APPLICATION NOTE

Testing GNSS Automotive and Telematic applications

For System Integrity

SPIRENT®

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Contents

Audience

This Application Note is for designers, developers, integrators and testers of GNSS receivers or systems, who need to ensure their products will perform in the automotive environment.

Spirent recommends you have a basic understanding of satellite navigation principles and awareness of RF simulation as a test method is desirable.

Introduction

There is a steady growth in the use of GNSS navigation systems in all areas of the automotive marketplace. A variety of GNSS receivers, commonly referred to as 'Sat Nav' systems, are now found in vehicles used for private and recreational purposes, as well as commercial and public transport. In some cases, these systems rely solely on standalone GNSS operation, in other cases they are coupled with an Inertial Navigation System (INS).

The increasing use of GNSS brings an increasing reliance on the technology. Individuals, businesses and organisations are all relying on the technology for anything from personal pleasure and safety to commercial advantage.

With this in mind, it is important for designers, manufacturers and consumers of these products to understand what to expect from GNSS systems, which requires an understanding of the limitations and problems of what can often be a fragile, prone to error, and easily disabled technology.

This application note discusses some of the main sources of error both specific to the automotive environment, and more generally applicable to GNSS systems. Complementary to this, it demonstrates how Spirent's range of GNSS Test Solutions enable the simulation of these conditions in a controlled and repeatable way, allowing a GNSS receiver and/or GPS + INS system to be properly tested for use in automotive applications.

The Automotive GNSS Environment

A GNSS receiver works best when it has a clear, un-interrupted view of the orbiting satellites transmitting the ranging and navigation signals. In the automotive environment this is often not the case and ranging measurements to the satellites are affected. As ‘radio ranging’ is the basis of satellite navigation, any degradation of the ranging measurement will cause degradation in the Position, Velocity, Time (PVT) solution calculated by the receiver.

Various environmental factors contribute to a receiver not being able to receive the necessary signals, generally referred to as obscuration.

The main causes are as below:

External obscuration can be defined as everything outside the confines of the host vehicle that blocks the LOS signal, preventing it reaching the receiver’s antenna. The automotive environment presents obscuration in a number of ways. Some are described as follows:

Roadside buildings

- Any structure that is adjacent to the roadway that stands in the way of the receiver’s direct view of the satellites.

Bridges

- Obstruction of the sky occurs progressively as a vehicle passes under a bridge. The duration of the signal blockage depends on the physical characteristics of the bridge combined with the speed of the vehicle.

Tunnels

- We can consider tunnels as an extension of a bridge. However, complete obscuration occurs for a period of time, and changes in vehicle direction can also occur while the vehicle is in a curved tunnel.

Underground and multi-storey car parks

- Affect a receiver in a similar way to tunnels. Disorientation is often a primary concern, particularly upon exit from the car park, when a quick navigational decision is required.

Cuttings

- Many roads are placed in cuttings, which reduce the visibility of low elevation satellites.

Natural terrain (hills, mountains, valleys, trees and vegetation)

- As with the above effects, obscuration is determined by the characteristics of the terrain. Hills, mountains and valleys block signals as a function of their height or depth. Trees and vegetation attenuate and block signals according to the type, density and water content of the foliage and structure of the trunk/branches.

Adjacent and passing vehicles

- Very dependant on the relative speed of the vehicles. The obscuration may be momentary, or last longer (for example a high-sided vehicle passing at a speed that is only slightly faster than the receiver’s host vehicle)

Highway equipment (street lighting, signs, gantries)

- Issues with periodic signal obscuration, causing complex signal disturbance effects.

GNSS system errors

Apart from the effects of the local automotive environment errors also exist due to the GNSS system, (satellite constellation and control/monitoring systems).

These are beyond the focus of this application note, which concentrates the automotive environment. However, they should not be ignored. For more information on GNSS system errors, and how to simulate them, download the E-Book "Common GNSS Errors".

Receiver errors

Another source of errors can be attributed to the receiver itself.

Modern receivers have multiple digital receiver channels, and with silicon chip integration densities increasing, more parallel processing is possible, leading to shorter time to first fix performance.

However, with increased processing comes increased noise, New designs are still susceptible to classical error sources such as LNA noise, PLL/FLL thermal noise, oscillator phase noise and ADC aliasing.

Reference 11 states that an average modern receiver should contribute less than 0.5 m rms error in bias and less than 0.2 m in noise.

Integrated GNSS + INS navigation systems

The use of GNSS + INS in automotive navigation systems is increasing, largely due to operational performance issues caused by some of the errors described above. These errors cannot be completely eliminated, even with an optimised standalone GNSS receiver. In many systems, primary navigation is based on signals from existing on-vehicle sensors (odometers, ABS wheel sensors, gyro's and so on) with GNSS position, velocity and time information providing a reference or 'calibration factor' that regularly corrects the diverging errors inherent in the INS system.

