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NRF National Research Foundation | SARAO South African Radio Astronomy Observatory

MO3AO04
Modelling and Control of a MeerKAT Antenna

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The South African Radio Astronomy Observatory (SARAO) is a National Facility managed by the National Research Foundation and incorporates all national radio astronomy telescopes and programmes.

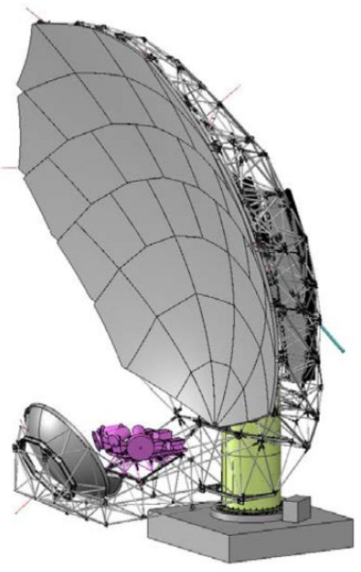
Outline

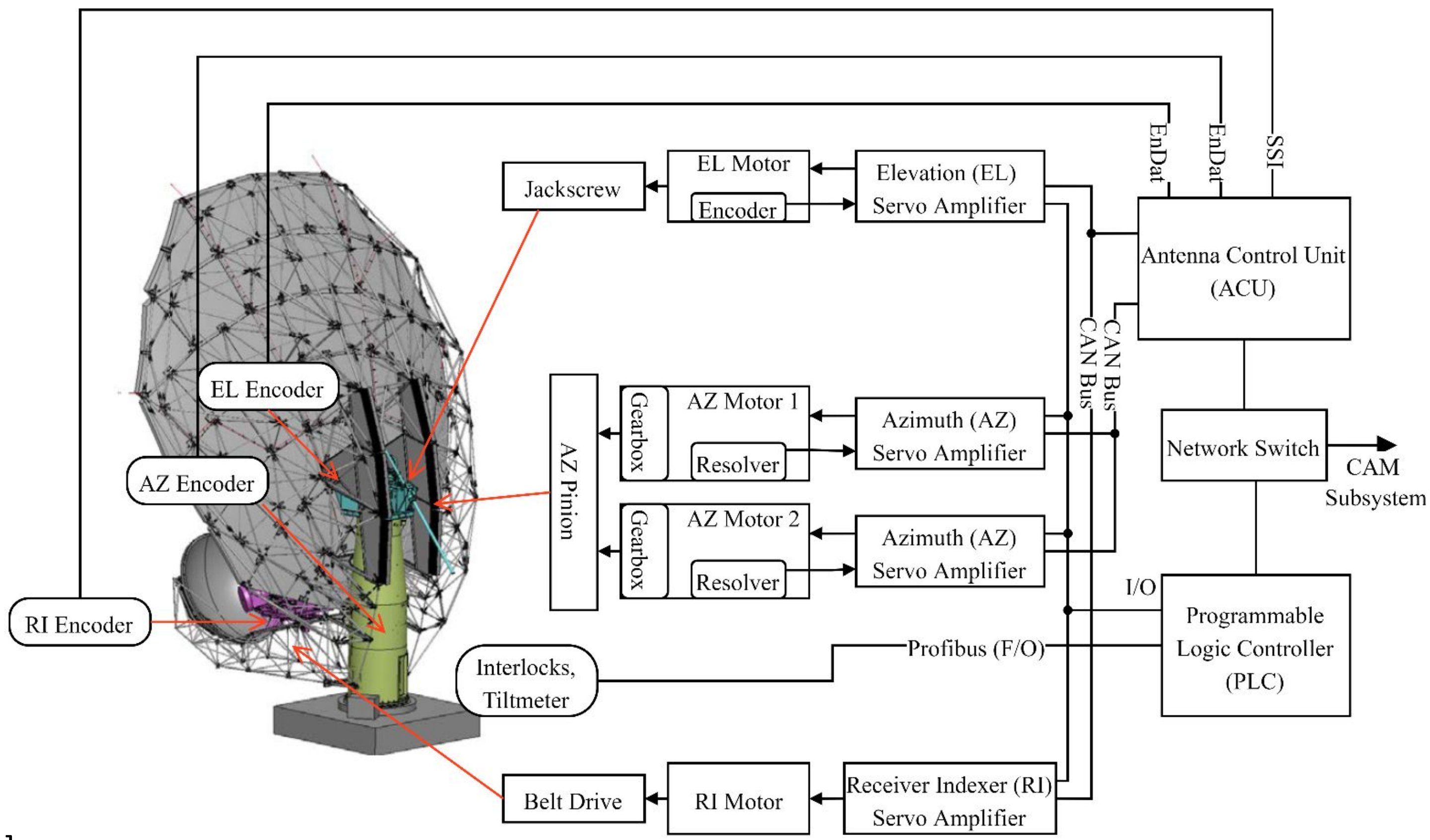
- Background and Motivation
- Drive Configuration
- Current Control Architecture
- System Modelling
- System ID
- Disturbance Modelling
- Model Performance
- Conclusions and Future Work

Background

- MeerKAT commissioned in 2018.
- “Black box” current control system = undiagnosed failures.
- Project objective:
    - Well documented, systematic feedback control system design of the MeerKAT Antenna Positioner (AP).
- Presentation objective:
    - Summarise the comprehensive approach to modelling for control system design for a MeerKAT antenna.

