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FIRST EVALUATION OF THE APPLICABILITY OF INFRARED-TRACKING-SYSTEMS FOR EXAMINING THE ACCURACY OF DGPS IN FIELD WORKS

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SUMMARY

Examinations on the accuracy of DGPS made by the Institute of Agricultural Engineering Freising-Weihenstephan using an Infrared-Tracking-System (ITS) as reference system for DGPS in five application, tilling and harvesting measures respectively show deviations of the systems to each other in the range of few meters and swaying in dependence of the position of the tracking prism in relation to the tachymeter site; there is no correlation to be recognized to important GPS parameters suggesting errors in positioning of the reference system, too. Tests of the tachymeter on a linear guidance in cooperation with the Institute of Geodesie show an influence of a time delay of distance measuring to angle measuring; but this delay cannot be the only explanation of the observed facts in the reference measurings. Therefore, an exact detection of all troubling influences on the tachymeter positioning and a respective calibration of the recorded data will be necessary before it can be used as reference for DGPS.

Key words: *DGPS, availability, accuracy, tachymeter, automatical tracking, magnetic track angle*

INTRODUCTION

The use of Differential Global Positioning Systems (DGPS) is indispensable in site-specific farming. DGPS enable the georeferencing of yield data, soil data and other spatially related data as basis for creating maps and the finding of specific sites and areas respectively in appli-cation measures. For the spatial relation, the quality of positioning has a crucial significance. Quality oi positioning means, besides the availability of the signals, especially the accuracy of positioning. The accuracy of positioning related to fixed positions can be analyzed in by measuring a point by DGPS for a long time and looking in which range the measured position values is dispersing.

Related to moving objects, a test of accuracy is much more complicated, because every second when a measured position is recorded, the object has another real position, so that each measured position has to be compared with his „own" real position. Therefore, a reference system is needed obviously. This has failed so far by the lack of low-priced and reliable systems, with the result that analyses in this matter were performed only rudimentarily [1; 2]. Actually, more precise quantification of the accuracy of positioning by DGPS in field works is enabled by the employment of automatically tracking tachymeters as reference-systems. First tests with such a tachymeter have been performed by the Institute of Agricultural Engineering in Freising-Weihenstephan.

METHODS

At the Institute of Agricultural Engineering the tachymeter Geodimeter System 4000 manu-factured by the firm GEOTRONICS is used as positioning and navigation system for an automatized stock management in open-air horticulture for some years and as reference-system of DGPS for the detection of its accuracy of positioning since 1998. It is an infrared based tachymeter swayable vertically and horizontically and automatically tracking (infrared-tracking-system; ITS). This system can detect the following parameters with the height of its objective above the chosen nadir and a zero direction (x-axis) input :

1. the real distance between objective and an active prism (with a diode switched on) by the running time of an emitted and reflected infrared laser beam,
2. by that and the objective height the distance between nadir and the prism,
3. the angle between (2.) and the vertical,
4. the horizontal distance between nadir and prism by (2.) and (3.),
5. the horizontal direction between nadir and prism related to the zero direction,
6. and by all these parameters the x-, y- and z-coordinates of the prism related to the nadir of the tachymeter [3].

The nadir is the zero point of the tachymeter coordinate system. In the tracking mode, a conic infrared beam for searching enables the tachymeter to be steadily aligned to the prism on top of a moving vehicle. According to the manufacturer, the system posseeds an accuracy in distance measuring of 0.2 to 1 mm and has a constant angle measuring error of 0.4 mgon [3].

For the examinations described here, the tachymeter was established on a stative on the bor-der of the field, vertically above a point measured by DGPS (this was the nadir; fig. 1).

