The effect of mechanical alignment errors on a Fork mounted Telescope

Introduction.

It is inevitable that a fork mounted telescope will have line of sight (LOS) pointing errors that vary across the hemisphere of the sky. To investigate the significance of, and the relationship between, mechanical and optical pointing errors, a mathematical model has been produced that shows the effect of the major contributors.

The two prime mechanical problems are the non orthogonal assembly of the DEC to RA axis, and the TUBE to DEC axis.

In a real world, with removable Fork Arms and Optical Tube Assembly (OTA) it is reasonable to expect that there will be assembly errors. It is the intention of this model to show the effect of the errors on a telescopes performance and to devise a better method of alignment.

Discussion.

When a fork mounted telescope is not perfectly aligned, the errors show themselves as an apparent RA rotation as a result of a DEC movement.

Both of the common misalignments, RA to DEC axis and OTA to DEC axis, produce similar errors, producing an apparent RA rotation for a DEC movement. However whilst similar they both have different mathematical functions.

The resultant error for the LOS of the telescope is the sum of the two errors, which in exceptional circumstances can in fact compensate each other, to reduce the net error to a minimum.

This minimum (best achievable error) can be displayed by a graph as in fig 1.

It has been found that there is a ñsweet spotòfor the OTA to DEC alignment that can compensate the RA to DEC orthogonal error. The graph is the ñsweet spotò OTA alignment against values for the DEC to RA error and it also shows the standard deviation (STDev) of the telescope LOS from the predicted pointing vector.

For reference; on an LX200GPS 8òscope, a 0.001òdifference in fork arm heights, produces a DEC axis error of 17.1 ArcSec, whilst a similar error on the OTA mounting produces a LOS error of 25.8 Arc sec. In such a case the ñsweet spotòalignment for the OTA is 12 Arc Sec., which would produce a LOS standard deviation of only 3 ArcSec from the ideal, over a DEC range of 1 to 89 degrees.

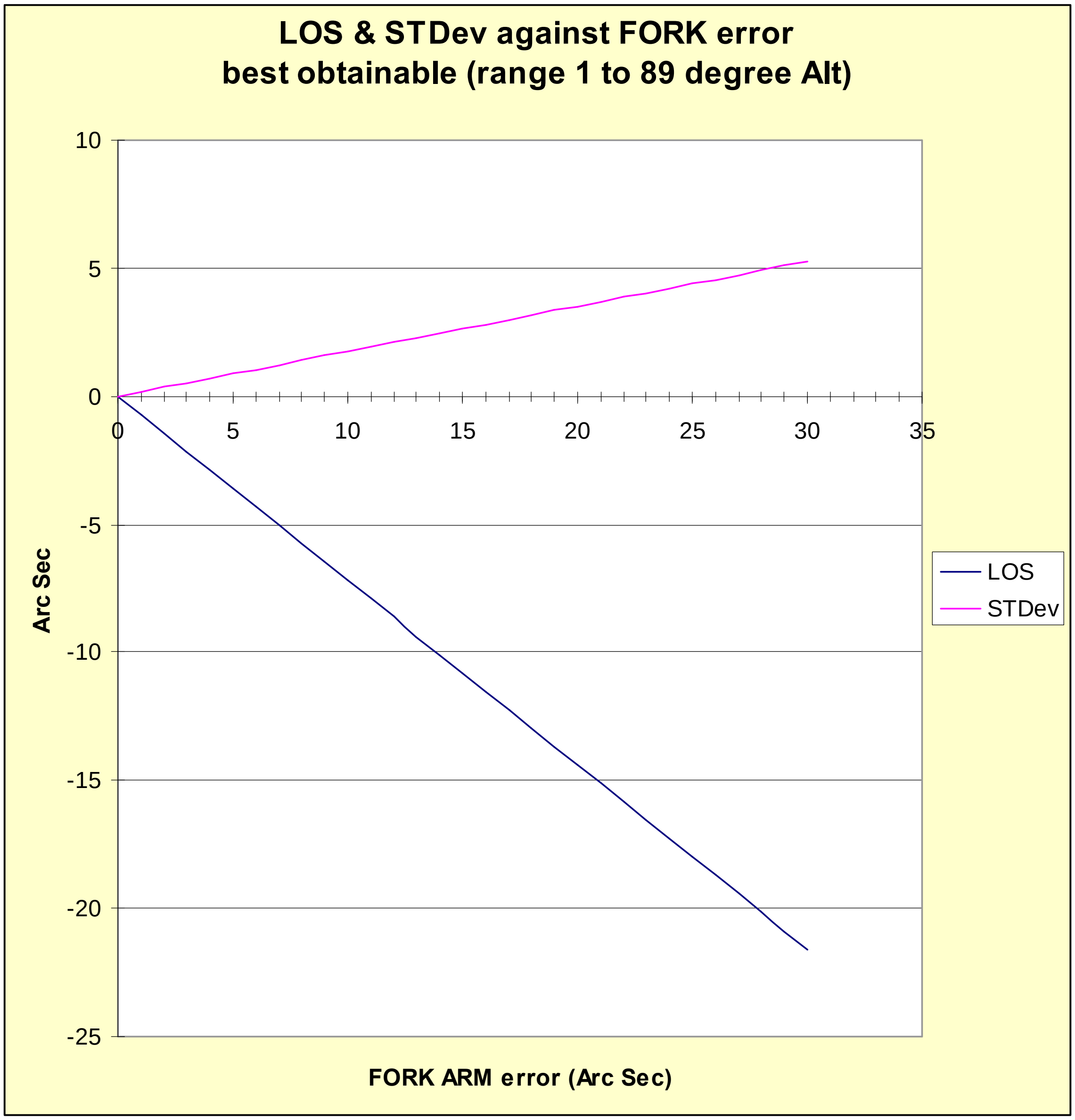

Figure1.

