Advanced motion control for high-precision motion systems

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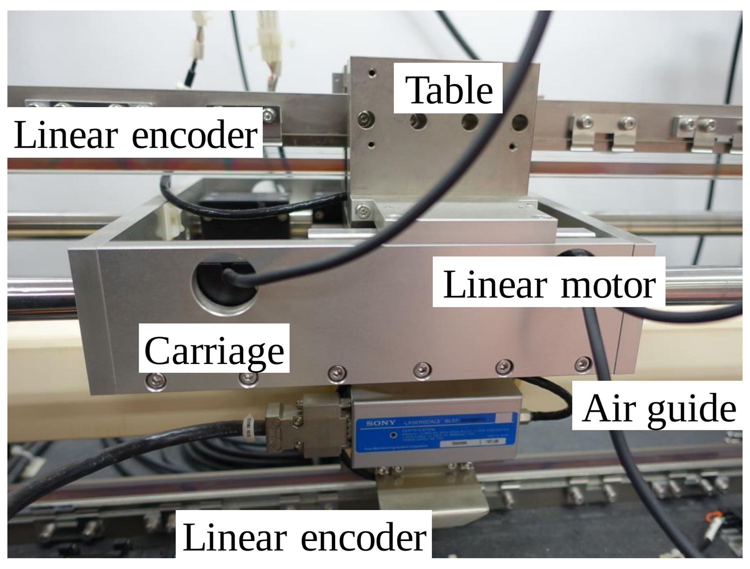
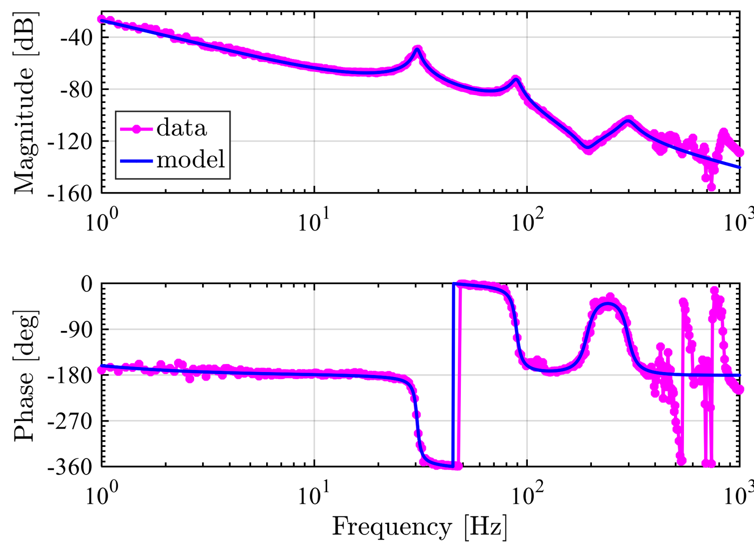
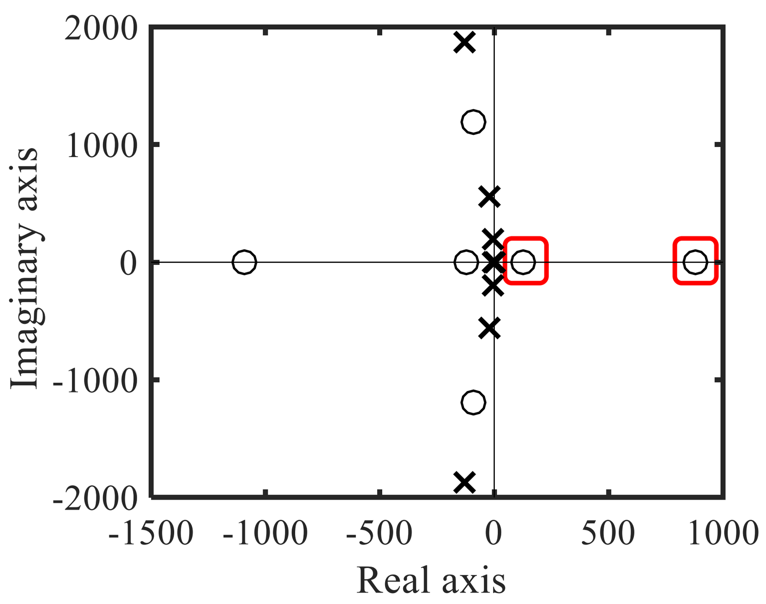
Preactuation perfect tracking control for system with unstable zeros



