Airborne GPS Tests with Javad Legacy Receivers

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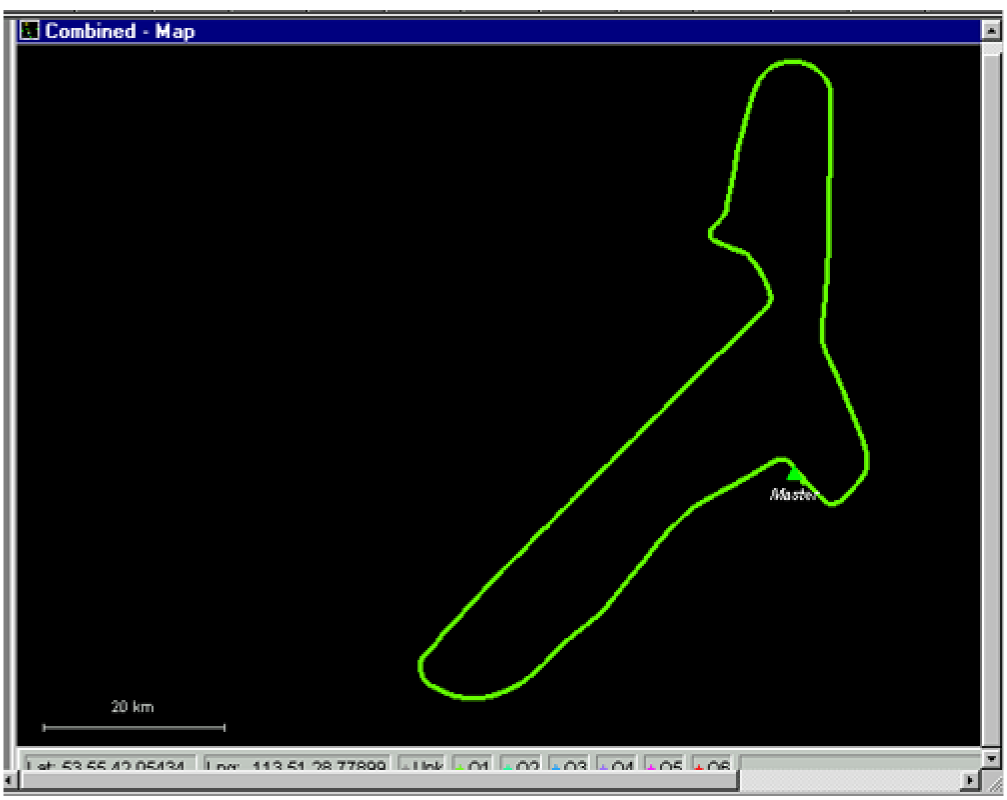
Introduction

This report is a description of airborne GPS tests with Javad Positioning systems (JPS) dual frequency GPS/Glonass receivers performed in January 1999 by John Welter of North West Geomatics. Post-processing of the binary JPS data was performed with Waypoint's GrafNav package. While only the GPS component of the receivers was examined, all of the data was processed in Kinematic Ambiguity Resolution (KAR) mode. On the fly ambiguity resolution requires clean, well-tracked phase measurements, preferably from dual frequency receivers such as those manufactured by JPS. This test was designed to see how effectively the JPS receiver could perform KAR at various baseline distances in a fairly rigorous dynamic environment (airborne photogrammetry).



