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# Geospatial Extension Program

P E R I O D I C R E P O R T

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## High-End DGPS and RTK systems

Over the past two years, there has been a surge in the purchasing and use of automatic steering and guidance systems in agriculture. These systems have been shown to save farmers both time and money. With the costs of these systems becoming more reasonable, there is no wonder that these top the wish list of most farmers today.

These and other precision agriculture technologies all rely heavily on the Global Positioning System (GPS) for location data. However, not all GPS packages are created equal. Certain applications in precision agriculture require more consistent and repeatable positional data. This is especially true with auto guidance systems used in row crops where cultivation, strip-tillage, and harvesting must follow the planted rows precisely, whereas yield monitors and weed mapping require far less precision.



High-end GPS receivers are usually divided into three segments: sub-meter, decimeter, and centimeter systems. This kind of division helps farmers visualize what kind of accuracy they can expect from a particular GPS receiver. However, it can be confusing because many vendors are overly optimistic on claimed accuracy, and most base that accuracy on pass-to-pass accuracy and not on repeatability (more on this later).

The following report is a quick overview of the various types of differential GPS (DGPS) and real-time kinematic (RTK) type systems.



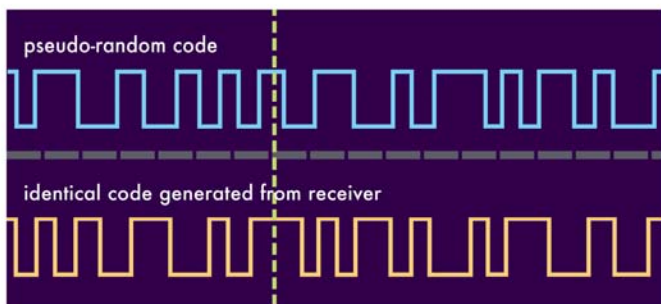
## DGPS Overview

DGPS systems require a differential signal from either a free service such as WAAS and Coast Guard Beacon, or a commercial service such as OmniStar or John Deere's StarFire system.

The cost of the subscription-based systems vary. OmniStar VBS costs \$800/yr and requires only a single channel receiver. OmniStar HP costs \$1,500/yr and requires a dual channel receiver. John Deere's DGPS systems can only be used on John Deere equipment. The StarFire I (SF I) is a free signal for those who buy the hardware, and the StarFire II (SF II) costs \$800/yr. SF II requires a dual channel receiver like OmniStar HP.

## The Carrier Phase Difference

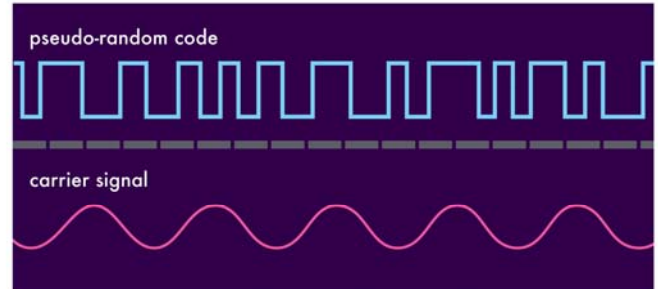
Most DGPS receivers resolve their position by analyzing the coarse acquisition (C/A) code broadcast over the L1 carrier signal (this is also referred to as the pseudorandom (PRN) code or noise). They measure the time it took the signal to travel from the satellite to the receiver. By multiplying that time by the speed of the signal, you get a range. This range is corrected by a differential signal that helps correct for atmospheric and satellite error.



The C/A or pseudorandom code that is broadcast from a GPS satellite lags behind the code generated by the receiver. The amount of time it lags is multiplied by the speed of the signal to give the satellite's range (distance to the satellite).

OmniStar HP, SF II, and RTK not only use the C/A code broadcast from the L1 channel, but also utilize the carrier phase from the L1 and L2 channels. The addition of the carrier phase analysis is what makes the SF II and HP systems so much better than their less expensive counterpart.

However, it is important to note that satellite-based DGPS signals, even those using carrier phase analysis, can not deliver repeatability. Repeatability, the ability to return to the exact same location at any time, can only be obtained using RTK.



