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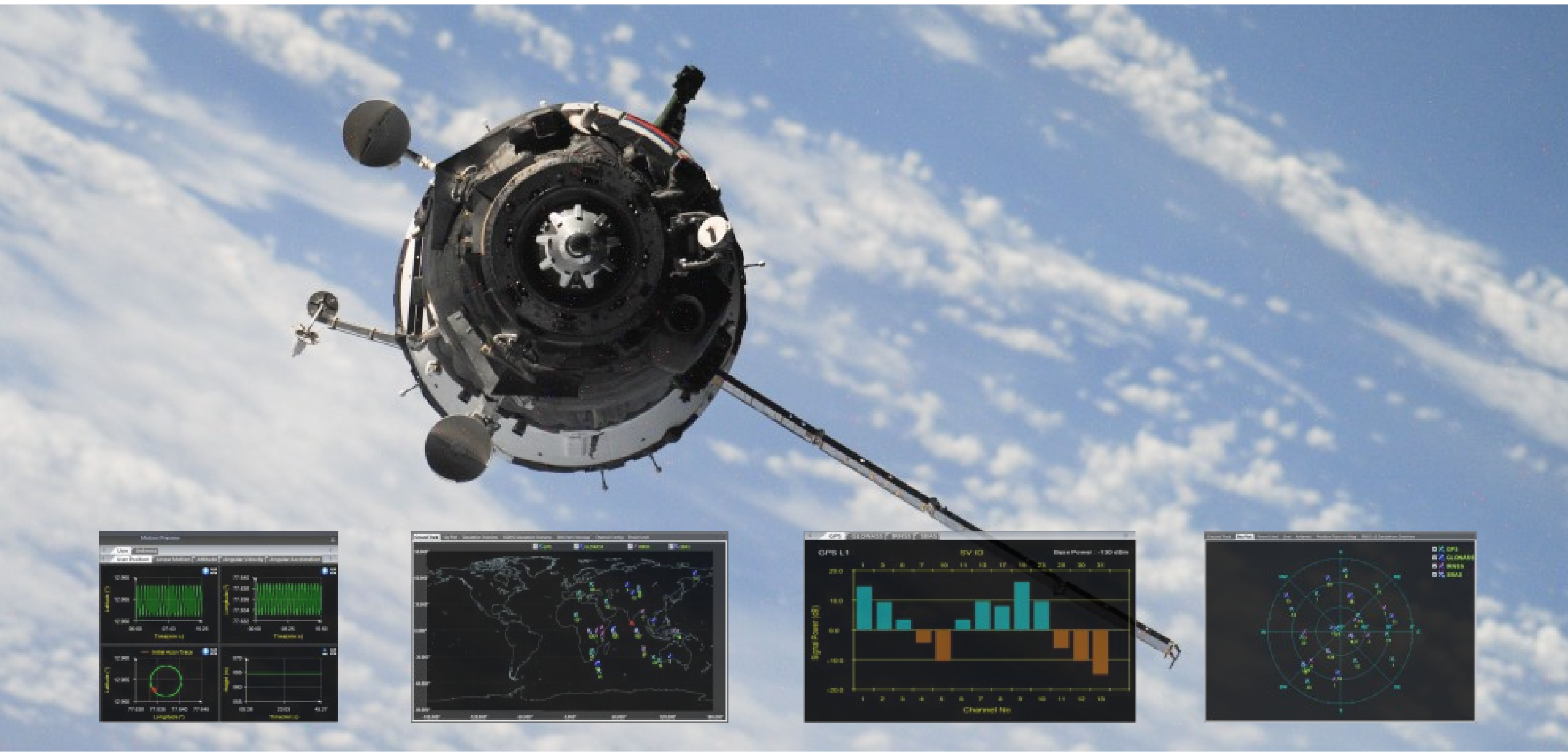

How to meet the demanding challenges involved in testing GNSS receivers?

Abstract

Modernization of GNSS systems have demanded the validation of receiver performance for all new upcoming signals. The traditional live antenna analysis can no longer be used to validate all kinds of signal/environment/user scenarios which has lead to the introduction of GNSS simulators. With the help of GNSS simulators, users are now able to test the receivers in lab for all kind of critical signal conditions including vehicle modelling and satellite motion, GNSS signal structure & atmospheric and other environmental effects that can affect receiver performance. Thus, simulations can provide a controlled, reliable and repeatable way to test and adequately identify any receiver design limitations. In this article, the various challenges involved in testing GNSS receivers are highlighted. Methodologies to effectively validate the receivers using simulators are provided along with Accord GNSS Simulator products.

