Tiemo Schwenke and Hermann Auernhammer, Freising

Avoiding GPS breakdowns

Support through radar sensor based systems with slope angle registration

Despite increasing precision and reliability with GPS, signal fall-out and shadowing can still be expected now and in the future, with dead reckoning having to be used in such situations. Investigations into this have looked at a system based on four identical microwave duplicator sensors (radar sensors) with 90° positioning as well as three radar sensors in Y positioning. Tests with the former indicated insufficient registering of curved routes whilst the latter positioning reliably recorded both straight and curved routes. The route covered and also vehicle slope angle errors could be determined from the resultant recording.

Prof. Dr. Hermann Auernhammer directs the specialist department Technology in Crop Production at the Department for Biological Raw Materials and Technology in Land Usage, TU Munich. Dr-Ing Tiemo Schwenke is on the scientific staff in the same specialist department, Am Staudengarten 2, D-85354 Freising; e-mail: *schwenke@tec.agrar.tu-muenchen.de*

Keywords

GPS, satellite positioning, satellite navigation, dead reckoning system, path measurement, velocity measurement

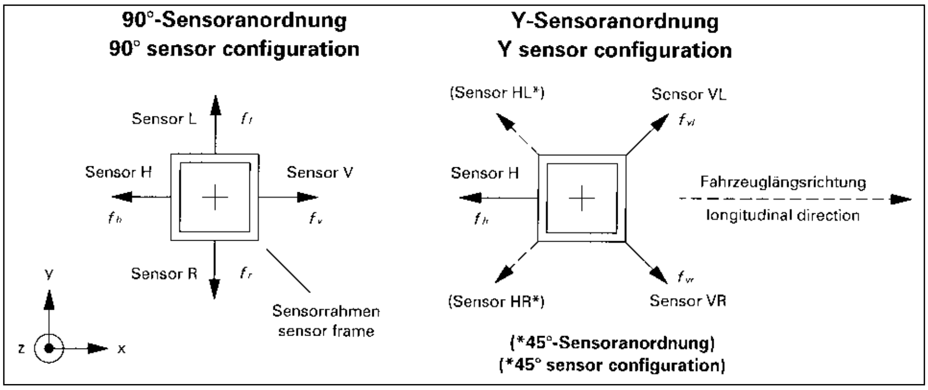

Fig. 1: Position of sensors

For dependable use of satellite positioning systems such as (D)GPS positioning precision and permanent availability of the satellite signal are of first importance. In agriculture problems such as shadowing and diffusion of the satellite signal through local specific conditions can crop up. Despite modern receiving technology and the availability of correction services faulty positional data or signal fall-out cannot be discounted.

Technology level

For bridging signal fall-outs or faulty positional data, dead-reckoning systems can be applied. Preferable here for integration into the system are remote sensors such as inertial ones. Optical, laser-duplicator and ultrasonic duplicator sensors don't meet the criteria for application in rough agricultural conditions, or only met them in some aspects. Investigations so far indicate the especial suitability of microwave duplicator sensors for wheelslip-free speed measurement in agricultural application.

Trial set-up

Following the selection of a sensor model capable of meeting the demands and also available on the market (Vansco TGSS model 338000) the different influence factors on this sensor's measuring precision were then considered. Special consideration was given to error sources caused by vehicle dynamics such as pitch and roll movements. For simultaneous registering of both lateral and longitudinal movement in direction of travel, several sensors of the same type are required and these must be integrated into a 90° sensor positioning and a Y-sensor positioning (*fig. 1*). As an alternative a 45° sensor positioning with *VR, VL, HR* and *HL* sensors was tried on the test stand. A simultaneously opened patent meant that field trials could not take place. For each of these positionings the mathematical relationship for determination of velocity in vehicle lateral and longitudinal direction as well as pitch and roll angles were set-up. The tachymeter Geodimeter System 4000 offered an auto-

Table 1: Slope angle for straight routes in Y positioning with varied angles of radiation

Measurement route number	f_h [Hz]	f_{vr} [Hz]	f_{vl} [Hz]	β [°]	S_β [°]	γ [°]	S_γ [°]
10	248	175	175	- 0,2	0,1	0,0	0,3
11	274	150	150	- 10,3	0,2	0,1	0,5
12	214	193	193	9,9	0,2	0,0	0,4
13	247	194	152	- 0,4	0,2	9,9	0,3
14	246	152	194	- 0,4	0,2	- 9,9	0,2
15	262	184	148	- 4,6	0,2	8,7	0,6

