GRDC GROWNOTES

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

Module 12
GPS systems
The options available

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Key points

- **Know what level of accuracy you require for spraying and other farming activities**
- **Ensure that any equipment purchased integrates well with the other equipment you already have – particularly the wheel centres – and the farming system you use**
- **Be aware of the systems available and how to best use the technology available to ensure it will meet your current and future needs**

1. Introduction

GPS auto-steer systems are now synonymous with farm machinery coming onto the market. Many tractors and sprayers already have the components fitted to the new machine, however an older machine retrofitted with a new GPS system may also suit your needs.

But what is GPS? How does it work? And what are the things a grower or spray applicator needs to consider when purchasing or upgrading a sprayer? Making a purchase decision can be confusing, especially when much of the sales literature looks the same.

There are three main components of a GPS auto-steer system that will be discussed in this module:

- **obtaining the position on the Earth's surface (GPS) and ways to improve its accuracy;**
- **the screen in the cab and what it can and can't do; and**
- **the method of actually steering the spray rig.**

These three parts are discussed in the following sections of this module.

2. Satellite constellations for positioning

For more information about how GNSS and GPS work, go to: www.maptoaster.com/maptoaster-topo-nz/articles/how-gps-works/how-gps-works.html

Global Navigation Satellite System (GNSS)

The Global Navigation Satellite System (GNSS) is a constellation of satellites orbiting the Earth that can determine the geographic location of a user's receiver anywhere in the world. It covers all constellations including the US Global Positioning System (GPS), the Russian GLONASS, the European Galileo, the Japanese QZSS and the Chinese BeiDou satellite systems.

The receiver needs to gather signals from at least four of these satellites to work in autonomous mode. A receiver will typically track all of the available satellites simultaneously, but only a selection of them will be used to calculate your position. In the future you will hear more about GNSS than GPS.

Global Positioning System (GPS)

The Global Positioning System (GPS) was first developed by the US Department of Defense and is now maintained by the US Government. It is made up of a network of 24 satellites and was originally intended for military use, but was made available to civilians in the 1980s. GPS forms only one part of the whole GNSS satellite constellation now available.

3. Correction signals to improve accuracy

The accuracy of the GNSS or GPS is affected by various factors. The timing of onboard clocks and transmitted location is affected not only by satellite signal quality but also by: satellite errors; interference from external sources such as motors may cause receiver errors; atmospheric errors can slow the signal speed; and continental drift also produces errors, which can be overcome by a fixed base station.

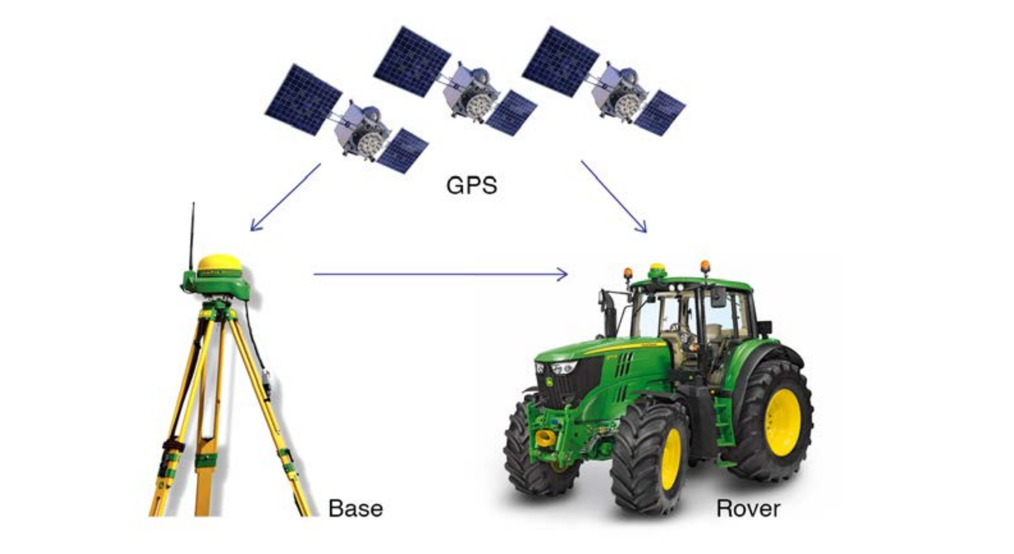
Typically, the accuracy of autonomous GPS (that is, with no correction) is about +/- 15 metres on the ground.

