REVISION BLOCK			
REV	DESCRIPTION	DATE	INCORP. BY
-	Initial "Release"	12/10/07	EAW

Background

This document compares the TCS1 actual operation with the SIMULINK model as of December 2007. Tracking, offset, and slew modes are compared using velocity magnitudes, pulse widths, acceleration, etc. Each page contains graphs and numerical results as well as a small comment section.

Overall Conclusions/Results

The model simulates the behavior of the TCS1 closely in some modes and not so well in other modes. The results are summarized in a table below for easier comparisons. Keep in mind that the feed forward values for both offsets and slews were chosen to make the model behave similar to what has been observed in TCS1. The actual values for TCS1 feed forwards have not been accurately measured at this time.

Page	MODE	HA Axis Parameter	TCS1	Simulink	Comment
2	Tracking @ 15 arcsec/s	Tracking Velocity Average	15 arcsec/s	15 arcsec/s	
2	Tracking @ 15 arcsec/s	Tracking Velocity (peak-to-peak)	3 arcsec/s	0.2 arcsec/s	Noise? TCS3 has peak-to-peak of 1 arcsec/s.
3	Tracking @ 15 arcsec/s	Backlash (opposing) Motor Current	2 Amps	2.17 Amps	
3	Tracking @ 15 arcsec/s	Tracking Driver Motor Current	5.1 Amps	2.25 Amps	Not sure of cause here.
4	Tracking @ 15 arcsec/s	Tracking Following Error (peak-to-peak)	0.3 arcsec	0.05 arcsec	Noise? TCS3 has tracking similar to this.
5	Offset West of 30 arcsec	West Drive Peak Current	12 A	13 A	
6	Offset West of 30 arcsec	Maximum Velocity	125 arcsec/sec	115 arcsec/sec	
6	Offset West of 30 arcsec	Movement Duration	1 second	0.8 seconds	
7	Offset West of 30 arcsec	Acceleration	540 (arcsec/s)/s	555 (arcsec/s)/s	Need to update this value.
8	Offset West of 30 arcsec	Tachometer "coupling"	100 arcsec/s	150 arcsec/s	This is somewhat subjective and dependent on conditions.
9	Offset West of 30 arcsec	Overshoot with feed forward?	Very Little	Very Little	General function verified visually. See graphs.
10	Offset West of 30 arcsec	Offset Settling Time (within 0.1 arcsec bands)	1.8 seconds	1.6 seconds	
11	SLEW West	Maximum velocity	2800 arcsec/s	1800 arcsec/s	Isn't 1800 TCS1 design? TCS1 issue?
12	SLEW West	Initial Current Drive	22 Amps	35 Amps	Likely caused by high acceleration command, PG13.
12	SLEW West	"Plateau"or Constant Slewing Current Drive	7 Amps	12	
12	SLEW West	East Motor Stopping Current for SLEW End	32 Amps	28	
13	SLEW West	Slew Acceleration	2436 (arcsec/s)/s	5859 (arcsec/s)/s	Electrical command issue in model?

University of Hawaii
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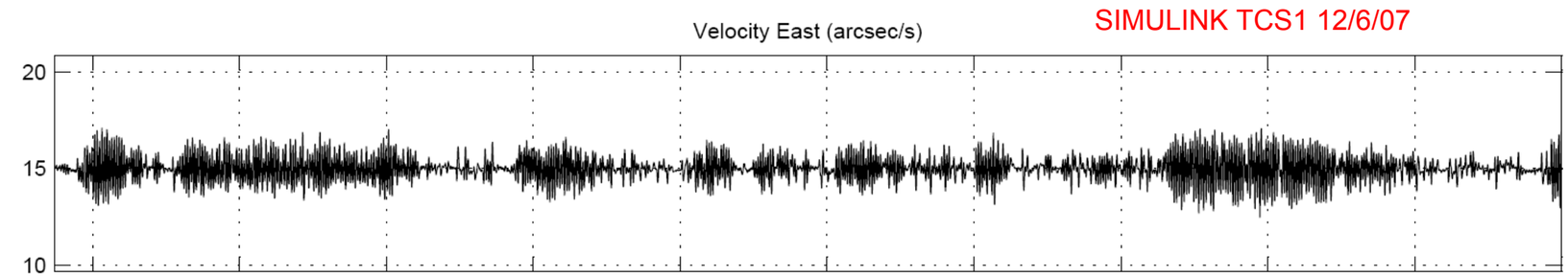
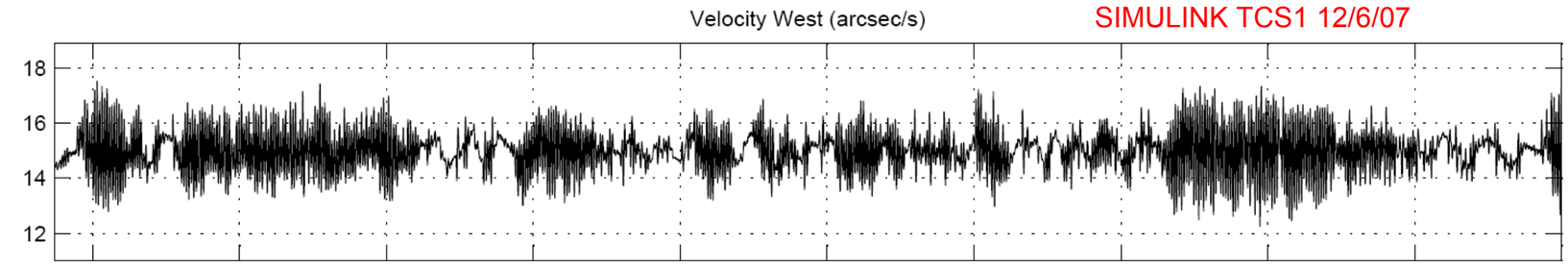
DWG #	REV	TITLE
TCS1-MvA	-	TCS1 Model vs. Actual

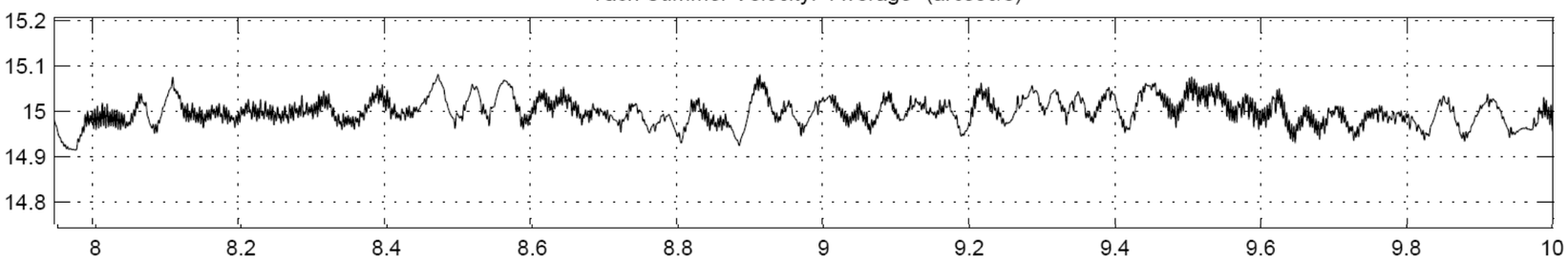
ENGINEER	LAST EDIT	SIZE	SHEET
E. Warmbier	12/13/2007 4:11:11 PM	B	1 of 13

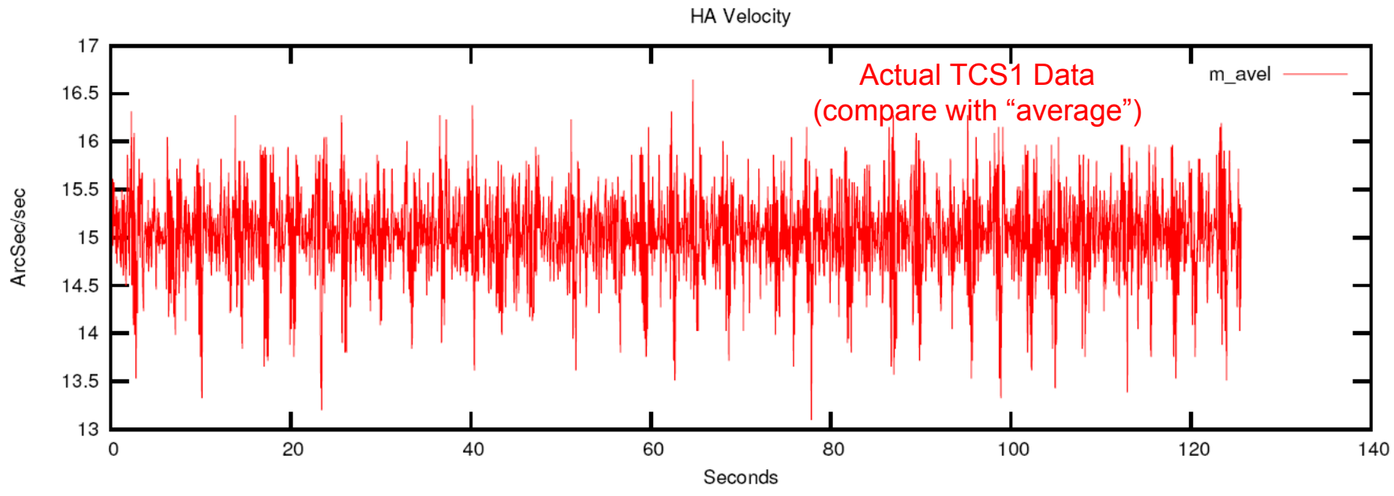
FILE: Z:\public_html\Presentation\TCS1 Model vs Actual 12_07_07.vsd

TRACKING @ 15 Arcsec/sec









RESULTS / COMMENTS

The model tracks at 15 Arcsec/sec just like the actual TCS1. However, the model has a peak-to-peak of less than 0.2 Arcsec/sec. The actual TCS1 has a peak-to-peak of about 3 Arcsec/sec. The model has large deviations in velocity on the tachometers, but it is filtered out though the tachometer summer and filter board.