(a) High-precision stage

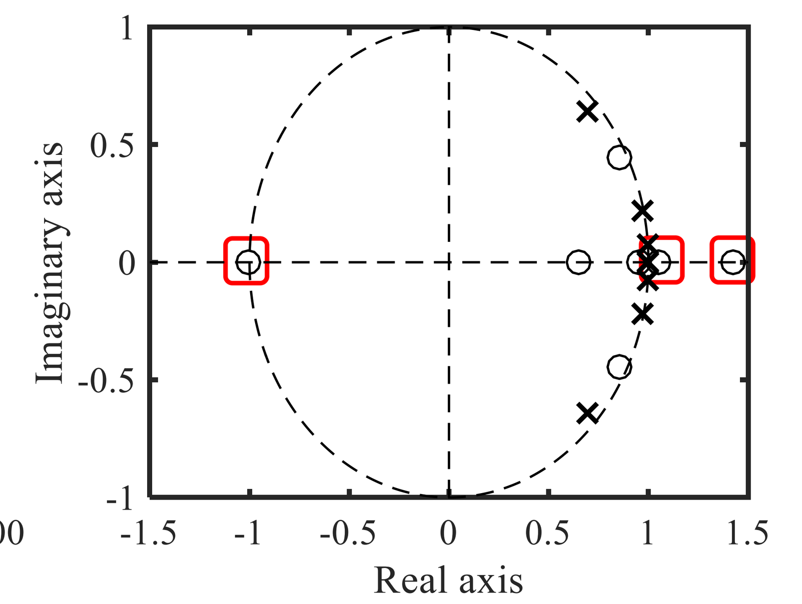


(b) FRF and 8th order model



(c) Continuous pz-map

Unstable zero × 2



(d) Discrete pz-map

Unstable intrinsic zero × 2

Unstable discretization zero × 1

Modeling results using frequency domain identification

Unstable zeros problem

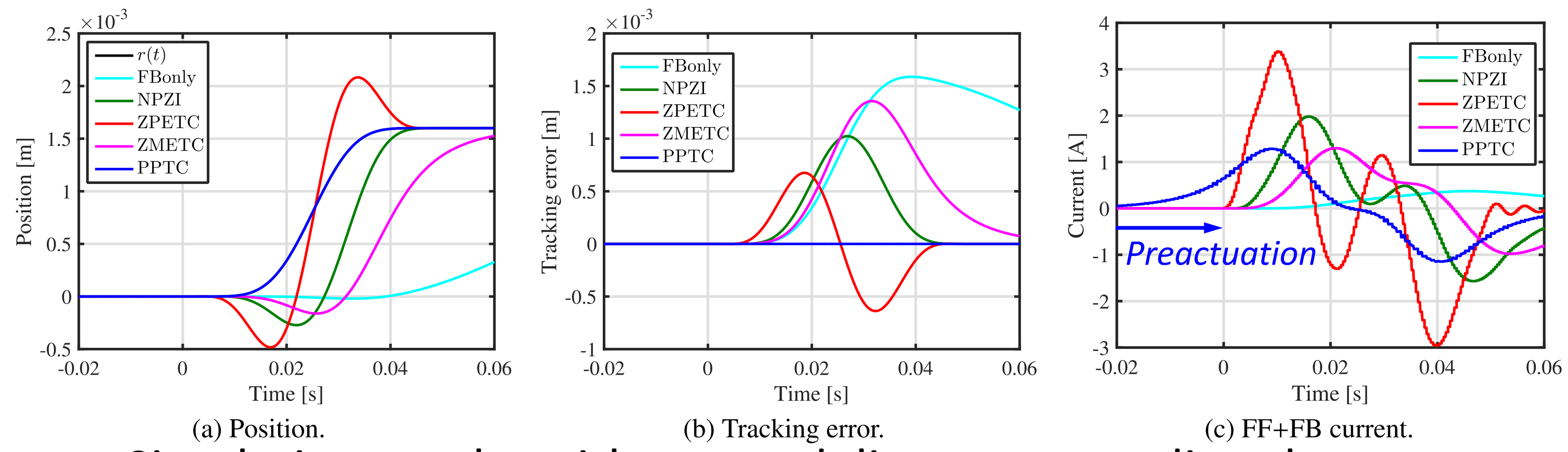
- Unstable poles in inversion system
- Undershoot in step response

