TOGAC11_MSD_R_AdmitConFeedbackandForwardVsFeedback.docx

This report reviews the work done to recreate the control scheme seen in the paper Towards Collaborative Drilling with a Cobot Using Admittance Controller and Stienen et al. (2018). The same values from the paper are used to recreate the basic structure of a feedback controller. Than the same feedforward design from the paper is used and the effects the this change is observed in bode plots. Then we changed the admittance mass and damping values of the controller to see the effects of the bode plots for the observed admittance Ya.

Contents

1. Controller initial parameters and transfer functions

See TOGAC15_MSD_ArvidAdmitConDesign.m

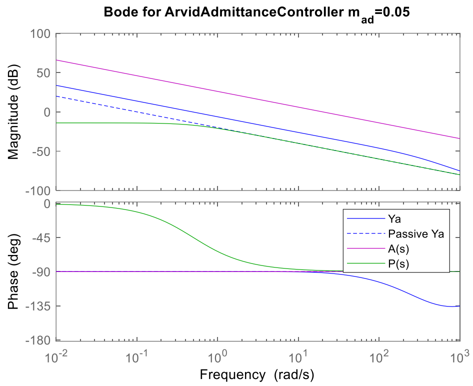
```
% Controller parameters. mass, gains, stiffness, damping coefficients,
% controller values for PID
mv = 2;
kr = 1;
mr = 10;
mps = 2;
br = 5;
kp = 100;
ki = 2000;

% Transfer function formulations
s = tf('s');
Yv = tf([1],[mv 0]); % Admittance controller tf
Yr = tf([1],[mr br]); % dynamics tf
Zps = tf([mps 0],[1]); % Impedance from robot inertia
C = kr*tf([kp ki],[1 0]); % Controller tf
Yabar = (Yr*(1 + C*Yv*kr))/(Yr*(Zps + C*(kr + Yv*Zps*kr)) + 1); % Closed loop tf from Fext to V
Yapi = tf([1],[mr 0]);
```

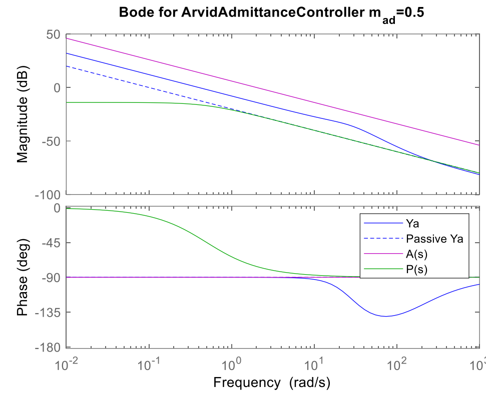
2. Transparency and Admittance Observations from bode Plots

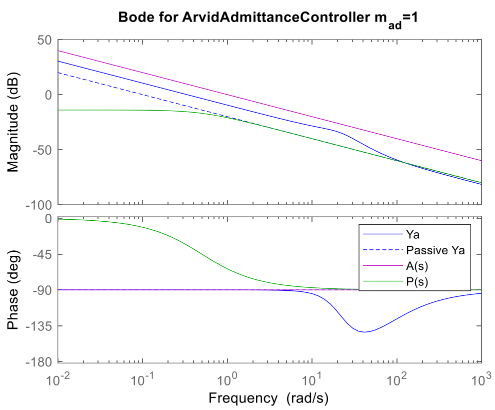
Below is the response from the controllers with difference admittance mass values. The closer Ya gets to P(s) the less transparency is observed by the user. If Ya is not bounded by A(s) or P(s) the admittance controller behaves very poorly. Observe the phase and gain margin of the systems as well to see how the stability is affected. A cost map is included to show the relative transparency of a given m_ad and b_ad value for the system. The bluer the more transparent the system feels. The feedforward system shows that the system is slightly more perceivably transparent than strictly feedback.

