6-axis robot for absolute antenna calibration at the US National Geodetic Survey

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Overview

NGS has a demonstrated history of providing antenna calibrations to the geodetic community, mostly through relative calibrations (since 1994), but with a brief period of GPS-only absolute calibrations.

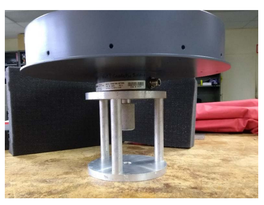
To provide GNSS absolute calibrations, **NGS has commissioned a 6-axis robot** which is capable of moving the antenna under test through the full range of angles and motions necessary for calibration. The new robotic calibration system is permanently installed at NGS's Testing and Training Center (TTC) in Woodford, Virginia.

Early results are encouraging, and the system shown here is still under development. This poster provides an update on the current status and future plans for NGS GNSS absolute antenna calibrations.

Equipment

KUKA KR60 HA

- HA: high accuracy (individually calibrated at factory) = 0.2 mm positioning?
- Up to 60 kg payloads
- 10 cm custom extension
- Can add additional 10 cm offset



Septentrio PolarRx2eH receiver

- Dual antenna rx = common rx clock for ref and AUT
- Not full GNSS

Calibration / Validation

- "High accuracy" robots still require in-situ calibration to achieve 0.1mm accuracy
- Outdoor environment = temperature-specific DH models, or real-time monitoring system (laser tracker or photogrammetry system with Spatial Analyzer)
- Collaboration with NIST - LAPS for indoor chamber calibration, robot metrology expertise

What's Next?

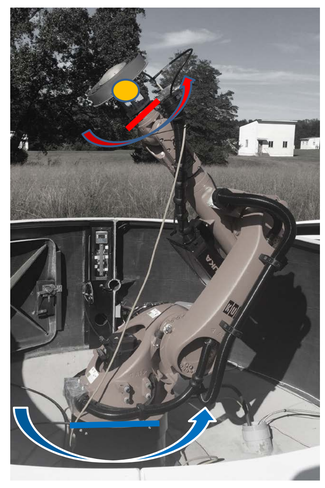
Upcoming Changes to Calibration System

- Debugging robot control program (ending before reaching lowest elevation angles in AUT frame)
- Use full GNSS receivers (two Septentrio PolarRx5)
- Install permanent pier for reference antenna
- Reanalysis of multipath reduction assumptions using multipath toolbox (A. Bilich, future publication)
- Check tracking on all GNSS frequencies and tailor observable type (for example, L2C) and tracking loops to eliminate overshoot
- Measure and account for flange-tool eccentricity
- Add flex cable to robot section

Method

Data Collection

- ARP of antenna under test (AUT) held fixed
- Actively steer to SV's in view, with grid search over 90° to -10° elevation
- Local elevation angle cutoff of 30° to minimize multipath
- Move every ~ 3 seconds, at 30% velocity
- Rotations at adjacent times to add angular contrast and remove multipath
  - A6 "wrist" rotations = AUT azimuth change
  - A1 "waist" rotations = AUT elevation change



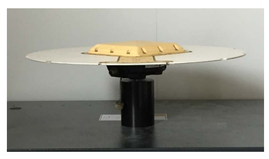
Models: phase windup, differential geometric range

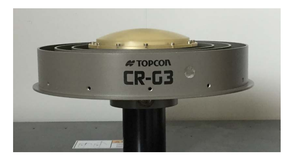
Data Analysis

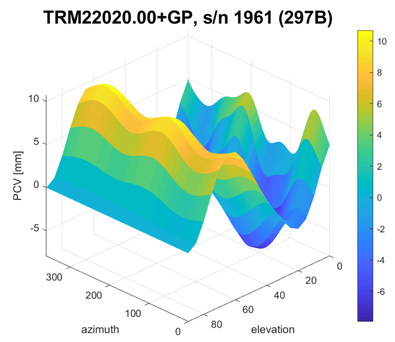
1. Two-station difference on short baseline (~ 5m)
2. Time difference between adjacent epochs (difference A1 and A6 spins)
3. Fit spherical harmonic (degree 8, order 5) to data, with SVD solver

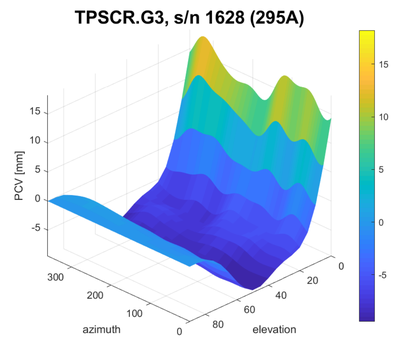
Preliminary Results

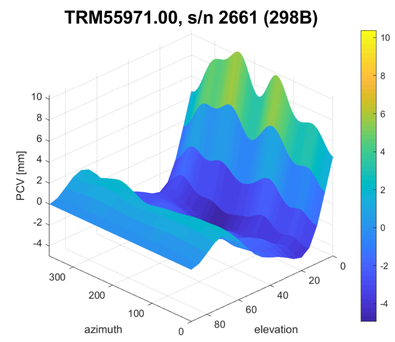
GPS L1: individual NGS vs. IGS14 type mean

