#91-3

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

HAYSTACK OBSERVATORY

WESTFORD, MASSACHUSETTS 01886

AR027.91 related (?)

4 April 1991

Telephone: 508-692-4764
Fax: 617-981-0590

To: J. Salah, R. Ingalls, J. Ball, R. Barvainis

From: Alan E.E. Rogers AEER

Subject: Corrector lens

In the event that it is difficult to remove all the deviations in the shape of the main reflector (let's hope no such difficulty is encountered), it may be possible to use a corrector lens in front of the subreflector. This lens would be made from a circular sheet of dielectric with segments cut out to make it fit onto the subreflector - see figure. The correction pattern for the lens would be derived from a holographic map and punched or drilled into the flat dielectric sheet by a PC-driven X-Y machine. (Providing an easy automatic way of cutting new sheets when needed for different elevations, changes in antenna, etc.)

<u>Scale size of surface deviations for which corrections can be made</u>

If a surface deviation has size S on the main reflector then the size of the image on the subreflector is

$$Sf/F$$

where

f = distance from subreflector vertex to prime focus ≈3/6'

F = focal length = 48'

For a wavelength λ the image on the subreflector must be capable of forming a beam with size smaller than S back on the main reflector so that

$$(F-f)\,(\lambda F)/(Sf) < S$$

$$S > (F\,(F-f)\lambda/f)^{1/2}$$

At λ = 3 mm scale sizes larger than 2.4 feet (2.2 inches on the subreflector) can be corrected at the subreflector provided the surface deviations δ are small enough that the slopes projected back to the subreflector are smaller than the image size. So that

$$\delta(F-f)/S < Sf/F$$

$$\delta < S^2 f/(F(F-f))$$

or

$$\delta < \lambda$$

Corrector lens thickness

Since only small surface deviations ($<\lambda$) can be corrected the lens would be thin. If the maximum lens one-way thickness is 180 degrees it would be capable of correcting phase paths of ± 180 degrees or surface deviations up to ± 30 mils at $\lambda = 3$mm. With a dielectric constant of $\bar{2}.5$ the sheet thickness would have to be about 100 mils for 180 degree phase path.

Correction pattern

The effective thickness of the sheet could be modulated by punching holes in it with variable density so that when the hole area equals the remaining material area, the phase path will be reduced by a factor of 2. In order to minimize scattering loss the holes should have a diameter less than a wavelength or about 1/20th of an inch. The sheet would be cut to lay flat on the subreflector so that the incident and reflected rays will pass through the same parts[1] of the sheet.

The Ruze loss

The Ruze loss becomes extremely steep when peak surface deviations are anti-phased and subtract from the antenna voltage. The loss can be significantly reduced by correcting only these peaks. In other words, since the loss is not very sensitive to the shape of the distribution[2], elimination of the peaks is the quickest way to reduce the r.m.s. A corrector lens may not have to accurately correct the surface for substantial improvement in aperture efficiency. A "one-bit" corrector lens would reduce r.m.s. by approximately a factor of 2.

Summary

The idea of a corrector lens should only be regarded as a back-up in case the rigging is unable to remove all the surface deviations to an r.m.s. of about 8 mils. I feel that every effort should be made to understand the mechanics of the surface and make the rigging work well enough. The ideas presented here are only intended to prevent any disappointment from turning to pessimism (either within or outside Haystack) in the event that the antenna adjustments fail to converge well enough. In the event that some kind of surface corrector is needed there are many other options (like mapping the deviations into the subreflector surface - this was done with moderate success at Kitt Peak). The ideas presented here may not turn out to be best - much more work is needed to develop the concept and compare the method with other schemes.

---

[1] It might be possible to map the correction pattern in a way that would allow a flat sheet to be mounted in front of the subreflector.

[2] A uniform distribution of surface deviations gives a $\mathrm{sinc}^2(4\pi\sqrt{3}\ \delta/\lambda)$ loss which is very little different from $(\exp -(4\pi\delta/\lambda)^2)$.

