

A white commercial airplane flying through a clear blue sky, viewed from a low angle looking up.

Spirent eBook:

How to choose a GNSS receiver



How to select a GNSS receiver for your **device design**

What to consider, and how to test

From critical infrastructure and military applications to smartphones, drones, wearables, and other consumer products, a huge variety of modern devices rely on Global Navigation Satellite Systems (GNSS) for positioning, navigation, and timing (PNT) information.

Each of these devices needs to be equipped with a GNSS antenna and receiver to receive and process the satellite signals; however, receivers are not created equal. They can vary wildly in terms of accuracy, robustness, cost, weight, size, and many other factors besides. Choosing the right one is essential - particularly

if your device must meet stringent performance requirements - and requires a rigorous approach to testing.

Unlike many other chipsets and devices there is no standard for GNSS receivers to conform to. They all work, at least to some degree, but there is no benchmark against which available products need to succeed. This eBook is designed to help designers and manufacturers choose the right receiver for a product design. Read on to discover why choosing the right receiver is critical, what to consider when evaluating different receiver options, and how to ensure your tests help you make the right decision.

Why choosing the right receiver **is critical**

There are many different receiver models and designs on the market, ready to be used in a variety of different devices and use cases. Some may be of general purpose, while others will target a specific application or capability.

Ultimately though, no receiver can do it all. There will always be trade-offs between receiver size, cost, accuracy, and resilience.

The key is to select a receiver that matches your users' needs. For instance, you might choose:

- A high-resilience receiver for critical infrastructure devices
- A smaller, power-efficient receiver for a new wearable
- A set of high-precision receivers for a precision survey drone design

Selecting the right receiver is the best way to meet the expected performance requirements for your application. Without doing so your product may be at risk of degraded performance and/or unexpected errors due to the selected receiver's behaviour.

Don't rely solely on manufacturer specifications

Often, manufacturers will release detailed specifications of how their receivers perform across a range of conditions. Unfortunately, there are no standardised performance tests used by the GNSS community, so it is difficult to reliably compare results between receivers.

For instance, when manufacturers supply the positioning accuracy measures they may use different metrics, e.g. horizontal root mean square (RMS) or circular error probable (CEP), making it difficult to compare a range of receivers like-for-like. Similarly, when reporting time-to-first-fix figures, there is no standard for how many satellites and what signal geometry to use.

More importantly still, you may not know for sure whether manufacturers have tested their receivers in real-world conditions, or in scenarios that reflect how customers will use your device.

Without conducting your own tests, you can't confirm exactly how one set of specifications compares to others you are evaluating or how they change in real-world conditions – the factors that make it both fit for purpose and the best fit for your purpose.

What to consider **when selecting a GNSS receiver**

You will probably already have a good idea of the ways in which your device will be used, and the functionality your users will expect of it. From there you need to consider the basic capabilities you'll be looking for in a receiver.

Those capabilities may include:

Positioning accuracy – (horizontal and vertical)

If you are designing a product that relies on

positioning and navigation features, you want to make sure it delivers readings within an acceptable level of accuracy based on intended use. A running tracker, for instance, might manage on sub-10m levels of accuracy, while precision surveying equipment might demand sub-1cm readings at least. There is usually a trade-off here to consider, though, as more accurate receivers will inevitably be more expensive, take up more space, or be less efficient than lightweight alternatives.

The two most common metrics used to express positioning accuracy are Root Mean Square (RMS) and Circular Error Probable (CEP). RMS refers to taking several readings of position accuracy error and then calculating the square root of the average of the squared errors. CEP – a measure often used in ballistics testing – is calculated as the radius of a circle centered on the antenna that encompasses 50% of the taken readings. Each has its merits and drawbacks, and it is very difficult to directly compare results as they are entirely different calculations.

Ideally, both RMS and CEP would be tested using several simulator-defined scenarios, with signal and environment degradation taken into account. Once the receiver has been measured and integrated, a set of 'live sky' tests should be carried out to verify the results in the true real-world environment.