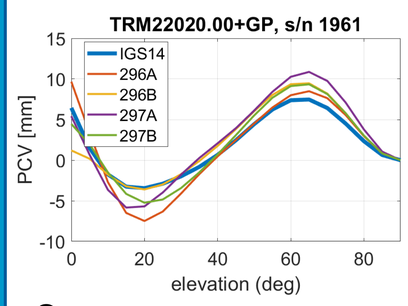


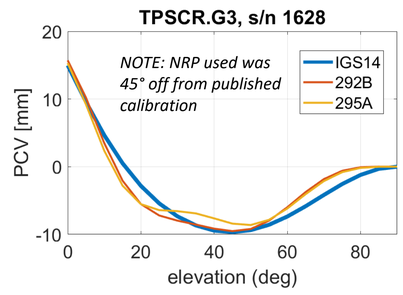


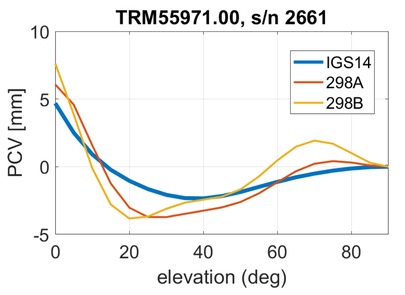












PCO

IGS (27)	1.25	-1.44	70.58
NGS (1) - 0.09	1.38	97.17	

IGS (16)	-0.17	0.30	88.41
NGS (1)	0.07	-0.36	115.05

IGS (58)	1.29	-0.19	66.73
NGS (1)	-2.58	-0.52	96.89

- Reasonable PCV and NOAZIM patterns
- ~ 30 mm systematic vertical PCO discrepancy requires further investigation

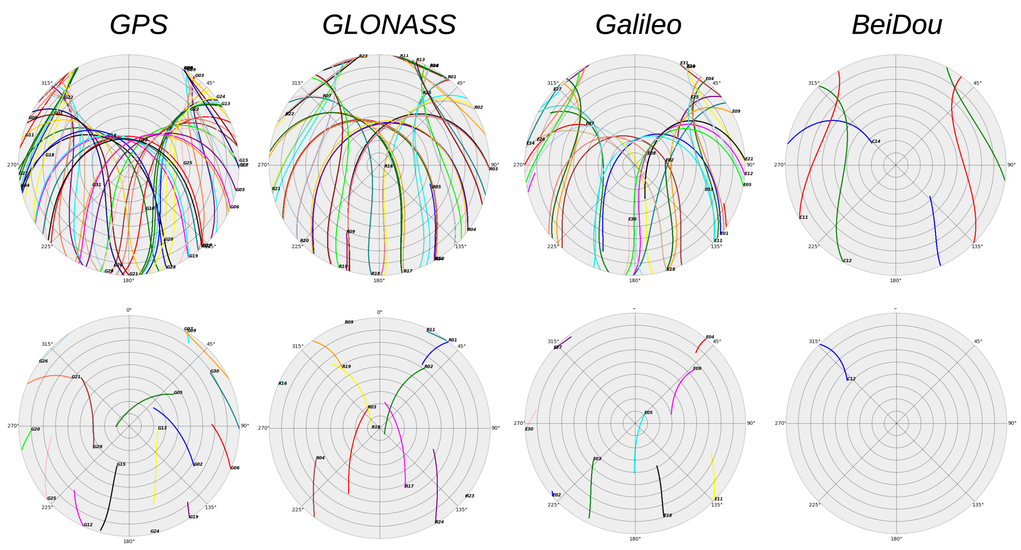
GNSS Visibility at TTC Site

Predicted visibility on 2018 Oct 12

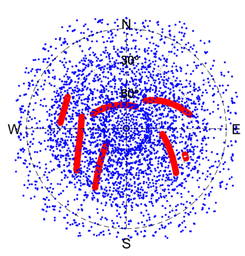
24 hours

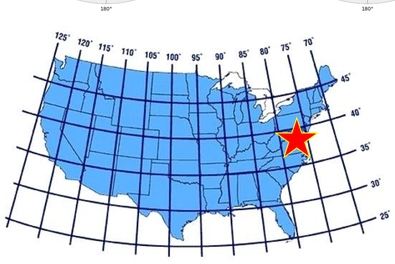
2 hours

1600-1800 UTC



- Active steering will enable GNSS calibrations with limited visibility





Future Work with IGS Colleagues

- "Ring calibration" with IGS antenna calibration centers
- Run control and processing code on KUKA robots at other facilities?