DLG-Test Report 6802

NovAtel

SMART 6L receiver

PPP Automatic Steering Test

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Overview

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A “DLG APPROVED test for individual criteria” quality mark is awarded to farm machinery that has passed a limited test programme within a DLG usability test, which is conducted in accordance with independent and approved assessment criteria. The purpose of the test is to highlight a product’s specific innovations and key features. The test may be carried out either to criteria laid down in the “DLG Full Test” framework for technical products or may include further features and properties that confirm a specific value to the product. The minimum standards to be applied to the product, the test conditions and procedures, as well as the criteria by which the test results are to be evaluated, are defined in cooperation with a DLG group of experts. These parameters reflect the acknowledged state of the art as well as scientific findings and agricultural insights and requirements. After a product has passed the test, a test report is published and the quality mark is awarded and will remain valid for five years from the date of award.

The systems that were submitted to the “PPP Automatic Steering Test” are the NovAtel SMART 6L Receiver with TerraStar-C and TerraStar-L correction services as one possible configuration of the Fendt automatic steering system “VarioGuide RTK”. For the test, a Fendt 828 Vario was used as the test tractor.

The DLG APPROVED full test for “Automatic Steering Systems” includes testing of the accuracy and operation of automatic steering systems in agricultural vehicles. In addition to measuring the steering accuracy under various operating conditions, examinations were also performed on operation, the system’s display and control elements, the operating instructions and help functions, and the safety devices. Other criteria were not investigated.

The test was performed without shading conditions, as Precise Point Positioning (PPP) correction signal shading needs an update of the DLG testing framework. The update of the testing framework as well as the re-examination will be carried out in the first quarter of 2018.

Assessment – Brief Summary

Fendt's newest version of their "VarioGuide" automatic steering system has separated the GNSS (Global Navigation Satellite System) receiver from the navigation controller. This allows customers to select and use different Fendt-approved GNSS receivers with their VarioGuide system.

In this report the NovAtel GNSS receiver SMART 6L was tested using two different types of NovAtel correction signals: the TerraStar-C signal provides centimetre level system accuracy, and, the TerraStar-L signal provides decimetre level system accuracy. Both correction signals are transmitted to the GNSS receiver on the tractor via geostationary satellites.

The NovAtel steering system tested provided a 2-3 cm system accuracy under a number of test conditions, when using the TerraStar-C correction signal. Using the TerraStar-L correction signal, the system reached accuracy values from 10 to 25 cm depending on the test setup.

In addition to the absolute accuracy values determined within this test, special attention was given to the pass-to-pass accuracy, as these results give an important indication of the system's ability to minimize overlap or skip between swaths. With the TerraStar-C correction signal, the NovAtel system achieved pass-to-pass accuracy below 3 cm whereas the TerraStar-L system's accuracy was around 15 cm.

The user-interface at the terminal is logically structured and achieved the best-possible ranking due to a very small number of steps for programming predefined settings and its overall easy handling.

Table 1:
Overview of results

Test condition	95 % class	
	TerraStar-C	TerraStar-L
A-B run on an even track at 8 km/h	2-3 cm	24-25 cm
A-B run on an even track at 15 km/h	3-4 cm	
Contour run at 5 km/h	2-3 cm	10-11 cm
Long-term accuracy: repetition after > 24h	3-4 cm	
1 h duration drive A-B run on an even track at 8 km/h	2-3 cm	17-18 cm
Pass-to-pass errors	< 3 cm (1h duration test)	< 15 cm (1h duration test) < 15 cm (three test runs with 1 min break between test runs)
1 h run with fallback from RTK to GLIDE with EGNOS solution	< 19 cm	
1 h duration test, pass-to-pass errors during fallback from RTK to GLIDE with EGNOS period	< 10 cm	

Operation/Ergonomics	Assessment
Operating instructions / help system	[+]
Operation	[+ +]
Terminal and control elements	[+ +]

Safety	Assessment
Safety devices acc. to ISO 10975	[+ +]