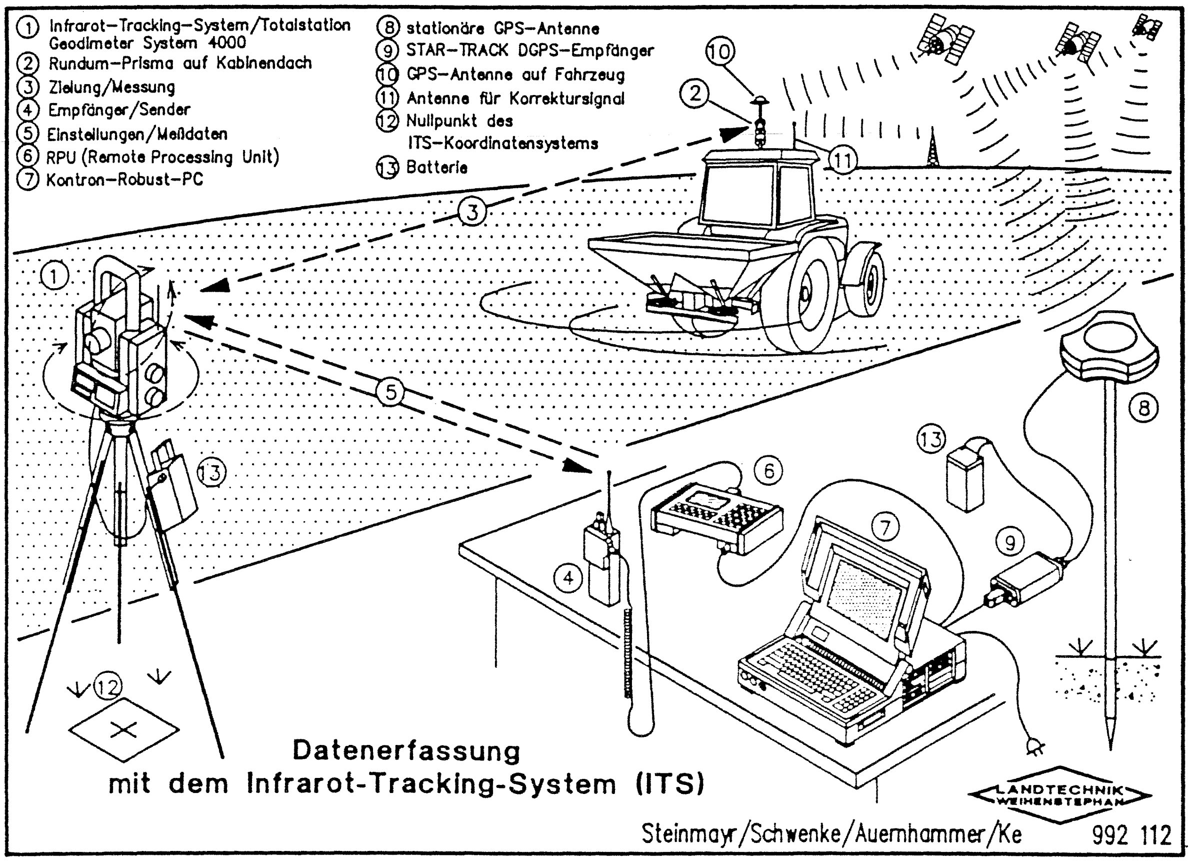

Figure 1. Experimental setup of the reference positioning using an infrared tracking system (1 = infrared tachymeter Geodimeter System 4000; surround view tracking prism; 3 = targetting/measuring; 4 = radio modem; 5 = settings/measured data; 6 = Remote Processing Unit; 7 = PC for data recording; 8 = stationary GPS-antenna; 9 = Startrak-DGPS-receiver; 10 = GPS-antenna on top of the tracking prism; 11 = antenna for the correction signal; 12 = zero point of the ITS coordinate system; 13 = batteries)

By aiming at a reference-point also to be measured by DGPS, the zero direction was estab-lished. Finally an active tracking prism on top of the standing vehicle was aimed at. The GPS-antenna of the DGPS-receiver in the vehicle was fixed vertically on top of the prism. The DGPS data of the vehicle were recorded on a pentop notebook (in application measures) or on a chipcard in the yield terminal (when harvesting).

In the tracking mode the tachymeter is sending the measuring parameters telemetrically via the radio modem to the RPU that is transmitting them to a robust PC (fig. 1) via a serial port. The data of the stationary DGPS were input to the computer by a second serial port. The tachymeter data and the data of the fixed GPS-antenna were recorded in the same time by a special program to one output file in order to get a comparative time scale for both the DGPS data of the vehicle and the tachymeter data by the GPS time.

In the next step the data had to be synchronized by means of the GPS time, that is to say a re-spective pair of x-/y-coordinates of the ITS was associated to each pair of WGS84-coordi-nates of the DGPS in the vehicle. As the GPS time is transmitted only each full second and in this period of time two to four position strings with actual system time of the computer are recorded, the x-/y-coordinates (related to the tachymeter coordinate system) for the exact GPS seconds were in post-processing interpolated using the recorded values by means of the system time.

