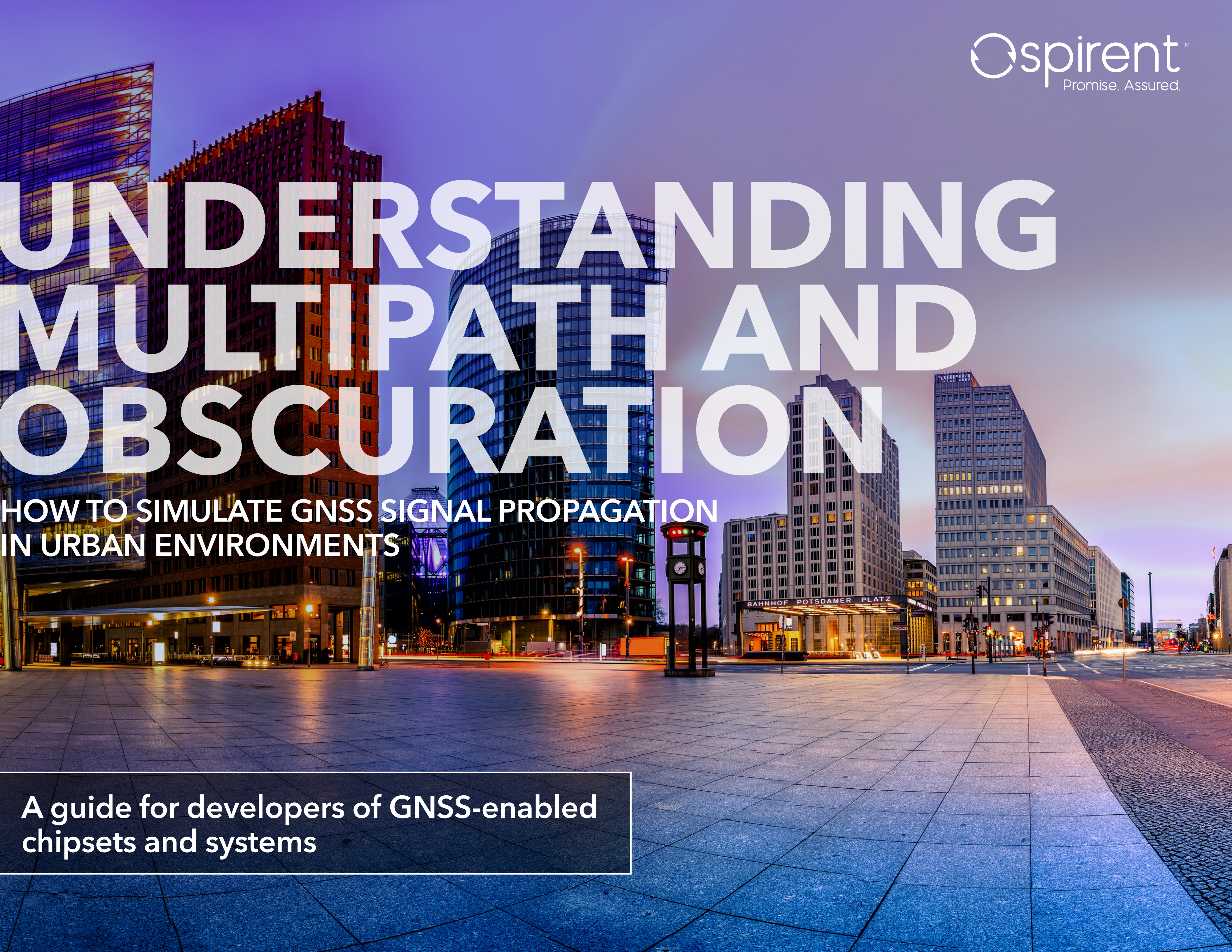

UNDERSTANDING MULTIPATH AND OBSCURATION

HOW TO SIMULATE GNSS SIGNAL PROPAGATION IN URBAN ENVIRONMENTS

A guide for developers of GNSS-enabled chipsets and systems

Spirent
Promise. Assured.

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INTRODUCTION

The Challenge of Reliable GNSS Performance in Urban Environments

Many modern applications and devices rely on continuous, accurate GNSS reception; from smartphones and wearables to advanced driver assistance systems (ADAS), energy grids and telecoms network infrastructure.

If the GNSS signal is impaired, the receiver risks outputting an inaccurate time or position, which could have a serious impact on the critical applications that rely on it.

