Patrick Ole Noack, Adelschlag

# GPS Based Automatic Steering Systems

*Gaps and overlaps can be reduced through exact farming operations. Automatic steering systems based on GPS technology help steer tractors and SP-machinery along virtual referential lines. With such systems tasks can be performed with optimal working width even when poor visibility (fog, dust or nightfall) impacts human vision. The system relieves the driver of navigating, so he can fully focus on properly supervising the implements within the mainland. Utilising automatic steering systems increases capacity especially in field crops, especially in intensive and in permanent crops, and reduces operations costs.*

Patrick Ole Noack is employed with geo-konzept GmbH in D- 85111 Adelschlag, Gut Wittenfeld;
e-mail: *pnoack@geo-konzept.de*..
geo-konzept GmbH has been developing and selling GPS and GIS systems for agricultural applications since 1992 and is authorised Trimble reseller.

## Keywords

GPS, automatic steering systems, market offers

## Literatur

Literaturhinweise sind unter LT 04510 über Internet http://www.landwirtschaftsverlag.com/ landtech/local/fliteratur.htm abrufbar.

In 2002 GPS based automatic steering systems have first been deployed on the European market. In opposition to steering systems based on lasers or mechanical row detection, GPS based automatic steering systems may be universally integrated in and used on all machinery with hydraulic or electronic steering.

During the 1990s autonomous vehicles based on GPS technology have been developed and field tested. Germany based GeoTec was awarded a DLG gold medal for their concept of an autonomous tractor during Agritechnica 1999 [1]. The University of Hohenheim (Germany) [4] is currently developing an automatic steering system for an autonomously navigating forage harvester based on GPS technology. Autonomous field robots using GPS for positioning have been presented by John Deere (Agritechnica 2001) and agricon GmbH (www.agricon.de; DLG field show 2004).

Automatic steering systems are not capable of replacing the driver as turning vehicles at the headlands still has to be performed manually. They are also not designed to impact the ground speed. Automatic steering systems have rather been derived from manual guidance systems, aiming at supporting the driver with navigating vehicles on tram lines. Manual guidance systems visually or acoustically indicate the offset from a defined track With human reactivity being limited, manual guidance systems cannot take full advantage of the accuracy which GPS systems can provide today. The accurate track-to-track alignment of implements necessary during sowing and hoeing between row crops can only be achieved using automatic steering systems.

### Functionality

GPS receivers determine their position by measuring the time it takes a signal to travel between different satellites and its antenna [3]. The timing information allows to estimate the distances (pseudoranges) to the satellites and therefore to determine the position of the receiver. Feeding GPS receivers with information on their position allows to calculate the error of the pseudorange measurements (base or reference station). When broadcasted these errors can be accounted for by mobile GPS receivers and helps them to improve their accuracy (DGPS differentially corrected GPS).

GPS satellites broadcast signals on two different frequencies (L1 and L2). The majority of GPS receivers only receive the L1 frequency and will reach a maximum absolute accuracy of 60 to 70 cm using differential corrections (2RMS4). The maximum absolute accuracy of dual frequency GPS receivers is in the range of 0.5 to 2 cm. When looking at parallel swathing applications like manual guidance or automatic steering systems, track-to-track accuracy is more relevant than absolute accuracy. Track-to-track accuracy defines the error in swath width caused by a manual or automatic parallel swathing system within a period of 15 minutes. Single frequency GPS receivers provide a track-to-track accuracy of 10 to 30 cm while dual frequency GPS receivers using corrections from a local base station maintain a track-to-track accuracy of 1 to 2 cm. The position output frequency of GPS receivers used for automatic steering systems is in the range of 5 to 20 Hz. Automatic steering systems are also determining attitude and roll of the vehicle. They compensate lateral roll-driven positioning errors and cross-validate GPS positioning measurements. Technically this information is gathered by gyroscopes or GPS antenna arrays. Roll and attitude are determined with a frequency of 20 to 100 Hz. Automatic steering systems on wheeled tractors additionally have a steering angle sensor installed.

All information gathered from the sensors above are being used by a navigation controller in order to determine the offset from a desired track and the steering angle necessary to match this track. A steering valve - sourced by the vehicles hydraulic circuit - actuates according to the steering angle determined by the navigation controller.

### Market survey

Agco provides their automatic steering system Autoguide for the Challenger MT series and for the AgChem product line. As from the end of 2004 Autoguide will also be available on Fendt Vario tractors. The Autoguide system is available ex factory or for retrofit installation. Agco has announced to make a

manual guidance system available which can be upgraded to automatic steering.

The Autoguide system integrates the navigation controller and the GPS receivers [2] which is contained in one roof mounted housing together with the sensors for attitude and roll determination. On the Challenger MT series the communication with the steering system is facilitated via CAN (Steer-by-Wire). Agco Autoguide is available with a track-to-track accuracy of 10 cm and 30 cm depending on the correction signal used (OmniSTAR VBS or HP). In the United States the system is available with a local base station providing a 2 cm track-to-track accuracy. Track data may be logged with a PDA installed software package.

