ADVANCED REAR SEAT SENSING – FURTHER IMPROVING OCCUPANT SAFETY, USING RF TECHNOLOGY

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ABSTRACT

Building on previously developed VitaSense technology, IEE has developed a single sensor, which is integrated behind the headliner of the vehicle, and can serve multiple detection purposes. The new low-power 79 GHz RF sensing unit is used as Occupant Detection Sensor (ODS) while driving, and makes this information available to the vehicle, as input for advanced seat belt reminder (SBR) systems. After the drive, the sensor keeps operating, and can thus detect left-behind occupants, including sleeping new-born children. The standalone sensor is hence capable to address two different functionalities playing a role in the Euro NCAP star rating. Advanced rear seat SBR is incentivised since 2018, and "Child Presence Detection" will become part of the rating scheme in 2022. As "VitaSense+ODS", the sensor addresses two rear seat safety issues: a) seat belt usage in the rear seats tends to be at least 10-15% lower than in the front seats, in some regions of the world even significantly worse; b) in-vehicle heatstroke of unattended infants and children in cars, which in 2018 reached a new record in the US with 51 resulting fatalities. Based on the driving tests performed, and static child detection tests, the 79 GHz RF sensing method has been found to be robust. It is important to note that the system presented serves as a reminder, which does not ensure the prevention of rear occupant injury or heatstroke fatalities per se.

INTRODUCTION

The protection of occupants in the front seats of light vehicles has reached a remarkable level. In the rear seat, however, there is still a significant potential for improvements. More and more vehicles are nowadays equipped with seat belt tensioners and load limiters on the rear seats too, but may occupants do not benefit from those modern restraint systems when they are unbelted. Seat belt usage in the rear seats tends to be at least 10-15% lower than in the front seats, in some regions of the world even significantly worse [1]. Advanced rear seat SBR systems with occupant presence detection have started to enter the market. Capable of triggering an audio-visual alert at the start of the journey, they can be expected to positively influence the seat belt wearing rates on the rear seats.

Another issue, that is predominantly of concern for children in the rear seats, is in-vehicle heatstroke, resulting in 51 child deaths in 2018 in the U.S. alone [2]. At the ESV conference 2017, IEE published a paper on VitaSense [3], capable of detecting even sleeping infants and thus support the vehicle in triggering alerts or initiating countermeasures. Based on radiofrequency signals in the 24 GHz ISM band, the first-generation VitaSense could, however, not be used to support an SBR function.

The novel sensing solution, presented in this paper, is a vehicle-integrated standalone sensor covering both functionalities described above: seat belt reminder and child presence detection. A low-power 79 GHz RF sensor is capable of detecting the seating position of adult rear seat occupants during a journey, and after the vehicle has been parked, it checks whether an occupant may have been left unattended.

REAR SEAT SAFETY ISSUES

Unbelted Occupants
Unbelted rear seat occupants remain a safety issue, as belt wearing rates continue to be lower than those on the front seats. The 2016 National Occupant Protection Use Survey (NOPUS) [4] states that seat belt use in the rear seat was only 80.6%, while on the front seats it reached 90.1%. A study published in 2014 by IIHS and The Children's Hospital of Philadelphia [5], found that unrestrained rear-seat occupants are nearly eight times as likely to sustain a serious injury in a crash as restrained rear-seat occupants. 2017 data from the Fatality Analysis Reporting System (FARS) shows 1341 fatally injured rear seat occupants aged 12 years and older. More than half of them, 801 (59,7%) did not wear their seat belts. Unbelted rear seat passengers can also be a threat for front seat passengers, slamming into them or pushing against the front seat backrest. Driver fatality risk doubles in such scenarios, according to a study of the University of Virginia [6].

Seat belt reminders on rear seats

Simple seat belt reminder (SBR) systems monitoring the belt status on the rear seats and providing a visual information to the driver at the start of the journey are already widespread in Europe due to Euro NCAP incentives. Starting September 2019, such systems will become a type-approval requirement for passenger cars in the European Union. In the US, however, such systems are much less available. In 2015 only 3 percent of new passenger cars had them fitted. More advanced SBR systems, including rear seat occupant detection allowing to trigger audio-visual warnings, have recently started to enter the markets in Japan (2014) and Europe (2017). Hence, rear seat occupant sensing is gaining relevance, and new non-seat-based sensing technologies may be a useful sensing alternative.

