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0.3		▪ OBB Scenario
0.4		▪ FGC Scenario
0.5		▪ Pictures in chapters 4 and 6 (Unai Alvarado, CEIT)
0.6		▪ Review of chapter 4
0.7		▪ Update Chapter 5, with test scenario details and pictures (Smita Tiwari, GMV NSL) ▪ Formatting updates (Madeleine McCreadie, GMV NSL) ▪ Update chapter 4, TELICE activities (Iván Rivera, TELICE)

HISTORY OF CHANGES		
Version	**Publication date**	**Change**
1.0	28/07/21	First version of the D8.1 ready for internal review.
2.0	29/08/21	Second version including internal review (contributors)
3.0		Third version including internal review (all partners), ready for external review (EUSPA)

Executive Summary

The SIA system subsystems to monitor the wheelset, rail, pantograph and catenary have been tested in three different scenarios. The present document describes the work carried out in relation to the installation and planning of the testing activities and the testing conditions.

The SIA system to monitor the interaction between the pantograph and catenary has been tested in a real railway operating environment in Ferrocarrils de la Generalitat de Catalunya (FGC). The main objective of this testing activity is to collect data for the validation of the developments. More precisely the monitoring system is composed by several accelerometers installed in the pantograph. By means of several models developed in the project indirect calculations are done to obtain the following information with the correct geo positioning data:

- The height and misalignment of the catenary
- The contact force of the pantograph

After several iterations of the installation plans, one of the main focuses for the test conditions are to ensure the safety of the railway systems and their components. The SIA components have been installed according to our plans in various types of railway vehicle and several sets of data have been collected for the testing activities. Further details of the test results are detailed in deliverable D8.2. During the testing, additional activities were done at FGC in order to obtain real conditions of the catenary to be able to calibrate the system.

The SIA system in relation to the monitoring of the interaction between the wheel and rail was tested in an operational railway environment in Österreichische Bundesbahnen (OBB), Austria.

It should be taken into consideration that due to restrictions imposed due to the COVID-19 pandemic testing was done in two phases. The first part of the testing was done at the end of 2020/beginning of 2021 with VIAS (this testing was carried out in a maintenance railway vehicle between Madrid and Seville on the high-speed line). Furthermore, the system to monitor the interaction between the rail and wheel was installed in a passenger train with OBB and DLR (without a full SIA-POS).

The second phase was done in mid-2021 when the positioning system was tested further in a FGC passenger train and an OBB locomotive.

Table of Contents

Abbreviations and acronyms

Acronym	Description
FGC	Ferrocarrils de la Generalitat de Catalunya
BV	Barcelona – Vallès line from FGC.
SIA_PANT	Pantograph/catenary interaction assessment subsystem
SIA_ABA	Wheel/rail interaction assessment subsystem
SIA_POS	Positioning subsystem
SIA_DH	Data Hub
SIA_CDM	Component Degradation modelling and algorithms
SIA_VP	Visualization Platform

Introduction

1.1 SIA Overview

The SIA project (System for vehicle-infrastructure Interaction Assets health status monitoring) has the objective of developing four ready-to-use new services (iWheelMon, iRailMon, iPantMon and iCatMon) to provide prognostic information about the health status of the railway's most demanding assets in terms of maintenance costs (wheel, rail, pantograph and catenary).

1.2 Purpose and Scope of this Document

The main purpose of this document is to detail and report the different phases of the tests of the developed system that are being carried out in the proposed different operational environments.

The organization and performance of each test comprises of different phases that are explained inside each section of this document, one section for each operational environment. The phases comprise, first of the context of the real operational environment, following that the installation details of the different components and their installation requirements. Hereinafter the organization of the installation and testing inside the operational environment that has to be carefully planned and finally the expected outputs of the testing are explained.

1.3 The Intended Audience and Distribution

This is a public deliverable, the reader should be aware that not all details are revealed here, for in depth details see reference deliverables: D3.2 for the SIA-POS hardware and software and D4.1 for the SIA-ABA and SIA-PANT hardware and software.

1.4 Structure of the Document

This document is divided in three main parts where the different testing scenarios are described. Each scenario includes an introduction, the details of installation and the planning carried out to make the tests possible.

These three parts are preceded by an introduction and the architecture review and are out closed with the conclusions.

Architecture Overview

According to the deliverable D2.2, and to fulfil the requirements defined in D2.1, the following sub-systems have been defined for the SIA system:

- Pantograph/catenary interaction assessment subsystem (SIA_PANT)
- Wheel/rail interaction assessment subsystem (SIA_ABA)
- Positioning subsystem (SIA_POS)
- Data Hub (SIA_DH)
- Component Degradation modelling and algorithms (SIA_CDM)
- Visualisation Platform (SIA_VP)

As a visual representation of the above subsystems, the following diagram has been created to define the overall architecture and the associated interfaces of the SIA system.

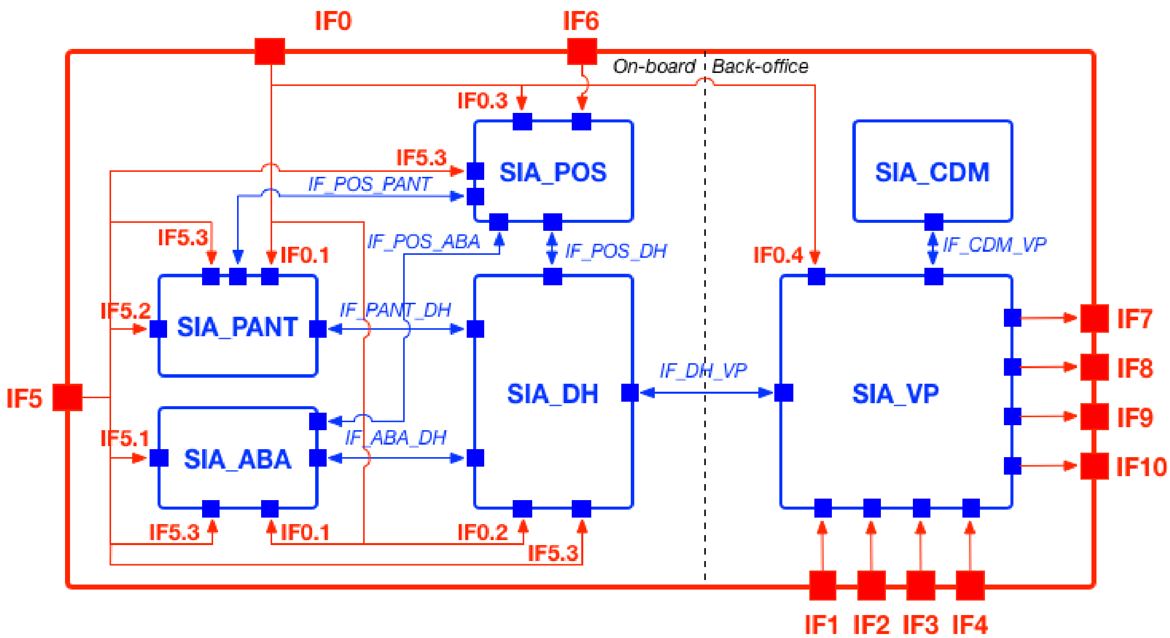

Figure 3-1: SIA Architecture

With this architecture, SIA will provide four services with characteristics defined below:

- *iWheelMon*, which is intended for TOCs and integrated operators, will provide real time information about wheel status (e.g., presence of wheel flats) and prognostic health status information within a certain time frame such as predicted wear, RCF and polygonization, and maintenance recommendations.

- *iPantMon*, which is intended for TOCs and integrated operators, will provide real time information about the pantograph status (e.g., incorrect vertical damping forces of upper arm) and prognostic health status information in a certain time frame such as wearing of contact stripes, and maintenance recommendations.

- *iRailMon*, which is intended for IMs and maintenance subcontractors, will provide real time information about the rail status (e.g., broken rail) and prognostic health status information in a certain time frame such as squats, corrugation, wear and RCF, and maintenance recommendations.

- *iCatMon,* which is intended for IMs and maintenance subcontractors, will provide real time information about the catenary status (e.g., wearing of cable) and prognostic health status information in a certain time frame such as inclination of the mooring balance with respect to the rail, break of the automatic regulation pulley, wear of cables, and maintenance recommendations.

These services will be delivered by the different sub-systems of the SIA system according to the next table.

SIA Subsystems	SIA Services			
	iWheelMon	*iPantMon*	*iRailMon*	*iCatMon*
SIA_PANT		√		√
SIA_ABA	√		√	
SIA_DH	√	√	√	√
SIA_POS			√	√
SIA_VP	√	√	√	√
SIA_CDM	√	√	√	√

Table 3-1: Table: SIA services mapped to sub-systems

The on-board data integration platform and train-track communication hub. On the other hand, the hardware specific version of the architecture is shown in Figure 3-2. It represents the main pieces of equipment, their location, whether they are out of the vehicle (roof) or inside the vehicle (cabinet), and how they are connected with each other.

As it can be seen that the antennas and SIA_ABA subsystem are wired to the equipment in the cabinet. As the system installed in the pantograph (SIA_PANT) is fully wireless, and the connection with the visualization platform (SIA_VP) is also wireless.

