DRAFT
Performance Testing of the Trimble GeoXT Global Positioning System Receiver

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Introduction:

The recently released Trimble Navigation GeoXT is a hand held 12 channel Global Positioning System (GPS) receiver. This receiver was tested by the U S Forest Service to determine performance under Western Oregon forest canopy conditions. The unit tested was configured without real-time differential correction capability. The tests were made between September 20 and Oct 7, 2002.

These GPS receiver performance tests were made at two sites. The first site is under Western Oregon forest canopy at the Clackamas Test Network. The other used was the open-sky National Geodetic Survey control station “Nelson” in Portland, Oregon. All tests were made with Selective Availability (SA) off. The tests were designed to examine the effect of tree canopy on the following:

1) The positional accuracy point features consisting of 1 position and point features consisting of 60 positions to determine what, if any, increases in accuracy occur through the averaging of more positions per feature.

2) The positional accuracy of post-processed differentially corrected GeoXT data using both Internal and External Antenna.

3) Receiver efficiency, which is the number of positions logged divided by the number of potential positions was qualitatively observed not quantitatively calculated. The efficiency figures in this report are my estimates.

Equipment:

This test was performed with the GeoXT package with 128 MB RAM, TerraSync & Pathfinder Office. Both the manufacturer’s standard equipment internal antenna and the GeoXT optional external antenna were used. The manufactures list price for this package is $5995. The external antenna PN 39002-00 is an optional item for the GeoXT the manufacturer’s list price is $45.

The GeoXT firmware version 1.00 was used for all tests. The data logging software used in this receiver is TerraSync version 2.20. The receiver serial number is 4236B12265

This receiver uses the Trimble Everest multipath reduction technology

Test Network and Survey Station Data:

Forested Site: The Clackamas Test Network is located in Western Oregon on the Mt. Hood National Forest. Clackamas GPS Test Network is a site for testing P and C/A Code (resource grade) GPS receiver performance under moderate to heavy western Oregon timber canopy. The vegetation at the site consists of Douglas Fir and Western Hemlock over story, these trees are approximately 24-40" d.b.h., with a Vine Maple and Red Alder under story. The terrain at the site is nearly flat with no terrain obstructions above 20 degrees. The test network is composed of

twelve points with known geographic positions. These twelve points were established by a conventional Total Station closed traverse survey, which was based on two GPS points adjacent to the site having satellite horizon. These two points were established by static carrier phase GPS survey connected to the Oregon High Accuracy Reference Network (HARN).

Open Site: The station “Nelson” was used as a control site due to its clear-sky nature with no obstructions. Station “Nelson” is an Oregon High Accuracy Reference Network (HARN) Order B survey mark established by the National Geodetic Survey in 1998, PID-A12002.

Reference Station: Differential Correction Base (reference) data was downloaded from the Community Base Station (CBS) at the Portland State University Geology Department in Portland, Oregon. The Portland State University CBS uses 12 channel Trimble Maxwell chip receiver recording SYNC measurements at 5 second intervals at a 10 degree elevation mask with Trimble CBS software version 2.67. This CBS is located approximately 84 Km from the Clackamas Test Network and 10km from station Nelson.

Field Data Logging Procedures:

All GPS observations were made at approximate antenna height of 1.5 meters. The receiver or external antenna with ground plane was mounted on a tripod for all tests.

All GPS data was logged at 1 position / second, the elevation mask used was 15 degrees.

Data Logging:

- Data was logged for 60 positions / point feature.
- Data logged with the Internal antenna was logged at Maximum PDOP of 8 and minimum SNR or 2.5
- Data logged with the External antenna was logged at Maximum PDOP of 7 and minimum SNR or 3.5
- Data was logged with internal antenna then the network was repeated with the external antenna.
- Data was logged during multiple days.

Office Data Processing Procedures:

Data post processed using the Trimble Pathfinder Office version 2.90 software package. Post-processing consisted of Differential corrections of the raw (.ssf) receiver files using the Portland State University CBS. The corrected (.cor) files were then exported in database .dbf format.

The data analysis was made using Microsoft Office 2000 Excel spreadsheet application.

The National Standard for Spatial Data Accuracy (NSSDA) was used to evaluate and report the positional accuracy of (see appendix 1 for formulas). The Federal Geographic Data Committee specifies that the NSSDA be used to evaluate and report the positional accuracy of geospatial data produced, revised, or disseminated by or for the Federal Government

The NSSDA reports accuracy values at 95% confidence. In other words, 1 out of 20 measurements made with the same receiver and data logging settings under similar forest canopy conditions should have errors larger than those published in this report.

All data was analyzed in the North American Datum of 1983 (NAD 83).

