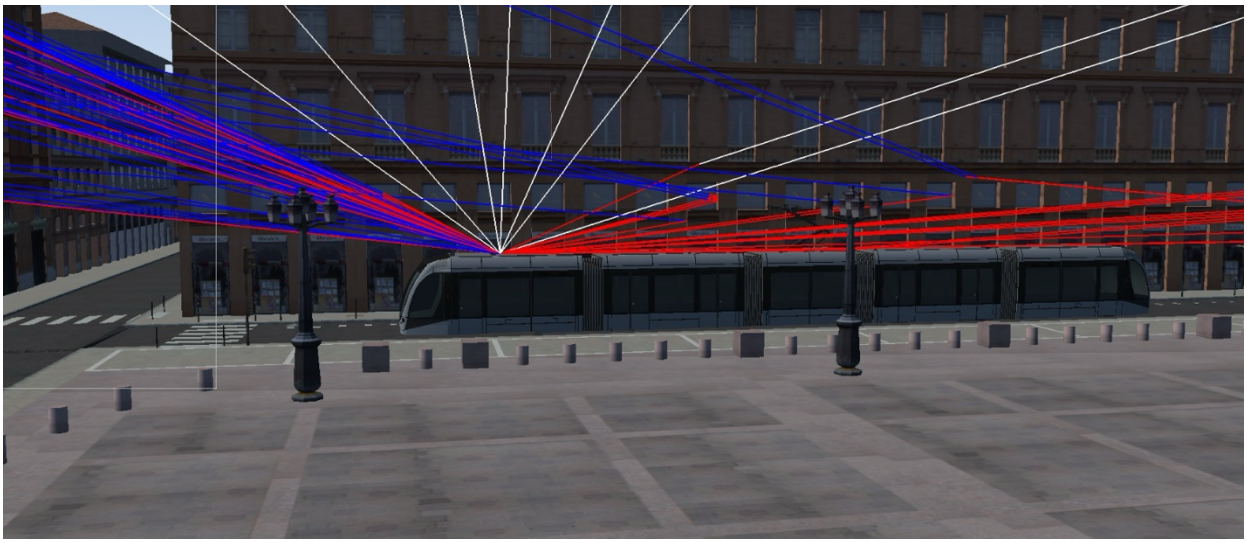
Sim3D

Realistic 3D Modeling of Multipath and Obscuration



Purpose of This Document

This datasheet describes the functionality of Keysight Sim3D, a realistic real-time multipath simulation software solution. This datasheet also provides technical product specification data and configuration information. Please speak to your Keysight sales representative to discuss your requirements.

KEYSIGHT

Table of Contents

Introduction

Keysight Sim3D is a unique approach to simulating multipath and obscuration based on a true-to-life synthetic environment. Different realistic environments can be modeled, such as urban, deep urban, dense forest, space, and highway. The interaction between the signal and the environment (e.g., buildings, cars, pedestrians, trees, solar panels) is calculated by considering shadowing and multipath effects.

Multipath can be one of the main sources of error in a global navigation satellite system (GNSS) receiver. Multipath errors can vary from a few meters to hundreds of meters due to the geometry of the satellites and environmental conditions. The characterization and study of multipath is complex, but is crucial when its effects need to be compensated in the position, navigation, or timing solution. Sim3D is an innovative real-time system that allows the reproduction of authentic multipath that strictly depends on the environment. The system combines a state-of-the-art GNSS simulator with an advanced GNSS propagation model. The propagation model relies on a 3D scene of the environment, which is used to generate the multipath and obscuration signature that strictly depends on the location of the receiver's antenna.

Features and Benefits

Keysight Sim3D provides the realism that simulation has been needing; the multipath and obscuration is simulated based on a synthetic 3D model. Real-life locations can be regenerated and used in simulation to recreate the multipath signature of that location. In addition, traffic, crowd, and other objects are used in the simulation to provide a level of realism and control not available in any other approach. The antenna's carrier can be defined as a vehicle, pedestrian, or other object; then the position of the antenna can be set relative to the carrier center of gravity (CofG). The multipath and obscuration is computed considering the antenna carrier body. This feature provides a valuable development tool, enabling users to optimize the location of the antenna for multipath/obscuration, optimize multipath mitigation algorithms, and analyze computed position based on the antenna position relative to the carrier and the mitigation methods implemented.

Sim3D provides a level of control not available in any other multipath/obscuration simulation approach. This enables the user to analyze the effect of multipath in more detail; for example, by isolating a particular satellite vehicle (SV) or a certain frequency band that may be contributing more in error than others.