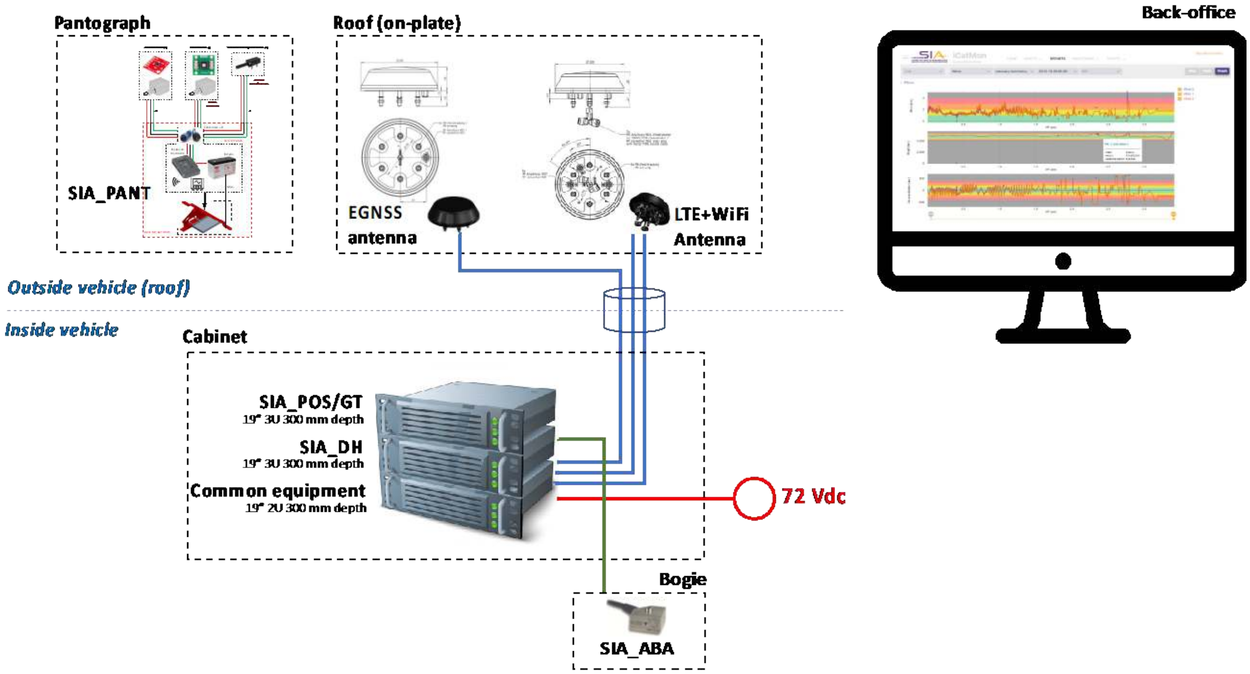

Figure 3-2. SIA system (simplified) Hardware architecture

The drawings inside Figure 3-2 are blurry for qualitative description purposes. The system is composed by the following main items, whose installation will be explained further in subsequent chapters.

On-board Equipment

- Installation in the pantograph
  - SIA_PANT subsystem (as described in deliverable D4.1)
- Installation in the bogie
  - SIA_ABA subsystem (as described in deliverable D4.1)
- Installation in the roof
  - EGNSS antenna (multi-frequency antenna, as described in deliverable D3.1)
  - LTE + Wi-Fi antenna for communications (as described in deliverable D4.3)
- Installation in the cabin
  - SIA_POS subsystem (as described in deliverable D3.1)
  - SIA_DH subsystem (as described in deliverable D4.3)
  - Other (common equipment), such as power supply, etc.

Back-Office Equipment

The back-office part of SIA system, comprises of software applications that are installed in a PC with access to the internet:

- iCatMon
- iPantMon
- iWheelMon
- iRailMon

FGC Scenario

The SIA project started in March 2018 with the aim of developing a monitoring system for the interaction between pantograph and catenary for use by FGC.

During the final months of the project, the system developed in the project has been tested in a real railway operating environment in Ferrocarrils de la Generalitat de Catalunya premises. The main objective of this test is to collect data for the validation of the developments. More precisely the monitoring system is composed by several accelerometers installed in the pantograph. By means of several models developed in the project indirect calculations are done to obtain the following information:

- Height and misalignment of the catenary
- Contact force of the pantograph

Getting this data is very valuable for FGC to obtain more information regarding the interaction of the pantograph and the catenary. And therefore, to increase the availability and the safety of the systems while improving the quality of the service offered.

In this section, the activities that were required in order to test the SIA developments in a real operational environment are reported. Firstly FGC, the railway operator and infrastructure administrator is presented and the testing scenario is described, afterwards the components of the system and their location are detailed and following this the testing activities are reported.

1.5 Introduction

Ferrocarrils de la Generalitat de Catalunya was founded in 1979 to operate and administrates two historical railway lines with their origins in 1863 in the introduction of the Barcelona – Sarrià suburban train service. Over the years, new lines have been added to FGC, the historical ones have been technically improved, and new passenger and freight services have grown in Barcelona and the surrounding areas.

This continuous growth, together with the diversification of the business into other sectors such as leisure and tourism has made of FGC an efficient public company distinguished all over the world by its high quality of service and efficiency in infrastructure management and transport operation.

Figure 4-1. FGC management and operation activities. Source: FGC.

Some figures of the company dimension are the following:

- 91 million passengers/year and freight transport.
- Workforce over 1900.
- 1301 circulations per day with minimum frequency of 112" in Barcelona-Vallès line.
- Rail network of 290 km of track with international, narrow and Iberian gauges.
- 107 stations.
- The only 2 rack railways existing in Spain.
- 4 funicular cable cars.
- Touristic activities: 47 ski lifts and 146 km of ski runs, touristic trains.

Testing of the developed SIA system will be performed in one of the two main lines of FGC, the Barcelona – Vallès (BV) railway line.

The BV line has metro services inside Barcelona city and has commuter services between Barcelona and surrounding areas. It has 53 km of double track with international gauge, it has a bifurcation in Sant Cugat del Vallès which leads to Terrassa Branch and Sabadell Branch. Inside Barcelona it has two more branches the Reina Elisenda branch and Tibidabo branch.

The service is provided in peak hours with 32 trains per hour in both directions with a minimum frequency of 112” between trains in the central core of the line. This serves to a demand of 62 million passengers per year.

The service is provided with 46 passenger trains which are fully maintained by FGC in the main workshop placed in Rubí, in Terrassa Branch. Strict and continuous maintenance processes are done to rolling stock to ensure the high-quality indicators with values of more than 99% of availability and more than 99% of punctuality over the year. These values are ratified by our client satisfaction index monitored through different surveys and focus group campaigns.

Figure 4-2. Barcelona – Vallès railway line. Source: FGC.

1.6 Installation details

The system to be validated in the FGC scenario is the one described in Figure 3-2.

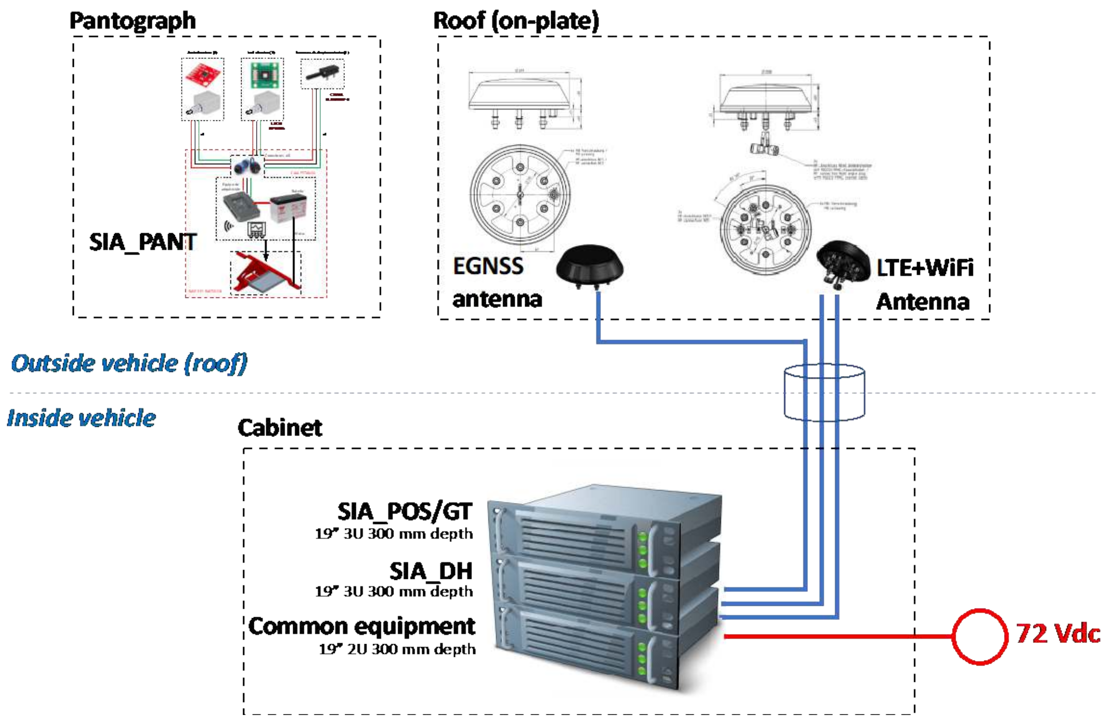

Figure 4-3. Installation overview. Source: CEIT.

Above is shown the general overview of the installation of the system. There are three main locations for the installation of the equipment

- Pantograph

SIA_PANT system is installed in the pantograph. The installation consists on several sensors placed along the arms of the pantograph and an enclosure with the acquisition system in the base of the pantograph. This system does not have physical connection with the rest of the elements to install.

- Roof

EGNSS antenna and LTE + Wi-Fi Antenna. These two antennas are installed in a new plate specially designed for the action. The antennas are connected through wiring to the equipment installed inside the cabin.

- Cabin

In a cabinet inside the cabin of the unit, in a special bracket is installed the acquisition and storage system of the SIA data.

1.6.1 Installation in the pantograph

The system to be installed in an FGC pantograph as well as the details of the installation described in deliverable D4.1 have been analysed by an external and independent safety audit body, and a corresponding risk analysis report has been produced.

Final installation details contain the mitigation measures proposed by CEIT which have been approved by FGC to mitigate the risks highlighted by the safety auditor.

The system does not have a physical connection with the equipment installed in the cabin neither in the roof. Data collected by the system is sent wirelessly to the equipment installed inside the cabin of the train. The qualitative scheme of the system and their representative components are depicted in the following figure.

