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Has the Parkes reflector surface changed as a result of the upgrade?

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Introduction

The focus cabin upgrade added a substantial load to the tripod support structure - we can therefore expect to see changes to the reflector surface. The questions one might ask are:

1. How will the gain-elevation function be affected?

2. Can we adjust the surface setting to minimise the effects?

We can draw on data from a variety of sources to explore these issues:

1. The 4 GHz holography in October 1995 (before the upgrade) and in June, 1996.
2. The 12.75 GHz holography in July, 1996.
3. An optical survey of two rings of targets on the surface - in October '95 and in July '96.
4. Gain-elevation curves at 8 and 22.5 GHz.
5. The focus curves (axial and lateral).
6. Connell-Wagner have provided us with their calculations of the expected deformations of the antenna, before and after the upgrade. These calculations are a valuable aid to assessing the observations.
7. Finally, we also have the detailed surveys of D.Yabsley (1964-66) which provided the deformation-elevation data, and which lead to the original bias-rigging of the surface.

Background

Qualitative Overview

The tripod structure attaches directly to the backup structure. This means that there is a substantial deformation to the structure in the immediate vicinity of the attachment points. At the zenith the deformation is the same at all three legs. As the antenna tips towards the horizon the load (and thus the deformation) at the lift leg increases. At the upper two legs the load decreases - at an elevation of about 45 degrees the load is zero; at elevations below 45 degrees the deformation is outwards. The surface was bias-rigged in 1966, so that the surface was a good approximation to a paraboloid at mid-elevation. (This very rough description of the bias-rigging operation is sufficient for this overview - a detailed description is given in a later section). Consider now the situation after the upgrade.

- The upper tripod legs.

  With the antenna at the zenith the surface load at the attachment point will have increased, and the local deformation will be below the 1965 setting. At 45 degrees the load will be zero (as in 1965), so the surface will return to the 1965 level. At elevations below 45 degrees the pull of the legs will raise the surface above the 1965 level. Thus we expect that there is little we can do for the area around the upper legs - the extent of the deformations will increase, but range will remain zero-centred. The question is how much has the range increased; ie, what is the performance loss.

- The lift leg.

  At the zenith the surface will be depressed below the 1965 level. As the antenna tips towards the horizon the load increases, so the surface falls increasingly below the 1965 level. Thus there is a gain to be had - we need to raise the surface around the lift leg in order to bias for zero offset at 45 degrees.

D. Yabsley Survey Data

A comprehensive study of the antenna was made in 1964-1966 by D.Yabsley and colleagues. The surface of the antenna was then adjusted to have minimum departure from the nominal paraboloid over the full elevation range. The original data, reprocessed in colour, are shown in 30 degree best fit paraboloid , 50 degree BFP, 70 degree BFP, 80 degree BFP and 90 degree BFP. (The "reprocessing" took the original survey data and applied the adjustment algorithm. Thus the figures should offer a good approximation to the real surface after the adjustment procedure).

Connell Wagner Predictions

Connell Wagner (Mr. J. Schafer) made extensive calculations of the expected deformations of the antenna as a result of the upgrade. Figure 6 shows a slice through their dataset. The data refer to the surface at a radius of 28m. The "azimuth" of the horizontal axis locates the points on the surface of the dish, with aziumth=180 degrees coinciding with the lift leg. Each trace refers to a different elevation setting. We find that in the vicinity of the upper tripod leg (azimuth = 60 degrees), with the antenna pointing at the zenith the surface will be now lie below the pre-upgrade surface, whereas at 30 degrees elevation the surface will be above the pre-upgrade surface.

Holography

The 4 GHz surveys

These surveys were made at an elevation of 43 degrees, with INTELSAT VII as target. Figure 7 shows the high resolution pre-upgrade image, figure 8 shows the high resolution post-upgrade image and figure 9 has the difference. (Warning: these images are large). These images have a surface resolution of 50 cm x 50 cm, and show that the bulk of the June-October differences lie in the vicinity of the lift leg - 3 mm on average in the perforated panel region, and somewhat more in the mesh panel area outboard of the leg attachment point.

Each pixel in a holography image is the average over the resolution cell; in a low resolution image the small scale panel variations will be reduced in amplitude, leaving the large-scale structural deformations to dominate. As the resolution improves, the small scale variations will rise in importance.

The two surveys have been analysed in terms of low and high resolution images. The analysis takes two forms:

- We look for the amplitude weighted half-path rms. This is the quantity that one would use in a Ruze analysis of the antenna's gain.

- We estimate the gain directly by forming the vector sum of the voltage distribution over the aperture plane.

These two approaches are clearly related, but they do provide a useful consistenncy check of the analysis. Table 1 below gives the full details of the analysis. In brief, the panel rms error is unchanged, (as expected); the error attributable to the large scale deformations of the antenna has deteriorated - from 0.5mm to 0.7mm when averaged over the inner 44m diamter; and from 0.9 to 1.5mm when averaged over the entire aperture.

