Micro-newton Thruster Modulation and Analysis for the LISA Pathfinder

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24 July 2014

Background

- eLISA – space-based gravitational wave observatory
- Free falling bodies and gravitational waves
- Inertial sensor and relative motion
- LISA Pathfinder (LPF) – technology demonstration package

Propulsion system

- Colloid micro-newton thrusters (CMNTs)
- Translation and attitude control
  - Test mass reference
- Configuration and control loop
- Consistency check and error tracking

Thrust modulation

- Thruster modulation frequency assignment
- Frequency-domain signal analysis
- Response amplitudes and directions
- Measurables: thruster calibrations, orientations, time delays
  - Location of space craft's center of mass?

“Raw” data

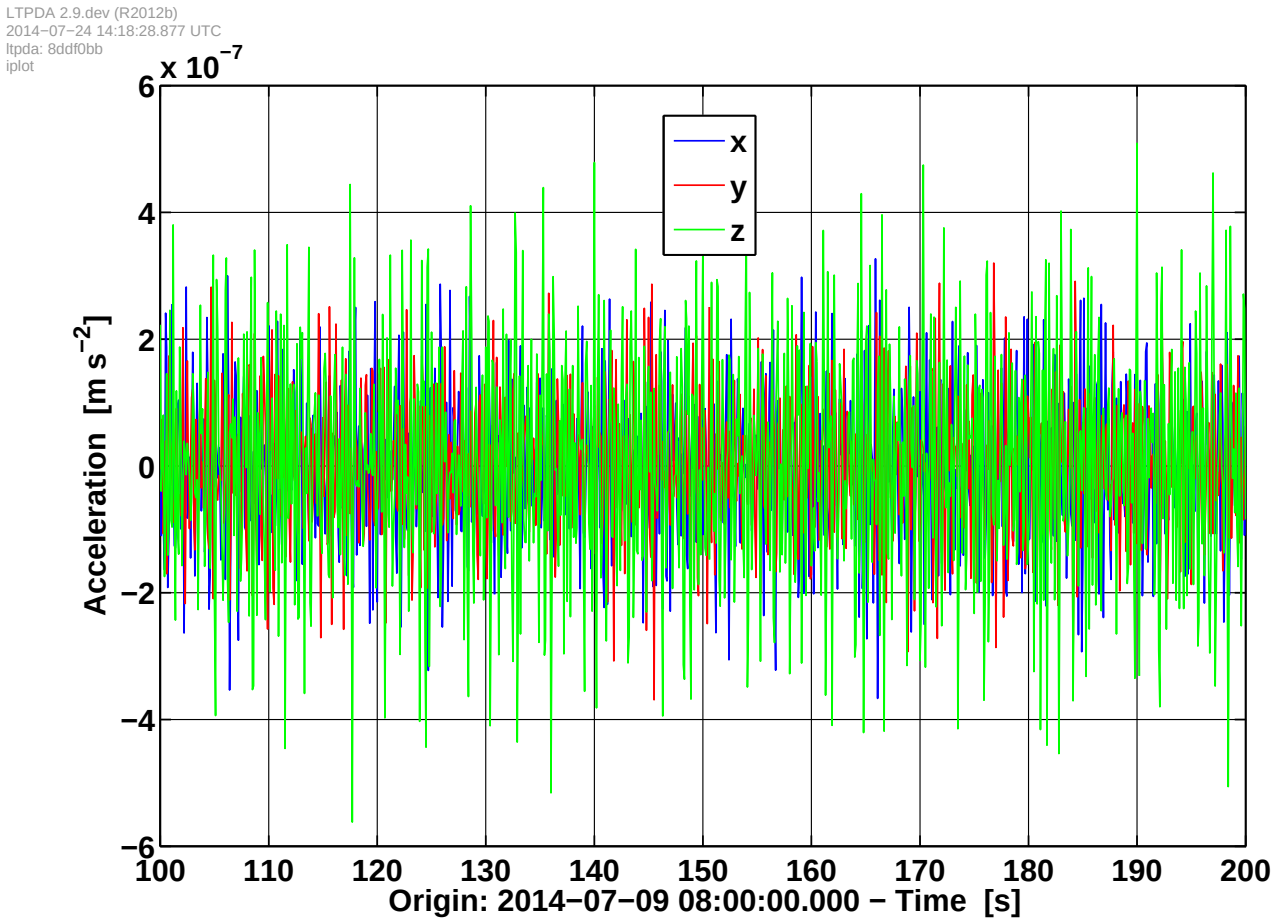

Figure 1: Linear accelerations of test mass 1 relative to space craft

“Raw” data (frequency domain)