Demand for accurate, continuous GNSS is especially high in cities, but urban environments pose many challenges for GNSS reception; notably signal obscuration and multipath. Receiver developers and integrators must understand how these effects impact the receiver in order to build in effective mitigation measures.

To date, however, it has been difficult to fully assess the impact of obscuration and multipath on a receiver or system design. Traditional methods of testing a receiver's handling of these effects are insufficiently rigorous for today's GNSS-dependent applications, creating a real risk that the device will not perform as expected in the real world.

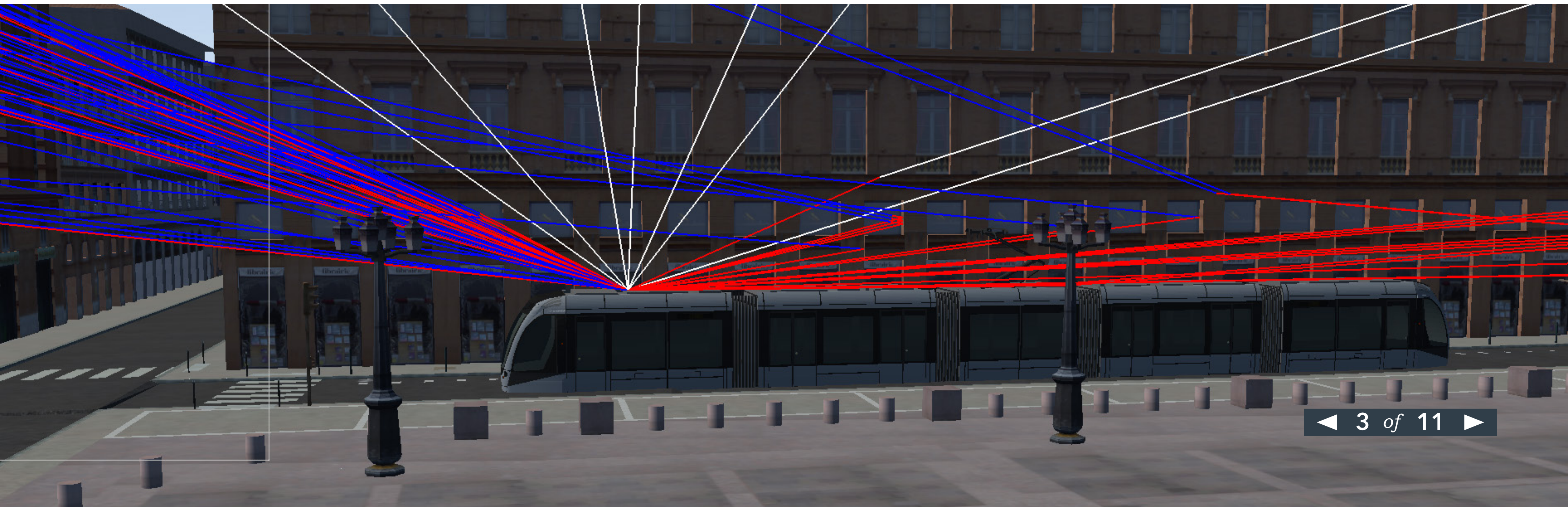
In this paper: why developers need greater realism in multipath and obscuration testing.

This paper will show that as reliance on GNSS receivers grows, it's no longer viable to assess their handling of multipath and obscuration using traditional methods like live-sky testing, record and playback, and statistical modelling.

Only realistic, real-time 3D simulation can provide the richness of detail necessary for characterising receiver performance in different urban environments.

With this in mind, we also introduce Spirent Sim3D, an innovative 3D modelling solution that creates a realistic environment for the testing of multipath and obscuration effects.

Sim3D environment modelling solution



What are Multipath and Obscuration?

Developers and integrators of GNSS receivers must understand how their products perform in the presence of many different types of interference. For systems designed to be used in urban environments, two key interference sources to evaluate are signal obscuration and multipath.

Obscuration refers to satellite signals, which work on line of sight, being blocked by objects in the environment such as buildings and terrain. A GNSS receiver must be able to receive signals from four satellites in order to compute PVT, but in an urban canyon fewer than four may be in view. Even when four satellites are visible, the dilution of precision (DoP) resulting from their proximity to each other may prevent the receiver from calculating an accurate position.

Multipath is a propagation phenomenon that results in a radio signal reaching the receiving antenna by two or more different paths. It is caused by reflection and diffraction of the original signal by any number of physical objects in the local environment, including buildings, vehicles, trees, pedestrians and the ground.

