First Results from the Processing of GRAS Raw Sampling Data

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with many thanks to M. Bonnedal, J. Christensen (both RUAG), and A.S. Jensen

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GRAS Measurement modes

Examples of raw RS data

Initial (bending angle) retrievals

An issue with GRAS: Closed loop data gaps not covered by raw sampling (yet)

Summary and outlook
**GRAS measurement Modes**

- **Dual Frequency Carrier Tracking:** code and carrier for L1 and L2 are tracked; both (+ C/A) are reported @ 50 Hz

- **Single Frequency Carrier Tracking:** C/A code and carrier phase are tracked; C/A code and carrier are reported @ 50 Hz

- **Single Frequency Raw Sampling:** C/A code tracked, 1 kHz sampling of carrier

- SF carrier tracking and raw sampling can occur simultaneously

- Either L2 or RS

- GRAS uses a geometrical doppler model (p vs SLTA) when in raw sampling:
  - Implemented as lookup table in the receiver (~ 10 Hz)
  - Transparent to the user / in the measurement reconstruction

- Tracking state information available
**Settable parameters:**
with default values given in SLTA
(and RTH)

**Rising:**
- **SLTA\_V** = -140 km
  (start C/A acquisition)
- **SLTA\_L2** = -35 km
  (start L2 acquisition)
- **SLTA\_A** = 0 km
  (delay L2 acquisition)

**Setting:**
- **SLTA\_AV** = -140 km
  (release SV)
  
  *(courtesy Saab)*

* This altitude is settable
GRAS Measurement Modes (Setting)

- C/A SF I’s and Q’s
- Dual branches due to navigation message (is usually removed via sign(I))
GRAS Measurement Modes (Rising, cont’d)

Channel 08

Time since 2007/09/06 00:00:00 (UTC)

C/A 1
C/A Q
R/S 1
R/S Q

Time since 2007/09/06 00:00:00 (UTC)

DF
SF
RS
Navigation Bit Removal

Uncorrected

Corrected

3 sec

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Navigation Bit Removal (cont’d)

- Currently using navigation bit archives from UCAR and GFZ (Thanks!!!)
- Considering implementation of an operational bitgrabber network for future operations (and at least the next 10+ years)

- Currently working on Q/C, data format specifications, prototype implementation, internal removal algorithms,…
Closed Loop vs. Raw Sampling Consistency

The diagram shows graphs comparing the performance of different sampling techniques over time. The x-axis represents time, with specific timestamps marked. The y-axis represents relative carrier amplitude (V @ 50 Ohm). Different lines represent L1, L2, and C/A signals, with each showing variations and consistency issues over the recorded period.
Co-channel Interference

- Other GPS SVs visible in the antenna beam appear in the spectrum...

- ...as CA code orthogonality is not perfect (25 – 30 dB only)

- Observed doppler offsets are consistent with actual GPS ephemeris
Measured Doppler vs. Model

Onboard doppler model

Enhanced doppler model

(analysis and figures courtesy RUAG)
Bending Angle Example - High Latitudes

- Note: impact parameter altitudes are ~ 3 km at the surface
- FSI @ 1kHz, CL upsampled
- Arne Jensen helped us a lot!
- We’re just learning how to do it (i.e., it’s preliminary)
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In rising occultations:

- Receiver must abandon RS tracking before it can start to look for L2 / DF carrier tracking.
- If signal dynamics is strong, GRAS may lose DF (and sometimes even C/A) carrier tracking after having terminated RS.
- Data gaps in C/A cannot be filled as RS was already abandoned.
Closed Loop Data Gaps in Rising Occ’s (cont’d)

Tracking States (Velocity Antenna / Rising Occultations)

Signal-to-Noise Ratio

9°N, 120°E
Closed Loop Data Gaps in Rising Occ’s (cont’d)

9°N, 120°E

28°N, 155°E

37°N, 147°E
Closed Loop Data Gaps in Rising Occ’s (cont’d)

- SLTA of highest gap in C/A carrier phase data (October 2007)
- About 33% of rising occultations are affected
- ...big problem!
Closed Loop Data Gaps in Rising Occ’s (cont’d)

- Large fraction of rising occultations affected (33 %)
- Can we adapt our algorithms to deal with these gaps (at least in historic data)?

- Mitigation:
  - Raise SLTA_L2 from -35 km (currently) to -10 … 0 km
  - Comes at the cost of loosing L2 data in tropospheric rising occultations
  - If ionospheric correction turns out to be problem:
    - considering to change GRAS S/W to re-enable RS data if data gaps occur (just as for setting occultation)

- SLTA raise (for testing) planned for later, possibly during in-plane maneouvre on Dec 10th
Summary

- **GRAS measurement modes**
  - closed loop (50 Hz, PLL plus I/Qs, so similar to open loop as long as PLL doesn’t fail completely)
  - raw sampling (1kHz, geometrical doppler model)
  - excellent consistency between closed loop and raw sampling data
  - high sensitivity (even cross channel correlations visible in the raw sampling data)
  - first retrieval results look promising, but we have some way to go yet
  - test data (including bending angles) widely available in a few weeks

- **Closed Loop Data Gaps in Rising Occultations**
  - significant fraction (33%) of rising occultations affected
  - SLTA’s of gaps latitude dependent, highest gaps in the tropics (up to -10 km, corresponding to tropical tropopause altitudes)

- **Other (minor) issues**
  - Occasional cross tracking in early rising RS data (means no data for proper measurements)
  - Occasional amplitude saturation events in RS under moderately high SNR conditions