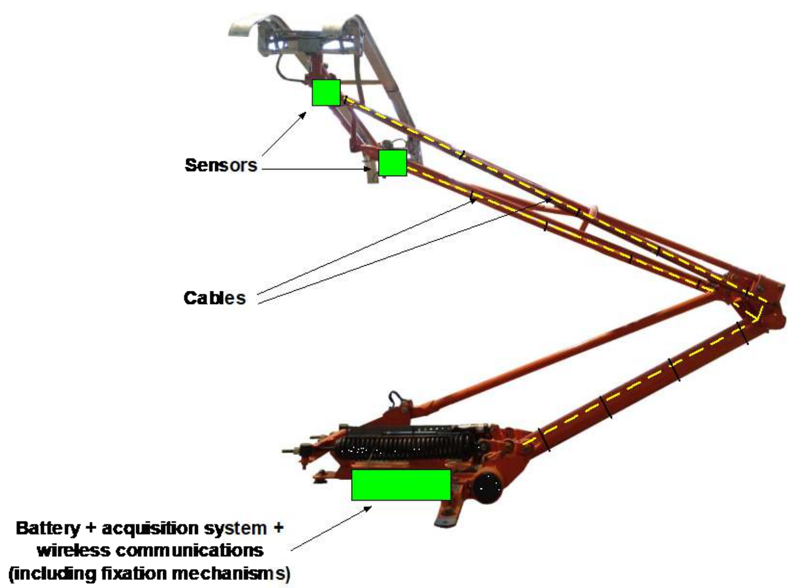

Figure 1. Pantograph system simplified architecture. Source: CEIT.

- Acquisition equipment

The equipment responsible for the acquisition and storage of the data collected by the different sensors for subsequent analysis. The equipment has a Wi-Fi connection to check the operation of the system remotely. The equipment is installed inside an IP67 watertight box together with the battery. The equipment is wired to the sensors and the battery.

- Battery

There is a 12VDC GEL battery to power the system. The battery is installed next to the acquisition system in an IP67 waterproof box.

The battery allows for about 50 hours of continuous measuring. The system can be switched on automatically remotely and data will be collected from the sections only of interest for the project, Rubi - Mirasol. If necessary, the battery can be replaced by a charged battery.

The negative terminal of the battery shall be connected to the pantograph structure and used as a reference voltage (i.e., virtual common ground) for the system, ensuring electrical isolation of the bodywork.

- Sensors

The sensors are installed on the pantograph head and arms. The sensors are installed inside IP67 enclosures, bonded to the pantograph with adhesive bi-component and secured with cable ties.

The wiring connectors are IP68 and the wiring is installed attached to the pantograph arms with cable ties.

1.6.2 Installation on the roof

Two antennas will be installed on the roof of the unit. The first antenna uses EGNSS signals which allows for accurate positioning of the signals received by the sensors, the second antenna corresponds to the LTE and Wi-Fi signal. Both antennas are approved for railway installations.

The LTE and Wi-Fi antenna enables remote connections to the system inside the train cabin and the extraction of the data collected by the system installed in the pantograph.

To install the antennas, on the roof of the unit there is already a metal plate where some antennas are installed (Figure 6-6). To accommodate the two antennas of SIA system an extension (metal) plate is needed (Figure 6-7).

The height of the total height from the existing plate is 126 mm, currently the maximum height is given by the TETRA antenna 100 mm.

The three cables connecting the antennas will be pulled out from the side of the junction box using watertight connectors and corrugation to the bottom of the extension board to connect to the antennas.

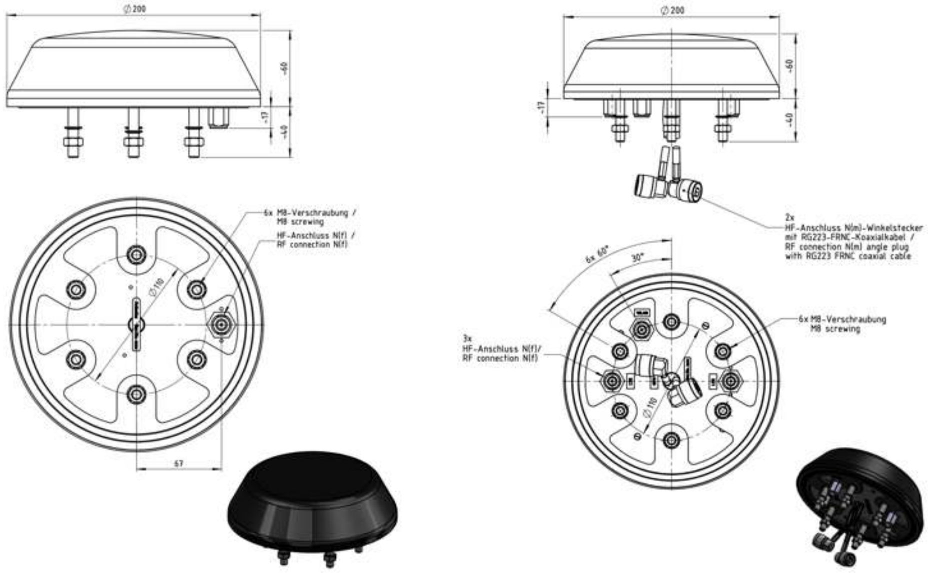

Figure 4-4. EGNSS antenna and Wi-Fi and LTE antenna

Figure 4-5. Roof plate

1.6.3 Installation in the cabin

In the cabinet inside the cabin, the positioning equipment and the acquisition system of the sensor system is installed.

In order to adapt the SIA equipment to the new available space and using the same 19” Rack format, it will be mounted inside an 8 U-high open-frame rack from Startech, model RK812WALLOA (Figure 6-9). This structure offers the possibility of having an adjustable depth from 12” to 20". As can be seen, it would not conflict with the 300mm depth of the existing hole. The distribution of the three units that compose SIA system is shown in Figure 6-10.

Figure 4-6. Open frame rack for the installation of 19” rack units

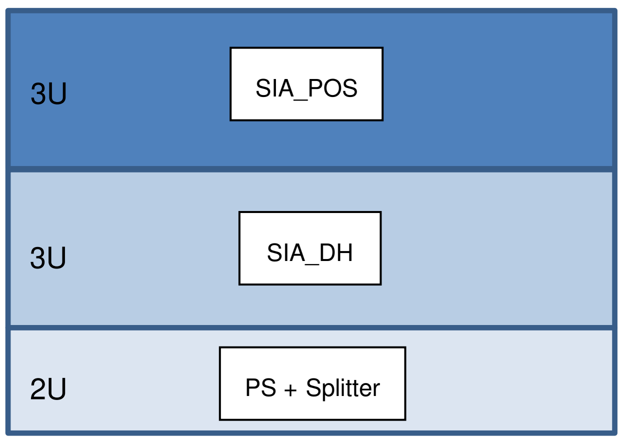

Figure 4-7. Distribution of SIA units in the open frame rack

1.7 Planning

To test the SIA system and collect data in a real railway environment high accuracy planning is required and an analysis of the details and implications due to the highly safety-oriented environment that a railway is and due to FGC's orientation to provide service to our clients for our normal activities. Furthermore, considering that the system that is going to be tested in FGC is not a commercial and railway homologated product. This is an experimental activity that must ensure both safety and availability of the rolling stock.

With these objectives in mind, the main activities that took place in coordination with FGC and the SIA project partners are explained below. The setup is divided into three phases: Pre-installation, measurement campaign and final installation.

1.7.1 Pre-installation

Some pre-installation activities are necessary to install the SIA system in an operational unit. These activities consist of several works done in the selected unit carried out by different teams and coordinated by FGC.

The new antennas of the SIA systems have three cables with 8mm each one approximately that must go from the equipment installed in the cabin to the equipment installed on the roof. The current unit conduits that are allowed to go from the inside of the unit to the outside are not able to fit in these cables with 24 mm diameter.

For this reason, the main purpose of the pre-installation is to enlarge the diameter of the current aluminium tube that allows cables of the antennas to go from the inside of the unit to the outside. This activity, that can be seen as trivial in a railway environment means that several safety related activities have to be coordinated and several teams and companies have to be consulted.

- The body of the train unit is made of aluminium as well as the tube that allow the connections from the inside to the outside. The uninstallation of the current aluminium tube and installation of a new one requires the intervention of external specialised company certified to do aluminothermic welding.
- Uninstallation of the current aluminium tube implies the uninstallation of current connection of the actual antennas closely related to safety of the operation. Reinstallation of them once the activities are done requires an external specialised company to do the correct installation and to emit the corresponding certification to note that the system is functioning.
- The uninstallation and installation of current FGC antennas requires coordination with the FGC communication team, in charge of this safety related systems.
- The uninstallation of current aluminium tubes and changing to new ones implies a substantial modification to a train unit, this situation requires evaluation by engineering rolling stock teams to ensure the proper procedures of units' change management system.
- The above-mentioned activities means stopping one unit for several hours with the time restriction between rush hours, when all the rolling stock do the normal FGC service.
- The kind of activities required for SIA means booking an inspection pit, normally used to work on scheduled maintenance activities.

- Work in the roof of a train unit in the FGC workshop requires personnel and teams involved in the works fulfil the corresponding prevention protocols and requires certification to work on heights.

All the above situations have been considered and organised to complete the pre-installation activity.

Finally, the pre-installation took place from 10:30 am 1st June to 2:00 am 2nd June, ensuring with this schedule that the unit had been able to run in morning peak hour.

Three teams worked on the activities in the Rubi workshop, in a booked pit, in coordination with four FGC areas.

Aluminothermic welding was done to install the new tube, antennas uninstallation and installation with the corresponding performance protocols were done and cables of SIA antennas were preinstalled. In the following pictures this is shown, on the left, the previous situation of the roof and, on the right, the new connections box with the new cables ready to connect to the SIA antennas.

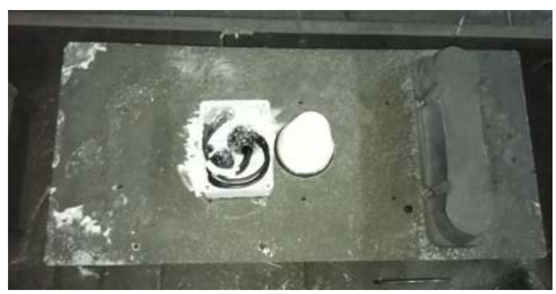

Figure 4-8. Left: Previous situation of the roof. Right: Final situation with new cables.

