# Evaluation of Different GPS Signal Corrections to Improve Field Accuracy of the Autopilot System

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**Abstract** – GPS positioning is the foundation of the precision farming or rather site-specific plant production technology. Positioning accuracy plays a key function both from technical and economic aspects. The authors investigated the effect of GPS accuracy upgrade on positioning accuracy in practice. For this purpose, the steering accuracy of a Trimble Autopilot hydraulic robot pilot system installed in a New Holland T 6030 tractor was investigated. Test runs were done in a real field in the four cardinal directions. Steering was controlled by a Trimble FMX display and data were recorded by another one. Test runs were done without correction, or rather using EGNOS, OmniStar VBS, OmniStar HP, and RTK corrections both from own base and GNSS network. The average steering error (offline distance) was defined in case of each run and the accuracies of steering using different corrections were compared. The effect of driving direction on accuracy with regard to the given correction signals was analysed as well.

**Keywords**: precision farming / autopilot / steering accuracy / GPS correction signal

## 1. INTRODUCTION AND LITERATURE REVIEW

Precision – or site specific farming is getting more and more popular in central and east Europe and appeared in West Asia or China and South Africa as well. The main reason of this spreading is the potential of efficiency increase may be achieved by decreased input utilization and improving quality. Beside economic advantages the precisely controlled and positioned chemical use and fuel saving has positive effect on the environment as reducing its load.

According to BLACKMORE (1999) precision farming is not a technology rather is to be considered as a management process. He mentioned some examples which represent that precision farming may be realised without applying new technique or elements. However, precision farming in case of intensive arable farming is based on high-tech equipments require significant investment. Similar opinion is stated by GYŐRFFY (2000) and supported by NEMÉNYI et al. (1998) as well according to whom precision farming means the complementation or rather the further development of modern agricultural machines. The fundamental of site specific technology is satellite system based positioning. Positioning accuracy of the applied GPS system may be defined by the demand of the given field operation but cost of accuracy upgrade of GPS receivers may be a limiting factor. 15-20 cm pass-to-pass accuracy with manual or assisted steering is accepted in case of fertilizer

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spreading or spraying but autopilot with 2.5 cm accuracy is needed for seeding or within-row cultivation. The cost of upgrade from 15-20 cm (EGNOS) to 6-10 cm (OmniStar) pass-to pass accuracy is approximately 1 500 EUR, while to 2.5 cm pass-to-pass and year-to-year level (RTK) is about 4 600 EUR. With respect to its cost or rather the accuracy demand of the field operations, the question raises whether to what extent can this positioning accuracy be realized in the level of steering of agricultural machinery.

Accuracy and availability of GPS positioning using different correction signals were investigated by many authors e.g. TAMÁS – LÉNÁRT (2003), TIBERIUS – VERBREE (2004), NOACK – MUHR (2008), EISSFELLER et al. (2011). TUCHBAND (2008) analyzed the absolute and relative positioning accuracy using code and phase measurements applying precise point positioning (PPP) method. The effects of different models (ionosphere, clock errors, and orbit models) on positioning errors were investigated as well.

