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Accuracy Analysis of the EGNOS System During Mobile Testing

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ABSTRACT: The European Geostationary Navigation Overlay Service or EGNOS has been operational and broadcasting signals on PRN120 and PRN126 as of July 2006. EGNOS is designed to broadcast embedded correction signals in Europe which will provide improved performance with GPS. There are three EGNOS geostationary satellites PRN codes 120,124 and 126. The three satellites have positions 15.5 degrees west fro PRN 120, 25 degrees east and 21.5 degrees east for PRN's 126 and 124. Satellite PRN124 is still in the test phase. The Space Research Centre has performed a mobile testing to demonstrate how EGNOS improves GPS accuracy. A mobile GPS laboratory was used to collect GPS data in the rural outskirts of Warsaw. Two receivers and one antenna were used to collect kinematic and navigation data. Post-processed GPS position and height deviations are compared to the solution given when GPS is augmented with EGNOS. The summarized results in this paper show that GPS augmented with EGNOS greatly improves position accuracy.

1 INTRODUCTION

The EGNOS overlay satellite system provides improved GPS performance in the areas of accuracy, availability, continuity and integrity. The objective of the research was to collect GPS and EGNOS data over short distances in clear surroundings. Three GPS monitors were mounted within the mobile test van. GPS and GPS with EGNOS data were collected. Static EGNOS and GPS data was also collected and used for post processing test data. This paper details the preliminary results and analyzes the horizontal and vertical accuracies from each data set.

2 TEST SETUP

2.1 *Equipment*

The equipment used in the mobile GPS laboratory is detailed in table 1.

Table 1. Test Equipment

GPS Receiver	Antenna
Trimble 5700	Trimble Zephyr
Septentrio PolaRX2	Aero AT 2775
CSI	N/A (navigation)
Dell and HP Notebook	

2.2 *Setup*

The test equipment consisted of three GPS receivers, two rooftop antennas and two notebooks for data acquisition. The Trimble Zephyr Antenna was magnetically mounted on the van rooftop and cable attached to the Trimble 5700 receiver. The Trimble receiver processed and stored data in RINEX format. The Aero antenna was connected to the Septentrio receiver. The GPS data from the Septentrio receiver was collected on the HP notebook in RINEX and NMEA format. The program RXControl 2.6 was used for data acquisition on the HP. The third navigation receiver, CSI, downloaded GPS and

EGNOS data to the Dell notebook in NMEA format. GPS data was collected at one minute intervals throughout the test route. The three receivers were mounted on a platform towards the center of the van.

3 TEST RUN

The test run route was formulated to include a mostly rural route with a few kilometres of urban areas. The rural route gave clear GPS conditions and minimized the time of unavailability. The 12 kilometre route took approximately ten minutes. The route was repeated six times for the various configurations.

An attempt was made to keep a constant velocity of about 50 km/hr. However, various outside factors prevented a constant velocity throughout the full test.

4 ANALYSIS OF RESULTS

4.1 *Post-processing*

GPS kinematic data from the Trimble and Septentrio receivers was post processed with Trimble Geomatics Office. The DGPS post-processed data was then used as a baseline against the navigation data from the Septentrio and CSI receivers.

4.2 *Satellite Availability*

Satellite availability for each test run is graphically represented above each deviation plot. During times of satellite availability the number of satellites averaged between six and nine. Data was masked at 0 and 15 degrees. Satellite availability was slightly reduced by about two satellites at a 15 degree mask. The gaps in data represent the times when it was not possible to compare the kinematic solution to navigation data.

4.3 *Coordinate Deviation Percentages*

The vertical and horizontal accuracy from the Septentrio navigation data was analyzed using the kinematic solution as the zero baseline. The summary of Septentrio accuracies with a 15 degree mask is listed in table 2. The Septentrio GPS data was augmented with EGNOS PRN 126.

The GPS only x-coordinate data had nearly 16% of the data within one meter accuracy. When augmented with PRN126 over 40% of the data was within one meter accuracy. Nearly 100% of the EGNOS augmented data was within 1.50 meter accuracy.