In order to be compared, both the WGS84 coordinates and the tachymeter coordinates were transformed to coordinates of a local cartesian coordinate system with the nadir of the tachy-meter as zero point using the following equations:

$$\text{DGPS: } X_t = R * \cos(N/180 * \pi) * (E - E_{zeropoint})/180 * \pi \text{ [m]} \quad (1)$$

$$\text{DGPS: } Y_t = R * (N - N_{zeropoint})/180 * \pi \text{ [m]} \quad (2)$$

$$\text{ITS: } X_t = X_{tachy} * \cos\beta + Y_{tachy} * \sin\beta \text{ [m]} \quad (3)$$

$$\text{ITS: } Y_t = X_{tachy} * \sin\beta + Y_{tachy} * (-\cos\beta) \text{ [m]} \quad (4)$$

with: R: earth radius [m], N: northern latitude [°], E: eastern longitude [°].

The parallel on which the zero point is lying, represents the x-axis (easting), the respective meridian the y-axis (northing). The angle β between the zero direction of the tachymeter coor-dinate system and the easting was calculated from the WGS84 coordinates of the reference point transformed in local cartesian coordinates by (1) and (2):

$$\beta = \operatorname{atan}(Y_{ref}/X_{ref}) \quad (5)$$

RESULTS AND DISCUSSION

In the year 1998 totalling six application, tilling and harvesting runs respectively on two fields of the experimental station Duernast were recorded by both DGPS and ITS. The results of two runs should be introduced examplarily. Fig. 2 is comparing the tracks of spraying on the field

D1 recorded by DGPS (Motorola-8 channel-receiver and ALF-correction data receiver) to those recorded by the infrared-tracking-system. The gaps of the tracks recorded by the ITS are resulting from interruptions of aiming the prism mostly for topographical reasons (optical obstacles like hills etc.). The arithmetic mean of the differences (value DGPS less value ITS) of 4.44 m in easting and –2.53 m in northing is an offset probably resulting from an insufficient (not long time enough) measuring of the nadir by DGPS. More important for the examinations are the standard deviations of the differences of nearly 3 m in easting and 3.2 m in northing what is corresponding to the accuracy of DGPS in the range of 1 to 5 m known so far.