Note. This is the optimized, OTA to DEC alignment, to give the minimum LOS pointing deviation for any given Fork Arm height error. This is the best possible alignment.

So what are the realities of life?

The next graph (figure 2) shows a typically assembled and aligned telescope. Here equal errors of 0.002ò have been applied to each axis. Also the OTA to DEC error is in the wrong direction. Typical of what is achieved by bouncing a laser off the corrector plate, or putting a dial gauge on the outside of the OTA.

The graph assumes that the telescope has been correctly Auto Aligned or leveled, then synchronized on a star at 45 degrees above the horizon.

Here it shows the apparent error in Azimuth (Az) caused by a movement in Altitude (Alt) for a Alt/Az mounted scope. Please note that these errors apply to polar mounting as well.

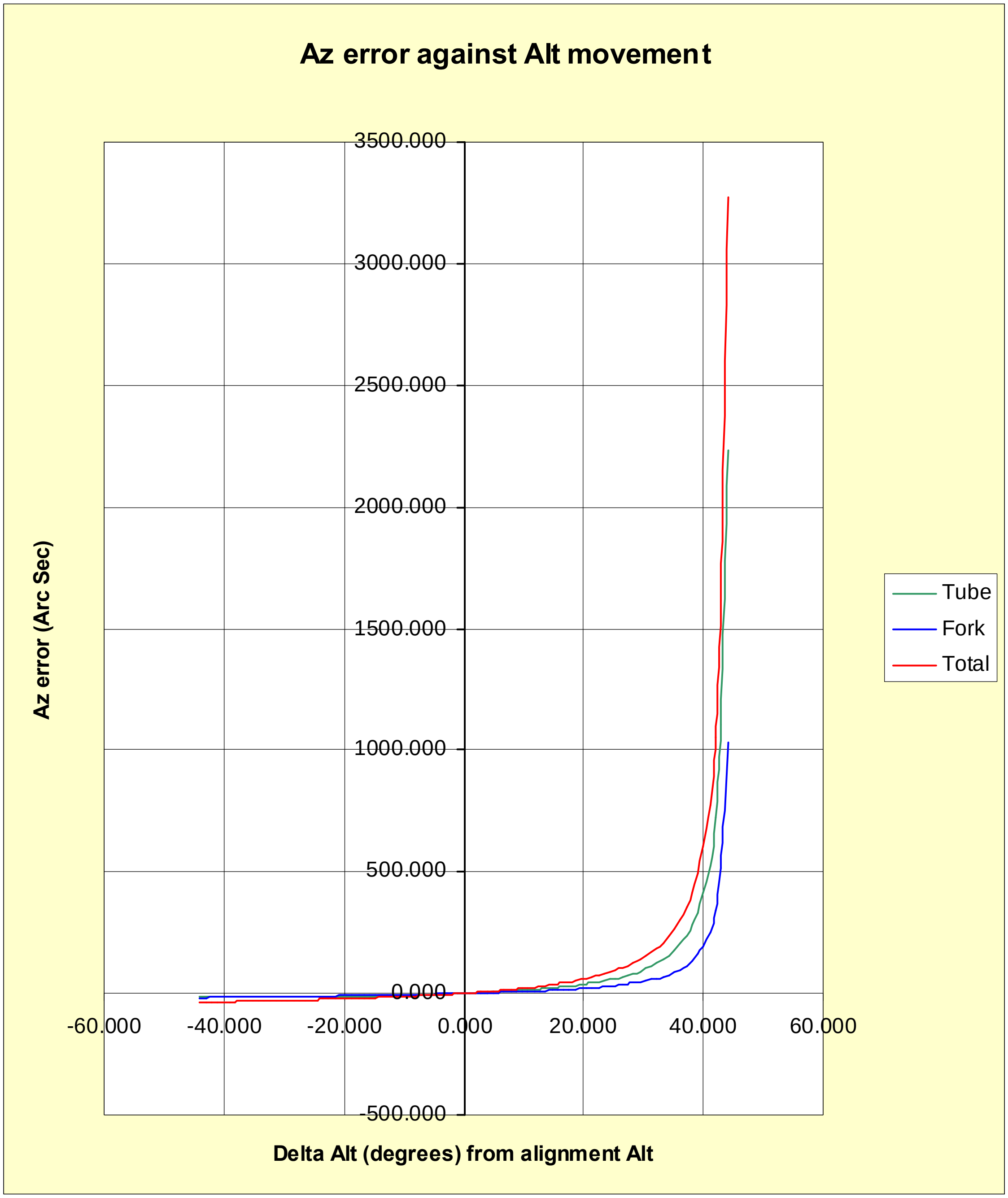

Figure 2.