A classic automotive environment problem is that of a curved road tunnel. GNSS receivers can become confused when they emerge from a tunnel heading in a different direction to that travelled upon entering the tunnel. With an INS coupled into the navigation system, information from the wheel sensors or gyroscope, corrects the heading change in the absence of the GNSS information. Navigation throughout the tunnel and beyond is maintained, without having to rely solely on the GNSS system which could be trying to correct itself from the confused state just described. This advantage is also true in other environments, for example underground car parks.

INS errors

Although a combined GNSS + INS navigation system solves many of the problems that inhibit standalone GNSS, they are still subject to errors that can corrupt the navigation solution.

This is particularly true in commercial automotive applications, which use cheaper, less accurate devices instead of the expensive, high accuracy sensors used in the aviation sector. In some cases, wheel sensors are the sole method of calculating vehicle heading rate, as 3-D gyros are prohibitively expensive. See Reference 10.

Common examples of errors include:

- **Wheel slips** – pulses from wheel sensors are sent to the navigation system at a particular rate-per-revolution. If a wheel looses contact with the road and spins, the rate of pulses increases, and is no longer matched to the physical distance travelled. Introducing an error.
- **Skidding** – When a skid occurs, the wheel slows down, or stops completely, leading to reduced or no pulses.
- **Dead-band error** – Active wheel speed sensors employ Hall-effect transducers, That have a minimum speed below which no motion is detected - the so-called 'dead-band' (in the order of 3 to 5 kph), The dead band can present real problems in urban areas, where the vehicle is progressing very slowly in traffic congestion and the navigation system's 'dead reckoning' algorithms are not able to cope with the condition.
- **Stuck gyroscope** – Gyros are mechanical devices and prone to failure or imperfections. Gyro-compasses output the difference between the fixed gyro heading and the physical vehicle direction, if however the gyro becomes stuck (due to a failure of the gimbal for example) the signals fed to the navigation system will be in error.

Simulating the Automotive GNSS Environment

In this section we look at how a GNSS RF Constellation Satellite Simulator enables the simulation of the conditions we have discussed in a controlled and repeatable way. This allows testing of a GNSS receiver and/or GNSS + INS system for use in automotive applications.

An RF Constellation Simulator reproduces the environment of a GNSS receiver on a dynamic platform by modelling the vehicle and satellite motion, signal characteristics, atmospheric and other effects causing the receiver to actually navigate according to the parameters of the test scenario.

If we consider the errors highlighted in the previous section, there is no need to simulate receiver errors as the receiver is included in the test and will contribute its own real errors. In all cases, we consider simulation of a Land Vehicle with one GPS antenna receiving GPS L1 C/A code signals using Spirent's GSS6700 Multi-GNSS Constellation Simulator System 12-channel L1 CA-code GPS/SBAS simulator with SimGEN™ software.

For more information on SimGEN™ software, see references 1 and 2, for the GSS6700 see reference 3.

Reproducing the effects

By its very nature, simulation is a representation of the real world. Simulation cannot reproduce the full richness of real world conditions.

A common misconception is the need to exactly replicate real world conditions for a GNSS test to be valid. However, application of representative effects via simulation is proven (over some 25 years of testing) to exercise receivers and adequately identify their limitations allowing for design centring and optimisation. More importantly, it gives complete repeatability, control and exact knowledge – down to bit level – of the signal stimulating the receiver. This is not possible in the real world. With this in mind, we should look upon simulator testing as representing the real world, rather than replicating it.

Spirent simulators include statistical models enabling simulation of richer multipath environments, but consideration of these is outside the scope of this document. Figure 1 shows the concept of simulation, using a GSS6700, L1 C/A code Multi-GNSS simulator.

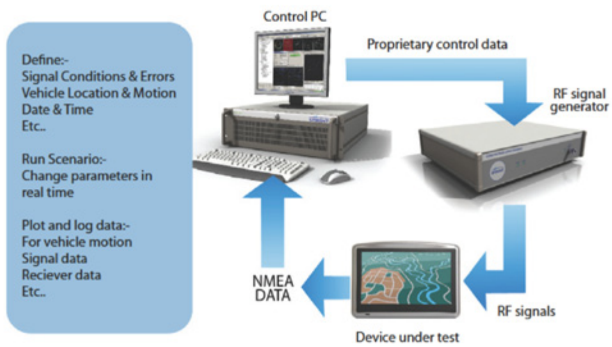


Figure 1: RF Simulation Concept

External Obscuration

In this section we consider simulation of physical objects external to the vehicle that obscure the GNSS signals.

Roadside Buildings and cuttings

Simulation of obscuration due to roadside buildings is possible using the Vertical Planes feature of Spirent's SimGEN™ for Windows® software. Vertical Planes allows you to define a series of vertical, rectangular obstructions or planes to the left and right of the vehicle, relative to the direction of travel. You define the distance, height and width (defined as duration). Signals will be obscured if the planes occur in the LOS path between the satellites and the vehicle antenna. Very high planes at a short distance from the vehicle will obscure more signals than low-height planes at an increased distance from the vehicle. Vertical Planes are a good way of simulating buildings in an urban canyon environment. You can increase the complexity of the obscuration by adding more planes with differing proportions.

