Simulation Versus Real World Testing

How to undertake controlled testing of your GNSS receiver design

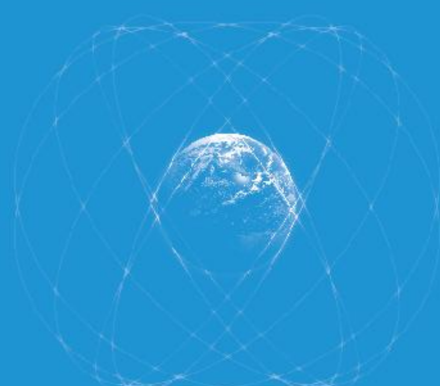
SPIRENT®

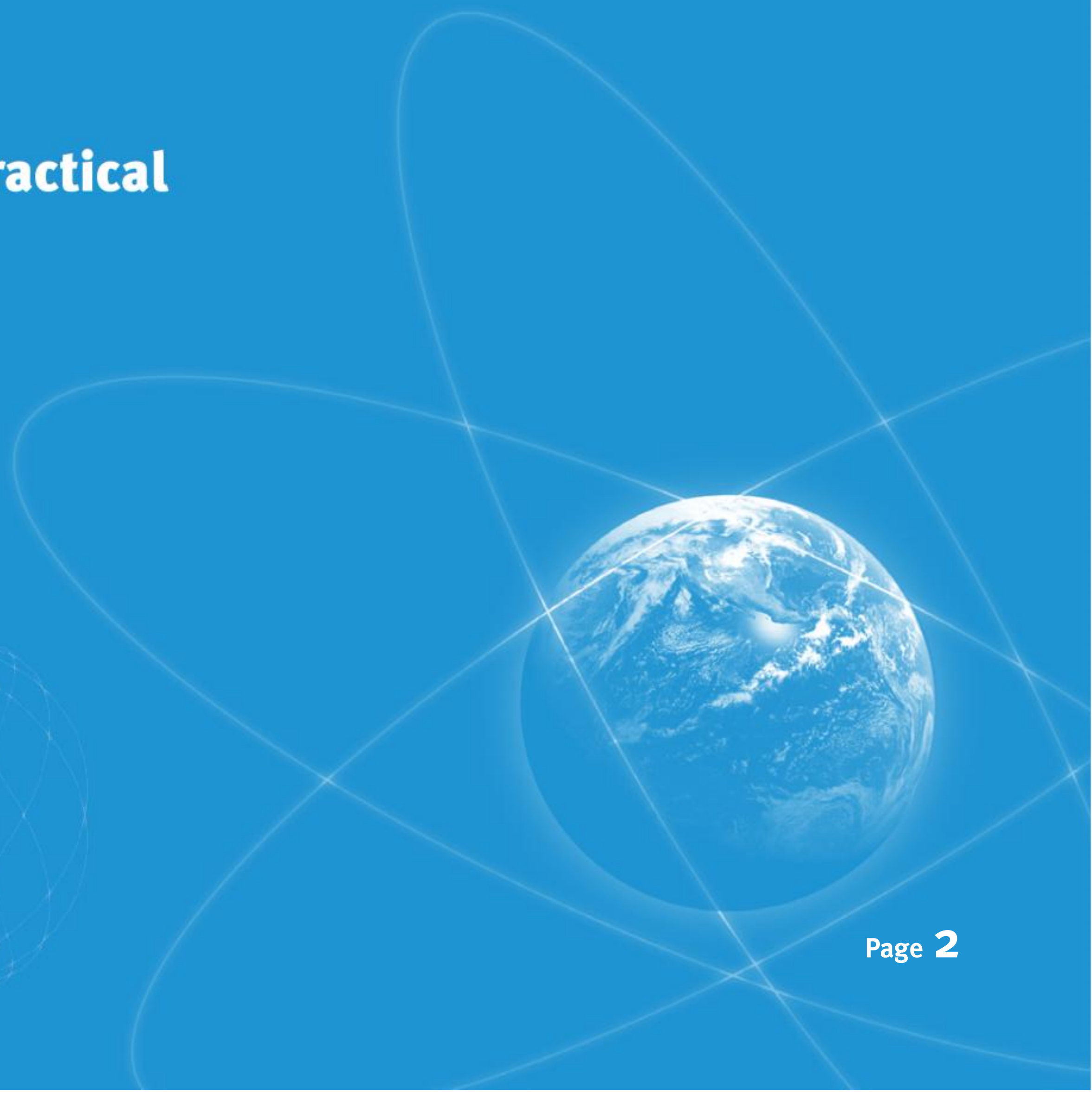
Should global navigation satellite system GNSS receivers ONLY be tested using real world signals to guarantee their proper operation?

