Trimble BD940 vs Leading Competitor

White Paper

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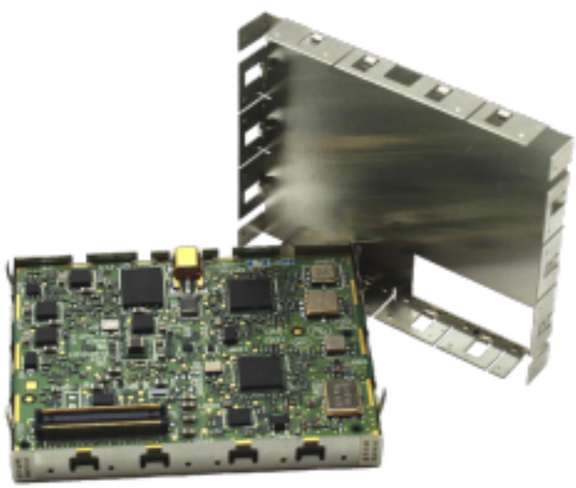
Section 1: Introduction to BD940 vs. Leading Competitor

In this white paper, Trimble's findings of multiple application testing scenarios between the Trimble BD940 receiver and a leading competitor's receiver will be shown. Overall, test results found that both units' performance was similar, however the Trimble BD940 outperformed the competitor unit.

The focus of testing was for industrial applications to see how they would perform in mixed environments. Industrial application equipment that uses GNSS for guidance may be setup in an RTK or SBAS mode, but the machinery needs to continue to operate, even if the solution drops to RTK Float, autonomous movement, etc. Therefore, all positions were considered in the analysis irrespective of the position type. In a survey application while the user is dynamic between points, during which time and corruption of the navigation filter can occur, the measurement is collected when the user is static for at least a few seconds over a point and only RTK fixed positions are considered. Static positioning is very different to dynamic positioning, as the multipath correlation time constant becomes substantially longer for the static case.



Trimble BD940

Section 2: Test Setup

For fair testing in each scenario, Trimble utilized a GNSS data record and playback system. The system digitizes the GNSS spectrum at the output of the antenna and allows the data to be replayed back in the lab into GNSS receivers. The use of a sample replay system results in time going backward relative to real-time. To prevent this resulting in any problem in the receiver, prior to the test commands were sent to the competitor's device to erase stored almanacs. After each "freset" command, the receiver rebooted which also reset the real-time clock as there was no battery backed up clock on the competitor's units. A similar approach was taken with the Trimble receivers. The appropriate data was erased via the web GUI and the unit rebooted. The NTP client feature of the Trimble receivers was turned off so the receiver was forced to get time from the playback system.

Section 3: Testing Scenario 1, SBAS

On November 14, 2017, a driving test in Sunnyvale, California captured RF samples, a POSLV™ system was used in real-time to capture GNSS and IMU data, and POSPac was used to generate a dynamic truth to show the distinction between the results of the two units. The test captured data in mixed environments:

- Freeways
- Open parking lot (no trees or obstructions)
- Downtown San Jose
- Urban
- Sunnyvale

The samples from the November 14th, 2017, were replayed and GNSS PVT data was captured. In the following images, the left image is from the competitor's receiver, and the right image is from the Trimble BD940. No external corrections were provided, as both units were confirmed to be operating in an SBAS mode. Neither unit had an IMU.

