GNSS Galileo Code Receiver

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Figure 1: (left) Receiver Hardware mock-up and (right) side by side of a small UAV (UAVISON UX-401L)

Abstract:

The company is a private Portuguese Aerospace Engineering company, delivering advanced design solutions and turn-key space SW systems. Building on a solid team of highly motivated and specialized engineers, the company is now a reference player in the European space sector.
The company offers the Galileo Code Receiver (GCR) - an advanced GNSS receiver targeting cost effective, high navigation accuracy (down to 20cm) requirements for professional applications. Its high multipath resilience and low tracking noise is ideal for harsh environments (e.g. urban environments, close to tree canopies and other objects), outperforming the existing GPS solutions. The company is opened to set up technology licensing agreements with end users and system integrators (OEM and Value Added Resellers) willing to take advantage of early access to its technology for new applications or improved systems.

Description:

GPS satellite navigation technologies has been powerful enabler of new products/applications and drivers of productivity gains in many economic activities. Still, high precision, real time dependable applications are still limited by the error prone GPS in many contexts, therefore making the use of GPS receivers either practically complex (and expensive) or even impossible.

With the advent of GALILEO, the possibilities will greatly increase. The company developed a GPS/GALILEO receiver that brings navigation accuracy to the centimetre level. The innovative technology is able to extract from the GALILEO signal an extremely robust and precise navigation solution, even in demanding environments.

Laboratory results so far indicate that the system could be used in applications requiring high accuracy positioning (few centimetre level) using code measurements instead of the traditional carrier phase measurements. Hence the name of the receiver: Galileo Code Receiver. This is possible thanks to an innovative combination of Galileo signals (more specifically AltBOC modulation in the E5 band with low noise characteristics and high robustness to multipath environments typical of urban environments) and dedicated navigation algorithms. The latter explores the low noise properties of the Galileo AltBOC code measurements combining then with Galileo signals on the E1 band for estimation of the ionospheric delays.

The following receiver characteristics can be highlighted:

- Fully configurable FPGA-based (Xilinx Virtex-6) 16-channel Galileo/GPS receiver (up to 160 real correlators)
- Embedded micro-processor
- BPSK/BOC/CBOC/AltBOC signal processing: Galileo E1 CBOC, Galileo E5 AltBOC, GPS L1 C/A, GPS L1C and GPS L5
- Interfaces: PCIe, Ethernet, CAN, UART, JTAG, GPIO (FMC and header pins), SMA
- Supports both single and dual frequency RF front-end
- Digital IF/baseband signals with up to 4-bits
- Includes a software package (receiver monitoring and control, measurement post-processing, navigation)

Potential applications include GNSS surveying in urban environments and use in Unmanned Aerial Vehicles (aircraft that flies autonomously or remotely, without carrying a human operator) which could be used for inspection of difficult to reach sites such as building structures, eolic generators, high voltage electric towers, all considered to have a niche market potential. Other applications where the proposed technology could enable an autonomous platform to perform the work are:

- Topography mapping;
- Agriculture imaging
- Surveillance autonomous missions in defined areas;
- Civil protection (Search & Rescue)
- Lawnmower (e.g. golf courses, stadiums)

The receiver, today implemented in a FPGA (see figures), is currently undergoing tests with live Galileo signals (a total 4 satellites have already been launched out of a total of 30 in the complete constellation) and has already been successfully demonstrated in laboratory conditions using a hardware mock-up.

The current receiver mock-up can be made available for testing in the desired applications and its integration in the end-user platform requires simple physical mounting, an Ethernet port, an antenna and power supply.

Innovations and advantages of the offer:

The receiver uses the Galileo E5 signal AltBOC modulation, which has an unparalleled (when compared to GPS) intrinsic characteristic of ultra-low noise and multipath robust Code observables (distance from satellite to receiver), in contrast to Carrier phase observables (distance from satellite to receiver which is more accurate but is ambiguous), which are prone to discontinuities (so called cycle-slips) and even loss of lock, especially in urban environments.

