NovAtel's SPAN® on OEM6™

Performance Analysis—October 2012

Abstract

SPAN®, NovAtel's GNSS/INS solution, is now available on the OEM6™ receiver platform. In addition to rapid GNSS signal reacquisition performance, SPAN now offers improved pseudorange positioning in difficult GNSS environments.

This paper compares the signal reacquisition performance of a SPAN enabled OEM6 receiver to a GNSS only OEM6 receiver. It also compares the position and attitude performance of SPAN on OEM6 versus SPAN on NovAtel's legacy OEMV® platform. Both SPAN systems were paired with an IMU-CPT and tested in an urban canyon environment. To verify the position and attitude accuracy of these systems, their solutions were compared to a navigation grade IMU post-processed GNSS/INS solution, computed using Inertial Explorer® software from NovAtel's Waypoint® Products Group.

SPAN on OEM6

With SPAN, the GNSS and INS technologies work synergistically. Through tight coupling, the INS improves the GNSS tracking and positioning performance. Stable, high precision GNSS measurements are used to update the INS to compensate for the inertial errors that accumulate with time.

Improved GNSS availability and quality enhances the INS by reducing complete outages and producing higher quality measurements to constrain any inertial error drift. SPAN's rapid GNSS signal reacquisition performance is maintained during short blockages and improved during prolonged or rapid, intermittent GNSS outages.

The increased processing capacity of OEM6 receivers allow all in view GPS and GLONASS satellites to be tracked while running SPAN. With more GNSS signals to use, SPAN's delta phase updates are more powerful on OEM6. When at least 2 satellites (of the same constellation) are available, a delta phase update is applied to control inertial errors.

The OEM6 platform features Receiver Autonomous Integrity Monitoring (RAIM), an algorithm that detects and excludes faulty signals that cause erroneous positions to be produced by the pseudorange positioning filter. This delivers better quality position updates for the INS, especially in environments where a Real-Time Kinematic (RTK) solution is not possible. SPAN further strengthens the RAIM algorithm, allowing for intelligent measurement selection. Only the cleanest measurements are included in the solution.

OEM6 allows GNSS logging rates up to 20 Hz simultaneously with raw IMU data and position, velocity and attitude solutions up to 200 Hz.

SPAN on OEM6 Enhancements

- Tracks all in view GPS + GLONASS signals
- Rapid GNSS signal reacquisition after blockages
- Improves positioning performance in difficult GNSS conditions
- Solves issues created by multipath
- Maximizes logging profile

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Test Description

The objective of our testing was to quantify SPAN on OEM6 signal tracking performance, under both favorable and challenging GNSS conditions. This analysis presents two ground navigation tests. The first test was conducted in open sky conditions, in suburban Calgary, Alberta. The second test was performed in downtown Calgary, a typical urban environment.

Test 1 and Test 2 used similar setups. The equipment was installed in a minivan, with the IMUs securely mounted to the floor. A NovAtel GPS-702-GGL antenna was mounted on the roof of the minivan. The vector between the IMU center and GNSS antenna was accurately surveyed using a total station and considered known to within 1 cm. The antenna signal was split between the SPAN on OEM6 system and the OEM6 or OEMV comparing system. Data was logged from the receivers to a laptop using the USB ports of the receivers.

In the second test, an OEM6 SPAN enabled receiver, with a navigation grade IMU, was also mounted in the minivan. This navigation grade SPAN system logged raw data for post-processing in Inertial Explorer as a reference to evaluate the positional error of the CPT SPAN systems. The navigation grade reference IMU specifications are stated in Table 1.