No

That would be wrong and impractical

Here’s why…

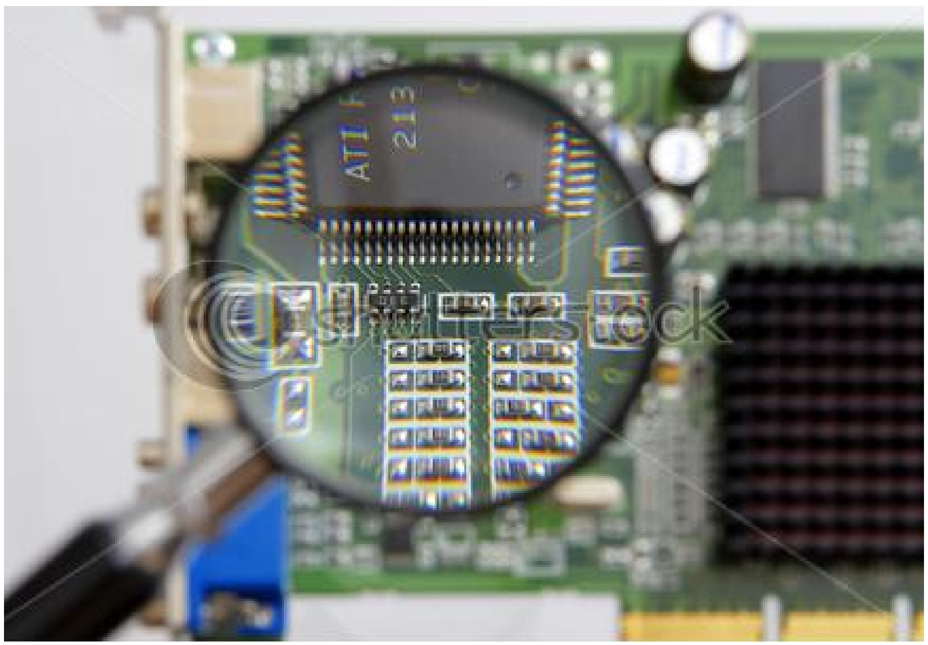




Here's why

Simulation, by definition, reproduces the signals and effects a receiver sees in the real world, but under the controlled conditions of the laboratory, making *GNSS receiver testing* a far more consistent and reproducible exercise.

Importantly, the signals from the simulator are exact known quantities... right down to the bit level. And, by providing the ability to test the different performance parameters of the receiver individually (or in concert), the simulated environment will provide much clearer insight into the true performance of the receiver.



The Nine Key Tests

There are nine key tests that together provide the fundamental characterisation of performance of any GNSS receiver:

1. Cold-start time to first fix
2. Warm-start time to first fix
3. Hot-start time to first fix
4. Acquisition sensitivity
5. Tracking sensitivity
6. Reacquisition time
7. Static navigation accuracy
8. Dynamic navigation accuracy
9. Radio frequency interference

Some tests may not be as critical as others, depending on the intended application of the receiver. But between them, these nine tests cover all the important aspects of receiver performance that will impact the end-user experience.

