D4.5 – Galileo demonstrator report

WP4000 - Education and training on GNSS-related issues

Galileo Information Centre for Mexico, Central America and the Caribbean

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1 Introduction

The scope of this document is to present the Galileo demonstrator to be used in the frame of WP4000 academic activities and courses.

This document is structured in the following way:

- Chapter 1 (this chapter) provides an introduction of the document including the purpose and scope.
- Chapter 2 lists the applicable and reference documents.
- Chapter 3 presents the selection criteria for selecting an appropriate architecture for the demonstrator.
- Chapter 4 presents the selected architecture of the Galileo demonstrator.
- Chapter 5 describes the main components of the Galileo demonstrator.
- Chapter 6 outlines the way forward in the Galileo demonstrator activity.

2 References

2.1 Applicable Documents

The following table provides the list of documents that are applicable within the scope and purpose of this document.

Id.	Títle	Reference	Issue	Date
[AD.1]	Grant Agreement for the action entitled Galileo Information Centre in the United Mexican States, Central America and the Caribbean	307/G/GRO/SAT/19/11167-2	--	December 2020
[AD.2]	PROPOSAL GALIC-MC2 DESCRIPTION OF THE ACTION B6		1.0	January 2020

Table 1: List of applicable documents

2.2 Reference Documents

The following table provides the list of documents that are referenced throughout this document for explanatory purposes.

Id.	Title	Reference	Issue	Date
[RD-1]	U-center. GNSS evaluation software for Windows	https://www.u-blox.com/en/product/u-center		15/07/2021
[RD-2]	U-blox M9 GNSS evaluation kit	https://www.u-blox.com/en/product/evk-m9		15/07/2021

Table 2: List of reference documents

3 Selection criteria of the demonstrator architecture

One of the objectives of the GIC project is the implementation of a demonstrator of the operation of the Galileo system to be used mainly in the EGNSS courses to be delivered at the UNAM (hands-on training).

This section presents the different architectures to implement this Galileo demonstrator. Moreover, various characteristics and benefits of each architecture are analysed, together with their advantages and disadvantages.

Four architectures have been proposed, as follows:

1. Architecture #1: A front-end RF (SDR) plus free and open software that processes the digitized GNSS signals from the front-end.
2. Architecture #2: A complete commercial system with proprietary front-end software and RF optimized based on required specifications.
3. Architecture #3: An evaluation board of a GNSS receiver module accompanied by its own software.
4. Architecture #4: A mobile application that takes advantage of the terminal's GNSS chip.

The Galileo demonstrator will be used to carry out promotion and demonstration activities related to training (a series of practices with the demonstrated to understand and observe the potential of the European GNSS system). One of the core aspects of GNSS system, and Galileo in particular, is the reception of signals on user terminals.

Thus, based on the use of a RF front-end, a demonstrator to show the reception of Galileo signals will be implemented with a two-fold scope:

- Demonstrate how Galileo signals are received and processed in real-time.
- Elaborate a laboratory for interested students for handy-man training.

The four architectural proposals have been evaluated considering the following selection criteria:

- The cost of architecture.
- The complexity of the architecture.
- The availability of architecture.

- The possibility of receiving single, multi-constellation and/or multi-band GNSS.
- The possibility of using assisted GNSS.
- The user-friendliness of the architecture, and specifically, the interface of the software to implement hands-on activities with students.
- Availability and time-to-serve
- Support from the manufacturer

4 Architecture of the Galileo demonstrator

Considering criteria presented in the previous section, we have selected **the third architecture** to develop the Galileo demonstrator.

This third architecture could be considered an intermediate architecture between the previous two, as it combines a software and a receiver (evaluation board) that is more professional than those of the first architecture (it resembles the second in this aspect) but allows modifications to be made and multi-constellation and multi-band without the need to pay licenses (much more affordable).

There are several companies that provide these evaluation boards like U-blox or STM. In this case, the U-blox EVK-M91 has been used together with the U-center, software that allows configuring the evaluation kit and observing (in real time) different parameters of the GNSS signals received.

