HALI-Berlin: Emergency vehicle preemption with Galileo PRS

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Abstract

The aim of the research project HALI-Berlin is to demonstrate the use of Galileo PRS (PRS = Public Regulated Service) for determining the position of emergency vehicles under real-life conditions in a complex urban environment. Based on this position determination, a preemption is given to emergency vehicles at traffic lights to cross safely and to maintain higher speeds towards their destination. In addition, HALI-Berlin significantly increases road safety for all road users and minimises the negative impact of emergency mission trips on the general traffic flow. Several fire brigade and police vehicles were equipped to receive Galileo PRS encrypted signals. Eight traffic lights in the Berlin-Moabit district were also enhanced with additional components. A HALI server in the background coordinates the triggering of the traffic lights along the emergency vehicles' routes. This paper presents a project overview, the applied HALI system components and the findings achieved so far.

Keywords:

Galileo PRS, traffic light coordination, emergency vehicle preemption

Introduction

Traffic light control has a major impact on quality, safety and environmental effects of traffic flow within urban road networks. With the aim to optimise these and similar parameters, a variety of different signal control approaches are applied worldwide. Although these approaches differ in their structure and complexity, they all try to exploit the intelligent infrastructure of an intersection for the best possible traffic control [1]. Currently, in addition to the use of novel data sources and algorithms [2], [3] for improved traffic flow, the focus has shifted more to preemption of certain vehicle groups like public transport and emergency vehicles. While different systems are deployed already to control traffic lights in favour of emergency vehicles, these systems have several shortcomings. Positioning is

often done with receivers that, in an urban canyon scenario subject to multipath and rapidly changing satellite blocking, cannot provide the required precision and availability for efficient and reliable traffic light coordination. Traffic light coordination is also often limited to the immediate next node instead of a longer route or corridor. Furthermore, it is a common approach to block all other traffic flow at a node, even though it might not be conflicting with the emergency vehicle's route. This contributes to unnecessary congestions and might slow down other concurrent emergency missions.

Finally, OS (Open Service) signals, such as GPS L1 C/A or Galileo E1 OS, might be subject to attacks that could impede or falsify positioning and thus disrupt the traffic light coordination. The HALI-Berlin research project [4] intends to address these shortcomings and demonstrate the optimisation of emergency vehicles routing and traffic light preemption based on the European GNSS (Global Navigation Satellite System) Galileo and its PRS (Public Regulated Service) positioning, subject to real conditions in a complex urban scenario. Proper coordination of the traffic lights based on the emergency vehicle's position and proposed optimal route should also minimise negative side effects to the remaining traffic and possible concurrent emergency rescue operations. Furthermore, the organisation of the traffic in favour of the emergency vehicles should also reduce the accident risk, which is otherwise elevated relative to normal conditions. Finally, Galileo PRS allows positioning for emergency vehicles also during possible crisis scenarios where other GNSS OS signals are less robust against jamming and could be spoofed or be unavailable, a situation in which the likelihood for the need of emergency operations is increased.

Galileo PRS

Galileo PRS is a special, cryptographically protected navigation service, which is only available to governmental or officially authorised users. Powerful encryption does efficiently prevent the deliberate falsification of time and position (spoofing). In addition, by using different frequencies, Galileo PRS also impedes the interruption or overlapping of the navigation signals by a jamming source. In this way, a variety of safety-critical and demanding applications can be realised, which are not possible with other navigation services in this form for non-military users. In order to meet the requirements regarding reliability, interference robustness and accuracy of the positioning of emergency vehicles under real operating conditions (harsh weather conditions, bumps, and accelerations), the German national "PROOF" PRS receiver [5], [6], [7] had to be further developed (see Figure 1). These existing receivers had previously only been run under laboratory conditions and were not suitable to withstand everyday use with being mounted on an emergency vehicle. As part of the project, new algorithms for the difficult urban environment were developed for these receivers, which, despite shadowing and signal multipath effects due to reflections, permits a robust and precise position determination with a high availability [8]. They were also optimised in terms of size and weight, as there is often very little available space on emergency vehicles. The receivers' energy consumption had also to be reduced before the devices could be used in practice, as they have to be powered by the vehicle's onboard supply. In addition, the necessary interfaces for connecting the vehicle sensor systems had to be

provided, in order to achieve a certain system performance in terms of continuity during operation, even when the Galileo signals are blocked.

