Using LEO STL® to Maintain Time Synchronization in High-Multipath Environments

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Abstract – Using LEO STL in High-Multipath Environments

High-multipath urban environments can be a significant challenge to telecom GNSS timing receivers, causing frequent, long-duration receiver lock loss and extended holdover times, resulting in excessive site alarms, performance degradation, and random loss of service.

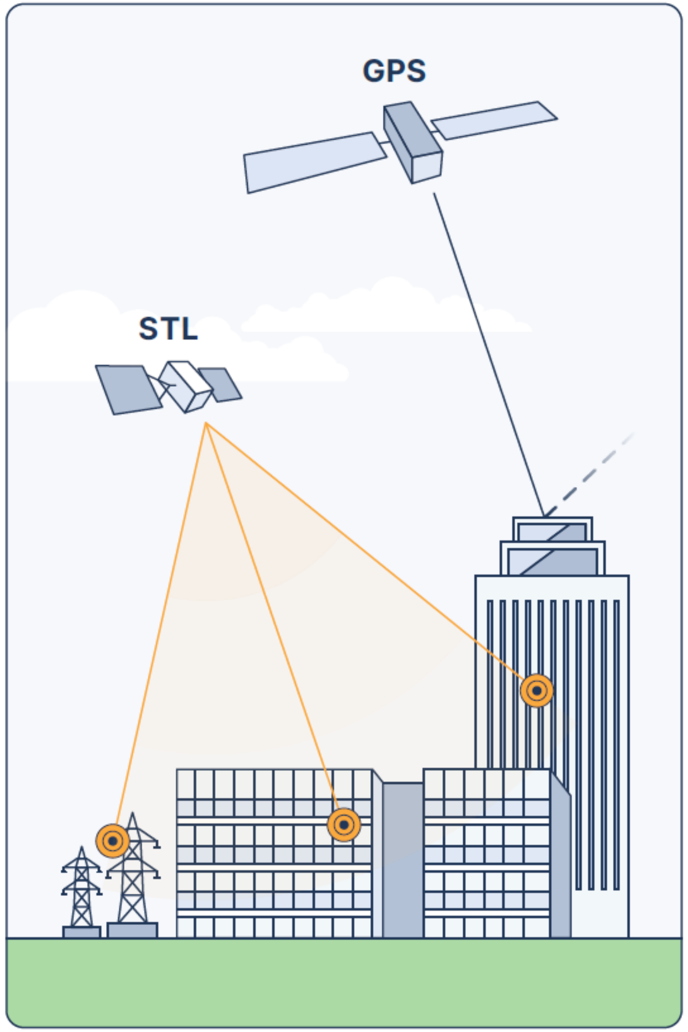
LEO satellites traverse the sky significantly faster than MEO GNSS satellites, resulting in extremely short-duration multipath components. LEO PNT receivers further benefit from higher received power levels and Doppler-assisted ranging, with a combined effect of being able to provide a stable timing clock that is significantly immune to urban multipath degradation.

This presentation explains multipath effects on timing receivers and presents side-by-side examples of GNSS and LEO STL timing receivers operating in extreme urban multipath conditions.

GNSS Synchronization

GNSS synchronization is the most accurate method to meet critical infrastructure timing requirements. However, it works poorly or not at all in:

- Urban canyons (limited sky view)
- High multipath environments (signal shredding)
- Indoors (excessive attenuation)
- Where jamming or spoofing exists



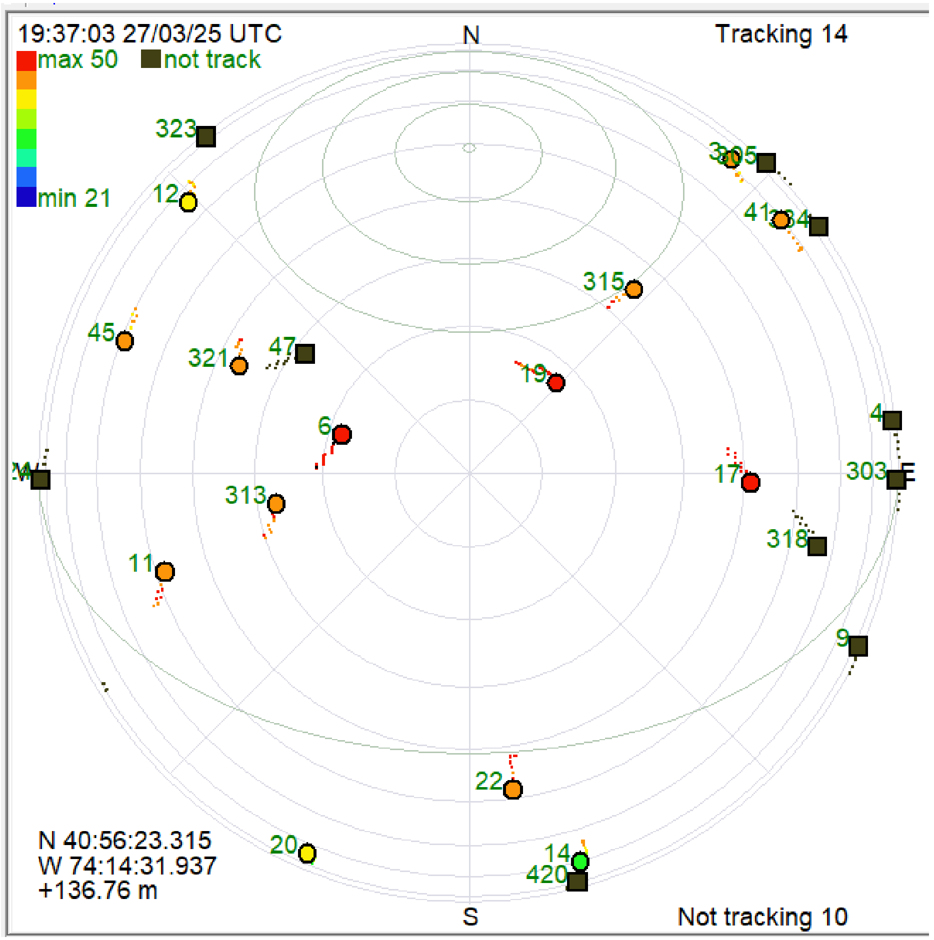
NOTE: Image depicts indoor reception of STL compared to GPS. Orbital altitudes not to scale.