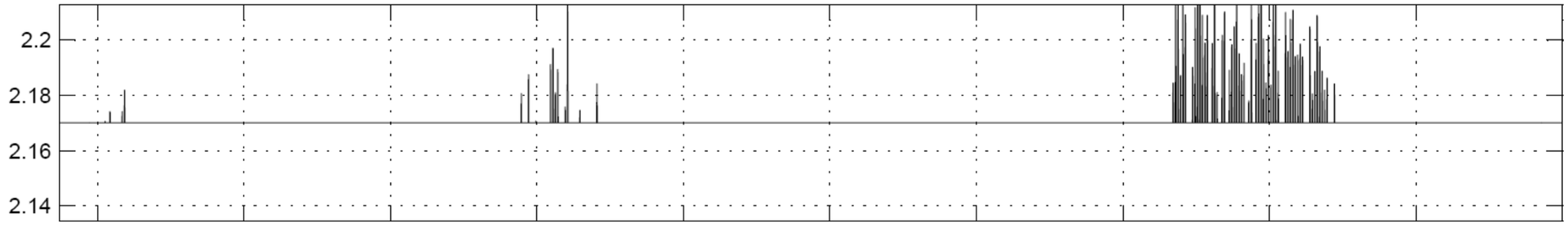
Possible explanations are:

1) Frequency content or noise amplitude of actual tachometers is higher.

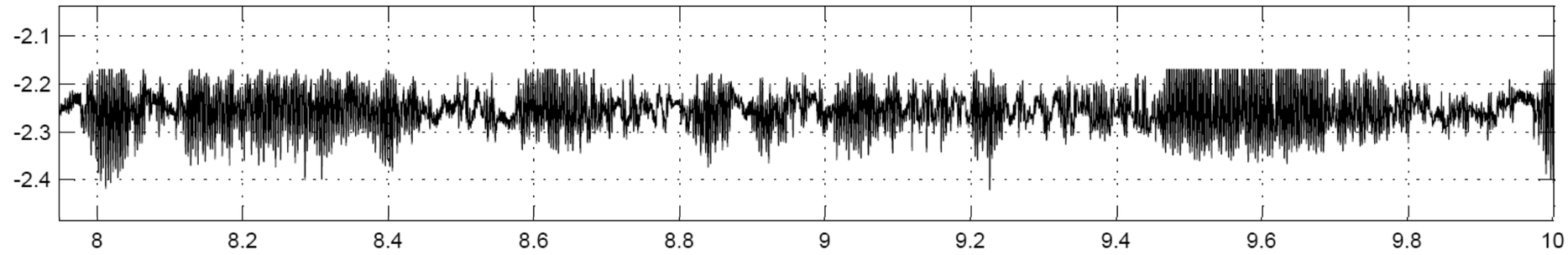
DWG #	REV	SHEET
TCS1-MvA	-	2 of 13

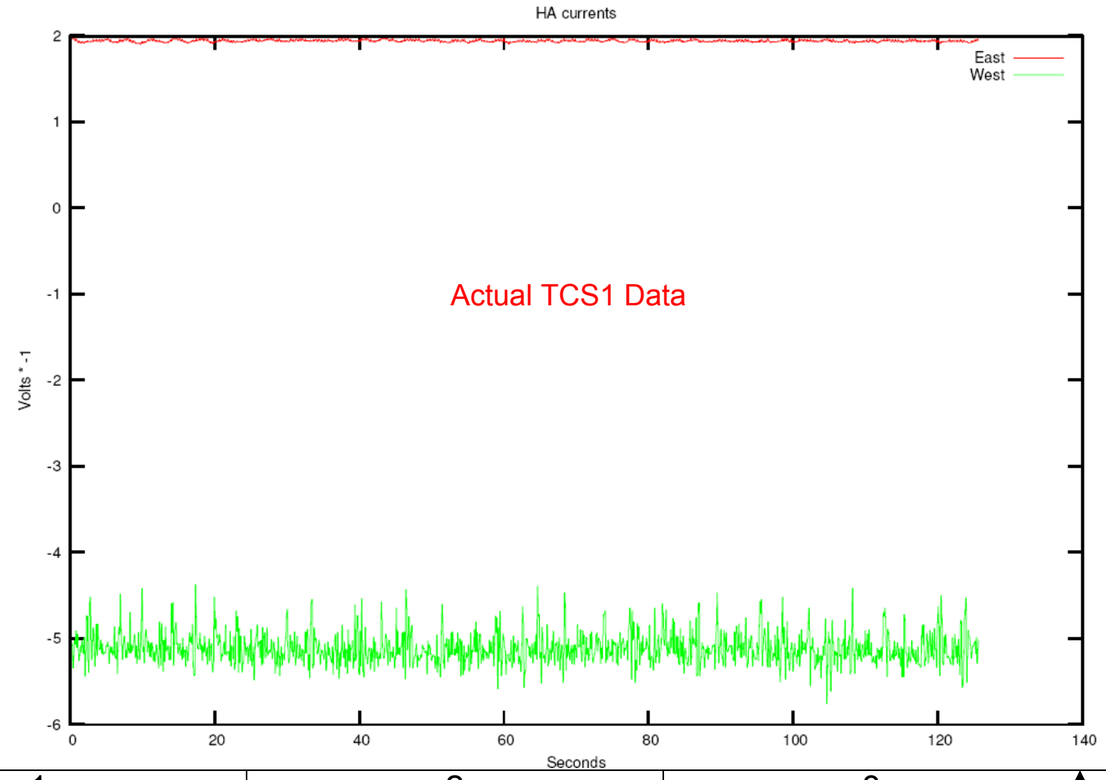
TRACKING @ 15 Arcsec/sec

East Actual Current (A) multiplied by -1 SIMULINK TCS1 12/6/07



WEST Actual Current (A) multiplied by -1 SIMULINK TCS1 12/6/07





Actual TCS1 Data

RESULTS / COMMENTS

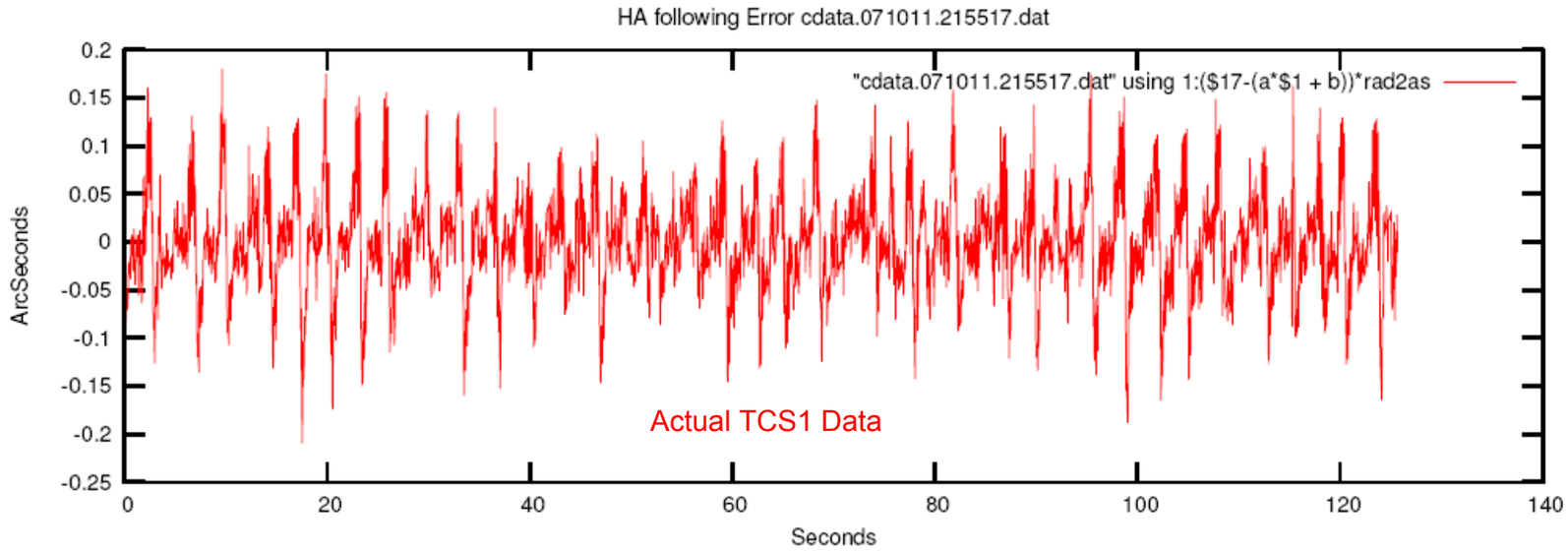
The model does not require a large a large current differential between the motors for tracking. In absolute terms, about 100 mV of difference between the two motors is shown. In actual operation, there is a difference of 3 amps.

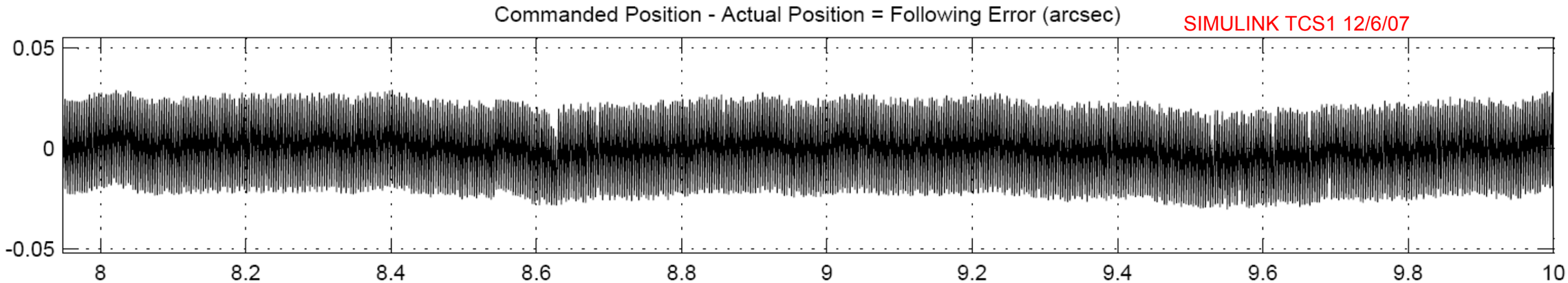
Possible explanations are:

1) Friction of some sort is too low in the model.

DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	3 of 13

TRACKING @ 15 Arcsec/sec



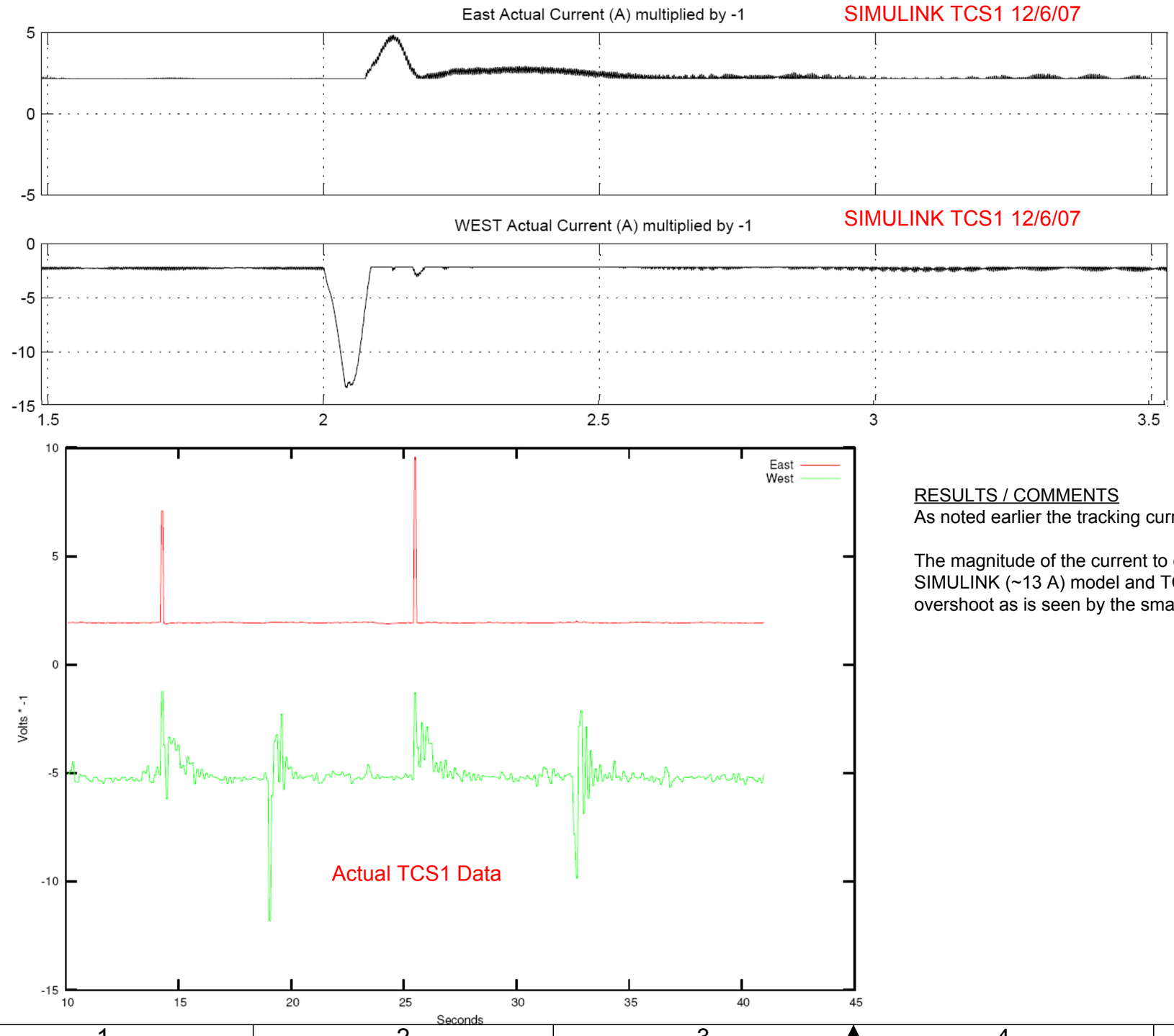


RESULTS / COMMENTS

The model has a better following error 0.05 Arcsec peak-to-peak vs. 0.3 Arcsec peak-to-peak for TCS1. Perhaps noise is present in actual tachs?

DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	4 of 13

TRACKING @ 15 Arcsec/sec then OFFSET 30 Arcsec



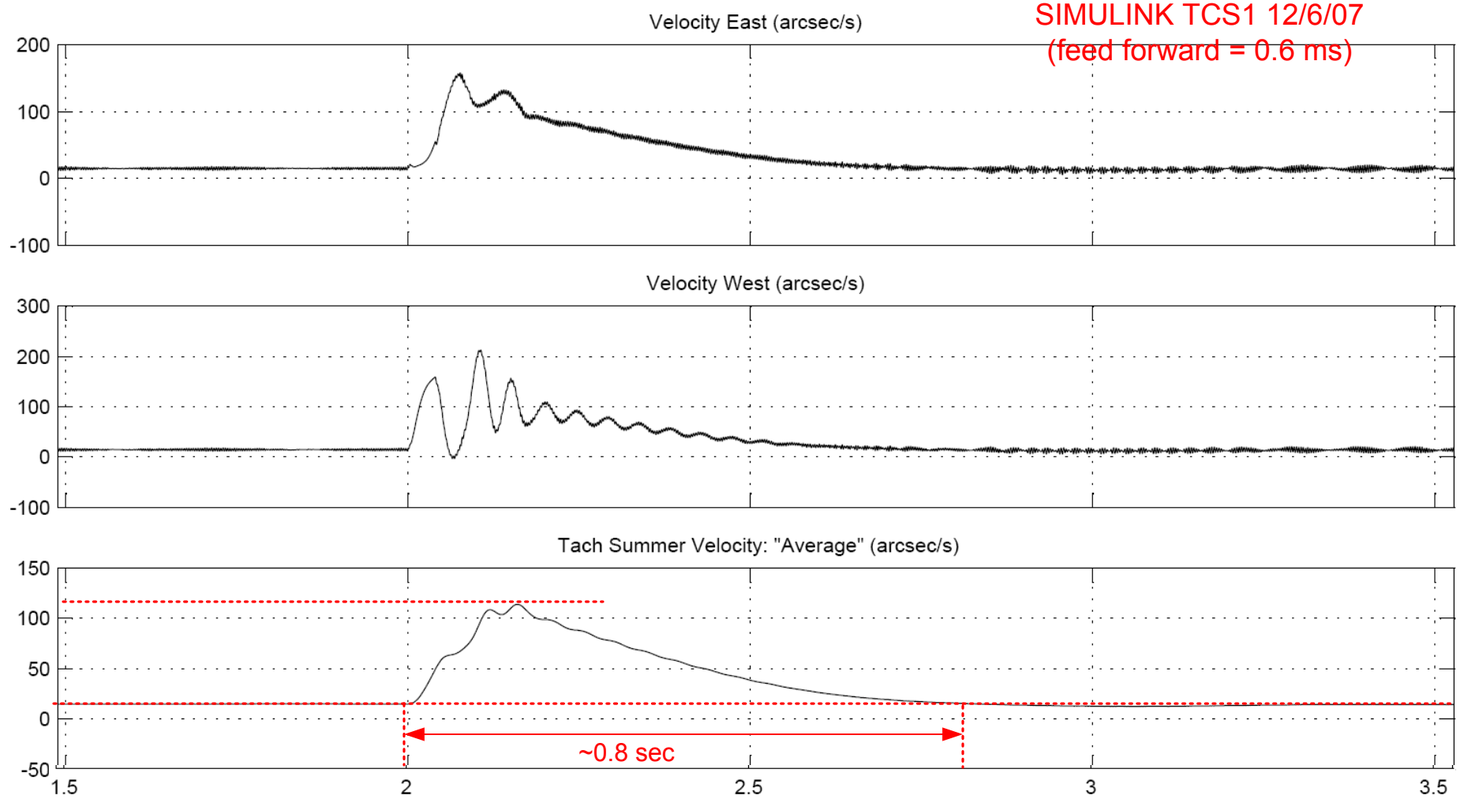
RESULTS / COMMENTS

As noted earlier the tracking current is very low in the model.

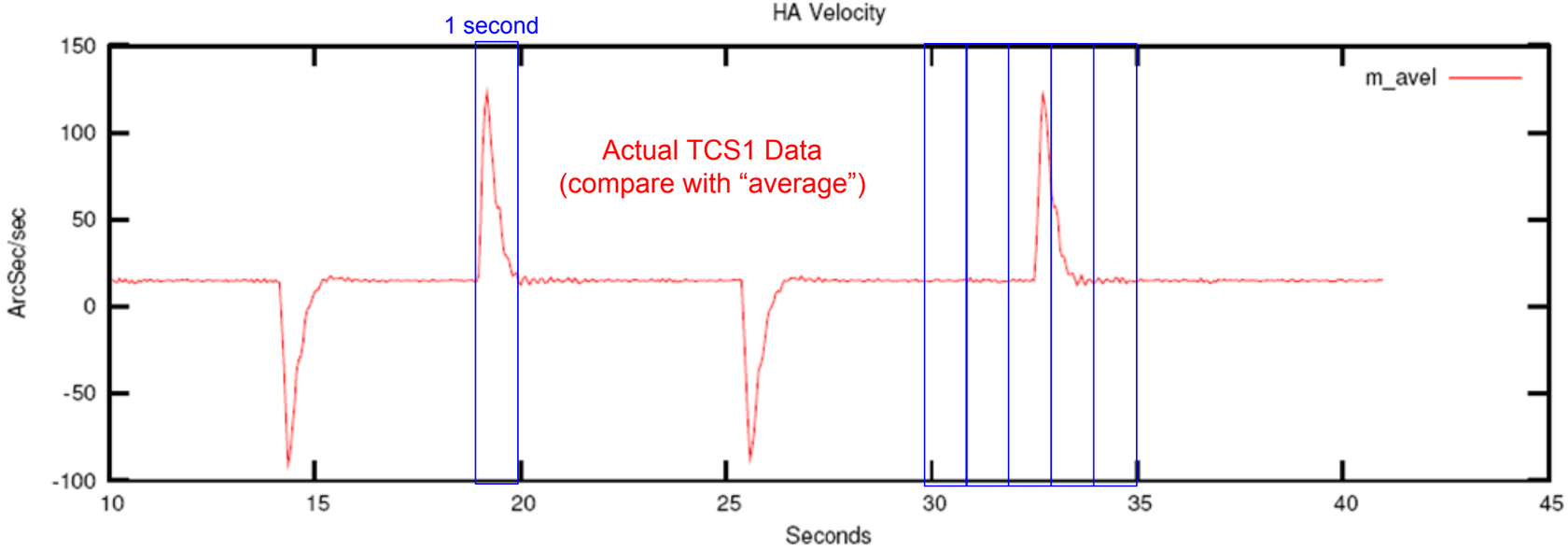
The magnitude of the current to drive the offset seems to be approximately equal in the SIMULINK (~13 A) model and TCS1 (~ 12 A) although the SIMULINK model has a slight overshoot as is seen by the small EAST current “bump”.

DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	5 of 13

TRACKING @ 15 Arcsec/sec then OFFSET 30 Arcsec



SIMULINK TCS1 12/6/07
(feed forward = 0.6 ms)

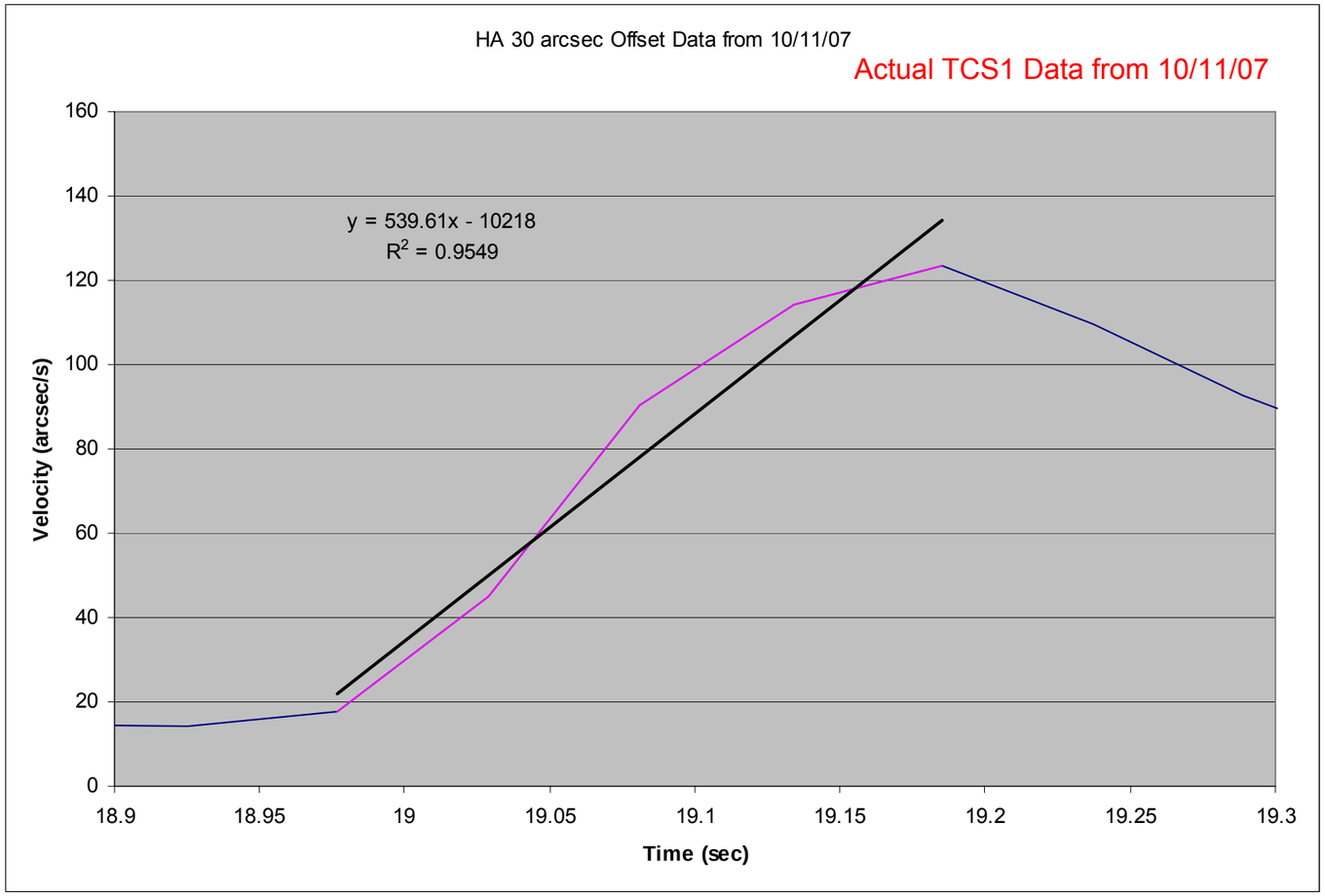


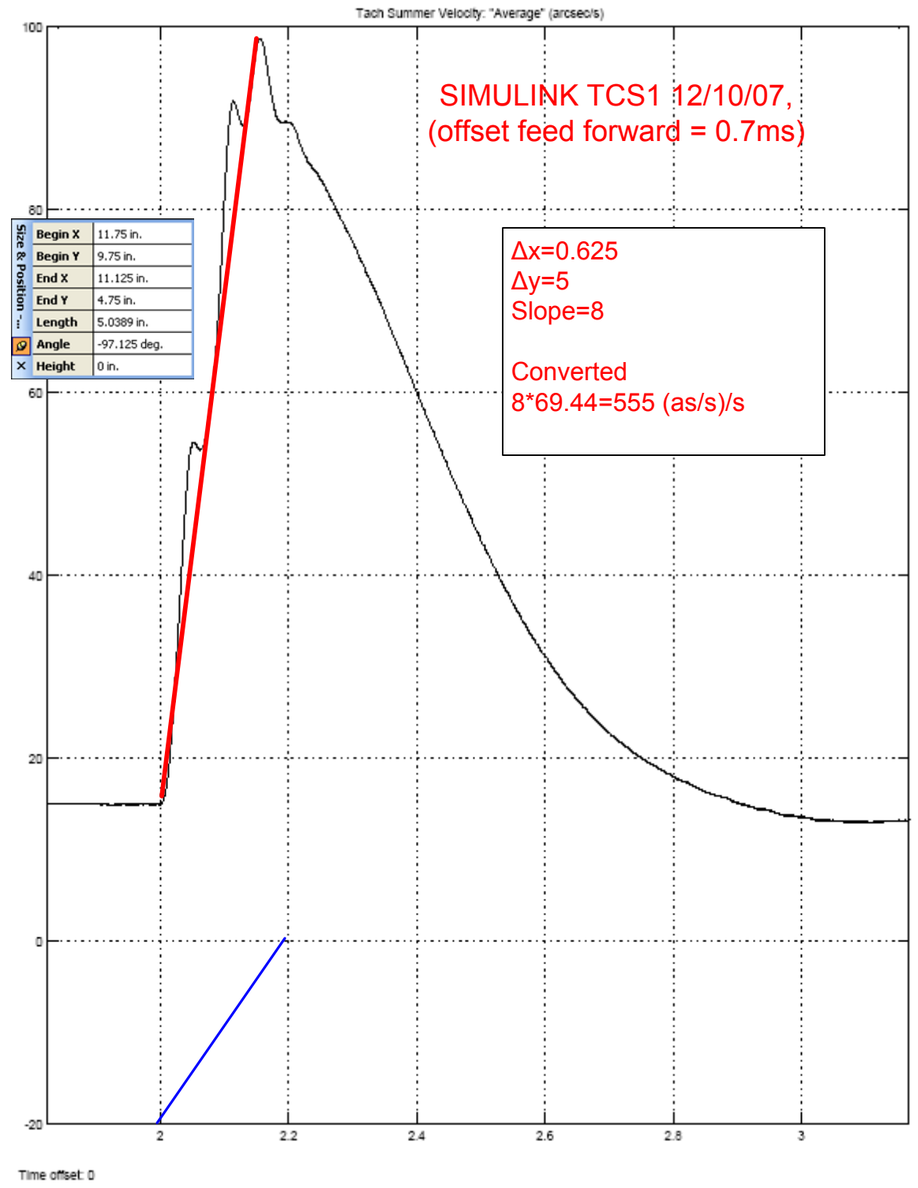
RESULTS / COMMENTS

The SIMULINK and TCS1 models appear to very close in magnitude. The SIMULINK model appears to reach a peak velocity of 115 Arcsec/sec and the TCS1 reaches about 125 Arcsec/sec. The movement time seems to be slightly longer for the actual TCS1, however, it is hard to determine precisely looking at these graphs with the present scaling. Approximately, the TCS1 appears to have a one second duration while the SIMULINK model has a 0.8 second duration.

DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	6 of 13

TRACKING @ 15 Arcsec/sec then OFFSET 30 Arcsec





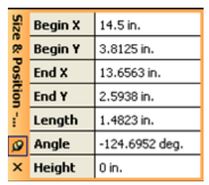
RESULTS / COMMENTS

The SIMULINK model and TCS1 appear to very close in offset velocity magnitude with 540 arcsec/s (TCS1) vs 555 arcsec/s (SIMULINK).

