GNSS Accuracy Improvements through Multipath Mitigation with New Signals and services

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Evolutions of positioning methods with GNSS signals

- Standalone
- DGPS and RTK
- Network RTK, VRS
- PPP, PPP-AR(PPP-RTK)

Years:
- 80-90
- 90-2000
- 2000-2010
- 2010-2020
Positioning with multi-system GNSS receivers

- GIS;
- DGPS, RTK
- Geodesy;
- RTK
- Machine control application;
  RTK
- Automatic Agricultural systems
  Stand Alone, DGPS, RTK
GNSS signals

GPS

ГЛОНАСС

Galileo

QZSS

COMPASS
Time to fix for ambiguities resolution of RTK for medium range base line
Time to fix for ambiguities resolution of RTK for long range base line

![Graph showing the time-to-fix for different scenarios: GPS+GLN_160km, GPS_only_160km, GLN_only_160km.](chart.png)
Static GPS/GLONASS RTK performances

RTK GPS-only solution:
At all epochs (GPS SVs: 6 ≤ SV ≤ 12)

RTK GLONASS-only solution:
At a subset of all epochs when total number of GLONASS SVs ≥ 7

Accuracy of GLONASS RTK positioning is the same as GPS RTK accuracy
Tracking example, Number of satellites – GPS/GLONASS/GALILEO/COMPASS/SBAS

Number of satellites

- GPS
- GLONASS
- GALILEO
- BEIDOU
- SBAS
- Tracked ALL

Epoch

12:00:00 14:24:00 16:48:00 19:12:00 21:36:00 00:00:00 02:24:00 04:48:00 07:12:00 09:36:00 12:00:00

0 5 10 15 20 25 30 35 40
Multipath error for different GNSS signals

Multipath envelopes for reflection signal with amplitude of 0.5
Multipath error for different navigation receivers technology

![Graph showing multipath error for different navigation receivers technology.](image-url)
GNSS signals for L1 frequency band

- GPS L1: BPSK(1), BOC(1,1)
- GLONASS L1: BPSK(1), BOC(1,1)

Frequency range: 1559 MHz to 1610 MHz, 51 MHz wide
Spectrum in L1 frequency band (GPS/GALILEO L1 and GLONASS L1)
Multipath error for wideband signal in L1 frequency band
Multipath error for DBOC signal

<table>
<thead>
<tr>
<th>Signal</th>
<th>Maximum code multipath error, m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C/A BPSK(1)</td>
<td>7.284</td>
</tr>
<tr>
<td>BOC(1,1)</td>
<td>3.86</td>
</tr>
<tr>
<td>BOC(10, 5)</td>
<td>2.8</td>
</tr>
<tr>
<td>DBOC</td>
<td>2.341</td>
</tr>
</tbody>
</table>
GNSS signals in frequency band of GPS L5, GALILEO E5, GLONASS L3

MPSK(k.m)
Multipath error wideband signal in E5 (L5/L3) frequency band
Precise Point Position

- Current PPP service
  - StarFire
  - OmniSTAR
  - TerraStar
  - IGS-RT

- Calculation of precise orbit and clocks
  - Base stations network
  - Calculation of satellite parameters
  - Real-time corrections

- User Positioning
  - Accuracy
  - Convergence time
Precise point positioning with precise orbit and clocks from different IGS analytic centres

**IGS**

after 30 min. accuracy ~40mm

**IAC**

after 30 min. accuracy ~50mm
PPP with GPS, GLONASS and GPS+GLONASS

Used Final Precise Orbits and clocks from Analytic center IGS.
Period of correction – 30 seconds;

Estimation of RMS solution after 20 minutes - period of convergence.

<table>
<thead>
<tr>
<th></th>
<th>GPS+GLONASS</th>
<th>GPS</th>
<th>GLONASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude RMS, m</td>
<td>0.005</td>
<td>0.018</td>
<td>0.019</td>
</tr>
<tr>
<td>Longitude RMS, m</td>
<td>0.019</td>
<td>0.018</td>
<td>0.019</td>
</tr>
<tr>
<td>Vertical RMS, m</td>
<td>0.019</td>
<td>0.018</td>
<td>0.019</td>
</tr>
<tr>
<td>2DRMS RMS, m</td>
<td>0.019</td>
<td>0.018</td>
<td>0.019</td>
</tr>
</tbody>
</table>
Regional PPP service: QZSS LEX signal

- Time multiplexing Long and Short Codes
- Chip rate 5.115 MHz
- The 4ms Short Code modulated by navigation information by using code shift keying
- 256 code shift position is used
- 2000 Bits/s data stream Reed-Solomon encoded
- The Long Code with length 410ms modulated by square wave with period 820 ms
Precise Point Positioning with Precise corrections from JAXA

- Precise ephemerides Data from JAXA SP3 final archive. Period of correction data – **300 seconds**.
- Only GPS Constellation
- Map View is presented below and estimated RMS solution after period of convergence – **30 minutes**.

<table>
<thead>
<tr>
<th>RMS, m</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Vertical</th>
<th>2DRMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPS</td>
<td>0.044</td>
<td>0.043</td>
<td>0.07</td>
<td>0.063</td>
</tr>
</tbody>
</table>
MADOCA-LEX Precise Point Positioning

- RTCM correction from QZSS, messages 1057, 1059, 1061, 1062, 1063, 1065, 1067, 1068
- Low elevation in test site
GNSS Signals with precise orbit and clock correction

Information about precise orbit and clocks requires fast update rate and can be useful for global region.

The QZSS transmitted precise orbit and clocks in MADOCA-LEX signal. GALILEO is planning to use E6 for commercial service.

Recommendation: PPP corrections from all GNSS providers should have free user access.

Possibility of interoperability of these services.
Summary

1. Possibility of global transmitting of precise orbit and clock corrections at high rate will improve accuracy of positioning with PPP methods in receivers.

2. Common wide band signal for all GNSS in E5 band (E5a/L5 + E5b/L3 band) and L1 band will minimize multipath error and improve time-to-fix for high precision applications and will be compatible with low-cost receiver when signals in half wide band are used.
Thank you for attention!