



Testing Multipath Performance of GNSS Receivers

How multipath simulation can be used to evaluate the effects of multipath on the performance of GNSS receivers



The multipath phenomenon

Multipath effects cannot be ignored as they can compromise the performance and accuracy of any receiver design

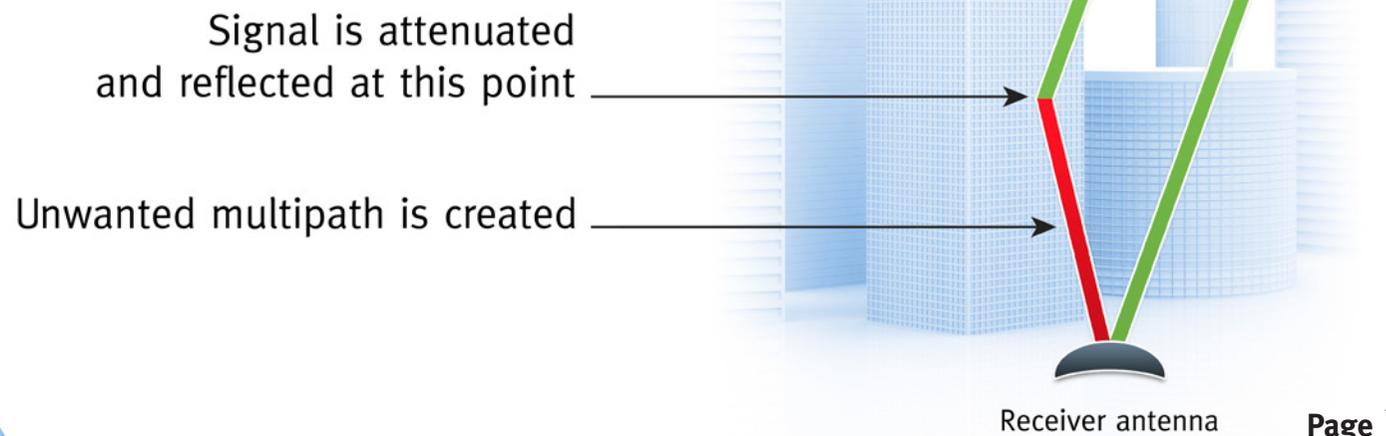
But how do you ensure rigorous testing of all the types of multipath effects?

Only through controlled simulation.



Put simply, **multipath** is the propagation phenomenon that results in any specific 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 phenomena, ranging from the built environment to geological features, trees, the ground and even water.

All of these factors, individually (and in combination) can cause multipath propagation.



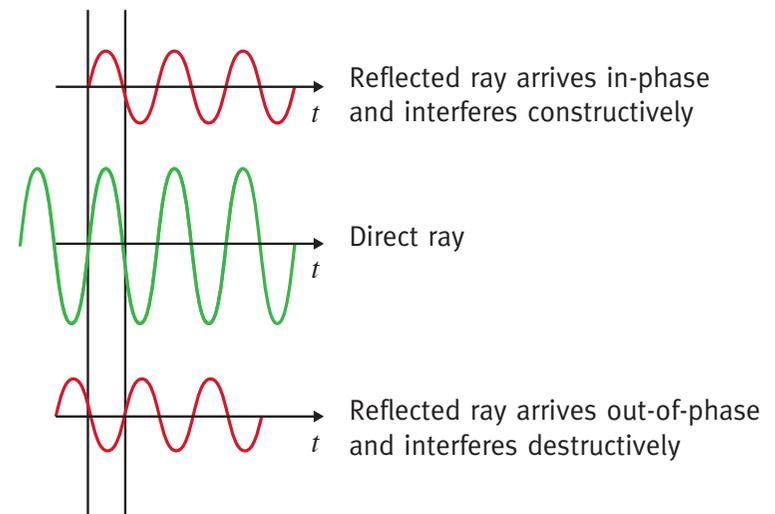
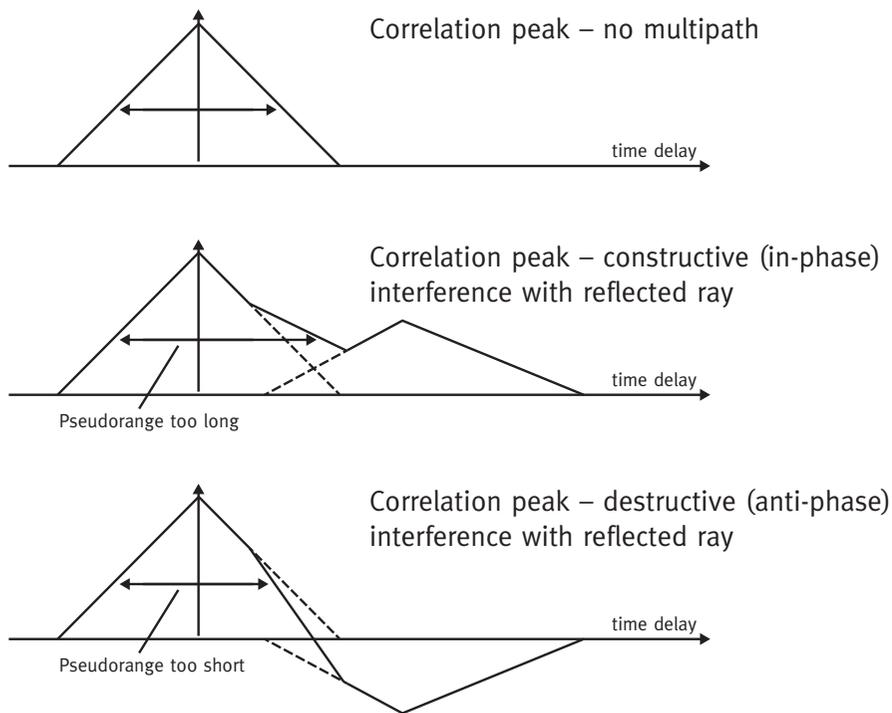
Types of multipath

