Antenna on the rail observations

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1 Introduction

This note addresses the question of whether observations could be made with the antenna parked on the rails, rather than on the station posts. G.Nelson and I (mjk) looked at this problem a number of years ago and concluded that the arrangement was not satisfactory. We raise the issue again for several reasons:

a. no report has been found for the earlier experiment, so no quantitative assessment of the limitations is possible.

b. doubts have been expressed about the original experiment; in particular, it is now recognised that a control valve is required in the eastern hydraulic circuit, and it seems probable that no such valve was in place previously.

c. new stations are being planned, for the N-S arm, and three on the E-W section. In addition, requests have been made for non-standard spacings for a few specific astronomical targets. Significant savings wouild accrue if the stations could be simplified.

We repeated the experiment under better controlled conditions on 17 September. The results were unexpected: it is true that the pedestal room moves by significant amounts; however the effects are quite benign as they translate to a simple squint in elevation which would be absorbed in the calibration process. Thus the trials suggest that this form of operation could be satisfactory for most observations other than the mm-wave observations.

2 Background

At present, the antenna is positioned on the station piers for all observations. The four piers of a station are part of a substantial reinforced structure with piers down to the softrock substrate. The pier tops were carefully adjusted to lie in the plane coincident with the plane tangent to the ground at station 35 (the western-most end of the track). The rail bed is substantial, but does not have the same stability as the station piers. The rail itself is tied laterally to the station piers in order to ensure that the antenna can always be positioned at a station.

It should be noted, however, that some stations have moved over the past years - station 30, for example, has tilted a few arcminutes due to pier movement.

3 The Question

Are observations possible at locations away from a station, using the long travel jacks to support the antenna. A number of problem areas have been identified:

3.1 The Hydraulics

The basic plan is to stop the antenna between stations, raised on the bogie jacks, leaving the hydraulic circuits individually isolated.

(a). How tight are the cylinder seals? The hydraulic experts assure us that the cylinders are such that no leakage will occur, and that the antennas can remain in this configuration for extended periods of time. We have yet to test this matter: although our tests showed no evidence of pressure decay, the time interval was too short (2 hours) for any useful conclusion. We note however that in the past nine years of operation there has been no evidence of seal leaking.

(b). Modifications required? A check valve is required to prevent twisting of the structure. During the long travel operations the antenna is raised off the station piers with hydraulic jacks attached to the bogies. There are three independent circuits: a separate circuit for each western bogie; the two eastern bogies share a common circuit. This is needed to minimise the twisting which could occur as the antenna moves along the rail, due to uneveness of the rail. In effect, we have a three-point mount.

The situation changes during observations with the antenna at a fixed position on the rail; twisting will occur unless we isolate the two eastern jacks, since the weight of the moving structure is not centered on the axis of the slewing ring, which means that the load on the jacks will vary as the antenna is slewed in azimuth.

3.2 Track ballast stability

Some concern centers on the possibility that the ballast could compact under the varying load as the antenna slews in azimuth and elevation, and is subject from time to time to wind loading. This could lead to non-repeatable tilts of the pedestal structure. These trials suggest that such deformations as occurred were quite elastic and repeatable, which would imply that the ballast compression played a minor role. Tests over a longer period are probably required.

Some ballast strengthening options should also be explored, such as additional shoulder ballast and ballast bonding.

3.3 Safety

(a). What happens if a seal fails? The situation is probably no worse than a failure during long travel - that is, presumably there is no fundamental mechanical obstacle to this mode. However, it would seem prudent to monitor closely the pressure, and to issue an alarm, and to switch on the hydraulic pumps should the pressure ever fall below some threshold.

(b). Wind forces. The station piers are 8m apart, so the dead-weight moment opposing the wind overturning moment is 10400 kN-m (=260 Tonnes * 4m). In addition, we have the typhoon tie-downs which will provide an additional 3200 kN-m [1]. The worst case wind turning moment (based on the JPL tests - R.Levy, 1996; Structural Engineering of Microwave Antennas), azimuth 0; elevation 0 degrees is :

[1] assuming a 20 tonne force limit at the tie-down

$$M = 0.5 \rho v^2 C_f A h$$

where :

ρ	$1.2 kg/m^2$	density of air
v		wind speed, m/sec
C_f	1.5	axial force coefficient
A	$380 m^2$	antenna area
h	11 m	height of the elevation bearing

This leads to an overturning wind speed of 60 m/s (216 km/hour).

