POTENTIAL OF A GALILEO TEST ENVIRONMENT FOR RAIL APPLICATIONS

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1. Abstract

The introduction of the European navigation satellite system Galileo promises advantages in terms of accuracy, availability and reliability compared to today's systems, like GPS and GLONASS. These advantages can be essential when using global navigation satellite systems (GNSS) in safety critical applications. Presently RWTH Aachen University is building two Galileo test facilities within the project 'Galileo above'[1]. These facilities offer the opportunity to develop innovative GNSS-based applications for automotive and rail prior to the launch of the Galileo system. In this paper special topics of Galileo are introduced in general and the Galileo testbed 'railGATE' is presented. An initial project dealing with automated shunting operations is described.

2. Introduction

2.1. Galileo

In addition to GPS and GLONASS, which were established as military systems, Galileo is the European GNSS with focus on civil use. Presently the system is being built and FOC (full operational capability) is expected in 2016. Galileo will be the first system with guaranteed availability. Beside the Open Service (OS), special services for commercial users are provided by the Commercial Service (CS).

It is crucial for safety critical applications to have reliable information. Galileo is planned to provide integrity information integrated in the system. This service will be called Safety-of-Life-Service (SoL).

Considering the described features, Galileo will be a step towards applications that will use safety critical position information. The use of Galileo within train control systems, for instance, is expected to result in an augmentation of line capacity and a reduction of infrastructure costs.

RWTH Aachen University intends to contribute to the use of satellite navigation in safety critical applications like train control. Therefore the Galileo testbed railGATE [1] is currently being built. It is part of Galileo above, a project dealing with the construction of two testbeds for automotive and rail. These testbeds permit the evaluation and testing of Galileo-based applications that demand high accuracy and high reliability of the GNSS signal. The aim of the linked initial projects is to show the potential of train control with GNSS.

2.2. Potential for railways

Like in other modes of transport Galileo has potential for safety critical applications in the rail sector, too. Presently applications based on GNSS can only be found in non-safety critical areas, like passenger information systems and traffic management, energy and fleet management. [2]

High requirements with regard to accuracy, availability and reliability have to be met when using GNSS signals in the railway domain. Track selective positioning is essential for many applications. 2 m accuracy is necessary for a usual track distance of 4 m. This can be achieved by augmentation systems and sensor fusion. The availability of the position information can be augmented by exploiting the characteristic of rail-bound traffic, namely the movement in one dimension along the track. Together with a digital track map, fewer satel-

[1] Sponsored by the Space Agency of the German Aerospace Centre (DLR) with funding by the Federal Ministry of Economics and Technology, in compliance with a resolution of the German Parliament (project/grant no. 50 NA 0902).

lites are needed to calculate the position solution.

A safety critical application for Galileo in the rail sector is train control. In higher levels of the European Train Control System (ETCS) a train needs to determine its position autonomously. The combination of Galileo with an odometry platform is a reasonable alternative for existing systems, especially on regional lines [3]. Between 2005 and 2008 the GRAIL consortium developed a strategy for the introduction of GNSS in the rail sector particularly for ETCS, funded by the Galileo Supervisory Authority (GSA) [4]. The consortium revealed potentials concerning the enhancement of the odometry platform accuracy, as well as train integrity check.

Another use case for GNSS in the railway domain is being developed by the German Aerospace Centre (DLR), especially for regional lines. The Railway Collision Avoidance System (RCAS) was presented in May 2010.

The feasibility of an automated shunting system based on GNSS will be demonstrated at RWTH Aachen University. The first steps are described in section 5.