Because of the huge diversity of structures and media involved, multipath phenomena can take a wide range of forms. However, there are two basic types:

Constructive interference occurs when the reflected signal arrives in-phase with the original (line of sight) signal.

Destructive interference occurs when the signals are out of phase.

Constructive interference will amplify the signal and increase the resulting pseudorange, whereas destructive interference will cause a signal fade and reduce the resulting pseudorange.



Why is this a problem for GNSS receivers?

In a global navigation satellite system receiver, multipath effects can cause a stationary receiver's output to imply that it is **randomly jumping from point to point or creeping**.



This is because the receiver uses the measured transmission time of the signal to determine its pseudo-range, and multipath effects will cause that time to vary. In-phase multipath will generally cause an over-reading of pseudo-range, and out-of-phase multipath will lead to an under-reading of pseudo-range.

When the unit is moving, the jumping or creeping will often be less pronounced, but it can still degrade the displayed accuracy to a point where the performance will be unacceptable.

Multipath mitigation

There are a number of multipath mitigation techniques used by receiver manufacturers, ranging from various mathematical correlation and filtering techniques to different antenna designs.

Multipath limiting antennas can be particularly useful when dealing with signals from satellites that are low on the horizon: the reflections causing multipath effects in these instances can be extremely complex, depending on the nature of the ground level surface.

Mathematical techniques include a-posteriori multipath estimation, which provides a measure of the multipath error by using the fourth replica of the pseudorandom number code. **However...**

No multipath mitigation measures can be taken without first establishing the scale of the problem for any specific GNSS receiver design...

...and that entails rigorous testing

Testing times

While it is true that GNSS receivers are expected to operate under real-world conditions, **the practicalities of testing how a receiver deals with multipath performance in the real world is very difficult.** The test setup would be unwieldy as it would be necessary to isolate and quantify all the signals reaching the receiver as well as assessing its own response to the signals. And the necessity to test the receiver with a representative sample of different multipath effects would make the process both long-winded and open to a myriad of uncertainty.

However, the use of a suitably equipped GNSS simulator in a laboratory environment provides both the flexibility to test **different scenarios** and the **repeatability** to assure the quality of the test results.

