Agriculture - North America

Leica mojoRTK
Two Inches is Enough!

RTK 'Sub-inch' Farming Mythology

The term 'sub-inch' originated in the Survey industry to describe the approximate accuracy of the RTK systems they use to measure land areas. In most surveying applications, surveyors have the luxury of working close to their RTK base station, and to them, 'sub-inch' has real-world meaning. The term became commonly used in Agriculture as RTK systems migrated to tractor autosteer applications in the late 90's. Unlike surveyors, farmers mostly do not have the ability to stay within a few hundred yards of the base station, so the term 'sub-inch' quickly loses its practical meaning.

Distance from the Base Station

We all know that metal machine parts like bearings are made and measured to within certain tolerances or accuracies. We also know that these tolerances can change as temperatures rise and fall causing the metal to expand and shrink. Analogously, RTK receivers have tolerances or errors in their position calculations, and in addition, these errors can change as the distance from the base station changes. As distances from the base rise, the position accuracy gets worse; and as it falls, the accuracy gets better. In the fine-print, GPS makers may quote accuracy in the following way:

- Leica 1200 Accuracy RMS* = ±0.4" + 1ppm, 1-Sigma
- Trimble 214 Accuracy RMS*= ±0.4" + 2ppm, 1-Sigma

±0.4"	1ppm	1-Sigma
This tells the accuracy or tolerance of the RTK Engine if your base was next to the machine's GPS receiver. The "±" indicates the error can be 0.4" to the left or right of the desired machine line.	This tells you how much worse the accuracy gets as you get further from the base station. "ppm" stands for parts-per-million; or 1ppm = 0.063" of error per mile from the base station.	This tells you that for each position measurement your RTK receiver calculates, 68% of them will be within the stated accuracy. Or 32% won't be! 2-Sigma is 95%; 3-Sigma is 99%.

Example 1

If you were farming 6 miles away from your base-station with your Trimble AutoPilot, your RTK Accuracy will be:

*Accuracy = 0.4" + {(2 x 0.063") x 6mi} = **1.156"***

This means that each position used by your AutoPilot with an AgGPS214 receiver has a 68% chance of being within ±1.2" accurate at 6 miles. This is not "sub-inch" - even before the terrain compensation errors creep in.

Example 2

If you were farming 1 mile away from your base-station with your Trimble AutoPilot, but this time with a Trimble AgGPS332 or AgGPS252 receiver (±0.98" + 2ppm, 2-sigma), your RTK Accuracy will be:

*Accuracy = 0.98" + {(2 x 0.063") x 1mi} = **1.106"***

This means that each position used by your AutoPilot with a 332 or 252 receiver has a 95% chance of being ±1.1" accurate at 1 mile range from the base station. Again, this is close, but not "sub-inch". At 6 miles this is ±1.7"... and so on.

It is clear that if you want to be 95% sure your autosteer system is going to be "sub-inch" then you have to stay about half-a-mile from your base-station. Of course this is not practical and we all know that autosteer has huge financial benefits to farms as it is. Buyers just need to better understand what they are purchasing in terms of accuracy.

*see datasheets attached. 1-sigma is commonly used as an approximation of 'RMS'. Trimble receiver specifications were obtained from their website in April 2007. This may be subject to change, upgrades or new product announcements by Trimble. Other receivers may be available for the AutoPilot so please check with Trimble for Specifications. Illustrations, descriptions and technical specifications are not binding and may change. 'Trimble' , AgGPS and 'AutoPilot' are the property of Trimble Navigation Limited.

- when it has to be **right**

Leica Geosystems

The Leica Approach to Accuracy

It is Leica's policy that we will not state an accuracy specification that cannot be practically met in the field by the machine. If the core GPS Engine in the autosteer system cannot measure "sub-inch" accuracies at a reasonable working distance from the base station, then ask yourself, what chance has the tractor/implement of achieving sub-inch on the ground? None. This highlights the practical difficulty in trying to translate GPS Engine Accuracies to Field Accuracy.

Field Accuracy versus GPS Engine Accuracy

- GPS Engine Accuracy is the error in the position of the GPS receiver measured at the center of the GPS antenna.
- Field Accuracy is the error in the position of the tractor and/or implement measured on the ground.

Specifying GPS Engine Accuracy is the most common practice amongst GPS companies because it is the easiest measure to create and compare statistically. Field Accuracy on the other hand is nearly impossible for GPS companies to specify. Why? Because GPS companies do not control the many combinations of these critical factors:

1. Quality of the terrain compensation measurements to account for machine tilt/movement;
2. Quality of the steering kit used by the machine (CAN vs Hydraulic vs Friction Motor);
3. Model, age and maintenance of the machine including tires, hitch, and hydraulics;
4. Type, quality and maintenance of the implement being used;
5. The field conditions including field moisture, compaction, cover and soil type.