Test 1: Cold-start time to first fix (TTFF)

This is one of the great tests of a GNSS receiver because it will be the first thing that a user notices. *Time to First Fix* is always an important metric, and the “cold-start” version is just that — the receiver is starting from scratch, with no memory of any previous reading.

The time is unknown, the current almanac and ephemeris are unknown, and (obviously) the current position is unknown.

It is also a test that is far better performed with a simulator, because, the sure way of measuring this quantity is to run a series of tests on each receiver and take an average time, with each test based on a completely new location – several thousands of kilometres from the previous one.

Try running that test using real-world satellite signals when time cannot be stopped or re-wound!

Test 2: Warm-start time to first fix

The second test is similar to the first, but the difference is important. For the so-called “warm start”, the time and almanac are retained within the receiver’s memory. However, the ephemeris data are either unknown or out of date and the position is within 100km of the last fix.

And while single measurements can be performed equally as well in the real world, the added control of using a simulator in the laboratory (and absence of outside influences) allows the test to be performed with **total certainty**. Using a simulator, it's also readily possible to take multiple measurements and average the results. And when you have altered your design or set-up, you can quantify the improvement by re-running exactly the same tests with exactly the same conditions.

Test 3: Hot-start time to first fix

Although the hot-start TTFF is the least arduous of the time to first fix measurements for the receiver, in many ways it's probably the most important, as this will be the performance that the end user will experience most often.

In this scenario, the receiver has full data on time, the almanac and the ephemeris, and the position is within 100km of the last fix. All that is required is for the receiver to collect the full navigation message from the simulator. As with other TTFF tests, and due to the importance of the measurement, it is advisable to run the test several times with different satellite geometries to calculate an average value for the TTFF.

Test 4: Acquisition sensitivity

The sensitivity of any GNSS receiver is key to its performance, and acquisition sensitivity is the first for these important measurements as it defines the minimum received power level at which the receiver can obtain a fix.

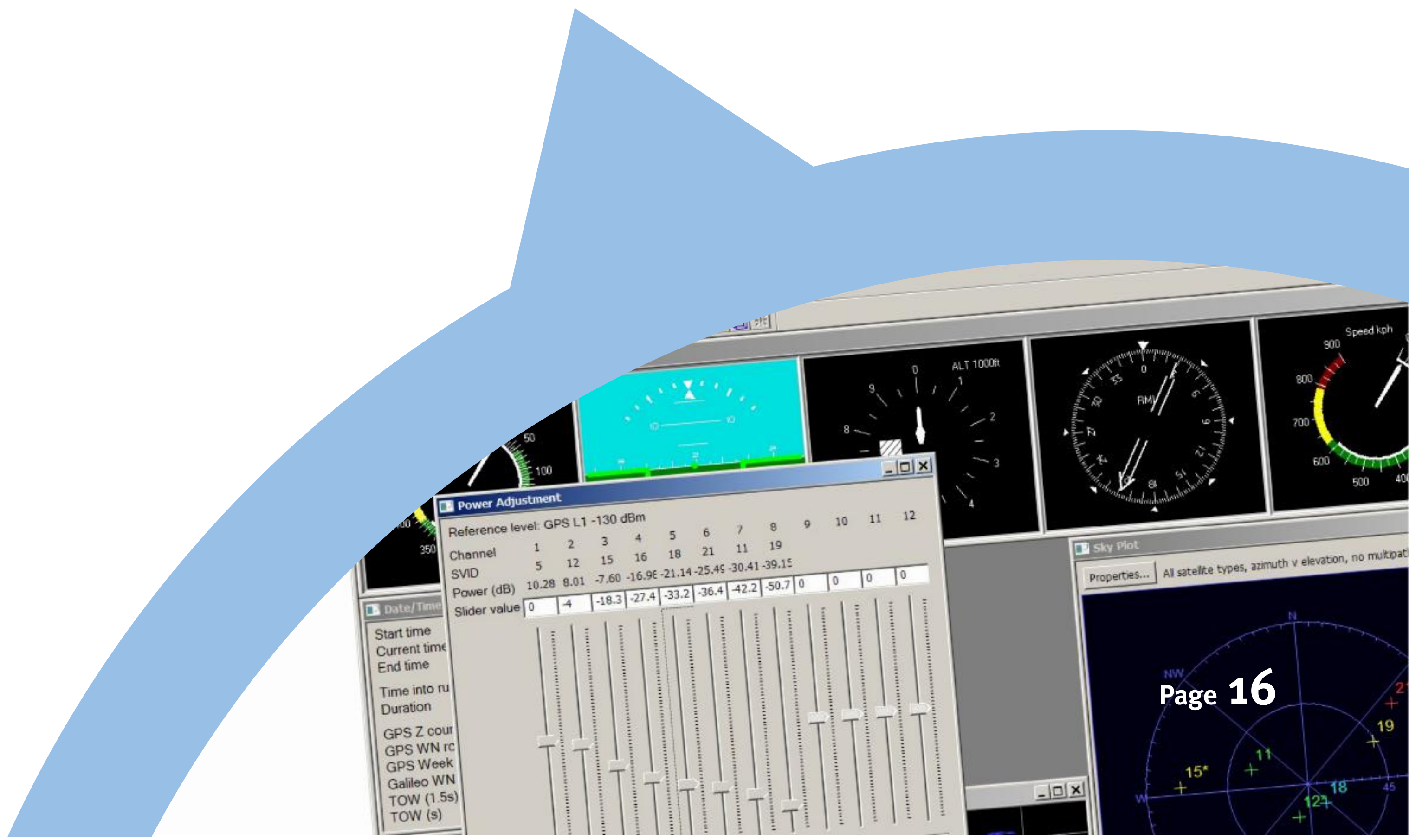
This is another test where the simulator is an essential tool. It is only through the ability to control the power output from the simulator (on individual satellites, or all at once) that an accurate measure of acquisition sensitivity can be obtained.