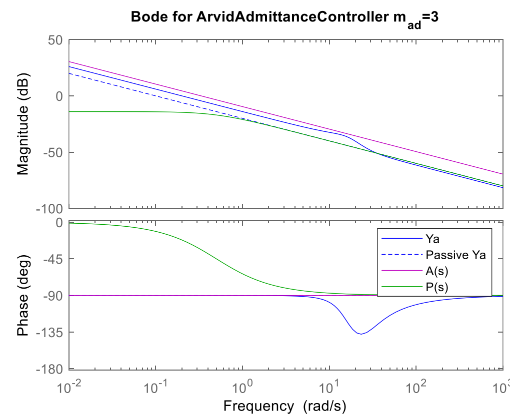
Ya: the apparent admittance
Passive Ya: admittance of passive system
A(s): the imposed admittance by admittance controller
P(s): The plant dynamics

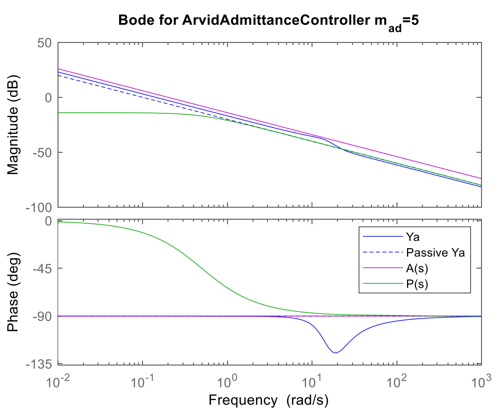
1. Baseline Feedback Controller

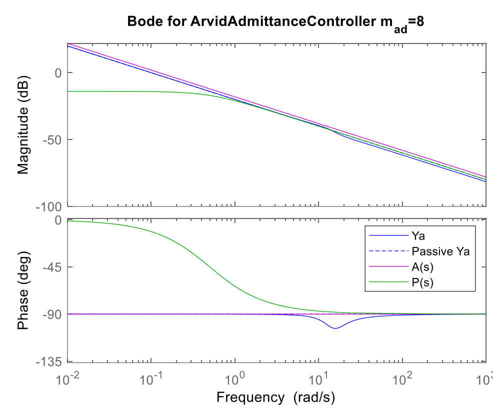


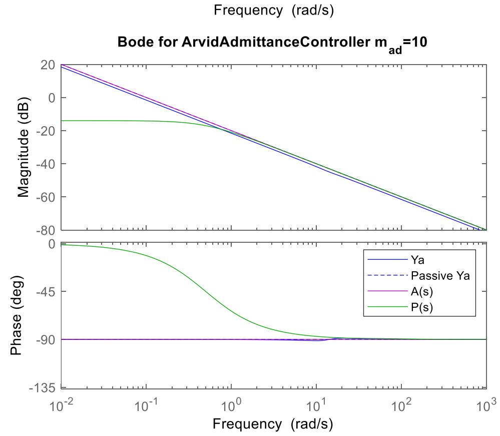


