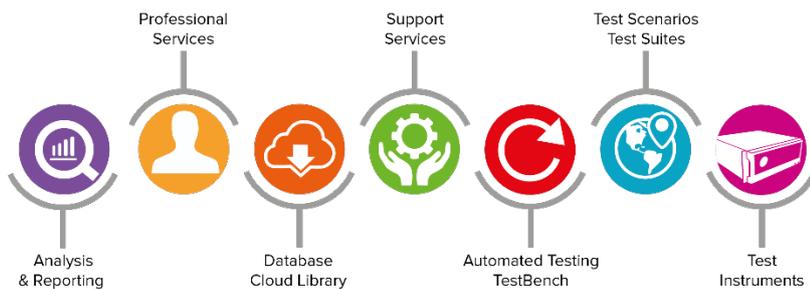
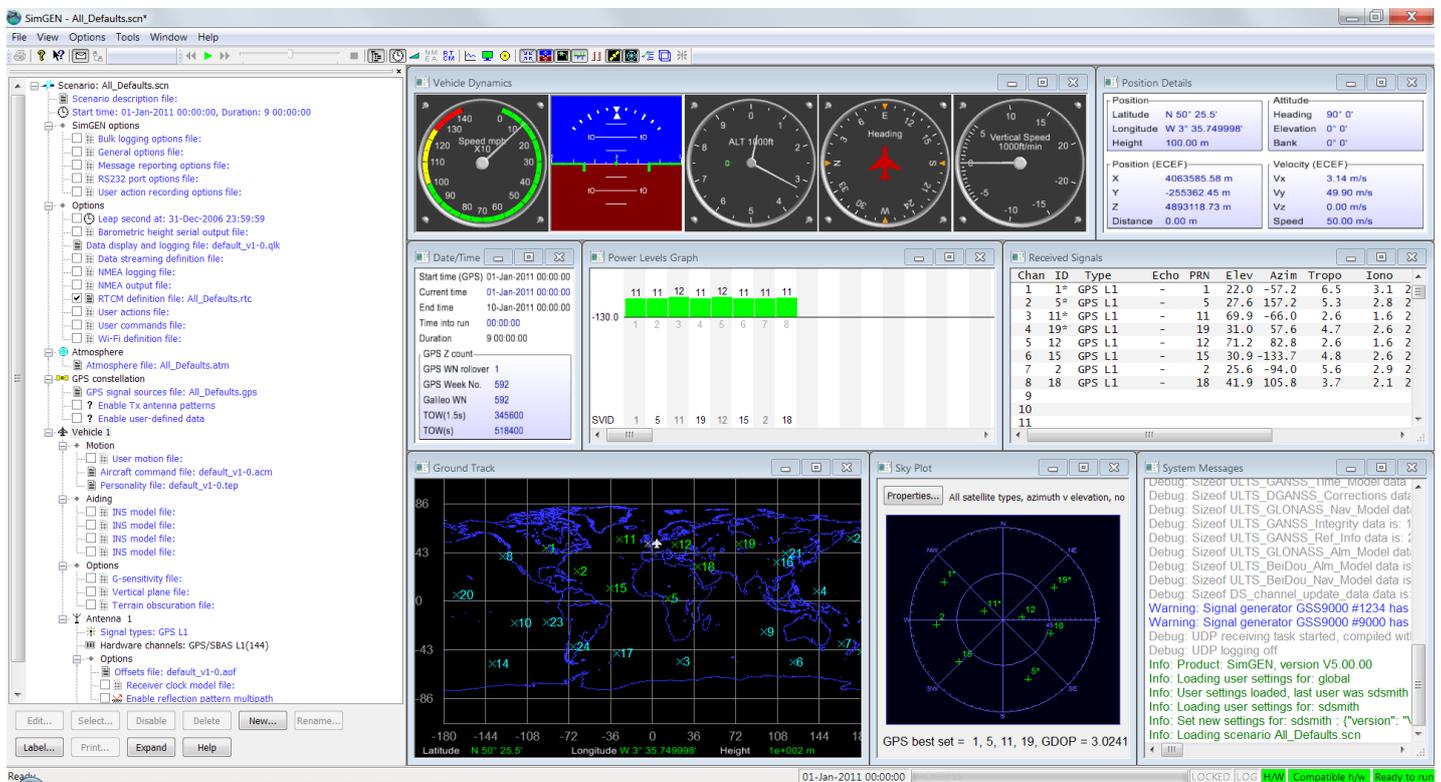


SimGEN[®] Software Suite for Spirent GNSS Constellation Simulation Systems



SimGEN® Software Suite for Spirent GNSS Constellation Simulation Systems

Purpose of this document

This document describes the principal features and capabilities of a comprehensive suite of Scenario definition and simulator control software called SimGEN for Windows (“SimGEN”) which, when combined with a compatible Spirent GNSS signal generator system, can be used to stimulate the GNSS signal and environment of a satellite navigation receiver system in a laboratory environment.

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SimGEN® Software Suite for Spirent GNSS Constellation Simulation Systems

Scope and applicability

This document describes the principal features and capabilities of a comprehensive suite of Scenario definition and simulator control software called SimGEN for Windows ("SimGEN") which, when combined with a compatible Spirent GNSS signal generator system, can be used to stimulate the GNSS signal and environment of a satellite navigation receiver system in a laboratory environment. A system may be augmented with a range of optional elements including Interference generators, and Inertial emulators, all controlled via SimGEN

In a Spirent GNSS simulator system, neither the signal generator(s) nor the PC/Host with installed SimGEN software is available separately.

The control interfaces between these elements are proprietary to Spirent and are protected. SimGEN software requires a licence, both to open and to access purchased functionality.

The GSS7000 is delivered with an embedded controller, the GSS9000 simulator is delivered with a C50r dedicated host.

The full issue of this document shall form the basis of any sales contract. In order to determine the detail of all features available in SimGEN it should be read in conjunction with the latest issue SimGEN Software User Manual (see reference [26] in Related Spirent product specifications section, page 42) and appropriate signal generator product specifications (refer to [29] & [36] on page 42).

Spirent GNSS simulator systems support public-domain signals, but some can be upgraded for authorised users only to generate authorised signals using combinations of hardware upgrades and additions to SimGEN. Spirent regularly updates SimGEN software. As such, graphical representations of the software appearing in this document should be considered as typical and for illustrative purposes and are subject to change and enhancement.

Introduction

Spirent provides a large range of GNSS RF Constellation Simulators.

Simulators emulate the presence of one or more GNSS constellations for use in laboratory, office or production environments in a development, qualification, certification or integration test role and for evaluating GNSS receiver equipment performance. Systems can be stand-alone or integrated into larger hardware-in-the-loop test systems using interfaces included as standard.

Spirent has a long and successful track record in providing GNSS simulators of the highest fidelity and scope.

When operated with SimGEN executive software, the comprehensive and flexible nature of Spirent's GNSS RF Constellation simulator products ensures that user equipment being stimulated behaves as if it were receiving RF signals from real satellites when installed on a vehicle including when performing complex and/or high-speed manoeuvres.

Standard capabilities enabled through SimGEN include simulation of atmospheric degradation of signals, multipath reflections, terrain obscuration, antenna reception gain and phase patterns, differential corrections, trajectory generation for land, air, sea and space vehicles and comprehensive error generation and system modelling.

These products can virtually eliminate the need to perform expensive field trials and provide an accurate, repeatable and controllable tool, free of the constraints imposed by testing in an operational system environment using actual satellite signals.

GNSSs comprise constellations of satellites capable of supporting precise positioning, navigation and timing.

The **GLOBAL POSITIONING SYSTEM or GPS** was conceived by the United States of America as a military navigation system, but via Presidential Directive has committed to provision of three purely civil signals. The GPS modernisation programme adds two new civil signals at L2 and L5 to the C/A code at L1, adds a new military signal (M-Code) at L1 and L2, and an additional civil signal at L1.

GLONASS is a Russian system similar in principle to GPS but which currently uses FDMA rather than CDMA to differentiate between satellite signals. Only the C/A civil signal with its navigation data message is officially available at both L1 and L2 for general use, although the precise military P-code is also used.

Galileo is a European constellation of earth-orbiting satellites capable of supporting precise positioning and navigation for both world-wide terrestrial and earth orbiting vehicles. The system provides a number of navigation and positioning services, including a free-to-use Open Service (OS), a Commercial Service (CS) a Safety-of-Life service (SOL), Search And Rescue (SAR) services, and a Public Regulated Service (PRS) for approved users that incorporates classified encryption and unauthorised access control.

BeiDou-2/3 is a Chinese regional satellite navigation system covering China and much of Asia and comprises principally GEO and IGSO satellites but also has a limited Global coverage via its MEO satellites. BeiDou is currently deployed in its second phase which is designated as BeiDou-2. A third phase, BeiDou-3, will add signals and frequencies as it expands into a full GNSS. The regional BD-II system provides two carrier frequencies and both Open and Closed access signals. BeiDou provides an SBAS component via its own GEOs.

Satellite Based Augmentation Systems (SBAS) provide enhanced accuracy, availability and integrity for GPS users in the civil community via one or more Geosynchronous satellites. WAAS (Wide Area Augmentation System) is a system under the auspices of the United States Department of Transport that covers the continental United States. Similar compatible systems are European Geostationary Navigation Overlay System (EGNOS) and the MSAS in Japan (see reference [3] in External documents section, page 41).

Spirent systems support SBAS at GPS L1 and L5.

Quazi-Zenith Satellite System is a constellation of IGSO satellites operated by Japan to provide regional civil GPS augmentation at all GPS frequencies for enhanced urban canyon coverage.

Spirent systems support QZSS at L1, L2 and L5

IRNSS (Indian regional navigation satellite system), with an operational name of **NavIC**, is an autonomous regional satellite navigation system that provides accurate real-time positioning and timing services. It covers India and a region extending 1,500 km around it, with plans for further extension. The IRNSS constellation consists of seven satellites, three in geostationary orbit and four in geosynchronous orbit. All satellites will be continuously visible from India for 24 hours a day.

Spirent systems support IRNSS at L5 and S-band.

In future SimGEN will be upgraded to cover additional GNSS and related signals when their ICDs become available. Please contact your Spirent representative for further information about new signals. In some cases, systems with a valid support contract will be upgraded for new signals as they become supported in SimGEN. In some cases, additional licences and/or hardware upgrades may be required.

For current ICD compliance, please refer to External documents section, page 41).

SimGEN® Software Suite for Spirent GNSS Constellation Simulation Systems

Systems

A GNSS RF Constellation Simulation system comprises two major sub-systems as shown in .



Figure 1 Example of SimGEN-based GSS9000 GNSS simulation system

- A dedicated, Spirent proprietary designed host (for GSS9000) running SimGEN that provides the comprehensive modelling capabilities described in this document.
- One or more sophisticated RF signal generators.

Together, these elements combine to generate high-dynamic RF simulations that represent both varied and challenging environments.

The GSS7000 platform operates autonomously with an embedded controller, peripherals are optional and can be customer furnished.



Figure 2 Example of GSS7000 GNSS simulation system

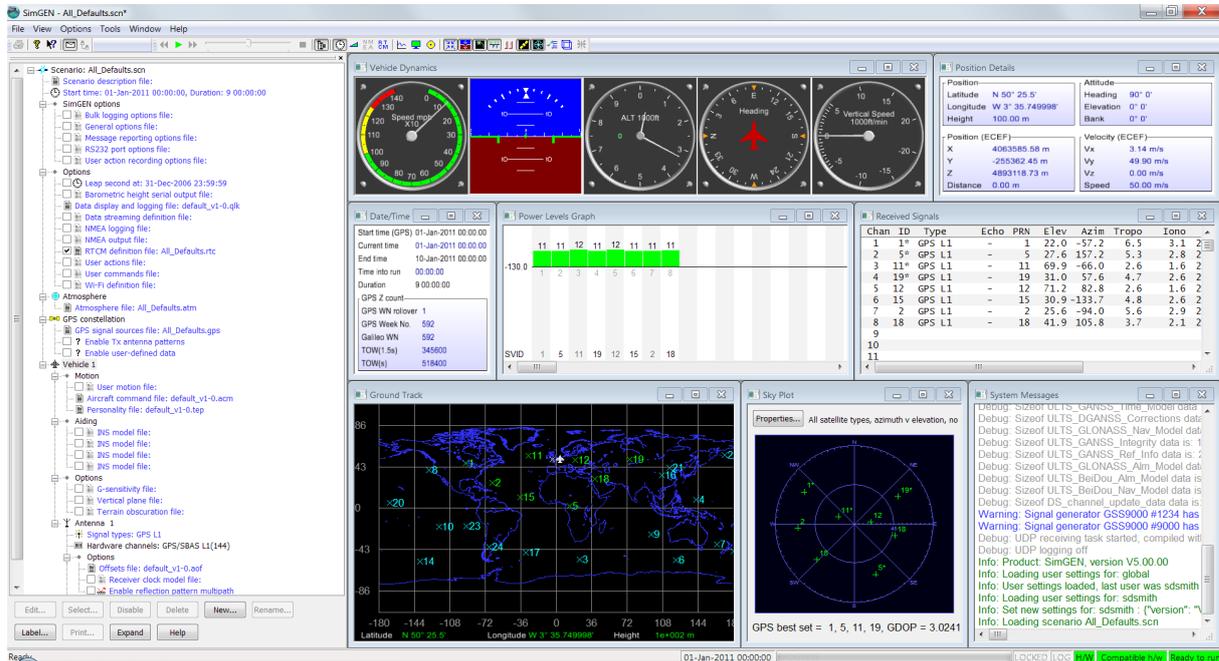


Figure 3 Example of SimGEN’s Graphical User Interface

SimGEN features

Functional description

SimGEN operation can be described in three phases:

Phase 1 - Test definition

The user defines and configures a set of information files (Source Files), using the comprehensive tools provided, that describe the trajectory of the simulated vehicle position and the complete Satellite operating environment. The collection of source files is known as a Scenario.