A diagram of this architecture (U-blox) can be seen in Fig. 1. The set-up of the lab is simple: the active antenna is connected to the SMA input of the evaluation board. The evaluation board is connected to the computer using the USB port. In the computer, the U-center is installed to control de board and introduce diverse configurations according to the lab requirements.

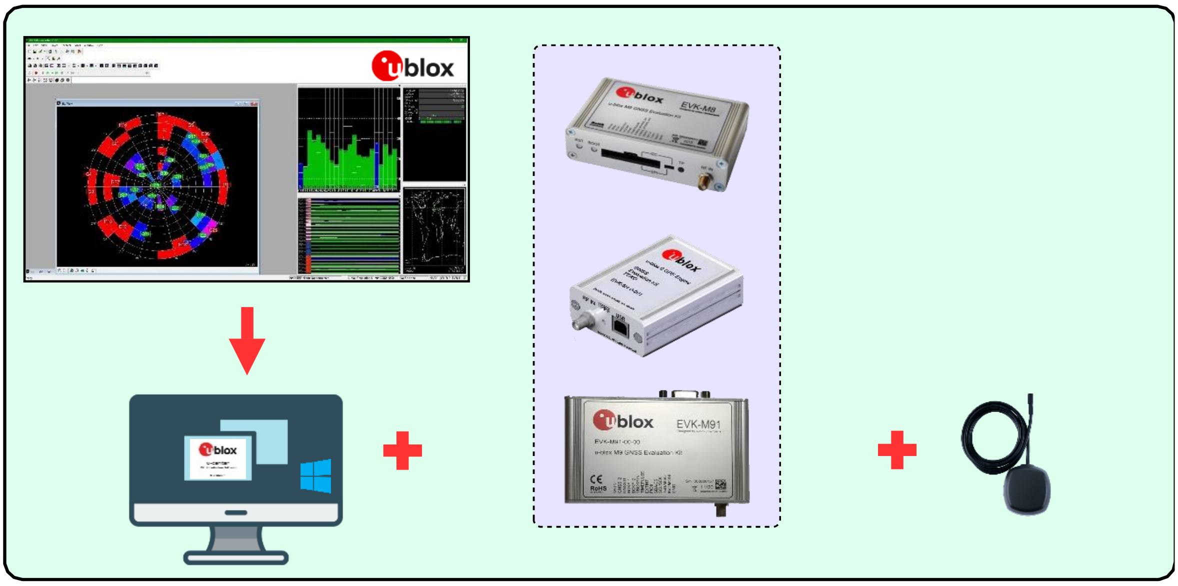

Fig. 1. Architecture 3 diagram - Evaluation board (U-blox).

The advantages of this architecture are:

1. Intermediate solution between the first two architectures.
2. Allows multi-constellation and multi-band receiver (in real time).
3. Allows to receive some SBASs (depending on the kit).

4. The U-blox evaluation kit specifically allows online and offline (internet) assistance.

5. Affordable price between 160€ and 310€ depending on the evaluation kit chosen. Free software (U-center).

6. Greater precision and reliability than architecture 1.

7. It is possible to use it in RTK scenarios.

8. Free technical support.

9. Easily portable.

10. Good way to understand the operation of a software receiver and signal processing (at least better than the second architecture).

The drawbacks of this architecture are:

1. Technical support could be improved.

2. Unlike architecture 1, the evaluation kit limits the number of constellations that can be received.

3. In many cases, the software scripts cannot be modified to suit the desired needs.

4. Most software is only available on Windows.

5. Precise positioning hard to obtain.

6. Although it is available from main global manufacturers (Mouser, Digikey) and the manufacturer (U-blox), delivery may be affected by electronic components supply chain.

Due to the mentioned advantages, this architecture has been proposed (and selected) as one of the possible architectures for the Galileo demonstrator.

5 Description of the demonstrator

5.1 EVK-M91 Evaluation Kit

EVK-M91 Evaluation Kit makes evaluating the high performance of U-blox M9 positioning technology simple (this module will be described later, in subsection 4.1.2). The built-in USB interface provides both power supply and high-speed data transfer, keeping the possibility to connect through 14 pin connector. EVK-M91 has versatile interfaces and measurement points that enable advanced evaluation needs. This evaluation kit is compact, and its user-friendly interface and power supply make them ideally suited for use in laboratories or vehicles.