Table Ia - Holography Summary. 4 GHz, high resolution, 44m aperture

	Oct	**June**
holography gain	**64.74 dB**	**64.48 dB**
zero-rms gain	**64.93 dB**	**64.82 dB**
effective rms	**1.25 mm**	**1.34 mm**
holography rms	**1.33 mm**	**1.39 mm**

Table Ib - 4 GHz, Low resolution, 44m aperture

holography gain	**64.96 dB**	**64.76 dB**
zero-rms gain	**64.99 dB**	**64.82 dB**
effective rms	**0.50 mm**	**0.70 mm**
holography rms	**0.46 mm**	**0.67 mm**

Table Ic - 4 GHz, high resolution, 64m aperture

holography gain	**67.23 dB**	**66.54 dB**
zero-rms gain	**67.78 dB**	**67.20 dB**
effective rms	**1.92 mm**	**2.33 mm**
holography rms	**2.04 mm**	**2.51 mm**

Table Id - 4 GHz, low resolution, 64m aperture

holography gain	**67.60 dB**	**66.90 dB**
zero-rms gain	**67.70 dB**	**67.16 dB**
effective rms	**0.91 mm**	**1.46 mm**
holography rms	**0.87 mm**	**1.53 mm**

Notes:

1. The 44m aperture analysis was chosen for comparison with the 12.75 GHz survey. It also allows us to separate the error contribution of the perforated panels (r < 22m) from the mesh panels (r > 22m).
2. The 4 GHz feed is designed to illuminate the entire 64m aperture - this means that the 44m aperture analysis is not far from providing uniform illumination over the aperture.
3. The "holography" gain is obtained by direct integration over the holography-derived aperture plane.
4. The "zero-rms" gain is derived from the observed illumination amplitude, setting the phase to zero. The difference between the observed and the zero-rms is a measure of the loss due to the surface rms.
5. The "zero-rms" gain in october is significantly greater than the june value. An examination of the radial illumination function shows the the feed pattern in june was narrower than the october setting. The Chapparal feed used does indeed allow the width of the pattern to be varied; in October it had been set for a F/D ratio of 0.37, and it is now set for a F/D ratio of 0.41.

The separation of large and small scale surface deformations

The low resolution images provide a measure of the large scale deformations. If we assume that the high resolution images show the effect of the quadrature sum of the large scale rms and the panel rms, then we can separate the two contributions, as summarised in Table II. .

Table IIa - Error Contribution Analysis, 44 m aperture

	Oct	**June**
Structural rms	**0.50 mm**	**0.70 mm**
Panel rms	**1.15 mm**	**1.14 mm**

Table IIb - 64 m aperture

Structural rms	**0.91 mm**	**1.46 mm**
Panel rms	**1.69 mm**	**1.81 mm**

Notes:

The separation structural/panel assumes that the scale size of the panel variations is comparable to our highest resolution (50 cm). An examination of the rms derived from a range of resolutions suggests that we have not yet reached the panel scale size: the rms continues to increase as the resolution improves. Further tests are required; the indications are that we are underestimating the true rms by a factor of 10%.

The difference in the structural rms of October and June is about 0.5 mm for the 44m aperture, and is consistent with two sectors (out of 30) depressed by about 3 mm.

The difference, for the 64m aperture, requires a depression of about 10mm, as observed.

The 12.75 Holography Survey

This survey was made at an elevation of 51 degrees, with Optus B3 as target. figure 10 shows the aperture plane amplitude illumination function and figure 11 shows the surface error distribution. The analysis, similar to Tables I and II is given in Table III.

Table IIIa - Holography Analysis, 12 GHz; high resolution, 44 m aperture

holography gain	**73.61 dB**
zero-rms gain	**74.49 dB**
effective rms	**0.84 mm**
holography rms	**0.85 mm**

Table IIIb - 12 GHz; low resolution, 44 m aperture

holography gain	**74.07 dB**
zero-rms gain	**74.47 dB**
effective rms	**0.57 mm**
holography rms	**0.57 mm**

Table IIIc - panel/deformation rms separation

structural rms	**0.57 mm**
panel rms	**0.64 mm**

Discussion

The comparison between the 4 and 12 GHz surveys, (in the 44m analysis) shows some surprising effects. The structural rms are comparable, but the panel rms are not. Two important factors will colour the results:

- the surveys were made at different elevations (51 and 43 degrees);

- the aperture illumination functions are quite different, which then changes the weighting functions. The 12.75 GHz data is biassed towards the central regions, whereas the 4 GHz data treats the entire surface with roughly uniform weight. Since the serious deformations are centred on the lift leg, attached to the surface at a radius of 22m, we can expect the 4 GHz survey to show a higher rms than the 12.75 GHz survey.

