



**HAL**  
open science

## Innovative simulations of GNSS performances in a realistic railway environment

Juliette Marais, Cyril Meurie, Amaury Flancquart, Simon Lithgow, George Barbu

► **To cite this version:**

Juliette Marais, Cyril Meurie, Amaury Flancquart, Simon Lithgow, George Barbu. Innovative simulations of GNSS performances in a realistic railway environment. CERGAL, International Symposium on Certification of GNSS Systems & Services, Jul 2014, Dresden, Germany. 5p. hal-01054770

**HAL Id: hal-01054770**

**<https://hal.science/hal-01054770v1>**

Submitted on 29 Oct 2024

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

# Innovative simulations of GNSS performances in a realistic railway environment

Juliette Marais<sup>\*</sup>, Cyril Meurie<sup>\*</sup>, Amaury Flancquart<sup>\*</sup>, Simon Lithgow<sup>\*\*</sup>,  
George Barbu<sup>\*\*\*</sup>

<sup>\*</sup> Univ Lille Nord de France, F-59000 Lille, IFSTTAR, LEOST, F59650, Villeneuve d'Ascq, France  
email: [Juliette.marais@ifsttar.fr](mailto:Juliette.marais@ifsttar.fr)

<sup>\*\*</sup> Spirent Communications plc, UK  
email: [Simon.Lithgow@spirent.com](mailto:Simon.Lithgow@spirent.com)

<sup>\*\*\*</sup> Union Internationale des Chemins de fer, Paris, France  
email: [barbu@uic.org](mailto:barbu@uic.org)

***Abstract:** The SATLOC project aims at demonstrating an innovative concept of applying the GNSS to railway safety and advanced operation on low traffic lines. One of the issues is to determine if GPS, Galileo and EGNOS are available along the track and can answer to the railway requirements even in the presence of masking obstacles along the track. This paper presents the simulation approach developed by Spirent and Ifsttar in order to simulate GNSS signals in a realistic masking environment known by image acquisition and processing. The paper illustrates the concept with results obtained at a tunnel output near to Brasov, Romania, and concludes with perspectives that could enrich the results, in particular by including multipath effects and not only line-of-sight satellites.*

## 1. Introduction

The potential to use Global Navigation Satellite Systems (GNSS), including the European Galileo satellite navigation system, in the railway environment offers significant potential advantages including vision to increase safety and efficiency through replacement of track-side signalling with on-board systems. Benefits include improved safety, management information and increased use of existing infrastructure. To realise this vision, controlled and progressive test approaches need to be planned, implemented and delivered. The potential to use laboratory based simulation has been recognised as a way to test in a wide range of situations including nominal, extreme and error conditions.

## 2. The SATLOC project

The SATLOC project is an FP7 project, item Galileo.2011.1.4-1 "Use of EGNOS and GALILEO for safety-of-life applications for all transport modes". The global project objective is to develop and demonstrate the innovative concept of applying the GNSS to railway safety and advanced operation on low traffic lines aiming at:

- Stimulate adoption of EGNOS in new innovative rail operation with important market impact and with important effects on socio-economic, mobility and environment.
- Prepare markets for Galileo introduction since EGNOS is the precursor of GALILEO and enablers will be created including the awareness and preparation of the railway to immediately apply the new system.
- Stimulate EU GNSS industry competitiveness in domains which are reputed (railway safety, railway integrated operations).

The overall objective provides live demonstration, validated and certified under the EU ruling and applied on the line Brasov – Zarnesti of the RCCF-TRANS (Romania).

This paper focuses on one of the objectives within the project that is to develop innovative tools for assessment, proof and validation of safety and the optimal use of GNSS and radio in locally determined conditions. Indeed the main objective of WP4.2 is to demonstrate the SATLOC concept exportation capability based on performance assessment of GNSS in any railway intended environment. The goal is to demonstrate how GNSS receivers can be exercised under a variety of conditions, using real obscuration data from actual railway routes.

### **3. The SPIRENT/IFSTTAR tool**

The tool is based on collaboration between IFSTTAR and Spirent.