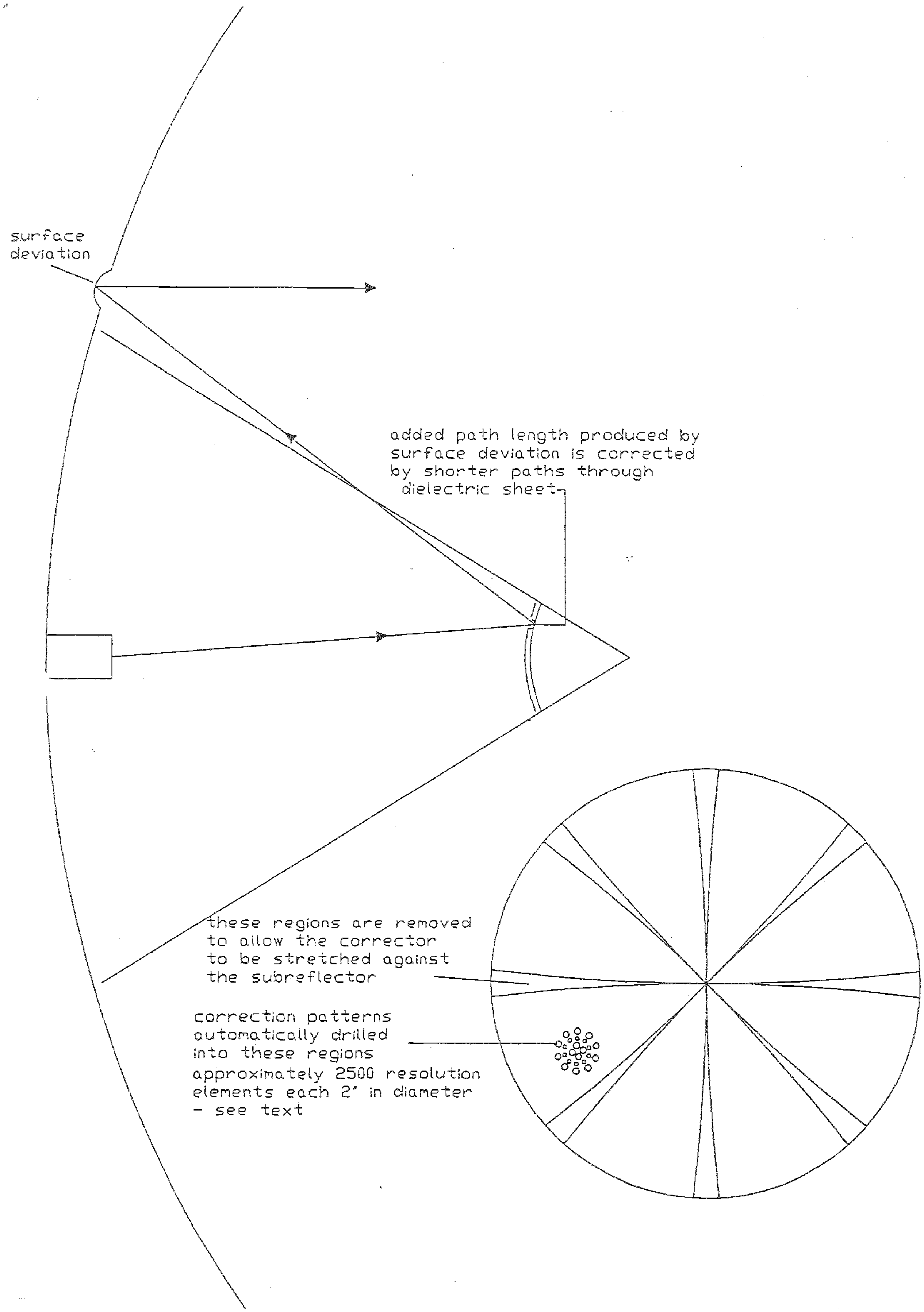

Figure - Method of correction of surface deviations using a dielectric sheet