FAQAnswers

Be Informed Buyers of GPS Guidance

Frequently Asked Questions and Answers

What is the Accuracy of my GPS ?

In agriculture, there are different types of GPS accuracy that you need to understand about your GPS. These are:

Static accuracy is the accuracy of the GPS data when it is collected over a long time period, typically, 24 hours. Many GPS manufacturers quote this accuracy estimate, as it is the easiest to measure. How do you measure an estimate? It's important to ask the GPS manufacturer what level of confidence they have with this answer. In other words is it 50% of the time, or 68% (1 sigma or 1 standard deviation) or 95% of the time (2 sigma or 2 standard deviations) that you will obtain that accuracy from the GPS.

Pass-to-pass accuracy is the accuracy from one swath relative to the next (i.e., how much overlap or skip between adjacent swaths). Typically the time from driving one swath to another is done within a short timeframe (e.g., 10-15 minutes). While moving there is reduced multipath (GPS signal reflection) and there are very few satellite constellation changes during short time frames. Therefore, the GPS receiver tends to provide you with much higher levels of pass-to-pass accuracy compared to the static accuracy value for the same GPS receiver. For example, a Trimble 50cm static accurate DGPS receiver can demonstrate a pass-to-pass accuracy of 10cm.

Relative accuracy is how close a GPS receiver is able to take you back to a known or previously mapped location, independent of a known point or local "truth". The best example in agriculture is performing a field operation with GPS guidance where you want optimum pass-to-pass accuracy from one swath to the next and it is therefore relatively accurate. Since this is not absolutely accurate, you cannot go back to the field to use the same swath lines on another day.

Absolute Accuracy is how close a GPS receiver is able to get you to the "truth". In agriculture, everyone uses various sources of differential correction (L-Band, Beacon, WAAS etc) such that finding a local "truth" is different for each of these differential correction methods. As a user, it is recommended that you pick one correction source and always use it for any one GPS receiver – this removes one more variable and improves your absolute accuracy (i.e., the ability to find a known spot or previously mapped feature again).

What does Repeatability mean ?

Repeatability is a term often used in precision agriculture today. This is generally understood to mean the ability of a GPS receiver or GPS guidance system to bring you back to the exact same spot in the field reliably each time you drive into the field, from year to year. Whether absolutely accurate or relatively accurate, agricultural guidance applications often demand good system repeatability. RTK or Real Time Kinematic GPS receivers with centimeter static accuracy are the best at providing high repeatability in an agricultural field. For example, the ability to come back into a field and place seed on top of a fertilizer strip in strip till; the ability to cultivate between crop rows; the ability to avoid ripping up drip tape during tillage between crops.

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Does tilt compensation improve the performance of my lightbar guidance system ?

In many situations there is no benefit from a tilt sensor in a manual guidance system.

There are two key problems with tilt compensation in a DGPS manual guidance system:

- In a manual guidance system, a tilt compensation device provides the operator with information that is 'outdated' or delayed several seconds. The tilt-adjusted position information shown to the operator on the lightbar is for positions where the vehicle has already driven.
- The resolution of a Differential GPS (DGPS) receiver is often not adequate for tilt compensation adjustment unless the slope is large. If the slope is very small, tilt adjustment is only beneficial with a higher accuracy GPS where the resolution of accuracy is finer. If the slope is large, then a DGPS receiver level of accuracy (i.e., resolution) used with an autosteer system can also benefit from tilt compensation. For example a GPS receiver mounted 12 feet in the air on top of a tractor displays an error of 2.5 inches for every 1-degree of roll.

There can be some small benefit from tilt compensation under certain conditions with a manual (lightbar) guidance system, which are:

- If the slope is constant and does not change along the swath, tilt sensors can provide some benefit – in this case, the delayed tilt compensation can apply to the entire swath length along the constant slope.
- Driving over large terraces may also see some benefit from tilt sensors. As the vehicles goes from the lower side of a large terrace and drives up over the terrace, the GPS position jump or difference as shown on the lightbar is reduced as the vehicle completes the terrace and levels out.