US based Integrinautics offers an automatic steering system called Autofarm. Integrinautics is currently not represented by a subsidiary or a dealer in Germany. However, Autofarm systems are being operated on several german farms. The Autofarm system can be fitted into tractors, self propelled machinery or combine harvesters equipped with hydraulic steering. The Autofarm system has not yet been homologated for use on public roads in Germany. The systems differs from all other automatic steering systems in the determination of roll and heading. Instead of gyroscopes Integrinautics uses a multiple GPS roof array to determine heading, roll, pitch and yaw. This technology allows to operate the automatic steering system at very low speeds. Before engaging automatic steering the GPS roof array takes about thirty minutes to initialise. Autofarm automatic guidance systems are available with 30 cm, 10 cm and 2cm track-to-track accuracy. 30 resp. 10 cm require a correction signal subscription, 2 cm can only be obtained with a local base station. Integrinautics does not offer manual guidance systems. A feature for recording data during operation will be made available soon.

John Deere has been offering their automatic steering system AutoTrac ex factory since 2001. Retrofit kits are available for the 7020, 8000, 8010, 8020 series and for all John Deere tracked vehicles. The AutoTrac automatic steering system is based on the components of John Deereís manual guidance system. It consists of a dual frequency StarFire GPS receiver, a module for terrain compensation (TCM), a GreenStar monitor and a GreenStar mobile processor unit. A StarFire 1 license (SF1) supplies differential corrections for obtaining a 30 cm track-to-track accuracy, subscribing a StarFire 2 license (SF2) provides a track-to-track accuracy of +/- 10 cm. In the United States AutoTrac is also available with a local base station (RTK) then reaching an accuracy of 2 cm. An RTK grade system is currently being prepared for introduction in Europe. The homologation for the use of a vehicle equipped with AutoTrac on public roads is maintained when the system is factory installed. The GreenStar Monitor allows for logging of data which can be viewed and administered with JD Office, a software provided by LandData Eurosoft.

Trimble started selling its Trimble AgGPS Autopilot system in 2001. Existing manual guidance systems can be upgraded to automatic steering systems. Trimble AgGPS Autopilot is available with single and dual frequency receivers providing three different levels of accuracy (30 cm, 10 cm, 2 cm). Attitude, roll, pitch and yaw are determined by six sensors which are integrated in the navigation controller. Currently these sensors require a minimum speed of 1.5 kph. While updating the information on vehicle's orientation with 100 Hz, rolling and pitching is accounted for very quickly and accurately. Trimble offers their automatic steering systems as a retrofit solution for all common wheeled and tracked tractors with hydraulic steering. The Trimble AgGPS Autopilot system has also been made available for different combine platforms and self propelled machinery. Ruggedised field computers for recording and managing field data as well as performing VAR applications are optionally available. Existing homologations of vehicles are not affected by the installation of the system.

## Literature


[1] *Bittner, G.*: AGRO NAV® Autonomous, off-road Vehicle Navigation and Implement Control System, using CDGPS and Inertial Backup. AgEng 2000, Proc. Int. Conf. on Agricultural Engineering, Warwick, Paper 0359

[2] *Deimert, K. and R. Mailler*: A Good Host. GPS World; http://www.gpsworld.com/gpsworld/article/articleDetail.jsp?id=81842

[3] *Muhr, T.*: Georeferenzierung und Navigation - Ortungssensoren als Schlüsseltechnologie für Precision Farming. VDI Bericht 1829, Hrsg. VDI, S. 37-44

[4] *Stoll, A.*: Automatic operation planning for GPS-guided machinery. In: Conference Proceedings. 4th European Conference on Precision Agriculture, Berlin, 15.-18. 6.2003, S. 657-664


*Table 1 : Automatic steering systems available on the German market*

| Supplier | Accuracy[3] [cm] | Price [1] [ ] | Models | Annual costs [ ] |
|---|---|---|---|---|
| Trimble | 30 | 13700 - 15700 | only retrofit [2]: all JD, CNH, | 0-795 |
| AgGPS Autopilot | 10 | 19600 - 21600 | selected AGCO models, basically | 1995 |
| | 2 | from 41000[4] | all tractors with hydraulic steering | 0 |
| John Deere | 30 | 16000-20000 | ex factory : all 6020s from 6420, 7020s, | 0-500 |
| AutoTrac | 10 | 16000-20000 | 8020s, 9020s, STS, retrofit[2] : 8000s, 8010s, 8020s, 7020s, 9020T | 1100 |
| AGCO | 30 | 14500-17500 | ex factory : Challenger MT700/800, | 0 - 795 |
| Autoguide | 10 | 20250-21500 | AgChem Terragator, Fendt Vario | 1995 |
| | 2 | 36000-46000[4] | Modelle from 2005, retrofit [2] on demand | 0 |
| Integrinautics | 30 | from 11000 | only retrofit [2], all tractors and | 0-750 |
| Autofarm | 10 | from 11000 | self propelled machinery | 1400 |
| | 2 | from 35000[4] | with hydraulic steering | 0 |

[1] net excl. VAT. [2] without installation
[3] track-to-track accuracy within 15 minutes, 2 RMS
[4] includes local base station , existing base station may be used with additional tractors