The error in a GNSS/GPS signal can be determined by recording the GNSS/GPS signal at a fixed location (base station). By comparing the GPS receiver position to the surveyed position, the physical error can be determined and the accuracy of the position can be improved.

Without a reference point to correct the signal, GPS accuracy would be plus or minus 15 metres.

Source: Bill Gordon

Correction of GPS signal using a base station



There are several forms of correction signals: dGPS, RTK, nRTK and PPP. These are explained in the following sections.

3.1 Differential Global Positioning System (dGPS)

The Differential Global Positioning System (dGPS) is a method of providing differential corrections to a GPS receiver in order to improve the accuracy of the navigation solution. dGPS corrections originate from a reference station at a known location. The receivers in these reference stations can estimate errors in the GPS because, unlike the general population of GPS receivers, they have an accurate knowledge of their position.

dGPS uses the known errors to correct GPS location. As a result, the accuracy of dGPS is greatly improved, at about +/- 50 centimetres. Examples of dGPS include John Deere SF2™ and OmniSTAR® HP (which guarantees 10cm accuracy). Users need to purchase a subscription to the correction stream for a fixed period and need to have a compatible receiver to receive the subscription.

dGPS generally improves accuracy to about 10cm, but requires a subscription to access the correction signal.

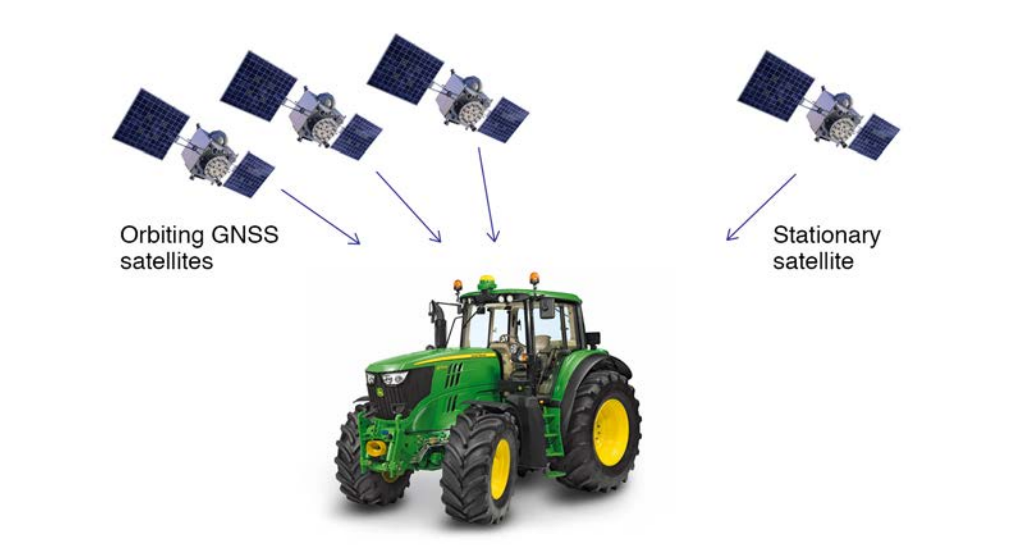
Source: Bill Gordon

For more information about RTK, go to: www.deere.com/en_INT/products/equipment/agricultural_management_solutions/displays_and_receivers/rtk_solutions/rtk_solutions.page

For more information about nRTK, go to: www.alldayrtk.com.au/ and smartnetaus.com/

Play YouTube video on how the CORS network works: www.youtube.com/watch?v=SI2PrkOBaxI

dGPS using a stationary satellite as the reference point



3.2 Real-Time Kinematic dGPS (RTK dGPS)

RTK is used to enhance the precision of satellite-based positioning systems by using a ground-based single reference point (base station) to provide real-time corrections and enable centimetre-level accuracy. It requires a local base station to be set up within a few kilometres (but typically no more than 20km to ensure high accuracy) from the rover (sprayer) and is usually positioned at a high point in the landscape to ensure maximum coverage and is then calibrated. It averages its location over a period of time ranging from 60 seconds to 24 hours. The John Deere StarFire™ RTK, for example, is reported to provide repeatable, sub +/- 2.5cm accuracy.