Contents

Introduction

Global Navigation Satellite Systems (GNSS) is a space-based radio navigation system capable of providing navigation data to users on or near the surface of the Earth any-time, any-where and under any-weather conditions. Due to its code division multiple access (CDMA) technique, it provides sufficient immunity to intentional/un-intentional jamming. With its design and modularity, these systems can provide standalone navigation without any aiding to a great extent.

GNSS comprises of navigation satellite systems from various pioneers including Global Positioning System (GPS) of the US[2], GLONASS of Russia, GALILEO of Europe, BEIDOU of China and Indian Regional Navigation Satellite System (IRNSS) of India[1, 4]. With the advent of emerging GNSS systems, receiver manufacturers across the world are constantly upgrading their basic GPS capable receivers to multi functionality receivers comprising of dual frequency, multi-constellation receivers, augmentation capable receivers, aiding receivers for inertial integration and many others. This has led to several variants of receivers being available in the market [5].

Need for GNSS Receiver Performance Validation

A typical GNSS receiver architecture is shown in Figure 1 consisting of a Radio frequency (RF) block, a Correlator and a Navigation processor. A typical GNSS RF block will have an ability to work either in L1/L2/L5/S signal bands in a standalone or combined mode. The main objective is to down convert the GNSS RF signal component to an intermediate frequency (IF) for ease of digital processing and rejecting any unwanted signals present in the out-of-band signal spectrum.

The correlator block is responsible for processing the IF samples, acquiring and maintaining tracking on the visible satellite signals. Further, it is also responsible for extracting the navigation data bits and decoding ephemeris and almanac data from the incoming signal and generating satellite measurement data like range and Doppler information. The navigation processor uses the information from the correlator block to compute the position-velocity-time (PVT) solution along with application specific outputs.

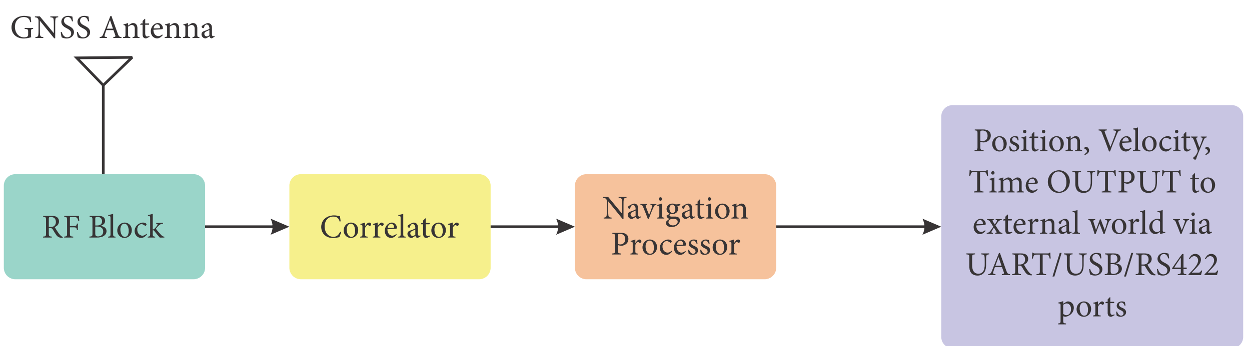

Figure 1 High level receiver architecture

The receiver top-level block diagram looks very simple and attractive to realize; however, the complexity grows upon addition of new signal or new constellation or new positioning algorithms and other performance features. This has led to abundant research opportunities for industry as well as academia to be available under the GNSS receiver domain, some of which are highlighted below:

- Development of all-in-view (AIV) GNSS software defined radios
- Algorithm development applied to static, kinematic, Precise point positioning for high precision applications
- GNSS for challenging environments like indoors, urban canyon, forest areas, ships, mountains and so on
- GNSS tracking devices for vehicles, employees, goods exchange and others (Vehicular and pedestrian navigation)
- GNSS in the presence of interference, multipath
- GNSS for drones, timing solutions
- GNSS independent features that includes error modelling algorithms for Ionosphere, Troposphere, clock errors, antenna modelling
- GNSS with aiding technology like satellite based augmentation system (SBAS), differential GNSS (DGNSS), inertial navigation system (INS) integration, GNSS clocks, Wireless location using GNSS pseudolites, ultra wide band (UWB) ranging
- GNSS jamming and anti-jamming models

Thus, whether you are an emerging receiver manufacturing company or a user buying receivers for system integration or academic institutions trying to explore new research areas, it is of utmost importance to validate the receiver performance independently for improved system reliability.