If the simulation is run at a different time and/or date, different obscuration will be seen, as the satellite geometry will have changed. Given this, you can build up a series of tests that give a complete 'picture' of the obscuration resulting from your set of vertical planes over a 12-hour period (which equates to one complete orbit for all satellites).
Figure 2 shows an illustration of Vertical Planes positioned to the right of the vehicle (left-side planes omitted for clarity).

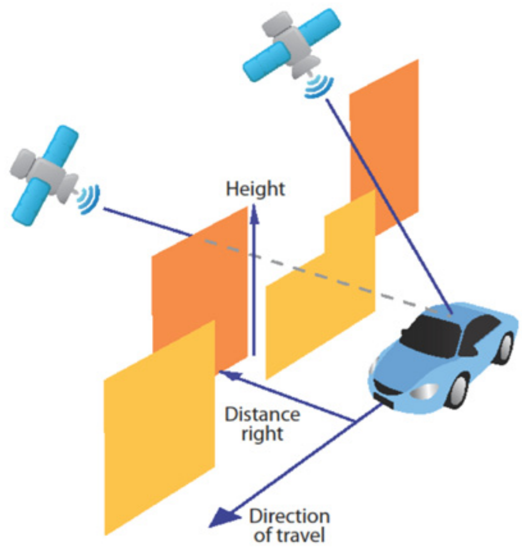


Figure 2: Vertical Planes Concept

SimGEN™ automatically considers the vehicle and satellite motion when determining which signals are obscured by the planes (and not present on the simulator RF output).

Cuttings can be simulated in a similar way to roadside buildings. Using Vertical Planes, you can replicate the obscuration of low elevation satellites by specifying a continuous plane either side of the vehicle at a height and distance that causes the same masking angle as the cutting. Figure 3 shows how two planes can be defined at left/right distance x and height y to provide the same masking effect as the cutting profile. The green shaded area indicates no obscuration. The un-shaded area represents obscuration.

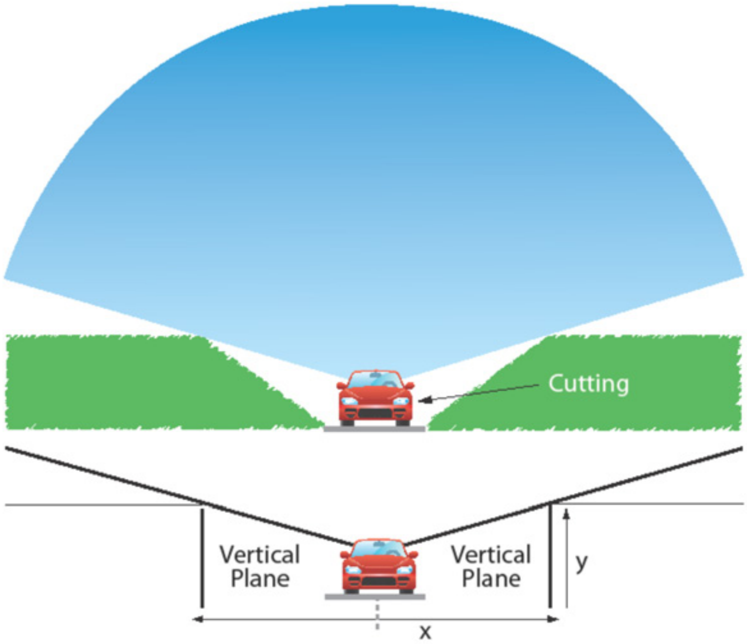


Figure 3: Example of Obscuration Due to a Cutting

Bridges

SimGEN™ can perform a representative simulation of a bridge, by simply turning off, and then on, all satellite signals for a certain period of time. The obscuration effect of the bridge is determined by the length of time the satellites are switched off. It is possible to switch off satellites in real-time, using the power control window in SimGEN™ , in a pre-ordered file of commands, or even using a remote command, if this method is being used to control the simulator.

Tunnels and covered car parks

In much the same way as bridges, tunnels and car parks are simulated by switching off all satellites, but for a longer period. During the off time, the vehicle may change heading, for example, representing a curved tunnel, or a car driving around in an underground car park.

Natural surrounding terrain

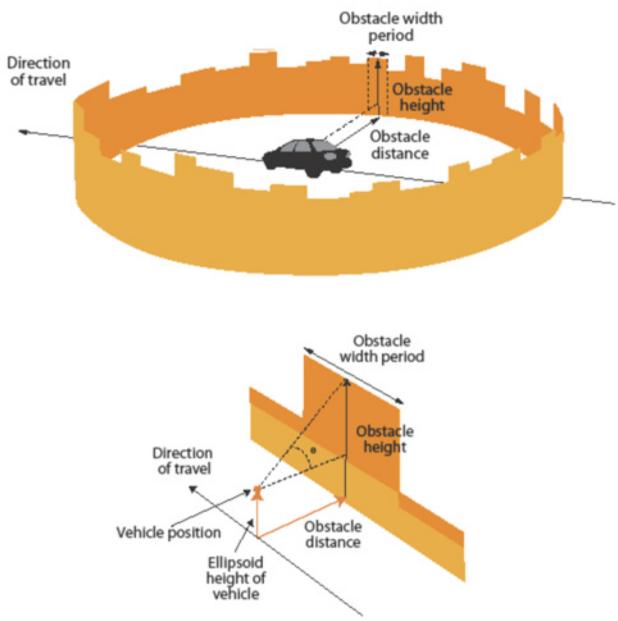
SimGEN™'s Terrain Obscuration feature allows you to apply omni-directional terrain obscuration with a profile modelled according to data sets you can modify. The terrain properties have Minimum Height and Maximum Height fields. The current obstacle height is pseudo-randomly selected between these limits each time an obstacle width period is completed.