The track spacing is 9.5m, which will raise the dead weight moment to 12350 kN-m, corresponding to an overturning wind speed of 58 m/s (208 km/hour).

We note however, that the bogies do provide a backup safety measure when the antenna is positioned on the station piers - thus the stations are probably the safest location for an antenna during seriously high winds.

(c). Stability in the east-west direction. The drive motor brakes are applied to prevent motion along the track; and wedges are available which will prevent a run-away.

(d). Long travel hydraulic cylinders. These were designed to cater for wind speeds of up to 20 m/s, with the antenna at the zenith. This is already greater then the current wind stow limit, of 45 km/hr (= 12.5 m/sec). (cf. fax from J.Schafer to J. Brooks, sept. 1997)

4 The experiment

The test equipment was installed on antenna 3, on station 8. The experiment was run on September 17, during the morning hours.

We installed tiltmeters next to the elevation bearing. Two tiltmeters were installed back-to-back parallel to the elevation axis, and two were normal to the axis. The tiltmeters have an rms error of 1 arcsec.

The antenna was tipped to 15 degrees elevation, then slewed 360 degrees in azimuth. Since station 8 is 2.8 km from station 35, we expect to see a sine function in the measured tilt as the antenna slews in azimuth, of amplitude 90 arcseconds. An additional offset will result if the station is tilted with respect to station 35. The pointing model determined prior to the experiment showed additional tilts of -11 (NS) and +21 arcsecs (EW) for this station. Figure 1 shows the raw data collected prior to the lift. This data corresponds to a mean tilt of 102.9 arcsec in the direction of 273 degrees azimuth. Figure 2 shows the polar wandering as the antenna slewed in azimuth. Except for the stow position (azimuth 90 degrees) the pole variation is small, adding 1.5 arcseconds (rms) to the pointing error.

After lifting the antenna about 3 mm above the station piers the antenna was tipped to an elevation of 15 degrees, and the azimuth slew repeated. The mean tilt increased to 113.9 arcsecs, towards azimuth 276 degrees. The polar wandering increased, as shown in figure 3. The wander will add 4 arcsecs (rms) to the pointing error. The increase in the mean tilt is not significant, as it depends on the specific pump rates which will govern the heights reached in each piston prior to isolating each cylinder. The polar wandering is important, however, and defines the highest usable frequency in this mode.

We also installed dial gauges to monitor the spacing between the station piers and the antenna structure. The dial gauges are accurate to 10 microns. Very little movement was detected as the antenna was tipped from the zenith to 15 degrees elevation. A 0.3 mm cycle was seen at each dial

