SimSENSOR

GNSS and Inertial Sensor Fusion Testing

SimSENSOR Overview

Keysight's PNT simulators produce a comprehensive range of emulated multi-GNSS, multi-frequency RF signals with class-leading flexibility, coherence, fidelity, performance, accuracy, and reliability. SimSENSOR is a software add-on that extends the capabilities of the PNT X, GSS7000, and GSS9000 simulators to develop and test GNSS and inertial sensor fusion or positioning engines.

SimSENSOR simulates the output of the key sensors commonly included in consumer location-aware devices, such as the inertial sensors typically found on an Inertial Measurement Unit (IMU):

- Accelerometers
- Gyroscope
- Magnetometer
- Digital compass
- Barometric height sensor

The simulated sensor outputs include user control of representative noise and errors (bias/drift).

SimSENSOR typical use cases include:

- Sensor fusion algorithm design and debugging (post-processing)
- Testing loosely/tightly coupled GNSS/IMU during outages
- Testing reacquisition capability with tightly coupled after outages
- Testing the accuracy of the system during the above

SimSENSOR reduces inertial field test time and the chances of errors when integrating GNSS with inertial.

SimSENSOR Setup

SimSENSOR runs in SimGEN or SimREPLAY+ on the host controller or embedded controller of a Keysight GNSS simulator (PNT X, GSS7000, or GSS9000). The solution uses the scenario reference trajectory and parameters (truth data) to generate two streams of data for a Unit Under Test (UUT):

- The GNSS RF
- The simulated sensor data

SimSENSOR accesses truth data relating to the simulated motion and orientation of the vehicle from SimGEN or SimREPLAY+. SimSENSOR is able to derive from the truth data the appropriate accumulated values for the simulated inertial sensor output data. A complete error model implemented as a DLL allows for representative sensor output.

All sensor data generated are fully synchronous and coherent with the GPS signaling provided by the GNSS simulator.

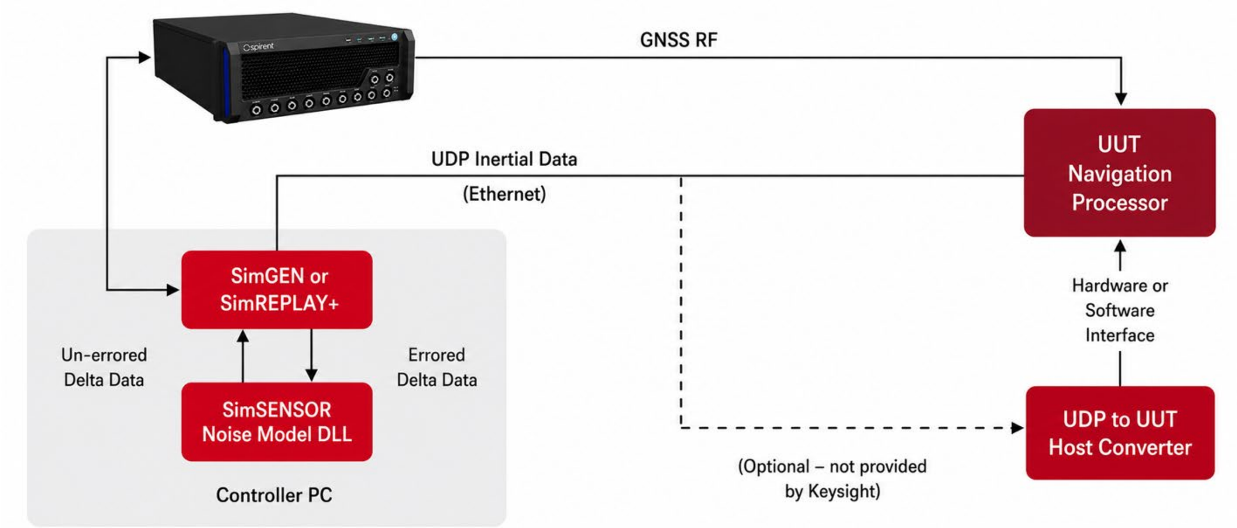

Figure 1. SimSENSOR architecture

The UUT is typically sensor fusion engine software that can be embedded in hardware (e.g. with a GNSS receiver) or standalone software. The simulated sensor data can be delivered to the UUT in two different ways:

- As a UDP/IP stream (Ethernet). SimSENSOR outputs the simulated sensor data as a UDP/IP stream. (The UDP packet structure is fully documented in the SimSENSOR user documentation.) Real-time injection of the inertial data to the UUT can require a tailored hardware or software interface. Since this interface is specific to the UUT model used, it is the customer's responsibility to implement the interface based on the documented UDP packet structure provided.
- As a file. In this case, the UDP/IP packets are logged to a file (.csv) that is locally generated on the simulator. The structure of the file follows the UDP packet structure and is also documented. The file can then be used as an input to the UUT for post-processing purposes.