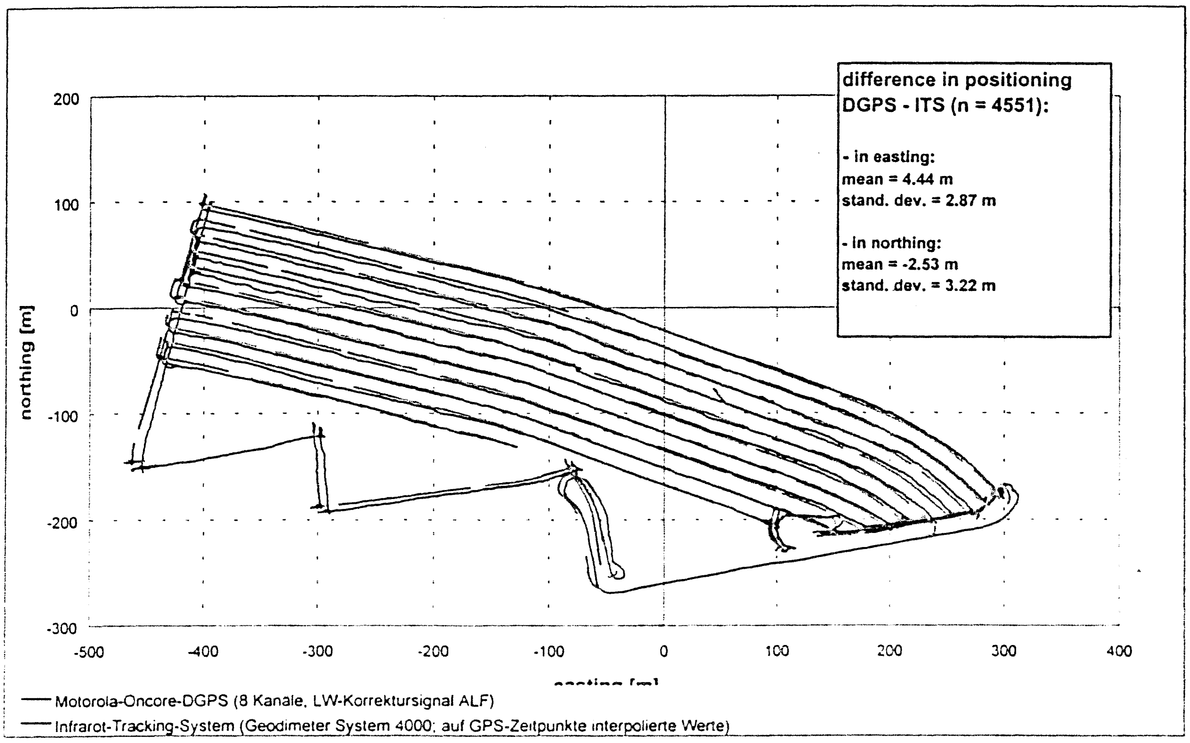

Figure 2. Tracks of the spraying on field D1, recorded by Motorola-DGPS and the ITS on 29 May 1998

In the four examinations the standard deviations are lying in the same dimension as in the spraying run, what is shown by Table 1.

Table 1. Summary of the results of the examinations of the infrared-tracking in 1998.

Field, work, date	difference in easting [m]	difference in northing [m]
Spraying D1, 05/29/98	mean: 4.44, SD: 2.87	mean: -2.53, SD: 3.22
Fertilizing D4, 06/10/98	mean: 0.61, SD: 3.13	mean: 0.87, SD: 2.47
Fertilizing D1, 06/22/98	mean: 4.67, SD: 3.05	mean: 3.11, SD: 3.95
Forage harvesting, D1, 09/25/98	mean: 0.97, SD: 3.0	mean: -0.78, SD: 3.88
Scarifying, D4, 08/13/98	mean: 1.01, SD: 1.88	mean: -0.47, SD: 2.26

In order to see a possible correlation to time and position of the vehicle in relation to the tachymeter site, the differences between the systems were dissolved by the time and compared to the magnetic track angle (direction in ° to northing).

It is shown that the differences of positioning in both dimensions are swaying with a very low frequency around zero, are increasing in tendency in southeast-northwest moving direction (track angles of ≈300°) and are decreasing in the reverse direction (track angles of ≈110°).

These wide swayings are superposed by many smaller ones in the range of less than a meter. In both dimensions the greatest positive differences occur near the turning points on the NW border (changing of track angle from 300° to 110°) and the largest negative differences on the SE border (110° to 300°) (fig. 3).

These facts could be explained by a not exact enough measuring of the reference point for determing β resulting in a incomplete „turning" of the ITS tracks. But as the reference points have been measured each for 45 min., this is not probable. Another explanation could be an influence of different angle increments $\Delta\alpha/\Delta d$ in relation to the distance to the tachymeter.

