application note

GPS Receiver Testing: Leap Second Testing Made Easy

spectracom

The next leap second will be added to the official time scale on December 31, 2016. It is the first end of year leap second since 2008. No doubt many GPS receivers, software and systems in current production have not experienced an end of year leap second event. For these reasons, it is strongly recommended to test the upcoming leap second event for all GPS receivers and systems to determine if algorithms and software successfully manages the leap second event and to uncover any detrimental effect of the leap second discontinuity.

Introduction

Spectracom's GNSS constellation simulators can easily simulate the leap second event of December 31, 2016. A typical test can take as little as 30 to 35 minutes to set up and run. A sample leap second scenario is available for download. This application note provides background on the leap second event and describes leap second testing with the Spectracom simulator.

What is a Leap Second?

Since the official definition of time is based on atomic standards, a leap second is inserted in the UTC time scale to keep it in step with the solar day much like a leap day is used to keep the calendar in step with the seasons. A leap second can be added or removed. It can occur at the end of the day on December 31 or June 30 and must be announced approximately 6 months in advance.

The sequence for adding a leap second to UTC compared to a normal day:

Normal Day	Leap Second Event
23:59:58	23:59:58
23:59:59	23:59:59
00:00:00	23:59:60
00:00:01	00:00:00

Figure 1. Adding a leap second

	No future leap second (last leap on June 30, 2015)	Leap second coming on December 31, 2016	Within ± 6 hours of the leap second on UTC midnight December 31, 2016	After January 1 (no future leap second)
Δt_{LS}	17	17	17 or 18 (depends if almanac updated and received)	
Δt_{LSF}	17	18	18	18
UTC	GPS Time + Δt_{LSF}	GPS Time + Δt_{LS}	GPS Time + Δt_{LS} + (Δt_{LSF} - Δt_{LS})	GPS Time + Δt_{LSF}

Figure 2. Key leap second parameters in the UTC calculation

The Case Against Leap Seconds

The last leap second event stirred a great deal of controversy about the need for the leap second due to the significant issues they can cause. However, the ITU decided to keep the practice of leap seconds until at least 2023. This debate underscores the need for leap second testing to ensure proper performance of GPS devices.

How GPS Manages Leap Seconds

The GPS (and other GNSS) system operates on the principal of synchronized precise time. Every satellite broadcasts "GPS Time" which was in sync with official UTC time at one point. GPS does not reconcile the discontinuity of a leap second in its time scale. It transmits GPS Time along with the number of leap seconds according to GPS Interface Specification IS-GPS-200H (latest September 2013). The responsibility to convert GPS time to UTC falls to the GPS receiver and supporting software.

The information about leap seconds is broadcast by the satellites as part of the almanac. The parameters that apply to the current and future leap second events are contained in subframe 4, page 18 of the navigation data message (see section 20.3.3.5.2.4 of the interface specification). The key parameters are as follows:

- Δt_{LS} – Current or past leap second value
- Δt_{LSF} – Current or future leap second value

For correct management of the leap second event, the receiver must determine which value to use (either Δt_{LS} or Δt_{LSF}, or both) for its UTC calculation.

For example:

1. If the present time is more than 6 hours before the leap second event, the receiver should use the value of Δt_{LS}.
2. If the present time is within a window of 6 hours before to 6 hours after the leap second event, the receiver is in a transition period where it looks at the difference between those 2 values and adds it to Δt_{LS} (so if Δt_{LS} is already updated in the almanac, zero is added, if not +1 is added).
3. If the present time is more than 6 hours past the leap second event the receiver will use the value for Δt_{LSF}.

Testing Leap Seconds with the GSG Series GPS Simulator

It's easy. "Leap second" is an easily edited scenario parameter from all the user interfaces (front panel, web browser UI, GSG StudioView software). A value of 1 adds an offset of 1 between Δt_{LSF} and Δt_{LS} (this value can also be signed to indicate a negative leap second). For example, if the leap second parameter is non-zero, then the simulation will indicate the leap second event occurs on June 30 at any time in the first half of the year and at December 31 for any time in the second half of the year.

A scenario file is available for download with the parameters in figure 3.

This scenario starts 30 minutes before midnight on December 31, 2016 (this is not exactly UTC, it is close because it is GPS Time, after all, we are just like GPS!). It runs for an hour with a leap second event at UTC midnight.

