

### Sustainable Agriculture through ICT innovation

### Actual and Global Precision of the Guidance System AutoTrac from John Deere

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### ABSTRACT

The main objective of the study was to determine the actual precision of the AutoTrac Guidance System according to different correction signals proposed in Belgium by John Deere: StarFire 1 (SF1), StarFire 2 (SF2) and RTK. The second objective was to observe the evolution of this precision in function of the return time between two passes in the field. Finally, the study aimed at fixing the limits of use of each correction signal. A theoretical case (specific tool especially designed for the trials) and a practical case (precision seeder for sugar beet) were studied on a tractor John Deere 6830 fully equipped. The observed precision of the correction signals was equal or better than the one announced by the manufacturer.

Keywords: GNSS, guidance system, tractor, actual precision, Belgium

### 1. INTRODUCTION

The use of guidance systems by satellites knows an increasing demand from farmers. Automated steering also interests more and more farmers because it largely facilitates control on field and improves comfort of the operator as well as the precision of work. Principal works for which automated steering is strongly required are the sowing and the plantation of traditional cultures like cereals, corn, beets and potatoes (Freycon, 1996). The precision sought for this work varies from 1 to 10 centimeters pass to pass according to the culture but also according to the working width of the tool. The possibility of increasing the daily working period by carrying out work in night condition plays a considerable part in the choice of this system (Dana, 2000). The Research Unit Agricultural Machines and Facilities underwent a study in collaboration with the Belgian importer of John Deere Cofabel on the Guidance System AutoTrac

The main objective of the study was to determine the actual precision of the Guidance System AutoTrac in function of the different correction signals proposed in Belgium by John Deere: StarFire 1 (SF1), StarFire 2 (SF2) and RTK. By actual precision of the Guidance System, we understand, the working precision of the machine measured directly in the field. Therefore the actual precision can be considered as the global driving precision of the combination tractor-machine that the user could obtain

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(Huyghebaert et al, 2007). The second objective was to observe the evolution of this precision in function of the return time between two passes in the field. The return time was the necessary time to go from one point in a parcel to the edge of the field and come back. This time was a function of the field length and could influence the driving precision of the guidance system (Adamchuk and al, 2008; Beguyot et al, 2004). Finally, the study aimed at fixing the limits of use of each correction signal with the AutoTrac.

### 2. MATERIAL AND METHOD

### 2.1 Vehicle and Correction Systems

During the trials, one tractor John Deere 6830 equipped with an integrated Guidance System AutoTrac, the new receptor STARFIRE 3000 and the interface GREENSTAR 2630. AutoTrac is a system of power-assisted steering allowing the operators to release the wheel while the machine (tractor, motorized vehicle...) follows the virtual guidance line. The new receiver STARFIRE 3000 is able to collect the signals from GPS and GLONASS constellations of satellites. The receiver accepts all the correction signals proposed by John Deere: SF1, SF2 and RTK. The tractor is mounted with "650/65" and "540/65" tires.

The 3 correction signals StarFire 1 (SF1), Star Fire 2 (SF2) and RTK, proposed by John Deere in Belgium, have been used and tested during the trials:

- Star Fire 1 (SF1) is a dGPS correction signal which has an announced precision of ± 30 cm pass to pass for 95% of the working time.
- Star Fire (SF2) is also a dGPS correction signal with an announced precision of ± 10 cm for 95% of the working time. This signal is subjected to a paying subscription.
- RTK correction signal has an announced precision of  $\pm 2$  cm. This system requires to invest in base station positioned near the field (< to 10 km).

### 2.2 Protocol and Method of Measurement

All the trials have been realized in the field in actual conditions. However, they can be divided in two parts: the "theoretical part" realized without machine and the "practical part" realized with a precision seeder for sugar beet.

For the "theoretical part", a specific tool especially designed for the trials (Huyghebaert et al, 2008) has been mounted on the three-point linkage of the tractor (Figure 1). This tool consists into a mono-disc of great diameter maintained in contact with soil by means of a spring system. The work of the disc had no stabilization effect as the working depth was not greater than 5cm. The sideways movement of the three point hitch was locked using the provided John Deere blocks. The distance between two small furrows of adjacent passes reflected the actual precision of the Guidance System (Figure 1). The main parameters studied during the theoretical part of the trials were: the tractor

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speed (6 km/h), the working width (3 m), the correction signals (StarFire 1 and 2), the return time between two passes of the tractor (5 min, 12 min and 20 min), and the driving mode (straight or curved line) (Huyghebaert & Dubois, 2009). For each combination of the parameters, 4 return passes have been operated and 18 measurements of the actual distance between two passes have been realized through 3 repetitions. Finally 864 measurements were carried out for the various test configurations.