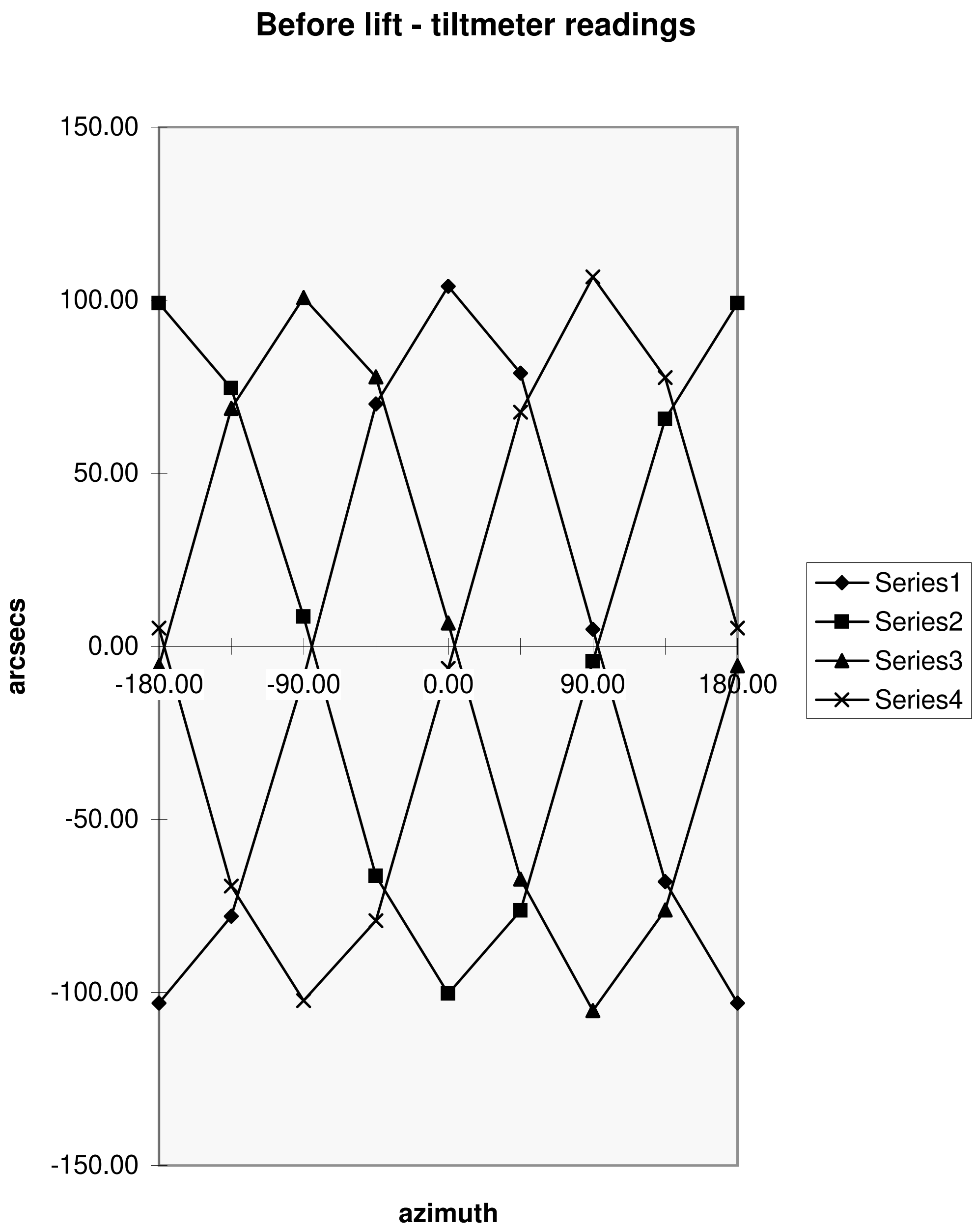

Figure 1: The tiltmeter readings, in units of arcseconds