* Definition: 95 % of all deviations from the reference line are <= the stated error class
Evaluation range: + + / + / ○ / – / – – (○ = Standard, N/A = Not Assessed)

The Product

Manufacturer and Applicant

NovAtel Inc.
1120 – 68th Avenue N. E.
Calgary, Alberta
T2E 8S5 Canada

Product:
NovAtel Automatic Steering System with TerraStar-C or TerraStar-L correction signals

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Description and Technical Data

The previous Fendt guidance/steering system consisted of two major parts:

(i) first, an integrated GNSS receiver and navigation controller that received GNSS and correction data, computed the position and used this position to generate steering commands, and

(i) second, the tractor hardware, steering controller, steering valve, sensors and the display terminal that controlled tractor lateral motion and provided the user interface for operation of the steering system.

The new generation of the Fendt "VarioGuide RTK" guidance/steering system has separated the GNSS receiver and navigation controller and moved the navigation controller to the tractor side of the system. This means that the corrected GNSS position is now transferred to the tractor instead of the steering commands (Figure 2). This provides a flexible solution for farmers to choose different Fendt-approved GNSS receivers that best meet their needs for use with their VarioGuide system.

The NovAtel system used in this test consisted of a NovAtel SMART6-L receiver in combination with two different types of NovAtel correction signals. The TerraStar-C correction signal provides a centimeter-level overall system accuracy. The TerraStar-L correction signal provides a decimetre-level system accuracy. Both correction signals are transmitted to the SMART6-L receiver on the tractor via geostationary satellites.

The NovAtel SMART6-L is a high performance, cost-effective GNSS-receiver solution. RTK accuracy can be achieved using NTRIP corrections transmitted over a cellular radio link. The receiver can provide RTK accuracy for up to one minute after losing RTK correction signals. The receiver can also bridge RTK outages beyond one minute when falling back to an