Example: High-precision stage, boost converter, airplane…

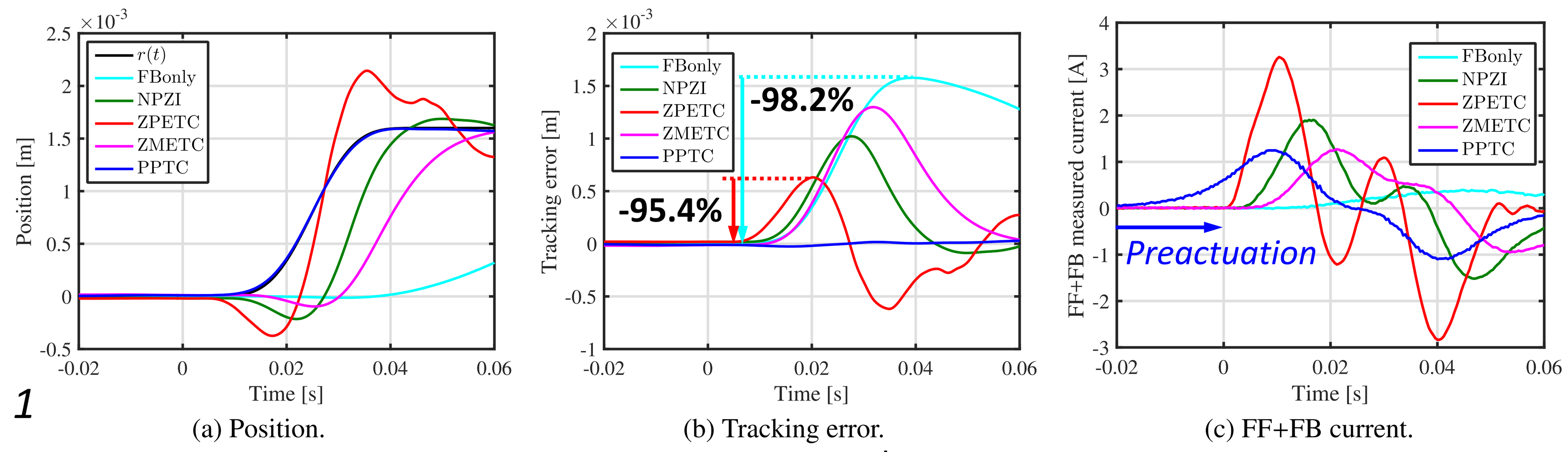
Solution

Stable inversion by

- Time axis reversal & Imaginary axis flipping
- Multirate feedforward



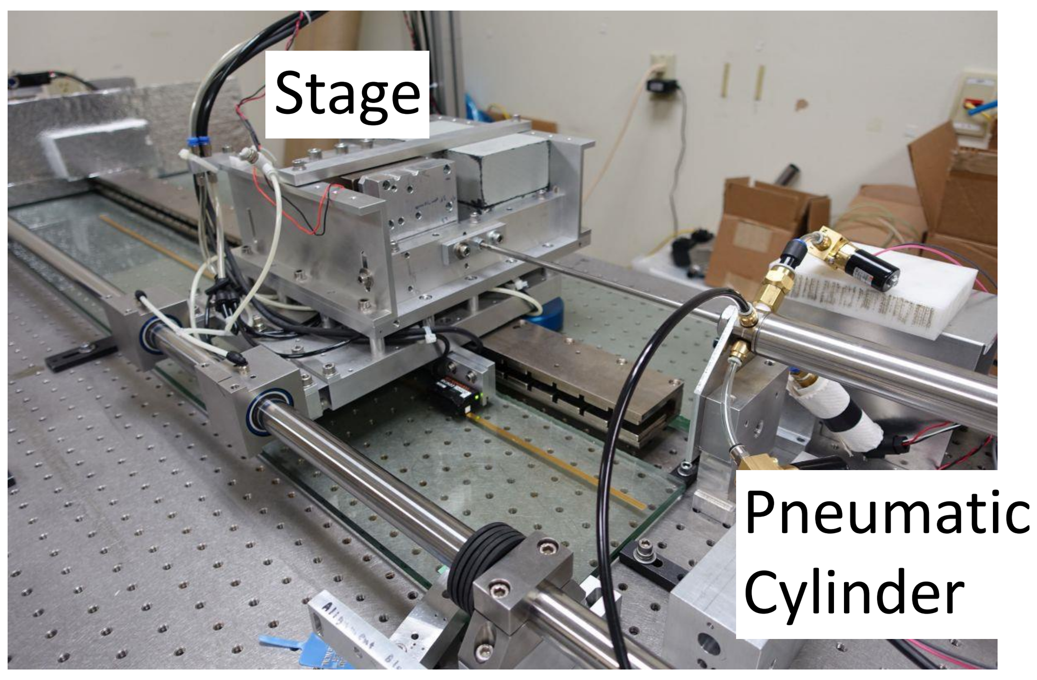
Simulation results without modeling errors or disturbances



