National Centre for Radio Astrophysics

NCRA • TIFR

Internal Technical Report

GMRT/SERVO/001-May 2013

Comparison of BLDC and PMDC System Tracking Accuracy

Amit Kumar

Email:amitkumar@gmrt.ncra.tifr.res.in

Shri Suresh Sabhapthy

Dr. B.C. Joshi

Revision	Date	Modification/ Change
Ver. 1	29 April 2012	Initial Version
Ver. 2	01 May 2013	Writeup modified

Executive Summary: A follow-up experiment to compare the tracking accuracy of BLDC system with PMDC system was carried out to confirm/refine the results of a previous study by Bhat et. al 2011. The new experiment uses engineering tests with the antenna in a track mode with a tracking speed of 15 arcmin/min. The measurements were carried out from the central building with 1 s sampling as well as from the base of the antenna with a finer sampling in contrast with the previous study, which made use of archival data gathered at central building with1 s sampling. The experiments were carried out in absence of wind gusts. This study shows that (a) the results are similar for measurements from the central building and the antenna base and with a finer sampling, (b) the RMS errors for both axes are about 5 arc seconds well within the GMRT specifications, and (c) RMS errors for the 4 antennas with upgraded BLDC systems and 2 antennas with upgraded PC/104 systems are similar to those for the older PMDC system. On the basis of this study, it is concluded that routine performance measurements using archival data with an appropriate statistical analysis for all 30 antennas from the central building are as accurate as controlled engineering tests, allowing this less time consuming and convenient method for antenna tracking error characterization in future.

Introduction

Upgrade of the GMRT antenna control systems with Brushless Direct Current (BLDC) motor drives and embedded PC/104 boards has entered into mass production stage. BLDC systems have been installed in C04, C10, C14, C00, S01, W02 till date. PC/104 based position controller have been installed in C01, C02, C03. As part of constant endeavor to monitor and thereby improve the system to achieve higher accuracies of the servo system, it is necessary to conduct tracking performance tests on these antennas.

This experiment was taken up as epilogue to one already carried out under the name 'Performance Comparison of Brushless Motor System and Brushed Motor System on GMRT Antenna' by Aditi Bhatt, B C Joshi, S N Katore in 2011.In this experiment, the servo data were acquired from the online archive and used to determine tracking error for a set of antennas, which included C04 with the first BLDC installation and some antennas with the older permanent magnet Direct Current (PMDC) motors. In that study, the data were collected from different antennas during the normal astronomical observations, statistical tools were used to compare the antenna performance. Moreover, the data were acquired using data logging at the GMRT central building with a coarse non-optimal sampling (1 s). It is likely that these measurements may be different, and less accurate, than dedicated engineering measurements during the track mode, particularly when such measurements are carried out at the base of the antenna with finer sampling. The new experiment, described in this report, was based on such dedicated engineering measurements and will be useful to (a) corroborate the results of earlier experiment and/or provide more accurate performance measurements and (b) validate a methodology for future measurements.

The new experiment will also extend the performance test to more number of antennas with the upgraded systems. This has been possible as there are more BLDC systems (4) to compare rather than only one antenna used in the previous experiment (C04). In addition, it provides performance measurements for antennas with PC-104 based position controller. Thus, these measurements will also be useful in validating the mass commissioning process.

The basic outline of the experiment has been kept same as in the previous study .The main difference has been to use a pre-defined track command in an individual axis instead of using archival data collected during the normal astronomical operation of the antenna, where track speeds may vary. The tracking speed used for this purpose was 15 arcmin per minute. Thus, the tests have been conducted in a controlled manner rather than using archival data.

The second new component of the experiment was to gather data at the base of the antenna as well. The PC-based data acquisition at the base of antenna using the program ***newsmu*** allows antenna data to be sampled every 1 s, whereas PC-104 based system allow data logging every 100 ms.

Thus at least in the case of PC-104 systems, a much finer sampling is possible. A comparison of the results of these systems based on measurements at central building and at the base of antenna will allow determining if equally good results are possible by making measurements at the central building, where it is easier and faster to gather data for 30 antennas. This may open up a way for routine performance measurements.

The analysis method followed in this report is also different from the previous study. The analysis is more numerical and less statistical for ease of comprehension. This was done to address concerns about interpretation of statistical results of the previous study. A more graphical display of data has been preferred to show range of root mean square (RMS) errors allowing a worst case judgement.

The tests were carried out when winds were almost absent. Thus, these results represent the antenna performance in "no wind" case only. No effort was made to extend the results of the previous study for windy condition. Such a study is planned at a future time when the winds are high.

Procedure for the Experiment :

Steps for acquisition of data:

1. From CONTROL ROOM

   a. Select 4 BLDC antennas (C04, C10, C14, and C00) and 4 PMDC antennas (two with PC104, two with 8086) in an array.
   b. Ensure that winds as read from wind anemometer are below 5 Kmph.
   c. Move Azimuth and Elevation Axis for 30 deg over period of 120 mins to achieve 15arcmin/min tracking speed
   d. Log servo parameters in a file. The parameters are : Time (Time Float Format), Encoder Current Position, Encoder Target Position, Wind speed and Tracking Flag.
   e. Use this file for analysis.

2. At ANTENNA BASE

   a. Connect Newsmu to Servo computer in data logging mode. Enable data logging option in PC/104 for the PC/104 based antennas.
   b. Ensure that winds as read from wind anemometer are below 5 Kmph.
   c. Move Azimuth and Elevation Axis for 30 deg over period of 120 mins to achieve 15arcmin/min tracking speed
   d. Log data after setting the track commands as stated above.

Steps for analysis of data:

1. Import data from the file into Open Office Spreadsheet or MS Office Excel.

2. Isolate data of individual antenna.

3. Check for tracking Status. Use only those readings for calculation of error which show tracking status as yes.

4. Calculate Tracking Error = Encoder Target position – Encoder Current Position.
   (Note: Current position = Current position after neglecting LSB)

5. Calculate RMS Error (First Square all the errors, then find mean of squares and then find its root of this value)

6. Plot histograms of Error vs Frequency of the error.

Use of Histogram:

Histograms are graphical tools for displaying the distribution and variation in the data in a huge collection of samples and help in determining the mean, acceptable range etc.

Overview of results :

Following are the RMS error value of the error calculated from the data collected from the **control room** :

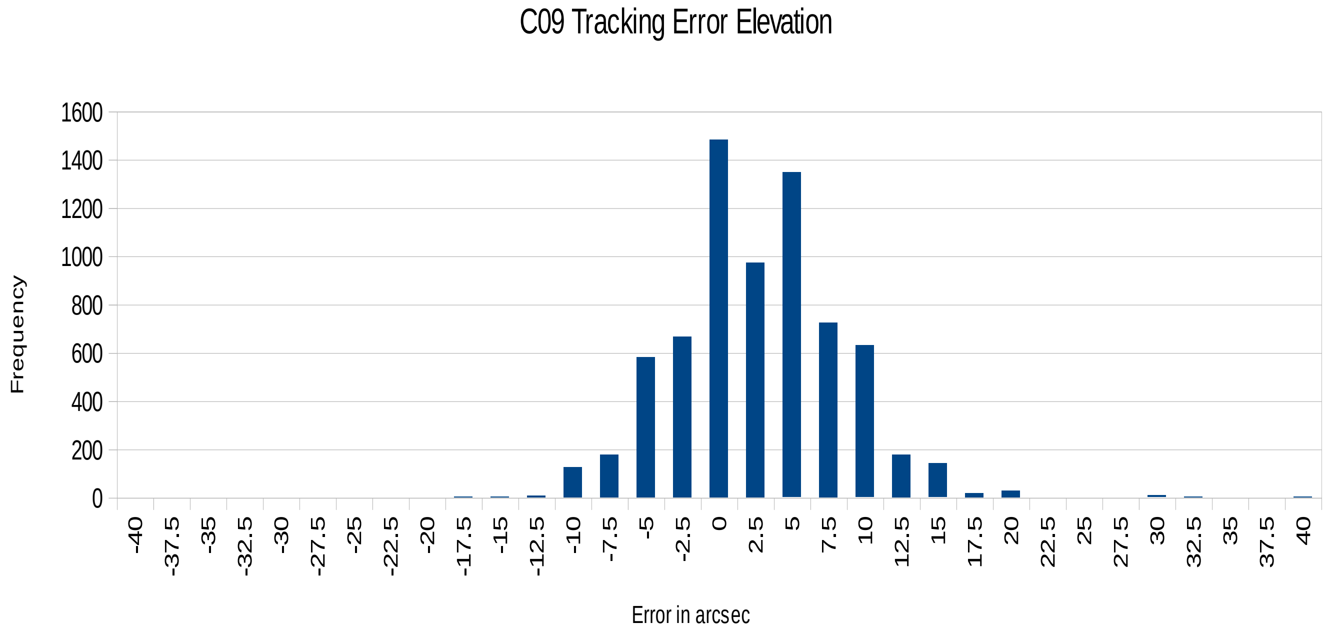
Antenna	System	RMS Error in EL (in arcsec)	Mean Error in EL (in arcsec)	RMS Error in AZ (in arcsec)	Mean Error in Az (in arcsec)
C09	PMDC	5.8	1.69	4.9	1.85
C11	PMDC	4.6	1.97	4.7	1.94
C04	BLDC	5.8	1.69	4.4	-2.6
C10	BLDC	6.1	-1.81	5.8	1.77
C14	BLDC	6.6	1.69	6.2	1.99
C00	BLDC	5.8	-1.88	5.8	1.83
C01	PMDC+PC104	5.8	1.91	8.4	1.41
C02	PMDC+PC104	5.3	1.51	5.2	-3.51
C03	PMDC+PC104	4.5	1.67	4.5	1.51

Following are the results of RMS value of the error calculated from the data collected from the **antenna base**:

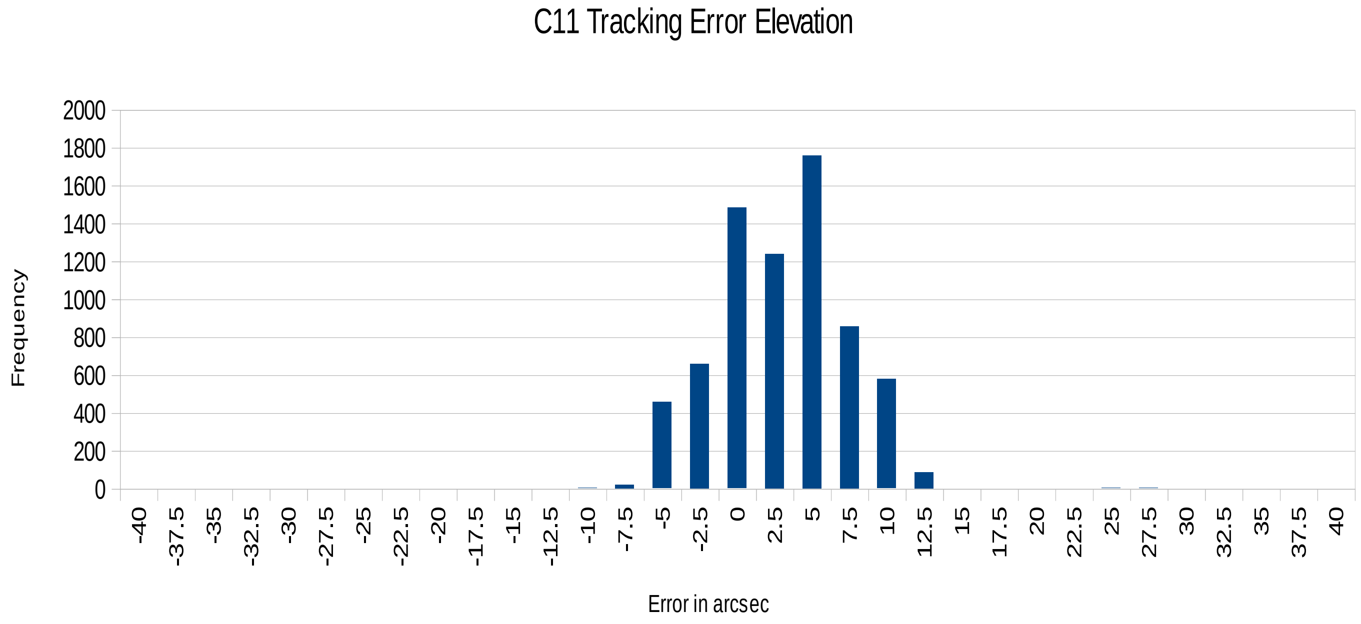
Antenna	System	RMS Error in EL (in arcsec)	Mean Error in EL(in arcsec)	RMS Error in AZ (in arcsec)	Mean Error in AZ (in arcsec)
C09	PMDC	4.6	1.93	5.1	1.98
C11	PMDC	4.5	1.86	4.6	1.88
C04	BLDC	5.4	1.95	5.2	2.09
C10	BLDC	6.0	2.07	6.2	1.91
C14	BLDC	6.7	1.91	6.6	1.84
C00	BLDC	5.6	-0.25	5.9	1.82
C01	PMDC+PC104	5.1	2.99	11.0	2.33
C02	PMDC+PC104	5.9	2.99	5.8	2.99
C03	PMDC+PC104	5.1	3.00	5.1	3.00

Histograms of Errors:

Following are the images of the histograms generated from the data taken from central building. Uniformity in x axis has been maintained by keeping the error interval as 2.5 arc sec. The first set of histograms in blue are of Elevation Axis. The second set of histograms in red are of Azimuth Axis.