Δx=0.8437"
Δy=1.2187"
Slope=1.44

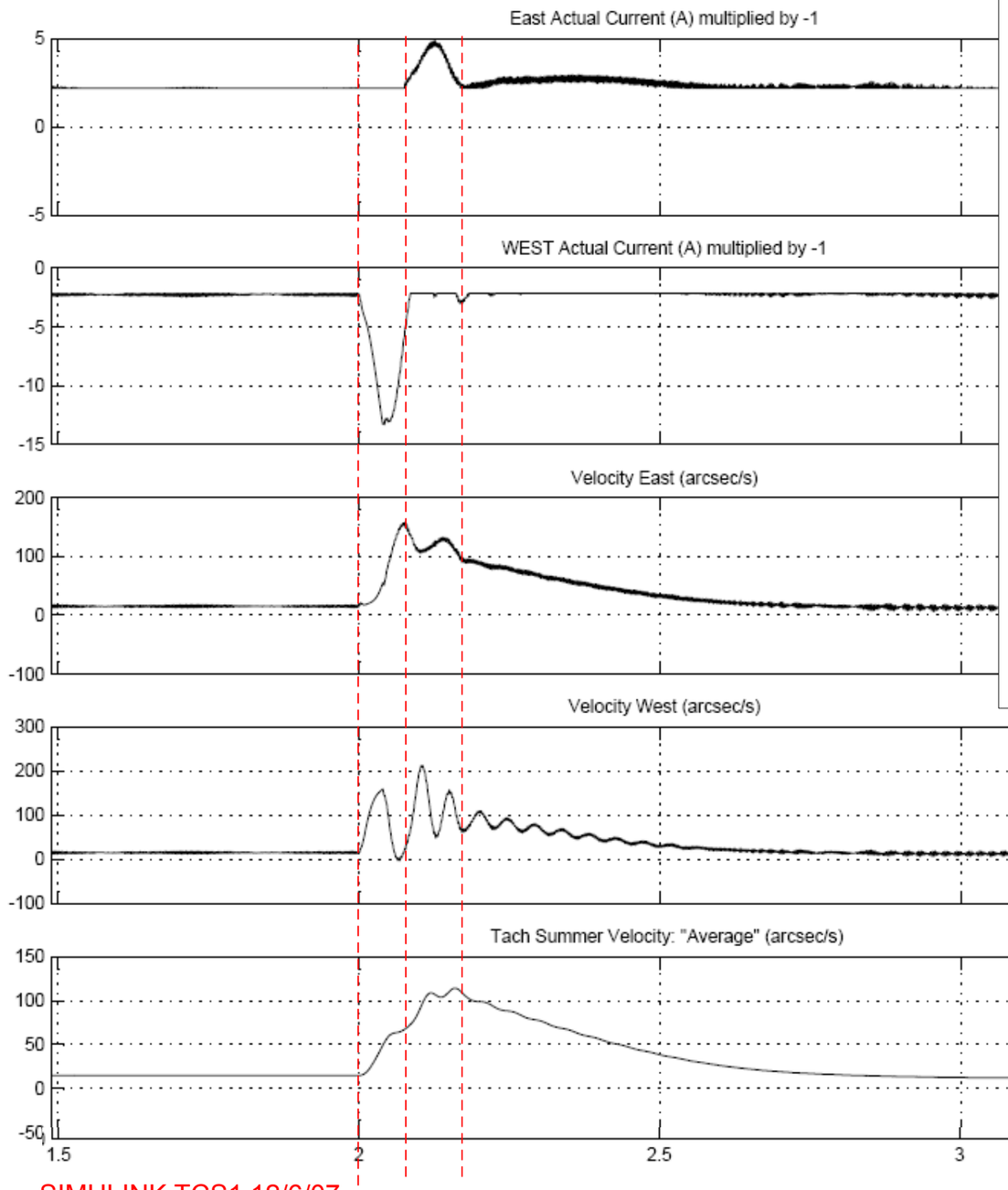
Δx=0.2 sec
Δy=20 as/s
Slope=100 (as/s)/s

1.44*x=100
X=69.44 (as/s)/s
(conversion)



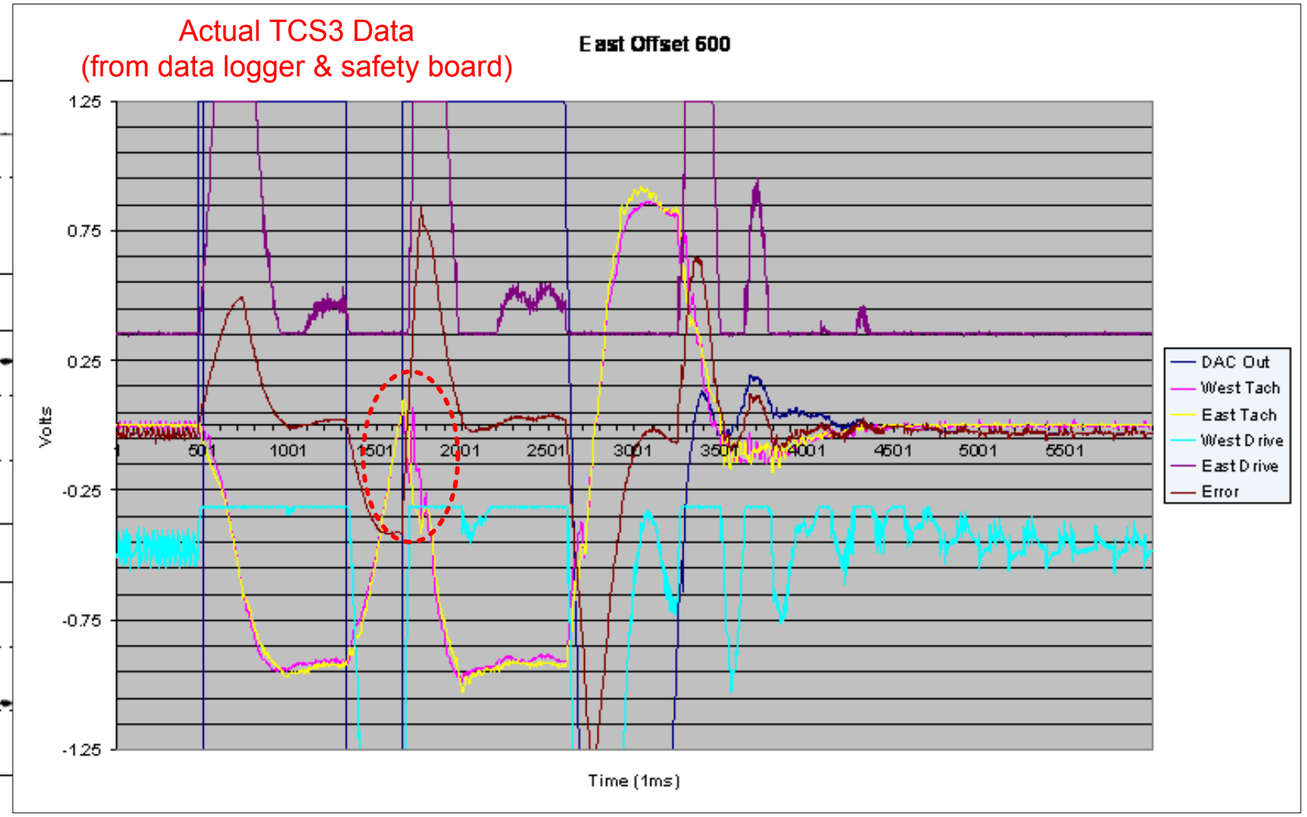
DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	7 of 13

TRACKING @ 15 Arcsec/sec then OFFSET 30 Arcsec



SIMULINK TCS1 12/6/07,
(offset feed forward = 0.6ms)

Actual TCS3 Data
(from data logger & safety board)



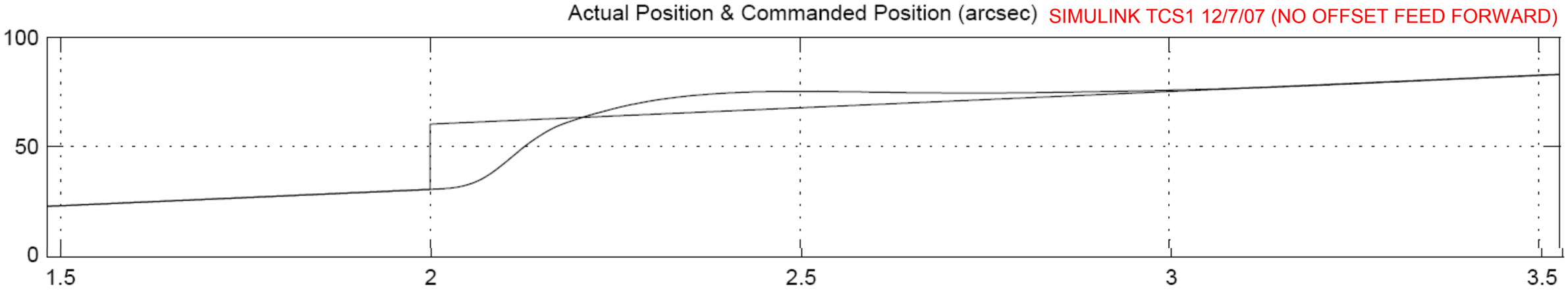
Tachometer scaling is approximately (500 arcsec/sec) per volt.
For reference, 150 arcsec/sec is 0.3V.

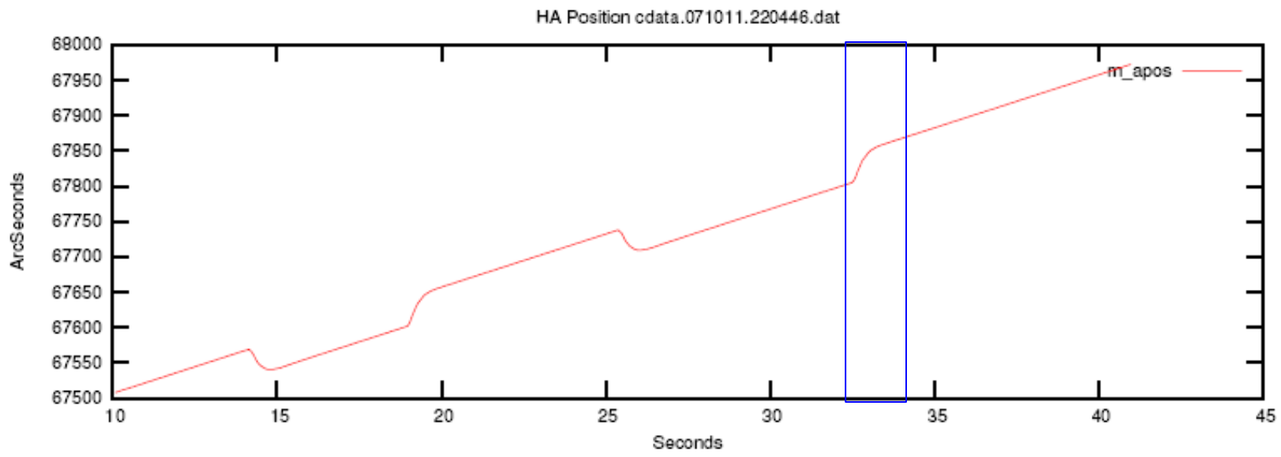
RESULTS / COMMENTS

Originally is was observed that the SIMULINK tachometers seemed to be less coupled to each other (through the bull gear) than the TCS1 tachometers. The difference in tachometer readings reach a maximum of nearly 150 arcsec/sec in the simulink model. In the TCS3 data logged graph above, the tachometers seem to follow each other fairly closely (within 25 arcsec/sec or 0.05V). However, there is a region (red dotted oval) where the tachometer difference is larger, somewhere on the order of 100 arcsec/sec. Notice the drive currents abruptly changed in this area creating torque in the opposite directly rapidly. Therefore, the model may be correct in this respect. Less coupled tachometers would be a worse case scenario which makes it acceptable for the model (as opposed to perfectly coupled tachometers with respect to each other).

DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	8 of 13

TRACKING @ 15 Arcsec/sec then OFFSET 30 Arcsec



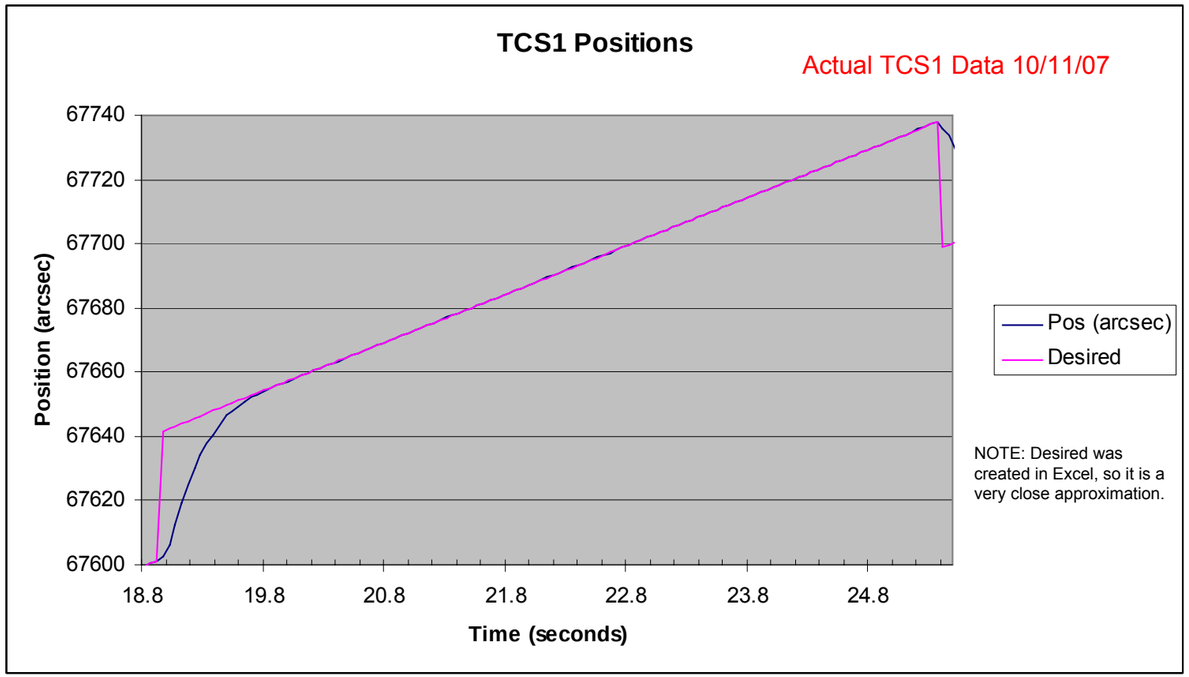


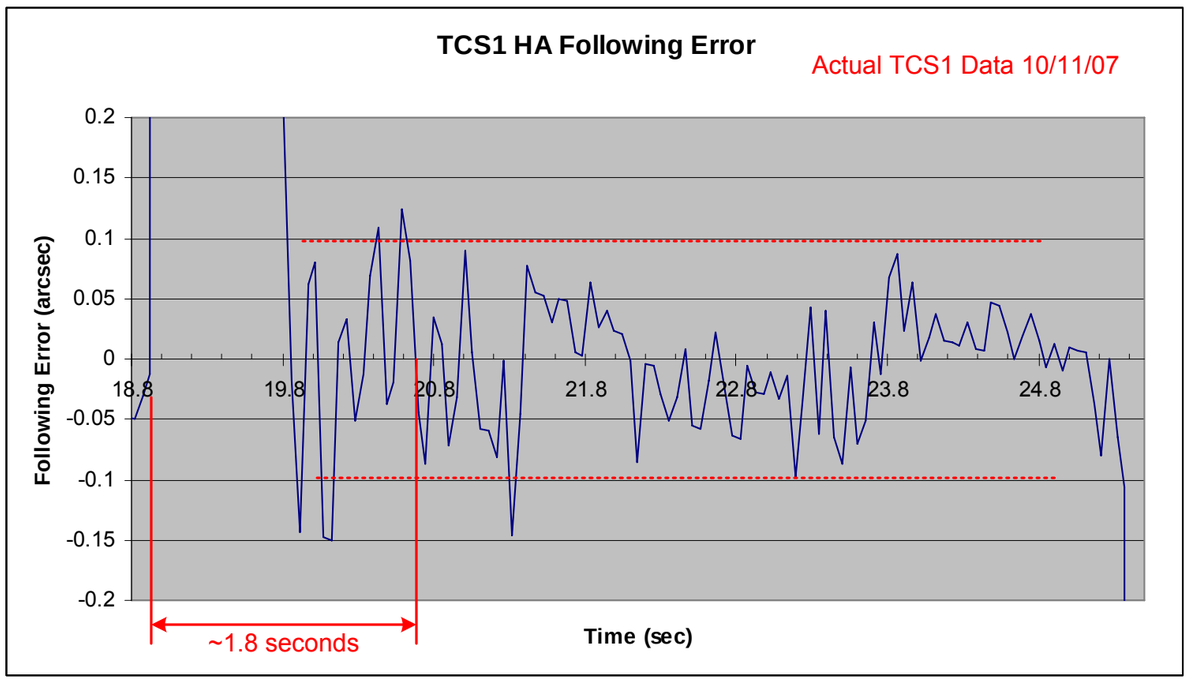
RESULTS / COMMENTS

The resolution on the graphs is coarse, however, notice the effect of the offset feed forward on the overshoot.

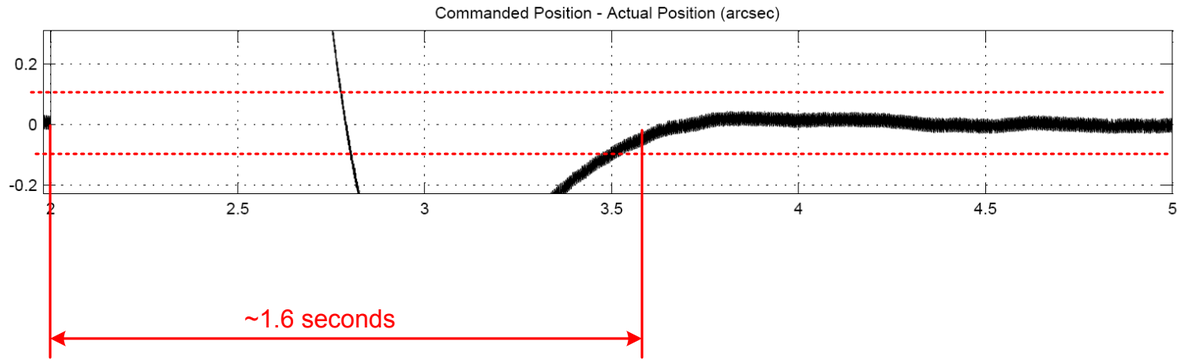
DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	9 of 13

