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Side-Pre-Crash Sensing System for Automatic Vehicle Height Level Adaptation

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***Abstract* —** This paper deals with a system for side-pre-crash recognition for passenger cars. A radar sensor observes the side area of a vehicle detects all objects, measures their distance, radial velocity. In the case when an object trajectory is directed to the own vehicle and becomes dangerous, the radar system deploys safety measures in the own vehicle. The goal is to enhance the occupant safety.

I. INTRODUCTION

There are currently different approaches to establish high occupant safety in case of a side-crash. Today's serial cars are equipped with high-sophisticated safety measures. These are mainly pure-passive measures, like mechanical stiff constructions in the passenger's doors. It is well-known that the structural enhancements in the vehicles have increased the safety of occupants in the recent years.

Nevertheless, there are permanent research activities to safe as many lives as possible and to decrease the injury level as much as possible. In this context a new approach was invented which is presented in the following.

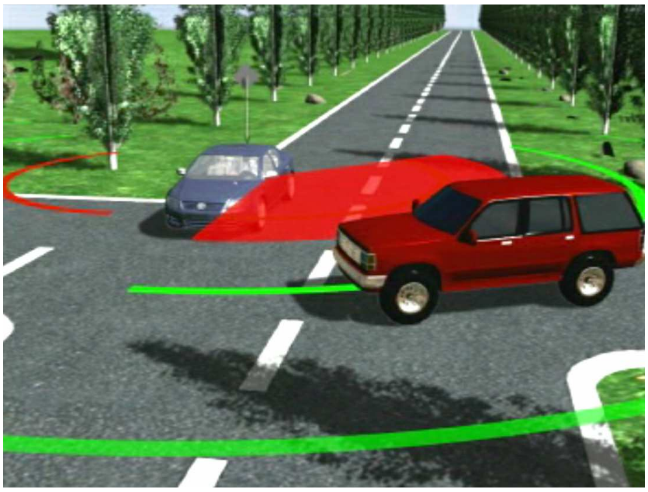
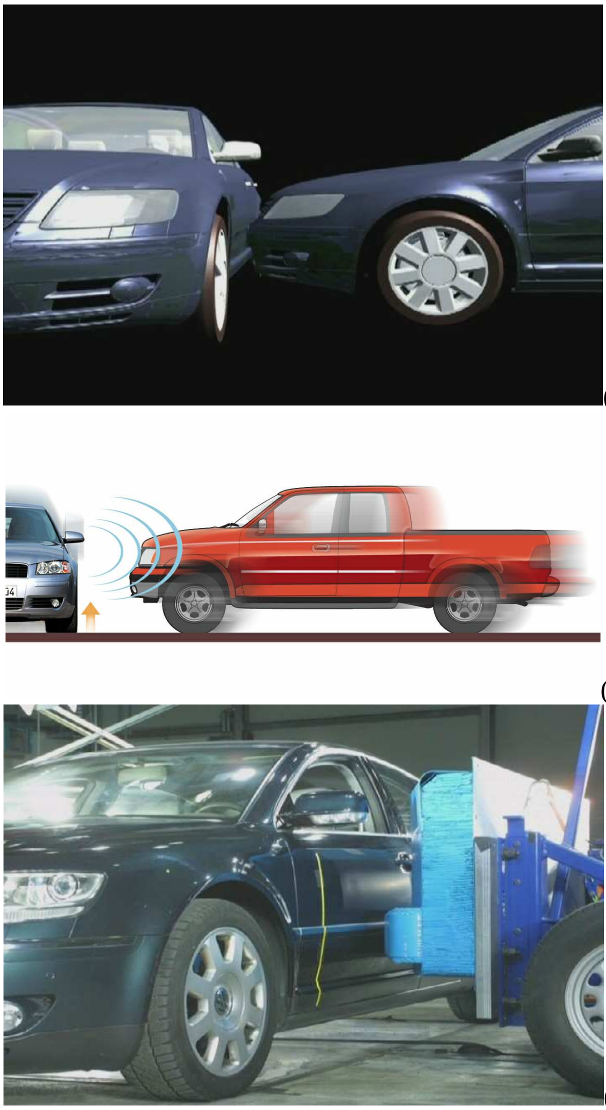


Figure 1. Dangerous situation for a SUV collision vehicle vs. passenger car.

In the United States one third of all vehicles are SUV (sportive utility vehicle). So, the market penetration is extremely high. In Europe the number of SUVs is lower compared to the US, but steadily increasing. Collisions between standard passenger cars and SUV are sometimes very critical due to the different heights of the bumpers. If a SUV is hitting a standard car at its doors the occupants are highly endangered, because the bumper of the SUV is relatively high compared to the standard height.