#### **The image-based environment knowledge**

In 2000, IFSTTAR has developed the PREDISSAT tool that provides captured data from real railway environments, specifically mask angles of embankments and other obstacles. Data are fish-eye images acquired with a camera oriented towards the sky in order to present the same “view” than the GNSS antenna. The image processing algorithms developed in this project, by the laboratory, detect automatically the horizon line, i.e. the pixels separating the sky area and the masking obstacles [1]. The pixels separating sky and non-sky areas are drawn in red on the right image in figure 1 and can be translated into elevations all around the antenna after characterization of the distortion caused by the lens of the camera. For each azimuth around the antenna, the height of obstacles is then quantified (in terms of elevation degrees).

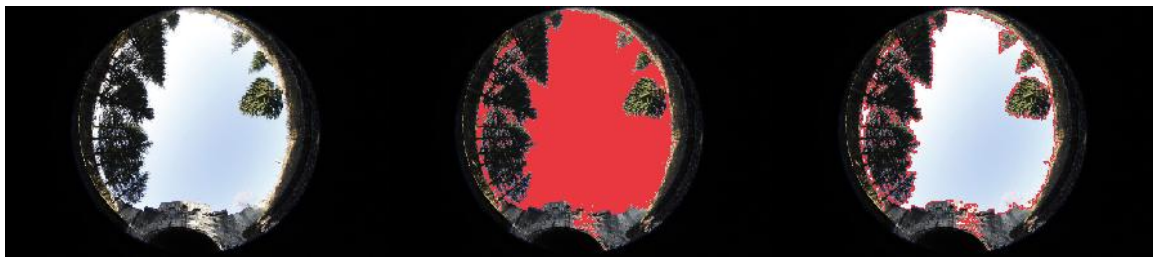


Figure 1. Fish-eye images and processing: acquired image (left), image with sky detection in red (middle), image with horizon line in red separating sky and non-sky areas (right).

Considering the image processing and the calibration process, a masking matrix is created. The matrix had a  $5^\circ$  resolution which matched the resolution of the Spirent category mask.

#### **The GNSS simulator**

A GNSS simulator produces a full constellation of GNSS satellites to the appropriate SIS-ICD. It reproduces the environment of a GNSS receiver on a dynamic platform by modelling the vehicle and satellite motion, signal characteristics, multipath, obscuration and other effects. The Spirent simulator control software, SimGEN allows extensive manipulation of many parameters, including the use of external data to manipulate the satellite signals and receiver environment.

The interests of the simulation of a receiver under real RF signals are the following:

- It reproduces the trajectory of a railway line.
- It reproduces the signal obscuration as measured by the PREDISSAT tool [2, 3].

- It allows different satellite constellation arrangements (and hence satellite obscuration) to be simulated.
- It allows 100% repeatability of the test, which is impossible using real field-trials due to the advancement of time and un-repeatable environmental conditions.

The Spirent GSS6700 was used to provide L1 signals for all three constellations at levels equivalent to live sky. The Septentrio RX3 receiver was connected by direct RF connection (figure 2). The test programme required that scenarios were developed using the hemispheric sky view images along with the obscuration matrix supplied, 5 degree resolution was requested in order to match the resolution of the Spirent obscuration mask.

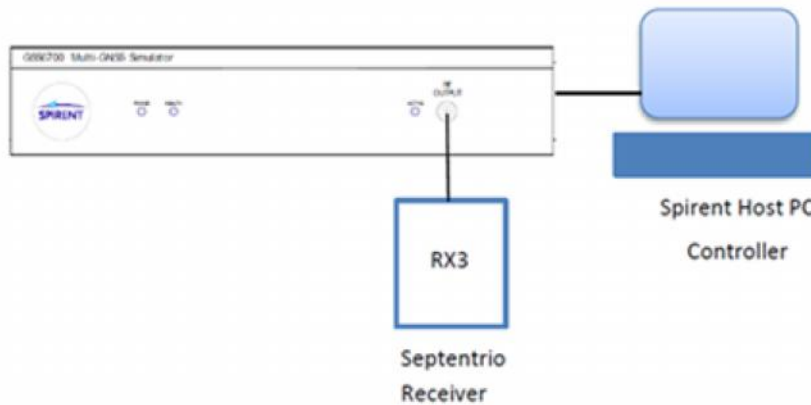


Figure 2. SATLOC Receiver Setup diagram

Translating the result of image processing into a matrix will give a representation on multipath and obscuration for a given location. Figure 3 represents how the masking matrix is used in the simulator. Only values for Line of Sight (LOS) and obscuration have been used for the category mask.