These investigations are very important in order to determine the factors are influencing positioning accuracy or rather their degree of impact. Operation of GPS receivers in agriculture is however significantly different. BAIO (2012) compared the navigation accuracy of manual steering and auto-guidance in case of sugar cane harvester. The author found that steering accuracy increased applying both in day and night whereas operational field efficiency was the same. HUDSON et al. (2007) made a very comprehensive study in the frame of which the accuracy (mean error and rms error) and precision (standard deviation of error) of three tractor-guidance methods – foam-marker, light-bar, and assisted-steering systems (Trimble EZ-Steer) – were investigated. Two different travelling speeds were applied (5.6 – and 11.5 km/h) during a total 504 field passes of parallel swathing operation. The authors found that steering using foam marker was significantly less accurate comparing to using light-bar or assisted steering. It was stated as well that field speed caused no significant difference in mean error and rms error. However, a significant interaction was found between guidance method and field speed for both mean and rms errors. According to the authors, both indices increased at higher speed in case of foam marker guidance and assisted steering whereas decreased when using light bar guidance. ADAMCHUK et al. (2008) carried out some series of examinations investigating the positioning accuracy of GPS receivers. They used a test cart carrying the GPS receivers running in an I-beam track and measured the steering accuracy of autopilot systems in field trials as well. For these latter measurements visual sensor-, or rather potentiometer-based systems were built and applied. ABIDINE et al. (2004) carried out similar investigation but from practical approach. The authors set up a split-plot trial in the frame of which field operations were done using an RTK autopilot controlled tractor. Steering accuracy was evaluated by measuring plant damage caused by the given field operation. According to the authors no significant plant damage occurred even at 7 miles per hour (mph) forward speed and cultivator disk spacing of 2 inches from the plant line. SZLÁMA (2011) carried out a comprehensive investigation with respect to achievable positioning accuracy using RTK system for agricultural purpose. He used John Deer's single RTK base station and repeater network in Hungary and investigated the positioning accuracy within different distances from the base stations. This so-called "RTK network" is in fact a group of single RTK base stations which was established in order to provide 2 cm accurate RTK correction signal for precision farming applications. The author analyzed the correlation between the distance from the base station and positioning accuracy or rather signal strength. It was stated that 2 cm accuracy could have been realized only if the distance of the base station was not more than 5.61 km. Unfavorable shading effects of natural and artificial objects (e.g. relief or building) were experienced as well. The results of this experiment are very remarkable from a farming point of view. However, it should be mentioned that measurements were applied are stationary type what is still differ from agricultural practice where kinematic positioning is needed.

The aim of the present investigation was not to identify the static or dynamic accuracy of the given GPS receiver. The primary goal was to investigate the achievable steering accuracy under real field circumstances using different correction signals with hydraulic autopilot system.

## 2. MATERIALS AND METHODS

The authors investigated the steering accuracy of a NH T 6030 tractor installed with Trimble Autopilot hydraulic robot pilot system controlled by a Trimble FMX display (FMX 1). The tractor was built in 2008 and was used for 2 769 operation hours till the beginning of the tests. All function of the display was unlocked by a Master Unlock Code was provided by Trimble Agriculture Europe Gmbh. With this, the receiver could have been set to use different source of correction and was able to receive the signal of GLONASS satellites as well. The firmware version of the FMX display was 5.11.52214 and 5.15 in case of the Navigation Controller, which is responsible for tilt compensation as well. The test tractor was installed with another FMX display (FMX 2) (firmware: 5.11.52214) using a Trimble Ag252 GPS external GPS receiver (firmware: 3.7) for recording position information as well. Test swats in North – South and East – West directions were marked out ensuring 200 m long straight sections after the turns. Autopilot was used following the same test AB lines in 10 repetitions in North – South, South – North, East- West and West – East directions. Repetitions were done in each directions using different GPS or rather correction signals such as no correction, EGNOS, OmniStar VBS, OmniStar HP, RTK from own base station or rather network RTK. The base station (Trimble AgGPS 450 RTK Base station with in-built radio) as well as the test field is owned by Helianthus Ltd. farming in town Adony, 60 km South of Budapest, capital of Hungary. The radio of the base station operated at 450.0000 MHz with 12.5 kHz channel spacing and 2 W output power. The base station was not GNSS unlocked, thus was not able to receive GLONASS satellite signal. The GPS coordinates of the test field are: N 47.103214, E 18.86393. The distance from the RTK base station was approximately 600 m. The base station was installed at the top of a silo tower, approximately 20-23 m above the ground level. When using RTK network, correction was obtained from the base station located in Budapest utilizing a Trimble AG3000 GPRS modem with Telenor SIM card. The test area was free of significant slope and plants, its surface was flat. The plot was opened from every directions, there was no natural neither artificial objects may have disturb the reception of GPS or rather correction signal. The soil was not freshly cultivated thus it was naturally compacted, the wheels of the tractor sunk into the soil only 5-6 cm deep. The average size of soil particles was in a range of 5-15 cm. They were chopped to a given degree during the pre-test runs thus test runs were done in a quite similar soil surface. The tractor was driven in 9$^{th}$ gear in a fixed engine revolution of 1 520 1/min ensuring 6.4 km/h travelling speed. FMX 1 controlled the Autopilot system and recorded a so-called “Track 3d” file consisting information about the test runs such as actual position, date and time of the given position record, source and age of correction, HDOP, height, heading and a value called “Offline” among others. The value offline shows the distance from the actual swath in centimetre. Same data file was recorded by FMX 2 using RTK correction from own base station all the time. The goal of this double measurement was to avoid or decrease the measurement error caused by the inaccuracy of the GPS signal. Using the same receiver for both Autopilot control and position mapping the error of positioning affects both processes and thus steering- and positioning accuracies cannot be separated. Even as application of different GPS signals causes different impact on the measurements. As position mapping was done using RTK positioning the effect of its inaccuracy can be considered identical during the experiment. The Autopilot system was calibrated according to the factory standard. Data collection started only after the tractor's hydraulic oil reached the normal operation temperature and the given correction signal had converged entirely. State of convergence was followed using Trimble's AgRemote application. Measurements took place between 11 – 17 August, 2011.