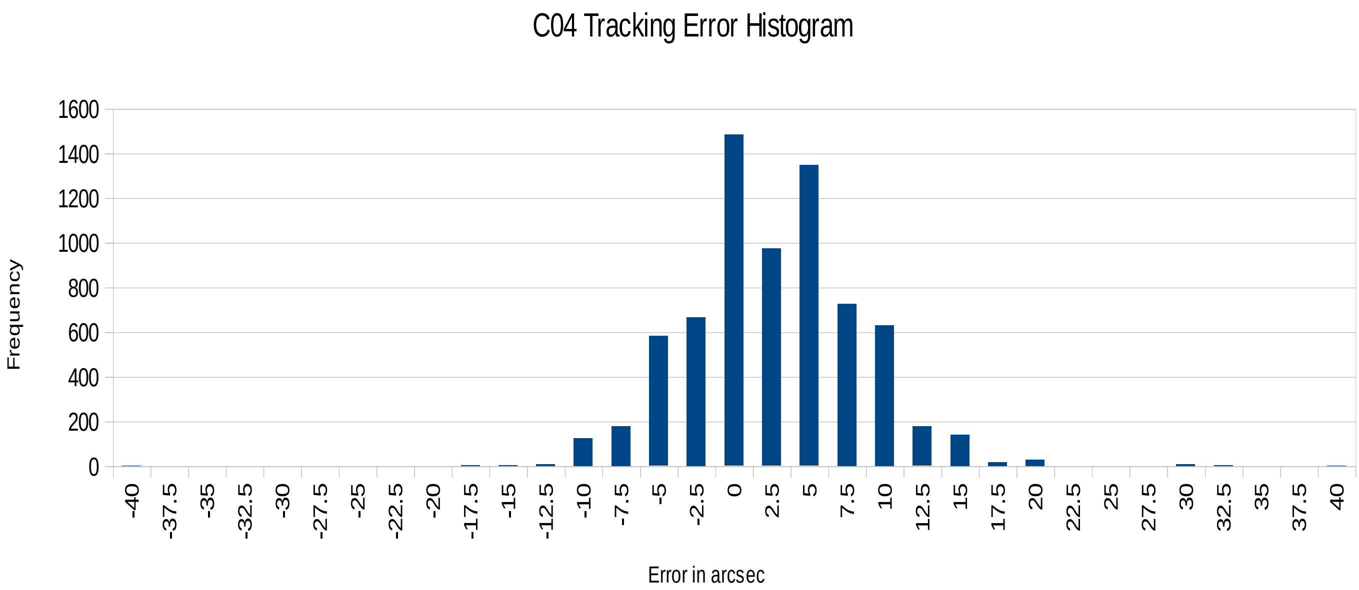


Brief Note: The errors are populated between -5 and 10 arcsecs.Highest error frequency occurs at 0 followed by at 5arcsecs.Histogram is symmetrical about 2.5arcsecs.



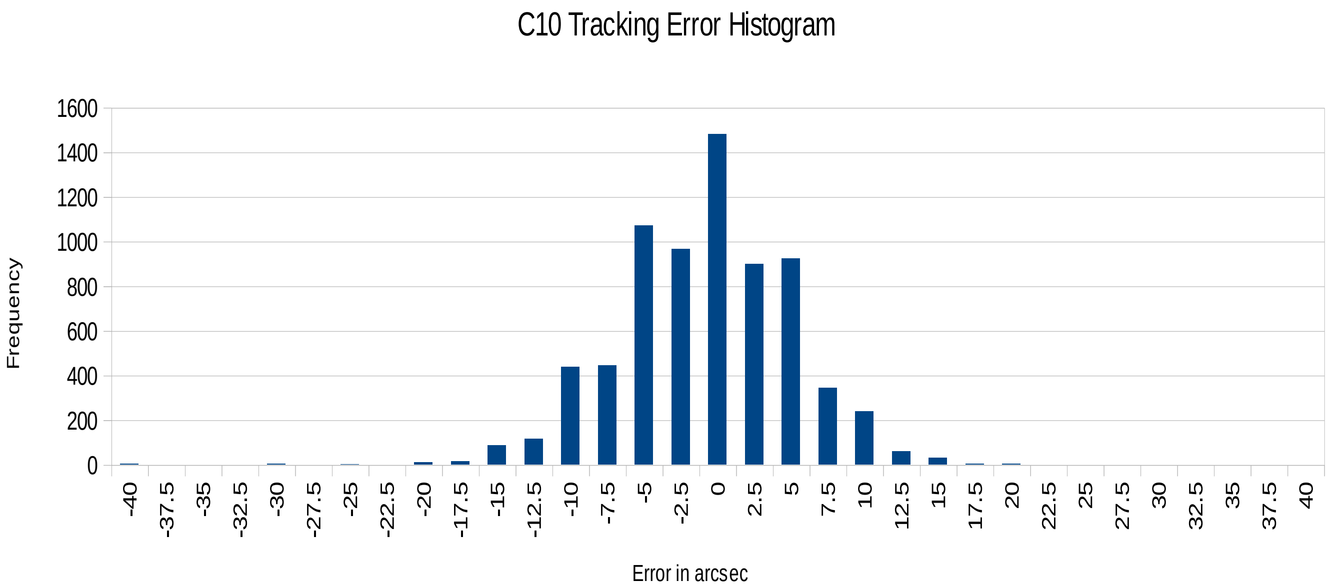
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency occurs at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5arcsecs.

C04 Tracking Error Histogram

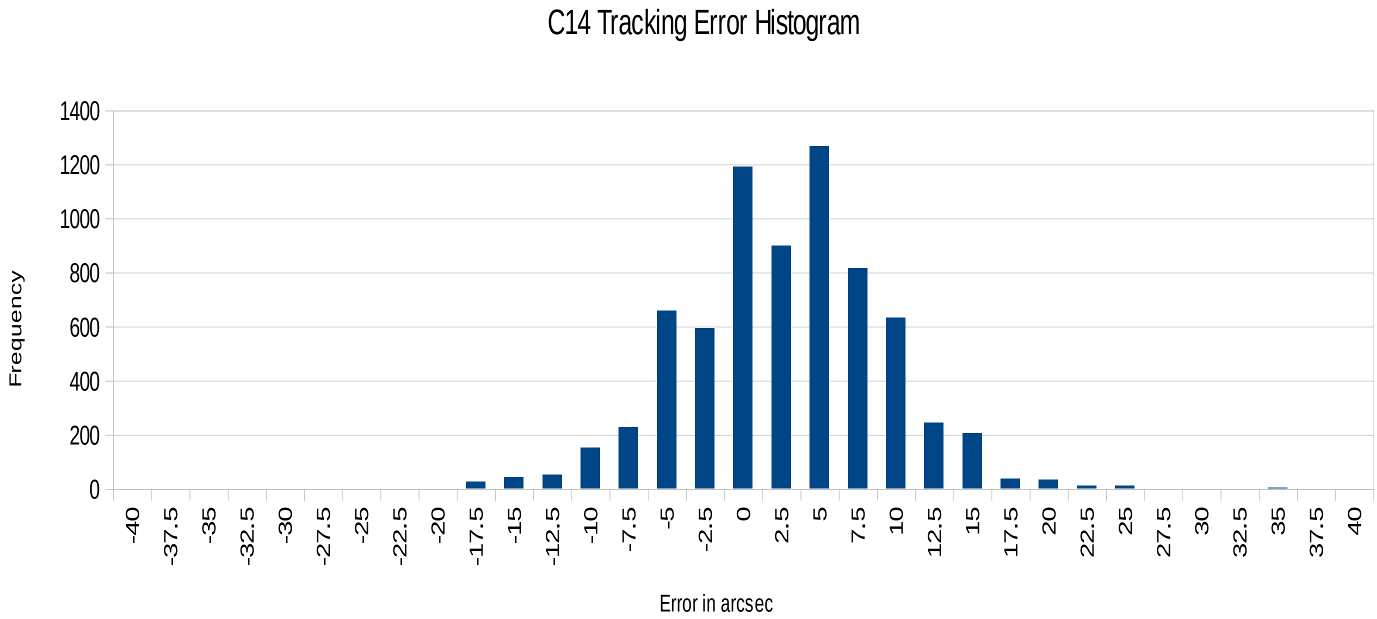


Brief Note: The errors are populated between -10 and 10 arcsec. Highest error frequency is at 0 followed by 5 arcsec. Histogram is symmetrical about 2.5arcsec.

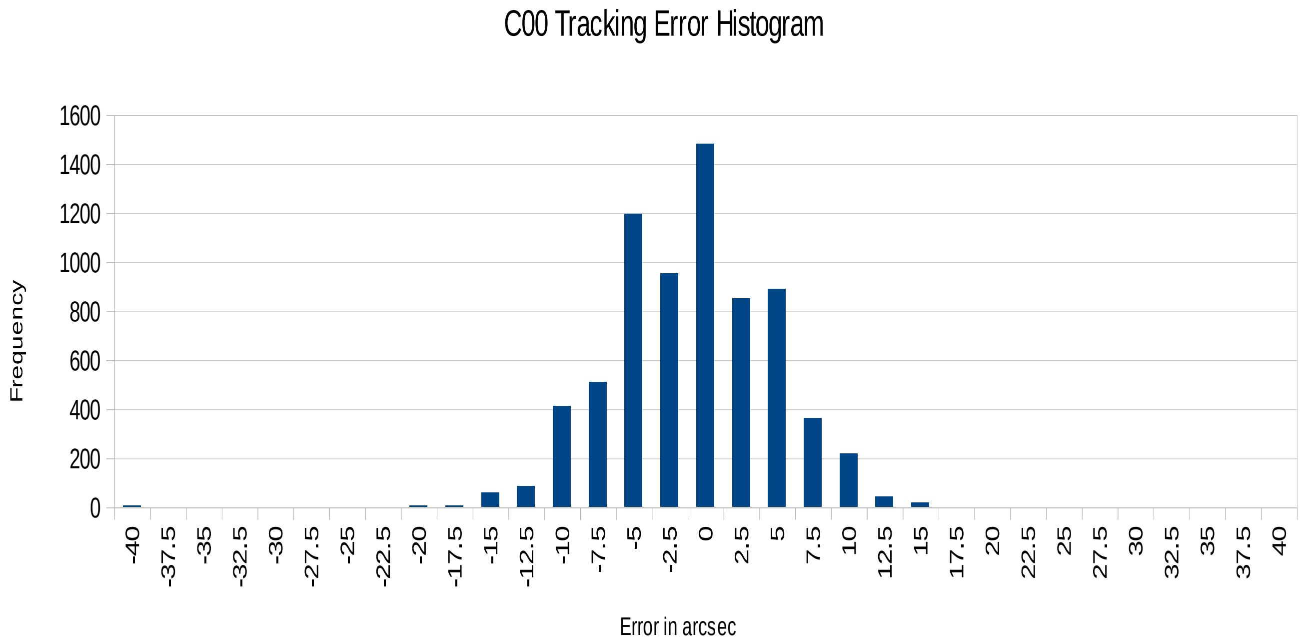
C10 Tracking Error Histogram



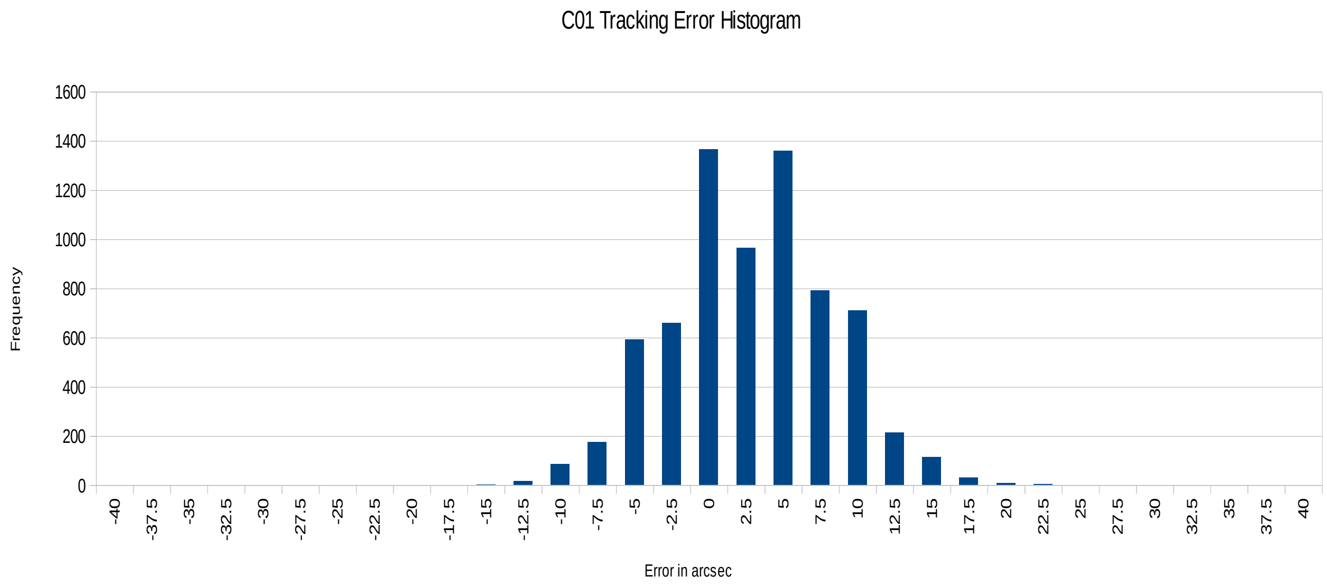
Brief Note: The errors are populated between -10 and 10 arcsec. Highest error frequency is at 0 followed by -5 arcsec. Histogram is symmetrical about 0 arcsec.