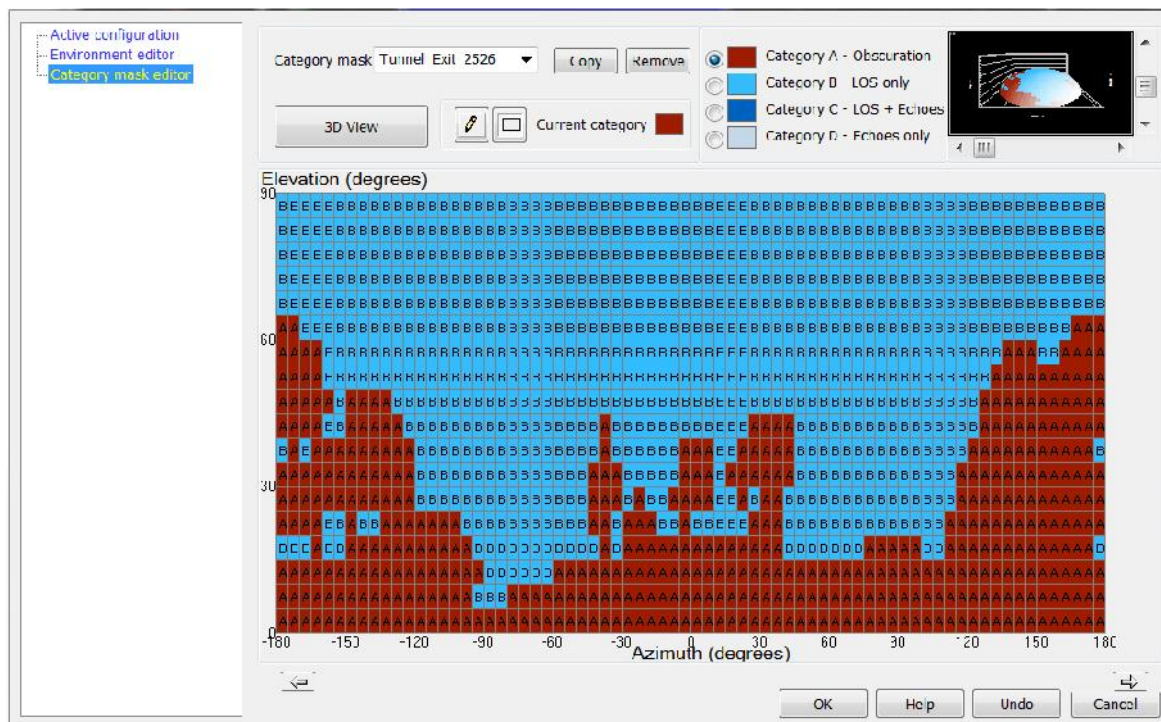


Figure 3. Model of masking and multipath effects in the SimGen software

In the project, scenarios have been built using Spirent’s SimGEN software suite by simulating signal conditions in a controlled and quantified way.

A hemispheric antenna pattern was used for all scenarios. The antenna was set at a height of 4m. The receiver used is the Septentrio PolarX3.

**Results**

The scenarios are static, and are developed for three signal types:

- 1. GPS + Galileo + EGNOS
- 2. GPS + Galileo
- 3. GPS + EGNOS

The simulation used PosApp software to model the obscuration picture for the GNSS antenna over time from a fixed location. This has been done utilising the land mobile multi path feature of the software and the antenna attenuation pattern editor to model the conditions. It was assumed the obscuration data was captured from a position that represents the level of the top of the train engine and represented the centre of the track. The duration of each scenario was 12 hours, in order to simulate a full constellation change over. A GPS almanac file was loaded to match the scenario date so that a realistic constellation pattern was in view. A full future constellation was simulated rather than the current limited constellation.