Sim3D is fully customizable to your testing needs. The solution can be personalized with additional options, allowing for the creation or import of your own 3D models with the level of accuracy desired. Many generic 3D-model formats are supported using provided converters. The user can also create or import different objects to use in the 3D model.

Sim3D features and benefits include:

- Support for all constellations, frequencies, and codes currently simulated by Keysight simulators

- The signal code, carrier, and power are manipulated based on interaction with the environment
- Supports static and dynamic scenarios
- Up to 31 multipath signals per line of sight (LOS) simulated
- Up to six reflections per multipath computed
- Ability to generate your own 3D models
- Import externally generated models and objects
- Multiple 3D models are included
- Dynamic trajectory generation
- Support for scene sizes of up to and above 5 km^2 for highway scenes
- Scene-less approach using the mono-object mode for high dynamics vehicles (e.g., LEO satellites)
- An unprecedented level of control
  - Constellation and frequencies to be used
  - Obscuration mode on/off
  - Multipath on/off
  - Number of reflections per multipath signal
- User-defined filtering algorithms to simulate only multipath in chosen delay/power ranges
- Visualize the multipath direction of arrival
- Building and object materials are modeled and taken into account during computation
- Support for hardware-in-the-loop (HiL) setups
- Ability to add new capabilities as options

Sim3D Base Overview

Software Package Explained

The Sim3D Base software package includes SE-NAV, SE-AGETIM-LIGHT, and SE-FFT.

SE-NAV

SE-NAV is a deterministic simulator dedicated to the assessment of GNSS signals reception in constrained environments. It assesses the performance (i.e., availability and reliability) of space and/or terrestrial GNSS systems in 3D virtual scenes representative of real areas. SE-NAV uses deterministic ray tracing to compute the obscuration effects and the multipath (reflections, diffractions, transmissions) generated by the objects in the environment. SE-NAV uses geometrical optics (for reflections and transmissions) and Uniform Theory of Diffraction (for diffractions) to model the interaction of buildings on the propagation of the GNSS signal.

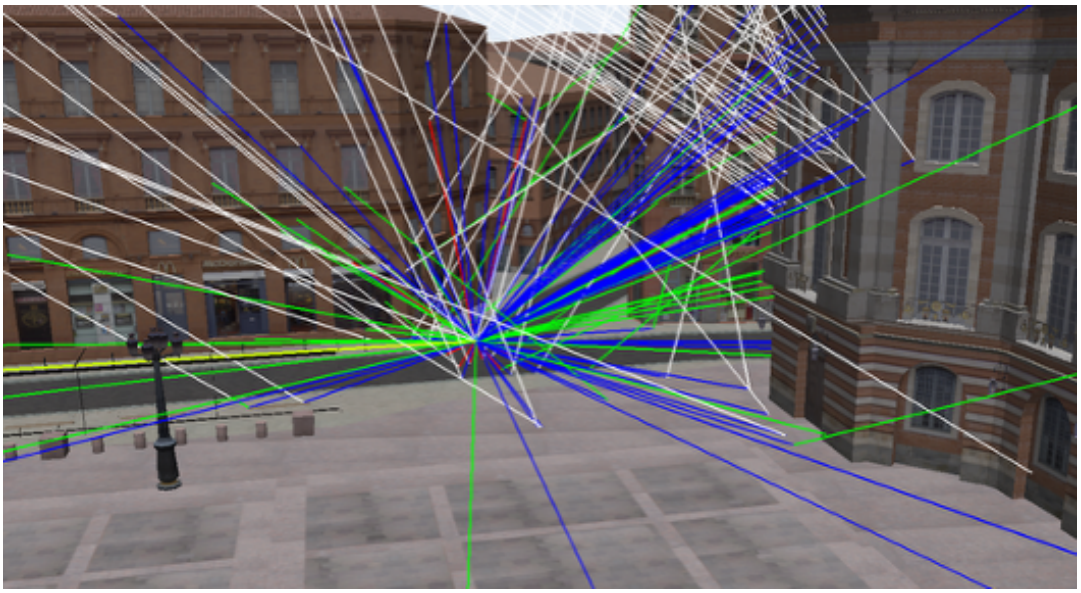


Figure 1. GPS reception in Toulouse (Place du Capitole); white rays model the incoming signal from the satellites (LOS). Blue (diffraction), red (reflections), and green (transmissions)

SE-NAV embeds a proprietary GPU core, providing the relevant outputs in record times. The principle is to use GPU resources instead of the CPU to perform ray tracing to decrease the simulation time significantly. SE-NAV includes a high-performance render engine that displays a 3D scene as well as 3D information such as the hiding mask, the multipath reaching the receiver, or the coverage within a given area. The electromagnetic parameters of each object of a scene are easily configurable by the user thanks to an intuitive interface.