Data processing was carried out using ArcGIS 10 GIS software and Microsoft Excel 2010 application. In the course of processing we used WGS84 geographical coordinate system, so the differences between the measurements can be determined in decimal degree. To convert decimal degree to meter unit we have used Spatial Analyst / Distance operator / Raster operation in ArcGIS 10. Our aim was to reach the mm precision in data processing, so the map resolution was 0.0000001 decimal degree. Accordingly, one pixel meant 0.0008 m (0.8 mm) on the resulted raster map. The standard deviations and averages were calculated and the diagrams were prepared in spreadsheet as visualization.

Data recorded by the FMX Display were downloaded and separated. Thus, it could be seen those turns, which were different to the replications. Based on the distribution diagram was created the data set recorded using GNSS correction was chosen as reference as its standard deviation was the smallest. Deviations of waypoints using each correction in each direction comparing to the midline of GNSS measurement were determined in ArcGIS 10 software environment.

Data were analysed following a different approach too. The statistical parsing of the offline distance values recorded by the FMX display has been carried out as well.

## 3. RESULTS AND DISCUSSION

The results of the ArcGIS based analysis shown that the highest steering accuracy was achieved using RTK correction from GNSS network and own RTK base station. In case of own base RTK, GNSS network and the XP-HP corrections the standard deviation values were lower in East – West and West – East directions than in North – South and South – North directions. Without correction is occurred reverse (*Table 1*). In case of Omnistar VBS, the standard deviation values of E-W direction were lower, while the highest values were detected in the case of without correction and EGNOS correction at the same direction.

*Table 1. Average standard deviation values in case of different corrections*

| Correction source | East-West | West-East | North-South | South-North |
|---|---|---|---|---|
| **GNSS** | 4.088 | 5.240 | 9.560 | 9.458 |
| **RTK** | 5.804 | 5.128 | 8.697 | 10.672 |
| **XP-HP** | 7.671 | 6.838 | 7.951 | 8.673 |
| **EGNOS** | 17.123 | 11.387 | 10.788 | 16.072 |
| **VBS** | 9.269 | 13.667 | 9.236 | 15.899 |
| **No CORR** | 53.687 | 44.805 | 18.953 | 27.847 |

Distance values defined in ArcGIS in pixel level were compared with the offline distance data of the FMX display. Direct statsitical coherence was not found. However, the standard deviation of GNSS reference data and offline distance data set were similar, but the values shown higher difference in N-S and S-N directions than in E-W and W-E directions.

Furthermore, data were classified into intervals of tenth of a millimeter. The more accurate steering was shown the less class intervals. According to this investigation the best performances were achieved using GNSS and base station RTK or rather OmniStar HP corrections (*Figure 1*).

