System Identification & Control Design of a 2DOF Hover

DDMaC Lab

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Aly Elbindary

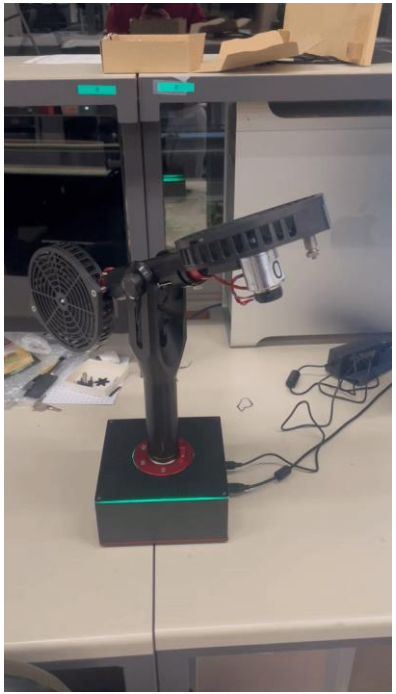
Outline

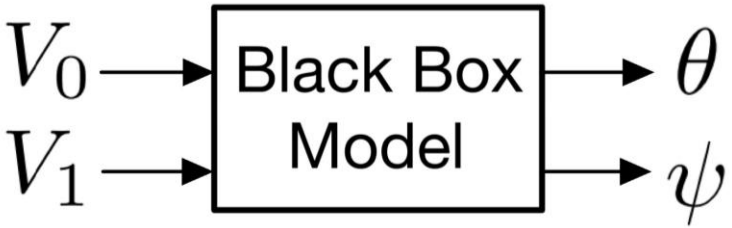
- Introduction
- Project Overview
- Methods
- Results

Introduction

Goals & Motivation

- What do we want to achieve? Why?





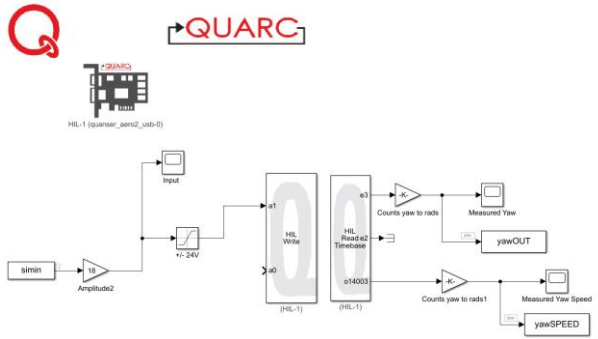
$$\begin{cases} \theta = G_{11}V_0 + G_{12}V_1 \\ \psi = G_{21}V_0 + G_{22}V_1 \end{cases}$$

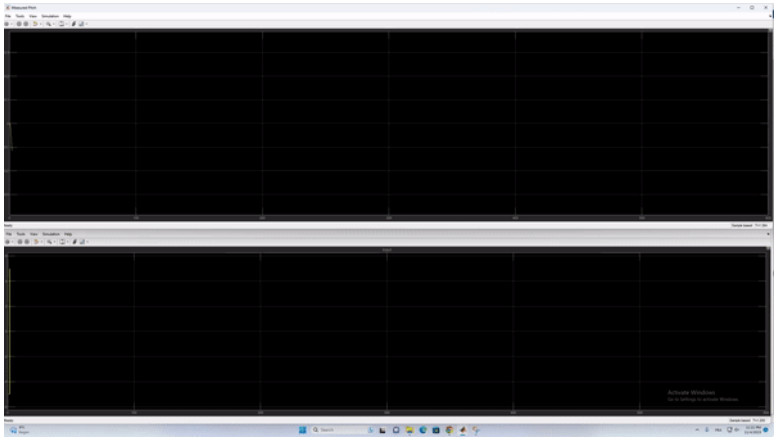
Project Overview

What are the main steps of the project?

Project Overview

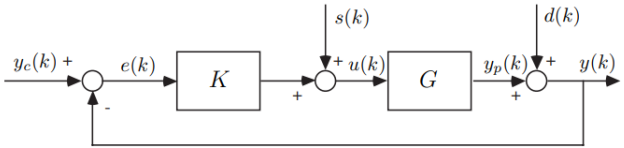
- Data Acquisition





Project Overview

- System Identification of Different Models through Different Methods



Structures without noise model (OE, FIR)

Assumption : noise is independent from input

$$y(k) = G_0(q^{-1})u(k) + n(k)$$

OE : $G_0(q^{-1}) = \dfrac{B_0(q^{-1})}{A_0(q^{-1})}$ **FIR :** $G_0(q^{-1}) = B_0(q^{-1})$

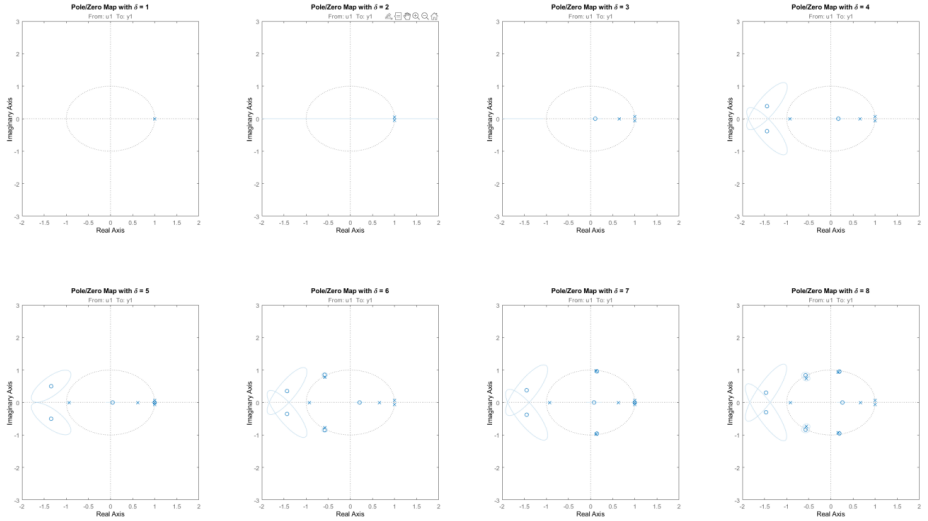
Structures with noise model (ARX, ARMAX, BJ)

Assumption : noise can be modeled by a filtered white noise

$$y(k) = \frac{B_0(q^{-1})}{A_0(q^{-1})}u(k) + H_0(q^{-1})e(k)$$

ARX : $H_0(q^{-1}) = \dfrac{1}{A_0(q^{-1})}$; **ARMAX :** $H_0(q^{-1}) = \dfrac{C_0(q^{-1})}{A_0(q^{-1})}$

BJ : $H_0(q^{-1}) = \dfrac{C_0(q^{-1})}{D_0(q^{-1})}$



Methods

Zoom into the Methods

Methods

- System Identification of Pitch Models : Classical System Identification

- Frequency Response Identification : Spectral & Fourier Analysis

$$G(e^{j\omega}) = \frac{\phi_{yu}(\omega)}{\phi_{uu}(\omega)}$$

- If input and output are periodic signals by Ignoring the Randomness of the Measurement Noise

$$G(e^{j\omega}) = \frac{\phi_{yu}(\omega)}{\phi_{uu}(\omega)} = \frac{Y(e^{j\omega})U(e^{-j\omega})}{U(e^{j\omega})U(e^{-j\omega})} = \frac{Y(e^{j\omega})}{U(e^{j\omega})}.$$

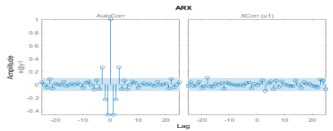
State-space representation

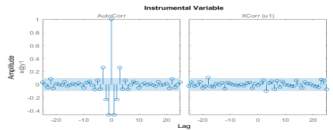
An LTI discrete-time can be represented in state-space form :

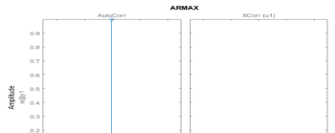
$$x(k+1) = Ax(k) + Bu(k) + w(k)$$
$$y(k) = Cx(k) + Du(k) + e(k)$$

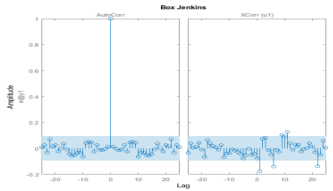
where $w(k)$ and $e(k)$ are state and output noise with the covariance :

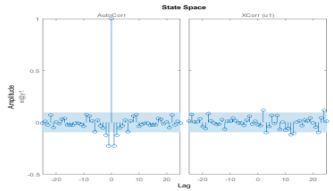
$$\mathbb{E}\left\{ \begin{bmatrix} w(k) \\ e(k) \end{bmatrix} \begin{bmatrix} w(k) & e(k) \end{bmatrix} \right\} = \begin{bmatrix} Q & S \\ S^T & R \end{bmatrix}$$