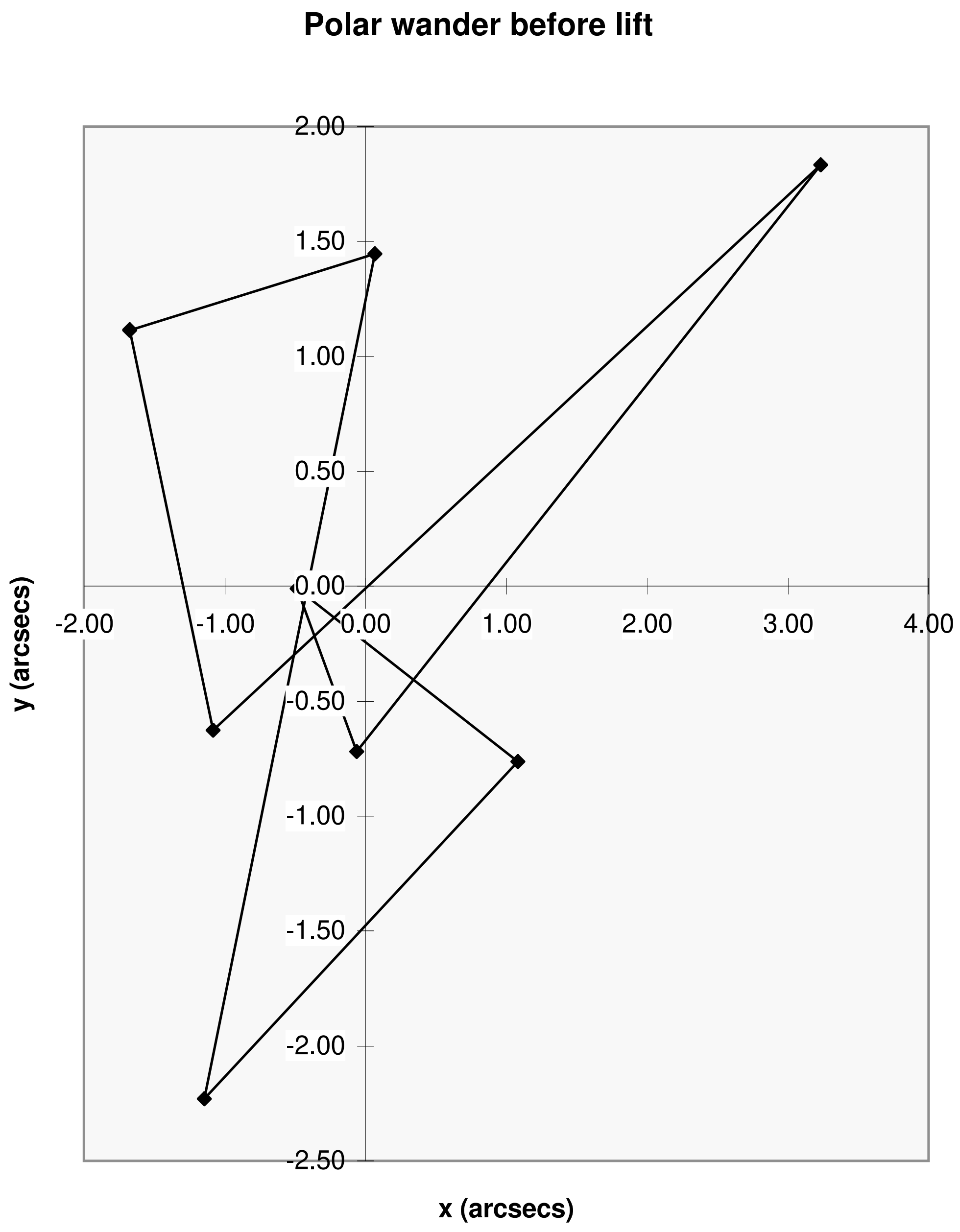

Figure 2: The polar wandering measured at the elevation bearing, before lifting the antenna

