

Development of a Low-Cost Commercial GNSS Simulator

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BIOGRAPHY

Bart Peeters is the Managing Director of Ursa Minor. He is the manager for the SAR/Galileo Test Beacon of the Test User Segment in the phases C0 and C/D/E1. Furthermore, he is the navigation specialist of the company and is involved in the engineering of the Galileo Test Beacon. Bart worked as a Young Graduate Trainee at ESA/ESTEC in the Galileo Project Office and completed his master thesis at this same office. He graduated from Delft University of Technology, faculty of Aerospace Engineering in 2001 as a Space Systems Engineer and gained the Master of Space Systems Engineering (MSE) degree from SpaceTech in 2006.

Peter Batenburg is co-founder of Carya Automatisering, a software firm specializing in industrial automation, in particular for research and development.

Leif Johansson is Business Development Manager for northern Europe at National Instruments. He is specialising in modular instruments and RF products. Leif is a long time specialist in the Test and Measurement Industry where he has been active for the last 25 years.

Nicholas Lan is a systems engineer at Ursa Minor and has been involved in SAR-TB development for the last 2 years. He was previously a Young Graduate Trainee in ESA's Advanced Concepts Team and holds an MSc in Astronautics & Space Engineering and a BSc in Astrophysics.

1. INTRODUCTION

With the forthcoming operational capability of the Galileo constellation, there is an accelerating

interest in both industry and government in the development and dissemination of technologies taking advantage of this constellation's enhanced abilities. In the search for innovative, attractive applications of the capabilities that will be provided by Galileo, significant emphasis is, for instance, put on the role of entities such as SMEs and newcomers to the field of location based services in generating and developing novel solutions with good potential for future uptake. A low cost GNSS signal simulator, including Galileo is therefore under development within Ursa Minor, in collaboration with Carya and National Instruments. The result should be a relatively cheap system with functionality tailored to specific customer needs. In addition to being a viable commercial product, it is hoped that this product will stimulate the development of new GNSS products and services through lowering one barrier to entry into particular markets in terms of cost.

The simulator is to be based on existing hardware for RF signal generation including the following features for the first basic product.

- Simulation of up to 12 GPS satellite signals simultaneously
- Simulation of up to 12 Galileo satellite signals simultaneously
- Automatic signal simulation for chosen receiver location from satellite almanac and ephemeris files
- Simulation of receiver movement
- User editable satellite pseudorange, Doppler, and power-level information
- Simulation of up to 12 GPS satellite signals simultaneously
- User editable satellite pseudorange, Doppler, and power-level information

In terms of hardware choice, project partners may provide a range of solutions with that may be tailored to the needs of particular user cases. Hardware choice for the first basic product will be presented along with rationale in terms of appropriateness for this particular product. Envisaged expansions to the product will be discussed with reference to the potential impact on required hardware.

Further functionality will be considered in light of planned work in terms of collecting user requirements for target markets with the intention of providing suitable low-cost solutions to increasing market areas where developments using advanced GNSS services may be stimulated.

2. HARDWARE SETUP, INTEGRATED TESTING AND CUSTOMISATION

This simulator development is a spin-off from developments made under ESA contract in the Test User Segment of SAR/Galileo. Specifically, the development is based on the Search and Rescue Test Beacon (SAR-TB) implementation, as illustrated in Figure 1, to be used for testing of Galileo IOV and FOC phases (Peeters and Stojkovic, 2008, 2009). One of the main advantages envisaged for the simulator product is the relatively low cost and versatility of the hardware to be used. Off the shelf hardware from National Instruments shall be used for all products. Potential customers may already have suitable hardware elements in this case. Hardware used will be similar to, and in some cases the same as, hardware utilised in the relevant parts of the SAR-TB development.



Figure 1: Relevant SAR/Galileo SAR-TB hardware on which GNSS simulator is based. The SAR-TB features custom PXI signal generator HW.

The HW platform that has been chosen to build this Simulator on is PXI (PCI eXtensions for Instrumentation) that offers a high performance low cost deployment platform for measurement systems.