The kit contains the following items:

1. EVK-M91 unit (NEO-M9N module with the UBX-M9140 chip).
2. USB 2.0 cable (type C).
3. Active GNSS antenna with 3 m cable.

Fig. 2 shows the front and back views of the EVK-M91.

Fig. 2. The front and the back panel of the EVK-M91 evaluation unit.

Table 3 shows the main specifications of the evaluation kit.

Table 3: Main specification of EVK-M91.

Parameter	Specification
Serial interfaces	1 USB 2.0 Type C
	1 UART, max baud rate 921600 bauds
	RS232 ± 5 V level

	14 pin -3.0 V logic
	1 I2C max 400 kHz
	1 SPI - max SPI CLK 5.5 MHz, max data rate 1 Mbit/s
Timing interfaces	1 Time pulse output
Dimensions	105 × 64 × 26 mm
Power supply	5 V via USB or powered via external power supply pin 14 (V5) and pin 1 (GND)
Normal operating temperature	-40° C to + 65° C

The EVK-M91 supports all three communication interfaces: UART, I2C and SPI. For connecting the EVK to a PC, use a standard SUBD-9 cable or the included USB Type-C cable depending on the interface in use. The U-blox M9 GNSS receiver has a USB interface which allows direct communication to the receiver by USB. Additional measurement equipment can be connected to the front connector.

Possible interface connections are:

1. Use the interface switch on the front panel to choose between I2C/UART and SPI communication ports. You must reset the unit by pressing the RST button after the interface switch setting has been changed.

    - I2C: In this selection the EVK operates with the UART (RS232 back panel or the 3.0 V level TXD (MISO), RXD (MOSI) at the pins front panel).

    - SPI: In this selection the EVK operates only with the SPI interface. RS232 is switched off.

2. The USB Type-C connector on the evaluation board can be used for both power supply and communication. The easiest way to evaluate the EVK-M91 operation is to connect the EVK to a PC by the USB-C 2.0 cable and then to use the U-center to configure and monitor the GNSS functions. The USB connector has a direct connection to the U-blox M9 receiver, which enables the USB interface to be used as a communication interface as well.

    When the board is connected to the PC, Windows creates a virtual COM port to the PC. This newly created virtual COM port needs then to be selected on the U-center application. The USB communication speed is by default set to 38400 baud. EVK-M91 supports speeds up to 921600 baud.

This is the interface connection that will be used to test the kit.

3. The evaluation unit includes two options for the UART connection, one is an RS232 port for serial communication with the PC and the other one is the 14-pin connector. We will not go into much detail with this interface, as it will not be used.

4. The SPI interface pins are available on 14-pin connector (frontal panel). If using the SPI interface, the Interface switch must be set to "SPI".

5. The 14-pin connector contains pins for evaluating I2C bus communication. If using I2C, the Interface switch must be set to "I2C". By default, the optional I2C pull-up resistors are not populated on the EVK board. The U-blox M9 GNSS receiver already contains internal pull-up resistors for normal use. If fast communication speed with long cable length is needed, the optional pull-up resistors can be placed to the reserved location on the EVK board.

To evaluate the GNSS reception, the GNSS signal must be supplied to the antenna input SMA connector of the evaluation board. EVK-M91 evaluation kit includes a GPS, Galileo, GLONASS and BeiDou antenna with a 3.0 m cable. It is possible to connect various active and passive GNSS antennas with SMA connectors or provide a signal from a recorded or simulated GNSS RF source to the antenna input.

An SMA female connector is available on the front side (see Fig. 2) of the evaluation unit for connecting an active or a passive antenna. The RF path on EVK-M91 contains an LNA and a SAW filter having 3.0 V DC voltage in the RF input. The recommended maximum antenna supply current for active antennas is 40 mA and is limited by the internal antenna short circuit detection feature. In addition to internal short circuit antenna detection feature, a hardware short circuit protection limits the maximum current to 100 mA.

The EVK includes a RST (reset) button and a BOOT button on the front panel to reset the unit and to enter safe boot mode respectively.

