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# CSIRO DIVISION OF RADIOPHYSICS

## EFFECTS OF AXIAL SUBREFLECTOR SHIFTS ON THE AT

### PROBLEM DEFINITION:

An axial subreflector shift (S/R) in the AT will result in an effective axial shift of the (feed) phase centre. It is clear that a small (~cm) subreflector shift will result in a proportionally larger feed phase centre shift. The relationship between the two shifts will be found.

### METHOD:

A ray tracing program has been set up for the AT optics. We define the 'path length excess at the aperature plane' as the excess distance a ray must travel (after two reflections in transmit mode) to reach the aperature plane relative to a central ray. For a shaped system which is collimated (and correctly designed) this number is zero for all rays striking the S/R at arbituary locations (from the feed). Shifts transverse or axial will in general destroy this property ie the phase will no longer be constant across the aperature.

Here we concern ourselves with axial shifts only. The problem may be reformulated as follows. Given a set feed shift, what is the required S/R shift that gives a best fit to a constant phase aperature distribution? 'Best fit' will now be defined.

Let the path length excess be given by z(r) where $0<r<11$ metres. Since the shifts are axial, the path length excess is a function of one variable (the radius) only ie the aperature distribution is circularly symmetric. Note that the phase error at radius r across the aperature is given by $2\pi z(r)/\lambda$ radians.

Define

$$z_{AV} \triangleq \int_{R_c}^{R_o} \frac{2\pi r\, z(r)\, dr}{\pi(R_o^2 - R_c^2)} \quad \text{metres} \qquad \text{....(i)}$$

the mean phase centre level relative to the central ray.

We choose to minimise the root mean square error of the phase distribution

$$\epsilon_{rms} \triangleq \sqrt{\left( \int_{R_c}^{R_o} \frac{2\pi r (z(r) - z_{AV})^2 dr}{\pi (R_o^2 - R_c^2)} \right)} \text{ metres} \quad \ldots.(ii)$$

for different sets of S/R shift.

The assumption is that the aperature magnitude distribution is constant, from Rc ,the feed cone base radius (~1.65 metres) to Ro (~11 metres) ,the limit of the ray optics (since the S/R is moved towards the main reflector (M/R) the extreme incoming rays near the M/R rim may miss the S/R rim upon reflection).

The actual technique is to evaluate (i) and (ii) numerically. The S/R was sampled by rays at forty intervals to give an accurate representation of the aperature 'phase' profile. Care is and was necessary to include the extreme point on the S/R rim from both the point of view that it defines the effective M/R diameter and numerically it has a significant effect since empirically the phase error is extreme at this point so it weighs heavily in the integration. In otherwords an oversize S/R would give slightly different results.

