Sentinel 3 USO observation with GNSS

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S3A Doris USO observation

Summary:

- S3A configuration
  USO observation using GNSS ground tests results

- first flight results

- observed characteristics
  high frequency anomaly in the observed USO data
  evolution during a Doris pass, observation of the SAA effect
  consequences on Doris performance
S3A satellite

GPS antenna

Doris antenna
USO monitoring for altimetry

Sentinel 3: USO reference frequency must be characterized using the S3 GPS receiver
(usually Doris is used for this, cf Jason, Cryosat, Saral)

USO monitoring:

**Doris**: pseudo range measurements, synchronization, mean term frequency identification
(degree 3 polynomial fitting on 2 days), delivery of mean observed frequency on each reference
beacon pass.

**GPS**: continuous monitoring of pseudo range and phase, possible to have an estimation of the frequency
over short intervals (sampling 1 s to 10 s)
Ground test
Receiver/USO ground test

Test performed at Ruag, 10,11,12 January 2012

Objectives: USO interface and compatibility with Ruag Receiver Sentinel 3
verify that the USO frequency can be observed using the GPS measurements (Rinex file)

GPS signal

→ Raw files

Ground processing (GMV - CLS)

→ Rinex files

S3 GPS

→ USO

GPS Ashtech

→ Rinex files

Reference receiver Ashtech, operated by CNES

Availability of the correct Rinex files for the Ruag receiver: end of 2013
Ground tests clock comparison, after PPP processing

S3 GNSS receiver in parallel with Ashtech receiver, same antenna, both receivers connected on the same reference frequency (Doris USO)

PPP processing and comparison of the observed receiver clocks

Sampling 30 s (IGS orbits/clocks for the constellation)
Common degree 2 polynomial removed for the plot, and bias between the two clocks
Fig. 7 – Identified oscillator frequency (in m/s), and errors relative to a third degree model, C1P, C2P case (blue), C1C, C2P+C2S case (green), Ashtech (red)
Flight results
Relativistic effect not modelled --> periodic orbital oscillations, constant amplitude
Some anomalies not due to relativity effects
Anomaly: the 1 s oscillations are too important (6 cm peak to peak)
- a millimeter value is expected
- the Doris residuals are correct (such amplitudes are not observed in the 10 s Doris measurements)
- stable and systematic effects (orbital period amplitude variations)
Clock 1 s variations, day 071, zoom

Beating between two close 1 Hz frequencies or aliasing of higher frequencies

100 s

6 cm
Clock, mid term evolutions (~1000s)

Mid term variations : ~2-3 cm for a Doris pass duration : effect of the Doris USO
Mid term frequency drift analysis

For the clock contribution, the Doris processing is equivalent to:

- remove the long term effect for the on board clock
  (here: second degree polynomial on one or two days)

- adjust a linear variation for a pass (typically 600 s duration)
  equivalent to the classical beacon frequency bias adjustment

impact of the actual on board frequency errors (w.r.t. long term model)
on the residuals
600 s interval linear adjustment

Sub daily clock variations

Residuals after 600 s interval linear adjustment
600 s interval linear adjustment (zoom)

Sub daily clock variations

Residuals after 600 s interval linear adjustment

Important parabolic signatures are remaining (~ 30 cm on one pass)
Geographic position of the anomalies

Estimation of the residuals curvature (600 s duration) normalized in [-1,1] → very clear SAA effect on the USO
600 s interval linear adjustment (small amplitudes)

Amplitudes of a few centimeters are frequent
Smaller geographic effects

Visualisation of the smaller amplitude effects (green corresponds to 0)

to be studied ....
Conclusion

The observation of the Doris USO with the GNSS is very promising for future improvements of the system.

There are still some unexplained signals (at 1 hz) in the GNSS solution but the precision is sufficient to monitor the USO on intermediate durations (Doris pass duration).

These high frequency perturbations are not present in the USO signal directly delivered to Doris.

The USO shows clearly frequency variations related to the South Atlantic Anomaly, and these variations could induce more than 10 cm vertical errors on a single pass.