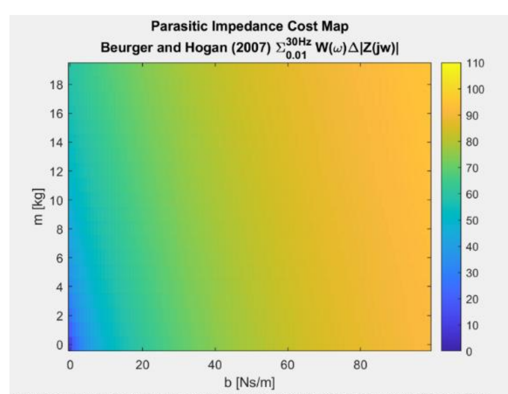




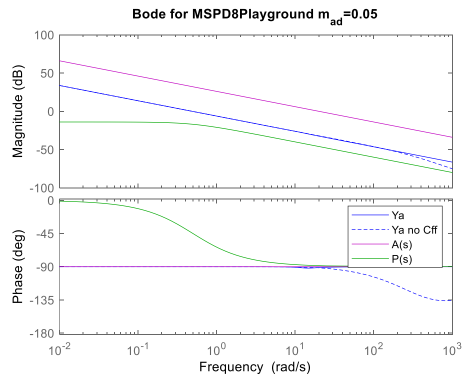


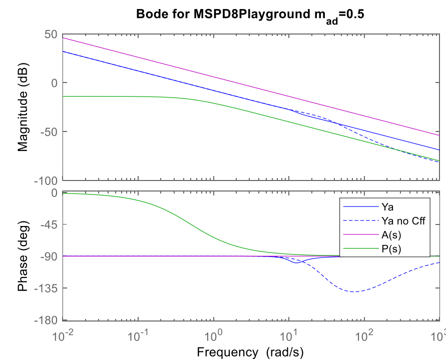


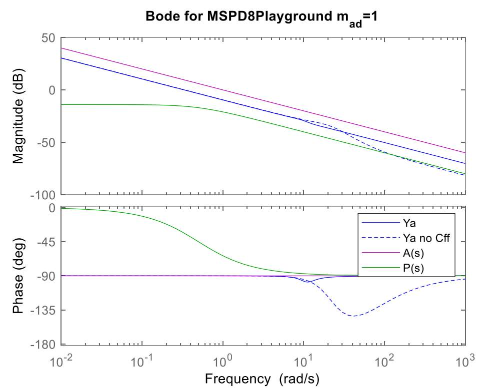


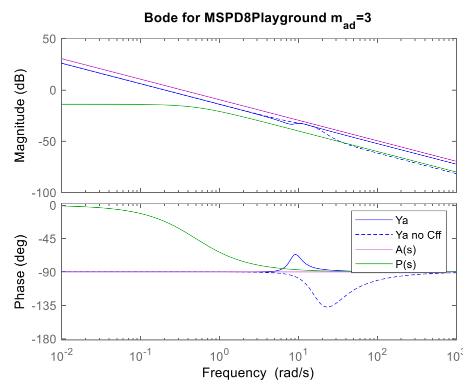


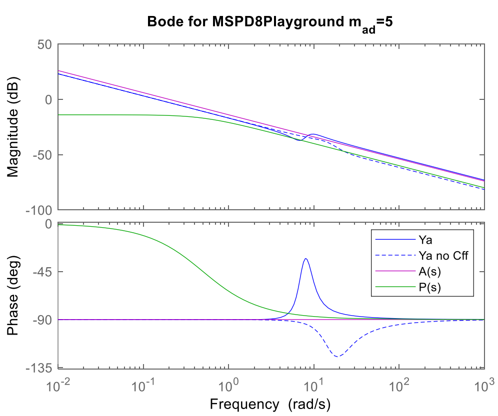
2. Feedforward and Feedback Controller

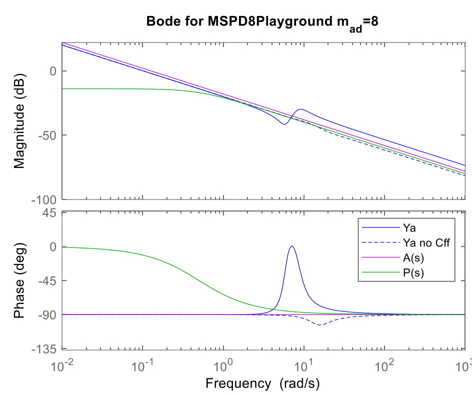


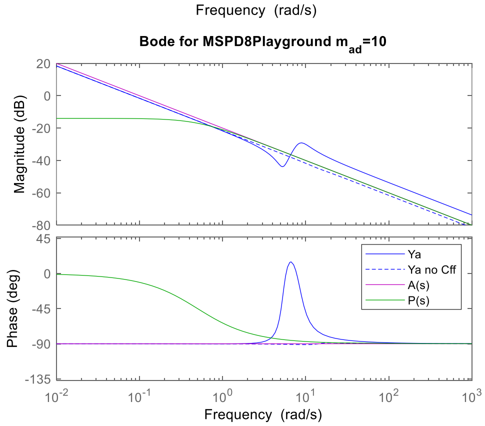