To get the most from GPS guidance systems, the farmer needs to constantly manage these factors effectively with the help of their GPS provider.

mojoRTK System Accuracy

The specified accuracy of the mojoRTK system is as follows:

±2.0" up to 4 miles range from the base station with a 99% reliability

While this does not comply with traditional survey accuracy statements, or with the new and very abused Ag accuracy statements such as "pass-to-pass" or "year-to-year"; it does give a repeatable accuracy guide to the farmer that they can understand and translate to an achievable field accuracy when the 5 factors noted above are taken care of.

Example 3

If you are farming 6 miles from your mojoRTK base station with your mojoRTK autosteer console, your GPS Engine Accuracy is calculated as:

$$Accuracy = 0.4" + \{(1 \times 0.063") \times 6mi\} = 0.778"$$

Even though the Leica GPS Accuracy is technically "sub-inch" at 6 miles, 68% of the time, we have chosen to state the more conservative accuracy estimate for our overall 'system' accuracy. 99% is a 3-sigma estimate which means that less than 1% of our system position calculations fall outside 2 inches. We take this stance because farmers don't farm only 68% of the time they are in the field and anything else would be misleading.

Conclusion

This paper has differentiated between GPS Engine Accuracy, Field Accuracy and System Accuracy, and we have discussed how the general misuse of the term "sub-inch" has incorrectly set farmers expectations regarding RTK autosteer accuracy. In addition, we have seen that RTK accuracy is very dependent on the distance you farm from the base station and is easily calculated from the manufacturers' datasheets.

GPS Accuracy = error + (ppm error x distance to base)

We have seen that the Leica GPS1200 Engine used in the mojoRTK system is every bit as accurate as those that claim to provide "sub-inch" accuracy - Leica simply chooses to be more practical in its statements. Autosteer has proven to be extremely valuable to farmers around the world, and with more understanding, even greater productivity can be derived. Deciphering manufacturer accuracy claims is key to farmers getting better value for their money.

*see datasheets attached. 1-sigma is commonly used as an approximation of 'RMS'. Trimble receiver specifications were obtained from their website in April 2007. This may be subject to change, upgrades or new product announcements by Trimble. Other receivers may be available for the AutoPilot so please check with Trimble for Specifications. Illustrations, descriptions and technical specifications are not binding and may change. 'Trimble' , AgGPS and 'AutoPilot' are the property of Trimble Navigation Limited.

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Accuracy (rms) with real-time/RTK

	ATX1230 GG / ATX1230 / GX1230 GG / GX1230	GX1220	GX1210
RTK capability	Yes, standard	No	No
Rapid static (phase), Static mode after initialization	Horiz: 5mm + 0.5ppm Vertical: 10mm + 0.5ppm		
Kinematic (phase), moving mode after initialization	Horiz: 10mm + 1ppm Vertical: 20mm + 1ppm		
Code only	Typically 25cm		

Accuracy (rms) with DGPS/RTCM

	ATX1230 GG / ATX1230 / GX1230 GG / GX1230	GX1220	GX1210
	DGPS/RTCM standard	DGPS/RTCM optional	DGPS/RTCM optional
DGPS/RTCM	Typically 25cm (rms)	Typically 25cm (rms)	Typically 30cm (rms)

Accuracy (rms) in single receiver navigation mode

	ATX1230 GG / ATX1230 / GX1230 GG / GX1230	GX1220	GX1210
Navigation accuracy	5–10m rms for each coordinate	5–10m rms for each coordinate	5–10m rms for each coordinate
Degradation effect	Degradation possible due to SA	Degradation possible due to SA	Degradation possible due to SA

On-the-Fly (OTF) initialisation

	ATX1230 GG / ATX1230 / GX1230 GG / GX1230	GX1220	GX1210
OTF Capability	Real time and post processing	Post processing only	No OTF
Reliability of OTF initialisation	Better than 99.99%	Not applicable	Not applicable
Time for OTF initialisation	Typically 8secs, with 5 or more satellites on L1 and L2	Not applicable	Not applicable
OTF Range* *Assuming reliable data-link is available in RTK case	Typically up to 30km in normal conditions Up to 40km in favorable conditions	Not applicable Not applicable	Not applicable

Position update and latency

	ATX1230 GG / ATX1230 / GX1230 GG / GX1230	GX1220	GX1210
	RTK and DGPS standard	DGPS optional	DGPS optional
Position update rate	Selectable: 0.05 sec (20Hz) to 60 secs	Selectable: 0.05 sec (20Hz) to 60 secs	Selectable: 0.05 sec (20Hz) to 60 secs
Position latency	0.03 sec or less	0.03 sec or less	0.03 sec or less