The terrain properties also have both Minimum Width and Maximum Width fields to further improve the realism of the effects. The obstacle width maps directly to distance travelled by the simulated vehicle and its period is dictated by vehicle speed.

The essential scheme of this feature is that when a specified trajectory is executed at different speeds, the obscuration pattern is repeated at an appropriately different rate, simulating a vehicle moving through the same terrain but at a different speed.

The terrain obscuration is omni-directional, so is at the same distance from the vehicle in all horizontal directions. It is analogous to a circle, where the vehicle is at the centre, and the terrain is around the circumference. Regardless of speed or trajectory, the vehicle remains at the centre of the 'terrain circle' Figure 4 illustrates this principle and shows the terrain definition in detail for one obstacle width period.

Figure 4: Omni-directional Terrain Obscuration



Adjacent and passing vehicles, highway equipment.

These are effects that are simulated using Vertical Planes. While the exact effect of an adjacent vehicle approaching, passing and receding, or passing street lights/sign gantries is not modelled precisely, a representative effect is applied. As already stated, exact replication is not necessary in order to 'exercise' the receiver appropriately, and determine its limitations.

For a passing vehicle such as a high-sided goods vehicle, you simply set up a vertical plane with a suitable height and distance offset. Equally, for highway equipment, you set up a vertical plane with the appropriate characteristics representing the object's physical form.

On-vehicle obscuration

So far we have considered physical obstructions existing externally to the host vehicle, that are changing as a function of vehicle motion. On-vehicle obscuration is, in almost all cases fixed and does not vary with vehicle motion. With this in mind, the best way of simulating such effects is by using SimGEN™'s Antenna Pattern features*. The simulator considers the receiver's antenna as the point at which signals are modelled. All pseudoranges, power, signals types, delays, motion and other effects are referenced to this point. The electrical properties of the antenna are most obviously and appropriately defined by its antenna pattern, but in this case so too are the fixed physical obscuration properties of the immediate environment surrounding the antenna like the vehicle body.

The orientation of the antenna pattern is always fixed with respect to the orientation of the vehicle, just as the GNSS receiver's antenna is fixed to the vehicle.

The Antenna Pattern Editor allows you to define the signal power level attenuation and phase delay for elevations of +90 to -90 for the full 360 degrees of azimuth around the antenna. The resolution can be as fine as 1 degree x 1 degree, allowing you to model the obscuration created by the vehicle's bodywork (doors, door pillars, roof etc.) and to specify areas where the antenna has a view of the sky (windows, windscreen, sun roof) Attenuation due to window tinting or de-mister/heater elements can also be factored in.

Figure 5 shows the Antenna Gain Pattern Editor with a simple representation of masking that might be experienced by an in-car dashboard mounted GNSS receiver.

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Figure 5 shows the Antenna Gain Pattern Editor with a simple representation of masking that might be experienced by an in-car dashboard mounted GNSS receiver.

*Download the Spirent Application Note **"Keeping your eye on the sky"** for more information on modelling your GNSS Antenna.