The evaluation board includes a super capacitor to supply the backup power domain of the EVK-M91 and is charged whenever there is a power supply available, either via USB or the 14 pins connector.

Fig. 3 presents the block diagram of the EVK-M91.

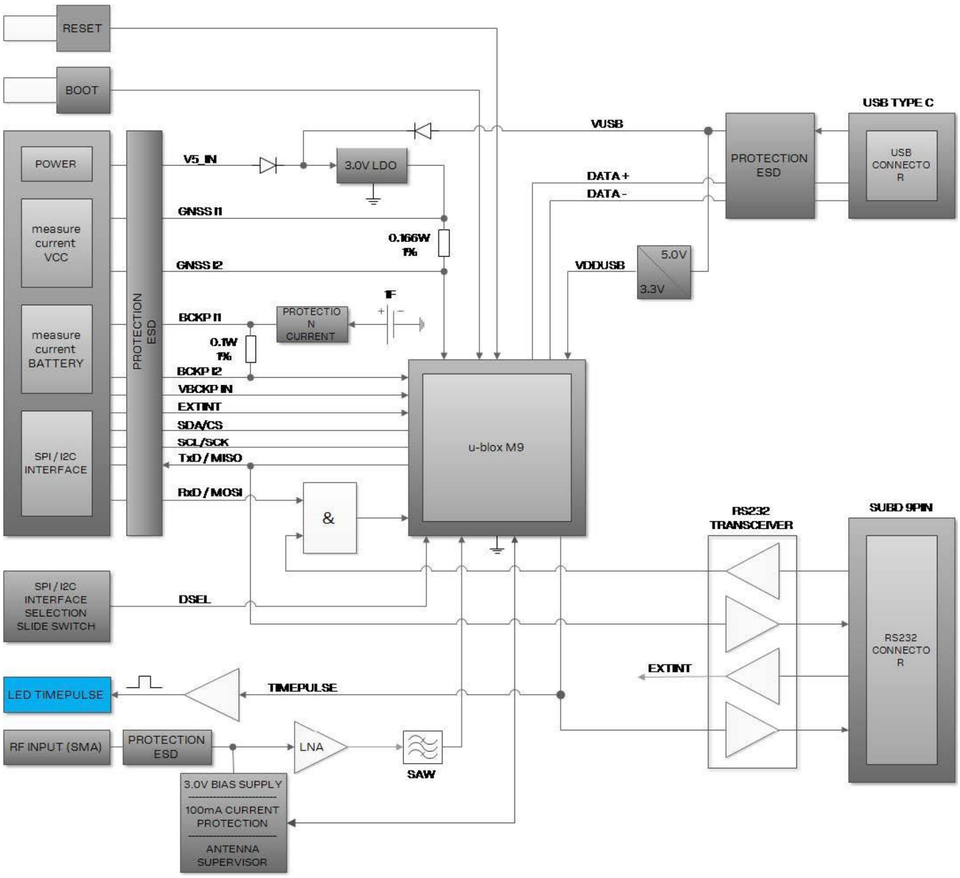

Fig. 3. EVK-M91 block diagram architecture.

5.2 NEO-M9N module: architecture

The NEO-M9N GNSS receiver features the U-blox M9 standard precision GNSS platform and provides exceptional sensitivity and acquisition times for all L1 GNSS systems (Galileo, GPS, GLONASS and BeiDou). U-blox M9 receivers are available in different variants to serve auto- motive and industrial tracking applications, such as navigation, telematics and UAVs.

U-blox M9 receivers support concurrent reception of four GNSS (as already mentioned). The high number of visible satellites allows the receiver to select the best signals. This maximizes the position accuracy, in particular under challenging conditions such as deep urban canyons. They can also detect jamming and spoofing events and report them to the host, which allows the system to react to such events. Advanced filtering algorithms mitigate the impact of RF interference and jamming, thus enabling the product to operate as intended. Table 4 shows the main specifications of the NEO-M9N module.

Table 5 shows the supported GNSS constellations and augmentation systems. All of them can work at the same time or separately, it depends on the configuration desired by the user.

Finally, Table 6 shows the protocols supported by NEO-M9N.

