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Contactless Vehicle Position and Path Measurement

Microwave Doppler sensors (radar sensors) are suitable for reliable, contactless path- and velocity measurement in vehicles. At the same time, a configuration of several radar sensors allows the path and inclination angle errors of the vehicle over ground to be determined. Thus, measurement errors caused by pitching and rolling movements during satellite positioning with (D)GPS can be compensated for. At the same time, this system works together with (D)GPS as a dead reckoning system.

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Keywords

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The positioning precision and permanent availability of GPS are criteria for the reliable use of satellite positioning systems. Despite modern receiver technology and the availability of correction services, effects such as shielding and multipath diffusion of satellite signals due to local, specific conditions may lead to inaccurate position data or signal failures.

In order to bridge signal failures or inaccurate position data, dead reckoning systems based on contactless sensors are used. For use in agriculture, microwave Doppler sensors (radar sensors) for slip-free velocity measurement have proven themselves.

Material and Method

For the measurement set-up, four radar sensors (VanscoTGSS model 338000) were available (*fig. 1*). In previous studies, three sensors arranged in the form of a Y were installed at the measurement cabin [2]. The M configuration is an extension of the Y configuration and has a fourth sensor [1]. The rear sensor pair HR/HL serves to measure the path, while the front sensor pair VR/VL primarily measures rolling movements. Pitching movements can be determined using the measurement values of both sensor pairs. For satellite positioning, the DGPS receiver Trimble AgGPS 132 with the satellite-based correction service OmniSTAR was used. The measurement data of the radar sensors and the DGPS were recorded synchronously at 1 Hz.

The sensor configuration was examined during measurement rides on straight and curvilinear paths. Test stand examinations of the individual sensors have already been carried out in a different trial set-up [2]. Error sources resulting from vehicle dynamics, such as pitching- and rolling movements, were given particular consideration in the trials. Rides over curbs served the selective measurement of vehicle inclination.

Before the trials, the curve ride behaviour of the tractor-measuring cabin system shown in *figure 2* was modelled. If the geometric parameters radiation angle, distance, and orientation of the sensors, as well as their height above the ground are considered, the measurement values of each sensor allow its velocity on the circular path to be derived. The ratio of the path velocity of the sensors HR and HL allows the curve radius and movement in the longitudinal and lateral direction of the vehicle to be deduced. The shifting of the sensors' measuring windows above the ground (footprint) which occurs