1.7.2 Complementary activities with Telice

Separate to the installation activities, a measurement campaign was organised to obtain information about track geometry and catenary geometry of a specific and concrete track section to be able to calibrate, compare and contrast between the data collected by the SIA system.

The measurement campaign was carried out by TELICE with the tCat® System. The system consists on a measurement stroller pulled by an operator and the system collect several information about the track and the catenary.

Measurements were carried out on the night of the 8th of June, during the night shift following the FGC procedure for night works. Homologated personnel from Catenary area of FGC were required during the night to accompany external TELICE personnel.

The activities were carried out in the night window from 1:00 to 4:00 am available for maintenance activities. Measurements were carried out in 1.5 km in track 2 from Stations Hospital General to Rubí. This is the control section for the rest of the tests.

1.7.2.1 tCat® workstation

The tCat® workstation is a trolley-based, LiDAR-enabled, sensor integration system whose primary purpose is to measure catenary and track geometric data.

The parameters that tCat® allows to record are the following:

- Height and stagger of the overhead contact line.
- Track cant.
- Distance travelled.
- GNSS satellite position.
- Tunnel profile.
- Catenary pole gauge.
- Gauge to other infrastructure elements.
- Electrical gauges between conductors and infrastructure elements.

tCat® allows the operator to automatically generate a measurement worksheet and enriches it with photographic data thanks to its two cameras: frontal and azimuthal.

The tCat® measurement procedure requires the tCat® to be placed on the track and to travel through the area to be measured with stops at the points of interest. The system is equipped with a dead-man brake to prevent uncontrolled rolling.

1. LiDAR (Laser scanner).
2. Track gauge sensor.
3. Rolling assembly.
4. Dead-man manual brake.
5. Front LED lighting.
6. Back LED lighting (position).
7. Left frame.
8. Right frame.
9. Odometer assembly.
10. Handlebar
11. Ruggedized portable PC.

Figure 4-9. tCat® OLE measurement workstation. Source: TELICE.

1.7.2.2 Measurement campaign

The measurement campaign was carried out by two staff members of TELICE. FGC provided support and determined timetables and access points to the track.

Measurements were carried out in track 2, between the stations of Rubí and Hospital General, (milestones 010+397 to 008+970), with a tCat® 1435 system, under all OLE poles.

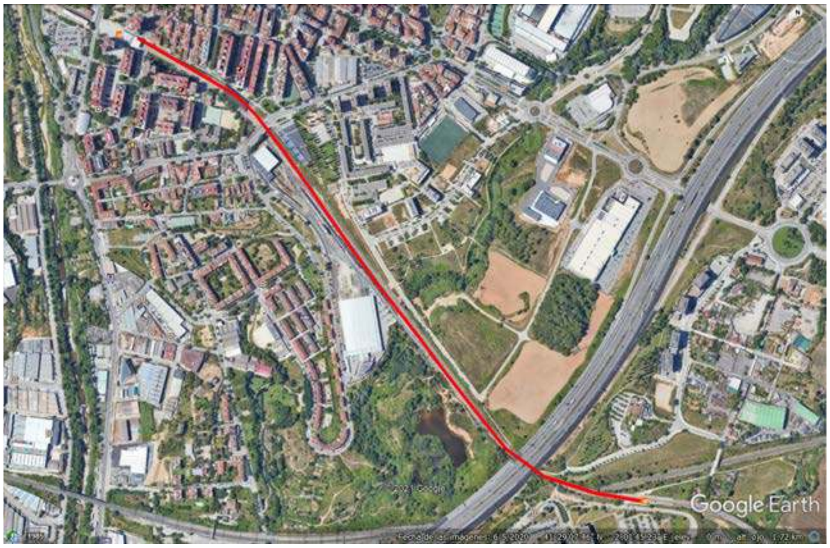

Figure 4-10. Track extent involved in the measurement campaign. Source: TELICE.

1.7.2.3 Results

The results of the measurements were shared with the project partners.

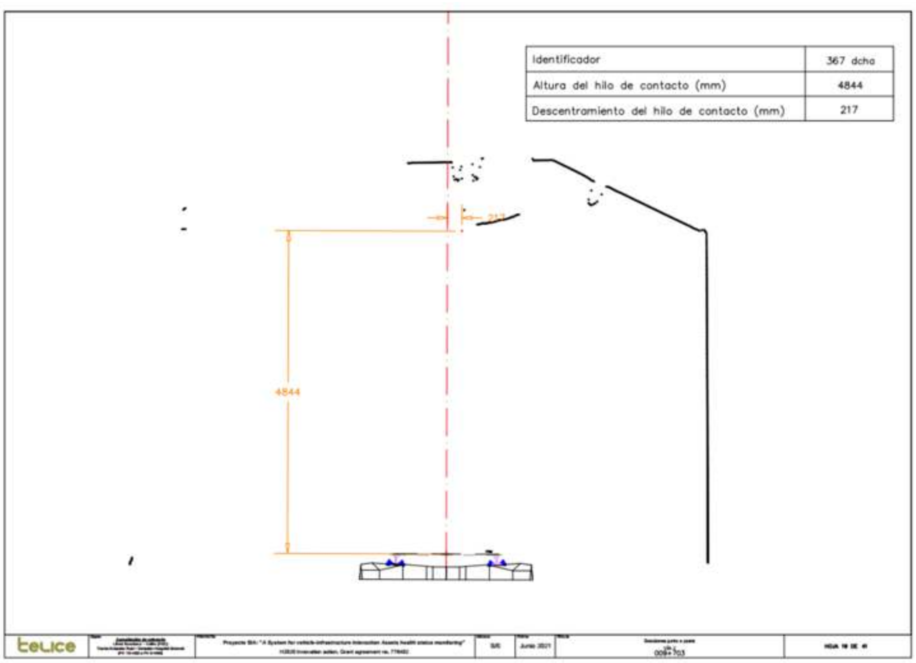

Figure 4-11. Typical measurement section. Source: TELICE.

Figure 4-12. Typical tCat® frontal camera capture. Source: TELICE.

Figure 4-13. Typical tCat® azimuthal camera capture. Source: TELICE.

1.7.4 The complete SIA System

To ensure the safety of the system in a real operational environment several stages have been defined before letting the system run alone during normal service.

- The installation of pantograph components and checks in the test bench with the disassembled pantograph
- The installation of the complete system in the unit and testing on a dynamic test track
- Testing of complete system in a dedicated night run
- Testing in normal service in the BV line.

These phases and the final uninstallation was planned for two weeks according to the Rolling stock and Operational availability to carry out the activities. The main critical points were that the unit cannot be stopped in the workshop during the morning rush hour due to the service requirements. This situation means that in the mornings the unit has to be ready to do the service, with or without the SIA system.

Furthermore, for the activities to take place corresponding Safety and Prevention meetings were completed in order to allow external companies to work in the FGC workshop and in the unit. In the following schedule the planning is presented.

	5/07	6/07		7/07		8/07	8 – 13/07	13/07
	CEIT	FGC	CEIT	FGC	CEIT	FGC y CEIT	FGC	FGC & Ceit
6:00 – 10:30	Pantograph installation in test bench	Installation revisión according to independent risk assessment					TESTS IN BV - LINE	
10:30 – 14:00			Installation of SIA system (roof and cabin) in 112.13	Pntograph isntallation in 112.13 and test in workshop dynamic track		Back up day for modifications in workshop		Deinstallation
14:00 – 22:00								
22:00 – 6:00				Testing in BV Line with 112.13 (According woks program)	Checks in situ and remotely. Final check of the system in the workshop	Back up day for tests in BV line		
				FINAL APPROVAL OF THE SYSTEM				

Figure 4-14. Installation plan. Source: FGC.

- Installation in dismounted pantograph.

The pantograph equipment for the SIA system was installed in a test bench of the workshop, in a dismounted pantograph. This activity was carried out during the first day with the support of FGC pantograph experts and workshop personnel.

During the second day the operation of each component of the system was supervised by the rolling stock team to ensure that normal operation of the pantograph would not be affected. Also, the independent risk assessment is checked according to the mitigation measures proposed.

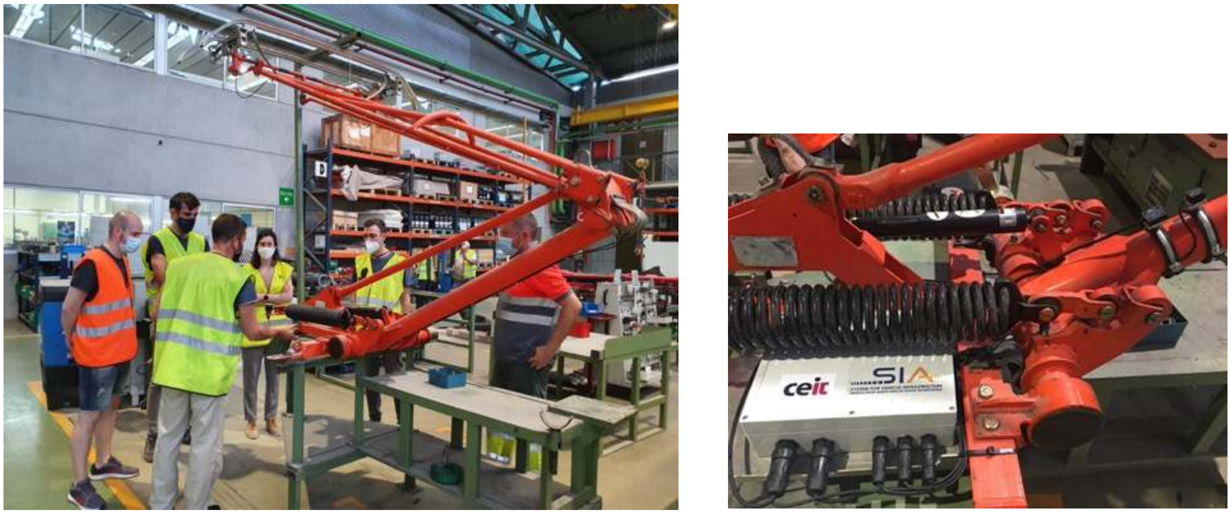

Figure 4-15. Testing in dismounted pantograph. Source: FGC and CEIT.

- Installation in train and dynamic testing in workshop.

