Real-Time Processing Strategeis - System 500

New Ambiguity Resolution Strategies

Improved Reliability in Difficult Environments

Shortened Ambiguity Resolution Times

Low Latency Results

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March 1999

MADE TO MEASURE

Introduction

In 1995 Leica Geosystems released its first high-precision real-time software for System 300. Over the years the performance has been improved incrementally for user's benefits. With System 500, Leica Geosystems makes a revolutionary step forward with a new set of algorithms and strategies which provide the user with the best possible performance in the field. System performance has been significantly improved :

- Greatly shortening the time to provide the high-precision position
- Improved reliability of ambiguity resolution over long baselines
- Improved reliability of ambiguity resolution in difficult environment
- Substancially reduced latency for providing the high-precision positions

This paper highlights the key performance improvements of the newly released System 500 performances compared to the performance of conventional real-time systems on the market.

System 500 offers additional major performance advantages in the newly developed hardware which are also exploited by the real-time computation software. For instance, as one part of the Leica ClearTrak™ technology employed by the receiver, the pseudorange quality has been improved by modern patented multipath mitigation techniques. Also over years faster processors became available to allow more sophisticated processing schemes. For more details on the improvements associated with ClearTrak™ the interested reader is referred to Stansell and Maenpa (1999).

Performance on Different Baseline Lengths

The GPS test facility at our plant in Heerbrugg was created which allows setting up long-term determination testing over various distances. The test configuration was chosen to represent a typical surveying environment, not to avoid typical problems encountered by users.

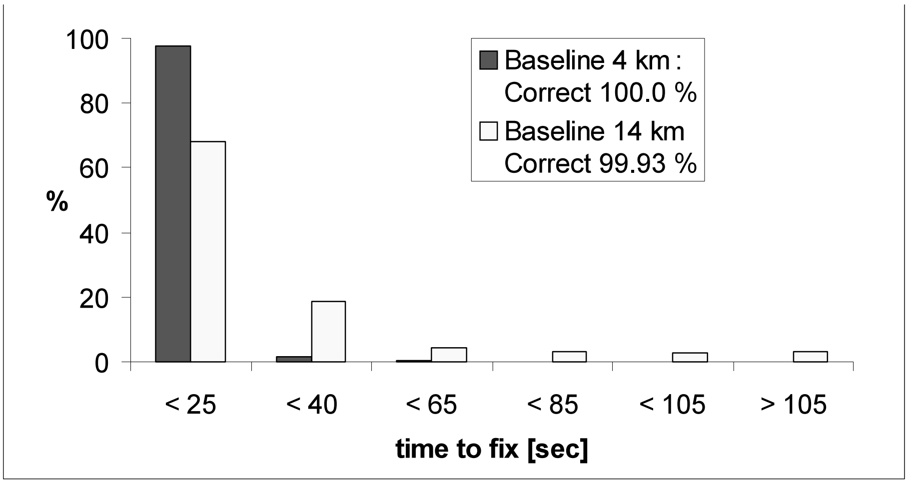

Figure 1 Ambiguity resolution time and reliability

Over the test period several thousand samples of baseline determinations were taken. Figure 1 shows the actual time until integer ambiguities were fixed and the system provided a high-precision centimeter level position. Since the systems were running 24 hours per day a variety of different constellations with 5 or more satellites were experienced when deriving the final position. Almost every fix on the 4 km baseline was achieved in less than 30 seconds. The ambiguity resolution needed a little more on the longer 14 km baseline, due to anomalies in the troposphere and the ionosphere, which cannot be modeled. However, there is still a quite significant improvement compared to other systems, since the cm-position was achieved 95% of the time within about one minute. Mostly constellations with unfavorable satellite distribution or redundancy are causing the longer ambiguity resolution times shown in figure 1. The ambiguity reliability was 99.93% on the 14 km baseline. Very few solutions under unfavorable conditions did not fit. The integer ambiguity resolution on the 4 km baseline was always correct.