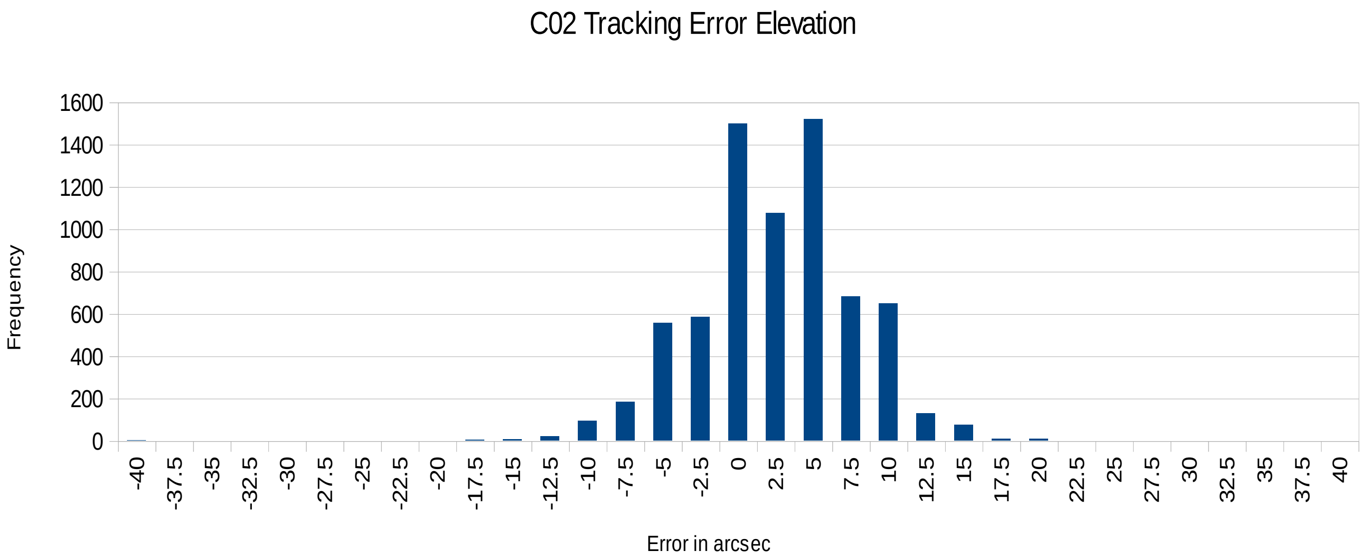
Brief Note: The errors are populated between -7.5 and 12.5 arcsec. Highest error frequency is at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



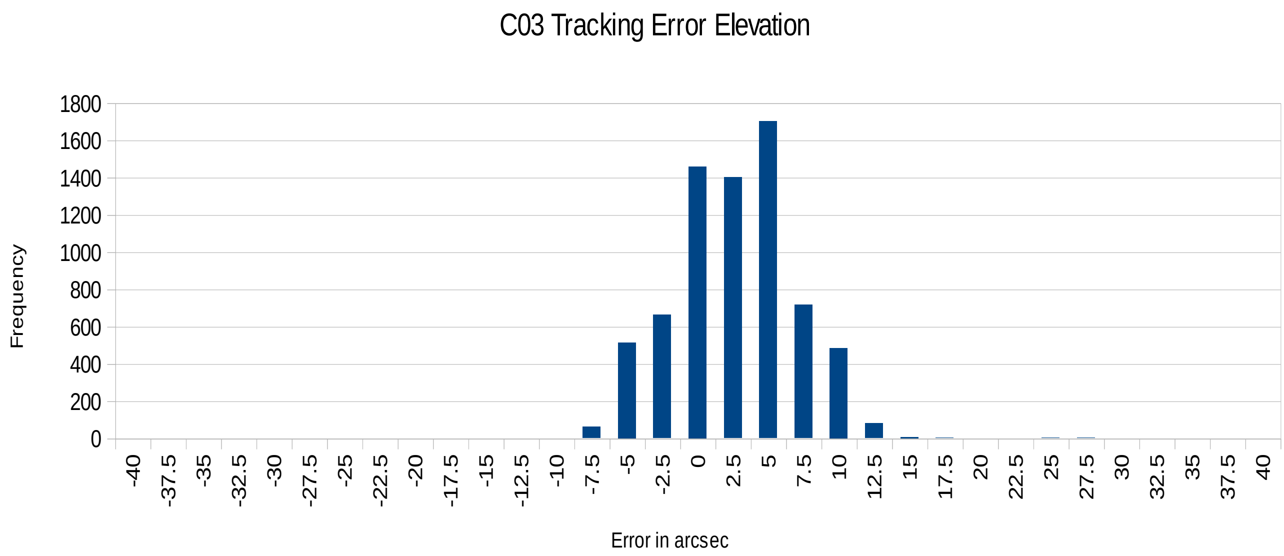
Brief Note: The errors are populated between -10 and 7.5 arcsec. Highest error frequency occurs at 0 followed by -5 arcsec. Histogram is symmetrical about 0 arcsec.



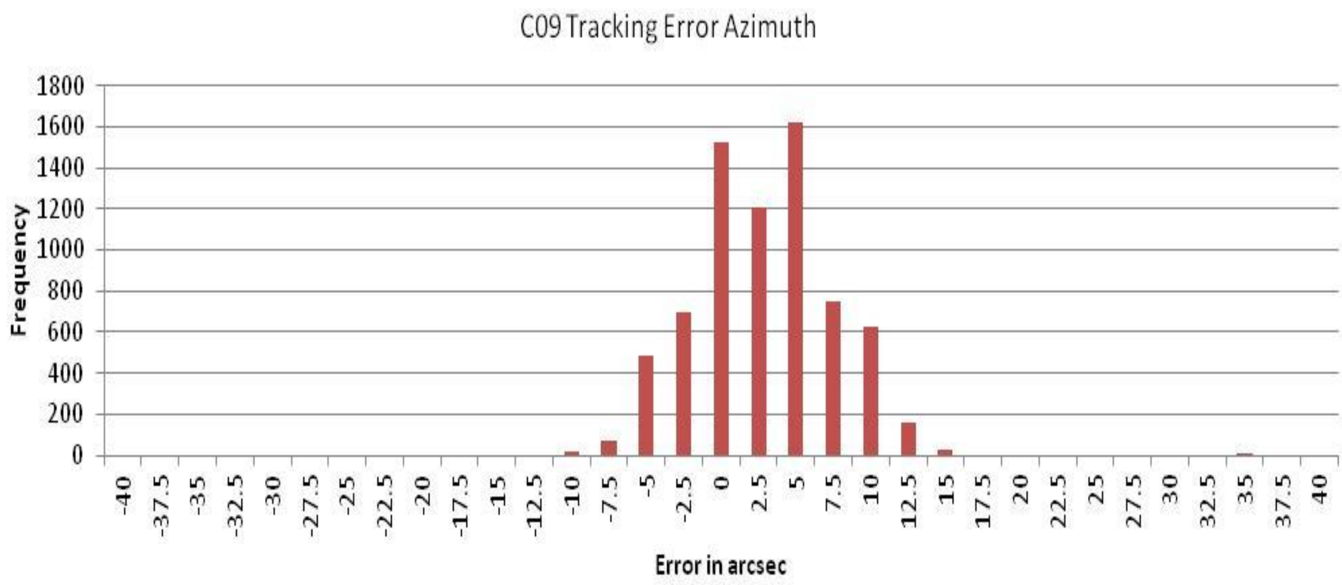
Brief Note: The errors are populated between -7.5 and 12.5 arcsec. Highest error frequency is at 0 followed by 5 arcsec. Histogram is symmetrical about 2.5 arcsec.



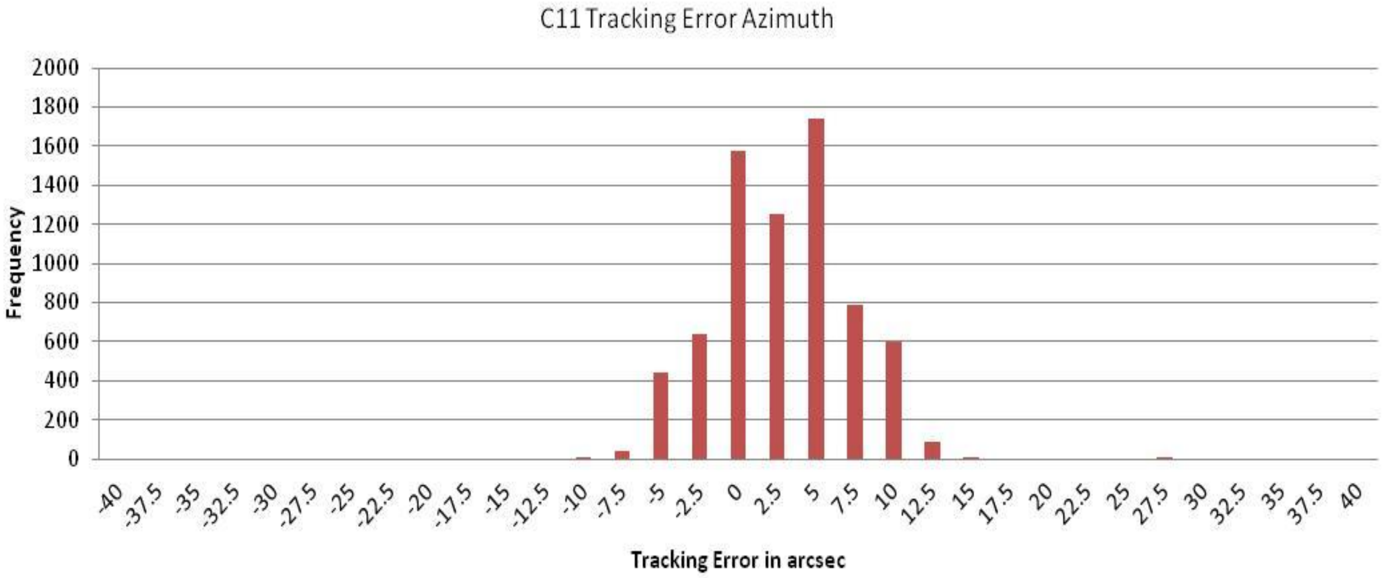
Brief Note: The errors are populated between -7.5 and 12.5 arcsec. Highest error frequency occurs at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



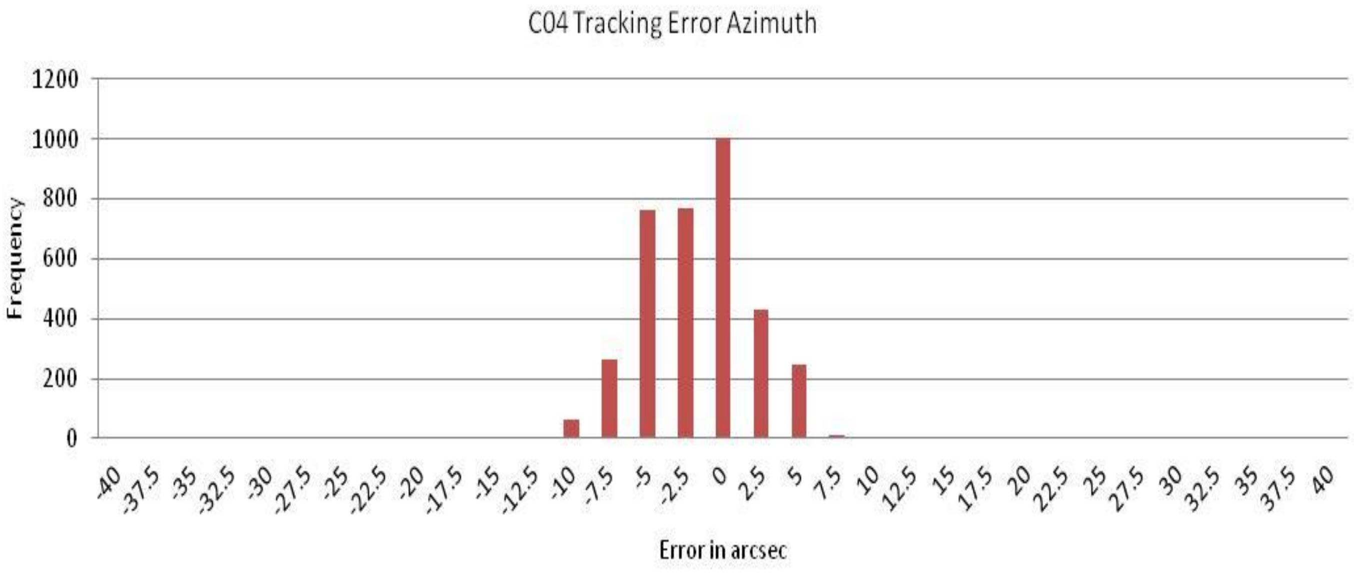
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency occurs at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