The graph shows the Az pointing errors verses the Alt movement from the Star synchronization point of 45 degrees Alt. Errors due to the Tube (OTA) and Fork arms are shown separately and combined. The STDev for the range of Alt = 1 to 89 degrees is 410 ArcSec.

This case is typical of the situation where good mechanical alignment is carried out without reference to the optical path through the OTA.

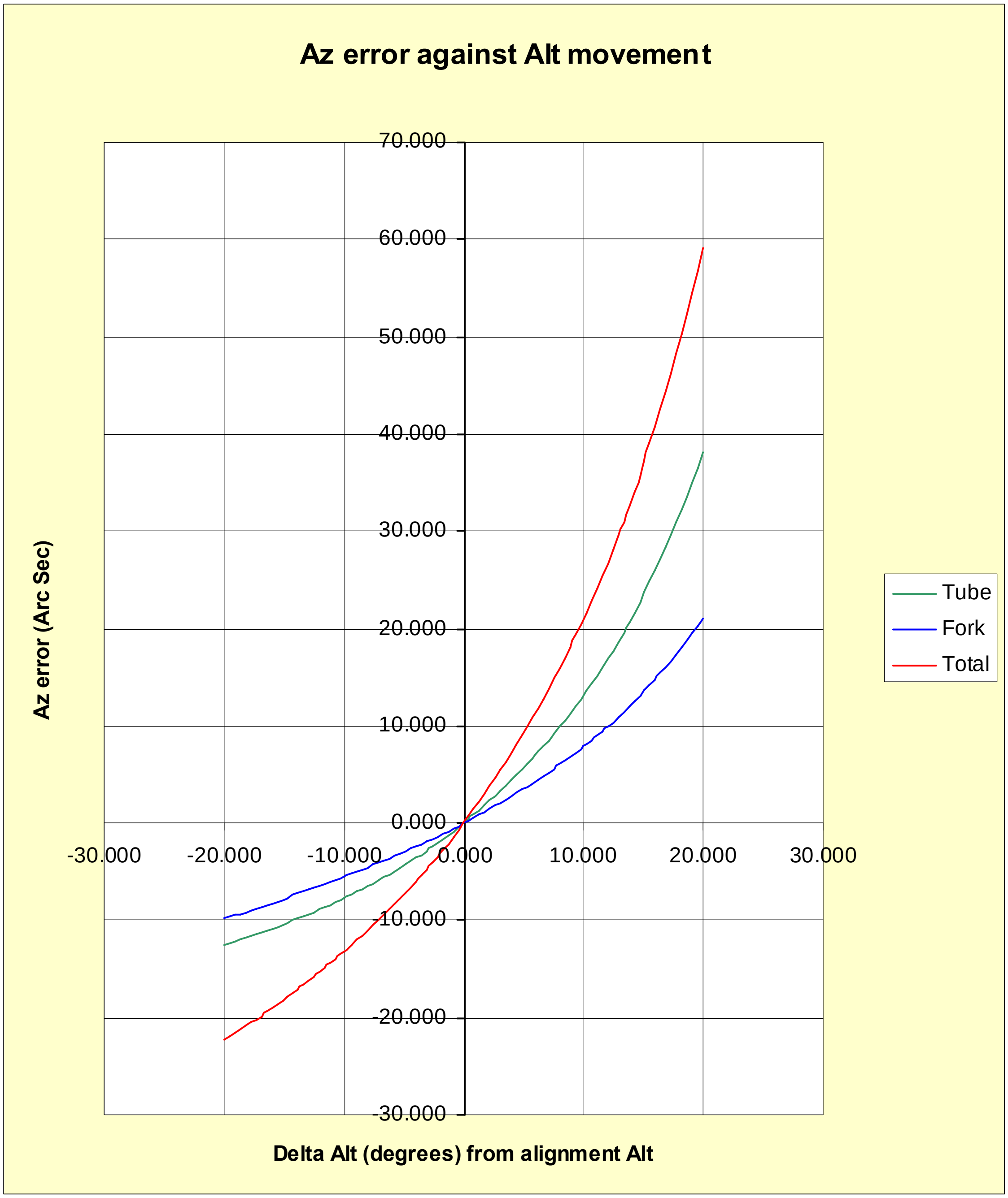

Figure 3.

Figure 3 shows the same data set as figure 2, but expanded to show, plus and minus 20 degrees of Alt about the synchronization star.

When the OTA is aligned to the DEC axis using an optical line of sight method, for example, Andrew Johansen's method, mirror mount above the OTA, which is pointing vertical, and aimed at a terrestrial object. The following results.