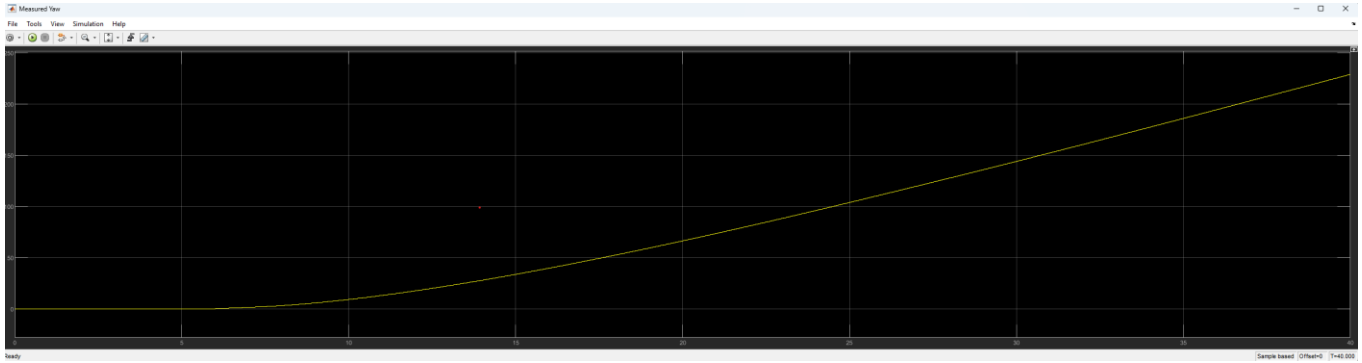






Methods

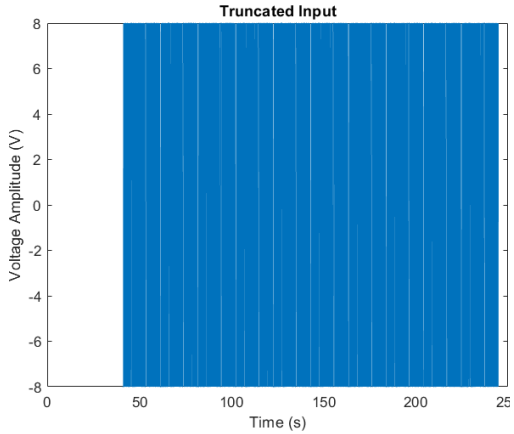
- System Identification of Yaw : Different Approaches

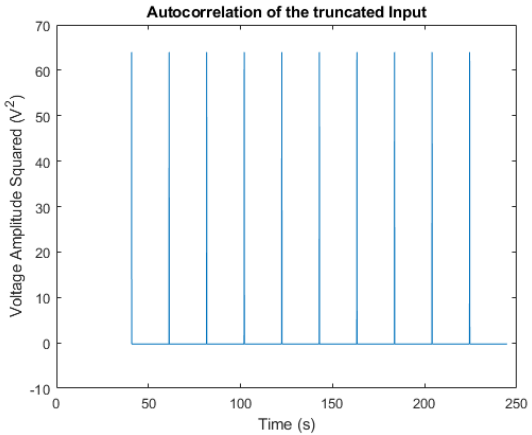


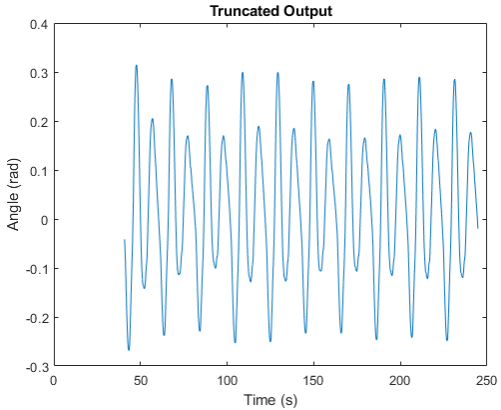
Results

Results

- G11 Identification – Input and Output Analysis

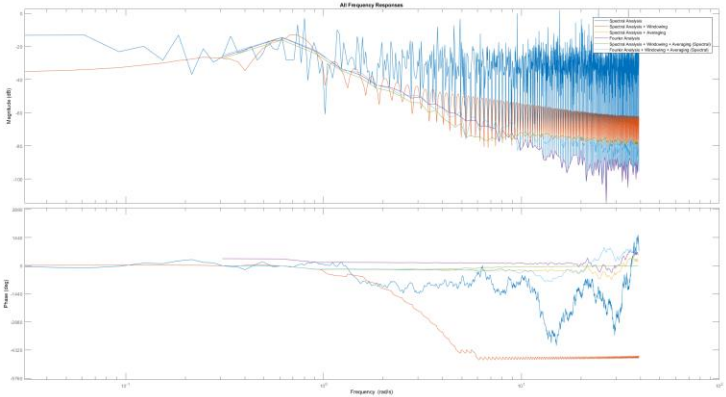


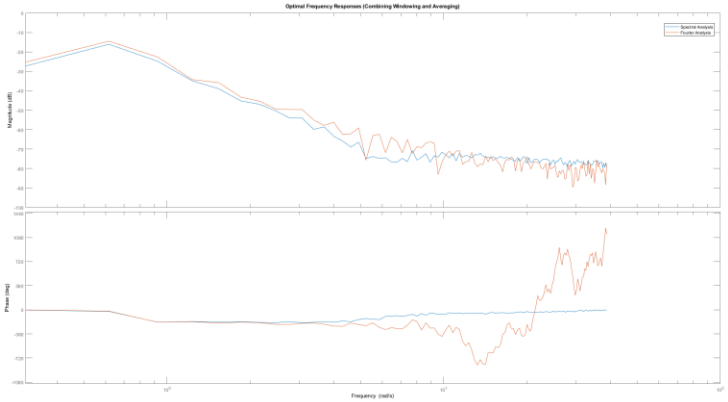




Results

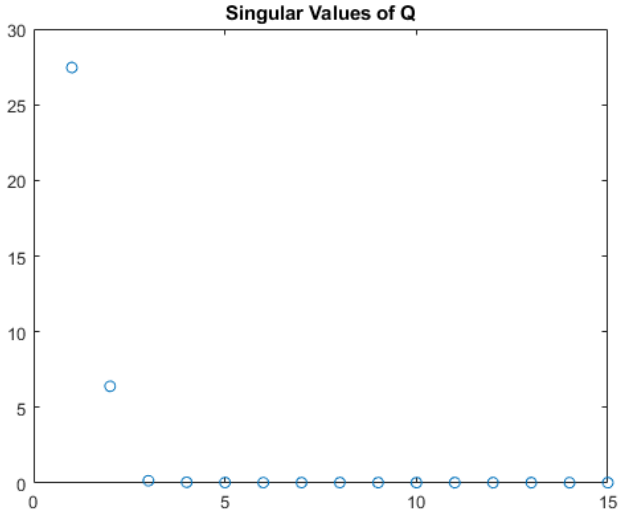
- G11 Identification – Frequency Response Identification

