Evaluating the Accuracy of Low-Cost Global Navigation Satellite System Receivers

What Was the Need?
To help keep track of its assets and to assist in surveying land before construction, MnDOT uses electronic receivers that help surveyors precisely map the locations of infrastructure, as well as other surface features and landmarks. These receivers establish location using signals from global navigation satellite systems (GNSS), the same systems used by GPS devices.

Because surveying requires a high degree of accuracy—to a margin of error of 1 centimeter or less—the data from these receivers must be corrected using data from a network of 130 base stations throughout Minnesota. Collectively referred to as the Minnesota Continuously Operating Reference Station (MnCORS) network, these base stations use highly accurate receivers to continuously collect radio signals broadcast by GNSS satellites. Users of less accurate mobile GNSS receivers can link to the MnCORS system and use its data to correct their own results, using an algorithm referred to as real-time kinematic (RTK) processing. MnCORS is available not just to MnDOT staff and contractors, but to members of the public engaged in projects that require the precise mapping of land surface feature locations.

Not all GNSS receivers are capable of linking to MnCORS and performing RTK, and because GNSS receivers capable of using MnCORS and RTK require precisely calibrated antennas, they have traditionally been bulky and expensive, typically costing more than $10,000. But as GNSS technology matures, costs associated with its operation are expected to decrease. In addition, manufacturers have recently started advertising compact RTK-capable receivers that cost less than $1,000. However, there is no publicly available data supporting manufacturers’ claims that their low-cost receivers currently provide centimeter-level accuracy. Research was needed to evaluate the performance of these low-cost receivers.

What Was Our Goal?
The objective of this project was to assess the accuracy of five low-cost, RTK-capable receivers and one midrange-cost, RTK-capable receiver.

What Did We Do?
Researchers evaluated the low-cost receivers by comparing them to the high-end, survey-grade receiver currently used by MnDOT. The performance of the high-end receivers, such as the Eclipse P307 used by MnDOT, is accurate and well-characterized, and so their results provide a baseline standard of accuracy. Researchers evaluated the offset in position between the readings of the low-cost and high-end receivers to determine whether the low-cost receivers provide the centimeter-level accuracy promised by manufacturers.

Researchers collected data while receivers were stationary and while they were moving, and in various environments with different levels of sky visibility and obstacles. They
performed stationary tests at documented geodetic markers in rural, suburban and urban environments using both a high-quality, survey-grade antenna and a low-cost, lower-quality antenna.

For mobile tests, researchers installed the receivers in a vehicle and collected data along three different routes: rural routes with no obstructions and a completely visible sky, rural routes that included bridges, and urban environments with a large number of obstructions.

What Did We Learn?
Results showed that while most low-cost receivers could achieve centimeter-level accuracy for static applications in rural environments with clear, open skies, they were not suitable to mobile applications or more complex environments. By comparison, the midrange-cost receiver, the Eclipse P307, performed well for both static and mobile applications with both the low-cost and high-quality antennas.

In static tests using a high-quality antenna in rural environments, low-cost receivers achieved an accuracy of between 1 and 10 centimeters. Using a low-cost antenna in rural environments, all but two receivers achieved an accuracy of 68 centimeters or worse (using 95 percent accuracy values). In urban and suburban environments, the accuracy of the receivers was, with a few exceptions, 80 centimeters or worse.

In mobile tests, accuracies ranged from 3.9 centimeters to 2 meters. Additionally, the receivers generally did not have a high uptime when it came to receiving the data required to use the most accurate form of RTK calculations, especially in more obstructed environments when using the low-cost antenna.

What’s Next?
The availability of low-cost RTK receivers with centimeter-level accuracy would lead to a surge in the user base demanding access to the MnCORS network, creating new applications for agriculture, construction and law enforcement. It is important for MnDOT to be aware of how mature such technologies are in order to make future plans regarding MnCORS network infrastructure. MnDOT may also conduct additional research to develop software that can be used internally and by the public to test the accuracy of GNSS receivers.

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“While there’s a lot of excitement about low-cost GNSS receivers, the technology is not quite mature enough for safety-of-life applications requiring centimeter-level accuracy, such as for autonomous vehicles.”

—Demoz Gebre-Egziabher, Director, Graduate Studies, University of Minnesota Department of Aerospace Engineering and Mechanics

“To better predict demand for MnCORS, MnDOT must be familiar with currently available GNSS receiver technology and, in particular, low-cost hardware that is more likely to see rapid adoption.”

—Nathan Anderson, Senior Land Surveyor, MnDOT Office of Land Management

Using GNSS receivers for surveying assists MnDOT with asset management, environmental stewardship, construction planning and a variety of other transportation engineering-related applications.