The base station transmits the corrections in real time (less than once per second) to the rover units using UHF and VHF radios, typically in the 450 to 900-megahertz range. In some cases, depending on the type and power of the radio in the base station, you may need to licence it. As a general rule you cannot communicate between different manufacturers' base stations/rovers.

If you have your own base station, then there will be no ongoing subscription costs.

3.3 Network Real-Time Kinematic (nRTK)

nRTK is a system that also offers centimetre-level accuracy in real time but without the need for an operator's reference or base station, as it uses GPS observations gathered from a network of Continuously Operating Reference Stations (CORS). The coverage of any nRTK GNSS service is only limited by the number of available CORS and the quality of the wireless data link used to transmit the correction to the users (i.e. mobile phone networks capable of allowing data, such as Telstra NextG).

nRTK requires payment of a subscription as well as the data costs. Some examples include AlldayRTK and SmartNetAus, which have established a network of CORS bases around Australia. SmartNetAus typically achieves a reported RTK accuracy of 1 to 2cm horizontally and 2 to 3cm vertically.

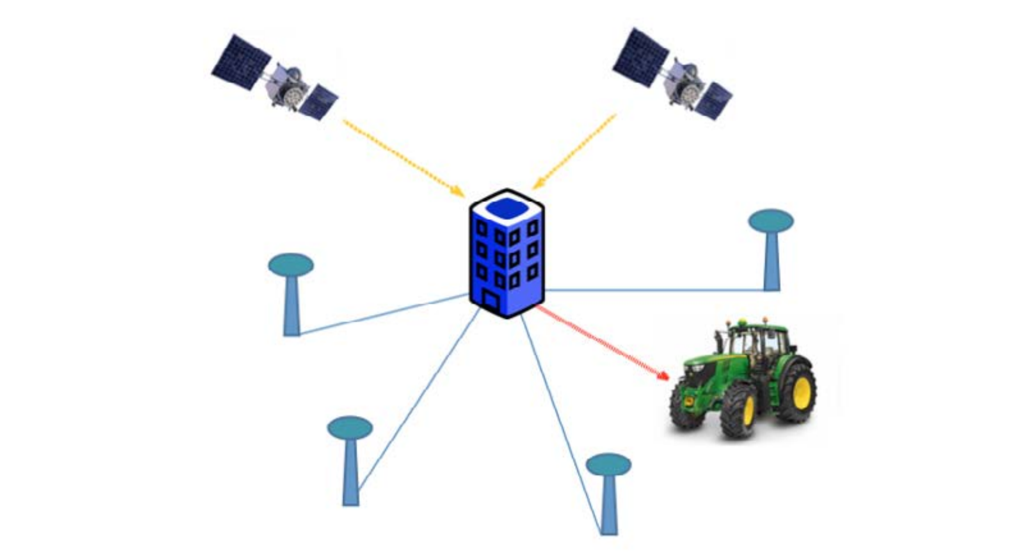
Access to nRTK and accuracy will be dependant on the number reference stations (CORS) in your area. This service is subscription-based.

Source: Bill Gordon

For more information about PPP, go to: www.lpi.nsw.gov.au/__data/assets/pdf_file/0005/184937/2013_Grinter_and_Roberts_IGNSS2013_real_time_PPP_are_we_there_yet.pdf

For more information about RTX, go to: www.trimble.com/positioning-services/centerpoint-RTX-standard.aspx

nRTK can offer 1 to 2 centimetre accuracy



3.4 Precise Point Positioning (PPP) and Real-Time eXtended (RTX)

PPP is a positioning method that employs widely and readily available GNSS) orbit and clock correction products to perform point positioning using a single GNSS receiver.

PPP methods differ from differential positioning methods in that differential or RTK techniques require access to the observations of one or more reference stations with known coordinates. This provides PPP with an advantage over differential techniques in that only a single receiver is necessary (at the user's end), removing the need for the user to establish a local base station. Consequently, the spatial operating range limit of differential techniques is negated, as well as the need for simultaneous observations at both rover and base for real-time applications.

However, one big disadvantage of PPP over differential GNSS techniques remains: large convergence times are needed to determine accurate coordinates due to the uncalibrated/unmodelled satellite and receiver hardware delays within the PPP solution.