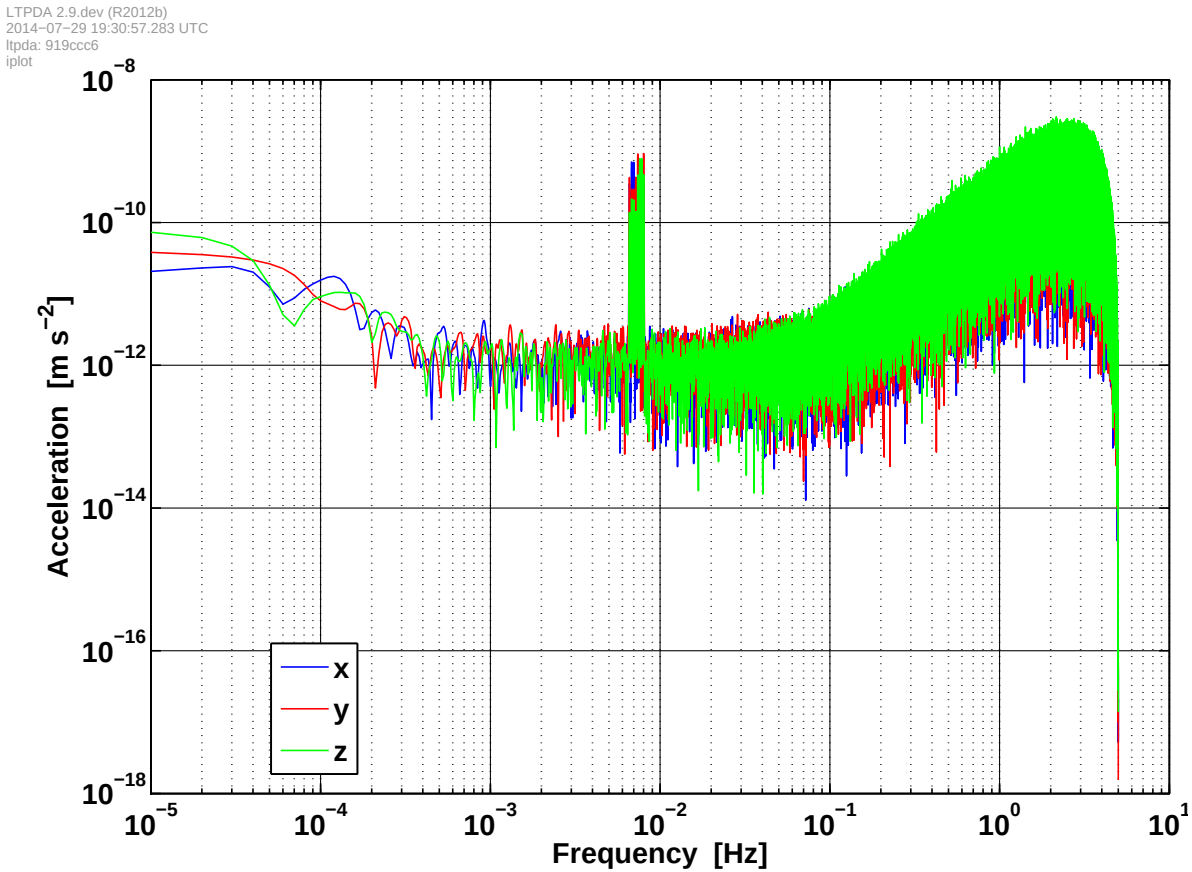

Figure 2: Frequency-domain linear accelerations of test mass 1 relative to space craft

