AutoTrac – Accuracy of a RTK DGPS based Autonomous Vehicle Guidance System under Field Conditions

M. Ehrl,
W.V. Stempfhuber, M. Demmel, M. Kainz, H. Auernhammer

Centre of Life Sciences Weihenstephan
Department of Bio Resources and Land Use Technology
Crop Production Engineering

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Outline

1. Objective
2. AGRO NAV system setup
3. Reference measuring system setup
4. Equipment verification
5. Results
6. Conclusions

Subject Matter

- **Since about two years, autonomous guidance systems are commercially available for agricultural machines**
- **The technology is generally based on GPS with Differential Correction (DGPS) or Real Time Kinematic GPS (RTK DGPS)**
- **Inertial guidance technology is often used for dead reckoning and roll and pitch compensation**

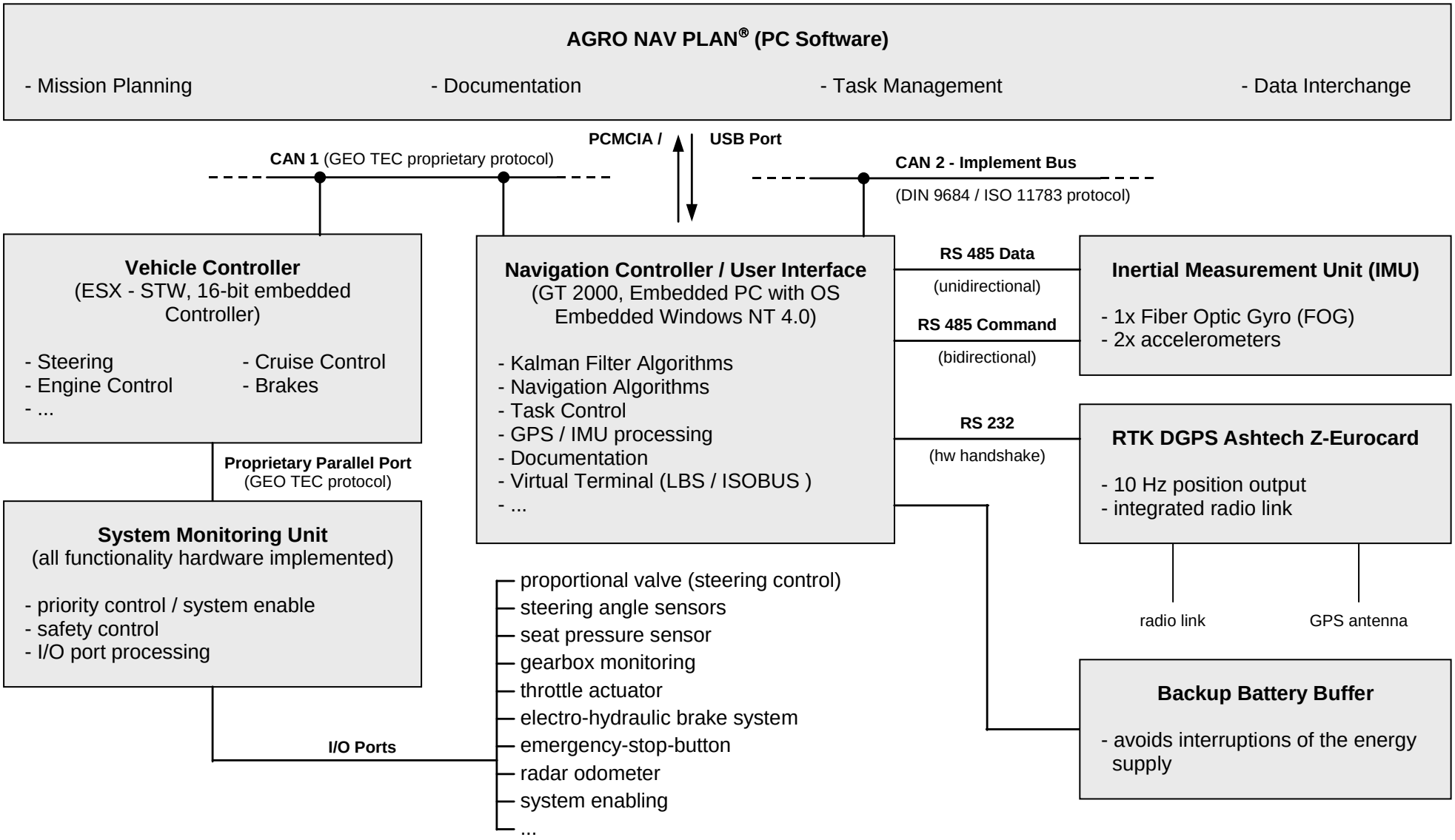
→ **Until now, only limited information is available on the accuracy in practical use under typical and often difficult agricultural field conditions (side slope, wheel slip)**

