Signal Studio for Global Navigation Satellite Systems (GNSS)

N7609B

– Create Keysight Technologies, Inc. validated real-time signals that simulate satellites from the U.S. Global Positioning System (GPS), Russian Global Navigation Satellite System (GLONASS), European Galileo system, or Chinese Beidou Navigation Satellite System (BDS, also known as Compass), Satellite Based Augmentation System (SBAS), or Quazi Zenith Satellite System (QZSS)

– Simulate up to 15 line-of-sight satellites for each GNSS

– Up to 40 channels for line-of-sight and multipath signals for any combination of GPS, GLONASS, Beidou, SBAS or QZSS, and 16 additional channels for Galileo E1 line-of-sight and multipath signals

– Support static scenarios for stationary receivers or dynamic scenarios for moving receivers

– Control satellite visibility, power, multipath, and pseudorange error in real time

– Create waveform files that simulate single or multi-satellite for GPS, GLONASS, Galileo, Beidou (Compass), SBAS, or QZSS for manufacturing test

– Accelerate the signal creation process with a user interface based on parameterized and graphical signal configuration and tree-style navigation

Simplify Global Navigation Satellite System (GNSS) Signal Creation

Keysight Signal Studio software is a flexible suite of signal-creation tools that will reduce the time you spend on signal simulation. For GNSS, including GPS, GLONASS, Galileo, Beidou and SBAS/QZSS, Signal Studio's performance-optimized signals—validated by Keysight—enhance the characterization and verification of your devices. Through its application-specific user-interface you'll create standards-based and custom test signals for receiver test.

Component and transmitter test

Using live off-the-air satellite signals for GNSS receiver verification is unreliable because of the high variability and non-repeatability of these signals. N7609B Signal Studio's advanced capabilities enable you to create signals that simulate satellites in the GPS, GLONASS, Galileo, or Beidou constellations for testing GNSS receivers in an accurate and repeatable manner. The application simulates multiple signals from many different satellites, with different time delays, Doppler shifts, and power levels. The N7609B software also has the capability to create and transmit impairments such as multipath signals, loss of satellite visibility, and ionospheric and tropospheric atmospheric attenuation, and can also add calibrated AWGN. The ability to add these impairments allows the N7609B to provide a complete suite of signals for full verification of GNSS receivers. Applications include:

– Performance verification and functional test of receivers, during RF/baseband integration and system verification
– Coding verification of baseband subsystems, including FPGAs, ASICs, and DSPs

The N7609B software's advanced capabilities operate in real-time mode, which is used to define the parameters of nonrepeating and dynamically changing signals needed for receiver testing. Its graphical interface provides a direct instrument connection for parameter transfer and interactive control during signal generation.

For receiver testing in production or simple receiver testing in R&D, the N7609B also offers a basic capability that uses waveform playback mode to generate signals. The waveform files simulate a single static satellite with fixed Doppler shift. These signals can be used to test receiver sensitivity, acquisition, and tracking. Single or multi-satellite satellite waveforms can be created for GPS, GLONASS, Galileo, Beidou (Compass), satellite-based augmentation systems (SBAS), or the Japanese Quazi-Zenith Satellite System (QZSS).

Apply your signals in real-world testing

Once you have setup your signals in Signal Studio, you can download them to a variety of Keysight instruments. Signal Studio software complements these platforms by providing a cost-effective way to tailor them to your test needs in design, development and production test.

For real-time signal generation with advanced capability options:
– X-series vector signal generators: N5182B MXG and N5172B EXG
– PXB baseband generator and channel emulator

For waveform playback using the basic capability option:
– Vector signal generators
  – X-series N5182B MXG and N5172B EXG
  – First-generation N5182A MXG
  – ESG
  – PSG
  – M9381A PXIe VSG
– EXT, E6630A, and E6640A wireless test set
– PXB baseband generator and channel emulator

Typical Receiver Measurements

Time to First Fix (TTFF)

