REPORT 3

NATIONAL RADIO ASTRONOMY OBSERVATORY
POST OFFICE BOX 2
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TELEPHONE ARBOVALE 456-2011

REPORT NO. 3
CONTRACT NO.
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PROJECT: LFSP
SUBJECT: Spillover shield

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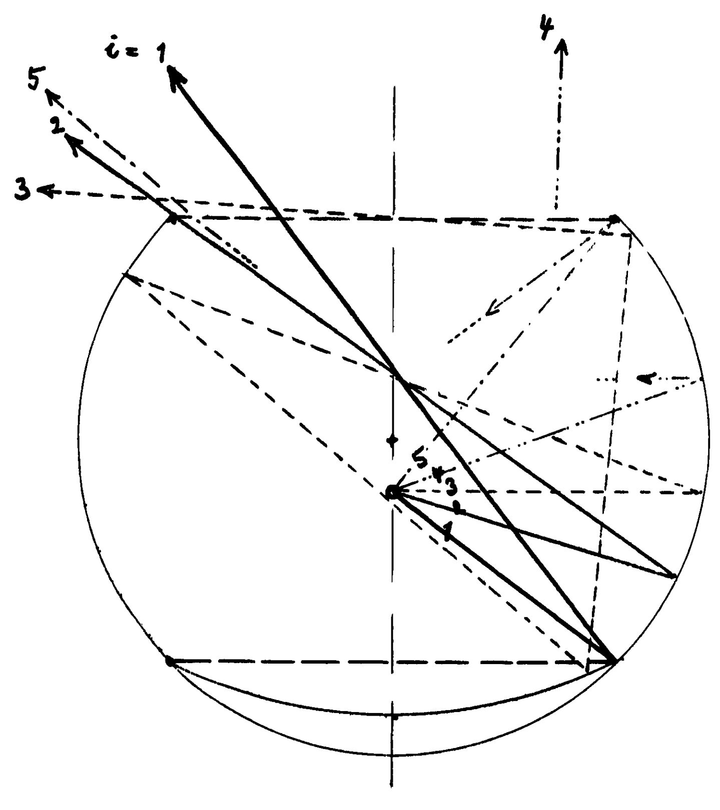
Spillover Shield

In one of the last LFSP meetings the question arose whether ground radiation, entering the floating sphere and being reflected at its inner walls, might give too high a contribution to the noise level, especially since this contribution might change rapidly with changing elevation angle. I would like to suggest a small, parabolic spillover shield; this is not confined to the floating sphere antenna, but could be applied to any antenna where the beam is smaller than 20 minutes of arc.

As an example I have adopted a 600 ft antenna within an 850 ft sphere, and a focal ratio of 0.5 (this gives a feed illumination angle of 106°, which is convenient for multi-frequency observation). The feed spillover then will look like drawn below:



Spillover in floating sphere.

Ray No. i is emitted at angle φ from the feed axis; it is reflected n times within the sphere; it begins to hit the ground if the telescope goes to zenith distance ϑ:

i	φ	n	ϑ
1	53°	1	53°
2	73°	1	36°
3	90°	4	4°
4	110°	5	85°
5	140°	7	38°

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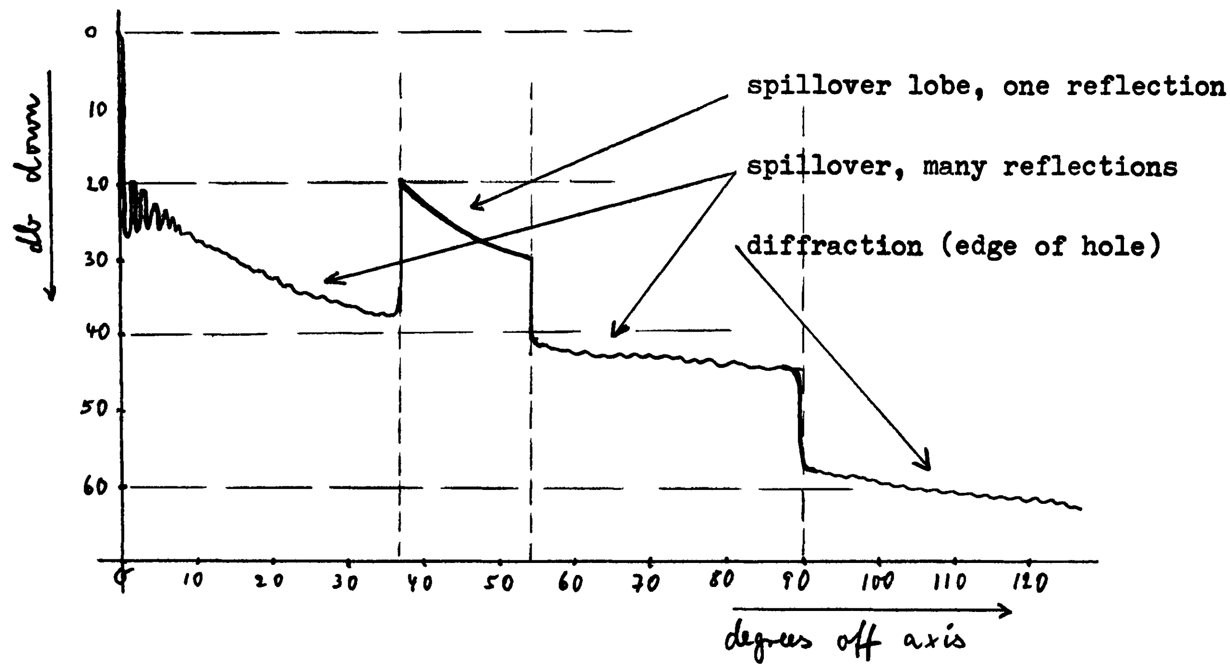
The stronger part of the spillover (next to the antenna) is only reflected once. It begins to hit the ground at 36° zenith distance (No.2) and will give the steepest rise of the noise level around 53° zenith distance (No.1). Rays with multiple reflections will fill the whole hemisphere (like No.3, hitting ground at 4° zenith distance) but only with a low energy level. A typical sidelobe picture might look about as follows:



Antenna pattern of floating sphere.