Subject of Investigation

- **The first commercial system for agricultural machines was AGRO NAV®, developed by GEO TEC electronics GmbH in Germany, accuracy ± 100 mm**

- **The tested system was implemented on a standard tractor (MF 4255) and utilized RTK DGPS and an Inertial Measurement Unit (IMU) for navigation**

Schematic System Setup of AGRO NAV®



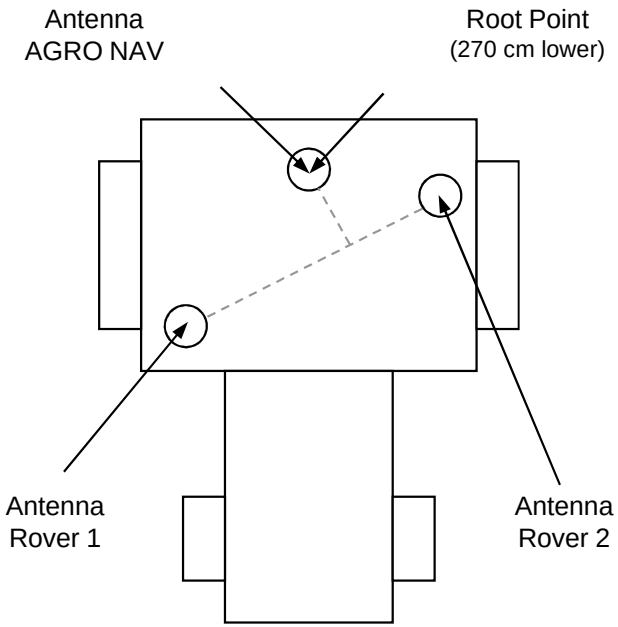
Reference Measuring System

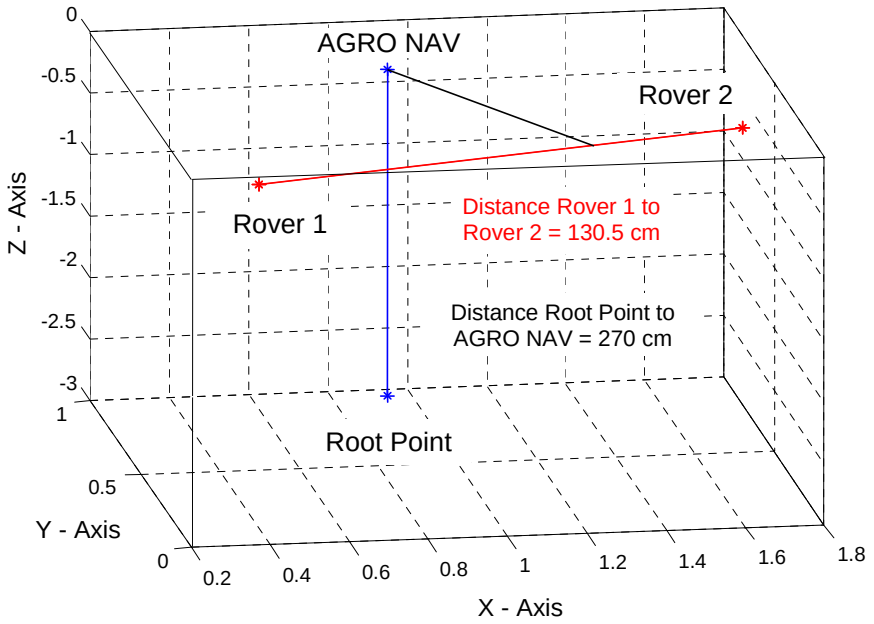
- **Needs to be a completely independent system which does not influence the system environment**
- **The degree of accuracy needs to be at least three times better than the desired resolution**
- **Capable for outdoor measurements in a rough and non-uniform environment**

The deployed position reference system consisted of two geodetic RTK DGPS receivers (Leica SR530, 10 Hz, rover mode) and one base station (Leica SR530, 10 Hz, base station mode)

Antenna Alignment

- **The accurately defined alignment of the antennas is important for data evaluation**
- **Position deviations in all three dimensions and inclinations can be measured**