*Ag*GPS AUTOPILOT TECHNICAL SPECIFICATIONS

Trimble Components:

- *Ag* GPS® 214 RTK Rover Receiver and antenna
- Steering Position Sensor (Wheeled tractors only)
- Navigation Controller
- Hydraulic Valve (Mechanical steering only)
- Autopilot Display
- *Ag* GPS 70 RDL Keypad and Data Logger
- *Ag* GPS Lightbar
- TRIMCOMM 900M Rover Radio and antenna
- Mounting Brackets

Also required:
- *Ag* GPS 214 Base Station System with TRIMCOMM 900M Base Station Radio

Standard Features:

Ag GPS 214
- Centimeter accuracy
- Real-Time Kinematic processing
- 9 channel L1/l2 full cycle carrier
- CMR & RTCM correction input
- RTK Fixed, RTK Float, and DGPS modes
- Three programmable RS-232 ports
- 1PPS output

Navigation controller
- +/- 90 degree Tilt/Roll compensated
- Internal data storage
- Water proof
- Externally mounted
- Fully integrated design
- Attitude sensors
- Embedded controller (no moving parts)

Autopilot display
- 31 keys with 10 digit numeric keypad
- 6 inch high resolution LCD display
- Water Proof

Ag GPS 70 RDL Keypad and Data Logger
- Compact Flash Memory card
- Splash proof
- 2 x 16 line character display
- Two Programmable RS-232 ports
- CAN 2.0B (J1939) Port
- 9 volt battery for data integrity
- A-B line logging
- Coverage Logging
- 3-D position or Topo logging
- Job download/upload

Performance Characteristics:

Ag GPS 214 Receiver

General	Dual 12 channel dual frequency Carrier phase receiver
Update Rate	10 Hz Standard: 20 Hz Optional With MS750 upgrade package
Carrier Phase Position Accuracy	1 cm+ 2ppm baseline distance - Horizontal 2cm+2ppm baseline distance - Vertical
Time to Fix	<30 sec, typical

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Table A.1 *Ag*GPS 252 receiver (continued)

Connectors	12-pin Deutsch connectors
Ports	Two connection ports, both of which support RS-232 and CAN
Mounting	Three holes for 10 mm (0.39 in) bolts
Compliance	FCC Part 15 Class A, C-Tick, E-mark, CE-mark

GPS Channels

Table A.2 lists the performance characteristics of GPS channels.

Table A.2 GPS channels performance

Item	Description
General	12-channel, parallel tracking L1 1571.42 MHz and L2 1227.60 MHz. C/A code and carrier phase filtered measurement.
Update rate	1, 5, 10 Hz
RTK speed accuracy	0.16 kph (0.10 mph)
RTK position accuracy	Horizontal 2.5 cm (0.98 in) + 2 ppm, 2 sigma, and vertical 3.7 cm (1.46 in) + 2 ppm, 2 sigma, if all of the following criteria are met: • At least 5 satellites • PDOP <4 • CMR corrections • Standard format broadcast from a Trimble MS750, *Ag*GPS 214, or equivalent reference station
Differential speed accuracy	0.16 kph (0.1 mph)

Item	Description
RTK position accuracy	***Horizontal 2.5 cm (0.98 in) + 2 ppm, 2 sigma, and vertical 3.7 cm (1.46 in) + 2 ppm, 2 sigma, if all of the following criteria are met:*** • At least 5 satellites • PDOP <4 • CMR corrections • Standard format broadcast from a Trimble MS750, *Ag*GPS 214, or equivalent reference station
Differential speed accuracy	0.16 kph (0.1 mph)
Differential position accuracy	Less than 1 m (3.28 ft) horizontal if all of the following criteria are met: • At least 5 satellites • PDOP <4 • RTCM SC-104 corrections • Standard format broadcast from a Trimble MS750, *Ag*GPS 214, or equivalent reference station
OmniSTAR HP speed accuracy	0.16 kph (0.1 mph)
OmniSTAR HP position accuracy	***10 cm (3.94 in) after convergence, 2 sigma, if all the following criteria are met:*** • At least 5 satellites • PDOP <4 • OmniSTAR HP corrections Convergence time can vary, depending on the environment. Time to the first fix (submeter accuracy) is typically <30 seconds; time to the first useable fix (<10 cm accuracy) is typically <30 minutes.
OmniSTAR XP position accuracy	***20 cm (7.87 in) after convergence, 2 sigma, if all the following criteria are met:*** • At least 5 satellites • PDOP <4 • OmniSTAR XP corrections Convergence time can vary, depending on the environment. Time to the first fix (submeter accuracy) is typically <30 seconds; time to the first useable fix (<10 cm accuracy) is typically <30 minutes
Time to first fix	<30 seconds, typical
Multipath mitigation	EVEREST technology