The spillover lobe will indeed cause some trouble for low-noise receivers. We could diminuish this lobe by using a large feed with sharp cut-off at theedge of the antenna; or we could move the spillover lobe close to the axis by using a Cassegrain mirror. But in both cases we would exclude simultaneous multy-frequency observation, as well as multy-beam observation. And no future large telescope should be limited this way.

I suggest focussing the spillover into the sky by attaching a small parabolic mirror around the feed, pointing upward, with a round hole at its bottom to allow the illumination of the antenna:

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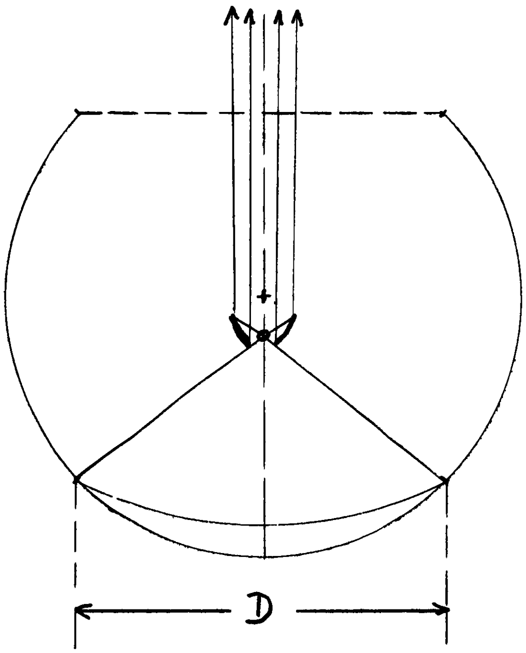

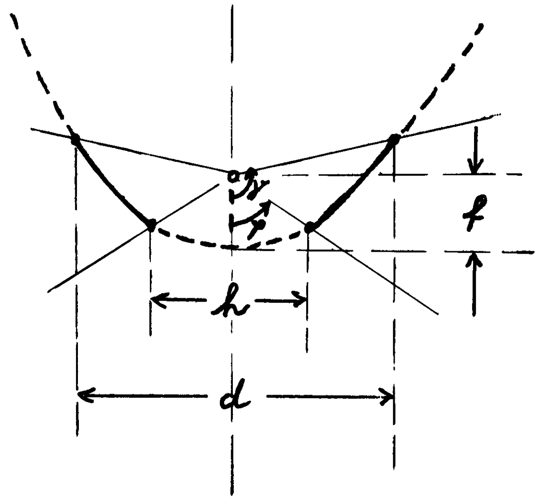

Shield mirror at focus.

We call f the focal length of this mirror, d its upper diameter, and h the diameter of the hole at the bottom. If 2φ is the feed illumination angle, and if we want to cut off any spillover up to an angle γ from the axis, then

$$h = 4f \tan(\varphi/2) \qquad \text{and} \qquad d = 4f \tan(\gamma/2) \tag{1}$$

and

$$\frac{d}{h} = \frac{\tan(\gamma/2)}{\tan(\varphi/2)} . \tag{2}$$

In our adopted antenna, for example, we have $\varphi = 53^\circ$, and if we cut off to $\gamma = 90^\circ$, we get

$$\frac{d}{h} = 2.00 \tag{3}$$

This shielding can only work if the diffraction around the hole is not too high, which means

$$\lambda \ll h \tag{4}$$

and if the shield does not cast too much shadow

$$d \ll D \tag{5}$$

or, with $d = 2h$,

$$2\lambda \ll d \ll D . \tag{6}$$

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We see that this method can be applied only at large telescopes, operating at short wavelengths. Let (4) and (5) be fulfilled by the same factor k:

$$D = kd = 2k^2\lambda . \qquad (7)$$

The beamwidth then is

$$\beta = 1.2 \frac{\lambda}{D} \text{ rad} = \frac{0.6}{k^2} \text{ rad} = \frac{2060}{k^2} \text{ min of arc} \qquad (8)$$

and for a telescope of given diameter D, the longest wavelength λ then is given by

$$\lambda = \frac{D}{2k^2} . \qquad (9)$$

k	β	λ	
		D=600 ft	D=140 ft
7	42'	190 cm	44 cm
10	21	92	21
15	9	41	10
20	5	23	5

We may regard k = 10 as the lower limit. The apperture blocking then is only 1%; and the edge of the shadow of the hole will be smeared out by about $\pm 5^\circ$, which means that the antenna should be larger than the geometrically illuminated part by a factor $(1 + 1/k) = 10\%$. Adopting $k \geq 10$, we find that the shielding can be applied to any telescope where the beam is 20' or less. For a 140 ft antenna, it can be used efficiently up to 20 cm wavelength, and up to 1 m for a 600 ft antenna.

A further advantage could be given to this shielding if the spillover mirror were made movable by some amount. The spillover beam then could be pointed to any convenient place in the sky. It could be pointed a little upward, for example, if one observes close to horizon.