Importantly, SimGEN calculates all simulation output in real-time, and hence this initial phase does not require pre-processing.

Phase 2 - Real time simulation

SimGEN runs the relevant models using the source files that were defined in Phase 1 and in real-time compiles the required data streams that drive the RF signal generator and on-screen displays. The resulting RF signals are used to stimulate the satellite navigation receiver input.

During this phase, the user has extensive, asynchronous access allowing changes to the pre-defined conditions that were specified in phase 1. This includes the ability to vary power levels, to apply Pseudorange Steps/Ramps, to create some Multipath reflections and to ‘Ban’ or ‘Force’ satellite selection. These User Actions are recorded to a script file to aid post-run analysis or to allow the same actions to be replayed in subsequent runs of this or other simulations. This script file may be edited and expanded to customise the actions for subsequent runs.

The user also has the ability to define and display tabular and graphical representations of parameters being generated, such as graphs of Latitude versus Longitude. The list of parameters selected for tabular display may be recorded, allowing simple re-use of the same parameter list in other simulations.

SimGEN[®] Software Suite for Spirent GNSS Constellation Simulation Systems

Data generated during phase 2 may be saved to a file for subsequent analysis. The user may specify all available data or selected subsets of particular interest.

Powerful facilities are provided for performing scripted events that locally use commands identical to those provided by the remote control function. Most of the interactions that may be performed manually during a simulation run may also be performed in this mode.

Facilities are also provided to run a sequence of scenarios consecutively from a command file.

Phase 3 – Post simulation analysis

The operator may generate tabular and graphical representations of data optionally stored in phase 2 using any commercial package compatible with Microsoft Windows that supports Comma Separated Variable file data, such as a spreadsheet.

SimGEN Graphical User Interface

SimGEN has an intuitive GUI with a combinations of data editing and entry windows and data/information display windows. The principal areas are:

Scenario Tree

The scenario tree contains all the editable files which form a test scenario. Key files being those defining the Constellation Signal Sources, the Vehicle, Antenna, atmosphere and Options. The Scenario tree is shown in

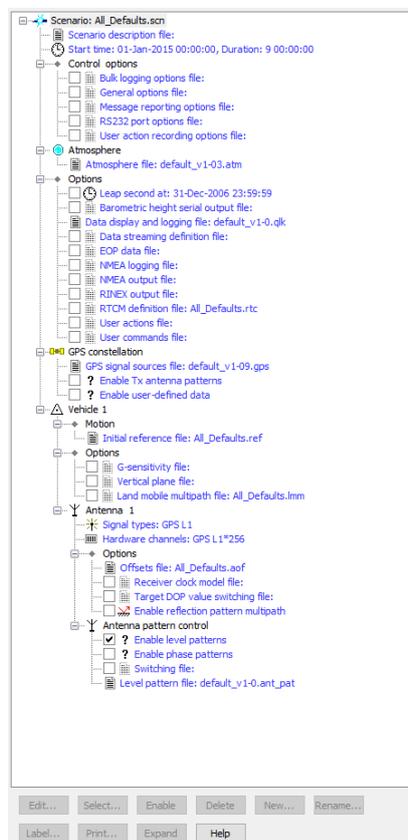


Figure 4 Scenario tree

Vehicle (antenna) position, motion and received signals displays

Various information pertaining to the simulated position, time, date, motion characteristics and the signal properties (received power, pseudoranges etc. are conveniently displayed as shown in

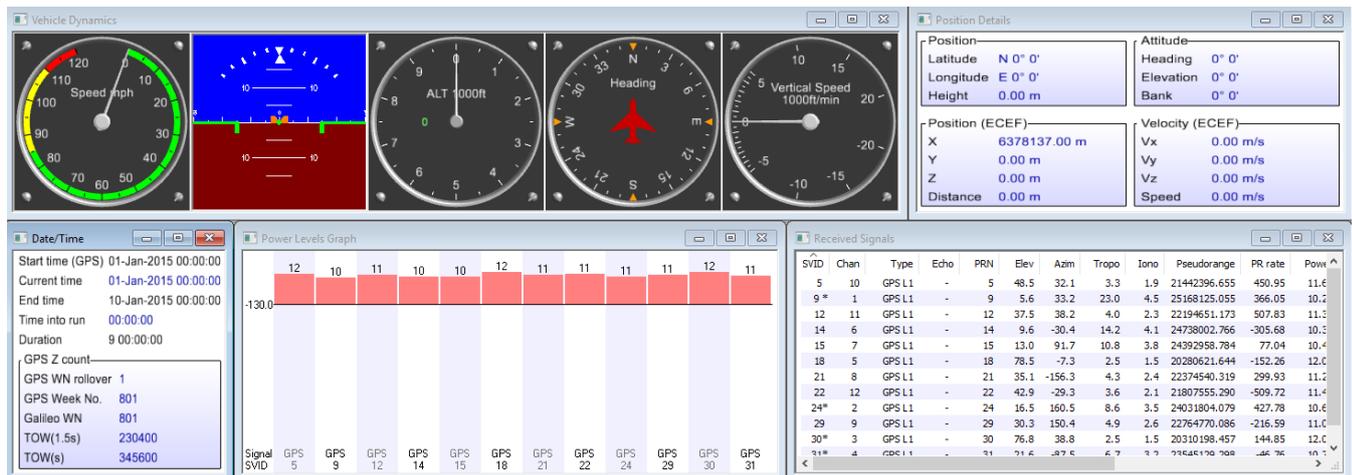


Figure 5 Vehicle (antenna) position, motion and received signals displays

Satellite ground tracks and sky plot

The positions of satellites simulated and those visible to the antenna at the simulated receiver location, together with a sky plot are displayed as shown in .

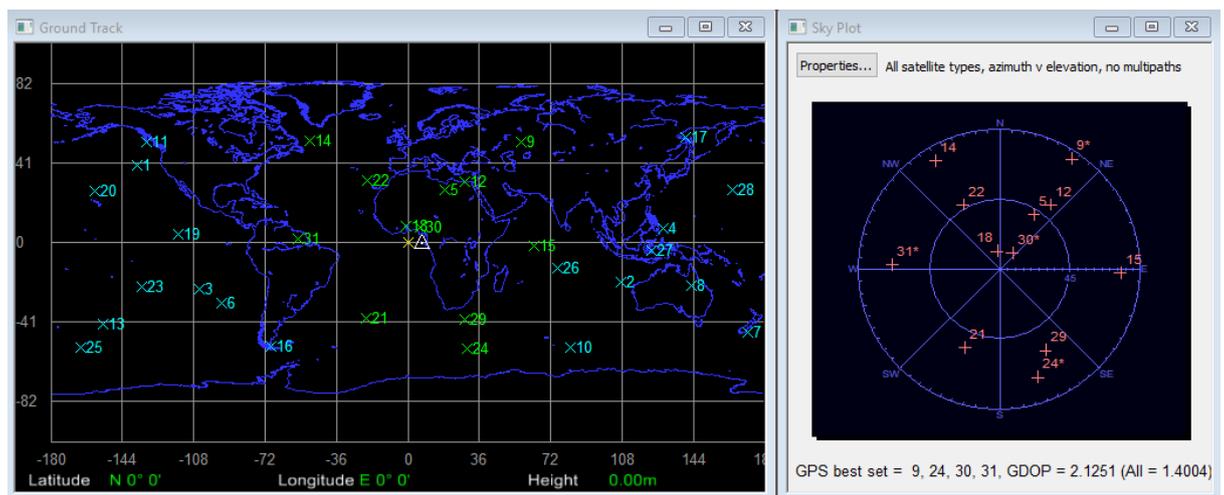


Figure 6 Satellite ground tracks and sky plot

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Source types

Test scenarios are defined using a collection of data source and scenario files defined by the user. The non-exhaustive simulated parameters listed below are all user-definable:

- Start Time and Date
- Definition of the appropriate GNSS Constellation(s)
- Atmospheric parameters for both the Ionosphere (from reference [1] in External documents section, page 41) and Troposphere. An additional Ionospheric model suitable for spacecraft is included.
- Vehicle performance envelope - Personality
- Antenna placement and orientation
- Satellite TX and receiver RX Antenna Patterns (Gain and Phase)
- Vehicle motion commands (Initial position and 6-DOF trajectory definition for one or multiple vehicles/antennas)
- Multipath definition
- Terrain obscuration

A 'shared' folder can be used to store favourite source files for rapid re-use in multiple different scenarios as required.

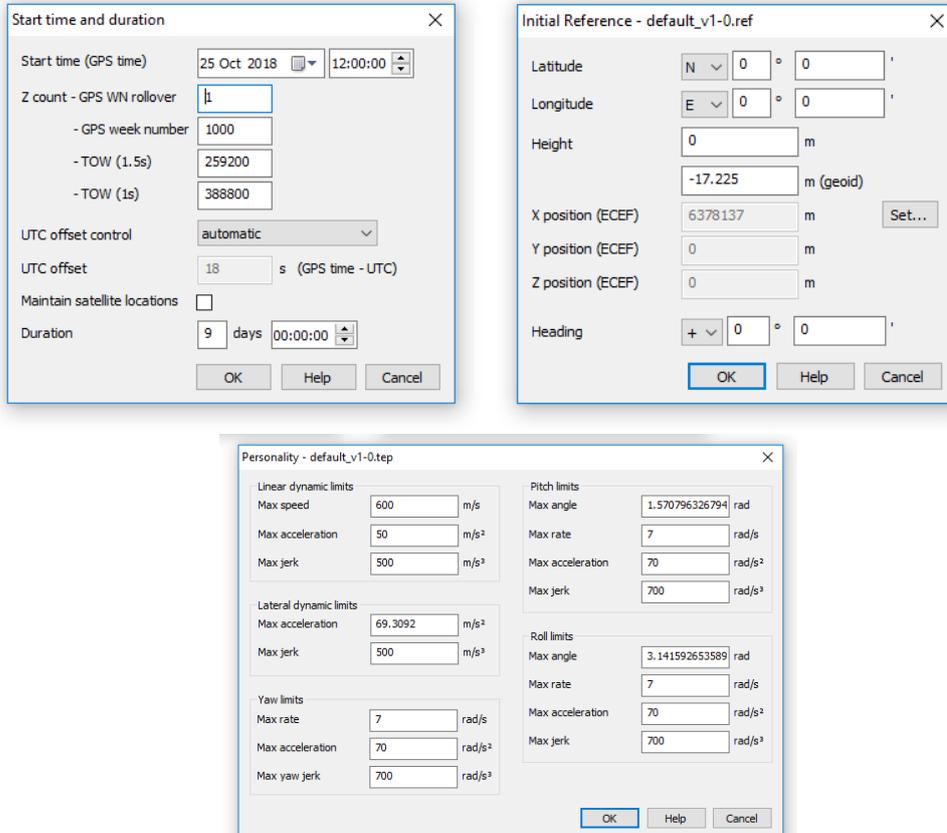


Figure 7 Typical source editors

Satellite modelling

SimGEN can calculate the positions and velocities of up to 63 navigation satellites per constellation (using the extended constellation) in user-defined constellations. Definition of the constellations is via comprehensive file editors, that independently describe the orbits of the satellites in the terminology of the relevant ICDs (see references [1], [2], [3], [5], [7], [8], [10] and [11] in External documents section, page 41 .