Table 1: Navigation Grade IMU Specifications

Gyro Bias	0.004 deg/hr
Gyro Scale Factor	5 PPM
ARW	0.0025 deg/√hr
Accel Bias	0.03 mg
Data Scale factor	100 PPM

Test 1

- 1 x GPS-702-GGL antenna
- 1 x FlexPak6™ GPS and GLONASS only enabled receiver
- 1 x FlexPak6 GPS and GLONASS SPAN enabled receiver plus IMU-CPT

Test 2

- 1 x GPS-702-GGL antenna
- 1 x FlexPak6 GPS and GLONASS SPAN enabled receiver plus IMU-CPT
- 1 x SPAN-CPT (GPS only OEMV SPAN combined system with same IMU as in the IMU-CPT)
- 1 x FlexPak6 GPS and GLONASS SPAN enabled receiver plus navigation grade IMU

Figure 1: FlexPak6

Figure 2: IMU-CPT

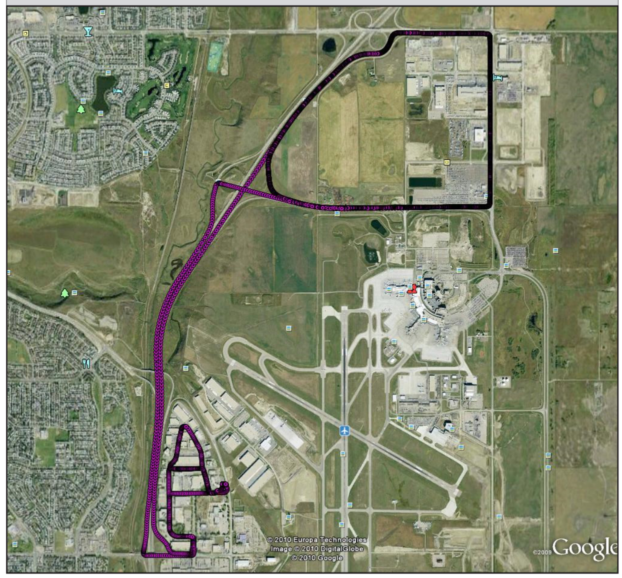
Test Methodology

Open Sky Signal Reacquisition Test

To evaluate the signal reacquisition capabilities of the deeply coupled SPAN system, an open sky route was driven. Specific signal blocking commands were simultaneously sent to both the SPAN enabled OEM6 receiver and the GNSS only OEM6 receiver. The signal blocking command forced the receiver to drop all signals tracked and wait 10 seconds before reacquiring any available GNSS signals. The time from the end of the signal blockage to the reacquisition of each available satellite was measured, for both the SPAN enabled and GNSS-only systems.

The minivan was driven in a suburban area on the edge of Calgary, in normal traffic conditions. Vehicle speeds varied from 50 – 110 km/hr, with occasional stops at traffic lights. A total of 30 signal block commands were sent, each separated by 100 seconds. The test lasted approximately one hour.

Figure 3: Test 1 - Suburban Open Air



Urban Canyon Performance Test

The minivan was driven through downtown Calgary, a dense urban environment. Both receivers were in single point (autonomous) mode. The real time trajectory, computed onboard the SPAN enabled OEM6 receiver, was logged at 10 Hz. The raw IMU data was logged at 100 Hz for post-processing evaluation.

SPAN collected raw GNSS and IMU measurement data for later use. Inertial Explorer software used the stored measurement data, post-mission, to generate a more accurate solution than the real time solution.

A base station was set up on the roof of NovAtel's corporate headquarters in Calgary, approximately 10 km from the test area in the city's downtown core. The base station data was used to post-process the trajectory in differential mode. The route was driven multiple times through the downtown core and is shown overlaid on Google Earth imagery in Figure 4.

Figure 5 shows a typical street view from the test route. As the photo illustrates, the test was undertaken in a dense urban environment, encountering severe multipath and obstructions. The test was performed under normal driving conditions and behaviors, with vehicle speed ranging from 0 – 50 km/hr. The test lasted approximately one hour.

The real time inertial position, velocity and attitude errors from the SPAN on OEM6 and SPAN on OEMV systems were computed by differencing the real time solutions with the post-processed navigation grade solution.

