Use of a Closed-Loop Tracking Algorithm for Orientation Bias Determination of an S-Band Ground Station

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Introduction

In 2015, the Space Communication and Navigation (SCaN) Testbed Project completed installation and checkout testing of a new ***S-Band Ground Station*** at the NASA Glenn Research Center in Cleveland, Ohio.

One aspect of checkout testing the GRC Ground Station (GRC-GS) was the derivation of misalignment angles associated with the installation of the gimbal to its roof-mounted pedestal.

Ground Station Description

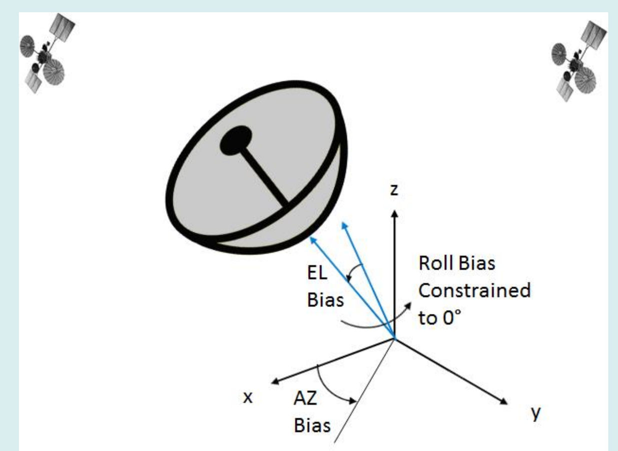
- An ideal ground station would have its ***Az***=0° angle aligned with true north
  - In the real world this is not always possible
  - The Solution is to determine bias angles after installation

GRC-GS Equipment Located on the Roof of Building 110 at the Glenn Research Center

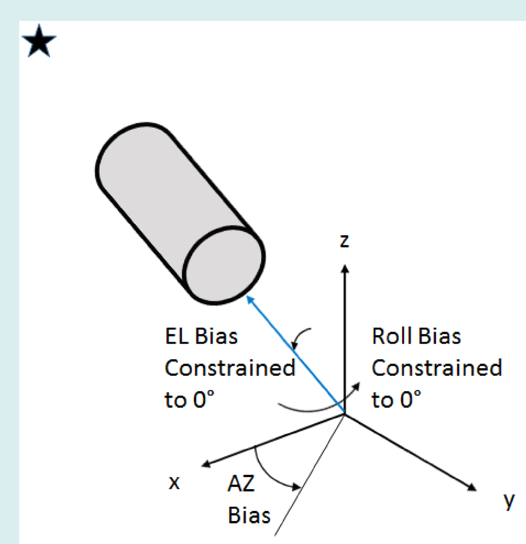
- The primary Equipment of Interest is the Moog QPT-500 Positioner
  - 420° ***Az*** and 180° ***El*** range of motion
  - 20°/s in ***Az*** and 4°/s in ***El*** slew rates
  - Used for tracking the International Space Station (ISS) and the Tracking and Data Relay Satellites (TDRS)
- Antenna is a 2.4m Parabolic Dish with circularly polarized Feed
  - 3.9° Beam-Width

Alignment Process

- Telescope gimbal manufacturers often use a two-star alignment process to determine the necessary Roll, Pitch and Yaw offsets
  - Can be used to solve for offsets in all three Cartesian coordinates
  - For best results stars must be in distinct regions of the sky



- Alternatively a one-star alignment can be used if we constrain the allowable motion
  - The gimbal must be level and unable to roll



FOR THE GRC-GS A HYBRID APPROACH WAS USED THAT COMPLETED A "ONE-STAR" ALIGNMENT WITH TWO DISTINCT TDRS

RF Alignment via TDRS

SETUP

- Using TDRS East and TDRS Spare Orbital Slots
  - Non-ideal for pointing diversity
  - Two opportunities to solve for bias angles
- SGP4 propagator derived from TDRS Two-Line Element (TLE) data
- GRC-GS measuring received power levels via a spectrum analyzer on a coupled port
  - Measurements feed into closed loop tracking control for the gimbal
  - Important to know predicted power level ahead of time to avoid a false lock on a side lobe

Control Modes

- Spiral Track – Searches for coarse alignment
- Two-Axis Dither – Maximizes received RF power