The y-coordinate also improved in accuracy when augmented with PRN126. Nearly 100% of the data was within 0.50 meter accuracy when augmented.

The height measurements also improve with PRN126. The accuracy improves from 50% to 85% for data within 0.50 meters. The accuracy of data within the range of 0.00 to 0.25 meters is more than double when augmenting GPS with PRN126.

The summary of Septentrio and CSI receiver coordinate accuracies with a zero degree mask is listed in table 3. A bigger improvement in data accuracy was seen by the CSI receiver. The x-coordinate deviation improved from 5% to 60% for data within 0.50 meter accuracy. The y-coordinate improved from 30% to nearly 90% for data within 0.50 meter accuracy. The Septentrio receiver had almost the same performance when comparing GPS only and GPS + PRN126 deviations. A major improvement can be seen in the x-coordinate in the 0.00 to 0.25 meter range.

Table 2. Accuracy of Septentrio Receiver

Receiver Septentrio PolaRx2, Mask: 15 degree		
X-coord (m)	**Only GPS**	**GPS + PRN 126**
<2.25; 2.00)	13.90%	0.00%
<2.00; 1.75)	14.95%	0.00%
<1.75; 1.50)	3.16%	0.19%
<1.50; 1.25)	21.05%	2.64%
<1.25; 1.00)	31.16%	54.34%
<1.00; 0.75)	12.84%	37.55%
<0.75; 0.50)	2.95%	4.53%
<0.50; 0.25)	0.00%	0.76%
< 1.00	**15.79%**	**42.83%**
Y-coord (m)		
<1.50; 1.25)	0.84%	0.00%
<1.25; 1.00)	13.90%	0.00%
<1.00; 0.75)	32.21%	0.57%
<0.75; 0.50)	25.26%	0.76%
<0.50; 0.25)	17.47%	39.25%
<0.25; 0.00)	10.31%	59.44%
<0.50	**27.79%**	**98.69%**
Height		
<2.25; 2.00)	0.21%	0.00%
<2.00; 1.75)	4.42%	0.00%
<1.75; 1.50)	5.05%	0.00%
<1.50; 1.25)	7.37%	0.00%
<1.25; 1.00)	13.05%	0.76%
<1.00; 0.75)	6.95%	3.02%
<0.75; 0.50)	13.48%	10.57%
<0.50; 0.25)	25.68%	26.42%
<0.25; 0.00)	23.79%	59.25%
<0.50	**49.47%**	**85.66%**

Table 3. Accuracy of Septentrio and CSI Receivers

Receiver Accuracies, Mask: 0 degree				
X-coord (m)	**Only GPS**		**GPS + PRN 126**	
	Septentrio	**CSI**	**Septentrio**	**CSI**
<2.25; 2.00)	0%	1.01%	0%	0.17%
<2.00; 1.75)	0%	1.34%	0%	2.40%
<1.75; 1.50)	0%	1.68%	0%	3.94%
<1.50; 1.25)	0%	4.20%	0%	3.94%
<1.25; 1.00)	5.09%	30.37%	1.55%	5.14%
<1.00; 0.75)	29.83%	41.11%	9.14%	5.48%
<0.75; 0.50)	39.83%	15.77%	28.28%	20.03%
<0.50; 0.25)	22.71%	4.20%	30.35%	17.47%
<0.25; 0.00)	2.54%	0.34%	30.69%	41.44%
< 0.50	**25.25%**	**4.53%**	**61.03%**	**58.91%**
<1.00	**94.92%**	**61.41%**	**98.45%**	**84.42%**
Y-coord (m)	**Only GPS**		**GPS + PRN 126**	
	Septentrio	**CSI**	**Septentrio**	**CSI**
<1.50; 1.25)	0%	1.68%	0%	0%
<1.25; 1.00)	0%	0.34%	0%	0.34%
<1.00; 0.75)	0.34%	17.95%	0.52%	4.62%
<0.75; 0.50)	3.39%	47.32%	3.45%	6.51%
<0.50; -0.25)	21.02%	29.53%	43.79%	28.25%
<0.25; 0.00)	75.25%	3.19%	52.24%	60.27%
<0.50	**96.27%**	**32.72%**	**96.03%**	**88.53%**

4.4 *Deviation Plots*

The following deviation plots visually exemplify the percentage results from the previous section. The top bar graph has two sections. Each section shows the number of satellites available for that specific configuration. Data is only shown when the kinematic solution was available.