1575.42 MHz is a Tough Spectrum

- The GNSS spectrum at 1575.42 MHz is a crowded **convolution of overlaid signals** from GPS, Galileo, Beidou, SBAS, QZSS, and NavIC.

- GNSS receivers often need to sift through direct signals from 12-20 satellites. Adding simultaneous multipath from these systems causes a **signal shredding** effect that results in a **severely degraded or uncorrelatable solution.**

- The **slow movement** of MEO satellites can result in complex multipath patterns than often **persist for hours,** causing frequent, long-duration receiver lock loss and extended holdover times, resulting in excessive site alarms, performance degradation, and loss of service.



This plot shows the slow movement of GNSS satellites during a 12-minute period **each moving only a few degrees**

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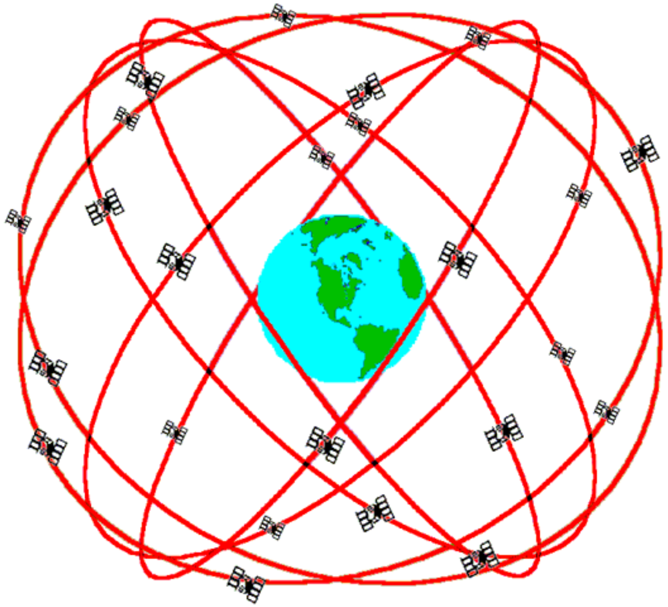
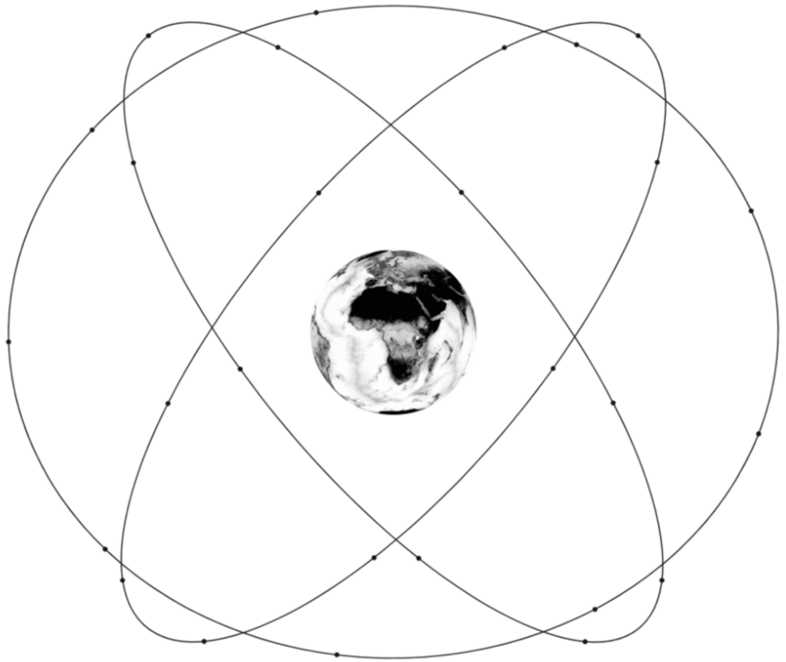
MEO vs LEO Constellations



