COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF KENTUCKY—COLLEGE OF AGRICULTURE

Elements of PRECISION AGRICULTURE

GPS Simplified

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Precision agriculture is rapidly becoming an important tool for Kentucky farmers. The Global Positioning System (GPS) is one of the key technologies that makes precision agriculture possible. GPS receivers with sufficient accuracy for yield mapping, grid sampling, variable rate application, and other precision activities are available at moderate cost. GPS receivers, which provide accurate, georeferenced position information, are often used with combine yield monitors, scouting equipment, or variable rate application machinery. Unfortunately, the technology behind GPS receivers is still a mystery to many users. This publication gives a simplified explanation of how GPS receivers work.

How GPS Works

The Global Positioning System is a $12 billion system of 24 satellites (plus a few spares) deployed and maintained by the U.S. Department of Defense (DOD). Each satellite passes around the earth twice in a 24-hour period at an altitude of about 12,500 miles. Radio signals from these satellites can be used to determine accurate georeferenced position information. Deployment of the satellites began in 1978, and the system became fully operational (i.e., offering uninterrupted global coverage) in 1995.

GPS receivers use a principle called triangulation, which is a method of determining the position of an object by measuring its distance from other objects with known locations. Each satellite's position is known very accurately. A GPS receiver uses the signals transmitted by a satellite to determine its distance from that satellite. If you know your distance from one satellite, you could be anywhere on a sphere around that satellite. If you add distance information from a second satellite, you narrow your location to the intersection of the two spheres around those satellites, which puts you somewhere on a circle. Addition of a third sphere narrows your position to two points, one of which can be eliminated because it is nowhere near the earth's surface. Because of some clock errors, which are discussed later, GPS receivers need a fourth satellite signal to compute a valid GPS position. Modern GPS receivers are equipped to receive as many as eight extra satellite signals, which are used to increase accuracy.

The information that is broadcast by each satellite includes a timing signal and satellite ephemeris (location). The timing data are generated by highly accurate on-board atomic clocks. The satellite's ephemeris is a set of orbit parameters used to calculate the location and orientation of the satellite.

A GPS receiver uses the timing data transmitted by the satellite to measure the amount of time it took the signal to travel from the satellite to the receiver. Because radio signals travel at the speed of light (186,000 miles per second), the distance between the satellite and receiver is the transmission time multiplied by the speed of light. The total transmission time is less than 0.07 seconds, so this calculation must be very precise to get an accurate position. The locations (ephemeredes) of the transmitting satellites are then used to triangulate the receiver position.

Sources of GPS Errors

Several factors, including the satellite and receiver clock limitations, ephemeris variation, satellite configuration, atmospheric interference, and multipath can cause errors in GPS position information.

Clock Limitations

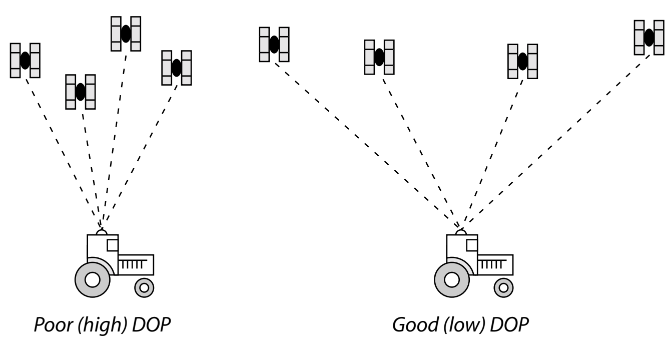
The internal satellite and receiver clocks have limited accuracy, and they are not precisely synchronized. Since position computations are highly dependent on accurate timing information, small clock errors can cause significant errors in position computations. As mentioned earlier, a signal from a fourth satellite is used to correct some of these clock issues.

Ephemeris Variation

Satellite orbits are difficult to predict over time and require periodic adjustment by system maintainers. Because these orbits change, errors can exist in the satellite ephemeris (location) data used in triangulation calculations.

Satellite Configuration

The configuration of the satellites in view to a receiver at any given time can affect the accuracy of position determination. For instance, if all of the visible satellites happen to be bunched close together, the triangulated position will be less accurate than if those same satellites were evenly distributed around the visible sky. The satellite configuration is quantified by the Dilution of Precision (DOP). Many GPS receivers will display DOP values. Lower DOP values indicate better satellite configurations. In general, DOPs less than 4 will give good position determinations.