Figure 1 - Development of the Galileo PRS receivers, starting from laboratory rack (left), to PROOF receivers (middle, applied in HALI-Berlin), to miniaturised chipset in future (right).

Equipping fire brigade and police vehicles

These advanced receivers were then installed in five emergency vehicles from the Berlin Fire Brigade and the Berlin Police Department. This includes an ambulance vehicle, a fire truck and three police patrol cars. Inside the emergency vehicles, a suitable place for the mounting of the receivers had to be found. The vehicles of the fire brigade offer a little more space to host the receivers, compared to the patrol cars of the police, where the devices have been placed into the spare wheel recess (see Figure 2). In addition to the receiver itself, a Galileo aerial was installed on each vehicle's roof to access the satellite signal. The aerial was integrated directly into the blue light bar of the police patrol cars, while for the fire brigade vehicles an additional housing was necessary on the roof. The receiver was then connected to the electrical system of the emergency vehicle to ensure the required power supply. In order to compensate for disruptions in satellite signal reception, e.g. in a tunnel, the receivers were coupled to the inertial sensor system of the emergency vehicles. With the provision of sensor data from an odometer (distance) and an inertial measurement unit (acceleration, angular rate) short-term gaps can be bridged until the satellite signal is available again.

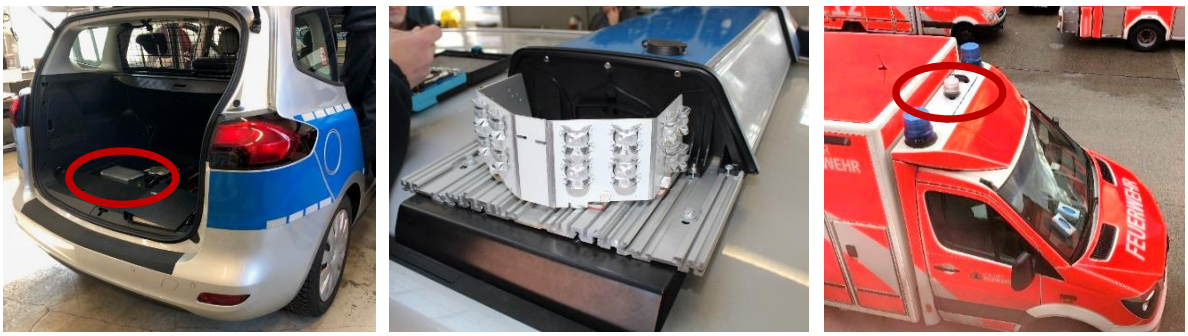

Figure 2 - Galileo PRS receiver in spare wheel recess (left), Galileo aerial integrated in blue light bar (middle), and mounted in an additional housing (right).