Experimental results using 8th order feedforward

[W. Ohnishi, T. Beauduin, and H. Fujimoto, *IEEE/ASME Trans. Mechatronics*, 2019.]

High-precision motion control by pneumatically actuated stage



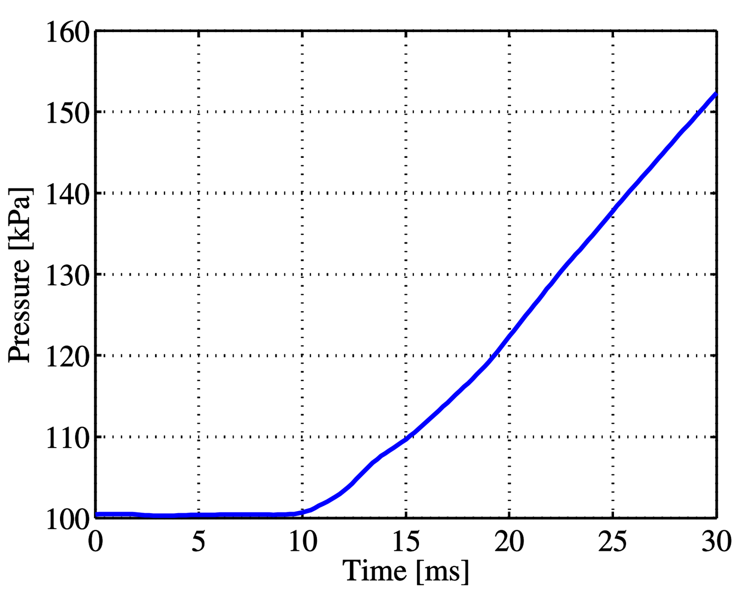
Pneumatic actuation

<u>Advantages</u>

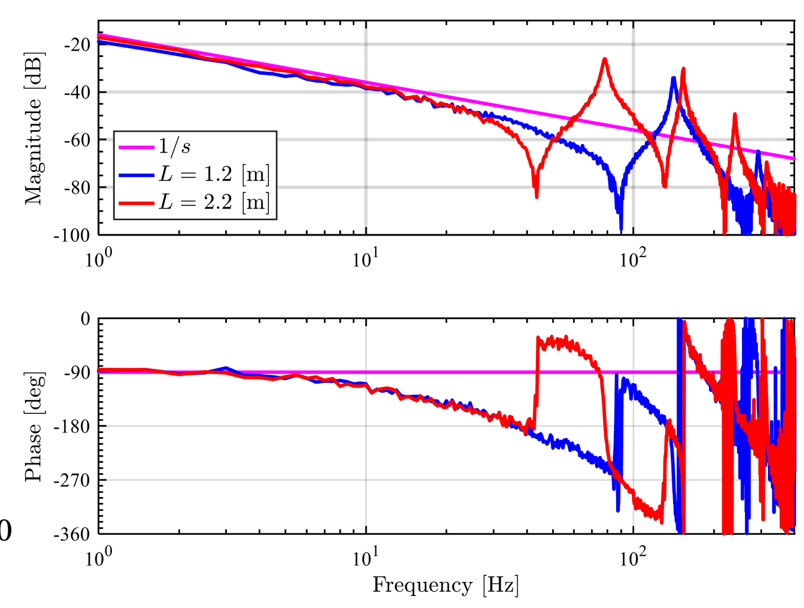
- High power to weight ratio
- Low heat generation
- Low cost