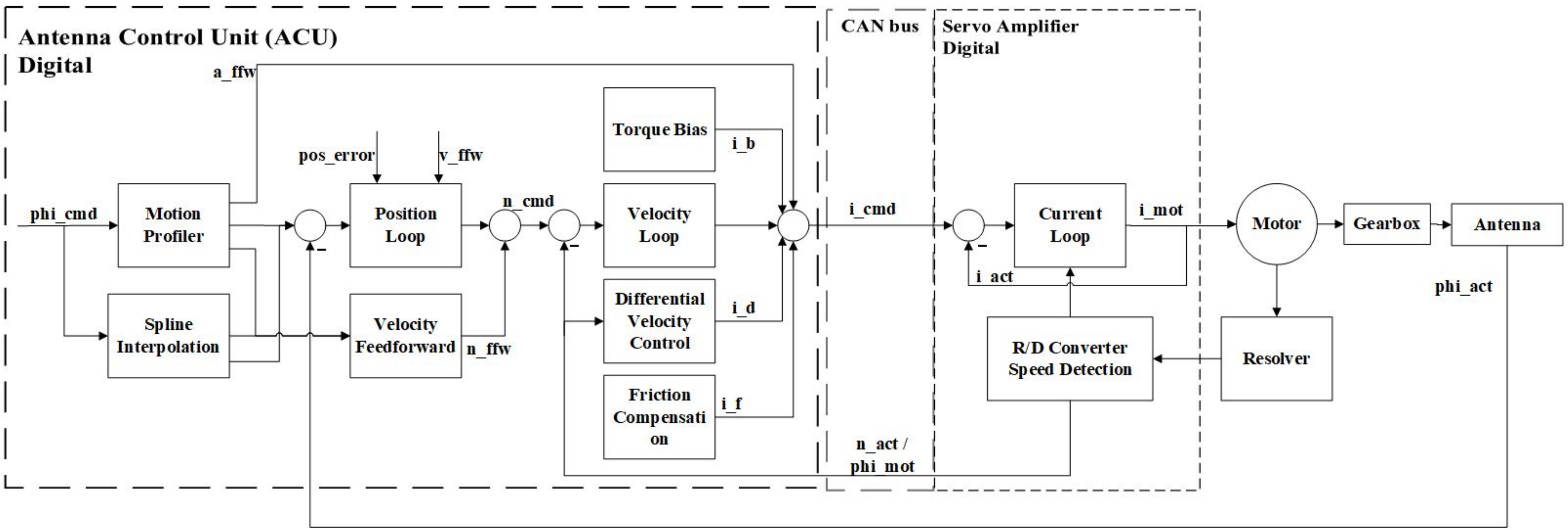
Drive Configuration





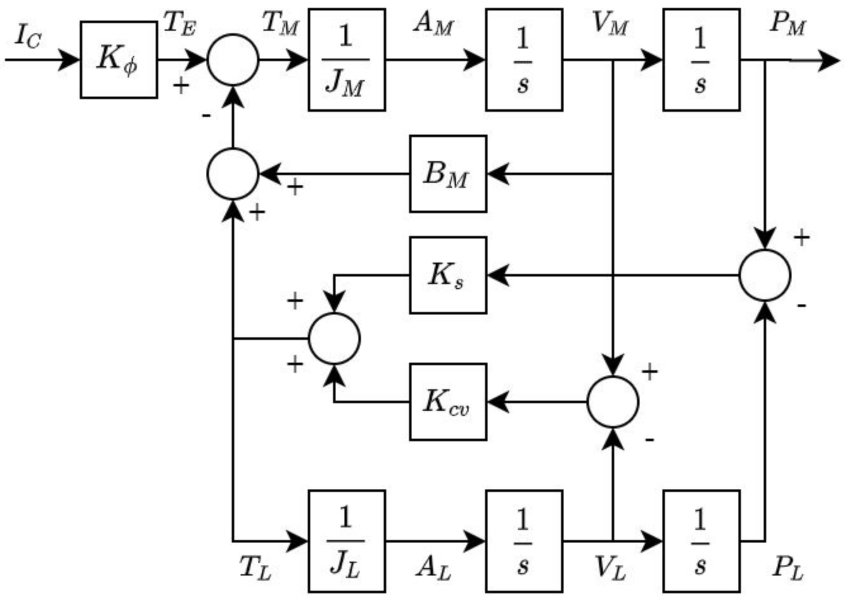
Render taken from [1]