Signal reception may be further affected by its transmission through different physical materials like glass, concrete and steel. Some materials will fully obscure the signal, whilst others will alter its properties during transmission.

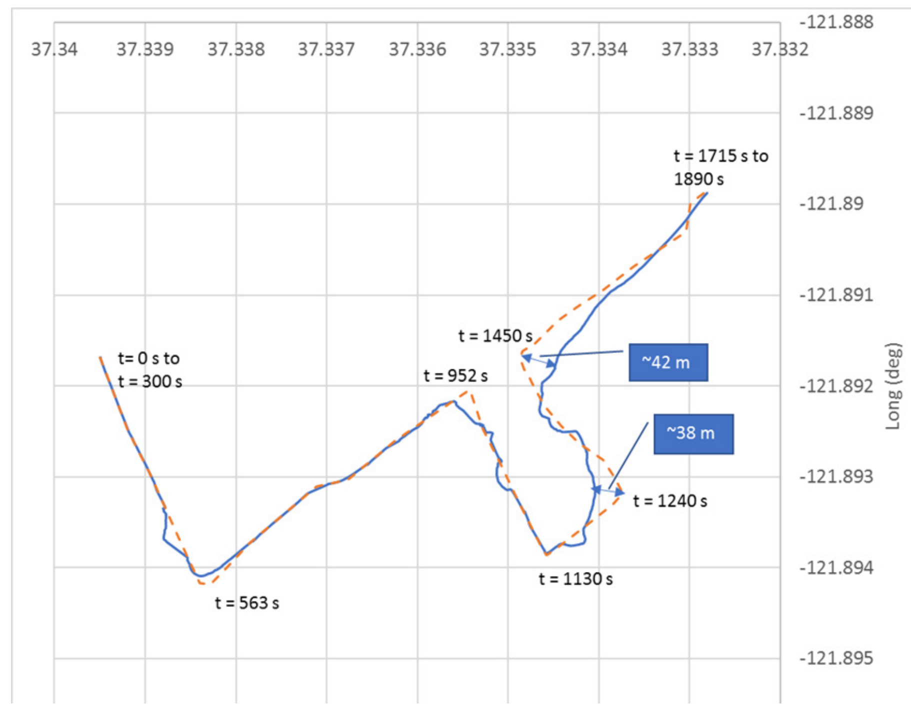
A GNSS receiver measure the propagation time of the incoming signals travelling through space at the speed of light, and multipath effects will cause that time to vary. Unless properly mitigated for, multipath can degrade the receiver's accuracy to a point where performance becomes unacceptable.

What is Reflection?

Reflection occurs when a signal reflects off a surface in the environment; altering its direction, reversing its polarity, introducing code and phase delays, and reducing its power. A signal may be reflected multiple times before reaching the receiver's antenna.

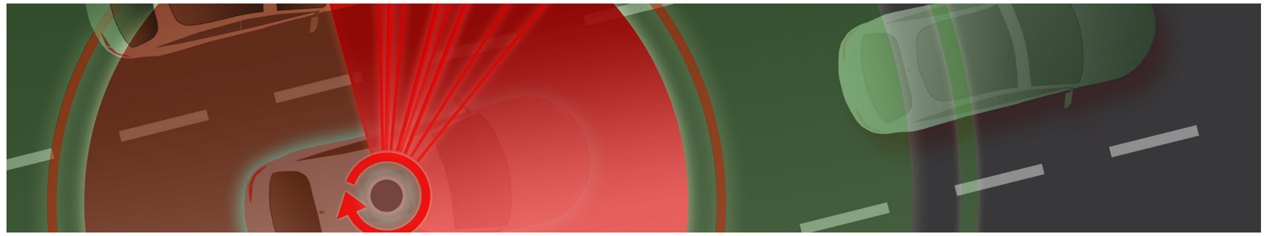
What is Diffraction?

Diffraction occurs when a signal bends around the edge of an object, causing it to take a longer path to the receiver's antenna than line of sight signals. The delay between the line of sight signal and the diffracted signal can cause the receiver to calculate an inaccurate time and position.