Figure 4: Test 2 - Urban Canyon

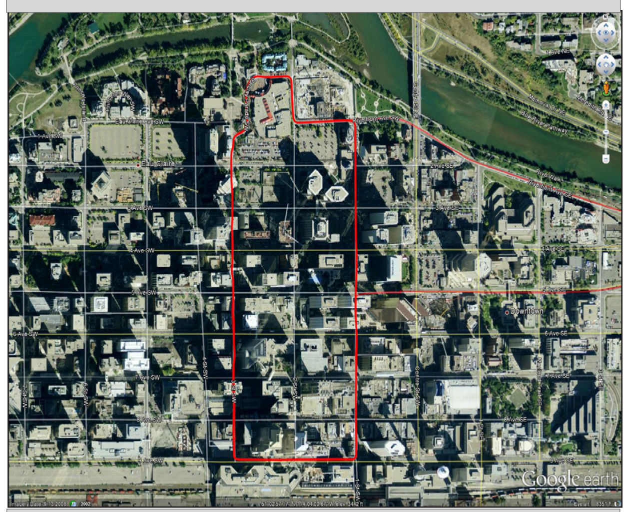
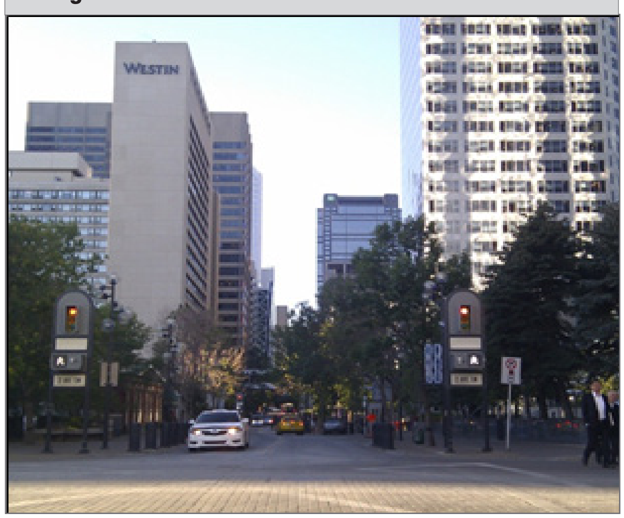


Figure 5: Test 2 - Street View



Test Results

Test 1 - Suburban Open Air

Figure 6 and Figure 7 along with Table 2 illustrate the signal reacquisition results from Test 1.