“Raw” data (frequency domain)

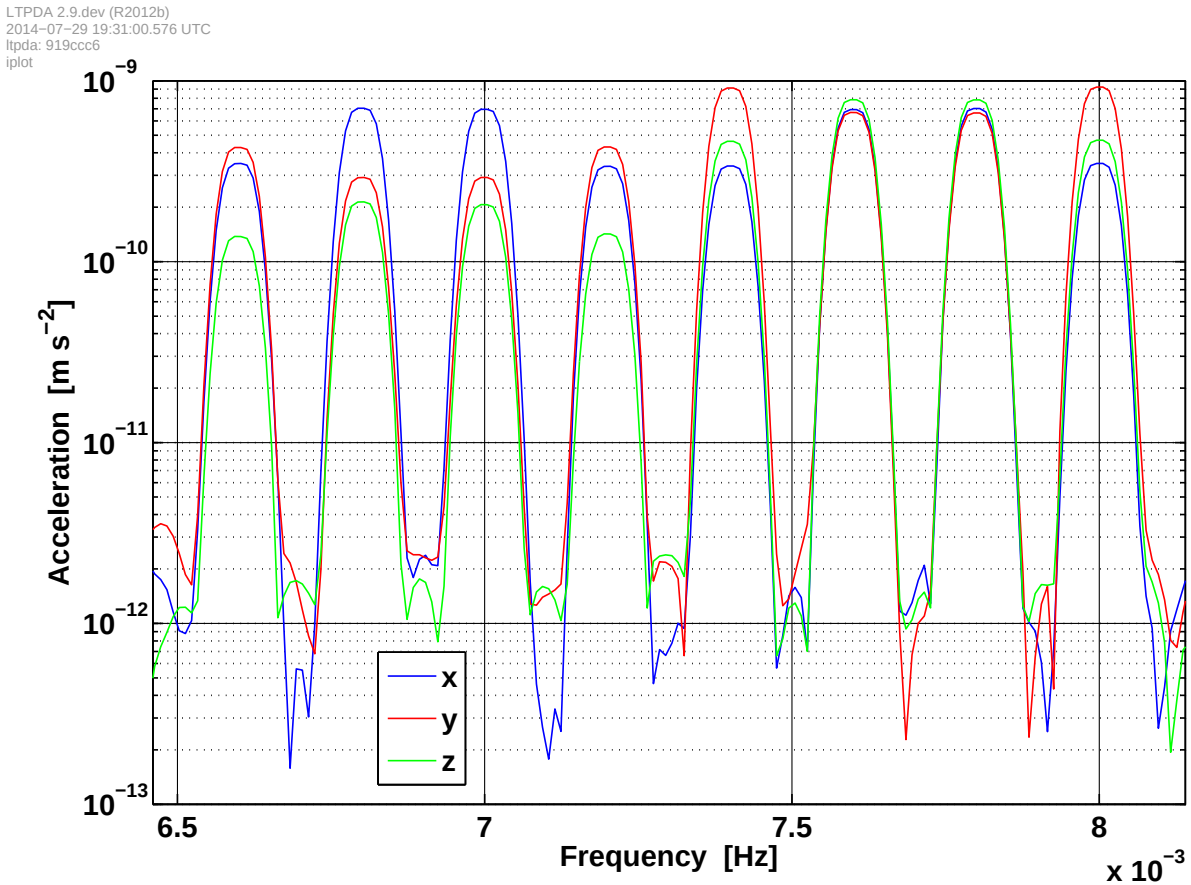

Figure 3: Frequency-domain linear accelerations of test mass 1 relative to space craft (zoomed in)

