Open-loop Step Responses of the MMT Azimuth Axis
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Introduction

During last June's data collection campaign, open-loop measurements were taken of the MMT absolute encoder and motor encoder position outputs when the motor amplifiers were driven by a slew-rate limited squarewave input. Slew-rate limiting keeps the acceleration of the torque input to the axis to values considered safe for the drivetrain and optics. During testing, the azimuth absolute and motor encoder outputs are sampled at 500Hz.

This report is the last of the series for the June 2010 testing period. A test of the building-telescope cross-coupling forces was unfortunately lost, and this experiment will be repeated in early 2011.

The Data

Only two of these step-response tests were performed; one with a fairly small squarewave input, and another with a larger amplitude. Due to the torque imbalance on the azimuth axis, the telescope tended to walk off during the test, so testing was suspended in favor of other experiments in the interest of time.

All the data arrays are from the file: *open_loop1.mat* in my data archive, available at the URL http://www.mmto.org/~dclark/AzimuthTesting/ for interested parties.

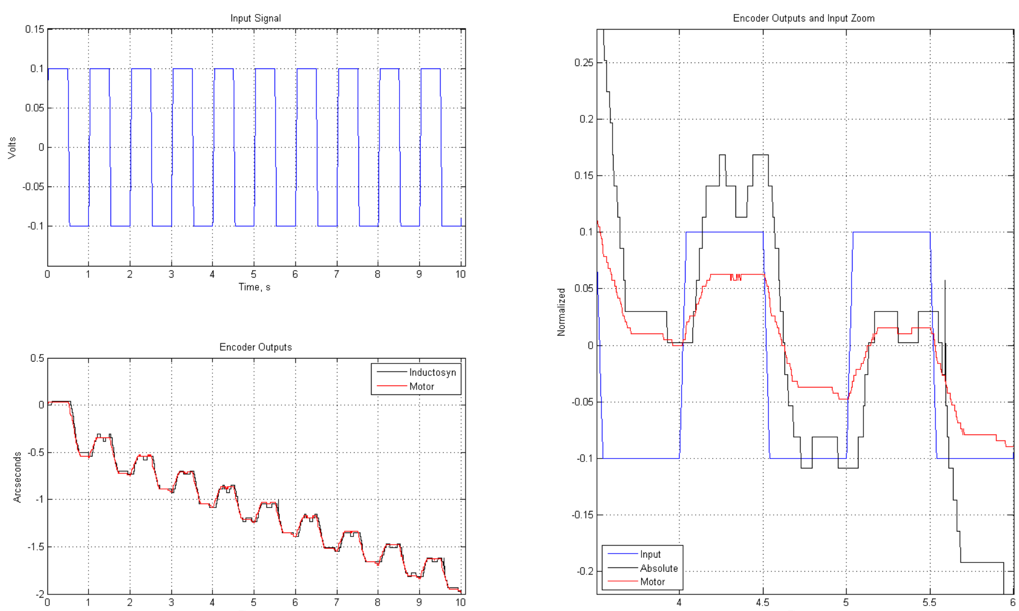

Figure 1. Small-signal azimuth step responses

The data to be gleaned from the above figure is that there is a very subtle “lost motion” between the absolute and motor encoders, visible in the zoomed portion of the data, when the telescope started moving again at each change in the input signal. Note that the ±0.1V input signal is not enough to overcome the static friction, so it stops moving during the peaks of the input. Quantization of the encoder values is also very visible in this data. For the purposes of servo design, we note that the phase shift at DC from input to encoder output is 0°; an important fact when developing the open-loop telescope model.

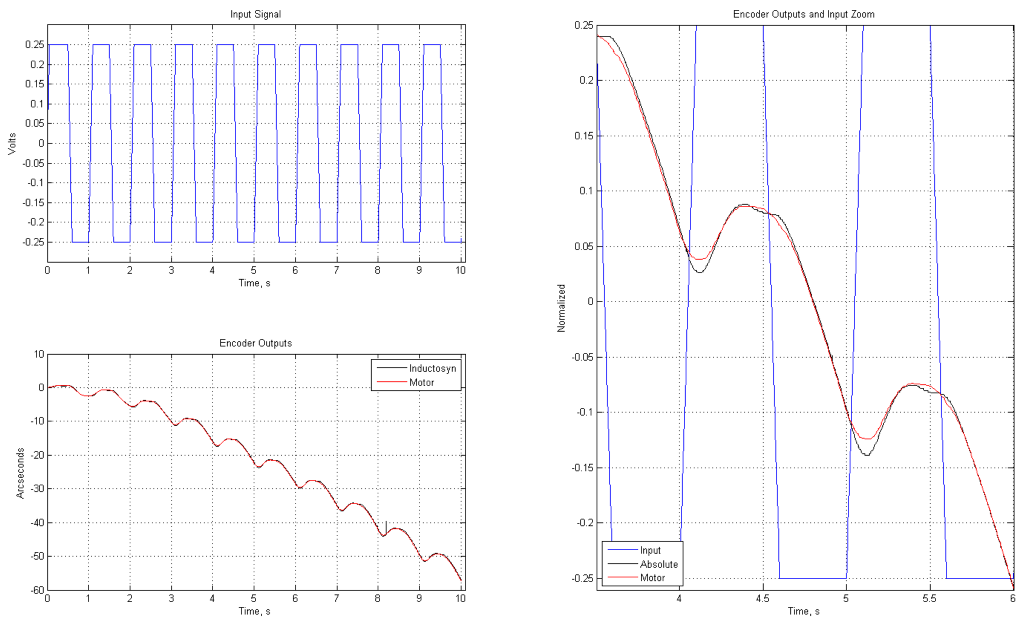

Figure 2. Larger azimuth step responses

In the above figure, we see that the telescope walked off in the same direction, with the addition that motion never really ceased. The encoder outputs are considerably smoother. It’s interesting to note a “dip” in the crests of the absolute encoder outputs where the motor shaft encoder no longer agrees with the absolute encoder. This is yet another example of windup in the gearboxes. It’s small, but significant when the sign of the position command changes (for example in guider or offset commands).

Conclusion

The telescope exhibits a significant amount of velocity damping when driven with squarewaves. This is not surprising given the large inertia of the azimuth axis, coupled with the friction reported earlier. Lost motion in the gearboxes is only of concern when using the motor feedback, and since the current servo design envisions using load feedback only, this is not a terribly important issue. I would like to understand the side-to-side torque offset in the drive system a little better, and am thinking about how to go about finding the source (e.g. different motor torque constants, utility maypole windup, etc.). However the data shown in this report reveal no great surprises, and so we may continue with development of the system models.