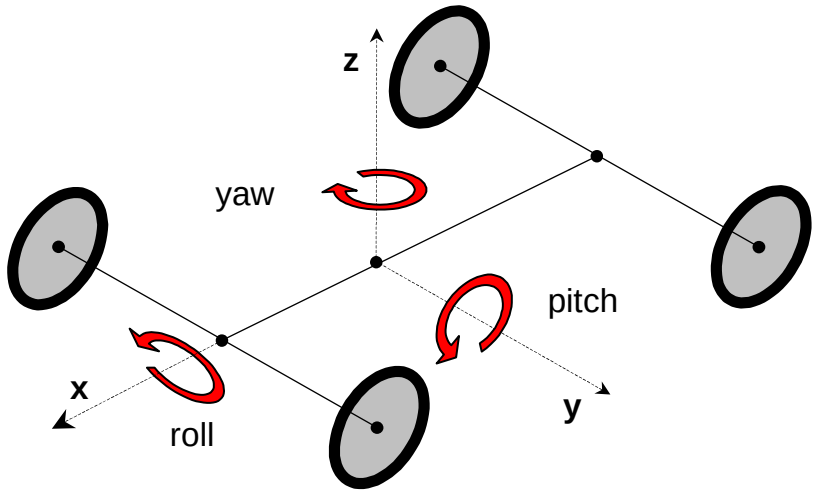


Equipment Verification

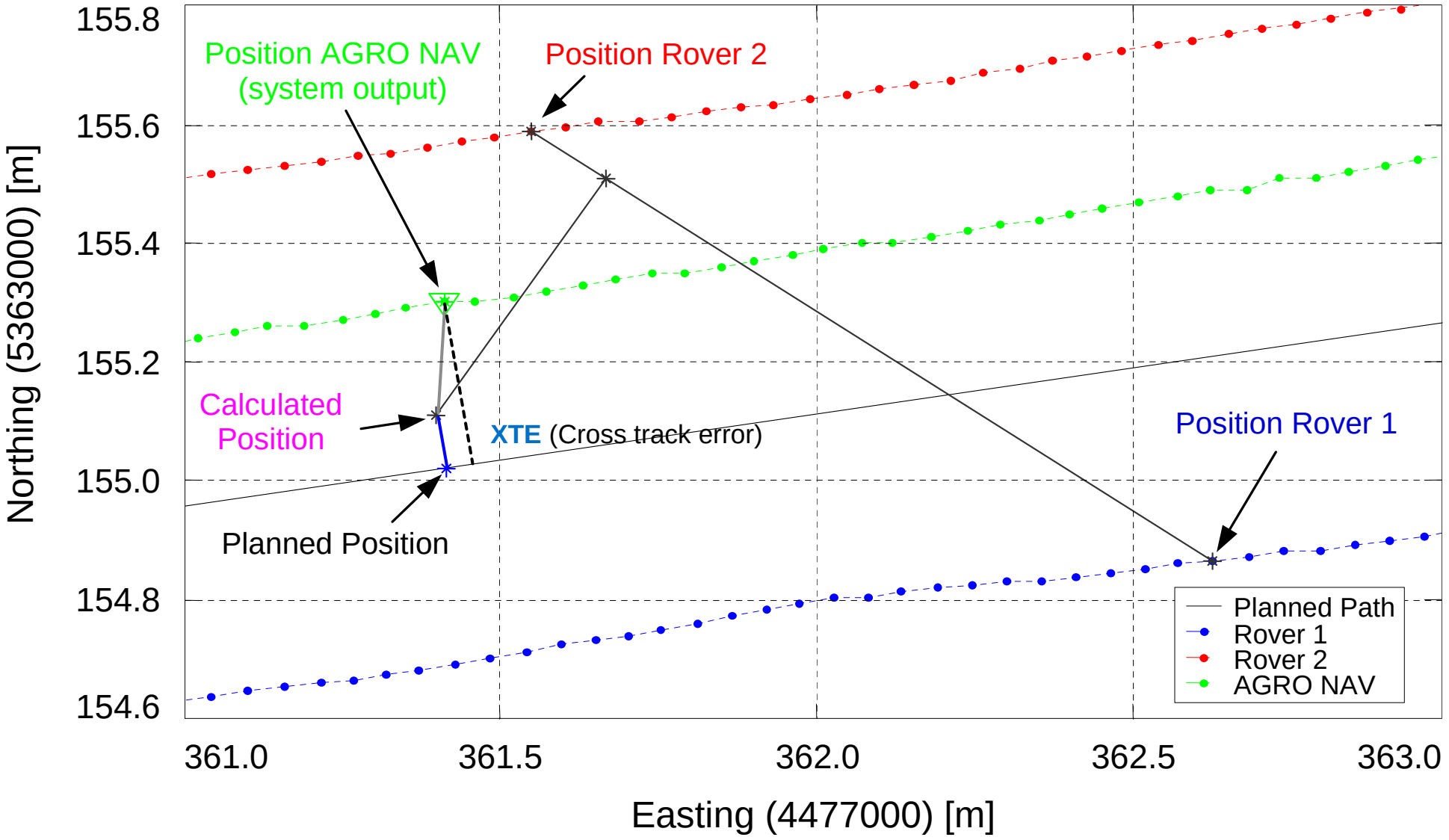
- **To verify the equipment, tests on a tarred road have been carried out**
- **By means of AGRO NAV PLAN®, a job consisting of a straight line of 180 m length was planned and transferred to the navigation controller**
- **Condition of the tarred road:**
  - **surface with single cross grooves**
  - **downward slope of about 4.5 percent**
  - **sidewise slope changing between 0.5 and 3.5 percent**
- **Several runs with speeds of 2.0, 4.0, 6.0 and 12 km/h speed were conducted**