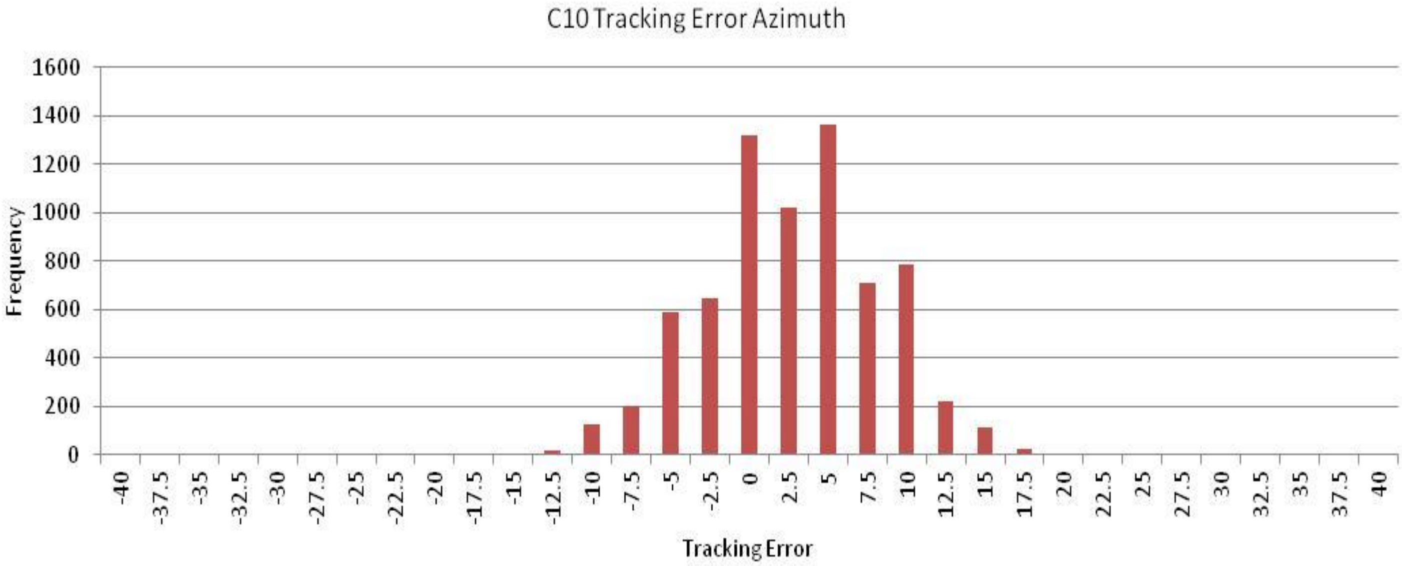
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency occurs at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



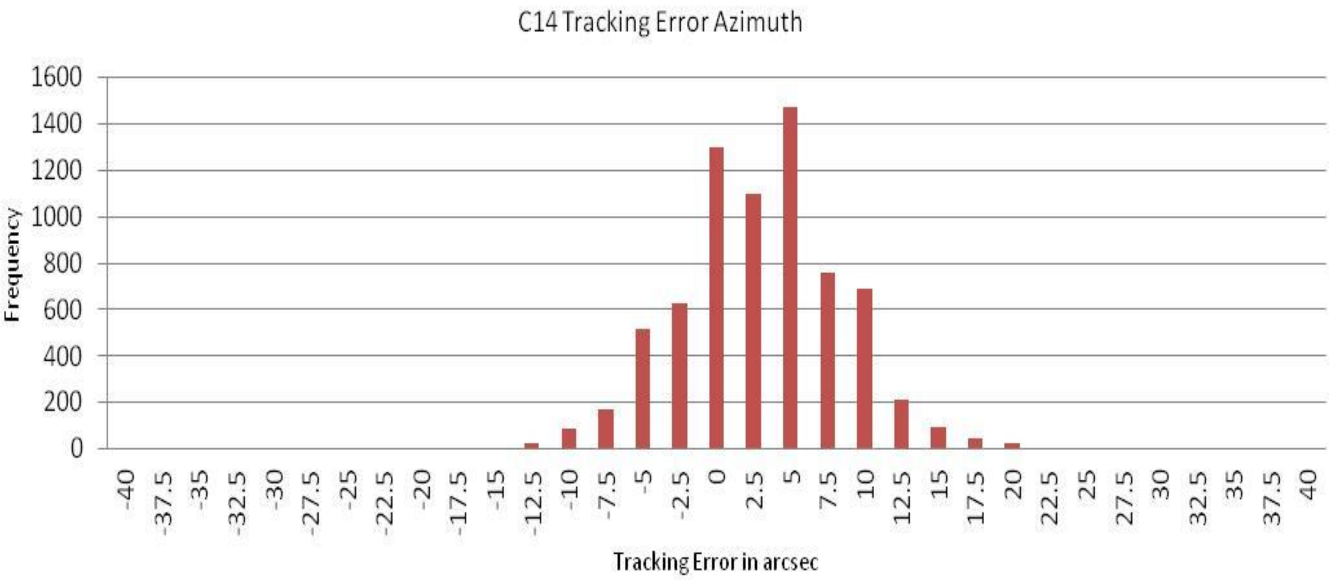
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency occurs at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



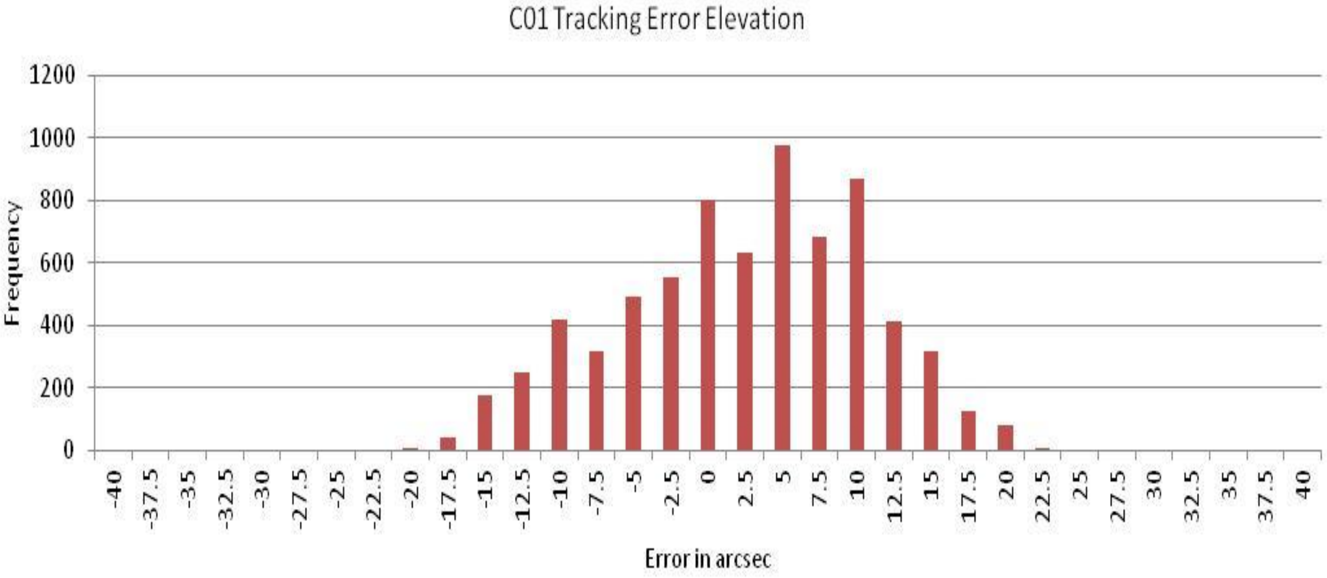
Brief Note: The errors are populated between -7.5 and 5 arcsec. Highest error frequency occurs at 0 followed by -2.5 arcsec. Histogram is symmetrical about -2.5 arcsec.



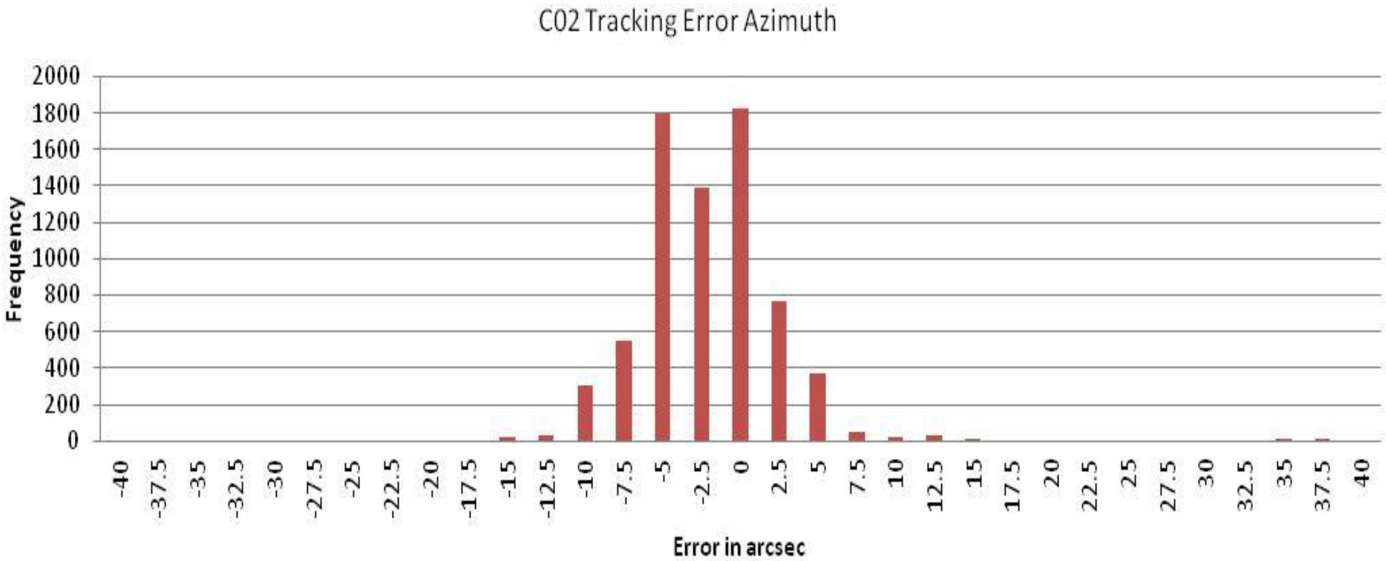
Brief Note: The errors are populated between -7.5 and 12.5 arcsec. Highest error frequency is at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



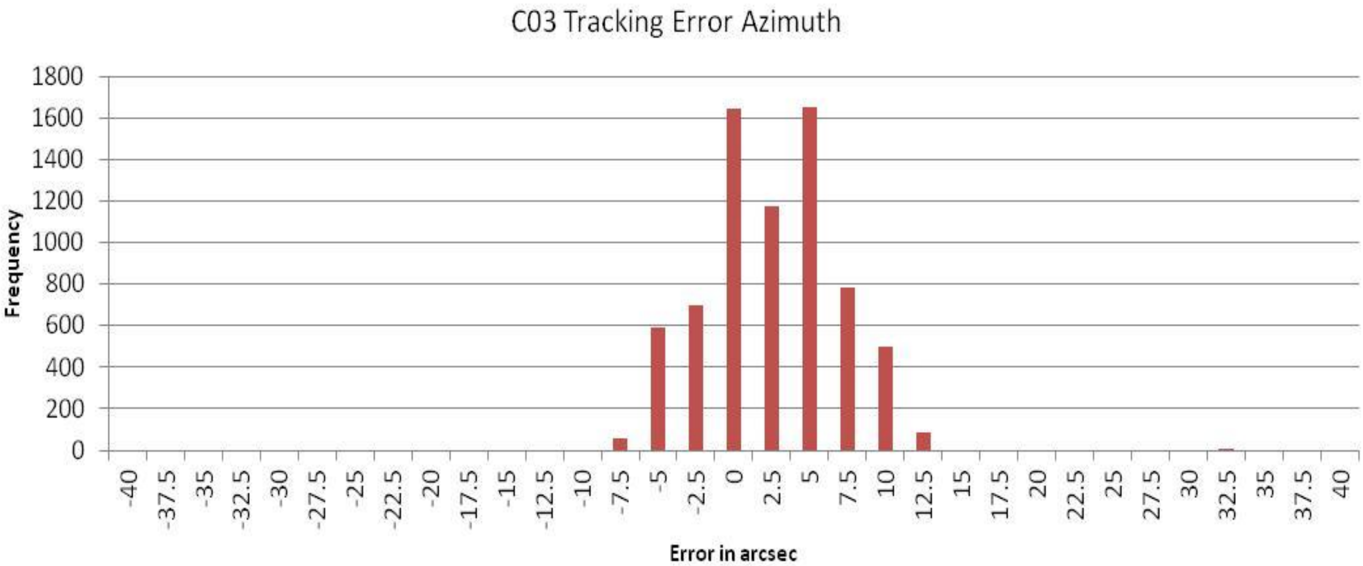
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency occurs at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



Brief Note: The errors are populated between -12.5 and 15 arcsec. Highest error frequency is at 5 followed by 10 arcsec. Histogram is symmetrical about 5 arcsec.