Figure 6: GPS Reacquisition Performance

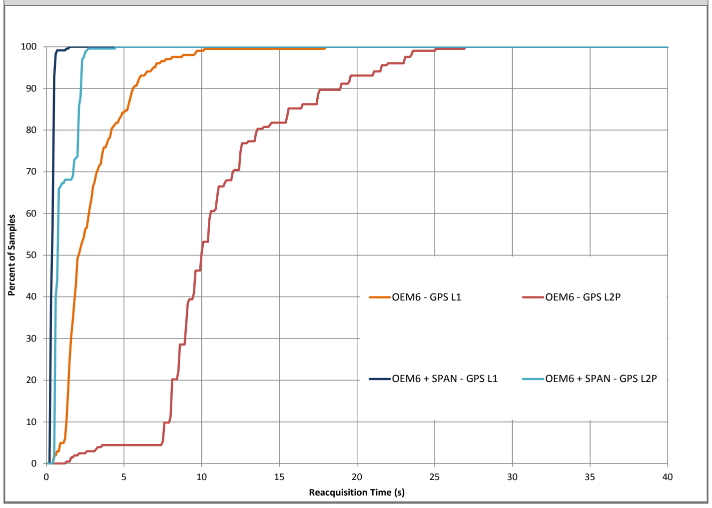


Figure 7: GLONASS Reacquisition Performance

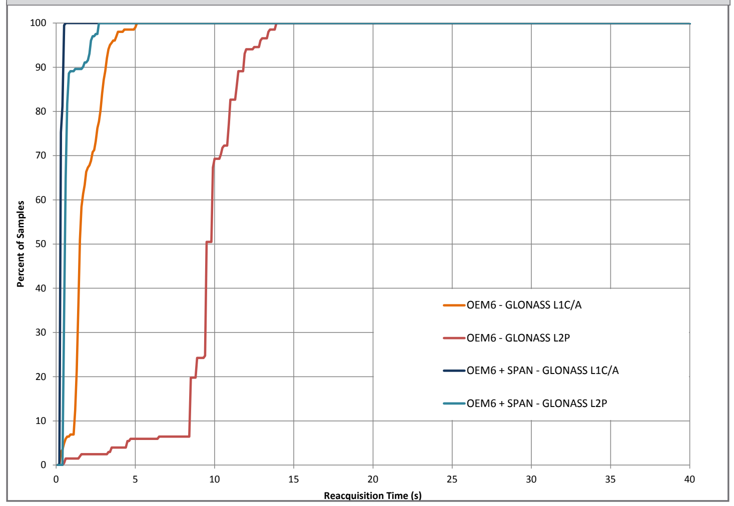


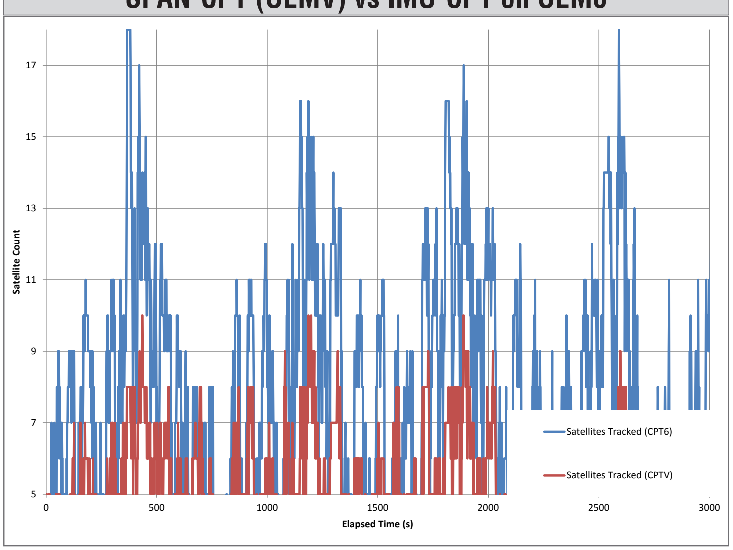
Table 2: GNSS Reacquisition Times

Signal	Mean Time to Reacquire	Standard Deviation of Reacquire Time	Time to 95% of Sample Reacquire
SPAN GPS L1	0.4 seconds	0.1 seconds	0.6 seconds
SPAN GPS L2	1.1 s	0.7 s	2.3 s
SPAN GLONASS L1	0.3 s	0.1 s	0.5 s
SPAN GLONASS L2	0.7 s	0.5 s	2.2 s

Test 2 - Urban Canyon

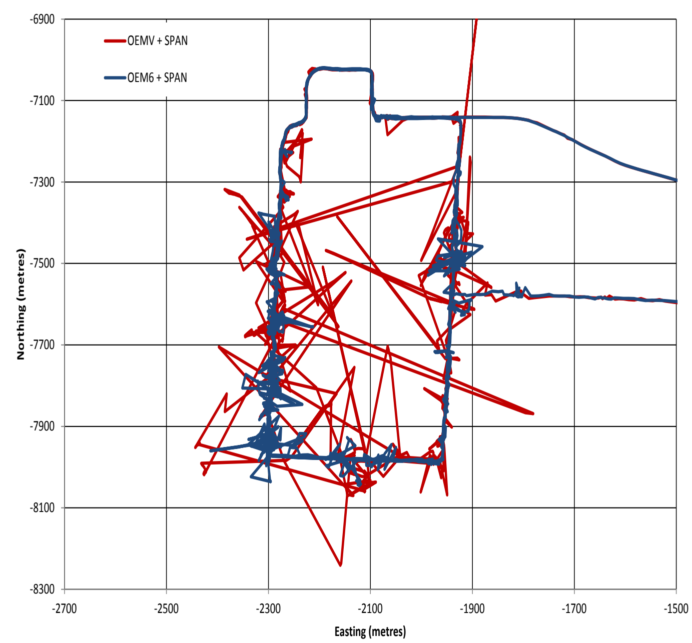
Test 2 illustrates the tracking differences between the OEMV and OEM6 systems in an urban canyon environment. Figure 8 shows the number of satellites tracked by both systems. The benefit of the GLONASS channels available on SPAN on OEM6 is clearly evident by the increased satellite count on the OEM6 for nearly the entire test.