Measured Parameters

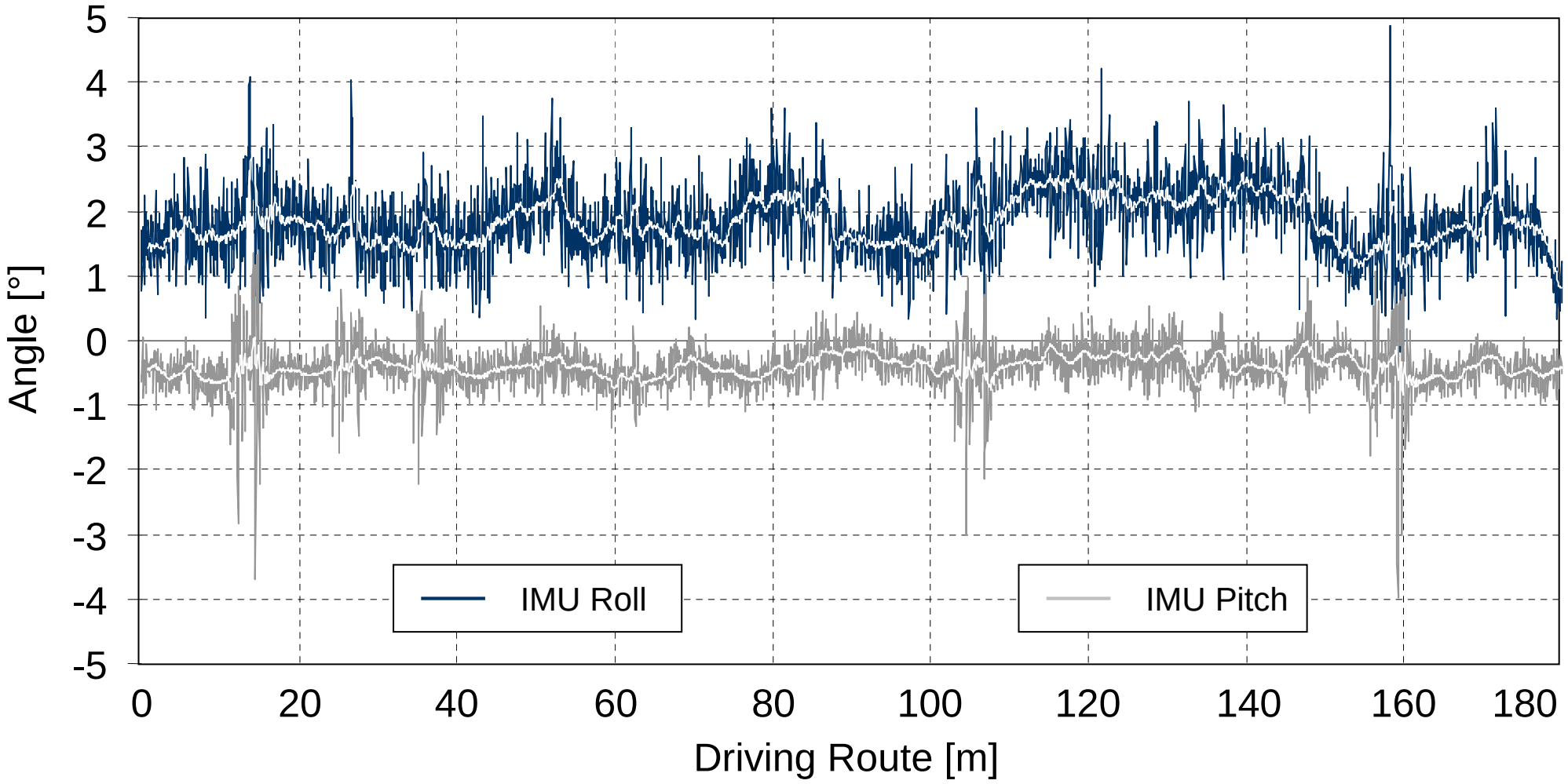
- **Cross Track Error (XTE) - most significant parameter, defined as the horizontal distance of the navigational point (center of rear axle) normal to the planned position (set point)**
- **Inclination values of AGRO NAV IMU (roll and pitch) in comparison to the calculated values of the reference measuring system**