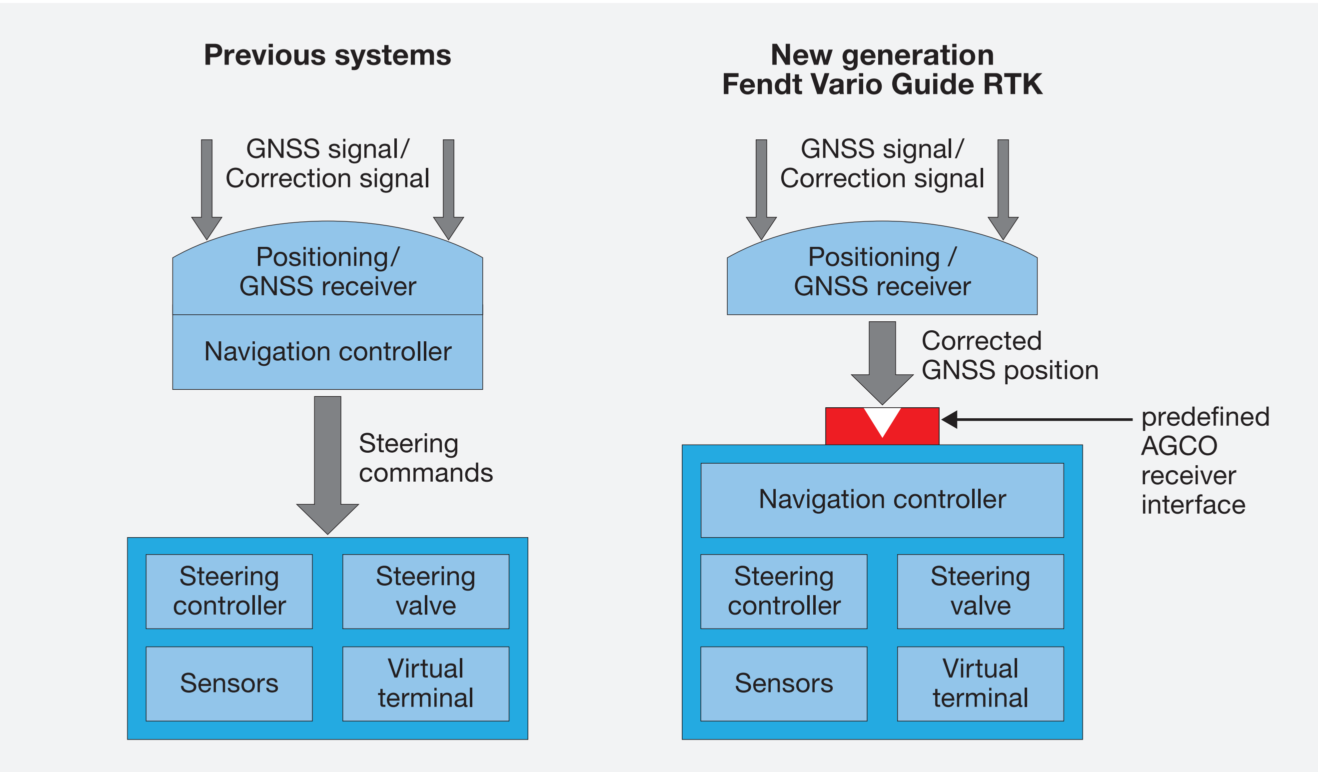


Figure 2:
Comparison of data transfer between old and new scheme of data transfer

EGNOS position. The fall back will smoothly and slowly transition between RTK and EGNOS level accuracy

The NovAtel System provides a special system to react to signal losses: GLIDE is NovAtel's proprietary filtering method optimized to provide a superior 15-minute (short term) pass-to-pass repeatability. GLIDE works best with SBAS corrections, such as EGNOS, but can also be used autonomously without corrections. The GLIDE filter provides smooth, robust positions making it especially effective when used as a fallback solution during RTK or TerraStar-C correction outages. NovAtel's STEADYLINE technology reduces position jumps that can occur when a GNSS receiver changes positioning modes. This effect is especially evident when a receiver transitions from a high accuracy RTK position solution to a lower accuracy solution such as PPP (TerraStar), DGPS, SBAS+GLIDE or even autonomous GLIDE™. Smooth transitions are extremely important for precision agricultural steering applications where sudden jumps are disruptive.

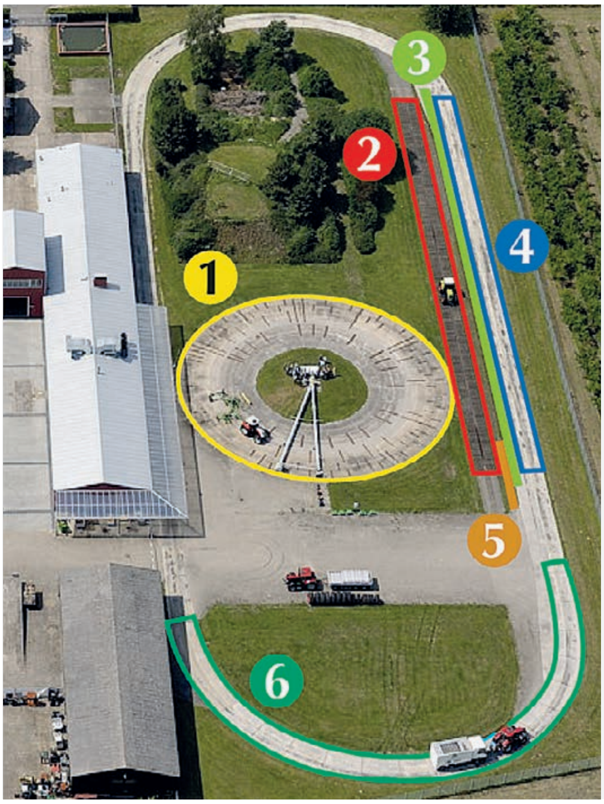
In the test, the NovAtel receiver was mounted on a Fendt 828 Vario tractor with 280 kW power according to ECE R24. Further technical data, the measured vehicle geometry, the tyres used, and the settings parameters used for the steering system are summarized in table 2. The steering system's settings were configured according to the manufacturer's specifications.