A relatively new example of a form of PPP is the Trimble CenterPoint™ RTX™, which delivers GNSS-enabled, repeatable, 3.8cm corrections to your receiver.

CenterPoint™ RTX™ Standard is delivered via satellite and doesn't require an RTK base station or mobile service. It leverages real-time data from a global tracking station network, along with innovative positioning and compression algorithms, to compute and relay satellite orbit, satellite clock and other system adjustments to the receiver, resulting in the real-time high accuracies. These adjustments are transmitted to the receiver via satellite (where coverage is available) and via data platforms worldwide. This is a subscription-based service.

Table 1 Summary of accuracies of each GPS/GNSS correction system.

	Accuracy	Coverage	Strengths	Weaknesses
Autonomous (no corrections)	+/- 1 metre	• Everywhere	• No cost	• Low accuracy • Not suitable for many broadacre sprayer-based operations
Differential Global Positioning System (dGPS)	+/- 10 centimetres up to +/- 1 metre	• Service covers whole of Australia	• No base station required • Suitable for contracting situations	• Subscription cost • Lower accuracy than RTK
Real Time Kinematic dGPS (RTK dGPS)	+/- 2 centimetres	• Approximately 20 kilometres from nearest base station	• No reliance on mobile coverage or third-party provider	• Requires base station • Manufacturer of base and rover needs to be the same (generally)
Network Real Time Kinematic (nRTK)	+/- 2 centimetres	• Most cropping areas of Australia (limited by mobile data coverage)	• No base station required • Reduced hardware costs • Elimination of radio issues • Reduced insurance costs	• Limited by coverage of mobile data • Reliant on third party for up-time and data • More complex than owning your own base station
Real Time eXtended (RTX) / Precise Point Positioning (PPP)	+/- 3.8 centimetres repeatable horizontal	• Australia-wide	• No base station or mobile service required	• Large convergence times are needed (time for receiver to become accurate)

4. Integration of GNSS/GPS with the spray rig

▶ **Download spreadsheet: Water Flush for Residuals Calculator.**

Once you have decided which GPS/GNSS level of accuracy is required for your operation, you need to consider how the GPS auto-steer system will actually steer and control your spray rig. The steering kit (which actually does the steering), the spray controller and the GPS/GNSS receiver on the roof of the cab are all controlled and connected by an in-cab screen or monitor.

There are many brands to choose from, starting from simple devices that don't record any information or perform any tasks except guidance, through to large touch screens that operate section control and record all of your spraying activities.

Some examples of the available systems and where to get further information are shown in the following diagrams and links, starting at simple guidance through to high-end screens.

▶ **Raven Cruizer™, ravenprecision.com/products/guidance-steering/cruizer-ii/**

Raven Cruizer™ Cruizer II. ▶

Trimble Ez-Guide 250®, www.trimble.com/Agriculture/ez-guide-250.aspx

Trimble Ez-Guide 250®.

John Deere GreenStar™ 2 1800 display, www.deere.com.au/en_AU/products/equipment/agricultural_management_solutions/displays_and_receivers/greenstar_2_display_1800/greenstar_2_display_1800.page

John Deere GreenStar™ 2 1800.

CASE AFS® Pro 700, www.caseih.com/northamerica/en-us/owners/afs-support/precision-farming-products/displays/afs-pro-700

CASE AFS® Pro 700.

Ag Leader® InCommand™ 800, http://www.agleader.com/products/displays/incommand-800/

Ag Leader® InCommand™ 800.

Trimble FMX®, www.trimble.com/Agriculture/fmx-display.aspx

Trimble FMX®.

John Deere GreenStar™ 3 2630 display, www.deere.com/en_US/products/equipment/ag_management_solutions/displays_and_receivers/greenstar_3_display_2630/greenstar_3_display_2630.page

John Deere GreenStar™ 3 2630.

4.1 Choosing an appropriate screen

As an operator you may wish to consider the following when deciding on the most suitable in-cab screen for your GPS/GNSS guided spraying activities.

