**Abstract**

This poster is a sequel to a paper presented at the 34th Annual AAS Guidance and Control Conference in 2011, which first introduced dither-based calibration of gyro scale factors. The dither approach uses very small excitations, avoiding the need to take instruments offline during gyro scale factor calibration. In 2017, the dither calibration technique was successfully used to estimate gyro scale factors on the GOES-16 satellite. On-orbit dither calibration results were compared to more traditional methods using large angle spacecraft slews about each gyro axis, requiring interruption of science. The results demonstrate that the dither technique can estimate gyro scale factors to better than 2000 ppm during normal science observations.

**Background**

**MOTIVATION**

- Gyro scale factor (SF) will drift after launch
  - Initial 15-yr stability estimate: 5%, 50000 ppm
- Scale factor error corrupts compensation of dynamic motion, which is needed to operate through thruster maneuvers
  - On-board instrument pointing (control)
  - Ground-processed image geolocation (knowledge)
- On-orbit scale factor calibration required
- Standard calibration methods require large angle slews, interrupting instrument operations, reducing science availability for ~1 hour
- Maximize science data availability
  - Meet science requirements during thruster maneuvers
  - Minimize downtime for calibrations

**NOTIONAL APPROACH**

- First presented in AAS 11-095, “GOES-R Gyro Scale Factor Calibration”
- Impart subsonic “tone” onto spacecraft attitude
- Tone is compliant with attitude, rate, torque allocations
- Detect imparted tone in gyro and star tracker data
- Compute ratio of amplitudes of detected tones
- Gyro / Star Tracker ratio is gyro scale factor estimate
- Repeat and average

**EXPECTATIONS**

- Simulated results in AAS 11-095
  - Calibration accuracy: 2150 ppm, 1σ
- On-Orbit calibration accuracy for GOES-R
  - Success Criteria <10000 ppm, 3σ
  - Goal = 5000 ppm

**Implementation**

**QUASI-SINUSOIDAL EXCITATION**

- Attitude Control System (ACS) response to dither step commands exhibits large but very repeatable overshoot
- Increased frequency of step commands to match half-period of overshoot to yield quasi-sinusoidal response

**Flight Results**

**ACCURACY**

- Variations of dither calibration with square and quasi-sinusoidal profile tested on-orbit, consistently beating 5000 ppm accuracy goal

**Requirements Compliance for Baseline Dither**

- Key Attitude Control Requirements

**GOES-16 Operations and Beyond**

**DITHER CALIBRATION**

- Dither gyro scale factor calibration baseline for GOES-16 operations
- Profile parameters:
  - Waveform
  - Amplitude
  - Period
  - Duration

**NEXT STEPS**

- GOES-S (soon to be GOES-17) GNBC FSW includes onboard sinusoidal dither generator
  - Harmonically purer excitation
  - More benign disturbances than current step commands
  - Less spacecraft commanding

**Conclusion**

- Dither calibration of gyro scale factors previously shown feasible in AAS 11-095 using high-fidelity simulation
- Dither method successfully demonstrated in flight on GOES-16 in 2016-17
  - Achieved <1200 ppm, 3σ accuracy
  - All instruments perform normal operations during calibration
- Dither calibration baselineed for operations on GOES-R Series
- Onboard dither excitation Incorporated into GOES-S, T, and U
- Dither Calibration is Patent Pending

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