# RADAR SENSORS FOR GPS BACKUP AND ANGLE MISALIGNMENT MEASUREMENT IN AGRICULTURE

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## PROBLEM

A central problem of satellite navigation and positioning is the lack of continuous availability of the satellite signals and their reliability. During the positioning and navigation by means of GPS, shading and multipath effects can occur. These effects are responsible for reduced accuracy of positioning and/or for the total loss of positioning. In this case dead reckoning systems support the positioning and navigation with DGPS.

## SOLUTION and RESULTS

Radar sensors (Vansco TGSS Model 338000) in various configurations were examined as sensors for dead reckoning system. These sensors allows a contactless and slip-free velocity and track measurement with high accuracy under difficult agricultural conditions. The tests took place with a dead reckoning system based on four identical radar sensors in a 90°-configuration at a mounting angle of $\alpha = 35°$ and three radar sensors ($\alpha = 35°$) in a Y-configuration (Fig. 1) respectively. Further studies in the test stand are concentrated on the registration of the pitch and rolling motions occurring in practice.

Because of the crossways sensitiveness of the sensors positioned to the left and right side the 90°-configuration is not able to detect or measure any right hand and left hand turns. Figure 2 shows a turn only in longitudinal direction in the testing stand with $f_{vl} = f_{vr}$. Without angle misalignment is $f_{vl} = f_{vr} = f_h/\sqrt{2}$. Different mounting angles between front sensors (*VL, VR*) and rear sensor (*H*) get $f_{vl} = f_{vr} \neq f_h/\sqrt{2}$, as shown in Figure 2 with a simulated pitch angle of 10°. A mean pitch angle ($n = 10$ repetitions) of $10,3°$ with a standard deviation $0,2°$ was calculated with the measuring data.

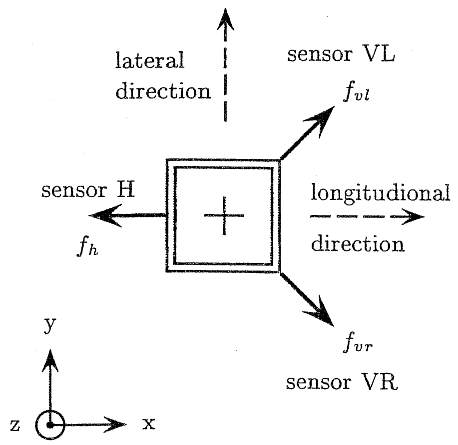


FIGURE 1. Y-configuration (top view)

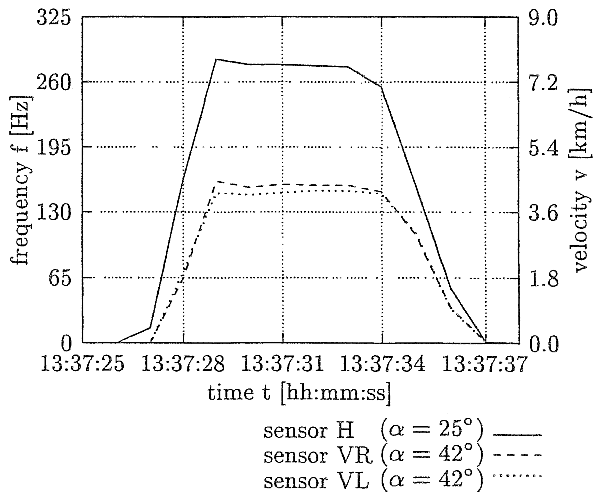


FIGURE 2. Frequencies (velocities) in dependence of the mounting angles (pitch angle=10°)

The results of a straight turn with a rolling angle of 10° simulated by modified mounting angles between both front sensors shows Figure 3. Sensor $H$ measured the real driving speed. With the differences between $f_{vl}$ and $f_{vr}$ a mean rolling angle of $9,9°$ ($n = 10$) with a standard deviation of $0,3°$ was calculated. Deviations in mounting position and angle of the radar sensors may be responsable for differences between desired value and calculated value.

The testing stand results were evaluated at a tractor with a measuring cabin in rear. The sensor performance on straight lanes and circular rides were examined on asphalt and grass. In these experiments the data of the radar sensors and from the DGPS are parallel recorded. As reference system an automatic geodetic total station Geodimeter® System 4000 was used. Figure 4 is an example for a right turn. The real driving path measured by the Geodimeter, is compared with the results of three optimization steps of the mathematical algorithm. The best match to the reference system was achieved with an integration factor of 230 and a resulting accuracy of approximately amounts 3 m.

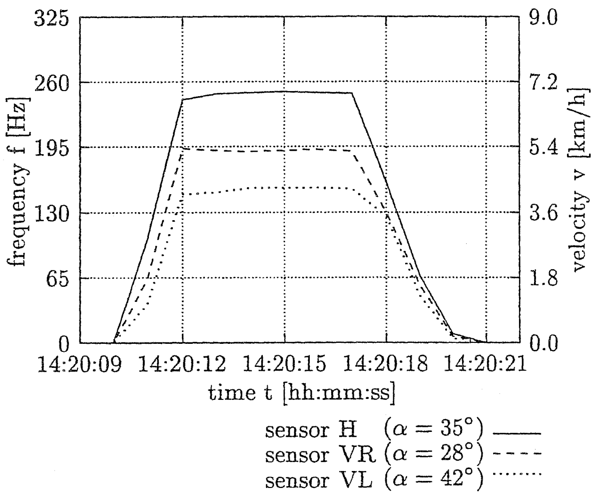


FIGURE 3. Frequencies in dependence of the mounting angles (rolling angle=10°)

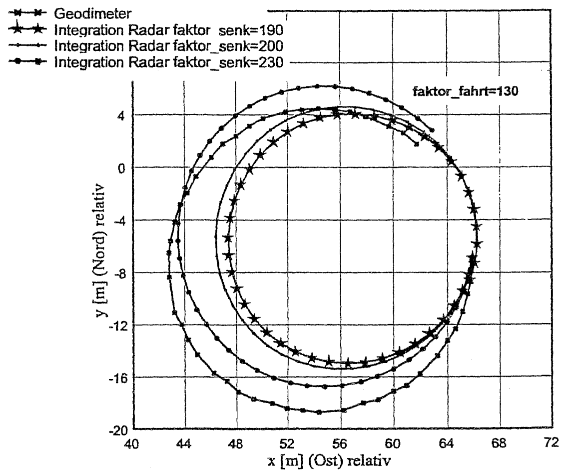


FIGURE 4. Turn comparision between radar sensor data and reference system

Angle misalignment measurements were also verified during field tests in straight lanes. Investigations show that the whole lanes and angle misalignment could be measured and calculated with radar sensors in Y-configuration.

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