The advantage of adjusting GPS positions for terrain with a tilt sensor is greatest with automated guidance systems. The Trimble *Ag*GPS Autopilot system has no driver error and the low latency inertial sensor tilt-adjusted positions are instantly communicated to the autosteer system to adjust the auto-steering. Autopilot also has a 3 axis tilt sensor which corrects for pitch, roll and yaw errors 50 times a second.

How do I benefit from having Trimble's look-ahead feature in the lightbar guidance system?

Look-ahead in the Trimble *Ag*GPS Parallel Swathing Option and *Ag*GPS EZ-Guide system is a time-based configurable option that is used to predict the vehicle's position into the future (typically 0-3 seconds). This means that at any point in time while driving the lightbar, you will get offline or guidance information on the lightbar that is from the predicted future position. This improves the operator's ability to be guided at any operating speed, and avoid over driving (fish-tailing) with the lightbar along the swath line. It is important to set the look ahead setting to match the vehicle's operating speed.

General rule of thumb – add 1 second look ahead for every 8 mph of speed

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How does adjustable LED spacing improve performance of my lightbar guidance system?

Trimble lightbar guidance systems allow you to adjust the LED spacing on the lightbar to a numerical value in inches or centimeters. This means you can customize the system to match the accuracy of the GPS receiver that you are working with and for the level of operator experience. Novice users of lightbars can set the system to a larger LED spacing, allowing them to become proficient at steering to the lightbar. As the operator becomes more experienced, an operator can elect to decrease LED spacing to improve performance.

What factors affect GPS guidance system performance in the field?

It is important to know that several factors can affect GPS performance and therefore guidance performance in the field. The following is a summary of the key variables that affect GPS guidance system performance.

Satellite Constellation & Geometry

The position of the satellites in the sky and their movements influence GPS performance. DOP or Dilution of Precision (including the sub-categories of DOP such as PDOP, HDOP, VDOP) is a measure used to indicate good or bad satellite geometry: a high DOP indicates poor satellite geometry; a low DOP indicates good satellite geometry. Furthermore, the blocking of some satellite signals to the GPS antenna by tall trees or buildings increases DOP and reduces GPS accuracy. For optimum performance of absolute or relative GPS accuracy, operate your GPS receiver in open fields maximizing a clear view of the sky. For guidance applications, users need to minimize horizontal error. Horizontal error is roughly proportional to HDOP. For topo mapping and land leveling applications with an RTK GPS receiver, users need to minimize vertical error. Vertical error is roughly proportional to VDOP.

Atmospheric Conditions

The ionosphere and troposphere layers of the atmosphere can introduce errors to GPS performance because a change in density of the atmosphere changes the length of the GPS signal. This effect varies at different times of year and in different locations. Ionospheric effects are more noticeable at high latitudes because the GPS signal has to pass through a larger cross-section of the ionosphere (i.e., at a more oblique angle). A main factor is high sun spot activity, which increases atmospheric sources of error. To minimize ionospheric errors, you should choose the correction source with the closest reference station to the area you are operating in, since the reference station will correct for most ionospheric errors within 100 miles. This may mean you need to use Omnistar or Thales corrections rather than using free beacon or WAAS corrections. This is an advantage of DGPS receivers that support multiple correction sources, like Trimble's *Ag*GPS 110, *Ag*GPS 114, *Ag*GPS 124 and *Ag*GPS 132.

Selective Availability

Selective Availability (SA) was an intentional source of error in the GPS system introduced by the US Department of Defense (DoD). This was removed in May 2000. Today the US DoD has another means of jamming the GPS system if required during times of combat.

Quality of GPS Receiver & Antenna Components

The components within a GPS receiver and antenna have a significant effect on the performance of the GPS receiver. If components are low quality, there will be more noise within the signal (i.e., similar to a bad radio that has a lot of noise or static in signal reception). High-quality-

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component GPS receivers experience less noise and, under optimum conditions, provide a more consistently accurate position output.

