What is GNSS Simulation?

And how can simulation help reduce your time to market?

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What is GNSS Simulation?

Accuracy, integrity and availability are all major challenges for satellite-based navigation systems, particularly in safety critical environments. Previously the sole system providing commercial satellite navigation was the US funded global positioning system's GPS L1 C/A code. The current revolution in new GNSS signal availability is requiring the navigation system designer to answer a number of new key design questions.

There are also many techniques and technologies currently existing, and under development, to improve the performance of GNSS systems. Examples include augmentation such as inertial sensors and Wi-Fi positioning techniques, as a compliment to GNSS.

The primary aim of this paper will be to explain what a GNSS simulator does and to present some of the key design questions and solutions for testing navigation and positioning systems under controlled laboratory conditions using simulation techniques.

Introduction

Global Navigation Satellite System (GNSS) is a general term for a system that provides navigation and other services to users worldwide. Each GNSS employs a constellation of satellites, which broadcasts signals that are then processed by GNSS receivers to determine location, speed, and time for users anywhere within range of the satellites. This is normally on or just above the Earth's surface, but can be in space as well. There have been a significant number of developments in the availability of new satellite navigation systems and services (GPS, Galileo, GLONASS, QZSS, Beidou, etc.) correspondingly driving a need for more testing to confirm the performance of these systems and associated enhancements in relation to the design, qualification and validation of navigation equipment, whereas in the past, GPS C/A code was the only available service for the majority of commercial applications.

Since the early days of GNSS, there have essentially been two major alternatives available to those wishing to test a navigation system: field test and laboratory simulation. Today, best practice indicates that most testing is done under controlled, repeatable conditions in a secure laboratory. This enables both nominal and adversarial conditions testing, including testing to the limits of both real and theoretical performance. It also allows development of receivers for GNSS systems that are currently unavailable or lacking a full constellation.

Global Positioning System (GPS) and Other GNSS systems

While the US sponsored GPS system is the only GNSS with a fully deployed constellation of operational satellites, other systems are either in planning or deployment stages. Laboratory testing here becomes of utmost importance due to the lack of the real live-sky signals.

Global Positioning System (GPS)

The GPS satellite navigation system was originally designed and funded as a military navigation system. The removal of selective availability (a deliberate degradation of the satellite's clock stability) in 2000 improved the accuracy for non-military applications using the L1 Coarse Acquisition (C/A) code to much better than 10m in many operational scenarios. This improved accuracy has enabled GPS to be used in many applications and led to the explosion of commercial GPS applications that we are seeing today.

In the military sphere, the L1 and L2 P(Y) code encrypted signals remain the NATO standard for military Precise Positioning System (PPS) receivers.

The United States continues to invest in the GPS system. This investment includes the specification, design and launch of new satellites including the new Military Code or M-code signal. The initial M-code satellites have already been launched, with additional launches planned over the next decade as the current satellites reach end of life. Additional civil GPS signals are also planned at the L2C and L5. The first L2C satellites have already been launched, although full operational capability is still several years away.

GLONASS

Development of the Russian GLONASS system began in 1976 and was completed in 1995. Recently Russia has, with India as a program partner, committed to restoring the system to full operational capability (FOC) by 2011. In fact, this looks on track to be completed by the end of 2010. Spirent has seen a recent upsurge in interest in combined GPS/GLONASS simulators. This is due to people wanting to take advantage of additional signals today to improve the availability of their receiver and system implementations.

Galileo

The European Union has committed to the design and validation of the Galileo system. A prime difference between this and the other systems is the proposed civil focus of the Galileo programme. Galileo is designed to be inter-operable with GPS raising the possibility of combined GPS/Galileo receivers in future, bringing benefits or users of additional satellite availability and improved integrity. Spirent is an official supplier of RF Constellation Simulators (RFCS) to the Galileo programme. The RFCS are being used for testing the ground monitoring stations and prototype user receivers. In early 2010 the Galileo project office announced that it had placed contracts for the first satellites, launch services and satellite control. In March 2010 the Galileo signal specification (ICD, interface control document) was issued formally with a free licence available to anyone who wants to use the information to develop Galileo receivers or services.

