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Performance Comparison of the LQG and PI Controllers in Wind Gusts

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The servo errors in wind gusts drop by a factor of 6.5 when the proportional and integral controller is replaced by the linear-quadratic-Gaussian controller.

The linear-quadratic-Gaussian (LQG) controllers replaced the proportional and integral (PI) controllers at the 34-meter and 70-meter Deep Space Network (DSN) antennas. Analysis showed significant improvement in pointing accuracy in wind gusts. However, there was no evidence from field measurements of how much improvement actually was achieved.

In order to show the improvement, on February 9, 2007, measurements of the servo errors were taken at the 34-meter beam-waveguide (BWG) antenna (DSS 55) at the NASA Madrid Deep Space Communication Complex (MDSCC) in Spain. During the measurements, the mean wind speed was 15 to 16 km/h. The measurements were taken with the PI coefficients and with the LQG coefficients, one after another, so that similar wind conditions were observed.

The wind velocity and the elevation servo error are plotted in Fig. 1. The wind data were obtained from the MDSCC Signal Processing Center 60 (SPC 60) media calibration subsystem for day-of-year 40 (February 9, 2007). The wind data were obtained at a rate of 1 sample per minute, while the servo data were obtained at a rate of 10 samples per second.

The mean wind velocity was 15.0 km/h during the PI test and 16.2 km/h during the LQG test. The measured servo errors were scaled to the wind velocity, 16.09 km/h (10 mph). The scaling factor for the PI measurements was $(16.09/15.0)^2 = 1.152$, and for the LQG measurements it was $(16.09/16.2)^2 = 0.987$. The scaled measured servo errors are plotted in Figs. 2 and 3. They are plotted simultaneously in Fig. 4, for better visualization.

The plots show that the elevation servo errors are significantly larger than the azimuth servo errors, which is typical for the BWG antennas. They also show that the servo errors for the antenna with LQG

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coefficients are significantly smaller than the errors with the PI coefficients (4.9 times smaller in azimuth and 6.5 times smaller in elevation); see Table 1. The mean radial error dropped by a factor of 6.5.

This first performance comparison of the PI and LQG controllers based on field data shows significant improvement in tracking precision, as predicted by the analysis.

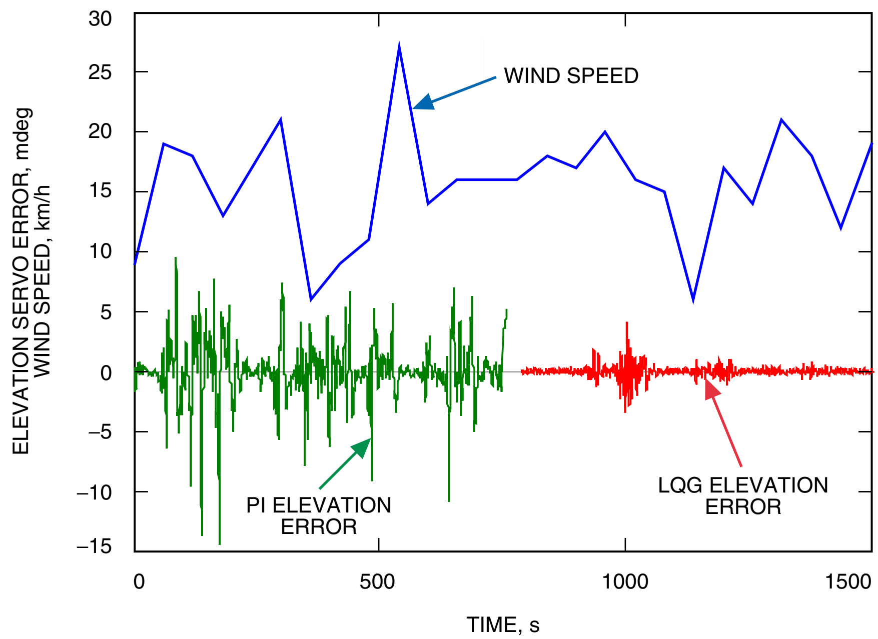

Fig. 1. Wind velocity and the elevation servo error during the test.