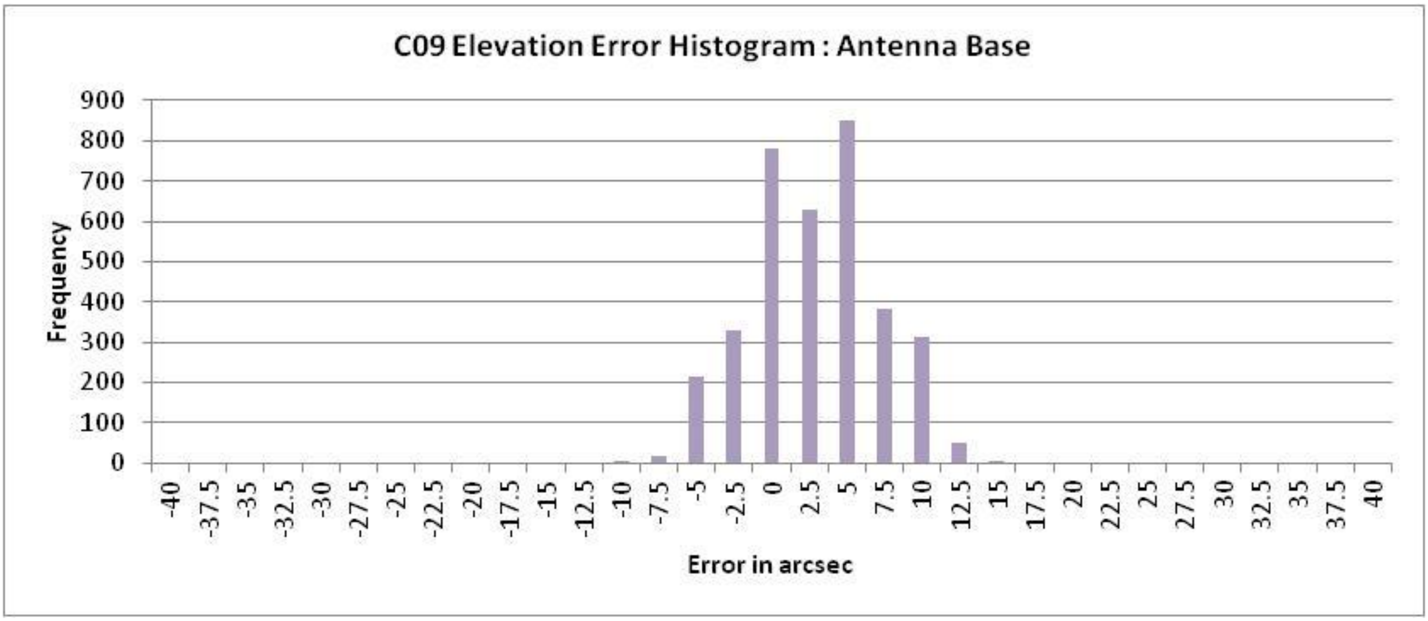


Brief Note: The errors are populated between -10 and 5 arcsec. Highest error frequency occurs at 0 followed by -5 arcsec. Histogram is symmetrical about -2.5 arcsec.

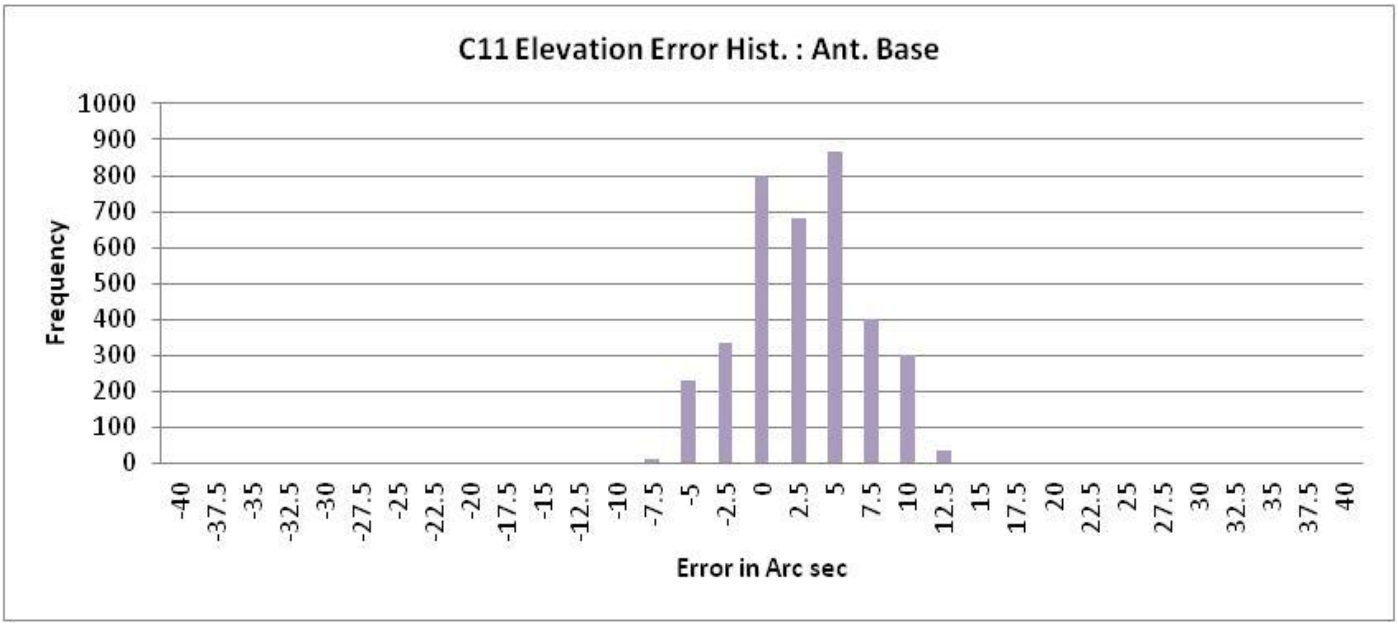


Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency occurs at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.

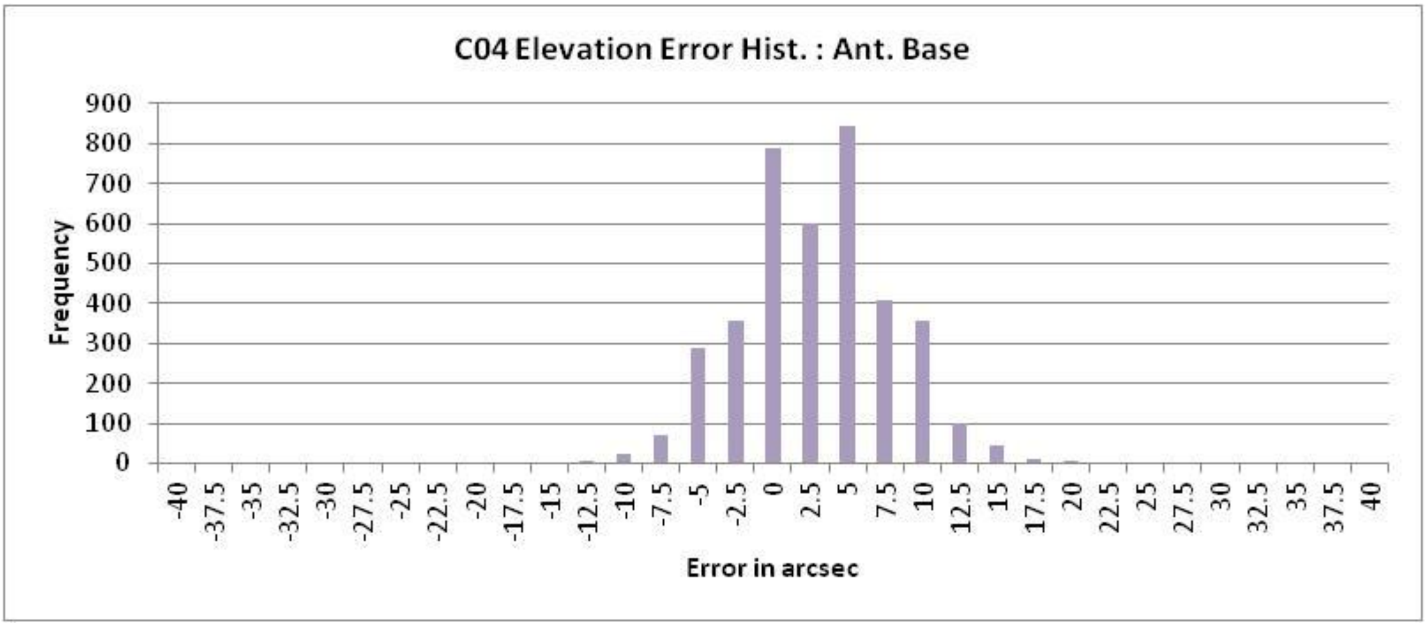
Following are the images of the histograms generated from the data collected at antenna base. The first set of histograms in purple are of Elevation Axis. The second set of histograms in green are of Azimuth Axis.



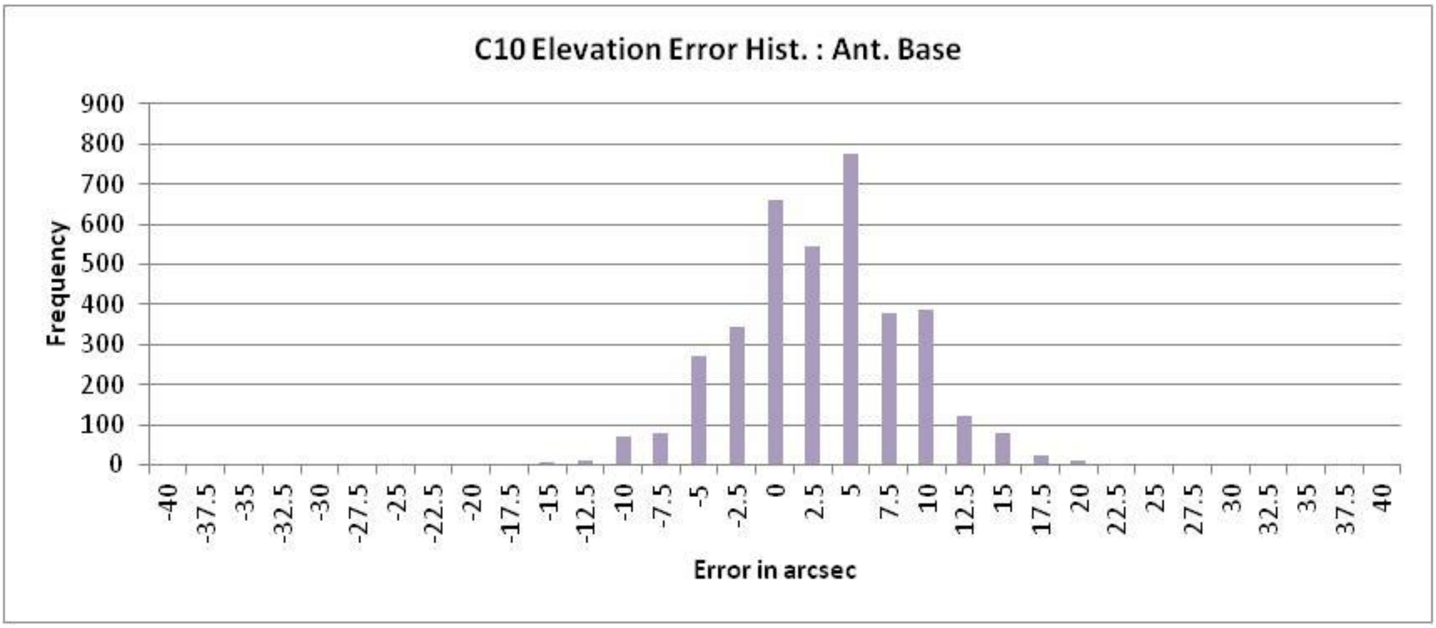
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency is at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



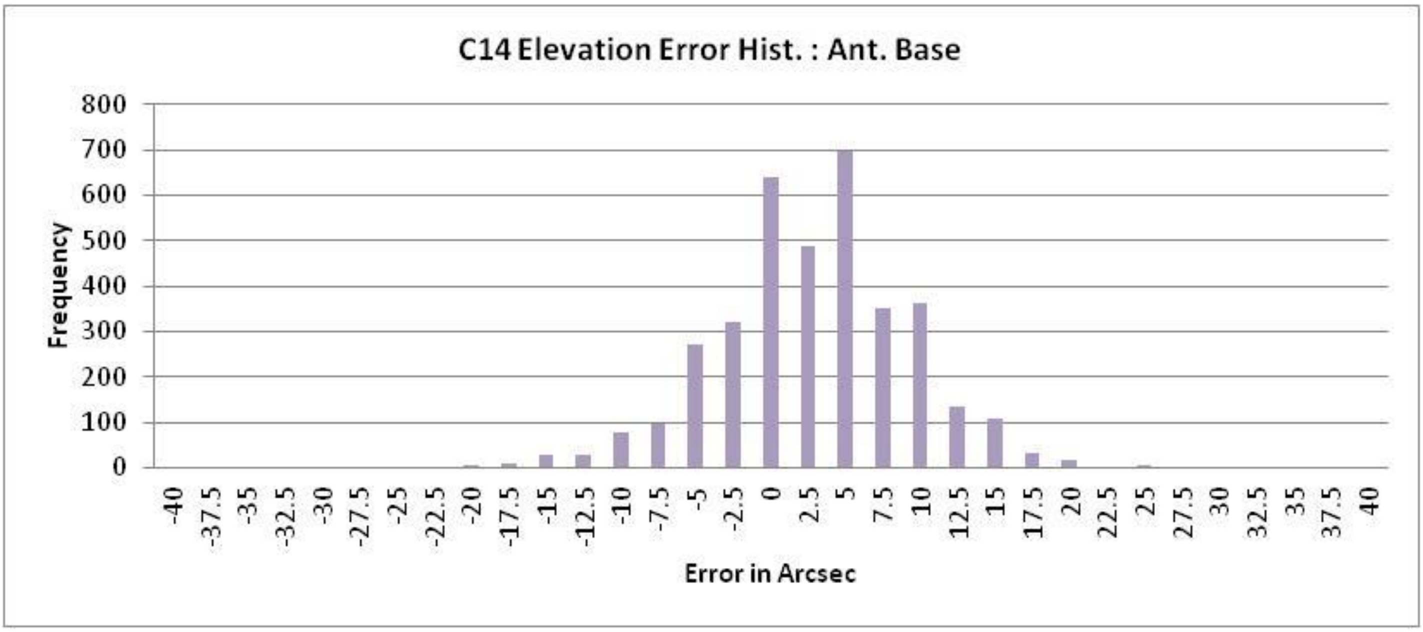
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency occurs at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



