Attitude and Orbital Control System (AOCS) & Communications System (COMMS) for RyeSat On-Orbit Assembler Satellite

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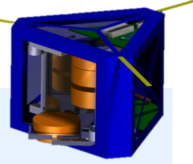
MOTIVATION

To develop an active attitude control system capable of stabilizing a satellite during de-tumbling and operation, as it assembles a TubeSat during orbit in space. This project provides a solution to address the challenge of on-orbit assembly attitude control and communications presently faced by the space industry.



BACKGROUND

A request has been made to have the previously designed RyeTubeSat satellite assembled in orbit. For this to be possible, a new satellite, RyeSat, was developed to perform this assembly operation. Consequently, RyeTubeSat has also been redesigned for modular assembly in space. The RyeSat Assembler Satellite consists of robotic arms capable of assembling the modules in space, and all the necessary subsystems to support this mission.

DESIGN APPROACH

AOCS

The design work consists of developing the following models, then integrating into the full satellite system:

- Actuators | Magnetorquers (ACT)
- Attitude Dynamics (DYN)
- Sensor Model | Simulated Magnetometer and Sun Sensor
- Attitude Determination (DET)

De-tumbling Control Law [1]

$$m = \frac{-k}{||B||} b \times \left[(I_3 - bb^T)\omega \right] \quad (1)$$

$$b = \frac{B}{||B||} \quad (2)$$

Active Control Law [2]

$$u = -[\epsilon^2 k_1 q_v + \epsilon k_2 \omega_r] \quad (3)$$

$$M = \tilde{B} u \quad (4)$$

$$\tau_c = M \times B \quad (5)$$

COMMS

The design work consists of performing the following:

- Antenna analysis
- Link budget
- Communication and testbed software development
- Circuit design
- Circuit testing

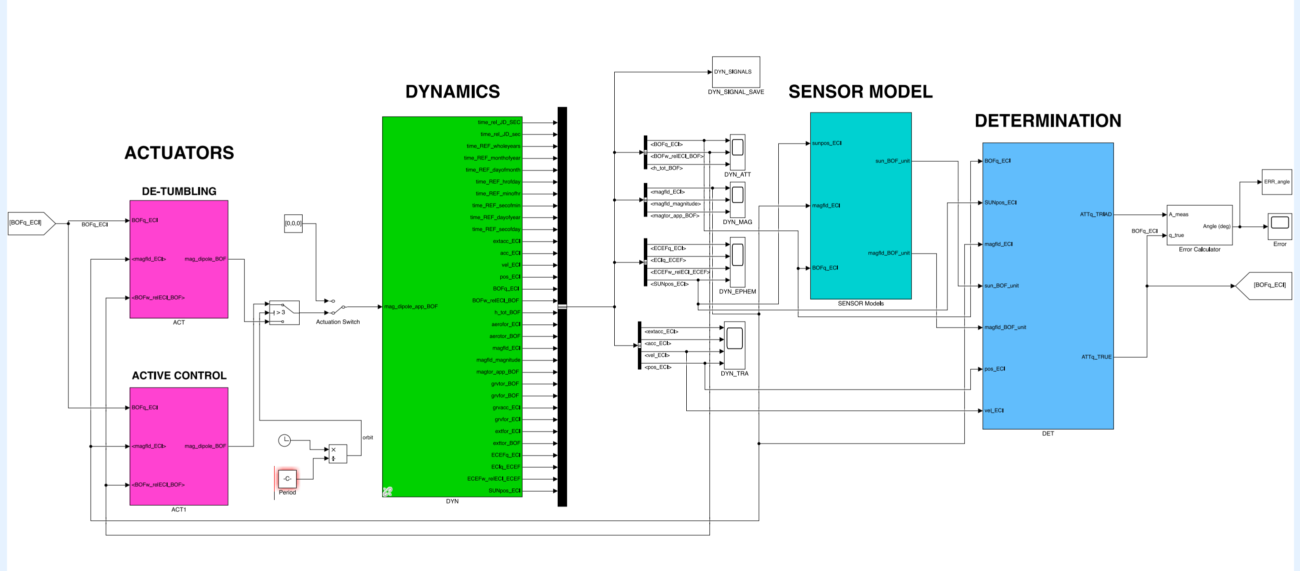
The following components were used for the testing apparatus of the system:

- Arduino Uno acting as a radio modem
- Arduino Nano acting as the Communications system
- PC acting as ground station and CD&H simulator

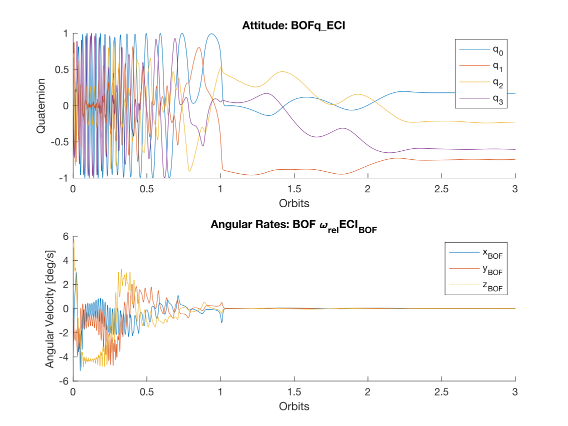
The link budget was governed by the following equation:

$$\frac{E_b}{N_o} = P + L_t + G_t + L_s + L_a + G_r - R - k - T_s \quad (6)$$

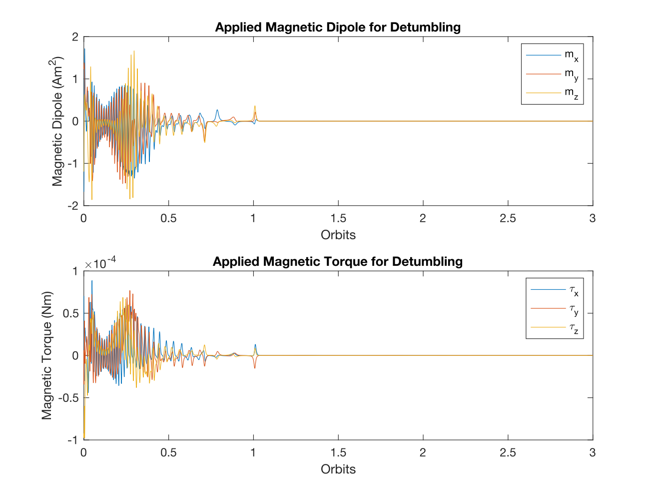
RESULTS | ATTITUDE CONTROL (AOCS)



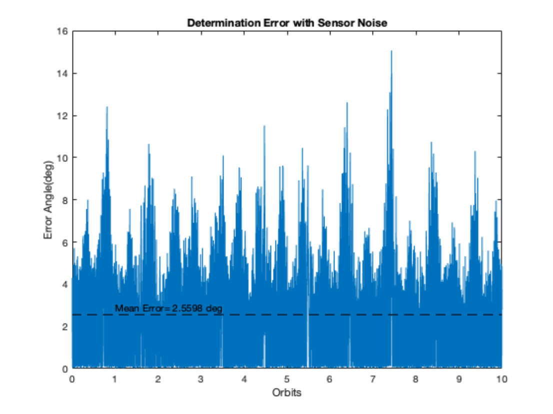
Complete AOCS Simulink Model



Quaternions and angular velocity during detumbling



Magnetic dipole and torque requirements during detumbling



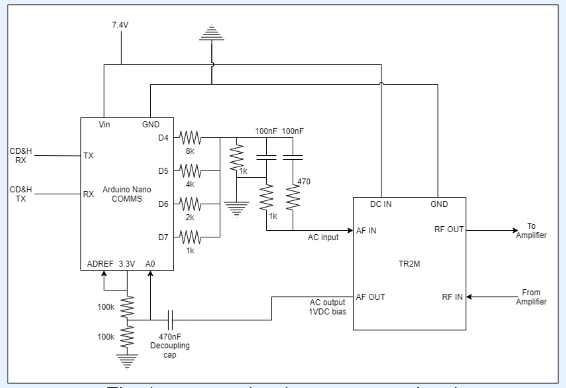
Error angles for attitude determination during orbit

New Space Systems NCTR-M002 Magnetorquer Rod

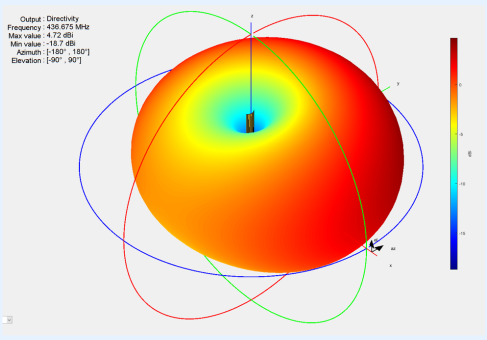
Dimensions: 70mm x ⌀10mm

Max. Magnetic Dipole Moment: 0.2Am^2

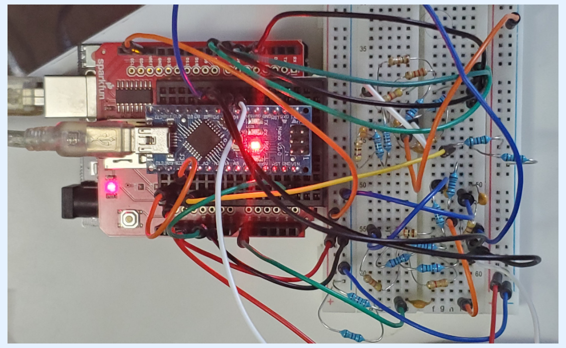
RESULTS | COMMUNICATIONS (COMMS)



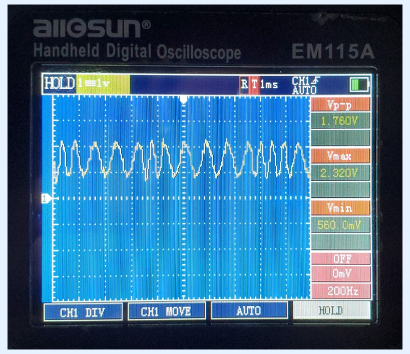
Final communications system circuit



Antenna radiation simulation



Physical circuit testing apparatus



Successful communication testing on Bell 202 standard

CONCLUSIONS AND REMARKS

Successfully developed a state feedback system capable of adjusting magnetic torquers to counterbalance external disturbances affecting the RyeSat's attitude during its mission.

AOCS Future Work:

- Modelling the RyeSat de-orbit sequence
- Increasing efficiency by testing different magnetorquer sizes
- Further tuning of active attitude controller gain

COMMS Future Work:

- Completion and debugging of COMMS and testing program
- Building circuit for modem connection to amplifier and antenna
- Full physical hardware and integration testing

REFERENCES

1 F. L. Markley and J. L. Crassidis, "Attitude Control," in Fundamentals of spacecraft attitude determination and control, SPRINGER, 2016, pp. 287-341.

2 A. van Hengel, " Magnetorquer Design and Attitude Control for SHAPE," Magnetorquer Design and Attitude Control for SHAPE, Nov. 2018.