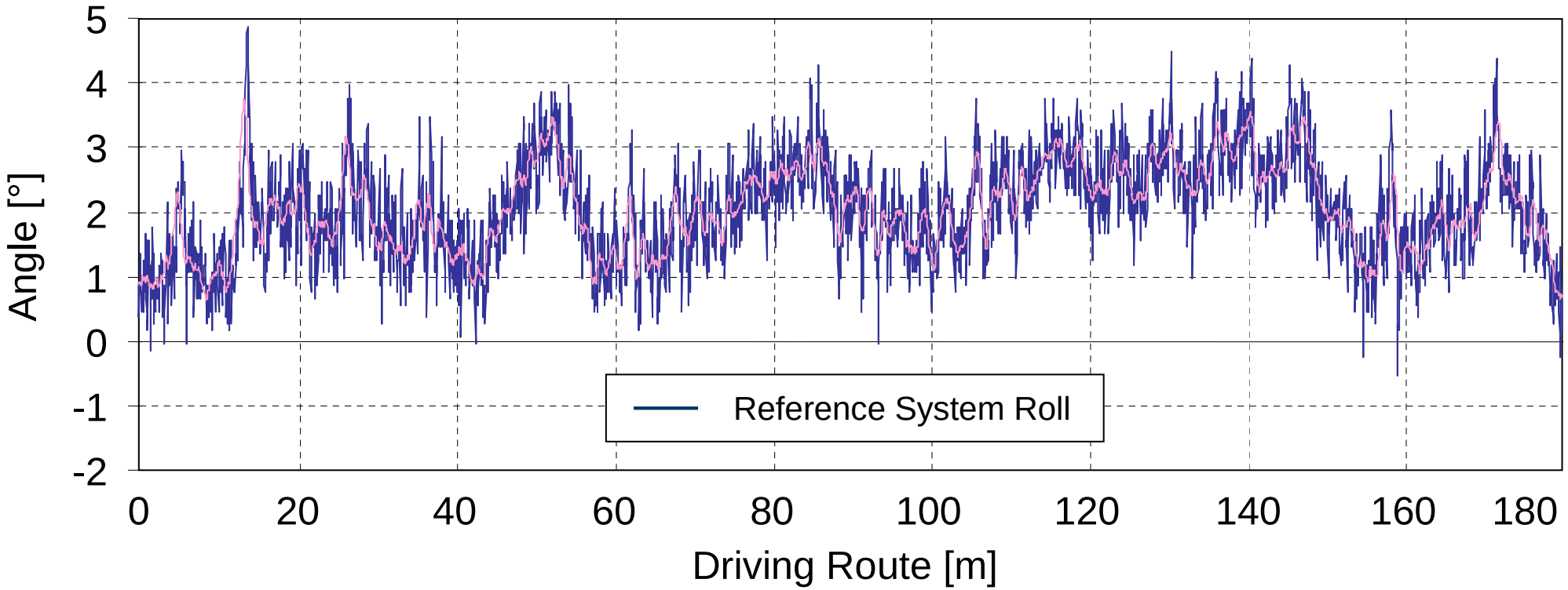
Spatial Relationships