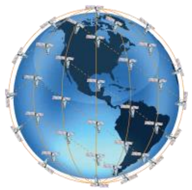
GPS MEO Constellation

24+ Satellites in 6 Orbital Planes
4 Satellites in Each Plane
20,180 km Altitude, 55 Degree Inclinations
Orbital Speed 14,000 km/hr (9k mph)
Orbital Period 12 Hours (2x/day)
Different Satellite in Each Plane Every 3 Hours



Galileo MEO Constellation

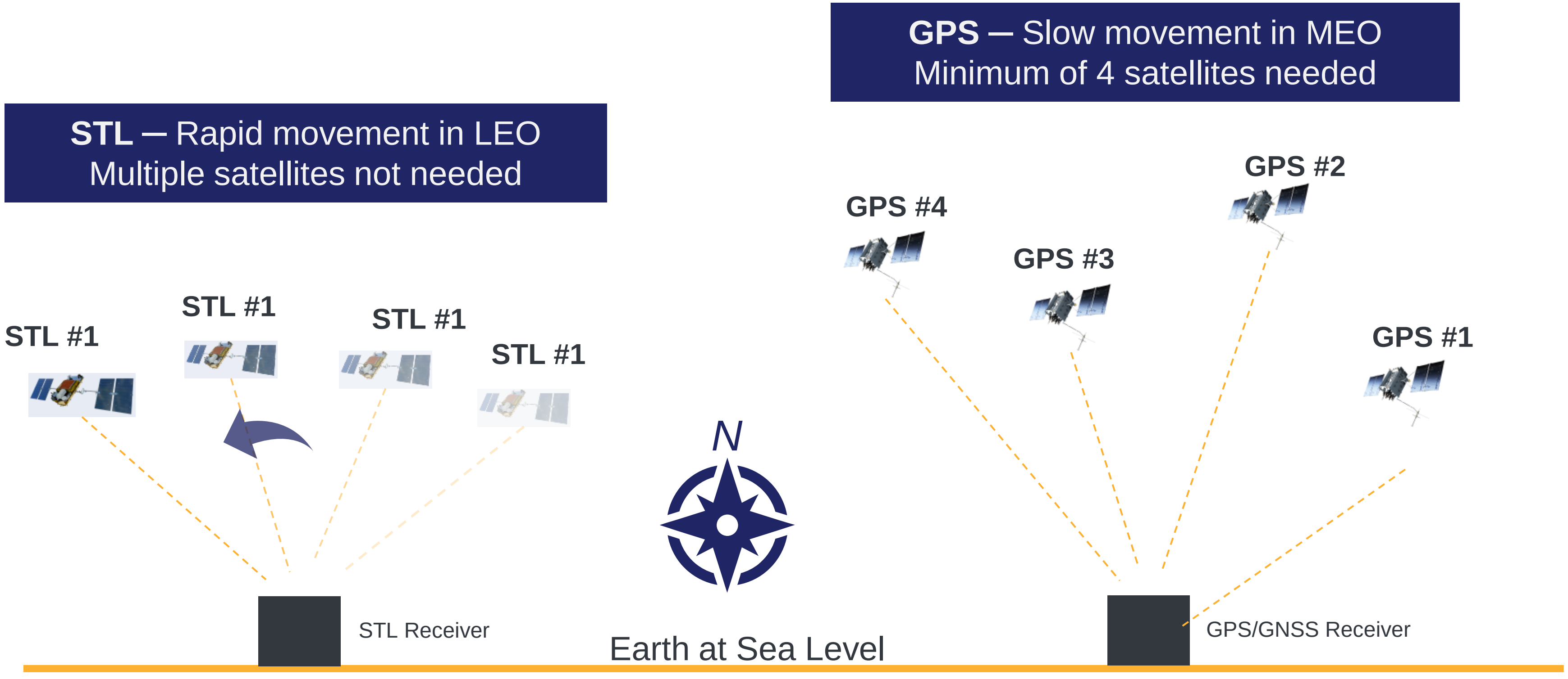
24+ Satellites in 3 Orbital Planes
8 Satellites in Each Plane
23,222 km Altitude, 56 Degree Inclinations
Orbital Speed 13,200 km/hr (8k mph)
Orbital Period 14 hours (~2x/day)
Different Satellite in Each Plane Every ~1.5 Hours



Iridium® LEO Constellation

66 Satellites in 6 Orbital Planes
11 Satellites in Each Orbital Plane, Spaced 30° Apart
781 km Altitude, Polar Orbits (86.4 Degrees)
Orbital Speed 27,000 km/hr (17k mph)
Orbital Period 100 Minutes (14x/day)
Different Satellite in Each Plane Every 9 Min

LEO Satellites Traverse the Sky in Minutes vs MEO in Hours



Orbit Earth every 100 minutes
(16 times per day)