The Importance of Rigorous Testing for GNSS Receivers

The need for realistic simulation of multipath and obscuration stems from a growing dependence on GNSS signals. A huge array of commercial and consumer devices, systems and applications now require continuous and reliable GNSS reception for accurate positioning, navigation and timing (PNT). Key applications that depend on GNSS in an urban environment include:



Smartphones and Wearables

Today, people use smartphone apps for in-vehicle navigation, pedestrian navigation, location-based games and exercise tracking, while smartwatches and dedicated wearables are also used for fitness tracking and wayfinding. Users of these devices have increasing expectations of accuracy, and can be extremely disappointed when their run, walk or gameplay is not recorded correctly.

If signal reception is compromised by obstacles in the environment, it creates the risk of a poor user experience and inaccurate data, resulting in negative publicity and possible customer defection.

Advanced Driver Assistance Systems (ADAS)

Vehicle control systems are coming to rely on continuous, accurate positioning for applications like lane-keeping and emergency services notification systems like eCall and ERA-GLONASS, as well as accurate timing for communications with other vehicles (V2V) and roadside infrastructure (V2I / V2X).

While GNSS isn't the only PNT sensor feeding into these applications, it plays a critical role in the vehicle's overall system of systems. Its importance will only increase as vehicles become more autonomous and further smart infrastructure is introduced.

Understanding how the GNSS receiver performs in the presence of signal obscuration and multipath is critical, particularly when designing sensor fusion algorithms that combine GNSS-derived position with position data from other sensors, and which orchestrate handoff to other sensors when GNSS is unavailable.

If multipath and obscuration are not properly handled in the receiver, it could lead to the failure of some elements of the ADAS, which can negatively impact on the vehicle brand and may even put safety at risk. Systems that are required to meet eCall and ERA-GLONASS standards may fail third-party conformance tests, delaying time to market. Smart infrastructure services, like real-time traffic flow management, may also fail to work as expected.

Telecoms and Energy Grid Infrastructure

Cellular telecommunications networks and energy grids rely on the high-accuracy time signal from GPS or other GNSS.

In cellular networks, precise timing synchronisation between base stations is essential for seamless data transmission for high-bandwidth services like video streaming and video calling. As base stations become more numerous, especially for coverage in urban areas, timing standards are becoming extremely strict. For example, the ITU's G.8272 standard for 4G and LTE networks specifies that all clocks in the network must be synchronised to within 100 nanoseconds of UTC, and this figure is expected to be far more stringent for 5G.

In power grids, synchronised timing is used to balance energy generation with energy demand, to regulate the flow of electricity across the network. Different tasks require different levels of synchronisation accuracy–ranging from 1 microsecond to 10 milliseconds[1].

System Function	Measurement	Time Requirement
Generation Control	Generator phase	10 ms
Event Recorders	Time tagging of records	1 ms
Stability Controls	Phase angle, ±1°	46 μs
Networked Controls	Phase angle, ±0.1°	4.6 μs
Traveling wave fault locators	300 meter tower spacing	1 μs
Synchrophasor measurements	Phase angle, ±0.022°	1 μs

Time synchronization requirements for the electrical power industry (source: NIST)

While most clocks in these networks keep time locally using an oscillator, that time quickly tends to drift, so they must regularly sync with a Primary Reference Timing Clock (PRTC). This is the clock that regularly obtains accurate UTC time from a GNSS constellation, and must be able to do so unhindered.

Multipath and obscuration can compromise the PRTC's ability to receive accurate time from GNSS, potentially causing issues ranging from dropped packets and glitchy transmission in telecoms networks, to blackouts in energy grids.

As user expectations increase in these and many other application areas, receiver developers and systems integrators must be able to understand the impact of urban obscuration and multipath on the receiver. There are several methods for doing this, but all are becoming inadequate for many of today's design and development testing needs.

1 Legal and Technical Measurement Requirements for Time and Frequency, NIST.

Why Current Obscuration and Multipath Test Methods are Insufficient

Historically, developers have had three main options for testing a receiver's handling of obscuration and multipath in urban environments:

Live-sky Testing: Field testing with live signals is essential in the final validation stages of a product design, as it's the only way to test with the full richness of the real-world environment. However, the lack of visibility and control over the environment makes it highly impractical for R&D, verification and conformance testing.

Without the ability to isolate obscured and multipath signals, the impact of specific effects in specific locations is impossible to assess. Conditions are also not repeatable, making live-sky invalid for testing iterative design changes. Live-sky can indicate the receiver's performance in the current environment, but provides no insight into performance with future signals or in other locations. Field testing in many locations can provide better data, but is extremely costly and time-consuming.