Control Architecture



System Model Form

Two mass model with resonant load



$$\frac{P_M}{T_E} = \frac{1}{(J_M + J_L)s^2 + B_M s}\left\{\frac{A}{B}\right\}$$

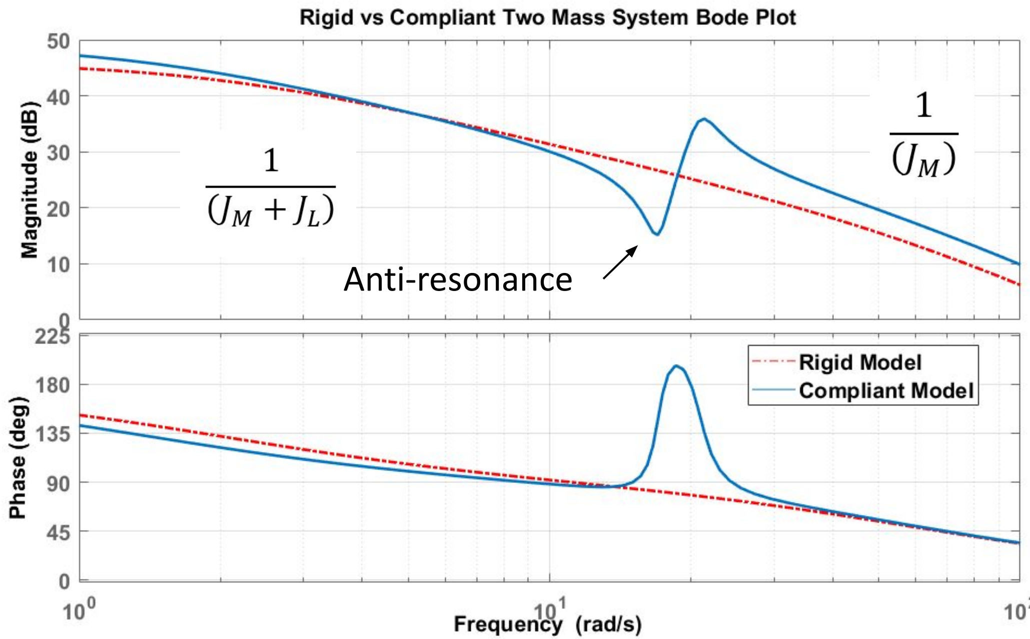
Where:

$$A = J_L s^2 + K_{cv} s + K_s$$

$$B = \left(\frac{J_M J_L}{(J_M + J_L)s + B_M}\right) s^2 + \left(\frac{J_M K_{cv} + J_L(B_M + K_{cv})}{(J_M + J_L)s + B_M}\right) s + \frac{B_M K_{cv} + (J_L + J_M)K_S}{(J_M + J_L)s + B_M} + \frac{B_M K_S}{(J_M + J_L)s^2 + B_M s}$$