Difficult Environment

Experienced GPS users are aware that the places where they need to find high precision coordinates are not always a favorable spot for GPS signal reception. The GPS adaptation of Murphy's law says that even when working in an environment of predommantly clear skies, one will be required to survey the position of at least one location that lies in the shade of a huge tree or another obstruction.

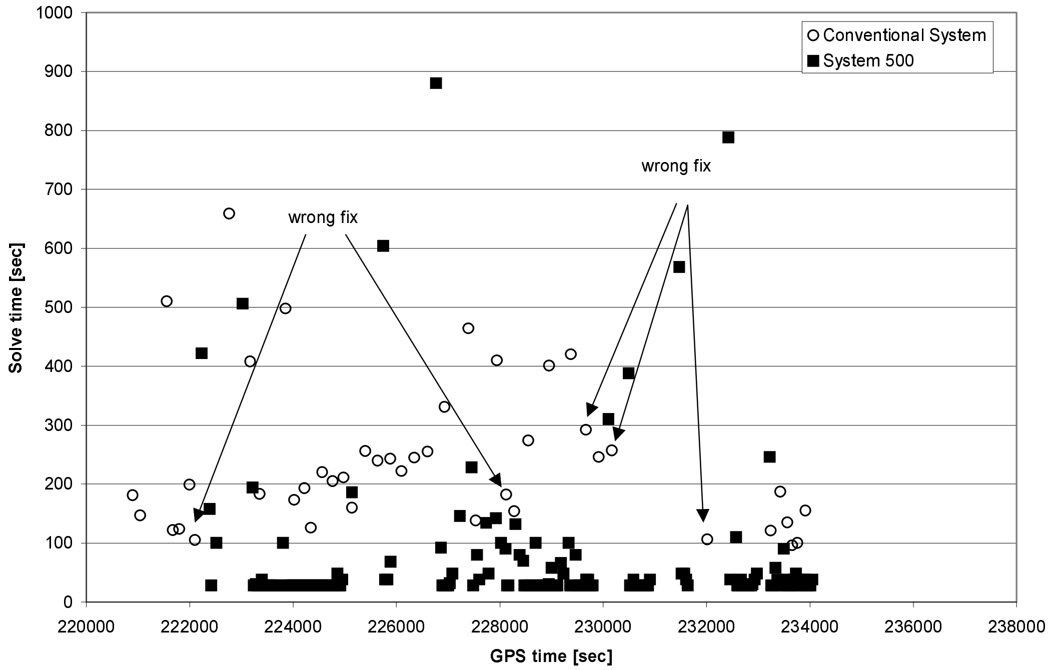

Figure 2 Comparison of time to resolve integer ambiguities under difficult conditions

Very often in the past GPS receivers did not provide any GPS observations under such obstructed conditions. Today's Leica Geosystems ClearTrak™ GPS receiver technology allows tracking satellites even in situations where no one would have tried to collect GPS observations years previously. In general, the observations generated in such environment are not as clean as under a clear sky. So, prior algorithms quite often struggled to provide the right solution. The new algorithm set now available in System 500 and other Leica Geosystems high precision GPS products allows best possible performance even in such difficult environments.

A test was conducted for comparing a conventional real-time system with our recently released System 500. Two reference sensors as well as two rover sensors were each connected to common antennas via an antenna splitter, for both the new real-time system and a conventional real-time system. Since both real-time systems obtained identical information from the antennas, the test shows the results of a head-to-head comparison. The reference station antenna was placed in an environment with little obstructions as an user might choose when setting up his reference station for a survey. The second antenna was placed aside some huge trees rising about 10-15 meters into the sky. From an antenna viewpoint, the trees and their foliage obstructed most of the Southern Hemisphere, degrading the line-of-sight to the satellites contributing the most to a good solution. Additionally, some closeby buildings obstructed the eastern section of the sky. Overall the environment was by no means the best place to survey with GPS.