Table 2:
Technical data, vehicle geometry, tyres and settings parameters of the steering system

Technical data Steering system		
Steering system type	VarioGuide RTK NovAtel	
GNSS receiver (incl. antenna)	NovAtel SMART 6L	
GNSS satellite reception	GPS, GLONASS	
Correction signal	NovAtel TerraStar	
Correction signal service Signal precision (manufacturer information)	TerraStar-C +/- 4 cm	
Correction signal service Signal precision (manufacturer information)	TerraStar-L +/- 50 cm (+/- 15 cm pass-to-pass)	
Technical data of the tractor		
Manufacturer	AGCO GmbH	
Type	Fendt 828 Vario	
Power (ECE R24)	280 kW	
Max. speed	60 km/h	
Tare weight	9,520 kg	
Total permitted weight	14,000 kg	
Measured vehicle geometry		
Axle height rear wheel	98 cm	
Distance rear wheel axle to three point lower links	156 cm	
Distance three point lower links to measurement point	25 cm	
Height of measuring point above ground	100 cm	
Tyres	**Front axle**	**Rear axle**
Size	600/70R30	710/70R42
Air pressure (manufacturer's specification)	1.3 bar	1.3 bar
Steering system settings		
Steering sensivity	high	
Steering angle sensor	not specified (integrated system)	
P-factor	not specified (integrated system)	
Steering behaviour	high	

The Method

The accuracy of the automatic steering system was determined by using measurements from an optical reference system. A tachymeter automatically followed a prism attached to the 3-point rear linkage and records the measured values. The measurements were taken on the testing ground of the DLG Test Center Technology and Farm Inputs in Gross Umstadt (see Figure 3) and were accompanied by one of the manufacturer's staff. All settings were configured according to the manufacturer's specifications.



① = Checking the tacheometer for radial run-out
② = Bumpy track
③ = A-B run with offset
④ = A-B run
⑤ = Gradient
⑥ = Contour

Figure 3:
Measurement tracks on the testing ground

Figure 4:
Measurement setup of the optical reference system

The following measurements were taken:

A-B run on an even track at 8 km/h or 15 km/h

The accuracy for a straight-line run was determined at various practice-relevant speeds while driving from starting point A to end point B on the level track.

To determine the long-term behaviour with respect to the stored A-B reference line, the test was repeated at 8 km/h after more than 24 hours. Additionally, a one-hour run with constant repetitions of the all-same A-B run for 60 minutes was carried out to determine lateral shifts as a function of time.

The size of the deviation from the reference value obtained in the reference run was determined from the root mean square of three measurement runs in each case.

The results were presented in error classes of 1 cm each and the resulting 95 % sum of the error classes; i.e. 95 % of all measurements lie within this range (only for TerraStar-C).

The pass-to-pass error was calculated for the one-hour duration test (for TerraStar-C and TerraStar-L).

Contour run at 5 km/h

For the contour run (along the semicircle of the test track), a reference line was driven manually and recorded by the steering system.

The deviation of the error classes was expressed in relation to the reference run.

One hour run with fall back from RTK to GLIDE with EGNOS

In this additional test we measured the performance of the positioning system when RTK corrections are lost and the receiver falls back to the GLIDE solution using STEADYLINE.

Operation and ergonomics

In the field of operation and ergonomics, the operating instructions and/or the help system accessible in the terminal, were first checked for completeness, clarity and comprehensibility. Further operational aids such as a quick-start guide or a help system accessible via the internet were also included in this assessment. Furthermore, the operation of the help features was tested specific questions:

(i) the definition of an A-B path

and

(ii) the help offered for "Troubleshooting signal faults". The operation of the system itself was characterised by the number of operating steps needed to teach on an A-B path and the subsequent activation of the automatic steering function.