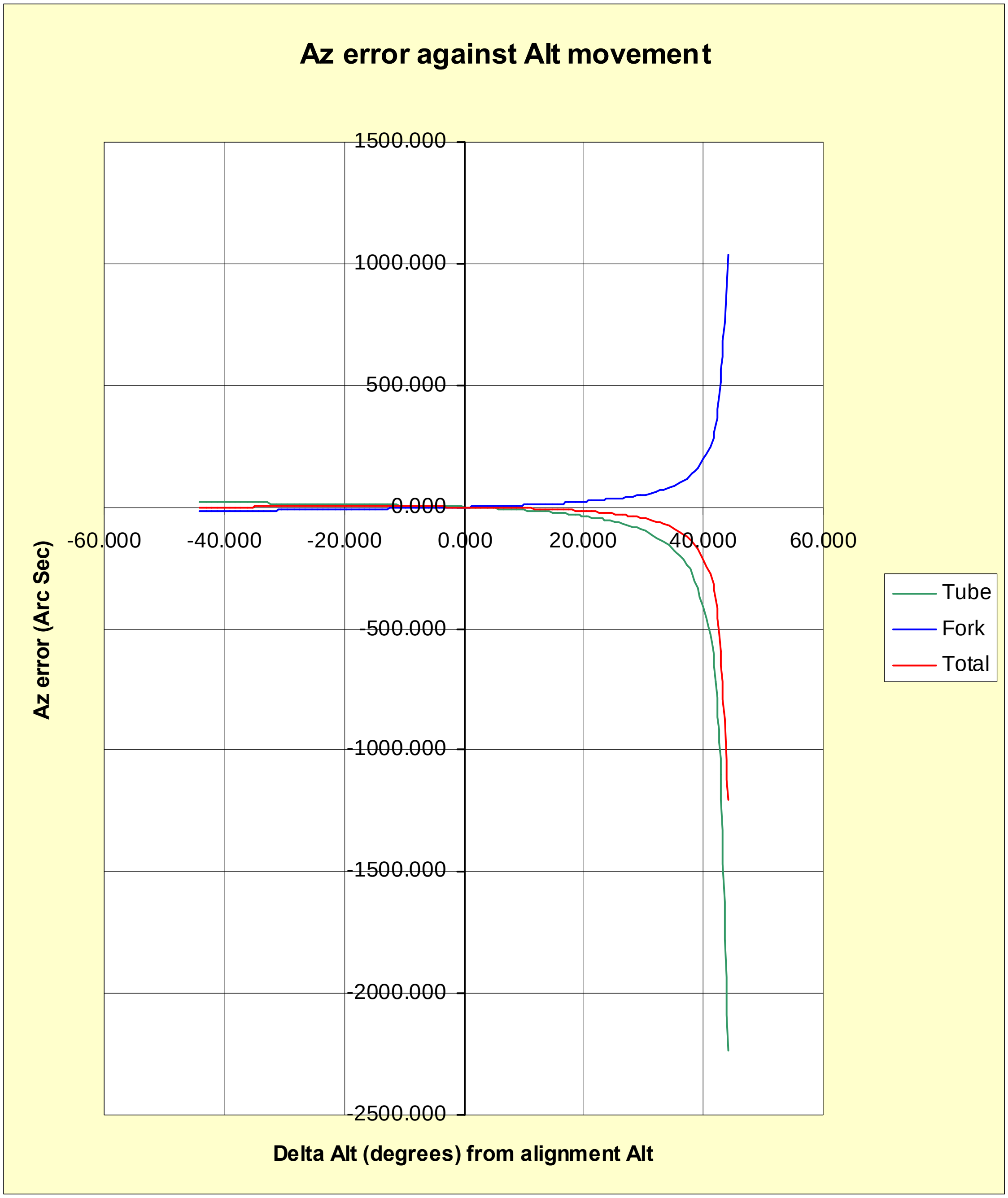

Figure 4.

The same mechanical precision has been applied, except in this case the optical LOS alignment has compensated for the Fork error with the correct direction of error for the OTA alignment. Note that the error STDev is now reduced to 149 ArcSec.