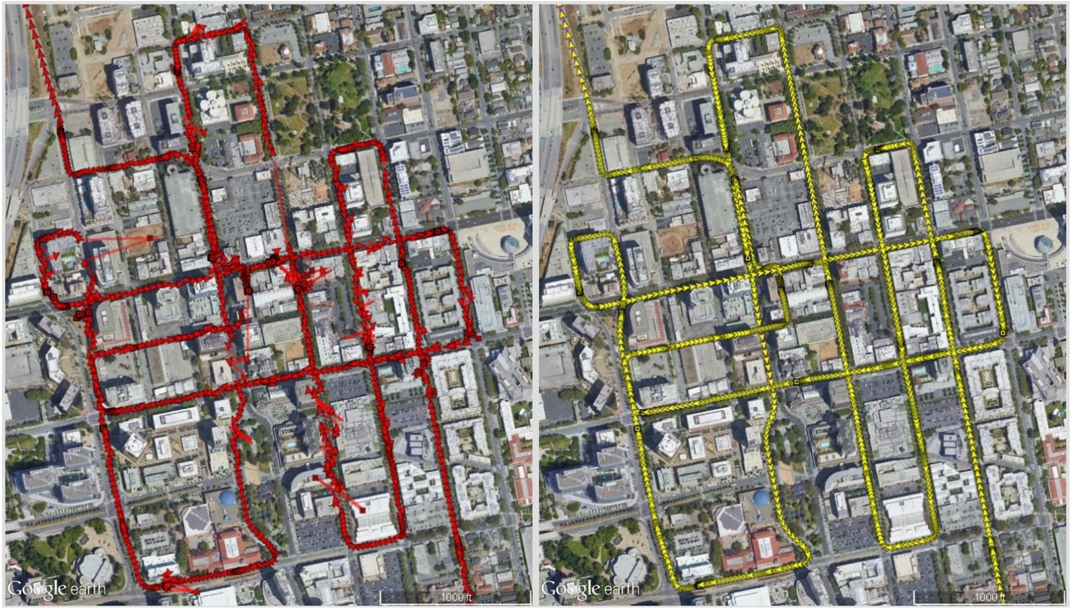


Figure 1. Downtown San Jose (Competitor left/Trimble right) – SBAS positions

Figure 2. Zoom of Downtown San Jose (Competitor left/Trimble right) – SBAS positions

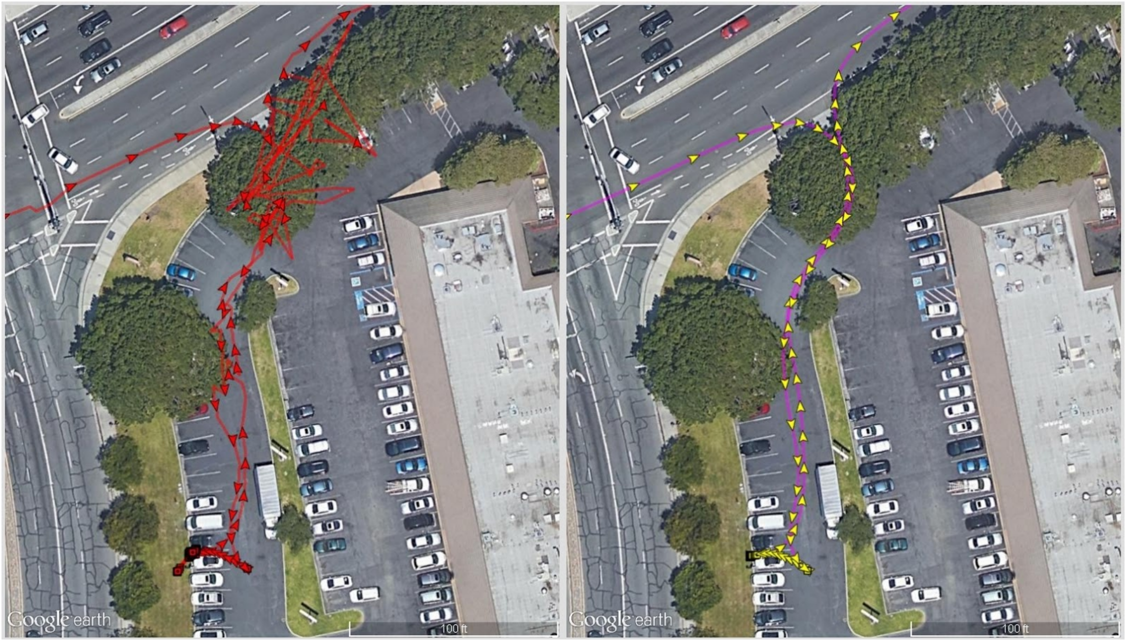


Figure 3. Parking lot with trees (Competitor left/Trimble right) – SBAS positions