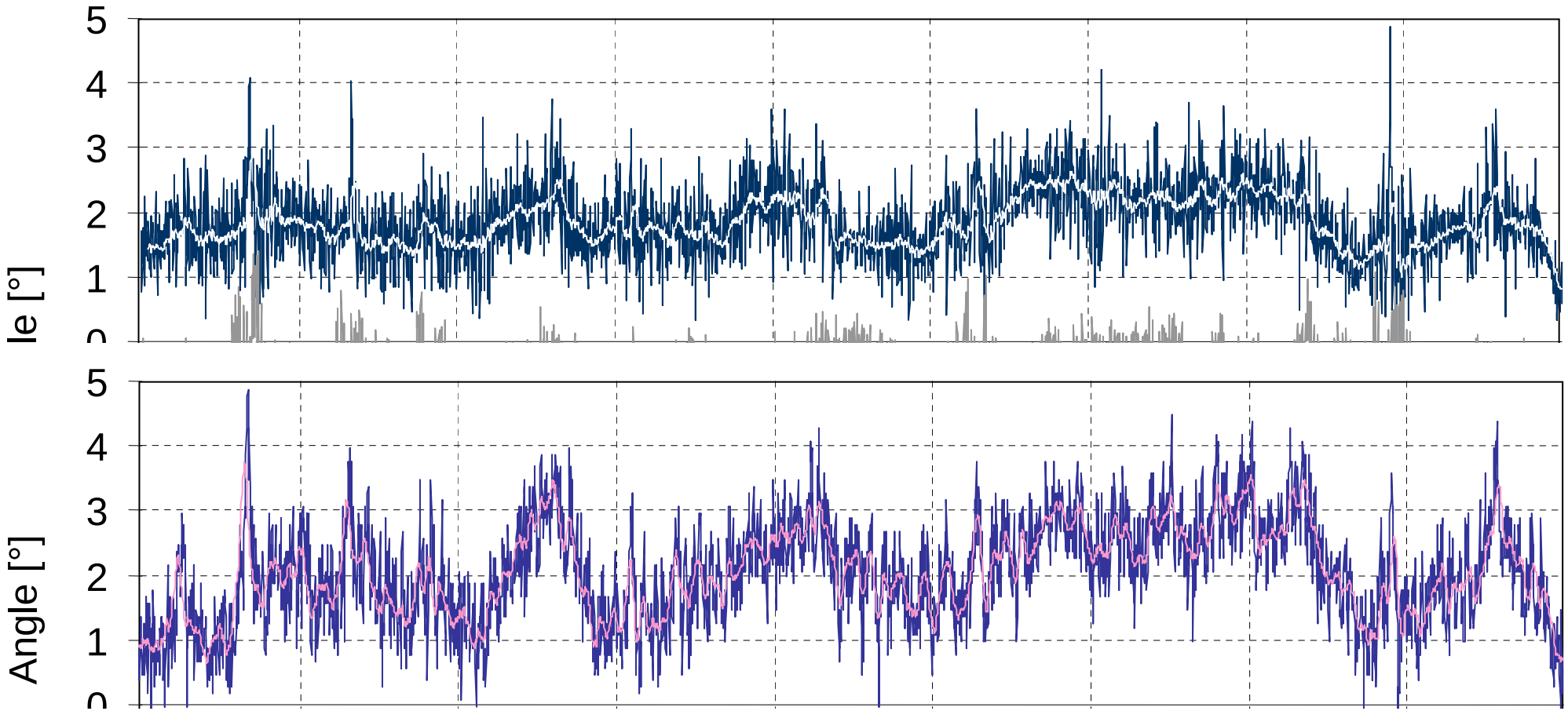
Results: Inclination Values of AGRO NAV IMU
at 2.0 km/h speed