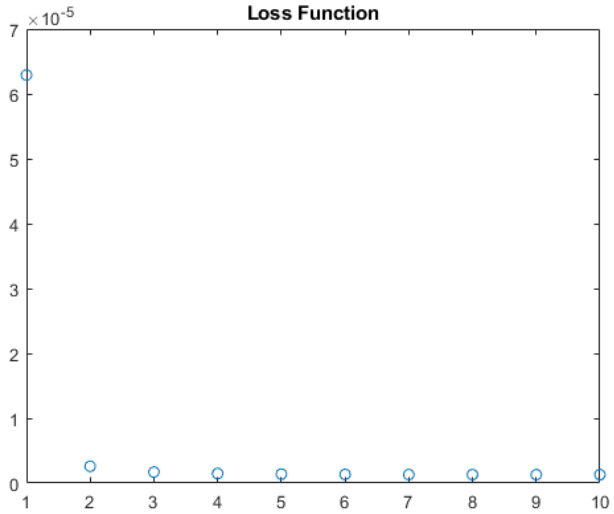




Results

- G11 Identification – Order & Structure Estimation





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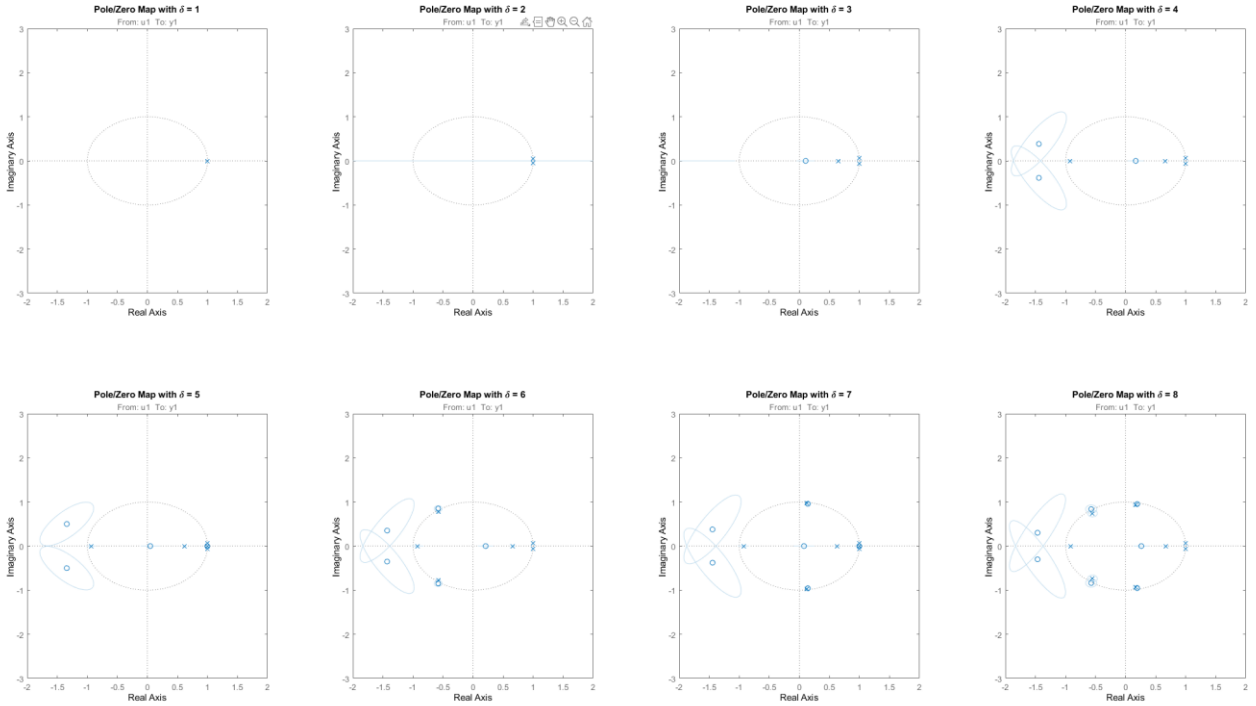

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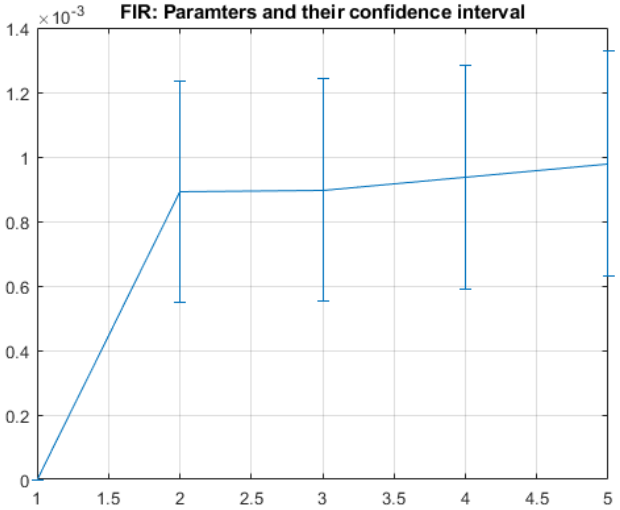
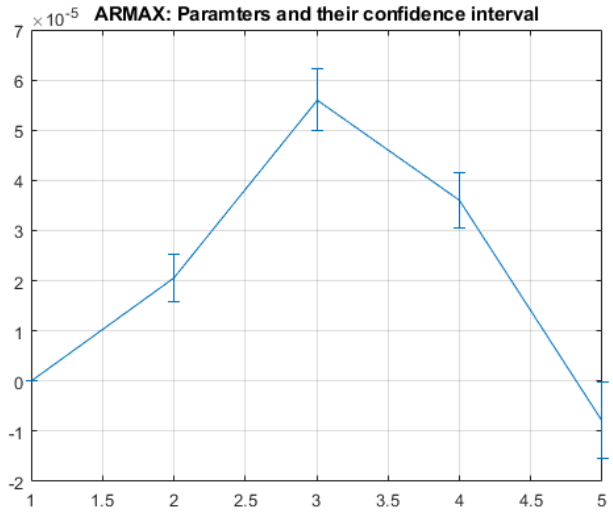
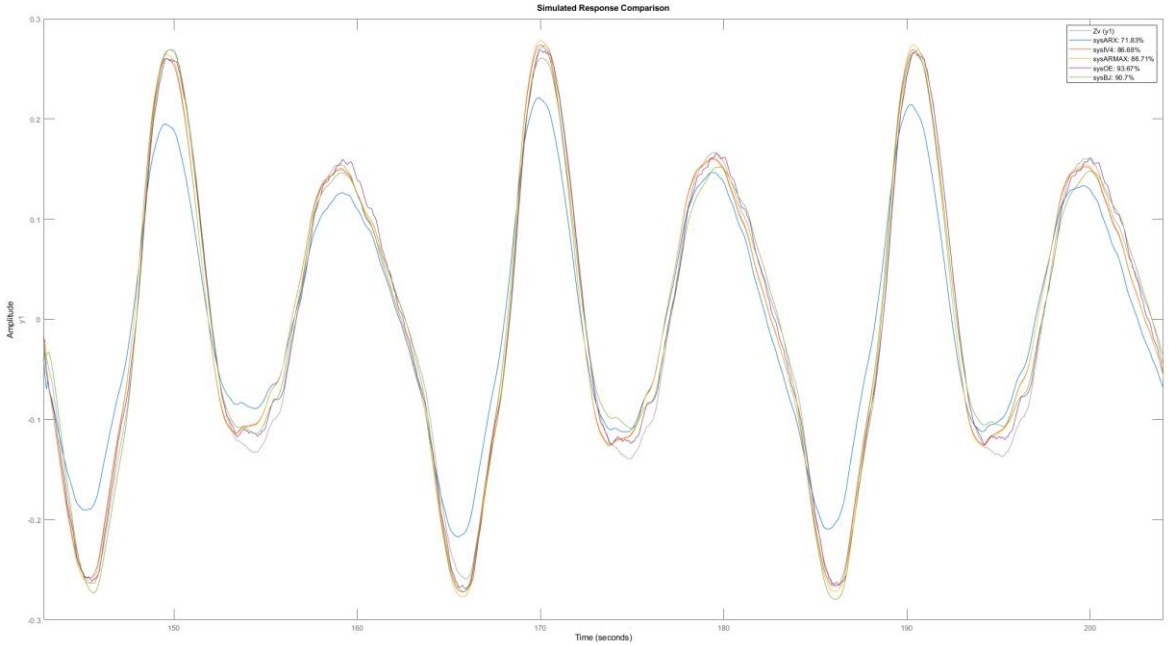




Results

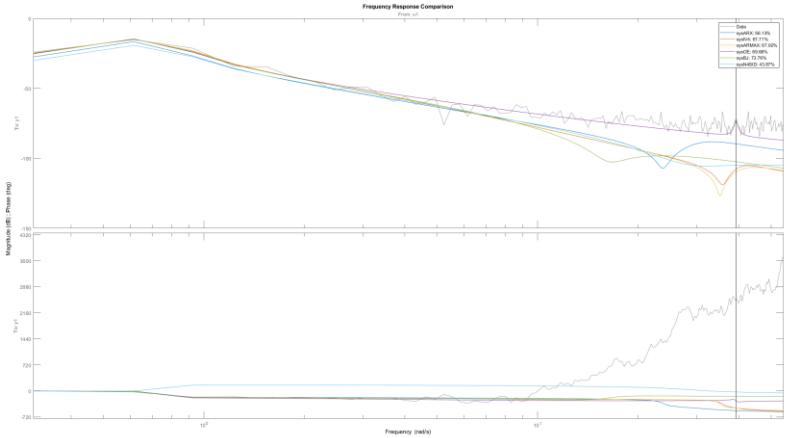
- G11 Identification – Parametric Models Identification & Comparisons