Signal filtering

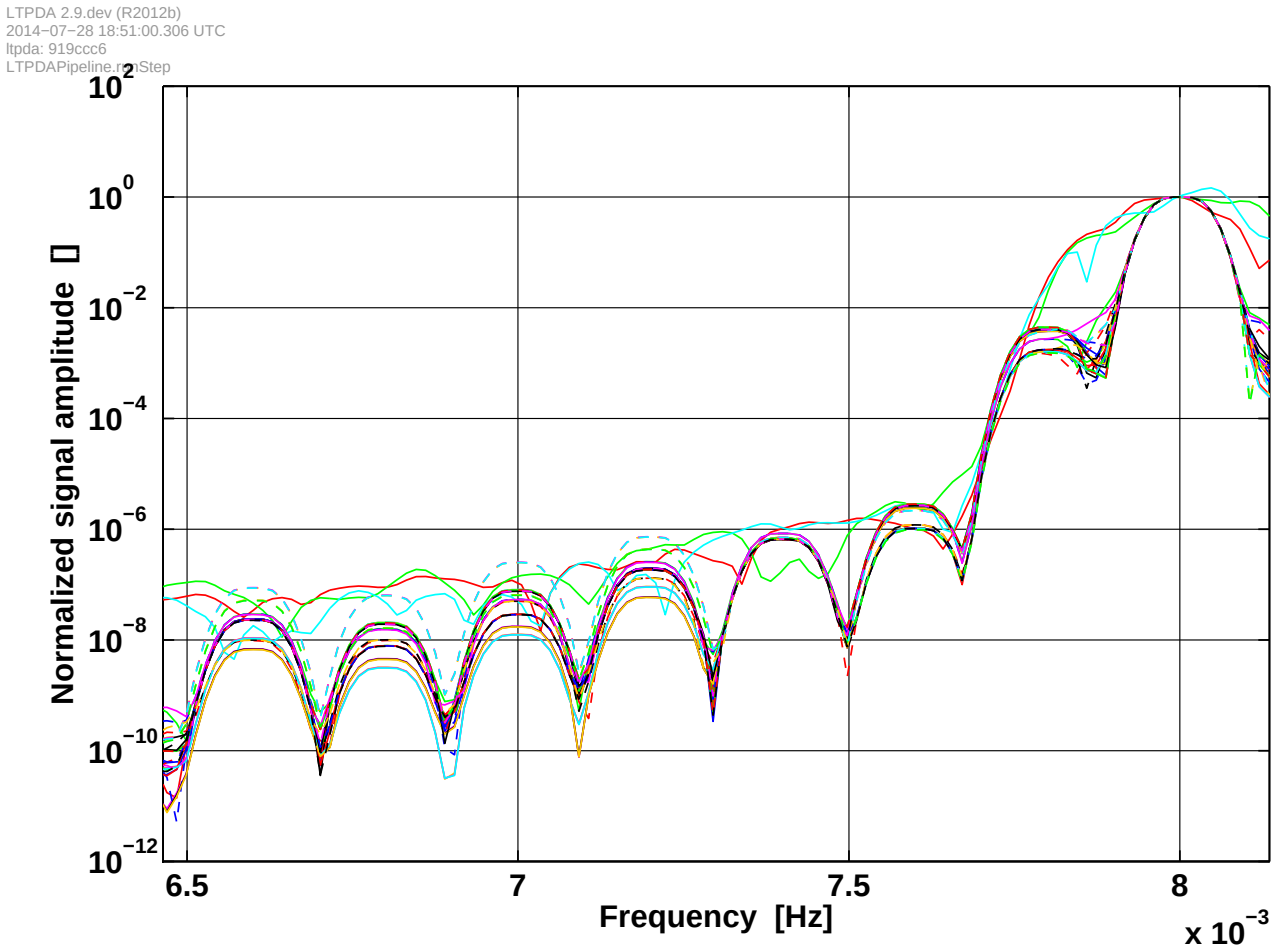

Figure 4: Data streams filtered at modulation frequency of thruster 1

Signal filtering

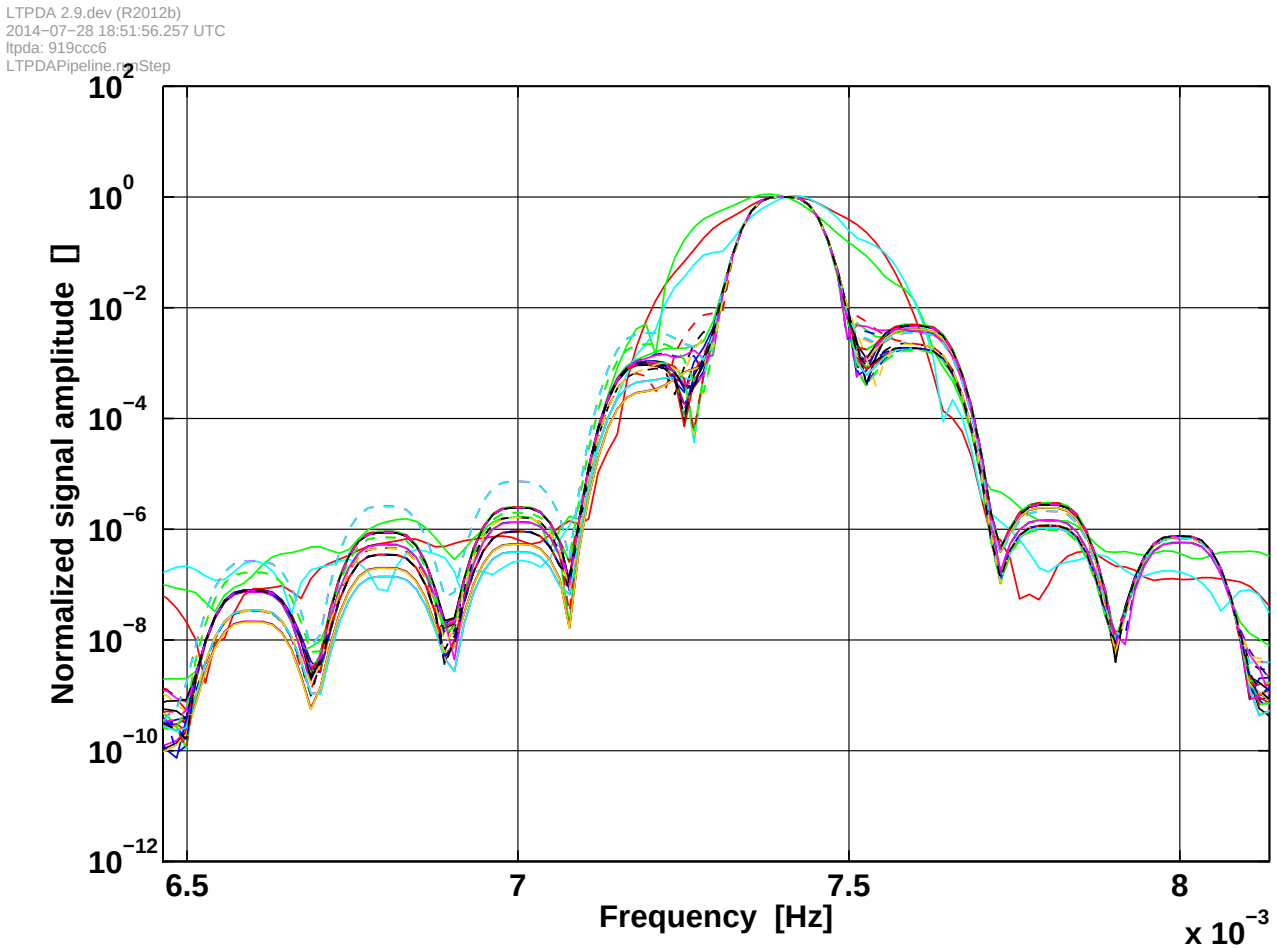