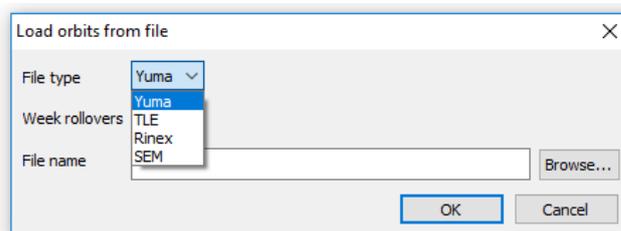
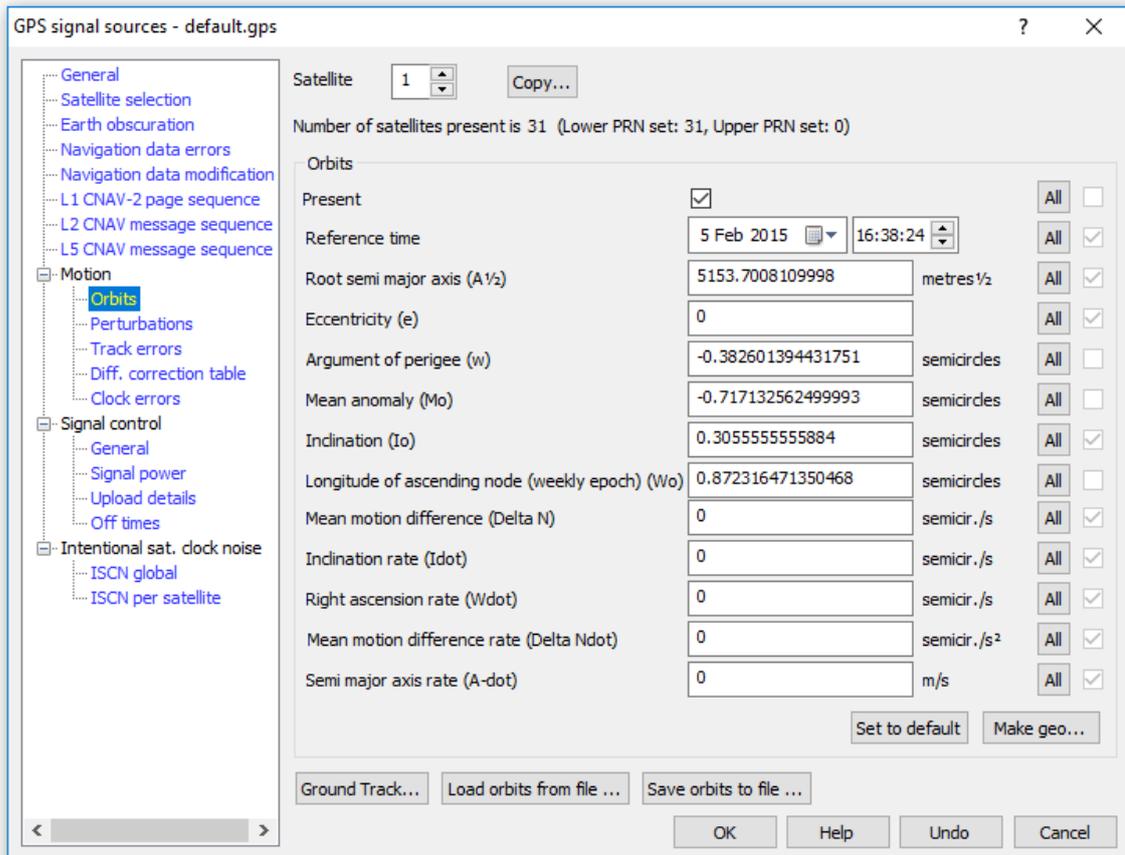


Figure 8 Typical Constellation Editor – GPS shown

SimGEN then calculates the orbital trajectory plus Almanac and Ephemeris data. A utility is also provided to create a constellation file from an ASCII source conforming to the US Coast Guard 'YUMA', RINEX and SEM formats.

SBAS satellites principally for augmentation of GPS, are separately specified in terms of PRN identity, position and power level. The user may specify clock bias terms and Issue of Data update times plus satellite residual motion. Three independent SBAS systems are supported simultaneously (WAAS, EGNOS & MSAS).

The signals from the satellites visible at the simulated vehicle position may be generated simultaneously at each available RF output, the number of signals and type being dependent on the signal generator hardware connected, and the available licence keys.

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The software applies the user-specified Dilution-of-Precision (DOP) algorithm to determine and optimise the simulated set at regular user-specified intervals during the simulation. Various DOP options are supplied including GDOP, PDOP, HDOP, VDOP and TDOP.

A facility is also supplied to superimpose undeclared clock biases and ramps onto the simulated signals, allowing RAIM testing of receivers.

Modelling of intentional GPS satellite clock degradation, which forms part of the US DoD Selective Availability implementation, is supplied using freely published material. Models supplied include, first and second order Gauss-Markov processes, digitally-filtered noise and a sum of sinusoids.

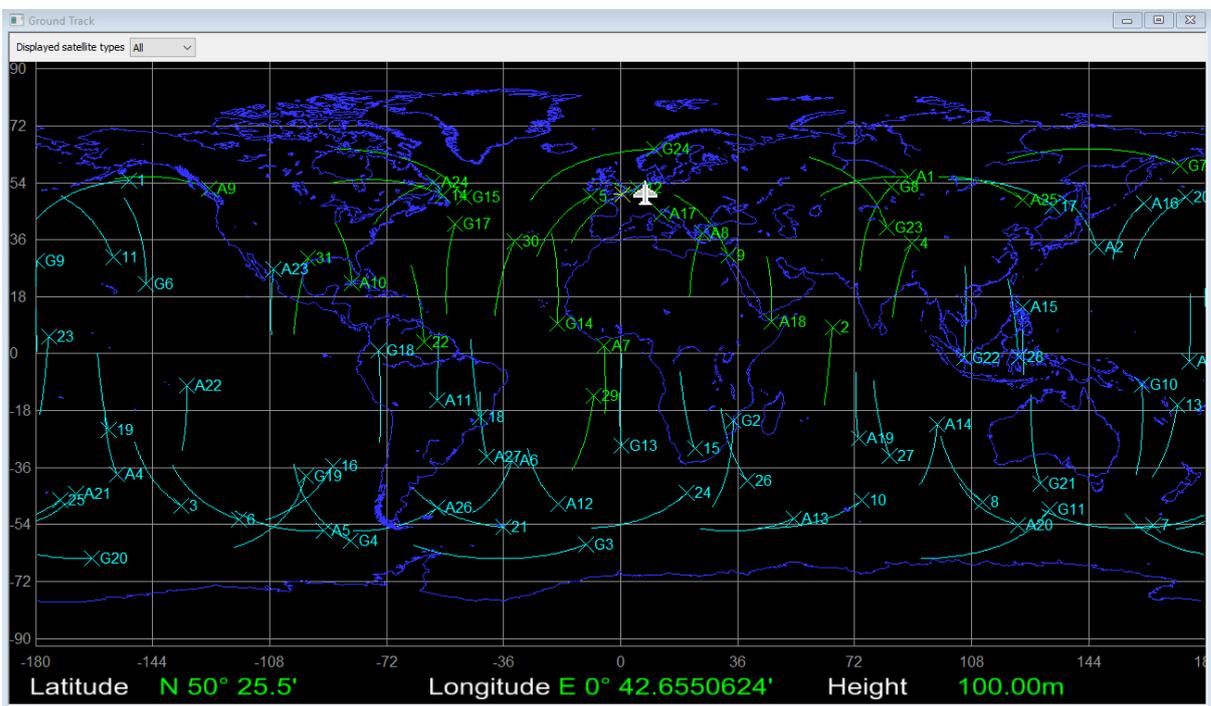


Figure 9 Satellite ground tracks

A wide range of user controls and error functions are also supported including the ability to enable or suppress elements of the transmitted signals on a per-satellite basis. This includes specifying the combination of the various ranging codes present on each of the available carrier frequencies as well as the Navigation Data message.

It is also possible to independently set the effective transmitted power of each satellite plus other parameters such as Inter-carrier group delay and even schedule the removal of an entire satellite from the constellation. Note that controls require appropriate hardware and licences.

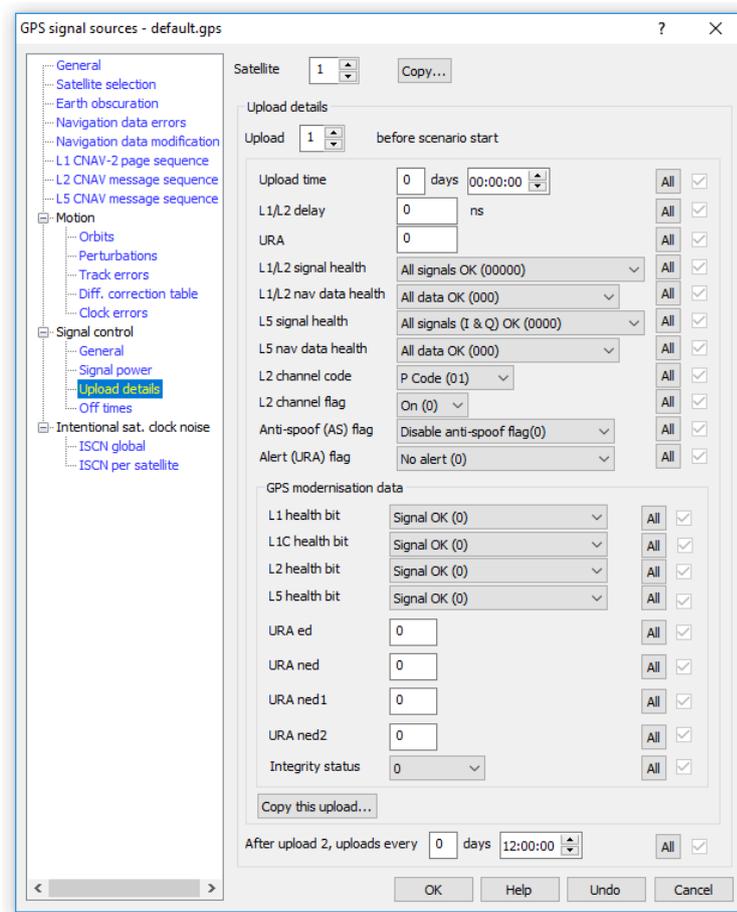


Figure 10 Signal Content Definition – GPS Shown

Ground-segment modelling

SimGEN allows the user to command a variety of Ground Segment activities.

A facility is provided to periodically remove any satellite from the simulated constellation and for this to be reflected in the transmitted Navigation Data message where appropriate.

The Navigation Data message associated with each satellite signal and service is automatically compiled into its respective format. Where the data is structured as messages that are broadcast on a schedule which is not fixed, such as for SBAS, GPS L2C, L5, and M-code (SimMCODE and SimMNSA upgrade required for M-code) facilities are included to define the rate or sequence at which the individual message types are broadcast.

Any Ephemeris or Almanac is derived directly from the orbital definition specified by the user. The data is extrapolated from the time-of-validity in the source file to the value that would be valid at the simulated time, including divergence after upload. This relieves the user of the need to relate constellation file data to simulation date and time. Data uploads and Ephemeris cutovers are fully supported where appropriate.

All GPS capability is fully compliant for testing End-of-Week and Week 1024 rollovers as well as leap second transition events.

SimGEN® Software Suite for Spirent GNSS Constellation Simulation Systems

Facilities are provided to specify the satellite health data fields and to manipulate various specific data fields and flags in the data messages. In addition, bit-wise message editors are included that allows manipulation of any field though bit forcing, clearing and inversion, whilst maintaining valid parity.

SBAS data messages (see reference [3] in External documents section, page 41), are fully supported and draw upon the error data generated by the various navigation satellite error models to define their content. The user may specify a network of up to 50 ground-station monitor locations and SBAS data messages are only generated for navigation satellites that are visible to that network.

SBAS data may also optionally be taken from a disk file prepared off-line.

For GPS constellations only, an alternative expert method of constellation and data message content definition is supported using ASCII files containing actual broadcast legacy navigation data content.

SimGEN supports the definition and modelling of the inter-system timing and time-base differences that exist between different constellations.

SimGEN also compensates its data in respect of the different geodetic reference frames (e.g. WGS-84) employed by the various constellations and satellite systems.

Atmospheric modelling

Satellite signals contain correction coefficients in their navigation message structure to support correction of Ionospheric delay on the transmitted signal. Inclusion of Ionospheric and Tropospheric effects (including a Wet/Dry element) is fully supported by SimGEN.

Separate modelling coefficient sets are provided; one set applied to the RF signal and one set for subsequent navigation message uploads; see . Deliberate divergence between the data in the RF and data broadcast sets allows pseudorange errors to be introduced.

