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15 April 1993

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To: Holographers

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Subject: Some Simple Thermal Tests of Antenna Panels

Introduction

While the 3mm performance of Haystack is relatively stable at night the daytime performance is very variable, especially during nice sunny weather. During the recent 3mm VLBI run (3-9 April 1993 between VLBI scans) several tests were performed to try and diagnose the "low gain" condition. A low resolution holographic map was made, sunscans were taken, and attempts were made to tune up the antenna by changing focus, astigmatism, and thermal control. The following are noted:

1] The holographic map (in daytime sunny weather) shows a ring structure which should be partly correctable by increasing the splice plate temperature to a value higher than being set by the thermal control.

2] On Venus (which is larger than the beamwidth) the efficiency could be increased somewhat by offsetting the thermal control to provide a higher splice plate temperature.

3] During a sunny day the antenna temperature is warmer than the back-up structure.

Other results which need further confirmation are:

4] The sunscan peak temperature is reduced - indicating an increase in small scale structure on the antenna.

5] Moving the antenna to a new source can rapidly change the antenna gain with a time constant of a few minutes.

One hypothesis for the loss of antenna gain (made by John Ball) is that temperature differences develop between the front and back faces of the antenna producing distortions in the surface. In this memo I examine this hypothesis further.

Panel conductivity

I obtained a small sample (1.75" x 1.25") of the honeycomb panel, measured the conductivity and obtained a value of

$$100 \pm 20 \ \mathrm{Wm^{-2}K^{-1}}$$

compared with a value of

$$80 \ \mathrm{Wm^{-2}K^{-1}}$$

obtained by Dynatech (J.G. Bourne, 18 June 1965).

This relatively low conductivity is largely the result of the low conductivity fiberglass and epoxy layers between the honeycomb and the aluminum faces. Figure 1 shows a microscope picture of a cross-section through a panel. On this sample there is a 6 mil separation between the honeycomb and face plate.

Panel Distortion

By setting a 6" x 8" panel sample on the base of measuring microscope I have measured the panel curvature change that results from differential heating. A diagram of the set-up is shown in Figure 2.

With a 10 watt heat source (see Figure 2), I observed a 6 micron depression in the center of the panel and a 1°F temperature difference between faces. The thermal time constant in this test was observed to be about 100 seconds.

The theoretical expression for the deflection between points a distance L apart is

$$L^2 \delta / (8\,t) \tag{1}$$

where

δ	=	thermal expansion coefficient ($29 \times 10^{-6}\ \mathrm{K^{-1}}$ for aluminum)
t	=	panel thickness (0.5")

from which the calculated depression is 5.7 microns for 1°F on a 7.5" base.

Model for Daytime . rms

Total solar input to radome	750 $\mathrm{Wm^{-2}}$
Energy directly transmitted to surface panels	37 $\mathrm{Wm^{-2}}$ (5%)
Energy captured in radome panels	187 $\mathrm{Wm^{-2}}$ (25%)
Energy re-radiated to surface panels	75 $\mathrm{Wm^{-2}}$ (10%)
Estimate of total energy input to front surface of antenna (assuming 50% absorbtivity)	56 $\mathrm{Wm^{-2}}$
Estimated average temperature difference across panels .	0.6°C

The temperature difference across the panels (if it really exists) will change the curvature of the individual panels where there is no constraint (in the tangential direction - scalloping) and will make the thermal control set the splice plate temperature too low (by half the temperature difference), since the panel temperature sensors are only on the back face.

The increased rms will result from 2 components as follows:

a) Ring structure from error in thermal control

coefficient $\approx$ 30 mils p-p/°C
$\approx$ 2 mils rms for 0.3°C

b) Panel scalloping (across panel width of approx. 60")

coefficient $\approx$ 26 mils p-p/°C (7.5 mils rms/°C)
$\approx$ 4.5 mils rms for 0.6°C

If these add in quadrature the 10 mils rms under good conditions will increase to 11 mils. This will result in a 20% loss of gain which is considerably less than observed. Possible reasons for inability of this model to account for the larger loss of gain (typically a factor of 2 or more) are:

1] The panel absorbtivity is higher.

2] Additional heat is transferred to the panels via convection.

3] The panel conductivity is variable and there are large regions with lower conductivity and hence higher front surface temperature.

4] There are other contributions to the surface distortion, i.e., temperature gradients in other directions; effects of back-up structure; changes in cable tensions.

5] The "sunny day" surface distortions are correlated with "rigged in" distortions and hence may add algebraically (in the worst case) rather than in quadrature.

6] Conditions at night are reversed and thus the dish was rigged with the temperature gradient across the panels from front to back reversed.

Suggestions for Further Tests

1] Measure temperature difference across panels (front to back) being careful to avoid locations where the faces are thermally shorted with a metal insert.

2] An instrument to measure the panel curvature (scalloping) in the tangential direction up on the antenna and check for day/night variations.