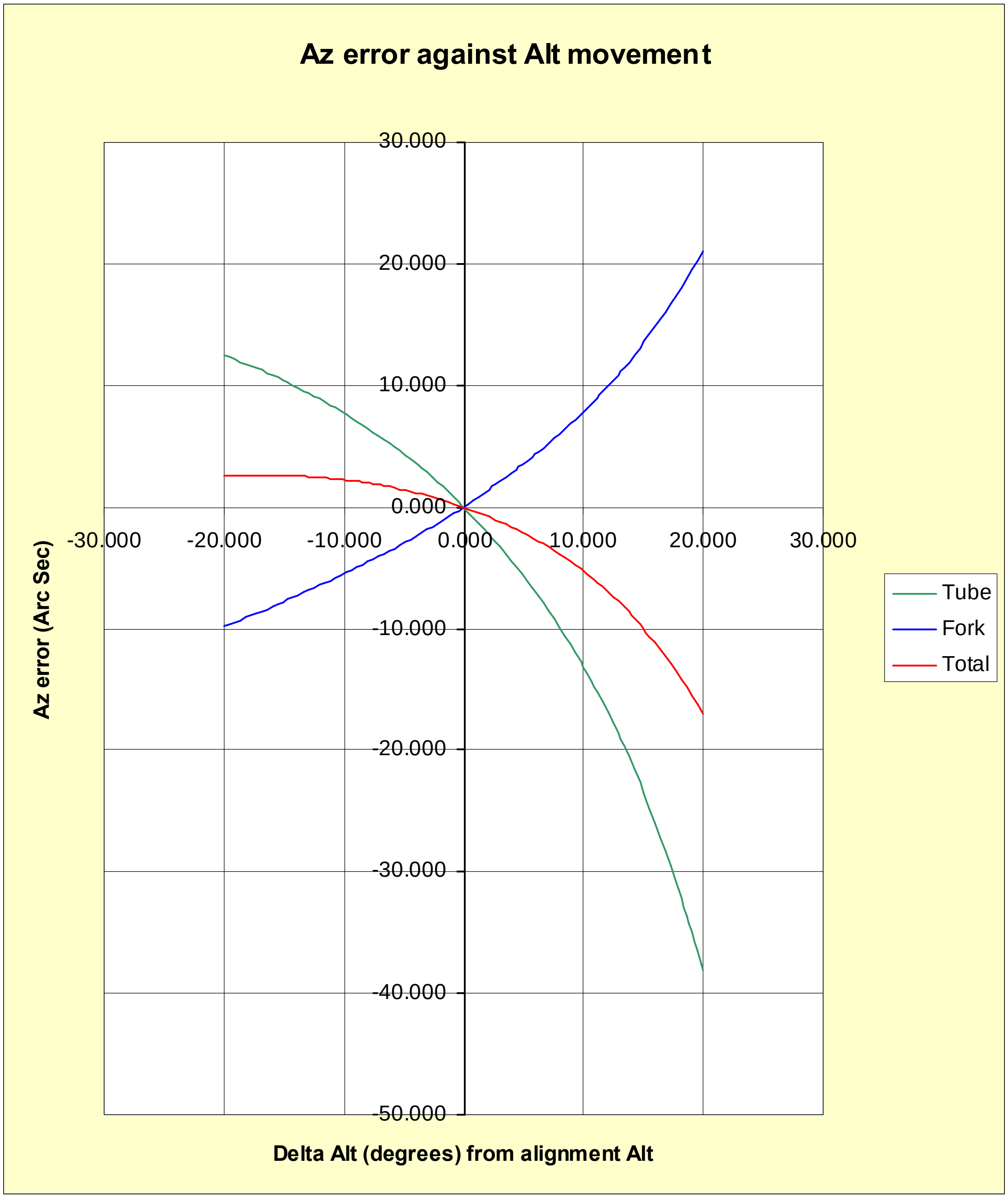

Figure 5.

This is as figure 4 but again expanded to show plus and minus 20 degrees from synchronization.

In this case there is considerable improvement in the pointing accuracy with acceptable working within a few degrees of a synchronization point, as would be the case if Smart Mount Technology (SMT) is employed.

The requirement for SMT can be negated if the OTA alignment is tweaked to find the ‘sweet spot’ as shown in the next graph.