## RESULTS

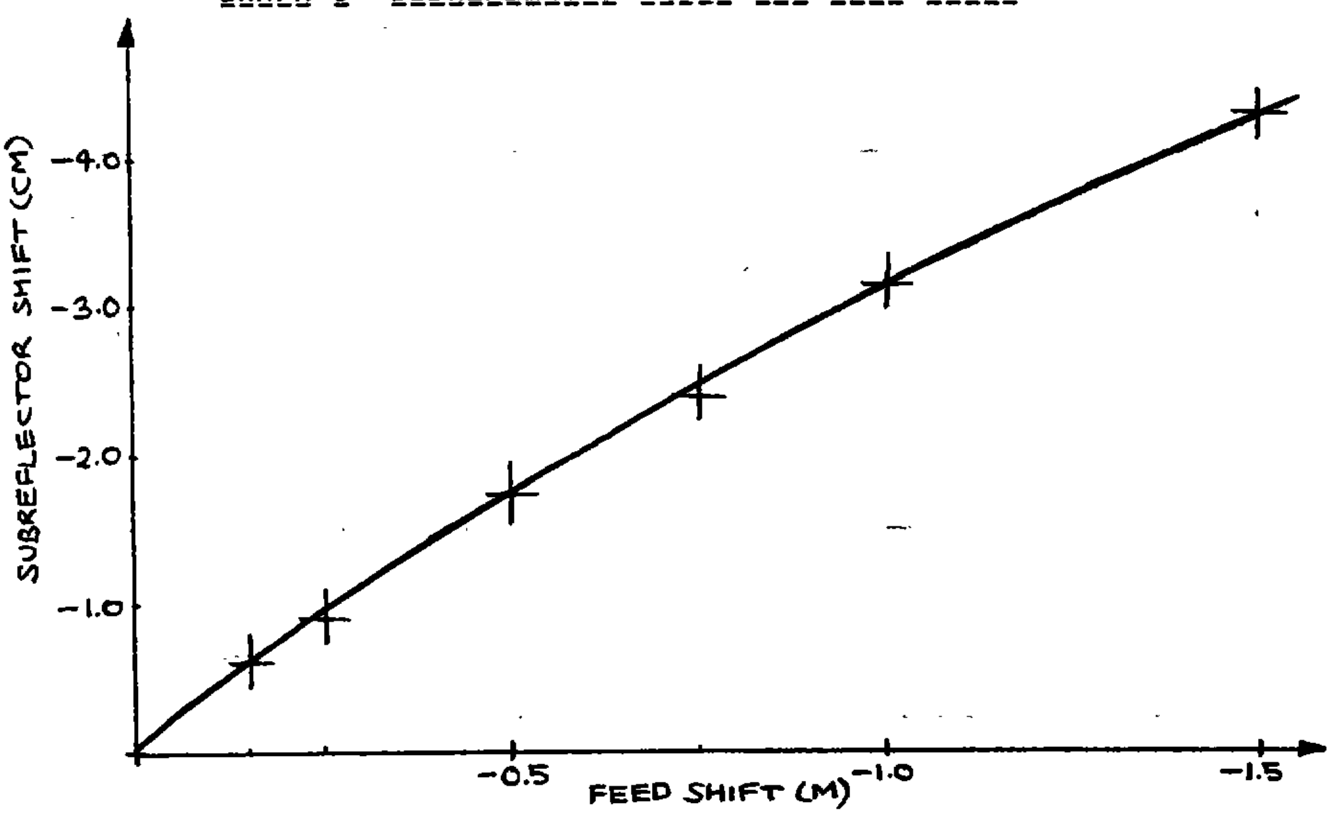
We tabulate the results as follows:

TABLE 1: NUMERICAL RESULTS

| FEED SHIFT (M) | S/R SHIFT (CM) | RMS PL ERROR (MM) | SHIFT COEFF |
|---|---|---|---|
| -0.15 | -0.60 | 0.46 | 25.0 |
| -0.25 | -0.90 | 0.78 | 27.8 |
| -0.50 | -1.75 | 1.51 | 28.6 |
| -0.75 | -2.40 | 2.16 | 31.3 |
| -1.00 | -3.15 | 2.72 | 31.7 |
| -1.50 | -4.30 | 3.67 | 34.9 |

The following graph displays the same information.

GRAPH 1 SUBREFLECTOR SHIFT VRS FEED SHIFT




Figures 1 through 6 show graphically the relative pathlength error across the aperature for the six cases examined above. These of course represent the optimun cases ie the S/R shift is matched to the feed shift ( rms minimun). The grid displayed represents stepping across the S/R in 0.1375 metre intervals (nb the radius of the S/R is 1.375 metres) and the angular (azimuthal) increment is 10 degrees. The raw data from which table 1 is derived is presented in the appendix.

