USE OF FOUR GNSS SYSTEMS IN OPERATIONAL PRECISE POINT POSITIONING SERVICE

Ole Ørpen, Rune Strandli, Javier Tegedor presented by Dr. Lee Ott
Fugro Satellite Positioning
Summary

- Background
- Galileo
- BeiDou
- Performance examples
- Use of Multi GNSS systems
PPP Services are used by Professional High End Users

- Orbit & clock Precise Point Positioning (PPP)
  - Using more accurate orbits than broadcast ephemeris and very precise real-time satellite clock corrections for world wide coverage
  - Using carrier phase dual-frequency measurements to get decimeter accuracy
Fugro Precise Point Positioning services

- Fugro launched in 2009 the G2 service using GPS and GLONASS:
  - Proprietary worldwide tracking network
  - Real-time estimation of orbits/clocks
  - Broadcast corrections using GEO satellites
  - Maritime professional users
  - Highly redundant service
  - Decimeter level accuracy

- Following GNSS evolution, new services have been introduced in Q1 2015:
  - **G2+**: ambiguity-fixed PPP
  - **G4**: addition of BeiDou and Galileo
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Fugro’s first Galileo Only Positioning, 18 March 2013

- Four IOV satellites used in Precise Point Positioning (PPP) at 10 cm level
- Fugro generated high accuracy Galileo orbit/clock data using Fugro’s tracking network
Galileo current status

- G4 system has been qualified for Galileo
- No Galileo corrections delivered to customers yet
- Galileo will be added to G4 when operational (Early Services 2016)

<table>
<thead>
<tr>
<th>Satellite</th>
<th>PRN</th>
<th>Launch</th>
<th>Status</th>
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<tbody>
<tr>
<td>IOV PFM</td>
<td>E11</td>
<td>Oct 2011</td>
<td>OK</td>
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<td>IOV FM2</td>
<td>E12</td>
<td>Oct 2011</td>
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<td>IOV FM3</td>
<td>E19</td>
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<td>IOV FM4</td>
<td>E20</td>
<td>Oct 2012</td>
<td>Only transmitting in E1</td>
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<td>FOC FM1</td>
<td>E18</td>
<td>Aug 2014</td>
<td>Non-nominal orbit</td>
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<tr>
<td>FOC FM2</td>
<td>E14</td>
<td>Aug 2014</td>
<td>Non-nominal orbit</td>
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<tr>
<td>FOC FM3</td>
<td>E22</td>
<td>Mar 2015</td>
<td>Under commissioning</td>
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<tr>
<td>FOC FM4</td>
<td>E26</td>
<td>Mar 2015</td>
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BeiDou, Chinese Satellite Navigation System

- Regional coverage in Asia
  - 3 MEO (Medium Earth Orbit)
  - 5 IGSO (Inclined Geosynchronous Orbit)
  - 5 GEO (Geostationary Orbit)

- Full worldwide Coverage (30 satellites) by 2020

- First BeiDou-3 satellite launched on March 31st
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Examples of BeiDou Coverage 14 October 2015

Satellites

Houston

Oslo

Kuwait

Satellites

Rio

Douala

Mumbai

24 Hours

24 Hours

24 Hours

24 Hours

24 Hours

24 Hours

24 Hours

24 Hours

GNSS planning: http://www.trimble.com/gnssplanningonline/#/Settings

Use of BeiDou in operational Precise Point Positioning service
Challenges for BeiDou PPP

- Challenges for precise orbit determination
  - Geometry
    - Orbit determination for GEOs is particularly challenging due to the static position with respect to the reference station network
  - Satellite attitude:
    - Orbit normal mode used by GEOs

Source: IGS MGEX
BeiDou, Approved by IMO for use at Sea

- BeiDou has gained approved for use at sea by the International Maritime Organization (IMO)

- Third IMO approved system after GPS and GLONASS

IMO Marine Safety Committee (MSC) has during its 94th session 17-21 Nov. 2014:

- recognized the BeiDou Navigation Satellite System (BDS), operated by China, as a component of the World-Wide Radionavigation System (WWRNS)

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Precise Point Positioning using only BeiDou – Perth (Australia)

- The use of GEO satellites in the G4 service allows you to obtain 24/7 PPP using only BeiDou
- Very good horizontal accuracy (<10cm)
- Vertical accuracy is a bit more variable due to GEO orbit errors
Satellite visibility from Oslo 31 July 2015

UTC: 2015-Jul-31 07:35:17
Latitude: 059° 55.117’ N
Longitude: 010° 41.161’ E
Height Above MSL: 37.35 m

SOG: 0 Kn
COG: 119°

Quality: Safe(0.3m)

Accuracy of Solution:
Position: 0.08 m
Height: 0.10 m
Position Type: G4
Corr. Age: 14 s
HDOP: 0.6
G2/XP Expiration Date: 2016-6-4 0:0:0
Expiration Date: 2016-6-4 0:0:0

Satellites used in solution: BeiDou GEO Satellite

Fugro Broadcast Satellite

BeiDou GEO Satellite
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Advantages of multi-constellation PPP

- Increased accuracy and reduced convergence time
- More robustness against:
  - Interference
  - Scintillations
  - Partial sky visibility
  - Spoofing
- Better RAIM protection (increased redundancy)

RAIM: Receiver Autonomous Integrity Monitoring

Lines of Position used in RAIM

Outlier

Use of BeiDou in operational Precise Point Positioning service
Possible future Multi-GNSS Integration

- When Galileo and BeiDou are fully deployed, new positioning scenarios can be envisaged:
  - Deliver two independent solutions
    - Independent GNSS’s and independent corrections
  - Independent of single-system failure
  - Integrity detection is possible by checking the two positions
Conclusions

- BeiDou has completed a constellation for regional 24 hour coverage in Asia.
  - 13 operational satellites
  - Coverage being extended worldwide (2020)

- Galileo moving towards Early Services (2016)

- Fugro introduced the G4 service with BeiDou in Feb. 2015

- Additional GNSS provides an opportunity for improved performance
  - Higher accuracy, reliability and availability
  - Independent solutions
Thank you for your attention!

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