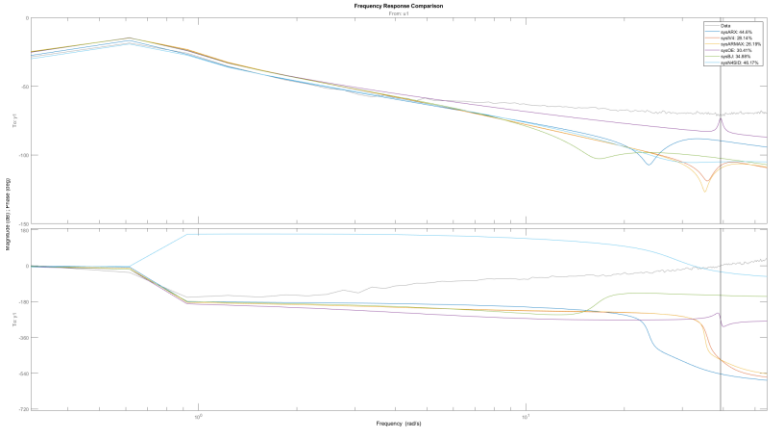
Results

- G11 Identification – Parametric Models Identification & Comparisons

  - Comparison with Fourier Method



  - Comparison with Spectral Method



Results

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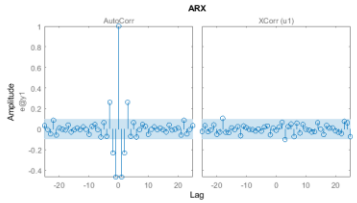
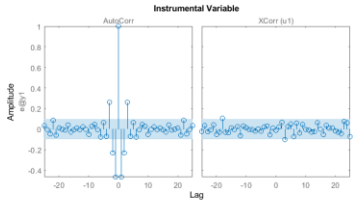
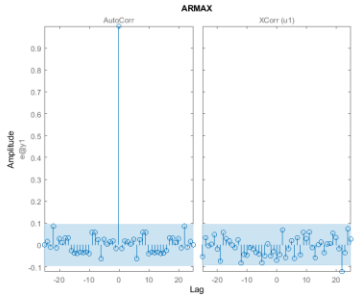
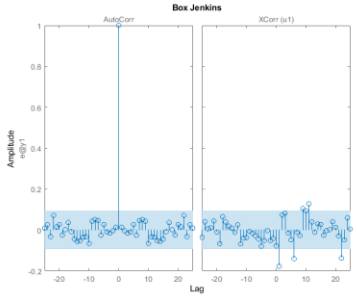
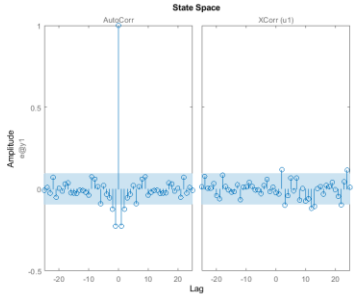




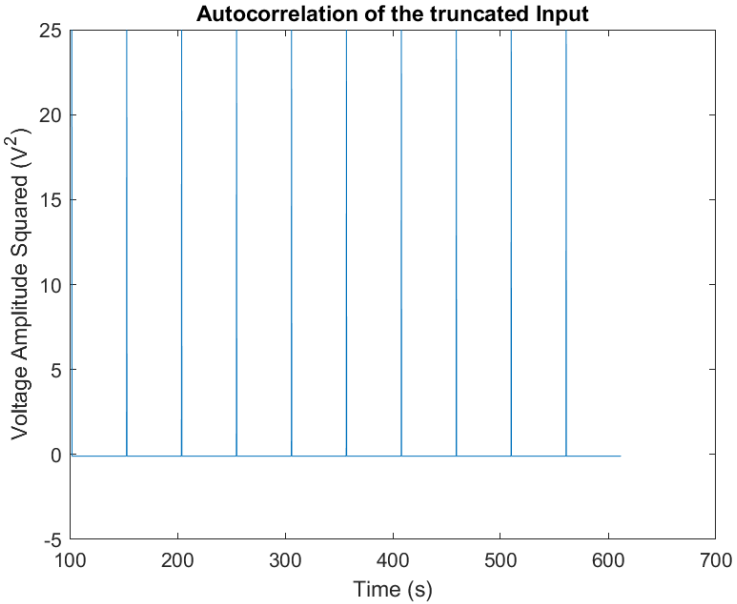


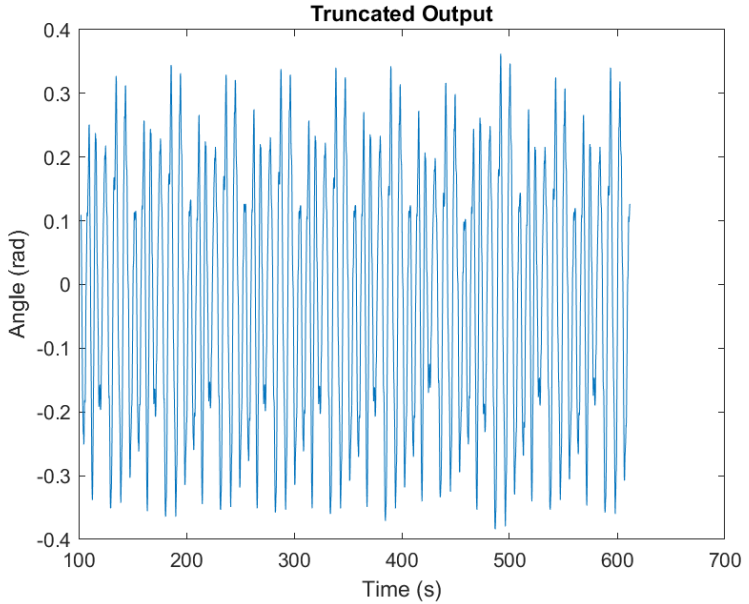




Results

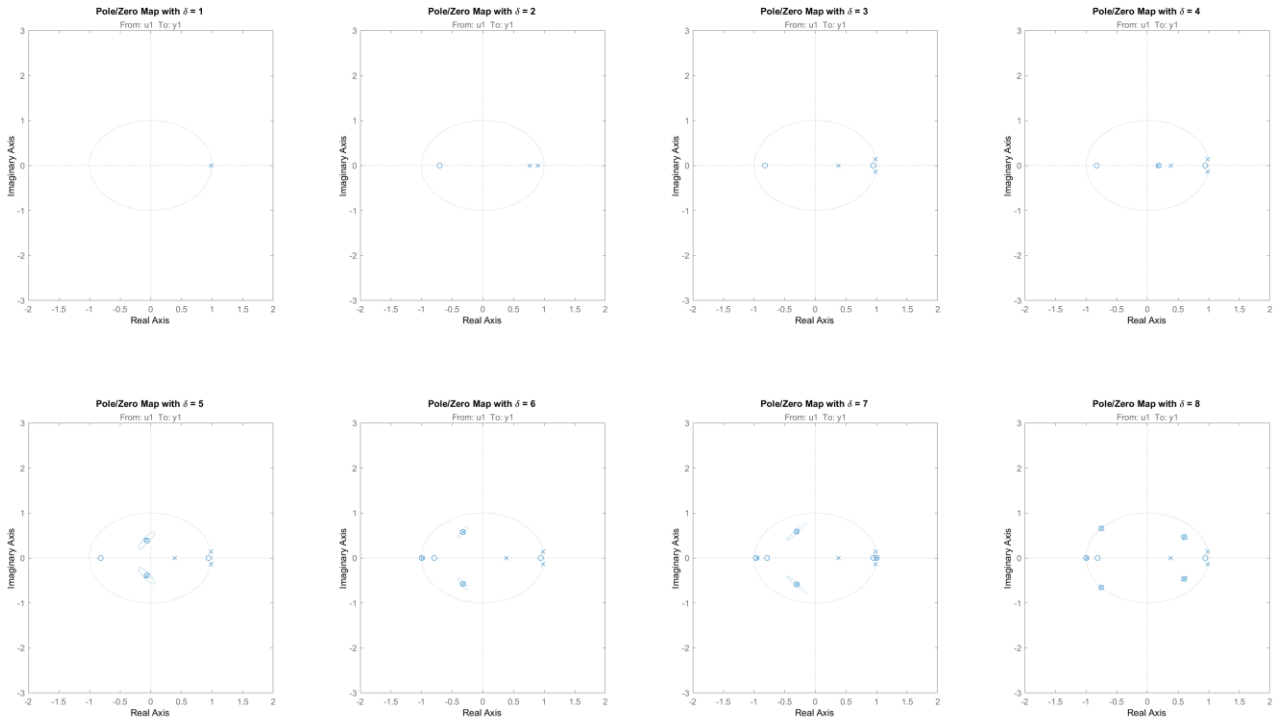
- G12 Identification – Input & Output Measurements