PATH LENGTH EXCESS AT APERATURE PLANE

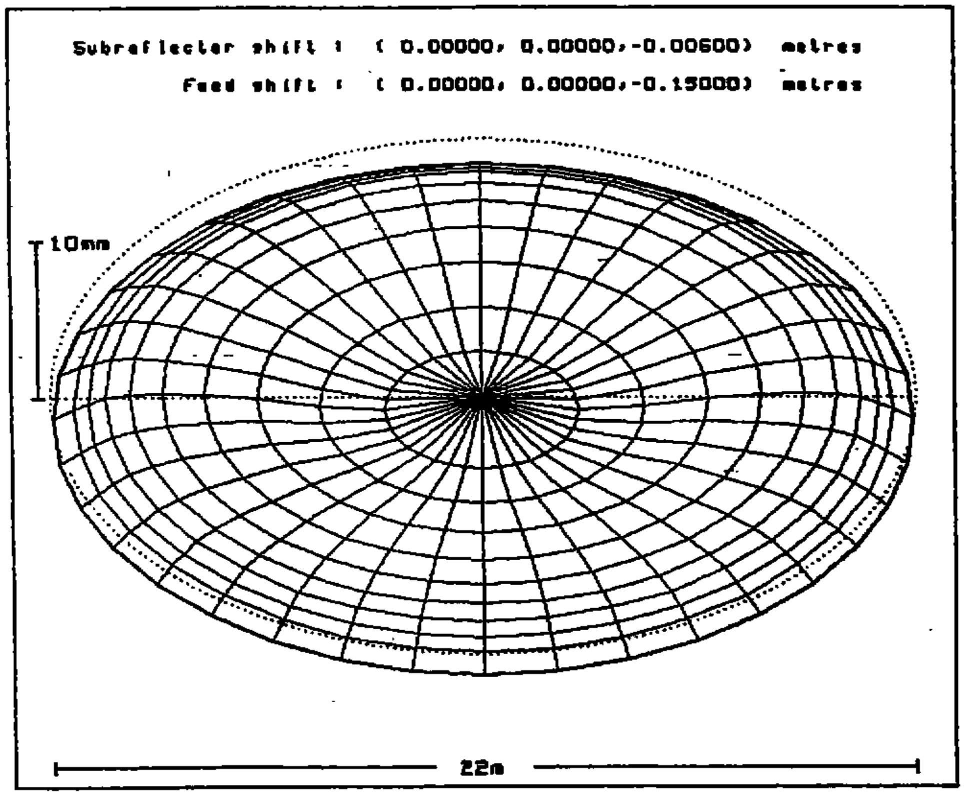



**FIGURE 1**

PATH LENGTH EXCESS AT APERATURE PLANE

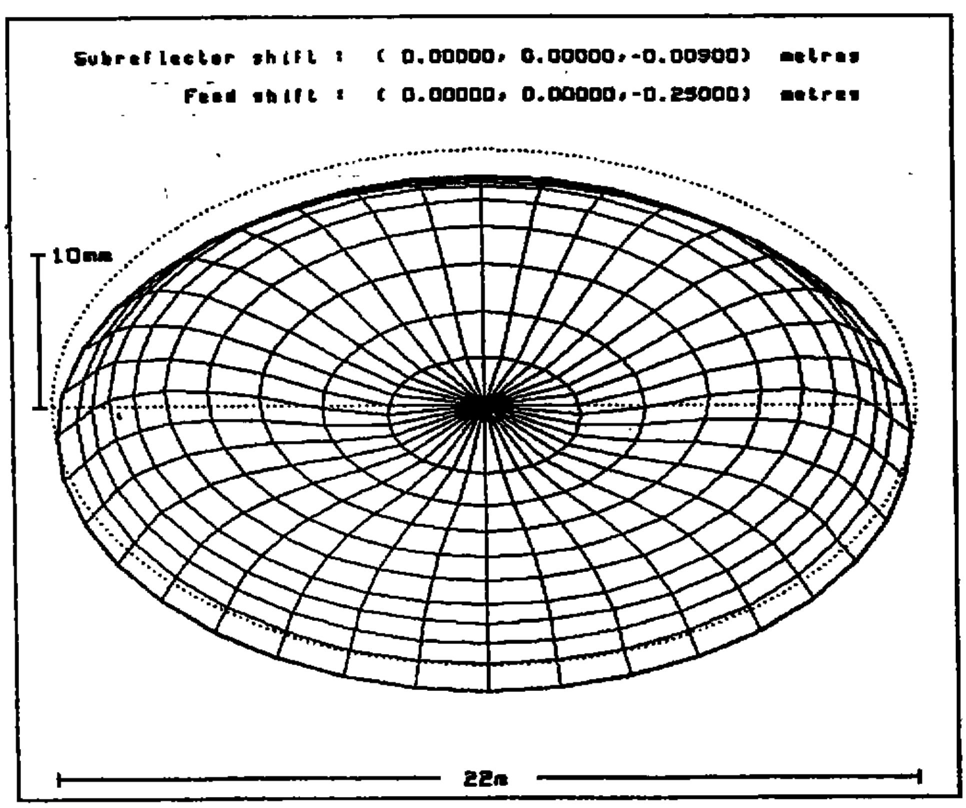



**FIGURE 2**

PATH LENGTH EXCESS AT APERATURE PLANE

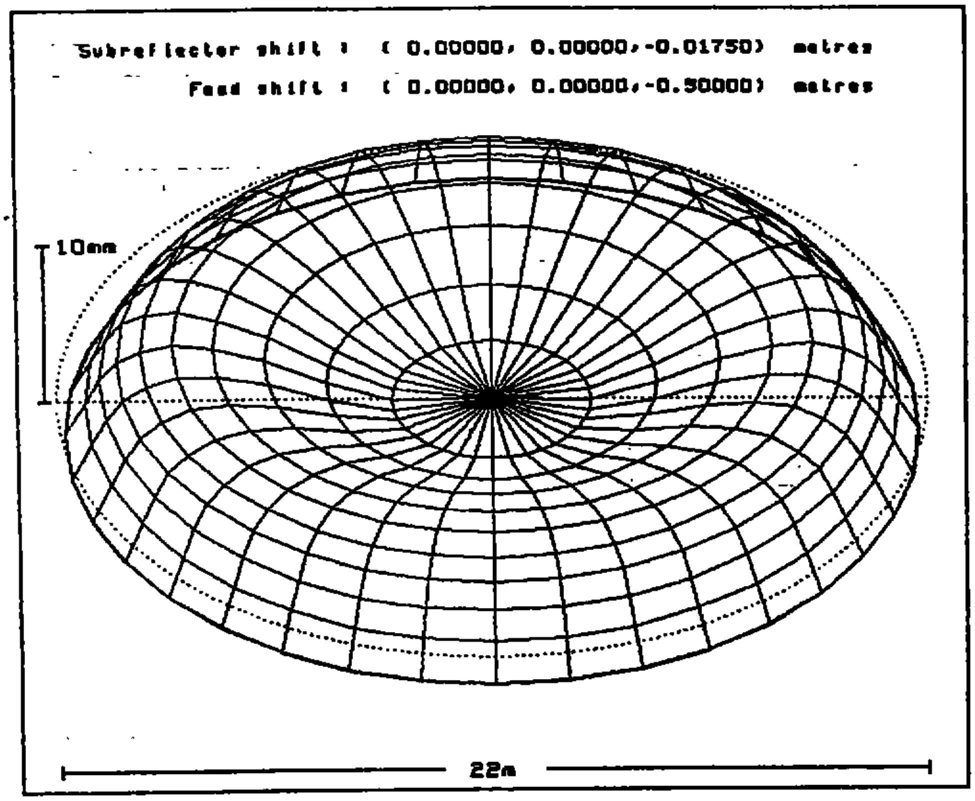



FIGURE 3

PATH LENGTH EXCESS AT APERATURE PLANE