TRACKING @ 15 Arcsec/sec then OFFSET 30 Arcsec





SIMULINK, “Offset FeedForward=0.7ms”, 12/07/07

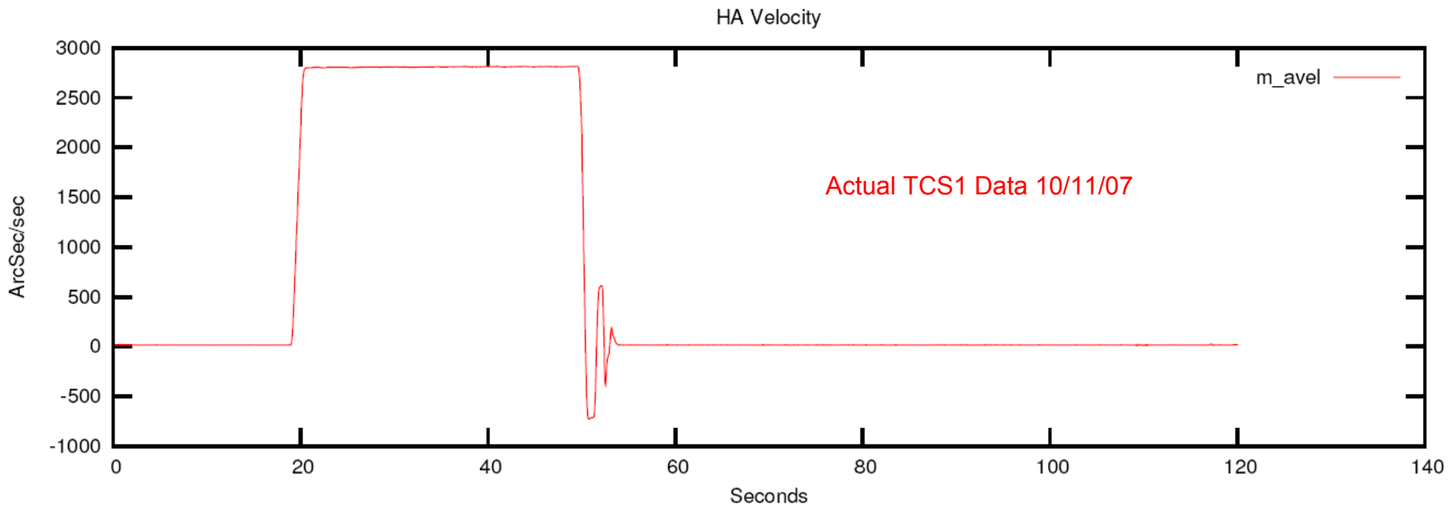


RESULTS / COMMENTS

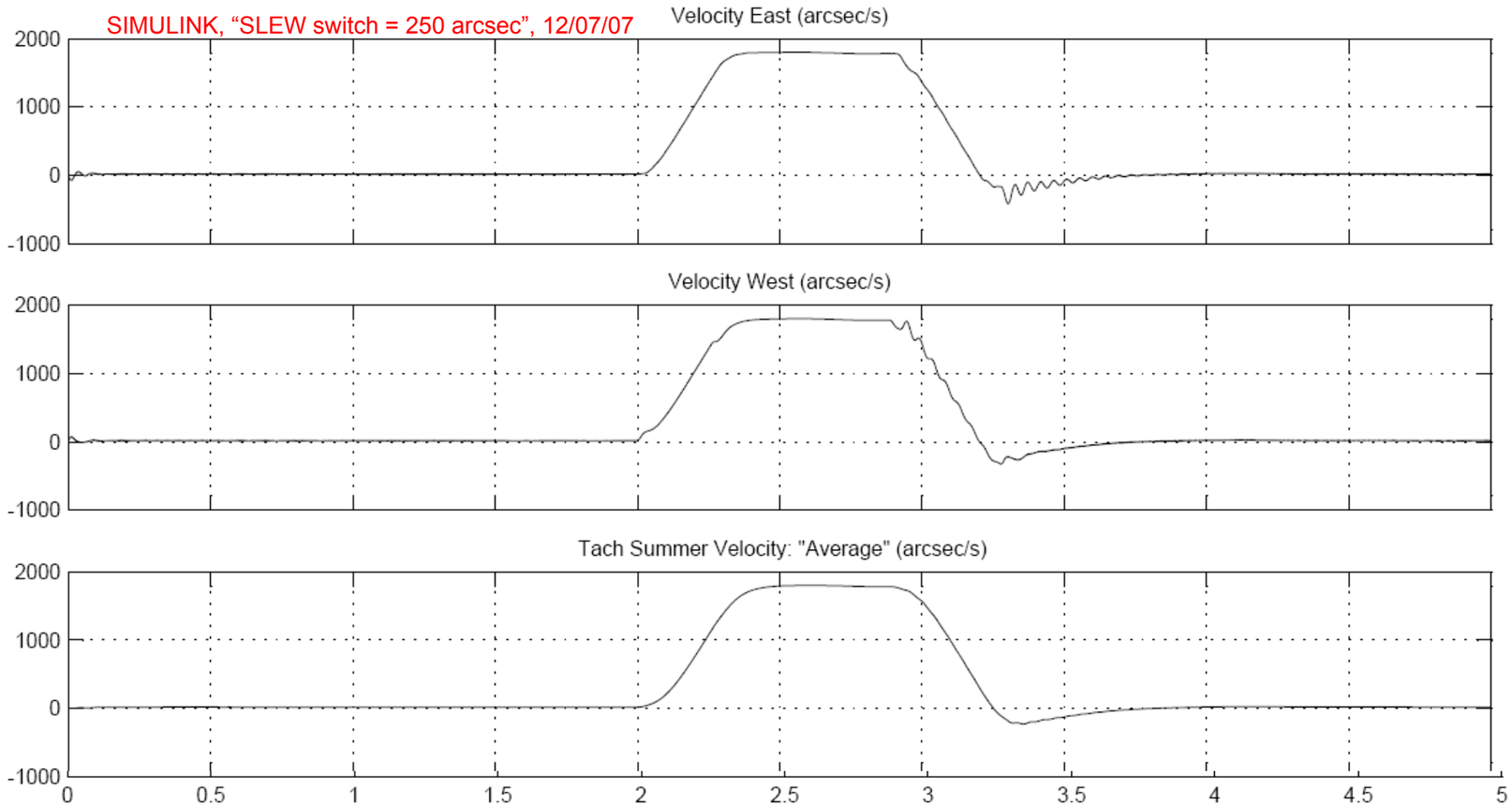
The SIMULINK and TCS1 models appear to behave similarly. Settling times are approximately equal (1.8s vs 1.6s). However, keep in mind that the offset feed forward has not been well characterized and therefore the value currently used in the SIMULINK model was set to match what has been observed with TCS1 operation in terms of current drive, settling, etc.

DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	10 of 13

SLEWING 1500 arcsec



SIMULINK, "SLEW switch = 250 arcsec", 12/07/07



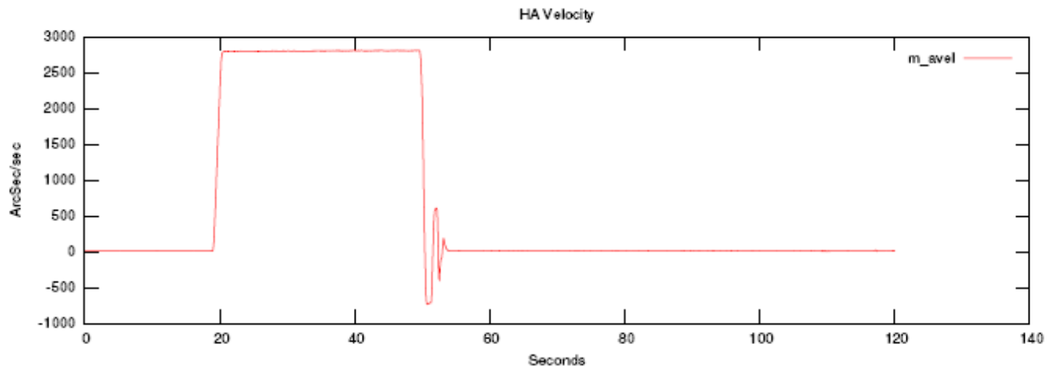
RESULTS / COMMENTS

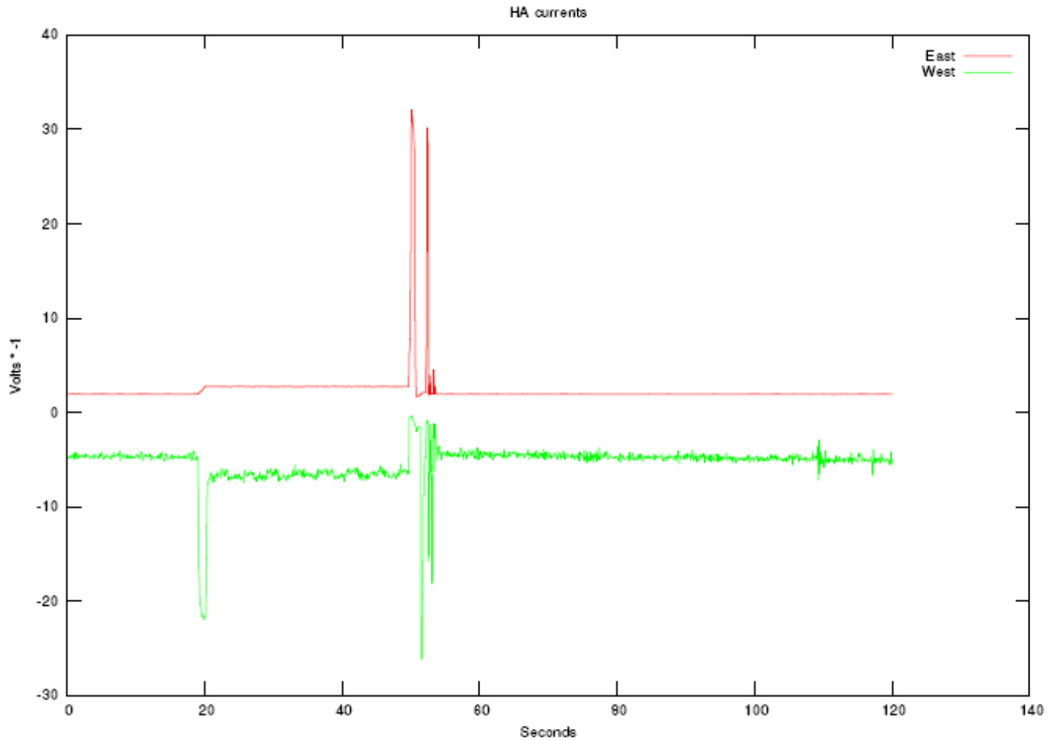
The SLEW maximum velocity is much higher in the actual TCS1 than the SIMULINK model. It is though or "known" that the TCS wasn't supposed to go much faster than 1800 arcsec/sec. It seems that it goes much faster than that at around a maximum of ~2800 arcsec/sec.