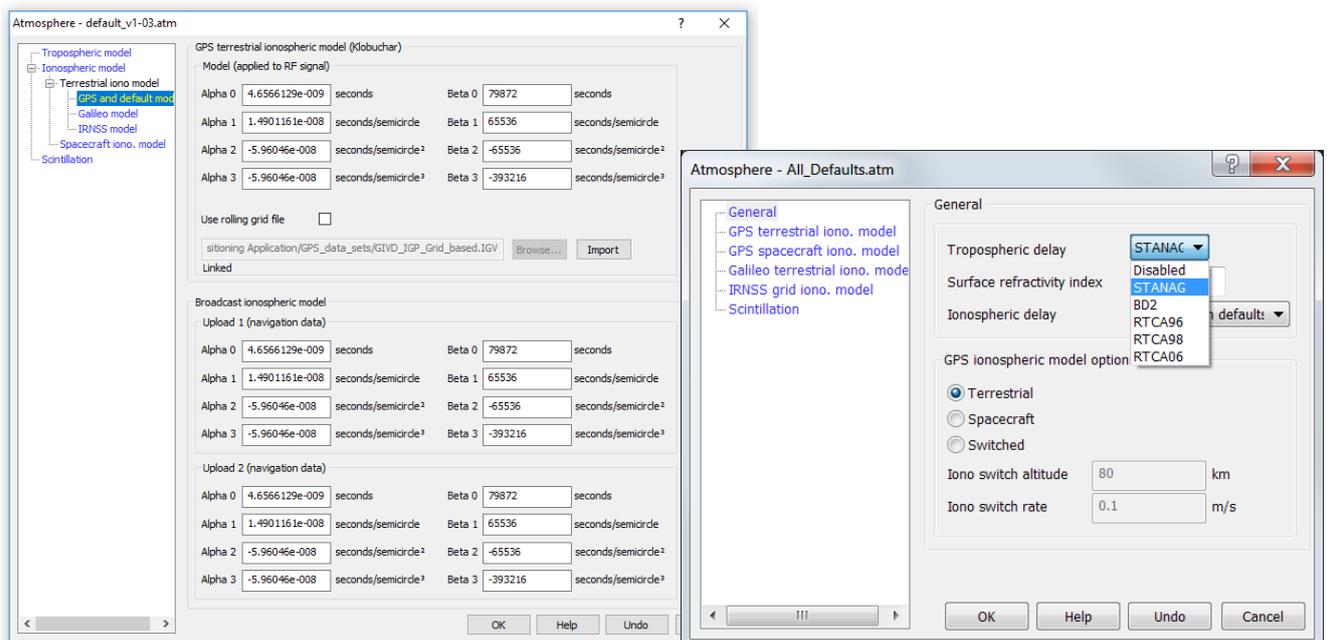


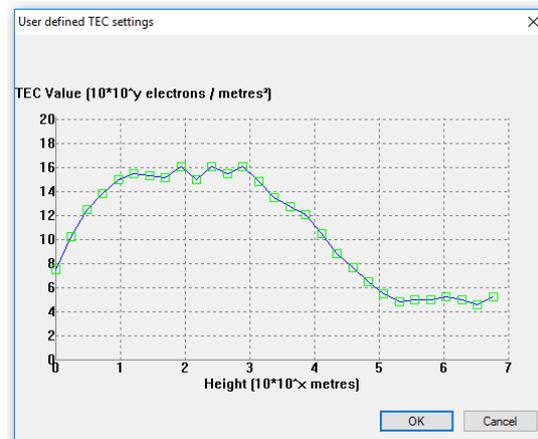
Figure 11 Atmospheric Model Coefficients

Delay is added to the true range of generated signals as appropriate to the carrier frequency of the simulation channel, taking proper account of code-to-carrier dispersion.

Ionospheric delay is added to the signal in accordance with the Klobuchar model defined in reference [1] in External documents section, page 41. For Galileo appropriate NeQuick model coefficients are derived from this, as is the IRNSS grid iono model.

For Spacecraft scenarios where the terrestrial models do not necessarily apply, a Total-Electron-Count (TEC) model is supplied (see reference [6] in External documents section, page 41). The operator may select from the following TEC model variants:

- Constant defined by operator
- Polynomial (fifth order) variation with height above reference
- Constant with sinusoidal variation with time, parameters specified by the operator
- Polynomial variations with height and sinusoidal variation with time
- Solar elevation relative term
- Polynomial variation with height and solar elevation relative term.



It is possible to perform a phased transition from the Terrestrial to the TEC model at a user-defined altitude for a simulated spacecraft launch or re-entry trajectory that is provided in a file or via remote control.

Changes to code and carrier phase and power level can also be applied by direct command over the SimREMOTE interface. This method allows data from external models or real-world observed events to be used to manipulate the simulated RF signal. For example, observed ionospheric scintillation events can be faithfully recreated in the simulator using remote commands to apply sets of data.

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Vehicle modelling

SimGEN is supplied complete with a range of vehicle trajectory models and data converters. These are designed to provide the user with all the tools necessary to describe complex dynamics that exercise all aspects of satellite tracking ability in the receiver or system under test.

All vehicle models generate trajectories centred on the vehicle itself. Additional dynamics and positional offsets due to user-specified antenna placement (lever arm) are fully supported by all models. Geodetic data for these models are calculated in the WGS-84 ellipsoid reference frame.

Each of the vehicle models describes in the following sub-sections support a range of manoeuvres that incorporate full 6-degrees-of-freedom (6DOF) motion. The principal motions for each vehicle are listed together with vehicle specific notes.

A user-defined vehicle personality that operates in 6DOF serves to ensure that manoeuvres don't exceed user-defined limits (excludes simple motion models) or to characterise the manoeuvre dynamics.

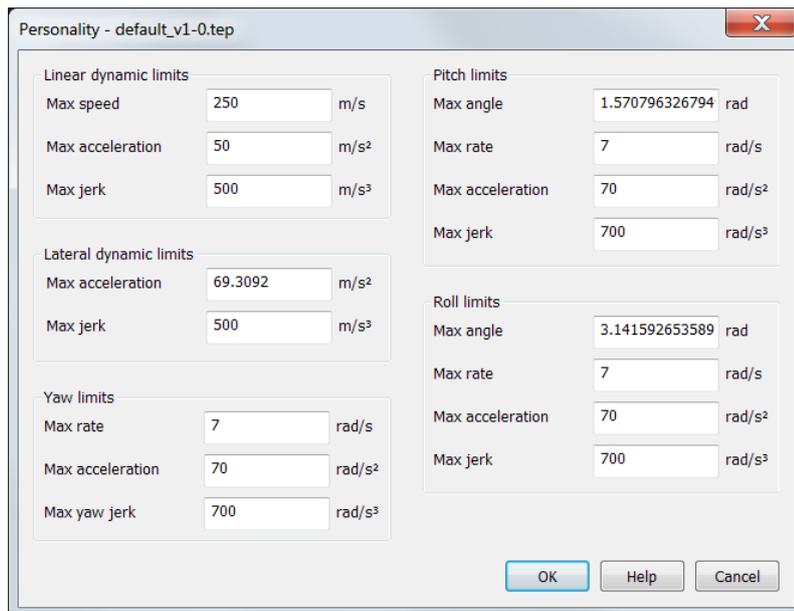


Figure 12 Personality editor defining vehicle performance envelope

Please note for each of the Terrestrial vehicle types, all manoeuvres start and finish with the vehicle in a straight and level orientation.

Simple motion

Rectangular racetrack

Note, this model is particularly relevant to 3GPP testing of A-GPS mobile telephones. Racetrack manoeuvres are described in Table 1.

Table 1. Rectangular racetrack manoeuvres

Manoeuvre	Description
DIMENSIONS	Specify track dimensions and corner radius.
INITIAL STATE	Specify start point and whether travel is clockwise or anti-clockwise.
DYNAMICS	Specify acceleration distance, minimum speed when cornering and maximum speed on linear sections.
REFERENCE	Specify location of bottom left corner.
ORIENTATION	Rotate entire track through the specified number of degrees.

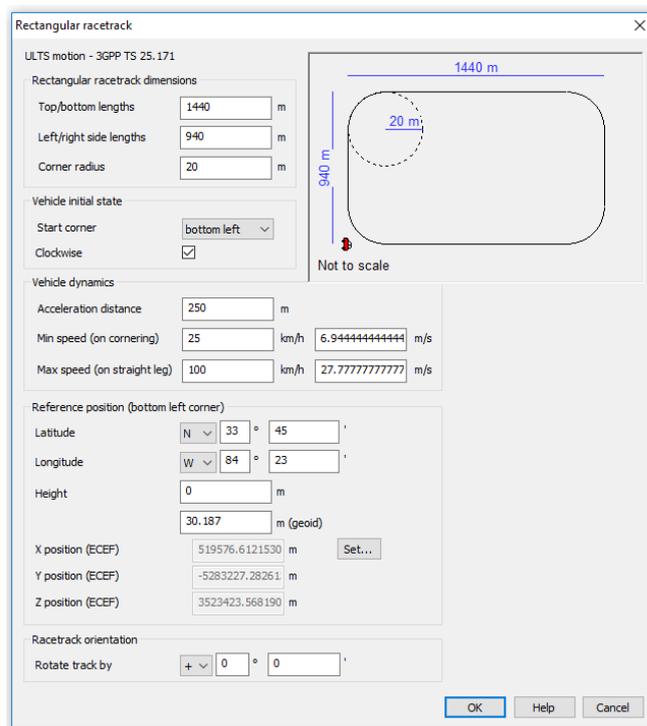


Figure 13 Racetrack editor

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Circular motion

Specify centre location and radius of circular motion, speed, direction and start bearing.

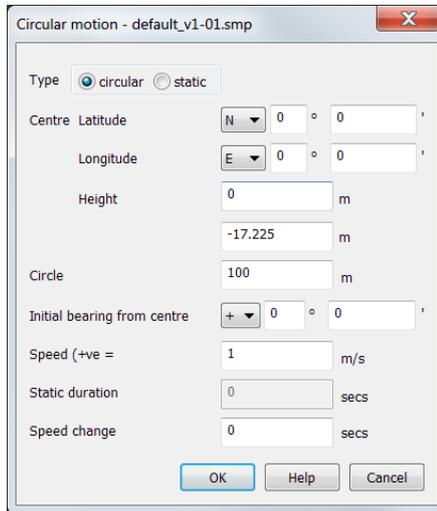


Figure 14 Circular motion editor

Aircraft

Aircraft manoeuvres are described in Table 2.

Table 2. Aircraft manoeuvres

Manoeuvre	Description
REFERENCE	Specify initial 3D position, heading and speed.
STRAIGHT	Maintain current altitude above the WGS-84 ellipsoid and maintain current horizontal speed and direction (Constant Heading or Great Circle) for the specified duration or distance travelled. Optionally apply axial yaw or pitch or roll offset.
ACCELERATE	Maintain current altitude, heading, and level attitude with respect to the WGS-84 ellipsoid whilst applying either the specified horizontal speed change (positive or negative) over the specified duration in seconds or distance in metres, or the specified final speed.
TURN	Maintain current altitude above the WGS-84 ellipsoid and horizontal speed whilst changing heading incrementally by the specified amount in degrees at the lateral acceleration specified in reference [7] in External documents section, page 41. In order to maintain the aerodynamic nature of the turn and prevent side-slip, the simulated aircraft will bank at rates consistent with the vehicle performance envelope (personality) specified by the user.
CLIMB	Maintain linear speed and heading, but incrementally change height by the specified amount (positive or negative) at the specified climb rate. The change from/to straight and level flight is governed by user-specified lateral accelerations. An optional pitch component can be added to aid in landing simulation.

Manoeuvre	Description
WAYPOINT	Describe a trajectory to intercept specified geodetic WGS-84 co-ordinates from current position at current speed. A lateral acceleration is specified for use when calculating trajectories between successive waypoints.
Other	<p>COMBINED ACCEL/TURN Changes are incremental only.</p> <p>COMBINED ACCEL/TURN/CLIMB. Changes are incremental only.</p> <p>HALT</p>

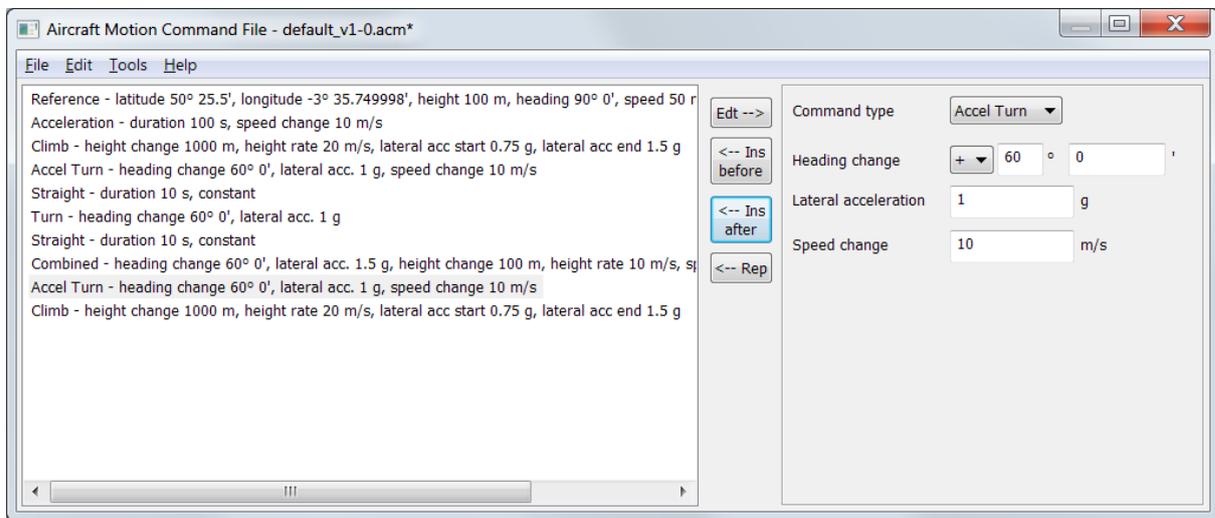


Figure 15 Aircraft motion command editor

SimGEN® Software Suite for Spirent GNSS Constellation Simulation Systems

Ship

Ship manoeuvres are described in Table 3.