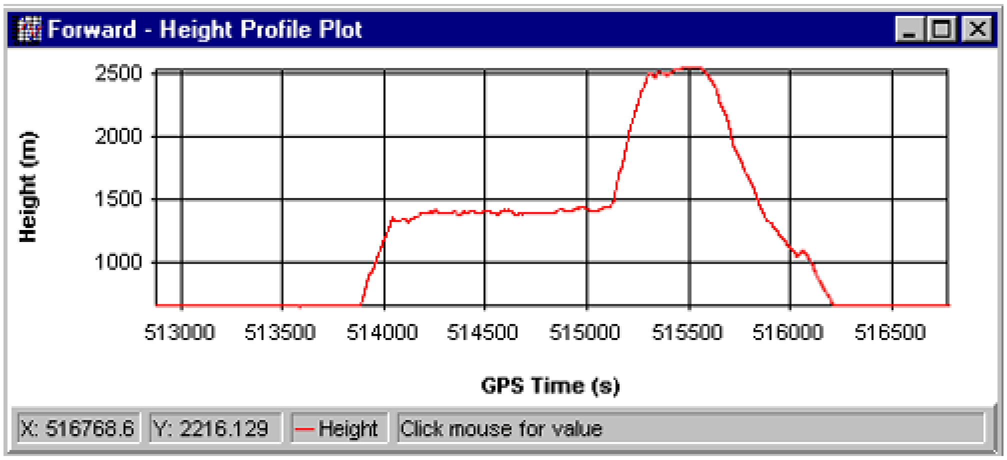


Figure 1: GrafNav Planimetric and Vertical Plots of the Flight Test

Figure 1 illustrates the path of the aircraft. It can be seen that maximum distance from the base station, represented by the triangle, is approximately 45 km while the maximum flying height is 2500 m ASL. The topmost plot in Figure 2 depicts the agreement between the independently processed forward and backward measurement data, and the bottom half of Figure 2 illustrates the east, north, and up components of the aircraft trajectory with respect to the base station.

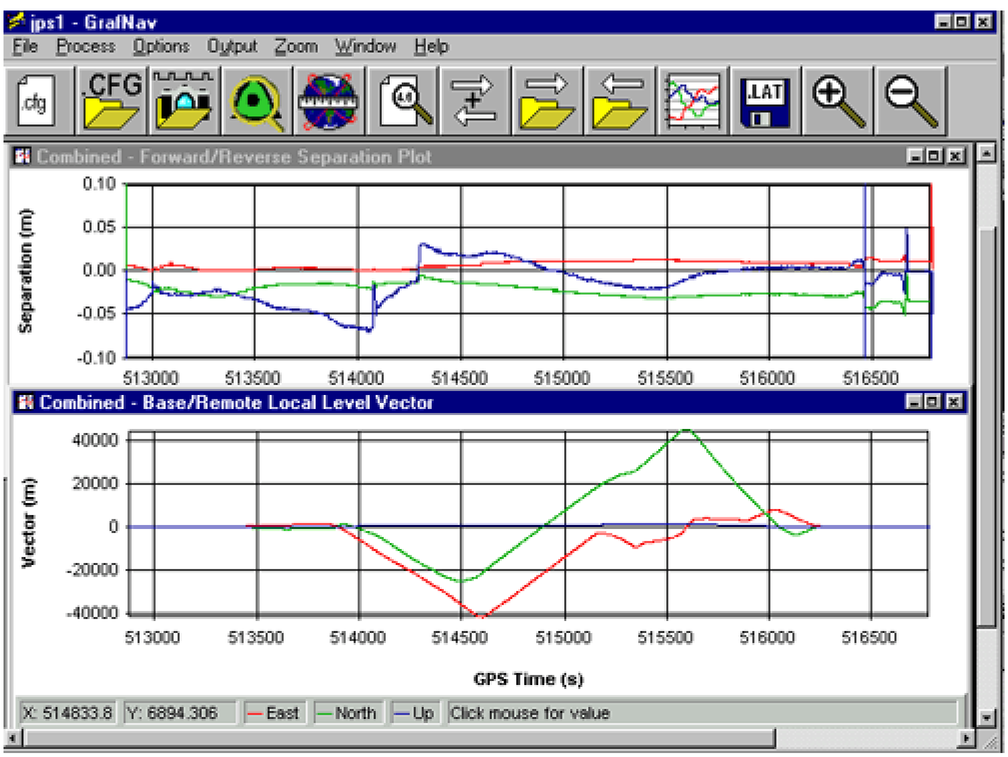


Figure 2: The Entire Data Set Forward / Reverse Separation and Local Level Vector wrt Base Station

It can be seen from the Combined Forward/Reverse Separation plot that the independent forward and reverse KAR solutions agree at all points to several cm horizontally and no more than 6 cm vertically. This solution was used as the baseline solution for all subsequent KAR on the fly ambiguity solutions. To perform KAR at various baseline distances, GrafNav was simply given different start times for each of 5 different processing runs.