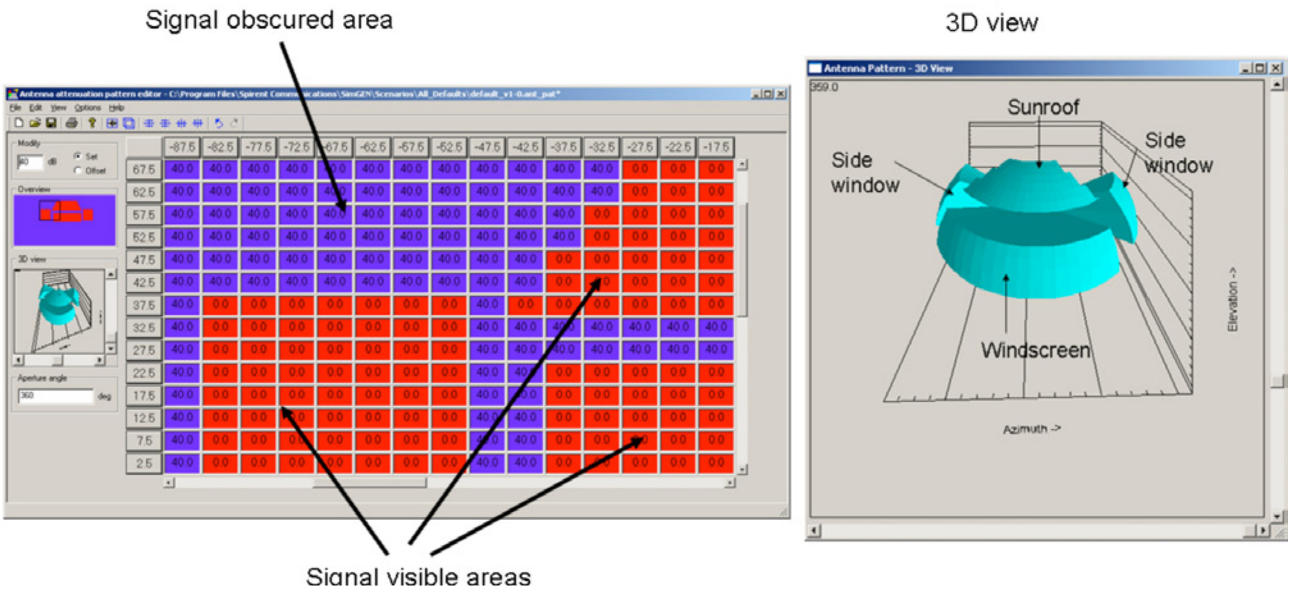


Figure 5: Antenna Pattern Editor

Multipath

Simulation of multipath effects is possible in a number of ways using SimGEN™. Some advanced techniques enable complex multipath to be created.

SimGEN™ allows you to create the following types of multipath:

- Fixed offset multipath
- Ground reflection multipath
- Doppler offset multipath
- Reflection Pattern multipath
- Vertical Plane multipath
- Polynomial multipath
- Legendre multipath
- Sinusoidal multipath
- Land mobile multipath

We will briefly consider two of these types here; **Fixed Offset Multipath** and **vv**.
Our Application Note **"Simulating Multipath"** looks in more detail at simulating multipath types.

Fixed Offset Multipath

This is the simplest method of simulating a multipath signal*. For a given satellite, it allows you to define an exact copy of the LOS signal from that satellite. It allows you to specify both a range offset in metres and attenuation in dB with respect to the LOS. The simulator will then, using a separate hardware channel, create this signal. The range offset is always positive, representing the multipath signal having travelled a longer path to the receiver than the LOS. The level can only be equal or lower power compared to the LOS, representing reflection loss experienced by the multipath signal.

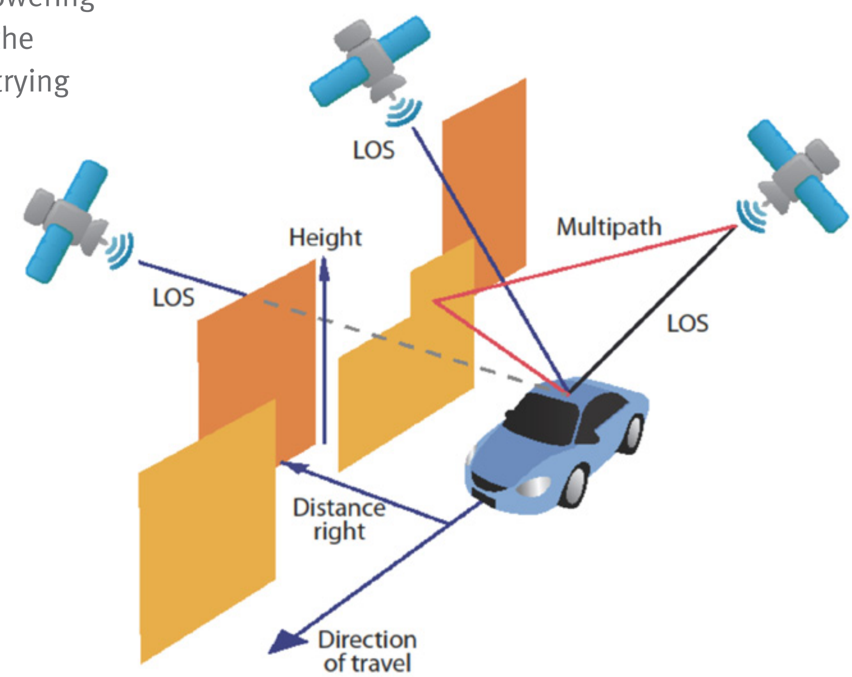
Using User Actions, you can define a Fixed Offset Multipath(s) either in real time using the GUI or remote control, or prior to the scenario run. User Actions is a file of pre-scripted commands executed at set times in the scenario. A receiver without multipath mitigation trying to track both signals will not be able to determine which one is the real signal, and will generate a range measurement error. You can then determine the receiver's multipath performance by - for example – lowering the power of the multipath until the correlator for that channel stops trying to track the unwanted signal.

*For more information on simulating multipath, download the **Spirent Application Note.**

Vertical Plane Multipath

We have already seen how SimGEN™'s Vertical Planes feature is useful for simulating the effects we have discussed, along with the associated multipath capability. Vertical Plane Multipath adds to the obscuration capabilities by allowing the geometric modelling of satellite signal reflections from the surfaces of the planes, that represent buildings in an urban environment. For pre-determined multipath signals, SimGEN™ calculates whether a reflection is possible based on the relative geometry of the selected satellites, vehicle and reflecting surfaces. Depending on this geometry, the receiver's antenna may 'see' just the LOS signal, LOS and multipath, just the multipath or no signals at all. With more complex planes and vehicle motion, more complex multipath will result. The key point is that all signals are calculated and therefore quantified. The combination of signals, however complex, will be repeated exactly run after run. Figure 6 shows an example of Vertical Plane Multipath.