Quasi-Zenith Satellite System (QZSS)

The Quasi-Zenith Satellite System (QZSS) is a regional multi satellite system, partly designed to provide 'GPS-like' signals from satellites in a Highly Elliptical Orbit (HEO) over Japan. The constellation and orbits have been designed to allow each satellite to dwell over the Japan land mass for more than 12 hours a day with an elevation above 70° providing improved coverage in urban and mountainous areas where the line-of-sight limitation of classic GNSS systems may be impaired. The first launch of QZSS is planned in 2010.

Beidou / Compass

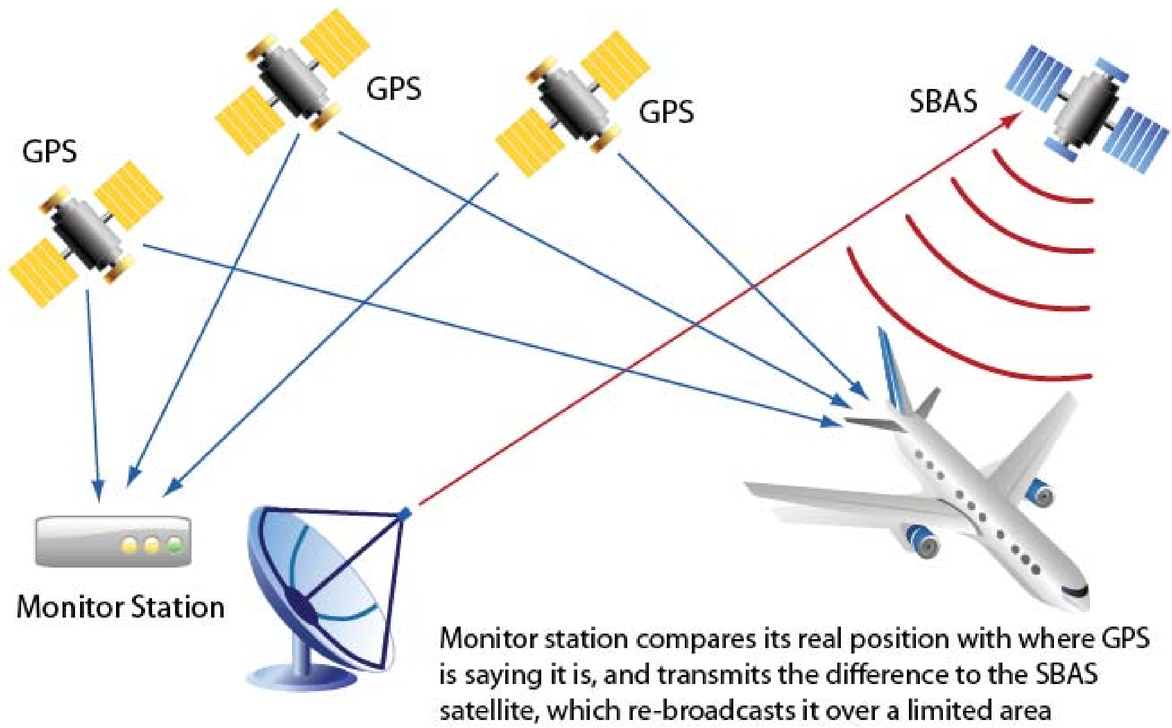
China has indicated it intends to expand the current geostationary Beidou navigation system into a full medium-earth-orbit GNSS constellation, according to China news agency Xinhua. Details are currently awaited by the industry on the capability and international availability of this system. In principle the Compass open civil signals should be interoperable with the other GNSS systems.

Augmentation systems

GPS alone does not always provide adequate performance, particularly in demanding environments or where a high level of integrity is required. The accuracy and integrity of GPS / GNSS can be greatly enhanced by the use of information derived from observations from others sensor technologies. The use of augmentation systems takes many forms but all share the same basic objective of improving GPS / GNSS performance and/or trustworthiness.