The pseudorandom code repeats itself every millisecond (1.023 MHz) while the carrier wave is repeated every 0.635 microsecond (1575 MHz). The above graph is not to scale.

## How Carrier Phase Is Used To Take Measurements

A common analogy between C/A code and carrier phase is that of two clocks, one with an hour hand and one with a hand that only measures seconds. You can usually guess pretty close what the minute is by looking at the hour hand, but you don't know for sure. You also know exactly what the seconds are by looking at the other clock, but because the exact minute is unknown (ambiguity), it isn't very useful.

The C/A code is like the hour hand. You can get pretty close, but you will probably never be exact. The carrier phase is like the second hand, it repeats itself constantly and there is no way to obtain the minute from the number of seconds that have elapsed. But by resolving that ambiguity, the exact time can be found (to the nearest fractional second).

The carrier phase has wavelengths of 19cm (L1) and 24cm (L2). When receivers are turned on, they measure a fraction of a wavelength and then begin to count whole wavelengths. The receiver does not know (ambiguous) the exact number of whole wavelengths (integer) between itself and the satellite.

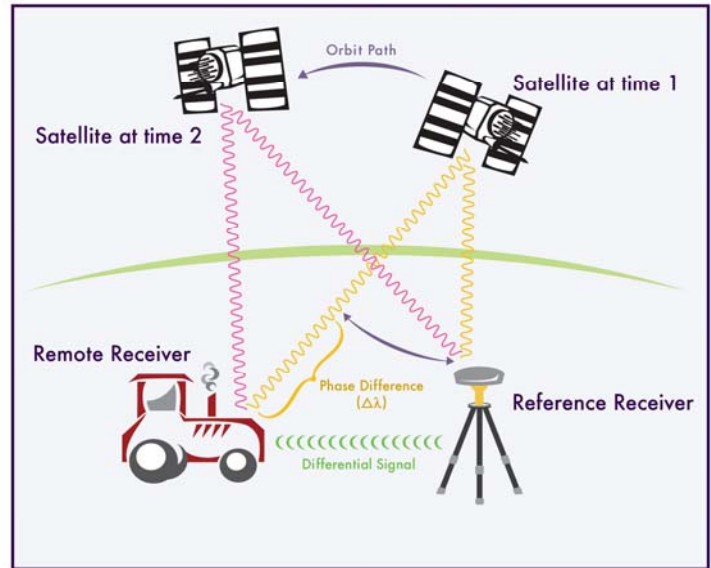


A stand-alone receiver can never resolve the integer ambiguity by itself. There must be two receivers that simultaneously track the same satellites to solve the ambiguity.

By using a method called Carrier Phase Differencing, the integer ambiguity is resolved. A base station with a known location tracks the satellites and has a true range to each satellite (the exact number of wavelengths between itself and the satellite). This information, along with its known location, is sent to the rover receiver. When the reference signal is compared to the signal received by the rover, there is a signal phase difference between the two.

After they are compared, a range is determined by adding the phase difference to the total number of waves that occur between each satellite and the receiving antenna.

### GPS Carrier Phase Positioning



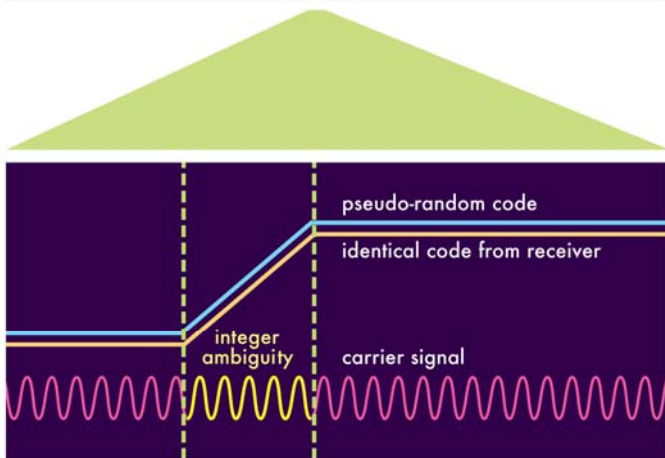
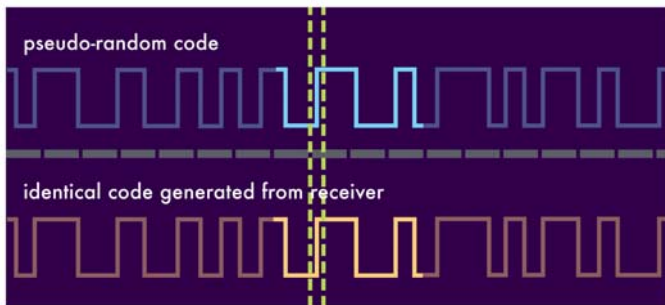
Remote Position = Reference Position + Difference in X, Y, Z derived from difference in carrier cycle measurements

