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RTK correction data networks for comprehensive, high-precision position determination in agriculture

GPS-based guidance systems can be achieved by the use of correction signals a high degree of accuracy in determining the position on the field. The greatest performance in comparison with other correction signals has Real Time Kinematic (RTK), which is increasingly used in agriculture. In a pilot project, a regional network RTK was set up in which several established a large gap reference stations were networked together. Thehighly accurate positioning minimizes overlapping of lanes and helps to increase work efficiency and reduces both the equipment cost and the abrasive wear.

Keywords
RTK correction data networks, (D)GPS, automatic steering systems

Abstract
Landtechnik 67 (2012), no. 3, pp. 162–165, 2 figures, 3 tables, 8 references

All parallel tracking systems and GPS-based documentation and management systems (Precision Farming) require exact positioning on the field surface via GPS [1]. GPS system precision can be further improved by reception quality (L1 and L2 bands) and through various correction signal systems (DGPS). In practice, the most important of these correction signals (see **Table 1**) are the coastal radio (”Beacon“), the satellite based systems EGNOS, Ominstar and Starfire as well as the high-precision RTK signals from a reference station near the field or RTK network via mobile telephone.

Use of correction signals

For most applications with automatic steering systems a high degree of precision for the correction signal must be aimed for in order to fully exploit the systems and their performance possibilities.

Automatic steering systems require a very precise GPS correction signal (see **Table 1**) with a track-to-track precision of under 10 cm. Only in this way can the available machinery be fully exploited. The difference between tracking assistance systems and automatic steering systems is mainly that the assistance systems can be retrofitted nearly everywhere. However, our experience has shown that assistance systems are a little less precise than automatic steering systems. This is mainly due to the control speed of the system, but also to the corrections for field characteristics (degree of slope, drift of steering axle, etc.) – above all, on undulant surfaces.

The more rapid reaction speed of the automatic steering systems combined with an RTK correction signal also enables

Table 1

Overview of the market correction signals available

Korrekturdienst *Correction signals*	Korrektur L1-Band *L1-frequency*	Korrektur L2-Band *L2-frequency*	Genauigkeit Spur zu Spur *Accuracy of track to track*	Genauigkeit Jahr zu Jahr *Accuracy year to year*
Beacon („Küstenfunk“) 1)	X		15 bis 30 cm	50 bis 75 cm
EGNOS 1)	X		10 bis 30 cm	1 bis 2 m
Starfire 1 1)	X		15 bis 30 cm	50 cm
Omnistar VBS 1)	X		15 bis 30 cm	50 cm
Starfire 2 2)	X	X	5 bis 10 cm	20 cm
Omnistar HP/XP 2)	X	X	5 bis 10 cm	20 cm
RTK	X	X	2,0 cm	2,0 cm

1) DGPS. 2) Satellitengestützte Korrektur/*satellite-based correction.*

Table 2

System characteristics and suitability for different applications

Maßnahme *Management procedure*	**Anspruch an die Genauigkeit** *Demand to the accuracy*		**Manuelle Parallelführung** *Manual steering system*		**Lenkassistenzsystem** *Steering assistance system*			**Automatisches Lenksystem** *Automatic steering system*		
	relativ *relative*	**absolut** *absolute*	**DGPS**	**Sat. Korr.** *satellite-based correction*	**DGPS**	**Sat. Korr.** *satellite-based correction*	**RTK**	**DGPS**	**Sat. Korr.** *satellite-based correction*	**RTK**
Bodenbearbeitung *Cultivation*	10-30 cm	gering/low	++	++	++	++	++	++	++	++
Pflanzenschutz im Vorauflauf *Plant protection without tracks*	10-30 cm	gering/low	++	++	++	++	++	++	++	++
Aussaat/*Sowing*	5-10 cm	30 cm	-	-	-	+	+	-	+	++
Controlled Traffic „Regelfahrspurverfahren“	2 cm	2 cm	-	-	-	+	+	-	+	++
Strip Tillage „Streifenlockerung“	2 cm	2 cm	-	-	-	-	+	-	+	++
Aussaat von Sonder- und Reihenkulturen *Sowing of special cultivated crops*	2 cm	2 cm	-	-	-	-	+	-	+	++
Pflege von Reihenkulturen *Care of row crops*	2 cm	2 cm	-	-	-	-	-	-	-	++
Anlage von Parzellenversuchen *Arrangement of small plots*	2 cm	2 cm	-	-	-	-	-	-	-	++

- ungeeignet, + gut geeignet, ++ sehr gut geeignet/- not acceptable, + good, + + very good acceptable

application in rowcrops or automated application in experimental trial plots.