During the second day the FGC unit 112.13 was prepared in one of the inspection pits. The CEIT team worked on the roof and in the cabin of the unit to install and ensure the =SIA system was working as expected. During the following day the FGC workshop team installed the pantograph equipped with the SIA sensors.

Once the system was ready, the unit was powered to 1.500 V through the instrumented pantograph, the SIA system performance was correct and a dedicated run in the rail yard of the workshop was completed to ensure that the unit and the system was working properly.

Figure 4-16. Installation of the instrumented pantograph in the vehicle. Source: CEIT and FGC

Figure 4-17. Installation in cabin and in the roof. Source: CEIT and FGC.

- Dedicated night runs.

The system was tested in real operational conditions initially in a dedicated night run. More precisely in the section of the line were TELICE took measurements of the track and catenary conditions. The track section and an FGC driver were booked for this activity, remote checks and in situ performance of the system were evaluated by CEIT.

Once the train entered the workshop a final revision was done by workshop personnel and CEIT and then final approval was communicated and the train unit was delivered for normal service.

- Normal service collecting data

From the 8^{th} to the 13th of July, the unit equipped with SIA system ran through the BV line completing different services and routes as agreed with CEIT.

Figure 4-18. SIA complete system installed in FGC train unit. Source: FGC.

1.8 Testing activities

1.8.1 Testing protocol

The testing of the SIA system in the FGC campaign involved all subsystems presented in the architecture in Figure 5-2 (except the SIA_ABA module which has been validated in the OBB campaign). The following activities have been/are going to be completed:

- Static tests in the workshop
- Functional check under electrification
- Tests in the workshop
- Tests in the track

1.8.2 Static tests in the workshop

In this activity, a few basic tests will be carried out in static condition. They will be used mainly to verify that the installation of the system is correct and according to the description of deliverable D4.1. The tests are described in Table 6-1.

Test ID	Test Description	Passed? (Y/N)	Comments
FGC_W_001	Visual inspection SIA_PANT subsystem after installation		
FGC_W_002	Visual inspection of the system: • Antennas are correctly fixed • Wiring of antennas to the electric box is correct • Wires enter the equipment cabinet without tension • Connections of the system are ok • SIA equipment is correctly fixed in the open frame rack • Open frame rack is correctly fixed in the equipment cabinet		
FGC_W_003	Free movement of the pantograph is not affected by the installation of SIA_PANT, including the cables • Option 1: pantograph disassembled		

Test ID	Test Description	Passed? (Y/N)	Comments
	• Option 2: pantograph already on the roof		
FGC_W_004	Connect the SIA_POS via antenna cable		
FGC_W_005	Power supply cable connect properly into supply connector of SIA_POS		The positive cable MUST be aligned with + (LEFT) and the negative cable MUST be aligned with the – (RIGHT) symbol.
FGC_W_006	Check that the input power supply should be between 9 and 36 Volts.		
FGC_W_007	Check Ethernet cable of SIA_POS is connected for internet connection.		
FGC_W_008	measure the 3-D offset (lever arm) from the centre of the IMU sensor to the GNSS antenna		
FGC_W_009	Power up the SIA_POS and check that the start-up process is successful (LEDs change to Green).		Leave them running for some time. (to check that all functionality of SIA_POS is working)
FGC_W_010	Use real time software to log GNSS, IMU, IONEX and RTCM data		

Table 4-1. Static tests in the workshop

1.8.3 Functional check under electrification

This activity aims at checking the functionality of the system (i.e., mainly SIA_PANT) when the pantograph is deployed and the train is electrified. The description of the activities is shown in Table 6-2.

Test ID	Test Description	Passed? (Y/N)	Comments
FGC_W_011	Visual inspection of the system (SIA_PANT) once the pantograph is contacting the catenary and the		

Test ID	Test Description	Passed? (Y/N)	Comments
	system is electrified. Performance looks normal.		
FGC_W_012	SIA_PANT is streaming data (connection via tablet)		
FGC_W_013	SIA equipment is powered-up		
FGC_W_014	Power up the SIA_POS and check that the start-up process is successful (LEDs change to Green).		Leave them running for some time. (to check that all functionality of SIA_POS is working)
FGC_W_015	Use real time software to log GNSS, IMU, IONEX and RTCM data		

Table 4-2. Functional check under electrification in the workshop

1.8.4 Tests in the workshop

Once the equipment's performance under electrification has been verified, a few basic cross-checking activities will be carried out in the workshop before starting the tests in the track.

Even though the verification plan described in D2.2 has been materialized in the lab and in field tests using a maintenance vehicle by VIAS, some of the tests will be repeated in FGC's workshop, according to Table 6-3.

Test ID	Test Description	Passed? (Y/N)	Comments
FGC_W_016	Configuration parameters can be received by: - SIA_PANT • SIA_POS • SIA_DH		
FGC_W_017	Following information related to Ambient can be received and processed by SIA: • Catenary-Pantograph contact, i.e., physical magnitudes (e.g., accelerations) that will be processed in order to assess		

Test ID	Test Description	Passed? (Y/N)	Comments
	the health status of both catenary and pantograph • Electric power supply		
FGC_W_018	Following information related to EGNSS can be received and processed by SIA: • GNSS signals • Inertial signals		
FGC_W_019	IF_POS_DH: Positioning related information can be sent by SIA_POS and received by SIA_DH		
FGC_W_020	IF_POS_PANT: Timing related information can be sent by SIA_POS and received by SIA_PANT		
FGC_W_021	IF_PANT_DH: Sensor information can be transmitted by SIA_PANT and received by SIA_DH		
FGC_W_022	IF_DH_VP: Generated data in SIA_DH can be transmitted and received by SIA_VP		

Table 4-3. Verification activities in the workshop

1.8.5 Tests in the track

It is essential to start the data collection couple of minutes before the train starts moving. The stationary data is required for IMU bias estimation.

Test ID	Test Description	Passed? (Y/N)	Comments
FGC_T_001	Configuration parameters can be received by: - SIA_PANT • SIA_POS • SIA_DH		

Test ID	Test Description	Passed? (Y/N)	Comments
FGC_T_002	Following information related to Ambient can be received and processed by SIA: • Catenary-Pantograph contact, i.e., physical magnitudes (e.g., accelerations) that will be processed in order to assess the health status of both catenary and pantograph • Electric power supply		
FGC_T_003	Following information related to EGNSS can be received and processed by SIA: • GNSS signals • Inertial signals		
FGC_T_004	IF_POS_DH: Positioning related information can be sent by SIA_POS and received by SIA_DH		
FGC_T_005	IF_POS_PANT: Timing related information can be sent by SIA_POS and received by SIA_PANT		
FGC_T_006	IF_PANT_DH: Sensor information can be transmitted by SIA_PANT and received by SIA_DH		
FGC_T_007	IF_DH_VP: Generated data in SIA_DH can be transmitted and received by SIA_VP		
	Other iCatMon / iPantMon		

Table 4-4. Tests in the track

OBB Scenario

This section describes two measurement campaigns / phases of the pilot operation that have been performed to test the different prototypes of the SIA system in the OBB railway network. The first is the SIA pilot operation on an OBB in-service train, the equipment was installed in October 2020 with the train operating from November 2020. The SIA unit used provides the complete SIA-ABA functionality and a preliminary SIA-POS sub-system. Secondly, as described below, an additional measurement campaign focused on the testing of the SIA-POS sub-system on an OBB measurement vehicle was completed in July 2021 with full Ground Truthing equipment.

1.9 Introduction

OBB, the Austrian federal railways, are Austria's largest mobility provider mainly covering passenger transport, freight transport and infrastructure management.

“We are the future of mobility”: the companies of the OBB Group together do everything a modern, reliable and environmentally friendly mobility chain needs. Whether rail network, stations or other facilities, OBB-Infrastructure plans, builds and operates the infrastructure of OBB in line with demand and reliably. We also manage the safe and punctual operation of all trains.

- 5,000 km route network
- 1,000 stations
- 6,700 trains per day
- 10 hydropower plants
- 18,600 employees
- 2,000 projects
- 7 freight centres and terminals
- 100 shunting areas

Figure 5-1, Track network of OBB-Infrastructure (overview) Source: OBB-Infrastructure.

One focus is to provide the network for our customers, the various railway undertakings, with the highest availability possible. Therefore, the status of the tracks and all other components of the railway system is of special interest. An extended OBB pilot operation starting in mid-2020 had been planned - for the collaboration of OBB, GMV NSL, and DLR this specifically concerned tests and the collection of data using the SIA-POS and SIA-ABA sub-systems.

Due to the historical Coronavirus pandemic the activities could not go ahead as planned. Reasons include traveling restrictions and a lack of access to workshops, laboratories and specific personnel of the different partners. With the obvious uncertainties, planning was complicated further.

In order to go ahead with the work, the individual partners advanced their software and algorithms using existing data (including the two-week SIA campaign data from September 2019). DLR prepared a SIA-prototype with the complete SIA-ABA sub-system and carried out lab tests, for instance, to test the recording of data. OBB prepared installation options on OBB in-service trains.

In September 2020 DLR colleagues could visit the responsible OBB workshop during a short window in order to evaluate the installation options for SIA-ABA on an in-service vehicle. Due to traveling restrictions for DLR following the rising COVID-19 cases in Austria and Germany this remained the only 2020 workshop visit. It was decided to have DLR make final adjustments to the SIA prototype and send the hardware with dedicated instruction manuals to OBB for installation in October 2020. The installation took place during a scheduled workshop visit of this OBB vehicle. At this time no external persons were allowed in the workshop area, so no detailed photographic documentation could be made.

SIA-ABA system has been in operation since mid-November 2020 in regular passenger transport. The pilot operation is planned until August 2021, when SIA ends, but an extension of the pilot operation is being considered at the time of writing.