Figure 1. View of the mono-disc and the furrows in the field

The « practical part » of the study, has been realized with a farmer for the sugar beet seeding (working width of 2.70 m). The tested parameters were the guiding mode (straight line), the tractor speed (6 km/h) and the correction signals (StarFire 1, StarFire 2 and RTK). Time between two passes was function of the length of the field and can vary from 5 to 16 minutes. The parameters were less numerous because the farmer rules and constraints have to be followed. Finally it was possible to produce 180 measurements for the SF1, 296 measurements for the SF2 and 99 measurements for the RTK correction signal. Spacing measurements were taken between the first sowing line and the last sowing line of the previous pass (Huyghebaert et al, 2008) (Figure 2).



Figure 2. View of the back side of the tractor with the seed drill and the spacing measurement

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The farmer used a combination of machines: on the front side of the tractor a roller tiller and a light cultivator, on the back side of the tractor, a rotary tiller followed by the mechanical seed drill. To avoid an unspecified slip of the back machines, the arms of the lifting device were blocked.

### 3. RESULTS AND DISCUSSION

The overall precision of a Guidance System depends on several factors as the precision of the signal, the configuration of the vehicle and the machines, the field and ground conditions. During the trials, these factors have been taken into consideration and optimized where possible.

#### 3.1 Theoretical Trials with the mono-disc

The distance between each pass has been measured and compared to the theoretical width (3 m). The distribution of the distance between two passes permitted to characterize the precision of the AutoTrac system used in different ways. The Table 1 gives the characteristics of the driving precision of the AutoTrack guidance system used in straight line mode of functioning. Each result corresponds to 72 observations.

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Return time (min)	5		12		20	
Correction signal	SF1	SF2	SF1	SF2	SF1	SF2
Average distance between two passes (m)	3.00	3.02	3.01	3.01	3.01	3.00
Mean of the absolute deviations from the theoretical distance (m)	0.04	0.04	0.06	0.04	0.09	0.03
Maximum observed deviation (m)	0.18	0.14	0.22	0.10	0.33	0.12
Maximum deviation for 95 % of the time (m)	0.13	0.11	0.13	0.09	0.24	0.07

Table 1. Characteristics of the straight line driving precision of the AutoTrack used with the correction signal SF1 and SF2, in function of the return time.

The global precision of the guidance system was better or in accordance with the precision announced by the manufacturer. The maximum observed deviation for 95 % of the working time was lower than 30 cm for the correction signal SF1 and was around 10 cm for the SF2.

On average the results don't show a significant difference between the two signals of correction (SF1 and SF2). The average distance between two passes is practically the same for both signals whatever are the return times.

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However the mean of the absolute deviations, the maximum observed deviation and the maximum deviation for 95% of the working time increase with the return time for the correction signal SF1 and remain constant for SF2.

The results obtained in curved line mode of functioning underwent the same analysis and shows the same trends. However, the mean of the absolute deviations increases more in function of the return time for the curved line mode than the straight line mode (Figure 3).



Figure 3. Evolution of the average deviation of the AutoTrack guidance system used with the correction signal SF1 and SF2, in function of the mode of functioning and the return time.

### 3.2 Practical Trials during Sugar Beet Sowing

The working width of the drill seeder was 2.70 m. The three correction signals (SF1, SF2 and RTK) have been tested. As the trials have been realized in practical conditions, the return times differ from one correction signal to another.

As the precision of the SF1 correction signal was lower, the farmer used the tracers of the seeder to visualize when the AutoTrack guidance system left the right trajectory. When the tractor deviated more than 10 cm from the right trajectory, the farmer took back manually the control, replaced the tractor in the right track and recalibrated the guidance system. Two parcels of different length (350 and 600 m) have been sowed using SF1 as correction signal. It allowed generating on average two different return times (10 and 16 min). The results of the precision given by the guidance system using SF1 correction signal during sugar beet sowing are given in the table 2.

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 Table 2. Guidance precision of the AutoTrack used with the correction signal SF1, in function of the return time (practical trials – sugar beet sowing).

Average return time (min)	10	16
Mean of the absolute deviations from the theoretical distance (m)	0.05	0.08
Maximum observed deviation (m)		0.20
Maximum deviation for 95 % of the time (m)		0.16

As observed during the "theoretical trials", the deviations tend to increase with the return time. The maximum observed deviation and the maximum deviation for 95 % of the time seem to be lower, but these results are non-comparable to SF1 results of the "Theorical trials", due to the regular recalibration that the farmer had to proceed during this work. These interventions are supposed to produce a too optimistic pass to pass accuracy for SF1.