The differences between standard height of passenger cars bumper and bumpers of SUVs are depicted in the following three figures.



(a)

(b)

(c)

Figure 2. Bumper heights of different vehicles: (a) passenger vs. passenger car; (b) SUV vs. passenger car; (c) SUV vs. passenger car (standardized crash-barrier).

In this publication an active safety system to adapt the passenger car's height in case of a pre-crash-situation is presented. When a hazardous from a side hitting car is detected the height of the own vehicle is increased by 100 mm within 300 ms.

This activity is necessary to avoid that the SUVs bumper hits the door, instead of this now it hits the part below the door which is extremely stiff. In consequence the mechanical load to the occupants is decreased dramatically.

II. System Description

The complete safety system including sensor and actuators was integrated into a Volkswagen Phaeton (see Figure 3).

Figure 3. Volkswagen Phaeton equipped with the pre-crash recognition system and actuators.

For detecting obstacles and other critical objects a 24 GHz radar sensor is used. The sensor was supplied by Smart Microwave Sensors (SMS) company. The sensor operates with a high-sophisticated continuous wave transmit signal. Of cause, the transmit signal is specially designed to be unlimited approvable with respect of frequency regulations (ETSI, RegTP, FCC, etc.). There are no limitations for the commercial use in duration, location and market penetration.

The antenna diagram was designed to cover the interesting area for typical side-crash scenarios. Figure 4 provides an impression of the antenna diagrams shape.

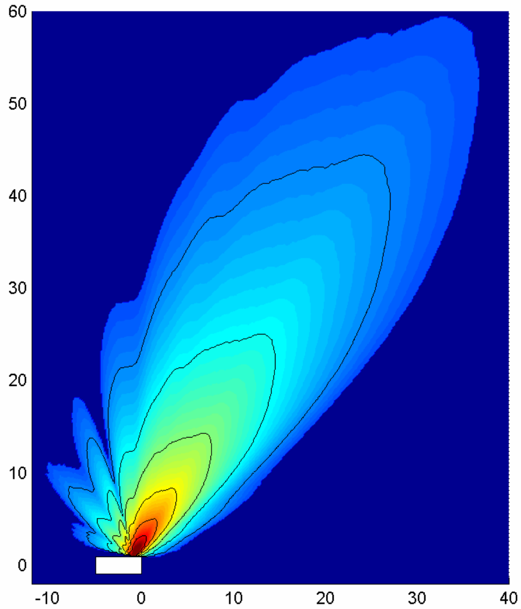


Figure 4. Antenna diagram.

The sensor is able to detect interesting objects (like passenger cars, vans, trucks, etc.) with high detecting probability and high measurement accuracy. This is the base for a trajectory estimation and risk assessment. When a trajectory is directed to the side area of the Phaeton the chassis will be activated automatically. Then the body of the Phaeton will be lifted up by 100 mm within 300 ms.

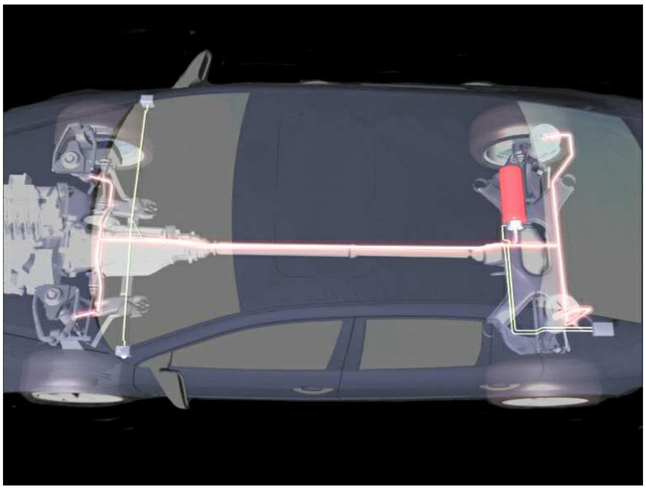


Figure 5. Scheme of the activated chassis.

This lift up mechanism shifts the collision point of the SUV bumper from Phaetons door down to the sill board (stiff part below the door). The consequence is that the intrusion is decreased dramatically; the injury level of occupants is decreased as well.

Figure 6. Phaeton before (left figure) and after lifting up the body (right figure).