Emergency vehicle preemption

Precise and reliable position determination via Galileo PRS is not sufficient to trigger a preemption of the equipped emergency vehicles along the traffic lights. For this, the traffic lights must also be prepared with appropriate technology and integrated into an intelligent background system. Different systems for preemption of emergency vehicles on traffic lights are in use worldwide, but in Germany these systems have not been able to prevail so far. A coordination of intersections along dynamic routes cannot be done very reliably due to shortcomings in the position determination of emergency vehicles and due to incompatibility of installed traffic light controls from different manufacturers. Therefore, the implementation of preemption systems in Germany is usually limited to single nodes in the immediate vicinity of fire and police stations or large hospitals. Although there are systems in Germany that allow the coordination of several traffic lights for emergency operations, they are often complex in design, not very dynamic, tied to the technology of a single manufacturer and its central traffic computer and therefore very expensive. In addition, the preemption is exclusively for a fixed, predefined direction of travel of the emergency vehicle. All other traffic flows are basically stopped, regardless of their direction, which further increases the waiting times for the surrounding traffic or other emergency mission trips especially at peak hours. In the project, therefore, the HALI approach [9] originating from Finland was taken up and extended to German conditions. This includes, besides the Galileo PRS usage, e.g. the possible integration of traffic light controllers from different manufacturers and the continuance of complex traffic dependencies at the local intersections. The HALI system also supports the control of the traffic lights for emergency vehicles in a convoy, so that a stable green phase for all emergency vehicles in the convoy is achieved.

Preemption by the HALI system works as follows (see Figure 3): First, the HALI system receives information from the fire brigade and police control systems (1) on the destination of an equipped emergency vehicle. Then the current position of the vehicle itself is determined (2) and used to calculate a route (3) to this destination. The route calculation includes typical routes that are frequently chosen by the emergency forces and considers the traffic situation. Along this recommended route, the traffic lights are triggered dynamically and at the right time depending on the current position of the emergency vehicle (4). The green time starts early enough that possible tailbacks have been cleared before the emergency vehicle arrives. As soon as the emergency vehicle has passed an intersection, it switches back to the normal program in order to obstruct other traffic as little as possible. If the emergency vehicle deviates from the recommended route, the route is automatically recalculated. As soon as the emergency vehicle has arrived at its destination the HALI system ends the emergency operation and the prioritisation (5).