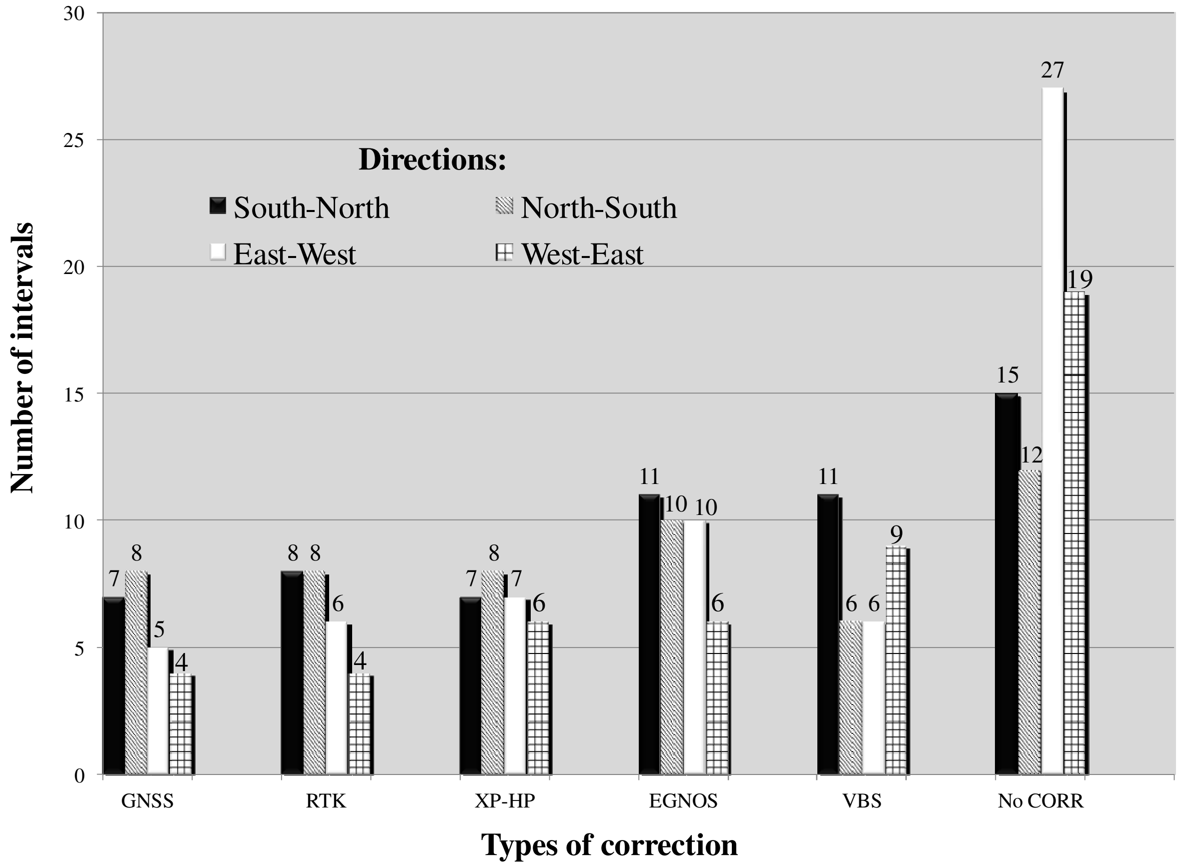


*Figure 1. The number of class intervals in case of different correction sources.*

## 4. CONCLUSION

The results of the present study justified, that the different correction sources are greatly influence the accuracy of any autopilot system. The performance of GNSS RTK correction signal surpassed even the own base RTK signal what is very remarkable, and attributable most possible to the fact that GNSS RTK is a more sophisticated technology comparing to the single base RTK. The results of the OmniStar signals noteworthy as well. The OmniStar XP/HP's performance is clearly comparable with single base RTK's one whereas VBS signal was more accurate and conseaquent than EGNOS.

Certain agricultural operations require different precision levels. In the case of fertilization the decimeter accuracy is accepted, but in case of seeding a steering inaccuracy less than 2.5 cm is expected. Choose and adjust to a given operation of the appropriate correction source is necessary for precision agricultural practice. Using inadequate correction signal could saddle surplus costs on the farmer, which could reduce the profitability of crop production.

Based on the results further experiments are planned in order to investigate the price and payback of efficiency in case of different GPS corrections.

**Acknowledgements**: The authors render their thanks to the Helianthus Ltd. for providing test field and tractor, to OmniStar for providing VBS and HP correction signal and to Geotrade

Ltd. for providing GNSS RTK correction signal for the investigation, and the TÁMOP 4.2.1/b-09/1/KONV-2010-0006 project for publication.

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