

Accuracies of Laser Rangefinders and GPS for Determining Distances on Golf Courses

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A Preliminary Word on Descriptions of Measurement Accuracy

All measurements are subject to “random” errors having patterns that can be described with statistics and probability. Such probabilistic descriptions are often used as accuracy statements. For example, the statement “distances measured with this device are ± 2 yards (68%)” means that 68% of the time, a measured distance will be within 2 yards of the true distance. Similarly, the statement “the horizontal accuracy of this GPS device is 7 meters (95%)”, means that 95% of the time, a measured pair of coordinates will fall within a 7-meter-radius circle having the true point at its center.

Accuracy statements that do not include the probability or percentage component are ambiguous and very hard to interpret. For example, what does “this distance is accurate to within 3 yards” mean? It can’t mean that the true value must be within 3 yards, because that is impossible. The nature of random measurement errors is that they can take on any value. It’s just that smaller values are more likely than larger values. Consequently, there are probability bounds on the range of likely values for errors. To be truly meaningful, comparisons of accuracies of different measurement methods or devices must be made at the same probability level. In our comparisons, we will use 95% probability.

Laser Ranging

A laser ranging device measures the distance from the ball to the flagstick directly. It does this by sending out pulses of light that bounce off the target and are returned to the device. The round-trip travel time for the pulse is divided by two and multiplied by the speed of light to obtain the distance. The accuracy of the result depends on how well the travel time can be measured and how much the speed of light is affected by the atmosphere along the laser’s path.

The great advantages of laser ranging are its simplicity and the fact that it yields yardage directly to the hole – the final destination of the ball. Unlike GPS, laser ranging does not require a clear view of the sky and can be used under trees and near obstructions, as long as there is line-of-sight between the ball and the flagstick. Of course, laser ranging also does not require maps or downloading of data about any particular golf course.

The laser beam spreads as it travels. This sometimes cause reflections from multiple targets. The devices are often programmed to show the distance to the nearest target or to the one that reflects the strongest signal. Very strong signals are returned from “retro-reflectors”, specially-built glass prisms that can be mounted on the flagstick. This method is used by Laser Link.

The accuracy of laser ranging is proportional to the measured distance. Medium distances are more accurate than long distances. Short distances are even more accurate. This is important and valuable in golf. The specified accuracy of Laser Link’s Quickshot device is $\pm 1\%$. This is with 98% probability. The corresponding 95% accuracy

is $\pm 0.84\%$. Therefore, a measured 100-yard distance is accurate to ± 0.8 yards (95%), a 200-yard distance is accurate to ± 1.7 yards (95%), and a 300-yard distance is accurate to ± 2.5 yards (95%). The device displays the measured distance to the nearest whole yard.

GPS

A GPS device determines a distance indirectly by computing it from measured coordinates at each end of a line. Coordinates of the ball are measured with the device and coordinates of targets are pre-measured, either by an on-the-ground survey or by digitizing a map, and stored in the device. Some golf products allow target points to be selected and digitized from a map in real time on the course.

GPS measures coordinates by analyzing radio signals from a number of specialized satellites. There must be clear line-of-sight from the GPS receiver to the satellites. So, tree canopies (an issue on golf courses) and other obstructions that block large portions of the sky can prevent reception from some or all of the satellites, either reducing accuracy or stopping measurements from being made at all. The accuracy of GPS-measured coordinates is also affected by receiver characteristics, atmospheric delays, clock errors, errors in the orbits of the satellites, and reflection of signals by hard surfaces (e.g., building walls) near the receiver. These things combine to produce horizontal accuracies of less than 7 meters (95%) in the devices used for golf. These accuracies can be improved to less than 3 meters (95%) if the device is receiving additional correction signals from the satellites of the Wide Area Augmentation System (WAAS). WAAS was designed to support high-precision GPS navigation of aircraft, not on-the-ground uses that can have significant problems with ground-level obstructions. WAAS satellites are "geostationary". That is, they appear fixed in the sky with respect to points on the ground. Once again, there must be line-of-sight between a WAAS-enabled GPS receiver and at least one of the WAAS satellites. Across the United States, WAAS satellites are in the southern sky and range in altitude from 10° to 55° above the horizon. Tree canopies and other obstructions that block this part of the sky prevent GPS devices from receiving WAAS corrections.