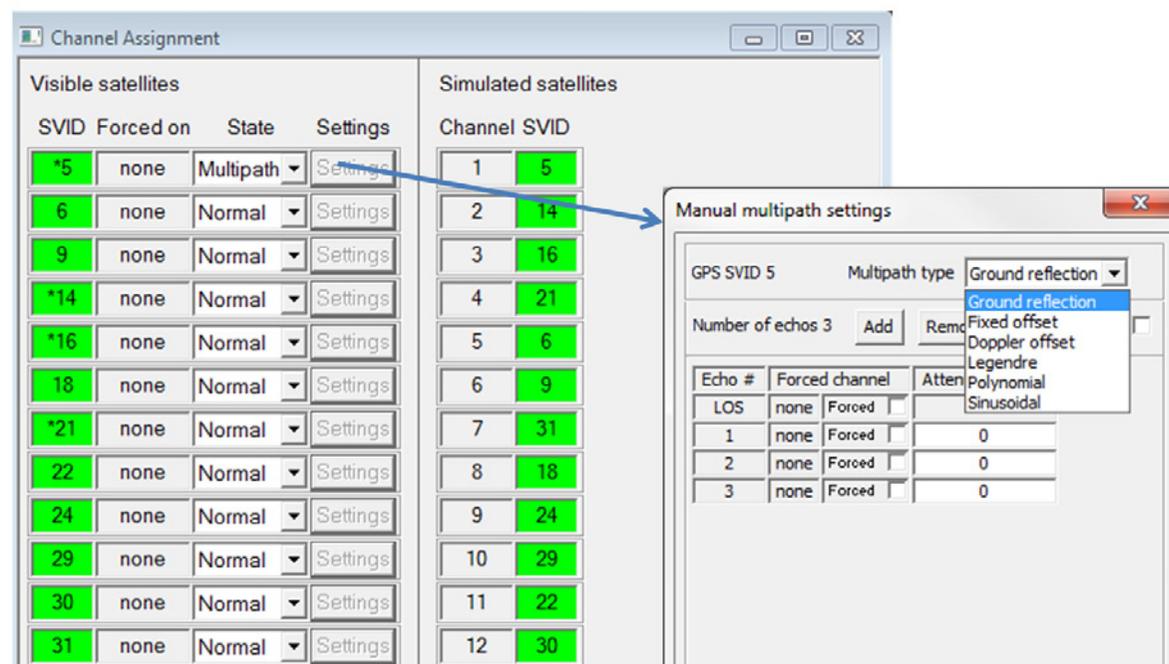


Simulating multipath effects

When choosing and setting up a GNSS simulator for multipath testing there are two important factors to consider.

1. The simulator must have a sufficient number of output channels to provide adequate coverage of multipath effects, which in some cases will mean one channel for the line-of-sight signal and several additional multipath signal channels for each satellite. Fortunately, multipath effects are most pronounced in restricted environments such as urban canyons where fewer satellites are visible to the receiver. **Hence 12 channels will generally be sufficient.**

2. Software control is essential. With a large number of measurements to be made and absolute repeatability essential, **suitable test software is not a luxury**. Spirent offers **nine different types of multipath models** or ways of applying multipath. Some are shown in the diagram below. Therefore the ability to automate test procedures is an important consideration in reducing time to market.



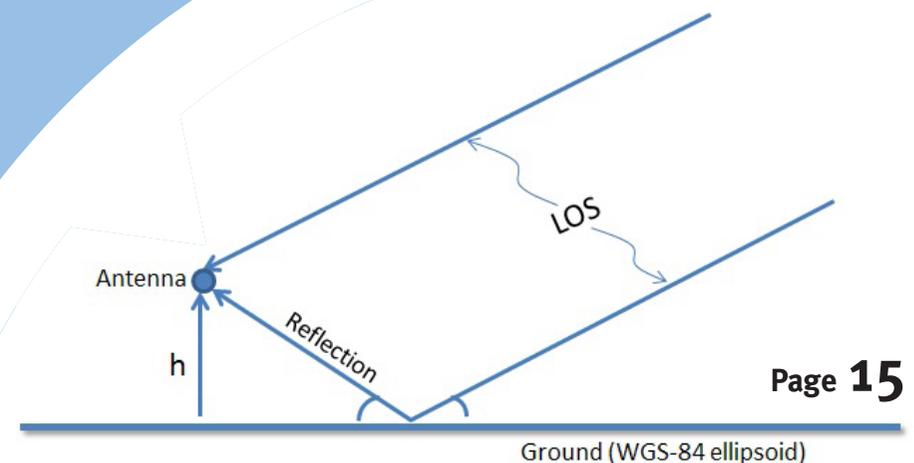
Fixed offset multipath

The fixed-offset multipath is the most basic test setup, under which the simulator produces a **simple “echo” signal** with a constant range and power offsets from the line-of-sight signal. Multiple echo signals can be produced up to the maximum channel count of the simulator, and the line-of-sight signal can be removed to simulate conditions where the main signal is lost.