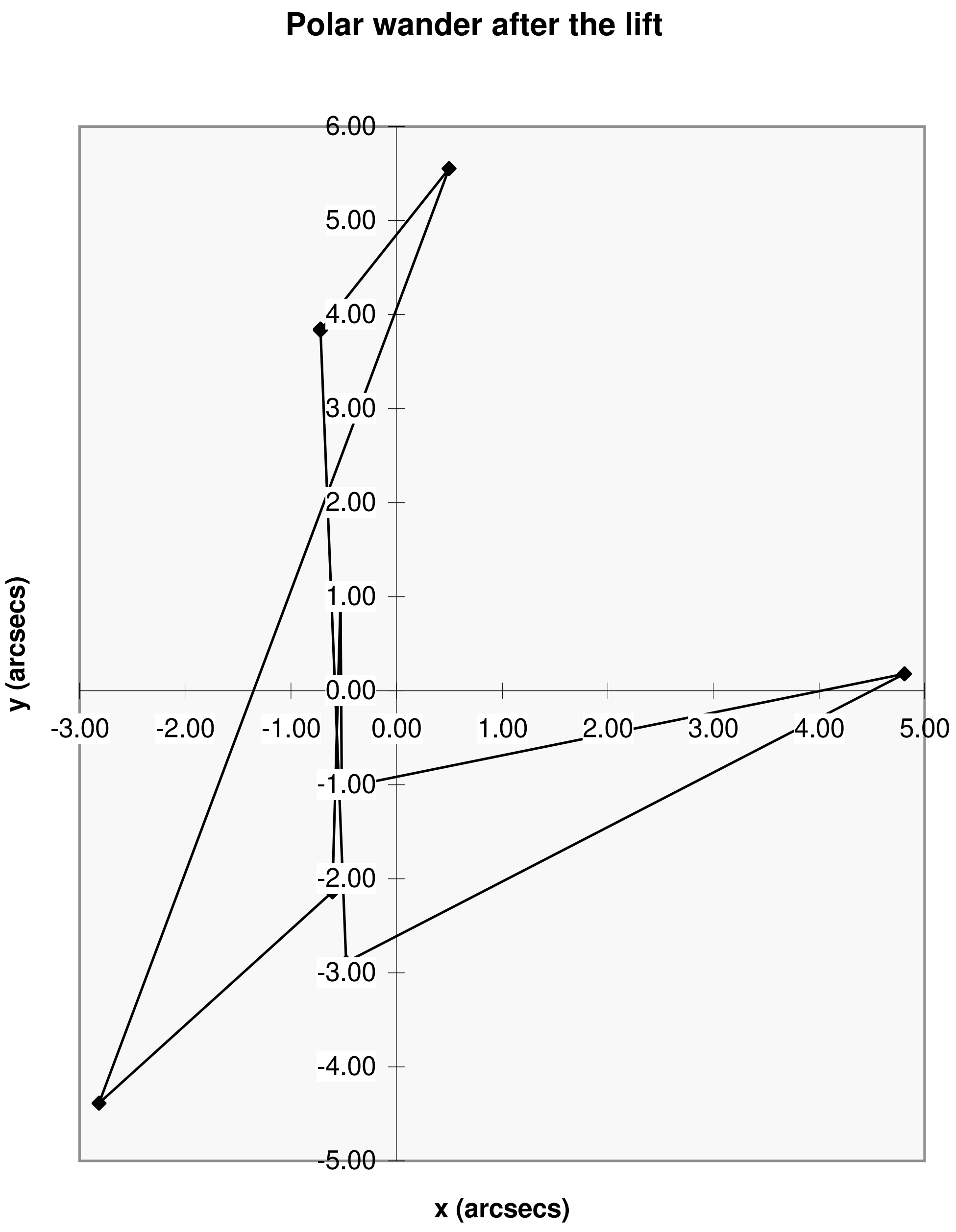

Figure 3: The polar wandering measured at the elevation bearing, after lifting the antenna