Figure 6: Vertical Plane Multipath



Signal Loss

The sensitivity of the GNSS receiver will determine how well it can track satellite signals. Very sensitive receivers will be able to track attenuated signals better than ones with poor sensitivity.

Generally, there are two parameters of concern: Acquisition Sensitivity and Tracking Sensitivity.

- **Acquisition Sensitivity** is the power level at which the receiver can recognise the signal as a GNSS signal within the noise (That is recognise the code).

- **Tracking Sensitivity** is the power level at which the receiver is able to track the signal and determine the satellites azimuth and elevation. In practice, this is usually a lower level than the Acquisition Sensitivity.

SimGEN™ allows you to control the power level of the simulated signal to a high degree of resolution and over a wide dynamic range. Power control can be carried out either in real-time while the scenario is running, or using a pre-scripted set of commands. Real-time control can be applied using the SimGEN™ GUI or remote commands (if the simulator is being controlled by a remote system).

It is possible to control the power independently on individual satellites, or on all satellites. Level can be displayed as absolute power, or relative to a reference. The resolution of power control (for the GSS6700 simulator) is very fine, being 0.1 dB over the range -130 dBm +15 dB, -20 dB.

This fine control allows you to accurately test a receiver's acquisition sensitivity and tracking sensitivity as well as other fundamental parameters such as TTFF in cold, warm and hot start conditions. For further reading on the subject of fundamental receiver performance characterisation, see our Application Note **"Fundamental GNSS Receiver Characteristics"**.

We have already seen how the Antenna Pattern feature can be used to simulate obscuration and signal attenuation due to the vehicle. It is also useful for simulating signal attenuation due to external objects. Because SimGEN™ allows definition of up to four different antenna patterns, it is possible to take the baseline pattern that includes the on-vehicle obstruction, and add extra attenuation at certain elevations and azimuths to simulate, for example high-sided motorway sound barriers of the type found adjacent to primary routes through urban areas. You can instruct SimGEN™ to switch to the modified pattern and switch back to the baseline pattern at discrete times in the scenario.

Figure 7 shows the concept of signal attenuation caused by motorway sound barriers and how the barriers are represented by an antenna pattern.

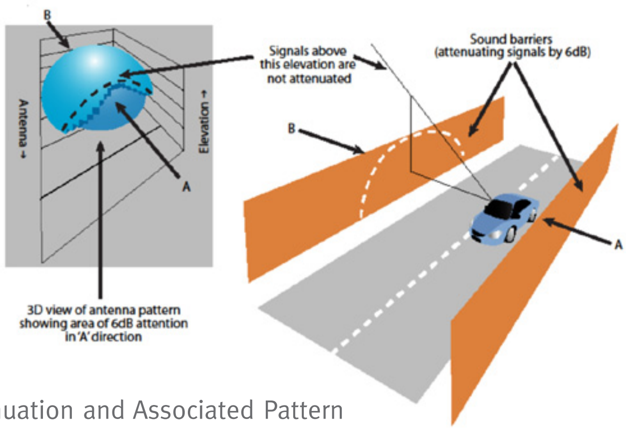


Figure 7: Signal Attenuation and Associated Pattern

Radio Frequency Interference

Spirent's GSS6700 and GSS8000 and GSS7900 series of simulators have an RF 'Jammer' input port that allows you to inject an external RF signal into the main GNSS signal path in a controlled way using a directional coupler inside the simulator.

Depending on the characteristics of the interference signal, you will be able to stop the receiver from navigating correctly. As we have seen in section 0, a relatively small interfering signal will stop a commercial GNSS receiver from working.

A signal injected from a third-party signal generator would not be coherent with the simulator's GNSS signal.

However, an Interference Simulation System option (GSS7765) is available for GSS6700 and GSS8000 series simulators.
This allows specific signal generators to be controlled by SimGEN™ in either a coherent or non-coherent way, with a variety of signal modulation types, and with modelled power, which simulates the relative distance effects of the interference source with respect to the simulated GNSS position.

For more information regarding the GSS7765 interference simulation option, see reference 4.

Figure 8 shows the concept of injecting an interference signal into the simulator.