Test Results

The results given in this section of the report show the differences between the KAR solutions made with the entire data set and KAR solutions produced by starting GrafNav at various points in time during the course of the mission. For instance, it can be seen from Figure 3 that if GrafNav is given a start time of roughly 514500 (GPS seconds of the week), then KAR must be performed on a baseline of some 40 km in length. Alternately, if the entire data set is used (Figure 2), the initial on the fly ambiguity resolution occurs on a baseline of only several hundred meters in length.

The results presented below are really internal comparisons made with respect to the solution encompassing the entire data set. It is understood that these results are not absolute expressions of the true error in the system. On the other hand, it is also very unlikely that the various KAR solutions are biased in the sense that canceling errors occur from one processed data set to the next. Furthermore, the GPS positions are relatively difficult to ground truth from a moving aircraft and in the absence of other data sources, these internal comparisons are very likely the best error indicators that we have.

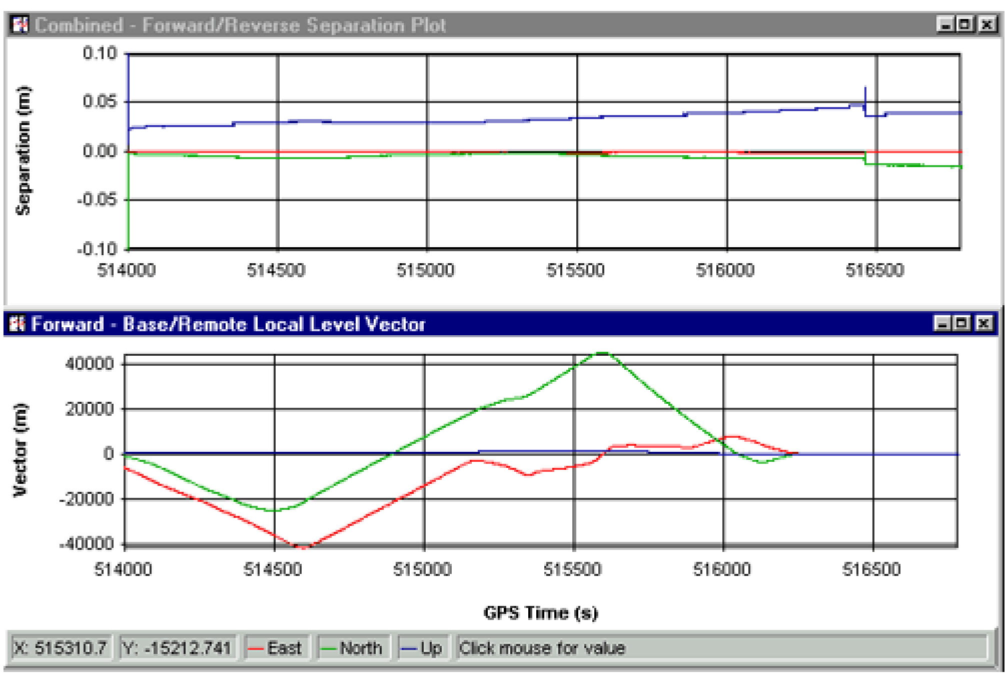


Figure 3: KAR at Time 514000 - Comparison to Entire data Set KAR Performed at Baseline Distance of 5883 m

The top half of Figure 3 represents the plot of the coordinate differences between the entire GPS data as seen in Figure 2 and an on the fly ambiguity determination computed by starting GrafNav at a time of 51400, at a distance of 5.8 km from the base station.

Similarly, Figure 4 shows the same coordinate comparisons with GrafNav started at GPS time 514500. At this juncture in the mission, the airplane was some 43.5 km from the base station at an altitude of roughly 1400 m ASL.