– Cold, warm, and hot start conditions

Receiver sensitivity

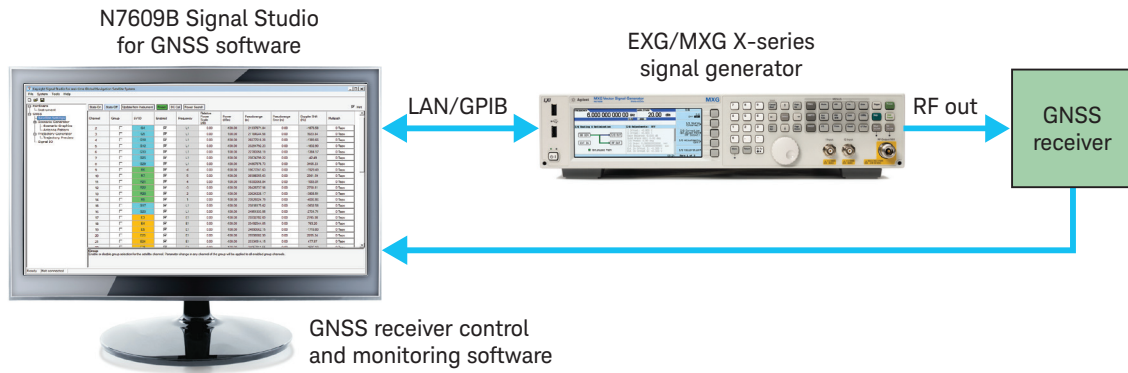– Acquisition sensitivity
– Tracking sensitivity

Location accuracy

– Relative and absolute accuracy
– Moving receiver accuracy

Receiver Test

Receiver test using real-time signals

Configuration 1: N7609B running on an external PC with the EXG or MXG X-series signal generator

Configuration 2: N7609B running inside the N5106B PXB to generate baseband signals, with an ESG, EXG, or MXG signal generator for RF signal output
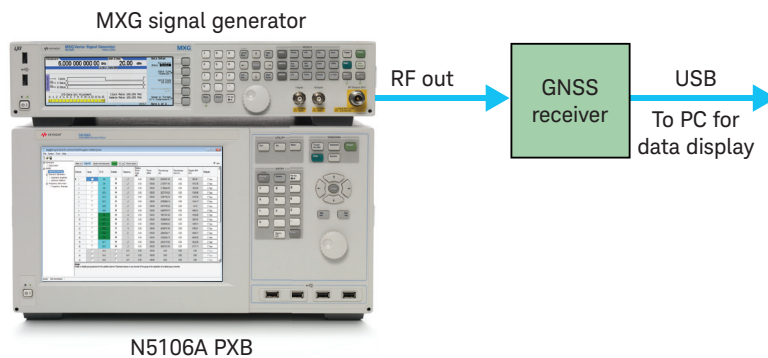

Figure 1. Generate real-time GNSS signals to test the time-to-first-fix (TTFF) or sensitivity of your receiver with Signal Studio's advanced capabilities with the two configurations shown.

Signal Studio enables you to easily create reliable and repeatable signals that simulate GPS, GLONASS, Galileo, and/or Beidou satellite signals for receiver verification tests. The flexibility and features of this intuitive software make it ideal for an R&D environment.

The software simulates up to 15 visible satellites per constellation, depending on the scenario and satellite visibility, and provides a total of 40 channels for satellite and multipath signals for GPS, GLONASS, Beidou and/or SBAS/QZSS. 16 additional channels are available for Galileo satellite and multipath signals. The real-time capability of the software enables you to change the satellite power and visibility while the signal is active, or add multipath or pseudorange errors. Use the static test mode to create simple static satellite signals with real-time adjustments for Doppler shift and delay, and individual power settings for each channel.