Figures one and two are the x and y coordinate deviations of the Septentrio receiver. The black line is GPS data augmented with PRN 126. The deviations from the kinematic solution improve when GPS is augmented. A clear improvement can be seen in the y-coordinate deviation plot.

Figure three is the height plot deviation for the Septentrio receiver at a 15 degree mask. Improvements can be seen throughout the plot, specifically from seven minutes till the end.

Figures four and five show the x and y coordinate deviations for the CSI receiver configured to a zero degree mask. Both graphs show improved performance when using GPS and PRN126 data. Also, a small spike is prevalent in both graphs at the five minute mark when using GPS and GPS with PRN126. At this point the GPS only data improves from 0.50 meter deviation to nearly zero. The GPS with PRN126 data jumps from about 0.25 meter to a one meter deviation. Overall, accuracy is greatly improved as shown in table three.

Figures 6 and 7 are the x and y coordinate deviations for the Septentrio receiver configured to a zero degree mask. Overall, as seen in table 3, deviations are nearly the same when comparing GPS only and the GPS with PRN126 data. From seven minutes to the end, Figure seven shows better accuracy for the GPS only data and Figure six shows improved accuracy for GPS with PRN126 data. The difference between the two is within 0.50 meters and is not a major concern.

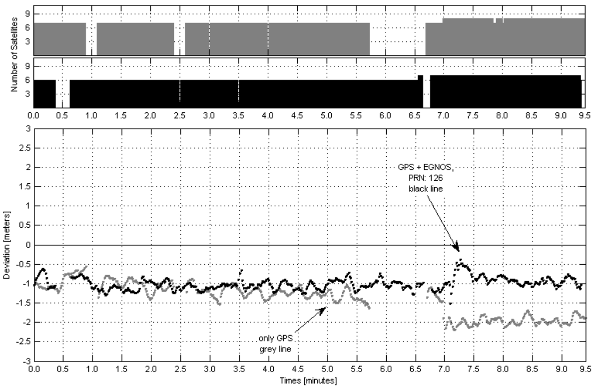

Fig. 1. Septentrio X Coordinate Deviation, 15 Deg. Mask

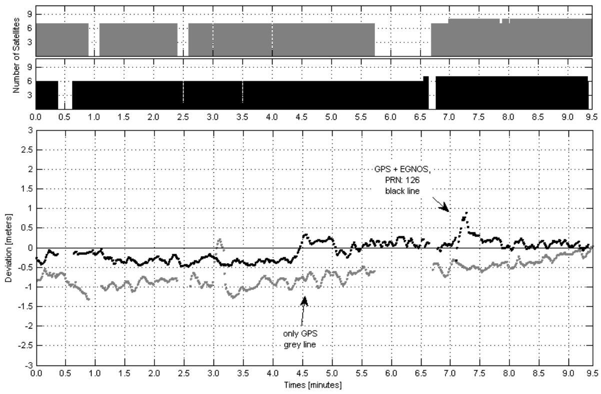

Fig. 2. Septentrio Y Coordinate Deviation, 15 Deg. Mask

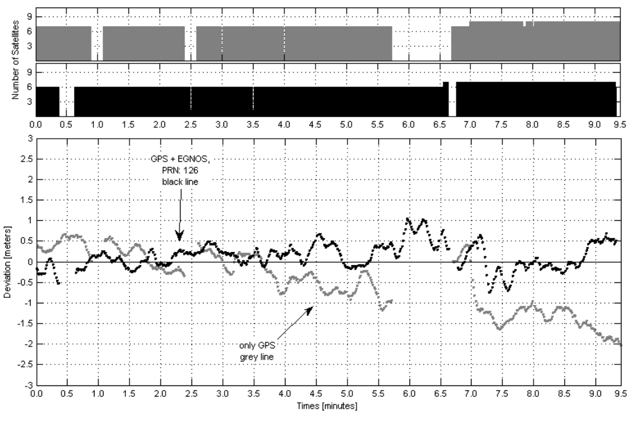

Fig. 3. Septentrio Height Deviation, 15 Deg. Mask

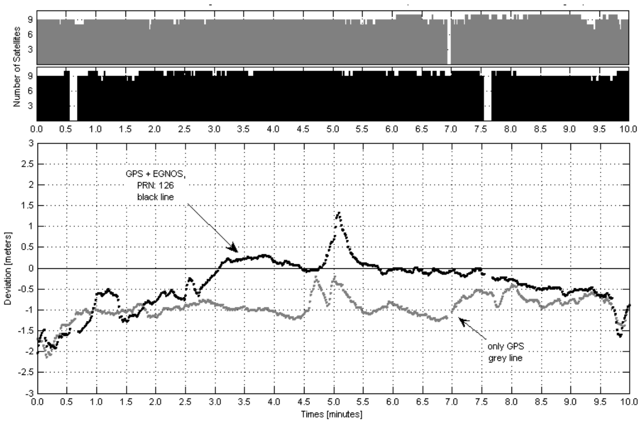

Fig. 4. CSI X Coordinate Deviation, 0 Deg. Mask

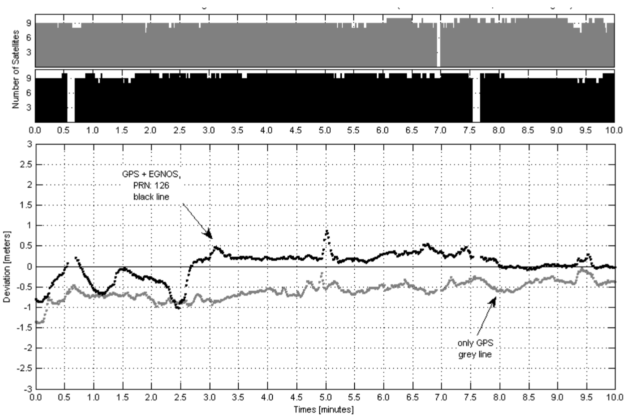

Fig. 5. CSI Y Coordinate Deviation, 0 Deg. Mask

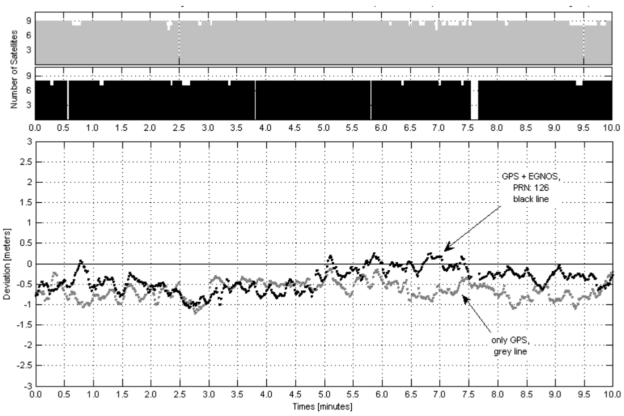

Fig. 6. Septentrio X Coordinate Deviation, 0 Deg. Mask

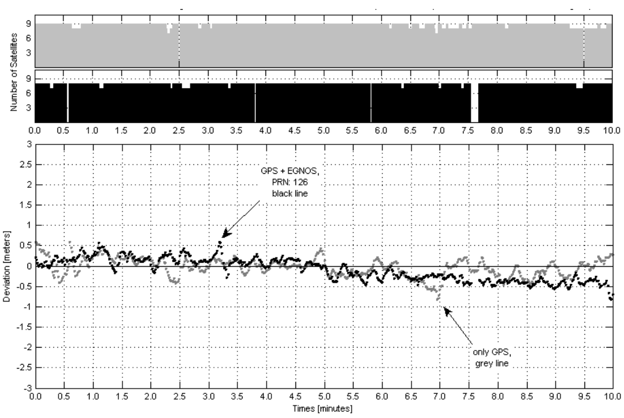

Fig. 7. Septentrio Y Coordinate Deviation, 0 Deg. Mask

4.5 *EGNOS and GPS Static Comparisons*

Static data used for post-processing was collected using two Septentrio receivers. The vector between the two receivers was seven meters; therefore, the constellation seen by the two receivers was identical. The next six figures directly compare the deviations of navigation and post-processed data between GPS vs. EGNOS augmented and PRN120 vs. PRN126.