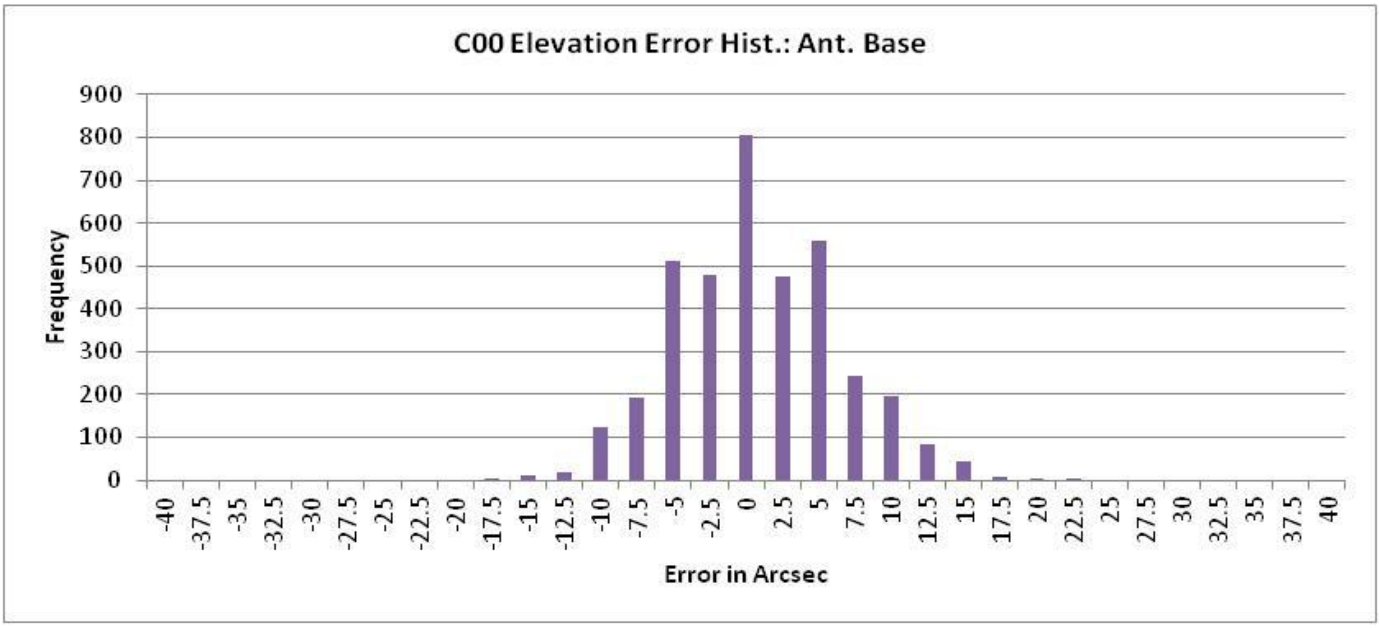
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency occurs at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



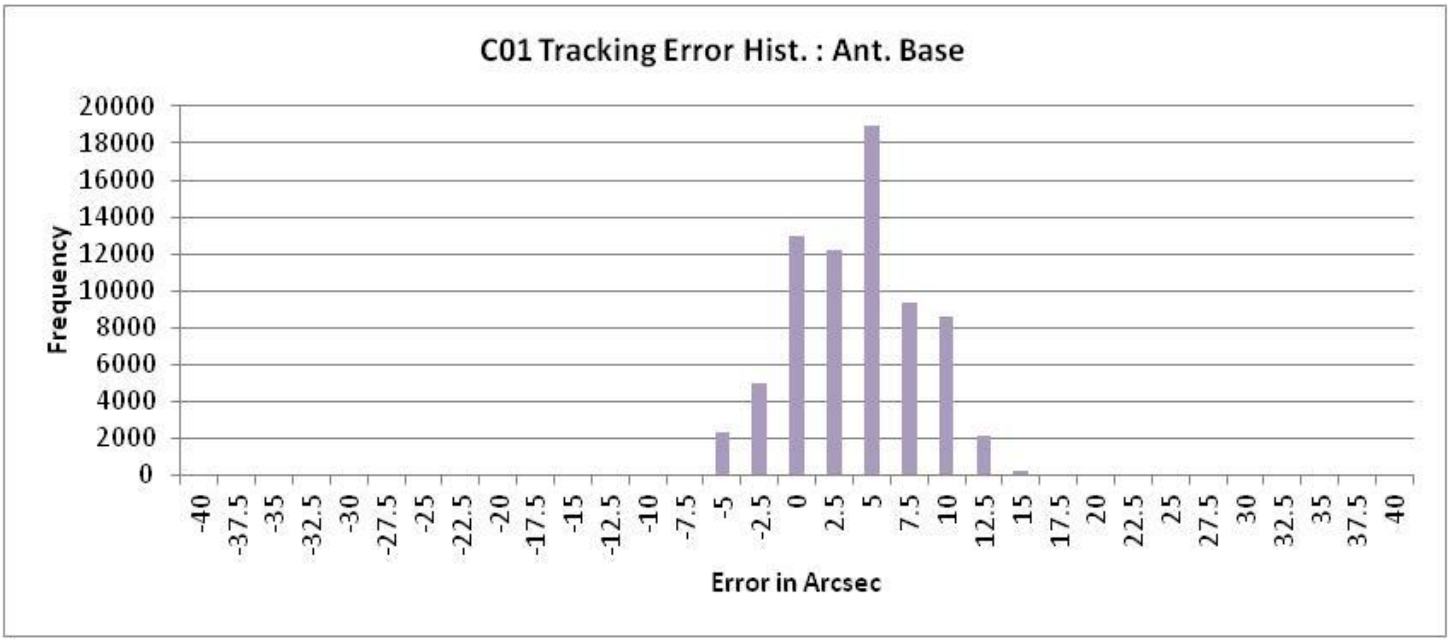
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency is at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



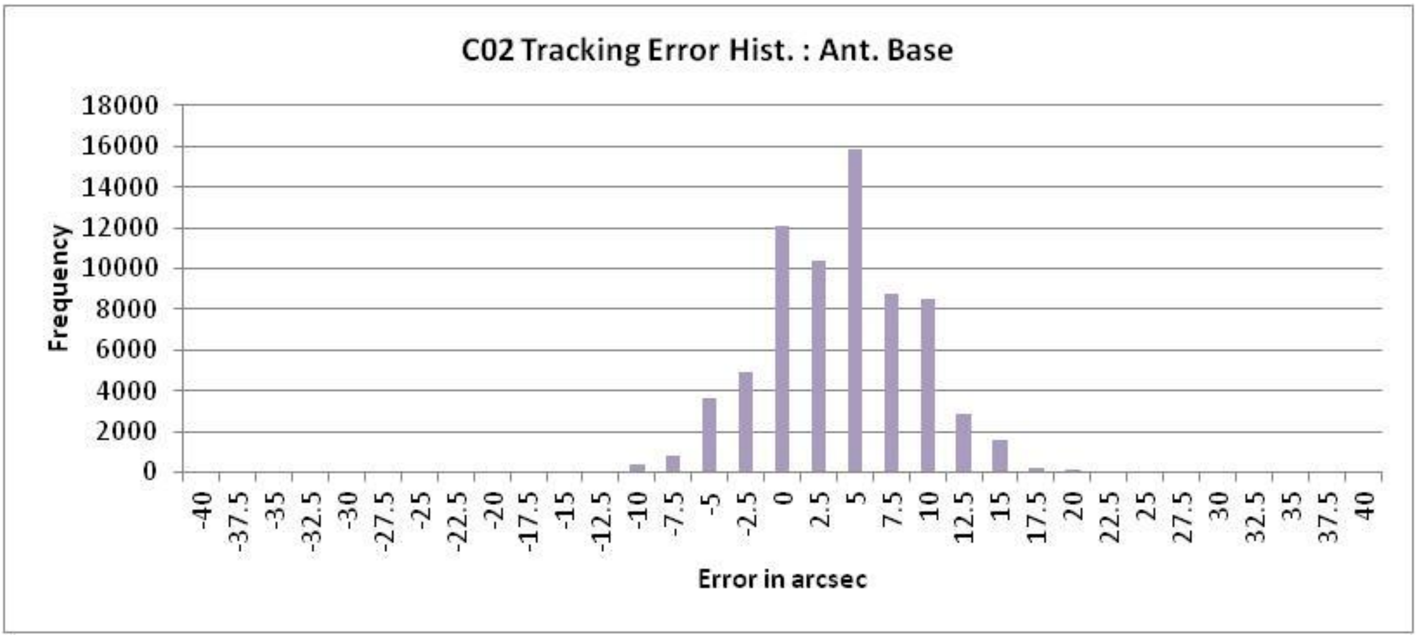
Brief Note: The errors are populated between -5 and 12.5 arcsec. Highest error frequency occurs at 5 followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



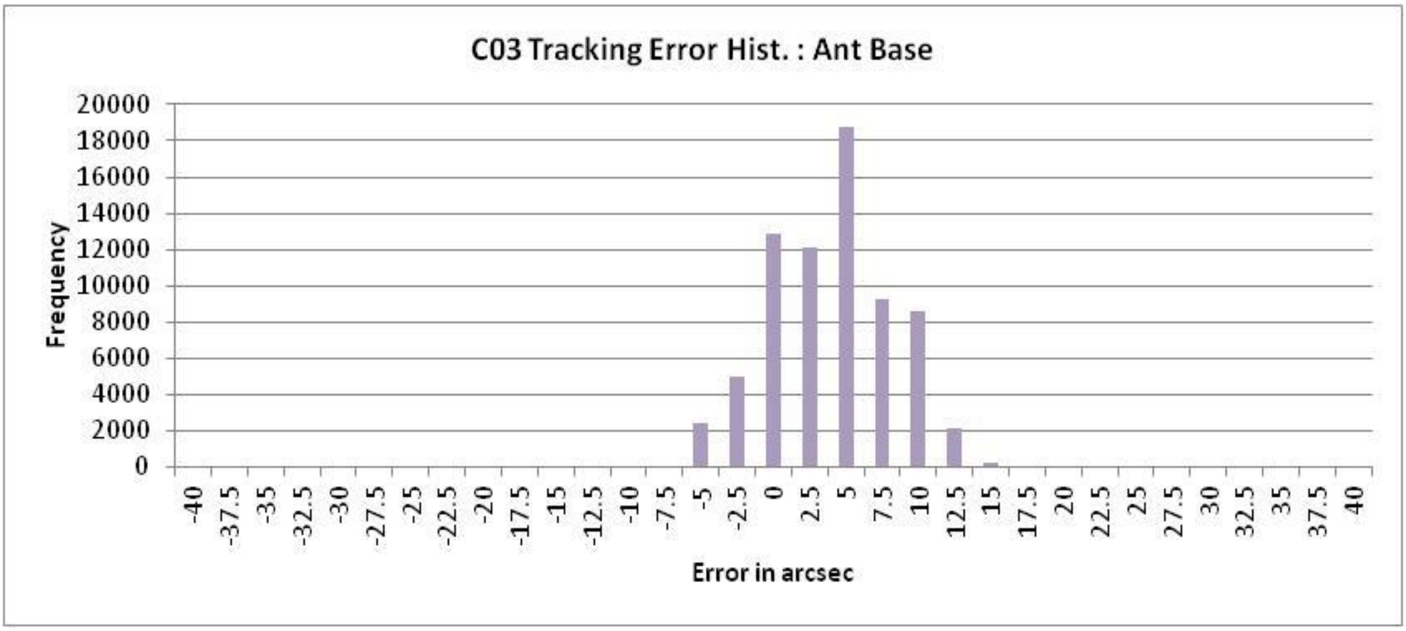
Brief Note: The errors are populated between -10 and 10 arcsec. Highest error frequency is at 0 followed by 5 arcsec. Histogram is symmetrical about 0 arcsec.