Real-time signals simulating orbiting GNSS satellites can be created in two different modes. The first mode uses a stored scenario file, containing the satellite information needed to simulate the signals visible to a receiver at a specific location and time, including the navigation messages. In this mode, signals up to 24 hours in duration can be simulated. A set of preconfigured scenario files is provided with the software. For longer simulations, a second mode uses the scenario generator settings to continuously create new scenario data. This mode requires a continuous data connection to the signal generator.
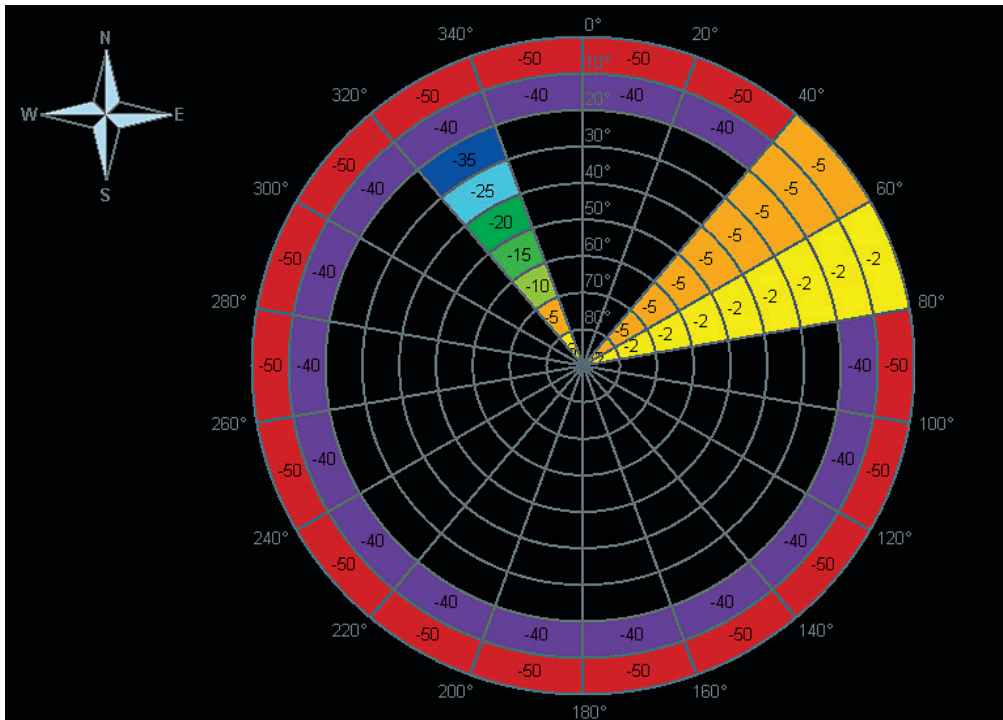
Figure 2. Antenna pattern view: elevation and azimuth grid allows you to specify the power offset for a cell, circle, sector, or any combination of these.

The scenario generator function enables you to create and play back custom scenario files. You can specify the location, date, time and duration for a scenario to simulate a stationary or moving GNSS receiver. Moving receiver scenario generation requires an NMEA (GGA format) message file containing the trajectory path information. These GGA message files can be recorded from a GNSS receiver, created using the trajectory generator utility in the software, or converted from a Google Earth KML format file.

Optional parameters for scenario generation include elevation mask angle and ionospheric and tropospheric atmospheric modeling effects. The elevation mask allows you to select only those satellites that are above a certain angle above the horizon to be used in the scenario. The ionospheric model (Klobuchar) and tropospheric model (NATO) parameters are put into the navigation message and the signal is impaired according to these settings. For Galileo, the scenario generator allows some parameters in the navigation message to be edited. The software also provides an antenna pattern gain mask that can be applied to the GNSS signals. This gain mask can be used to simulate the characteristics of a receiver's antenna, or to simulate the effects of obstructions in the environment.

Scenario files can also be modified with the scenario editing function which provides these capabilities:

– Delete Channel: deletes a channel from the scenario
– Apply Power Offset: applies a power offset to a channel over some time period
– Equalize Power: sets the power for all channels to be the same
– Create Multipath: creates a multipath signal based on a visible satellite's channel
– Trim: creates a new scenario file that contains a portion of time from the selected file