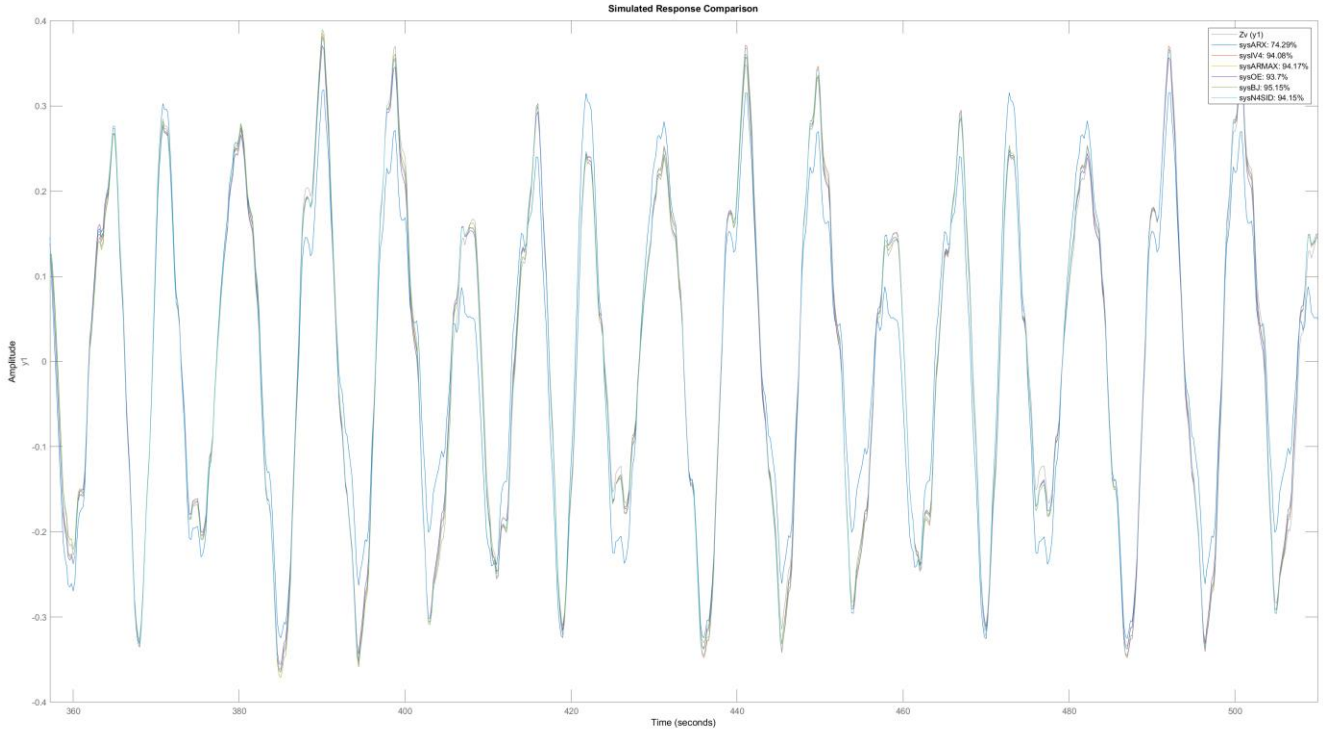
Results

- G12 Identification – Order & Structure Estimation



Results

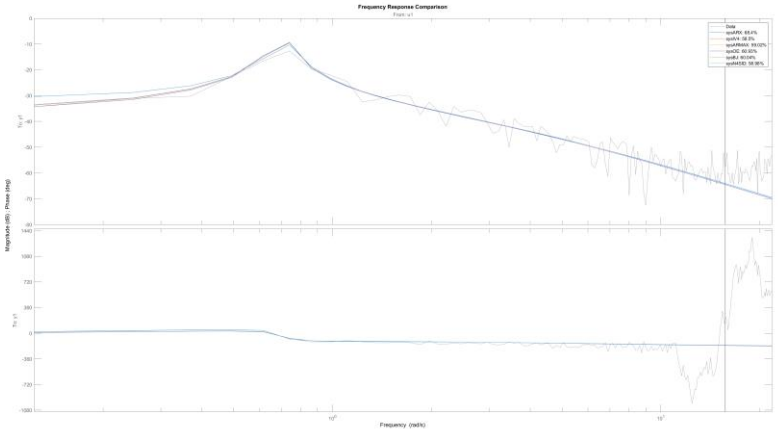
- G12 Identification – Parametric Models Identification & Comaprisons



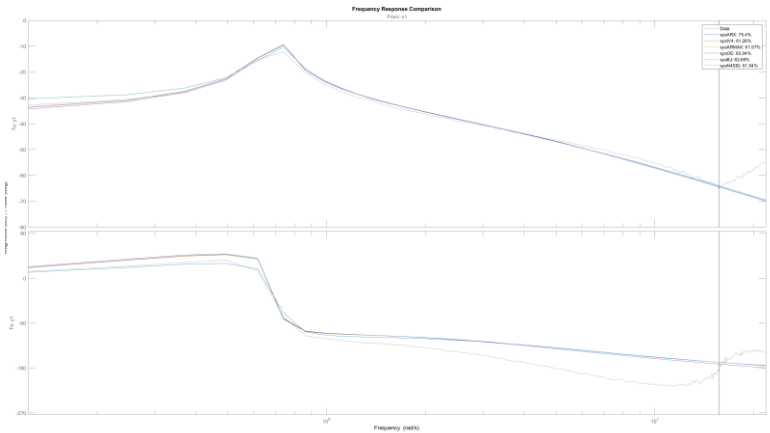
Results

- G12 Identification – Parametric Models Identification & Comparisons

  - Comparison with Fourier Method

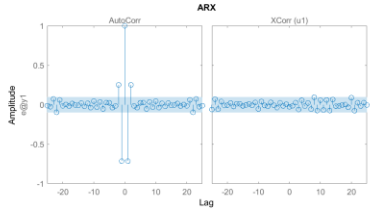


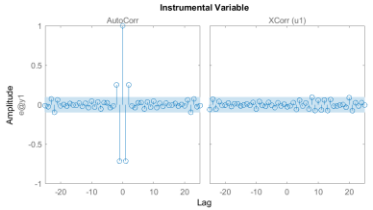
  - Comparison with Spectral Method

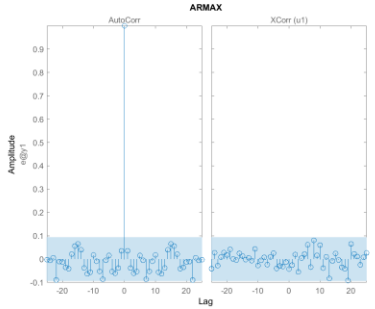


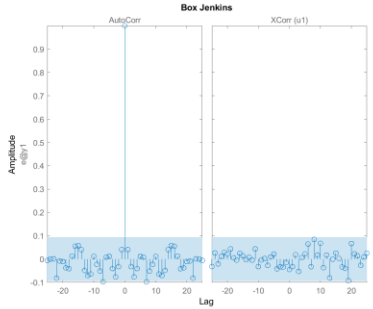
Results

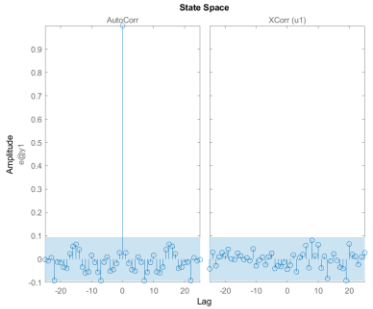
- G12 Identification – Parametric Models Identification & Comparisons





