ATNF antenna optics

M.Kesteven & B. Parsons

April 26, 2000

As part of the MNRF upgrade of the Narrabri antennas, we have started a program of careful measurements to ensure that optics are correctly aligned.

Our starting point is the main reflector surface, adjusted following the holography measurements made in October, 1999.

We are now working through each antenna in turn, to define in a permanent fashion, the optical axis of the main reflector; we can then position the feeds and the subreflector on the optical axis, at the correct distance from the reflector vertex.

We find that in all the antennas surveyed the receivers have been installed with precision - they are all within an error circle of radius 10mm. Only at the highest frequencies (80 GHz and above) will greater precision be required, as far as efficiency is concerned.

The offsets do have some consequences for other frequencies:

- **Pointing** Different receivers will have different squint terms in the pointing model (the pointing error is 3.6 arcsec/mm for feed offsets).

- **Subreflector Setting** The holography data contain an error signature of the combined (sub-reflector + feed offsets). We need to ensure that both the holography receiver and the mm receiver have the same offset (preferably zero).

1 Background

An antenna operates at peak efficiency when all the optical elements (main reflector, sub-reflector and feed) are at their designed locations. For the AT antennas, the subreflector vertex should be 6.430mm above the main reflector vertex; the feed should be 1.509mm above the vertex. Departures from the nominal alignment will reduce the antenna's performance. Figures 1 and 2 show the subreflector focus curves; the corresponding curves for feed offsets are similar in shape, but scaled by the magnification factor (M=26 in the axial direction, and M=7 in the lateral direction). Since the losses result from a phase distribution over the aperture plane, we can counter a feed offset with a subreflector adjustment, although we can never fully recover all the gain.

However, all the feeds in an antenna should have the similar offsets since the AT has no mechanised lateral adjustment of the subreflector.

Holography is a powerful tool to measure the alignment of the optics; however it is difficult to distinguish between subreflector and feed offsets since their error signatures are similar. The saving grace is the scale: a feed offset Δx is effectively equivalent to a subreflector offset $\Delta x/M$, where M, the magnification, is about 7.0 for the AT. If we can start with feed and subreflector set with comparable accuracies, then the holography will show primarily the subreflector error.

The work described in this note emphasises this approach: we provide the basis to ensure that the feeds are accurately positioned. We also ensure that the subreflectors are close to their designed location, and assume that holography/pattern-cuts will be used to refine the subreflector setting.

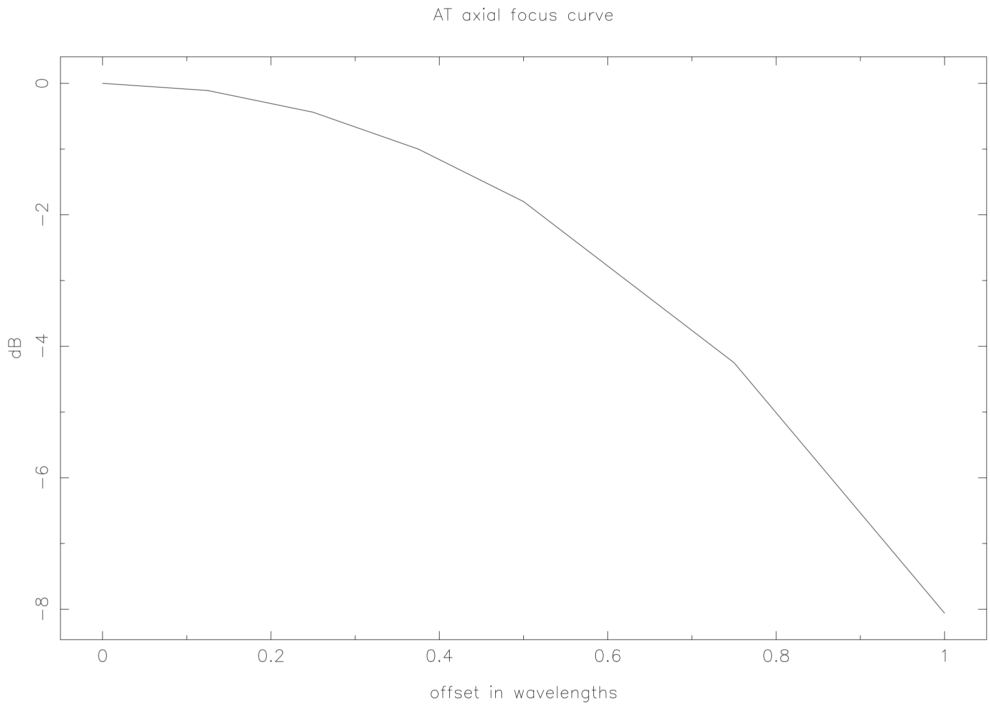

Figure 1: The normalised axial focussing curve for the AT antennas

2 The Reference Jig

We have built a reference beam for the AT antennas which, when installed on precisely defined locating pins in the vertex room roof, locate the optical axis of the antenna.