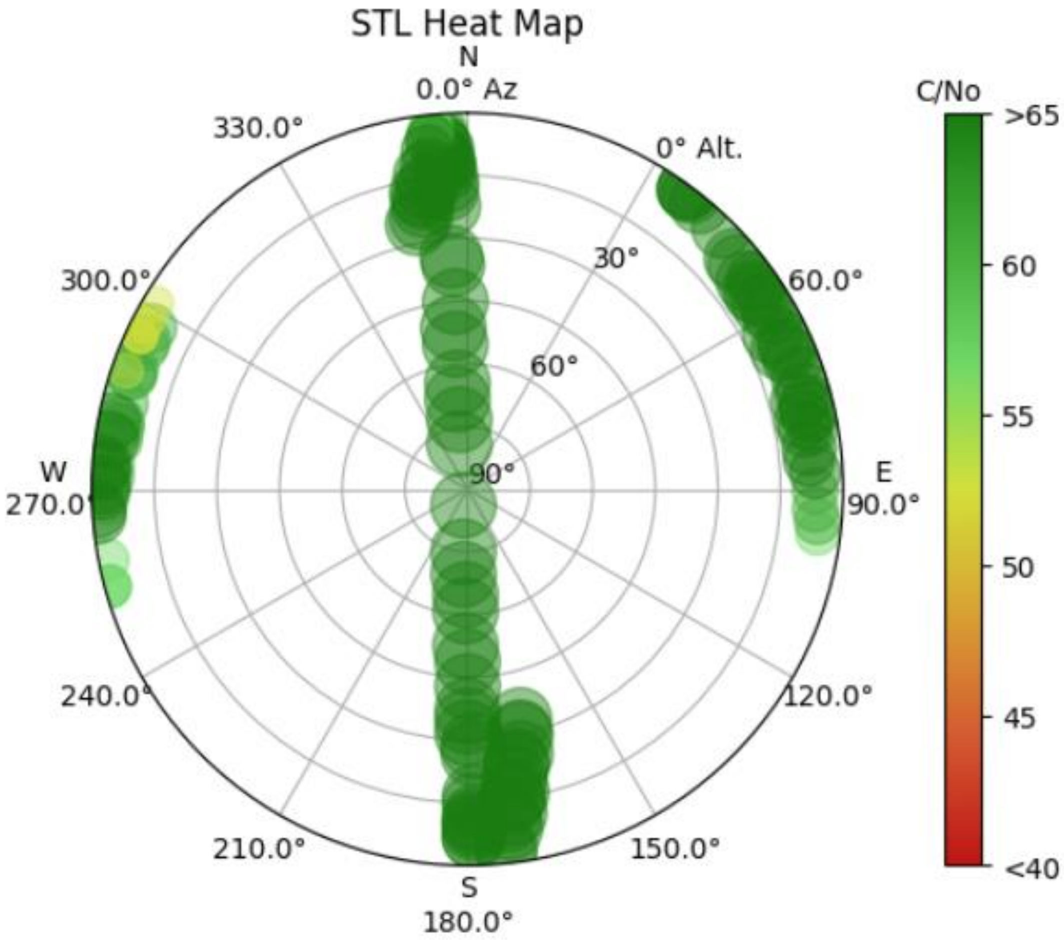
Orbit Earth every 12 hours
(2 times per day)

The rapid velocity of LEO satellites results in negligibly short duration multipath

The slow velocity of MEO satellites results in long duration multipath

LEO Signals are Significantly Unaffected by Multipath

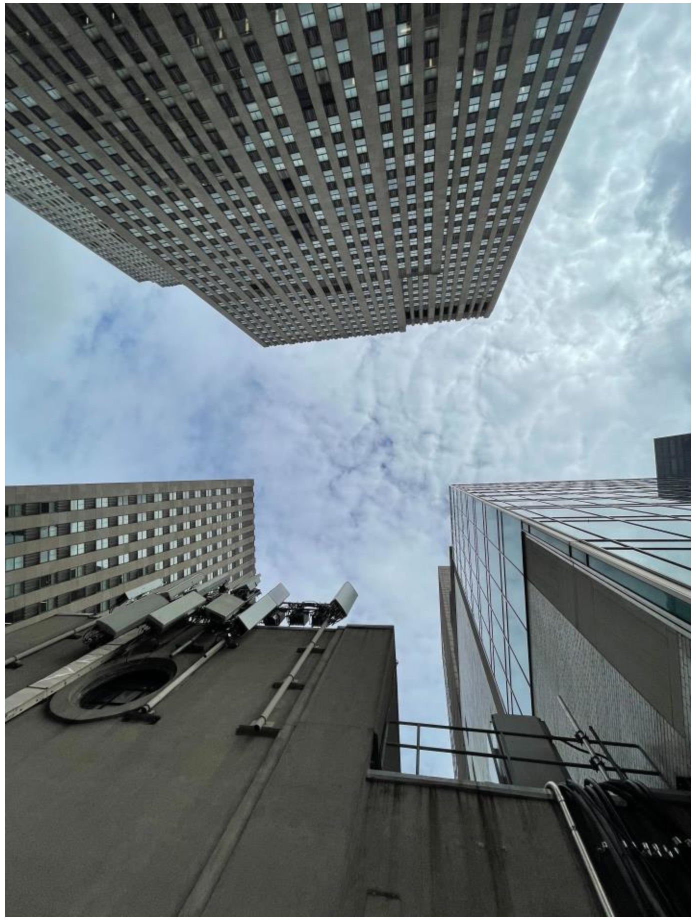
- LEO satellites that use dedicated (unshared) spectrum have the benefits of **reduced signal noise and greater signal robustness.**
- The **rapid movement** of LEO satellites results in simple multipath patterns that typically **persist for only a few seconds,** preserving receiver lock with no site alarms, timing degradation, or interrupted service.
- LEO PNT receivers further benefit from higher received power levels (typically 30 dB stronger than GNSS) and Doppler-assisted ranging, with a combined effect of being able to provide a stable timing clock that is **significantly immune to urban multipath degradation.**