Especially with mounted or trailed implements working on slopes, an additional GPS receiver is required on the implement so that implement position can be determined and adjusted by the tractor or, where possible, corrected through active steering of the implement.

Various experiments [3–5] under practical conditions show that because of hilly terrain, poor visibility (darkness, dust, etc.) wide working widths and minimisation of production risks, overlapping is accepted in practice with this accounting for between 3 and 7 %. This means that for a 16 m tramline system with overlapping of 7 % there's a double coverage of 1.12 m per tramline or, for 32 m tramlines, a double coverage of 2.24 m upon which too much seed, fertiliser and plant protection spray is applied.

Hereby sowing is the most important pass, with the tramlines established then to guide further operations. The sort of precision required is ±2 cm, in other words RTK quality standard and this standard is also required for recording and storage of tramline or guide line positions so that these can used in following years. For the tramline-based operations following sowing the classic DGPS receivers can also be used for documentation of application amounts or for mapping of positions on the field (**Table 2**).

The benefits of RTK-systems

The high-precision RTK signals are up until now dependent on the reference station in the vicinity of the field or at the farm buildings, the RTK station signal radius suitable for high precision work is 10–15 km on level ground and around 5–8 km in hilly East Holstein or in the vicinity of the coast, because there transmission performance of stations is limited by the federal network agency. So far, this has meant in practice that agricultural contractors or farms with various separate tracts of land exceed the action radius required for high precision and thereby are only able to realise the advantages of higher precision with considerable effort (e.g. through using mobile stations with smaller effective radii, more expense and time in setting-up). Therefore in many cases they have to accept the higher costs of overlapping seed, fertiliser and spray input through being unable to apply the highest precision (± 2 cm) for parallel tracking, as emphasised by the following table with own measurements (**Table 3**). Duplication of inputs on overlapped areas is reduced in this case by more than 40 ha on 1 000 ha cropland, in other words by 4 %. Every crop management action (1st to 4th N application and the 5 to 7 spraying passes) uses the advantages of tramline accuracy and the inputs are reduced by the same amount at every pass.

The requirement for high-precision determination of in-field position in RTK standard (± 2 cm) is very high. All farms, even smaller-scale family units, are required under Cross Compliance rules [6] to complete comprehensive documentation of all working operations. Especially the obeying of mandatory fertiliser and spray application margins to water or to biotopes is of great importance in this respect.

Table 3

Benefit of parallel tracking systems at the tram lines - reducing the overlap (24 m wide, 1 000 acres net area, 4.2 % overlap)

	Ohne Lenkhilfe *Without parallel tracking*	**Manuelle Lenkhilfe** *Manual steering system*	**Automatisches Lenksystem** *Automatic steering system*	**Automatisches Lenksystem mit RTK** *Automatic steering system with RTK*
Überlappung *Overlap* [%]	4,20	0,92	0,20	0,08
Überlappung *Overlap* [m][1)]	1,00	0,22	0,048	0,02
Ges. Fläche durch Überlappung *Total area due to overlap* [ha]	1042	1009,2	1002	1001

1) Messergebnisse aus eigenen vergleichenden Untersuchungen in 2005 und 2010/*results of comparative studies in 2005 and 2010.*

System comparion of the RTK network and the RTK station

The project reported here targeted easier accessibility for everyone, even on small farms, especially for the complex and cost-intensive RTK technology. For this reason, the project included establishment and testing for practicability of a state-wide RTK network, at first accessible to project partners and some selected agricultural contractors and farm businesses but later to other local contractors and farms so that they too, might have the possibility of using their existing equipment more effectively.