From a mechanical point of view the lift up is very challenging. Due to the strong requirements

- extreme short action time (of approximately 300 ms),
- the high mass of the Phaeton body (of around 2,000 kg) and
- high lifting up distance of 100 mm

special modifications on the chassis were necessary. In the Phaeton air springs (refer Figure 7) were connected with air pressure vessel via valves.

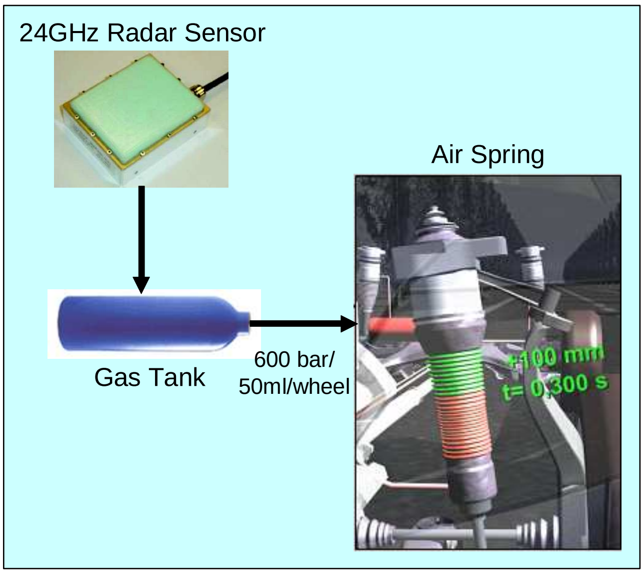


Figure 7. Activation of Air Spring.

When the deployment signal arrives the valve opens and the air of the vessel is applied to the air spring. Then the air springs move out the spring struts and the vehicle lifts up. A similar concept can be realized by hydraulics.

III. SYSTEM VALIDATION

The validation of the system was done in two steps:

- Collision tests/ Nearly-collision tests at a proving ground using soft objects (see Figure 8) and
- Driving long distances to find out how the system performs in normal driving conditions (without collisions)
- Real crash test (refer Figure 9).

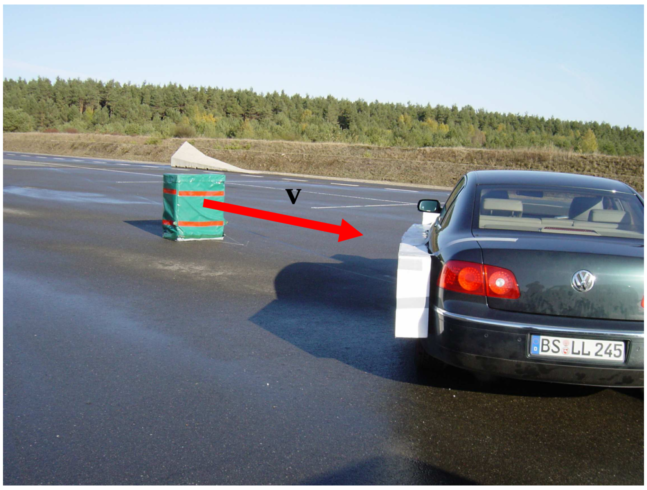


Figure 8. Pre-Crash-Evaluation of the equipped Phaeton using a dynamic collision object (green cuboid).

The results of these tests were very promising. Test drives about several thousands of kilometers showed very excellent performance in terms of correct deployment and false alarms. The concept of a single-sensor set-up for this task was confirmed herewith. The coverage area of the antenna seems to be totally sufficient. Furthermore, the intelligent transmit waveform leads to a system without any limitations regarding frequency regulation. Therefore, it seems to be a high-potential candidate for safety (and comfort) applications for future vehicles.

The real crash was performed under IIHS test conditions, namely barrier weight of 1,500 kg, impact angle of 90°, speed of barrier 50 km/h. Figure 9 shows the test configuration just before the performed crash test.

Figure 9. Phaeton just before real crash in a crash facility using IIHS barrier.

The intrusion in the area of the B pillar is a very important value for vehicle's safety. The reduced intrusions of the project vehicle (orange bars) are compared to the intrusions of a standard Phaeton vehicle (blue bars). The dramatic lowering can be seen in the figure below. At the three measurement points "upper door", "door middle" and "H-point" the test resulted in reductions between 19% and 24%. These are some relevant values for the occupants. The mitigation of intrusion is compensated (according to the concept) by an increased intrusion at sill beam, which has no negative effect to the driver. By a well-done dimensioning a "good" evaluation can be achieved relatively easily.