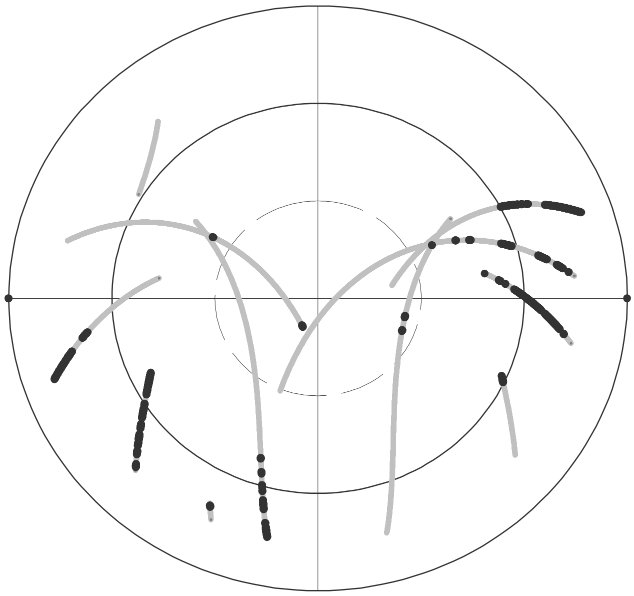

Figure 3 Elevation-Azimuth plot of satellite constellation during observation period

The elevation-azimuth plot which shows the satellite traces during the test period (figure 3) illustrates the effect of the obstructions. Sections with heavily disturbed signals are marked black. More normal tracking is indicated by the traces given in grey. The signals were fair during these sections.

The real-time integer ambiguity resolution time for System 500 was typically around 30 seconds. During more difficult constellation periods when the risk of wrong fixes increased, the system needed more time to resolve to ensure a correct solution for the user.

In comparison, the conventional real-time system needed considerably more time to fix integer ambiguities. While System 500 did not show any wrong solutions, the conventional real-time system came up with 5 wrong solutions. Experienced real-time users know that most conventional real-time systems are eventually able to recognize when the integer ambiguity choice is not correct, but this needs time and when the user is not able to spend these extra safety minutes to wait, a wrong solution may result.

The strategies of the newly released algorithms are specifically targeted to provide fast and reliable ambiguity resolution. The overall averaged integer ambiguity resolution time was 70 seconds for System 500 while the conventional real-time system needed on average 270 seconds during the test. This improvement by a factor of about 4 between the conventional system and System 500 integer ambiguity resolution times provides concrete proof of the superiority of the new System 500 strategies. Even the daily obstacles in a surveyor's life were mastered.

Real-Time Positions in Kinematic Mode

The applications of kinematic real-time positioning have become manifold since the real-time systems have proven their reliability. Applications such as machine automation and hydrographic survey need reliable positioning for automation of tasks or simply for combining with other measurements for storage in a database. In a land-surveying environment, fast, responsive, and highly accurate positioning helps to enhance productivity while stakeout. All these applications need fast update rates for high resolution of the path of motion and, for many applications, low latency of positions is critical for proper system response.