The PXI platform was introduced in 1997 as an open industry specification to meet the increasing demand of complex instrumentation systems. Because PXI is an open specification, any vendor is able to build PXI products it also allows for customer to build specific module that can be integrated to the platform. CompactPCI, the standard regulated by the PCI Industrial Computer Manufacturers Group (PICMG), and PXI modules can reside in the same PXI system without any conflict because interoperability between CompactPCI and PXI is a key feature of the PXI specification.

Today PXI has evolved into PXIe based on the PCIe technology that will offer higher data speeds increasing the available bandwidth from 132 MB/s with PXI to 6 GB/s for a more than 45X improvement in bandwidth while still maintaining software and hardware compatibility with PXI modules.

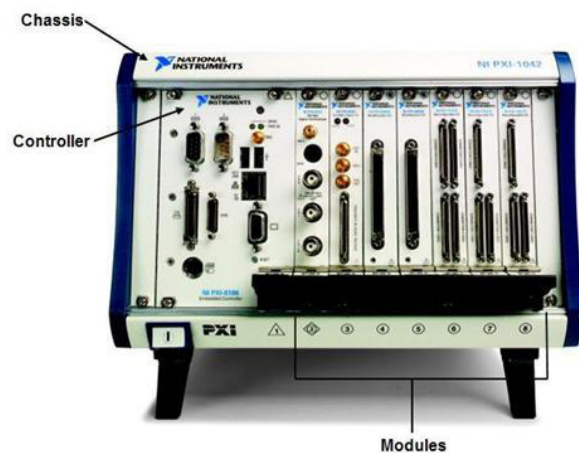


Figure 2: PXI systems are composed of three basic components — chassis, system controller, and peripheral modules in our case we are using RF generators and analyzers.

The PXI backplane has as an addition to PCI also a built-in timing and triggering buses. The PXI bus adds a 10 MHz reference clock, PXI trigger bus and a star trigger bus to address the needs for advanced timing, triggering and synchronization between modules (and even chassis).

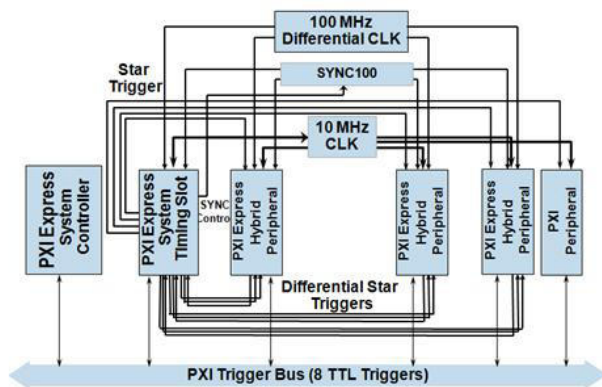


Figure 3: PXI Timing and Triggering Buses – PXI combines industry-standard PC components, such as the PCI bus, with advanced triggering and synchronization extensions on the backplane.

One of the key features of this backplane infrastructure is the capability to stream real-time data to hard disc and retrieve it in real time as well. This allows us for example to record real time GPS or GIOVE signals from within a vehicle and play it back in the lab or use it for simulations.

There is a large selection of PXI chassis, controllers and modules readily available from multiple manufacturers. National Instruments supplies a large number of PXI modules in the following categories:

- Switch modules featuring general-purpose relays, multiplexers, and matrices Data acquisition modules for multifunction analog, digital, and counter I/O
- Bus interface modules for Gigabit Ethernet, GPIB, serial, IEEE 1394, CAN, VXI, and other buses
- Motion, vision, and analog and digital I/O modules for industrial applications
- Synchronization modules for multichassis and advanced multidevice synchronization
- Modular instruments for analog and digital I/O ranging from high-resolution DC to 6 GHz RF

Using this modular approach allows us to scale our system to customer needs and, for example, change performance parameters like number of channels, available signal bandwidth, multiple navigations system, interference signals etc.

3. SOFTWARE IMPLEMENTATION

Continuing from SAR-TB developments, simulator software will be largely implemented in LabVIEW. Initial RF signal generation has been achieved using LabVIEW. Phased implementation will be

employed such that useful products may be released quickly.