<u>Disadvantages</u>

- Time delay
- Position-dependent resonances
- Valve & air dynamics nonlinearity



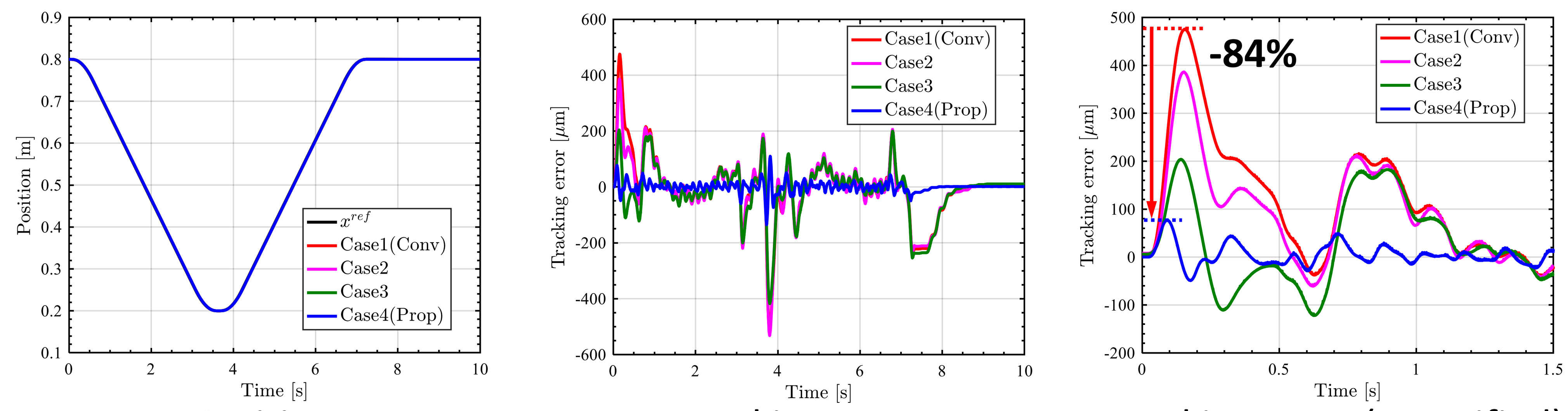
Time delay



Position dependent resonances

[W. Ohnishi et al., *IEEJ J. Ind. Appl.*, 2018]

Time delay compensation by modified Smith predictor



Position | Tracking error | Tracking error (magnified)

Pressure FB bandwidth

Conv : 9.4 Hz (Gm:13dB, Pm 35deg)

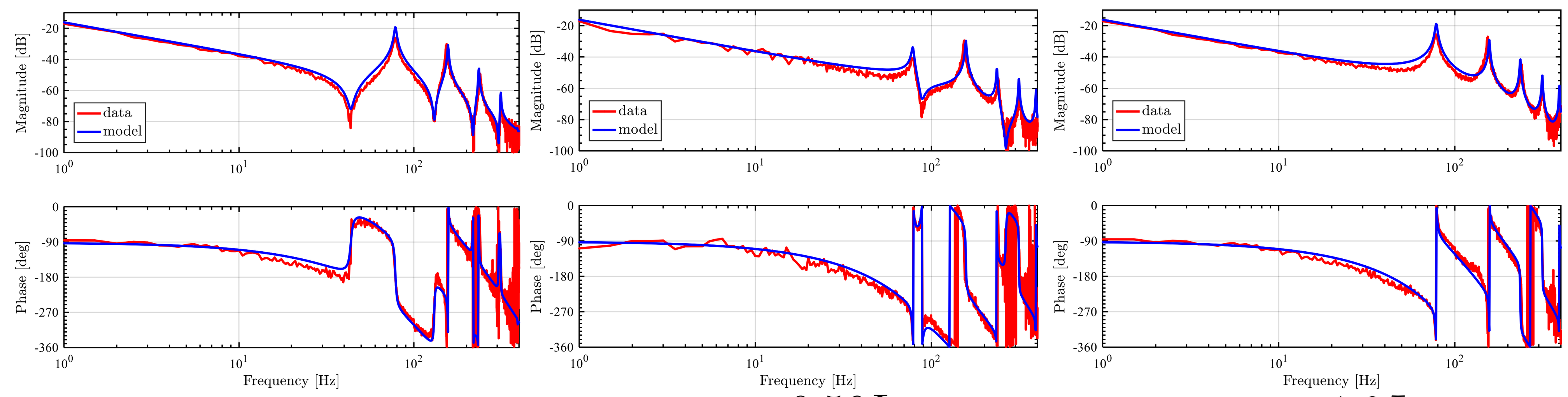
Prop : **31Hz** (Gm:6.4dB, Pm:35deg)