Timing accuracy

Many modern systems rely on the timing signals transmitted by GNSS satellites. As well as offering a low-cost solution, GPS is a preferred provider as it offers strict traceability to Universal Co-ordinated Time (UTC).

If you are selecting a receiver to use in a precision timing device - for example to synchronise activity across an energy grid or financial trading network - you'll want to test

that your clock can report time accurately and precisely and distribute it across the network effectively.

Some industry standards call for accuracy to within very narrow margins: for example, the ITU G.8272 standard for next-generation mobile networks requires the output of a Primary Reference Timing Clock (PRTC) to be within 100 nanoseconds of UTC.

Where timing accuracy is quoted – typically in designated timing receivers – it will be expressed in nanoseconds, and is measured as the error when already tracking. Another important factor to consider, and one that is not covered in specifications, is the stability of the receiver time delay.

Time to first fix

Time to first fix (TTFF) represents how quickly a receiver can acquire satellite signals and start tracking them. For a consumer device where GNSS functions will likely be turned on and off regularly, this is an important capability to consider. For emergency locators such as Emergency Position Indicating Radio Beacons (EPIRBs) the ability to quickly deliver positioning data isn't just important – it could mean the difference between life and death if someone needs to be rescued from cold waters.

Cold TTFF is how long it takes a GNSS receiver to acquire satellite signals and to start providing GNSS data following a complete hard reset

with no ephemeris data being present (a cold start). Many definitions exist for “cold start” and it is important to understand the differences in the definition and the consequences of it. After repeated use, receivers can “learn” to acquire and track satellites more quickly as a result of downloaded satellite ephemeris information and this information is used when performing a “warm start”. TTFF is typically much quicker from a warm start.

It's important to assess TTFF from both cold and warm starts when selecting a receiver for certain applications. A mobile phone, for instance, will be expected to acquire position quickly, and may travel around the world in flight mode and be expected to acquire a new position upon landing.

Imagine you are driving up the ramp from an underground car park and need to know: left, or right? Your navigation system will only have a few seconds visibility of the sky before you need to know which lane to get into it. At this point TTFF is much more important than position accuracy.

Receiver sensitivity

Acquisition sensitivity is a measure of the minimum signal power level required to obtain a position, velocity, and time reading from a satellite. Tracking sensitivity refers to how strong a signal needs to be for the receiver to maintain a satellite lock once it has been established.

Both have significant implications on battery drain and the capability to receive accurate positioning or timing data in difficult environments, making this an important capability for any use case demanding sustainability, longevity, and use in various scenarios.

Receiver sensitivity is typically quoted in dBm for both tracking and acquisition modes. The test set up for doing this would normally be to use a simulator (minimising variance of the C/N0) with the RF outputs suitably attenuated, and to then measure the outputted C/N0 with an RF power meter. This would be carried out using a number of different satellite geometries - including worst case scenarios.

Resilience

Resilience has become an increasingly important concern for manufacturers, integrators and users of mission-critical location and timing-reliant devices. GNSS is particularly vulnerable to effects ranging from ionospheric scintillation and space weather to multipath reflections, RF interference, and satellite segment errors - and that's before considering deliberate attempts to disrupt GNSS signals, such as malicious jamming and spoofing.

It is important to understand how receivers perform when exposed to these kinds of threats as they are capable of behaving unexpectedly. It is possible for a receiver to provide misleading position or timing information under some circumstances, and the conditions under which this could occur need to be well understood

and/or protected against. GNSS receivers can incorporate several features to mitigate the impacts of interference, such as:

- Improved antenna systems
- Multi-constellation multi-frequency GNSS
- Improved DSP algorithms
- RAIM (Receiver Autonomous Integrity Monitoring)

For devices that need to deliver guaranteed positioning, navigation, and timing data, it's important to test these capabilities and completely understand how the receiver responds to interference.

Things to test for in **common use cases**

Once you have established the key performance criteria for your GNSS receiver, you'll need to be able to test its performance in specific real-world scenarios your device may encounter. Here are some examples of things to test for across a range of common GNSS use cases. These examples are by no means exhaustive, but help to give an idea of some factors to consider in varying applications, as well as some insight into why they differ.