Figure 2 shows a typical setup for testing sensor fusion software. The software unit under test could be a Kalman filter of a loosely or tightly coupled INS and GNSS system.

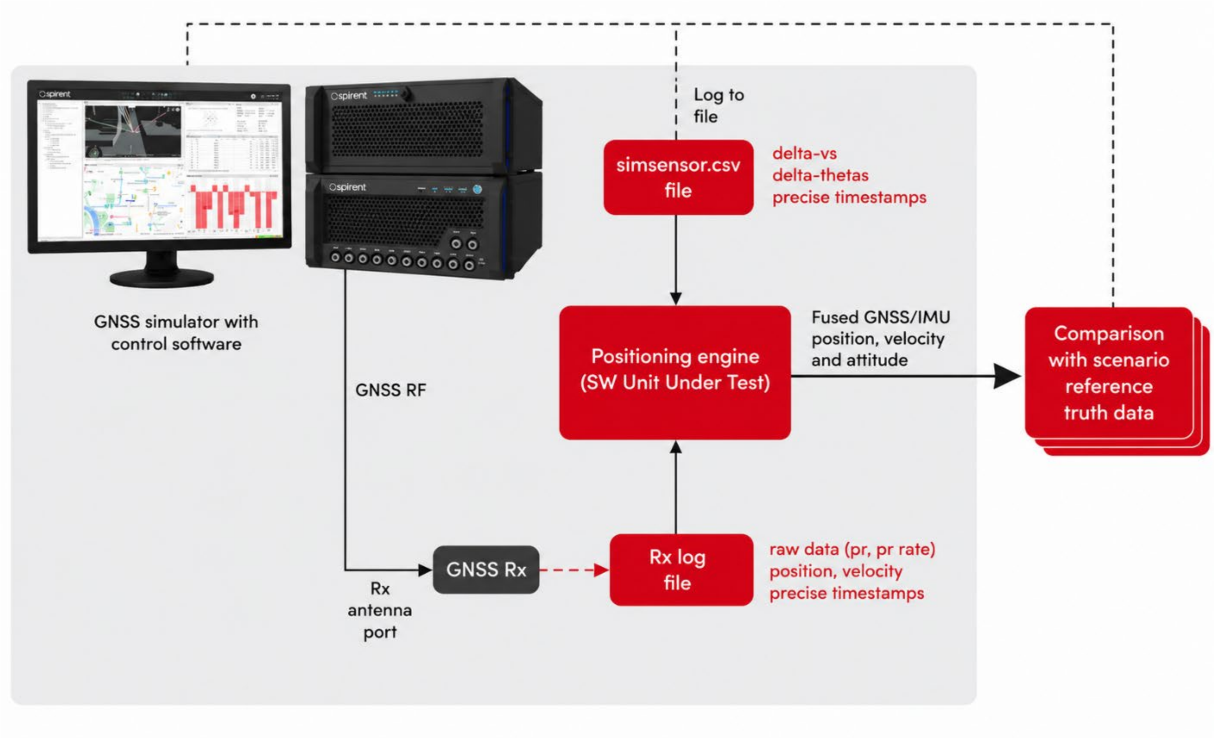

Figure 2. SimSENSOR typical setup (post-processing)

Timing Consideration

The simulated sensor data is made available at user-definable rates anywhere from 10 Hz to 10 kHz. These data packets are outputted over UDP/IP at the Simulation Iteration Rate (SIR). The range of available SIR varies depending on the GNSS simulator used. If the SIR is lower than the sensor update rate, then more than one packet of data will be transmitted at the SIR epoch. The UDP data frames are time stamped with the simulation time into run and the precise time of validity of the data.

For example, if the SIR is 100 Hz, and the sensor update rate is 500 Hz, then five packets of UDP/IP data will be transmitted every 10 ms. The separate packets of data will be time stamped with their precise time of validity/applicability. The UDP/IP packets will be transmitted at least one SIR epoch in advance so the receiver of the data has time to process it.

Multiple Inertial Interface Configurations

SimGEN and SimREPLAY+ support multiple devices under test. Each device under test can be provided with up to four SimSENSOR streams. Each stream supports all the sensor outputs and errors/noise models. With multiple SimSENSOR outputs, it is possible to test multiple "what-if" scenarios concurrently.

SimSENSOR can be run independently of RF output. This means that even in no-hardware mode, SimGEN or SimREPLAY+ can still produce sensor outputs.