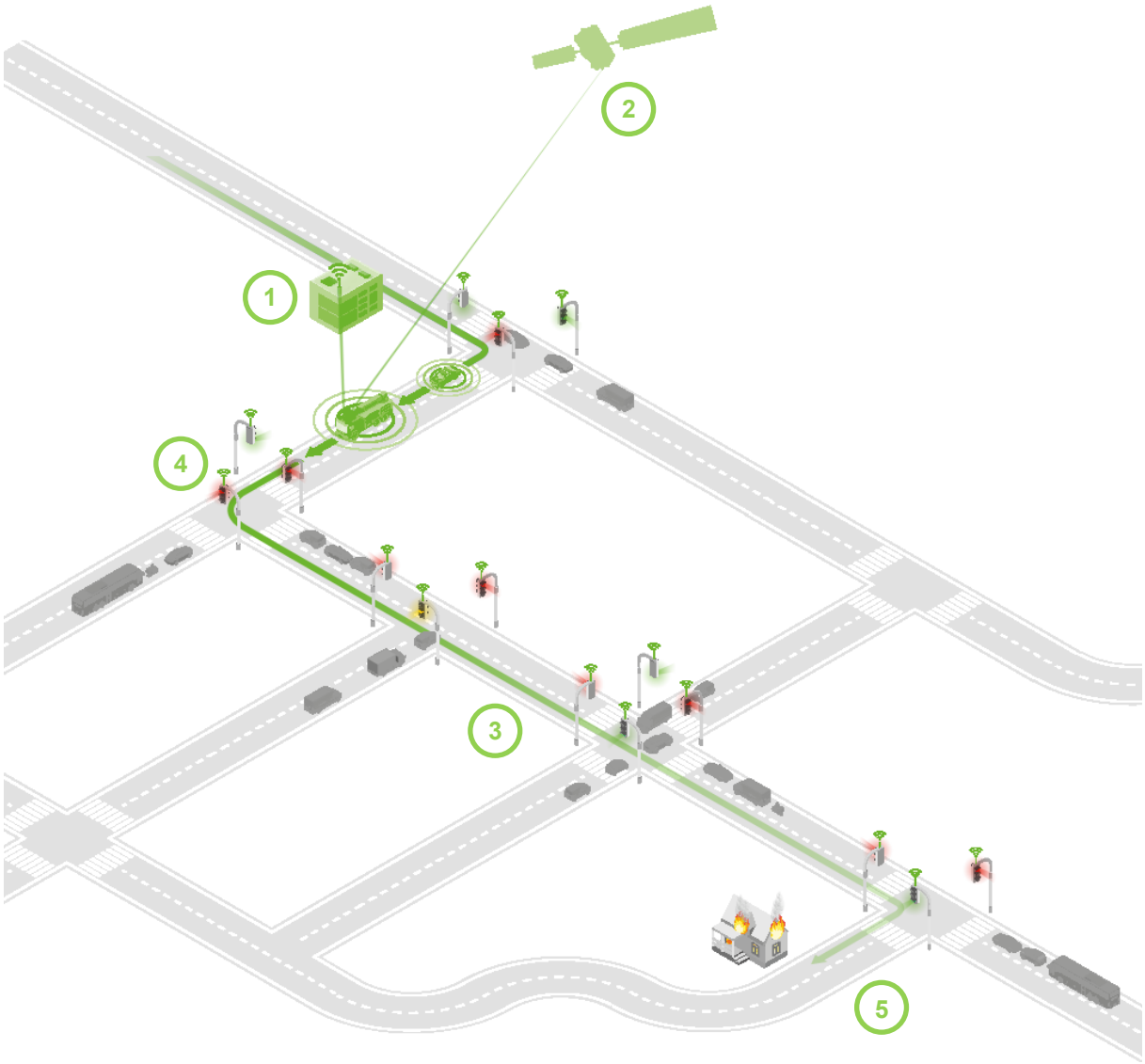

Figure 3 – Process of a preemption within the HALI system.

Inner-city testbed

The inner-city district of Berlin-Moabit was selected as the testbed for the HALI system. The fire brigade and police stations are located in this densely built-up area with streets that get congested regularly. Deep urban canyons make it difficult to receive satellite signals. These conditions represent an ideal and realistic test environment for the Galileo PRS system. The five equipped emergency vehicles are all used regularly within the Moabit district. In order to be able to implement the prioritisation triggered by the HALI system in the field, eight traffic lights were technically upgraded. This included establishing a secure connection to the HALI server and importing special signal programs. For this purpose, each traffic light in the field was equipped with an industrial mini PC (IPC), which communicates with the HALI server and can receive switching requests for preemption. To forward the received switching requests to the traffic light, the IPC was connected to the signal

controller unit via a Modbus module to create a communication interface. Several special signal programs were deployed to each traffic light, which support and represent the most frequently used driving relations of emergency vehicles at an intersection. These special signal programs were created individually for each intersection and approved by the Berlin traffic management authority before applying. Whenever the HALI server sends a request to activate one of the special signal programs, the IPC accepts this request and uses the Modbus module to set a specific pin on the signal controller unit. The signal controller unit reads this pin and, depending on which pin was set, runs the associated special signal program for the preemption of the approaching emergency vehicle.