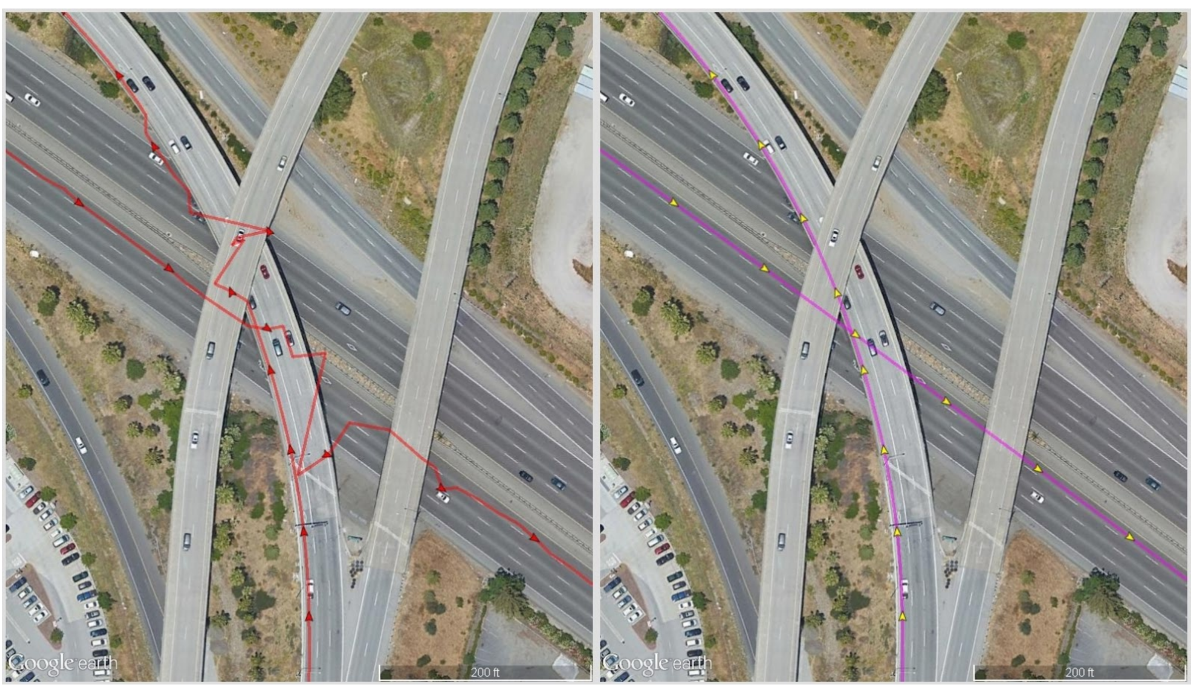


Figure 4. Freeway overpass (Competitor left/Trimble right) – SBAS positions

Figure 5. Urban (Competitor left/Trimble right) – SBAS positions

Figure 6. Trimble campus (Competitor left/Trimble right) – SBAS positions

If the competitor (left plots) and Trimble (right plots) are compared in Figures 1 - 6, it is shown that the SBAS GNSS only pseudorange position returned by the Trimble unit is significantly better than the competitor receiver when there's a more challenging environment. The competitor receiver delivers insufficient performance, unless it is in an open area.

In addition to insufficient position performance, the yield (percentage of the time the unit provides a position) of the competitor receiver is lower than the Trimble BD940. This is seen in the following table, the BD940 has 100% yield for all environments tested, and many of the extra positions are in tough environments:

Table 1. Position Yield

	BD940	Competitor
Freeway	100%	98.217%
Open Parking Lot	100%	100%
Trimble Campus	100%	100%
Urban	100%	99.935%
Downtown San Jose	100%	97.645%

Section 4: Testing Scenario 2, RTK

The logged RF data from November 14, 2017, was replayed a second time, this time in RTK mode. During this test a second Trimble BD940 was added, and the receiver had the head of CVS from January 23, 2018. In the RTK test, Trimble reviewed the data from the customer's perspective, in which a position every epoch was expected so all data is analyzed irrespective of whether the receiver returns RTK Fixed, RTK Float, DGNSS, SBAS, autonomous etc. A summary of the results are provided below:

Table 2. BD940 vs Competitor 2D Error

	BD940			Competitor		
	68% [m]	95% [m]	100% [m]	68% [m]	95% [m]	100% [m]
Freeway	0.035	0.434	3.681	0.040	0.832	314.674
Open Parking Lot	0.016	0.026	0.040	0.018	0.028	0.040
Trimble Campus	0.055	0.627	1.441	0.062	1.040	11.525
Urban	0.027	0.464	4.254	0.029	0.442	51.504
Downtown San Jose	0.388	2.481	49.166	1.124	4.022	NaN

The following table provides the percentage of the time each unit reported an RTK fixed solution for the different environments. This is informational only, all available positions are included in the analysis irrespective of the position type. The goal is to analyze the position performance for industrial applications and not survey, in which many applications the platform needs to continue to operate irrespective of the position mode of the receiver. While the customer's desire is for the system to be in a high accuracy mode as much as possible, today all GNSS systems downgrade during tougher environments, so the end customer expects the device to deliver as good a position as possible in all PVT modes.

Section 5: Observations

In both SBAS positioning and real world RTK positioning the current BD940 is at least similar in performance to the competitor's board, and often much better.

An initial test of the competitor unit shows that it has challenges around trees and buildings. In a pseudorange solution (e.g. SBAS) when the competitor unit is in a default configuration, Trimble performs substantially better in most environments with the performance only close in a benign environment. The Trimble unit by default provides a Kalman filter for positioning, the competitor unit only provides a Kalman filter for an extra fee.

From an SBAS perspective, the testing focused on a comparison of the default product behavior. The competitor board does have a Kalman filter and this has been evaluated in a follow-on document, found at the following link:
https://docs.google.com/document/d/1vJbUBRG1dBGzcTRHB2XcsJ3yQcddVZyA3TQ0WvmsxPA/edit

In RTK mode, Trimble outperforms the competitor unit, but the performance difference is not as large. There are challenges in the Trimble data at the tail of the RTK test's 2D error distribution, the outliers appear to be RTK-Float and in some cases RTK fixed solutions and not a downgrade to a code solution. However, the competitor unit is even worse at the tail of the distribution.

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