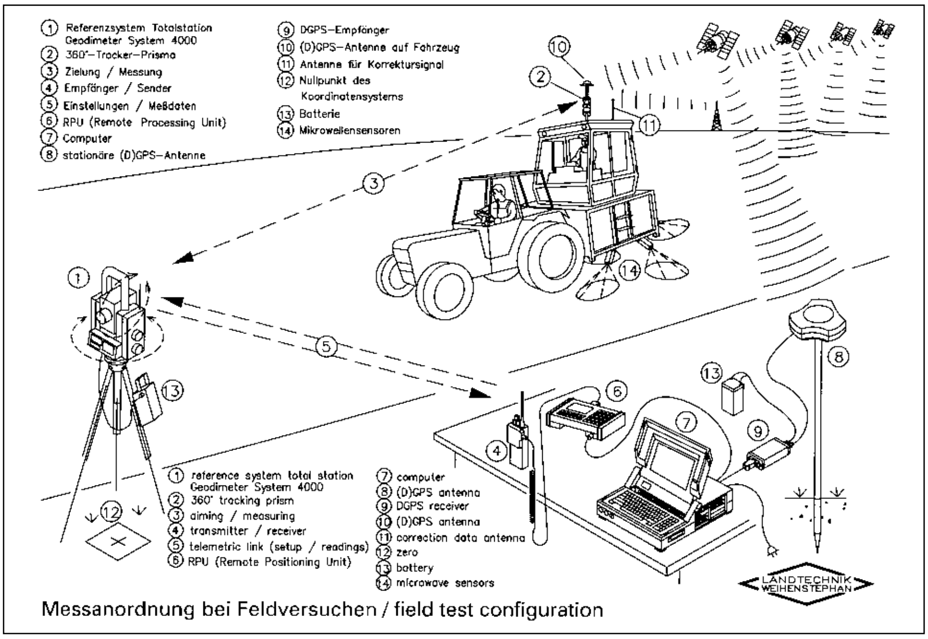

Fig. 2: Measurement set-up for field experiments

matic target-following reference system for all trials. For evaluation and comparison of the results the microwave duplicator sensors, the (D)GPS and reference systems were necessary for spatial positioning and time synchronisation of the results. Alongside the velocity-proportional frequencies of the radar sensors *f* and the (D)GPS data, the values from distance and angle measurements of the reference system for driving line determination were also recorded (*fig. 2*). The work was completed with help of coordination transformations from a local northeast coordinate system and time synchronisation via (D)GPS data stream (UTC).

The programme included test stand and field trials. Simulated on the test stand were different routes plus pitch and roll movements. Field trials were used to verify test stand work with straight driving routes as well as circular, oval and figure of eight ones. Additionally measurement of slope angle errors resulting from defined pitch and roll movements took place.

Results

The test stand investigations confirmed that the 90° sensor positioning was partially suitable only in that relative sensor errors of 10% were already apparent from sensors R and L with straight routes due to the influence of longitudinal route direction speed on results. On the other hand, the results from the Y sensor positioning for all routes met with expectations. Through variations in the beam angle $\alpha = 35°$ at the sensors, a simulation of slope error was possible in the test stand. From the Y positioning results the preset pitch and roll angles could be determined. Investigated for this were a number of preset vehicle angles in the measurement route number 10 (pitch angle β = roll angle γ = 0), 11 (β = -10, γ = 0), 12 (β = 10, γ = 0), 13 (β = 0, γ = 10), 14 (β = 0, γ = -10) and 15 (β = -5, γ = 10). *Table 1* shows the results of the calculation of pitch and roll angles taken from the average from in each case 10 repeats per recorded drive as well as the related standard deviations.

The field trials confirmed the test stand results of the 90° sensor and the Y sensor positionings. Registering curved route drives was not possible with the 90° sensor positioning meaning this was not applicable in such cases. But the Y positioning offered determination of straight as well as curved routes. Driving direction change, too, as in driving round a figure of eight or oval could be registered by the recordings. With straight routes vehicle movement caused slope angle errors in the form of pitch and roll movements could be determined.

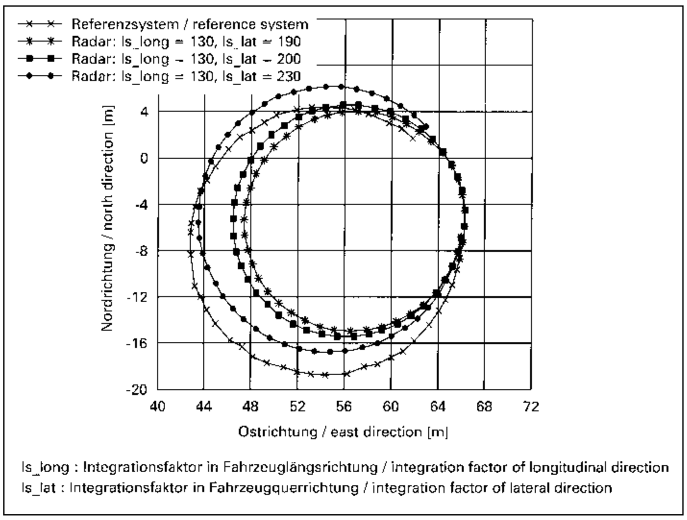

Fig. 3: Comparing of routes registered by radar sensor data and by reference system

On a circle route the Y positioning proved itself for determining driving movements (*fig. 3*). On the basis of the radar sensor results three routes were calculated in different optimisation steps. The route (integration radar factor_senk=230) with the greatest possible agreement with the reference route (Geodimeter) achieved deviations less than three meters out compared with the reference route. With this, the Y positioning in the current stage of development offers precision comparable to that realisable with currently available GPS receivers.

Outlook

Further development potential is to be expected in the optimising of sensor positioning for such work with integration of Y positioning in a module and fine-tuning of evaluation algorithms for route calculation. An additional steering angle sensor would make easier the tracking of curved routes and thus determination of slope angle errors in curved routes.

Literature

Books are signified •

[1] • *Schwenke, T.*: Experimentelle Untersuchungen von Koppelortungssystemen für GPS auf Basis von Mikrowellensensoren im landwirtschaftlichen Einsatz. Dissertation, TU München – Weihenstephan, 2001, Forschungsbericht Agrartechnik 371

[2] *Schwenke, T. und H. Auernhammer*: GPS-Stützung mit Mikrowellensensoren in der Landwirtschaft. VDI-MEG Tagung Landtechnik 2000, Münster, VDI-Verlag Düsseldorf, S. 301-306

[3] *Schwenke, T. und H. Auernhammer*: Untersuchung eines Koppelsystems zur Unterstützung der autonomen Positionierung landmobiler Anwendungen mit GPS. DGON-Seminar Satnav 98, DGON, Bonn, 1998, S. 141-146