This plot shows the rapid movement of LEO (STL) satellites during a 12-minute period **traversing the sky from horizon to horizon**

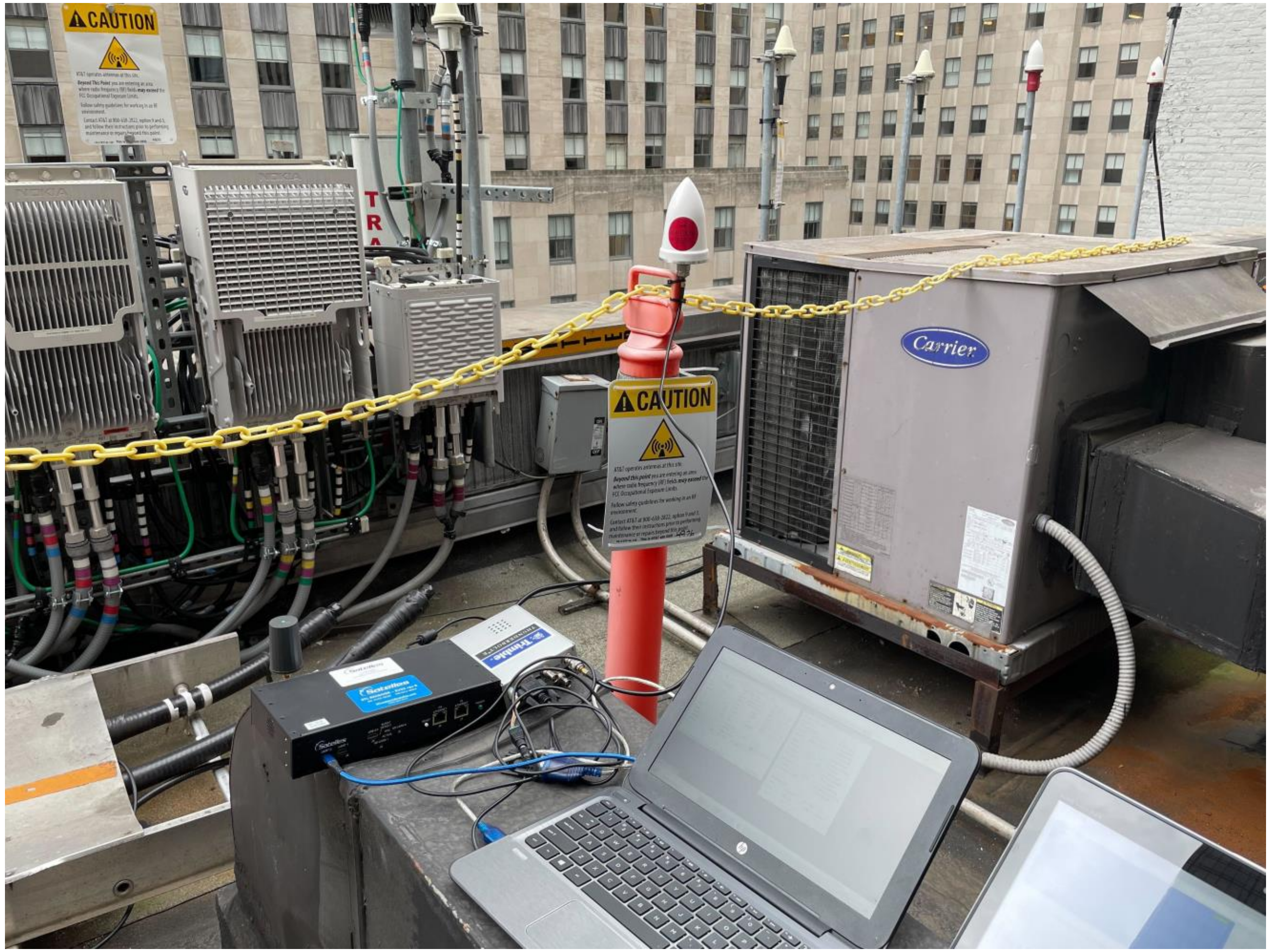
Multipath Test Location

To test GPS vs LEO, an urban location in New York City was chosen. This strategic site is used by three different wireless telecom providers and is well known for having unresolvable GPS multipath, causing the equipment to take hours to initialize and operate almost continuously with synchronization alarms.