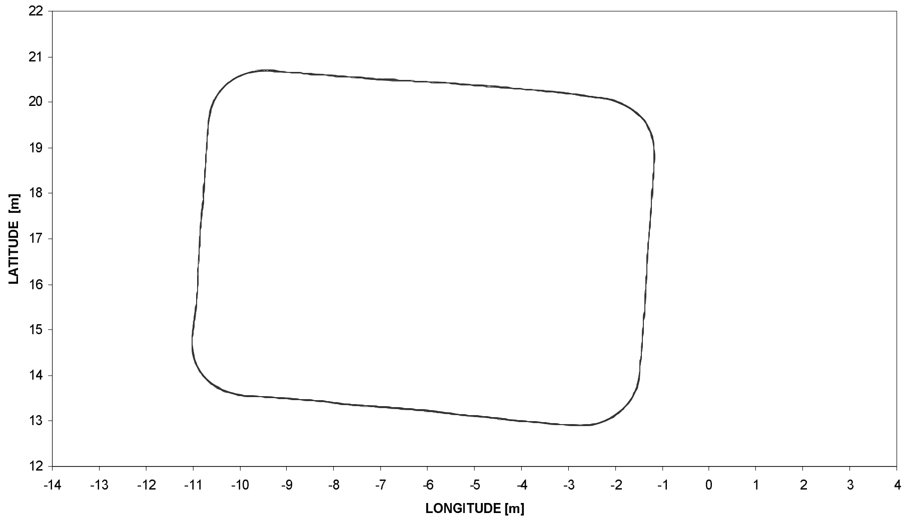

Figure 4 Horizontal track of kinematic test

The new Leica Geosystems processing strategy also provides faster position update rates at extremely low latencies to benefit users in a kinematic environment in real-time. In conventional systems, the limiting factor for data transfer between reference station and rover is often the data-link. Depending on the baud rate for the data link, the time to transfer observations between reference and rover might add up to 1 second in delay for generating the position on the rover. Faster update rates for the data-link can provide less latency in the transfer of data, but under most circumstances this technique reduces the area of data-link coverage and, moreover, the gain is not sufficient enough to satify most applications.

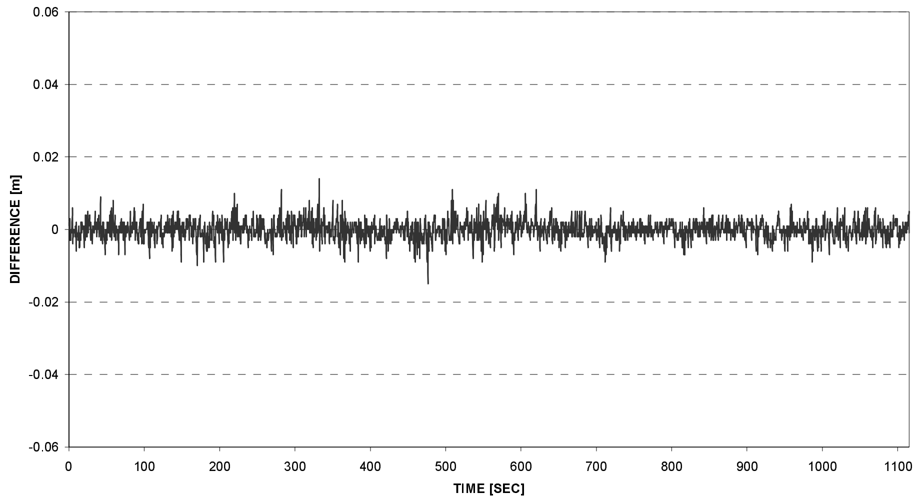

Figure 5 Differences of low latency real-time and post-processing results (latitude)

In contrast, System 500 employs a proprietary state-of-the-art prediction and communication technique for optimizing the data transfer. This method ensures that the user is provided with position information at high update rates and high precision of positions at extremely low latency. In contrast with conventional systems, with System 500, the baud rate does not have to be higher than 4800 baud for 5 Hz updates with high precision.