In-Vehicle Heatstroke

2018 marked a sad record with 51 in-vehicle heatstroke fatalities in the US. On average there were 38 fatalities per year in the timeframe 1998 – 2018. The victims were either forgotten (54%) or knowingly left (18%) in the car, and some gained access (26%) to unlocked vehicles. A large majority of the heatstroke victims are aged 2 years or younger (74%), and they are mostly "forgotten" or "knowingly left". The "gained access" type of incidents typically occurs for children aged 3 and older. They manage to access the vehicle but do not get out anymore e.g. due to child safety door locks. Infants easily fall asleep in a car, and so they can easily be out of the mind of the driver. In addition, it is known that changes in the daily routine, stress, distractions or misunderstandings play a key role in the situations when children are forgotten in a car. When children are knowingly left in a car, the caretaker either underestimates the risks or falsely assumes to be back soon enough. In-vehicle heatstroke fatalities occur anywhere in the world; however, they are not systematically documented outside of the US.
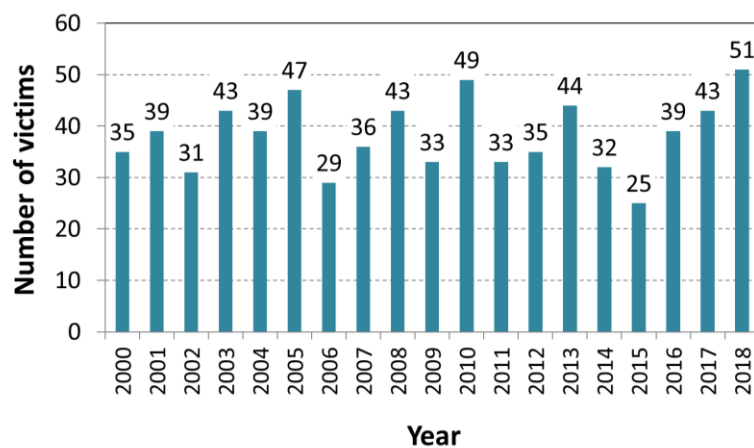

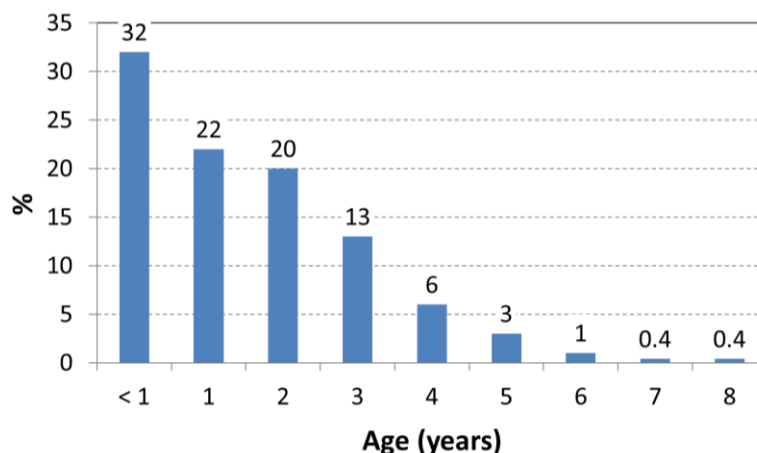*Figure 1. Overview on yearly in-vehicle heatstroke fatalities in the US*

Figure 2. Share of heatstroke victims by age group

NCAP INCENTIVES

NCAP's are frequently having a lead role in promoting novel vehicle safety solutions. Usually being announced in roadmap documents, these new functions then make it into the rating scheme, where they help to improve the vehicle's safety ratings if the functionality complies with the NCAP protocol.

Advanced Rear Seat SBR
In 2011, Japan NCAP took a leading role in defining incentives for rear seat SBR systems capable to trigger an audio-visual warning at the start of the journey. Such a function, known since more than 20 years for the front passenger seat, requires occupant detection technology. In 2014, a first vehicle scored points for such an advanced rear seat SBR system.

Euro NCAP offers incentives for advanced rear seat SBR systems since 2018. Vehicles can score 0.5 point in the "safety assist" category for the advanced rear seat SBR, while a simpler belt status information function scores 1.5 points. In the first assessment year, a remarkable share of 38% of the tested vehicles already offered an advanced rear seat SBR function. In 2020, Euro NCAP will increase the relevance of the advanced function, by allocating 1 point (while the belt status SBR score will decrease to 1 point). The incentives will also be applicable for Australasia NCAP, having aligned their rating with Euro NCAP in 2018.

ASEAN NCAP is the latest NCAP having announced incentives for advanced rear seat SBR in 2021, as part of their Roadmap 2021-2025.

Child Presence Detection
In its Roadmap 2025, Euro NCAP has announced the introduction of incentives for Child Presence Detection in 2022. As for SBR, this will also be applicable to Australia NCAP. Four points will be available in the "vehicle-based assessment" part of the child safety protocol [7]. Some of the elements allowing to score today up to four points in the vehicle-based assessment will be removed or downgraded in order to allow for the integration of the four Child Presence Detection points.