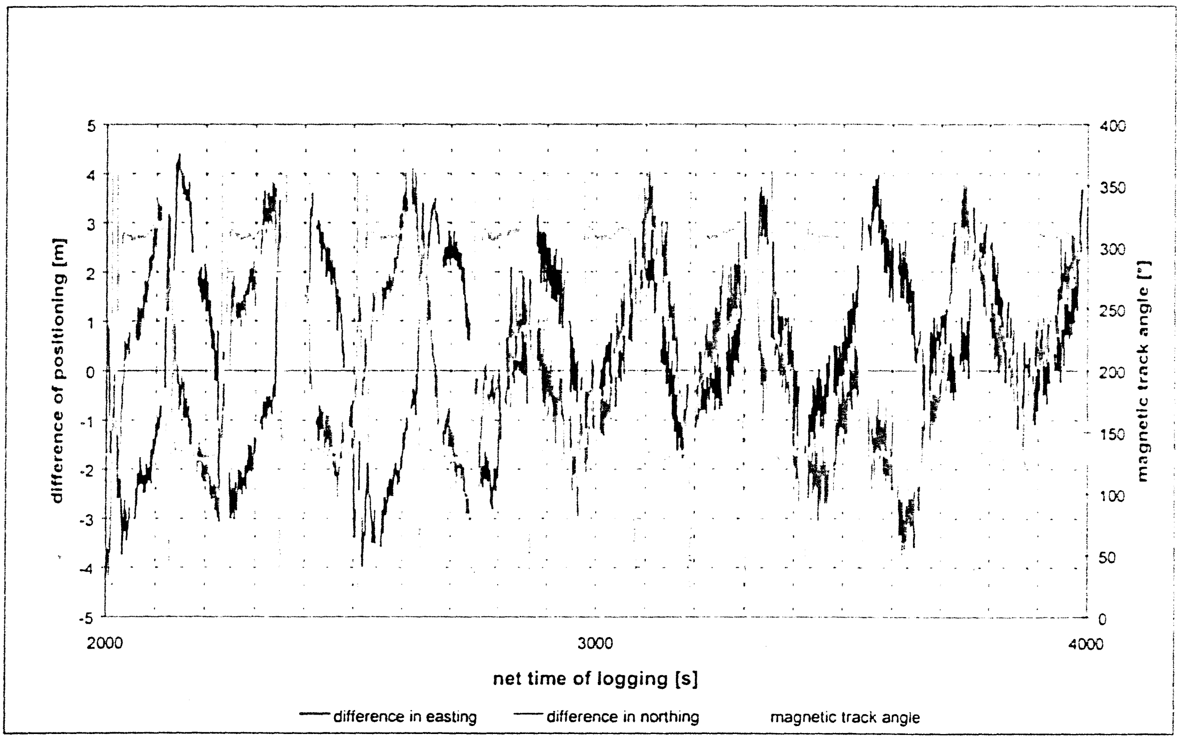

Figure 3. Differences in positioning of Motorola-DGPS – infrared tracking system and the magnetic track angle, scarifying D4 on 08/13/98 (extract)

A known problem of tachymeters is the fact that there is a time delay between angle measuring and distance measuring. This is no problem when measuring a point by a tachy-meter, but a big problem when tracking because the two parameters are calculated to a certain position although each of them is referring to a different real position of the tracked prism. Examinations in the Geodetic Institute in Munich using a prism on a linear guidance show an offset of the measured positions from the real track with in average smaller x-values (nearer to tachymeter) or with larger x-values (fig. 4).

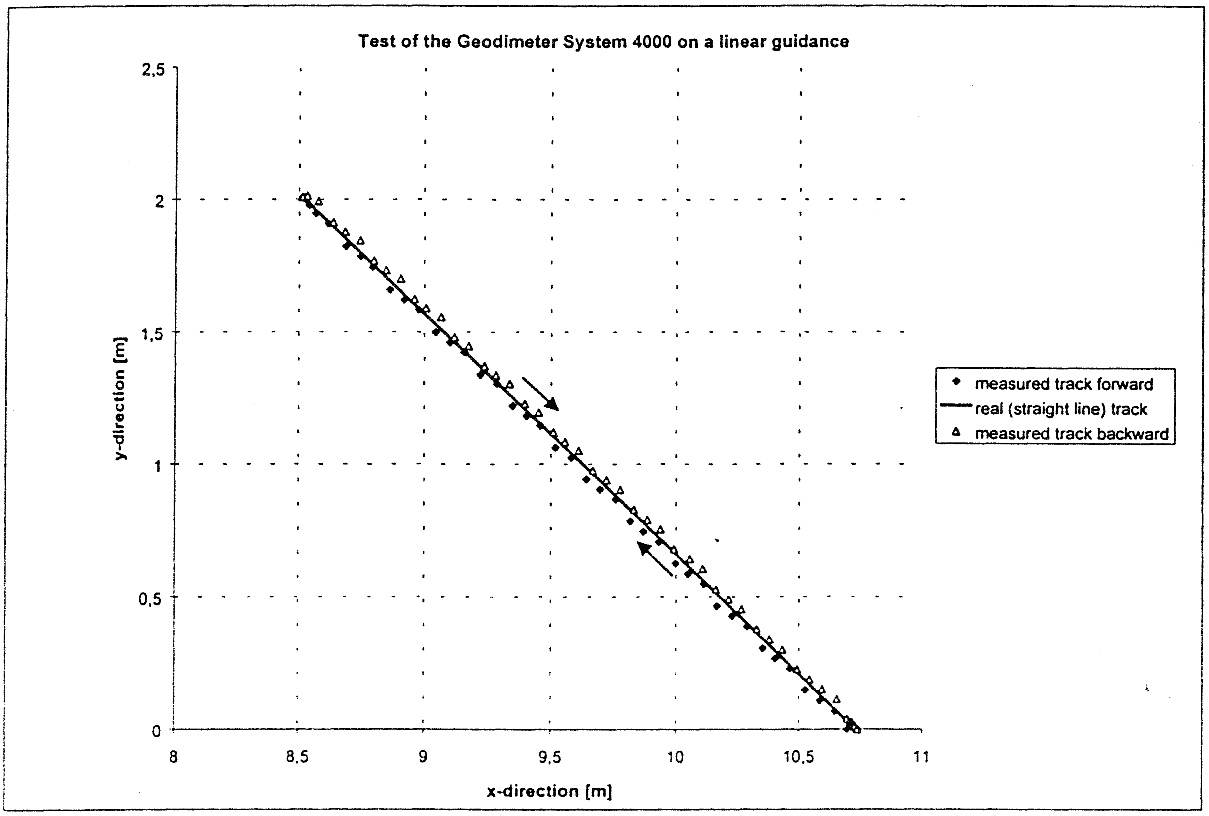

Figure 4. Test of the Geodimeter System 4000 on a linear guidance (ca. 3 m)