Space based Augmentation Systems (SBAS)

Space Based Augmentation Systems (SBAS) are typically designed to improve GPS /GNSS system integrity and accuracy for aircraft navigation and particularly landing. SBAS satellites broadcast correction messages back to Earth, where suitably enabled receivers use the SBAS corrections and integrity information to improve accuracy and integrity. The USA, Europe and Asia are developing their own SBAS systems. In Europe, the European Geostationary Navigation Overlay Service (EGNOS) system exists and is now operational. In the USA there is the Wide Area Augmentation System (WAAS), in Japan the Multi-functional Satellite Augmentation System (MSAS) and India is focusing on the GPS Aided Geo Augmented Navigation (GAGAN) system.



Ground based Augmentation Systems (GBAS)

An alternative approach to space-based augmentation is to transmit correction messages from ground-based systems. An example is the Local Area Augmentation Systems (LAAS), which allows a suitably equipped receiver to derive enhanced accuracy and integrity information in a local area, at an airport for example, where there are stringent requirements necessary to be met to land a commercial aircraft. LAAS can be tested using Spirent's unique LAAS VHF data broadcast signal simulator, the GSS4150.

GNSS Simulation: General Principles

The core requirement of any GNSS receiver test, whether for development, integration or production purposes, is for a controlled, repeatable signal. For many tests, the signal control includes flexibility over test case, or scenario, conditions that enable performance testing at nominal and extreme or error-state conditions.

Real-world, live-sky testing has significant drawbacks which, in practice, preclude controlled testing. Some of the drawbacks of live-sky testing and the advantages of simulation are summarised below:

Advantages of Simulation

- Signal effects such as atmospheric disturbances, multipath and obscuration are quantified, controlled and precisely repeatable
- Vehicle and satellite trajectory and associated dynamics are modelled
- Future signals (e.g. Galileo, GLONASS and modernised GPS signals) can be generated to allow testing against new signals before a complete constellation of satellites are transmitting the Signals in Space (SIS)
- GNSS RF constellation simulators can be used in various configurations enabling, for example, use of remotely generated trajectories and generation of interference signals as well as simulated GNSS signals

Drawbacks of live sky

- An end user or test site cannot have any control over the GNSS signal being transmitted
- The signal seen incident upon the GNSS receiver antenna is never repeatable between two different tests. This is because of the constantly changing GNSS satellite positions, environmental effects and objects around the antenna (e.g. cars and trucks in different positions on different days)
- There are signal errors, often unknown to the receiver at the time
- Atmospheric conditions change significantly and have a significant impact on single frequency systems

Questions Facing Modern Developers

In the past, designers of satellite-based navigation systems have been mostly restricted to using a single system and service, the GPS L1 C/A code.

With new systems and services available now, and even different service levels, the question of which system or blend of systems a GNSS designer should consider, along with the potential for multiple services is thus an entirely new consideration.

The application of the receiver under development may define the answer to this new conundrum to some extent, but in many cases the best way to answer the question fully before committing to a particular design path is to investigate the performance of different options available using a GNSS simulator.

While questions surrounding the pure accuracy of any given receiver using either one or multiple GNSS systems or services need to be answered, there are also a multitude of associated questions regarding device performance, such as power consumption, interface, multipath and interference resistance etc. that also need to be answered.

The availability of multi-frequency, multi system, multi service GNSS simulators allows the GNSS developer to answer these questions with complete confidence in the final design choice. Furthermore, the simulator is invaluable in the actual design effort and integration of the receiver into a given application.

Spirent's GSS8000 Multi-GNSS Simulator

What is a GNSS simulator and how can it help solve your problems?

A GNSS simulator reproduces the environment of a GNSS receiver on a dynamic platform by modelling vehicle and satellite motion, signal characteristics, atmospheric and other effects, causing the receiver to actually navigate according to the parameters of the test scenario. It provides an effective and efficient means of testing GNSS receivers and the systems that rely on them.

It provides control over the signals generated over the global test environment all within a box, so that testing can be conducted in controlled laboratory conditions.

A GNSS simulator provides a superior alternative for most testing compared to using actual GNSS signals in a live environment. Unlike live testing, testing with simulators provides full control of the simulated satellite signals and the simulated environmental conditions.

With a GNSS simulator, users can easily generate and run many different scenarios for diverse kinds of tests, with complete control over:

Date, time, and location

Simulators generate GNSS constellation signals for any location and time. Scenarios for any location around the world or in space, with different times in the past, present, or future, can all be tested without leaving the laboratory.

