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To: Holographers

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Subject: Panel curvature** ("scalloping")

Introduction

One of the significant contributions to panel rms is the deviation of transverse curvature from the correct curvature for the focal length of the antenna. If we have a bias in the curvature then small changes in curvature can have a relatively large effect as correlated surface deviations add algebraically rather than in quadrature.

Consider the following effects on curvature:

1] Temperature differences across the panels - (I have tentatively concluded that this might be significant - but the hypothesis lacks confirmation and the effect may be much smaller than my estimates - see earlier memos.)

2] Gravity - (In the appendix of this memo I estimate the effects of gravity - this is very tentative, and quite likely to be in error.)

3] Rigging bias - (This is on more solid ground - there is clearly still a bias in the panel curvatures evident in the high resolution holographic maps.)

Added effects of gravity, thermal and rigging bias

While estimates for the effects of gravity, temperature difference across the panels, and rigging bias are separately quite small, they will add algebraically. Consider the following for example (this is only an example):

1] Panel temperature difference	7.5 mils rms	from cold night to hot sunny day
2] Gravity	-5 mils rms	from horizon to zenith
3] Panel curvature bias	7.5 mils rms	

which gives panel curvature rms values for the following conditions:

A] Clear, cold night at 30°	0 - 2.5 + 7.5	= 5 mils rms
B] Clear, cold at horizon	0 + 0 + 7.5	= 7.5 mils rms
C] Clear, cold at zenith	0 - 5 + 7.5	= 2.5 mils rms
D] Sunny at 30°	7.5 - 2.5 + 7.5	= 12.5 mils rms
E] Sunny at horizon	7.5 + 0 + 7.5	= 15 mils rms
F] Sunny at zenith	7.5 - 5 + 7.5	= 10 mils rms

**This is an extremely speculative memo which I am reluctantly issuing in the hope that it might help us to think of effects which have been previously overlooked.

Total rms would have the large scale value (and other random small scale) of about 10 mils added in quadrature giving a variation from 10 to 18 (condx. E) mils rms. If there is, in fact, a significant panel curvature bias (as can be clearly seen in the high res. holography maps) it would be most advantageous to remove it as can be clearly seen in this example.

Appendix:

Hoop tension

When the antenna is pointed at the zenith the panels will tend to fall apart unless held together with cable tension. The tension needed to support a panel section of radial length d between circumferential cables (assuming little influence of the back-up structure)

$$2\rho d \Delta r K / \sin\phi \approx 250\,lbs\ at\ edge\ of\ dish$$

where

ρ	=	density of aluminum (0.1 lbs/cu")
Δ	=	panel skin thickness (0.016")
r	=	radius of panel section (720" at edge of dish)
K	=	actual panel wt. per unit area divided by wt. of aluminum faces (accounts for honeycomb and epoxy) (2.5)
ϕ	=	zenith angle panel section ($\approx 32°$ at edge of dish)
d	=	distance between cables ($\approx$24")

Strain developed at panel junctions and change in cable tensions

The change in compressive strain developed by a change in hoop tension of 250 lbs/24" is

$$250/(24 x 0.016 x 2 x E) = 30 x 10^{-6}$$

where

E = Young's modulus for aluminum (10^7 psi)

assuming perfect panel joints. However, the panel joints are made only at the expanders so the joints are more compliant. In the vicinity of the joints the strain will be enhanced by the ratio of the spacing between expanders to the expander length which is about a factor of 24 thereby increasing the strain to about

$$800 \times 10^{-6}$$

This strain will result in a change in cable tension of about

100 lbs (1/8" diam. cable with $E = 10^7$ psi)

assuming that the cable friction limits slipping and rotation of the "pulley" guides so that stain change occurs over $\approx$24" (which is the separation between guides).

Cable tension and panel curvature

With a uniform shell held together with circumferential cables of uniform tension there will be no change in transverse curvature ("scalloping") with cable tension. However, the cable arrangement can produce curvature changes. For example, the guide on the center of each panel is adjustable in a manner that can be used to decrease the panel curvature by pressing on the center. From beam theory, the maximum panel deflection is

$$\delta = Wl^3/(48EI) \approx 5\,mils/lb$$

where

W	=	applied force
l	=	distance between guides on either side of adjustable guide $\approx 48''$
E	=	Young's modulus
I	=	M.I. = $\Delta\, t^2/2$

For a cable tension of 600 lbs and a cable guide adjustment of 1" the applied force is 50 lb and we get a deflection of

$$250\ mils/inch$$

for the outermost panels. (This assumes all cable guides are changed and doesn't account for coupling between adjacent adjustable guides on the same panel.)