The scenario graphics display allows you to visualize the scenario parameters such as satellite visibility, playback time, and channel designation (represented satellite). It also contains a record of the changes that have been made during the editing session (see Figure 3).
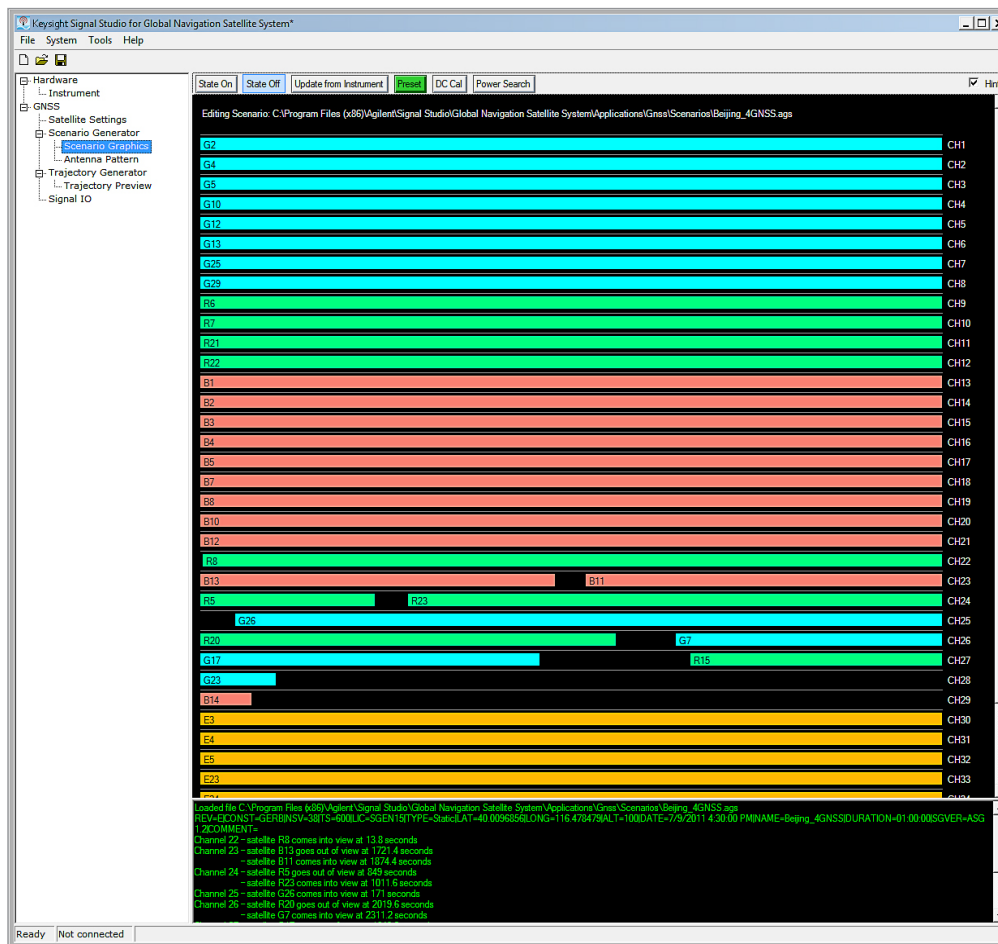

Figure 3. Graphical display of scenario parameters and editing changes.

Real-time scenario information displays

Real-time scenario information displays provide several intuitive views that convey the current scenario playing status from a receiver's point of view. Real-time sky view displays the location of all visible satellites in the sky. The location of a satellite is updated in real-time as its elevation/azimuth changes over time. When a user moves the mouse onto a particular satellite, a tool-tip will be displayed to show detailed real-time information about the satellite, including SVID, power, psudorange, doppler and multipath taps. Instant DOP values (HDOP and PDOP) and number of satellites for each constellation are also displayed in this view (see Figure 4). The real-time power view displays the instant power of all visible satellites in a bar view. The real-time trajectory view displays the history trajectory of the playing scenario. Detailed information including UTC, longitude, latitude, altitude, heading, and velocity are also provided in the text.
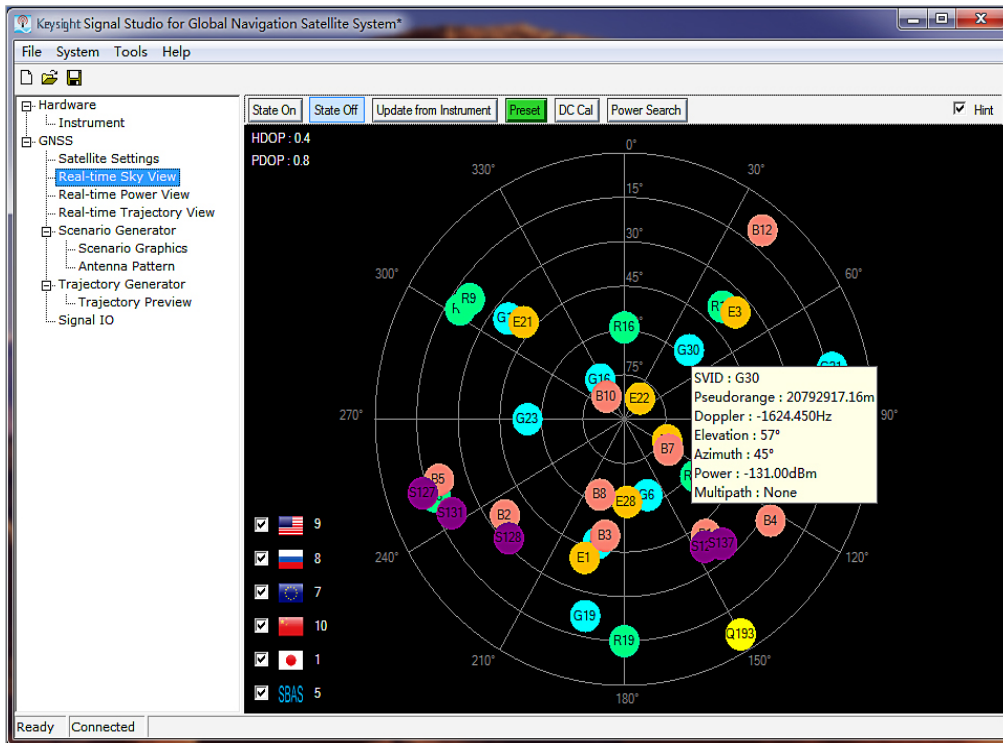
Figure 4. Real-time sky view display with tool-tip showing detailed real-time satellite information in the sky.

