Increasing the Accuracy of Orbital Position Information from NORAD SGP4 Using Intermittent GPS Readings

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12 August 2009

23rd Annual Small Satellite Conference – Logan, Utah, USA
CanX-2

- Canadian Advanced Nanospace eXperiment 2
- 34x10x10cm; 3.5kg - Nanosatellite
- GPS Occultation: Investigate water vapor in the Troposphere & electron density in the Ionosphere
- Uses SGP4 for onboard orbital propagation
CanX-2

- TLE versus CanX-2 GPS lock – April 20, 2009

CanX-2 TLE vs GPS

CanX-2 GPS error estimates
Motivation

• GPS receiver obtains meter-level accuracy.
• Can we use the GPS receiver on CanX-2 to improve our propagated PVT estimates?
• Limited availability: - GPS occultation experiment
  - Very power hungry

Novatel OEM4-G2 GPS Receiver, courtesy of Novatel inc.

SFL Ground Station and Mission control
Objective

• Develop methodology to use GPS readings in SGP4
• Determine the accuracy of the SGP4 propagator using intermittent GPS measurements.
• Determine GPS duty cycle required to remain within a given error tolerance.

Purpose:

• Increase accuracy of orbital position information
• Increase reliability of the error estimates
• Account for the infrequent basis on which the TLEs are issued
Methodology

- GPS – For initial PVT acquisition (CanX-2)
- Convert osculating state vector into the mean orbital elements in TLE format – suitable for SGP4
  - VEC2TLE - *Ernandes (1994)*
- Retrieve TLE from NORAD - for B* term from most recent epoch
- Input into the SGP4 propagator
- Comparison to CanX-2 GPS measurements & STK’s HPOP
Results

Initial GPS PVT:

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
<th>$1\sigma$ Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
<td>2808187.5186</td>
<td>1.9796</td>
</tr>
<tr>
<td>y</td>
<td>1330229.2195</td>
<td>1.6605</td>
</tr>
<tr>
<td>z</td>
<td>-6273855.7531</td>
<td>2.9577</td>
</tr>
</tbody>
</table>

Velocity (m/s) - ECEF

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
<th>$1\sigma$ Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>x-dot</td>
<td>-4697.6095</td>
<td>0.2366</td>
</tr>
<tr>
<td>y-dot</td>
<td>-5076.8138</td>
<td>0.1985</td>
</tr>
<tr>
<td>z-dot</td>
<td>-3185.8990</td>
<td>0.3535</td>
</tr>
</tbody>
</table>

Computed mean orbital elements:

<table>
<thead>
<tr>
<th>Time: 20 Apr 2009 06:57:53.000 UTCG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoch [yyddd]</td>
</tr>
<tr>
<td>Inclination (i)</td>
</tr>
<tr>
<td>Right Ascension of the Ascending Node (Ω)</td>
</tr>
<tr>
<td>Eccentricity (e)</td>
</tr>
<tr>
<td>Argument of the Perigee (ω)</td>
</tr>
<tr>
<td>Mean Anomaly (M)</td>
</tr>
<tr>
<td>Mean Motion (n)</td>
</tr>
<tr>
<td>B* [1/Earth Radii]</td>
</tr>
</tbody>
</table>
Results

CanX-2 GPS lock Comparison – 12 minutes

- Errors (RIC) – Radial, In-track, Cross-track error
Results – 12 hours

HPOP Comparison

Error (km)

GPS Time (s) - Week 1528
Conclusion

• In order to remain within 2km, the GPS should update PVT every 6.5 hours.
  – Approximately once every 4 orbits (LEO)

• In order to remain within 1km, the GPS should update PVT every 4.5 hours.
  – Approximately once every 3 orbits (LEO)

• Assumptions
  – STK’s HPOP has no error
  – GPS error estimates are correct
Conclusion

• Advantages
  – Attitude determination estimate – Magnetometer/IGRF comparison → Minimal
  – Communications – scheduling/tracking → Minimal
  – Payloads – Autonomous Imaging → Valuable
    – On board processing → Valuable

• Feasibility
  – Minimal impact on the existing infrastructure
  – However does require code-upload.
The authors would like to thank the following contributors:

- Ontario Graduate Scholarships (OGS)
- Dr. Susan Skone, University of Calgary
- Defence Research and Development Ottawa
- Canadian Space Agency (CSA)
- Natural Sciences and Engineering Research Council of Canada (NSERC)
- MDA Space Missions
- Ontario Centres of Excellence (OCE)
- Sinclair Interplanetary
References