This is depending on the angle of the guidance to the zero line and on if the prism is moving away from the zero line (forward direction) or in reverse (backward) direction.

The offsets can be explained by the named time delay of angle measuring (first) to distance measuring (second): when moving away frome the zero line, the point on the linear guidance whose angle related to the zero line is measured is obviously lying further away from the zero line than the point whose distance from the tachymeter site is measured. It is to be shown easily that the measured angle together with the distance measured before results in a calcula-ted position lying outside the real straight track. When the prism is moving in the reverse di-rection, the effect is contrariwise.

This principle applied to the scarifying D4 (Fig. 3), it can be shown that, when the vehicle is driving NW to SE (track angle ≈ 100°), at positions west of the tachymeter there must be an offset of the detected position from the effective track to north and at positions east of the tachymeter an offset to south; in the near of the tachymeter the offsets must be smallest. The opposite is given when the vehicle is moving in the inverse direction. This can explain the swaying of the differences in positioning of DGPS less ITS, because an offset of the tachymeter positioning to north could result in a large positive difference DGPS less ITS and an offset to south vice versa. But on the other hand, the differences in positioning are only dependent on the position in relation to the tachymeter and independent from the driving direction (fig. 3) so that there must be still other factors influencing the tachymeter mea-suring.

CONCLUSIONS

The examinations on the accuracy of DGPS in several field works by means of an automatically tracking infrared tachymeter show that the tachymeter itself is subject to troubling influences because the observed swayings in differences in positioning between the two systems are not to be correlated to any GPS parameters. But there is evidently a distinct correlation to the position of the tracked vehicle in relation to the tachymeter. The standard deviation of the single differences seems here not to be measure of the accuracy of DGPS.

A sequence of tests of the tachymeter on a linear guidance suggest an easily to be explained influence of a time delay of angle to distance measuring still to be quantified. Therefore, an algorithm has to be created to adjust the tracking data concerning the time delay. Nevertheless, this delay seems not to be the only reason for the observations made in the described application and harvesting measures. There are obviously additional factors influencing the positioning by an ITS which still have to be detected. The detection of all these factors and the calibrating of the recorded tracking data in post-processing is therefore indispensable for using an infrared tracking system as reference for DGPS.

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PRVO VREDNOVANJE PRIMJENJIVOSTI SUSTAVA INFRACRVENOG PRAĆENJA ZA ISTRAŽIVANJE PRECIZNOSTI DIFERENCIJALNOG SUSTAVA GLOBALNOG POZICIONIRANJA (DGPS)

SAŽETAK

Ispitivanja preciznosti DGPS-a pri Institutu za mehanizaciju poljoprivrede Freising-Weihstephan obavljena su korištenjem infracrvenog sustava navođenja (ITS) kao referentnog sustava za DGPS u pet primjena. Mjerenja pri obradi i žetvi prikazuju međusobna odstupanja sustava u rasponu od nekoliko metara i kolebanja u zavisnosti od pozicije prizme za navođenje ovisno o položaju mjerača brzine. Također nije primijećena zavisnost među važnim parametrima GPS-a koji bi upućivali na pogreške pozicioniranja referentnog sustava. Ispitivanja mjerača brzine pri pravocrtno vođenju, u suradnji s Institutom za geodeziju, prikazuju utjecaj vremenskog kašnjenja pri mjerenju udaljenosti na mjerenje kuta. Ovo kašnjenje ne može biti jedino objašnjenje uočenih pojava u referentnim mjerenjima. Stoga je neophodno točno određivanje svih štetnih utjecaja na smještaj mjerača brzine i odgovarajuća kalibracija dobivenih podataka, da bi sustav mogao biti upotrijebljen kao referenca za DGPS.

Ključne riječi: *DGPS, valjanost, preciznost, mjerač brzine, automatsko vođenje*