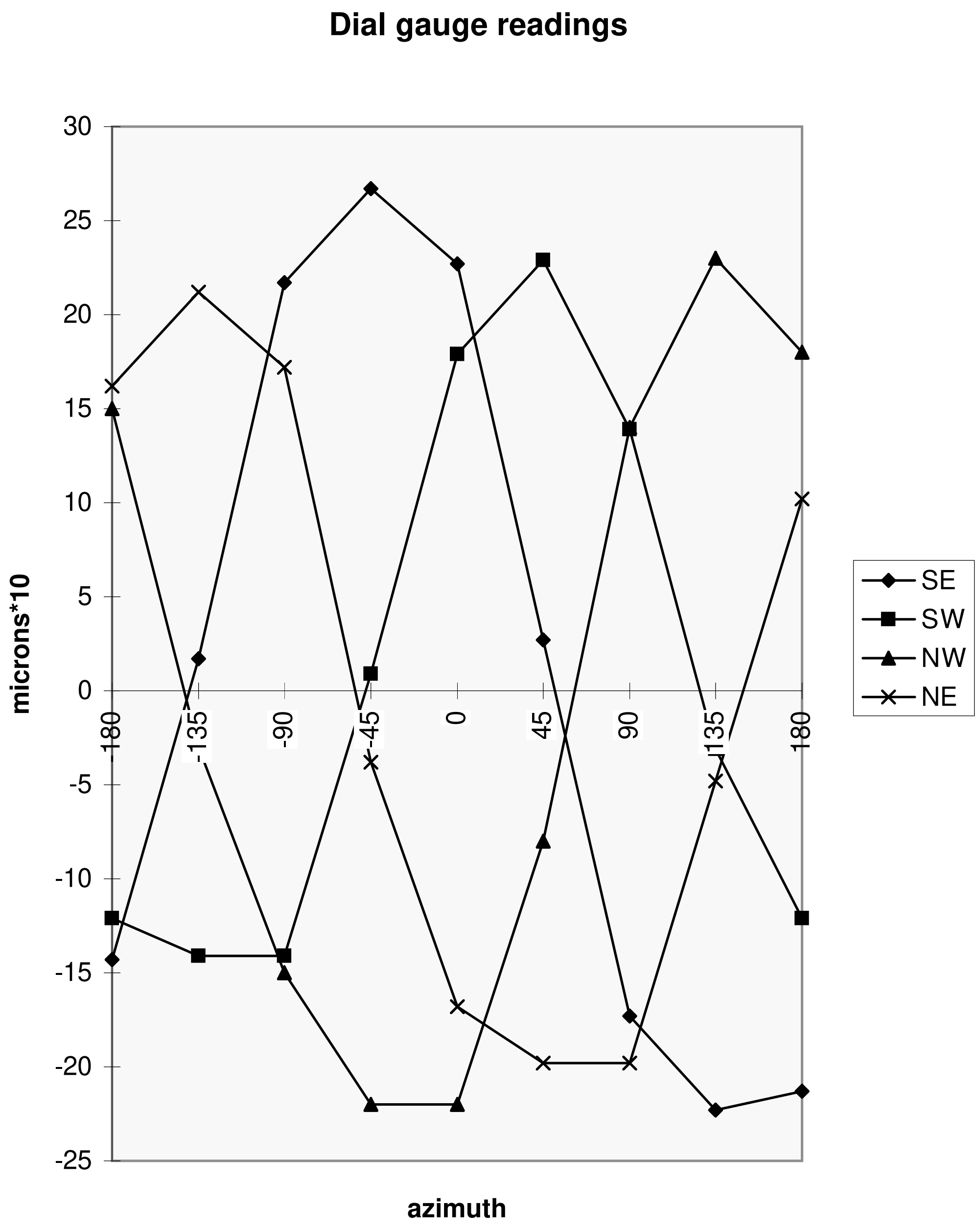

Figure 4: The dial gauge readings, in units of microns*10

gauge as the antenna slewed in azimuth. The phase of the cycle was different for each gauge as seen in figure 4. It is known that the alidade is not symmetrical, with a moment of about 250 kN-m at the slewing ring. (J.Schafer fax to J.Brooks, 1988); if the structure below the slewing ring is flexible, then the azimuth axis will tip. The tilt is always about the elevation axis, and therefore appears as a constant squint in elevation. The azimuth axis wobble is shown in figure 5. The difference between the observed locus and a circle will contribute to the pointing error - from this restricted dataset the rms looks to be of order 2-3 arcsecs.

To first order the deformations are elastic.

A 6 arcsec wobble is also present when the antenna on the station piers; in this case the flexibility is in the pedestal room structure. See AT/21.1.2/074 (1987).

We can use the alidade imbalance to calibrate the antenna and assess the sensitivity to wind loading. The imbalance moment is 250 kN-m; the corresponding worst case wind loading that could equal this moment has a wind speed of 8 m/s; in other words, a 10 m/s wind would lead to a non-repeatable tilt of about 8 arcsecs. The median wind speed of 2 m/s would lead to an error of 0.5 arcsec.

5 Conclusions and Recommendations

1. The preliminary indications are that observations with the antenna on the rail are feasible for all but the mm observations. Several potential problem areas have been identified, so further tests are needed.

   New stations are required for the N-S spur; but a case can possibly be made that the new stations on the E-W arm could be simplified by dispensing with the piers. The non-standard spacings could be satisfied with this mode.

2. Operating the antenna on the long travel jacks degrades the pointing accuracy by about 3 arcsecs.

3. The antenna is slightly more sensitive to wind loading, but the error will be insignificant for the wind speeds characteristic of narrabri.

4. We have not tested the long term (several weeks) stability of the ballast. Settling may occur on such time scales, if the antenna is driving and vibrating the rails and ballast.

5. We have not tested the long term pressure stability in the hydraulic systems; we note that the hydraulic experts have argued that no problems are likely.