3. Galileo Testbeds

To establish the use of GNSS sensors in safety critical applications, still a large research effort has to be made. To contribute to this work, Galileo test environments are built. The Space Agency of the German Aerospace Centre (DLR) funds the installation of Galileo Test Environments (GATEs). There will be five GATEs in Germany. Each has a different focus. The GATE in Berchtesgaden [5] is the first GATE in Germany and is operational since 2008. The focus is mainly the development of receivers and applications in general. Users have the chance to test their equipment with regard to Galileo specification. In the sea port of Rostock maritime Galileo applications can be tested with the Sea Gate. Within the project a Galileo-based docking assistant was developed for the "Mecklenburg-Vorpommern" ferry as a reference application. The application is based on the Sea Gate's accuracy of 0.5 m. In the research airport of Braunschweig the aviationGATE is being installed and will be in regular service at the end of 2010. The focus of aviationGATE is the use of Galileo pseudolite systems for the start and landing phase of planes.

4. The railGATE

For the project railGATE RWTH Aachen University is building a so-called pseudolite system. This system allows positioning with a specified accuracy of 0.8 m (1σ, carrier phase solution); the update rate will be 20 Hz. Complex scenarios can be demonstrated in the test environment because of the system's ability to serve multiple users. The pseudolite transmitters will be placed on poles that already exist or have to be erected. The new poles will have a height up to 60 m in order to guarantee an optimal coverage of the test area. Applications can be tested in the test environment before the start of Galileo. After FOC, the system can also be used as an addition to Galileo. Applications can be tested in arbitrary and reproducible scenarios.

The railGATE will be installed in the Siemens Test- and Validationcenter Wegberg-Wildenrath (PCW, [6]). PCW is used by many European manufacturers for testing not only vehicles but also infrastructure elements. On its 28 km of railway tracks the PCW allows tests of nearly any kind of vehicle, from trams to high speed trains, under realistic conditions and independent of constraints encountered on regular tracks. Therefore PCW offers ideal conditions for research activities.

Figure 1: Siemens Test- and Validationcenter Wegberg-Wildenrath, © Siemens AG

Figure 2 shows the track system of PCW as well as the position of the eight pseudolite poles. A special challenge is the partly dense vegetation of the area. For railGATE six of eight poles have to be newly erected. First system tests are planned for springtime 2011. railGATE is expected to be fully operational in autumn 2011.

4.1. Technical Properties

Like regular navigation satellite systems railGATE is divided into three segments:

- transmitting segment / space segment
- user segment
- monitor and control segment

A wireless network will be installed for communication purposes. All components send their data to a central server that records all data for replay and evaluation of tests.

A. Transmitting segment / space segment
RailGATE consists of eight pseudolites, which cover the area with signals similar to the Galileo SIS ICD. The message broadcast by the pseudolites is freely scalable and thus can be adapted to specific application purposes. A pseudolite consists of the components:

- Galileo signal generator
- Timing unit for synchronizing individual pseudolites among each other
- Communication component for communication between the pseudolites and the control station

B. User segment
In the user segment standard Galileo receivers are used, that are capable of receiving the pseudolite signals. The raw data is processed by a computer-based evaluation unit that calculates the user position. Presently no navigation message is defined for local elements in the SIS ICD. Therefore the user segment needs the information of the pseudolites' position to be able to calculate a user position from the pseudorange measurements. This is done by the evaluation unit. The data is then provided to a user in the standard NMEA format. The user segment calculates actual data on time, position, speed and direction of the user's motion. The user segment has to work in a rough environment, therefore it will be a compact and robust mobile box, that can be installed on any kind of ground-based vehicle. Additionally the user segment can use multiple data sources. It can combine pseudolite and GNSS satellite data. For example, these modes of operation include information from GPS satellites and EGNOS in any reasonable combination.