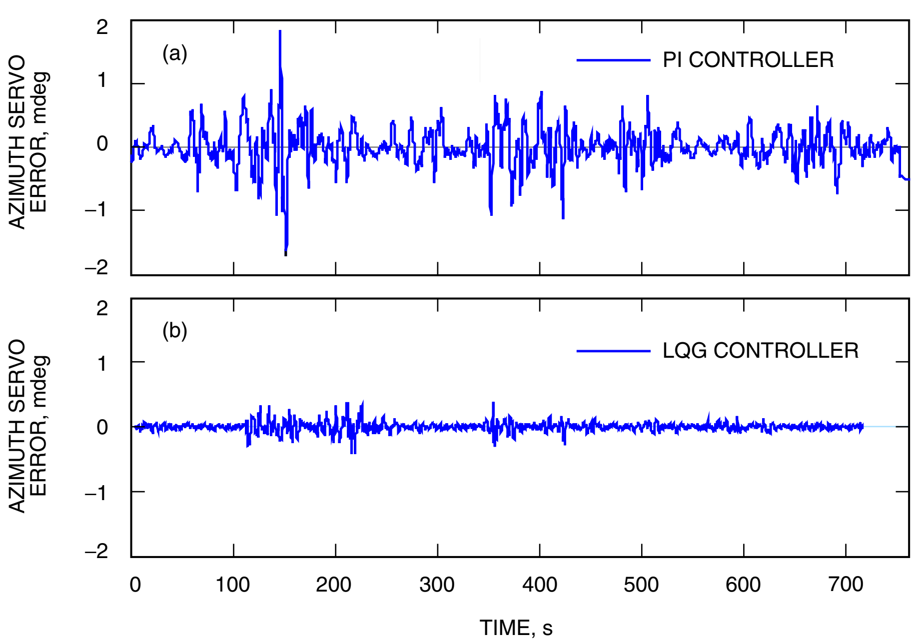

Fig. 2. Azimuth servo errors in 16.1-km/h (10-mph) wind, for the DSS-55 antenna with the (a) PI coefficients and (b) LQG coefficients.

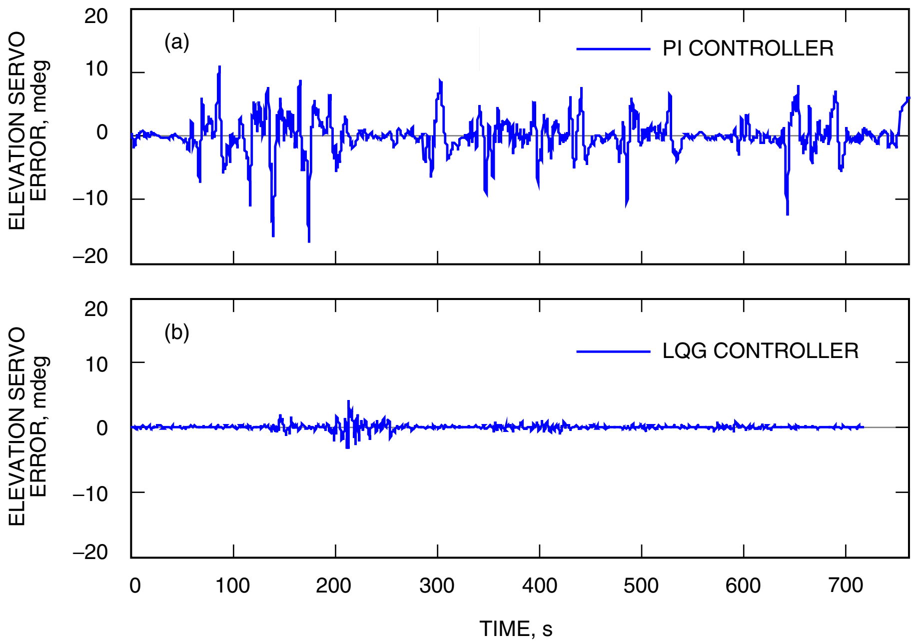

Fig. 3. Elevation servo errors in 16.1-km/h (10-mph) wind, for the DSS-55 antenna with the (a) PI coefficients and (b) LQG coefficients.

Table 1. Servo errors in 16.1 km/h (10 mph) wind for the 34-meter antenna with PI and LQG controllers.

