GNSS space clocks assessment based on different IGS and MGEX data

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INRIM and GNSS Time Metrology

- INRIM is involved in characterization of atomic clocks and timescales in GNSS applications since about 15 years, through different projects with ESA, GSA, Thales Alenia Space, etc.
- Investigations on GNSS experimental data are done on a regularly basis for research activities (automatic detection of clock nonstationarities, statistics on clock frequency jumps, assessment of space clocks performances..) based on IGS and MGEX public data for
  - GPS
  - Galileo
  - Beidou
  - GLONASS
- Analysis of space clocks is made in terms of:
  - Time offset after second order drift removal,
  - Normalised frequency offset,
  - Frequency stability (Allan deviation),
  - Frequency drift.
A project exploiting 9 new time services has been carried out.

The service **TIME INTEGRITY** is a first step towards a GNSS time integrity service and during the experimentation it was based on the RINEX for clocks available on the IGS/MGEX website.

An error in the estimate of on board satellites clocks leads directly to a user degraded performance, so a detection in almost real time of possible feared events is crucial for GNSS systems.

The service monitor the status of the Galileo satellites detecting possible anomalies and generating automatic alerts in case the satellite have not to be used by the final user.

[https://www.demetratime.eu](https://www.demetratime.eu)
DEMETRA project: Time Integrity Service
## IGS product availability

<table>
<thead>
<tr>
<th></th>
<th>Sample Interval</th>
<th>Latency</th>
<th>Continuity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>GPS Satellite Ephemerides / Satellite and Station Clock</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ultra-rapid (predicted half)</td>
<td>Orbits</td>
<td>15 mins</td>
<td>Predicted</td>
</tr>
<tr>
<td></td>
<td>Sat. Clocks</td>
<td></td>
<td>Daily, at 03, 09, 15, 21 UTC</td>
</tr>
<tr>
<td>Ultra-rapid (observed half)</td>
<td>Orbits</td>
<td>15 mins</td>
<td>3-9 hours</td>
</tr>
<tr>
<td></td>
<td>Sat. Clocks</td>
<td></td>
<td>Daily, at 03, 09, 15, 21 UTC</td>
</tr>
<tr>
<td>Rapid</td>
<td>Orbits</td>
<td>15 mins</td>
<td>17-41 hours</td>
</tr>
<tr>
<td></td>
<td>Sat. &amp; Stn. Clocks</td>
<td>5 mins</td>
<td>Daily, at 17 UTC</td>
</tr>
<tr>
<td>Final</td>
<td>Orbits</td>
<td>15 mins</td>
<td>12-18 days</td>
</tr>
<tr>
<td></td>
<td>Sat. &amp; Stn. Clocks</td>
<td>Sat.: 30s; Stn.: 5 mins</td>
<td>Weekly, every Thursday</td>
</tr>
</tbody>
</table>

[http://www.igs.org/products](http://www.igs.org/products)
GPS space clocks assessment using IGS clock products
GPS space clocks *anomalies detection* using IGS clock products

FREQUENCY DATA G02 IGS Product comparison
Frequency jump on 23-Jun-2016

\[ 1 \times 10^{-12} \text{ rel. units} \]
## MGEX product availability

<table>
<thead>
<tr>
<th>Institution</th>
<th>Source ID</th>
<th>Products</th>
<th>Sample Interval</th>
<th>Latency</th>
</tr>
</thead>
<tbody>
<tr>
<td>CODE</td>
<td>com</td>
<td>Clk</td>
<td>300 s</td>
<td>14 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sp3</td>
<td>900 s</td>
<td></td>
</tr>
<tr>
<td>Wuhan University</td>
<td>wum</td>
<td>Clk</td>
<td>300 s</td>
<td>3 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sp3</td>
<td>900 s</td>
<td></td>
</tr>
<tr>
<td>CNES/CLS</td>
<td>grm</td>
<td>Clk</td>
<td>30 s</td>
<td>5 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sp3</td>
<td>900 s</td>
<td></td>
</tr>
<tr>
<td>GFZ</td>
<td>gbm</td>
<td>Clk</td>
<td>30 s</td>
<td>1 day</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sp3</td>
<td>900 s</td>
<td></td>
</tr>
</tbody>
</table>

[http://mgex.igs.org/IGS_MGEX_Products.html](http://mgex.igs.org/IGS_MGEX_Products.html)
Galileo space clocks assessment using MGEX clock products
Galileo space clocks assessment using MGEX clock products

- Each analysis center has freedom in choosing algorithms and reference clocks
  → might change on a daily basis, which can explain significant day boundary jumps.

⇒ Choose one station (STN) as reference throughout analysed period:

\[
(SVN-REF) - (STN-REF) = SVN - STN
\]
Conclusions

• IGS clock products can be used to assess space clocks performances.
  – Ultra-rapid products have to be properly treated with outliers removal.
• MGEX clock products broaden the analysis to other constellations.
  – Data pre-processing actions have to be taken to reveal true behaviour of space clocks (change of reference station, outliers removal,..).
• INRIM uses IGS and MGEX public clock products for different research activities; GNSS clock characterization can be useful for:
  – GNSS users, in order to improve both position and timing accuracy,
  – Space clocks manufacturers to understand clocks behaviour after launching,
  – Scientist interested in GNSS space clocks nonstationarities detection and performances.
References


Thank you for your attention