Table 3. Ship manoeuvres

Manoeuvre	Description
REFERENCE	Specify initial 2D position, heading and speed.
STRAIGHT	Maintain current speed and direction (Constant Heading or Great Circle) for the specified duration or distance travelled.
ACCELERATE	Maintain current heading whilst applying the specified horizontal speed change (positive or negative) over the specified duration in seconds.
TURN	Maintain horizontal speed whilst changing heading by the specified amount in degrees over the duration specified. In order to simulate the outward 'heel' effect, the simulated ship will roll to the nominal angle specified at a rate consistent with the vehicle performance envelope (personality) specified by the user.
WAYPOINT	Describe a trajectory to intercept specified geodetic WGS-84 co-ordinates from current position at current speed. The maximum heel angle applied in navigating between successive waypoints is user specified.
Others	HALT

Notes:

- Apart from the WAYPOINT and HALT commands, all manoeuvres are incremental.
- A sea-state model is included where the user may specify up to 10 different levels of wave severity. Each manoeuvre may be associated with a particular sea-state. The sea-state model will modulate the trajectory as appropriate applying pitch, roll and heave motion.

Land Vehicle

Land vehicle manoeuvres are described in Table 4.

Table 4. Land vehicle manoeuvres

Manoeuvre	Description
REFERENCE	Specify initial 3D position, heading and speed.
STRAIGHT	Maintain current height above the WGS-84 ellipsoid and maintain current horizontal speed and direction (Constant Heading or Great Circle) for the specified duration or distance travelled.
ACCELERATE	Maintain heading whilst accelerating to the specified speed over the specified distance in metres. Vehicles may travel forward or in reverse.
TURN	Maintain horizontal speed and height whilst either changing heading to that specified or by the amount specified with the specified turn radius. No 'rolling' of the chassis is simulated.
CLIMB	Maintain linear speed and heading, but change height above the WGS-84 ellipsoid either to that specified or by the value specified within the specified horizontal distance travelled. The change from/to straight and level attitude is governed by a user-specified smoothness factor.
WAYPOINT	Describe a trajectory to intercept specified geodetic WGS-84 co-ordinates from current position at current speed. The turn radius to be implemented in navigating between successive waypoints is specified.
Others	HALT

Note: All manoeuvres can be configured to be absolute to aid translation from a map or similar.

Spacecraft

The Spacecraft Vehicle trajectory model allows initial definition of Earth Orbit in a number of forms, all of which support attitude orientation as Earth, Sun or Inertial Pointing mode and specification of initial attitude. The current attitude orientation mode can be switched to another at any time during the simulation. All support a full 6 degrees-of-freedom.

- Keplerian orbit parameters (Mean Anomaly, Right Ascension, Eccentricity, etc.)
- Geodetic (Latitude, Longitude, Altitude, Speed, Attitude)
- State Vector (XYZ position, Speed, Attitude)

The Geodetic and State Vector options may be operated simultaneously, with automatic translation from one co-ordinate frame to the other while editing. However, data is not translated when moving to and from the Keplerian option. The supported reference frames are J1950 and J2000.

The initial orbital trajectory specified will be subject to the supplied gravity models plus user configurable effects such as atmospheric drag. Both the GEM10 and the more recent JGM3 gravity models are available. Each can be calculated to an order of 2 through 30 terms depending on the precision required.

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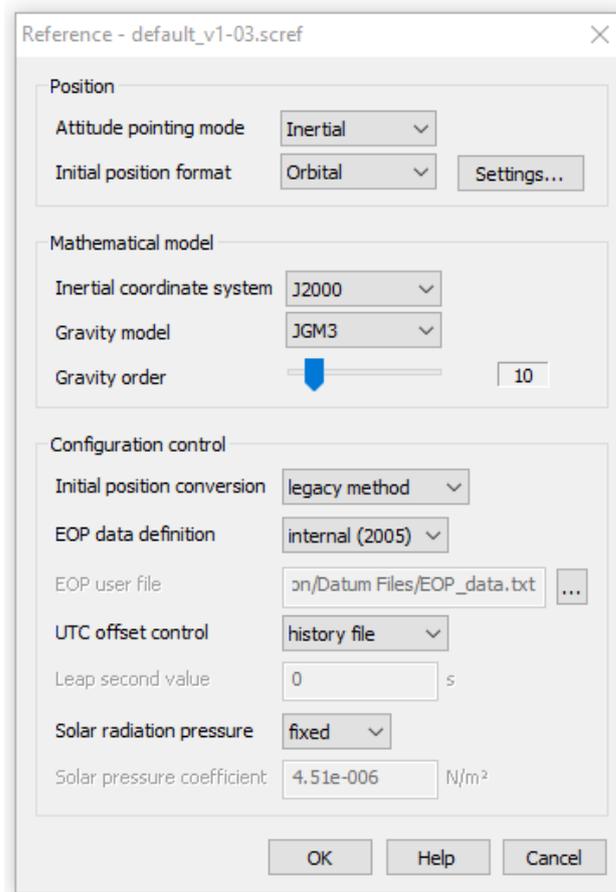


Figure 16 Spacecraft position editor

Manoeuvres are supported to perturb the orbit simulating thrusts and rotations as described in Table 5.

Table 5. Spacecraft manoeuvres

Manoeuvre	Description
ROTATE	Rotate the vehicle about the specified vehicle axis (X, Y or Z) at the time specified through the angle specified. The direction, duration and dynamics of the rotation are user specified. Multiple time-coincident rotations about different vehicle axes allow complex rotations to be performed.
ACCELERATE with respect to BODY AXES	Apply a thrust along the specified body axis (X, Y or Z). The direction, duration and dynamics of the acceleration are user specified. Multiple time-coincident accelerations along different vehicle axes allow complex accelerations to be performed.
ACCELERATE with respect to INERTIAL AXES	Apply a thrust along the specified Earth-Centred Inertial axis (X, Y or Z). The direction, duration and dynamics of the acceleration are user specified. Multiple time-coincident accelerations along different inertial axes allow complex accelerations to be performed.

User trajectory

The user may choose to supply a trajectory independent of the models supplied. The user defines the trajectory in an ASCII form supported by many commercial packages that support comma-separated file output, such as spreadsheets. The format of each data record is the same as that used for external trajectory data

- The data is read and used in real time.
- Lever-arm effects due to antenna positioning are handled automatically.

SimGEN can also use trajectory information from NMEA data and from Google Maps using Spirent's SimROUTE™ trajectory generation tool

External trajectory - hardware-in-the-loop (HIL)

User trajectories may be supplied in real-time as standard via Ethernet using TCP/IP Sockets.

This feature, known as SimREMOTE™ (see reference [20] in Related Spirent product specifications section, page 42) is an extremely powerful capability allowing full Hardware-in-the-loop capability for simulation of feedback control systems or for integration with vehicle motion simulators.

- True system latency in closed-loop can be as low as 6ms and an effective system latency of 0ms can be easily obtained for all trajectories where there is no step change in jerk.
- Time stamped data can be supplied asynchronously at any rate, including variable rate, up to 1000Hz (on the GSS9000 platform). Missing data records are handled gracefully.
- Lever-arm effects due to antenna positioning are handled automatically.
- The same syntax is supported via IEEE-488 bus and SCRAMNetGT interfaces, for which Spirent can optionally supply a suitable expansion card for the system PC plus a PCI synchronisation timer card if required. Details of the command syntax are available upon request.

SimREMOTE™ also supports a large range of remote-control functions, such as selection of scenario, variation of power level and variation of code and carrier phase of the satellite signals.

Terrain obscuration

A comprehensive Terrain Obscuration model is included for terrestrial vehicles, which simulates the temporary and intermittent masking of the GPS Satellite signals when manoeuvring at low altitude in mountainous terrain. Whilst this does not represent an actual region of the earth, the effects perceived by the receiver-under-test are typical of those experienced in a terrain of the specified type.

The input to the model is the vehicle height above the WGS-84 ellipsoid and the arrival elevation vector of the satellite signal.

The terrain is user configurable in terms of the proximity of the terrain, its maximum and minimum height above the ellipsoid, and its maximum and minimum width. Terrain height and width are varied pseudo-randomly, and the pattern of interruption is accurately repeated on consecutive simulation runs with the timing of changes proportional to the vehicle speed.

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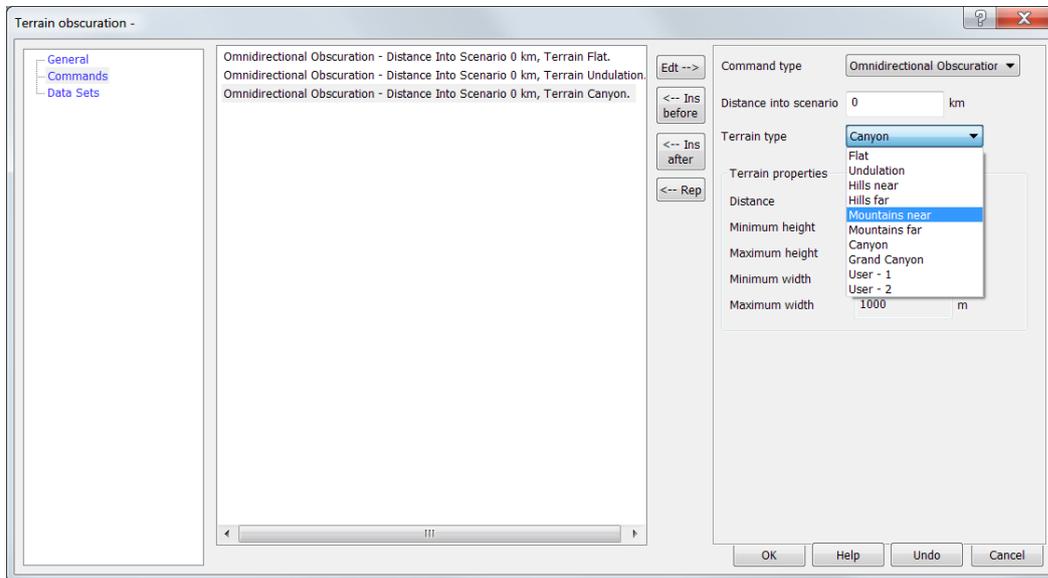


Figure 17 Terrain obscuration editor

The terrain type can be modified during the simulation, with horizontal distance travelled governing the point at which the terrain is deemed to have changed.

Executing the same vehicle trajectory at a different vehicle speed increases or decreases the interruption rate appropriately.

Antenna modelling

SimGEN supports modelling of both the satellite transmit antenna patterns and the reception pattern of the navigation sensor's antenna in terms of amplitude and phase with selectable resolution up to 1° in both azimuth and elevation (5° minimum resolution for $\geq 100\text{Hz}$ operation).

The gain pattern may represent the composite effects of the free-space reception pattern and the on-vehicle obscuration of the vehicle body.

The patterns are fully linked to the vehicle trajectory, allowing automatic simulation of masking of satellite signal due to vehicle obscuration during manoeuvres. This feature is also fully supported during operation in the Hardware-in-the-loop mode of operation (see External trajectory - hardware-in-the-loop on page 25).

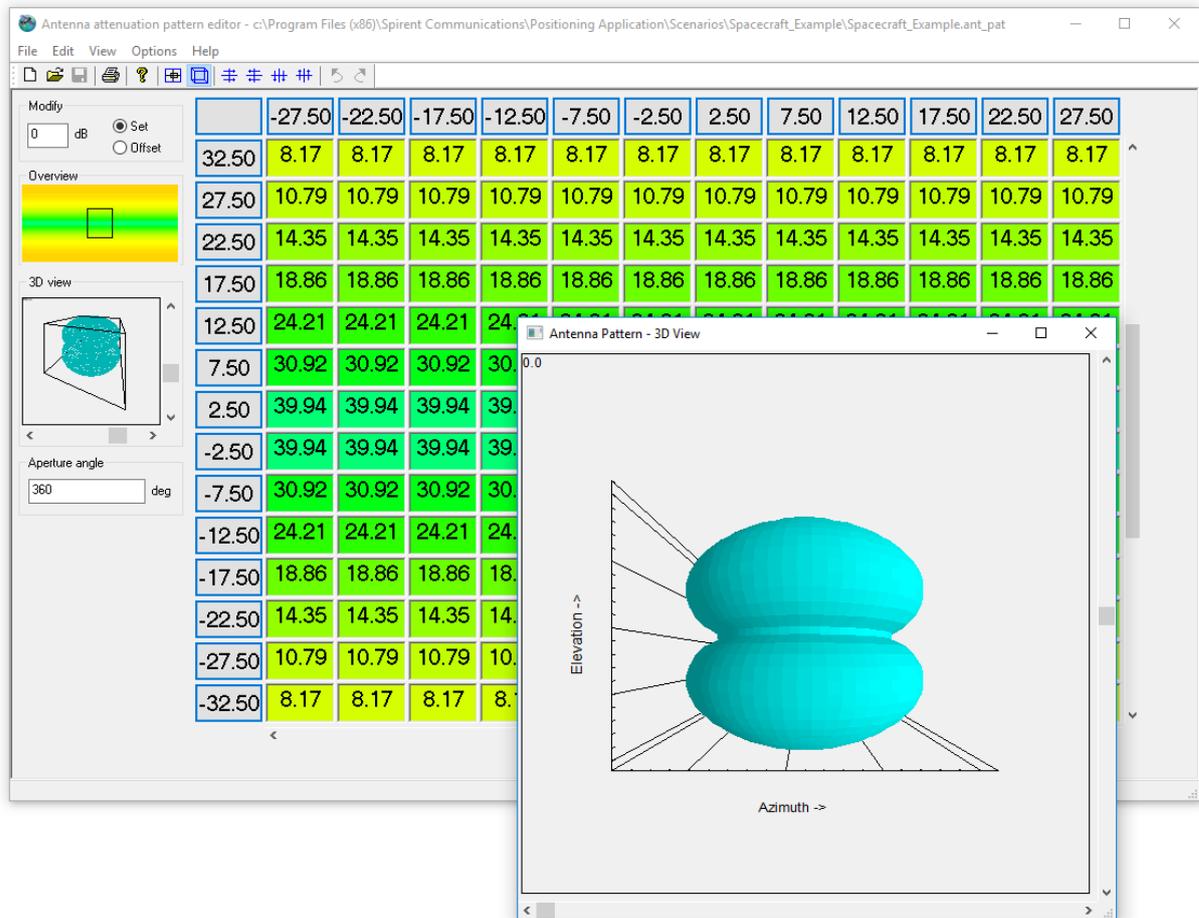


Figure 18 Antenna pattern editor

Additional antenna pattern flexibility is provided by the facility to download a pattern to the SimGEN controller in the popular comma-separated ASCII format.