The process of establishing a position by calculating the difference between carrier phase signals of a base and rover receiver is called initialization. By becoming initialized and obtaining a fix on the carrier phase, RTK systems provide accuracy many times greater than less expensive systems.

### RTK Systems

RTK is a GPS-based survey that utilizes a fixed, nearby ground base station that is in direct communication with the rover receiver through a radio link. RTK is capable of taking survey-grade measurements in real time and providing immediate accuracy to within 1-4cm.

RTK systems are the most precise of all GPS systems. They are also the only systems that can achieve complete repeatability, allowing a farmer to return to the exact location, indefinitely. All this precision and repeatability comes at a cost, however. A full RTK system with base station, rover, data logger, and software will usually cost around \$40,000.



On the timing edge of the pseudorandom code, tens of microseconds pass between each bit. This time between bits is the greatest limiting factor for standalone receivers that rely on the C/A code for position. By solving for the integer ambiguity in the carrier phase, a true range can be found.



There are drawbacks to RTK that are not limited to just the cost. For instance, RTK requires that a base station be within 6-10 miles of the rover, and there always needs to be line of site between the two. The further you get from the base station, the more error you will see creep into the positional accuracy.

The rover must also simultaneously track 5 satellites to become initialized, and then continue to track 4 satellites to remain initialized. Once communication with the base station is lost, initialization will be lost and the point will move from a 'fixed' point to a 'floating' point. At that time, initialization must be regained to return to an accurate 'fixed' position. Most base stations can be moved from field to field to ensure line-of-site, but must be set-up on the exact location each time. Many farmers pour concrete pads to ensure the base station is returned to the correct spot.

Another drawback of RTK systems is the time it takes before initialization can begin. This can take upwards of 30 minutes on some systems, keeping you from jumping in and going to work. Other systems have a fast restart option, and as long as you do not move the tractor between initialization, the start-up time is significantly reduced.

### Conclusion

Before you shell out \$50,000 for a new auto-steering system, it is best to understand your needs and find what will work for your particular operation. It is very important to determine your minimum requirements for precision, and then choose a system that will meet those guidelines at least 99% of the time.

For instance, if you use auto-steer to cultivate potatoes and you choose a decimeter DGPS system, don't be surprised to see a big drop in the quality of your potato crop. It's simply not accurate enough. However, if you are only using that same system for herbicide application, you probably paid for more than you need.

### For More Information:

Trimble Online Tutorial  
<http://www.trimble.com/gps/advanced1.html>

Topcon Tutorial  
<http://www.topcongps.com/images/tutorial.pdf>

GIS Development Tutorial  
<http://www.gisdevelopment.net/tutorials/tuman004pf.htm>

	WAAS	Sub-meter	Decimeter	Centimeter- RTK
Price Range	\$100-\$500	\$500-\$2500	\$2500-\$7500	\$15,000-\$50,000
Source of Differential Signal	WAAS	Coast Guard, OmniStar VBS, StarFire I, local differential services	OmniStar HP*, StarFire II*, (requires dual-channel receiver)	Real-time kinematic systems require a base station within 6-10 miles
Accuracy	1-3 meters	1-3 feet	3-12 inches	< 1-2 inches
Advantage	Low cost, small handheld unit	Better accuracy	Best accuracy without using RTK	Highest accuracy, repeatability
Uses	Mapping, yield monitor	Mapping, yield monitor, VRT, limited guidance	Guidance (probably not row-crop), VRT	Precision guidance, elevation mapping, survey-grade mapping



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