SE-NAV produces numerous data stored in ASCII files (SCILABTM/MATLAB format). SE-NAV computes the complete link budget of each transmission channel. The received powers of every multipath — as well as the composite powers of every channel — are provided. SE-NAV also computes geometrical output such as visibilities (LOS, NLOS, deep NLOS), dilutions of precision (HDOP, VDOP, TDOP, PDOP, and GDOP) or Doppler shifts.

Additional features are available as options to complete and personalize user testing and simulation needs.

SE-AGETIM-LIGHT

SE-AGETIM-LIGHT is an easy-to-use terrain generation tool. It allows users to generate a virtual 3D scene, ready for simulation with Sim3D. Existing data (planimetry, altimetry, photography) can be imported and modified. The data is automatically treated (corrected, simplified, kept, or ignored in the generation process), and the result is a virtual mockup ready to be imported by SE-NAV.

SE-AGETIM-LIGHT features included are:

- Source data acquisition via the internet
- Terrain generation (minimizing GIS operation)
- Priority to the realism and aesthetics of the generated 3D model
- Robustness regarding the quality of source data

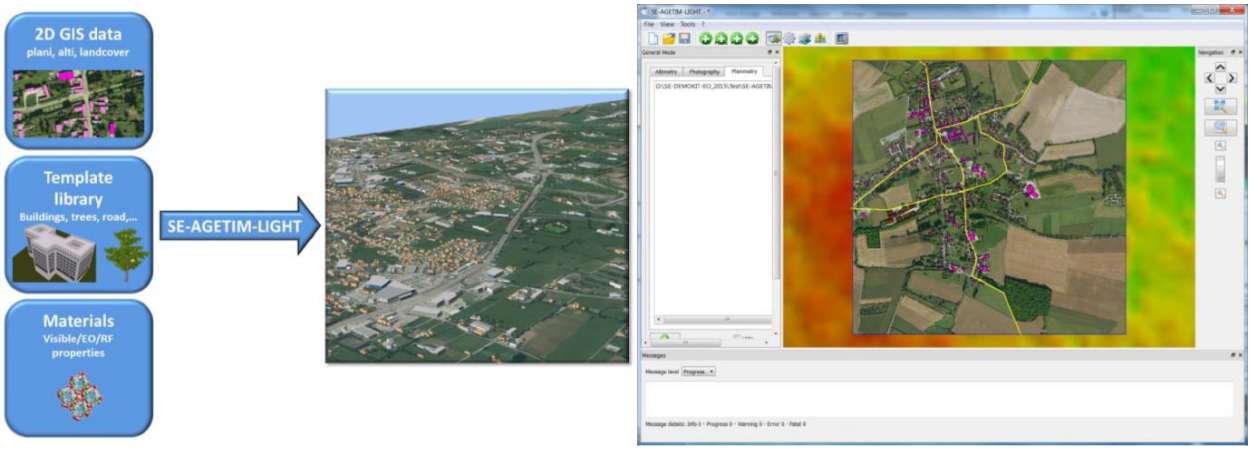


Figure 2. SE-AGETIM-LIGHT terrain generation tool

SE-FFT and Plugins

SE-FFT is used to convert an existing 3D model into Sim3D format. SE-FFT consists of a set of bi-directional conversion tools used for the import/export from/to SDM format (standard Sim3D format) from/to other standards formats, i.e., Open FLT, DXF, and VRML. The software is delivered

with plugins to 3DSMax and SketchUp that enable the import/export and modification of many 3D formats for objects geometry and meshing.

Our plugins can convert many formats such as:

- COLLADA, SKP, KMZ, DEM, OBJ
- VRML, STL, VIZ, 3DX, 3DS, FTL, IGES

Note: Additional formats can be converted; please contact your Keysight representative for further information.

Sim3D Options

Additional features can be added to the Sim3D Base Package to adapt the product capabilities to the user's testing needs.

Traffic of Vehicles and Pedestrians Option

This option enables realistic simulation and testing in crowded environments taking into account vehicle and/or pedestrian flows.

Vegetation Option

This option enables realistic simulation of environments such as forests or orchards

Ground Transmitters Option

This option enables the use of ground-based transmitters as RF sources in the simulated scenarios.