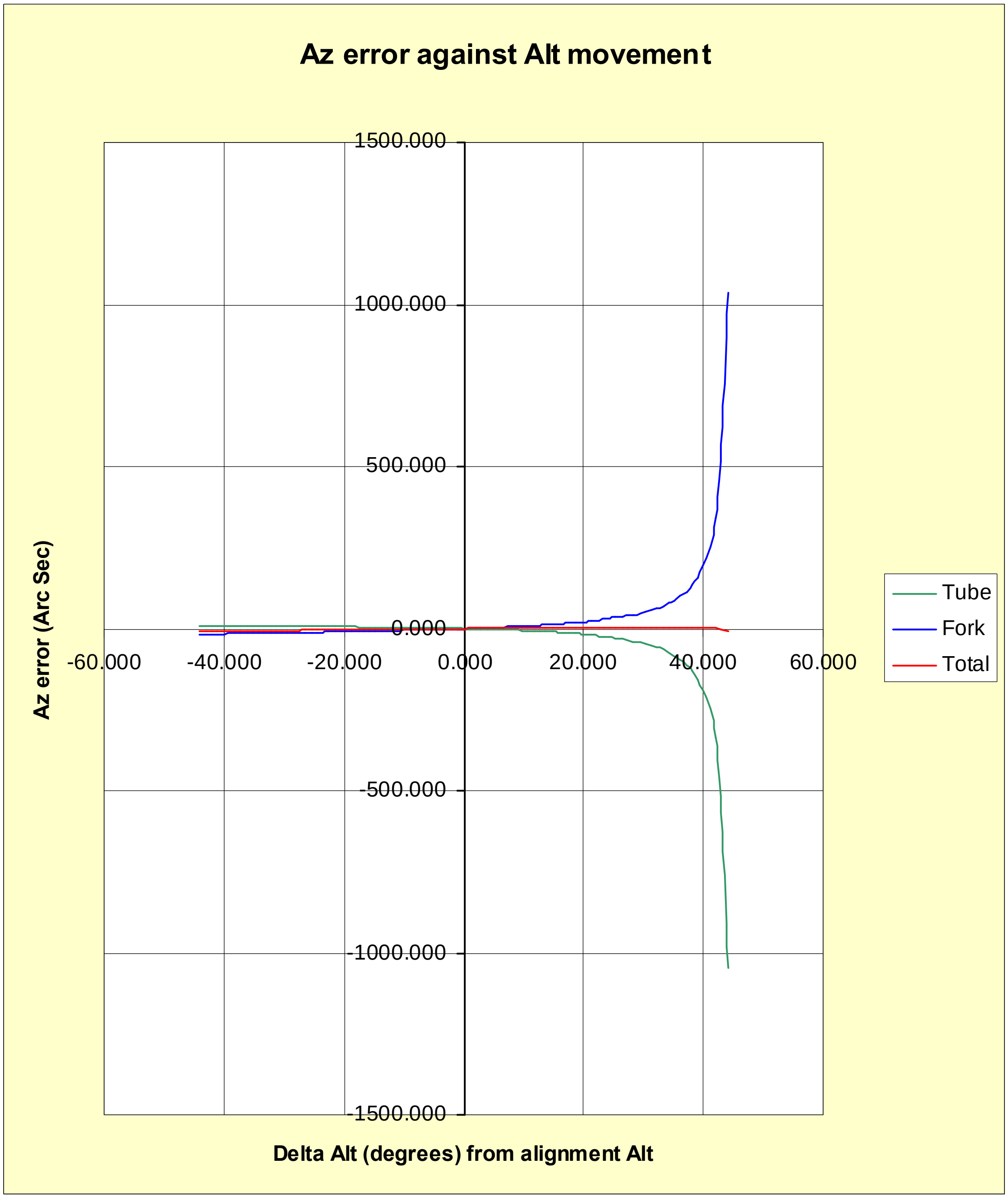

Figure 6.

This is the same Fork arm error as in figure 4, except the OTA alignment has been tweaked by star alignment error analysis to find the ‘sweet spot’. This results with a STDev of only 4.6 ArcSec over the 1 to 89 degree Alt range. The resultant OTA alignment was tweaked to -18.7 ArcSec offset.

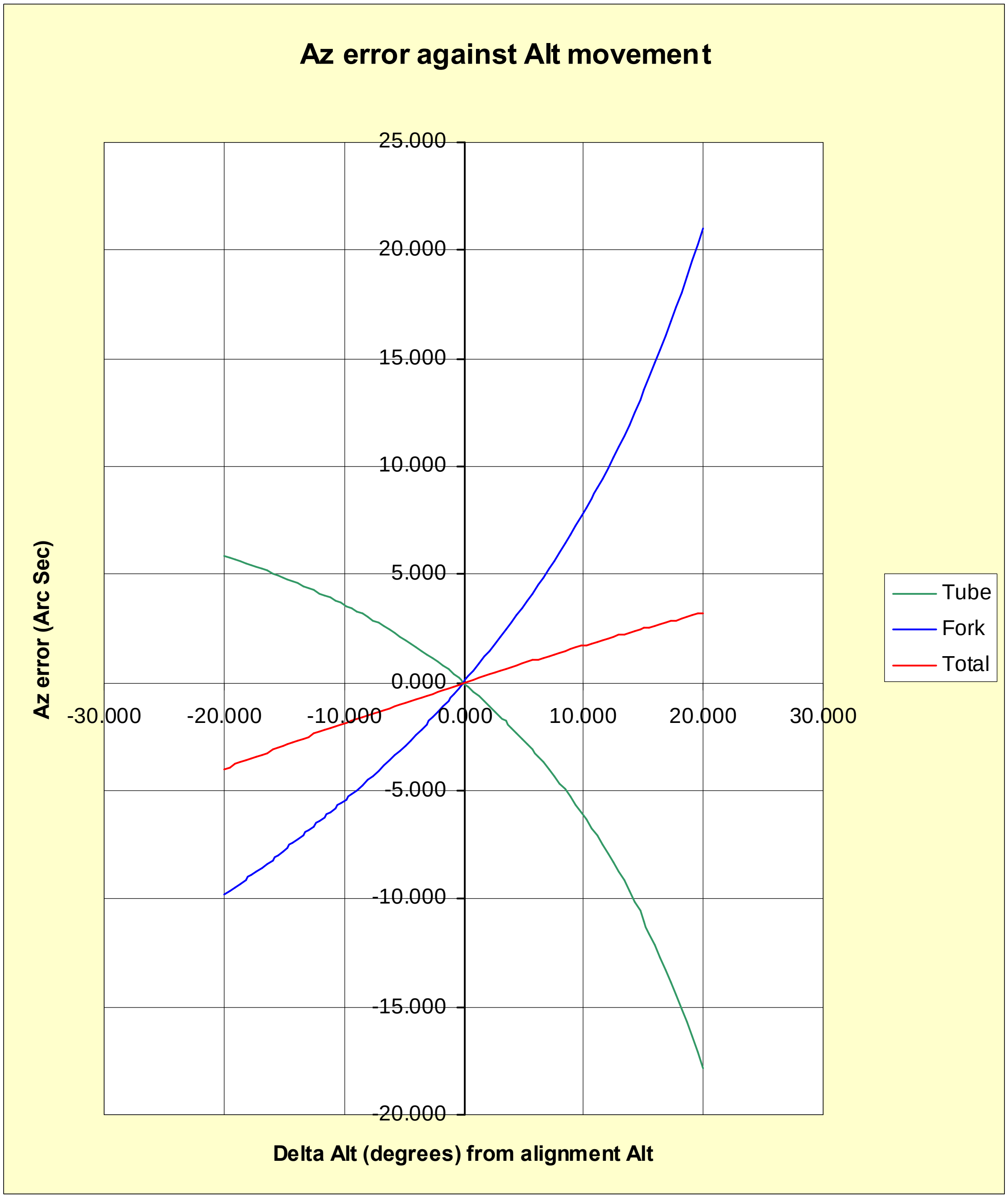

Figure 7.