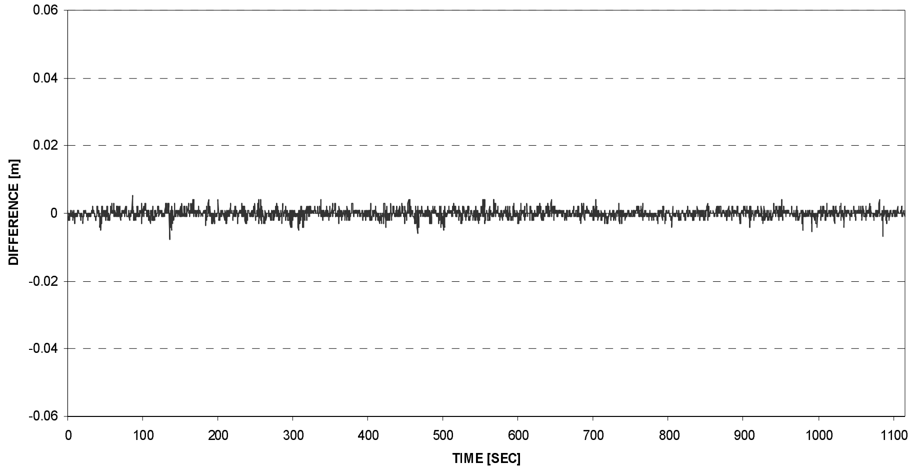

Figure 6 Differences of low latency real-time and post-processing results (longitude)

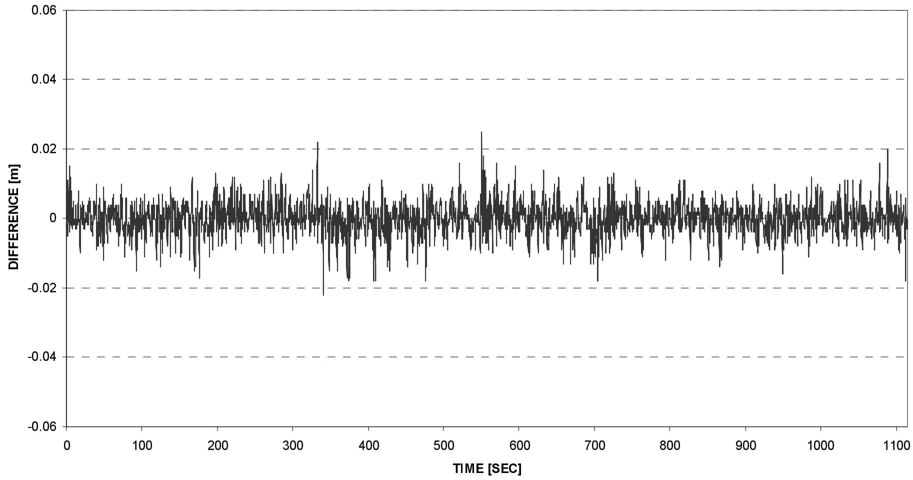

Figure 7 Differences of low latency real-time and post-processing results (height)

At the Leica Geosystems facility in Heerbrugg, a small model train was specifically configured to support kinematic test measurements. Figure 4 shows the ground track of several runs for a kinematic test.

The examples shown (figures 5-7) were observed in a 5 to 6 satellite constellation with GDOP values between 2.9 and 4.2. The raw observations as well as the real-time positioning were collected. The real-time positioning used the low latency 5 Hz computation for the positioning. The raw data was processed later on for comparison to the real-time results. The difference between real-time positioning and the post-processed results are partly because of the observation prediction. They are the combination of raw phase errors used in the post-processing and the prediction errors used in real-time.

The low latency objective does not allow waiting for the actual identical data measurement epochs of reference station and rover station to be processed. The problem of designing a real-time system is to overcome the degradation of accuracy created by the latency of the data-link. Very often the transmission time of the data-link adds 0.5 or even 1 seconds to weaken the latency performance of conventional real-time systems. For optimum latency the new Leica real-time system predicts the observations with almost negligible influence on the resulting position accuracy.