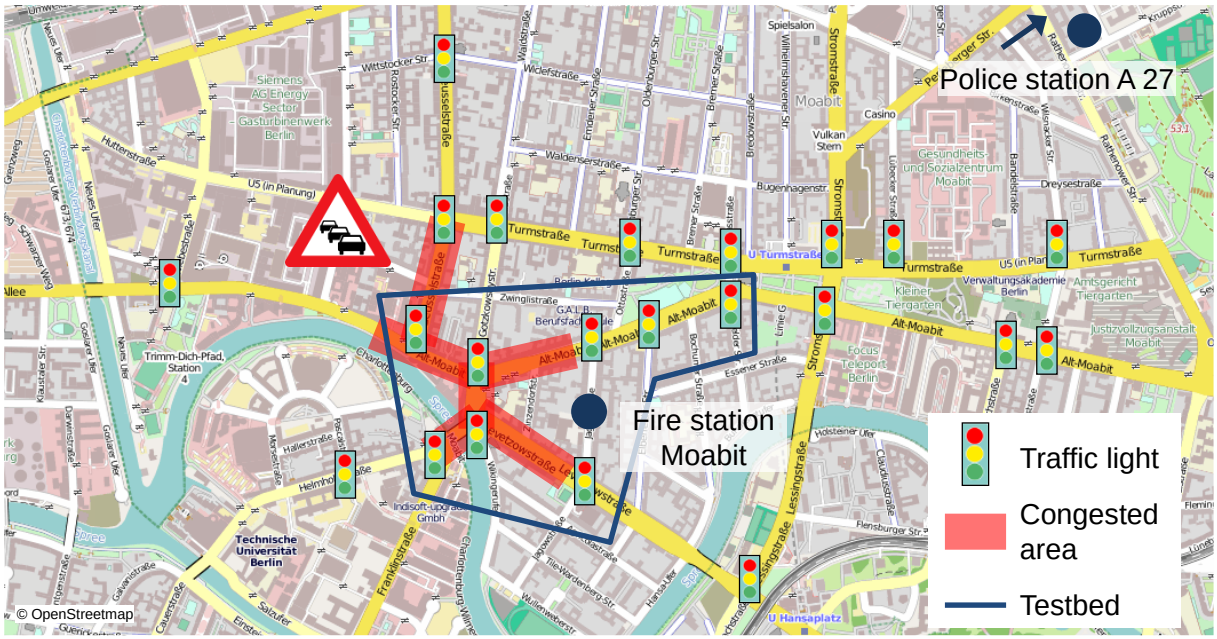

Figure 4 – HALI testbed in the inner-city Berlin-Moabit district.

Test runs and validation

The whole system, comprising the five with Galileo PRS equipped emergency vehicles, the eight controllable traffic lights and the central HALI server in the background, underwent several weeks of a first testing by the Berlin fire brigade and Berlin police. During testing, the precision of the determination of vehicle positioning was examined in day-to-day operations, as well as the quality of registration and de-registration at the traffic lights and resulting travel times. Figure 5 shows a comparison of travel times for 17 trips with active HALI preemption and 23 trips without any preemption. In principle, the HALI system enables shorter travel times. The overall variance in travel times is less for trips with HALI preemption. However, the mean values of the travel times with and without preemption hardly differ from each other. This is due to the still very small number of observed comparable trips. Within these initial operational trials, the HALI system proved its effectiveness. The receivers provided sufficiently precise vehicle positions based on Galileo PRS for effective traffic light preemption (see Figure 6). Data from the vehicles' inertial sensor systems, such as odometers and inertial measurement units, ensured that the emergency vehicles could be precisely located even in the case of satellite signal disruption, e.g. in a tunnel.

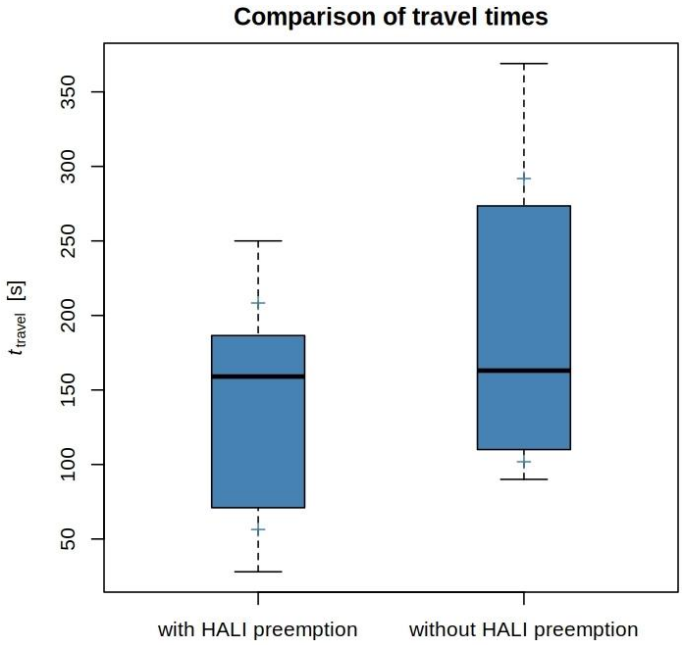

Figure 5 – Comparison of mean travel times for several emergency trips with/ without active HALI preemption.