Antenna lever arm offsets with respect to the centre-of-motion reference may be fully specified, along with antenna angular orientation with respect to the body frame.

Additional dynamics associated with the lever arm as a result of rotations of the body axes during manoeuvres are fully applied to the RF signals.

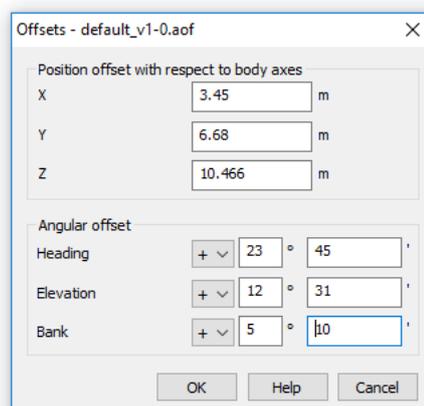


Figure 19 Antenna lever arm

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Multipath modelling

Extensive Multipath modelling is supported within SimGEN allowing the user to test in an environment that is subject to reception of reflected signals.

There are two principal approaches to multipath modelling. 1) Discrete/analytical, where specific signal parameters are manipulated in a controlled and analytical way and, 2) Via 3-dimensional environment and signal modelling where the multipath and obscuration is simulated based on a synthetic 3D model, from which real-life locations can be regenerated and used in simulation to recreate the multipath signature of that location. This capability requires Spirent's Sim3D™ software product. Please see reference [25] in Related Spirent product specifications section, page 42)

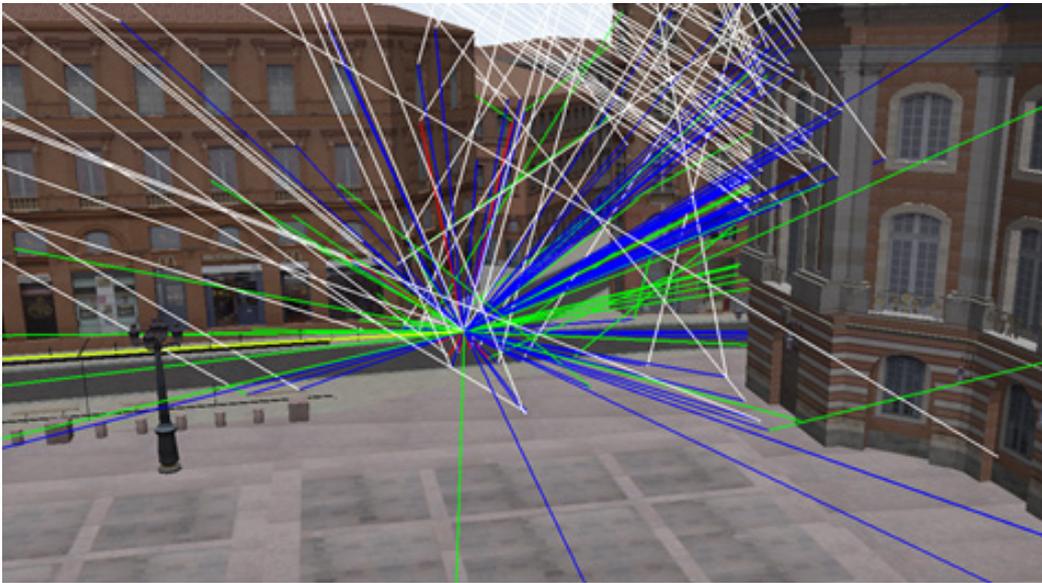


Figure 20 Sim3D™ environment representation

In most cases, Multipath reflections (echoes) are simulated using a signal generator channel. Note that an embedded 4-tap delay-line is additionally supported on GSS9000, GSS8000 and GSS7800 platforms.

At least five main discrete models are supplied:

- **Fixed offset**
where the reflected signal is subjected to a fixed loss and delay, both of which are user-defined.
- **Ground Reflection**
where the reflected signal suffers a specified, fixed ground loss plus a delay based upon simulated vehicle height above the ellipsoid. The elevation angle of incidence of the original line-of-sight signal is inverted for the purposes of antenna reception-pattern effect simulation.
- **Vertical Plane**
where the user specifies an array of vertical planes that is logically distributed to the right and left of the simulated vehicle. The height, width and distance of these vertical planes is specified by the user and those to the right are independent to those on the left. The impact of these vertical planes in terms of obscuration and/or their ability to create an echo is assessed and if appropriate the signals are either obscured or a ray-traced echo created with the appropriate delay and loss.
- **Reflection Pattern**
where the delay and loss of a specified echo is determined from a look-up table driven by the azimuth and elevation of the signal incident at the simulated antenna site.

- **Statistical**

where channels are assigned to signals based on a category mask, driven by arrival angle of the line-of-sight signal, and where the characteristic of the signal impairment is driven by elevation angle and specified environment, such as Urban Canyon, Rural, etc. See .

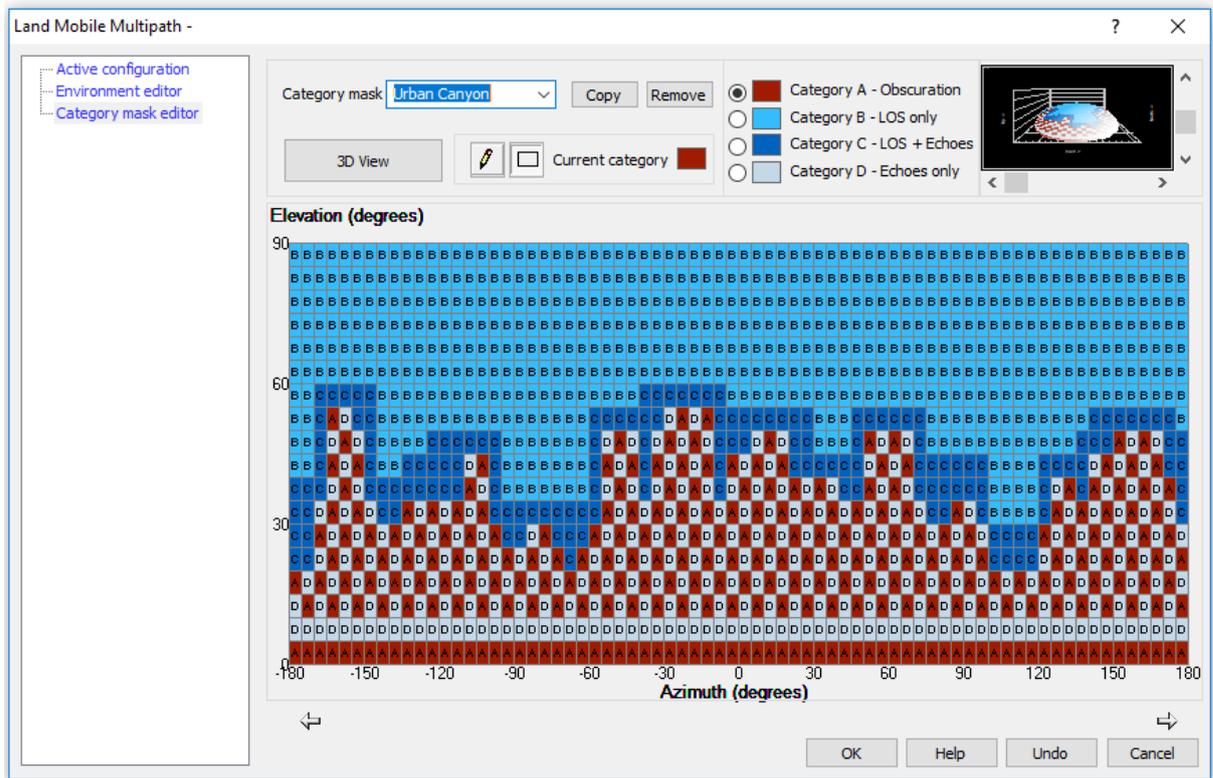


Figure 21 Statistical multipath category mask editor

Changes to code and carrier phase and power level can also be applied by direct command over the SimREMOTE™ interface.

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Multi-copy constellations (licenced feature for GSS9000 only)

SimGEN supports generation of multiple copies (up to 10) of an entire constellation, each with a full constellation editor. This allows sophisticated spoofing testing scenarios to be created by manipulating the parameters of the constellation copies. Multi-constellation applies to satellites (orbital) as well as Pseudolites (Ground-based, interference/jamming signal sources)

Position modes can be set as appropriate:

- Orbital
- Ground Tx absolute
- Ground Tx vehicle relative

2-vehicle to 1RF (licenced feature for GSS9000 only)

SimGEN supports the simulation of 2 independent vehicles (and their respective trajectories) under one antenna. This feature allows trajectory spoofing and meaconing to be carried out. For the purpose of a spoofing (meaconing) attack, a two-vehicle scenario can be created, static and dynamic, each vehicle will be originally co-located and will be assigned a separate constellation, the dynamic vehicle could then be defined to move away from the original position.

FLEX Simulation (licensed feature for GSS9000 only)

FLEX simulation comprises built-in and user-configurable control and set-up of non-current SIS ICD PRN codes, nav data content, nav data rate, chipping rate, edge shaping, and modulation types.

Table 6 FLEX Simulation

Carrier	Signal types
L1,L2,L5,E1,E5,E6, B1,B2,QZL1	User-definable codes – See Table 7

Three user-definable codes are supported per FLEX channel which corresponds to a single simulated SV. The Galileo E5 AltBOC signal structure is not supported on FLEX channels.

Table 7 FLEX Option Signal Definitions

Parameter	Value	Units
Codes	Three user-definable codes per SV	
Code Assignment	+I, -I, +Q, -Q	
Code Definition	User-definable memory codes (primary and secondary)	
Base Chip Rate	1.023	Mcps
Chip Rate Multiplier	1, 2, 2.5, 3, 4, 5, 6, 7, 8, 9, 10	
BOC Rates Multiplier	Integer multiple of Base Chip Rate	
Nominal Signal Level	-123 to -133	dBm
Nav Message	Standard for constellation	

Ground-based interference (GTx) (licenced feature for GSS9000 only)

SimGEN supports the simulation of multiple interference sources which can be modelled in physical locations in the scenario. Interference sources are assigned to the GNSS antennas. They can be static or have motion, and the signal power can be fixed or modelled relative to the distance from the GNSS antenna. A variety of interference signal types can be generated.

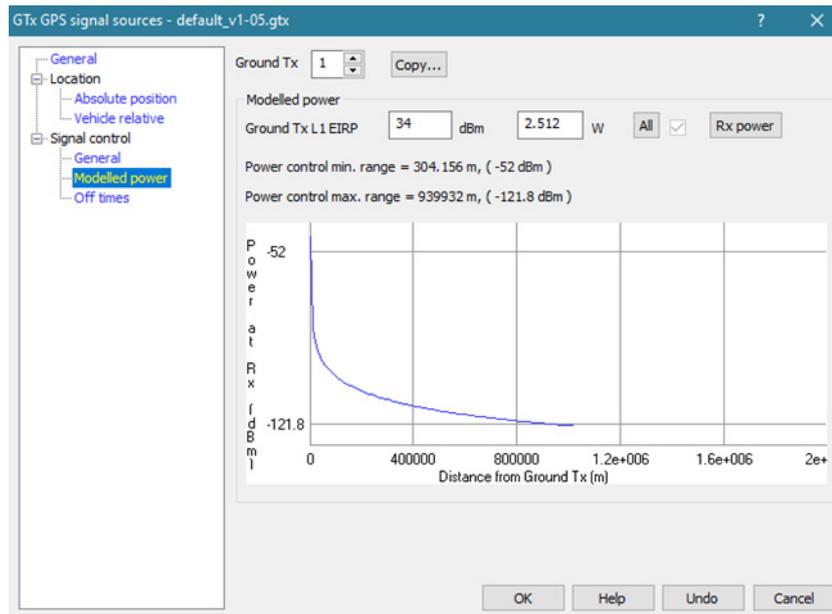


Figure 22 Power vs distance modelling for GTx

Data access

Graphical and textual data may be displayed whilst the scenario is being run in real-time, a process known as QUICK-LOOK. All scenario data generated by SimGEN can be optionally stored for off-line processing using commercially available packages, such as spreadsheets, that offer graphing capabilities. Data stored includes (but is not limited to) all vehicle position and attitude data, pseudorange data, signal amplitudes, error values, and transmitted data messages.