For COVID-related reasons (workshop access, shipping and traveling restrictions) not all SIA System hardware could be included in the above pilot operation. Therefore, it was decided to perform additional tests in the OBB network in July 2021 using SIA-POS only. To provide a real time GNSS+IMU positioning solution a SIA prototype with the complete SIA-POS sub-system has been developed and tested by GMV NSL. It was planned that for the qualification and validation of SIA, a long term real time test will be carried out in three scenarios (FGC, ÖBB and VIAS). However, due to delays in performing other tests because of the Coronavirus pandemic and the availability of the SIA-POS sub system, the ÖBB test duration has been altered and finally planned for a full day test only, but on the same line as SIA-ABA tests to give the opportunity for cross-analysis and evaluation.

1.10 OBB Pilot Operation using SIA-ABA

1.10.1 Planning

The initial planned start of the OBB pilot operation in mid-2020 could not be completed due to the Coronavirus pandemic. The following months were determined by many challenges, including traveling restrictions, very limited access to labs and workshop, shipping delays, and limited access to certain staff. With the inherent uncertainties of the 2020 pandemic, long-term planning was not possible for many aspects. In order to nevertheless complete the SIA pilot operation in the OBB rail network, some compromises and quick decisions had to be made.

With very limited workshop access (even office access) and the uncertain COVID-19 situation, the partners had to wait at first. During the spring and summer of 2020 the work therefore concentrated on the analysis of data during the 2019 campaign on an OBB measurement vehicle.

Regarding the SIA hardware, DLR prepared a SIA system for pilot operation and performed lab tests for, e.g., the autonomous recording of data over longer periods. During the late summer 2020 OBB could provide the option to install the SIA system on an OBB in-service train. A short visit was planned between DLR and the OBB staff responsible for the vehicle and the workshop in September 2020. OBB communicated the scheduled time interval (October 2020) that the train would spend in the maintenance workshop. The SIA unit was presented (slides, results from the 2019 measurements on an OBB maintenance train). Final required information and adjustments were agreed upon, for instance, to ensure the rail-certification of the GNSS antenna and that the SIA unit does not pose a fire hazard. Since the vehicle is used in regular passenger transport, all regulations have to be fulfilled by the system components. The vehicle was investigated to find appropriate installation options, clarify the mounting of sensors and cables, and discuss later access to the unit by DLR and OBB staff. It was planned that the installation would take place during early October 2020 with the participation of a DLR employee.

These plans could not be realized due to traveling restrictions within Germany and Austria. Therefore, the information from the workshop visit was used to make the final adjustments to the SIA unit at DLR. Installation and operation manuals were prepared and sent to OBB. OBB performed the installation without DLR staff. This plan was realized in October 2020.

Figure 52, ABA-Sensor and Box.

Figure 53, OBB passenger wagon with an overview of sensors and data box.

The installation went well and DLR could verify the proper system operation by remote access to the SIA unit. With a small delay (not related to SIA) the OBB train could resume regular operation on November 11, 2020. In late January the train was again taken to the workshop for an unscheduled and SIA-unrelated maintenance stop for several weeks. Since March 2021 the train and SIA unit are again in full operation at least until August 2021.

During the pilot phase the SIA unit is monitored remotely. Because it collects large amounts of ABA data (from two ABA sensors sampled at kHz rates) it was decided to have regular checks by an OBB employee, who can connect a laptop to an Ethernet port of the SIA unit and copy the collected raw sensor data to an SDD. These SDD with data of the SIA unit are then backed up locally at OBB and sent to DLR via mail for further analysis.

For specific tests and the illustration of project results the railway line between Linz and Summerau was selected from the different OBB lines being frequented by the train.

1.10.2 Testing activities

Testing took place at a regional line in the north of Austria, from Linz to the north to Summerau near the Czech border.

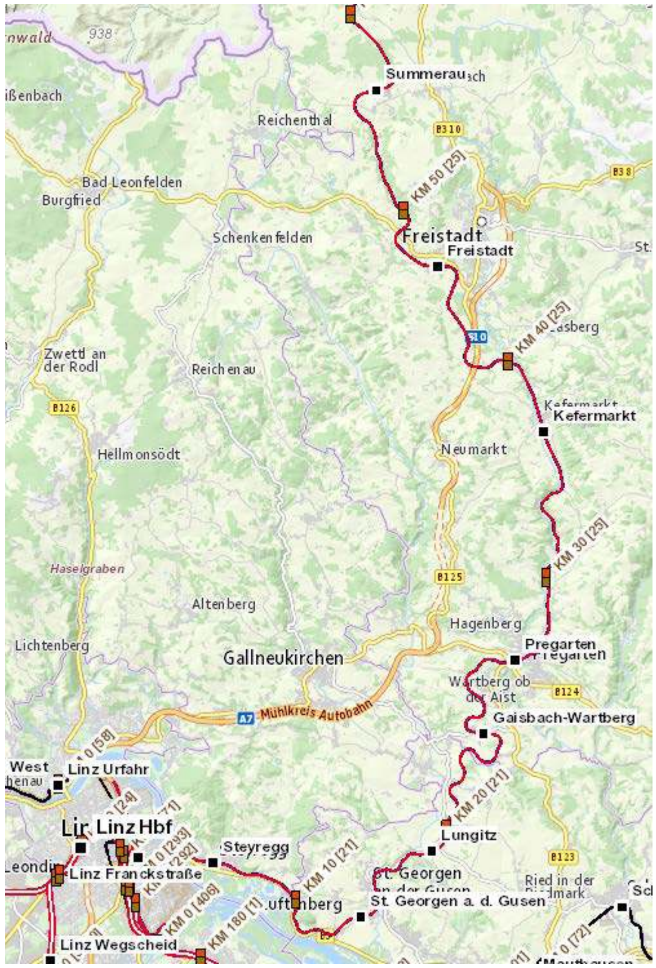

Figure 54, Track network of OBB-Infrastructure, Linz to Summerau. Source: OBB-Infrastructure.

The equipment was installed into the passenger waggon during a maintenance visit at the workshop in October/November 2020. Measurements started on Nov 26th, 2020. For recording purposes, a total on-board disk amount of 1TB was integrated in the autonomous system design. Facilitating the entire set of sensors, in daily full operation, this volume was filled up within a time period of about two weeks. Due to the fact that the wagon was in daily use and travelling on varying routes with its home base being in Linz, the coordination of data transfer with scheduled timetable was absolutely essential, because one person had to get on the train and start the data transfer while travelling. Main issues of the data transfer process were firstly to assure data transfer without implication for the ongoing process of acquisition and data storage itself. Secondly it was important to ensure that the data transfer took place before the train reached the end of the journey, since any stay on board of the train in unattended parking position is strictly forbidden. Also, ongoing energy supplies is not assured in parking positions (shut down of the system). The copying process itself took about 3 hours for approx. 1 TB of data.

Measurements took place from November 2020 to May 2021, with an unexpected interruption in February 2021, caused by revision and repair of the wagon. Within this measurement campaign, about 5000 files with more than 4TB of data were stored and copied in the SIA system. Data delivery had to be done by shipment of the external hard disks directly to DLR for the further data analysis.

For the rest of the measurements (May to at least August) the rate of data collection was decreased to save storage. Switching to full operation mode is possible at any time due to remote connection.

1.11 OBB Pilot Operation using SIA-POS

1.11.1 Planning

Two testing activities were planned in parallel with OBB and FGC during July 2021, this was due to the previous delays incurred in the project due to COVID-19. Because of this, we took the opportunity to complete the testing with OBB and FGC for the project when possible to do so. However, because of this it was difficult to arrange the delivery of another dual frequency antenna in our time scale and therefore OBB kindly offered us the possibility of using their spare dual frequency Galileo enabled antenna.

Another issue was that a SIA-POS unit was needed for the testing with FGC, therefore our initial interim version of SIA_POS was used that was used for the testing with VIAS with some modifications for the OBB scenario to collect enhanced data.

These modifications were made as per our plans and because for the testing activity with VIAS we found that that there was an absence of any nearby reference stations so it was difficult to generate true reference coordinates for the positioning performance analysis. Therefore, following an assessment of the available space in SIA_POS Unit 1 (interim version), GMV NSL decided to install a GNSS Inertial Measurement System (Novatel SPAN) to generate precise reference coordinates.

Moreover, due to limited time period, it wasn't possible to book a passenger train. Therefore, OBB agreed to book a special measurement locomotive only for this test. OBB also arranged the required power supply and internet needed for the SIA-POS unit.

The testing activity was scheduled to take place on a section of track running from Vienna to the west to Linz, then going north to the Czech border and returning on the same route as shown in Figure 5-10. This is the same route used by DLR for the validation of the SIA ABA sensors; using this route allows us to have multiple sensor data for the same line of track which will be useful to post processing and comparison.

The testing activity with OBB was scheduled to take place with the SIA POS unit in mid-July. The objectives of this testing campaign were:

- To validate further, in a real time operational scenario, the integration of the SIA POS subsystem at a functional level (for this campaign we also had a Novatel SPAN to generate reference trajectory)
- To collect further EGNSS data to validate the algorithms of SIA_POS

After successfully testing the equipment, on 21st July 2021 OBB installed the GNSS antenna on the roof of the locomotive and setup the SIA-POS unit inside the cabin for data collection.

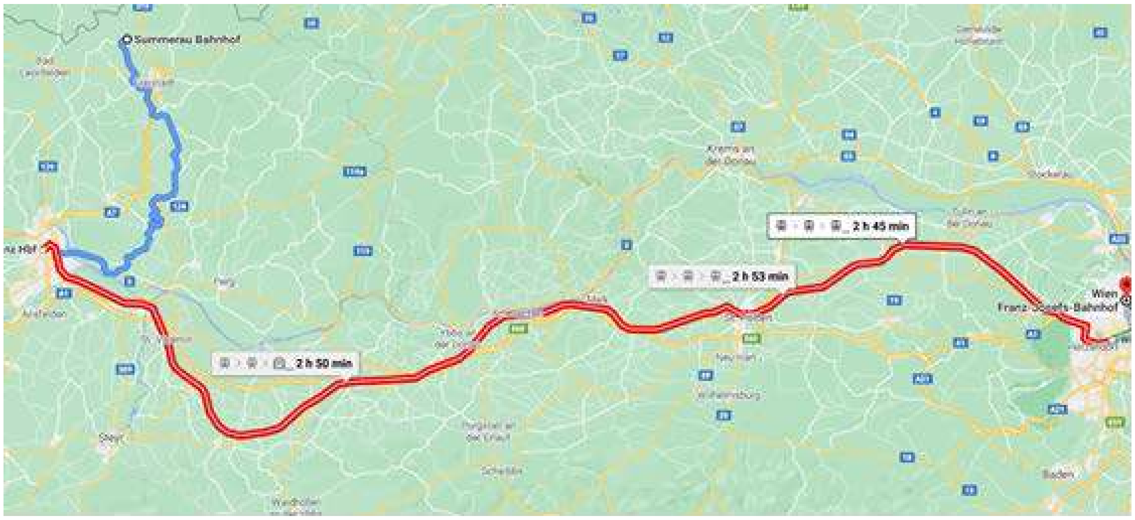

Figure 5-5: Route for OBB Testing Activity with SIA POS (July 2021)

1.11.2 Pre-installation

Before the full test with the OBB locomotive, some pre-installation activities were necessary to test the equipment before it was installed in an operational locomotive.