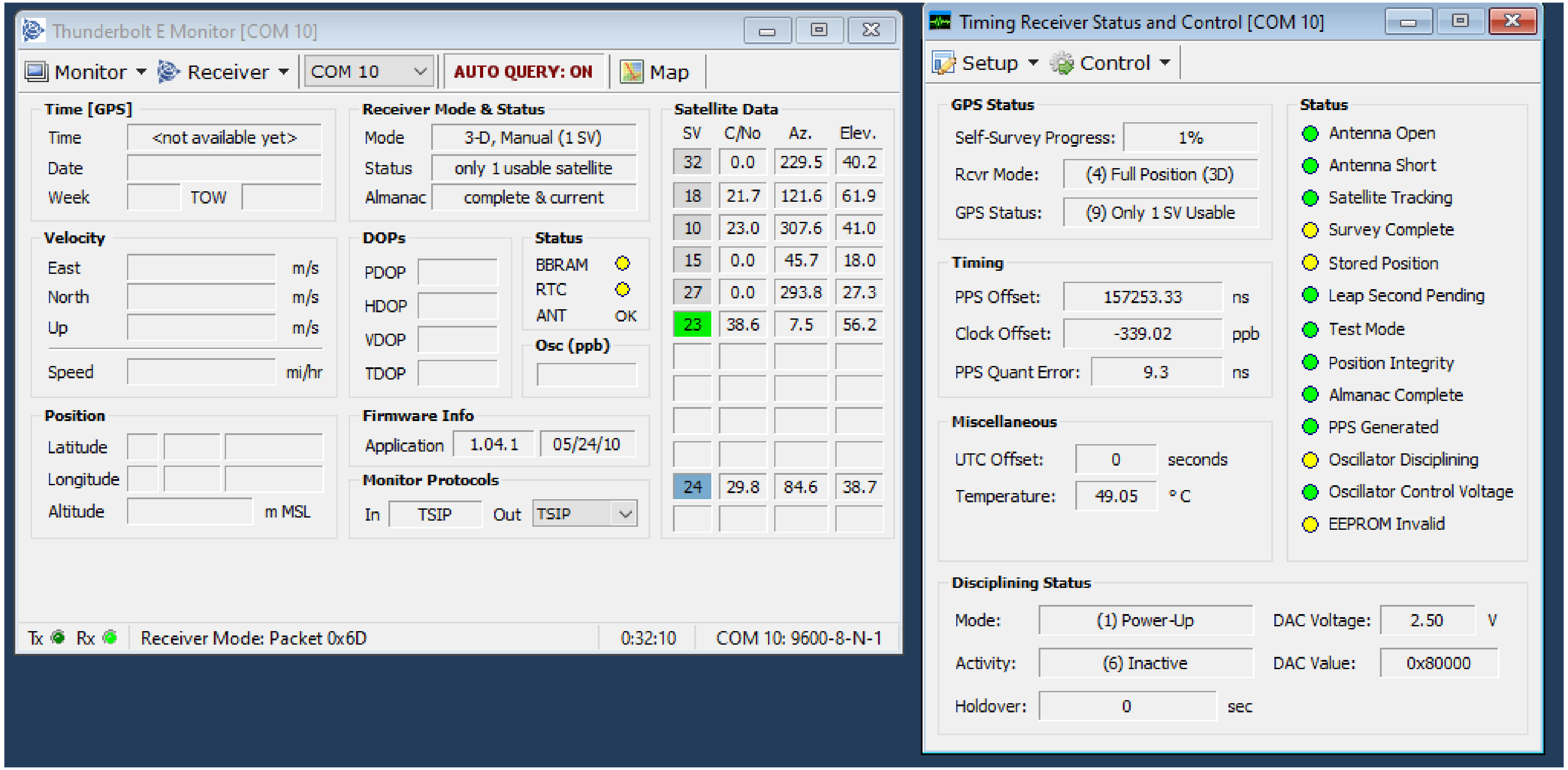
Multipath Test Setup

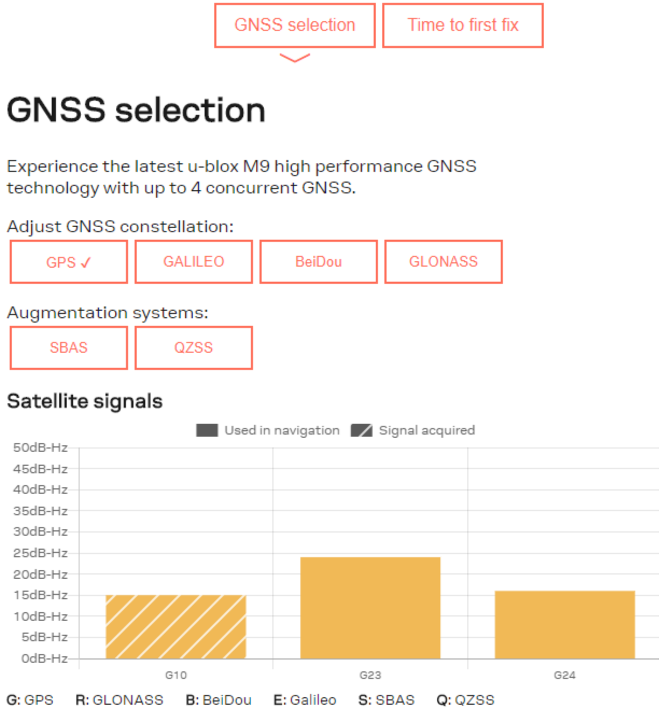
Timing receivers from three different GPS vendors and three different LEO (STL) vendors were set up at the test location. One of the GPS receivers used the standard GPS antenna typically used at wireless telecom sites, and the others used similar antennas.