Figures 8-10 compare GPS results with EGNOS PRN126. When using GPS augmented with EGNOS, fewer satellites were available for data collection. The number of GPS satellites ranged from seven to fourteen and only four to ten GPS satellites with EGNOS corrections were available.

The x and y coordinate data were within two meters of accuracy. There were a few data spikes in the y-coordinate for PRN126 that can be attributed to satellite availability. Overall, the GPS data augmented with EGNOS provided a slight improvement in accuracy.

4.6 *EGNOS PRN120 vs. PRN126*

Figures 11-13 compare the static data for the two S-bus EGNOS satellites 120 and 126. Data plots from both satellites gave near mirror-image results in the horizontal and vertical directions. The gaps in the charts that show the times when EGNOS corrections were not available.

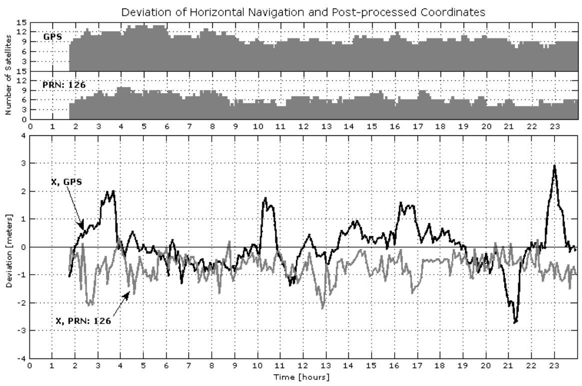

Fig. 8. GPS vs. PRN126, X-Coordinate

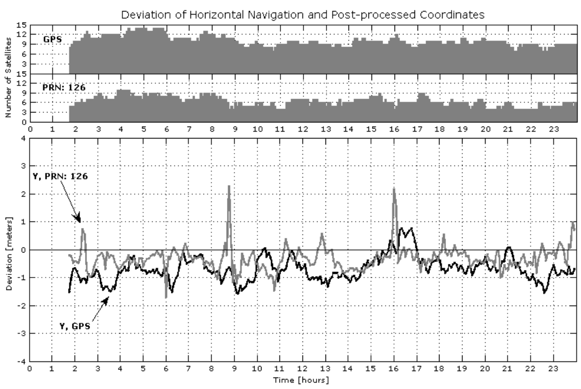

Fig. 9. GPS vs. PRN126, Y-Coordinate

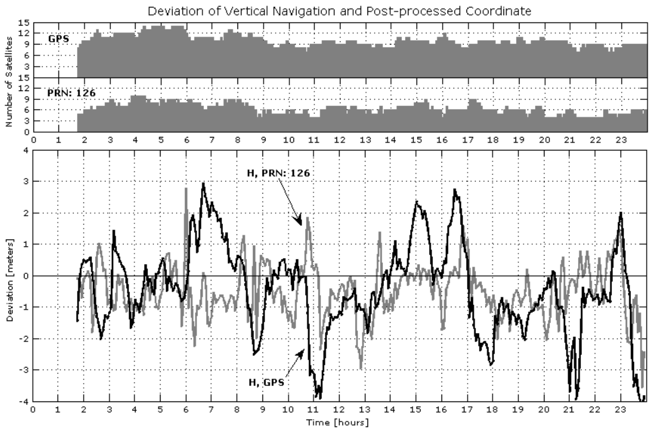

Fig. 10. GPS vs. PRN126, Height

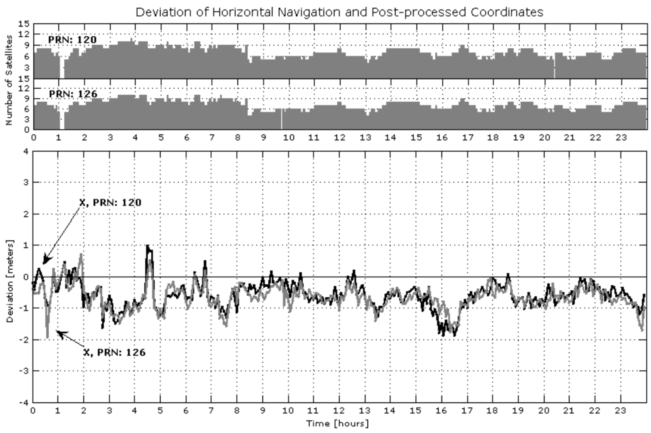

Fig. 11. PRN 120 vs. 126, X-Coordinate

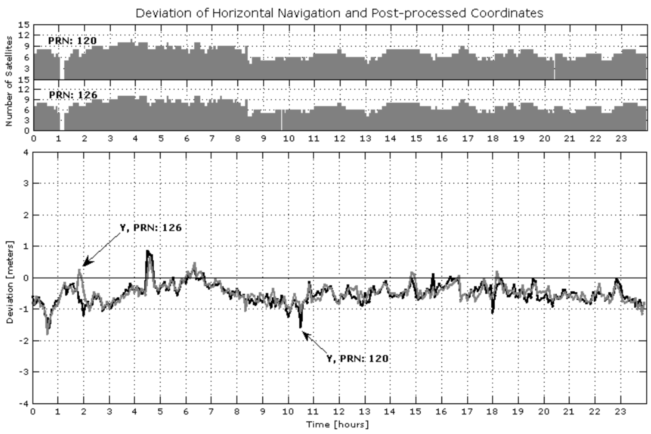

Fig. 12. PRN 120 vs. 126, Y-Coordinate

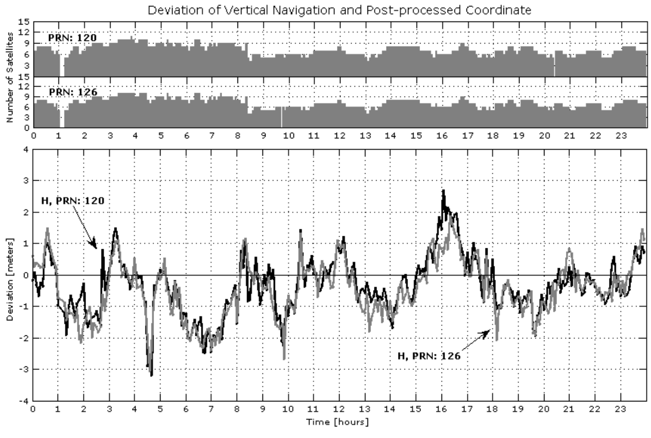

Fig. 13. PRN 120 vs. 126, Height

5 CONCLUSIONS