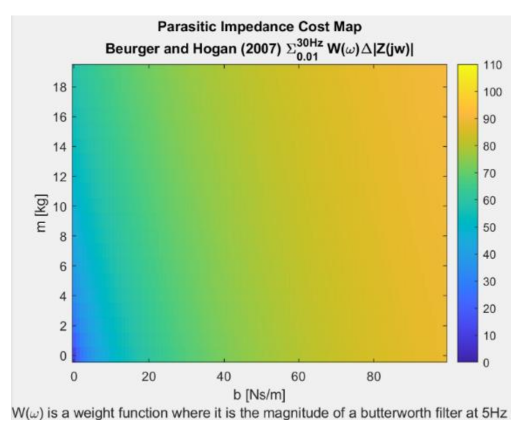




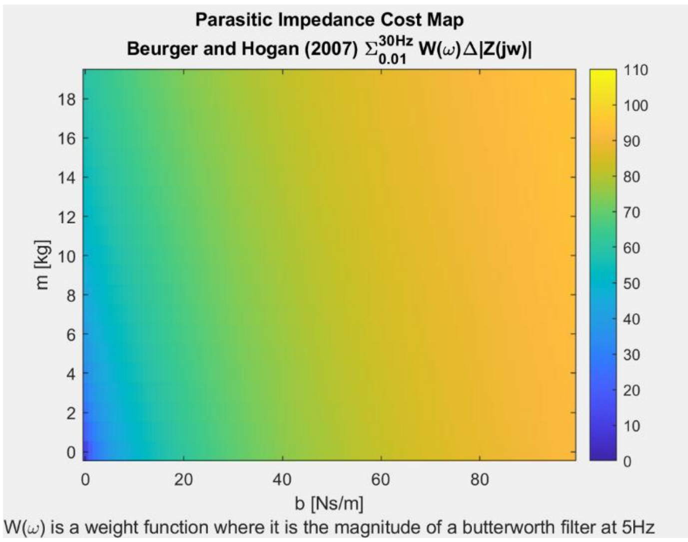


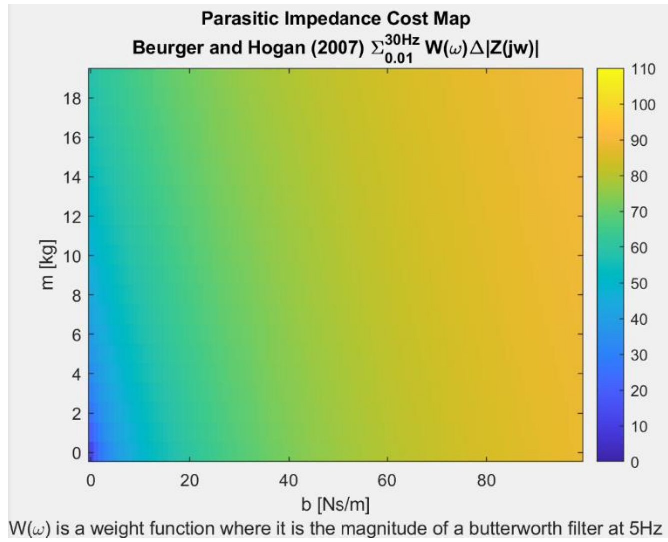


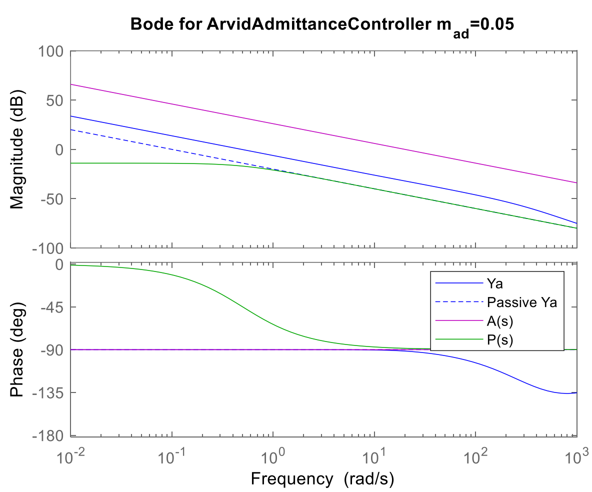


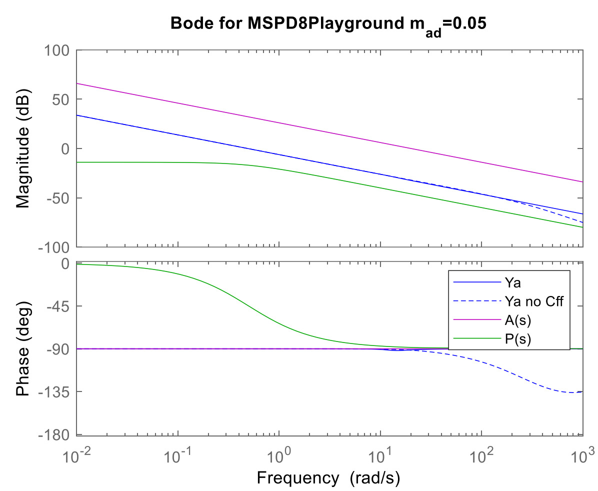


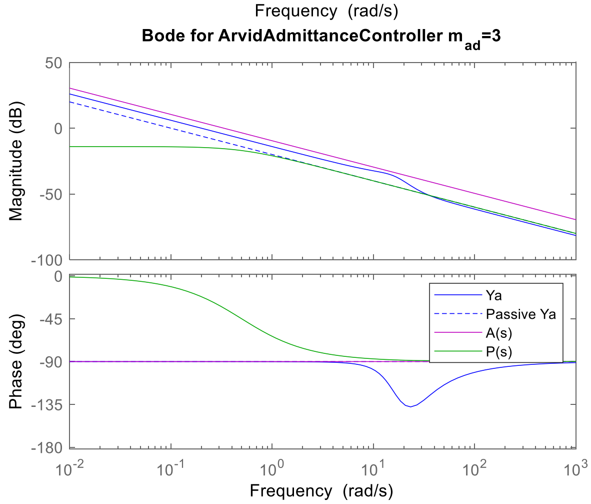
3. Feedback on the left. Feedforward on the right

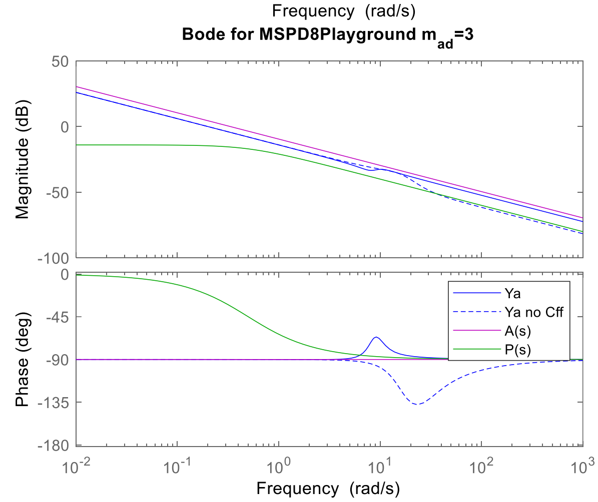