Drones

Drones are designed and built for a wide range of applications. From ISR to precision agriculture and surveying, and from hovering in place to flying over and through cities. The positioning performance priorities across these use cases could vary in a number of ways.

For instance, a drone that is intended for use in

land surveying will need to be able to maintain an extremely high degree of positioning accuracy. It will also need to be able to track signals effectively, making tracking sensitivity a primary consideration.

Conversely, a drone intended for use in inspecting power lines would need to demonstrate high resilience to interference. It would also be operating beyond line of sight, so reacquisition sensitivity becomes a primary concern.

For more information, you can read this eBook:
[An Introduction to Testing Navigation and Positioning Performance in Drones, UAS and UAVs](#)

Power station clocks

A critical infrastructure device such as a Primary Reference Time Clock (PRTC) in a power station will have very specific needs to ensure it can distribute timing data across the grid and synchronise the management of the energy supply.

Anything that prevents the clock from receiving, processing or distributing precise time can affect the working of the grid. If the system is dependent on GPS derived precise timing data then it is important to evaluate the chosen GPS Receiver to make sure that it does not behave unexpectedly when a real-world GNSS threat is encountered. As with many critical infrastructure applications the cost of failure in this area could be high. It is also vital to understand how the whole timing system would manage during periods of GPS signals being degraded or even denied. Therefore, an appropriate receiver for a critical PRTC would score highly on both resilience and re-acquisition time.

In addition to these factors, evaluating how a

receiver handles redundancy is vitally important. In this respect a high score for tracking sensitivity can actually be a bad thing; satellite vehicles with low C/No can degrade the solution by introducing reduced accuracy.

Fitness trackers

GNSS-enabled fitness trackers require a receiver that can accurately track the user's position without adding too much weight or bulk to the device – or draining the battery too quickly.

With a broad and varied campaign of test cases, you can find the right low-profile chipset that offers the levels of sensitivity and accuracy users demand. And as consumers also often expect to hit the ground running with their exercise, the inclusion of tests for cold and warm time to first fix will help to ensure continued customer satisfaction.

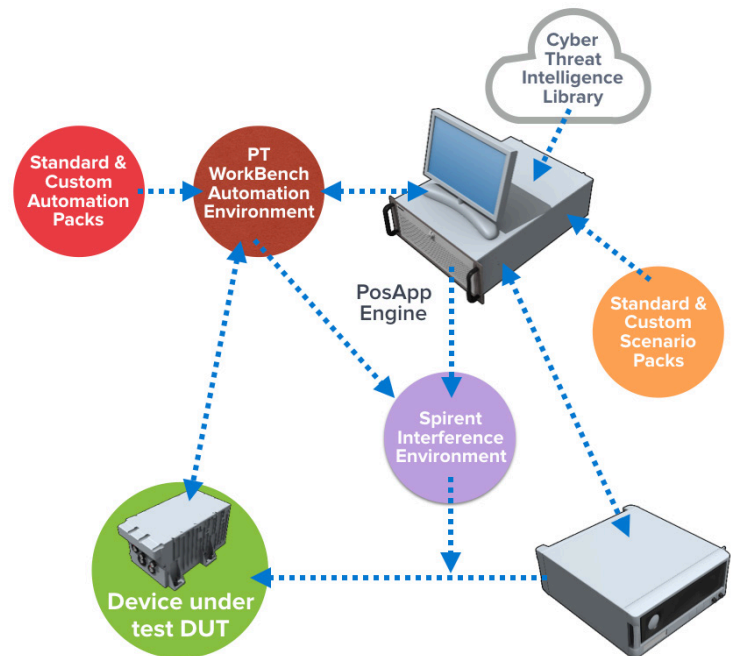
[Click here to access our eBook: "The Four Considerations to Prevent Damaging Your Wearable Brand."](#)

Why lab-based testing is important

Whether you're looking to test general receiver performance, or you want to analyse how a receiver responds to a very specific set of interference conditions, it's important to test in a controlled and repeatable environment. Only by being able to run the same tests again and again can you accurately compare different receivers – and ultimately select the right one for your product.