Quick look

Quick look provides access to categorised data for display in either tabular or graphical format. Multiple Graphical plot windows are supported. The operator selects parameters from the categorised lists:

- Time – Run time, UTC, GPST, GPS-UTC offset, Z count, etc.
- Vehicle - Centre-of-Gravity Position (XYZ or LLH), Velocity (XYZ or END), Attitude (body axes, Heading, Roll, Pitch) and rate, vehicle speed, etc.
- Antenna - Similar to Vehicle, but relevant to the antenna location
- Satellite - Position (XYZ or LLH), Velocity, Identity, etc.
- Signal - Range, Pseudorange and PR-rate, Arrival angle, Ionospheric Delay, Tropospheric delay, Power Level, Identity, etc.
- External - Data captured from an external source, such as a receiver. See Data capture on page 33.

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After compiling a list of parameters for tabular data or a set of graphical plots, the operator may save the list and/or set to file for use in subsequent scenarios, removing the need to re-specify a favourite set of quick look data.

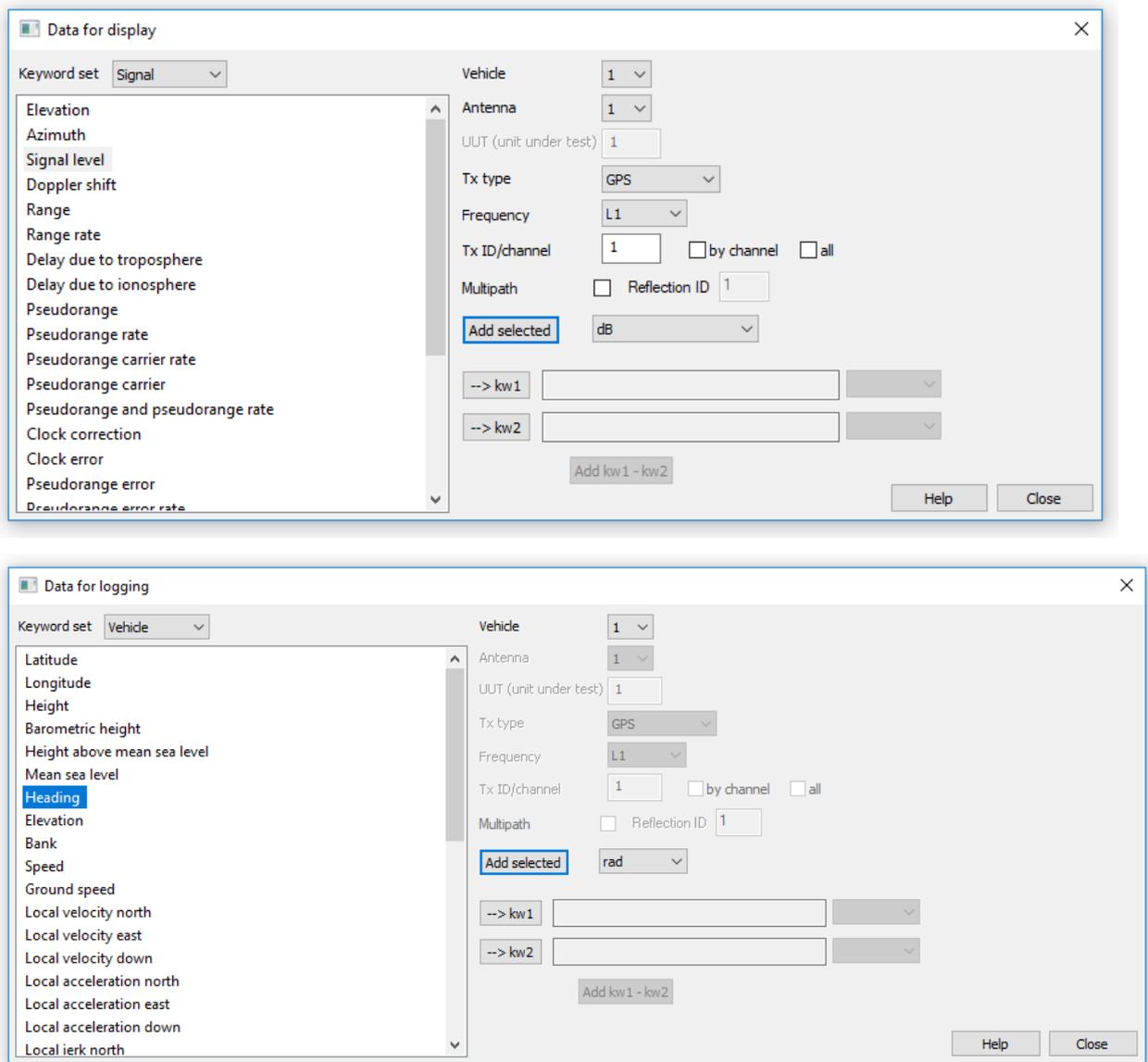


Figure 23 Quick Look Selection and Logging

Data storage

While scenarios are being run, the operator may choose to log generated data to a file. SimGEN supports data generation at variable sample rates up to a maximum of 1000Hz (signal generator hardware dependent).

Multiple files may be created to contain different data sets at different rates, if required. The data set chosen may be saved for use as standard templates for other scenarios, removing the need to re-create the format for multiple simulations. A bulk logging option is also provided to capture all vehicle and signal data.

The file format is selectable by the user to be either Comma Separated ASCII, a format supported by many spreadsheets and mathematical-analysis software packages, or binary data.

Data streaming

Simulation truth data can also be streamed in real-time at rates up to 1000Hz.

Data includes vehicle motion parameters and satellite parameters.

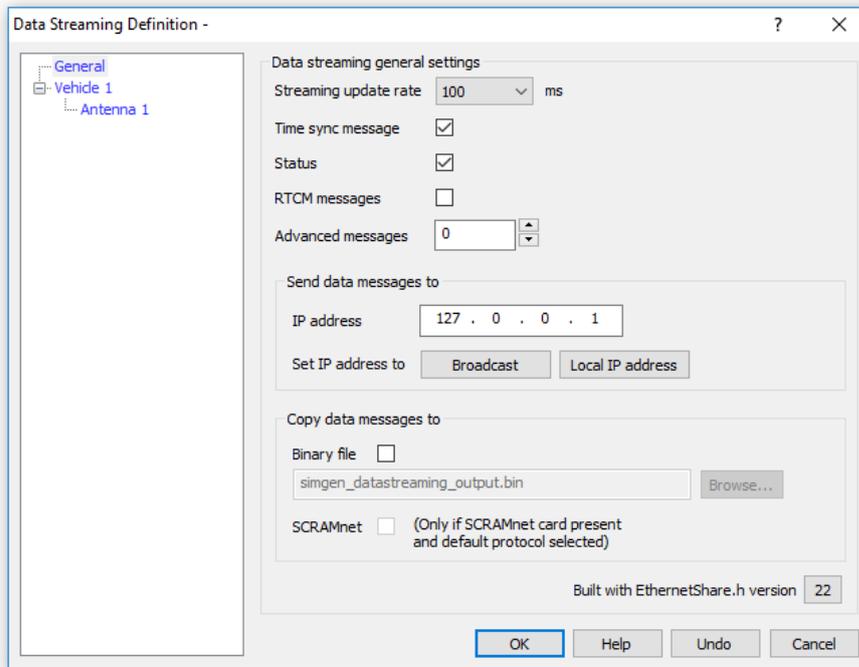


Figure 24 Data streaming

Data can be directed to an Ethernet port using UDP protocol or can be directed to another application running on the SimGEN PC/host via an operating-system socket connection.

Data capture

SimGEN supports capture of data from an external source, typically a receiver navigating from signals generated by the simulation system.

Two standard capture tools are included: NMEA and Generic.

NMEA data capture

Many receivers include a data port that outputs navigation and other performance data via a series of messages in the NMEA-0183 standard. This is usually transmitted over a serial bus such as RS-232C.

The user simply connects the receiver's data port to an RS-232C port on the computer system using a suitable cable. Utilities are included to set the Baud rate and protocol to match that of the receiver. The user then selects the message types to be captured and interpreted and SimGEN is able to extract the embedded data and associate it into keywords that may be used in real-time by the QUICK-LOOK facility. The data can also be stored to disk for off line processing.

SimGEN is compatible with a range of Spirent signal generator platforms that are capable of supporting a variety of signal structures (Table 8).

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GNSS signal constellation types

SimGEN offers the user choices for selecting the GNSS constellations to be simulated that are consistent with installed hardware, licenced constellations, options and hardware types.

Depending on the configuration of the simulator, the simulated signal types may be selected as shown in the example in

For a detailed definition of the signals simulated for each constellation, please refer to the Product Specifications for the GSS7000 and GSS9000 respectively (see references [17] and [24] in Related Spirent product specifications section, page 42)

For details regarding the functionality and control of the licenced GNSS signals, see the SimGEN User Manual in reference [26].

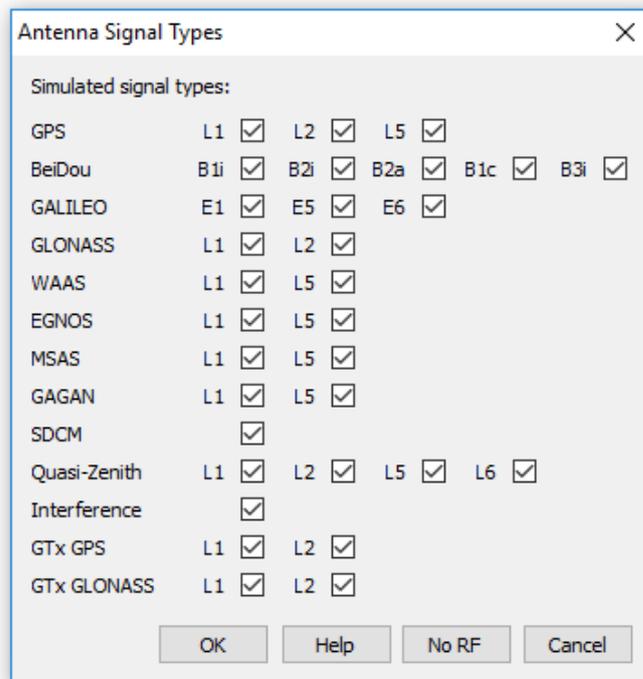


Figure 25 Signal type selection

Hardware supported

Table 8 lists the current generation of RF signal generators supported by SimGEN along with the appropriate hardware specification datasheet reference.

Table 8 Current generator platforms supported by SimGEN

Product ID	Description	Reference (in Related Spirent product specifications)
GSS9000	Multi-GNSS, Multi-Frequency RF Constellation Simulator – all GNSS navigation signals	[17]
GSS7000	Multi-GNSS, Multi-Frequency RF Constellation Simulator – all GNSS non-classified navigation signals	[24]
GSS7765	RF Interference Simulation System	[21]

SimGEN Support for Previous Generator Platforms

Table 9 lists previous generations of RF signal generators that are supported by SimGEN.

Table 9 Previous Generator Platforms supported by SimGEN

Product ID	Description
GSS6560	GPS 12 channel L1 C/A simulator
GSS7700	GPS Multi-Channel GPS – all SBAS – L1/L5
GSS6700	Multi-GNSS RF Constellation Simulator GPS L1C/A, Galileo E1B/C, GLONASS L1, BeiDou-2 B1I
GSS8000	Multi-GNSS, multi-frequency RF Constellation Simulator GPS – all navigation signals Galileo – all navigation signals GLONASS – C/A and P code BeiDou – B1I and B2I QZSS – L1 C/A+SAIF SBAS – L1/L5
GSS7800	Galileo Multi-Channel Galileo – E1/E6/E5ab
GSS7790	Multi-RF Output (one-per-satellite) GPS L1/L2

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Product ID	Description
GSS7900	GPS/Galileo Multi-Channel GPS L1+ Galileo E1/E5ab
STR4760	GPS Multi-Channel GPS – L1/L2 Legacy SBAS – L1
GSS4750	GPS Multi-Channel GPS – L5
STR4780	GLONASS Multi-Channel L1 C/A
GSS4765	RF Interference Generators
GSS4150	LAAS/VDB VHF Signal Generator

SimGEN also allows you to save test scenarios for replay via Spirent’s other simulation control software variants; SimREPLAYplus™ and SimTEST™. Licensing conditions apply to some features.

Optional and extended capabilities support

Spirent offers a range of product extensions that are compatible with SimGEN and enhance the simulation system performance beyond standard GNSS simulation.

Commercial extensions

Interference simulation

SimGEN supports the integration of Interference simulation via its general-purpose GSS7765 product (see reference [21] in Related Spirent product specifications section, page 42).