Furthermore because it was the first time that OBB was going to operate SIA-POS, and also due to COVID-19 restrictions, GMV NSL could only support remotely for the installation and testing process. Therefore, it was decided that OBB will first operate the SIA-POS unit from the office to understand the operational procedures and then go to the workshop for the trial and final test run.

1.11.3 Full Test Installation

Following the pre-installation activities the equipment was installed into OBB’s locomotive. Figure 5-2 shows an overview of the setup of the SIA-POS system for the OBB test. The following major key components were installed:

- GMV NSL SIA-POS unit
- JAVAD AirAnt dual frequency antenna
- Power supply
- Internet connection
- Antenna cable
- Power cable
- Ethernet cable

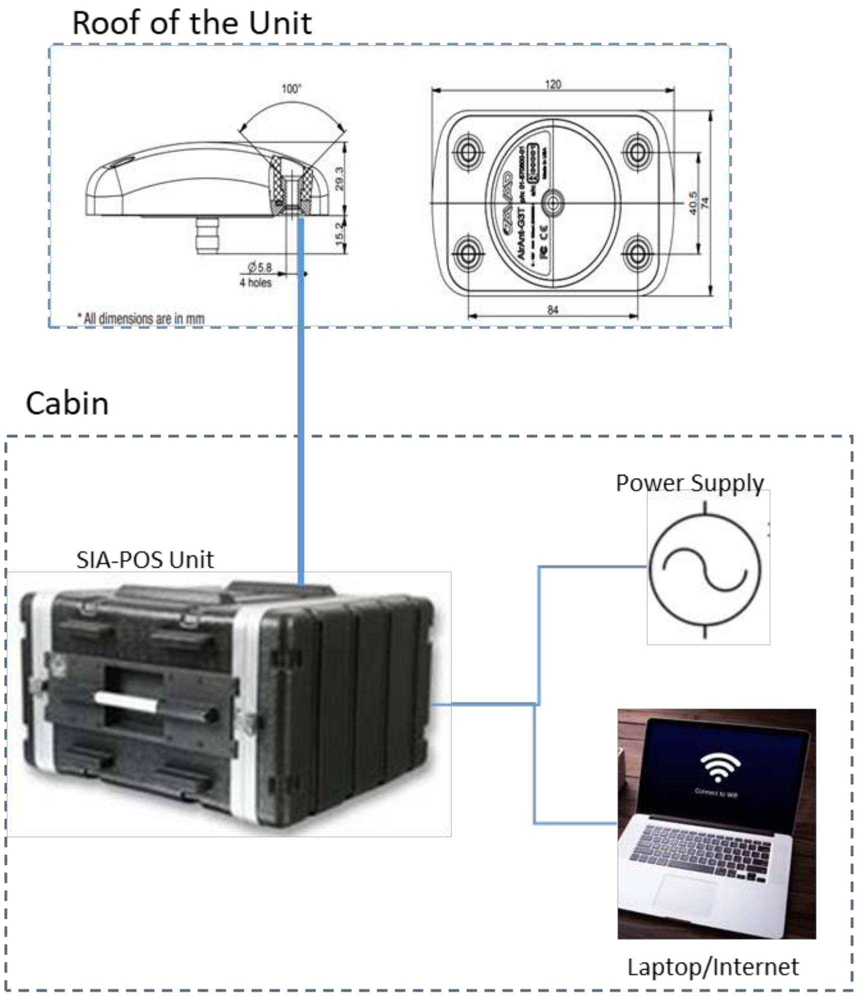

Figure 5-6 SIA-POS Installation overview. Source: OBB.

There are two main locations where SIA equipment was installed for this test, the roof of the train and inside a train cabin.

On the roof, the dual frequency Javad AirAnt EGNSS antenna was installed on a magnetic plate. The antenna was connected to the equipment installed inside the cabin. In the cabin, the SIA-POS unit was installed, which was tightly secured to a plate to protect it from any movement when train is running at high speed.

1.11.3.1 Antenna Installation

The GNSS antenna is fixed to the roof of the train using a magnetic mount. The antenna and the box must be installed on the same coach. The antenna cable is passed from the roof to the coach through the door joints and connected to the SIA_POS unit.

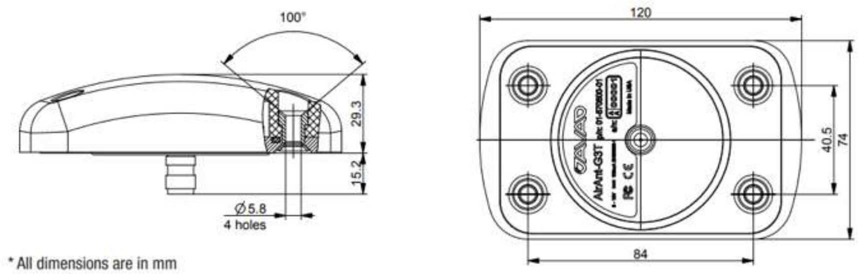

Figure 5-7 Javad AirAnt Antenna Schematic

To install the antenna, on the roof of the unit there is an existing magnetic plate where the antenna could be mounted. (Figure 5-5). A Javad AirAnt was used for this test.

Figure 5-8 Magnetic plate on the roof of the test Unit. Source OBB.

1.11.3.2 Installation of SIA_POS

The entire SIA POS system (except the antenna) is fitted within a flight case shown as below.

Figure 5-9: SIA POS Enclosure

For the installation, the SIA_POS unit was mounted on the train in a manner deemed suitable. There is an arrow on the unit that indicates the direction of travel in relation to the IMU inside. This arrow must be pointing towards the direction the train will move in so the IMU is orientated correctly. The control panel is on the top of the unit.

Figure 5-10: Control panel on top of unit with power supplied, Ethernet cable connected to GNSS board and GNSS cable connected.

Figure 5-11: Direction of travel marker on top of unit (in this instance, direction of travel is to the right of the picture)

Figure 5-12: Control Panel in relation to direction of travel marker unit (in this instance, direction of travel is to the right of the picture).

The SIA POS unit receives power from the train. Finally, the SIA POS unit is connected to the antenna via an antenna cable. A laptop equipped with Wi-Fi was connected to the units via an Ethernet cable in order to provide an internet connection to the unit. The laptop was also used for monitoring the data collection process.

1.11.3.3 Installation in the train and dynamic testing in workshop

Figure 5-13 Vehicle used for OBB scenario. Source: OBB.

As mentioned above, for this test with OBB, the SIA-POS (Positioning) Unit was installed inside the train cabin along with a dual frequency GNSS antenna on the roof of the train. It is noted that the SIA-POS unit in the OBB scenario is different in dimension from the one which was used in the FGC test scenario.

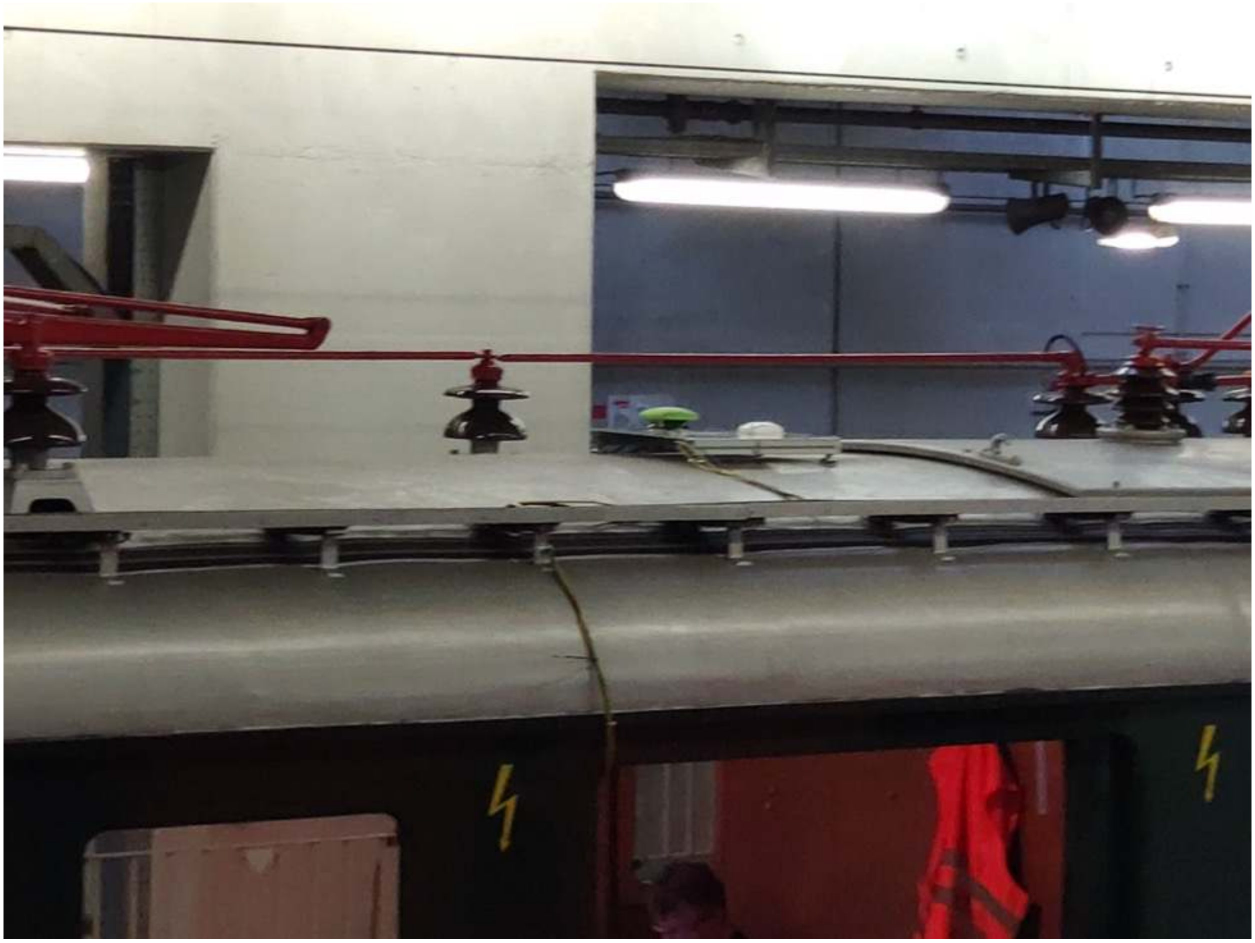

Figure 5-14. Installation of antenna on the roof. Javad AirAnt antenna in white. Source: ÖBB.