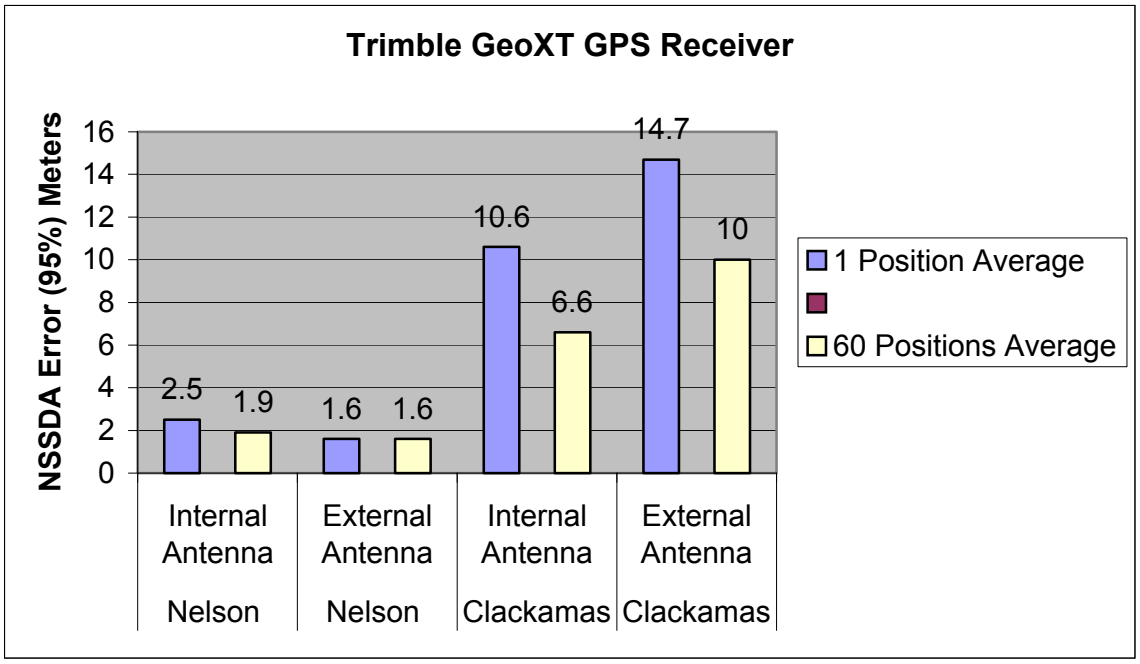
SITE CONDITIONS:

These tests were made under generally dry canopy conditions.

Test Results:

The test results for all observed data are illustrated in Chart 1.

Chart 1:



The open site accuracy at station Nelson was very good. Very little difference in positional accuracy was noted was noted between both the 1 position averages and the 60 position averages using both the internal and external antenna. The observed efficiency was 100%.

The forested site accuracy at the Clackamas test network was good considering the canopy conditions. The results were notable in 2 respects:

- The external antenna yielded much higher efficiency even at harder to achieve receiver settings than the internal antenna. This was expected based on previous receiver tests. It was observed that the SNR for individual satellites increased from 3-4 units with the external antenna. The External antenna yielded an estimated efficiency of 90%. When the internal antenna was used at using the same receiver settings of PDOP 7 and SNR 3.5 the observed efficiency the 30% range. By modifying the receiver settings to PDOP 8 and SNR 2.5 the internal antenna yielded about 80% efficiency.
- The internal antenna yielded higher accuracy than the external antenna. This was result was unexpected based on past tests.

The accuracy at the open site Nelson was essentially the same with both the internal and external antennas.

The difference in antenna performance was discussed with engineers from Trimble. It was explained that the Everest technology resides on the GPS chip. It is designed to improve GPS accuracy in harsh or hi-multipath environments. Trimble states that Everest examines the polarity of GPS signals, which will have right hand polarity if undisturbed and left polarity if they have taken an extended path due to signal disturbance, multipath, or other factors. Everest is used

with both the internal and external antennas, however the internal antenna feeds the GPS signal in a bandwidth that is optimized for accuracy and the external antenna feed is optimized to improve efficiency rather than accuracy.

At station Nelson with internal antenna the maximum PDOP = 3.2 and the average PDOP 2.6; with the external antenna the maximum PDPP = 3.0 and the average PDOP=2.5.

At the Clackamas Network with the external antenna the maximum PDOP = 7.4 and the average PDOP = 4.6; with the internal antenna the maximum PDOP = 7.9 and the average PDOP = 4.1.

Recommendations for the GeoXT:

The following are general recommendations for using this receiver for mapping applications.

For open sites:

- Point features can consist of only 1 position per feature.
- The manufacturers recommended receiver settings of SNR 3.5 and PDOP 7 can be used, although they will often be exceeded due to available satellites.
- Internal and External antennas yield similar accuracy.
- 2.5 meters at 95% confidence (NSSDA) can be achieved with these receiver settings and the internal antenna.

For Forested Sites:

- Point features should consist of at 60 positions per feature.
- The receiver settings should be modified to SNR 2.5 and PDOP 7.
- The internal antenna should be used for best accuracy.
- 6.6 meters at 95% confidence (NSSDA) can be achieved with these settings.

Appendix 1: **Horizontal Accuracy using NSSDA formulas**:

Determine the radial Root Mean Square Error (RMSE) for the GPS data set:

$RMSE_r = sqrt[\Sigma ((Xdata - Xcheck)^2+(Ydata – Xcheck)^2)/n]$

where:

Xdata, Ydata are the coordinates of the check point in the GPS data, i data, i
Xcheck, Ycheck are the coordinates of the check point in GPS test network.

Modify RMSE error to NSSDA 95% probability:

$NSSDA\ Accuracy_r = 1.7308 * RSME_r$

Appendix 2: Photo of GeoXT (Photo from Trimble Navigation)