So far, such networks have only been available for surveying and the military, sectors requiring high precision which meant that the systems were too costly for agricultural application [7].

The network is built up in the following manner (**Figure 1**): Each of at least five RTK stations is connected with the network server which calculates the correction data. Transmission of the correction data takes place via Ntrip modem over mobile telephone. The network server identifies the user and transmits to him/her the real-time correction data as average over all stations with consideration of the respective distance to the vehicle. The nearest RTZ station is heavily weighted in the correction data calculation compared with the further away stations [8].

Fig. 1

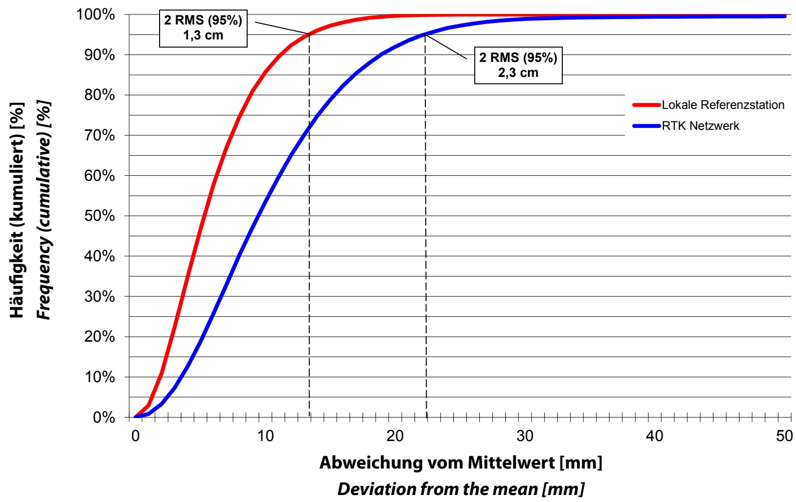
RTK network - schematic, 1 connect, 2 correct, 3 measure

To the above mentioned reductions in inputs can be added easier documentation of each individual management operation which, especially for plant protection sprays, helps ensure the obeying and documentation of mandatory application margins from non-spray areas, reduces by a multiple factor pollution risk in areas not targeted for spraying and permits the exact documentation of every action including tramline identification and amount sprayed.

The main aim of this project is the creation of a state-wide network solution independent of individual manufacturers and to enable access for everyone interested in its application – independent of the type of tractor used or the steering system already installed. Additional cost reductions are possible through the minute-exact calculation of application. Suitable software is being developed within the project to facilitate this. A further important question is that of costs and the absolute precision achievable. In the **Figure 2** a comparison is shown between a fixed RTK station and an RTK network.

This comparison indicates that the 111 m distanced RTK station delivered very high precision (< 2 cm). But the RTK network with 2.3 cm absolute precision over 24 hours also lay within the precision acceptable for agriculture and the system also allows logging of positions for permanent tramlines. On this location the RTK network realised a precision comparable with the installed RTK station. Own investigations show that, for a single user, the flexibility/freedom of movement in the region increased, independently of where and how far away the RTK stations were sited. For Schleswig-Holstein the calculated target of total-cover availability of RTK signals required 43 RTK stations (coverage radius round the signal point: 15 km, 40 % overlapping with neighbouring stations 40%) whereas our own project managed with four stations. Based on the necessary number of stations this delivered a theoretical savings potential of 390,000 € (station price: 10,000 € net). In practice, the sav-

Fig. 2



Correction signal compared over 24 h with RTK Network (blue) and RTK Stationary (red)

ings potential was still higher in that the required correction data format can be made available for every steering system manufacturer so that a manufacturer-independent solution can be produced.

Conclusions

Through the reduction of application overlapping when using tramlines in crop management over-fertilisation or increased plant protection spray in food crops is avoided. As a contribution to future-oriented, sustainable agriculture the project described here helped to make available expensive, but very precise, technology to every farmer and agricultural contractor – first of all in Schleswig-Holstein. In further experiments tests are now being conducted with various steering system manufacturers and types of vehicle. The aim of this project is the identification of a network that is thoroughly tested and affordable for all users and accessible at every location.

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