RF Record and Playback: Record and playback offers a more efficient way to test a receiver in real-world conditions. By recording the real RF environment and replaying it in the lab, developers can test the impact of iterative design changes with real GNSS signals–albeit at a (sometimes much) lower resolution than reality.

Recording different environments around the world is a cost-effective alternative to field testing in multiple locations. However, its usefulness in testing handling of multipath is limited, as developers can't isolate or control the recorded multipath signals in order to focus specifically on how the receiver handles them. Additionally, as with live-sky testing, record and playback only provides the ability to test with current signals, and does not allow developers to model and run "what if" scenarios.

Simulation with Statistical Modelling: For the reasons we have just outlined, the vast majority of today's R&D and verification labs use simulation to characterise receiver performance in a wide range of environments and conditions.

Many GNSS signal simulators include the option to "switch on" obscuration and multipath effects, using statistical models derived from many recordings of RF environments. The issue with this approach is that the models tend to be relatively simplistic, relying on empirical parameters that can be difficult to tune to fit to real environments.

Although statistical modelling provides some value in understanding multipath, it can never recreate the richness of the real-world multipath environment, whose signature is constantly changing depending on the location of the receiver's antenna under test.

For that reason, a receiver that appears to handle multipath adequately in a statistical simulation may produce unexpected errors in the field.

Method / Attribute	Live-Sky	Simulation	Record & Playback System
Repeatable	X	✓	✓
Controllable	X	✓	Partial
Reference Truth		✓	X
Realistic	✓	Representative	✓

Comparative benefits of live-sky testing, GNSS signal simulation and GNSS Record and Playback

The limitations of the existing options are leading developers to seek a richer and more realistic way of simulating GNSS signal propagation in real or fictional urban environments. They want to understand how obscuration and multipath affect the receiver in real time, as it moves through a complex built-up environment with many static and dynamic obstacles.

To do that, they need to be able to model existing or geo-realistic 3D urban environments, including features like trees, pedestrians, traffic and building materials. They then need to be able to simulate the signal propagation effects from the relevant satellite constellations in real time as the device under test moves through the environment. This includes not just current signals, but also future signals whose interface control documents (ICDs) are known.

Only this level of 3D modelling and real-time simulation can provide the detailed insight that developers need to truly characterise receiver performance in a complex urban setting. The ability to simulate a rich, realistic environment in the lab delivers many benefits, including:

Robust and Future-Proofed Receiver Designs: A better understanding of receiver performance allows developers to design more robust and resilient mitigation features, which can be tested in multiple real and realistic urban environments, with current signals and planned future signals.

Faster Product Development: The ability to create a richly detailed 3D environment means more testing can happen in the lab before the device is taken for field testing, accelerating the development process. Test automation can accelerate the process still further.

Accelerated Conformance: The more thoroughly tested the receiver, the higher the likelihood it will pass any third-party conformance tests, minimising re-work and further speeding time to market.

Compelling Performance Specs: Integrators and OEMs are becoming increasingly rigorous in their selection of chipsets for GNSS-dependent systems. Detailed evidence of the receiver's ability to handle multipath and obscuration will be a compelling—and potentially differentiating—feature.

Reduced Risk of Real-World Performance Issues: The more issues that can be identified and remedied in the lab, the lower the risk of issues arising once the device is in the hands of users. That can deliver competitive advantage in terms of enhanced brand reputation, favourable comparisons with competing devices, and increased market share.

Introducing Sim3D:
The First Realistic Simulation Solution for Multipath and Obscuration

Mindful of the issues outlined in this paper, Spirent has been working for several years in collaboration with OKTAL-SE to develop a commercial solution for advanced 3D environment modelling and real-time signal propagation simulation. That solution is now available as Spirent Sim3D.

Sim3D is an innovative real-time system that enables the reproduction of an authentic multipath environment. It combines a state-of-the-art GNSS simulator and 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—whether static or dynamic.

Sim3D implements a deterministic ray tracing algorithm on NVIDIA GPU architecture, coupled with geometrical optics and uniform theory of diffraction. With Sim3D, every possible multipath that could reach the device under test will be computed and displayed. Key features of Sim3D include:

Realistic Multipath and Obscuration Simulation: Based on a synthetic 3D model, Sim3D allows real-life locations to 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 not available in any other product in the market.