Multipath and GPS Interference
The presence of tall metal buildings/objects or certain reflective objects close to the GPS antenna can cause reflection of the GPS signal. This results in a phenomenon called multipath. Special software in the GPS receiver can minimize the effects of multipath (e.g., Trimble's *Ag*GPS receiver Everest Multipath Reduction Option).
Trees and other objects can also interfere with or block the GPS signal on its trajectory from the satellite to the GPS receiver. For optimum performance to minimize multipath, position your GPS receiver antenna as high on the vehicle roof or cab as possible (and also away from other communications antennas to minimize interference). When using an RTK system you can minimize multipath and maximize accuracy by putting the base station in the middle of a field away from any buildings or vehicles – this is especially important if you are using RTK GPS for topographic mapping or leveling.

Filtering & Smoothing Algorithms in GPS Receivers and Guidance Systems
Many GPS receivers and guidance systems have software that adjusts the performance of the GPS. This includes filtering or smoothing in the software or firmware to reduce the effects of satellite constellation and geometry changes. *Ag*GPS receivers allow you to select several levels of filtering to give fast response in normal conditions, or you can increase the filter setting to reduce jumps if accuracy is degraded due to poor geometry, atmospheric instability, or multipath errors.

Tilt Compensation for Pitch and Roll
Terrain can have a significant effect on GPS performance. The advantage of adjusting GPS positions for terrain is greatest with automated guidance systems such as Trimble's Autopilot system; because there is no driver error and Autopilot uses a 3 axis low latency inertial tilt sensor, the accuracy improvement due to tilt is more noticeable. If the slope is small, tilt adjustment is more beneficial with a higher accuracy GPS where the resolution of accuracy is finer. If the slope is large, then DGPS receivers can also benefit from tilt compensation. For example a GPS receiver mounted 12 feet in the air on top of a tractor displays an error of 2.5 inches for every 1-degree of roll.

Guidance System Settings
Each guidance system has its own unique settings based on the product design and different settings that are user configurable (e.g., lightbar LED intervals). Some systems provide other features such as the configurable look-ahead ability (as in Trimble's *Ag*GPS guidance systems). This effectively anticipates vehicle position 1, 2 or n seconds ahead, reducing the driver's tendency to over-steer and "fishtail" either side of the swath centerline. GPS performance in the field is affected by all of these settings individually and in combination with each other.

Driver Experience and Driver Error
The driver's experience with the vehicle and implement as well as with the guidance system itself affects overall GPS guidance performance in the field. Tests conducted by Trimble have shown that an inexperienced driver can learn and become proficient at operating agricultural vehicles faster with GPS lightbar guidance than with more traditional methods such as foam markers, row markers or "by-eye" methods.

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RF Interference or Noise
There are many potential sources of electromagnetic noise that can affect GPS receiver performance. Sources include electronics and motors within an agricultural vehicle, power lines, radio antennas, alternators, blower motors, microwaves, radar and some vehicle electronics. High-quality GPS units often have RF interference protection to minimize these sources.

Differential Correction Source
Agricultural use of GPS has significantly expanded with the development of widely available differential corrections. However, the availability and inherent performance of differential corrections plays a very important role on overall GPS performance.
Today there are four main types of differential correction available: -

- DGPS Radio beacons (e.g., US Coast Guard DGPS beacons along major waterways)
- L-Band (Fugro's OmniSTAR differential service; Thales Landstar differential service)
- SBAS (Space-Based Augmentation Systems) such as WAAS (USA); EGNOS (Europe); and MSAS (Japan)
- Dedicated base stations and extensions of these.

What is a check list to consider before I purchase a GPS guidance system ?
Key items to check and decide upon before you purchase a GPS guidance system for agriculture include:

Agricultural Practices

- Which management practices (planting, seeding, tillage, applications) will you use your system with? Different practices often require different types and levels of accuracy and different software features. The more applications you have planned for your GPS guidance system, the faster the payback on the investment.
- Portability - Check that the guidance system components can be easily transferred to a combine for yield mapping or other vehicle as required.
- Modularity - Make sure the system is modular so you can easily add on more advanced options or field computers later for other agricultural operations when you are ready.