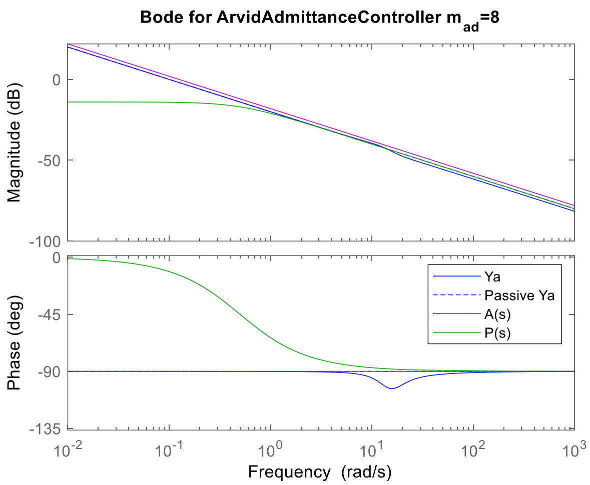


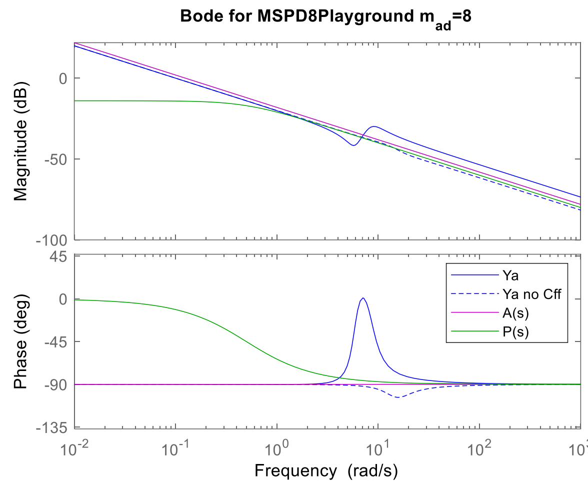












3. Methods to improve transparency from Stienen et al.

The Stienen et al (2018) paper outlines many ways to improve the response of the admittance controller to help it feel more stable. Observe the methods and control boxes below. See the paper for more details.