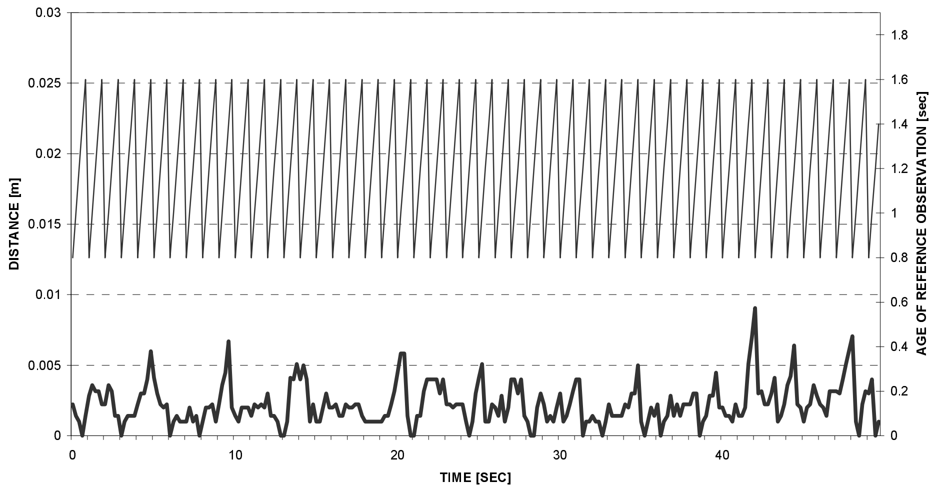

Figure 8 Comparison of post-processing and low latency real-time results

To illustrate this point, the upper graph in figure 8 shows the actual age of the reference data used to produce the results. The lower graph shows that the proprietary method used in System 500 dilutes the high precision results of the position only minimal. For System 500, the real-time computed positions have a latency of less than 50ms and are available every 0.2 seconds. It is also important to emphasize that in System 500, each of these real-time positions is computed independently, unlike some competitive systems which employ position extrapolation techniques which degrade accuracy as the position update rate is increased.

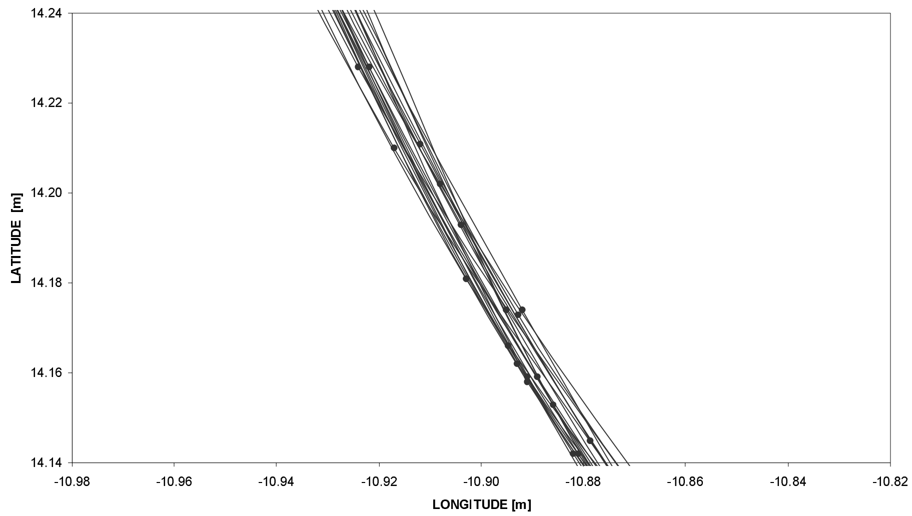

Figure 9 Repeatability of the ground track during the whole test

Conclusions

This paper highlights the state-of-the-art performance of Leica Geosystem's recently released System 500, which sets a new standard for real-time GPS positioning. Very low resolution times on different baseline lengths show the superiority of the integer ambiguity resolution needed for high precision results in real-time. Also the high quality and reliability of results is described.

The very low 50ms latency of the high precision 5Hz positions is unmatched by other systems. These capabilities provide substantial value to the user for surveying in real-time.

Acknowledgement

The authors would like to thank the whole System 500 development team in Heerbrugg and Torrance. Without their joint effort such a remarkable performance of the system would not be possible. Special thanks to Dietmar Benz and Dieter Kehl for carrying out the tests and collecting the data used in this paper.

References

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