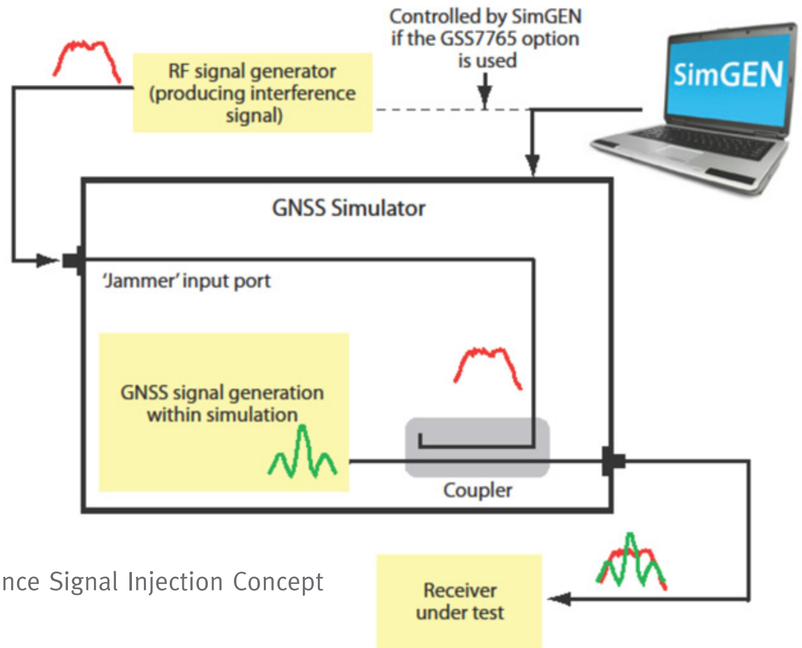


Figure 8: Interference Signal Injection Concept

GNSS + INS

Spirent Simulators that are controlled by SimGEN™ have an optional capability called SimAUTO. This option provides the ability to simulate signals that would normally come from dead-reckoning vehicle sensors.

SimAUTO comprises of software features in SimGEN™ and Digital and Analogue IO cards fitted to the SimGEN™ host PC. Signal and data cable sets are also provided.

SimAUTO has the ability to generate simulated signals for the following parameters:

- **Vehicle Heading Rate** - This bipolar analogue voltage output can be used to simulate the output of a Rate Gyro. The voltage of the signal is proportional to the angular rate at which the vehicle heading is changing.

- **Vehicle Absolute Heading** - This bipolar analogue voltage output can be used to simulate the output of a gyro or compass. The voltage of the signal equates to the vehicle heading.

- **Turntable Control** - As an alternative to emulating sensor outputs, and with suitable safety precautions taken, built in sensors may be stimulated on a rate table. SimAUTO supports this application with a suite of calibration procedures to aid in the determination of the appropriate scale factors and DC offsets. Analogue voltage signals representing turntable speed and positions are also provided.

- **Vehicle Speed and Direction** - Seven digital outputs are allocated to the simulation of vehicle speed, four of which can be directly mapped to represent independent wheel speed sensors.

- **Digital Speed Pulses** - Seven digital outputs are allocated to the simulation of vehicle speed, four of which can be directly mapped to represent independent wheel speed sensors. Table 1 shows the mapping of the seven outputs.

The signals presented are square waves (50% duty cycle) where the frequency is proportional to the vehicle speed and a user-specified scaling factor. A separate, independent scale factor can be specified for each of the seven signals though the four wheel sensor outputs would normally use a common scale factor.

Output	Signal
1	Vehicle Centre speed.
2	Front Wheel Odometer (speed calculated as average of the 2 front wheels)
3	Rear Wheel Odometer (speed calculated as average of the 2 rear wheels)
4	Front left wheel speed
5	Front right wheel speed
6	Rear left wheel speed
7	Rear right wheel speed

Table 1: Speed Sensor Output Allocation

SimAUTO is capable of simulating various 'events' which cause a disturbance or error on the signals.

- **Wheel Speed Events** – You may simulate zero wheel speed, such as during a skid where one or more wheels lock up. Faster or slower wheel speed, such as occurs during a wheel slip or partial skid. Algorithmic errors, simulating randomised and systematic errors defined by a formula.

- **Gyroscope Events** – You may simulate a stuck gyro, randomised gyro noise and giro bias in sympathy with a temperature ramp or fixed value.

- **CAN-Bus Messages** – SimAUTO can generate CAN messages consistent with modelled sensor behaviour. Spirent can modify these to your requirements.

Figure 9 gives an overall schematic showing the principle of SimAUTO's operation in conjunction with the standard SimGEN™ + RF Simulator system.

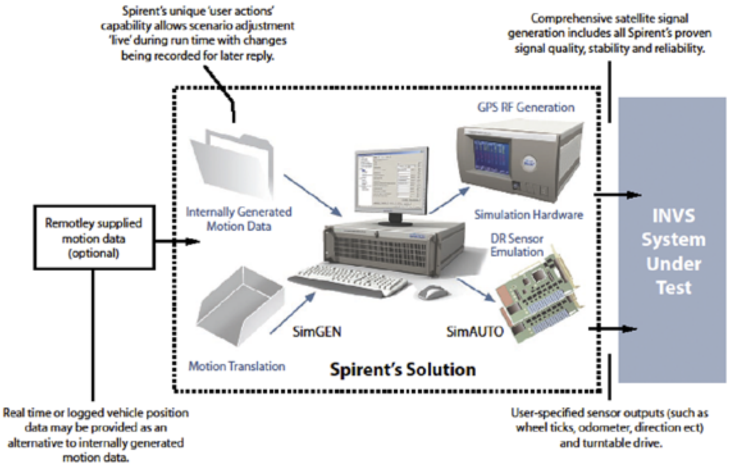


Figure 9: SimAUTO Operational Overview

Reproducing real drive tests

We have seen how powerful a simulator can be in allowing you to define representative tests to simulate many different conditions. However, a standard SimGEN™ application allows you to take data from real field tests and convert it into a motion file, used to simulate the vehicle motion trajectory. Without leaving the lab you can reproduce an identical journey. This is a very useful feature that can dramatically reduce the cost, eliminate the un-repeatability and save the time associated with real drive tests. It also allows reproduction of signal obscuration through use of appropriate data.