Table 4: Main specification of NEO-M9N module.

Parameter	Specification
Receiver type	Multi-constellation GNSS receiver
Accuracy of time pulse signal	RMS 30 ns 99% 60 ns
Frequency of time pulse signal	0.25 Hz to 10 MHz (configurable)
Operation limits[1]	Dynamics ≤ 4 g
	Altitude: 80,000 m
	Velocity: 500 m/s
Velocity accuracy[2]	0.05 m/s
Dynamic heading accuracy[2]	0.3°

Table 5: Supported GNSS constellation and augmentation systems by NEO-M9N module.

GNSS constellation	
Galileo	E1-B/C (1575.42 MHz)
GPS	L1 C/A (1575.42 MHz)
GLONASS	L1OF (1602 MHz + k*562.5 kHz, k = 7,..., 5, 6)
BeiDou	B1I (1561.098 MHz)
Augmentation systems	
QZSS	L1s (SAIF)

Other SBASs	EGNOS, GAGAN, MSAS and WAAS

Table 6: Supported protocols by NEO-M9N module.

Protocol	Type
UBX	Input/output, binary, *U-blox* proprietary
NMEA 4.10	Input/output, ASCII
RTC 3.3	Input, binary

Fig. 4 depicts the block diagram of the NEO-M9N module. It can be seen that this module incorporates an RF enhancement composed of a notch filter, a SAW and a LNA. This block is connected to the UBX-M9140-KB (the core of the NEO-M9N module) which in- corporates an RF block (that works in baseband) that includes another LNA and a front-end RF connected to a synthesizer attached to a TCXO (with 1 PPM stability). After this block (inside the UBX-M9140-KB), the signal is processed digitally, all of which is subject to an RTC crystal. It is also indicated an interface module that allows communication between the module and the outside.

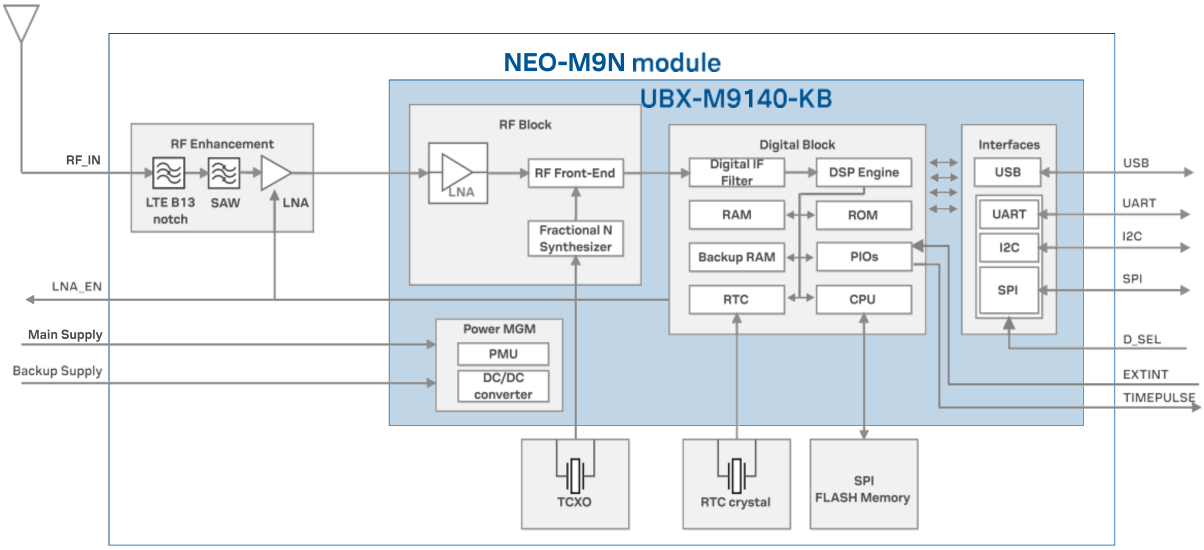

Fig. 4. NEO-M9N block diagram.

6 Current status and next steps

In the final version of the deliverable, we will present the activities carried out with the demonstrator in the region of interest of the project.