Accuracy

- Do you need good absolute or good relative pass-to-pass accuracy or both?
- If you need to navigate back and find exact locations for spot spraying or guidance along existing rows or drip tape, then you will need a guidance system using a GPS that high absolute accuracy or ability to come back to that known spot
- If you do not need to navigate back to recorded areas in the field, then you require a system optimized for pass-to-pass or relative accuracy. Some GPS guidance systems let you configure the GPS to suit either accuracy situations. The AgGPS Parallel Swathing Option and the AgGPS EZ-Guide system let you adjust the level of filtering used to optimize for mapping a feature or obtaining relatively accurate guidance from one swath to the next. High-accuracy GPS systems (e.g., RTK systems) provide the ultimate in performance that is optimal for both absolute and relative accuracy (e.g., AgGPS Autopilot RTK).

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- Check that the differential correction of your choice is available in your region. If signal reliability is not good in your area (i.e., down time could disrupt work), then consider commercially available differential correction services.

Expandable Product Line

- Check that the guidance system you choose will let you upgrade later to more advanced guidance capabilities or additional features such as mapping, sampling, autosteer and variable rate when you are ready to do so.
- Check that the GPS receiver or other system components provide enough ports to interface to any other devices you may have or may want to add later.
- Check that it is capable of outputting data and appropriate protocols to other devices (e.g., rugged field computers).
- Check that any logged or recorded data is in a format that your office software can work with.

Convenient Form Factor & Portability

- Is the hardware a suitable form factor for your vehicle and cab? Most GPS receivers consist of a box and antenna combination or a single smart antenna system. Generally a single smart antenna is easier for mounting and transferring to other vehicles.
- Ensure that the lightbar, display or keypad all easily fit in the vehicle cab.

Configurability of the System

- Determine who will be driving the system. Can you adjust the system to accommodate the level of experience you or any other drivers will have with GPS guidance systems? For example: Can you ensure that the user interface is easy to learn and use so new operators can quickly become proficient?
- Can you adjust the lightbar (or guidance device) sensitivity such that novice drivers can grow accustomed to steering to a lightbar and experienced users can increase sensitivity to increase accuracy?
- Can you adjust the look-ahead of the guidance system so that the lightbar displays a vehicle's "anticipated" position some number of seconds ahead of the vehicle's current location? This greatly reduces the degree of "fishtailing" or over-reacting to the lightbar along the swath line, often seen with novice users.
- Can you adjust the brightness or visibility of the guidance device so that operation can be optimized for day or nighttime use?
- Can you select different languages if required for each operator?

Ruggedness & Reliability

- Ensure that the system you select will be reliable in the rugged environmental conditions that agriculture presents:
    - vibration and sealing is critical in agricultural environments.

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  - operating or storage temperature ranges must be practical for winter and summer extremes
  - unit protection for reverse polarity and any spikes in voltage
  - connector ruggedness for multiple connects needs to be adequate
- Check that you are happy with the standard or extended warranties on any systems.

Update Rate

- Make sure that your GPS receiver can provide update rates that meet your needs. Most GPS receivers provide a 1 Hz update rate (Hz means positions per second); some provide 2-, 5- or higher update rates. 5 Hz update rate is required for good guidance performance. This is especially important with faster vehicle speeds.

Service and Support

- How close is your nearest dealer?
- Will you be able to get support when you need it?
- What kinds of warranties and extended warranties are available on the system?

Ergonomics

- Is the system easy to use and ergonomic for the way you operate the rest of your tractor, truck or combine equipment? For example, it is often important to have easy access to limited controls (i.e., via remote keypads) so it is easy to drive vehicles, spray/boom switches or other in-cab controls.
- Can you mount a guidance lightbar or guidance device directly in front of the operator for ease of use, without obscuring visibility to maximize safety?

Price and Payback

Perhaps most importantly is the ability to determine your Return On your Investment (ROI) or payback on the system you are wishing to purchase. There are many ways to estimate payback for using a GPS guidance system and it is very dependent on specific crop and farm management practices. There are also many benefits that are not easily quantified in dollars.

Trimble is currently working with University Researchers to develop some payback models for manual as well as automated guidance systems. Some preliminary payback calculators have been developed.

An example is for an *Ag*GPS EZ-Guide system purchased for use in tillage, seeding, spreading, spraying and harvesting operations on a 500 acre Mid-West broad-acre farm (wheat) is paid back within a single season (8 months). This payback is mainly due to savings on improved in-field productivity, resulting in lower labor and fuel costs as well as reduced overlap that results in lower input costs.

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