The dowel pins were installed in the Mopra antenna in January, and in CA03, CA04 and CA02 in April.

3 The Permanent Targets

We have also provided a set of permanent targets on the main reflecting surface which can be used to determine the location and orientation of the subreflector relative to the main reflector.

The targets are 1/16 holes drilled in the panel surface, at the eight cardinal points, at the inner edge of ring 1, and at the outer edges of rings 5 and 6.

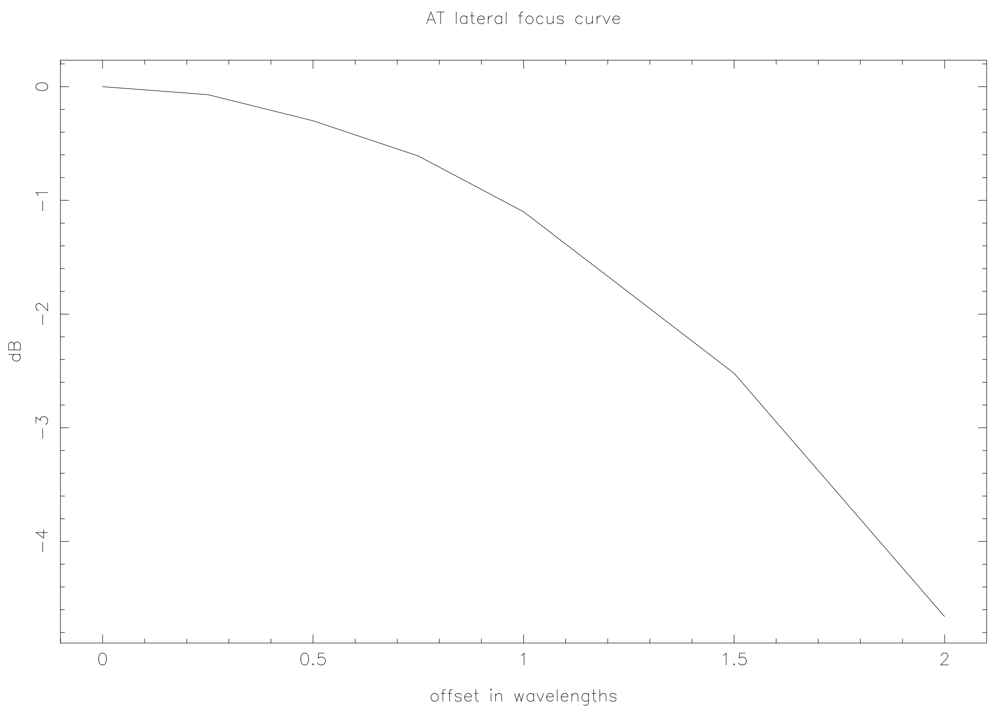

Figure 2: The normalised lateral (in the focal plane) focussing curve for the AT antennas

4 Measurements

Errors We estimate the accuracy associated with these results to be 2mm.

TERMINOLOGY We refer to positions on the reflector in terms of "compass" bearings - if the antenna were pointing towards the horizon, and you were looking towards the surface, North is the highest point, East is to your right, South is the lowest point, and West is to your left.

4.1 CA02

The location of the various receiver packages is given in Table 1, and shown in figure 3

Receiver	E-W offset (mm)	N-S offset (mm)	notes
C/X	-1.0	+2.3	
L/S	+1.0	+11.0	

Table 1: Antenna CA02 - receiver locations, relative to the main reflector optical axis

Subreflector

- The subreflector's axis is parallel to the main reflector axis to within 0.5 arcmin (NS) and 2.6 arcmin (EW).

- The subreflector's axis is offset from the optical axis 1mm towards the North, and 1mm towards the

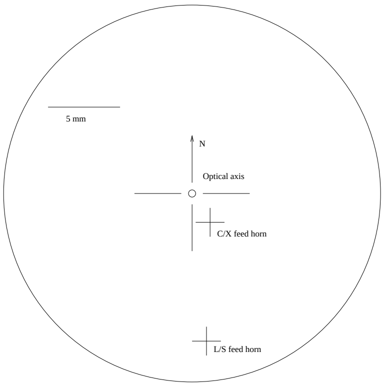

Figure 3: Antenna CA02 - receiver locations, relative to the main reflector optical axis

East.

The Targets

	radius(mm)	height above vertex (mm)
R1 (inner)	1889	133.1
R5 (outer)	9338	3147.8
R6 (outer)	10937	4279.1

The lower surface of the optical-axis locating jig is 1522 mm above the vertex.

4.2 CA03

The location of the various receiver packages is given in Table 2, and shown in figure 4

Receiver	E-W offset (mm)	N-S offset (mm)	notes
22 GHz	-8.5	-7.0	
C/X	+7.5	-1.25	(before index adjustment)
	+0.5	-1.25	(after index adjustment)
L/S	+5.0	-10.0	

Table 2: Antenna CA03 - receiver locations, relative to the main reflector optical axis

22 GHz receiver

The face of the 22 GHz feed horn (below the clamping ring) is 1450 mm above the R1 (inner) targets.

subreflector

- The subreflector's axis is parallel to the main reflector axis to within 2.5 arcmin (NS) and 1.24 mm (EW).