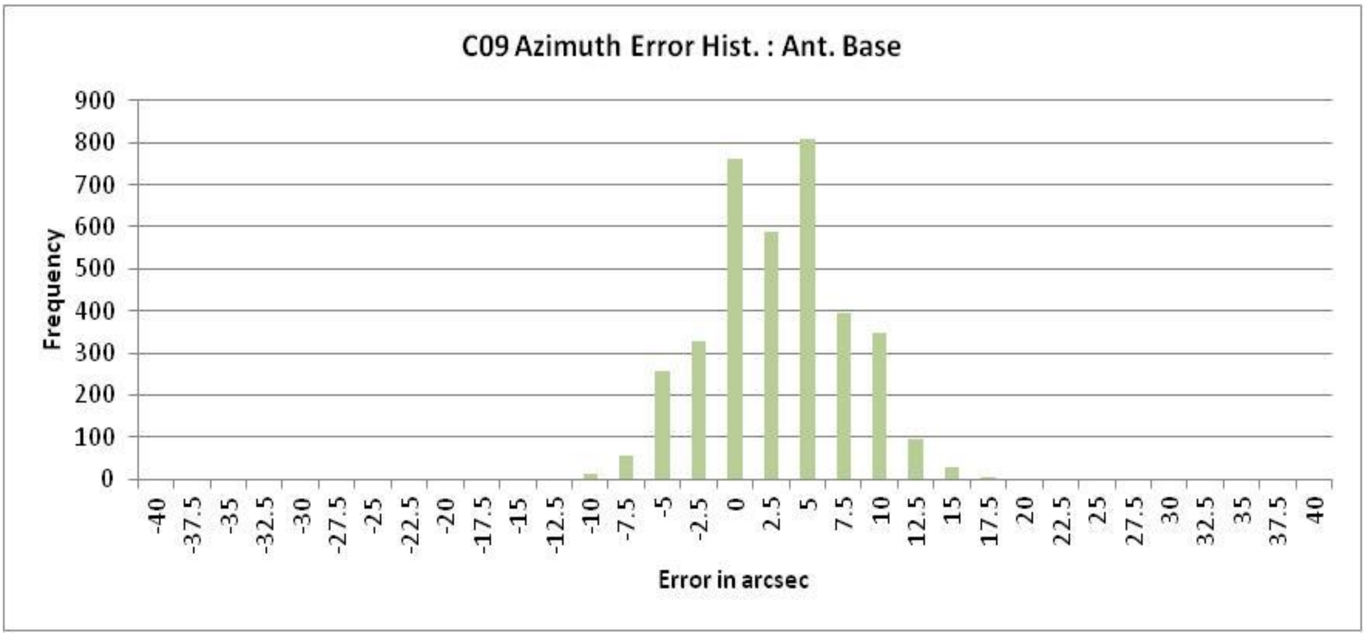
Brief Note: The errors are populated between -5 and 12.5 arcsec. Highest error frequency occurs at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 5 arcsec.



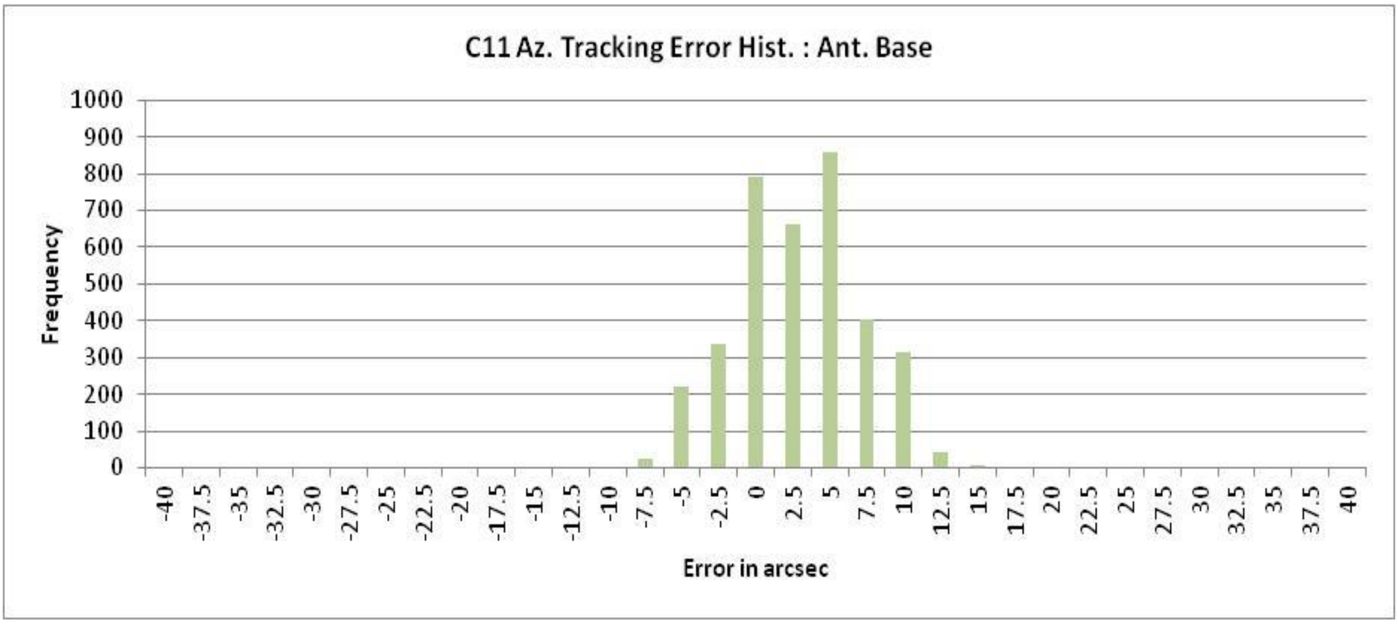
Brief Note: The errors are populated between -5 and 12.5 arcsec. Highest error frequency is at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 5 arcsec.



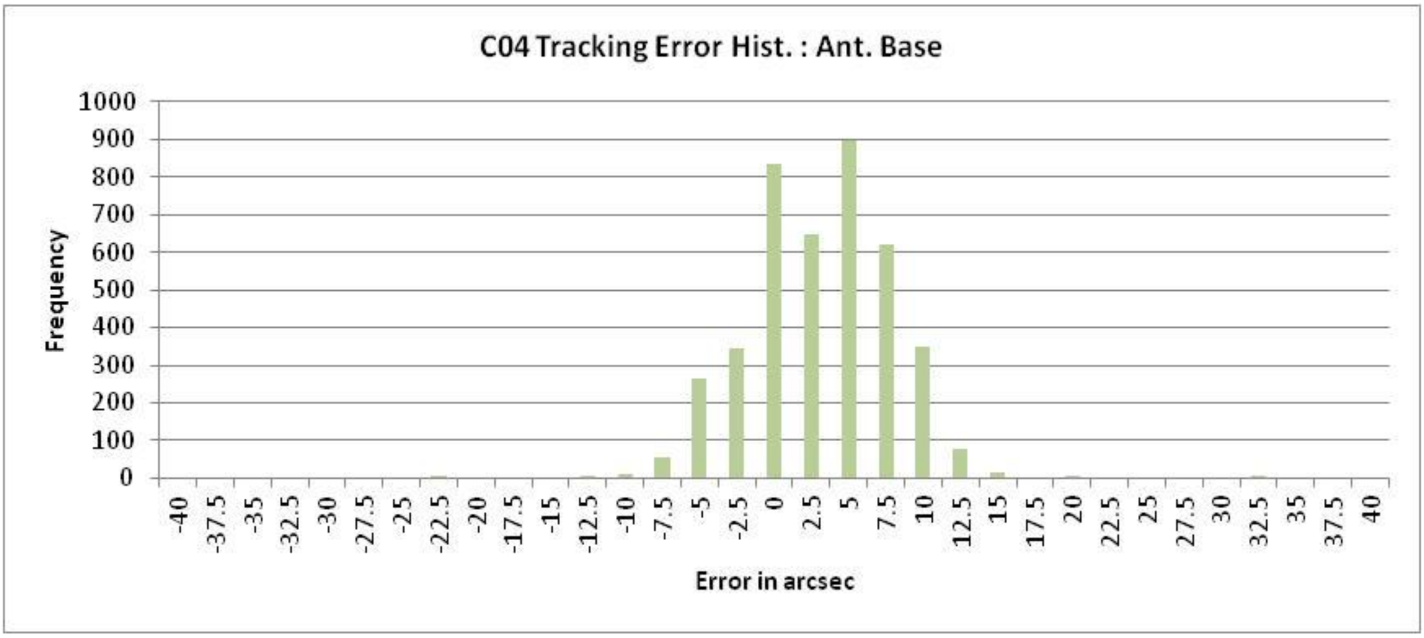
Brief Note: The errors are populated between -5 and 12.5 arcsec. Highest error frequency occurs at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 5 arcsec.



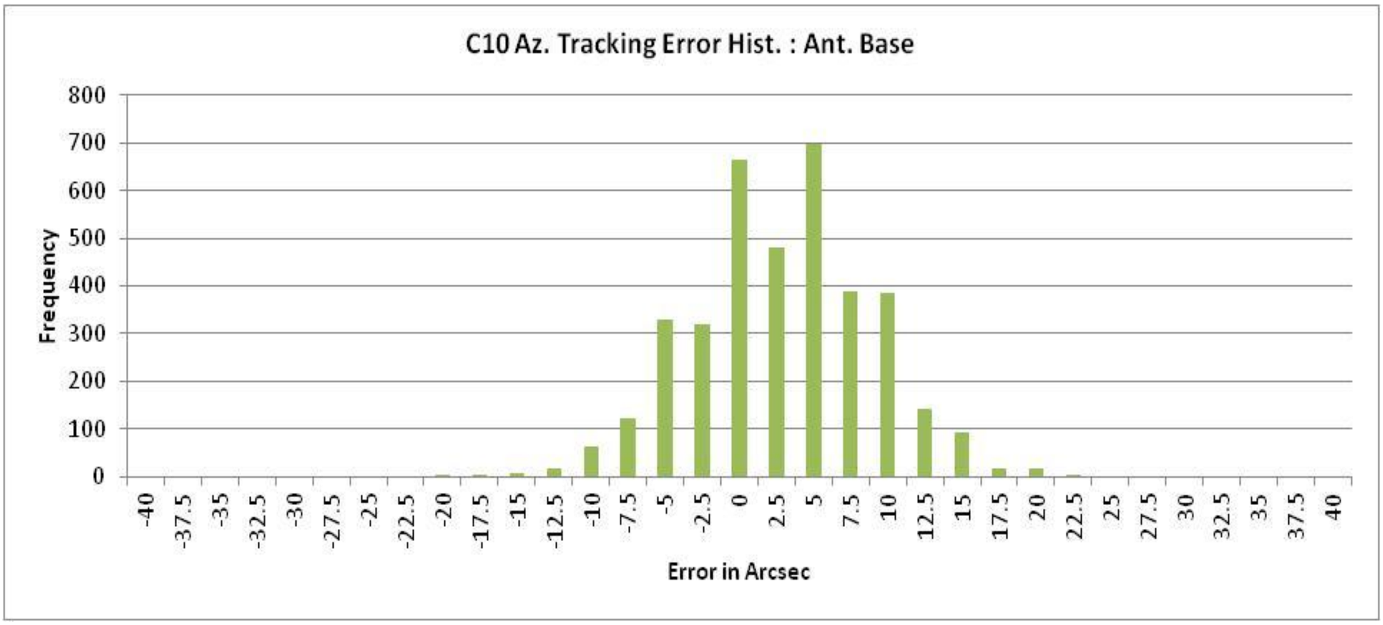
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency occurs at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



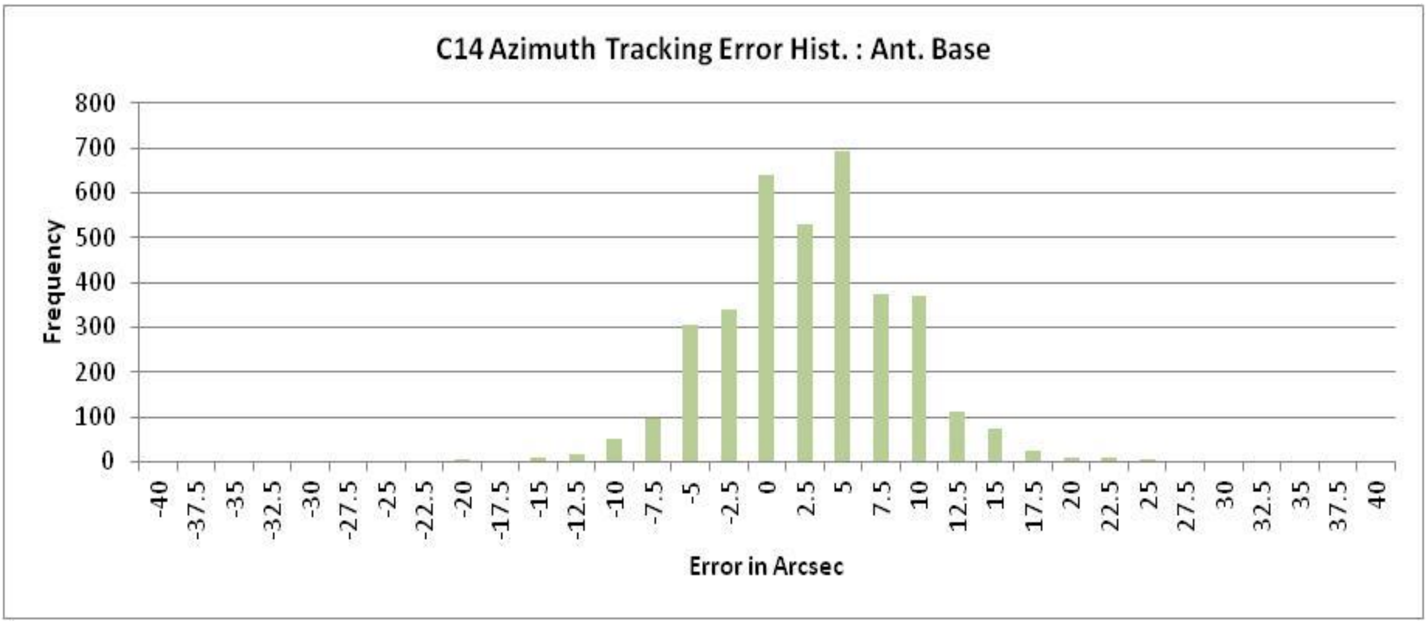
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency occurs at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