Figure 8: Satellite Tracking Count - Urban Canyon SPAN-CPT (OEMV) vs IMU-CPT on OEM6



As discussed previously, SPAN provides better pseudorange positions by aiding the RAIM algorithm. Figure 9 shows the pseudorange positions from the SPAN on OEMV versus SPAN on OEM6 system. Note these are the pseudorange positions only, with no INS contribution. The impact of the RAIM algorithm on OEM6 is evident by the reduced pseudorange position errors on the OEM6 when compared with the OEMV trajectory.

Figure 9: Pseudorange Trajectories OEMV+SPAN vs OEM6+SPAN



The Root Mean Square (RMS) position, velocity and attitude errors for the SPAN OEM6 and SPAN on OEMV systems for Test 2 are shown in Table 3. The errors were computed by differencing the real time SPAN solutions with the post-processed reference solution. The reference solution was translated and rotated in post-processing to the position and orientation of the test IMUs.

Table 3: Position, Velocity and Attitude Errors (RMS)

	IMU-CPT on OEM6	SPAN-CPT on OEMV
2D Position Error (m)	1.75	3.43
Height Error (m)	1.10	3.04
2D Velocity Error (m/s)	0.06	0.11
Up Velocity Error (m/s)	0.03	0.09
Roll Error (degrees)	0.02	0.03
Pitch Error (degrees)	0.03	0.03
Azimuth Error (degrees)	0.09	0.10

Also from Test 2, Figure 10 and Figure 11 show the trajectory computed from both systems at particularly challenging areas of the test route. (The areas shown in Figures 10 and 11 are the intersections of 3rd Street and 2nd Street with 9 Ave SW, respectively.) Each area was driven through multiple times.

Figure 10: Inertial Position Comparison

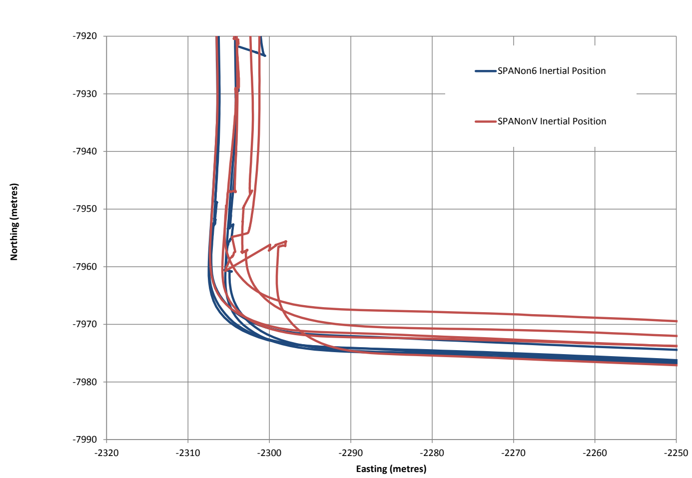
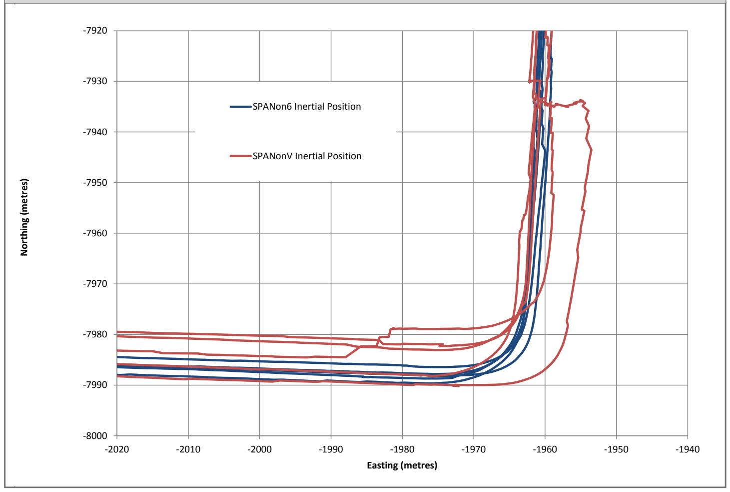