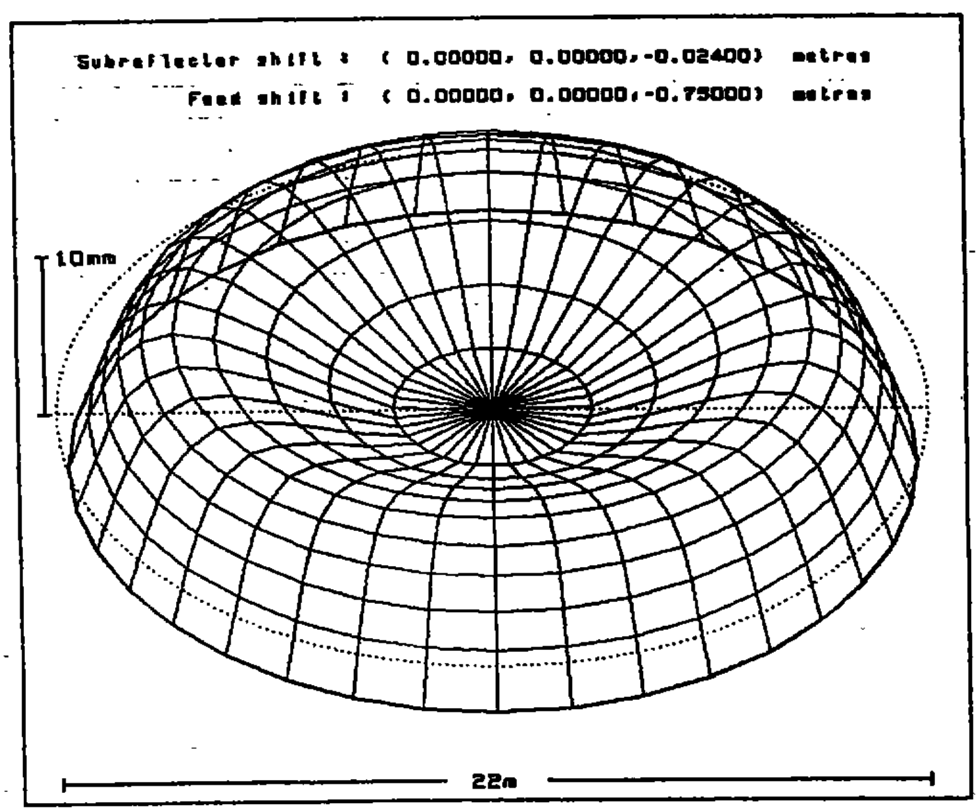



FIGURE 4

PATH LENGTH EXCESS AT APERATURE PLANE

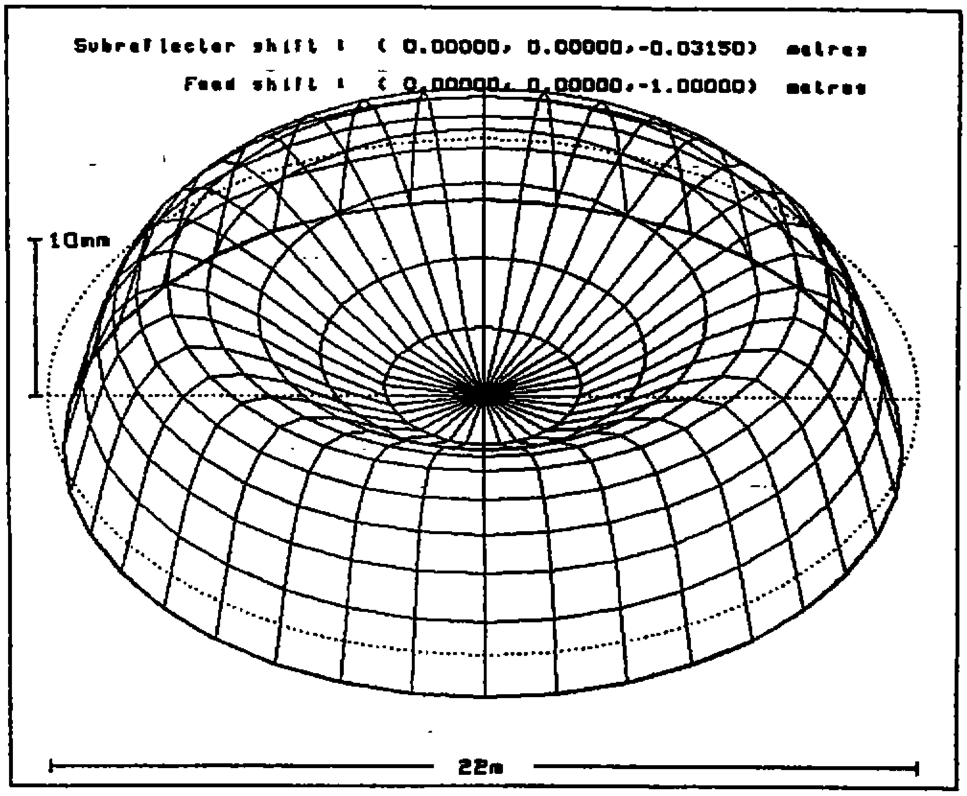



**FIGURE 5**

PATH LENGTH EXCESS AT APERATURE PLANE

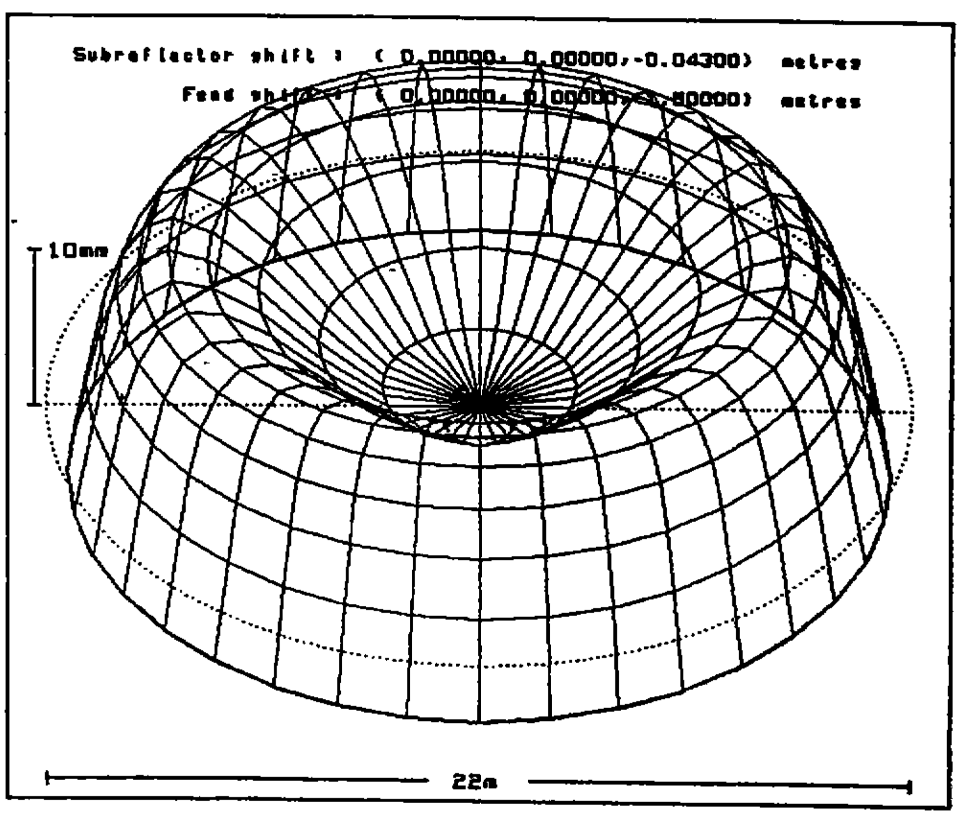



**FIGURE 6**

## SUMMARY

The results show that the feed position moves of the order of 25-30 times the corresponding S/R movement. The relation is approximately linear however a well defined non-linear trend is apparent, tending to make movements more sensitive for larger S/R shifts.

As shown in the appendix, unless the S/R is made oversize, that on the basis of ray optics the effective diameter of the telescope could go down to 21.0 metres given a system where the S/R movement is such that the feed phase centre is moved back 1.5 metres (worst case). Note that this reduction is apparent in figures 1 through (and especially) 6.

The rms phase error across the aperature, for a given frequency, can be recovered from $2\pi\epsilon_{rms}/\lambda$ radians. Whilst the peak phase errors can be extracted from figures 1-6.