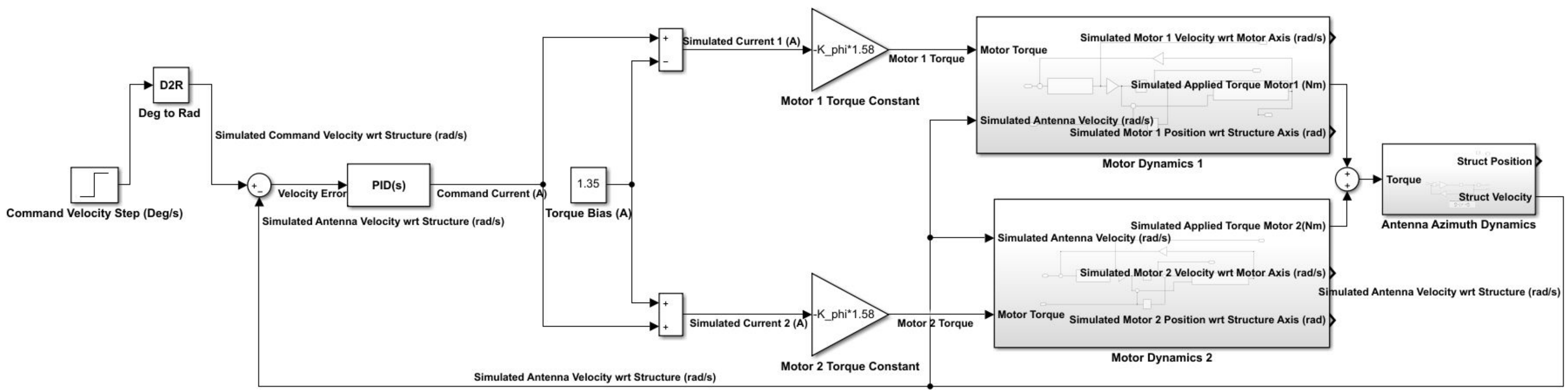
Rigid vs Compliant

$$F_{AR} = \sqrt{\frac{Ks}{J_L}} rad/sec$$

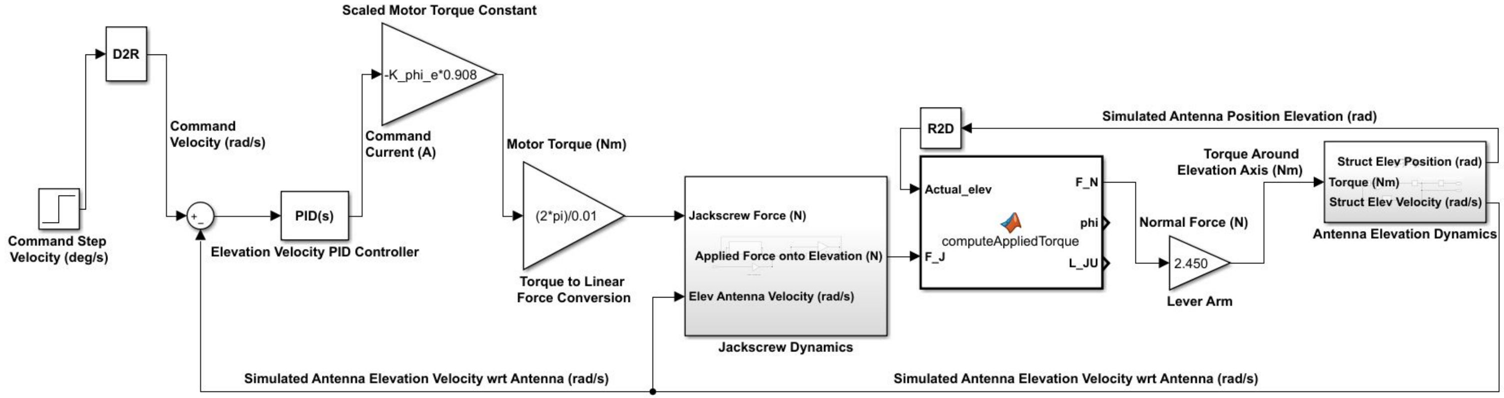


Simulink Model - Azimuth

Torque Bias

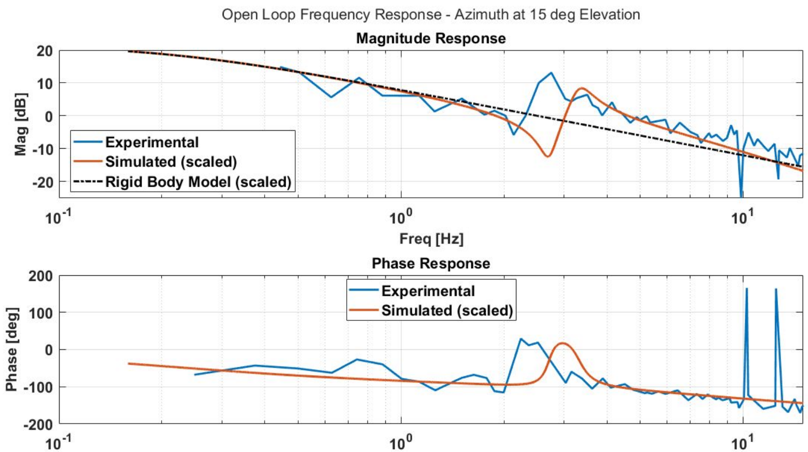


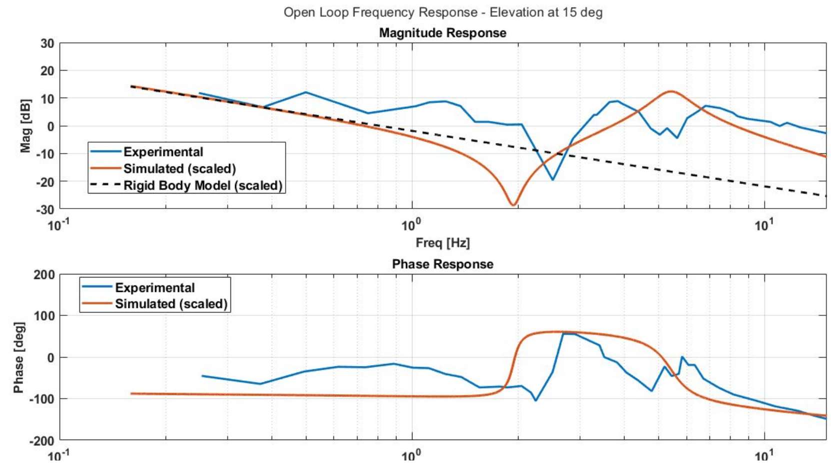
Simulink Model - Elevation



Linear to rotational

System ID


Open Loop Frequency Response - Azimuth at 15 deg Elevation
Magnitude Response
Mag [dB]
Freq [Hz]
Experimental
Simulated (scaled)
Rigid Body Model (scaled)
Phase Response
Phase [deg]
Experimental
Simulated (scaled)


