes. All members stable for survival, weight = 506 US tons; rms deviation = .0011 inch for any tilt.

Future work: (a) replace more members by pipes, 1/2 ... 2/3 (replacing all seems not possible); (b) provide space and structure for vertex cabin; (c) reduce counterweight, 100 tons at present; (d) clean up several things geometrically; (e) special design details for feed legs, suspension, optical platform.

IV. Cost Estimates

Scaling from 300-ft (= 8.28M$) gives 4.28M$, including 10% contingency. The expected changes are:

Up:
- (a) better surface accuracy (more ribs, adjustment).
- (b) lighter built-up members with more $/lb.

Down:
- (a) 90 ... 260 identical plates (instead of all different for 300-ft).
- (b) panels: 4 ... 16 identical ones, and much simpler (7900 pipes instead of 110,000).
- (c) replacing 1/3 ... 2/3 of built-ups by single pipe.
- (d) simpler built-up members.

In any case: **Total $\leq$ 6.0M$.**

cc: J. W. Findlay
H. Hvatum
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