Ideally, the simulator should be capable of very fine power control to within 0.1dB to obtain the most accurate possible measure of acquisition sensitivity.

Test 5: Tracking sensitivity

As with acquisition sensitivity, **the fine control of power levels is essential in determining tracking sensitivity** – the minimum power level at which the receiver can maintain lock. Crucially, it is tracking sensitivity measurements that will highlight the errors inherent in the design of the receiver's PLL-based tracking loops. These include phase error, dynamic stress error and thermal noise.

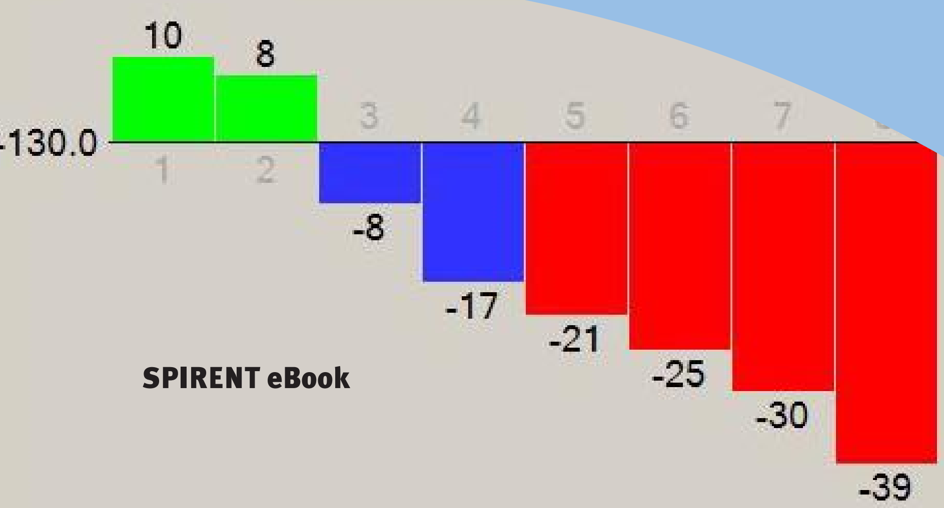
The test itself is relatively easy: with the receiver locked on to the simulator's output, simply lower the simulator power output until the lock is lost. Multiple repeats of the test with different satellite geometries will ensure that an **accurate average measure** is recorded.