Open Loop Frequency Response - Elevation at 15 deg
Magnitude Response
Mag [dB]
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Experimental
Simulated (scaled)
Rigid Body Model (scaled)
Phase Response
Phase [deg]
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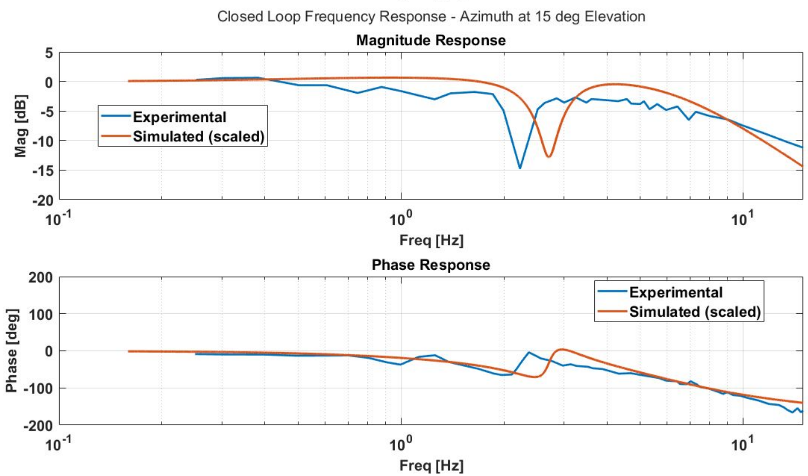
Simulated (scaled)


Closed Loop Frequency Response - Azimuth at 15 deg Elevation
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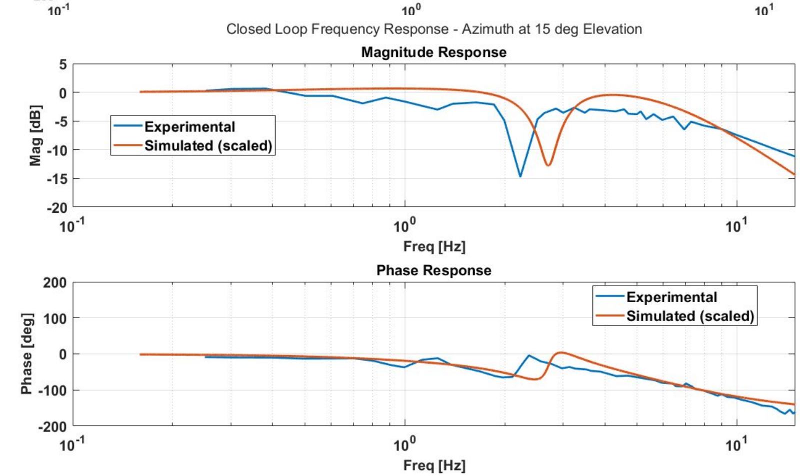
Simulated (scaled)
Freq [Hz]

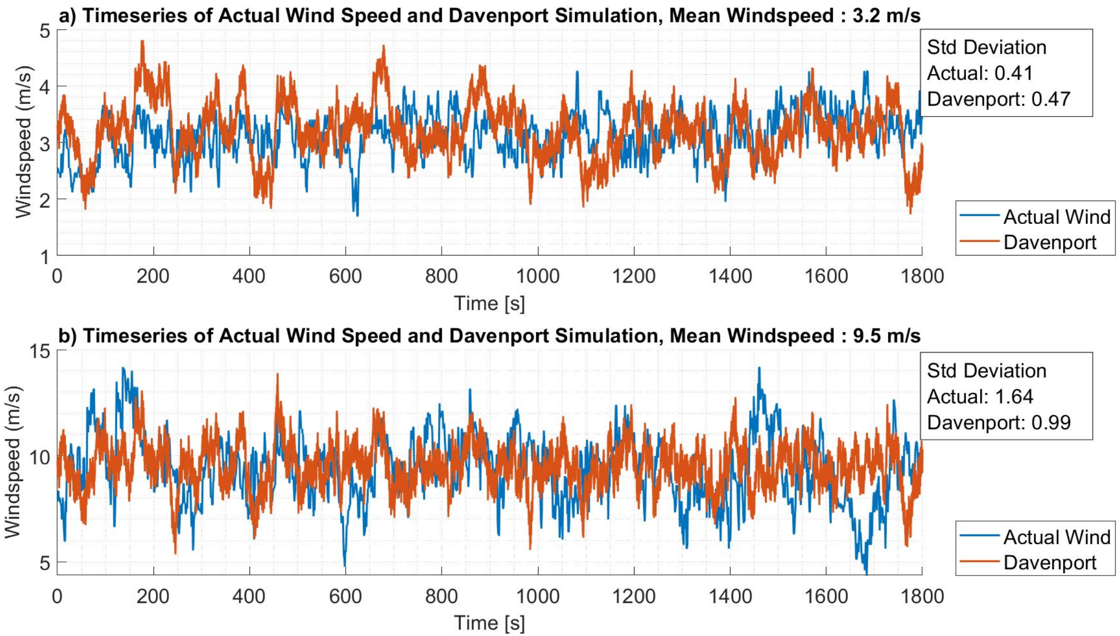

Closed Loop Frequency Response - Azimuth at 15 deg Elevation
Magnitude Response
Mag [dB]
Freq [Hz]
Experimental
Simulated (scaled)
Phase Response
Phase [deg]
Experimental
Simulated (scaled)
Freq [Hz]