Mono-Object Mode Option

This option enables an additional mode of operation for Sim3D in which a scene is not needed due to the high-dynamics nature of the scenario — where the multipath and obscuration is only caused by the vehicles present in the scene, such as the solar panels of a LEO satellite.

Over-The-Air Option

This option enables Sim3D to work on an over-the-air setup, such as an anechoic chamber.

How Sim3D Works

Sim3D consists of:

- **PosApp**, which simulates the GNSS constellation, antenna/vehicle dynamics, and location
- **SE-NAV**, which models GNSS signal propagation, i.e., obscuration, multipath reflection, transmission and diffraction

- A **TCP/UDP interface**, based on the Keysight SimREMOTE protocol, which enables PosApp and SE-NAV to communicate in real time

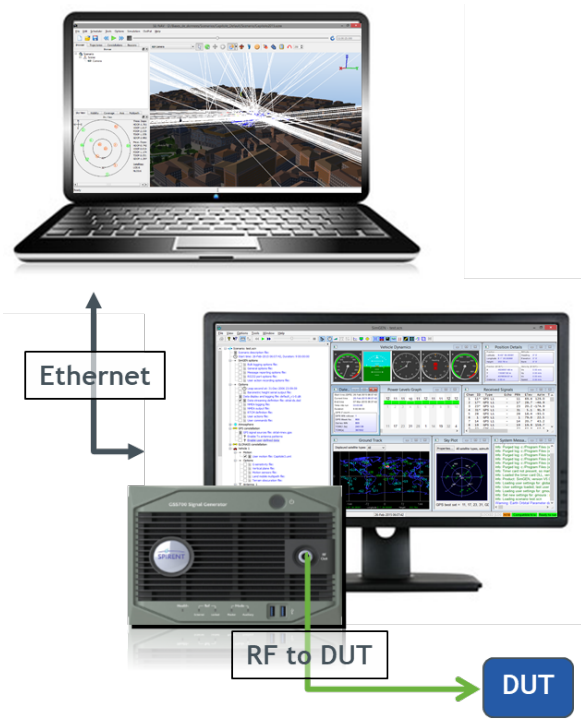


Figure 3. Sim3D connection diagram

Sim3D supports up to 100 Hz multipath update rate. This means that at each epoch, e.g., 10 ms, the following takes place:

1. PosApp sends in real time to SE-NAV:

- Satellite and signal information
- Vehicle/antenna location
- Vehicle/antenna attitude

2. SE-NAV computes in real time based on the local environment:

- Signal Power (LOS/NLOS)
- Code offset (NLOS)
- Carrier offset (NLOS)
- Azimuth and Elevation (NLOS)

3. PosApp enables multipath channels and updates the RF output to the DUT according to the provided data from SE-NAV.

PosApp supports up to 2 kHz simulation iteration rate when running Sim3D, using interpolation techniques to update the HW between each of the multipath update samples.

Motion Simulation

Sim3D is capable of simulating scenarios with motion. The trajectory and attitude of the vehicle are defined and controlled in PosApp as per the standard PosApp tools. Sim3D offers the opportunity to create a trajectory within the 3D model and then convert it to a UMT format ready to be used in PosApp. In addition to defined trajectory, Sim3D is fully compatible with low latency HiL setup where remote motion is injected to PosApp.

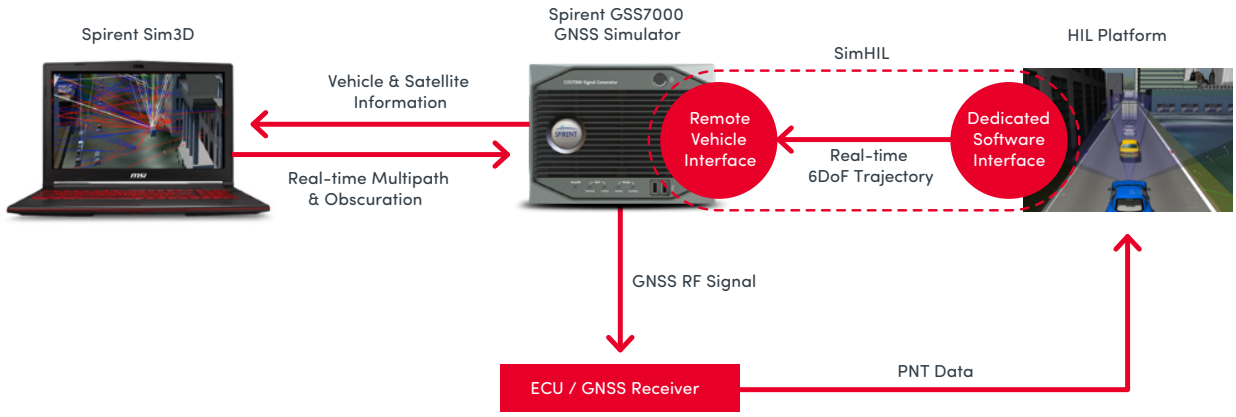


Figure 4. Sim3D and SimHIL integration

Full Level of Control

All available simulation parameters that currently exist in PosApp are available for Sim3D. This includes:

- Start time and date
- Definition of the appropriate GNSS Constellation(s)
- Ionospheric parameters
- Vehicle performance envelope — Personality
- Antenna orientation and polarization
- 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)
- And much more

Other multipath-specific control available in Sim3D:

- Ability to enable reflections only, diffractions only, or both
- Ability to enable transmission
- Obscuration mode (switch multipath off)
- Ability to control the maximum reflections calculated per ray
- Ability to choose the multipath to be simulated in a certain range of delay/power
- Ability to filter out even reflections
- Ability to create heatmaps for visibility, DOPs

Multipath Filtering

Sim3D's ray tracing algorithm computes every ray (multipath) for each SV in view. The multipath filtering algorithm enables the user to control the maximum number of multipaths simulated by PosApp, as well as giving the user control over which to send to PosApp from the vast number of multipath rays calculated by Sim3D.

In addition, the multipath filtering algorithm can be a very useful tool for understanding DUT behavior based on different sets of multipath characteristics. The filtering algorithm gives users the opportunity to define one or multiple ranges of power (dBm) and delay (m) to be simulated in PosApp.

Number of Multipath for Each LOS

Due to the physical limitation in the number of hardware channels available for the simulator, the number of multipaths that can be simulated per SV in view can also be restricted. In most cases, it has been observed that four multipaths per SV in view are needed to ensure that realistic behavior is simulated. However, the number of multipaths required should be determined according to the application under analysis.

The number of multipath per SV available for the user relies on multiple factors:

- Maximum number of channels enabled per constellation ($chan_{per\_const}$)
- Max SV in view per constellation in the simulation (SV_{in_view})

Maximum desired multipath per SV in view (MP_{per_LOS}) can be computed as below:

$$MP_{per\_LOS} = \frac{Chan_{per\_const} - SV_{in\_view}}{}$$

Table 1. Example of Number of Multipath per SV

Max LOS per constellation	Max Multipath per LOS
4	15
6	10
8	7
10	5
12	4
16	3

Note: The example in Table 1 assumes 64 channels per constellation are available.

3D Models (Synthetic Environment)

Sim3D uses synthetic environments to carry out a simulation. A synthetic environment is a virtual representation of a real environment. It mimics the geometries (terrains, buildings, vehicles, etc.) as well as the physics (material, atmosphere, etc.).

Synthetic environments are defined into three categories:

Fictional: 3D scenes which do not model any real or realistic environment. Can be employed to study impact of geometric/physical differences on GNSS. For example, modification of roof shape (realistic roof vs. flat roof vs. no roof, etc.) to assess the variation in multipath impact and visibility of satellites.

Geo-typical: 3D scenes that model a realistic environment, e.g., a typical scene such as a dense city or a mountainous area. Based on real parameters such as real building heights and areas; however, some elements such as doors and windows are randomly defined. Templates of buildings are used to characterize the shapes of the buildings to be created. Mainly used to assess the performance of GNSS systems in typical environments and used for statistical studies.

Geo-specific: 3D scenes which model a real environment. Accurate in terms of geometry and physics. Used to either reproduce a real reception signature (e.g., for mission debriefing), or to forecast reception (e.g., for mission planning). The quality of the 3D data has a strong impact on the simulation performance. Correct geometries of buildings and obstacles (such as streetlights, road signs, vehicles, etc.) impact the correlation to real life measurements — but can also cause higher GPU load.

The Sim3D software package includes all the necessary tools and instructions to create a 3D model with the desired accuracy level. Easy to use converters and plugins are also provided as standard for the user to import their own 3D models/terrains, e.g., DTED, DEM, Google, and other formats.

Note: Additional scenarios can be obtained; please contact your Keysight representative.