For customers with access to test systems employing one or more signal generators, it is possible for each signal generator antenna output to operate with a different instance of SimSENSOR.

Please contact your Keysight sales representative for further information.

SimSENSOR Outputs

Inertial Sensor Data Sources

SimSENSOR accesses truth data relating to the simulated motion and orientation of the vehicle from SimGEN or SimREPLAY+. SimSENSOR is able to derive from the truth data the appropriate accumulated values for the simulated inertial sensor output data. The inertial sensors are typically accelerometers and gyros.

All data generated are fully synchronous and coherent with the GNSS signal provided by the GNSS simulator.

Delta-V

Accelerometers detect changes in vehicle velocity in three orthogonal physical axes. These axes can be aligned with the natural body frame of the host vehicle. Where they are not aligned, their contributions can be translated into the body frame.

In the test environment, simulated vehicle motion is usually referred to the body frame, and SimSENSOR makes the translation to the sensor frame.

This is normally referred to as the 'delta-v' or δv data.

Delta-Theta

Gyroscopes or gyros detect changes in the orientation or attitude of a moving vehicle. As with acceleration sensors, gyros are usually organized around three orthogonal axes, and translation to body axes may again be performed through SimSENSOR.

This is normally referred to as the 'delta-theta' or $\delta\theta$ data.

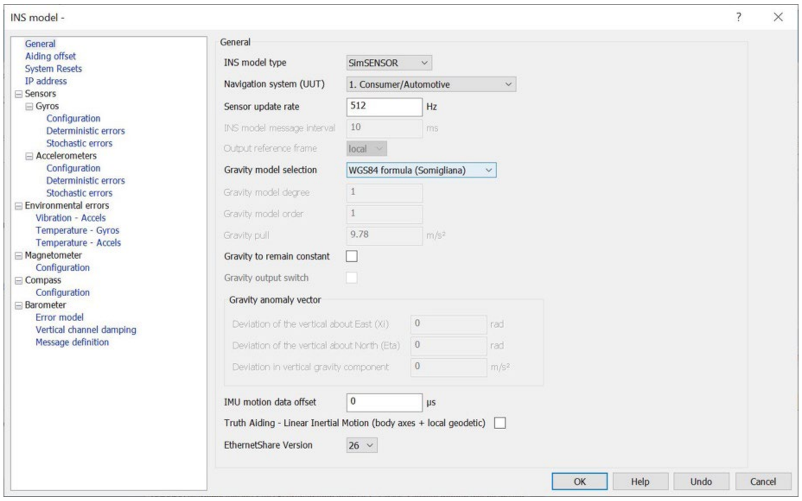

Figure 3. SimSENSOR interface

Magnetometer

A magnetometer model provides magnetic flux density measurement output along three mutually perpendicular axes. Magnetometer readings are output within the UDP frame as measured magnetic flux density resolved in the body-frame axes. Bias, scale-factors, sensor noise, and quantization levels make up the error model for the magnetometers in SimSENSOR.

Compass

A three-axis or two-axis compass model outputs magnetic heading, true heading, measured bank, and elevation. Inputs to this model are the outputs of the magnetometer; as such the same error types can be applied.

The three-axis compass determines magnetic and true heading from the magnetic flux density and specific force along three mutually-perpendicular axes. This model assumes the instruments are either stationary or moving at constant velocity. If the device under test is subject to acceleration, the model produces erroneous results.

The two-axis compass determines magnetic and true heading from two perpendicular magnetic flux density measurements in the horizontal plane. The magnetic compass must be kept horizontal and has no restrictions on acceleration.

Barometer

A barometric altimeter model outputs the barometric height. The model can be set to induce ramp or sinusoidal errors, as well as first-order random noise.

Error Modeling

Inertial Sensor Error Model

Physical sensors such as accelerometers and gyroscopes suffer from a complex range of imperfections that yield errors in the measurements made. In order for a test system to reproduce operationally representative sensor outputs, it is necessary to apply an error model to the nominal δv and $\delta\theta$ data produced by the base simulation.

SimSENSOR uses a generic error model – the Allan variance noise model.

The "strap down" model includes a quaternion co-ordinate transformation from the body frame to the sensor frame, and the user may specify the coefficients of this model that cover scaling factors, biases, misalignments, lags, and stochastic error terms.

Pre-populated error models are available for Consumer/Automotive, Industrial, Tactical, and Navigation performance grades of IMUs.