GPS Receiver Performance

The GPS receivers operated with unacceptably poor performance. They were typically locked to only one or two satellites (sometimes none), had very low C/N_0 levels, and very large error estimates.





Only 2 GPS sats with C/N_0 <25 dB

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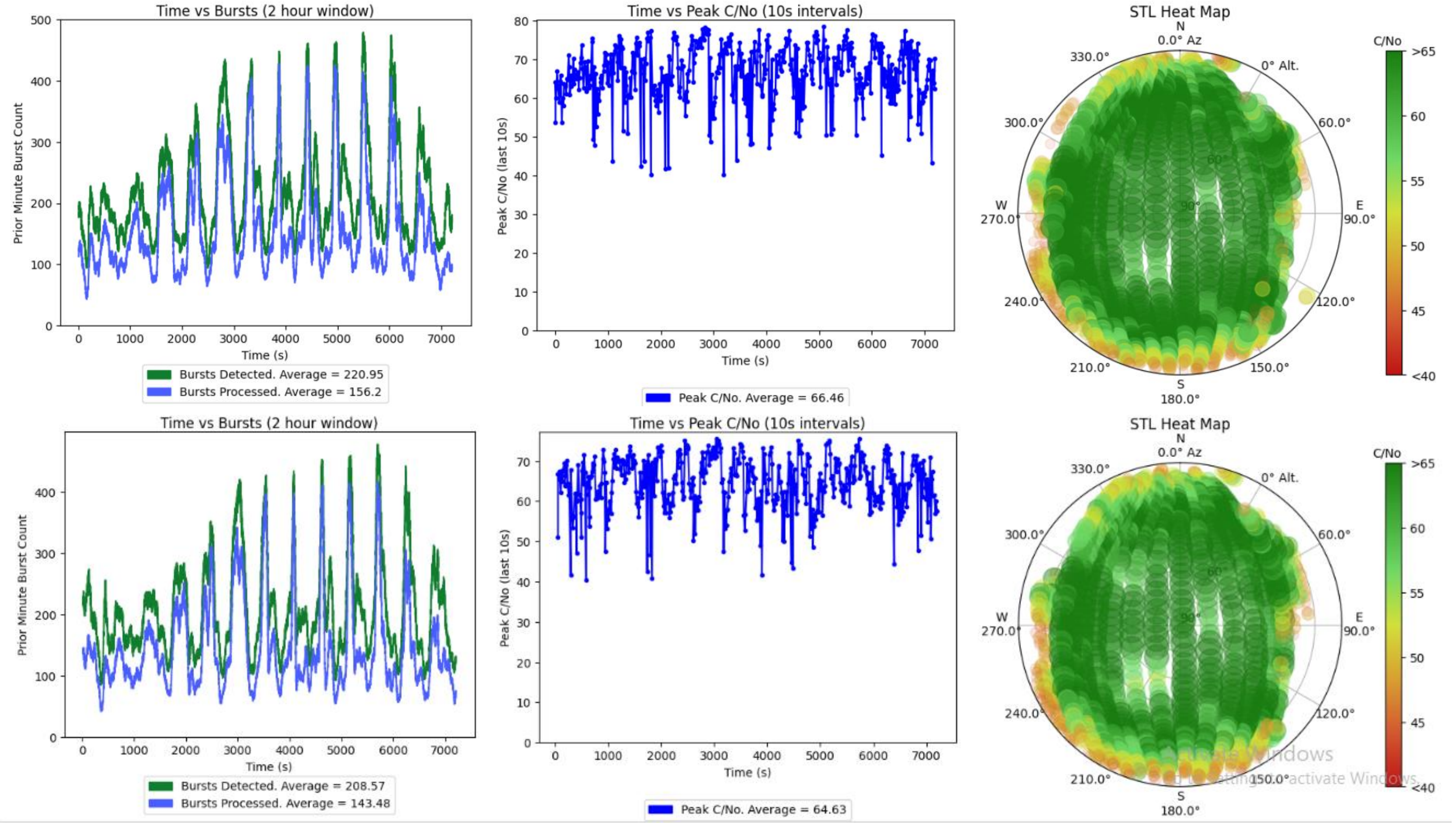
LEO Receiver Performance

The LEO receivers operated excellently with strong reception signal characteristics, continuous lock, and no degradation from signal multipath. LEO satellites are highly immune to urban multipath due to their significantly faster orbital velocity and Doppler-assisted ranging.