Controller	Azimuth rms[a] error, mdeg	Elevation rms error, mdeg	Mean radial error, mdeg
PI	0.32	2.69	2.71
LQG	0.066	0.42	0.42
Error ratio (PI/LQG)	4.9	6.5	6.5

[a] rms = root-mean-square.

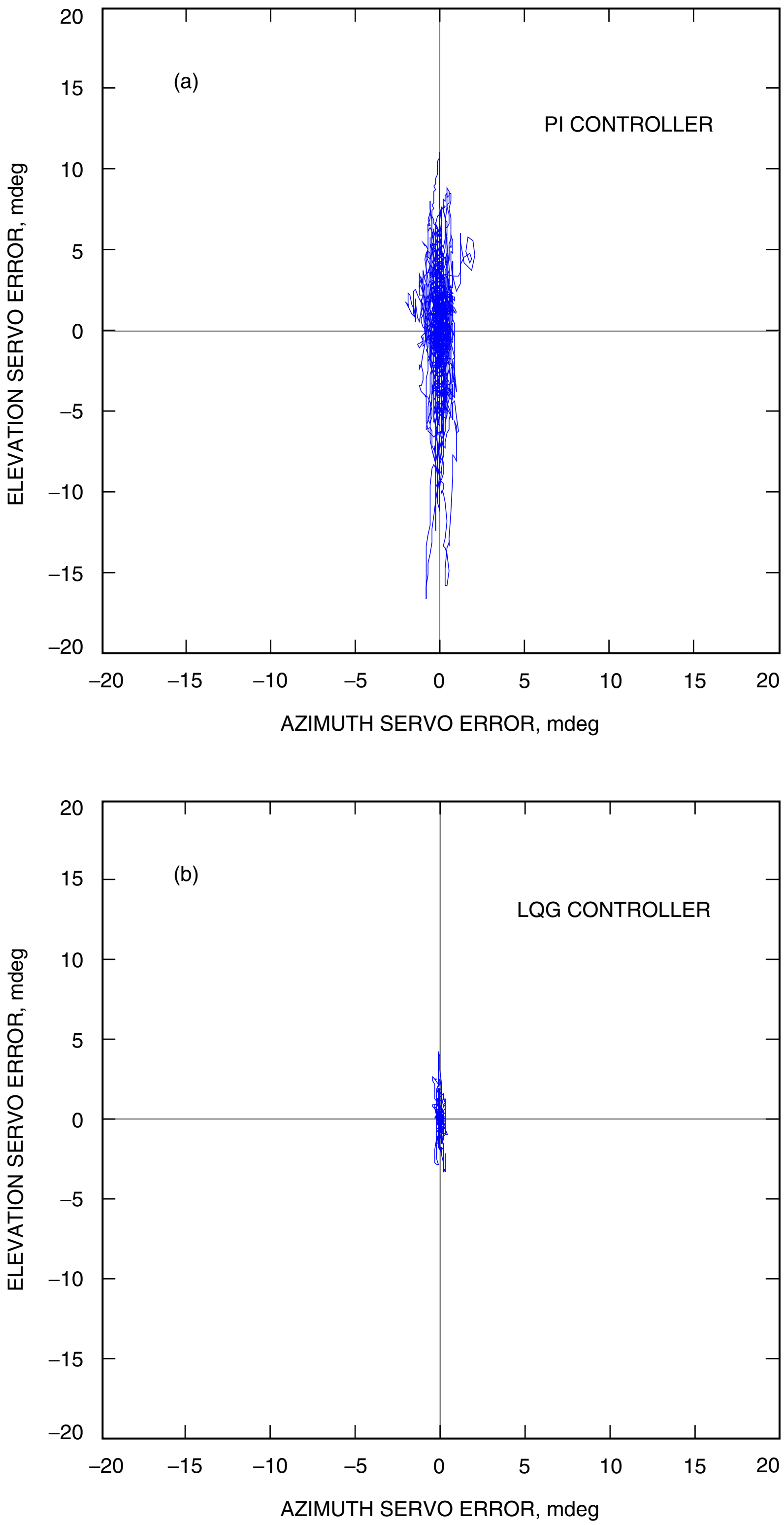

Fig. 4. The servo errors in 16.1-km/h (10-mph) wind, for the DSS-55 antenna with the (a) PI coefficients and (b) LQG coefficients.