RF Alignment via TDRS

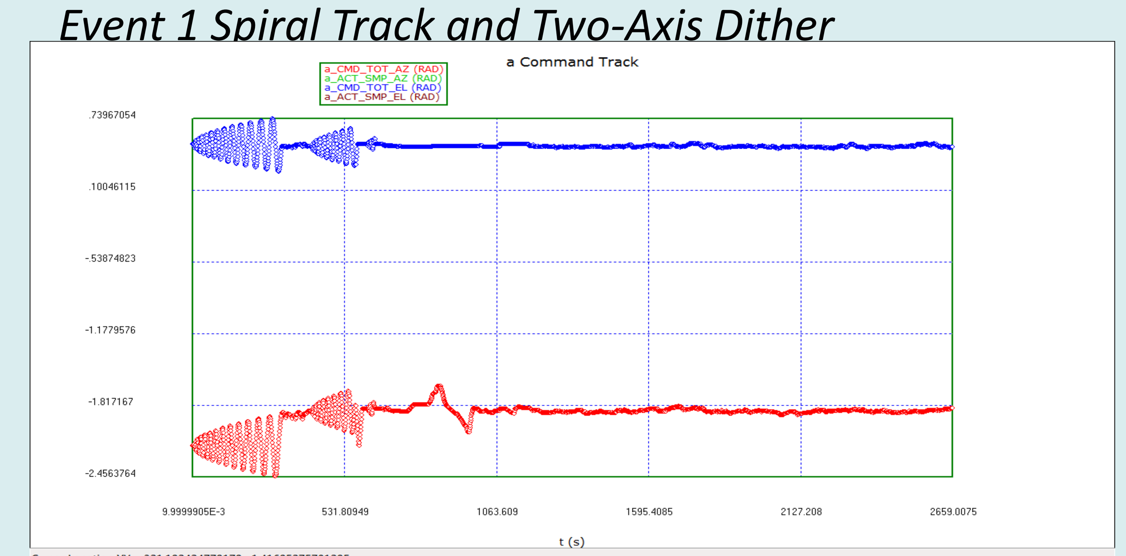
Expected Uncertainty

Error Source	Cartesian Error	Angular Error	Total Error
TDRS Position	50m	7.16E-5°	---
SGP4 GEO Error	910m	1.30E-3°	---
Gimbal Step Size	---	0.01°	---
Wind Oscillation	---	0.02°	---
Cumulative Error	---	---	2.23E-2°

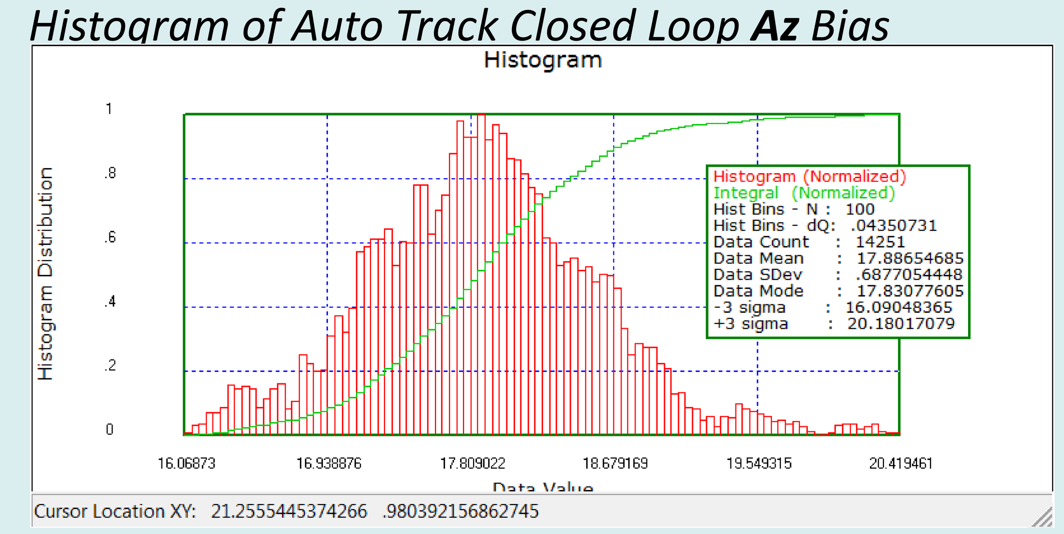
Alignment Test Information

Event	Year	Day of Year	Source	Start Time	Stop Time
1	2014	211	TDE	19:17:00	20:01:12
2	2014	212	TDS	16:44:20	17:24:59