- **Do you want to control each boom section? If so a bigger screen with inbuilt features will be a better investment in the long term.**
- **Is your cab already cluttered with screens? If so, then consider one of the high-end options as you may be able to include some of the functions currently done by the other screens/controllers already in your cab.**
- **Do you have a manufacturer preference or have existing screens in other machines? It certainly simplifies things when they are from the same manufacturer.**
- **Touch screen or buttons? This is personal preference – both can fail over time.**
- **Having trouble seeing? Make sure you get a good size screen that is readable in daylight.**
- **Do you want to utilise full auto-steer? If not then you can use a smaller, lower-cost screen and follow the light-bar instead. Obviously auto-steer is preferable as it reduces driver fatigue and enables you to better focus on the job at hand.**
- **Do you want to collect data about the spray job in the screen? The lower-cost, smaller screens often only show a coverage map of the current job and don't save or record any of the activity. Bigger screens can now record a large amount of information about the job including operator, weather conditions, chemicals applied, rates, speed etc.**
- **Is the screen going to be used for other activities, such as planting? If so, pick a screen not only suited to spraying.**

PLAY VIDEO

Tyre tip – aligning tyre centres

5. Steering options

There are several ways to actually steer the spray rig, including fully integrated, partially integrated and steer assist, which are explained below.

5.1 Fully integrated steering

The guidance system is fully integrated with the machine and it comes complete from the factory ready to go. These systems are characterised by a single display across machines that can interface with your existing equipment.

Most new machines are coming equipped with a full CAN bus/ISO bus system and manufacturers can control the steering directly from this.

An example includes Leica's SteerDirect CAN solutions, which connect the guidance system directly to the machine's CAN bus. The device communicates directly with existing controllers, valves and sensors already on the sprayer.

5.2 Partly integrated steering

Partly integrated is where the sprayer is not fitted with an auto-steering kit from the factory, but has one added after-market. In many cases this involves fitting a hydraulic value and wheel angle sensor, which communicate with the auto-steer system in the cab. On older sprayers you need to decide whether the additional cost of installing a partly integrated steering solution is justifiable given the expense.

5.3 Steer assist

You can retrofit GPS capability if you decide to add guidance to existing equipment instead of buying new. Easily installed, most of these devices fit the majority of sprayer models without having to remove the steering wheel.

The EZ-Steer® system

Also from Trimble, The EZ-Steer® system turns the steering wheel for you by combining a friction wheel and a motor with guidance from any Trimble display.

OnTrac3™ assisted steering system

Ag Leader has the OnTrac3™ assisted steering system that can help improve pass-to-pass accuracy without hooking into hydraulics.

Photo: Ag leader

6. Considerations and requirements of GPS/GNSS for spraying operations

Accuracy

There are many terms used to describe GPS/GNSS accuracy. Below are common types of accuracy and their meaning.

6.1 Mechanical or field accuracy

This refers to the ability of the auto-steer or assisted-steer to react to the GPS information and maintain the appropriate path in the field. Many factors will affect this including 'play' in the steering components, the agility of the spray rig, suspension of the cab, wheel ruts, wheel centres and tyre pressure, which all influence steering stability.

6.2 GPS accuracy

This refers to the inherent accuracy of the GPS receiver and signal type that you are using. GPS accuracy is classified into three levels of accuracy: 50 per cent, 90 per cent and 95 per cent. This is based on the number of readings that a stationary receiver makes that are within the specified accuracy limits during a specified timeframe.

Most manufacturers with guidance products on the market today have a pass-to-pass accuracy listed using the 95 per cent level, but there are still a few manufacturers that list their accuracy based on the 50 per cent level. Be careful not to confuse these accuracy statements with 'pass-to-pass' and 'repeatable' (described below), which are related to the time period in which the testing has been conducted.

6.3 Pass-to-pass accuracy

Manufacturers typically report pass-to-pass accuracy in product literature. This value represents the short-term (<15 minute) relative accuracy of a GPS receiver, but does not necessarily reflect long-term accuracy, which includes GPS drift.

GPS accuracy relies heavily on satellite configuration, which is constantly changing as the satellites orbit the Earth. However, it can be assumed that the satellite configuration will not change considerably within a 15-minute period. If a different satellite configuration is used to determine GPS receiver position, the reported position will almost certainly not correspond to that obtained previously. This 'shift' of reported GPS receiver position over time is termed GPS drift.