- the panel rms is harder to explain. It suggests that there is a grading in rms, higher towards the edge. It is the case that the inner 17m surface has a surface error which is lower than the outer perforated panels. Finally, the perforated panels beyond a radius of 16 m are quite large, with a manufacturing tolerance of ?? mm (rms); in addition, there are suggestions that the panels do not conform to the global paraboloid - a comparison against a profile template indicates a gentle "cusping" along the radial edges.

Antenna Gain - absolute estimate

We can derive the true antenna gain from the holography gains after applying a number of correction factors:

- the blockage area is not treated correctly in the holography analysis; (that analysis only accounts for the gaps in the aperture plane; an additional allowance is needed in the gain calculation).

- the spillover efficiency is not included (10 %)

Table IVa 12 GHz analysis

holography gain	**73.6 dB**
blockage	**0.3 dB**
spillover	**0.5 dB**
predicted gain	**72.8 dB**
efficiency	**55%**

Table IVb 22 GHz analysis (prediction)

uniform illumination gain	**80.3 dB**
feed illumination	**0.9 db**
scaled rms loss	**2.7 dB**
full blockage	**0.6 dB**
spillover	**0.5 dB**
predicted gain	**75.6 dB**
efficiency	**34 %**
measured (JER)	**22%**

How much gain was lost in the upgrade?

The 4 GHz data for the full 64m aperture (Table Ic) show that the effective rms (weighted by the illumination function) has degraded from 2.0 to 2.4mm. This translates to a loss of :

2.6 GHz	10.0 GHz
2%	17%

The Optical Surveys

Two rings of targets were surveyed, in October 1995 and July 1996. The inner ring was at a radius of 9m, at the boundary between the solid and the perforated panel surfaces; the second ring was at a radius of 22m, just at the edge of the perforated panels. The antenna was at the zenith.

The inner ring shows no difference between the the two surveys - the rms is consistent with the surveying accuracy - about 1 arcsec.

The outer ring shows pronounced dips at the azimuths of each of the tripod legs. The deformation is 2 - 3 mm deep. Figure 12 shows the comparison between the Connell Wagner predictions and the survey (difference between October '95 and July '96). The match is excellent.

Comparison - Prediction and Observation

We are able to compare the predictions with observations in two cases - the optical survey at the zenith Figure 12, and the holography profile (fig. 13) drawn from the holography images taken at around 45 degrees elevation.

The focus calibration data provide a further consistency check; the DEY survey data allow us to estimate the location of the Best Fit Focus at the various survey elevations. The CW predictions for the movement of the focus cabin are the second ingredient. These two factors should combine to form the focus curves; this they do. Figure 14 shows the axial focus curve, and figure 15 the lateral curve. It is worth noting that both functions are frequency dependent - the highest frequencies which use just the inner 45m aperture have steeper focus curves. The results are summarised in Table V.

Table Va - Lateral focus function

	inner 45m	full 64m
BFF shift	1.97 mm/degree	1.47 mm/degree
Cabin shift	1.0	1.0
Total	2.97	2.47
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Observed (current calibration)	2.98	2.48

Table Vb - Axial focus function

BFF shift	58 mm/sin(E)	40 mm/sin(E)
Cabin shift	28	28
Total	86	68
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Observed (current calibration)	83	58

This suggests that the axial movement of the focus cabin is a bit less than predicted - that the additional movement (due to the upgrade) is closer to 3 mm than to the predicted 5 mm.

Adjustment strategy

The surface was adjusted The guiding principle was to minimize the extrema. A displacement vs elevation function was derived for each point on the surface. A nominal paraboloid was defined (focal length = 26.3m), and each point was adjusted to lie on the paraboloid at the mid-point of its displacement function. Since there is no generic displacement function this means that there is no elevation where the surface is perfect; but the extreme departures from the paraboloid are minimised. Since much of the surface deforms monotonically with elevation, the optimum elevation is likely to be around 60 degrees. The holography at 51 and 43 degrees suggests that the guiding principle was relaxed somewhat, putting the optimum elevation closer to 50 degrees.

Recommended Strategy

We could use the 12.75 GHz survey as guide for the inner section, and raise the panels adjacent to the lift leg. This would set the optimum elevation at 50 degrees, skewing slightly the gain-elevation function, but in terms of the radio source distribution (as observed) this is probably acceptable.

We would need to use the 4 GHz survey as guide in the adjustment of the outer mesh panels; this survey was at 43 degrees elevation, so the adjustment should leave the lift-leg area slightly depressed.

Summary

1. There is excellent agreement between the CW predictions and the observations.
2. At 45 degres elevation the large scale deformations have increased the effective surface error (rms) from 2.0 to 2.4mm, averaged over the full 64m aperture. This translates to a gain loss of 2% at 2.6 GHz rising to 17% at 10 GHz.
3. A re-adjustment strategy has been outlined.