Figure 5:
Control and display elements

The legibility and operation of the terminal during day and night are particularly important for practical use. Sunlight from behind during the day is especially problematic for the users because they cannot see the display due to reflections and, where applicable, cannot operate the elements on the touchscreen. At night, the terminal must not cause any glare or fatigue for the driver (Figure 5).

The safety devices for an automatic steering system are essentially predefined in the ISO 10975 standard. For example, the presence of a driver must be verified using a seat contact, and the automatic steering must automatically deactivate itself in the event of manual intervention or signal faults. The driver should be informed of the deactivation visually or acoustically.

The Test Results in Detail

As shown in the example of the A-B runs at 8 or 15 km/h, the NovAtel automatic steering system with TerraStar-C correction signal on a level track in Figure 10, the 95 % class of deviations is determined using the frequency distribution and the deviation class. At a driving speed of 12 km/h, the system achieved accuracy in the 2-3 cm class in 95 % of the cases; in the long-term test with a repetition after more than 24 hours the values remained in the 3-4 cm class. The other results are summarised in Table 3 as well as in Figures 6, 7 and 8.

With the TerraStar-L correction signal, the measurements were in the region of 24-25 cm for the 95 % class of deviations in the case of an A-B run on an even track at 8 km/h. The pass-to-pass error remained below 15 cm for both the 1 h duration test as well as three single test runs with a one-minute break after each run. The other results are also summarised in Table 3 as well as in Figures 9 and 10.

To determine the accuracy in the contour run, a reference line was manually driven along the semi-circular section of the test track and was recorded by the steering system. The deviation in the error class is expressed in relation to the reference run. At a contour run at 5 km/h the TerraStar-C system reached the 2-3 cm class, while the TerraStar-L system reached the 10-11 cm class.

Table 3:
Accuracy classes achieved under various test conditions

Test condition	95 % class	
	TerraStar-C	TerraStar-L
A-B run on an even track at 8 km/h	2-3 cm	24-25 cm
A-B run on an even track at 15 km/h	3-4 cm	
Contour run at 5 km/h	2-3 cm	10-11 cm
Long-term accuracy: repetition after > 24h	3-4 cm	
1 h duration drive A-B run on an even track at 8 km/h	2-3 cm	17-18 cm
Pass-to-pass errors	< 3 cm (1 h duration test)	< 15 cm (1 h duration test) < 15 cm (three test runs with 1 min break between test runs)
1 h run with fall back from RTK to GLIDE with EGNOS solution	< 19 cm	
1 h duration test, pass-to-pass errors during fallback from RTK to GLIDE with EGNOS period	< 10 cm	