Figure 5: Data streams filtered at modulation frequency of thruster 4

Signal filtering

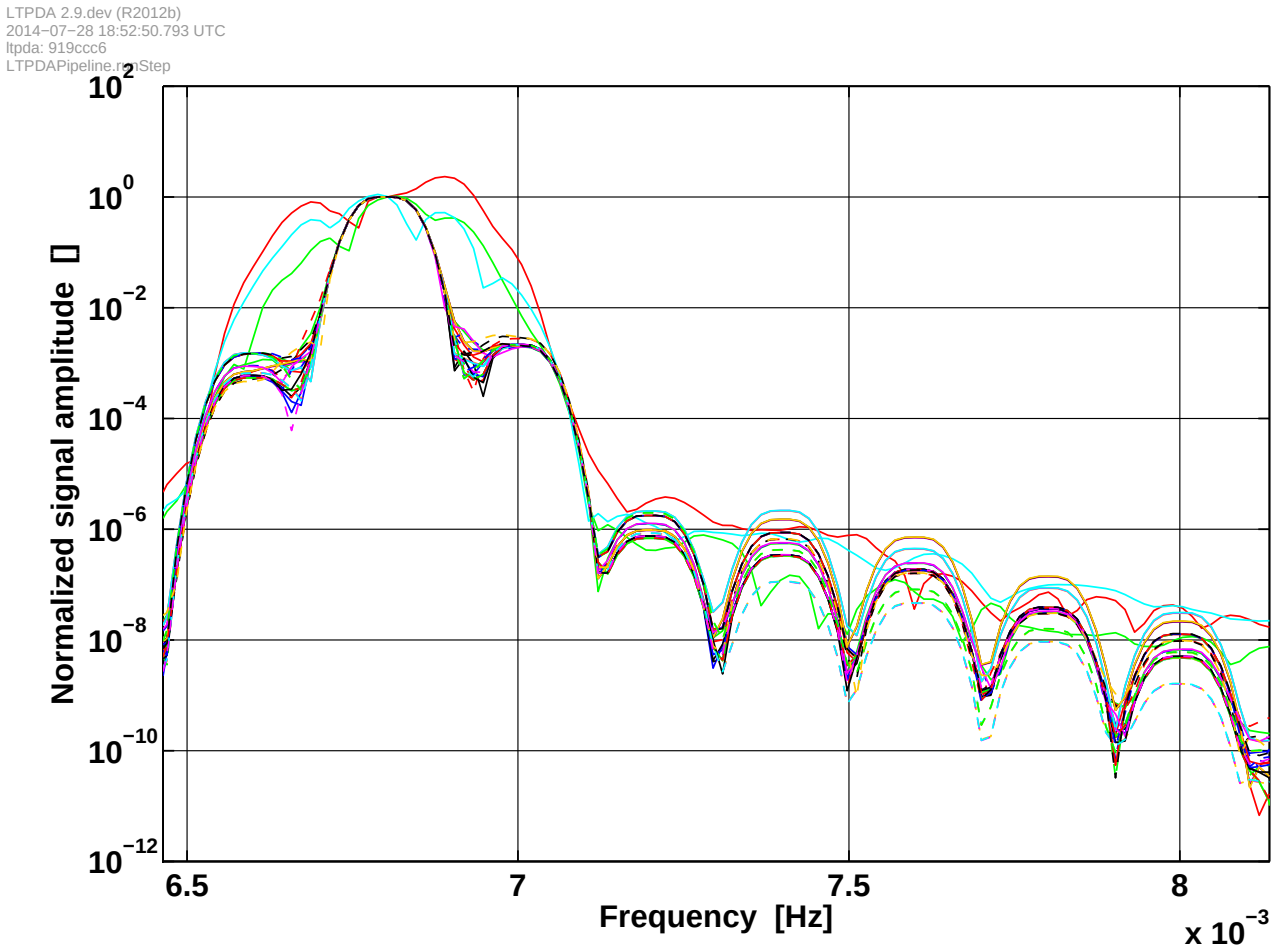

Figure 6: Data streams filtered at modulation frequency of thruster 7

Data analysis

- Principal component analysis (PCA)
  - Time-independent linear and angular acceleration vectors
- Covariance matrix
  - Eigenvectors and eigenvalues

$$C_{ij} = \langle (x_i - \langle x_i \rangle)(x_j - \langle x_j \rangle) \rangle$$