6.4 Year-to-year repeatable accuracy

This is the measure of repeatable accuracy, which means that you can drive the same rows a day, week, month or year later. Thus +/- 2.5cm year-to-year accuracy means you can drive the same rows next year within 2.5cm of this year's rows, typically 95 per cent of the time.

7. Section or swath control

For more information about Field-IQTM, go to: www.trimble.com/Agriculture/field-iq.aspx

For more information about Ag Leader swath-control products, go to: www.agleader.com/products/directcommand/liquid-application/

Section or swath control allows you to automatically turn 'off' appropriate boom sections (or even individual nozzles) when the sprayer enters an area where product has already been applied. It automatically turns them back 'on' when leaving a pre-applied area. This has numerous benefits including less overlap, reduced wastage, minimised damage from residual chemicals and lower costs.

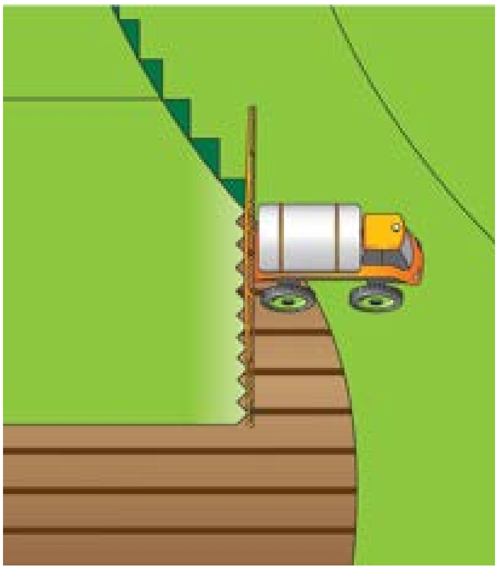
Trimble's Field-IQ™ crop-input control system is an example of a system that enables you to:

- **control up to 48 sections or nozzles and shut off sections in waterways and point rows;**
- **see where you have been and what you have done with overlap detection; and**
- **eliminate overlap by adding Tru Count LiquiBlock™ Valves.**

Ag Leader DirectCommand™ also provides application-rate control. The machine's 'AutoSwath' feature reduces over-application and product waste by automatically turning the applicator 'on' or 'off' based on field boundaries and already-applied areas as it passes over the field. The system reduces input costs and increases application accuracy by minimising skips and overlaps at end rows, fence rows and along waterways.

GPS accuracy and the number of sections on the sprayer will determine the level of reduction in chemical use and over-application or misses.

Figure 4 How section control works.



Source: Ag Leader

For more information about how pulse width modulation systems can be used for section control, go to: ravenprecision.com/products/application-controls/hawkeye-nozzle-control-system/

7.1 Considerations when using swath/section control

- **Correction signal – the greater the GPS accuracy the less chance there is of misses and overlaps based solely on the repeatability of the system. If you have individual nozzle control and 2km-long runs, for example, then you are unlikely to get the full benefits using a dGPS level correction.**
- **Length and number of boom sections – by increasing the number of boom sections, the more precise you can become with section control and the greater the reduction in overlap.**
- **Nozzle control systems – these allow for precise sprayer application to reduce spray drift. For example, the Hawkeye® Nozzle Control System allows each nozzle to be controlled by its own individual pulsing valve to achieve a more consistent spray pattern. The system is built on the ISO bus communication platform, which allows it to work with ISO Task Controllers.**

8. Variable-rate application (VRA)

Variable-rate spray applications allow the operator to automatically vary the spraying rates within a paddock based on a pre-defined map or sensor. This has the ability to optimise crop protection, improve efficiency and reduce chemical usage.

Two basic technologies for VRA are map-based and sensor-based (not covered in this chapter). Map-based VRA adjusts the application rate based on an electronic map, also called a prescription map. Using the field position from a GPS receiver and a prescription map of desired rates, the concentration of input is changed as the applicator moves through the field.

For map-based weed-control VRA systems, some form of 'task computer' is required to provide a signal indicating the target rate for the current location, and therefore the higher-end in-cab screens are necessary. Second, a system for physically changing the application rate to match the current prescribed rate is required. There are a number of different types of control systems on the market today that are adaptable to VRA.

8.1 Flow-based control of a tank mix

The flow-based control of a tank mix is the simplest of the three types discussed here. These systems combine a flow meter, a ground-speed sensor and a controllable valve (servo valve) with an electronic controller to apply the desired rate of the tank mix.