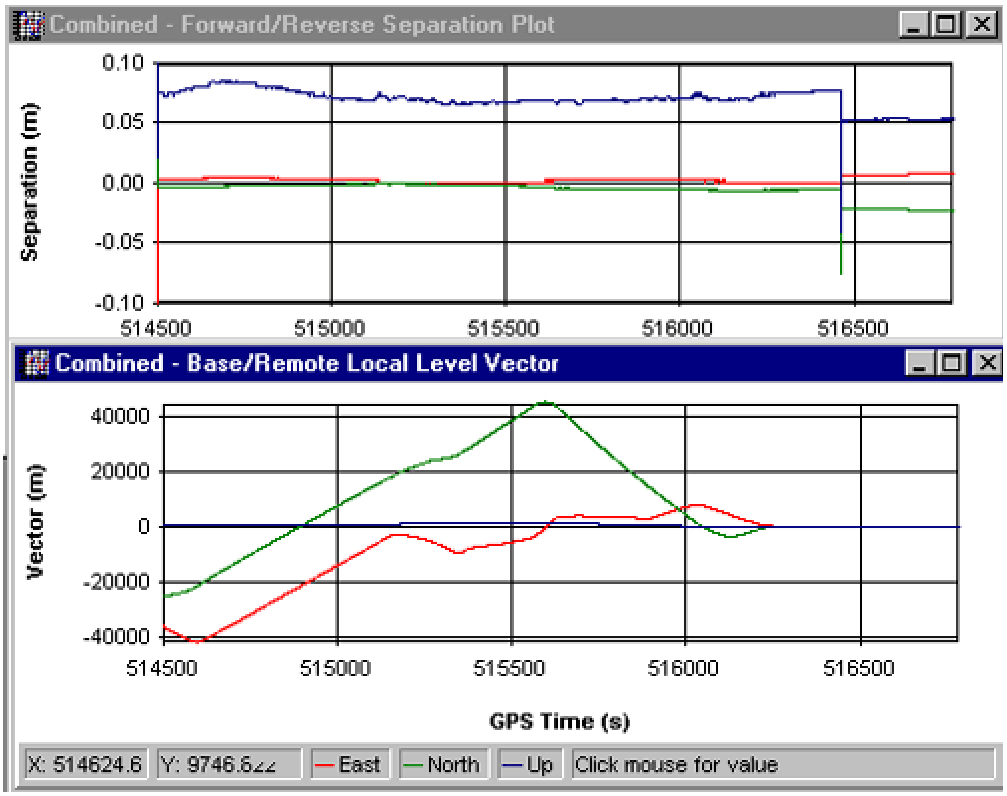


Figure 4: KAR at time 514500 - Solution Compared to Entire Data Set KAR Performed at Baseline Distance of 43564 m

Both graphs illustrate centimeter level agreement in the east and north components, while a height bias of some 0.04 - 0.07 m is clearly apparent, depending at least partly on the baseline distance. This type of bias in the height coordinate is a phenomenon reported in many photogrammetric surveys. The systematic offset in height is largely attributable to differential troposphere effects between the signal propagation paths at the base station and aircraft. Residual ionosphere effects also exist at longer distances. Additionally, there will be a slight increase in the error budget at the extremities of the survey due to broadcast ephemeris. Measurement noise and multi-path effects contribute to small high frequency variations in the different KAR solutions.