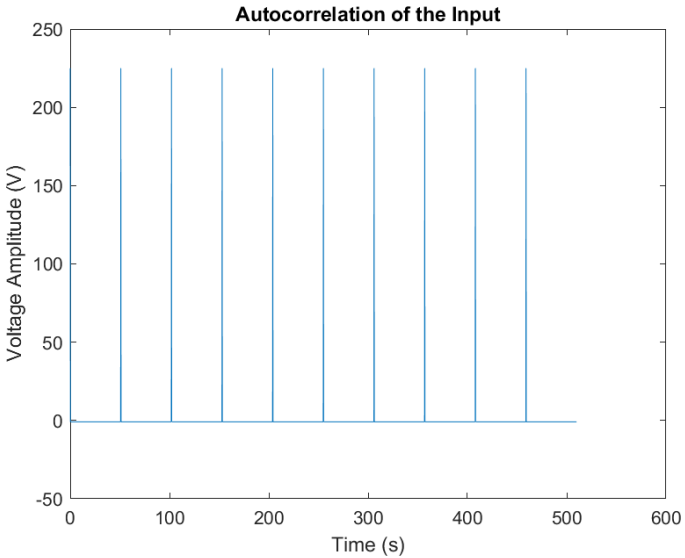


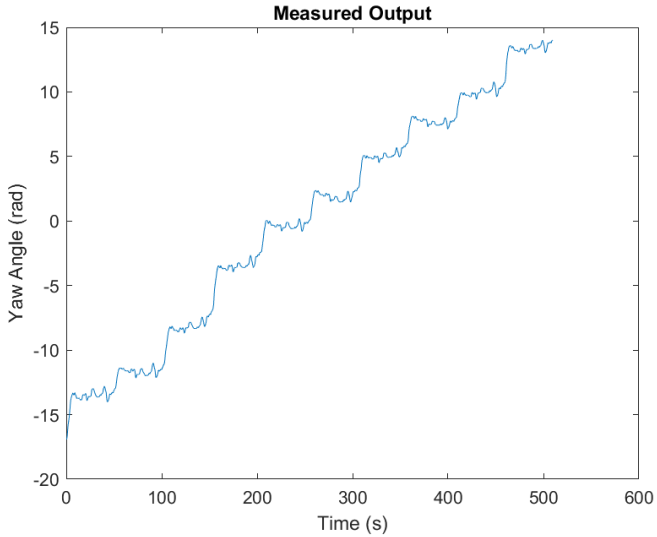




Results

- G22 Identification – Directly Fitting on Data with Drift





Results

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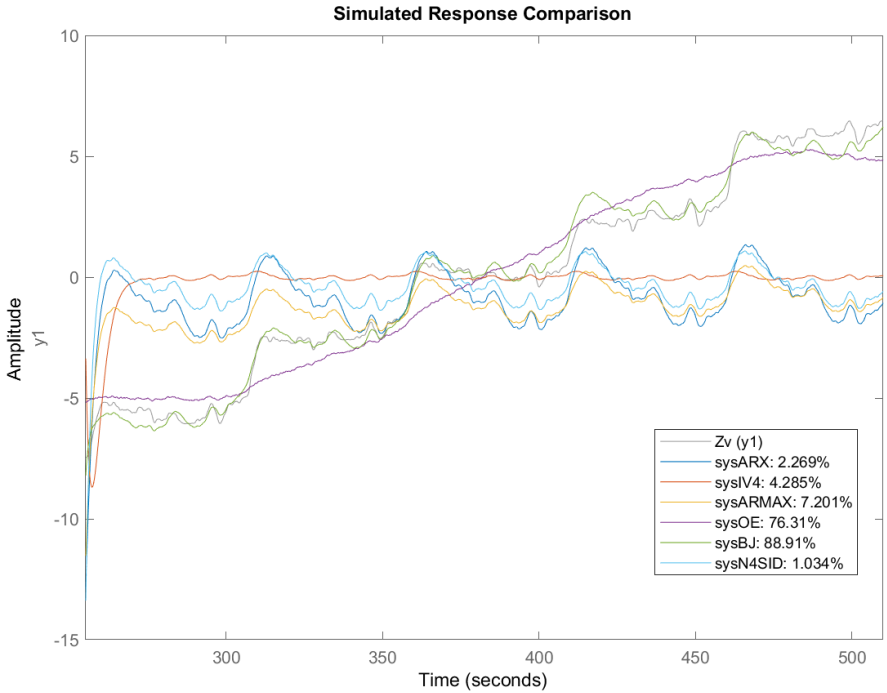

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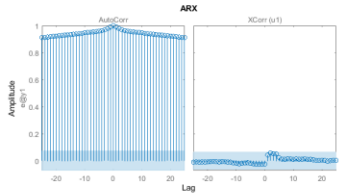
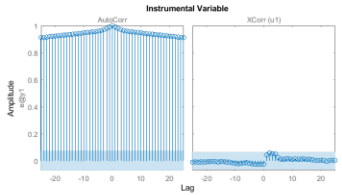
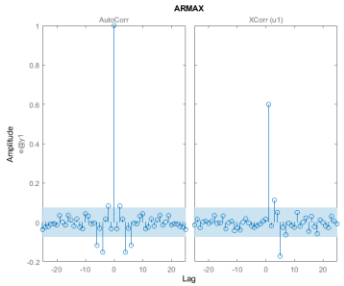
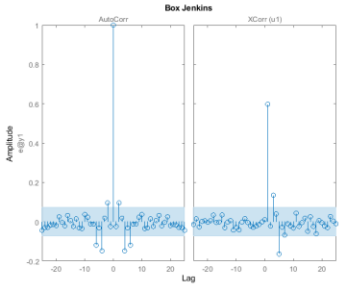
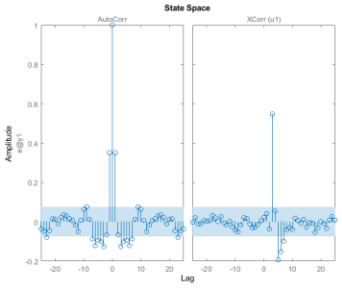




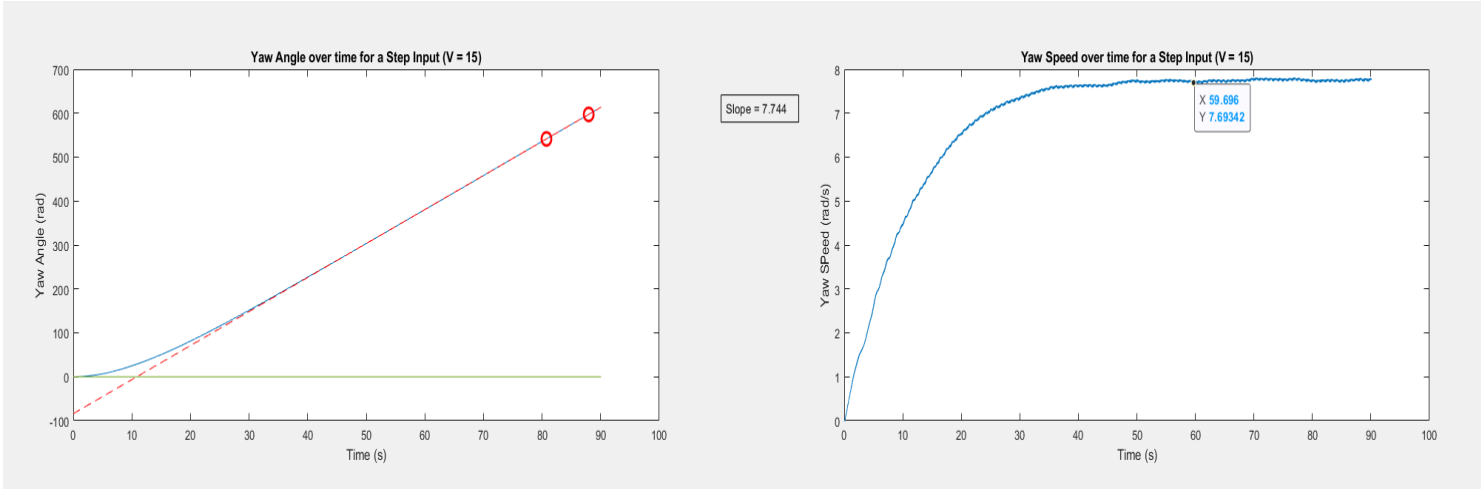






Results

- G22 Identification – Speed Model



Results

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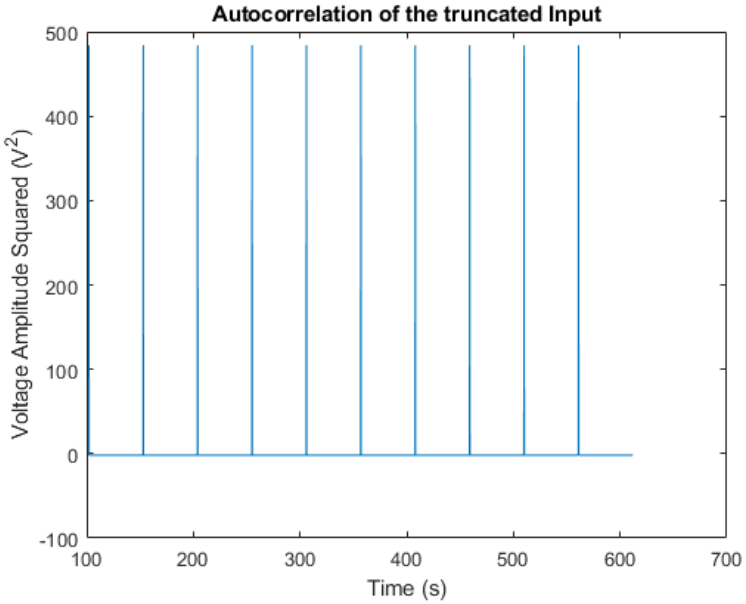