Figure 5-15 SIA-POS set up inside the cabin Source: OBB

- Test runs

For the test run, the SIA-POS was setup in the locomotive and was tested in real operational conditions on 21st July 2021. The trial run was only for an hour and the main purpose was to check that all equipment/connections (including the SIA-POS unit, the antenna, and the power supply and internet connection) were working properly ready for the longer data collection activity. After a successful trial run, a final check was done in the workshop to confirm that the unit is ready for the final test.

- Final Ride for collecting data

On 21st July 2021, the locomotive was equipped with the SIA_POS unit and was running through the line mentioned in Figure 5-10. The system was set to log the real time GNSS data and position solution.

1.11.4 Testing Activities

1.11.4.1 Testing protocol

The SIA-POS system was tested in the following scenarios whilst it was installed in the OBB locomotive:

- Static tests in the workshop
- Functional check under electrification
- Tests in the workshop
- Tests in the track

1.11.4.2 Static tests in the workshop

For this activity, a few basic tests were carried out in static conditions. They were used mainly to verify that the system is correctly installed and according to deliverable D4.1. The planned tests are described in Table 6-1.

Test ID	Test Description	Passed? (Y/N)	Comments
OBB_W_001	Visual inspection of the system: • Antenna is correctly fixed on the top of the test train. • Wires enter the equipment cabinet without tension • Connections of the system are ok		
OBB_W_002	SIA-POS unit placed on the train in a suitable secure manner		
OBB_W_003	On the SIA-POS unit is an arrow that indicates the direction of travel. Check that arrow must be pointing towards the direction the train will move in so the IMU is orientated correctly.		

Test ID	Test Description	Passed? (Y/N)	Comments
OBB_W_004	Connect the SIA_POS via antenna cable		
OBB_W_005	Power supply cable connect properly into supply connector of SIA_POS		The positive cable MUST be aligned with + (LEFT) and the negative cable MUST be aligned with the – (RIGHT) symbol.
OBB_W_006	Check that the input power supply should be between 9 and 36 Volts.		
OBB_W_007	Check Ethernet cable of SIA_POS is connected for internet connection.		
OBB_W_008	measure the 3-D offset (lever arm) from the centre of the IMU sensor to the GNSS antenna		Make sure this must be final measurement from the antenna to the SIA_POS.

Table 4-1. Static tests in the workshop

1.11.4.3 Functionality check under electrification

This activity aims to check the functionality of the SIA_POS system when it's deployed and the train is electrified. The description of the activities is shown in Table 6-2.

Test ID	Test Description	Passed? (Y/N)	Comments
OBB_W_009	Power up the SIA_POS and check that the start-up process is successful (LEDs change to Green).		Leave them running for some time. (to check that all functionality of SIA_POS is working)
OBB_W_010	Use real time software to log GNSS, IMU, IONEX and RTCM data		
OBB_W_011	Use Novatel Application Suite (NAS) software to log data from SPAN		Make sure that a local drive has been selected to save the logged data.

Table 4-2. Functional check under electrification in the workshop

1.11.4.4 Test in the workshop

Once the equipment's performance under electrification has been verified, a few basic cross-checking activities will be carried out in the workshop before starting the tests in the track.

Test ID	Test Description	Passed? (Y/N)	Comments
OBB_W_012	Configuration parameters can be received by: • SIA_POS		
OBB_W_013	Following information related to EGNSS can be received and processed by SIA: • GNSS signals • Inertial signals		
OBB_W_014	Following information related to EGNSS can be received by SPAN: • GNSS signals Inertial signals		

Table 4-3. Verification activities in the workshop

1.11.4.5 Tests on the track

Once the equipment's performance has been verified whilst in the workshop, the tests in the track will be completed as follows.

Test ID	Test Description	Passed? (Y/N)	Comments
OBB_T_001	Configuration parameters can be received by: • SIA_POS		
OBB_T_002	Following information related to EGNSS can be received and processed by SIA: • GNSS signals • Inertial signals		Follow the SIA_POS user manual to cross check that it's working properly.

Test ID	Test Description	Passed? (Y/N)	Comments
OBB_T_003	Configured parameters can be logged by SPAN.		

Table 4-4. Tests in the track

VIAS Scenario

1.12 Introduction

VIAS is currently the specialized company leading the railway construction sector in Spain, (and nowadays extending to various other countries). Some objective data backing up this claim include the fact that it is the company that has built the most kilometres of the Spanish High-Speed Railway Network (2nd longest in the world) with 26.2% of the total // over 2000Km. It also holds the highest share of maintenance work (over 3000Km), and has participated in the construction of a major length of railway platform, in the main track-laying depots and in the most prestigious and important projects in this network, such as the tallest high speed railway bridge in the world at 384 feet - 117 metres - (Ulla viaduct), some of the longest railway tunnels (Guadarrama, etc…..) as well as the main stations (Atocha, Sants…)

The test has been done in the Madrid – Seville High Speed Line, it was inaugurated on 14 April 1992, was the first high-speed and international gauge railway built in Spain, The Madrid-Seville High-Speed Line became a key indicator for demonstrating the impact of High-Speed trains on socioeconomic development and on territorial structure between the regions within its sphere of influence. This caused a 'springboard' effect favouring the development of the rest of Spain's high-speed network, to the point where Spain has become a world leader in terms of its knowledge and experience of this mode of transport.

The main characteristics of the infrastructure are:

- Length: 471 km
- Gauge: UIC 1435 mm
- Max speed: 300km/h
- 32 bridges
- 17 tunnels
- Electrification: 1 x 25kV 50Hz CA
- Signalling: ASFA200 y LZB
- Communications: GSM-R
- Passenger stations.

Figure 6-1. Madrid – Seville High speed line. Source: VIAS.

1.13 Installation Details

The installations of the different devices have been done in a Tamping Machine, Unimat 08-475/4S, it is a Turnout tamping machine associated to a maintenance depot located in Mora de Toledo, Spain.

The equipment installed was:

- SIA_PANT: only accelerometers were installed in the bogie of the vehicle, to test the functionality of the acquisition system and the reliability of sensors in a harsh environment. Apart from that, the complete hardware of SIA_PANT as described in D4.1 was installed.
- SIA_POS. A first prototype unit was installed inside the cabin of the vehicle.
- SIA_DH. A preliminary prototype unit of SIA_DH was installed also inside the cabin of the vehicle and connected to SIA_POS.

Figure 6-2. Vehicle used for VIAS scenario. Source: VIAS.

Figure 6-3. Installation of antennas. Source: VIAS.

Figure 6-4. Installation of sensors for functional tests. Source: VIAS.

1.14 Planning

This test scenarios was carried out from the 24th of March 2020 when all the devices were installed until April the 9th. The objectives of this testing campaign are:

- To validate, in an operational scenario, the integration of the different subsystems (except SIA_ABA) at a functional level
- To collect EGNSS data to validate the algorithms of SIA_POS

Figure 6-5. Data collection. Source: VIAS.

1.15 Testing activities

The following tests will be carried out in this scenario to validate the integration of SIA components:

Test ID	Test Description	Passed? (Y/N)	Comments
VIAS_T_001	Configuration parameters can be received by: - SIA_PANT • SIA_POS • SIA_DH		
VIAS_T_002	Following information related to Ambient can be received and processed by SIA:		As the vehicle used is not electric, SIA_PANT cannot be installed in

Test ID	Test Description	Passed? (Y/N)	Comments
	• Wheel-Rail contact, i.e. physical magnitudes (e.g. accelerations) • Electric power supply		the pantograph. However, for functionality checking purposes, accelerometers are installed in the axle box of the vehicle to have a more representative use case.
VIAS_T_003	Following information related to EGNSS can be received and processed by SIA: • GNSS signals • Inertial signals		
VIAS_T_004	IF_POS_DH: Positioning related information can be sent by SIA_POS and received by SIA_DH		
VIAS_T_005	IF_POS_PANT: Timing related information can be sent by SIA_POS and received by SIA_PANT		
VIAS_T_006	IF_PANT_DH: Sensor information can be transmitted by SIA_PANT and received by SIA_DH		
VIAS_T_007	IF_DH_VP: Generated data in SIA_DH can be transmitted and received by SIA_VP		

Table 5. Tests in the track

Conclusions

From an end-user perspective, the testing of experimental new systems is always challenging. These activities require the collaboration of several teams, from investigation engineering related personnel to day-to-day operational personnel including equipment providers. These situations are even more challenging in a railway environment to ensure that all the safety and availability requirements are met.

Regarding the SIA testing, promising results have been established and they will be really useful to railway operators. Specifically, the information regarding the interaction between pantograph and catenary that nowadays is not known as well as the interaction between the wheel and rail. The information is also complemented and enhanced with the positioning E-GNSS system data providing the precise points of the track that could influence both components.

References

1. FGC website: https://www.fgc.cat/en/