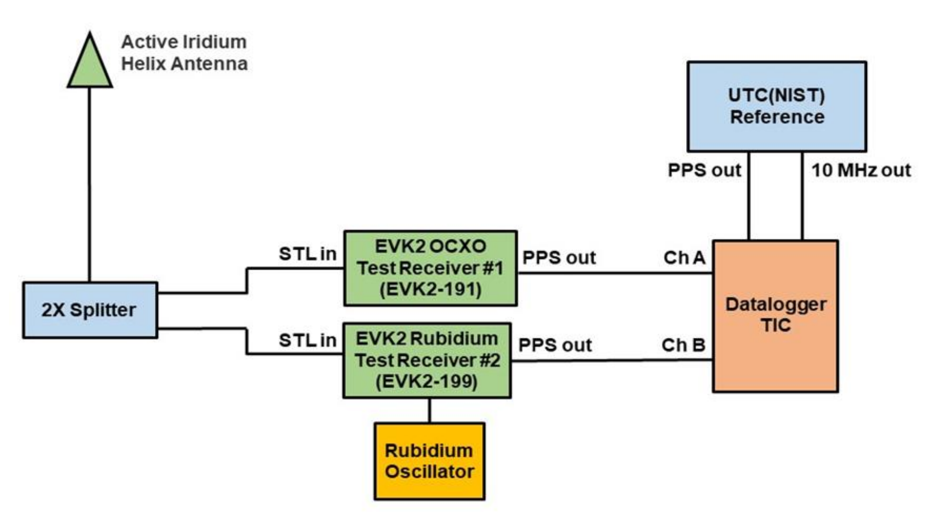


All LEO sats were easily tracked with an average C/N_0 > 60 dB

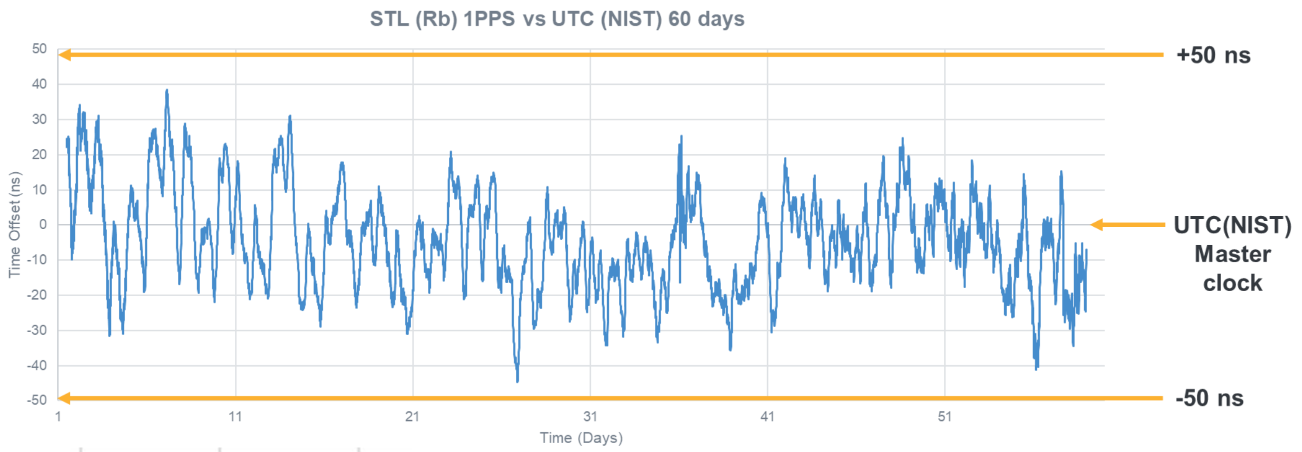
Results from Joint NIST Evaluation of Iridium STL

In a joint study by Satelles (Iridium) and the U.S. National Institute of Standards and Technology (NIST), the long-term timing performance of the Iridium PNT signal (STL) was measured against UTC(NIST), the timing reference at NIST.

The data showed that the LEO PNT receiver with a rubidium oscillator (MAC) was able to provide an extremely stable timing solution with a maximum error of less than 50 nanoseconds of UTC(NIST) over a period of 100 days, and with an average long-term error (TDEV) near zero nanoseconds.



Test Setup



Max	38.48	ns
Min	-44.73	ns
Average	-4.42	ns
STDEV	13.95	ns
MTIE	83.21	ns

Results

Meets ITU-T G.8272 PRTC-A Performance

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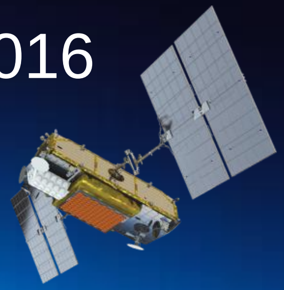
Iridium Satellite Time and Location® (STL):
Alternative LEO PNT

- Resilient to multipath
- Powerful signals
- Secure service
- Global availability
- Available when GNSS is not

- Timing accuracy of 10-100ns (oscillator dependent)
- Location accuracy of 10-30 meters (static)
- Traceable to UTC(NIST) and UTC(USNO)
- Commercially available since 2016



Questions?

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