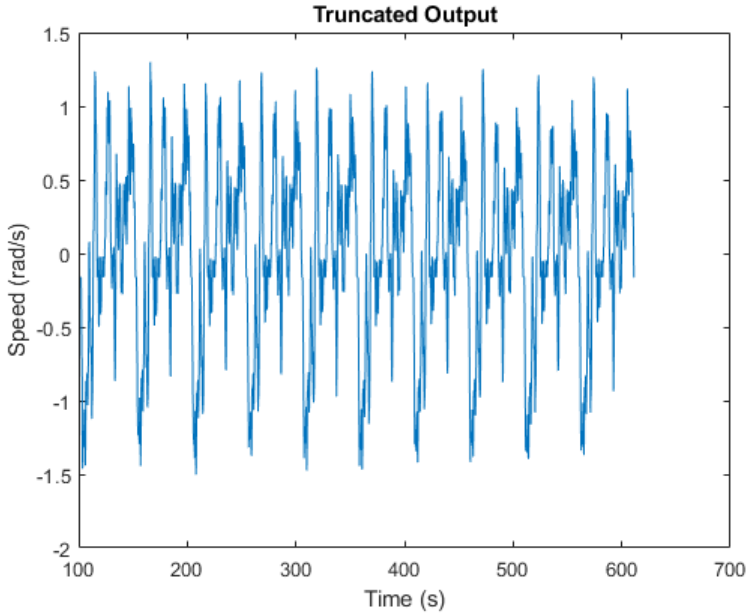

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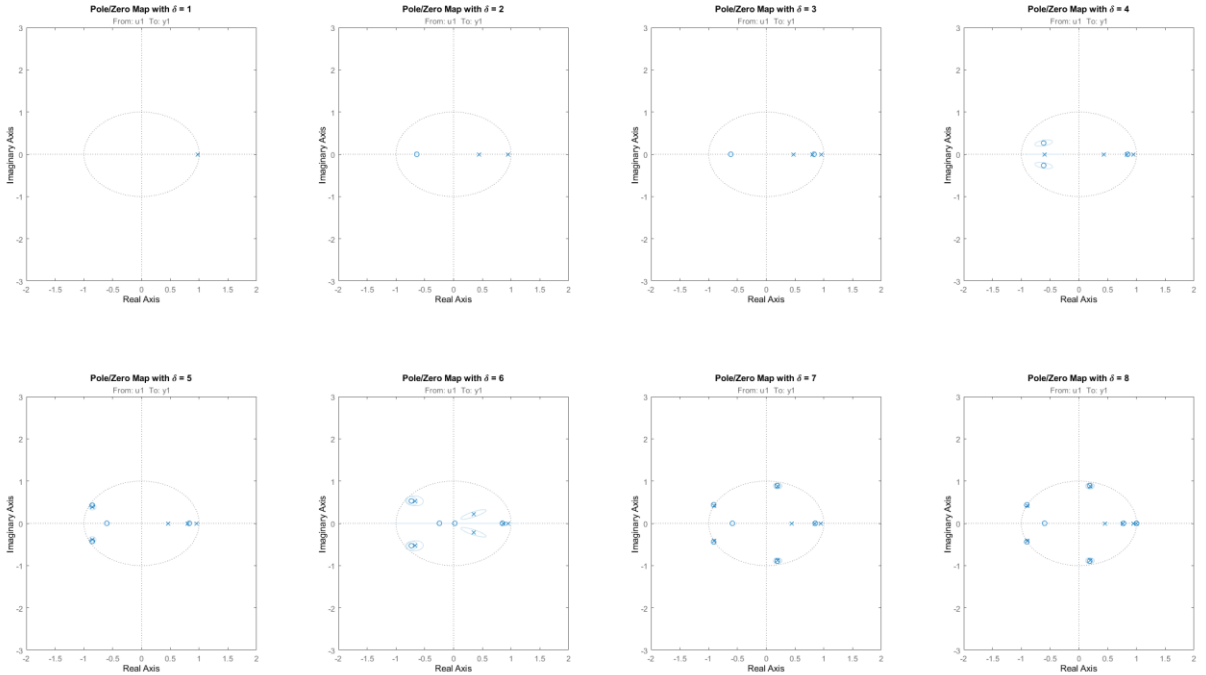

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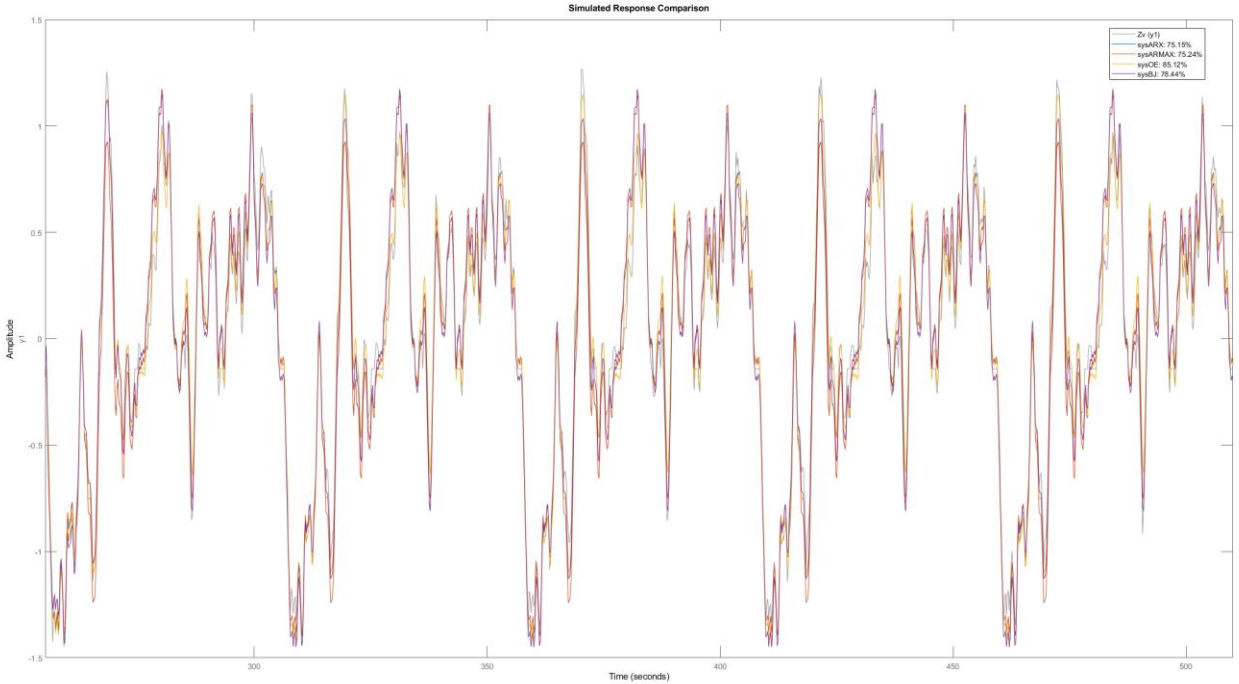
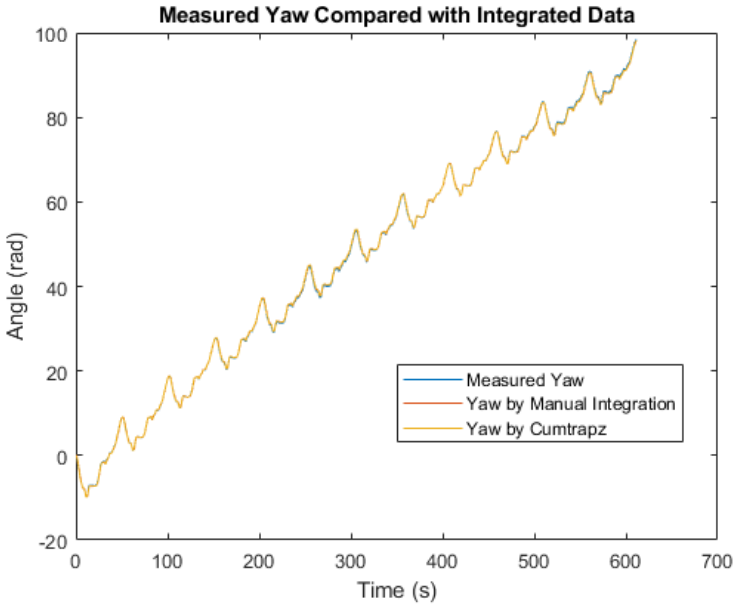
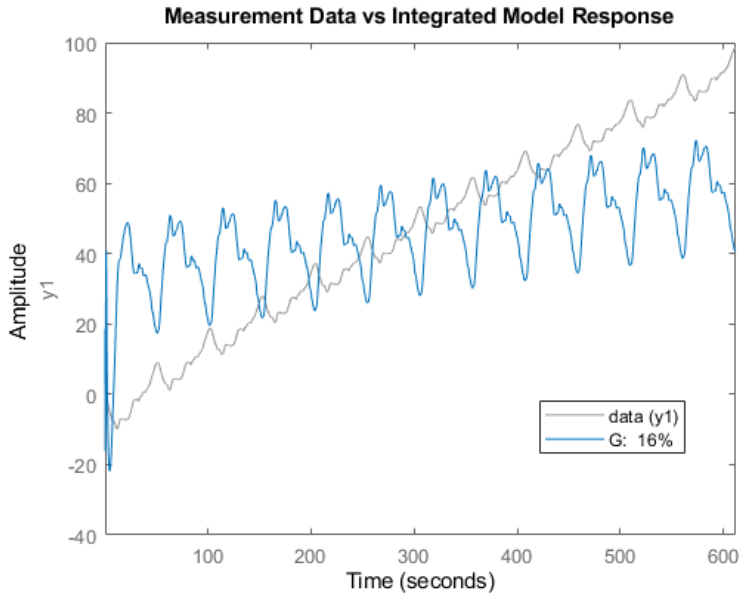