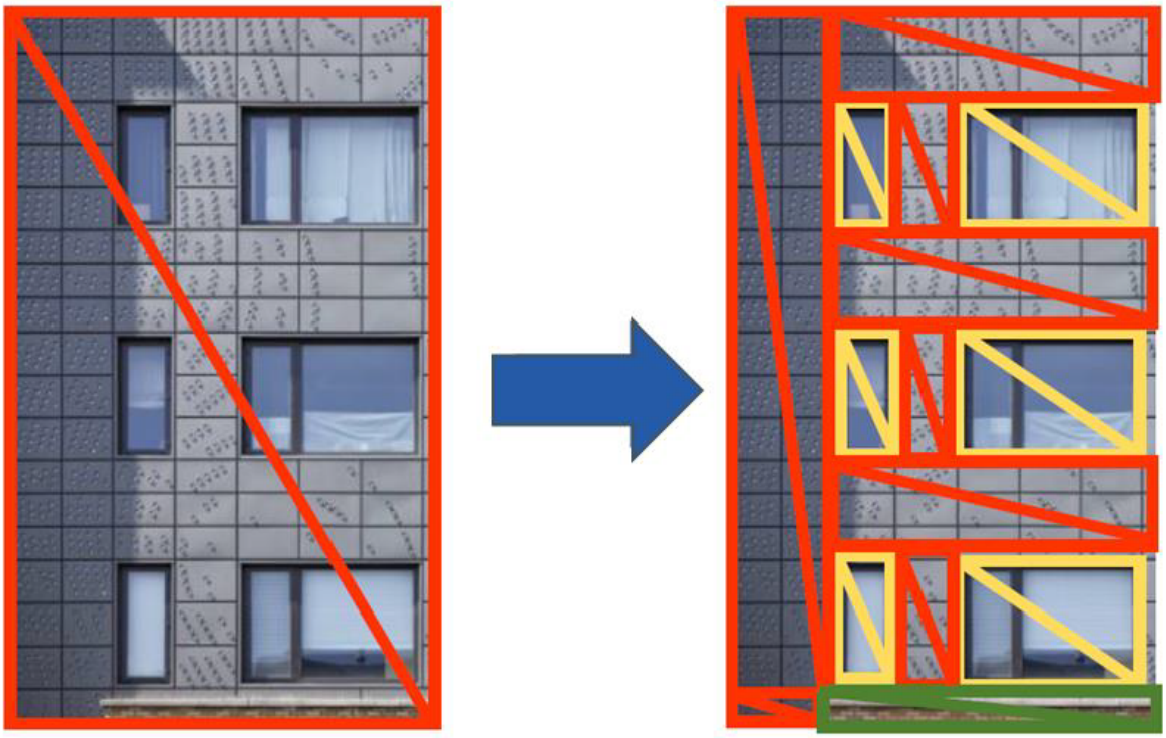


Figure 5. Geo-typical vs. geo-specific 3D models; detail level

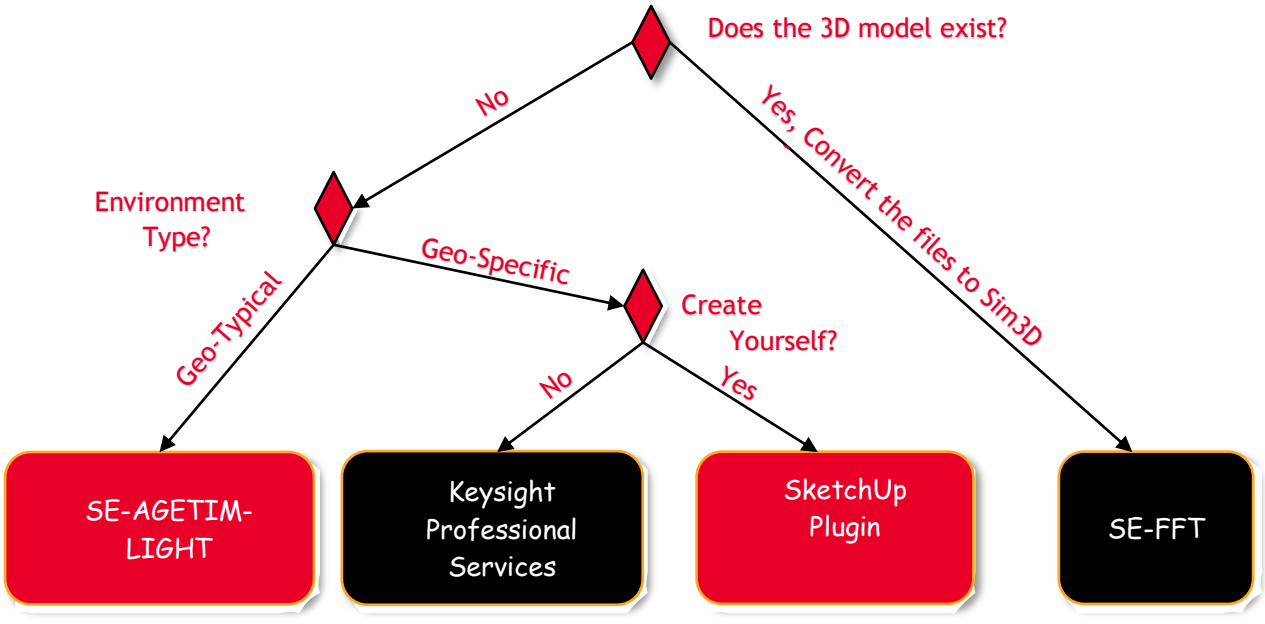


Figure 6. 3D models; creation options

Sim3D GEO-TYPICAL

Sim3D GEO-TYPICAL enables the user to simulate multipath and obscuration effects in pre-canned geo-typical 3D models available with the SW package. The pre-canned 3D models cover most common test needs in different environments, e.g., Urban, Peri Urban, etc. The user can define their static DUT location anywhere in the 3D model or define a motion trajectory within the 3D model. This entry-level offering of Sim3D offers the ability to simulate multipath and obscuration effect at a level above and beyond what PosApp internal models offer.

- Delivered with 5 x Geo-Typical 3D models
- Geo-localization of the 3D model anywhere, e.g., Modify the Lat/Lon/Height
- Allow the user to create trajectory and convert it to UMT
- Allow the user to convert coordinates from SE-NAV to PosApp format
- Allow the user to define the number of reflections/transmission and diffraction
- Allow the user to set the maximum number of multipaths per LOS and take advantage of all the user-defined filtering algorithms available.
- Allow moving vehicles as an antenna's carrier
- Allow pedestrian as an antenna's carrier
- Allow the user to choose from a set of vehicles models
- Allow the user to choose from a set of pedestrian models/dynamics
- Allow the user to set the DUT position relative to the carrier
- Allow visualization of multipath in SE-NAV GUI

The following features are **not possible** in Sim3D GEO-TYPICAL:

- Load any custom 3D models supported by Sim3D
- Load any custom 3D objects supported by Sim3D
- Use of traffic and crowd models
- Simulate in vegetation environment