Results from the test run were as expected with the GPS/EGNOS data clearly improving horizontal and vertical accuracy. At a 15 degree mask the Septentrio deviations improved significantly when GPS was augmented with PRN126. The x-coordinate deviation from one meter improved from 15% to 43%. In the y-coordinate accuracy improved from having 30% to nearly 100% of the data within a 0.50 meter deviation. For the height, the number of data points within 0.50 meters of zero deviation improved from 50% to 86%.

The next configuration analyzed was with each receiver having a zero degree mask. The biggest improvement was seen in the CSI receiver when augmented with EGNOS PRN126. The x-coordinate deviation improved from having 5% to 60% of the data within 0.50 meters. For the y-coordinate, it improved from 32% to 88%. The Septentrio receiver had mixed results. In the x-coordinate, data improved from 25% to 60% of the data within 0.50 meter deviation. In the y-coordinate there was no overall improvement, the two data sets were equally within 0.50 meters throughout the test.

EGNOS has been shown to improve horizontal and vertical GPS accuracy during periods of availability. EGNOS PRN 120 and 126 have similar accuracy performance in the horizontal and vertical coordinates. In order to get an accurate representation of GPS/EGNOS performance more test runs are planned over the next few months. Continued observations throughout the following months will be compared to these preliminary results in order to better understand deviations in performance.

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