NMEA 0183 messages

Most GNSS receivers output data in the NMEA format for position, velocity, SNR, satellite visibility etc. This data is used by the receiver's control software, for example, to provide a navigation solution to a display. For more information, see the National Marine Electronics Association website: www.nmea.org

NMEA Conversion Utility

NMEA conversion is performed using a tool within the SimGEN™ application called SimPROCESS (see reference 1)

The SimPROCESS application is a compiled MATLAB standalone application that uses a full encrypted component-runtime installation of MATLAB. As such it makes available a very powerful set of data analysis and visualisation functions free of charge to SimGEN™ users.

SimPROCESS itself should be seen as a software toolbox which uses a standardised user interface for accessing any number of SimPROCESS tools which will be made available in the future. The NMEA to motion utility converts your receiver log file containing NMEA GGA messages into a motion file (*.umt) for replay in SimGEN™.

The motion file contains motion commands at 100 ms intervals.

The utility also uses satellite CNR data from the NMEA GSV messages to replicate the satellite power levels as seen at the receiver's antenna. You can replicate a real drive test, where the receiver is subjected to obscuration, which will be reflected in the GSV message of the logged data, (and can therefore be replicated by the simulator).

With this capability, you can replicate any obscuration present on the real route without using SimGEN™'s features.

The limitation of this approach is that the simulated trajectory will not necessarily be exactly the same as the receiver position when the NMEA data was recorded, this is because it is based on NMEA data recorded from a real receiver subjected to all the environmental conditions and signal errors already described. Of course, manual manipulation of the NMEA data to remove obvious gaps or errors is always possible (and Spirent recommends this approach). However, SimGEN™ will faithfully convert the data it is given, regardless of its original accuracy.

The key principle here is the simulation can be repeated time and again. While the data may not represent the physical route precisely, the repeatability is precise. In some cases, having inaccurate but repeatable trajectory data is actually beneficial. Many in-car GNSS systems employ map matching algorithms and snap-to-road features, you can test the robustness of these features using imperfect trajectory data and subsequent attempts at improving the algorithms can be re-tested using the same data.

For more information on how to reduce drive test times, download the Spirent Application Note "Reduce Real World Drive Test Times".

Conclusions

This Application Note has explored some of the main problems experienced by GNSS receivers operating in the automotive environment. It has shown how proper product testing during design, development, integration and production phases is of paramount importance to prove its suitability for the intended application. This Application Note has highlighted the ways in which an RF Simulator can readily be used to perform representative tests addressing each of these problems. By using a simulator you can reproduce the effects exactly either one-by-one, in any combination or all together with absolute control of the simulation parameters. The approaches described will maximise test effectiveness and ensure maximum fitness for purpose of the developed product while minimising your development cycles.

Referenced Documents

Unless otherwise stated, reference to the latest issue of each document is inferred.

1. DGP00686AAA SimGEN™ Software User Manual
2. MS3008 SimGEN™ for Windows Product Specification
3. MS3067 GSS6700 Multi-GNSS Constellation Simulator System Product Specification
4. MS3055 GSS7765 Interference Simulation System Product Specification
5. MS3023 SimAUTO Product Specification
6. MCD00065AAA SimAUTO data sheet
7. DAN002 Testing GNSS System Errors [Spirent Application Note]
8. DAN004 Simulating Multipath [Spirent Application Note]
9. DAN003 Fundamental GNSS receiver characterisation [Spirent Application Note]
10. Turn Turn Turn, Wheel-speed dead-reckoning for vehicle navigation. [C. Hay, GPS World Oct 2005]
11. Global Positioning System: Theory and Applications [Bradford W. Parkinson, James J. Spilker Jr]
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13. Vulnerability assessment of the transportation infrastructure replying on the Global Positioning System [John A. Volpe, NTSC, Aug 29th, 2001]

Glossary of Terms

Almanac	Approximate satellite orbit information
CAN Bus	Controller Area Network Bus
Ephemeris	Detailed satellite orbital positional data
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
GUI	Software Graphical User Interface
INS	Inertial Navigation System
IVNS	In-Vehicle Navigation System
LOS	Line of sight
Navigation Data	50bps data message broadcast by GPS satellites
Pseudorange	Satellite to receiver distance as measured by radio ranging
PVT	Position Velocity & Time
Scenario	A pre-defined test running on SimGEN™ software
SNR	Signal to Noise ratio, as measured at baseband by a receiver
TTFF	Time To First Fix

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