- Simulate traffic of vehicles or crowds
- Logging of SE-NAV commands
- SE-NAV Standalone capabilities, e.g., Heatmaps
- SE-NAV remote interface
- Antenna management in SE-NAV
- Carry changes to the physical materials of the buildings
- Additional features — Options

An upgrade route is available from Sim3D GEO-TYPICAL to Sim3D Base.

Note: Additional scenarios can be obtained; please contact your Keysight representative.

Sim3D Offerings Comparison

Table 2. Sim3D Base vs Sim3D GEO-TYPICAL Comparison

Feature	Sim3D Base	Sim3D GEO-TYPICAL
Simulate multipath and obscuration effect based on 3D model	√	√
Interface with PosAPP to allow realistic RF simulation	√	√
Support for all constellations and frequencies currently supported on the Keysight simulator	√	√
Support for static and dynamic simulation	√	√
Ability to set a static location in the 3D model and convert it to PosAPP location	√	√
Ability to create a trajectory in the 3D model and convert it to a UMT file to be used by PosAPP	√	√
Ability to use a vehicle and pedestrian as receiver carrier	√	√
Ability to define and control the number of reflections, transmission, and diffraction	√	√
Ability to set the DUT position relative to the carrier	√	√
Library of 3D models available with the package	√	√
Geo-localization of the 3D model anywhere, e.g., Modify the Lat/Lon/Height	√	√
Load any 3D models supported by Sim3D	√	X
Load any 3D objects supported by Sim3D	√	X
Access to Options	√	X
Logging of SE-NAV commands	√	X
SE-NAV standalone capabilities, e.g., heatmaps	√	X
SE-NAV remote interface	√	X
Antenna management in SE-NAV, i.e., RHCP/LHCP	√	X
Carry changes to the physical materials of the buildings	√	X
Complete SW package to allow the creation of own 3D models and objects	√	X
Import user-existing 3D models and objects to Sim3D	√	X