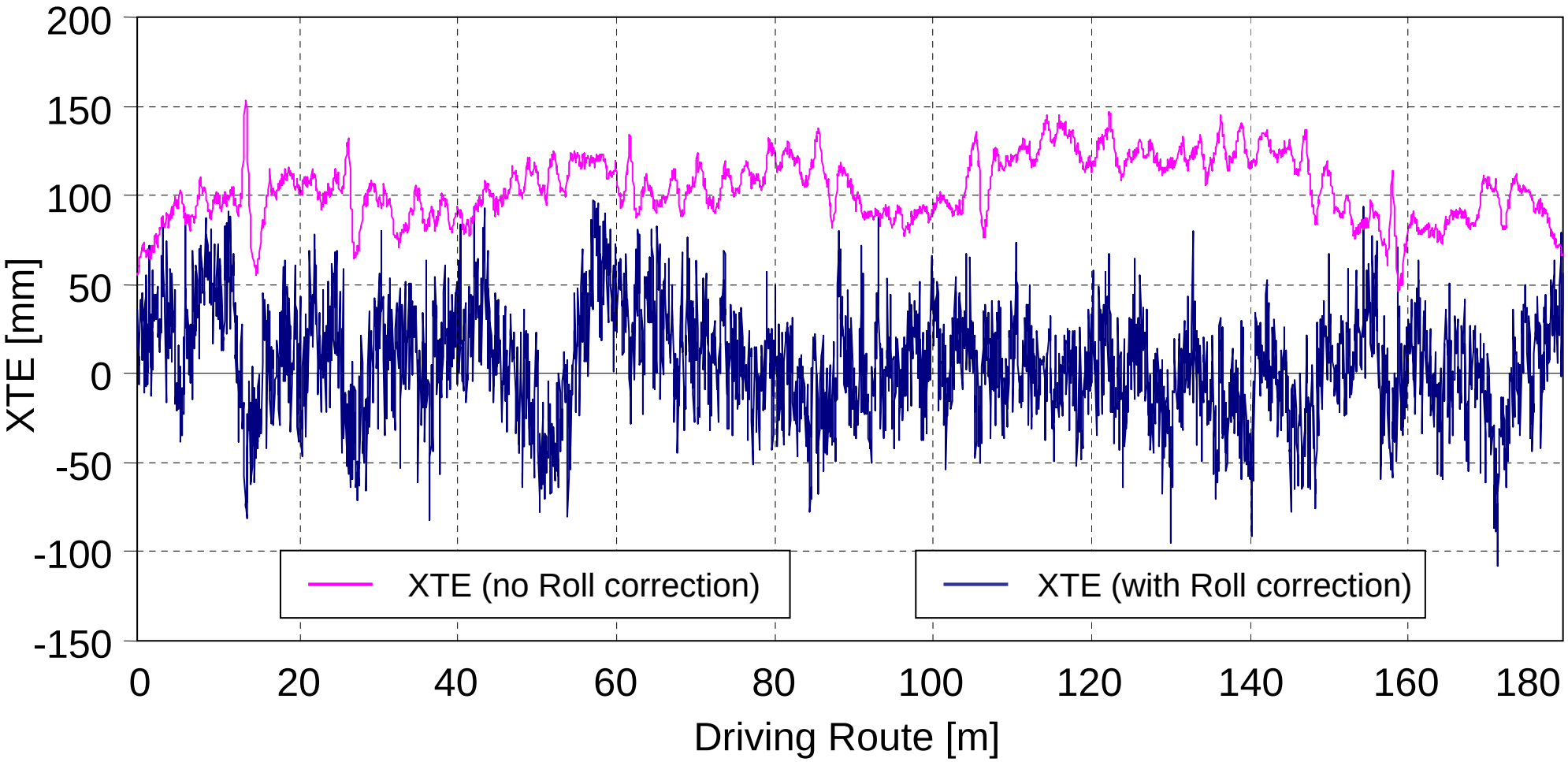
Results: Calculated Roll values of Reference System at 2.0 km/h speed



Comparision:
Measured inclination values of AGRO NAV IMU and calculated inclination values (at 2.0 km/h speed)

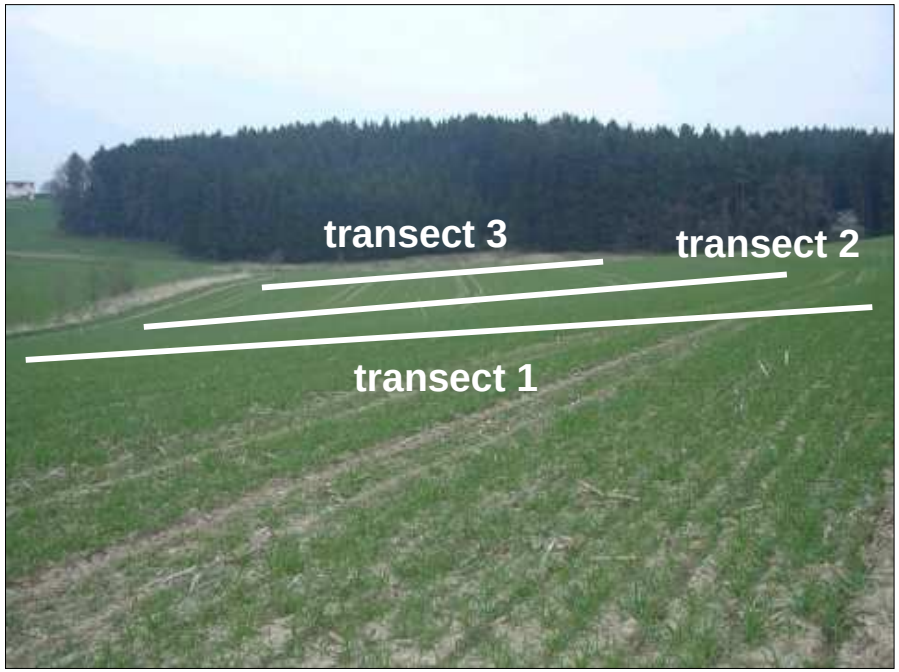


Results: XTE measured by Reference System at 2.0 km/h speed



Practical Investigations

- **MF 4255 tractor unmanned with a rear mounted combination of rotary harrow and air-seeder (3.0 m working width)**
- **Conditions: autumn, wet soil, winter wheat seeding, field with side hill slopes between 0 and 14 percent**