A-B runs at 8 or 15 km/h

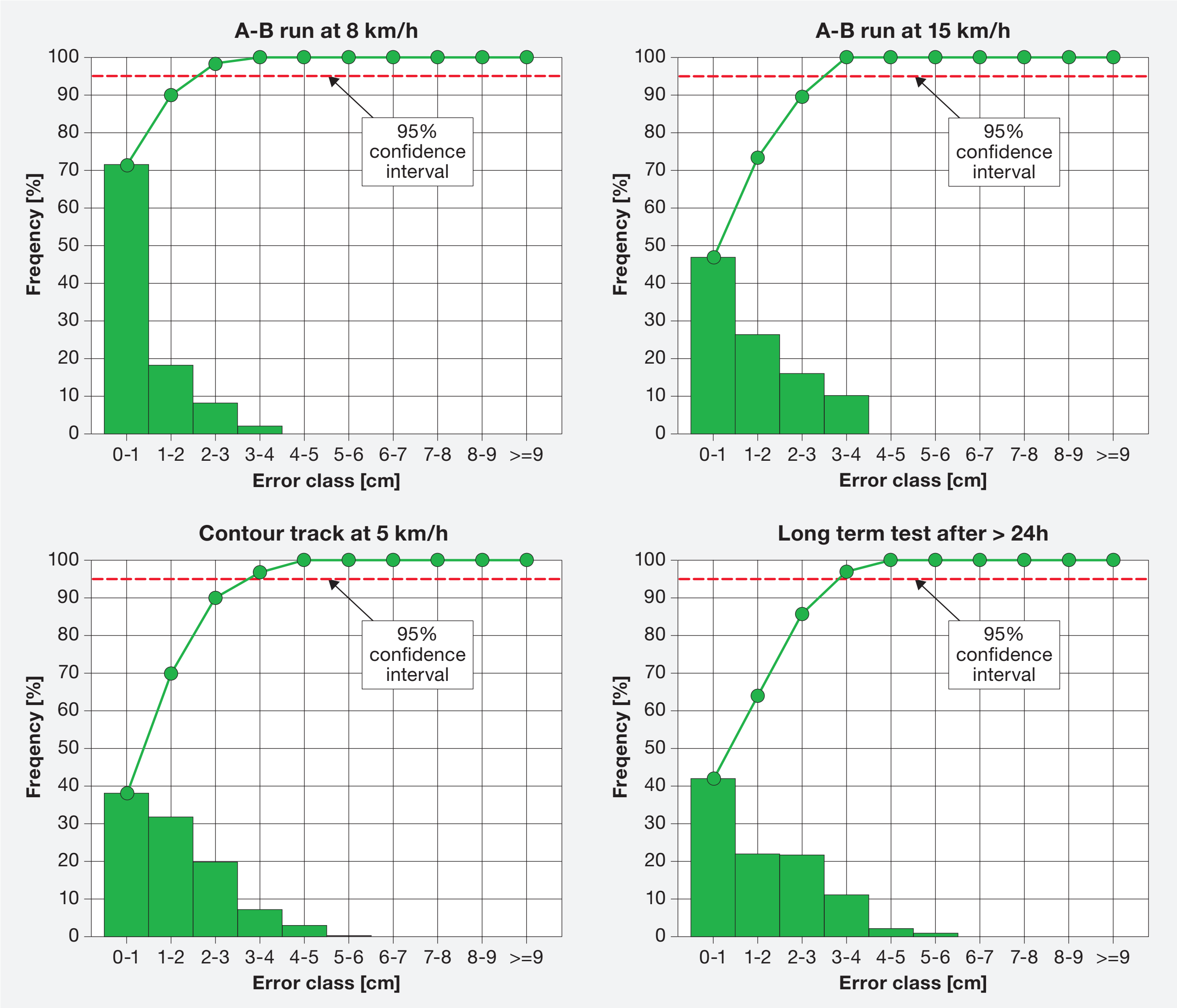


Figure 6:
TerraStar-C Deviation rates

1 h duration drive A-B run on an even track at 8 km/h

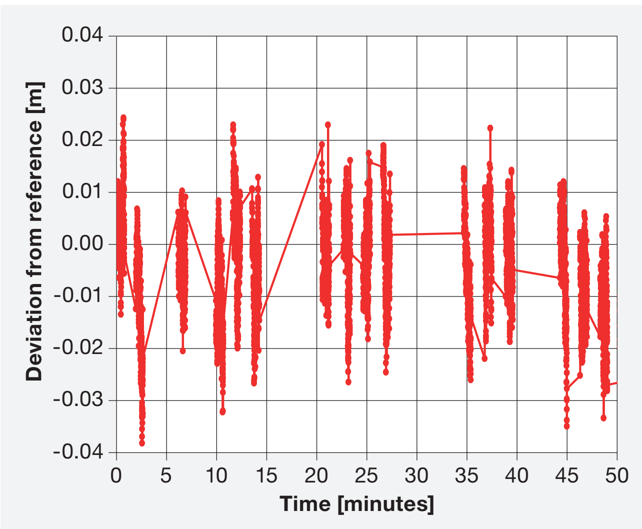


Figure 7:
Pass-to-pass errors of TerraStar-C

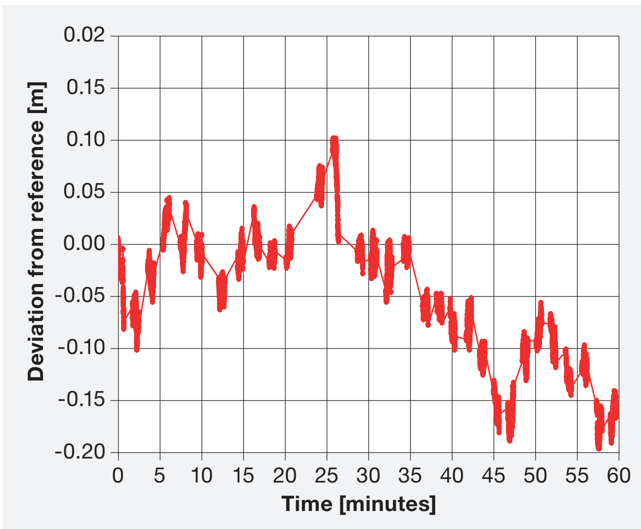


Figure 8:
Pass-to-pass errors of TerraStar-L

One hour run with fall back to GLIDE with EGNOS

Within the measurement of the performance of the positioning system when RTK corrections are lost and the receiver falls back to the GLIDE solution using STEADYLINE, the system reached the 18-19 cm class of deviations during the one hour run with fall back to GLIDE with EGNOS solution. In a one hour duration test, pass-to-pass errors during a fallback to GLIDE with EGNOS period reached the 10-11 cm class.

The suggested solutions to two predefined problems were determined in order to assess the operating instructions and the help system. Both a description of how an A-B track can be defined and an indication and possible solutions for signal errors like GPS or correction signal losses are available in the user manual. The assessment is, therefore "[+] = Better than the standard".

For teaching in of an A-B track not more than two operating steps in the menu and one step for the use of the function "Quick-Jump" have to be carried out. Also the activation of the automatic steering function after teach-in is very easy. The assessment for both functions as well as the handling in total is therefore "[++] = Significantly better than the standard".

The terminal is integrated into the control unit in front of the right armrest and accessible in a very easy way. The display can be adjusted into all directions. Therefore, readability during daytime is always possible, even in the case of direct sunlight from behind. Also during night time, which was simulated in a dark hall at the DLG Test Center, readability of the display was very good. All three functions as well as the control elements and terminal in total were assessed with "[++] = Significantly better than the standard".

The essential safety functions according to ISO standard 10975 (Tractors and machinery for agriculture – Auto-guidance systems for operator controlled tractors and self-propelled machines – Safety requirements) were evaluated as outlined in table 6.