Performance Specification

Table 3. Sim3D Performance Specifications

Parameter	Value	Note
Supported constellations and frequencies[1]	GPS L1L2L5 GLO L1L2 GAL E1E5E6 BEI B1IB2IB1cB2aB3I QZSS L1L2L5L6 SBAS L1L5	Constellations are subject to separate Keysight licenses
Supported codes	GPS L1: C/A, P, M noise, L1C Pilot, L1C Data GPS L2: P, C/A (L2C), M noise GPS L5: I, Q GALILEO E1: E1-A, E1-A PRS Noise, E1-B, E1-C GALILEO E5A E5B: E5a-I, E5a-Q E5b-I, E5b-Q GALILEO E6: E6-A, E6-A PRS Noise, E6-B, E6-C BEIDOU: B1I, B2I, Ba1, B1c, B3I	Codes may be subject to separate Keysight licenses and governmental limitations
Maximum SV per simulation	45	This is the maximum visible SVs across all constellations at any one time during the simulation
Supported simulator	PNT X GSS9000 GSS7000	GSS9000, PNT X: SimGEN SIR 100Hz: up to 320 channels with 2 x GSS9000 simulators and 1KHz for up to 160 channels with 1 x GSS9000 simulator GSS7000: up to 256 channels at SimGEN SIR of 10 Hz or 100 Hz
Supported software level	SimGEN SimREPLAYplus SimTEST	
Maximum number of vehicles in PosApp scenario	1	
Maximum number of antennas in PosApp scenario	1	
Types of vehicle supported in PosApp scenario	Static Rover Remote	
Maximum multipath per LOS	31	This is the maximum number of multipath associated with a LOS

[1] All supported constellations by PosApp are available.

Parameter	Value	Note
Maximum reflection per multipath	6[2,3]	This is the maximum number of reflection per multipath before it reaches the receiver
Maximum 3D model size allowed	5Km^2	This is the maximum allowed 3D model size loadable in Sim3D — not applicable for Mono-object Mode **Note:** A greater size scene is available for highway testing

System Iteration Rate

Table 4. Sim3D Iteration Rate

Parameter	Value	Note
Supported PosApp iteration rate (SIR)	100 ms (10 Hz) 10 ms (100 Hz) 1 ms (1 kHz)	The rate at which PosApp computes the required data and updates the hardware
Sim3D update rate	1 s (1Hz) 500 ms (2 Hz) 100 ms (10 Hz) 10 ms (100 Hz)	The rate at which Sim3D updates PosApp with the multipath parameters, i.e., MOD command update rate. PosApp uses interpolation techniques to meets its SIR rate
Sim3D maximum logging rate	100 ms (10 Hz)	The rate at which Sim3D logs incoming and outcoming data
Supported PosApp logging rate	100 ms (10 Hz) 10 ms (100 Hz) 1 ms (1 kHz) 0.5 ms (2 kHz)	The rate at which PosApp logs the data
Sim3D GUI update rate	1 s (1Hz) 500 ms (2 Hz) 100 ms (10 Hz)	The rate at which Sim3D updates its GUI with new multipath ray. **Note:** For computation demanding scenarios, 1 Hz is recommended

2 Keysight recommends a maximum of six reflections; increasing the number above this will add extra computation power on SE-NAV that might result in higher latency or missed data due to the maximum number of SVs.
3 Any reflections above six are most likely very weak in power and will have a negligible effect on the receiver.

Deliverables

Table 5. Sim3D Base Deliverables

Item No.	Quantity	Description
1	1	Keysight Sim3D Host Laptop
2	1	Keysight Sim3D Base Software Package: • SE-NAV ◦ Ability to add features as options • SE-AGETIM-LIGHT • SE-FFT (Including SketchUp/3DSmax plug) • One Geo-Specific 3D models • Five Geo-Typical 3D models • Additional options
3	1	Ethernet Kit

Table 6. Sim3D GEO-TYPICAL Deliverables

Item No.	Quantity	Description
1	1	Keysight Sim3D Host Laptop
2	1	Keysight Sim3D GEOTYPICAL Software Package: • SE-NAV • Five Geo-Typical 3D models
3	1	Ethernet Kit

Please contact a Keysight sales representative to discuss the purchase of additional channels, capabilities, constellations, or scenarios.

Glossary of Terms

Az	Azimuth
COTS	Commercial Off The Shelf
DoA	Direction of Arrival
DUT	Device Under Test
El	Elevation
GNSS	Global Navigation Satellite System
GPS	Global Positioning System US GNSS system
GUI	Graphical User Interface
HiL	Hardware-In-the-Loop
LOS	Line of Sight
MP	Multipath
NLOS	None Line of Sight
OS	Operating System
OTA	Over the Air
R&D	Research and Development
SDM	Signed Differential Mapping
SIR	Simulation Iteration Rate
SV	Satellite Vehicle
CofG	Center of Gravity