Figure 11: Inertial Position Comparison



Performance Analysis

Test 1 results illustrate the excellent signal reacquisition performance of SPAN on OEM6. With the SPAN enabled receiver, 95% of the time all available L1 signals were reacquired in 0.6 (GPS) and 0.5 (GLONASS) seconds. For L2, all available signals were reacquired within 2.3 (GPS) and 2.3 (GLONASS) seconds, in 95% of the time. The stand alone GNSS receiver took 6.9 (GPS) and 3.4 (GLONASS) seconds for L1; 21.6 (GPS) and 12.9 (GLONASS) seconds for L2, 95% of the time. This demonstrates the SPAN enabled receiver delivered more GNSS measurements than the GNSS only enabled receiver.

Because SPAN technology is tightly coupled, the SPAN enabled receiver is able to reacquire lost signals quicker than a standard receiver. Faster reacquisition of GNSS signals after a blockage results in more GNSS measurements, which reduces the amount of time the INS filter was unaided, producing a more accurate navigation solution.

The results of Test 2 show the improved performance of SPAN on OEM6 in an urban environment experiencing numerous signal blockages from tall buildings and pedestrian overpasses. Because SPAN on OEM6 tracks GLONASS as well as all in view GPS satellites, the total number of satellites tracked was nearly doubled (refer to Figure 8).

With additional signals tracked, the pseudorange positioning algorithm could be very selective about which measurements were used. The OEM6 uses a RAIM method to detect and reject multipath or direct reflected signals. SPAN on OEM6 further aided RAIM with inertial positioning, allowing better rejection of poor measurements, especially when fewer satellites were available. As Figure 9 shows, the combination of more available measurements and robust measurement selection resulted in a greatly improved pseudorange position.

Before a GNSS position was accepted as an update to the inertial computation filter, SPAN performed a rigourous quality check. With the improved pseudorange positions, more positions were accepted as an update for the inertial filter, which increased the frequency of updates. Due to the increased number of satellites tracked, many more phase updates were available with SPAN on OEM6. Table 3 shows that the resulting INS position error was reduced by 50% horizontally and 64% vertically. The SPAN on OEM6 trajectory was much smoother and repeated passes around the test route agreed more closely (refer to Figures 10 and 11).

Conclusion

Test 1 confirmed that SPAN enabled receivers provide more GNSS measurements by rapidly reacquiring all available satellites after signal blockages. The increased number of GNSS measurements benefit systems using lower quality IMUs, as the affected GNSS outages are shorter when compared to GNSS only systems.

Test 2 confirmed the superior performance of the SPAN on OEM6 receiver platform in urban canyon conditions. With intelligent measurement selection and carefully qualified position updates for the INS, the SPAN enabled OEM6 receiver is less susceptible to multipath or rapid changes in the pseudorange measurements, resulting in smoother and more repeatable solutions.

Benefit of SPAN on OEM6

SPAN on OEM6 is the evolution of NovAtel's SPAN technology. The benefits offered by the legacy OEMV generation of SPAN products are enhanced by the addition of the GLONASS constellation and NovAtel's innovative tightly coupled GNSS and IMU measurements. The result is a new level of robust position, velocity and attitude performance, even in the most challenging circumstances.

Available on a variety of hardware platforms, SPAN on OEM6 runs on both the OEM628 and OEM615 GNSS cards. The OEM628 is available in the FlexPak6 enclosure and can be paired with any of the existing NovAtel IMU enclosures. If enclosures are not needed, products are available at board level as well. The OEM615, paired with the Micro Electromechanical Systems (MEMS) Interface Card (MIC), provides the optimal choice for size and weight constrained applications.

The supported IMUs are:

- Honeywell, HG1900, HG1930, HG1700
- Northrop Grumman LN200, LCI-1 (non-ITAR)
- IMU-CPT (commercial)
- iMAR FSAS (commercial)
- Analog Devices ADIS16488 (commercial)

For more information on the NovAtel range of SPAN systems, please visit:

http://www.novatel.com/span

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