Again Figure7 is an expanded view of figure 6. Note that the pointing error is now reduced to about ±4 ArcSec of Az, over a 40 degree Alt range

To find what might be the limit of accuracy achievable, a LX200GPS 8ò was modified and aligned mechanically to set the fork arms to an accuracy about 8.2 ArcSec, then star aligned to tweak the OTA to DEC axis alignment to the ñsweet spotò

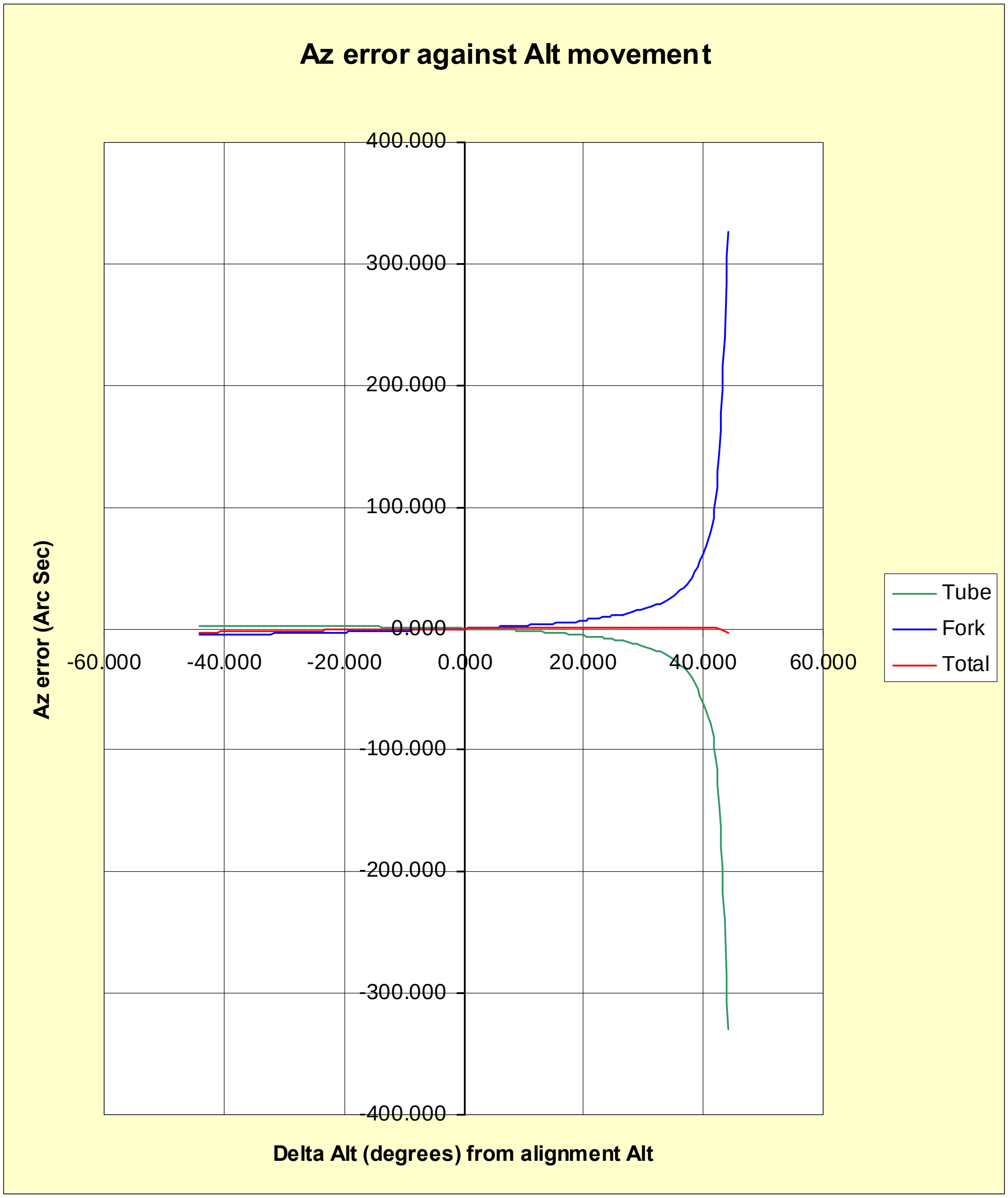

Figure 8.

An optimally mechanical aligned telescope. The STDev over the range of 1 to 89 degrees is only 1.4 ArcSec.