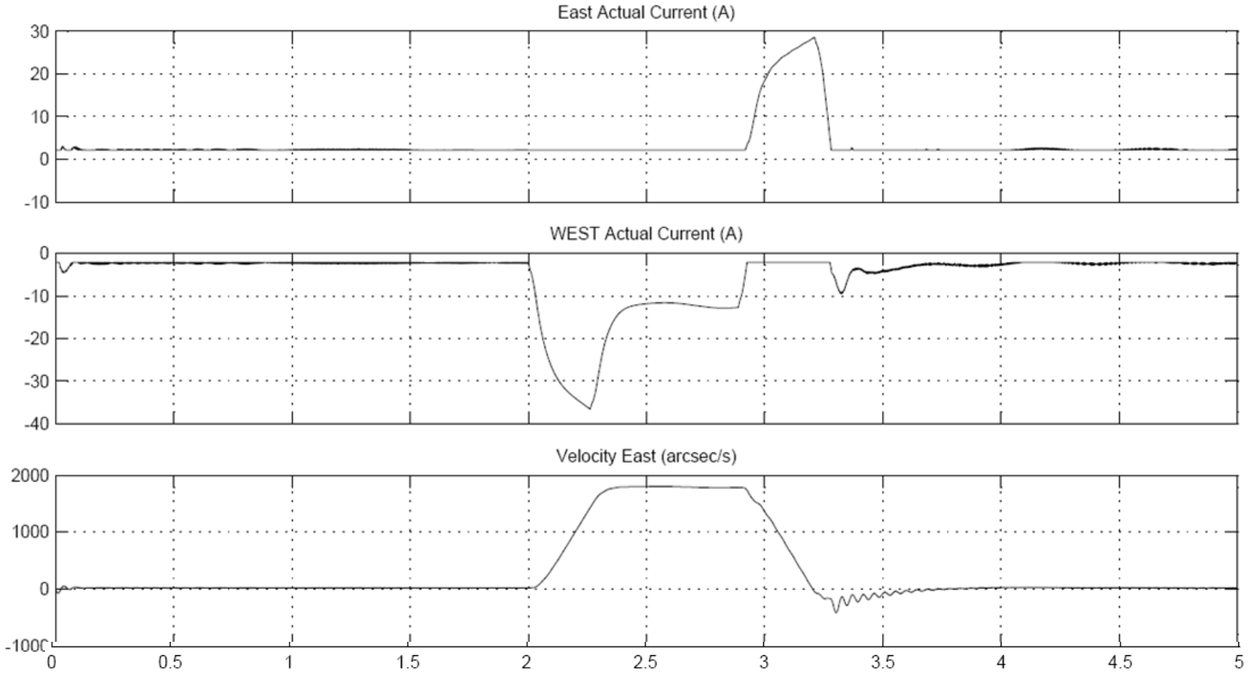
Also, the variable in the model that determines when the SLEW mode re-enters normal mode is 250 arcseconds from the desired end position. It isn't known what value the actual system uses at the moment. 250 was chosen because it gives a reasonable response in the model.

DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	11 of 13

SLEWING 1500 arcsec







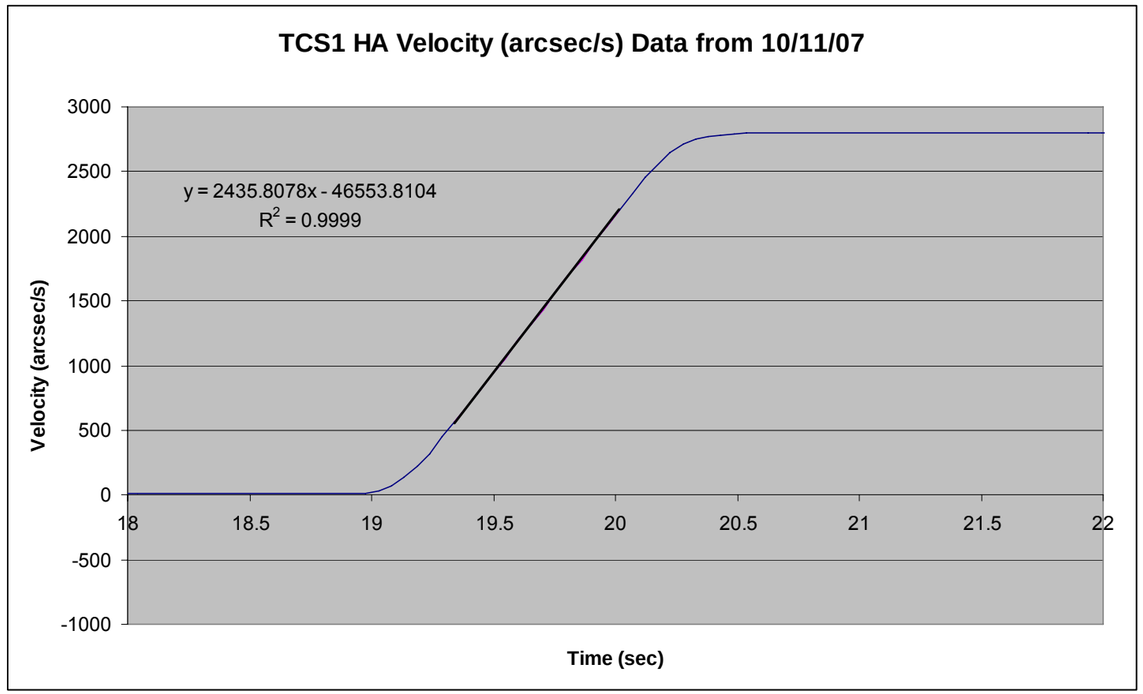
RESULTS / COMMENTS

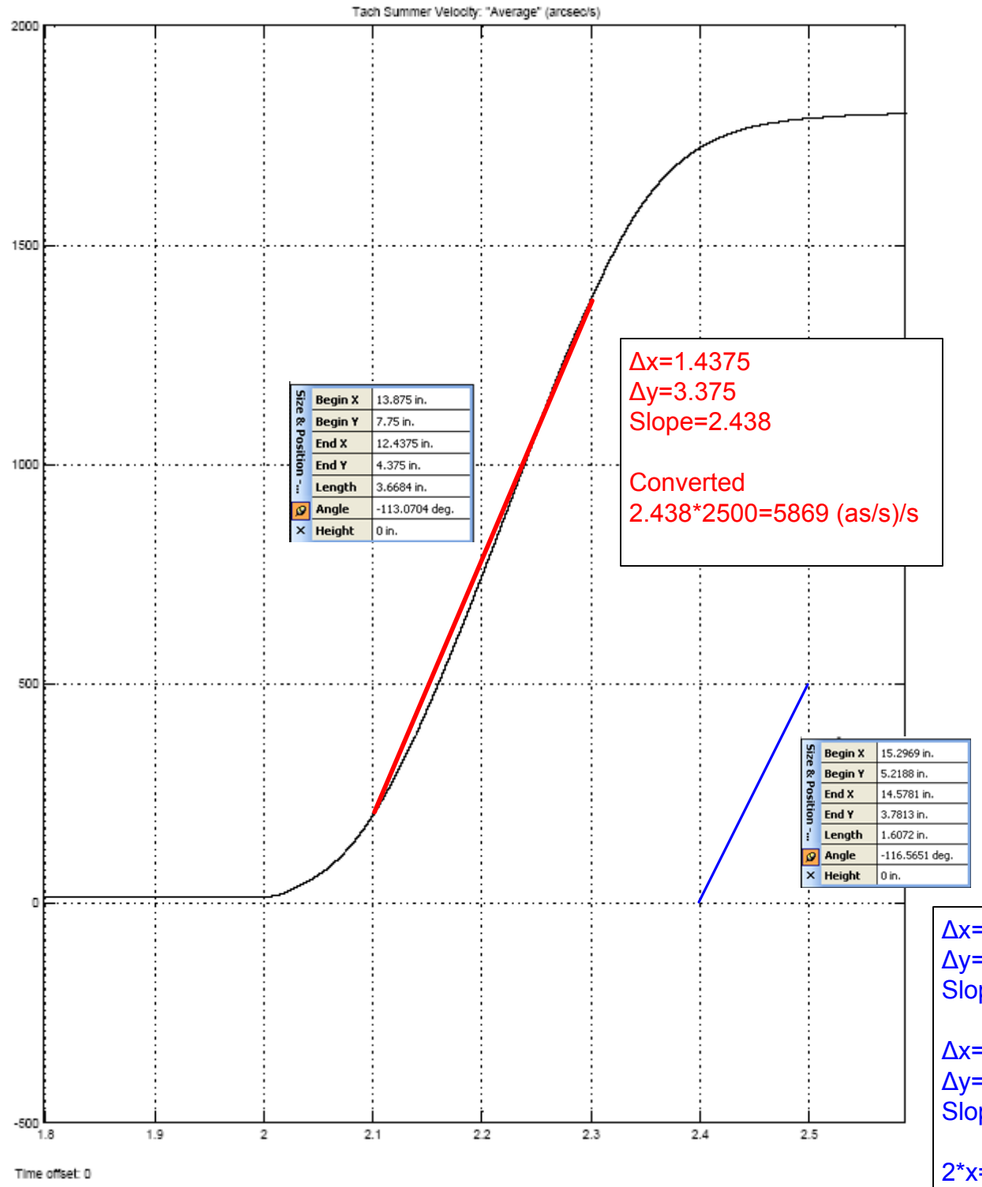
The TCS1 SLEW waveform shape is similar. It has a large current pulse to initiate movement followed by a plateau once it is moving and then an oscillation between the two motors to bring the telescope to a rest, which is an overshoot. The SIMULINK model does not exhibit large or multiple oscillations when coming to a stop.

The amplitudes of the currents for the motors are quite different. The initial pulse is ~22A followed by a plateau of ~7A for the TCS1. The reverse pulse is ~32A. The SIMULINK model has an initial pulse of ~35A, followed by a plateau of ~12A and a reverse pulse of 28A. The current required for the SIMULINK model is higher. The high initial current drive can be explained by the higher acceleration observed in the model. See slew acceleration section.

DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	12 of 13

SLEWING 1500 arcsec





Δx=1.4375
Δy=3.375
Slope=2.438

Converted
2.438*2500=5869 (as/s)/s

Δx=0.7188"
Δy=1.4375"
Slope=2

Δx=0.1 sec
Δy=500 as/s
Slope=5000 (as/s)/s

2*x=5000
X=2500 (as/s)/s
(conversion)

RESULTS / COMMENTS

The SIMULINK model has an acceleration that is (5869/2436) 2.41 times that of the actual TCS1. This could be an electrical control issue since there is a velocity command generated and a velocity loop to drive the motors to that desired velocity. This could explain the higher current used to initially drive the motors in the SIMULINK model during a SLEW.

The SIMULINK tool has a basic, somewhat crude graphing system. Therefore, slope has to be derived off the graph. In this case, the blue line determines the slope to (as/s)/s conversion.

DWG #	REV	SIZE	SHEET
TCS1-MvA	-	B	13 of 13