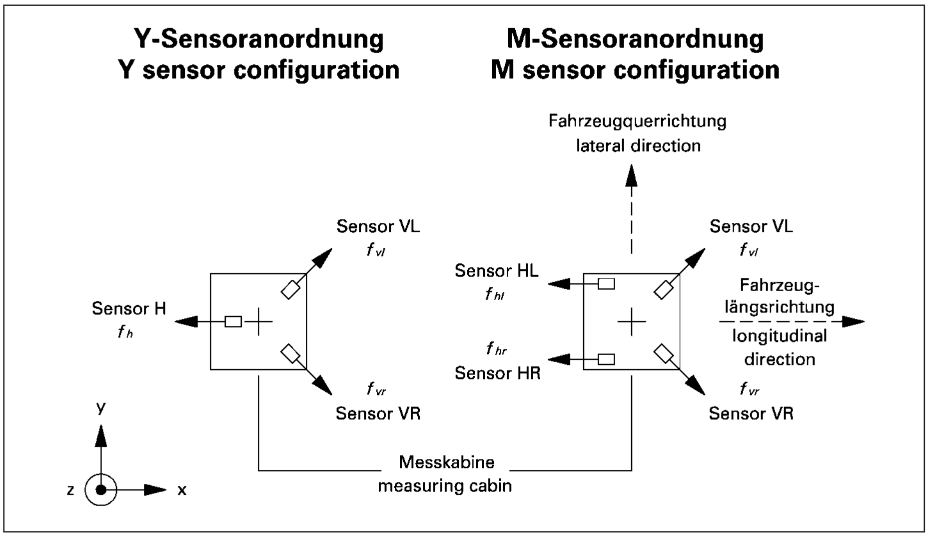

Fig. 1: Position of sensors

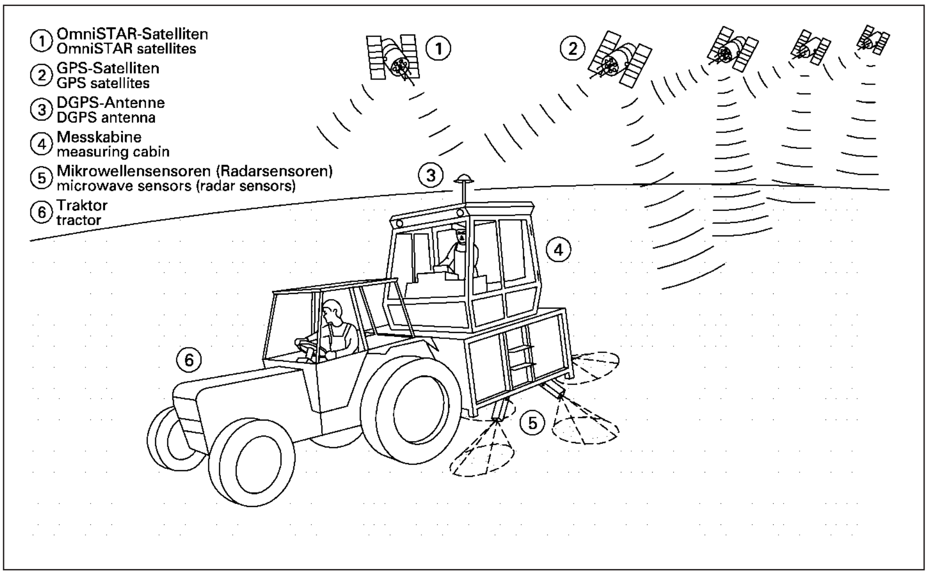

Fig. 2: Field measurement setup

during pitching- and rolling movements leads to a loss in accuracy which can be compensated for by calculating the pitch- and rolling angle.

Results and Outlook

On straight paths, the mean speed error between the radar sensors and DGPS amounts to 0.47% and is thus within the accuracy range of ± 1% at 3 to 70 km/h indicated by the sensor manufacturer. Rolling movements have no influence on the measurement result of the sensors HR and HL. Only as of a rolling angle of 15° does a measurement error of 1.2% occur for speed in the longitudinal vehicle direction determined by the front sensor pair. However, a pitch angle of 10° leads to a measurement error of 4% for speed in the longitudinal vehicle direction. The correction of the speed measurement values with the aid of the calculated pitch- and rolling angles compensates for these measurement errors.

The mean error of curve radius determination with the aid of the sensors VR/VL during clockwise rides (measurements number 4, 5, and 6) and counterclockwise rides (measurements number 1, 2, and 3) amounts to 6.6%. The average error caused by the sensors HR/HL is 5.4% (*table 1*). Nevertheless, the deviation of individual curve radii of the sensors VR/VL from the DGPS curve radius is too significant for a reliable path calculation to be carried out. As shown in the model, the sensors HR/HL take over this task. The radius calculated based on the rear sensors enables a set-value ratio for the front sensors to be derived. If this ratio is used to correct the front sensors, this would allow the approximate rolling angle to be determined even during curve rides. When the average speed over all radar sensors is compared with the DGPS speed, deviations of -0.8% to -2.3% are measured. The temporal course of a curve radius determined using the sensors HR/HL is shown in *figure 3*.

With the M configuration, an efficient system for the determination of straight and curvilinear paths as well as occurring vehicle inclinations is available. The achieved accuracies allow GPS signal failures to be bridged. GPS positioning errors due to vehicle inclinations can be corrected. The optimisation of the radar sensors for the individual mounting position and the integration of a distance-selective measurement algorithm provides further development potential.

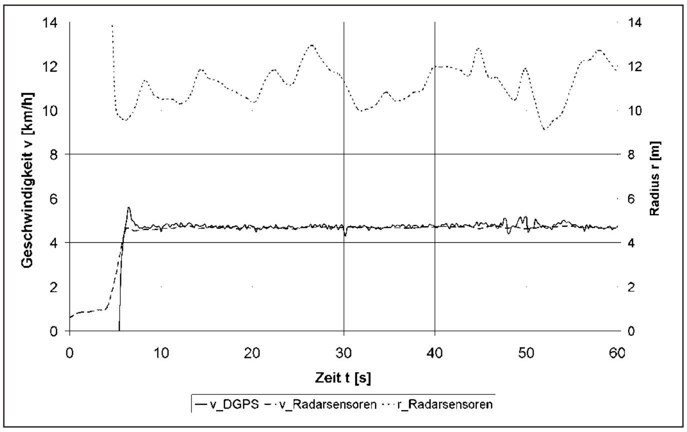

Fig 3: Velocity and radius of a circular path

Table 1: Velocity and radius measurement with DGPS and radar sensors on a circular path

M-Nr.	Speed DGPS [km/h]	Speed Radar sensors [km/h]	Speed Error [%]	Radius DGPS [m]	Radius Radar sensors HR/HL [m]	Radius Error [%]	Radius Radar sensors VR/VL [m]	Radius Error [%]
1	4,75	4,70	-1,1	10,68	11,22	5,1	10,94	2,4
4	4,79	4,68	-2,3	10,94	11,78	7,7	12,73	16,4
2	6,67	6,62	-0,8	10,77	11,28	4,7	10,98	1,9
5	7,22	7,09	-1,9	11,15	11,79	5,7	12,55	12,6
3	10,04	9,97	-0,8	10,89	11,32	3,9	10,62	-2,5
6	9,61	9,41	-2,1	11,04	11,62	5,3	12,03	9,0

Literature

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