- The subreflector's axis is offset from the optical axis 1mm towards the East

The targets

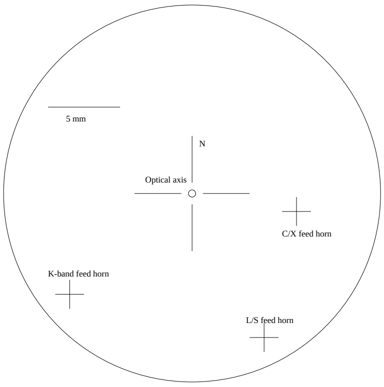

Figure 4: Antenna CA03 - receiver locations, relative to the main reflector optical axis

	radius(mm)	height above vertex (mm)
R1 (inner)	1841	127.1
R5 (outer)	9267	3101.0
R6 (outer)	10936	4278.4

The lower surface of the optical-axis locating jig is 1515 mm above the vertex.

4.3 CA04

The location of the various receiver packages is given in Table 3, and shown in figure 5

Receiver	E-W offset (mm)	N-S offset (mm)	notes
22 GHz	-3.0	+5.0	
C/X	-3.3	-6.3	
L/S	+4.0	-0.7	

Table 3: Antenna CA04 - receiver locations, relative to the main reflector optical axis

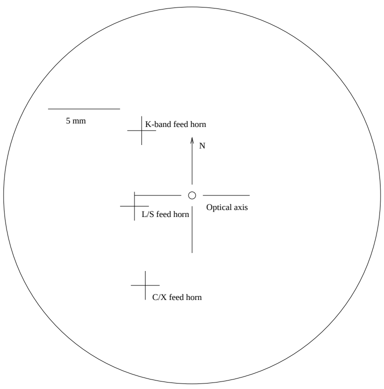

Figure 5: Antenna CA04 - receiver locations, relative to the main reflector optical axis

22 GHz receiver

The face of the 22 GHz feed horn (below the clamping ring) is 1442 mm above the R1 (inner) targets.

Subreflector

- The subreflector's axis is parallel to the main reflector axis to within 0.5 arcmin (NS) and 2.24 arcmin (EW).

- The subreflector's axis is offset from the optical axis 1mm towards the North, and 5mm towards the West.

The Targets

	radius(mm)	height above vertex (mm)
R1 (inner)	1867	130.7
R5 (outer)	9335	3145.8
R6 (outer)	10935	4277.6

The lower surface of the optical-axis locating jig is 1511 mm above the vertex.

4.4 MOPRA

The mopra antenna was checked in January, 2000. The C/X receiver was found to be within 2 mm of the optical axis; the mm receiver was 10mm offset. Since a repositioning of the index pin locator could not reduce this error, we moved the receiver. The error is now less than 3 mm.

Subreflector

- The subreflector's axis is parallel to the main reflector axis to within 0.75 arcmin in both directions.

- The subreflector was adjusted laterally, 6.5 mm in the NE direction.

5 This Data and the October, 1999 Holography

The holography surveys of the Narrabri antennas made in October, 1999 measured the subreflector positions; these are in reasonable agreement with the alignment observations. We can combine the receiver and subreflector measurements to predict the offsets that would be seen by the holography.

antenna	EW offset (mm)	NS offset (mm)	predicted EW	predicted NS
CA01	+0.7	-0.1		
CA02	+0.7	+0.0	+1.0	+1.0
CA03	-2.5	+1.2	(-1.8)	0.
CA04	-3.9	+0.5	-4.0	0.
CA05	+1.5	-2.5		

Table 4: The subreflector positioning, measured by holography (first two columns) and predicted from the survey data

The holography receiver (at 12.75 GHz) was installed over the C/X frame, so should share the feed offsets of that receiver. The results for CA03 are unclear, as the C/X turret location has been adjusted twice since the holography observations.

6 Discussion and Recommendations

- All the receivers measured were installed with more than adequate precision to ensure that the antenna gain was never compromised. You need $(\Delta/\lambda) \sim 7$ to see a 1dB reduction in gain.

  The new 80 GHz receivers are just at the point where higher precision is relevant.

  We expect to make the final sub-reflector adjustments on the basis of holography measurements. Since the error signatures of feed and sub-reflector offsets are so similar, we should ensure that the holography and mm receivers have the same offset - and preferably zero offset.

- The feed offsets lead to a pointing error, described as the squint term in the pointing model. It amounts to 3.6 arcsec/mm at all frequencies. This means that we need receiver-specific pointing model corrections, as we need to be able to transfer pointing models from one frequency to another.

———————————————————————

file:/nfs/corfu0/survey/txt/nbr_report.tex