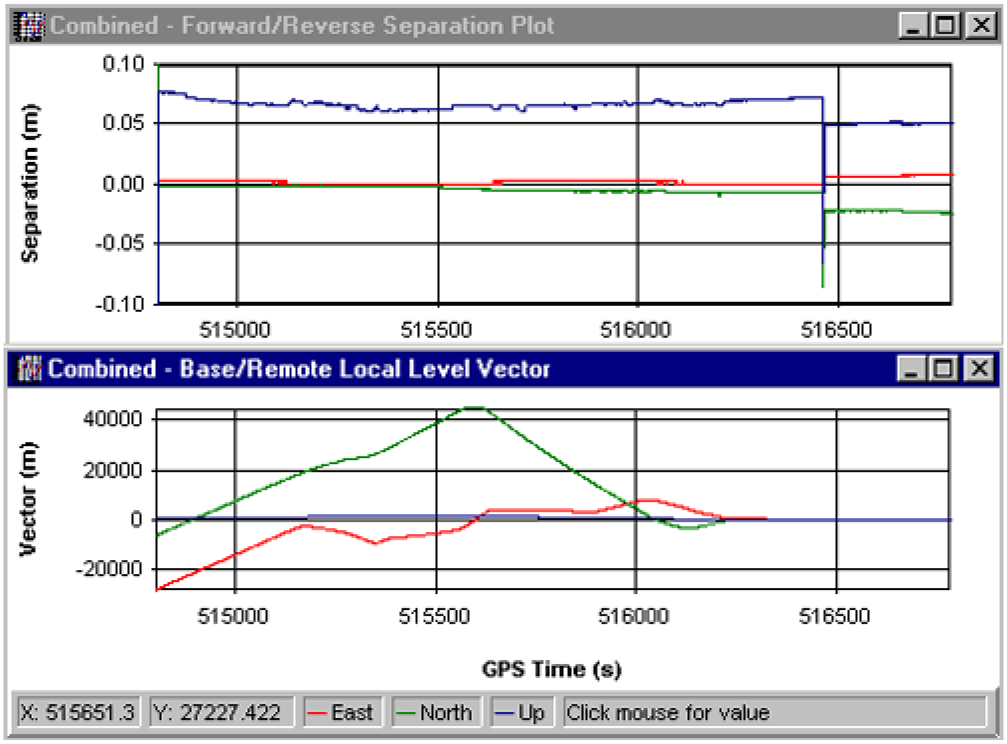


Figure 5: KAR at time 514800 - Solution Compared to Entire Data Set KAR Performed at Baseline Distance of 27931 m

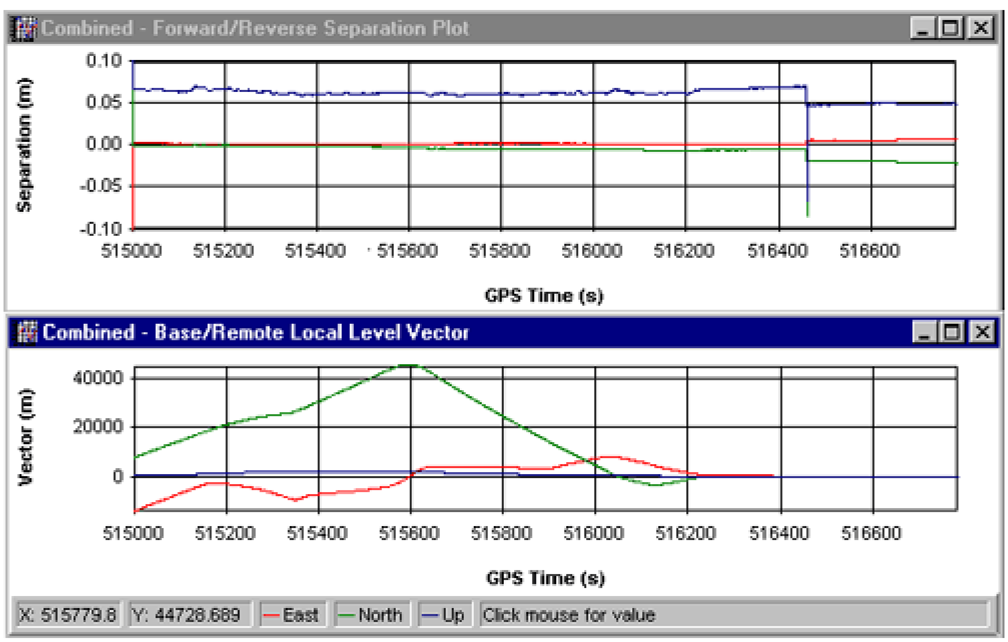


Figure 6: KAR at time 515000 - Solution Compared to Entire Data Set KAR Performed at Baseline Distance of 15868 m

Figure 5 and 6 depict two more independent KAR solutions. In Figure 5, it can be seen that GrafNav began processing the data at GPS time 514800, halfway through the flight. At GPS time 515000, the airplane is just about to begin its descent into the airport. The horizontal agreement between the entire data set and those portions of the data set processed from 514800 to mission end, agrees to the centimeter level. The height component still shows a small, but significant offset. This bias does not disappear until the descending aircraft resumes an elevation reasonably close to that of the base station at GPS time 516200.