For each scenario, the outputs are: the total number of satellite in view, the number of tracked satellites and the average signal to noise ratio, as well as the receiver plan error.

The results corresponding to the point represented in figure 1 are summarized in table 1.

Satellites simulated	Results
12 Hour duration GPS up to 9 Galileo up to 12, EGNOS 3	Maximum satellites in view 16 minimum 10. Maximum tracked 9 minimum 3 Maximum plan error 2.76m
12 Hour duration GPS, Galileo	Maximum in view 23, minimum in view 16. Maximum tracked 9, minimum tracked 3. Maximum plan error 1.42m
12 Hour duration GPS, EGNOS	Maximum in view 23 minimum in view 18 Maximum tracked 9, Minimum tracked 3 Although the plan error plot looks drastic the resultant maximum plan error is 3.68m

Table 1. Availability and accuracy results

From the simulation, GNSS performances will be analysed considering real masking environments but with the possibility to make changes within the constellation, the time or to observe the behaviour of the receiver faced to failures in realistic environments.

Here are the conclusions:

- 1. The Railway presents a challenging GNSS environment due to the high chance of obscuration and multipath signals. It is not yet known what is considered an acceptable figure of plan error for the railway industry. Plan error experienced did not exceed 6.5 meters in a 12 hour period. Spherical error is slightly higher. This will incorporate an error in the height value given by the receiver. This set of tests did not demonstrate an advantage of using a

multi constellation receiver over a single constellation receiver. Extended testing would explore the advantages of the use of SBAS signals.

2. The receivers NMEA GSV message provides a reliable figure for satellites in view and associated signal to noise figures the NMEA GPS satellites in view ranged from 9 to as few as 4.

3. Signal to Noise levels remain constant throughout the 12 hour period. There is no apparent difference in receiver accuracy between the scenario runs where GPS and EGNOS and/or Galileo are tracked. This is due to the receiver set up. Further testing would reveal what ratio of each constellation is being used to provide the PVT solution.

#### **4. Conclusions**

The SATLOC project aims at demonstrating along a real railway line that GNSS-based absolute positioning can be used in trains for primary safety in a control application. However, the demonstration of exportability of the concept with real data is time consuming and expensive as it requires access to the operational railway. This is the reason why a combination of image acquisition and simulation has been developed in order to re-produce the trajectory and obscuration as recorded by the data. The tool allows us to repeat exactly, time and again, or re-run with many different parameters (satellite constellations, atmospheric conditions, multipath, interference etc.) but without the need to go back onto the operational railway.

- Compared to the results presented above, some perspectives are identified to enrich the study: Motion based scenarios will serve useful for exploring how quickly a trains PVT solution will recover after a period in a tunnel or prolonged period of obscuration.
- The addition of multipath (MP) areas to the category mask will make the scenario more realistic. Multipath signals could lead to the degradation of the Position accuracy of a receiver, it is difficult to give an accurate figure for the level of degradation, some receivers are better at discriminating against MP signals than others.

Moreover future testing will allow the comparison of different receivers as well as the use of inertial and gyro aided systems.

This approach aims to reduce significantly application certification costs and timescales, which is an important consideration in the current economic climate.

#### **Acknowledgments**

This work has been performed within the SATLOC project funded by FP7 and thanks to CISIT support.

#### **References:**

- [1] Juliette Marais, Cyril Meurie, Quantify and improve GNSS quality of service in land transportation by using image processing, First CNES-ONERA Workshop on Earth-Space Propagation, ONERA, Toulouse, France, 21-23 January 2013
- [2] Juliette Marais, Amaury Flancquart, Sébastien Lefebvre, Satellite availability in a railway mountainous environment: can we use satellite positioning for safety applications? World Congress on Railway Research (WCRR), Montréal, 2006.
- [3] Dr. Juliette Marais, Sébastien Lefebvre, Dr. Marion Berbineau, Satellite Propagation Path Model along a Railway Track for GNSS Applications, IEEE Vehicular Technology Conference, (VTC 2004), Los Angeles, Sept. 2004.