Position FB bandwidth

Conv : 5.3 Hz (Gm:7dB, Pm 22deg)

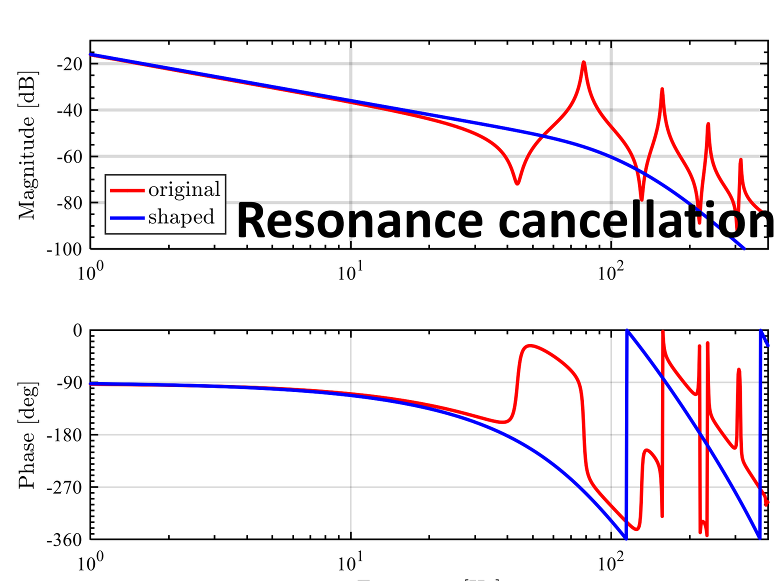
Prop : **11Hz** (Gm:9.6dB, Pm:26deg)

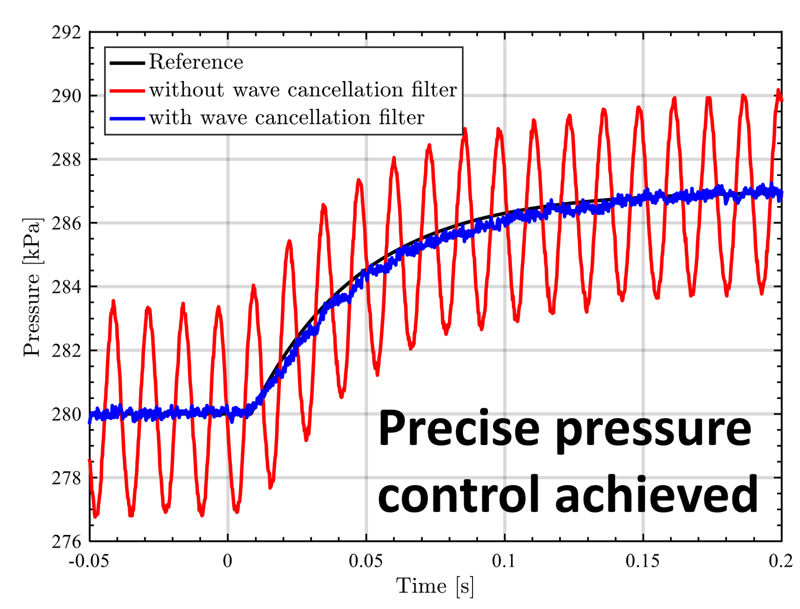
Acoustic wave equation based modeling and vibration cancellation



$x = 0.10L$ $x = 0.56L$ $x = 1.0L$

Precise modeling by damping considered wave equation





Resonance cancellation by wave equation based SINGLE filter