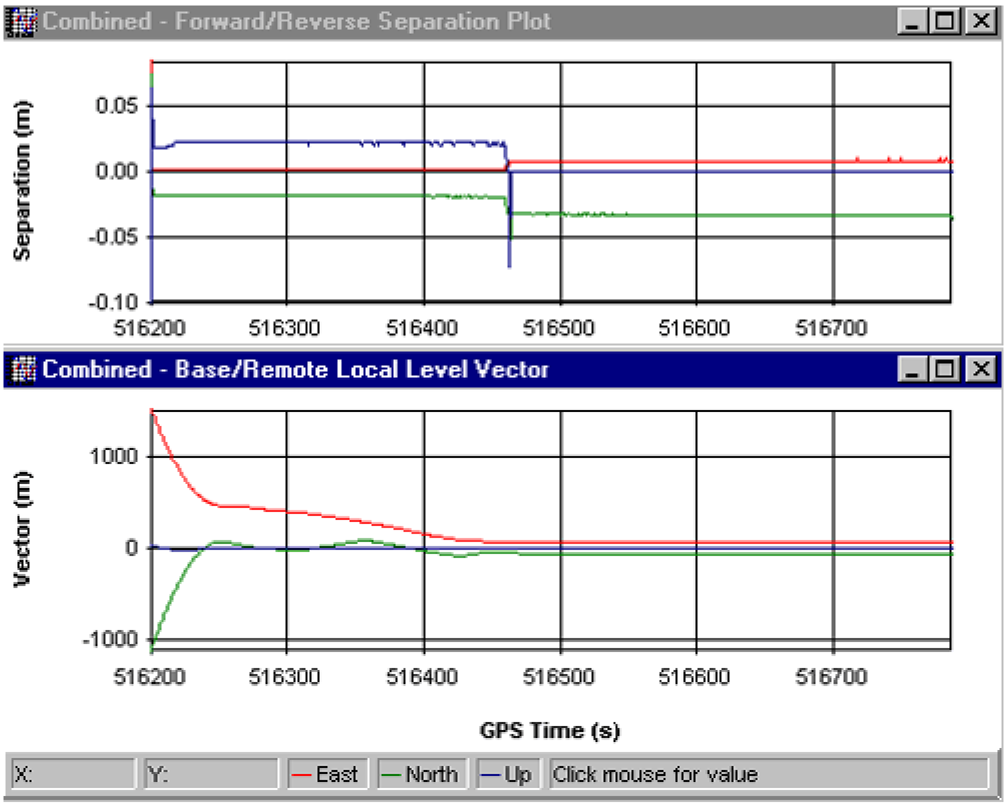


Figure 7: KAR at time 516200 - Solution Compared to Entire Data Set KAR Performed at Baseline Distance of 1129 m

Figure 6 shows the results of a KAR solution at GPS second 516200 or just as the aircraft begins to land. It can be seen that the height bias has decreased with coordinate differences of about 0.02 - 0.03 m built up in all three coordinate axes. These are the cumulative results of system noise in the entire data set versus the KAR solution obtained by forcing GrafNav to resolve ambiguities near the end of the data set.

Conclusions

The dual frequency GPS component of the JPS receiver has been tested in an airborne environment by North West Geomatics of Edmonton, Alberta, Canada. Utilizing Waypoint's GrafNav post-processing module, on the fly ambiguity determination was performed at various times and various locations in the flight path. Error analysis was accomplished by first generating a baseline solution for all of the data. To obtain this set of coordinates, Kinematic Ambiguity Resolution was performed at the beginning and end of the data set with the aircraft on the runway in each case. These results provided the "true" data set. GrafNav was then started at different GPS times in the binary data stream with Kinematic Ambiguity Resolution being performed at baseline distances of 1, 5, 15, 29 and 43 km. These different solutions were all compared against the "true" set of baseline coordinates. The plots of these coordinate differences are presented above. It can be seen that the coordinate agreements between the six different solution sets are in the order of 0.02 m horizontally and about 0.05 m vertically. These errors are consistent with those expected in a reasonable error budget for this kind of airborne mission. Given that the dynamic environment and baseline lengths involved were up to 50 km, the JPS receiver certainly performed favorably compared to other top of the line GPS dual frequency engines.

Further tests of the JPS Regency-2 receivers are planned in parallel to our production NovAtel equipment on projects in Texas, Georgia and South Carolina in early 1999. Much longer missions over increased baseline distances will be analyzed. Waypoint Consulting's GrafNav package will also be used for data processing and analysis.

Special thanks go to Javad Ashjaee, Sergei Yudanov, Sergei Organov, and Konstantin I. Saliy of Javad Positioning Systems for providing technical support that was instrumental in allowing the support for the JPS GRIL data format quickly and addressing some early pre-production firmware issues in a quick and professional manner.