The results showed that emergency journeys from the Moabit fire station could maintain higher speeds, with reduced travel times and a decreased number of stops for the emergency vehicles. With consistent green lights, unnecessary breaking and acceleration at intersections could be avoided, while safety during crossings was significantly increased, not only for the emergency vehicles but for all road users. For the police similar experience were reported, although police vehicles are often on patrol and therefore do not start at their station.

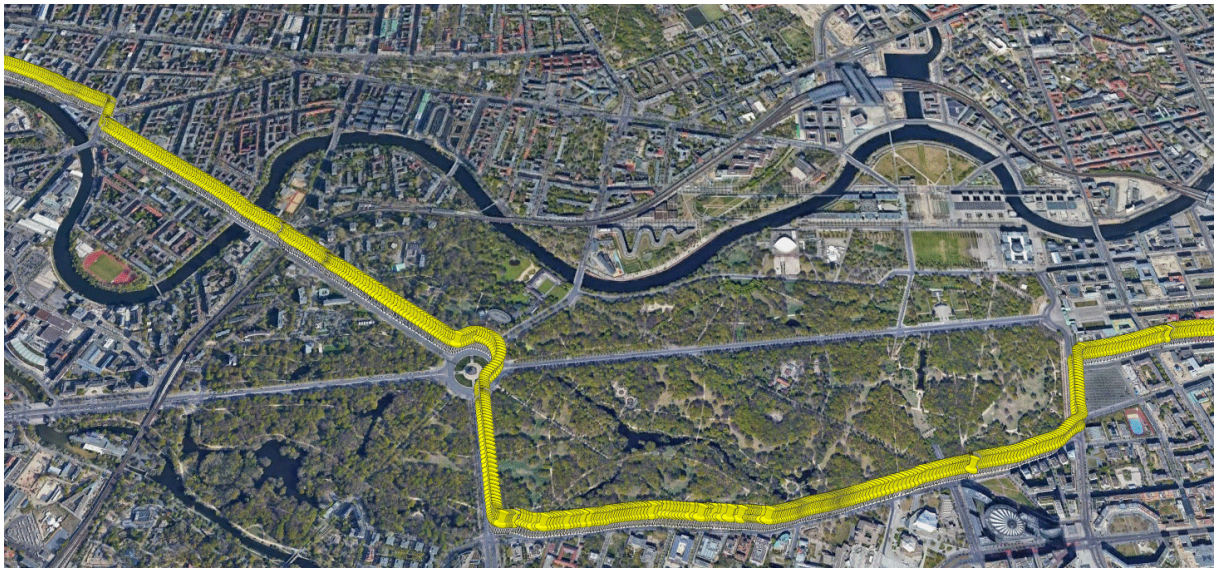

Figure 6 – Accurate tracking of an emergency vehicle based on Galileo PRS positioning in Berlin.

Outlook

Due to these promising first results, the Berlin fire brigade and police have called for a long-term test to further refine the HALI system. This long-term test is currently still running. As part of this long-term test, some improvements are still being made to the components of the HALI system, especially to the Galileo PRS receivers. The experiences and opinions of the emergency service personnel are also incorporated to improve the technology to a degree where it can be transferred to other emergency vehicles, traffic light systems, as well as to other municipalities. In addition, various data are still collected over a long period of time in order to make the effects observed so far more verifiable with a wider range of statistical figures. These figures will become available in the coming months and can then be evaluated in a detailed analysis. At this point in time, it can already be stated that precise, fail-safe position location of emergency vehicles combined with an intelligent traffic light preemption system can make day-to-day emergency service operations considerably easier, faster and safer.