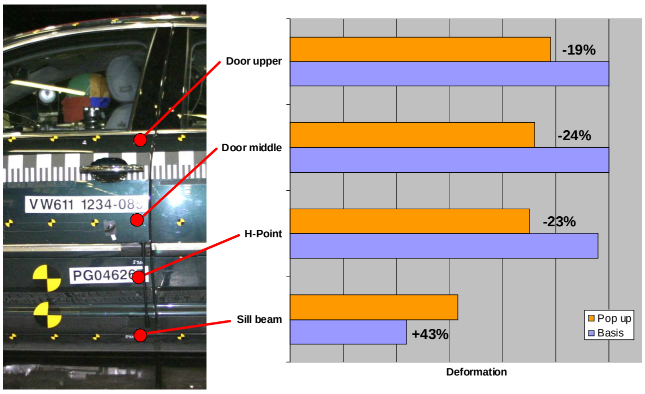


Figure 10. Reduced intrusions in the area of B pillar (blue: standard Phaeton; orange: project Phaeton).

The loads applied to the human body were measured by using SID II dummies on the driver seat and fond seat behind the driver. 26 different parameters (like forces and accelerations) per dummy were recorded during the test. The total loads were reduced by 28,7% in average by this new measure. A selection of load parameters collected from the dummy on driver's seat measured at its head, its ribs and its iliac positions is shown in Figure 11 in comparison to the standard vehicle.

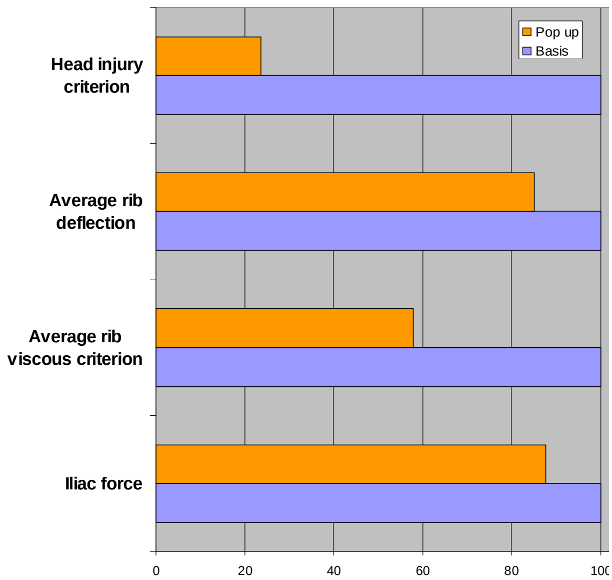


Figure 11. Relative dummy loads [%] on the driver compared to the standard vehicle (blue: standard Phaeton; orange: project Phaeton).

IV. Conclusion

In this publication a new concept for enhancing occupant safety in side-crash situations was presented. Lifting up a vehicle can be one measure to shift the collision point from SUVs from the door down to the stiffer areas below the door (door sill). This concept seems to be an effective method to avoid those heavy intrusions into the passenger area.

Aspects of the sensor system and the lifting system were described. Further information regarding economical serial production conditions was provided.

Overall, the system showed excellent performance in normal public road conditions and in "real" collisions scenarios.

V. References

[1] Broggi, A.; Fascioli, A.; Carletti, M.; Graf, T.; Meinecke, M.-M.: "A multi-resolution approach for infrared vision-based pedestrian detection" IEEE Intelligent Vehicles Symposium, Parma/ Italy, June 14-17, 2004.

[2] F. Kruse, F. Fölster, M. Ahrholdt, M.-M. Meinecke, H. Rohling: „Object Classification with Automotive Radar" International Radar Symposium, Dresden/ Germany, September 30 – October 2, 2003.

[3] Marc-Michael Meinecke; Marian Andrzej Obojski: „Enhancing Pedestrian Safety by using the SAVE-U pre-crash system" IEEE ITSWC, San Francisco/ USA, November 6-10, 2005.

[4] Merrill I. Skolnik: "Radar-Handbook, Second Edition" McGraw-Hill Publishing Company, 1995.

[5] Meinecke, Marc-Michael; To, Thanh-Binh; Obermann, Jan: "A 24 GHz radar-based automotive pre-crash system" International Workshop on Intelligent Transportation, Hamburg/ Germany, March 23-24, 2004.

[6] S. Munder, M.-M. Meinecke, D. M. Gavrila, M. A. Obojski: „SAVE-U: Driver Warning and Vehicle Actuator Concepts (Deliverable D22)." EU-Project SAVE-U, www.save-u.org, 19.08.2005.