Interference and its impact on GNSS receiver performance is a key test criteria for many applications, both commercial and Military.

The GSS7765 provides the ability through SimGEN to position interferers in the scenario with user defined characteristics or to simply set up pre-defined Interferer situations.

The GSS7765 comprises hardware signal generators and a signal combiner system plus the SimGEN extensions.

Spoofing simulation

SimGEN supports the spoofing of GNSS receivers by several methods, including inherent features already described such as Multiple-copy Constellations, 2-vehicle 1-RF and the general signal and data manipulation features available by default. Spoofing is also supported via Spirent’s SimSAFE™ Spoofing Simulation Software. Please refer to the SimSAFE™ Product Specification reference [27] on page 42.

Automotive extensions

SimGEN supports simulation of automotive dead reckoning sensors via its SimAUTO extensions (see reference [23] in Related Spirent product specifications section, page 42).

SimAUTO™ uses plug-in hardware and equips SimGEN with extensions that configure and provide:

- Pulses representing wheel speed sensor outputs
- Heading or rate gyro voltages
- Forward/Reverse sensor output
- CAN bus data

Models are included to degrade the accuracy of sensor outputs, including events such as wheel skid/slip and gyro bias and drift.

The ability to drive a single axis rate is also supported.

Ground based augmentation systems

SimGEN supports simulation of ground based augmentation systems (GBAS), (see reference [4] in External documents section, page 41).

Spirent's GSS4150 is required to generate the VHF VDB signals for this capability via the appropriate software extensions to SimGEN.

The user may define a reference receiver location at which the enhanced SimGEN determines the errors that would be introduced by models applied to simulated GPS satellite signals at that location. These include Ionosphere, Satellite Clock terms, Clock Noise (simulated Selective Availability) and Ephemeris errors. These errors are compiled into differential correction data for subsequent transmission to an airborne receiver under test using the message types defined for the system. Apart from the differential corrections, fixed data related to the airport and the landing system setup is also included in these data messages. The SimGEN add-in provides forms to allow the operator to simply enter this static data as part of the simulation definition. It is also possible to define transmitted data errors.

Message types 1, 2 and 4 are supported. The user may define the rates at which the messages are transmitted and define system latency for message generation.

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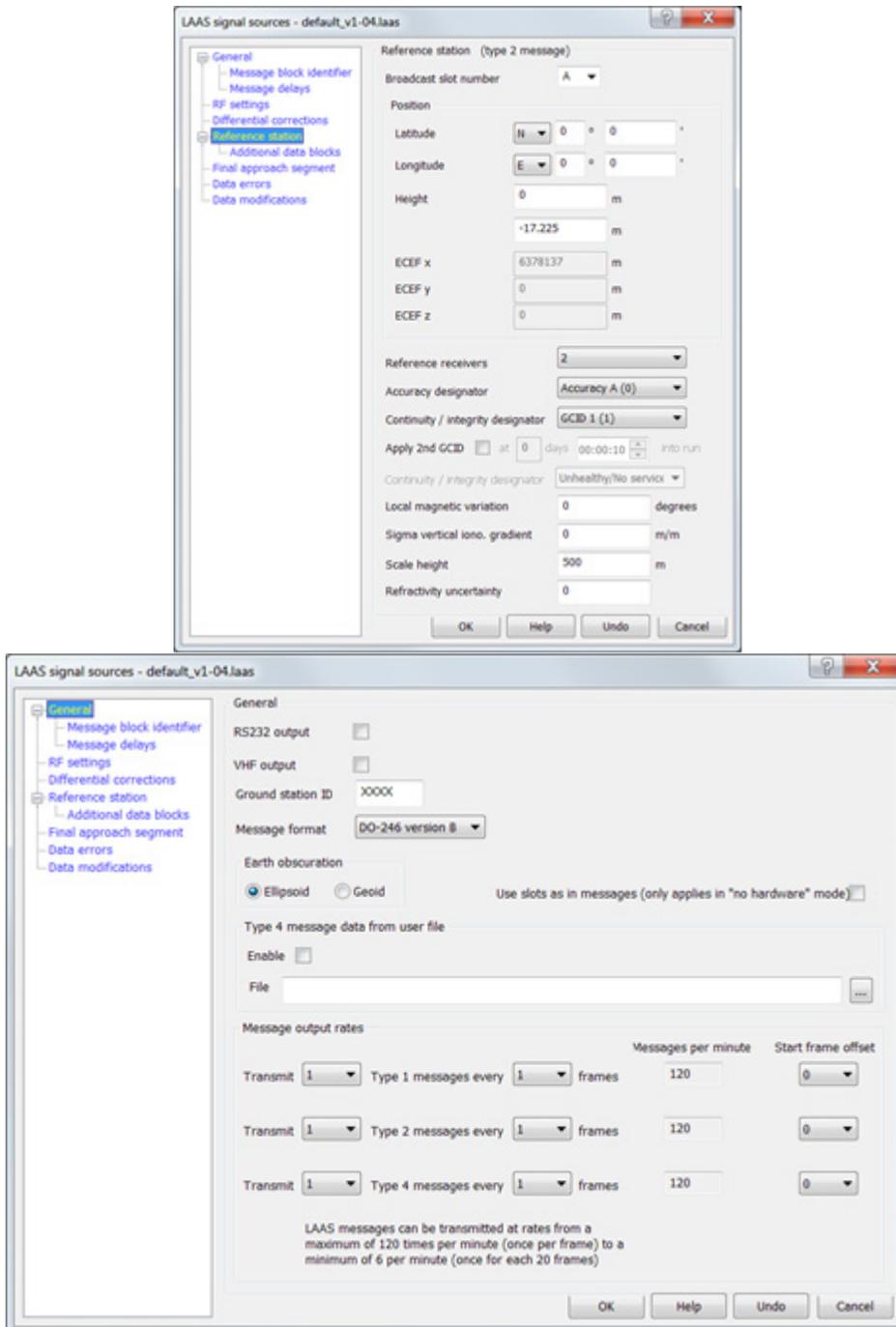


Figure 26 GBAS message type 1 and 2 editor examples

The enhanced SimGEN supports two methods for delivery of the messages:

- Via RS232 port on the SimGEN PC/host
- Via the VHF link provided by the Spirent GSS4150 VHF Data Broadcast Simulator hardware.

Authorised testing extensions

A number of SimGEN extensions are available to authorised customers. Many of these features are subject to export approvals

In general, access to these features is via the supply of additional DLLs and/or licencing compatible with SimGEN and some form of hardware upgrade.

Inertial simulation extensions

SimGEN supports simulation of Inertial sensor outputs (from accelerometers and gyroscopes) via Spirent's SimINERTIAL™ package (see reference [36] in

Related military/government product specifications, page 43) which provides for testing support for a broad range of specific EGIs and IMUs, plus the generic NATO Standard STANAG 4572.

These upgrade products enable SimGEN's data streaming capability to provide the raw data needed to compute the sensor outputs on an additional computer equipped with application software and specific interface cards.

SA/A-S extensions

SimGEN supports the SimCLASS™ extension (SimSAAS in the USA, developed and supplied by Spirent Federal Systems, Inc) (see references [31], [32] and [33] in section, page 43) that provides the ability to generate the Military Y-code (Anti-Spoof or A-S), on compatible hardware systems and to simulate Selective Availability (SA).

Encryption devices are required.

SimCLASS™ is available to authorised users only and is subject to Export Approvals.

GPS M-Code extensions

SimGEN supports the SimMCODE™ extension (see reference [29] in

Related military/government product specifications, page 43) that provides the ability to generate the AES-M-Code signal on compatible GPS L1/L2 platforms.

A Hardware upgrade is required.

SimMCODE™ is unclassified but its availability is controlled by Export Licence.

An extension to SimMCODE™ providing MNSA M-Code via SimMNSA™ capability is also available for authorised US customers only. Please contact Spirent Federal Systems in the USA directly for more information.

Galileo FOC extensions

SimGEN supports the encrypted SimCS™ extension for GSS9000 (see reference [34] in

Related military/government product specifications, page 43) that provides the ability to generate encrypted signals for Galileo Commercial Service and Safety of Life services which are part of Galileo Full Operational Capability (FOC)

A Hardware upgrade is required.

Galileo PRS extensions

SimGEN supports the **LZE GmbH PRS[WARE] extension** (see reference [35] in

Related military/government product specifications, page 43) that provides the ability to generate the PRS signal for Galileo on appropriate L1/E6 platforms. A Hardware upgrade is required.

SimGEN[®] Software Suite for Spirent GNSS Constellation Simulation Systems

PRS[WARE] is classified EU CONFIDENTIAL and both PRS[WARE] and SimCS™ availability is subject to export controls and only available to customers individually authorised by the Galileo System Authority.

If you require any capability which is for authorised users, we recommend you contact Spirent for specific information and advice.

Warranty and support

Spirent's simulation systems and signal generators are supplied from new with a 12-month hardware and software warranty.

To remain protected after the expiry of the warranty, Spirent recommends that all customers purchase Spirent Support Services, as described in this specification.

The Spirent Support Service is designed to make it easy to keep the GNSS test system up to date with the latest software releases, maximising the benefit derived from using a Spirent GNSS test system.

Spirent Support Service Plans

The Spirent Support Service is designed to make it easy to keep the GNSS test system up to date with the latest software, maximising the benefit derived from using a Spirent GNSS test system. The Spirent Support Service Plans are described in MS3089 (see reference [28]).

Referenced documents

The following documents are referenced in this publication:

External documents

Reference	Document no.	Title	Issue
[1]	IS-GPS-200H	Navstar GPS Navigation User Interfaces	H
[2]	IS-GPS-705D	Navstar GPS User Segment L5 Interfaces	D
[3]	RTCA-DO229D	WAAS MOPS	D
[4]	RTCA-DO246D	GBAS (LAAS) Signal in Space ICD	Partial D
[5]	GLONASS SISICD	GLONASS Interface Control Document (GICD)	V5.1(2)
[6]	NASA ref 88 FM1/JSC - 32064	Refraction Corrections for Orbiting Vehicles	
[7]	GAL-ICD-ESA-SYST-X-0027	Galileo Signal-In-Space ICD	1-20
[8]	IS-QZSS-PNT-001	Interface Specification	001
[9]	IS-QZSS-L6-001	QZSS Interface Specification Centimetre Level Augmentation Service	Draft Edition, 001
[10]	Galileo OS SIS ICD	Galileo Open Service Signal-In-Space ICD	Issue 1.10
[11]	BeiDou OS SIS ICD	Beidou Navigation Satellite System Signal-In-Space ICD Open Service	Version 2.1
[12]	BeiDou OS SIS ICD	Beidou Navigation Satellite System Signal-In-Space ICD Open Service B1C and B2A	V1.0
[13]	BeiDou OS SIS ICD	Beidou Navigation Satellite System Signal-In-Space ICD Open Service B3I	V1.0
[14]	NavIC SIS ICD	ISRO-IRNSS-ICD-SPS	V1.1
[15]	NMEA	NMEA-0183	V4.10
[16]	RINEX	Receiver Independent Exchange Format	V3.00

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Related Spirent product specifications/documents

Reference	Document no.	Title
[17]	MS9000	GSS9000 Series GNSS Multi-GNSS, multi-frequency Constellation Simulator Datasheet Specification
[18]	MS3057	GSS8000 Series GNSS Multi-Channel Constellation Simulator Datasheet Specification
[19]	MS3058	GSS8700 Advanced GPS Multi-Channel Constellation Simulator Datasheet Specification
[20]	MS3015	SimREMOTE Remote Control for Spirent GPS Simulators Datasheet Specification
[21]	MS3055	GSS7765 Interference Simulation System Datasheet Specification
[22]	MS3067	GSS6700 GNSS Multi-Channel Simulator with SimGEN Datasheet Specification
[23]	MS3023	SimAUTO Automotive Upgrade Datasheet Specification
[24]	MS7000	GSS7000 Series GNSS Constellation Simulator datasheet with product specification
[25]	MS3105	Sim3D Multipath Simulation Software datasheet with product specification
[26]	DGP00686AAA	SimGEN Software User Manual – latest issue
[27]	MS3092	SimSAFE v3 Datasheet
[28]	MS3089	Spirent Support Service for Positioning Technology Products Datasheet with Product Specification

Related military/government product specifications

Reference	Document no.	Title
[29]	MS9018	SimMCODE Upgrade for GSS9000 Product Specification
[30]	MS3025	GSS7790 Multi-Output GPS Simulator Product Specification
[31]	MS3020	SimCLASS SA/A-S Upgrade Product Specification (for non-USA only)
[32]	MS9020	SimCLASS SAAS Upgrade for GSS9000 Product Specification (for non-USA only)
[33]	SF1001	SimSAAS SA/A-S Upgrade (for USA Only)
[34]	MS9041	SimCS Galileo FOC CS and SoL option for GSS9000
[35]	MS9042	SimPRS Galileo Public Regulated Service option for GSS9000
[36]	MS3030	SimINERTIAL Packages Product Specification

SimGEN® Software Suite for Spirent GNSS Constellation Simulation Systems

For more information

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