- Model (in)dependence

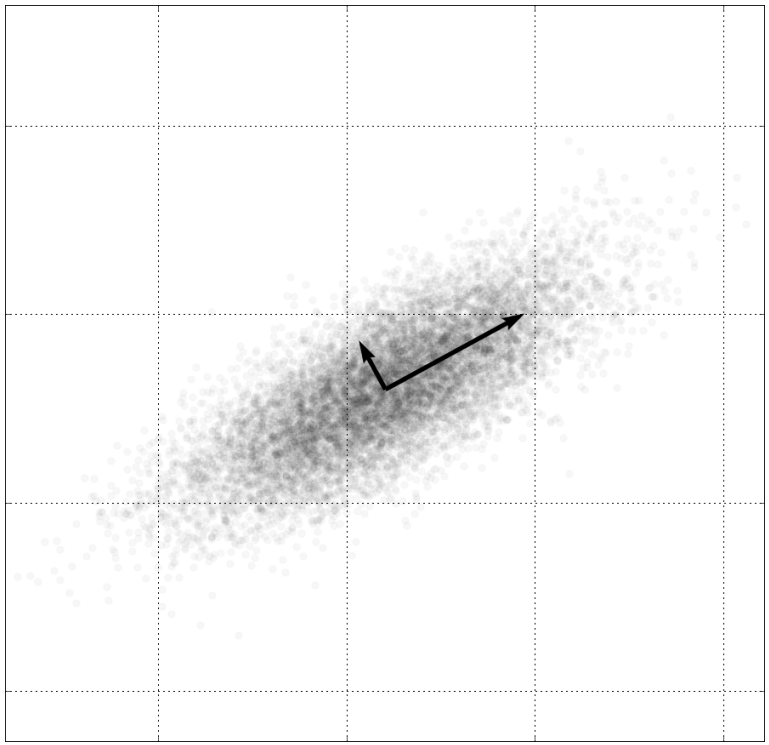

Figure 7: PCA sketch

Data analysis

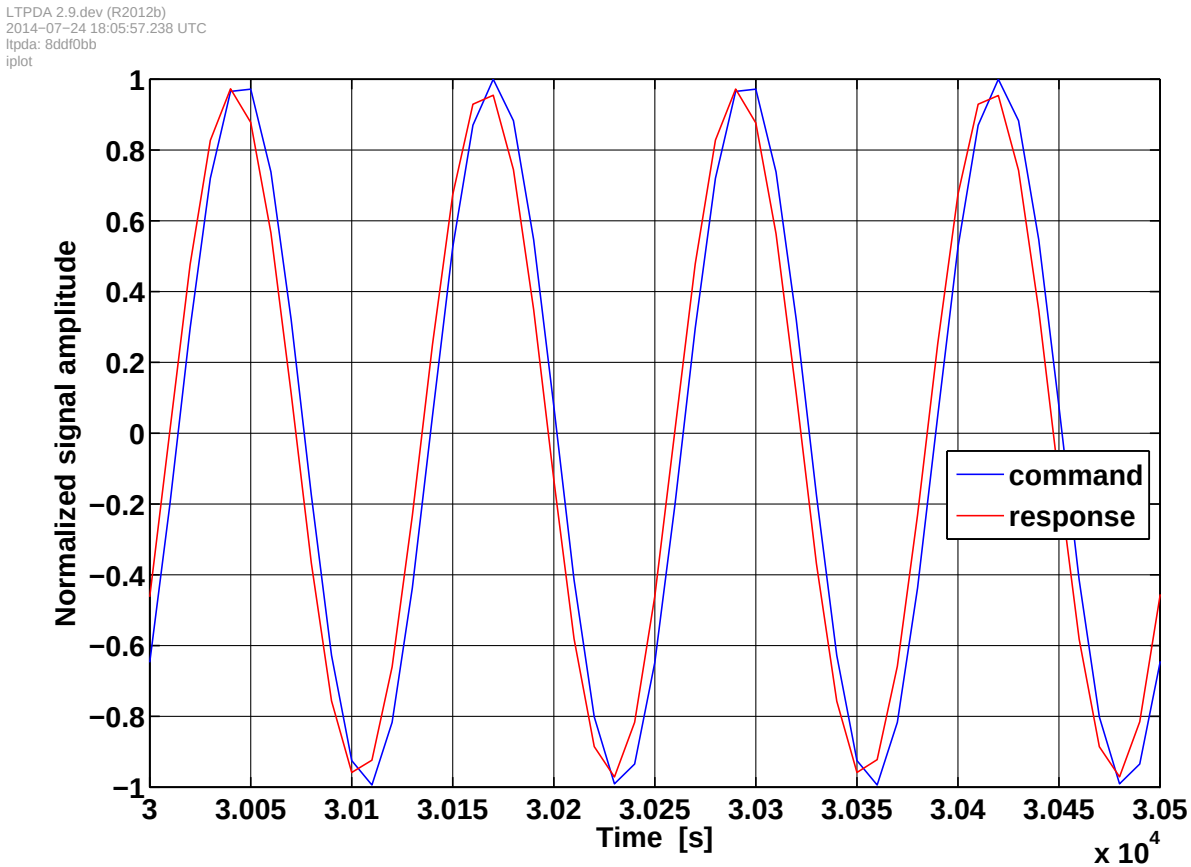

Figure 8: Normalized modulation commanded to thruster 1 and angular acceleration of test mass 1 about x-axis.

Confidence intervals

- Spacecraft sub-system model