Cable friction forces will produce a bending toque because the guides are displaced from the panel center. These torques will be most important across the panel joints owing to the severely reduced bending strength across the joints. The maximum panel deflection for torque T is

$$\delta = Tl^2/(8EI) \approx 1\ mil/\ inch\text{-}lb$$

assuming the joints act as hinges. For a cable displacement of 0.3" from the panel center, 100 lbs change in cable tension will produce 30 inch-lb of torque and a 30 mil panel deflection.

As the dish goes from the horizon to the zenith the cable tension will increase. This increase may significantly alter the panel curvatures in two ways. First by a change in torque applied across the joints (assuming cables do not slip on the guides) and secondly (much less important), change the force on the cable curvature adjustment guides.

The attached figure illustrates the influence of gravity and differential temperature (see memo dated 15 April 1993) on panel curvature.

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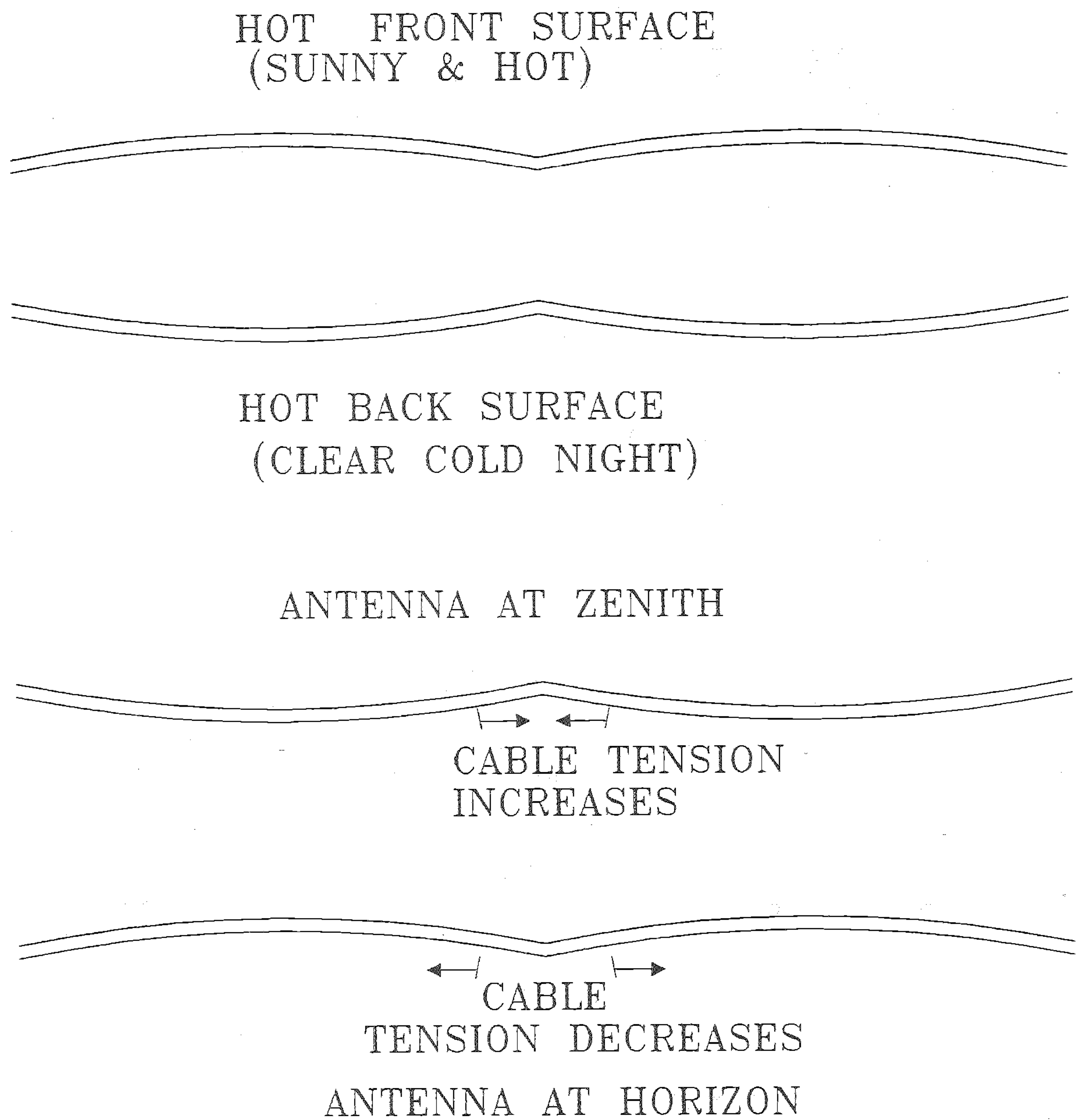

Fig. Expected changes in the panel transverse curvature