Receiver test using waveform playback

Signal Studio's basic single and multi-satellite waveform capability allows you to create and play back waveform files that simulate a single static GNSS satellite with a fixed Doppler shift or simulate multiple satellites. These signals can be used to perform simple receiver tests, such as testing the receiver's ability to detect, identify, and track the satellite signal, test receiver sensitivity, or test Time To First Fix (TTFF) and static location accuracy. When used with an instrument that has the calibrated AWGN option, the receiver can be tested with varying C/N ratios. This basic capability provides a more economical solution for manufacturing test.

For single-satellite waveforms, users can select the SV ID (PRN) and Doppler shift for simulating GPS, Galileo, Beidou, SBAS, or QZSS. For GLONASS, users can select a frequency channel and Doppler frequency, which will be used to set the frequency of the signal. Since the same C/A code is used for all GLONASS satellites, the same waveform file is generated for all GLONASS settings, but the frequency of the signal generator is set based on the satellite channel.

For multi-satellite waveforms, users first need to select a scenario file and then choose one constellation inside the scenario file from among GPS, GLONASS, Galileo, Beidou, SBAS or QZSS, or choose a multi-GNSS scenario from among GPS+SBAS+QZSS, GPS+Beidou, or GPS+Galileo. Users can specify the scenario start time, satellite power from either range based or equal power, sample rate and waveform length up to 120 seconds. ARB memory of at least 256 MSa is required, based on the chosen constellation.

Both single satellite and multi-satellite waveform files can be used with waveform 5-pack or 50-pack licenses in compatible instrument platforms.

Features Summary

GNSS	Receiver testing	
	Basic waveform playback mode	**Advanced real-time mode**
Single satellite waveform	– Simulate single satellite with C/A code for GPS, GLONASS, Galileo, Beidou, SBAS (WAAS, EGNOS, MSAS, GAGAN), or QZSS – Specify SV ID (PRN) for all constellations except GLONASS – Specify the frequency channel for GLONASS – Specify the dynamic pattern: Static, constant velocity, constant acceleration or sinusoidal – Specify the navigation message as PN9, PN15 or a user defined pattern – Add calibrated AWGN for control of C/N ratio (requires AWGN option in instrument)	
Multi-satellite waveform	– Simulate multi-satellite signals – Choose the single constellation from GPS, GLONASS, Galileo, Beidou or multi-constellation from GPS+SBAS+QZSS, GPS+Beidou or GPS+Galielo (requires at least 256 MSa ARB memory) – Specify the satellite power, sample rate and waveform length – Add calibrated AWGN for control of C/N ratio (requires AWGN option in instrument)	
GPS, GLONASS, Galileo, Beidou, SBAS or QZSS real-time signal generation		– Simulate up to 15 line-of-sight satellites for each constellation: GPS L1 C/A (Option PFP), GLONASS L1 C/A (Option SFP), or Beidou B1 (Option WFP) – Provides 40 channels for line-of-sight satellites and multipath combined for GPS, GLONASS, Beidou, and/or SBAS/QZSS – Simulate up to 16 line-of-sight or multipath Galileo satellite signals (Option UFP) – Supports static scenarios for stationary receivers or dynamic scenarios for moving receivers – Up to 24 hours of playback using scenario files – Provides real-time control for individual satellites, including satellite on/off, absolute or relative satellite power, adding multipath, and applying a pseudorange error – Add calibrated AWGN for control of C/N ratio (requires AWGN option in instrument)