Some of the critical receiver features [3] that needs to be formalized before system integration/ development are consolidated below:

- Time to first fix: measure of time taken by the receiver to provide initial position.
- Reacquisition time: measure of time taken to reacquire a satellite after a defined time of blockage and re-introduction.
- Acquisition and Tracking Sensitivity: measure of the acquisition and tracking thresholds for input signal strength
- Location accuracy: measure of receiver computed position, velocity and time parameters
- Testing dynamics of a moving receiver: measure of receiver performance to handle dynamics motion
- Long term stability: measure of receiver performance in continuous modes of operation
- Influence of interference, multipath reception, atmospheric modelling: measure of receiver performance in presence of external degrading factors

For example, to test the reacquisition timing feature, one must physically block the angle of arrival direction of a particular satellite when testing using live antenna, which is a tedious job to be handled when the tests needs to be performed over multiple satellites.

Further, absolute position accuracy either in static or dynamic conditions cannot be guaranteed as there is no control over satellite configuration or external environment factors leading to ambiguity in the receiver characteristics. The shortcomings to validate a GNSS receiver effectively using live antenna has paved the path for the usage of GNSS simulators.

GNSS Simulators

As mentioned above, static testing with live antenna provide minimal control of inputs that are not repeatable allowing execution of limited tests cases and not covering all performance features of the receiver effectively. Further, the dynamic trials that include field testing on vehicles inherently possess lots of unknowns (like multipath, refraction), costly when performed for Flight/Missile/Spacecraft testing.

As observed in Figure 2, a GNSS simulator is required to simulate all the available GNSS satellites as per user selection, introduce signal anomalies like satellite orbit and clock errors, environment models for ionosphere and troposphere, different antenna models, receiver clock errors along with multipath and signal interference effects.

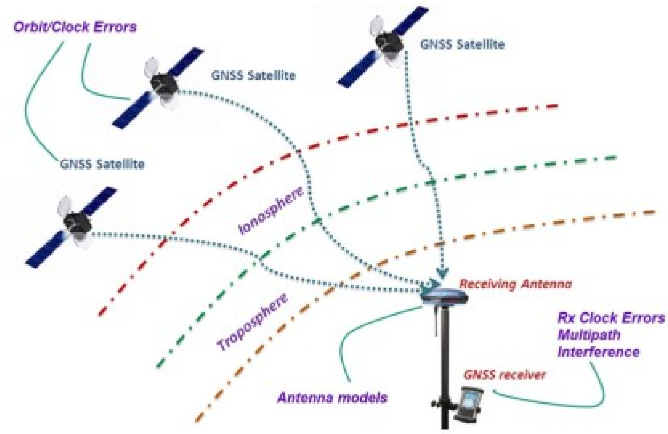

Figure 2 GNSS system simulation

To conclude, simulation is one of the best efficient means that is cost effective and repeatable with many more advantages that include the following:

- Provides full control over selection of GNSS constellations
- Complete control over external factors like ionosphere, troposphere, multipath, antenna model effects
- Repeatable with/without interference signals
- Can include/exclude signal impairments like clock errors, satellite anomalies, orbit errors
- Flexibility to test future and in-progress GNSS signals
- Provides full control of navigation data modelling to test signal exceptions.