Disturbances - Wind

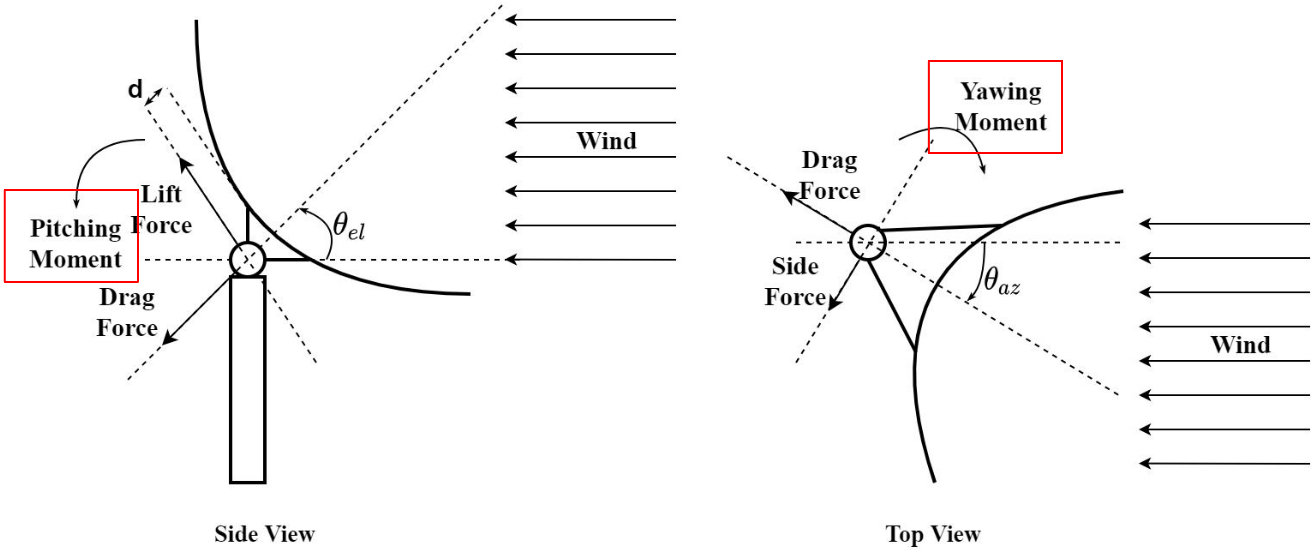
$$S_d(\omega) = 4800 v_m \kappa \left(\frac{\beta\omega}{(1+\beta^2\omega^2)^{\frac{4}{3}}} \right)$$

$$\kappa = \frac{1}{\left(2.5\, ln\left(\frac{z}{z_0}\right)\right)^2}$$

$$\beta = \frac{600}{\pi v_m}$$ [2]