# APPENDIX A

## RAW DATA FROM ANALYSIS

### TABLE A.015

Parameters:

Feed shift -0.15 metres
Ro 10.93 metres
Rc 1.70 metres

| S/R SHIFT (CM) | MEAN PL (Zav MM) | RMS PL ERROR (MM) |
|---|---|---|
| -0.45 | -0.76 | 0.559 |
| -0.50 | -0.61 | 0.503 |
| -0.55 | -0.47 | 0.473 |
| -0.60 | -0.20 | 0.461 |
| -0.65 | 0.07 | 0.475 |
| -0.70 | 0.33 | 0.497 |
| -0.75 | 0.58 | 0.567 |

### TABLE A.025

Parameters:

Feed shift -0.25 metres
Ro 10.89 metres
Rc 1.70 metres

| S/R SHIFT (CM) | MEAN PL (Zav MM) | RMS PL ERROR (MM) |
|---|---|---|
| -0.80 | -0.20 | 0.834 |
| -0.85 | 0.04 | 0.802 |
| -0.90 | 0.27 | 0.782 |
| -0.95 | 0.50 | 0.792 |
| -1.00 | 0.73 | 0.788 |
| -1.05 | 0.98 | 0.792 |
| -1.10 | 1.20 | 0.839 |

## TABLE A.050

Parameters:

| | | |
|---|---|---|
| Feed shift | -0.50 | metres |
| Ro | 10.79 | metres |
| Rc | 1.69 | metres |

| S/R SHIFT (CM) | MEAN PL (Zav MM) | RMS PL ERROR (MM) |
|---|---|---|
| -1.20 | -0.56 | 1.871 |
| -1.60 | 1.24 | 1.545 |
| -1.70 | 1.69 | 1.514 |
| -1.75 | 1.97 | 1.506 |
| -1.80 | 2.13 | 1.511 |
| -1.90 | 2.58 | 1.551 |
| -2.30 | 4.37 | 1.879 |

## TABLE A.075

Parameters:

| | | |
|---|---|---|
| Feed shift | -0.75 | metres |
| Ro | 10.70 | metres |
| Ro | 1.69 | metres |

| S/R SHIFT (CM) | MEAN PL (Zav MM) | RMS PL ERROR (MM) |
|---|---|---|
| -2.00 | 1.00 | 2.353 |
| -2.30 | 2.35 | 2.184 |
| -2.40 | 2.79 | 2.158 |
| -2.50 | 3.25 | 2.162 |
| -2.60 | 3.69 | 2.171 |
| -2.70 | 4.14 | 2.206 |
| -3.00 | 5.49 | 2.393 |

## TABLE A.100

Parameters:

| | | |
|---|---|---|
| Feed shift | -1.00 | metres |
| Ro | 10.62 | metres |
| Rc | 1.68 | metres |

| S/R SHIFT (CM) | MEAN PL (Zav MM) | RMS PL ERROR (MM) |
|---|---|---|
| -2.60 | 1.91 | 2.920 |
| -3.00 | 3.67 | 2.747 |
| -3.10 | 4.14 | 2.730 |
| -3.15 | 4.31 | 2.723 |
| -3.20 | 4.63 | 2.735 |
| -3.30 | 4.95 | 2.750 |
| -3.70 | 6.70 | 2.966 |

TABLE A.150

Parameters:

| | |
|---|---|
| Feed shift | -1.50 metres |
| Ro | 10.47 metres |
| Rc | 1.68 metres |

| S/R SHIFT (CM) | MEAN PL (Zav MM) | RMS PL ERROR (MM) |
|---|---|---|
| -4.10 | 5.34 | 3.686 |
| -4.20 | 5.75 | 3.675 |
| -4.30 | 6.20 | 3.669 |
| -4.40 | 6.61 | 3.678 |
| -4.50 | 7.05 | 3.714 |
| -4.60 | 7.48 | 3.721 |
| -4.70 | 7.92 | 3.760 |

Definitions:

Ro is the ray optics effective radius of the M/R based on the S/R rim

Rc is the radius of the feed cone base

PL stands for Path Length

Positive shifts are in the direction in which the telescope is pointing.

The feed cone base radius given corresponds to the numerical value chosen by the program rather than the correct value required (1.65 metres). Note that in general both Rc and Ro vary within each of the tables above however due to the small variation encountered only an average value is given in the header.

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The second report will deal with the aperture.