Indeed, such environments are rich GNSS reflected signals from buildings, trees, bridges and other large objects (so called multipath) which can contaminate Code and Carrier observables, often requiring the use of additional sensors (accelerometers, gyroscopes, ultra-sonic and barometers) thus increasing costs and complexity, especially if high accuracy and continuous navigation solution is required. Additionally, for surveying applications, existing high accuracy RTK receivers rely on carrier phase measurements, which under harsh environments can be a major difficulty due to cycle-slips. Even receivers using carrier-code smoothing can suffer from errors in the initial convergence process.

If real-time (RT) navigation is desired the solution often involves expensive (tens of thousands of euros) bulky (few kg) high grade inertial sensors, ultra-sonic sensors, cameras, or even barometers. If non-real-time is acceptable the solution involves post-processing techniques for smoothing navigation outputs, including the use of information available from others sensors. Sometimes it is even necessary to return to the field for additional data collection (as in the case of surveying application).

Indeed, the previous RT and non-RT solutions are suboptimal for the following reasons:

- Unmanned Aerial Vehicles (e.g. model aircraft (MA) category, up to 20 to 35 kg) need to be cheap, light and need to operate in urban environments and with RT requirements, therefore requiring a robust and accurate navigation solution. For instance, for applications where the UAV is used for inspections of infrastructure (e.g. power lines, windpower generator rotor blades) it is necessary to fly close (few meters) to the object we are monitoring;

- Even if RT capability is not required, existing GPS receiver manufacturers do not recommend the use of high precision GPS in urban environments or even close to trees for the reasons explained before (multipath, cycle-slips). Here, the use of high quality inertial sensors or other sensors and techniques are required for post-processing if high accuracy is required.

The navigation algorithms will then use code measurements of the dual frequency receiver and extract the ionosphere effects using an innovative concept: it uses the low noise properties of E5 AltBOC and combined with the with E1 MBOC signal to estimate the ionospheric delay, instead of the conventional dual frequency ionospheric error free combination. Such a combination preserves the low noise properties of E5 AltBOC for use in the navigation solution and using precise or broadcast real-time orbits and clocks allows a real-time high accuracy and robust positioning (7 to 14 centimeter).

Further Information:

Several technical publications can be made available upon request:

- Ismael Colomina et al, "The Accuracy Potential of Galileo E5/E1 Pseudoranges for Surveying and Mapping", Proceedings of the ION GNSS 2011
- Pedro Silva et al "Galileo AltBOC Signal Processing for Precise Positioning - Experimental Results", Proceedings of the ION GNSS 2012

Application:

GNSS high accuracy positioning for

- Guidance and control applications (UAV and other unmanned vehicles)
- Inspection of difficult to reach sites such as building structures, windpower generators, high voltage electric towers
- Agriculture imaging
- Surveillance autonomous missions in defined areas;
- Civil protection (Search & Rescue)
- Autonomous agro/forest equipment (tractors, cutters, lawnmowers, (e.g. golf courses, stadiums), etc)
- GNSS surveying in harsh environments (urban, dense forestry, remote rural settings)

Space Heritage:

The receiver uses measurements obtained from Galileo satellites thus it is considered a space-based technology.

Broker comments:

Application outside space:

DEIMOS Engenharia is currently developing a TT project with this technology (for inspection of difficult to reach sites - building structures, windpower generators, high voltage electric towers), funded by the NTTI-Portugal. This transfer was already under study by the company when the PTTI appeared. This Tech Description looks to support the TT and present the technology potential to other non-space applications.

Application in space:

GNSS Reflectometry involves taking measurements from the reflections from the Earth of signals transmitted by GNSS satellites. It has been already demonstrated using GPS and allowing to measure moisture, snow dept and wave motion and windspeed of oceans. These applications can also benefit from more accurate measurements present in the E5 band. This is currently investigation by DEIMOS under a Portuguese national research initiative (POR-QREN) project called SARGO.