This results in a precision of plus / minus 1 ArcSec of Az error, over the Alt range of 20 degrees above and below the synchronization star. This is depicted in figure 9.

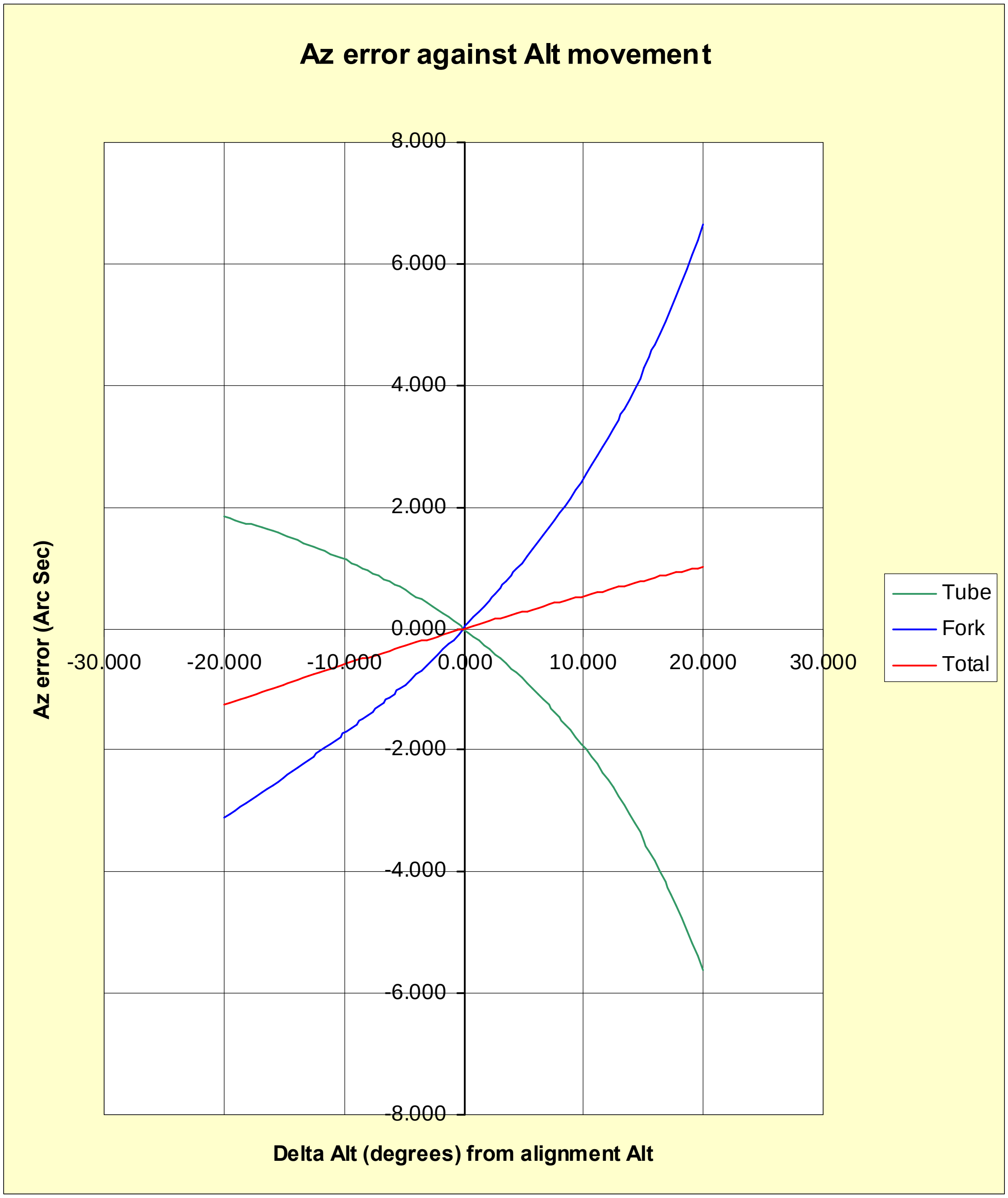

Figure 9.

Summary.

This model allows star alignment to be used to identify the location & magnitude of mechanical errors in a Fork Mounted Telescope. Once the location and magnitude of the error is determined the successive adjustment and star alignment, allows the Fork arm error to be minimized and then the OTA to Dec axis alignment sweet spot to be found.

Whilst it might be expected that the OTA to DEC axis alignment should be equal and opposite to the Fork arm error, this is not the case.

The sweet spot comes from aligning at an Alt of 45 degrees and compensating two different error functions with each other over an 88 degree dynamic range.

It should also be noted that both error functions independently give a 90 degree Az shift at the point where ALT is 90 degrees. However the OTA to Dec axis generated Az error is not 0 at an Alt of 0. It is a finite value which is the alignment error.

The fork arm function does give a zero Az error at a Alt of zero.

Why is the ñSweet Spotò alignment of importance?

In Alt/Az mode it allows precise tracking of fast moving objects across the sky. Also it extends the period for photographic imagery. Removes the need to employ SMT.

In polar mode the ñSweet Spotò alignment removes the effect of apparent RA time shift when moving from one DEC to another. Particularly important at DEC values approaching the Pole.

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