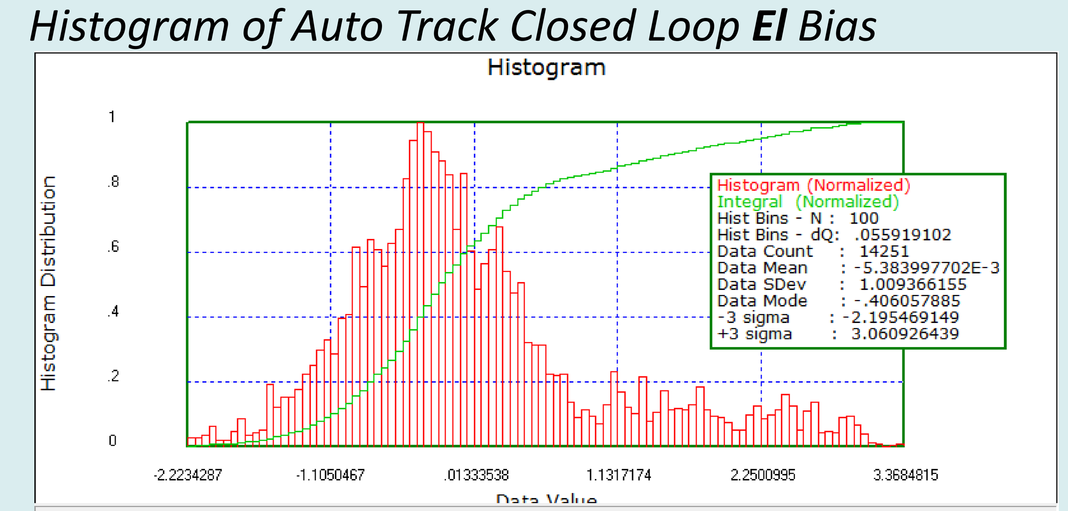
Event 1 Spiral Track and Two-Axis Dither



*Histogram of Auto Track Closed Loop **Az** Bias*



*Histogram of Auto Track Closed Loop **El** Bias*

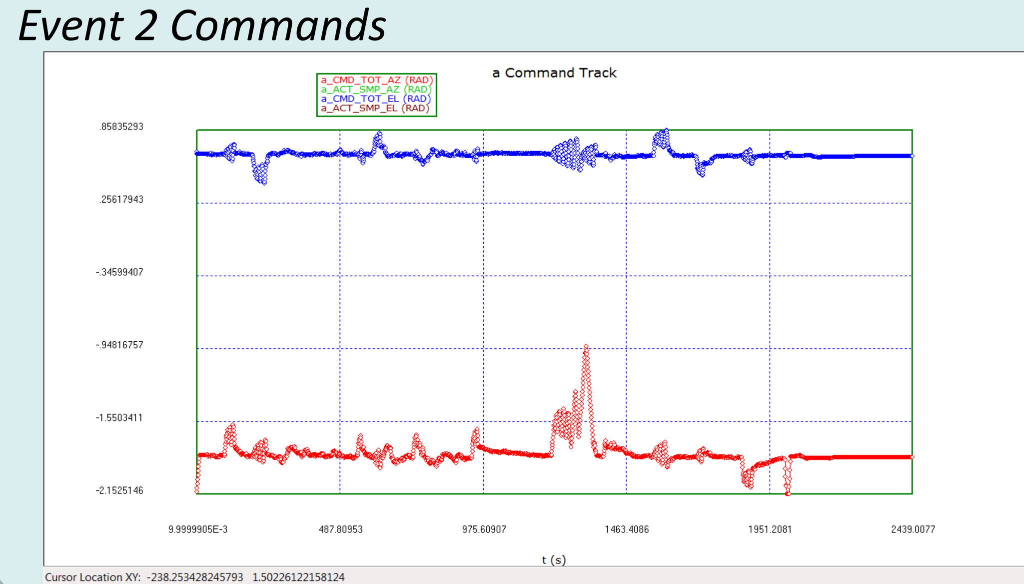


Event 1 Results

- **Auto-track converged on an *Az* bias of 17.9°**
- **Confirmed *El* Constraint of 0.0°**

RF Alignment via TDRS

Event 2 Commands



Conclusions

- Able to use Bias angles from event 1 to lock and reacquire during event 2
- Demonstrates this method is a useful alternative to site surveys for determining ground station bias angles
- Several important dependencies
  - RF Source location needs to be stable and well known
  - Requires stable closed loop tracking setup and control
  - RF Source and environment should be well understood

Acknowledgments

The authors would like to thank the SCaN Testbed Project for allowing the opportunity to derive the Ground Station alignment via a high-fidelity approach, as well as to the SCaN Testbed Mission Operations Team for their efforts in coordinating TDRS events directed to the NASA Glenn Research Center to enable this type of testing to be performed for the first time.

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37th Annual AMTA Symposium