Acknowledgement

The authors would like to thank the Federal Ministry for Digital and Transport for financial support, and the city of Berlin, the Berlin Police and the Berlin Fire Brigade for providing the location and vehicles for testing, and the always open and friendly support in the implementation. This work has been carried out within the HALI-Berlin project, funding codes 50NP1702 and 50NP1703, sponsored by the Federal Ministry for Digital and Transport within their national PRS Program.

References

1. Oertel, R., Eggers, K. J., David, H., Lehmann, H., and Hesse, M. (2021) *Intelligent Cooperative Intersection for Future Urban Traffic in Hamburg*. 27th ITS World Congress, 11.-15. Oct. 2021, Hamburg, Germany.
2. Oertel, R., Erdmann, J., Mann, A., Trumpold, J., Wagner, P., 2016. *VITAL - Vehicle-Actuated Intelligent Traffic Signal Control: Validation of two new Control Approaches in the Field.* In: Proceedings - 11th ITS European Congress. ITS European Congress 2016, 06.-09. June 2016, Glasgow, Scotland.
3. Oertel, R., Erdmann, J., Hesse, T., Markowski, R., Trumpold, J., and Wagner, Peter (2017). *VITAL: traffic signal control based on C2I communication data – application and results from the field.* In: Proceedings - mobil.TUM 2017 - Intelligent Transport Systems in Theory and Practice, 04.-05. Jul. 2017, Munich, Germany.
4. Osenberg, H., and Oertel, R. (2021) *Rescue services surf a green wave – Uninterrupted journeys for emergency vehicles with innovative Galileo satellite navigation technology*. DLR COUNTDOWN, 02/21 (41), pp. 79-87, German Aerospace Center (DLR), ISSN 2190-7072.
5. Wendel, J., Schubert, F., Rügamer, A., Neumaier, P., Garzia, F., Sommer, P., Rohmer, G., Sgammini, M., Konovaltsev, A., Meurer, M. and Baumann, S. (2013). *BaSE: Development of a Galileo PRS Receiver*. In: Proceedings of the 6th European Workshop on GNSS Signals and Signal Processing, Munich, Germany.

6. Rügamer, A., Neumaier, P., Sommer, P., Garzia, F., Rohmer, G., Konovaltsev, A., Sgammini, M., Meurer, M., Wendel, J., Schubert, F., and Baumann, S. (2014). *BaSE-II: A Robust and Experimental PRS Receiver Development Platform*. In Proceeding of ION GNSS+ 2014. The Institue of Navigation. 27th International Technical Meeting of the Satellite Division of the Institute of Navigation (ION GNSS+ 2014), 8.-12. Sept. 2014, Tampa, Florida, the USA.

7. Rügamer, A., Stahl, M., Lukčin, I., and Rohmer, G. (2014). *Privacy protected localization and authentication of georeferenced measurements using Galileo PRS.* 2014 IEEE/ION Position, Location and Navigation Symposium - PLANS 2014, Monterey, CA, 2014, pp. 478-486.

8. Rügamer, A., Garzia, F., Meister, D., Merwe, J. R., Taschke, S., Zubizarreta, X. Kunzi, F., Plata, R. M. G., Urquijo, S., Miksovsky, Ch., Felber, W., Wendel, J. (2020). *Enhanced Robustness and Spoofing Resistance by Galileo PRS Processing*. In: Proceedings European Navigation Conference 2020, 23.-24. Nov. 2020, IEEE online conference.

9. Talvi, J. (2015). *Always green for emergency vehicles*. TRAFIK & VEJE, Sep. 2015, pp. 32-34.