Horizontal accuracies of targets digitized from maps vary widely depending upon the quality of the map and the ability of the person doing the digitizing to identify and point on desired targets. The horizontal accuracy of well-defined points on one of the most-readily available satellite image maps is 4.3 meters (95%). Targets such as the middle of a green or a lay-up area are not well-defined, especially if the green has an irregular shape, so their digitized coordinates will be less accurate than those of other points on the map. Holes change location, so to try to digitize them on a static map or to pre-survey them on the ground would be pointless. Although GPS devices do not store locations of the holes, an advantage of GPS devices is their ability to store many other kinds of target points such as hazards, lay-up areas, and front and back of green.

So, how do the various horizontal accuracies for the ball and target points translate into accuracies of computed distances? For 95% accuracies, the appropriate equation is

$$DistanceAccuracy = 0.8\sqrt{(BallAccuracy)^2 + (TargetAccuracy)^2}$$

This equation allows us to compute accuracies for distances under different sets of circumstances. For example, if the ball location is measured by GPS that is not WAAS enabled and the target location is digitized from a good satellite image map, the computed distance will be accurate to ± 6 yards 95% of the time. If the GPS device is WAAS enabled and the same satellite image map is used for target location, the distance accuracy will be ± 4 yards (95%). If both the ball and target locations are measured by non-WAAS-enabled GPS, the distance accuracy will be ± 7 yards (95%). These accuracies do not depend on the values of the measured distances. Distances from 30 to 400 yards will all have the same accuracy if the ball and target locations are measured in the same ways.

The accuracies described in the preceding paragraph do not account for adverse effects such as weak satellite configurations, sunspot activity that disturbs the upper atmosphere, reflection of the satellite signals off hard surfaces such as building walls, and poor visual definition of target points on satellite image maps. Such things can significantly degrade the expected distance accuracies.

Summary

Laser ranging provides direct measurements from the ball to the flagstick. The accuracy of a measurement is proportional to the distance. For the Laser Link Quickshot, 95% accuracies are ± 0.8 at 100 yards, ± 1.7 at 200 yards, and ± 2.5 at 300 yards. Laser ranging must have line-of-sight from the ball to the flagstick. Accuracies depend upon how well the device can determine the travel times of laser pulses and upon atmospheric effects.

GPS devices do not measure distances directly. Rather, distances are computed from measured coordinates of the ball and target points. Target points do not include the hole location. The accuracy of a computed distance depends upon the circumstances of coordinate measurement, but it does not depend upon the distance itself. 95% distance accuracies range from ± 4 yards to ± 7 yards for the described scenarios. GPS accuracies are affected by receiver characteristics, atmospheric delays, clock errors, errors in the orbits of the satellites, and reflection of signals by hard surfaces (e.g., building walls) near the receiver. There must be line-of-sight from the receiver to the satellites, so tree canopies and other obstructions can diminish or altogether prevent GPS measurements. Accuracies of targets digitized from maps depend on the quality of the map and the ability of the person doing the digitizing to identify and point on the selected targets. Targets such as the middle of a green or a lay up area are not well defined visually on maps and cannot be as accurate as other well-defined points.

It is important to remember that that the described accuracies for both laser ranging and GPS are associated with 95% probabilities. 5% of the time, errors in the distances will be larger than the stated accuracy bounds.

Given the results of this discussion and my 35 years of teaching and research in surveying and mapping, I am not at all surprised that nearly all professional golfers use laser ranging on the golf course. I think laser ranging is the best technology for determining distances on golf courses.