Results

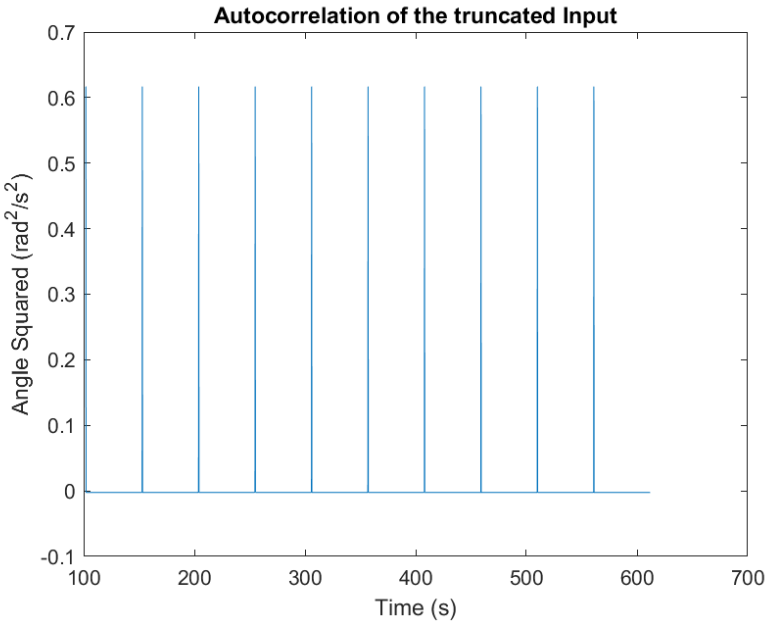
- G22 Identification – Speed Model

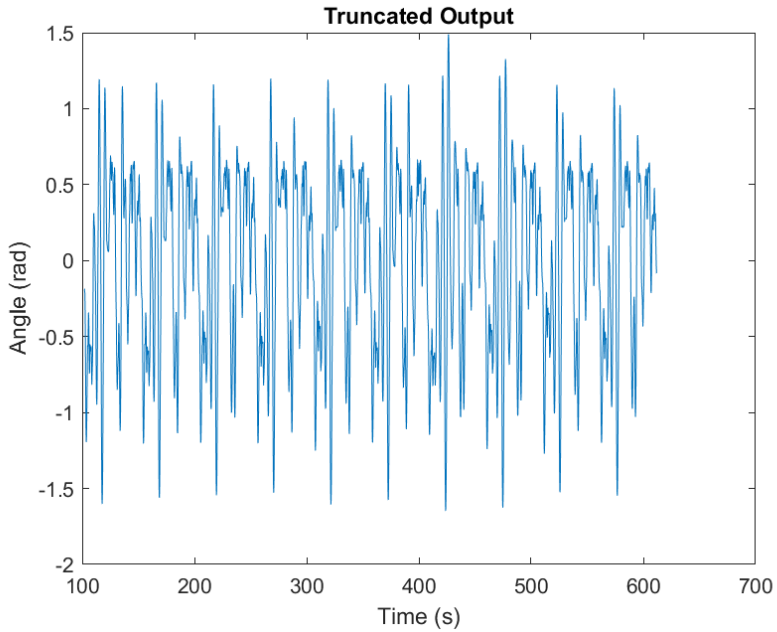




Results

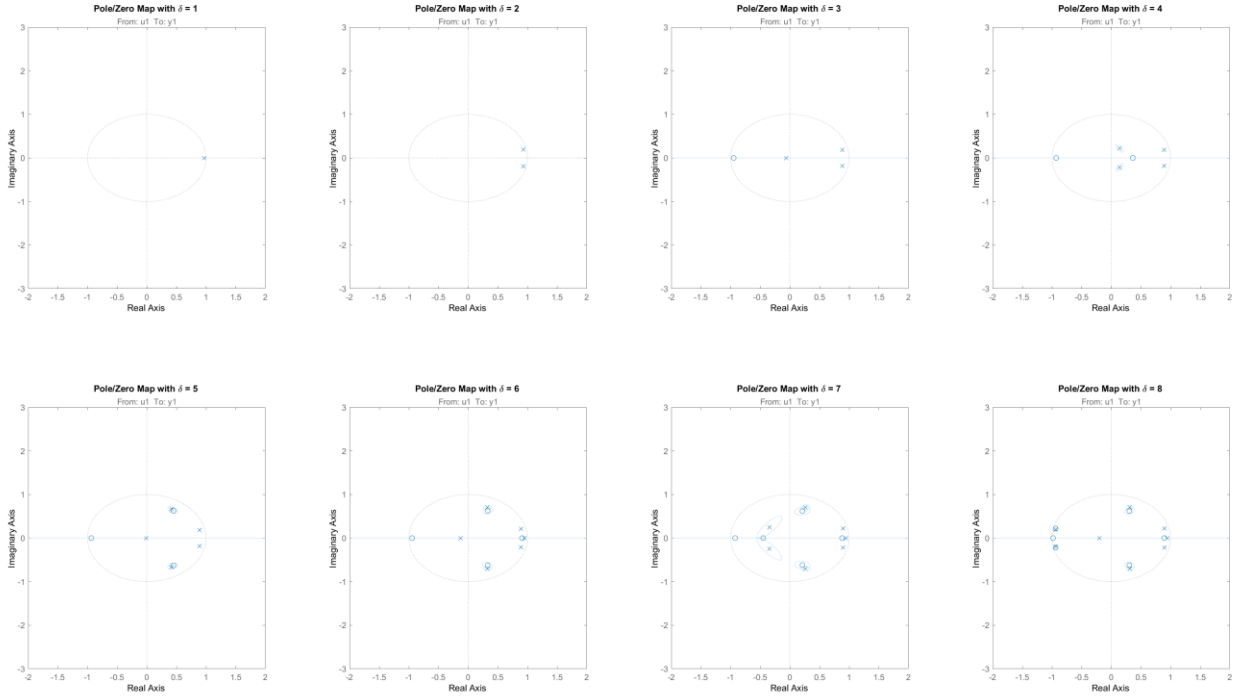
- G22 Identification – Closed-Loop System Identification





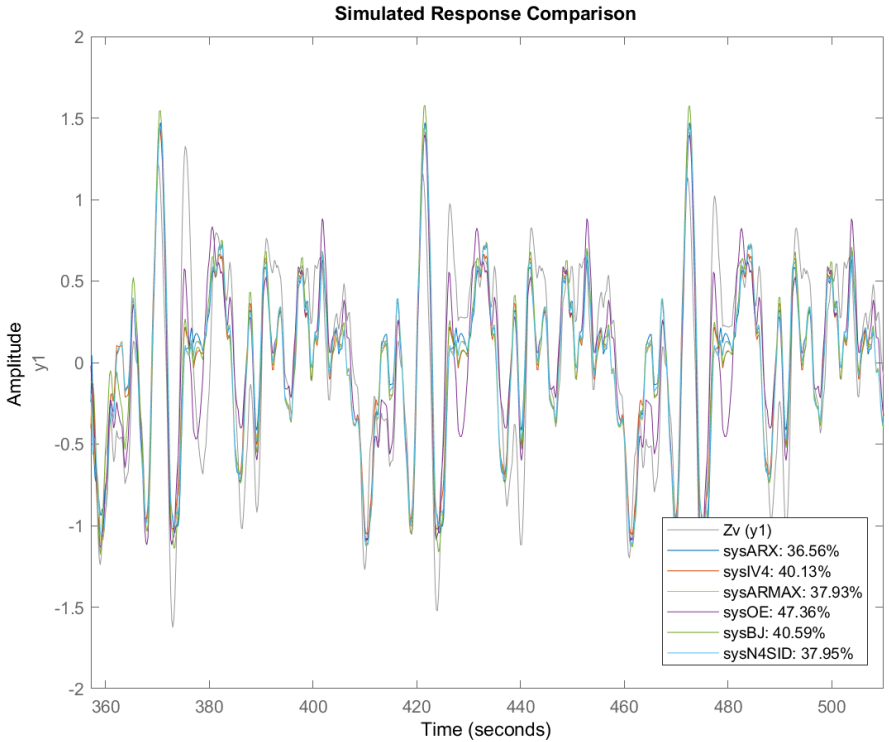
Results

- G22 Identification – Closed-Loop System Identification



Results

- G22 Identification – Closed-Loop System Identification



Summary & Conclusion

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