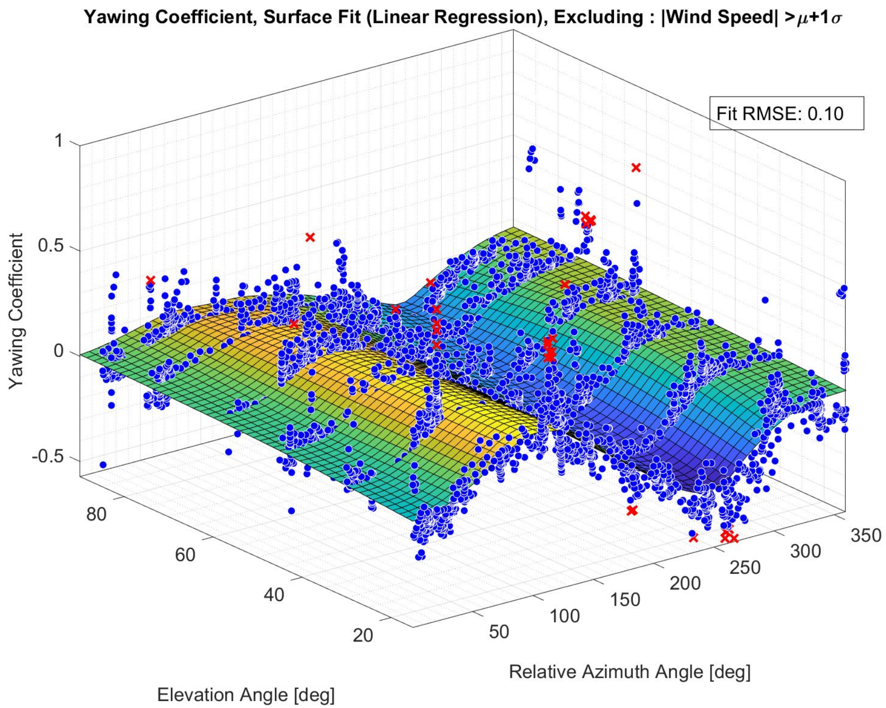


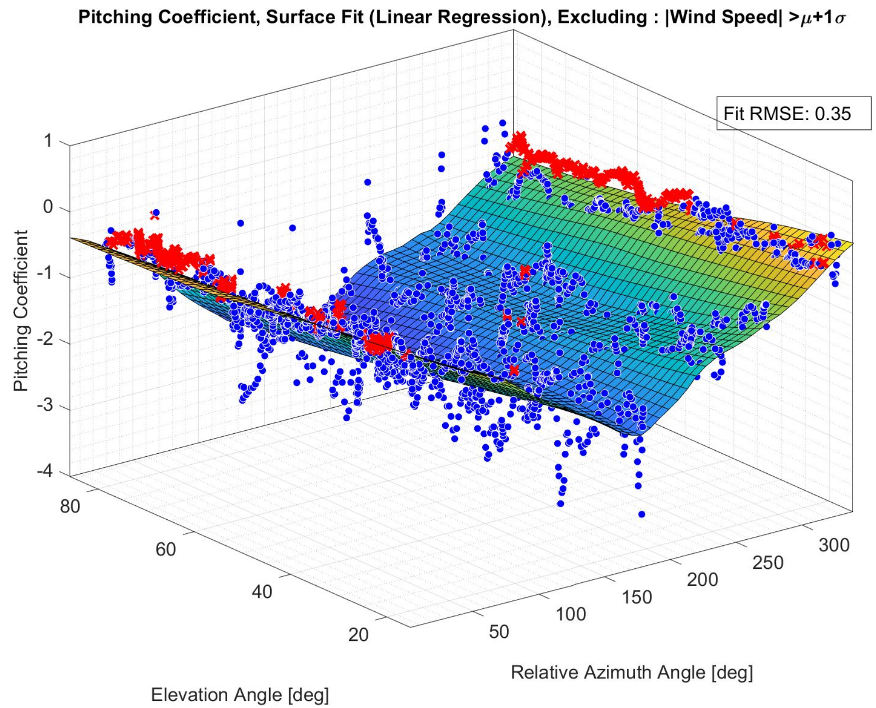
Antenna Loading



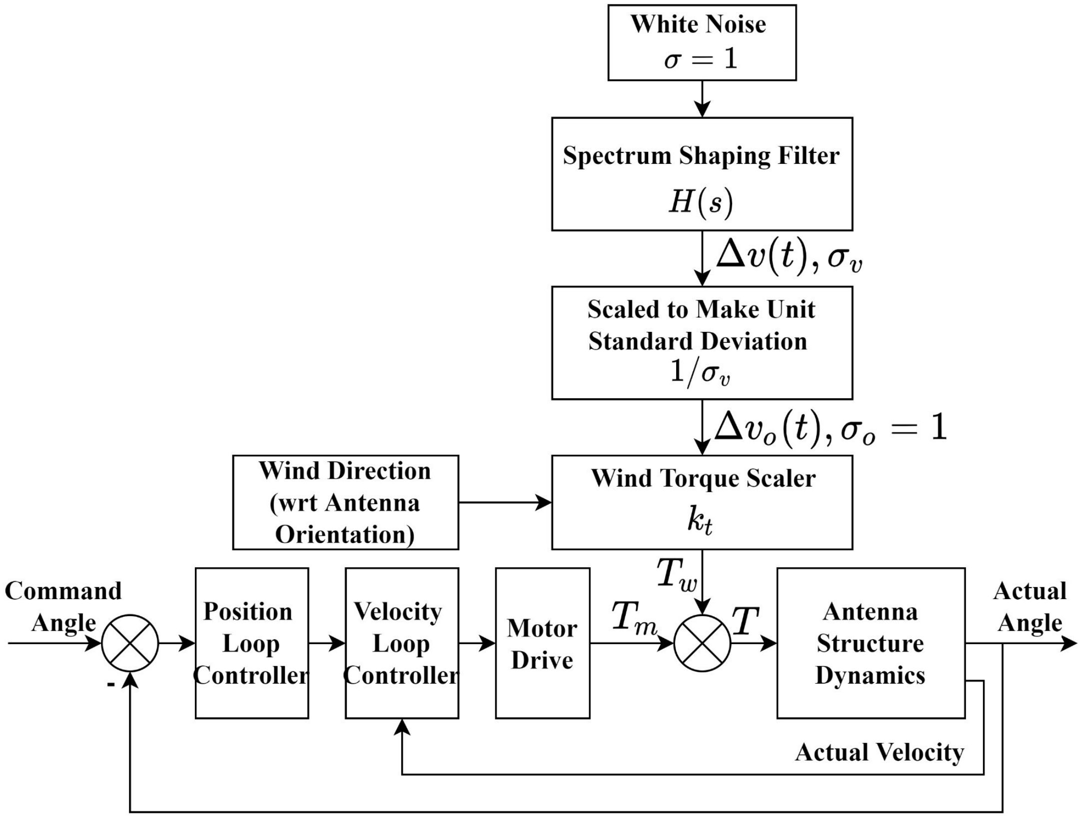
$$\tau = \frac{T}{0.5\rho v_m^2 AD}$$

Torque Coefficients





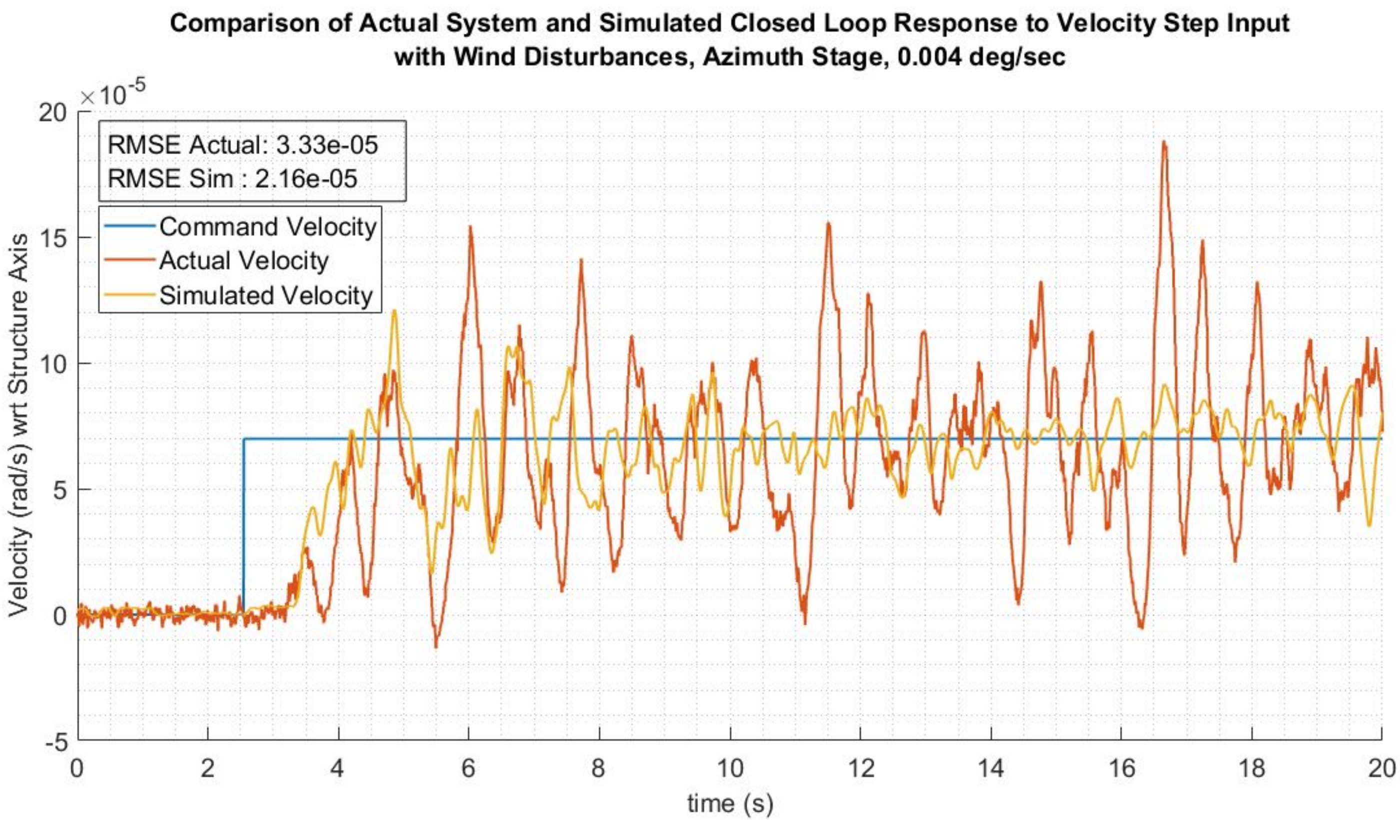
Gusting Wind Disturbance



$$k_t = \frac{2(\tau 0.5 \rho A D)\sqrt{6\kappa}}{N} v_m^2$$

see [3]

Integrated Model



Conclusions, Future Work

- Understanding current architecture
- Understanding model structure
- Developing simulation tools
- Developing disturbance models
- Systematic control system design
    - QFT? LQR?
- Controller Implementation
    - RFI / EMI
    - Compatibility
    - Pointing/Tracking Performance

References

[1] R. Masey, “13.5m MeerKAT dual offset antenna system description document,” Vertex Antennentechnik GmbH, Description Document OD-1012033-01-01, Oct. 15, 2014.

[2] W. Gawronski, B. Bienkiewicz, and R. Hill, “Wind-induced dynamics of a deep space network antenna,” Journal of Sound and Vibration, vol. 178, no. 1, pp. 67–77, Nov. 1994, issn: 0022460X. doi: 10.1006/jsvi.1994.1468.

[3] W. Gawronski, “Three models of wind-gust disturbances for the analysis of antenna pointing accuracy,” IPN Progress Report 42-149, May 2002

Thank You!

Questions?

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