Zero, single and double difference analysis of GPS and GIOVE-A/B L1 and L5/E5a pseudo range and carrier phase measurements

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Overview

- Short and zero baseline measurements

Part I
- Analysis of L1 pseudo range noise for GPS, GIOVE A/B and EGNOS
- Analysis of L1 carrier phase noise for GPS, GIOVE A/B and EGNOS
- Conclusions

Part II
- Analysis of L5 pseudo range noise for GIOVE A/B and GPS 01
- Conclusions
Short baseline measurement in field near Delft with simultaneous tracking to GIOVE A and B.
Short Baseline

Short baseline - $CN_0$ versus Elevation

Measured $CN_0$ [dB-Hz]

GPS WEST
GPS EAST
GIOVE A
GIOVE B
EGNOS 120
EGNOS 126

Satellite elevation [°]
Zero baseline
Stand alone receiver code-minus-phase observations for GPS PRN 18. Both the zero difference observations and the measured C/N₀ show a periodic effect, most likely caused by multipath. The time differenced observations do not show these variations but the variance of the noise does change with the C/N₀.
Standard deviation of code-minus-phase versus measured $C/N_0$ of standalone receiver for data segments of 120s after removing instrumental delays, ambiguities, and low frequency multipath and ionospheric delay. The standard deviation for a $C/N_0$ of 45 dB-Hz is estimated by fitting an exponential curve.
Analysis and grouping of the results

- Short and zero baseline measurements were used to determine the measurement noise of GPS, EGNOS and GIOVE-A/B pseudo range and carrier phase observations, under real operational conditions.
- Zero, single, double and time differences were used to estimate the different stochastic properties of the observations, and group the estimated stochastic properties according to their noise properties.
- Were able to group the different results into 4 groups.
- See Table on next slide...
Normalized standard deviations of the code noise in meters for C/N0 = 45 dB-Hz for each GNSS and multiple analyses techniques. The results are grouped in 4 groups based on noise characteristics.

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Thermal noise...</th>
<th>GPS</th>
<th>Galileo</th>
<th>EGNOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standalone &amp; Short baseline</td>
<td>+ multipath</td>
<td>0.20</td>
<td>0.14</td>
<td>0.59</td>
</tr>
<tr>
<td>Standalone &amp; Short baseline; Time difference</td>
<td>- time correlation</td>
<td>0.10</td>
<td>0.07</td>
<td>0.39</td>
</tr>
<tr>
<td>Zero baseline</td>
<td>- common LNA noise</td>
<td>0.11</td>
<td>0.06</td>
<td>0.21</td>
</tr>
<tr>
<td>Zero baseline; Time difference</td>
<td>- time correlation - common LNA noise</td>
<td>0.07</td>
<td>0.04</td>
<td>0.16</td>
</tr>
</tbody>
</table>
Zero baseline (LNA) cross-correlation, time correlation and thermal noise (without multipath) as determined from Table on previous slide.

<table>
<thead>
<tr>
<th></th>
<th>Group</th>
<th>GPS</th>
<th>Galileo</th>
<th>EGNOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time correlation [-]</td>
<td>3 and 4</td>
<td>0.63</td>
<td>0.56</td>
<td>0.46</td>
</tr>
<tr>
<td>LNA correlation [-]</td>
<td>2 and 4</td>
<td>0.57</td>
<td>0.77</td>
<td>0.85</td>
</tr>
<tr>
<td>Thermal noise [m]</td>
<td>2, 3 and 4</td>
<td>0.18</td>
<td>0.12</td>
<td>0.57</td>
</tr>
</tbody>
</table>
Results

• The Galileo E1BC signal has less thermal noise ($\sigma=\pm 0.12 m$) than GPS L1C/A ($\sigma=\pm 0.18 m$) and EGNOS signals ($\sigma=\pm 0.5 m$).

• There is significant time correlation on the code observations ($0.4 < \rho_{\Delta} < 0.6$)

• Code and phase observations show strong cross-correlation ($0.5 < \rho_{LNA} < 0.9$) for the zero baseline setup.
Short Baseline

ZD and SD - Code-minus-phase - G18 - Short baseline

- $C_L$ [m]
- $SD\text{[m]}$ [m]
- $C/N_0$ [dB-Hz]

UTC 6-July-2008
Ambiguity Resolution

Zero baseline

Short baseline

DD code-minus-phase measurement error - Zero baseline
dataset: 120s - success rate: 99.7908%

DD code-minus-phase measurement error - Short baseline
dataset: 3600s - success rate: 76.5714%
Double Difference Carrier Phase

Short baseline DD phase observations, Doppler offsets and receiver clock rates

Zero baseline DD phase observations, Doppler offsets and receiver clock rates
Short baseline DD phase observations, ΔDD phase observations and measured C/N0
Standard deviation ΔDD - Phase observations - Short baseline
datasegment: 120s

GPS
GALILEO
EGNOS

0.01139*10⁻⁶(C/N₀ - 45)⁻²⁰

Short baseline ΔDD phase observations versus measured C/N0
L5 Tracking (Part II)
Standard Deviation - Code-minus-phase - Receiver on roof
datasegment: 120s

GPS
GALILEO

$0.10314 \times 10^{-\left(\frac{C/N_0 - 45}{20}\right)}$

$0.07504 \times 10^{-\left(\frac{C/N_0 - 45}{20}\right)}$
Standard Deviation - Δ - Code-minus-phase - Receiver on roof
data segment: 120s

- GPS
- GALILEO

\[ 0.05001 \times 10^{(C/N_0 - 45)/20} \]
\[ 0.06285 \times 10^{(C/N_0 - 45)/20} \]
Conclusions

- The Galileo E1BC signal has less thermal noise ($\sigma=\pm.12m$) than GPS L1C/A ($\sigma=\pm.18m$) and EGNOS signals ($\sigma=\pm.5m$).
- There is significant time correlation on the L1 code observations ($0.4<\rho_{\Delta}<0.6$)
- L1 Code and phase observations show strong cross-correlation ($0.5<\rho_{\text{LNA}}<0.9$) for the zero baseline setup.
- The L1 phase observations perform very similar for all three systems ($\sigma<1\text{mm}$).
- L5 code noise is much smaller than L1 both for GPS and GIOVE A/B