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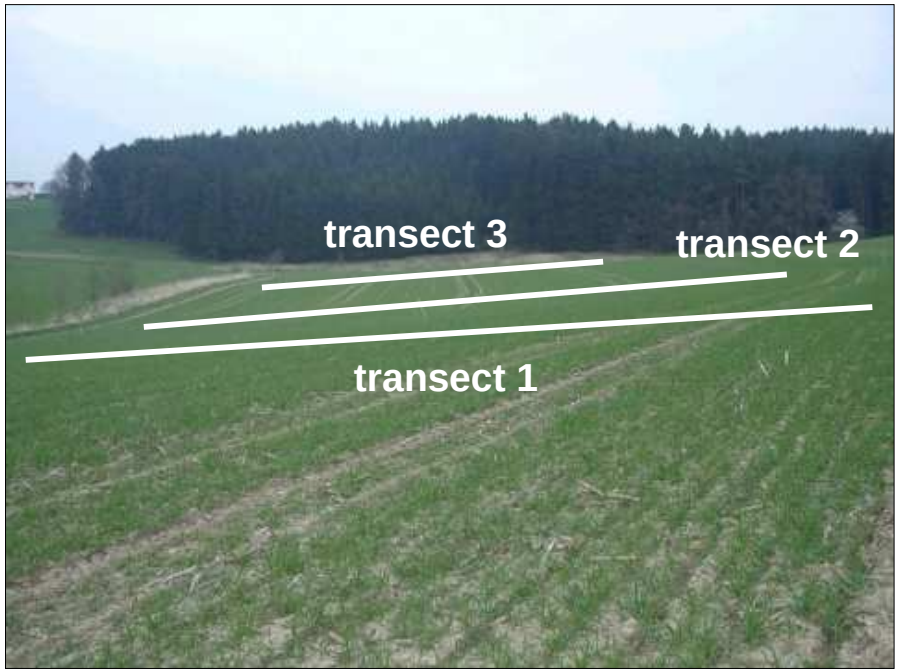

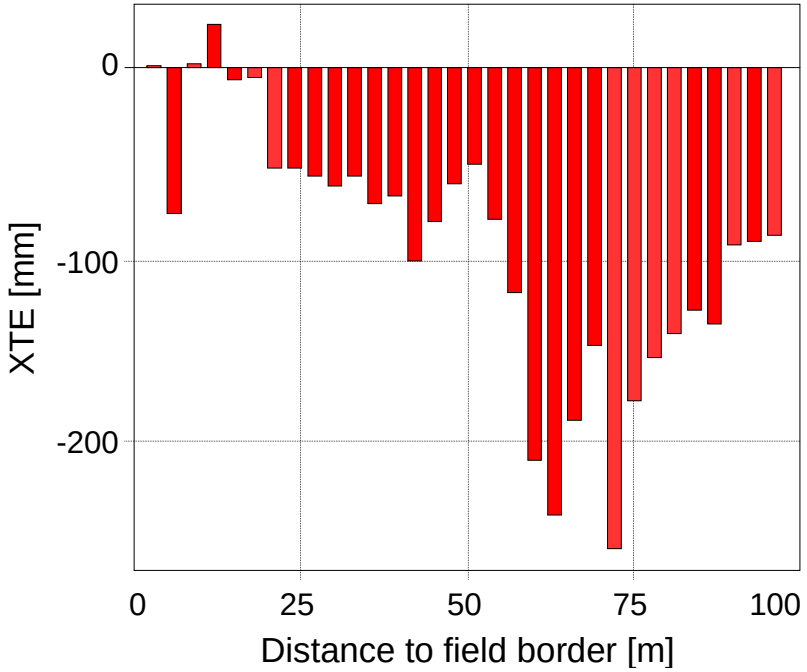

Results

- **Accuracy showed similar results as on the tarred road**
- **Wheel slip and downhill drift of the tractor have also been properly controlled by the guidance system**
- **Work result was not in the expected range of ± 100 mm**
- **Deviations of up to 240 mm from path to path were caused by the downhill yawing of the rear of the tractor**
- **Possible Solutions:**
  - rigid connection of the implement
  - implement mounted antenna instead of tractor mounted
  - sensing the relative position of implement and tractor (e.g. for trailed implements)

Conclusions

- **Reference measuring system has proofed practicability**
- **Reference system is able to measure inclinations - accuracy can be improved by an extended antenna spacing**
- **AGRO NAV® was in the specified range of ± 100 mm for speeds up to 10 km/h (for 12 km/h in the range of ± 130 mm)**
- **Deviations on a sloped field up to 240 mm caused by yawing of the implement**
- **Planning Software was only able to create jobs in 2D (x-y plane) instead of 3D – sloped contours were not considered**
- **The great potential of RTK DGPS based auto guidance technology for agricultural vehicles was clearly demonstrated**