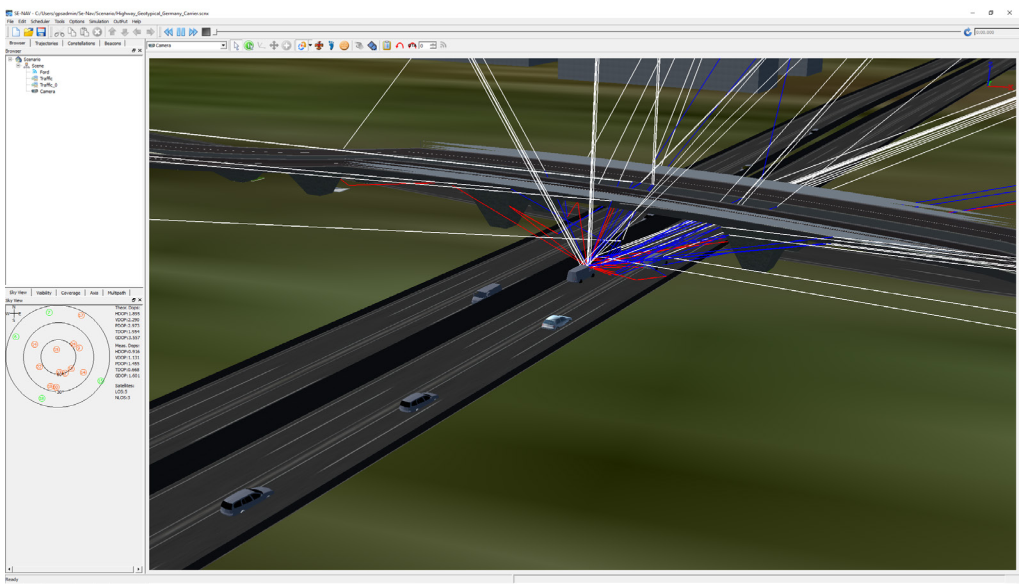
Ability to Simulate Real Life Applications: Sim3D allows you to define your antenna carrier as a vehicle or pedestrian, then position your antenna relative to the carrier centre of gravity. The multipath and obscuration are computed considering the antenna carrier body position and motion. This provides valuable insight for optimising the location of the antenna for multipath/obscuration.

Better Level of Control and Analysis: Sim3D provides a level of control not available in any other multipath/obscuration simulation approaches. You can choose which constellations to simulate, the number of reflections per multipath, the number of multipath signals per LOS, and much more.

Fully Verified with Real-Life Data: The performance of Sim3D simulation relative to field data has been exhaustively assessed, with good indicative results shown.

Full Level of Customisation: Sim3D enables you to create your own 3D models with the level of accuracy you desire. It provides converters for many generic 3D model formats, allowing you to easily import existing or purchased models.

GSS7000 multi-frequency multi-constellation simulation system



Sim3D

Conclusion

In this paper, we've discussed how developers working on new generations of highly-accurate, highly-reliable GNSS chipsets and systems must have a good understanding of how those devices handle obscuration and multipath effects in urban environments.

Traditional methods of testing receiver performance with obscuration and multipath are rapidly becoming inadequate—being either impractical, too costly, too time-consuming, insufficiently realistic, or a combination of these factors.

To guarantee the levels of performance increasingly required by today's systems integrators and OEMs, GNSS receiver developers need a solution that offers realistic, highly-configurable 3D environment modelling and signal propagation simulation.

Spirent's Sim3D is the first multipath and obscuration simulation solution capable of meeting these emerging requirements, and is available now to purchase from Spirent or an authorised Spirent partner.

Learn More about Sim3D for Multipath and Obscuration Simulation

To learn more about Sim3D, you can:

Download the Sim3D brochure

Ask Spirent for a demo

Why Spirent?

With experience gained over more than 30 years of supporting GNSS development, our systems offer the proven performance and reliability our customers demand. They have been successfully deployed globally in over 50 countries and approved by all major GNSS design authorities

Spirent offers:

- Comprehensive features as standard
- Highly extensible and future-proofed solutions
- Ongoing investment in cutting edge developments and continuous improvements
- Quality systems backed up by a global support network
- Tailored Solutions capability to support special applications and configurations
- Large team dedicated to implementing new signals and ICDs

About Spirent

About Spirent Positioning Technology

Spirent enables innovation and development in the GNSS (global navigation satellite system) and additional PNT (positioning, navigation and timing) technologies that are increasingly influencing our lives.

Our clients promise superior performance to their customers. By providing comprehensive and tailored test solutions, Spirent assures that our clients fulfill that promise.

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