The Case for GPS Simulation

Overview

As demand for precision GPS receivers continues to grow through a number of industries and applications, increased attention to focused GPS receiver test can land you ahead of the competition.

For each of the many steps that a GPS receiver must go through in order to accurately provide position and timing information, errors are introduced. By testing each step in an isolated fashion and with controlled introduction of signal impairments, you can target your troubleshooting and invest in areas of the design that will offer the greatest returns. While a drive test may allow you the most realistic reproduction of the environment the GPS receiver will be found in, it offers little information about the specific impairments present in the signal or what you can do to improve your design.

With a GPS Simulator, you have full control over signal power levels, Doppler shifts, ephemeris errors, multi-path fading, ionospheric effects, and many other impairments found in real-world GPS signals. By simulating a GPS signal, you can introduce each of these impairments individually or in scenario-specific combinations for the targeted troubleshooting needed to truly improve your design.

Introduction

Design validation tests can be organized by looking at the process a GPS receiver goes through in order to calculate a position solution.

A receiver must first pick up a spread spectrum signal at 1575.42 MHz with a power level of a mere -130 dBm. Next, the signals of at least four satellites must be distinguished from one another even though as many as 12 satellite signals are present at once in the same band along with any interfering transmissions. Once the satellites have been properly identified, demodulation of the incoming transmission is possible and performed. Then, a number of calculations can be done to find accurate distance measurements from each satellite to the receiver (pseudoranges). Knowing the location of the GPS satellites from the transmitted message, the pseudoranges can now be used to calculate the receiver's position by trilateration. During all of this, any impairment to the GPS signal will affect some or all of these steps and therefore, the accuracy of the position solution.

To verify the performance of a GPS receiver under these test conditions, there are a few well defined tests that can be performed. The most common of these measurements are sensitivity, time to first fix (TTFF) or time to subsequent fix (TTSF), position and tracking accuracy. These are covered in detail in the NI Developer Zone Tutorial: GPS Receiver Testing. National Instrument's GPS Simulation Toolkit and GPS Simulator allow for each of these tests to be performed under a number of signal impairments. A few of these impairments such as Doppler shift caused by receiver motion, varying power levels from each satellite, ephemeris errors as well as signal jamming are introduced in the following sections.

Doppler Shift

GPS Satellites orbit about 20,200 km above the earth which results in an orbital period just under 12 hours and an orbital velocity near 3,900 m/s. This would result in a Doppler shift in a single satellite signal of up to ±20 kHz from the satellite motion alone. When combined with the rotation of the Earth and the subtle Doppler shift from the mobile receiver, the GPS signal takes on a new shape and the receiver should be tested under these conditions.

With the NI GPS Simulation Toolkit, you can create custom motion profiles in order to simulate receiver motion. The benefit of this type of simulation over a traditional drive test is two-fold. First, you are able to simulate speeds, altitudes, latitudes and longitudes that simply aren't feasible in a drive test. For example, from your desk in Austin, Texas, you would be able to verify the GPS receiver's performance at 500 m/s (about 1,100 mph) while cruising at 4,600 m (about 15,000 ft) over the Andes. Second, you are able to introduce the Doppler shift impairments to the signal in the absence of any other signal impairments, thus facilitating targeted design improvements.

More information about the trajectory script feature of the GPS Simulation Toolkit can be viewed in the Webcast: Creating Custom Motion Profiles.

Satellite Signal Power Levels

Whether it's passing under a tree or between a pair of tall skyscrapers or even going through a tunnel, a GPS receiver will be faced with GPS satellite signal drop-outs. Since four satellites are required for a position fix and more satellites in view translate to a more accurate solution, it is very beneficial for the receiver to aptly handle these types of environments. In addition to these types of situational tests, the control over individual power levels can also be used in more advanced inter-channel biasing tests in multi-channel receivers.

The NI GPS Simulation Toolkit for LabVIEW gives you the ability to adjust each of up to 12 simulated GPS signals power levels. With this flexibility, the GPS receiver can be sent through alleyways, underground, or through a walk in a heavily shaded wood for scenario specific test and troubleshooting. As mentioned above, your multi-channel receiver's performance can also be evaluated, and in the absence of additional impairments.

Ephemeris Errors

To arrive at a position solution, a GPS receiver simply needs to know how far away it is from at least 4 fixed points in space. If one of the fixed points, however, is not really transmitting from where it told you it would be, then an error is introduced in the solution.

The source of this problem is the transmission of erroneous or inaccurate ephemeris data. The ephemeris is the precise orbital information for the transmitting satellite. The ephemeris contains the parameters necessary to calculate a long, smooth arc representative of the satellite's path as a function of time. As with any such prediction, however, the error increases over time and for this reason, ephemeris data is only regarded as valid for four hours. For this reason, control stations located around the globe constantly upload the latest ephemeris data to the satellites. Additionally, the uploaded data may contain inadvertent errors or the satellite may introduce errors upon transmission.

All of these situations pose different problems to the receiver and can be simulated by supplying an altered ephemeris file to the GPS Simulator. The NI GPS Simulation Toolkit allows you to specify your own ephemeris file path (in RINEX 2.0 format) for this type of isolated and targeted testing.

Signal Jamming or Interference

Intentional Jamming or spoofing of the GPS signal or unintentional interference to the GPS signal will both have adverse effects on the position solution achieved. Designing algorithms and methods to limit the effects of these unwanted, and in many cases, malicious signal impairments will greatly increase the reliability of the GPS receiver under test.

By adding an additional vector signal generator to your test system, you are able to combine an interference signal of your own creation with the clean simulated GPS signal and isolate the effects that signal interference introduce to your GPS solution. National Instrument's modular and software-defined approach to instrumentation provide the flexibility and scalability that is necessary to seamlessly add this functionality to your test system. For more information about the NI modular instrument platform, please visit NI Modular Instruments.

Conclusion

GPS Simulation offers the control needed for the targeted troubleshooting and test necessary to isolate errors and improve GPS receivers. The NI GPS Simulator and the NI GPS Simulation Toolkit for LabVIEW deliver the fast and flexible design validation or production test system in order to meet that need.

The ultimate test for your GPS design of course will be to expose the receiver not only to all expected impairments, but also introduce anything else it may run into in the real world. For that purpose, a drive test or the more flexible and repeatable NI RF Record and Playback System will allow you to accurately reproduce the real world scenarios that the GPS receiver will encounter.

By combining these test methods, you are able to fine tune the performance of GPS receivers and make targeted improvements to the largest error in the system and thereby achieve the largest gains in receiver performance.