> *“GNSS Simulators are cost effective, highly reliable test solution providing users with complete control over signal dynamics, environment and signal errors among many others.”*

Accord's Indigenous GNSS Simulator

In pursuit of the above, Accord has been developing state-of-the-art GNSS signal simulator. Accord's indigenous GNSS simulator SIMAC6 can generate RF signals for GPS, GLONASS, GALILEO, BEIDOU, QZSS and various SBAS (all in L1 band including WAAS, EGNOS, MSAS and GAGAN signals) and IRNSS (Standard Positioning Service (SPS) in L5/S band). It has a user friendly graphical front end through which user can easily configure and track the status of a simulation. Following are some of the highlight features of Accord's GNSS Simulator:

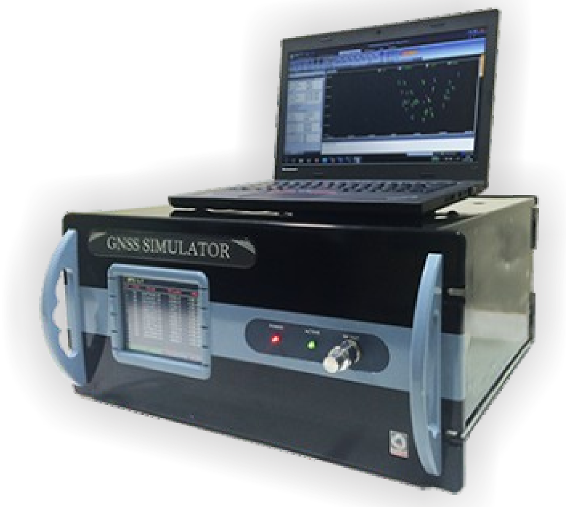

Figure 3 GNSS Simulator (SIMAC6)

- Configurable dual frequency IRNSS, GPS/GLONASS/GALILEO/BEIDOU/QZSS/SBAS simulator
- 10/100 Hz hardware-in-loop simulation (HILS) capability
- Supports DGNSS (includes DGPS, DGLONASS and DIRNSS)
- Processes National Marine Electronics Association (NMEA) input/output messages for receiver profiling
- High dynamics simulation via ASCII file input or motion commands for different user profiles like land vehicle, aircraft, missiles
- Waypoint navigation
- Error modelling for receiver autonomous integrity monitoring (RAIM) tests including Ramp/Step/Doppler offsets
- Multiple signal impairments include Ionosphere, Troposphere, Clock noise models, Multipath modelling
- Navigation data modelling for satellite anomaly testing

A sample overview of Accord's GNSS simulator graphical user interface (GUI) is shown in Figure 4. All the features are provided in a user-friendly manner for easy access in the form of ribbons and tabs. Dockable panes are provided for quick retrieval of frequently used windows in the right-hand side of the view (like "Simulation time" dockable pane).

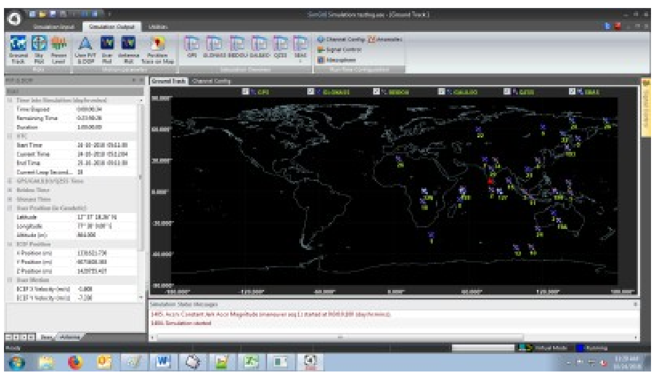

Figure 4 GNSS Simulator GUI Sample View

System testing with Accord Simulator

A typical test setup involving Accord GNSS simulator and GNSS receivers is provided in Figure 5. The test setup comprises of a simulator connected to a GNSS receiver via a RF cable and receiver data logged via Ethernet/USB/RS232 interface in the host pc. This test setup is applicable for most of the test cases involving characterization of receiver performance.

Additionally, the test setup can be upgraded to include interference tests where the RF output from simulator can be combined with an external interference source before connecting to a receiver output. Further, receiver data along with inertial sensor data can be integrated and tested to assess the integration performance. Thus, Accord simulator provides multiple test features for receiver evaluation; some of which are described below:

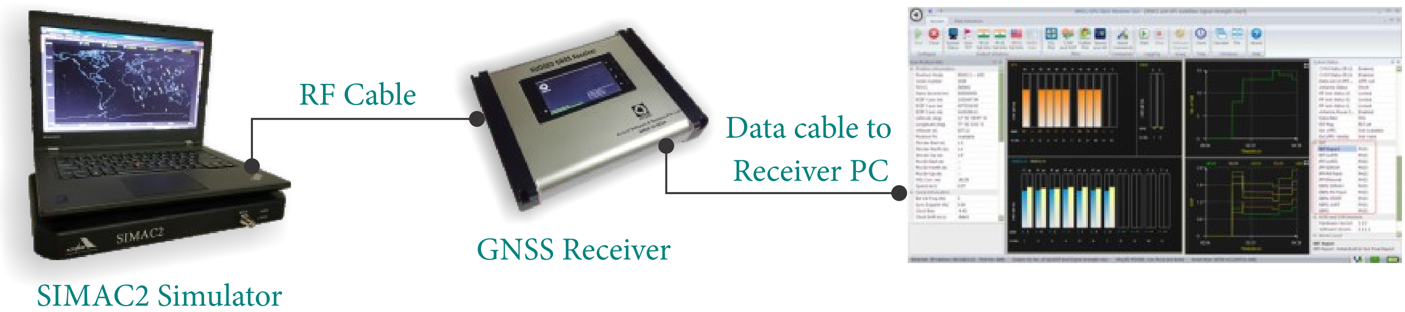

Figure 5 GNSS Receiver test setup using Simulator

- Start time configurability to test week cross overs, day crossover over tests and leap second corrections
- Simulation mode configurability to execute simulation in either normal mode, virtual mode or trigger mode to synchronize with other systems
- Satellite Configurability to validate YUMA/ RINEX/ AGL input file types for different constellations, modify satellite orbit and clock parameters
- Satellite augmentation to facilitate SBAS message analysis, future satellite configurability and reference station monitoring and receiver augmentation testing for DGNSS and SBAS corrections
- Navigation Data configurability to test receiver performance for data variations in the satellite transmitted data
- Signal configurability to facilitate GNSS signal fluctuation analysis, cross-correlation analysis and new code generators for future signals
- Error Configurability to facilitate Model validation and Receiver performance analysis with error parameters like ionosphere error, troposphere error, receiver/satellite clock errors
- Multipath simulation to test Urban canyon simulation and Satellite inclusion /exclusion evaluation
- User Dynamics Selectivity to test different Dynamics design analysis and Trajectory motion analysis

- Antenna configuration for Receiver performance with different antenna types and characterization of receiver for installation
- Signal obscuration to facilitate automatic satellite visibility for satellite/spacecraft models
- Signal anomalies like Doppler offset, step error and ramp error for receiver error monitoring tests that includes RAIM
- Data logging for off-line receiver analysis with truth data from simulator.

Accord GNSS simulators are available in two different product lines – SIMAC6 for high end and SIMAC2 for portable solutions as shown in Figure 6. Both are available either as a rack mountable or desktop variant to meet different user requirements. The rack mountable version consists of the signal generation unit (SGU) (SIMAC6/SIMAC2), a monitor and a work station hosting the Accord proprietary GNSS simulation software with the rack being a standard 19”design and minimum 15U usable. The table top simulator version includes a SGU (SIMAC6/SIMAC2) along with a laptop or work station hosting all the required features of signal simulation. The work stations and/or laptops hosts an optional real time operating software that is a proprietary design for execution of the simulation software.

SIMAC2 Simulator

SIMAC6 Simulator

Figure 6 Accord GNSS Simulator Varient

References

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About the Author

Pratibha B Anantharamu holds a doctoral degree in Geomatics Engineering from University of Calgary, Canada in October 2011. She is currently working as a technical lead, GNSS and aerospace electronics division in Accord Software and Systems Pvt.Ltd. She has been involved in GNSS research since 2005. Her research interests include the field of GNSS signal simulation, location and navigation and receiver validation methodologies.

About Accord Software & Systems

Accord Software & Systems designs and manufactures innovative solutions to help customers maintain a competitive advantage in their markets and achieve their business goals. We provide cutting-edge Positioning, Navigation and Timing products and solutions to industry leaders in the Defence, Commercial and Semiconductors Business areas.

Accord has developed a vertically integrated GPS/GNSS portfolio consisting of Semiconductor ICs, Modules and solutions that cater to a variety of applications like Avionics, Automotive, Industrial, IoT, Marine, Telecommunications.

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Accord Software & Systems Private Limited

No 72 & 73, K.R. Colony, Domlur Layout,
Bangalore - 560 071. INDIA.
Tel: +91 - 80 2535 0105   Fax: +91 - 80 2535 2723
Email: ibd@accord-soft.com
Web: www.accord-soft.com