In a successful test, we expect the receiver receives the information about the current number of leap seconds, the future leap seconds about 10 minutes after scenario start.

The receiver reports the leap second on time and the current number of leap seconds as shown by the receiver updates from 17 to 18. At this time the almanac for the leap second values has not updated, it still reports the last received almanac information.

Sometime between 9-10 minutes after the leap second has occurred, the receiver receives the updated almanac information and the leap second values are now the same.

Conclusion

The management of a leap second event should be tested in critical GPS applications. The only way to test leap seconds is through simulation. The alternative is to "hope and pray" when living through an actual leap second event in which case it is too late to fix something the has gone wrong. Spectracom's GSG series of GPS simulators lives up to its promise of delivering easy and thorough testing tools. The company is especially suited for testing timing function due to its heritage with precision timing systems. Please contact us for more information.

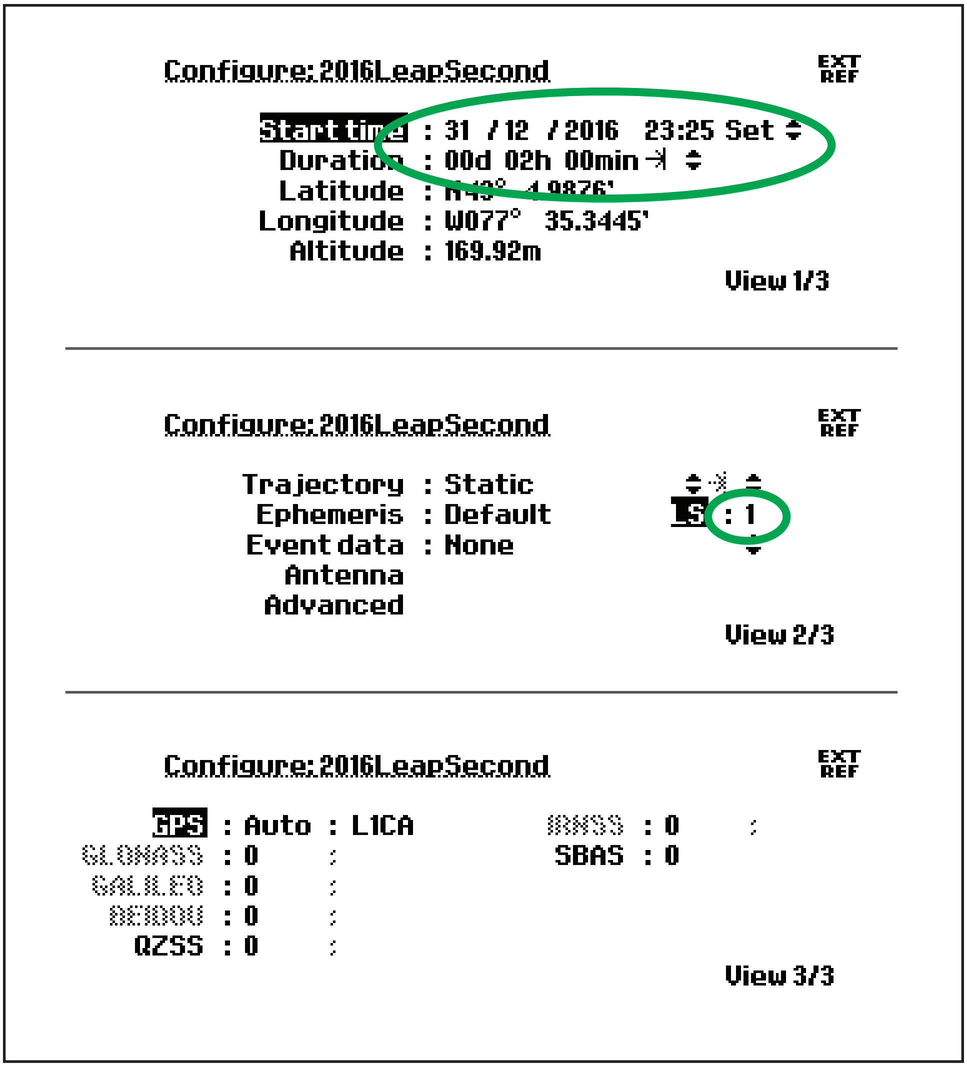

Figure 3. Configuration scenario parameters