6. The stow position in antenna 3 seems slightly damaged, at the 5 arcsec level. (see figure 2 Remedial action is probably impractical, but efforts to prevent further damage would be wise. These checks should be carried out on the other antennas.

7. A comprehensive study of the safety in very high winds is advisable.

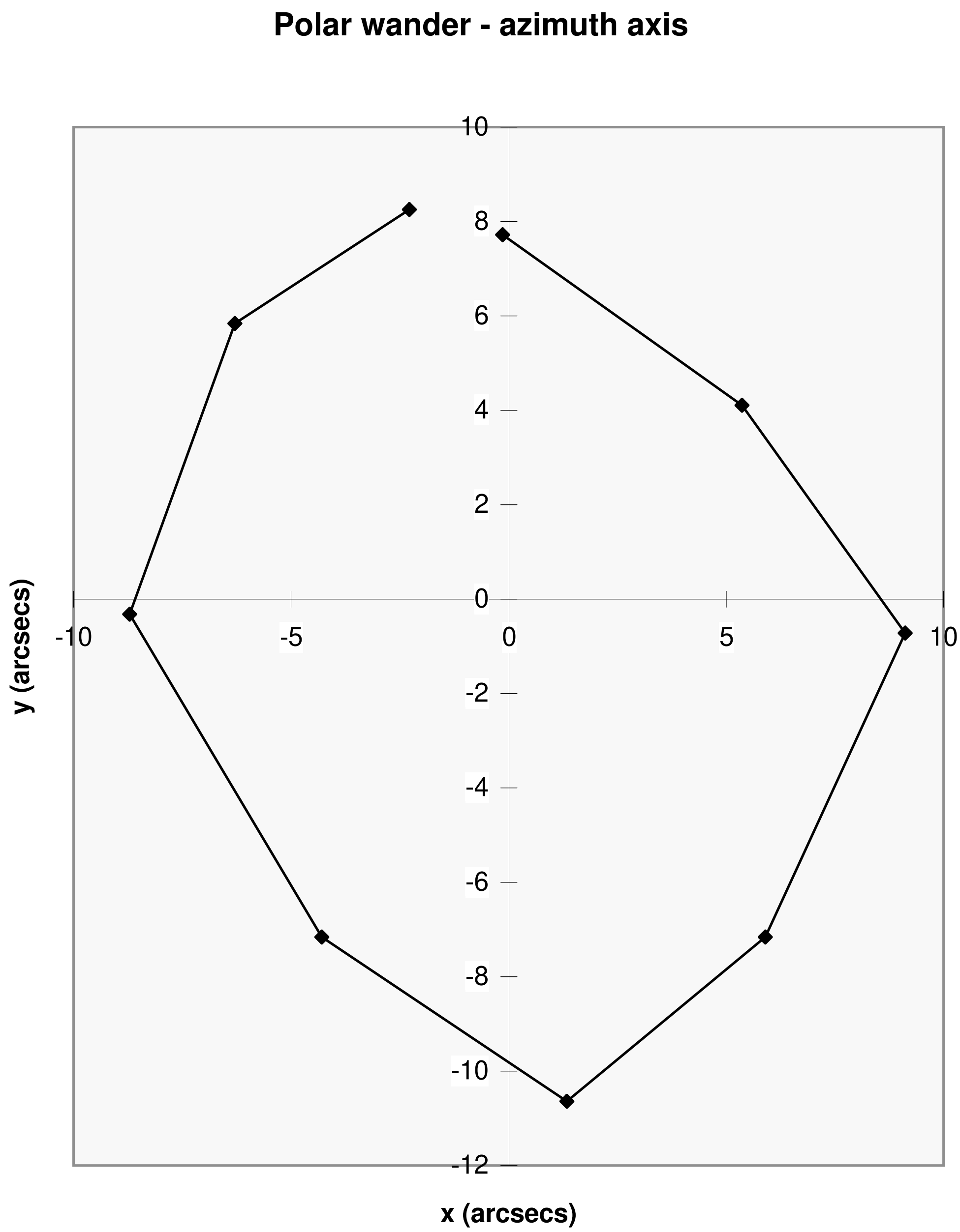

Figure 5: Polar wandering of the azimuth axis