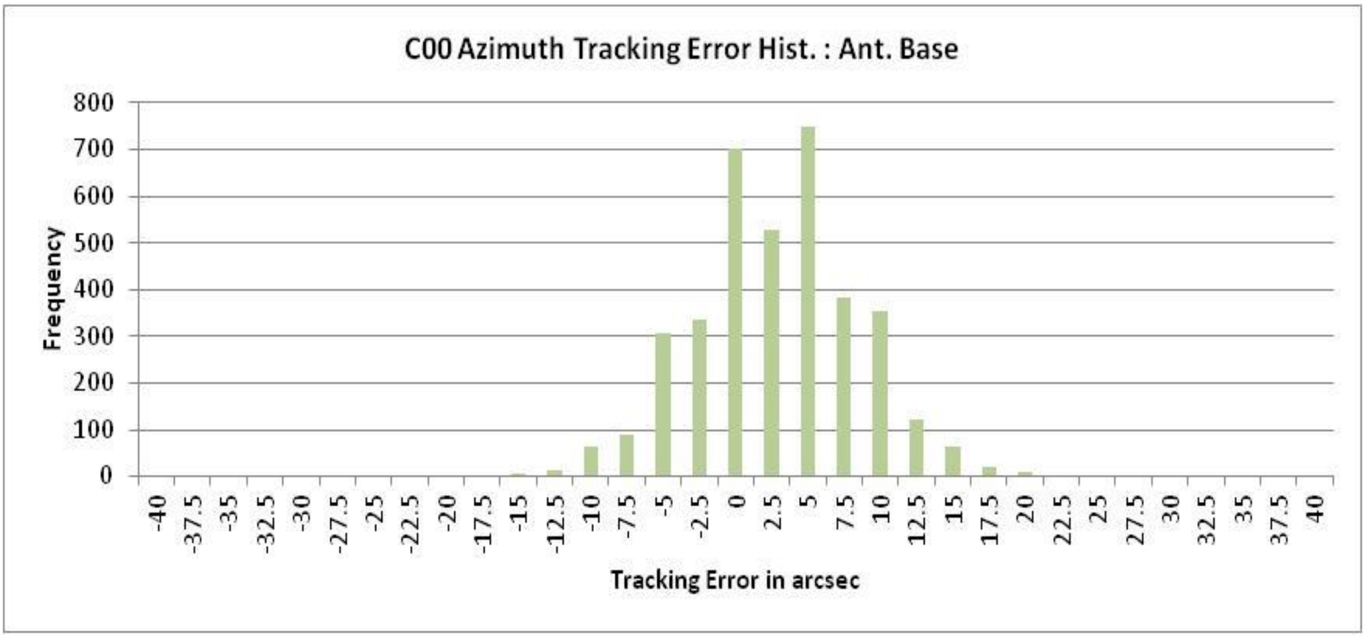
Brief Note: The errors are populated between -5 and 10 arcsec. Highest error frequency is at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



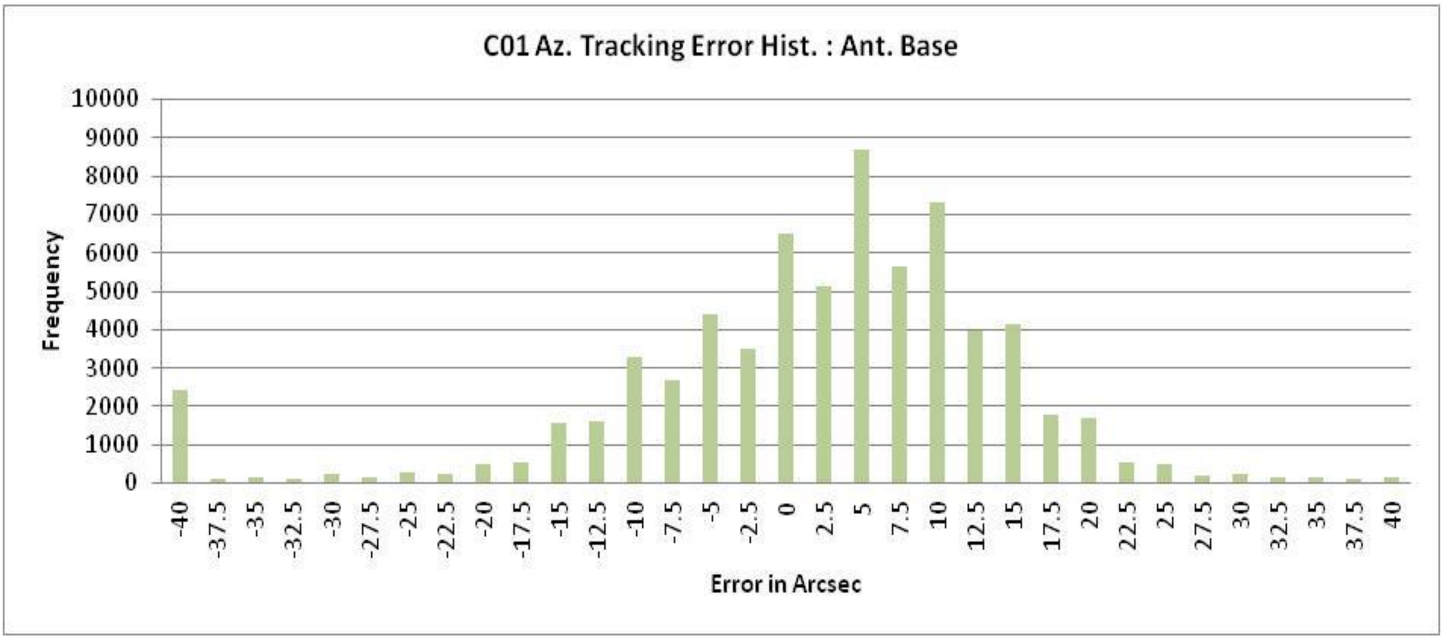
Brief Note: The errors are populated between -7.5 and 12.5 arcsec. Highest error frequency occurs at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



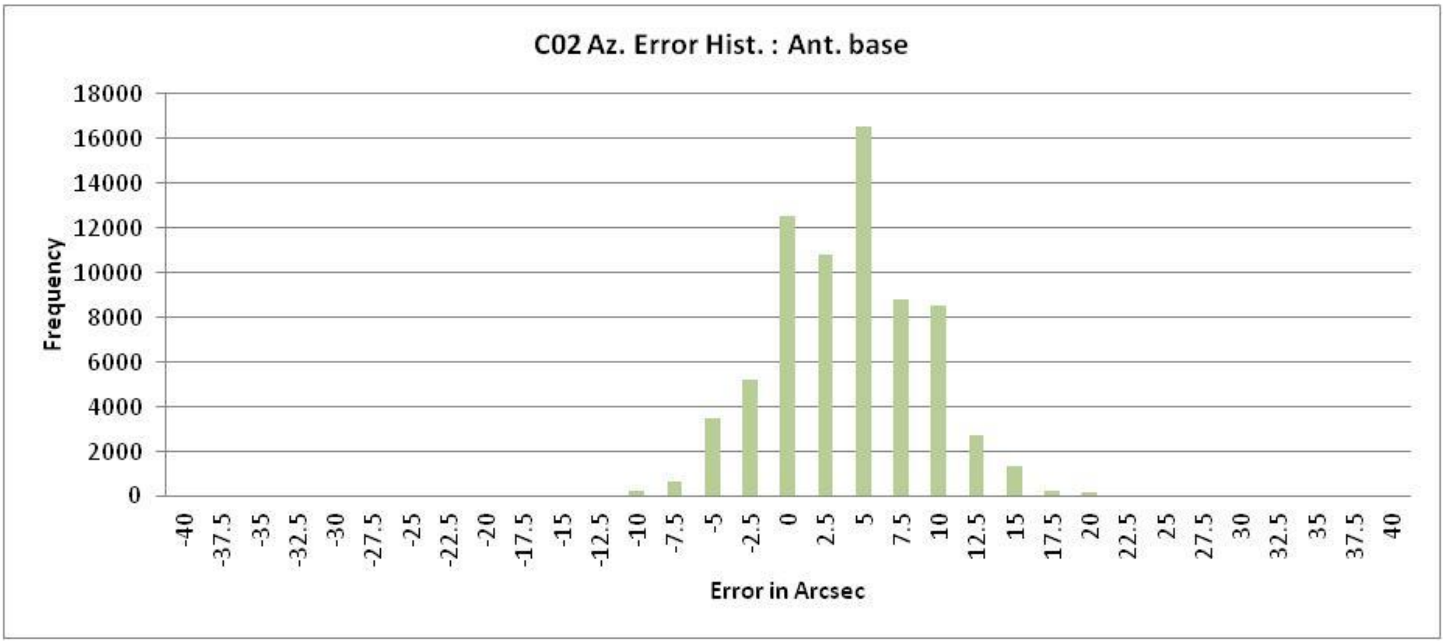
Brief Note: The errors are populated between -7.5 and 12.5 arcsec. Highest error frequency occurs at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



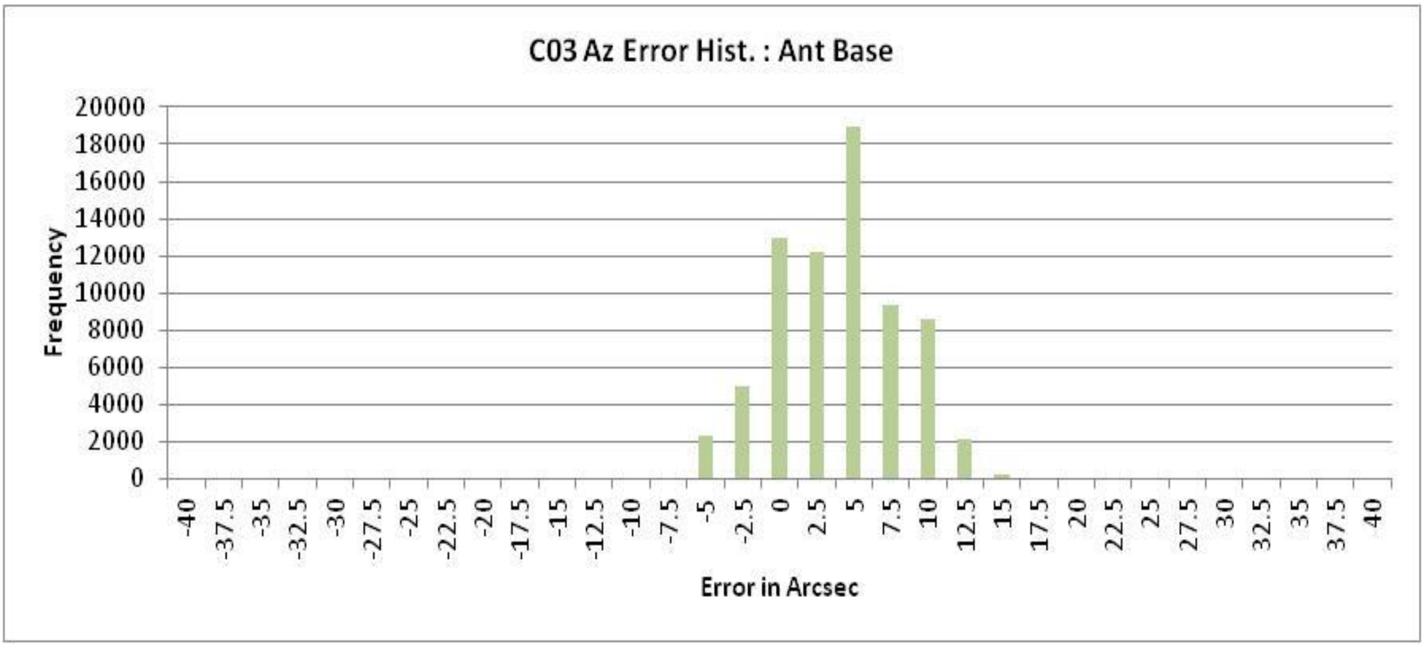
Brief Note: The errors are populated between -5 and 12.5 arcsec. Highest error frequency occurs at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 2.5 arcsec.



Brief Note: The errors are populated between -40 and 20 arcsec. Highest error frequency is at 5 arcsec followed by 10 arcsec. Histogram is symmetrical about 5 arcsec.



Brief Note: The errors are populated between -5 and 15 arcsec. Highest error frequency occurs at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 5 arcsec.



Brief Error: The errors are populated between -5 and 12.5 arcsec. Highest error frequency is at 5 arcsec followed by 0 arcsec. Histogram is symmetrical about 5 arcsec.

Conclusions

Following are the conclusions derived from the tests:

1. The data taken at antenna base give the same results as the data taken from the central building
2. The data taken at the antenna base with finer sampling time of 100 ms for the antennas with the PC/104 data logging give the same results as the data taken from the central building.
3. Average of RMS error in elevation axis in BLDC antenna is 6.1 arcsec. Average of RMS error in elevation axis in Non-BLDC antenna is 5.2 arcsec. The least error case is C03 which has PMDC with PC104 with an error of 4.5 arcsec. The highest error case is C14 which has BLDC with an error of 6.5 arcsec.
4. Average of azimuth axis RMS error in both PMDC and BLDC antennas is almost same.
5. As is evident from the summary table, RMS error for both axes for all antennas except C01 are of the order of 5 arcsec. Given the least count of the absolute encoder, this is expected RMS error for the antenna
6. The case of C01 antenna is being investigated

Future work

Another set of experiments can be done with more BLDC antennas apart from the central square ones. This could be done during windy conditions to study the effect of wind on error and hence the stability of system at varying loads.