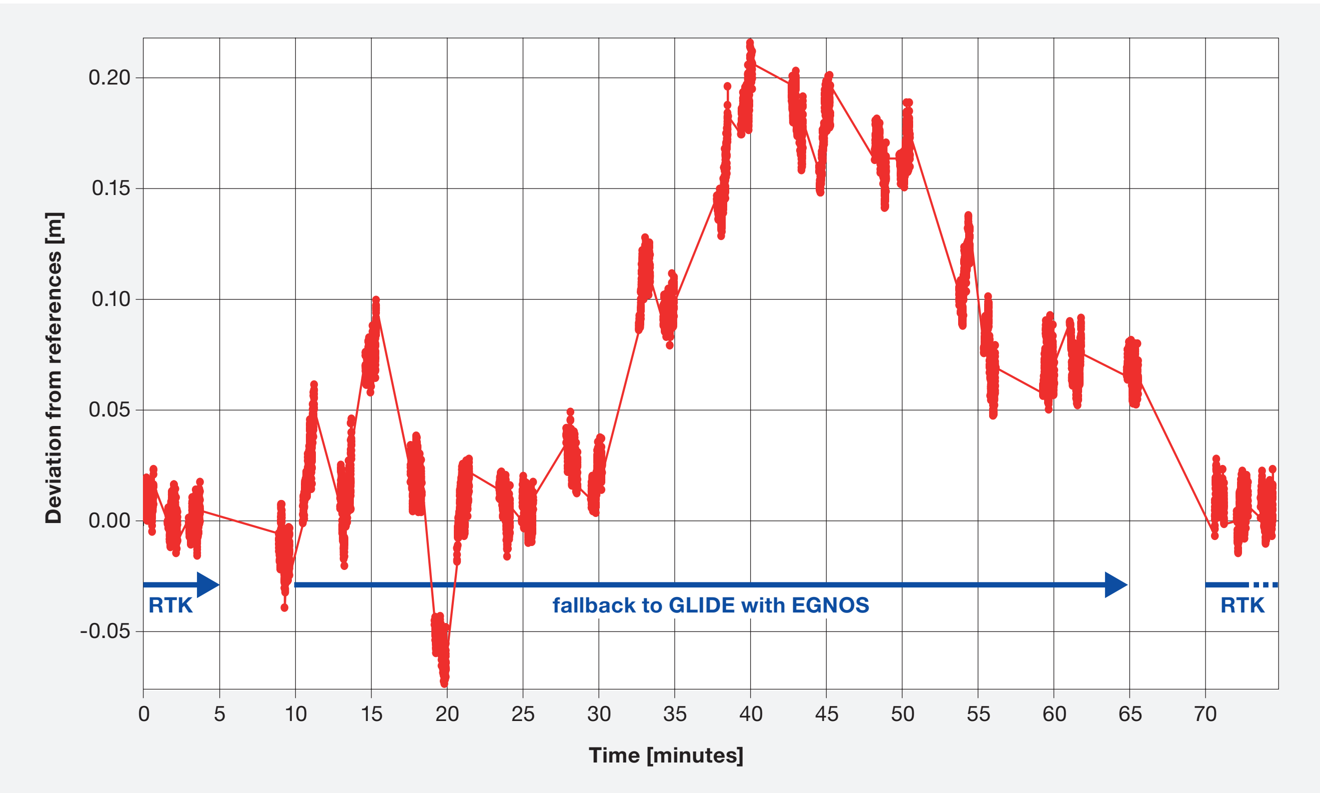


Figure 9:
Deviation rates and pass-to-ass errors RTK with fallback to GLIDE with EGNOS –
1 h run with fallback to GLIDE with EGNOS, switching back to RTK

Table 4:
Results of the safety evaluation

Specification	Result
Inspection of driver presence (e.g. by seat contact)	Yes
Deactivation of automatic steering upon manual operation of steering	Yes
Warning notice upon start or activation of automatic steering	Yes, notice on the terminal upon start
Deactivation of automatic steering during signal errors (GNSS or correction signal)	Yes, additional message on the terminal
Remarks	All error conditions are expressed by a signal tone.
Total result of safety evaluation	**[++] = Significantly better than the standard**

Conclusion

The criteria of the test for a DLG-APPROVED quality mark for the single criterion “PPP autosteering test” assess the basic function of a system, as well as the deviations from the ideal line as described in detail above.

On a Fendt 828 Vario, the NovAtel SMART 6L receiver with the TerraStar-C correction system represents a state-of-the-art automatic steering system and can be recommended for use in agricultural machines and tractors The combination with the TerraStar-L correction system is recommended for purposes with a demand for lower accuracy.

More information

Further tests on automatic steering systems are available for download at: **www.dlg-test.de/lenksysteme**. The DLG committee of experts for “Labour Management and Process Technology” has published two instruction leaflets on the topic of “automatic steering systems” with the titles “GPS in Agriculture” (Instruction Leaflet 316) and “Satellite Positioning Systems” (Instruction Leaflet 388). These are available free of charge as PDF documents at: **www.dlg.org/merkblaetter.html**

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DLG test scope

„Automatic Steering Systems“ (Version V 9.14/2016)

Department

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The DLG

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The DLG Test Center Technology and Farm Inputs

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As an accredited and EU registered testing laboratory the DLG Test Center Technology and Farm Inputs offers farmers and practitioners vital information and decision support for the investment planning for agricultural technology and farm inputs through recognized technology tests and DLG testing.

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