Vehicle motion

Simulators model the motion of the vehicles containing GNSS receivers, such as aircraft, ships, or automobiles. Scenarios involving vehicle dynamics for different routes and trajectories anywhere in the world can all be run without moving the equipment being tested.

Environmental conditions

Simulators model effects that impact GNSS receiver performance, such as atmospheric conditions, obscuration, multipath reflections, antenna characteristics, and interference signals. Various combinations and levels of these effects can all be tested in the same controlled laboratory environment.

Signal errors and inaccuracies

Simulators provide control over the content and characteristics of GNSS constellation signals. Tests can be run to determine how equipment would perform if various GNSS constellation signal errors occurred.

Why use a GNSS Simulator?

Testing with simulators is the widely-accepted best practice for validating the performance of GNSS receivers and systems in many different scenarios and operating conditions. Simulators are used extensively in academia and industry, in virtually all GNSS receiver manufacturing and major system integration, and in many different application fields, including navigation, positioning, telecommunications, aviation, automotive, and space, for both civilian and military applications. Using simulators facilitates several stages of research and product development, including requirements analysis, design and development, integration, production, maintenance, and support.

GNSS simulators provide many benefits, including:

- **Control**. Simulators allow complete control over all a spects of test scenarios, including GNSS constellation signals and environmental conditions.
- **Flexibility**. Users can easily define different scenarios for different testing needs.
- **Completeness**. Equipment can be tested under different operating conditions, ranging from nominal to extreme, including conditions that are impractical or impossible to produce in live testing.
- **Repeatability**. Test scenarios are the same every time they are executed.
- **Reliability**. Because all test conditions are controlled, test results are reliable, and equipment performance can be evaluated against known truth data.
- **Cost**. Tests are conducted in the laboratory, without extra expenses for field tests and test vehicles. Field testing is very often more costly and time consuming than laboratory testing.
- **Efficiency**. Many different tests can be completed in the same laboratory test bed, without reconfiguring or relocating equipment. New test scenarios can be created and

executed quickly.

- **Realism**. The performance of GNSS receivers and systems are tested end-to-end using real signals. Simulators with real-time control capabilities support advanced hardware-in-the-loop (HWIL) testing.

- **Future**. Simulators provide effective means of testing new and future GNSS capabilities that are not yet supported by actual constellations, such as the GPS L2C and L5 signals and the Galileo system.

A summary of the advantages of testing with GNSS simulators, compared to live testing with actual GNSS constellations, is shown in the table below.

Live Testing with Actual GNSS Constellations	Laboratory Testing with GNSS Simulators
• No control over constellation signals	• Complete control over constellation signals
• Limited control over environmental conditions	• Complete control over environmental conditions
• Not repeatable; conditions are always changing	• Fully repeatable
• Unintended interference from FM, radar, etc.	• No unintended interference signals
• Unwanted signal multipath and obscuration	• No unwanted signal effects
• No way to test with GNSS constellation errors	• Easily test scenarios with GNSS constellation errors
• Expensive field testing and vehicle trials	• Cost-effective testing in laboratory
• Limited to signals available in GNSS constellations	• Testing of present and future GNSS signals
• Competitors can monitor field testing	• Testing conducted in secure laboratory

Spirent GNSS Simulators

Spirent is the industry leader for GNSS simulator products. Spirent offers several different models of GNSS simulators that support a variety of different applications and cover the full spectrum of civilian and military GNSS testing needs. Spirent products range from basic single-channel simulators, suitable for simple production testing, through multi-channel, multi-constellation simulators, suitable for the most demanding research and engineering applications.

For more comprehensive testing, Spirent also offers products that simulate additional system elements simultaneously with the GNSS constellation signals, such as inertial sensors, various automotive sensors, Assisted GPS (A-GPS) data, SBAS and GBAS augmentation system signals, and interference signals.

With almost 25 years of GNSS simulator experience, Spirent provides GNSS simulators with unparalleled performance, features and comprehensive support.

Spirent's Multi-GNSS simulation platforms

Spirent GSS8000 Multi-GNSS Constellation Simulator

Spirent GSS6700 Multi-GNSS Constellation system

Spirent GSS6300 Multi-GNSS Signal generator

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