Monitoring the Time Bias in laser ranging stations thanks to the T2L2 experiments

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**Context**

**GGOS Recommendations**

Network accurate at **1 mm** and stable at **1 mm/y**

[Plag et al. 2009]

**ILRS Recommendations**

Laser Ranging stations synchronized at +/- **100 ns** w.r.t. UTC

[Pearlman et al. 2002]

**Detect and reduce the systematic errors**

**Time Biases**
Origin of Time Biases in laser ranging stations

<table>
<thead>
<tr>
<th>Origin</th>
<th>Stability</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Cables</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Event Timer</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Reference points and calibration</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Receiver [Lombardi 2008]</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Human factor</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
**T2L2 experiment on-board Jason-2**  
*(Time Transfer by Laser Link)*

**T2L2:**
- On-board Jason-2 Satellite [Samain et al. 2008]
- Operational from June 2008 to April 2018
- Aims to synchronize on-board and ground clocks
- Time colocation in space

**TIME BIAS DETERMINATION:**
- Direct and independent
- Received the GPS PPS, accuracy at: 10/15 ns [Exertier 2010]
- Ground to Ground synchronization at ns level accuracy [Exertier et al. 2014, 2017] and sub-ns [Samain et al. 2018, IEEE]
Time Bias history for almost 10 years (Yarragadee and Mt Stromlo)
What we learnt from T2L2

• Powerful tool (direct and independent) to determine time bias.
• Laser Ranging station are NOT synchronized to the UTC into the 100 ns requirement, and could even reach several of microseconds.
• Time biases evolve rapidly and randomly and are correlated to the events in the laser station.
• Microsecond time biases lead to millimeter effects on geodetic products (Station positioning, POD) [Exertier et al., 2017]
• [Belli et al. 2017]
Yarragadee Moblas-5: E.T. changed 9/11/2017

Graph showing data with Time Bias and RMS (ns) over time from 2016.00 to 2018.00.
Hartebeesthoek Moblas-6: E.T. changed 11/29/2017

The graphs show the Time Bias (μs) and RMS [ns] versus Time [year] from 2016.25 to 2018.00. The top graph depicts Time Bias with blue dots, and the bottom graph shows RMS with red dots. The data points are scattered across the time periods with some clustering in specific time frames.
Changchun
Herstmonceux
After T2L2 and conclusions

ACES-ELT – ISS (2020)

New “T2L2”, on GNSS (i.e. LTT)?

Stations need to calibrate the time distribution!

Geodesy, navigation...
[Exertier et al. 2018]

• T2L2 determined Time bias with a ns accuracy
• Independent from orbit and direct method
• Stations improved, but still need to meet the ILRS recommendation
• We noticed TB changes (e.g. Event timer)
Thank you for your attention!

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Bibliography