Features Summary

GNSS	Receiver testing	
	Basic waveform playback mode	**Advanced real-time mode**
Scenario generation and editing		– Create custom scenarios with your choice of location, date, time, and duration for either static or moving receivers – Continuous scenario generation for simulations longer than 24 hours (for N7609B running directly with EXG/MXG, continuous LAN or GPIB connection to the EXG/MXG is required) – Ionospheric and tropospheric modeling – Elevation mask for controlling satellite visibility – Graphical display to show editing results – Leap seconds information editing – Edit Galileo navigation message parameters – Antenna pattern modeling – Scenario editor to add multipath channels, apply power offsets to a channel, delete a channel, or trim the scenario length in a scenario file – Trajectory generator to create NMEA GGA format message files for moving receiver scenarios, with utility to convert Google Earth (*.kml) file into an NMEA GGA message file – A-GNSS assistance data for each scenario – Output raw scenario data (truth data) for comparison with receiver test results
SBAS		– Provide the SBAS message editor to configure the SBAS message for Type1 (PRN Mask), Type2-5 (Fast Correction), Type7 (Fast Correction Degradation Data Factor), Type12 (Network Time), Type18 (IGP Mask), Type25 (Long Term Correction), and Type26 (Ionosphere Correction).
Real-time CW interference		– Add CW interference signal to real-time GNSS signals within GPS, GLONASS or Beidou bands – Up to 4 CW interference signals can be added, which share the 16 channels of the Galileo constellation
Real-time display		– Real-time sky view of visible satellites – Real-time satellite power per GNSS – Real-time simulation of receiver trajectory

Supported Standards and Test Configurations

The following standards are supported by the N7609B Signal Studio for GNSS application.

Constellation	Specification	Release date
GPS	Interface Specification IS-GPS-200E, Navstar GPS Space Segment/Navigation User Interfaces	2010
GLONASS	Global Navigation Satellite System (GLONASS) Interface Control Document, Edition 5.1	2008
Galileo	European GNSS (Galileo) Open Service Signal In Space Interface Control Document (OS SIS ICD), Issue 1.1	2010
Beidou	BeiDou Navigation Satellite System Signal In Space Interface Control Document, Open Service Signal B1I, Version 1.0	2012
SBAS	Federal Aviation Administration Specification For the Wide Area Augmentation System (WAAS)	2001
QZSS	Quasi-Zenith Satellite System Navigation Service Interface Specification for QZSS (IS-QZSS) V1.4	2012

Test configurations for general GNSS receivers

For typical GNSS modules or receivers that are integrated into products that are not cellular devices, receiver verification can be performed using one of the configurations shown in Figure 1. For manufacturing test applications using basic waveform playback mode, Configuration 1 may be used with the EXG, MXG, ESG, or PSG vector signal generators, the M9381A PXIe VSG, or the EXT E6630A or E6640A wireless test sets.

Test configuration for assisted GPS (A-GPS) and assisted GLONASS for cellular devices

Keysight's GS-9000 A-GPS design verification test systems allow you to verify that your UMTS or cdma2000® mobile device meets CTIA standards for A-GPS operation and integrates seamlessly into cellular networks. The GS-9000 systems include both hardware and software to enable mobile device A-GPS testing in a conducted environment. The hardware includes an 8960 wireless communications test set for base station emulation and a GNSS simulator to emulate the GPS satellites. The GNSS simulator may consist of the N7609B Signal Studio for GNSS with either the EXG/MXG or the PXB with an RF signal generator, or an E4438C ESG vector signal generator with the Option 409 GPS Personality.