Test 6: Reacquisition time

Reacquisition time is a particularly important measurement for vehicle-based receivers, which will inevitably lose satellite signals when travelling through tunnels or even under bridges. For example, the end user will not be impressed if the receiver misses a turn instruction because it has not reacquired the signal after passing such an obstruction.

Again, **the simulator allows total control over the test,** reducing the signals from each satellite by at least 60dB to ensure that the receiver loses complete lock, raising it again to normal power and measuring the time taken to reacquire the lock.



Test 7: Static navigation accuracy

This is in many ways the most difficult test to predict, as there are so many different factors – both internal and external – that can affect a receiver's performance. So this is **another case where the controlled environment of the laboratory is essential** to remove external variables such as the effects of the ionosphere and troposphere – or indeed include them, but in a quantified way.

A useful tip here is to simulate a static position of 0 degrees latitude, 0 degrees longitude and 0 metres elevation, as it will make it easy to observe the receiver's divergence from the simulated position.

Again, multiple measurements should be taken to allow for different satellite positions and factors such as receiver thermal performance. The resulting metric is typically quoted as a statistical average of the many performance measurements.

Test 8: Dynamic navigation accuracy

Particularly important for vehicle-mounted receivers, dynamic navigation accuracy involves taking a series of measurements while the receiver is moving in one, two or three axes. While such measurements could theoretically be taken reproducibly on a test track, the simulator again has a trick up its sleeve that inevitably leads to improved measurement accuracy.

The simulator control software has the ability to simulate the relative motion of the receiver and satellites. And with a high dynamic performance simulator, this means that **virtually all types of vehicle motion profiles can be simulated**, with high fidelity even with the most extreme maneouvers.

Test 9: Radio frequency interference

Because GNSS receivers are such sensitive instruments, it is almost inevitable that they are susceptible to radio frequency interference – most of which will be accidentally generated. However, there are also instances where a jamming signal might be deliberately broadcast in order to lock out a navigation system.

There are many commercial interference simulators on the market that can be used to obtain a measure of a receiver's susceptibility to any given frequency of RFI. However, by using a coherent interference source that is directly coupled to the GNSS simulator and dynamically controlled by the same system software, **far greater insight into a receiver's performance can be obtained**, allowing designers to take appropriate filtering measures to improve their products' performance.

To conclude

The use of a multichannel RF constellation simulator in testing the performance of a GNSS receiver has many benefits.

Indeed, many of the parameters that are key to the performance of a receiver simply cannot be reliably tested in the real world – in some cases due to simple practicality, in others because of external variables that render test results unreliable.

It is only by rigorous simulator-based testing, under the controlled conditions of the test laboratory, that the nine key performance indicators of any GNSS receiver can be determined with absolute certainty and full repeatability. Armed with these results, *GNSS receiver developers* can perfect their designs, leading to improved products that exceed users' expectations.

Spirent GNSS Simulators

Spirent is the industry leader for GNSS simulator products. Spirent offers several different models of GNSS simulators that support a variety of different applications and cover the full spectrum of civilian and military GNSS testing needs. Spirent products range from basic single-channel simulators, suitable for simple production testing, through multi-channel, multi-constellation simulators, suitable for the most demanding research and engineering applications.

For more comprehensive testing, Spirent also offers products that simulate additional system elements simultaneously with the GNSS constellation signals, such as inertial sensors, various automotive sensors, Assisted GPS (A-GPS) + Assisted GLONASS (A-GLONASS) data, SBAS and GBAS augmentation system signals, interference signals and Wi-Fi Positioning.

Spirent GSS8000

Multi-GNSS Constellation Simulator

Spirent GSS6700

Multi-GNSS Constellation system

Spirent GSS6300

Multi-GNSS Signal generator

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