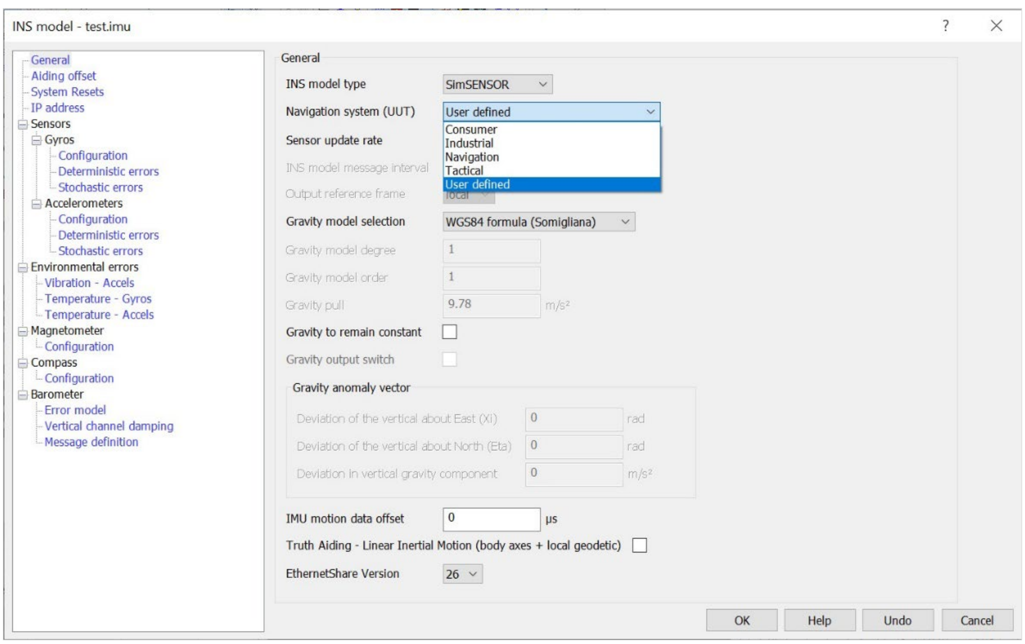

Figure 4. SimSENSOR error model

Temperature and Vibration Models

The effects of environmental errors such as temperature and vibration on inertial sensors are applied via embedded temperature and vibration error models.

Vibration-induced errors affecting accelerometers are simulated via a vibration model based on MIL-STD-810-H. The model includes the pre-defined vibration profiles defined in the standard (e.g. aircraft, helicopter, shipboard), as well as user-defined ASD vs. frequency vibration profiles. Multiple vibration profiles can be applied at different times in a given scenario.

The temperature model is based on two industry-recognized research papers and simulates the effects of temperature on Micro Electro-Mechanical Systems (MEMS)-based accelerometers and gyroscopes. The user can define the scenario temperature profile and set the values of critical temperature parameters.

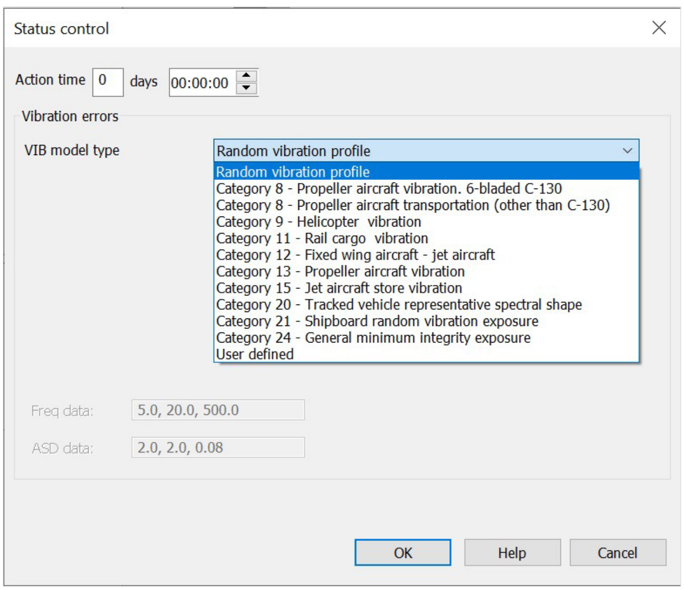

Figure 5. Vibration error model

GNSS-to-Inertial Bias

SimSENSOR is able to adjust the relative timing between the generation of the GNSS signals and the simulated inertial sensor data to ensure that these are coherently presented to the embedded navigation algorithms and hardware being tested.

Related Product Publications

Related Product	Description	Datasheet / Specification
PNT X	PNT X Datasheet	MS10000
GSS9000	GSS9000 GNSS Simulator Series Datasheet	MS9000
GSS7000	GSS7000 GNSS Simulator Series Datasheet	MS7000
SimGEN	GNSS Application Software Suite	MS3008