Similar testing will likely be required for mobile devices that support A-GLONASS and other A-GNSS in the future. The N7609B scenario generator provides assistance data and ephemeris files to support this testing.

Performance Characteristics

Definitions

Characteristic performance:

Non-warranted value based on calculated values for expected performance. This data is not warranted and is subject to change without notice.

Features	Characteristic values
Doppler shift frequency range	± 125 kHz
Doppler resolution	0.02 Hz
Doppler accuracy	± 0.01025 Hz
GPS reference frequency (f0) default	1.023 MHz
Code phase accuracy	± 3.8 ns
Signal dynamics:	
– Maximum relative velocity	600 m/s (Scenario generator supports higher velocities but accuracy has not been verified)
– Maximum relative acceleration	100 m/s2 for GPS, Galileo, or Beidou; 50 m/s2 for GLONASS
Pseudorange error	± 0.002 m RMS (averaged over 1 minute)
Amplitude resolution	See data sheet for RF signal generator (N5172B EXG, N5182A/B MXG, or E4438C ESG)
Amplitude (output power) range	See data sheet for RF signal generator (N5172B EXG, N5182A/B MXG, or E4438C ESG)
Amplitude level accuracy	See data sheet for RF signal generator (N5172B EXG, N5182A/B MXG, or E4438C ESG)

Ordering Information

Software licensing and configuration

Signal Studio offers flexible licensing options, including:

– **Fixed license:** Allows you to create unlimited I/Q waveforms with a specific Signal Studio product and use them with a single, specific platform.
– **Transportable/floating license:** Allows you to create unlimited I/Q waveforms with a specific Signal Studio product and use them with a single platform (or PC in some cases) at a time. You may transfer the license from one product to another.
– **Waveform license:** Allows you to generate up to 545 user-configured I/Q waveforms with any Signal Studio product and use them with a single, specific platform.

Fixed, transportable, and trial licenses for the N7609B Signal Studio software are available with all supported instruments. Waveform licenses are available for the EXG, MXG, ESG, EXT, E6630A, and E6640A.

The table below lists fixed, perpetual licenses only; additional license types may be available. For detailed licensing information and configuration assistance, please refer to the Licensing Options web page at www.keysight.com/find/SignalStudio_licensing

N7609B Signal Studio for Global Navigation Satellite Systems (GNSS)

Model-Option	Description
Connectivity	
N7609B-1FP	Connect to E4438C ESG signal generator
N7609B-2FP	Connect to E8267D PSG signal generator
N7609B-3FP	Connect to N5182/72 MXG/EXG signal generator
N7609B-6FP	Connect to N5106A PXB baseband generator and channel emulator
N7609B-8FP	Connect to EXT wireless communications test set
N7609B-9FP	Connect to M9381A, E6630A
Capability[1]	
N7609B-EFP	Basic single and multi-satellite waveforms
N7609B-PFP[2]	Advanced GPS real-time and scenario generation
N7609B-SFP[2]	Advanced GLONASS real-time and scenario generation
N7609B-UFP[2]	Advanced Galileo real-time and scenario generation
N7609B-WFP[2]	Advanced Beidou real-time and scenario generation
N7609B-NFP[3]	Real-time CW interference signal
N7609B-XFP[3]	Advanced SBAS/QZSS real-time and scenario generation

1. The separate scenario generator options that were previously available for each GNSS (Options RFP, TFP, VFP) have been combined with the advanced real-time options for each GNSS, and the scenario generator options will be discontinued.
2. Available for N5172B EXG, N5182B MXG, and N5106A PXB only.
3. Available for N5172B EXG and N5182B MXG only.

Hardware configurations

To learn more about compatible hardware and required configurations, please visit: www.keysight.com/find/SignalStudio_platforms

PC requirements

A PC is required to run Signal Studio. www.keysight.com/find/SignalStudio_pc

Additional Information

Websites

www.keysight.com/find/SignalStudio

Access the comprehensive online documentation, which includes the complete software HELP

www.keysight.com/find/n7609b
www.keysight.com/find/signalstudio

Keysight's GNSS test solutions

www.keysight.com/find/gnss
www.keysight.com/find/agps

Literature

GPS Receiver Testing, Application Note, 5990-4943EN

Signal Studio Software, Brochure, 5989-6448EN

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus

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