Functional requirements and scoring details are currently under discussion in a dedicated Euro NCAP working group. The assessment protocol will consider how the assumed or actual presence of a child is evaluated (indirect vs. direct systems), what warnings or countermeasures the vehicle can initiate, and whether an escalation of warnings is possible. One general principle has been agreed on: the better the Child Presence Detection system and the more effective the vehicle's countermeasure warnings and interventions, the higher the score. Target is to have a finalised protocol by the end of 2020.

Another NCAP having decided to address in-vehicle heatstroke fatalities is ASEAN NCAP, having announced incentives for 2021 in their Roadmap 2021-2025 document.
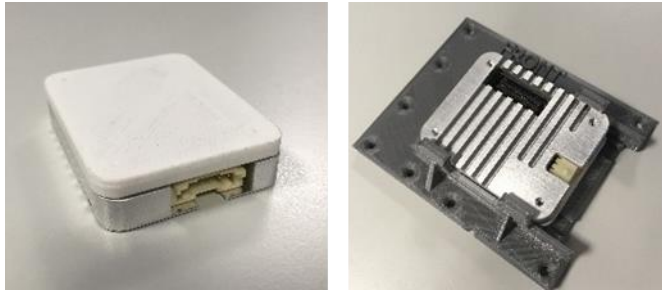
THE RF SENSING SYSTEM

Building on previously developed VitaSense technology, IEE has developed a single sensor, which is integrated behind the headliner of the vehicle, and can serve multiple detection purposes. The new low-power 79 GHz RF sensing unit is used as Occupant Detection Sensor (ODS) and makes this information available to the vehicle, as input for advanced seat belt reminder (SBR) systems. After the drive, the sensor keeps operating, and can thus detect left-behind occupants, including sleeping new-born children – a function called UCD (Unattended Child Detector) by IEE.

Developing an occupancy detection function is not as evident as it may sound: It is important to understand the functional requirements in a vehicle, which is at standstill, going slowly on a smooth road or driven off-road. Setting up use cases for simple static occupancy presence sensing or using test procedures that were developed for another technology may not be appropriate.

Test procedures have thus been developed, which take vehicle use cases into consideration. These test procedures contain an element of static and dynamic vehicle situations. The static tests involve measurement of occupants in nominal and due-care positions, as well as specific objects, which the end customer would place in the rear seat under normal circumstances. The objects include back-packs, laptop bags, amongst others.

Based on the driving tests performed, and static detection tests, the module's sensing method has been found to be robust.

Figure 3. VitaSense+ODS RF sensing unit (40 x 48 12 mm)

To ensure a satisfactory user experience, it was found that a system should be allowed to react to state changes only after a certain qualification period, to allow for people and objects moving around, but not actually changing seating position. Likewise, the occupancy status change while driving will have to be slightly delayed, because occupants must be allowed to move around, reach out for something, without potentially getting an unnecessary seat belt reminder warning.

The Unattended Child Detection function is implemented in a similar manner to our previous generation sensor, which means that it properly detects a range of occupants, including sleeping new-born children. This sensor function is only activated after the vehicle has reached a condition where there is risk of entrapment, e.g. when the driver locks the car after leaving. Typically, presence is detected within a few seconds. To cover specific circumstances, like children holding their breath for a period, the sensor typically operates for 60 seconds.

CONCLUSIONS

The standalone 79 GHz RF sensor can address two different functionalities that will help to improve rear seat occupant safety and thus save lives. In addition, both functionalities will play an important role in improving the Euro NCAP star rating. Advanced rear seat SBR is incentivised since 2018, and "Child Presence Detection" will become part of the rating scheme in 2022.
Based on the driving tests performed, and static child detection tests, the 79 GHz RF sensing method has been found to be robust. The 79 GHz RF sensor successfully detects rear seat occupants while driving and meets requirements for non-detection of objects on the seat, meaning that the sensor can be used as an occupancy detection sensor for an advanced rear seat belt reminder, capable of initiating an audio-visual warning at the start of the journey. When the vehicle is parked, the sensor can even detect the small breathing movements of a sleeping baby and can detect the child under difficult circumstances, such as through the sunshade of a rearward-facing child seat. As the sensor is vehicle-based, the child is detected independent of the specific child seat used, and the vehicle's infrastructure can be used to ensure appropriate countermeasures.
It is important to note that the system presented serves as a reminder, which does not ensure the prevention of rear occupant injury or heatstroke fatalities per se.

REFERENCES

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