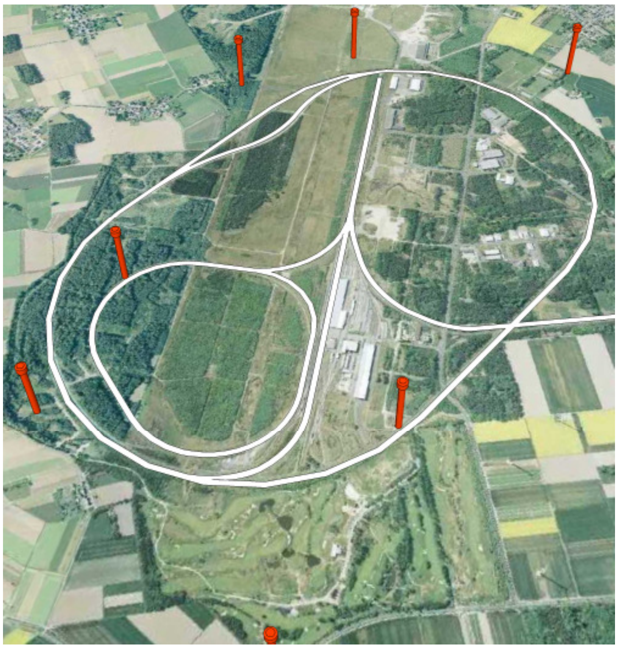

Figure 2: Illustration of the railGATEs pseudolites, © RWTH/IRT

C. Monitor and control segment (MCS)
The MCS consists of a reference receiver within the testbed and a central server that records and analyses data. It monitors and controls the pseudolites in terms of timing, e.g. It can also provide information for a differential working mode of the system. The MCS can influence and degrade the system purposefully, if a special GNSS scenario is needed. The incoming data is visualized. For example it will be possible to monitor the position of each receiver in the testbed. Relevant system data, like accuracy are also shown to the operator.

5. Initial project

The initial project rail has two focuses. First it has to proof the proper function of railGATE; secondly it is a first step towards the use of Galileo pseudolites in a rail application. The project goal is an accurate satellite-based stopping at a defined point. This is a basic function of the automated shunting system described in [7]. To make the transport of cargo on rails more attractive, the project's goal is to optimize the shunting process on small railroad lines. The main part of cargo is processed in few huge and highly automated shunting yards. Because of the high degree of automation these yards are highly efficient. When transporting small amounts of cargo long retention times in the shunting yards decrease the attractiveness of this mode of transport. The efficient marshaling in small, local yards seems to bring advantages in certain constellations. These advantages can be increased if labour cost can be reduced when the process is further automated. Considering that rail-bound systems are suitable for automation because of their specific properties, the development of an automated shunting system is obvious.

Figure 3: Test Vehicle of RWTH Aachen, © RWTH/IFS

The system will be semi-automated in the first implementation, which means that the shunting operation is done automatically, but every task will be acknowledged by an operator before it is executed. The system is subdivided into three parts. A disposition system is the main controller of the system. It optimizes the system's actions and sends information to the other components. The other components are the shunting locomotive with its controller and the Human-Machine-Interface (HMI). The HMI is a handheld computer that an operator uses to interact with the system. All components are connected to each other by wireless radio. The shunting locomotive receives shunting tasks, which are autonomously fulfilled by the controller. The safety of the automatic shunting system depends on the ability of the locomotive to accurately stop at a predefined point. This guarantees, that a locomotive stops exactly at a car, so it can e.g. be coupled without further actions. The research is presently done at the Institute of Automatic Control of RWTH Aachen University in cooperation with the Institute of Railway Systems. For the project a test vehicle is used.

The vehicle is equipped with a Diesel aggregate and a control unit that executes the driving commands. The control unit is a rapid control prototyping system, which can be adapted and programmed quickly. The test vehicle has a large variety of sensors, which can be used for control algorithms. Based on the sensor information the locomotive's movements are influenced. Beside a GNSS receiver (presently GPS, it will be replaced by a railGATE Galileo receiver) the sensors are an optical velocity sensor, a wheel pulse sensor and an inertial measurement unit. Furthermore it has to be figured out which sensors have to be used in addition to the satellite signal to provide the required system performance. At the railGATE test environment, the robustness of the system in different error scenarios will be tested.

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