This means that live-sky and field testing alone are seldom fit for parametric performance testing. And in the case of testing for more specific interference effects based on ionospheric movements and environmental hazards, this kind of testing can be impractical, costly, and often impossible to reliably conduct.

The alternative is to either record a signal spectrum for playback in the lab, or to make use of a GNSS simulator that allows testers to generate repeatable signals.



Required equipment for **lab testing**

To conduct tests that cover the full spectrum of GNSS receiver capabilities, testing labs will need:

A GNSS signal simulator:

Depending on whether your receiver supports multiple GNSS constellations, you may need additional simulators to cover different satellites and frequencies.

An interference simulator:

If you need to generate specific man-made or natural interference, your lab will need to be kitted out with the right kind of interference simulator.

A record and playback device:

Recording a snapshot of a GNSS signal environment and repeating it in the lab can offer an alternative to simulation-based testing.

Required equipment for **lab testing**

With the right recording device, engineers can also capture atmospheric and RF interference as well.

Test cases and automation tools:

A series of test cases will tailor your testing efforts to make sure you continue to assess the right criteria in a controllable, repeatable manner. Automation tools can help accelerate the testing process to help you get results faster – and make sure you're selecting the right receiver.

Representative antenna models:

In order to make sure testing reflects how the receiver will perform when integrated.

Dynamic models for dynamic applications:

A rate table, for instance, can help to introduce the movement a device would experience when in use.

Testing the **right criteria** in the **right conditions**

For a positioning or timing-reliant device to succeed, it must meet user expectations across a range of key criteria. Testing a selection of GNSS receivers for these criteria in a controlled lab environment is a practical and reliable way to ensure that you have selected the right one to be integrated into your device.

Above we've outlined the importance of selecting the right GNSS receiver, the need to test key criteria yourself in controlled conditions, and a selection of criteria to consider testing based on your device use cases.

We've also highlighted some of the equipment required to test for these criteria in your own labs. While that's really all you need to start effectively testing GNSS receivers, additional expertise can help improve test campaigns, deliver more conclusive testing results, and help you make more informed decisions about your product – and what GNSS receiver will be the best fit for it.

Spirent offers a broad range of simulators, record and playback systems, tests cases, and even a standardised “vendor selection” professional service.



GSS6450 – RF Record & Playback



GSS7000 – GNSS Simulator

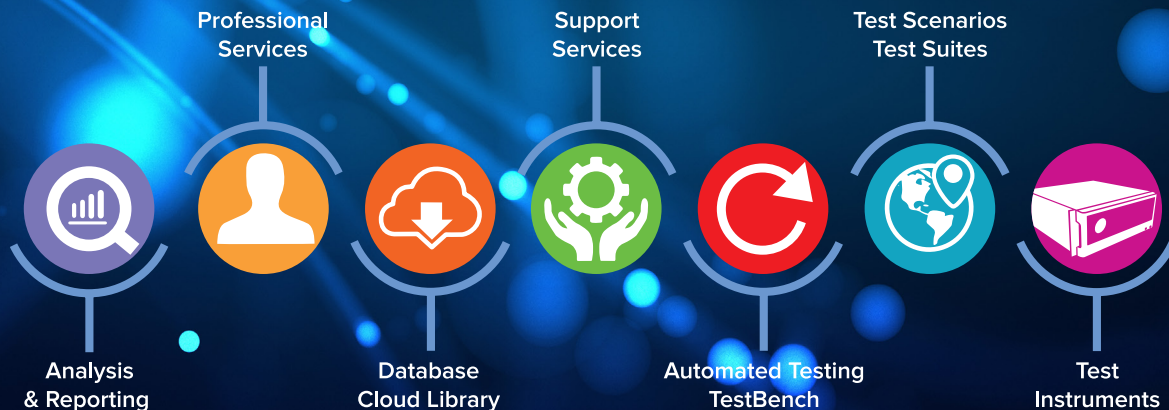


GSS9000 – GNSS Simulator

If you have any questions about the testing process, or on how to select the right GNSS receiver for your device, get in touch to see how Spirent can help.

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