The simplicity of the fixed-offset multipath test is in that it does not include the effects of movement of either the satellites or the receiver, relative to any physical obstruction and the **pseudorange changes** due to satellite and vehicle relative motion are the same for line-of-site and multipath signals.

Ground reflection multipath

The ground reflection multipath test is particularly useful in modelling the multipath effects of satellites that are low on the horizon. It is also particularly pertinent for receivers that are intended for marine applications as the sea is a particularly effective reflecting medium for GNSS signals.



The only major requirement for the test is that **the antenna of the receiver** is positioned above the ground to receive the reflected signal.



Doppler offset multipath

The Doppler offset multipath test involves a more complex test scenario that was originally devised for the **3GPP TS25.171** mobile phone standard. In addition to the range and power offsets specified in the fixed-offset test, the user also specifies a **Doppler frequency offset**, which will cause the delay between the multipath and the line-of-sight signal to vary over time.

Reflection pattern multipath

Reflection pattern multipath testing is particularly useful as it allows the user to model the electrical properties of a simulated antenna for the test, rather than use the receiver's antenna itself. This then **removes any variations** there may be in the reception pattern of the receiver antenna and tests the receiver itself. It is ideally applicable to systems where the host vehicle itself is a major source of the multipath signals.

It allows you to specify **different multipath delays** for different signal arrival angles. There will be greater variation in multipath delay when the relative movement of the antenna with respect to the arriving satellite signals increases.

Legendre multipath

This model is ideal for modelling multipath signals in a relatively static environment, Legendre multipath testing uses a fifth-order Legendre polynomial to create the relative amplitude and delay of the imposed signals. And while the reflected signals are not necessarily representative of the relative geometry of the satellites and the receiver, the technique is highly reproducible, and can be used to **create particularly complex interference patterns.**

Polynomial multipath

The polynomial multipath scenario is similar to the Legendre case, but the polynomial coefficients are less rigorously defined. The downside of this is that the **multipath profile does not have fixed boundaries** like the Legendre polynomial, and so the same offsets cannot necessarily be applied to tests of differing durations.

Sinusoidal multipath

The sinusoidal multipath overcomes the limitation of the standard polynomial multipath by producing a **time-varying multipath signal** that is well bounded and easily defined.

Land mobile multipath (LMM)

Developed specifically to simulate the signal environment experienced by portable devices such as **mobile phones**, the LMM model is considerably more comprehensive than any of the other multipath test scenarios. And, consequently, software control is essential.

Land mobile multipath simulation software allows the test engineer to define the signal conditions from a menu of predefined environments for each test. These provide statistical models that produce: direct line-of-sight signals with Rician fading (as in destructive multipath); reflections with Rayleigh fading (as in constructive multipath), power decay and exponential decay; and deep fading of echoes, providing a Doppler offset. The Spirent simulator software comes with a variety of **pre-programmed routines** that simulate specific environments such as urban canyons, flyovers and trees.

Fader multipath

The final test scenario is also different in nature to all the others in that it overcomes the requirement to have a dedicated hardware channel in the simulator for each signal. Fader multipath testing allows the user to produce up to **four multipath signals** from each simulator channel, with each different sub-channel separated digitally in the simulator hardware. This approach allows **highly flexible modelling** in which the level, delay and phase of each sub-channel can be independently defined.

Case proven

With end users of GNSS receivers becoming ever more accustomed to pinpoint location accuracy in every possible environment, multipath effects cannot be ignored, as they have the potential to compromise the performance and accuracy of any receiver or system design. **Multipath mitigation is essential**, and this must entail testing the design to ensure that the mitigation techniques chosen are effective for the **receiver's normal usage** scenario.

And...

Because real-world testing can only (by definition) produce complex, largely unquantifiable and unrepeatable multipath environments, **a GNSS simulator offers the only practical option for multipath testing that is both accurate and repeatable** in the controlled environment of the test laboratory.



Spirent GSS8000
Multi-GNSS Constellation Simulator



Spirent GSS6700
Multi-GNSS Constellation system

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