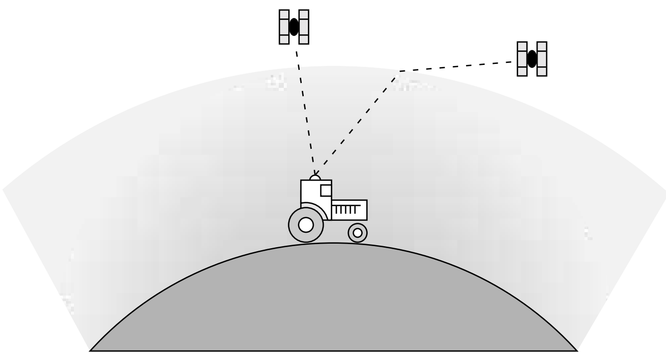


Dilution of Precision

Atmospheric Interference

Moisture and ions in the earth's atmosphere can change the speed at which the satellite radio waves travel. Additionally, the radio waves are bent (refracted) when they enter the earth's atmosphere, which actually changes the length of the path the radio signal takes to get to the receiver.

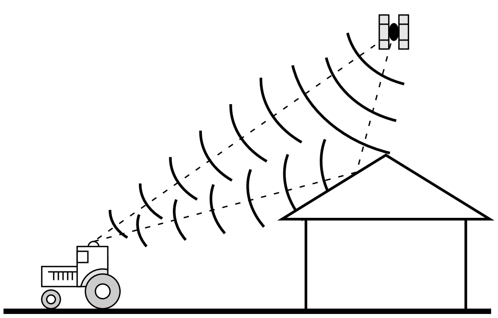
Atmospheric effects are usually greater for satellites low on the horizon; therefore, some GPS receivers allow the user to ignore or mask satellites below a set angle above the horizon.



Atmospheric Effects

Multipath Errors

Multipath means that the same radio signal is received several times through different paths. For instance, a radio wave could leave a satellite and travel directly to the receiver, but it also bounces off a building and arrives at the receiver at a later time. The most common causes of multipath errors in agricultural settings are buildings, ponds, and lakes. With advanced antenna-filtering techniques, most new GPS receivers are very effective at minimizing multipath errors.

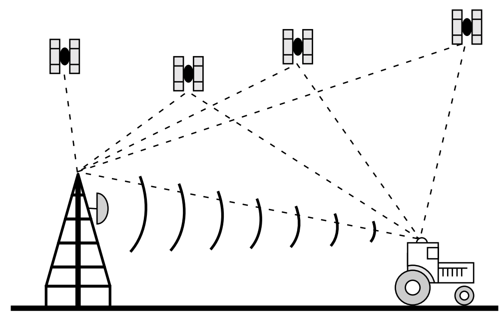


Multipath Errors

Counteracting GPS Errors with Differential GPS (DGPS)

In agricultural applications, the most common way to counteract GPS errors is by using Differential GPS or DGPS. In a DGPS system, a GPS receiver is placed at an accurately known location. This *base station* receiver will calculate GPS errors by comparing its actual location to the location computed from the GPS signals. This error information is sent to the *rover* receiver, which uses it to correct the position information it computes from the GPS signals. Accuracies of DGPS systems can range from 15 feet to 3 feet depending on system configuration.

DGPS corrections can be broadcast by tower-based or satellite-based systems. They can be provided free of charge by government agencies or at an annual fee by commercial providers.



Differential GPS System

U.S. Coast Guard Ground Network

The United States Coast Guard (USCG) has established a network of land-based broadcast towers near major navigable bodies of water. The major advantage of the USCG signal is that it is a free service. One disadvantage is that coverage is limited to areas near the base stations. Also, signal strength will decrease and the correction information itself becomes less accurate as the user moves farther from the base station. In Kentucky, there is good USCG coverage in all but the very eastern portions of the state.

Commercial Correction Services

Several commercial companies have established satellite-based differential correction services. These organizations have installed GPS base stations at various locations in their geographic region of interest. Error corrections computed by these stations are sent to a communication satellite (separate from the GPS satellites) and broadcast back to the user. These satellite-based corrections tend to have a more widespread coverage than the tower-based broadcasts, and system accuracy is not greatly affected by the user's distance from the base station receivers. Most of these service providers, however, require an annual fee for usage.

Wide Area Augmentation System (WAAS)

Recently, the Federal Aviation Administration has established a free satellite-based differential correction service called the Wide Area Augmentation System (WAAS). Although not officially completed, many GPS manufacturers are incorporating WAAS capabilities into newer, lower-cost receivers, which are showing promise for use in agriculture.

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