The trials realized with the correction signal SF2 didn't ask to recalibrate the system. Also two parcels of different length have been sowed permitting to generate on average two different return times (12 and 16 min). The results of the precision given by the guidance system using SF2 correction signal during sugar beet sowing are given in the Table 3.

Table 3. Guidance precision of the AutoTrack used with the correction signal SF2, in function of the return time (practical trials – sugar beet sowing).

Average return time (min)	12	16
Mean of the absolute deviations from the theoretical distance (m)	0.04	0.04
Maximum observed deviation (m)		0.16
Maximum deviation for 95 % of the time (m)	0.08	0.11

Ninety percent of the observed deviations are within the range of  $\pm 5$  cm whatever the time between two passes is. Considering 95 % of the time, the maximum observed deviations reach  $\pm 8$  cm and  $\pm 11$  cm following the return time. For the rest of the time (5%), the observed deviations never exceed  $\pm 9$  cm and  $\pm 12$  cm respectively for a return time of 12 and 16 minutes.

The RTK correction signal allows to centimetric accuracy. Before the trials (24 hours), the RTK base station has been located at the edge of the field so as to reach a high precision. The field was shorter and allows generating only a return time of 5 minutes. The results of the precision given by the guidance system using RTK correction signal during sugar beet sowing are given in the table 4.

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 Table 4. Guidance precision of the AutoTrack used with the correction signal RTK for a return time of 5 minutes (practical trials – sugar beet sowing).

Average return time (min)	5
Mean of the absolute deviations from the theoretical distance (m)	
Maximum observed deviation (m)	
Maximum deviation for 95 % of the time (m)	

The average observed deviation reach 2 cm. Sometimes, we observed deviation reaching 7 cm but that concerns in fact only very few measurements.

Thanks to the high precision of the RTK correction signal, we carried out a skip pass, which means that we skipped voluntarily passes in order to improve the half-turns at the end of line. This practice kept the same level of precision as in normal work.

### 3.3 Discussion

The "theoretical trials" with the mono-disc showed that the Guidance System AutoTrac generates on average the same driving precision whatever the dGPS correction signal is (SF1 or SF2). However the variability of the observed deviations is much more restricted when the Guidance System is adjusted with the correction signal SF2. That reflects the stability of this signal. This observation is confirmed by the independency of the correction done by the SF2 regarding the return time.

The importance of the return time on the driving precision has been highlighted during the practical trials (sugar beet sowing). When using the SF1 correction signal the farmer had to recalibrate regularly the system to keep an acceptable driving precision. In the parcel of 600 m length (average return time of 16 minutes), the user needed to recalibrated so many times that he decided to take back manually the control of the tractor. For the parcel of 350 m length (average return time of 10 minutes), the user proceeded differently. He recalibrated the system at the end of the line during the half-turn. In this way, the Guidance System kept the course adequately.

The use of SF2 as correction signal did not require any recalibration during all the sowing day even with a period of time between two passes of more than 20 min.

#### 4. CONCLUSIONS

The automatic steering of the tractor is more and more used by farmers. It gives a great comfort to the operator, it is easy to use and can fit to numerous agricultural works (ploughing, sowing, planting, spraying...). Its limits of use are strongly linked the requested precision by these applications. The driving precision of a Guidance System is a function of its different components: the correction signal, the tractor configuration, the soil and field conditions, etc.

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The study aimed at determining the actual precision of the Guidance System AutoTrac in function of the different correction signals proposed in Belgium by John Deere: StarFire 1 (SF1), StarFire 2 (SF2) and RTK.

The observed precision of the free correction signal SF1 is better than the one announced by the manufacturer. Following the observations made in practical conditions, the maximum deviation is around 15 cm with a return time of 12 minutes. This correction signal could be advised for works of great width requesting a lower precision than the seeding.

The correction signal SF2 fits totally to the precision announced by the manufacturer. The maximum observed deviation is lower than 11 cm. The great advantage of this correction signal is that it didn't ask a re-adjustment during the day which is time consuming. The level of precision given by this correction signal allows the realization of the most of the works, from the seeding to the harvesting.

The RTK was the signal which gave the best precision and regularity. The maximum observed deviation was lower than 5 cm. This correction signal needs nevertheless the use of a base station.

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