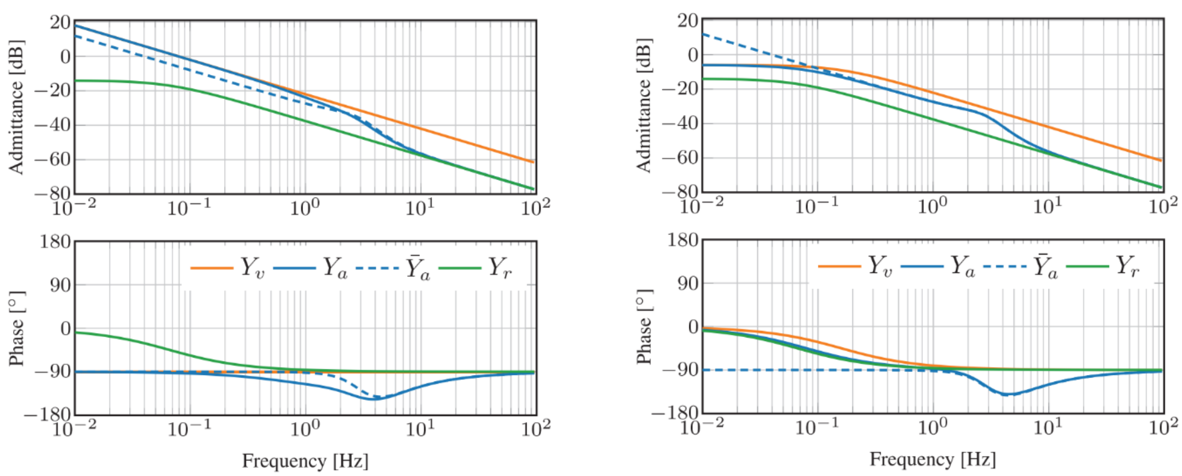


Figure 1 Left: Post Sensor Compensation. Right: Virtual Damping Influence

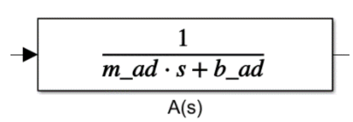
Keemink AQ, van der Kooij H, Stienen AH. Admittance control for physical human–robot interaction. The International Journal of Robotics Research. 2018;37(11):1421-1444. doi:10.1177/0278364918768950

Post Sensor Compensation

$$\hat{Z}_{ps} S_a = \frac{\mu_c}{\tau_c s + 1}$$

Sort of an observer on Acceleration

Virtual Damping Influence



Adding a b_ad term to the Admittance Controller

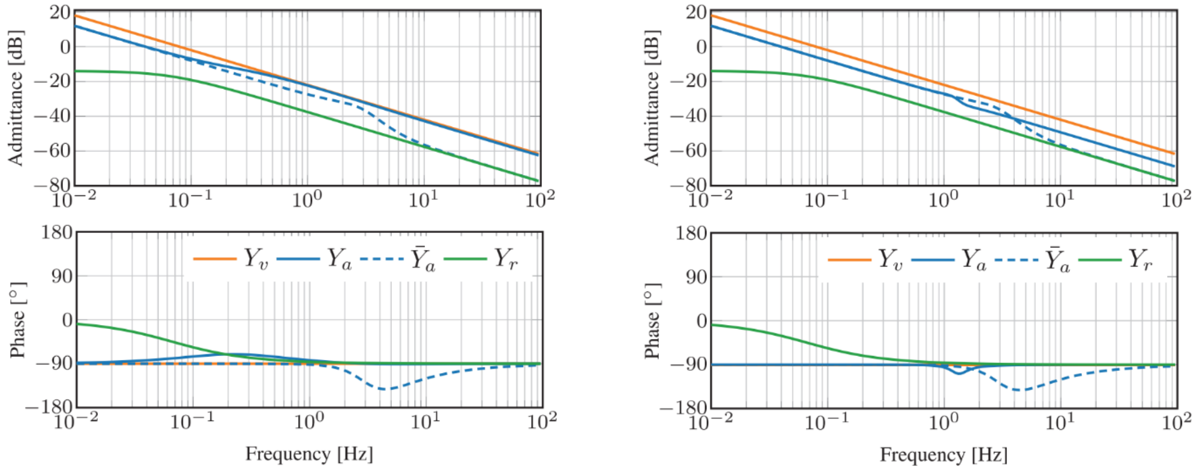


Figure 2 Left: Modified Velocity Reference Right: Increase Velocity Loop Bandwidth

Modify the Velocity Reference

$$Y_v = (sk_a + 1)\, Y_v'$$

A form of feedforward gain on acceleration

Increase Velocity Loop Bandwidth

$$C_{fb} = k_p + \frac{k_i}{s} + \frac{k_d s}{\tau_d s + 1}$$

Low Pass filtered differential gain.

$$H_{ZOH} = \frac{1 - e^{-sT_s}}{sT_s}$$

Alternatively add a Zero Order Hold