LabVIEW runs on a Windows platform which gives the user access to common Windows tools and easy access to drivers for the HW. The software philosophy of PXI is one of Virtual Instruments, which means that we are easily able to change the behaviour and use of the different HW instrument modules. With the use of this interchangeable software function we can for example change the Galileo HW RF module to a W-LAN, ZigBee or GSM signal generator. This allows for a cost effective, integrated test environment.

4. RF SIGNAL RESULTS

As a first step in developing a GNSS signal generator we considered the Galileo E1 signal. The format of this signal is described in the current release of the Galileo signal ICD (ESA, 2008).

The (open part of the) E1-signal consists of E1-B, the data channel, which contains the navigation data and E1-C, the pilot channel. Both channels are modulated by a combination of BOC(1,1) and BOC(6,1) modulation (MBOC-modulation). The characteristic feature of this modulation is the dip in the power spectrum at the carrier frequency and an increased side lobe at around 6 MHz.

To investigate the capability of the hardware to produce a MBOC-modulated signal, we generated random data for the data and pilot channel of the E1 signal, modulated the signal with the BOC(1,1) and BOC(6,1) modulation. The simulated signal is presented to the AWG and upconverted to the E1-carrier frequency of 1575.42 MHz. The generated RF-signal is then downconverted. The power spectrum is determined with RFSA-Scope.

The measured power spectral density of the simulated signal (in black) is shown (in black) in Figure 4. We observe the dip at the carrier frequency (set at zero frequency) and the characteristic shoulders at ± 6 MHz. There is a good match between the measured spectrum and the exact MBOC-PSD (shown in red).

Other measurements indicate that our development hardware is capable of accurately representing signals with a bandwidth of 2×12 MHz (around the E1 carrier frequency of 1575.42 MHz). Additional expansion of this bandwidth is possible with other COTS PXI HW modules.

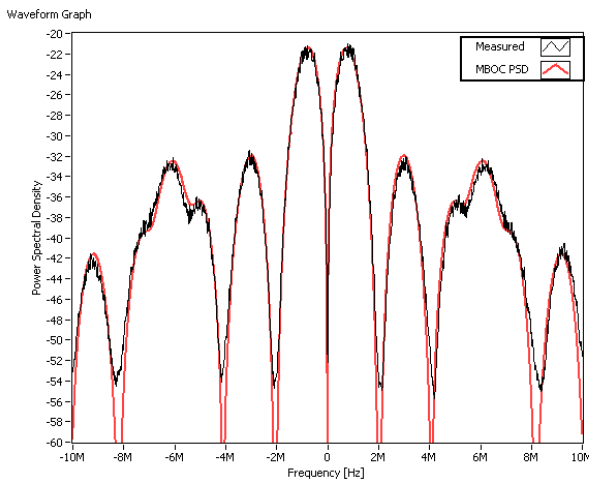


Figure 4: Measured simulated signal vs. Exact MBOC Power Spectral Density

5. WORK TO BE DONE

With the signal generation at the stage described in section 4, a first basic product may be released within the next few months.

In the future, users will be consulted to assess the value of implementing extra functionalities in the simulator. Currently, however, it is envisaged to implement the following functionalities to provide a low-cost, yet functional integrated GNSS simulation product.

- Simulation of up to 12 GPS satellite signals simultaneously
- Simulation of up to 12 Galileo satellite signals simultaneously
- Automatic signal simulation for chosen receiver location from satellite almanac and ephemeris files
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- Simulation of up to 12 GPS satellite signals simultaneously
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6. CONCLUSIONS

A low cost yet functional integrated GNSS signal simulator development has been described, along with plans for its development in the near future to provide a range of commercial products.

This product is anticipated to not only be a successful commercial product due to its low cost and partnership with National Instruments, but also an enabling solution for stimulated development of novel GNSS services and technologies. By lowering

the cost of entry for such testing equipment in conjunction with appropriate marketing and iterative development with user feedback, it is hoped that this product will facilitate innovation in industry.

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