A microprocessor in the console uses information about sprayer width and prescribed application rate to calculate the appropriate flow rate (litres per minute) for the current ground speed.

The servo valve is then opened or closed until the flow-meter measurement matches the calculated flow rate. If a communication link can be established between this controller and a map system, a variable-rate application can be made.

These systems have the advantage of being reasonably simple. Consideration needs to be given to the impact that changing flow rates has on nozzle pattern (while maintaining a desired pressure range) and what the critical levels (maximum and minimum) of flow are.

8.2 Chemical-injection-based control and chemical-injection control with carrier

An alternative approach to chemical application and control uses direct injection of the chemical into a stream of water. These systems utilise the controller and a chemical pump to manage the rate of chemical injection, rather than the flow rate of a tank mix. The flow rate of the carrier (water) is usually constant and the injection rate is varied to accommodate changes in ground speed or changes in prescribed rate. Again, if the controller has been designed or modified to accept an external command (from a GPS signal and prescription map), the system can be used for VRA.

Chemical injection with carrier control requires that the control system change both the chemical-injection rate and the water-carrier rate to respond to speed or application-rate changes. One control loop manages the injection pump while a second controller operates a servo valve to provide a matching flow of carrier. A perfect system of this type would deliver a mix of constant concentration as if it were coming from a pre-mixed tank.

For more information about variable-rate systems, go to: pubs.ext.vt.edu/442/442-505/442-505_PDF.pdf

8.3 Modulated spraying-nozzle control (MSNC) system

Modulated spraying nozzle control (MSNC) systems permit VRA with spray-drift control under a wide range of operating conditions. MSNC controls the timing and duration of discharge from nozzles. High-speed valves are used to regulate the amount of time that spray is delivered from conventional nozzles. The systems offer the ability to change flow rate and droplet size distribution on the go.

8.4 How is variable-rate application actually achieved?

The VRA map is loaded into the screen in the cab, which is often also the guidance screen (e.g. John Deere GreenStar™ 3 2630, CASE AFS® Pro 700 or Trimble FMX®). This map needs to be in the right format for the screen to be able to read it and control the rates. The screen is connected to the controller, which actually varies the rate (depending on which system is used above).

Some examples of variable-rate control systems from different manufacturers include the Trimble Field IQ™, Ag Leader DirectCommand™, CASE AIM Command® and John Deere GreenStar™.

9. Summary: questions to ask before purchasing a system

Investment in any technology has to be well researched. Whichever system the grower or spray applicator chooses, it must work well with the other equipment on-farm, now and into the future.

There are a number of questions that growers and spray applicators should first ask themselves before purchasing a new auto-steer system for their sprayer.

Age of machine

Depending on the age of the sprayer, is it worth spending money to retrofit new technology onto an ageing machine? Or are you better off upgrading your machine and getting auto-steer at the same time?

Should you get auto-section control?

To answer this question you need to know if your boom is capable of section control, how wide it is and how many sections it has. In most cases, auto-section boom control payback period is very short and is a very good investment in any reasonable-sized rig with three or more sections.

Warranty

Possible warranty issues can arise if, for example, you have plugged a third-party controller into your machine's CAN bus. Check with the manufacturer before making changes and clearly identify who is responsible for each component of the system.

What are the other systems on the farm?

If you have implemented a controlled-traffic farming (CTF) system, consideration needs to be given to the size of your sprayer, and its wheel and nozzle spacings, in relation to your other machinery. For example, ideally your sprayer and spreader would be three times the width of your seeder (e.g. 9m seeder and 27m sprayer and spreader).

Wheel spacings should also be matched, most commonly at 3m (make sure that metric and imperial systems are not mixed together; use one or the other.) CTF considerations are important and different GPS systems can use quite different methods for steering control. Be aware that trying to get A/B lines from different auto-steer manufacturers to line up in a CTF/row crop system can be quite challenging and sometimes impossible. In this case, using the same GPS/GNSS manufacturer across the farm with a common base station will give the best results.

NEXT MODULE

SPRAY APPLICATION MANUAL FOR GRAIN GROWERS

Module 13 Rate-controller functions and settings Getting the best out of the functions available