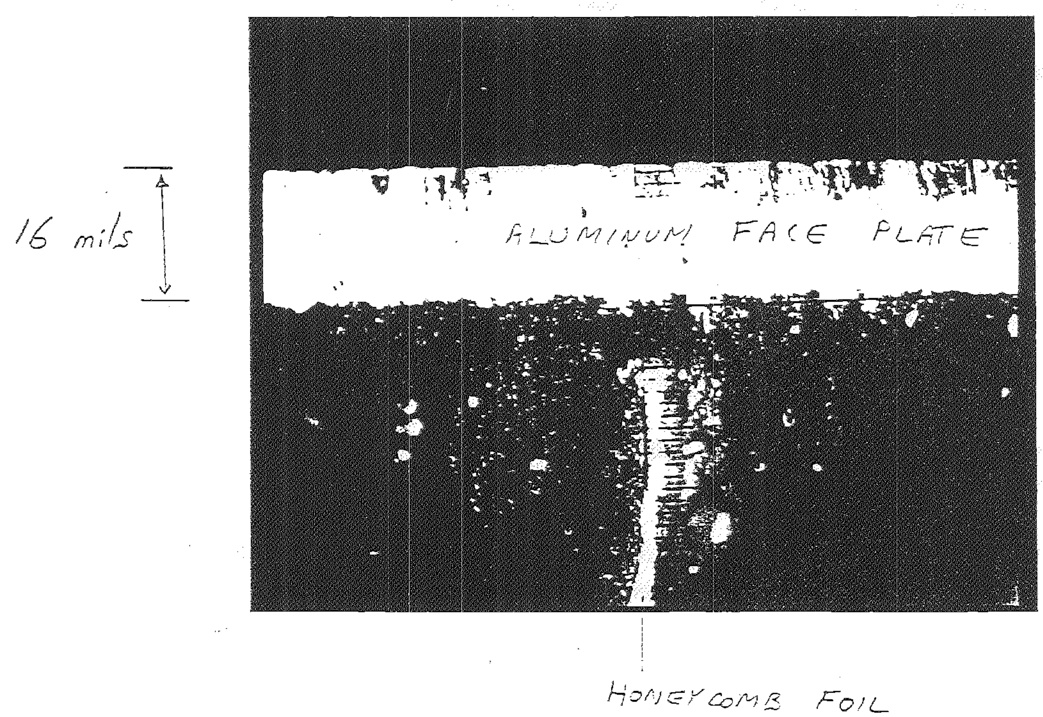

Fig. 1 Panel cross section

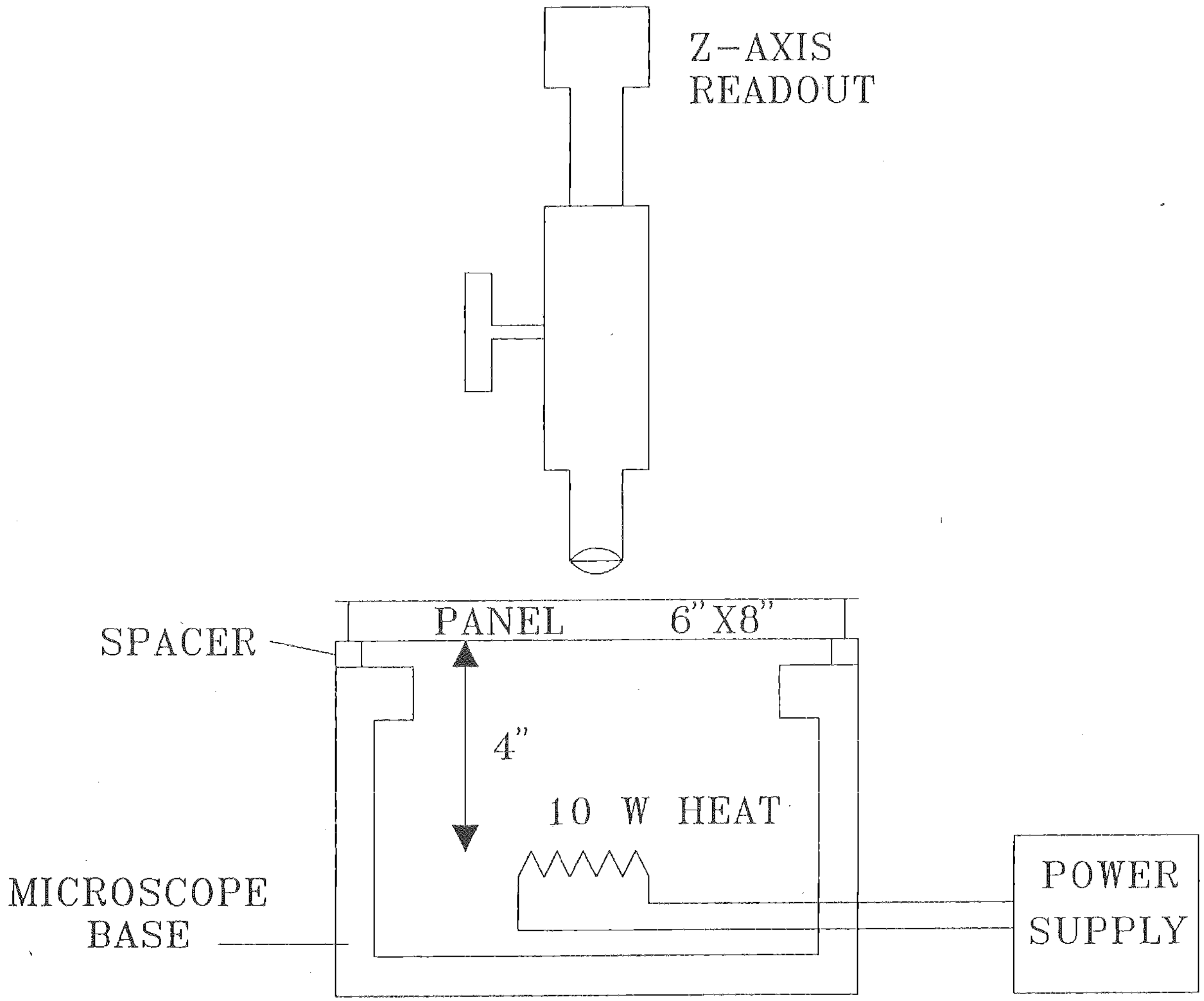

Fig. 2 Set-up to measure panel curvature change with heating