- "Residual" signals
- Variation of thruster parameters
- Noise-weighted inner product

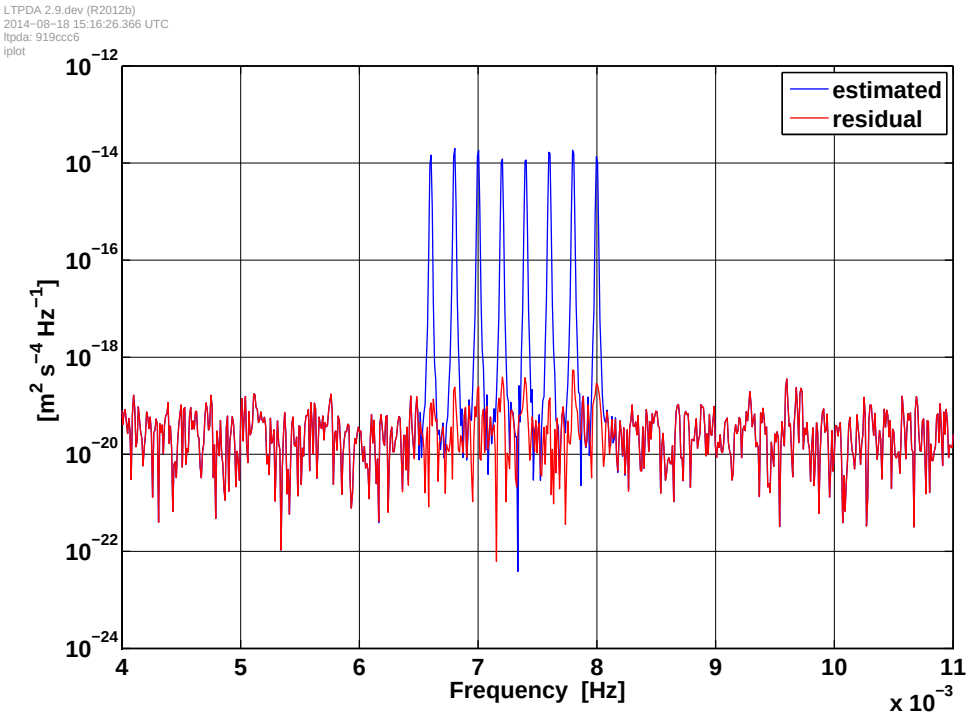

Figure 9: Linear acceleration accelerations of test mass 1

Future efforts

- Testing various space craft models
- Porting code to LTPDA infrastructure
- Alternate characterization methods

Thank you